FOI 190204
Document 1

05 August 2018

Jacque Comery
Project Engineer
Australian Antarctic Division
Department of the Environment and Energy

Our ref: 21/27531/
Your ref:

Dear Jacque

Potable water treatment at the Casey, Mawson, and Davis research stations
Initial Stage 1 review and Proposal for Stage 2 and 3

This document summarises our initial desktop review of the background reference information supplied by AAD, and includes our proposal for the work required in Stage 2 and 3 as requested by your brief.

In preparing this document, we have held a kick-off teleconference with AAD, conducted initial desktop review of water test results, photos and other water system information supplied, and held a detailed teleconference with Tim Price of AAD to ensure we have a good understanding of the existing system, its problems and the possible causes.

Stage 2, as described by your brief, is to investigate potential solutions to the corrosion problems currently experienced. Separate draft and final Investigation and Concept Design Report for each station will be prepared as requested.

Stage 3 is to prepare separate functional description for each station to facilitate procurement of a system as identified in concept in Stage 2. A shortlist of nominated suppliers to assist the AAD in approaching the market will also be prepared.

An important success factor for Stage 2 and 3 will be contribution from AAD on the practicality and operability of the proposed solutions that we identify. Feedback from AAD on our proposed solutions will be required, and a face-to-face meeting with AAD in Kingston has been included in Stage 2 as requested by your brief.

We trust this document has met your needs. Please don't hesitate to contact me if you require any further information on this document. We are ready to proceed to Stage 2 and 3 and look forward to our continued involvement in this project.

Sincerely

Calvin Lai
Service Line Leader - Water Treatment & Desalination, Australia
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1 Initial Desktop Review

1.1 Casey Station

1.1.1 Understanding of System

Drinking water for the Casey Station is sourced from a lake system located behind the Tank House. A melt bell is used to melt the ice in the lake and two progressive cavity pumps transfer the melted water to three water storage tanks located inside the Tank House. Water temperature as it enters the tanks is around 2 – 2.5 deg C (checked by AAD), but as the Tank House is heated, water temperature rises to approximately 18 deg C over time.

From the storage tanks, water is pumped around a ring main to the buildings by a set of pressurising pumps and circulation pumps. The ring main is a combined potable / fire supply line and serves to supply potable water to all cold and hot water taps as well as the fire sprinklers within the buildings. If the fire hydrants / fire sprinkler system is required, the ring main is closed and the fire pumps are activated to meet fire water demand in the opposing direction. A calcite filter and a ceramic filter are installed on the ring main, but does not treat the water within the storage tanks. There is no disinfection provided in Casey.

Materials of construction are:

- Outside Tank House to Melt Bell – copper with HDPE insulation
- Inside Tank House to Water Storage Tanks – copper
- Water Storage Tanks – cast iron with bitumen lining. Bitumen lining has deteriorated and is exposing the cast iron tank to the water. Tank floor was recently grouted with mass repair mortar then sealed with Hydrepoxy (approximately 2013)
- Ring main – HDPE. Flow is continuously circulated.
- From ring main to hot and cold water taps (internal building hydraulics) – copper. Flow is stagnant until someone uses the hot or cold water tap.
- From ring main to fire sprinkler lines – galvanised steel. Flow is stagnant.
- Fire sprinkler lines (in buildings) – PE. Flow is stagnant

1.1.2 Review of Existing Corrosion and Likely Causes

Iron based materials

AAD staff reports extensive corrosion is observed in the three water storage tanks, resulting in a build-up of sludge (iron corrosion products) on the tank floors. The sludge is drawn into the ring main and is potentially fouling the calcite filter, reducing its effectiveness. The sludge is also accumulating in the ring main. Under normal recirculating flow the sludge is relatively undisturbed, but when the fire system is operated (at a higher flow rate and in a reversed direction), this sediment is disturbed and mobilised. Once the ring main is placed back into normal operation, water contaminated with the mobilised sediment is introduced to the point of use.

The corrosion observed in the tanks is believed to be caused by a combination of soft water and microbiologically induced corrosion (MIC). A review of water quality data provided by AAD clearly shows that the water in the tanks is soft with low alkalinity (LSI as low as -5.92 in February 2017 samples). With such soft water, a protective layer of calcium carbonate cannot form on the exposed cast iron surfaces, leaving the natural corrosion process unchecked. In addition, since the water is not disinfected, iron bacteria has proliferated, accelerating the corrosion process due to MIC (confirmed by ALS report).

Other metals

Water quality test results from samples collected during January and February 2017 indicated the presence of metals at some of the sample points. Results indicated that levels of lead and copper exceeded the health guideline values specified in the Australian Drinking Water Guidelines 2011 at three of the test locations. It was suspected that the metals were entering the water supply due to contact with metallic parts of the water storage and pumping system.

Levels of lead and copper exceeding the health guideline values were present in sediment from the bottom of one of the water storage tanks. A level of lead exceeding the health guideline value was present in the station circulating mains water. A level of lead exceeding the health guideline value was present in the washing up sink water outlet in the Red Shed kitchen.

Water samples from all of the other tested locations, including the source water from the melt lake, were within health guideline values.

Copper piping with lead joints is the major source of copper and lead in drinking water. As the melt water is naturally soft, all copper piping in the system exposed to this water is at risk of corrosion, including the copper piping within the Tank House to the storage tanks. Piping with long detention time or stagnant water is the most at risk, such as taps that are rarely used, or the galvanised steel connecting pipe between the HDPE ring main and the PE fire sprinkler main. Review of the October 2017 metals result shows there is a marked increase in copper in the samples taken from the tanks to that from the melt water (0.064 mg/L in Tank 1 vs 0.023 mg/L in the melt water). An even higher copper reading was found in the ring main (1.64 mg/L in EPH_217). From this simple analysis, it would appear that the majority of copper / lead is being contributed by copper piping downstream of the water storage tanks. Even though there is a calcite filter on the ring main, it is unable to correct the corrosiveness of the water (LSI's of the October 2017 samples are still around -2, with the calcite filter apparently only increasing the alkalinity of the water from about 8 mg/L to about 28 mg/L).

1.2 Mawson Station

1.2.1 Understanding of System

The source water at Mawson is similar to that at Casey in that it is also from melting ice, hence, it is equally soft and corrosive. The difference is that the water is passed through a calcite filter before it enters the water storage tanks, whereas in Casey, the calcite filter is only treating the water in the ring main. Otherwise, the water system in Mawson is very similar to that at Casey, in that water is pumped around a ring main by a set of pressurising pumps and circulation pumps from the tanks. The ring main is also a combined potable / fire supply line. This is also no disinfection in Mawson.

The condition of the water storage tanks is also similar to Casey: cast iron with bitumen lining, which is failing, and tank floors have been grouted with mass repair mortar then sealed with Hydrepoxy (this was completed approximately in 2011). All other materials of construction is the same as in Casey.

1.2.2 Review of Existing Corrosion and Likely Causes

Iron based materials

Similar to Casey, AAD staff reports extensive corrosion in the three cast iron water storage tanks, resulting in a build-up of sludge (iron corrosion products) on the tank floors. The sludge is drawn into the ring main by a similar process as in Casey and consequently is suffering from much the same problem.

Having the calcite filter at the inlet to the tank did not appear to correct the corrosiveness of the water. A review of January 2018 water quality data provided by AAD clearly shows that the water within the tanks is still soft and corrosive (LSI is still -3.76 in tank 1 and alkalinity marginally improved to 10 mg/L from 3 mg/L in the raw water sample).

Other metals

Testing during January 2017 found lead levels close to or slightly exceeding the health guidelines in a number of cold water taps. Lead was not detected in samples from the water tanks, site services potable water reticulation, or taps across various other buildings. The test results indicate that the source of this lead is through contact with older pipework which contains traces of lead and is localised to these buildings.

Review of the January 2018 metals result shows high level of nickel in one of the sample site (0.153 mg/L in STR_18).

Again, it would appear that soft water in combination with MIC (due to a lack of disinfection), is the cause of the iron corrosion in the water tanks and leaching of metals from other metallic pipework that contains copper / lead / nickel.

1.3 Davis Station

1.3.1 Understanding of System

Source water for Davis is different to that for Casey and Mawson in that it is from a saline tarn. For this reason, a desalination plant (UF / RO) has been installed to treat this water before it is stored in 2 x 600 kL tanks. These tanks are located outdoor, constructed from steel panels, and have a liner inside that separates the water from the steel panels.

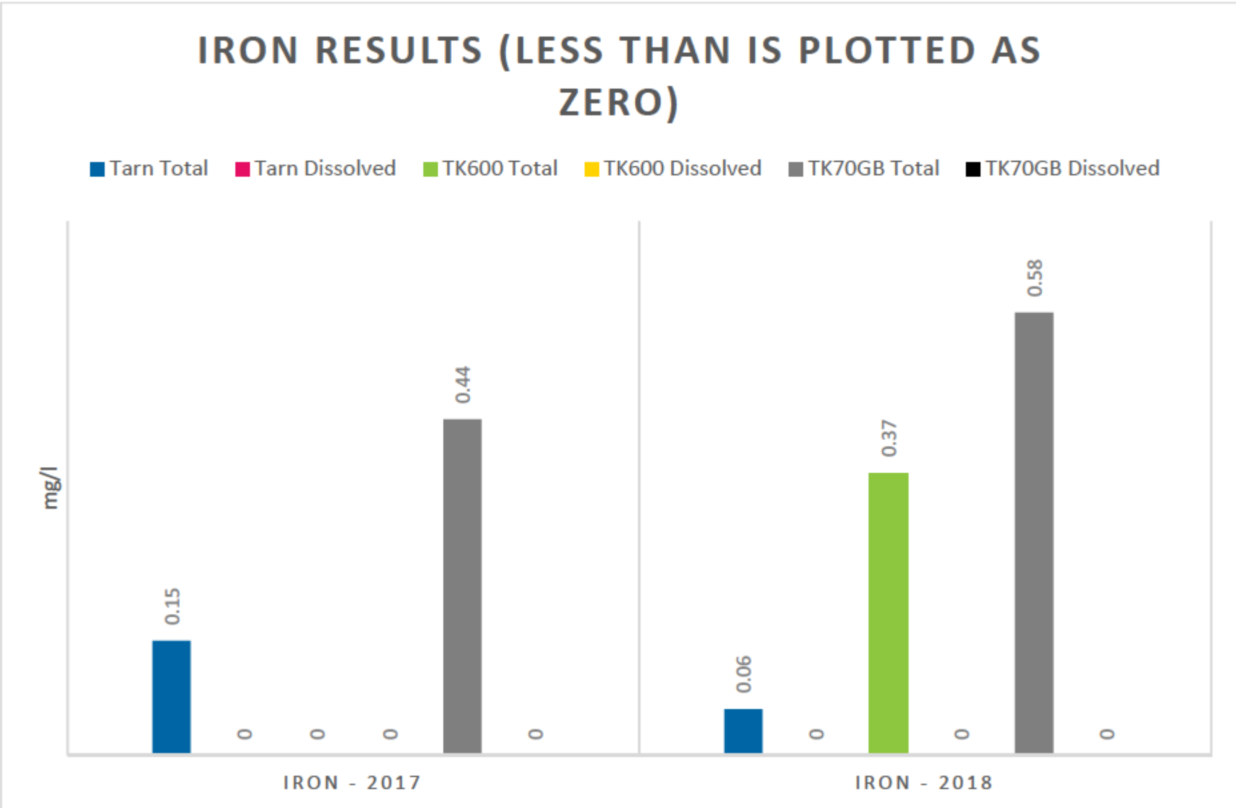
From there, the system configuration is similar to Mawson, in that a calcite filter treats the water before it is transferred to 2x2 service tanks located indoor. These service tanks are of similar construction as for Casey and Mawson, and of similar condition. The tank floors have similarly been repaired with mass repair mortar and sealed with Hydrepoxy, which was completed approximately in 2008.

Another minor difference at Davis, compared to Casey and Mawson, is that a UV disinfection unit has been installed on the circulating ring main. Otherwise, all other system configuration, mode of operation, and materials of construction, are similar to Casey and Mawson.

1.3.2 Review of Existing Corrosion and Likely Causes

Iron based materials

Similar to Casey and Mawson, AAD staff reports extensive corrosion in the cast iron bitumen lined water storage tanks. This corrosion can be illustrated by plotting the iron level in the water through the process from the tarn to the tanks, as shown below, that highlights the dramatic increase in particulate iron in the storage tanks compared to that in the 2x600 kL storage (after the UF/RO treatment). An interesting observation from the chart below, is that there appear to be an accumulation of particulate iron in the 600 kL tanks in 2018 that was absence in 2017. The source of this iron in the 600 kL should be investigated, as it may indicate a possible leak in the internal liners resulting in corrosion of the steel panels.



Review of LSI, alkalinity, and hardness (a measure of calcium) data confirms that the water post RO is corrosive, with low LSI (mostly between -3 to -4), low alkalinity (mostly 7 – 10 mg/L), and low hardness (mostly 20 to 30 mg/L). There is no evidence of the calcite filter adding any significant calcium carbonate to the water, as reflected by the low alkalinity and hardness.

Other metals

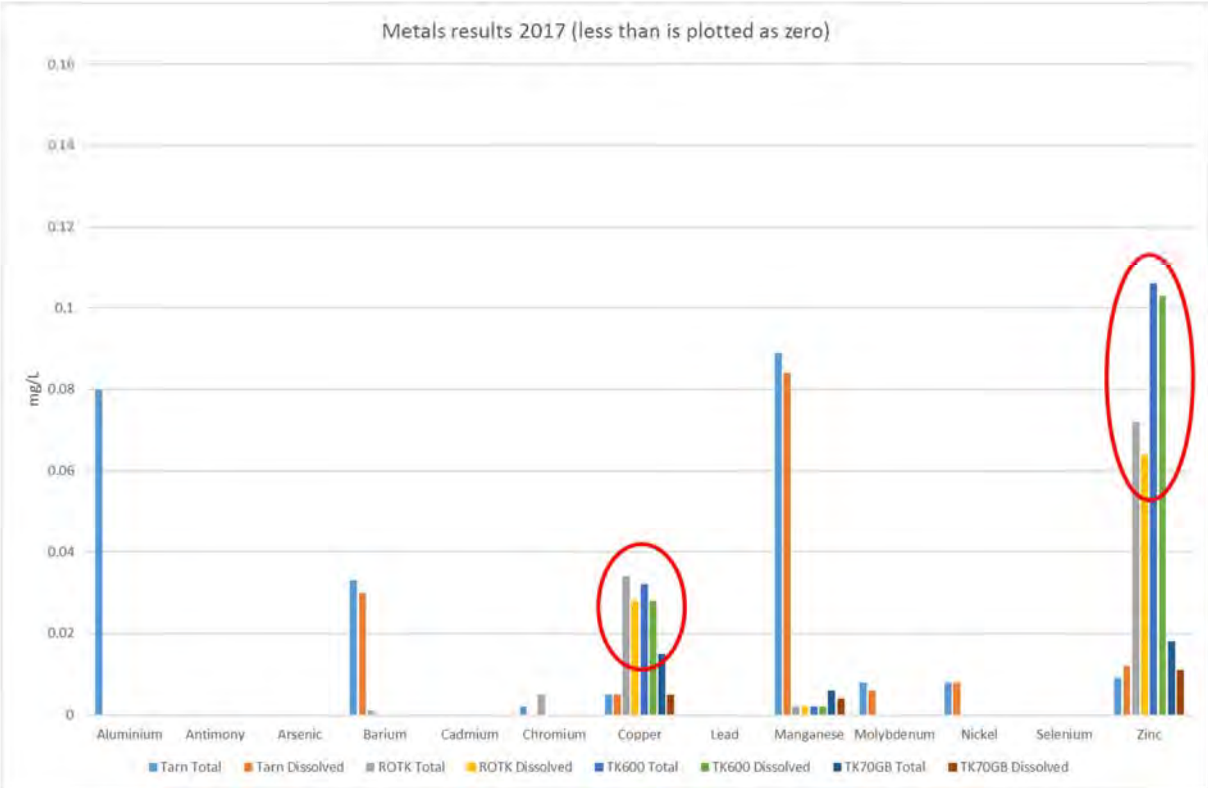
Sampling by AAD in February 2017 and February 2018 found lead, nickel, and mercury marginally above the Australian Drinking Water Guidelines (ADWG) in some of the taps. These results are summarised below.

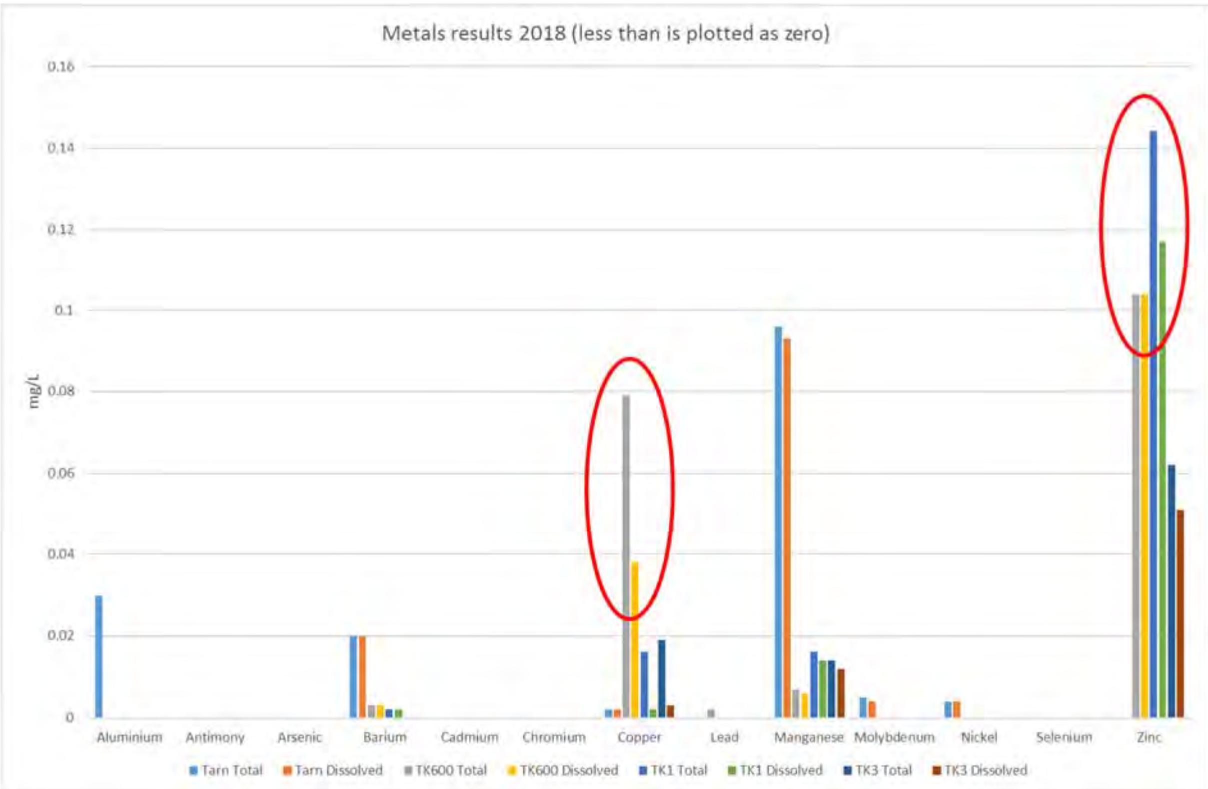
	Lead [mg/L]	Nickel [mg/L]	Mercury [mg/L]
ADWG health guideline value	0.01	0.02	0.001
Location (Feb 2017)			
Main powerhouse sink tap (non-flushed)	0.013	0.191	None detected
Main powerhouse sink tap (after 1 minute flush)	0.003	0.011	None detected
Brewery wash-up sink hot tap (non-flushed)	0.038	0.014	0.0012
Brewery wash-up sink hot tap (after 1 minute flush)	0.025	0.009	0.0011
Location (Feb 2018)			
Sample DVS_SCI_218 (non-flushed)	0.002	0.023	Not available
Sample DVS_SCI_218 (flushed)	0.002	0.005	Not available

AAD believes that, for cold water taps, lead and nickel is being leached from the local plumbing fittings due to the combination of soft water and MIC. In the Sleeping and Medical Quarters, AAD suspects that metals may be present in water from all hot taps and are entering the building's hot water supply due to contact with metallic parts of the hot water heating system.

Analysis of the data by GHD supports the suspicion that the metals are from local plumbing rather than from the tanks or ring main. Metals result from the two sampling periods along the process train from the tarn to the storage tanks are plotted below. These charts show that there is very little (if any) lead in the source water and nickel was below detection after the UF / RO plant.

An interesting observation with the charts below is the increase in copper and zinc following the UF / RO plant, although the levels detected are well below the ADWG. There is insufficient data to determine the source of this increase in copper and zinc.


Metals results 2017 (less than is plotted as zero)
mg/L
0.16
0.14
0.12
0.1
0.08
0.06
0.04
0.02
0
Aluminium
Antimony
Arsenic
Barium
Cadmium
Chromium
Copper
Lead
Manganese
Molybdenum
Nickel
Selenium
Zinc
Tarn Total
Tarn Dissolved
ROTK Total
ROTK Dissolved
TK600 Total
TK600 Dissolved
TK70GB Total
TK70GB Dissolved


Metals results 2018 (less than is plotted as zero)
mg/L
0.16
0.14
0.12
0.1
0.08
0.06
0.04
0.02
0
Aluminium
Antimony
Arsenic
Barium
Cadmium
Chromium
Copper
Lead
Manganese
Molybdenum
Nickel
Selenium
Zinc
Tarn Total
Tarn Dissolved
TK600 Total
TK600 Dissolved
TK1 Total
TK1 Dissolved
TK3 Total
TK3 Dissolved

2 Review of Existing Calcite Filters

A review of the water quality data (LSI, alkalinity, hardness) has shown that the existing calcite filters are ineffective in correcting the corrosive nature of the natural melt water in Casey and Mawson, and RO treated water in Davis. The location of the calcite filter in Casey is also not ideal, as it does not provide any protection for the storage tanks from the corrosive water.

Calcite is a stable mineral of calcium carbonate that is found in abundance in limestones, dolomites, and marbles. Its abundance and stable nature makes it an ideal alkali chemical for water treatment in remote communities. When dissolved in water, calcite adds calcium and carbonate ions that adds both hardness and alkalinity. When sufficient hardness and alkalinity has been added to water, it is said to be “stable” (the alkalinity creates a buffer that resist pH changes) and “non-corrosive” (the water is able to deposit a layer of calcium carbonate on metal surfaces that protects or slow down the natural rate of corrosion and does not tend to leach calcium ion from cement surfaces). For this reason, calcite filters have found applications in correcting corrosive water from desalination plants and other soft waters.

However, the rate of dissolution of calcite is affected by many factors, including:

- The amount of calcite contained in the media used to fill the calcite filter. A media with the highest calcite content will have the highest rate of dissolution.
- The purity of the calcite. Impurities such as aluminium, silica, and iron have found to retard the dissolution rate of calcite by forming a residual layer on the media surface as the calcite is dissolved.
- Surface area of the media. A greater surface area that is in contact with the water will permit a greater rate of dissolution of calcite from the media. Hence, dissolution rate can be affected by the size of the media, its shape and its porosity.
- Water temperature. The colder the water temperature, the slower the dissolution rate.

For the calcite filters installed at Casey, Mawson and Davis to be successful, they must retain the water long enough to match the dissolution rate of the calcite, such that sufficient hardness and alkalinity can be added to the water (preferably) in a single pass. This may require very large (or a series of smaller) filters at the stations. Alternatively, hydrated lime (calcium hydroxide) can provide a much faster reaction, but needs to be combined with carbon dioxide to provide both hardness and carbonate alkalinity.

At Casey, additional treatment of the corrosive water in the storage tanks is required. Solution may include:

- Additional calcite filter on the inlet to the tanks.
- Incorporate the tanks in the circulation loop so the water is treated by the existing calcite filter on the ring main.

3 Proposed Actions for Stage 2 and 3

The following scope of works is therefore envisaged for Stage 2 and 3.

Stage 2:

- Confirm with AAD our initial understanding of the problems and causes as described above. Conduct additional investigation if necessary.
- Review sizes and location of calcite filters at each station to optimise treatment effectiveness.
- Investigate alternative chemicals to calcite for hardness and alkalinity addition, if necessary.
- Confirm most appropriate type of treatment for stabilising the water and reducing their corrosiveness.
- Investigate and recommend options for disinfection to control MIC. Common disinfection options are sodium hypochlorite, calcium hypochlorite, UV, ozone, chlorine gas.
- Meeting with AAD in Kingston to finalise short and long term solutions (may require replacement of storage tanks, metallic piping, etc, in the long term).
- Prepare draft and final Investigation and Concept Design Report for each station.

Stage 3:

- Prepare separate Functional Specification for each station, to facilitate procurement of a system as identified in concept in Stage 2.
- Prepare a shortlist of nominated suppliers to assist the AAD in approaching the market.

Our program for completing these tasks is attached. The meeting with AAD in Kingston has been scheduled for the 23 August.

4 Lump Sum Fee for Stage 2 and 3

To complete the tasks as listed above, we estimate the following efforts are required:

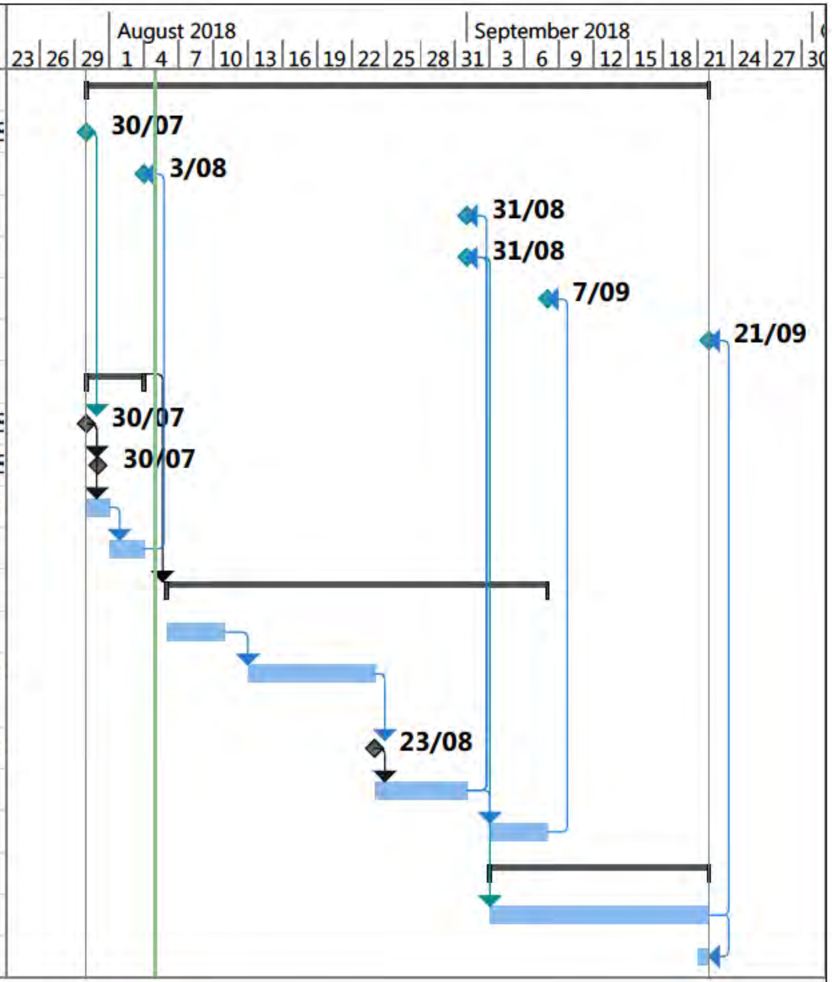
- Calvin Lai – 70 hours (including face-to-face meeting with AAD in Kingston – assume one day only)
- Dorota Wandolowska – 200 hours
- Equivalent fee - s47G(1)(a)(inclusive of GST).

We are happy to offer this as a lump sum plus travel expenses.

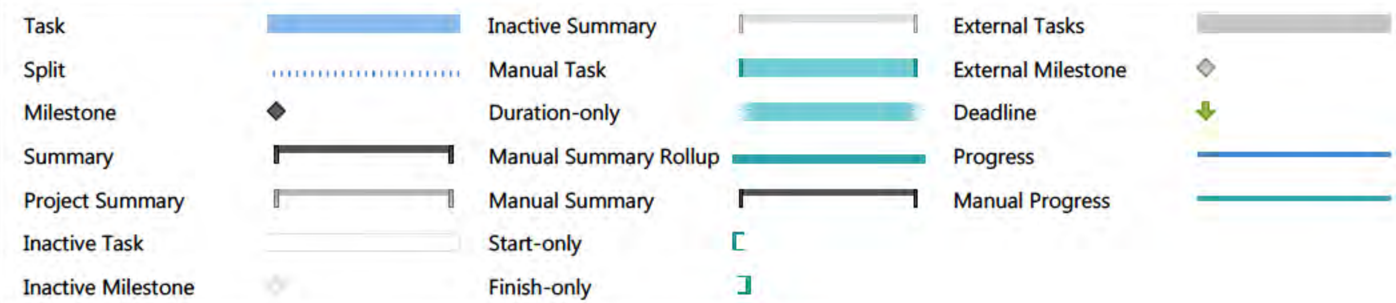
Additional work under this project can be conducted at the rates in the Standing Offer, that is:

Name	**Classification**	**Hourly rate (inclusive of GST)**
Calvin Lai	Principal Professional 2	s47G(1)(a)
Dorota Wandolowska	Professional 3	s47G(1)(a)

ID	Task Name	Duration	Start	Finish
1	**Project Milestones**	**40 days**	**Mon 30/07/18**	**Fri 21/09/18**
2	Project commence	0 days	Mon 30/07/18	Mon 30/07/18
3	Preliminary review and submit LS for Stage 2	0 days	Fri 3/08/18	Fri 3/08/18
4	Delivery and presentation of draft options reports	0 days	Fri 31/08/18	Fri 31/08/18
5	AAD advises preferred option	0 days	Fri 31/08/18	Fri 31/08/18
6	Delivery of final options reports	0 days	Fri 7/09/18	Fri 7/09/18
7	Delivery of functional specification	0 days	Fri 21/09/18	Fri 21/09/18
8	**Stage 1**	**5 days**	**Mon 30/07/18**	**Fri 3/08/18**
9	Initial kick off meeting	0 days	Mon 30/07/18	Mon 30/07/18
10	Detail P&ID review meeting	0 days	Mon 30/07/18	Mon 30/07/18
11	Initial desktop review of data	2 days	Mon 30/07/18	Tue 31/07/18
12	Submit initial review and LS for stage 2	3 days	Wed 1/08/18	Fri 3/08/18
13	**Stage 2**	**25 days**	**Mon 6/08/18**	**Fri 7/09/18**
14	Confirm causes of corrosion issues	1 wk	Mon 6/08/18	Fri 10/08/18
15	Review treatment options for stabilisation and disinfection	9 days	Mon 13/08/18	Thu 23/08/18
16	Meeting with AAD in Kingston	0 days	Thu 23/08/18	Thu 23/08/18
17	Prepare draft options reports	6 days	Fri 24/08/18	Fri 31/08/18
18	Prepare final option reports	1 wk	Mon 3/09/18	Fri 7/09/18
19	**Stage 3**	**15 days**	**Mon 3/09/18**	**Fri 21/09/18**
20	Functional Specification	3 wks	Mon 3/09/18	Fri 21/09/18
21	Shortlist of nominated suppliers	1 day	Fri 21/09/18	Fri 21/09/18



Project: Project timeline
Date: Sun 5/08/18



FOI 190204
Document 2

Department of the Environment and Energy
Australian Antarctic Division

Potable Water Treatment Strategy
Casey Station

February 2019

Executive summary

The Department of the Environment and Energy, Australian Antarctic Division (AAD) is responsible for providing safe potable water supply to expeditioners working and living at Casey station in Antarctica. The AAD have engaged GHD to;

- review water quality test results that previously have indicated the presence of metals exceeding health guideline values,
- identify problems in the water supply systems, and
- provide advice on options for solving and/or managing these problems.

The review of the water supply infrastructure and water quality at Casey station has indicated that corrosion observed in the potable water storage tanks is most likely caused by a combination of soft water and microbiologically induced corrosion (MIC). This corrosion and iron-rich sediment build-up in the storage tanks is a major source of iron and suspended solids contamination in the water supply system. Exposure of copper piping (and possible lead joints) to the naturally soft and corrosive melt water is a major source of copper and lead contamination in the drinking water.

To correct the corrosiveness of Casey's water, calcium and alkalinity must be added. The microbiologically induced corrosion (MIC) also needs to be addressed, with key contributing factors including a lack of a persistent disinfectant, warm water, presence of organic carbon, and stagnant flow. Thirdly, dirty water events that have occurred at Casey are attributed to iron corrosion products in the storage tanks being drawn into the ring main (as well as biofilms being dislodged) by the high flows generated when exercising the fire water pumps.

Measures explored to address each of the above-mentioned water quality issues included:

- pH and alkalinity adjustment through chemical dosing
- Disinfection of the water supply to prevent bacteria and biofilm (and hence MIC)
- Filtration to remove suspended solids (as a result of corroding tanks and pipework) from the water supply

GHD investigated a short term and a long term solution to the water quality issues at Casey station. The suggested short term solution includes:

- Remove all iron corrosion products from existing storage tanks
- Minimise further corrosion in existing storage tanks through pH/alkalinity adjustment
- Remove all corrosion products / biofilm from existing pipes (scour and flush)
- Provide filtration to minimise future dirty water events
- Add a persistent disinfectant to control future biofilm growth (chlorinated water supply)
- Deal with stagnant sections of pipe (flush before use policy)

However, GHD's conclusions and recommendations from this investigation is for the AAD to focus on the Long Term Solution now. That is; replace the corroding water storage tanks, scour and flush the pipework, and fast-track replacement of metallic pipework with non-metallic plumbing as much as practicable. This should avoid the need for pH and alkalinity correction, as there will be minimal exposed metal in the system and hence no corrosion. Removal of corrosion by-products from the system should negate the need for filtration, as the source water is naturally low in sediment. Implementation of a long-term disinfection solution is recommended. However, this would only be for biofilm control and not for primary health considerations.

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1. Introduction

1.1 Purpose of this report

The Department of the Environment and Energy, Australian Antarctic Division (AAD) is responsible for providing safe potable water supply to communities working and living on its Antarctic stations at Casey, Davis and Mawson. As the water supply at each of the stations are low in mineral content, hardness and alkalinity, AAD staff have reported extensive corrosion in the steel pipes and storage systems at all three stations. Furthermore, water quality test results indicate the presence of metals at some of the sample points, where levels of lead and copper exceeded the health guideline values specified in the Australian Drinking Water Guidelines (2011).

AAD have engaged GHD to review these test results, identify problems in the water supply systems, and provide advice on options for solving and/or managing these problems.

This report for Casey Station summarises the findings of a Stage 1 desktop review of the test results and existing water supply system, options available to solve or manage the problems identified, and provide concept sizing of the recommended solution.

1.2 Scope and limitations

This report has been prepared by GHD for the Department of the Environment and Energy, Australian Antarctic Division (the Client), and may only be used and relied on by Department of the Environment and Energy for the purpose agreed between GHD and the Client as set out in Section 1.1 of this report. GHD otherwise disclaims responsibility to any person other than the Client arising in connection with this report. GHD also excludes implied warranties and conditions, to the extent legally permissible.

The services undertaken by GHD in connection with preparing this report were limited to those specifically detailed in the report and are subject to the scope limitations set out in the report.

The opinions, conclusions and any recommendations in this report are based on conditions encountered and information reviewed at the date of preparation of the report. GHD has no responsibility or obligation to update this report to account for events or changes occurring subsequent to the date that the report was prepared.

GHD has prepared this report on the basis of information provided by the Client, which GHD has not independently verified or checked beyond the agreed scope of work. GHD does not accept liability in connection with such unverified information, including errors and omissions in the report which were caused by errors or omissions in that information.

The opinions, conclusions and any recommendations in this report are also based on assumptions made by GHD described in Section 1.3 of this report. GHD disclaims liability arising from any of the assumptions being incorrect.

1.3 Assumptions

GHD has not had the opportunity to attend site to visually inspect and validate information provided about the existing water supply system, or to understand potential site constraints for mitigation solutions GHD has suggested and recommended. GHD relies on AAD staff to validate our understanding of the system and our interpretation of the data provided, and that AAD will assess site condition (space, electrical infrastructure, constructability, etc) and inform GHD if they believe site condition prohibits GHD's recommended solution or result in severe OH&S issues.

2. Existing system overview

2.1 Existing water supply infrastructure

Drinking water for Casey Station is sourced from a lake located behind the Tank House. A melt bell is used to melt the ice in the lake and a progressive cavity pump transfers the melted water to three water storage tanks located inside the Tank House. Water temperature as it enters the tanks is around 2 – 2.5 degrees C, but as the Tank House is heated, water temperature rises to approximately 18 degrees C over time.

Each water storage tank has a capacity of 90 kL and thus a total capacity of 270 kL can be stored within these tanks. All three tanks are plumbed alike, in that each tank has a high level potable water outlet and a low level fire water outlet. The high level potable water outlets allow for approximately 1/3 of tank volume in each tank to be used as potable water. The low level outlets are to access the remaining approximate 2/3 of water volume in each tank, ensuring a dedicated minimum fire water storage is available at all times.

From the storage tanks, water is pumped around a ring main to the buildings by a set of pressurising pumps and circulation pumps. The ring main is a combined potable / fire supply line and serves to supply potable water to all cold and hot water taps as well as the fire sprinklers within the buildings. If the fire hydrants / fire sprinkler system is required, the ring main is closed and the fire pumps are activated to meet fire water demand in the opposing direction. A calcite filter and a ceramic filter are installed on the ring main, but does not treat the water within the storage tanks. A bag filter is installed between the tanks and the ring main. There is no disinfection provided in the Casey potable water supply.

Materials of construction of the major infrastructure are:

- Outside Tank House to Melt Bell – HDPE with galvanised steel casing
- Inside Tank House to Water Storage Tanks – copper
- Water Storage Tanks – cast iron with bitumen lining. Bitumen lining has deteriorated and is exposing the cast iron tank to the water. Tank floor was recently grouted with mass repair mortar then sealed with Hydrepoxy (approximately 2013)
- Ring main – HDPE. Flow is continuously circulated.
- From ring main to hot and cold water taps (internal building hydraulics) – copper. Flow is stagnant until someone uses the hot or cold water tap.
- From ring main to fire sprinkler lines – copper to alarm valve, then galvanised steel. Flow is stagnant.
- Fire sprinkler lines (in buildings) – steel (unsure if galvanised or not). Flow is stagnant

A schematic diagram of Casey's water supply system is provided in Appendix A.

2.2 Water demands

The Casey Station is home for up to 95 expeditioners and scientists over the summer months and about 25 expeditioners over the long winter months.

The summer months are spent pumping the lower melt lake in order to maintain storages to service the expanded summer population. At times of peak demand, water may be pumped from the upper melt lake, transferred into either the lower melt lake or directly into the internal 90 kL storage tanks. During winter, whilst the population is smaller, pumping continues on a daily basis.

AAD estimates the annual water consumption at Casey to be approximately 3 ML. Summer demand averages about 70 to 80 kL per week, with a peak day of about 15 kL. Winter demand averages about 35 to 40 kL per week, with a peak day of about 8 kL. Most of the usage is understood to be in the kitchen, laundry (on weekends), and evening showers.

2.3 Review of water quality

2.3.1 Iron

AAD staff reports extensive corrosion is observed in the three water storage tanks, resulting in a build-up of sludge (iron corrosion products) on the tank floors. The sludge is drawn into the ring main and is potentially fouling the calcite filter, reducing its effectiveness. The sludge is also accumulating in the ring main. Under normal recirculating flow the sludge is relatively undisturbed, but when the fire system is operated (at a higher flow rate and in a reversed direction), this sediment is disturbed and mobilised. Once the ring main is placed back into normal operation, water contaminated with the mobilised sediment is introduced to the point of use.

The corrosion observed in the tanks is believed to be caused by a combination of soft water and microbiologically induced corrosion (MIC). A review of water quality data provided by AAD clearly shows that the water in the tanks is soft with low alkalinity (LSI as low as -5.92 in February 2017 samples). With such soft water, a protective layer of calcium carbonate cannot form on the exposed cast iron surfaces, leaving the natural corrosion process unchecked. In addition, since the water is not disinfected, iron bacteria has proliferated, accelerating the corrosion process due to MIC (inferred from findings at Davis Station - ALS Report No. 62408-1-1Eng, 10 July 2018).

2.3.2 Other metals

Water quality test results from samples collected during January and February 2017 indicated the presence of metals at some of the sample points. Results indicated that levels of lead and copper exceeded the health guideline values specified in the Australian Drinking Water Guidelines (2011) at three of the test locations. It was suspected that the metals were entering the water supply due to contact with metallic parts of the water storage and pumping system.

Levels of lead and copper exceeding the health guideline values were present in sediment from the bottom of one of the water storage tanks. A level of lead exceeding the health guideline value was present in the station circulating mains water. A level of lead exceeding the health guideline value was present in the washing up sink water outlet in the Red Shed kitchen.

Water samples from all of the other tested locations, including the source water from the melt lake, were within health guideline values.

Copper piping and possible lead joints is the major source of copper and lead in drinking water. As the melt water is naturally soft, all copper piping in the system exposed to this water is at risk of corrosion, including the copper piping within the Tank House to the storage tanks. Piping with long detention time or stagnant water is the most at risk, such as taps that are rarely used, or the copper / galvanised steel connecting pipe between the HDPE ring main and the fire sprinkler main. Review of the October 2017 metals result shows there is a marked increase in copper in the samples taken from the tanks to that from the melt water (0.064 mg/L in Tank 1 vs 0.023 mg/L in the melt water). An even higher copper reading was found in a branch line and associated tap at a trough in the Emergency Power House (1.64 mg/L in EPH_217). From this simple analysis, it would appear that the majority of copper / lead is being contributed by copper piping downstream of the water storage tanks. Even though there is a calcite filter on the ring main, it is unable to correct the corrosiveness of the water (LSI’s of the October 2017 samples are still around -2, with the calcite filter apparently only increasing the alkalinity of the water from about 8 mg/L to about 28 mg/L).

2.3.3 Other water quality risks

A potential water quality issue associated with pink snow algae detected in the melt lake in summer 2017 was identified in the Drinking Water Quality Management Plan dated 27 July 2018. The propensity for this algae to bloom, the condition that would trigger it, and the possible impacts including toxins production, are currently being investigated. This water quality risk has not been considered in this water treatment strategy report.

3. Causes and mitigation options

3.1 Corrosive water

Metals, when submerged in freshwater, can suffer from several types of corrosion (i.e. seawater related chloride corrosion is not considered here). Uniform corrosion can occur when there are dissimilar metals in contact with each other, such as when copper piping is connected to mild steel. Pitting, or concentration cell corrosion, can occur when the oxygen concentration near a pipe wall is different to the bulk water, such as under deposits.

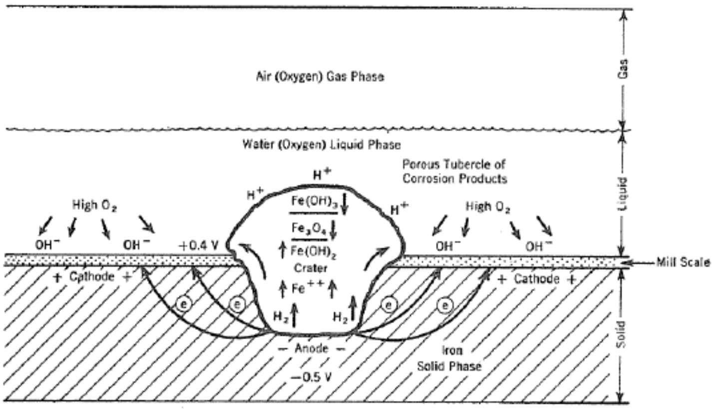


Figure 1 Pitting of iron by tuberculation and oxygen concentration cells (by Obrecht and Pourbaix)

Figure 1 shows pitting of iron and formation of tuberculation due to oxygen concentration cell and this appear to be the principal corrosion mechanism occurring in the storage tanks at Casey based on previous reports and discussions with AAD.

Freshwater can help slow this form of corrosion (but not uniform corrosion due to dissimilar metals) by depositing a layer of calcium carbonate on the metal surface. However, the source of water at Casey, being from melting ice, is too low in calcium and alkalinity to deposit a protective calcium carbonate film to slow the natural corrosion of exposed metals. Such water is termed corrosive water.

In contact with concrete material, freshwater with low calcium content also has a tendency to leach calcium from the cement, weakening their structure. Fortunately, the grouting of the tank floor was sealed with a protective epoxy, protecting the repaired tank floor from the effect of the corrosive water.

To correct the corrosiveness of Casey's water, calcium and alkalinity must be added such that the water has a tendency to deposit calcium carbonate. This tendency for deposition of calcium carbonate can be measured by the Langelier Saturation Index (LSI) of the water. A positive LSI indicates a propensity to deposit calcium carbonate, while a negative LSI indicates a tendency to leach calcium from cement. At LSI equal to zero, the water is said to be saturated with respect to calcium carbonate and is neither corrosive nor scaling. As excessively high LSI can mean excessive scaling of pipes and appurtenances by calcium deposit, typical target is a LSI of between -0.3 and +0.3.

Common chemicals used that can add calcium and/or alkalinity are compared in Table 1 below.

Table 1 Chemicals for addition of Calcium / Alkalinity

Chemical	Advantages	Disadvantages
Calcite ($CaCO_3$)	Stable natural chemical, simple to use, suitable for small and remote sites. Adds both calcium and carbonate alkalinity. Difficult to overdose.	Slow dissolving, particularly in cold water.
Hydrated lime (CaOH)	Faster reaction	Difficult to handle. Adds impurity. Only adds calcium but no carbonate alkalinity. Typically used in conjunction with carbon dioxide

Chemical	Advantages	Disadvantages
		to add carbonate alkalinity which adds complexity to the system (i.e. liquid CO_2 in pressurized tanks).
Calcium chloride (CaCl)	Easy to handle and dissolves quickly.	Only adds calcium but no carbonate alkalinity.
Soda ash ($NaHCO_3$)	Reacts quickly	Only adds carbonate alkalinity but not calcium.

Hydrated lime is a commonly used chemical in water treatment for pH adjustment and addition of calcium. However, it has significant handling issues including being hydroscopic, is dusty, and causes scaling in dosing equipment and dosing lines that requires significant maintenance to maintain operations.

Adding both calcium chloride and soda ash is a possible solution to add both calcium and carbonate alkalinity to the water, however, the use of two chemicals increases the cost of chemicals significantly.

Only calcite can add both calcium and carbonate in a simple filter arrangement. The chemical is stable and is easy to handle. Calcite is therefore the recommended chemical to address the corrosiveness of the water at Casey.

AAD should note that by adding sufficient calcite to reach a target LSI of between -0.3 and +0.3 would raise the water pH to between 9 and 10. Water with high pH may have an unpleasant taste, and the high pH can also impart a soapy feel to the water. Fish placed in high pH water can also be affected adversely (e.g. if fish tanks were being maintained at the station). To avoid high pH water, carbon dioxide would need to be added to lower the pH without removing the carbonate alkalinity added by the calcite. However, this would add complexity to the system, and is not recommended, noting that the existing system is already adding calcite without pH correction.

The use of corrosion inhibitors such as inorganic phosphates or sodium silicates was also considered but discarded. This is because care must be taken with the use of such chemicals since they are added to the water and are therefore consumed together with the drinking water. Dosage of such chemicals therefore must be carefully controlled to avoid over-dosing, and the chemical must be sourced from reputable manufacturers who can demonstrate compliance with relevant standards for chemicals used in drinking water treatment. The cost of such chemical is typically higher than calcite, and moreover, the use of phosphate based corrosion inhibitors would result in an increase in phosphate load to the on-site wastewater treatment system.

3.2 Microbiologically induced corrosion

Microbial action can sometime accelerate the rate of natural corrosion that occurs in water systems. The mechanism of such microbiologically induced corrosion (MIC) is not well understood, but contributing factors include a lack of a persistent disinfectant, warm water, presence of organic carbon, and stagnant flow.

The water supply system at Casey has many of the contributing factors listed above, such as a lack of disinfection and stagnant flow where biofilm can proliferate over time. Biofilm are complex structures that once formed cannot be removed by disinfectant level normally found in drinking water. Therefore, the biofilm that has formed must first be removed (e.g. by scouring and superchlorination) and a persistent disinfectant added to the water to moderate their growth to minimise future risk of MIC and biofilm related dirty water events.

Common disinfection options are compared in Table 2 below.

Table 2 Disinfection options

Option	Advantages	Disadvantages
Ultraviolet light (UV)	UV systems require relatively low maintenance and do not require the addition of chemicals.	High doses of UV is required for bacteria and does not provide a disinfection residual.
Ozone	A strong disinfectant that is effective against most microbial.	Specialised equipment is required to generate ozone on site (ozone cannot be stored). Ozone does not provide a disinfection residual, and the gas is pungent and can be dangerous.
Chlorine gas	A strong disinfectant that is effective against bacteria and viruses.	Specialised equipment is required handle the gas. Chlorine gas is dangerous
Sodium hypochlorite (liquid)	Easy to handle and use. 12% sodium hypochlorite is relatively safe.	Relatively short shelf life. Degrades to form chlorite ion, which is undesirable in drinking water.
Sodium hypochlorite (on-site generation)	A weak, 0.8% sodium hypochlorite is generated on site from high quality salt and electricity. Resolves degradation issues associated with 12% sodium hypochlorite. Only need to transport and store potable grade salt.	Relatively more maintenance compared to 12% sodium hypochlorite or calcium hypochlorite option due to maintenance of the electrolytic cells.
Calcium hypochlorite (solid)	Easy to handle and use. Available as dry briquettes with long shelf life.	Slow dissolving.

To effectively manage the risk of MIC, an option that provides a persistent disinfectant in the water is necessary. UV and ozone are both ruled out on this basis. Chlorine gas is a dangerous gas and 12% sodium hypochlorite has a short shelf life. Both are not suitable for a simple system in a remote location. The water quality issue associated with degradation of 12% sodium hypochlorite can be resolved with an on-site generation system, which can generate 0.8% sodium hypochlorite on demand, or the use of a calcium hypochlorite tablet system. An on-site generation system requires slightly more maintenance than a calcium hypochlorite system due to the need to maintain the specialised electrolytic cells that are the heart of an on-site generation system, whereas the calcium hypochlorite involves simple dosing pumps only that are simple to maintain. Calcium hypochlorite is therefore recommended (chemical datasheet is provided in Appendix B).

The provision of a persistent disinfectant is expected to be effective for controlling MIC in the main recirculating loop where flow is continuous. However, in stagnant lines, such as those servicing taps that are rarely used, the disinfectant would lose its effect over time and biofilm would again take hold. The only mitigation for possible dissolved heavy metals in these taps served by stagnant lines is to implement a “flush before use” policy at the station.

3.3 Dirty water events

It is understood that dirty water events that have occurred were due to iron corrosion products in the storage tanks being drawn into the ring main as well as biofilms in the ring main being dislodged by the high flows generated when exercising the fire water pumps.

Biofilms, as discussed in Section 3.2 above, must first be removed and a persistent disinfectant added to the water to moderate their future growth. This should address future dirty water events caused by a build-up of biofilms in the ring main.

In term of iron corrosion products, AAD advised that, due to the confined space nature and multiple cross-bracing design of the existing storage tanks, it would be unsafe and impractical to sand-blast their interior to remove all existing iron corrosion and tubercules and prevent future corrosion by epoxy coating the interior. AAD has already made provisions to replace the storage tanks in the near future.

GHD recommends that the future tanks be constructed from corrosion resistant materials, such as epoxy coated concrete or steel panels, glass-fused to steel panels, or fibreglass. An alternative option for corrosion resistant tanks is to look to plastic tanks or framed water bladder tanks. As these essentially have no exposed metal components, they will not corrode. They can be supplied as food grade and ae reasonably temperature resistant (both hot and cold) upon selection of the appropriate materials of construction. Whilst the plastic and bladder style tanks would be expected to be substantially cheaper to purchase, they will not necessarily have the same expected service life as for glass-fused steel or fibreglass. Hence cost of replacement would need to be factored in. As mentioned previously, the suitability of the materials of construction for transportation, both from an extreme cold and wear and tear perspective, would need to be considered.

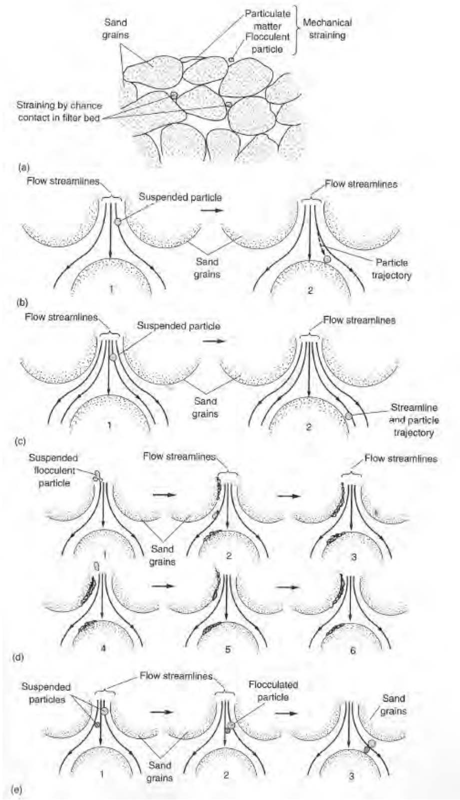


Figure 2 Depth filtration mechanism (by Metcalf & Eddy)

In the short term, corrosion of the existing tanks is expected to continue, and a method to remove the iron corrosion products from the water is required to minimise the risk of future dirty water events associated with operations of the fire water pumps.

Existing mitigations implemented includes the use of bag filters (5 micron), a JPF screen filter, and point-of-use cartridge filters (5 micron). These filters are not appropriate technologies for this application because they operate as “strainers”, which are effective only if the particle size being removed is larger than the openings of the filters. As the iron corrosion products are very fine, and there is no chemical being added to coagulate them to form larger particles, the iron corrosion products would simply pass through the filters under pressure.

GHD recommends the use of granular media filters (e.g sand filters) for this duty. This is because granular media filters operate in “depth” filtration mode where particles are trapped within the interstices of the granular media via various mechanisms that are not dependent on size. Some of these removal mechanisms within a granular media filter are straining, sedimentation, interception, adhesion, and by flocculation as shown in Figure 2. The use of granular media filters is expected to perform better than the existing strainer type filters and these existing filters can be removed from service. The down side of granular media filtration is the filters do require periodic backwashing to maintain filtration capacity and performance. The disposal of the backwash water would need to be considered in the process augmentation.

Size and arrangement of the recommended granular media filters are discussed in Section 4.2 below.

It is possible to source cartridge filters with smaller nominal micron removal ratings. These can be sourced either as melt blown polypropylene, pleated cartridges either manufactured from polypropylene or a mixture of thermally bonded microglass fibers and cellulose infused with ceramic. These filters also operate (to a lesser extent than granular media) as a form of depth filtration. The benefit of these is the simplicity of their operation, change-out instead of backwashing requirement and the AAD staff familiarity with the existing bag and cartridge filter operation. The negatives of this option is the change-out cost of these particular cartridge filters, which can be of the order of $700 and upwards per cartridge. They may not be able to reliably filter to the same micron level (e.g. less than 0.5 micron) as granular media is able to do.

3.4 Short term management solution

In summary, the following short term management solution is recommended.

Table 3 Short term management solution

Steps	Recommendations	Comments
1. Remove all iron corrosion products from existing storage tanks	• Pressure clean with high pressure cleaner	• Removing all corrosion product from the tanks will minimise future dirty water events.
2. Minimise further corrosion in existing storage tanks	• Correct LSI of stored water with calcite	• Refer to Section 4.1 for configuration options and Section 4.3 for sizing of calcite filter.
3. Remove all corrosion products / biofilm from existing pipes	• Flushing and pigging • Superchlorination	• Removing all corrosion products / slimes from pipes will minimise future dirty water events. • There may be a period of dirty water events after the clean as new slimes are establish and dead slimes are removed.
4. Provide filtration to minimise future dirty water events	• Granular media filters are recommended, as the most robust option.	• Refer to Section 4.2 for sizing.
5. Add a persistent disinfectant to control future biofilm growth	• Calcium hypochlorite dosing	• Refer to Section 4.4 for sizing
6. Dealing with stagnant sections of pipe	• Implement a “flush before use” policy at rarely used taps	• Stagnant sections of pipe will remain at risk of MIC. • Flush before use will minimise potential exposure to heavy metals from the drinking water.

3.5 Long term solution

In the longer term, it is understood that AAD plans to replace the existing cast iron storage tanks. GHD recommends that the future tanks be constructed from corrosion resistant materials, such as epoxy coated concrete or steel panels, glass-fused to steel panels, fibreglass, or possibly food grade HDPE or framed bladder tanks using flexible polymer materials. The suitability of the material for the extreme temperatures of Antarctica during transportation and operations must also be confirmed. Additionally, copper piping, which are potential source of copper and lead in the water, could be replaced with non-metallic materials as the opportunity arises.

Once the water network becomes largely non-metallic, the need for continuous calcite and granular media filters could be re-assessed. The dosing of a persistent disinfectant could also be reduced or ceased, but would need to be balanced against the need to control biofilm, which could still give rise to dirty water events if build-up becomes excessive.

Table 4 long term solution

Steps	Recommendation	Comments
1. Replace cast iron storage tanks with corrosion resistant tanks	• Common options are glass lined steel panel tanks, steel or concrete tanks with epoxy coating, FRP, HDPE. • Choice of material must also be suitable for the extreme temperature that could be encountered during transport to Antarctica.	• Epoxy coating will have limited life and will require re-coating in the future. • If concrete tank without epoxy coating is used, will need to ensure the LSI of the stored water is not corrosive to the concrete.
2. Replace stagnant sections of pipes with non-metallic materials such as HDPE.	• Any non-metallic plumbing must meet the latest requirements of the Building Code of Australia.	• Replacement of stagnant sections of pipe with non-metallic material will remove the risk of potential exposure to heavy metals from the drinking water.
3. Periodic flushing of pipes	• Flushing and pigging • Superchlorination	• Periodic removal of slimes from pipes may still be required to prevent dirty water events. • There may be a period of dirty water events after the clean as new slimes are establish and dead slimes are removed.

4. Treatment configuration and sizing

The preceding sections confirmed the need in the short term to:

- Correct the corrosive nature of the water stored in the water tanks by the use of a calcite filter,
- Filter the water to remove iron corrosion products by the use of granular media filters, and
- Dose calcium hypochlorite into the water to control the growth of biofilm.

This section describes the configuration options and the sizing of major equipment.

4.1 Treatment configuration options

Three alternative treatment configurations were considered for Casey:

1. Provide calcite filter on the inlet to the water storage tanks.
2. Provide calcite filter on a recirculating loop from the existing ring main back to the water storage tanks.
3. Provide calcite filter on a new recirculating loop from the suction main of the fire supply pumps back to the water storage tanks.

Option 1 was eliminated because the water from the melt bell is still very cold (2 – 2.5 deg C) and this would have an adverse affect on the performance of the calcite filter (dissolution rate would be very slow). Compounding this problem is that a calcite filter on the inlet treats the incoming water once only, which means a very large calcite filter is necessary to provide the required contact time to overcome the slow dissolution rate and correct the corrosiveness of the water.

Option 2 and 3 has the calcite filter on a recirculating loop downstream of the water storage tanks. In this configuration, not only is the water temperature higher due to detention in the tanks, but the recirculating loop means that the calcite would have multiple opportunities to treat the water, eventually reaching calcium carbonate saturation (i.e. LSI = 0). Such multi-pass calcite treatment is therefore recommended.

In Option 2, an analysis of the existing system was conducted to assess the capacity of the existing pressuring pump to supply the flow of the recirculating loop. Figure 4 below is a plot of the pressure pump's (LOWARA SV1603F30T) operating range at various speeds. The Grundfos recirculating pump does not affect this hydraulic analysis since its function is only to provide a recirculating flow and there is no "loss" in the recirculating system.

AAD advised that the pressure pumps are operated to maintain pressure between 30 m and 32 m, with a pressure setpoint of 30.9 m. These settings are superimposed onto the pump curves below and it shows that the pressure pump (variable speed) is continuously changing speed to meet water demand while maintaining system pressure at the setpoint.

During low demands, water consumption ranges from zero to probably up to 8 m^3/h (assuming conservatively that the peak day usage is all consumed within 1 hour), suggesting that the pressure pump would probably operate at a speed of between 38 Hz to say about 40 Hz to supply the instantaneous demand.

As demand increases, water consumption may increase to probably up to 15 m^3/h (again conservatively assuming all the peak day's usage is all consumed within 1 hour), suggesting that the pressure pump would probably operate at a speed up to around 44 Hz (may be slightly higher in short bursts if there is coincidence of usage) to meet supply.

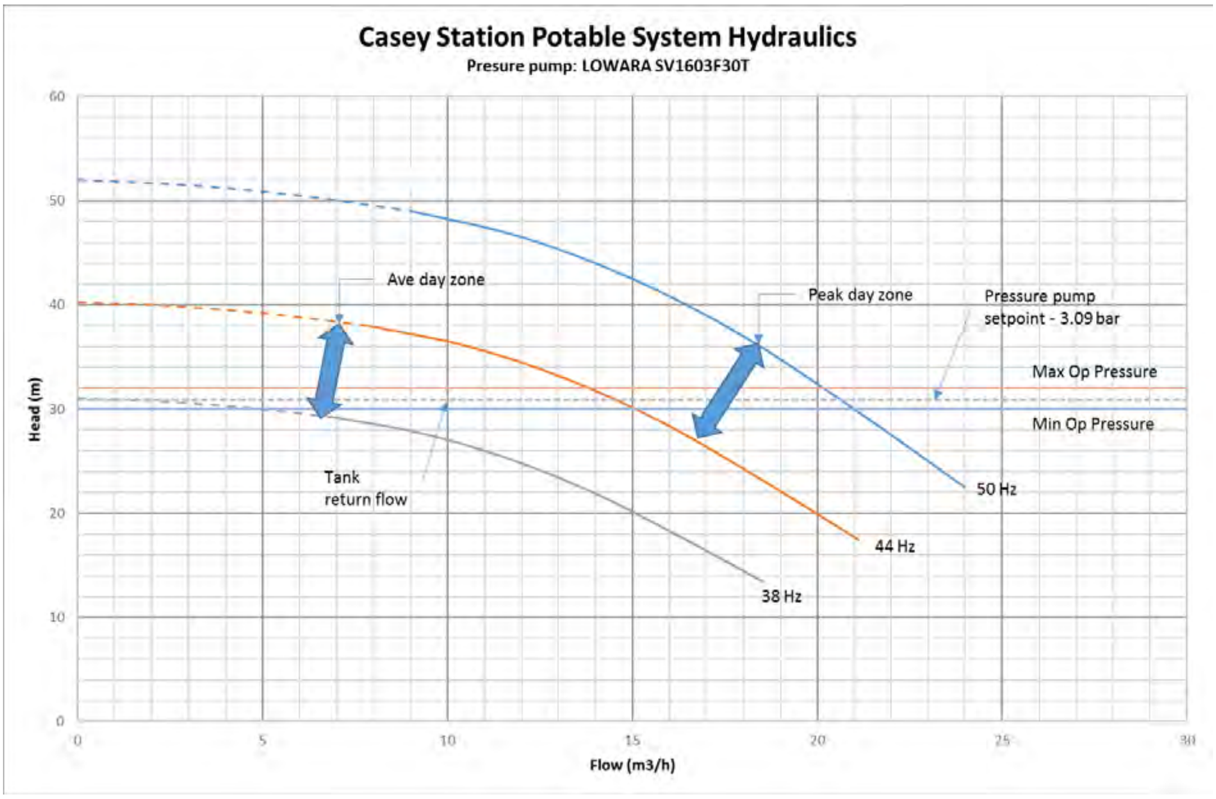


Figure 4 Existing potable system hydraulics

The above analysis is indicating that the existing pressure pump is adequately sized and should be able to supply a CONTINUOUS tank return flow of say 10 m^3/h. This tank return rate would allow the peak day's volume to be treated by a calcite filter at least once in 1.5 hour, and turnover of the entire tank volume of 270 m^3 in 27 hours.

Based on this analysis, a recirculating flow rate of 10 m^3/h is recommended.

Configuration for Option 2 is shown in Figure 5 below. A bleed line sized for 10 m^3/h with a pressure sustaining valve (PSV) would be created on the new recirculating main. This PSV will be set with an upstream pressure of 30.9 m (same as the pressure pump setpoint). As a PSV opens when the upstream pressure is above the setpoint, the PSV will allow a continuous flow back to the tanks as long as the pressure pump is able to maintain a pressure of 30.9 m in the existing ring main. If instantaneous demand in the system is such that the pressure pump is unable to maintain pressure, the PSV would close, temporarily stopping the tank return flow, so that normal demand can be met by the existing pressure pump. This tank return flow would pass through the granular media filters (to protect the calcite filter from fouling), the calcite filter to correct the LSI of the water, and three return lines each with an adjustable control valve to spread the flow evenly back into each tank. In effect, this bleed line would act as a "demand" on the pressure pump, even when there is a backwash on the granular media filter, and would make the pressure pump operate continuously at a higher speed (around 41 Hz) than it currently does. The advantage of this option is that it avoids the need for a new set of recirculating pumps, however, there is still a potential for iron corrosion products to accumulate in the storage tank floors and be drawn into the ring main when the fire supply pumps are operated.

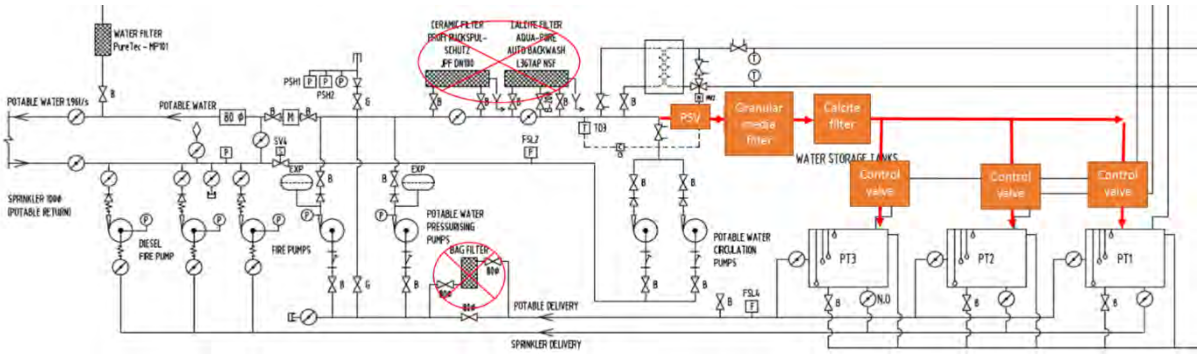


Figure 5 Schematic of recirculation loop from existing ring main

Option 3 (shown in Figure 6 below) addresses the deficiency of option 2 above by configuring the new recirculating loop from the suction main of the fire supply pumps, which, since it is drawn from the base of the storage tanks, increases the potential for removing iron corrosion products accumulating in the tanks via the proposed granular media filters. While this option requires a new set of recirculating pumps (10 m^3/h capacity), it resolves the issue of future dirty water events better and is therefore recommended.

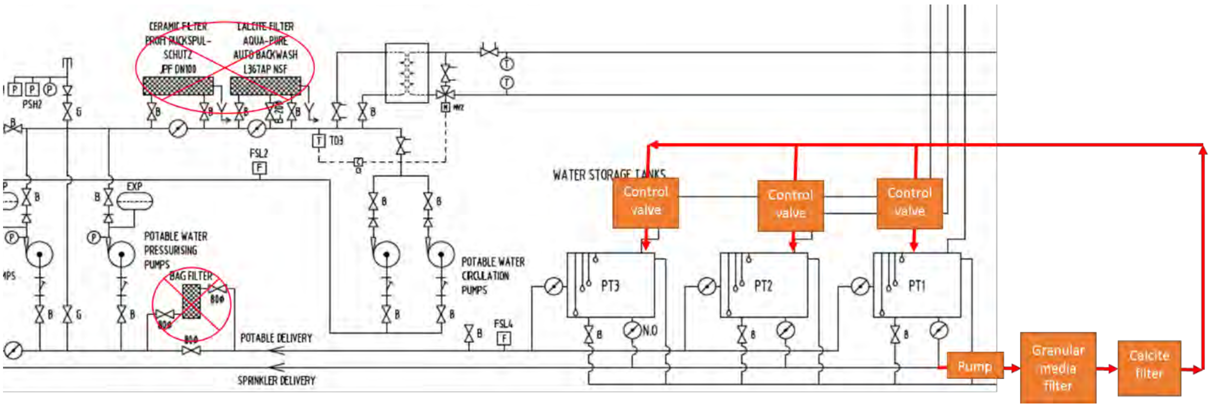


Figure 6 Schematic of recirculation loop from suction main (fire pumps)

Sizing of individual elements of the scheme is provided in the sections below.

4.2 Granular media filters

4.2.1 Filter types

Granular media filters can be configured as open gravity filters or as pressure filters contained in fibreglass pressure vessels. Open gravity filters are the choice for large plants but for smaller installations such as Casey, pressure filters offer simpler backwashing arrangement and installation.

Due to the size and remoteness of the installation, pressure filters are recommended for Casey.

Figure 7 Typical pressure filter (courtesy of Waterco)

4.2.2 Filter media selection

Commercially available filter media that is suitable for Casey are:

- Silica sand (S.G. of 2.65)
- Filter coal (S.G. of 1.4 to 1.5)
- Glass beads (S.G. of 1.55 to 1.65)

The main selection criteria are cost, durability, inertness, particle size (and size distribution), and specific gravity (for backwashing consideration). Of the three filter media listed above, silica sand has the highest specific gravity and therefore would require the highest backwash rate to effectively fluidise the bed to remove trapped particles when backwashing. When used in a pressure filter arrangement, where backwash flow is normally provided by the inflow, the use of the heavier silica sand effectively limits the size of the filter that can be used (so that a suitable backwash rate can be achieved). For this reason, the use of the lighter media such as the filter coal or the glass beads is preferred.

Durability, inertness and particle size distribution requirements for filter media are specified in the American Water Works Association standard B100, and this standard would apply to filter coal. Waterco supplies a glass beads media (Glass Pearls) with their range of pressure filters with a specification shown in Figure 7. The inertness and durability of glass means that such filter media would also be acceptable.

Technical Specifications	
Filtration Media	Glass Pearl
Effective Size (mm)	0.61
Uniformity Coefficient	1.21
Bulk Density	1.61
Mohs Hardness	7.0

Chemical Compositions	
Silicon dioxide (SiO2)	70.00 - 75.00%
Sodium oxide (Na2O)	12.00 - 15.00%
Calcium oxide (CaO)	7.00 - 12.00%
Magnesium oxide (MgO)	approx. 5.00%
Aluminium oxide (AL2O3)	approx. 2.50%
Potassium oxide (K2O)	approx. 1.50%

Figure 8 Glass pearl filter media (courtesy of Waterco)

The effective size and uniformity coefficient for the Glass Pearls are shown as 0.61 and 1.21 respectively. This media size and distribution is suitable for small scale pressure filters and would also apply if filter coal is used.

4.2.3 Filter size and arrangement

Critical parameters for a successful and robust filter design are:

- Filtration rate: expressed in m/h (equivalent to $m^3/m^2/h$), it is a measure of how quickly the water will travel through the media bed.
- Filter depth: should be proportional to filtration rate, since detention time in the filter bed increases particle removal by the various removal mechanisms that exist in a filter bed.

Based on a recirculating flow of 10 m^3/h, the filtration rates and detention times achievable for a range of standard pressure filters (datasheet from supplier is provided in Appendix B) are shown in Table 5 below.

Table 5 Granular media filter size range

Filter dia (mm)	Filter Area (m^2)	Filter depth (mm)	Filtration rate (m/h) and detention time (min)			Backwash rate (m/h)
			1 filter	2 filters	3 filters	1 filter
500	0.20	500	50 (0.6)	25 (1.2)	16.7 (1.8)	50
600	0.28	500	35.7 (0.8)	17.9 (1.7)	11.9 (2.5)	35.7
750	0.44	500	22.7 (1.3)	11.4 (2.6)	7.6 (4.0)	22.7
900	0.64	500	15.6 (1.9)	7.8 (3.8)	5.2 (5.8)	15.6

Filter size should also be cognisant of the backwash rate achievable by the inflow (without providing a separate backwash pump). Appropriate backwash rate is a function of water temperature, filter media size and distribution, and specific gravity, and is shown by Figure 8 for 20 degree (for lower water temperature, the required rate is reduced due to viscosity of the water). For the preferred filter media, appropriate backwash rate is about 0.38 m/min (or 22.8 m/h).

Suitable filter size and arrangement is therefore 3 x DN750, which enables a suitable backwash rate (when washing one filter at a time) while providing adequate detention time that maximises particle removal. Having larger filters may improve particle removal but is at the expense of poorer backwash rate.

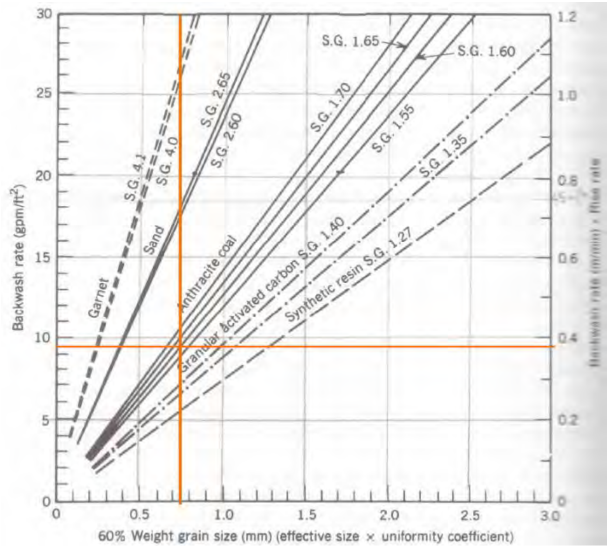


Figure 9 Granular media backwash rates

3 x DN750 pressure filters are therefore recommended.

4.2.4 Operations and maintenance

It is expected that the filters will be manually operated. In normal operations, all three filters would be filtering unless there is a fault in which case the faulty filter will be manually isolated. Reasonable performance is expected even with two filters and hence a standby filter is not recommended.

The only maintenance required is to backwash the filters periodically, which can be activated manually via a multiport valve (datasheet from supplier is provided in Appendix B) supplied with the filter. The function of this multiport valve is shown in Figure 10 below. To achieve the required backwash rate, the operator would manually close the other two filters while backwashing the third. Each backwash is expected to take around 2 to 4 minutes and all three filters would be backwashed sequentially.

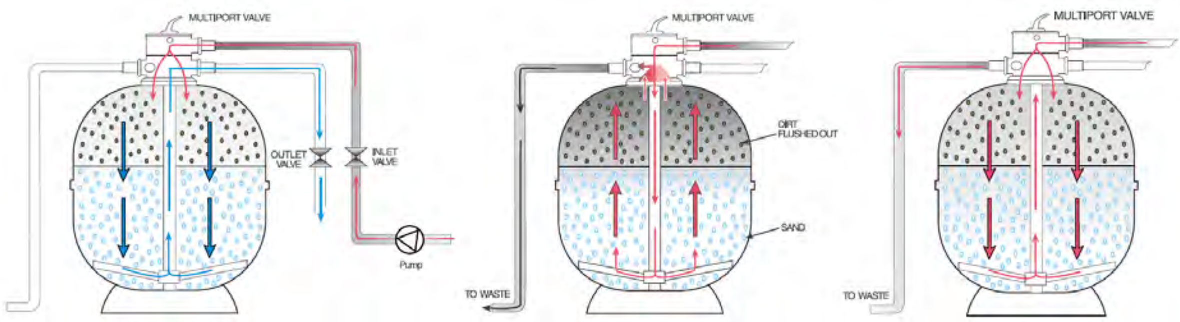


Figure 10 Backwashing of pressure filters using multiport valve (curtesy of Waterco)

Backwash waste would need to be managed on site. It should be suitable to send the backwash waste to the on-site wastewater treatment facility for disposal, subject to an analysis of the hydraulic capacity of the treatment facility. A temporary holding tank may be necessary to hold back the backwash waste and release it at a reduced rate to the treatment facility.

4.3 Calcite contactor

4.3.1 Calcite media

As this is a drinking water system, the calcite media used must conform to recognised standards for chemicals used in the drinking water industry. There is currently no Australian Standards for calcite. We therefore recommend that the calcite media to conform to:

- *British Standard EN 1018:2013+A1:2015 Chemicals used for treatment of water intended for human consumption - Calcium carbonate*

4.3.2 Contactor size and arrangement

British Standard EN 1018 states typical size range for calcium carbonate as 1 to 3 mm, with a bulk density of between 1 kg/L to 1.5 kg/L. In size, they are therefore similar to sand and are typically arranged in similar fashion as sand filters. To avoid the need for re-pumping after the calcite contactor, the use of pressure vessels to house the calcite, similar to that of a sand filter above, is appropriate.

A single contactor arrangement would be acceptable, as there should be no need to backwash the calcite in normal operations (although backwashing would be provided by the multiport valve similar to the granular media filters above, which could be used to occasionally flush out any residual calcite in the contactor if required).

There are two sizing criteria for sizing calcite contactors:

1. That it is sufficiently sized to retain the water in the contactors long enough to dissolve the calcium carbonate for the water to reach the target LSI.
2. That it is sufficiently sized to hydraulically pass the design flow without excessive headloss.

At the design flow rate of 10 m^3/h, a single DN600 pressure filter (Waterco W600, datasheet from supplier provided in Appendix B) would be suitable. The filter would be supplied with calcite rather than sand, but with the multiport valve for isolation and backwash if required.

Model No:	MPV Size	Filter Bed Depth	Filter Bed Area	Filtration Flow Rates		Backwash Flow Rates		Filter Bed Volume	Sand 16/30	Zeoplus
				36m³/hr/m²	36m³/hr/m²	40m³/hr/m²	40m³/hr/m²			
	(mm)	(mm)	(m²)	lpm	m³/hr	lpm	m³/hr	(litre)	(kg)	(kg)
W250	40	600	0.05	30	1.8	33	2	41	60	49
W300	40	600	0.07	42	2.5	47	2.8	58	85	70
W350	40	600	0.10	60	3.6	67	4	79	115	95
W400	40	600	0.13	78	4.7	87	5.2	79	115	95
W500	40	600	0.20	120	7.2	133	8	123	180	148
W600	40	600	0.28	168	10.1	187	11.2	175	255	210
W700	40	600	0.38	228	13.7	253	15.2	240	350	288

Figure 11 Small pressure filter range (courtesy of Waterco)

Rate of dissolution of calcite is a function of:

- Initial water quality – TDS, calcium, alkalinity, and pH
- Water temperature

A limestone bed contactor model developed by the State Health Department of Santa Rosa was used to assess the adequacy of the calcite contactor sized based on hydraulic consideration above. The result is shown in the figure below and it shows that it would require 2.7 minutes for the water to reach the theoretical calcium carbonate saturation point (LSI = 0). As the contactor sized above has a media depth of 600 mm, it would take approximately 3 passes through the calcite contactor for the water to reach this theoretical saturation point, which is acceptable.

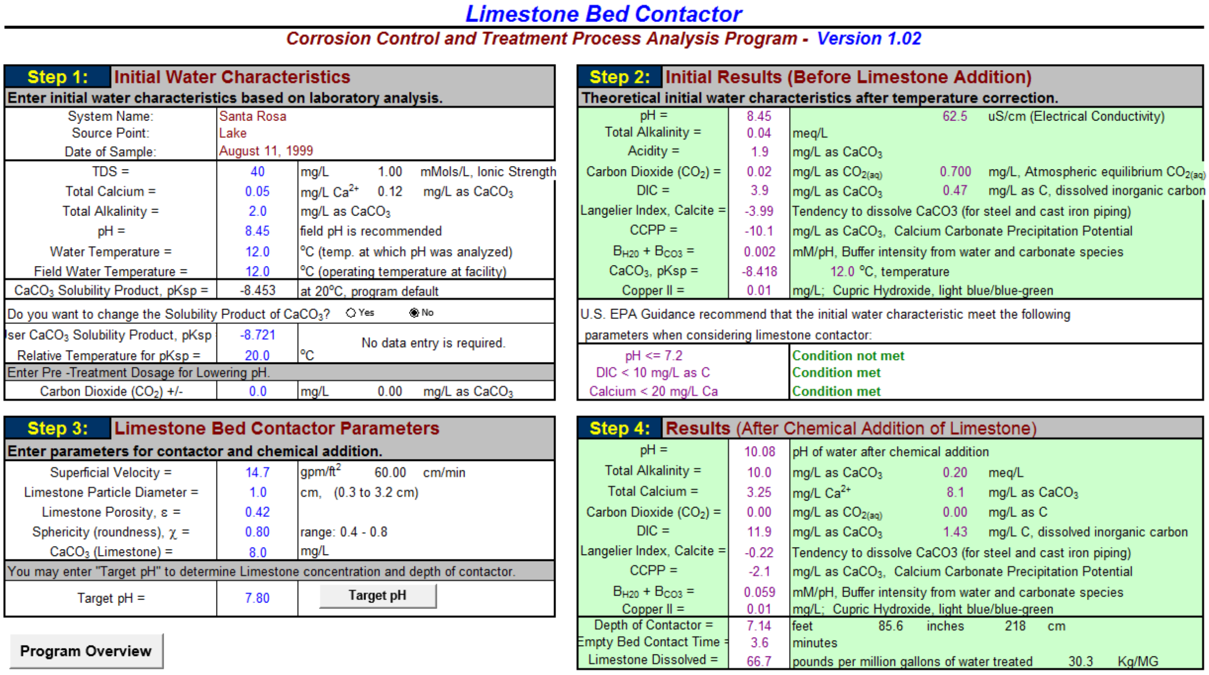


Figure 12 Calcite contactor model - Casey

The above model also shows that the theoretical consumption of calcite when treating this water is 38.2 kg per million gallon of water treated. At Casey, where the annual water consumption is expected to be about 3 million litres (0.8 million gallon), the calcite filter above, with 175 L of bed volume, should last between 5 to 8 years.

4.3.3 Operations and maintenance

As the proposed design includes a set of granular media filters upstream of the calcite contactor, no significant maintenance is expected to be required other than periodic inspections.

Since the calcite bed is gradually being dissolved into the water, its bed volume will diminish, and time to reach target LSI would increase. The rate of dissolution of calcite should therefore be monitored and the bed topped up regularly.

Calcite media conforming to the nominated British Standard should have a high purity of > 97% calcium carbonate. Hence, accumulation of inert within the contactor should be minor. If required, the contactor could be backwashed using the multiport valve to flush out and remove any residual calcite.

4.4 Calcium hypochlorite dosing unit

4.4.1 Recommended hypochlorite dose

The Australian Drinking Water Guidelines (ADWG) is the authoritative source of guidance document for drinking water quality in Australia. In the document, the ADWG emphasizes the importance of maintaining adequate disinfection residual throughout the distribution network to provide protection against accidental backflow, and inhibit biofilm growth. A free chlorine residual of at least 0.2 mg/L is considered desirable in ADWG.

When calcium hypochlorite dissolves in water, it forms hypochlorous acid (HOCl) and hypochlorite ion (OCl^-). Hypochlorous acid is a very effective bactericide but hypochlorite ion is not. The percentage of hypochlorous acid versus hypochlorite ion is dependent on the water pH. To achieve adequate disinfection, the goal is therefore to achieve at least 0.2 mg/L of hypochlorous acid, which means, at the higher water pH that will be at Casey, an equivalent chlorine dose of around 2 mg/L would be required (as shown in Figure 12).

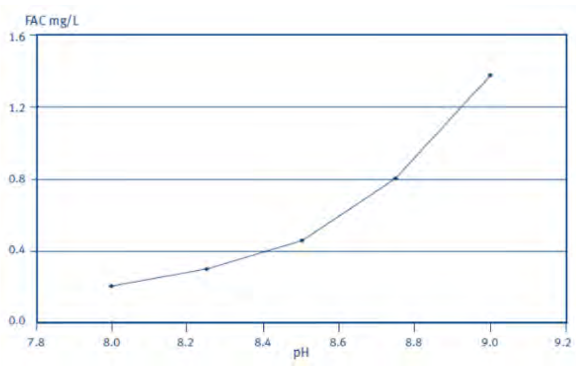


Figure 13 Equivalent free available chlorine vs pH (NZ Drinking Water Guidelines)

Some users of this water may object to this level of chlorine due to perception of taste and odour. Some latitude is possible for this system to reduce the chlorine dose as there is no primary disinfection required (no foreseeable harmful bacteria or viruses). A goal of the operator of the system is therefore to balance the need to minimise microbial activities in the system (which contributes to possible MIC) with the desires of the users.

4.4.2 Dosing equipment selection

There are currently two types of dosing equipment in the market for dosing calcium hypochlorite. The erosion type has a storage reservoir of calcium hypochlorite briquettes, where the water is piped through for treatment. The movement of water through the briquettes erodes and dissolves the calcium hypochlorite, resulting in disinfection. The advantage of such a system is its simple design, with very little moving parts to maintain. However, the control of chlorine dose in such a system relies on the flow rate of the water through the briquettes, which is difficult to control, resulting in variations in the level of disinfection (an example is shown Figure 14 below).

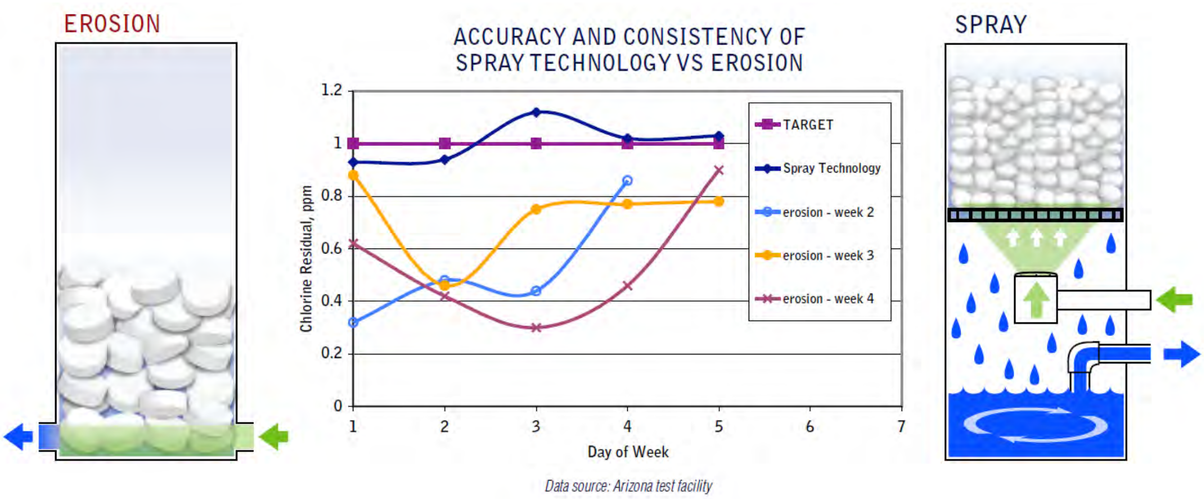


Figure 14 Consistency of chlorine dose with erosion vs spray type equipment (courtesy of Hydromet)

An alternative design in the market sprays a portion of the water to be treated upward into a bed of briquettes, creating a solution of hypochlorite with about 1.5 to 1.8% available chlorine. This solution is then metered out via a chemical dosing pump to disinfect the entire volume of the water to be treated. A residual chlorine analyser would be used to provide feedback control of the chemical dosing pump to provide targeted dosing of hypochlorite. This alternative design has more moving parts to maintain but the system allows a more accurate control of chlorine dosing and is therefore recommended.

The Constant Chlor® Plus Model MC4-50 calcium hypochlorite dosing system manufactured by Arch Chemicals (local Australian distributor is Hydramet) is one such spray type dosing equipment suitable for Casey (datasheet from supplier is provided in Appendix B). This unit stores approximately 30 kg of calcium hypochlorite briquettes, which is sufficient for about 3 years based on annual water consumption of about 3 ML at the nominated dose rate.

4.4.3 Operations and maintenance

The supplier of the dosing unit will have a list of recommended operations and maintenance tasks associated with their equipment. One of the common issues with these systems is scaling due to their use with hard water. As calcium hypochlorite is dissolved in the water, it increases the water pH, which in hard water, can result in precipitation of calcium carbonate. However, as the water at Casey is soft, this issue is unlikely to cause major problem.

The only other operations and maintenance task is periodic top up of calcium hypochlorite briquettes, and maintenance of the dosing pump and residual chlorine analyser.

4.5 Recirculation pump

A 10 m^3/h centrifugal pump is required for the recommended treatment configuration option. However, an appropriate discharge pressure of the pump can only be determined on site with knowledge of the required static lift and friction loss of the system. Adequate pressure allowance would also be required to overcome increasing friction loss in the granular media filters as iron corrosion products accumulates. This pressure allowance would be sought from the suppliers of the pressure filters.

Variable speed pumping is recommended to ensure target flow is maintained as headloss increases in the system. The three throttling valves at the storage tanks would be adjusted to provide even distribution of the return flow and the necessary back pressure for the pump to deliver 10 m^3/hr at commissioning. As headloss increases to an unacceptable level, or at regular time interval whichever comes first, the granular media filters should be backwashed to restore flow.

A flow meter should be provided on the discharge of the recirculating pump for commissioning and control of pump speed during operations.

4.6 Approximate space requirement

Based on the sizes of equipment nominated above, a space of approximately 5 m x 2 m has been estimated. A conceptual layout for the major equipment is shown in Figure 15 below, however, the most appropriate layout must be determine by AAD based on actual site constraints with consideration of access for operations and maintenance.

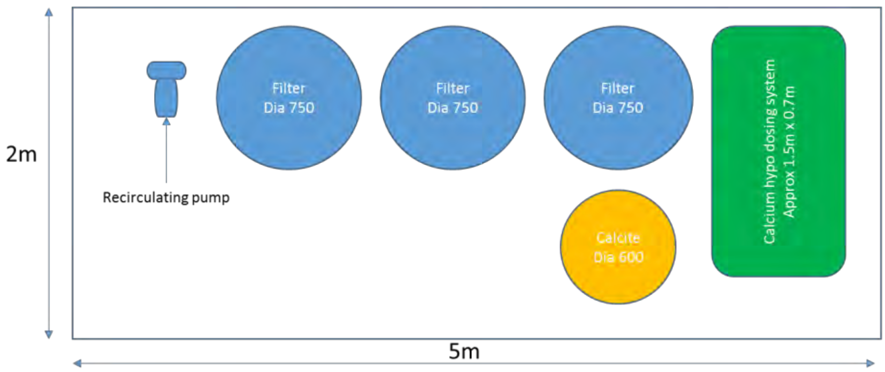


Figure 15 Concept layout of treatment option

5. Conclusions & recommendations

In response to reports of extensive corrosion in the steel pipes and storage systems at Casey station, and water quality test results indicating the presence of elevated metals at various sample points, the AAD have engaged GHD to;

- review water quality test results that previously have indicated the presence of metals exceeding health guideline values,
- identify problems in the water supply systems, and
- provide advice on options for solving and/or managing these problems.

The review of the water supply infrastructure and water quality at Casey station has indicated that corrosion observed in the potable water storage tanks is most likely caused by a combination of soft water and microbiologically induced corrosion (MIC). This corrosion and iron-rich sediment build-up in the storage tanks is a major source of iron and suspended solids contamination in the water supply system.

Exposure of copper piping (and possible lead joints) to the naturally soft and corrosive melt water is a major source of copper and lead contamination in the drinking water.

To correct the corrosiveness of Casey's water, calcium and alkalinity must be added such that the water has a tendency to deposit calcium carbonate. Common chemicals used that can add calcium and/or alkalinity include calcite, hydrated lime, soda ash and calcium chloride. The best option for this application is a calcite filter as it can add calcium and carbonate in a single simple filter arrangement.

The microbiologically induced corrosion (MIC) also needs to be addressed, with key contributing factors including a lack of a persistent disinfectant, warm water, presence of organic carbon, and stagnant flow. The provision of a persistent disinfectant is expected to be effective for controlling MIC in the main recirculating loop where flow is continuous. For the purpose of disinfection, calcium hypochlorite dosing is recommended, as it involves a simple dosing pump arrangement that is relatively easy to maintain.

However, in stagnant lines, such as those servicing taps that are rarely used, the disinfectant would lose its effect over time and biofilm would again take hold. The only mitigation for possible dissolved heavy metals in these taps served by stagnant lines is to implement a "flush before use" policy at the station.

Finally, dirty water events that have occurred at Casey are attributed to iron corrosion products in the storage tanks being drawn into the ring main (as well as biofilms being dislodged) by the high flows generated when exercising the fire water pumps. To date bag filters have been used with mixed success. Alternative options include depth filtration, either using a cartridge filter system or via granular media filtration. The granular media filtration option is expected to have the most consistent performance in terms of solids removal.

GHD investigated a short term and a long term solution to the water quality issues at Casey station.

The recommendation for the short term solution involves:

- Removal of all iron corrosion products from existing storage tanks
- Minimising further corrosion in existing storage tanks through pH/alkalinity adjustment
- Removal of all corrosion products / biofilm from existing pipes (scour and flush)
- Provision of filtration to minimise future dirty water events

- Addition of a persistent disinfectant to control future biofilm growth (chlorinated water supply)
- Dealing with stagnant sections of pipe (flush before use policy)

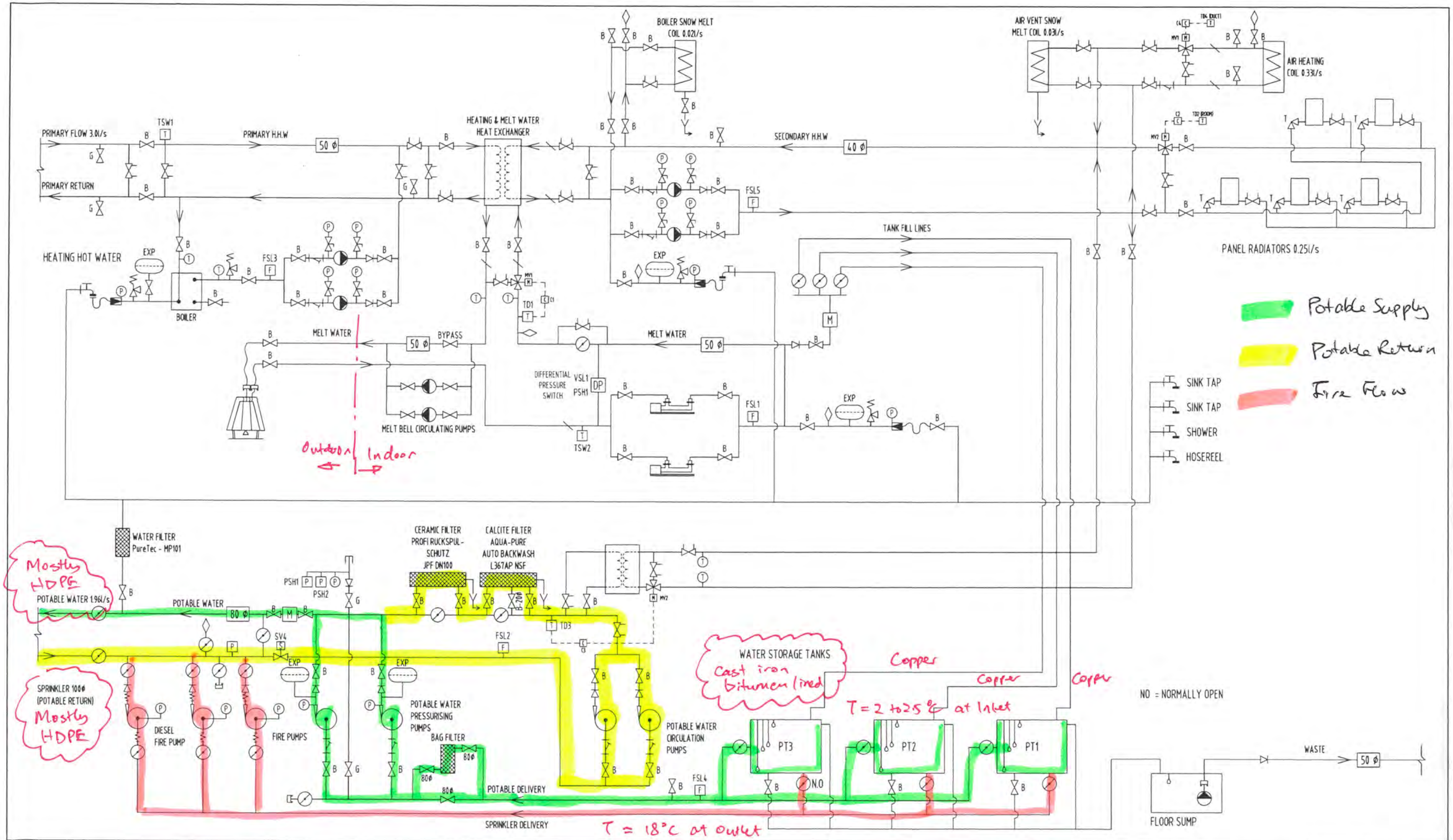
The recommendation for the long term solution involves:

- Replacement of the corroding water storage tanks with those manufactured from corrosion-resistant materials of construction
- Scour and flush all station pipework to remove existing corrosion products and biofilm
- Fast-track replacement of metallic pipework with non-metallic plumbing as much as practicable.
- Implementation of a permanent disinfection system to prevent further biofilm growth

However, GHD's final conclusion and recommendation from this investigation is for the AAD to focus on the Long Term Solution now. This should avoid the need for pH and alkalinity correction, as there will be minimal exposed metal in the system and hence no corrosion. Removal of corrosion by-products from the system should negate the need for filtration, as the source water is naturally low in sediment. Implementation of a long-term disinfection solution is recommended. However, this would only be for biofilm control and not for primary health considerations.

Appendices

Appendix A – System schematic



REVISION		DATE	APPD
C	MELT BELL CIRCULATING PUMPS ADDED	06/07/16	T PRICE
B	REVISED	21/06/18	T PRICE
A	AS INSTALLED	13/06/17	T PRICE

Drawn:
Checked:
Approved:
Enquiries:
Scale: AS SHOWN
Date of Issue:
Date for Revision:

Australian Government
Department of the Environment and Energy
Australian Antarctic Division

CASEY STATION
TANKHOUSE

WATER SCHEMATIC

Drawing No. L1056-H-SCH01

Maximo Location

Original Dwg.Size A3

Appendix B – Supplier's datasheets

GLASS PEARLS

Superior filter media

Waterco's Glass Pearls deliver
outstanding water clarity.

enviropro
SAVE TIME, WATER AND ENERGY

SAVE TIME
SAVE WATER
SAVE MONEY

WATERCO
water, the liquid of life

www.waterco.com


Purity. Safety. Clarity.

Waterco's Glass Pearls are manufactured from 100% pure glass and offer much finer filtration than conventional filter media.

SUPERIOR PURITY

Whereas other filter media may contain a variety of contaminants, Waterco's Glass Pearls are chemically inert for superior purity. In fact, Glass Pearls have been independently lab tested for leaching contaminants and found to be well within Australian Drinking Water Guidelines.

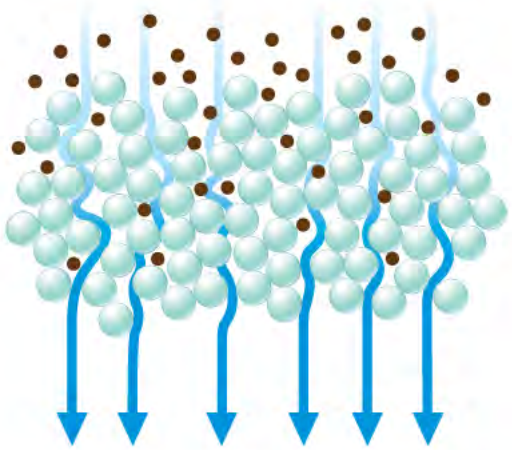
Their superior purity greatly reduces its initial backwashing requirements, prior to commissioning a filter, enabling a rapid start up of media filters.

SAFE

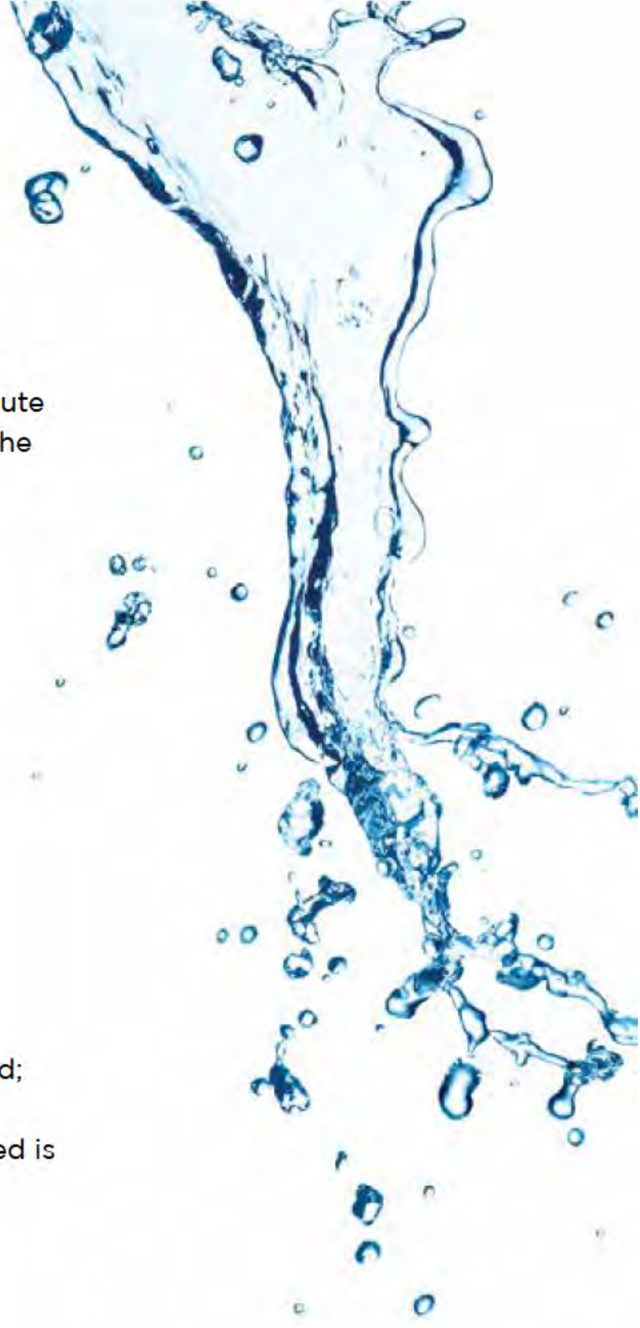
Glass Pearls are safe to handle & safe to service in comparison to other glass media options as crushed glass. Glass Pearls are spherical and do not have sharp edges, making them really safe to use. And if there's ever a failure, of the filter's laterals and Glass Pearls flow into the swimming pool, they pose no risk of injury to swimmers.

SUPERIOR DEPTH FILTRATION

Glass Pearls operate on the basis of “depth filtration”; dirt is driven through the filter bed and trapped in minute spaces between the particles of filter media allowing the cleansed water to pass through.



Conventional media such as sand is crushed and sieved; they generally have an irregular structure and a larger variation in particle size. A conventional media filter bed is more porous and unable to trap fine particles.



Glass Pearls are man-made to specific geometrical shapes providing an extremely narrow particle size range of 0.6mm to 0.8mm, enabling the creation of a dense homogeneous filter media bed, capable of filtering particles down to 3 microns. A micron is equivalent to one millionth of a metre.

Glass Pearl Media

Sand Media

BULK DENSITY

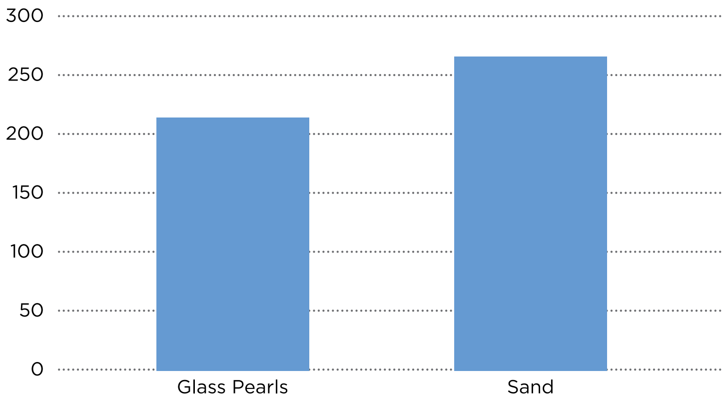
The chart below demonstrates that Glass Pearls have a higher bulk density than crushed glass and sand.

Media	Bulk density, g/cm3
Glass Pearls	1.61
Sand	1.47
Crushed Glass	1.33
Bulk density is a measure of mass per volume.	

SAVE WATER

The water saving ability of Glass Pearls are due to their spherical smooth shape, as this result in a low coefficient of friction. After each backwash, Glass Pearls are effectively cleansed of their trapped contaminants.

Glass Pearls require up to 20% less backwash water than sand, saving time and water.

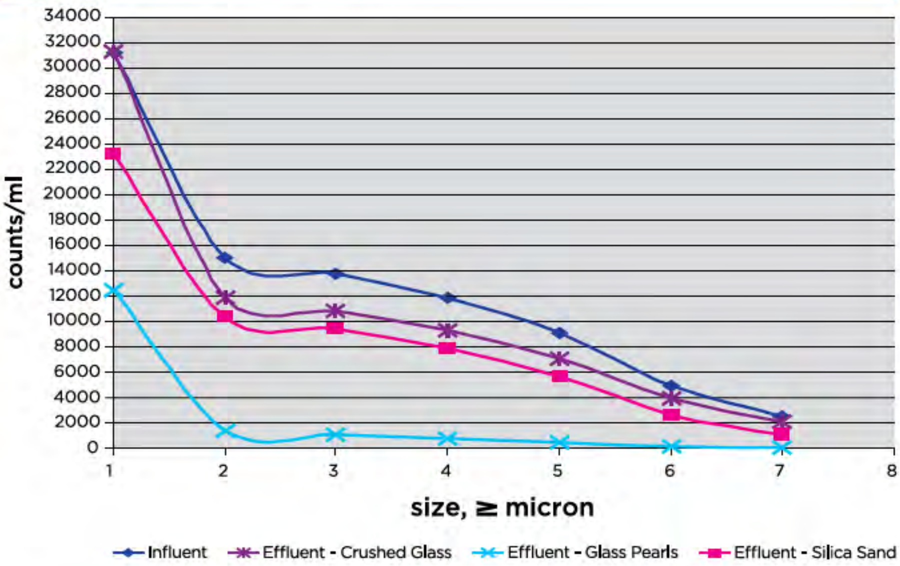


Glass Pearls required 215 litres to successfully backwash a Waterco S600 Media Filter, whereas sand required 266 litres.

Waterco Glass Pearls have been evaluated by TUV SUD PSB and are suitable for both domestic and commercial swimming pools, aquaculture, water treatment and industrial applications.

TUV test reports can be made available upon request.

Particle Count Comparison



Technical Specifications

Filtration Media	Glass Pearl
Effective Size (mm)	0.61
Uniformity Coefficient	1.21
Bulk Density	1.61
Mohs Hardness	7.0

Chemical Compositions

Silicon dioxide (SiO2)	70.00 – 75.00%
Sodium oxide (Na2O)	12.00 – 15.00%
Calcium oxide (CaO)	7.00 – 12.00%
Magnesium oxide (MgO)	approx. 5.00%
Aluminium oxide (AL2O3)	approx. 2.50%
Potassium oxide (K2O)	approx. 1.50%

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Waterco's head office is situated in Sydney, Australia with international offices, manufacturing plants and warehouses located in Australia, New Zealand, Malaysia, Indonesia, Singapore, China, the US, Canada, France and the UK.

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water, the liquid of life

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ZZB1469 04/14

MC4-50 Feeding System

Dry Calcium Hypochlorite For Municipal Applications

The smarter way to water quality

PATENTED SPRAY TECHNOLOGY

DELIVERS UNPARALLELED CONSISTENT RESULTS

Constant Chlorplus®

The Constant Chlor® Plus MC4-50 Dry Calcium Hypochlorite Feeding System

Designed via feedback from actual field users, **The Constant Chlor® Plus MC4-50 dry calcium hypochlorite feeding system** prepares and automatically delivers a consistently accurate dose of liquid available chlorine for disinfection applications. This feeding system can supply up to 50 pounds of AvCL/day on a sustained basis without the storage and handling issues associated with liquid bleach or chlorine gas.

With the ability to stand alone or be integrated with other process and control equipment, this highly customizable feeder uses NSF Standard 60 listed **Constant Chlor® Plus dry calcium hypochlorite briquettes** and patented spray technology to produce fresh liquid chlorine solution as needed. The reservoir is filled and volume maintained via an electronically controlled spray manifold where it is continually circulated to maintain unparalleled solution consistency.

FEATURES

- Unit constructed of high impact HDPE; all wetted areas, internal fittings and level controls constructed of suitable plastics or other non-metallic material
- Utilizes patented spray technology
- Patent-pending mixing mechanism within solution reservoir
- SCADA compatible
- Automatic solution tank refill
- Mechanical overflow-prevention valve
- Large 62 lb. capacity briquette hopper
- Delivers up to 50 lbs. AvCL per day
- Skid mounted with secondary containment
- Area for pump mount

BENEFITS

- Compatible with all types of pumps including positive displacement pumps
- Customizable, convenient and easy to use
- Effective, safer, easier & less expensive alternative to gas and liquid bleach
- Reduced regulatory compliance required including eligibility for Material of Trade (MOT) exceptions for transport
- Efficiencies in bulk storage and man hours
- Consistent and reliable chlorine solutions
- Operates at normal atmospheric pressure and is readily serviceable for refilling and cleaning while in operation
- Eliminates metering pump air locks due to off-gassing
- Eliminates transfer spills
- Minimizes man hours for maintenance and shut downs
- Pre-plumbed and skid mounted for ease of installation
- Internal mixing mechanism enables sustainable homogeneous solution and prevents solids build-up
- Option for pre-treatment

Specifications

Chlorine Delivery Rate*	1.0 - 50.0 lb. AvCl/day with 70° F inlet water temp.	Dry Chemical Capacity	62 lbs.
		Site Requirements:	
Discharge Pressure Range	50 - 150 psig	Inlet Water	1.0 gpm @ 50 - 150 psig
Water Inlet Size	1/2 inch, FNPT	Electrical	20 amp @ 120V/1ph/60Hz
Solution Outlet (Injector) Size......	1/2 inch, MNPT	Operating Temperature	40° - 105° F

**Delivery rate is dependant on the dosing pump size*

Municipal Applications

Arch Chemicals, Inc. provides municipalities across the country with products that meet the toughest regulations and standards including NSF/ANSI 61 for our feeding equipment and NSF 60 for **Constant Chlor® Plus Briquettes**, allowing the public to rest easy about the quality of their water supply.

- Remote Well Sites
- Booster Stations
- Waste Water
- Reclaimed Water
- Surface Water Treatment Plants
- Ground Water Treatment Plants

Potable Water

- Provides hypochlorination to disinfect water supplies in smaller communities
- Requires low initial investment
- Maintains economical operating costs

Private Water Supplies

- Sanitizes wells, natural springs, cisterns and storage tanks by destroying microbes
- Purifies by destroying harmful organic matter

Other Water Treatments

- Controls slime and maximizes cooling efficiency in cooling towers, ponds and reservoirs of power plants
- Controls growth of slime in commercial air conditioning systems, improving cooling efficiency and eliminating unpleasant odors
- Destroys disease-producing organisms in raw or treated sewage
- Keeps decomposing septic sewage odors and masonry disintegration in check by "up sewer hypochlorination"

Patented Spray Technology

Patented Spray Technology + Constant Chlor® Plus Briquettes = Consistently Accurate Hypochlorite Solution

How it Works

Markedly different from erosion feeders currently on the market, the **Constant Chlor® Plus MC4-50 feed system** injects supply water into the unit by spraying upward into a bed of briquettes; **this short intermittent spray cycle contacts the entire bottom of the bed evenly, not just the material resting on the grid.**

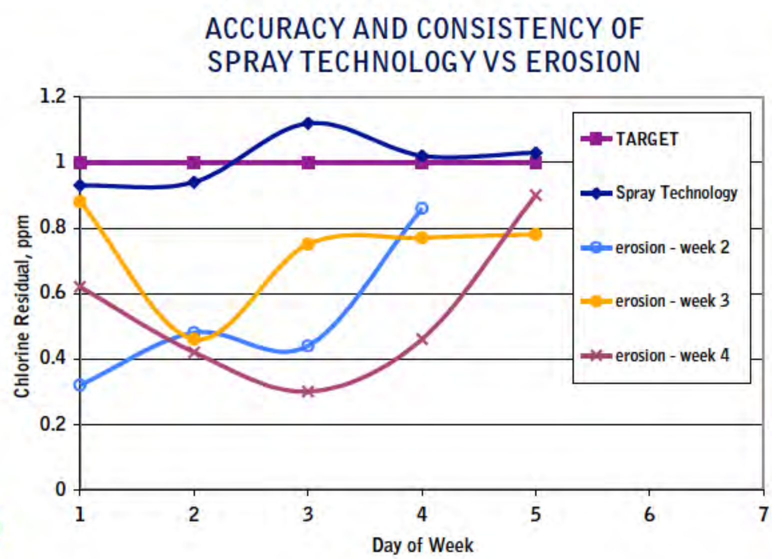
Specifically designed for use in the Constant Chlor® Plus Spray Technology feed systems, the briquettes are relatively small, smooth and "pillow shaped", for maintaining optimum packing in the spray bed.

Maintaining a well-packed bed of briquettes significantly reduces the potential for large voids in the spray surface that can result in inconsistent residual concentration in the final solution.

The hypochlorite solution produced by the unit's spray cycle is collected in a 13-gallon solution tank, where the total volume is slowly and continuously mixed, further enhancing concentration consistency.

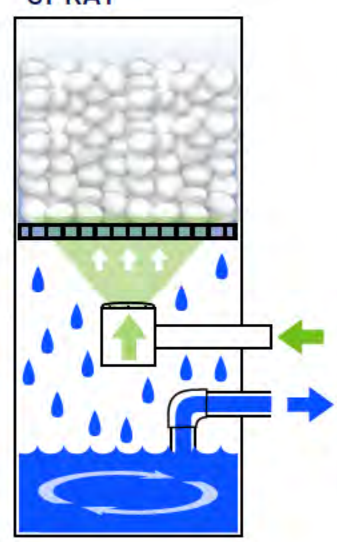
Unlike an erosion feeder, the Constant Chlor® Plus MC4-50 feeder sprays upward to a well packed bed of briquettes, contacting the entire bottom of the bed evenly. The chlorinated solution flows to the lower reservoir where it is continuously mixed. The accuracy and consistency of the resulting solution concentration far exceeds that achieved by an erosion feeder. Consequently, operator dosage adjustment is minimal.

EROSION



Data source: Arizona test facility

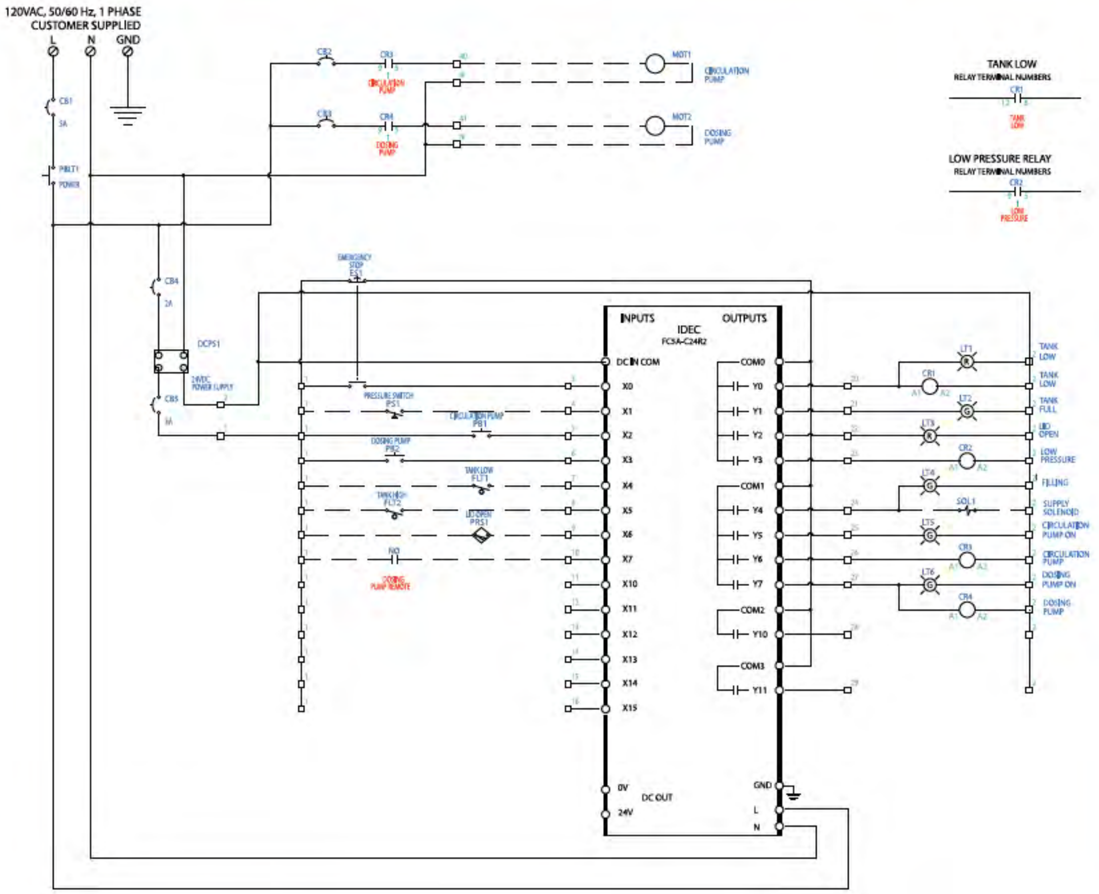
SPRAY

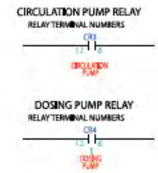


Product Stewardship

Protecting Health, Safety, and Environment — Product Stewardship

Arch is committed to maintaining and improving our leadership in Product Stewardship – from manufacture, marketing, distribution, use, recycling and disposal. Successful implementation includes educating all involved of their responsibilities to address society's interest in a healthy environment and in products that can be used safely. We are each responsible for providing a safe workplace, and all who use and handle products must follow safe and environmentally sound practices.





120/240VAC, 50/60Hz, 15/10A, 1 Phase

4 Normally Open Contacts for Remote Interface. 1 Dry Contact for Remote Start of Dosing Pump

24VDC Control Power

PLC with 14 input/10 outputs

6 Inputs and 2 Outputs Available for Systems Integration

8 BUTTONS / INDICATORS

- E-STOP: Push-Button emergency stop for the unit. Turns OFF every function.
- OFF/ON Indicator: Push-Button to turn the unit ON or OFF.
- CIRCULATION PUMP: Circulation pump is interlocked with TANK LOW and will not operate if TANK LOW alarm is activated. Lamp flashes is circulation pump pressure drops below 5 psi. Push-Button to turn ON or OFF.
- DOSING PUMP: Chemical dosing pump is interlocked to the system. Will not pump if LOW CHLORINE SOLUTION alarm is activated. Remote or manual start capability. Push-Button to turn ON or OFF.
- LID OPEN: Prevents the unit from operating if lid is opened.
- FILLING: Indicates that the solenoid is energized and unit is making solution.
- TANK FULL: The high float is engaged and tank is full of chlorinated solution.
- TANK LOW: Solution inside tank is low, alarm condition.

Constant Chlor® Plus Briquettes

Constant Chlor® Plus Briquettes are designed for use in the **Constant Chlor® Plus MC4-50 feeding system.** The briquettes provide chlorine solution for use in many applications including treatment of surface and groundwater for municipal drinking water use, industrial process water as well as pre- and post-harvest food safety.

These patented, pillow-shaped briquettes contain a scale inhibitor designed to reduce maintenance and improve reliability of the feeder system.

FEATURES

- Dry Solid Product
  - Longer shelf life than liquid bleach
  - Occupies much less space than liquid bleach
  - Less hazardous than liquid bleach or gas chlorine
  - Easier to handle than liquid bleach or gas chlorine

SCALE INHIBITED

- Patented formulation
- Reduces maintenance of equipment

REGULATORY

- EPA No. 1258-1179
- NSF Standard 60, Drinking Water Additives
- Meets AWWA Standard B300

PROPERTIES

• Available Chlorine (wt%)	65% minimum
• Scale Inhibitor (wt%)	0.5%
• Weight	0.25 oz. (7 grams)
• Dimensions	1-1/4 in. X 3/4 in. X 1/2 in.
• Appearance	Pillow Shaped Briquettes

PACKAGING

Constant Chlor® Plus Dry Chlorinator Briquettes are available in 50 lb. plastic pails

Arch also produces **Dry Tec® FG Briquettes** (Food Grade) for use with **the Constant Chlor® Plus MC4-50 feeder. Dry Tec® FG** contains an anti scale formulation for food industry applications.

Hydramet

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hydrasa@hydramet.com.au

VIC & TAS
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hydravic@hydramet.com.au

NSW & ACT
(02) 4350 8200
hydransw@hydramet.com.au

QLD
(07) 3802 9500
hydraqld@hydramet.com.au

 #49769 2M 6/10

MC4-50 Feeding System

Dry Calcium Hypochlorite For Municipal Applications

The smarter way to water quality

PATENTED SPRAY TECHNOLOGY

DELIVERS UNPARALLELED CONSISTENT RESULTS

Constant Chlorplus®

The Constant Chlor® Plus MC4-50 Dry Calcium Hypochlorite Feeding System

Designed via feedback from actual field users, **The Constant Chlor® Plus MC4-50 dry calcium hypochlorite feeding system** prepares and automatically delivers a consistently accurate dose of liquid available chlorine for disinfection applications. This feeding system can supply up to 50 pounds of AvCL/day on a sustained basis without the storage and handling issues associated with liquid bleach or chlorine gas.

With the ability to stand alone or be integrated with other process and control equipment, this highly customizable feeder uses NSF Standard 60 listed **Constant Chlor® Plus dry calcium hypochlorite briquettes** and patented spray technology to produce fresh liquid chlorine solution as needed. The reservoir is filled and volume maintained via an electronically controlled spray manifold where it is continually circulated to maintain unparalleled solution consistency.

FEATURES

- Unit constructed of high impact HDPE; all wetted areas, internal fittings and level controls constructed of suitable plastics or other non-metallic material
- Utilizes patented spray technology
- Patent-pending mixing mechanism within solution reservoir
- SCADA compatible
- Automatic solution tank refill
- Mechanical overflow-prevention valve
- Large 62 lb. capacity briquette hopper
- Delivers up to 50 lbs. AvCL per day
- Skid mounted with secondary containment
- Area for pump mount

BENEFITS

- Compatible with all types of pumps including positive displacement pumps
- Customizable, convenient and easy to use
- Effective, safer, easier & less expensive alternative to gas and liquid bleach
- Reduced regulatory compliance required including eligibility for Material of Trade (MOT) exceptions for transport
- Efficiencies in bulk storage and man hours
- Consistent and reliable chlorine solutions
- Operates at normal atmospheric pressure and is readily serviceable for refilling and cleaning while in operation
- Eliminates metering pump air locks due to off-gassing
- Eliminates transfer spills
- Minimizes man hours for maintenance and shut downs
- Pre-plumbed and skid mounted for ease of installation
- Internal mixing mechanism enables sustainable homogeneous solution and prevents solids build-up
- Option for pre-treatment

Specifications

Chlorine Delivery Rate*	1.0 - 50.0 lb. AvCl/day with 70° F inlet water temp.	Dry Chemical Capacity	62 lbs.
		Site Requirements:	
Discharge Pressure Range	50 - 150 psig	Inlet Water	1.0 gpm @ 50 - 150 psig
Water Inlet Size	1/2 inch, FNPT	Electrical	20 amp @ 120V/1ph/60Hz
Solution Outlet (Injector) Size	1/2 inch, MNPT	Operating Temperature	40° - 105° F

**Delivery rate is dependant on the dosing pump size*

Municipal Applications

Arch Chemicals, Inc. provides municipalities across the country with products that meet the toughest regulations and standards including NSF/ANSI 61 for our feeding equipment and NSF 60 for **Constant Chlor® Plus Briquettes**, allowing the public to rest easy about the quality of their water supply.

- Remote Well Sites
- Booster Stations
- Waste Water
- Reclaimed Water
- Surface Water Treatment Plants
- Ground Water Treatment Plants

Potable Water

- Provides hypochlorination to disinfect water supplies in smaller communities
- Requires low initial investment
- Maintains economical operating costs

Private Water Supplies

- Sanitizes wells, natural springs, cisterns and storage tanks by destroying microbes
- Purifies by destroying harmful organic matter

Other Water Treatments

- Controls slime and maximizes cooling efficiency in cooling towers, ponds and reservoirs of power plants
- Controls growth of slime in commercial air conditioning systems, improving cooling efficiency and eliminating unpleasant odors
- Destroys disease-producing organisms in raw or treated sewage
- Keeps decomposing septic sewage odors and masonry disintegration in check by "up sewer hypochlorination"

Patented Spray Technology

Patented Spray Technology + Constant Chlor® Plus Briquettes = Consistently Accurate Hypochlorite Solution

How it Works

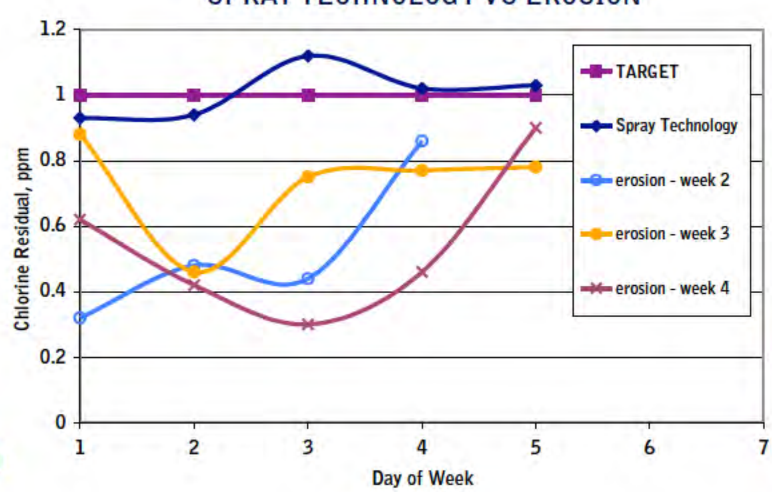
Markedly different from erosion feeders currently on the market, the **Constant Chlor® Plus MC4-50 feed system** injects supply water into the unit by spraying upward into a bed of briquettes; **this short intermittent spray cycle contacts the entire bottom of the bed evenly, not just the material resting on the grid.**

Specifically designed for use in the Constant Chlor® Plus Spray Technology feed systems, the briquettes are relatively small, smooth and "pillow shaped", for maintaining optimum packing in the spray bed.

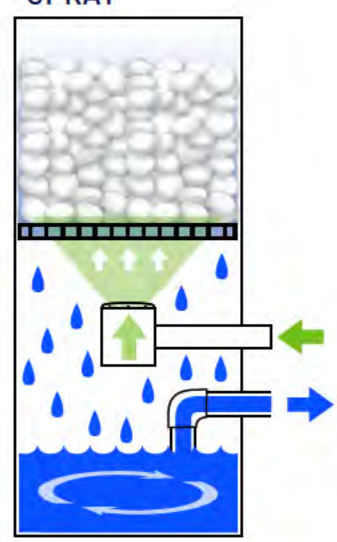
Maintaining a well-packed bed of briquettes significantly reduces the potential for large voids in the spray surface that can result in inconsistent residual concentration in the final solution.

The hypochlorite solution produced by the unit's spray cycle is collected in a 13-gallon solution tank, where the total volume is slowly and continuously mixed, further enhancing concentration consistency.

Unlike an erosion feeder, the Constant Chlor® Plus MC4-50 feeder sprays upward to a well packed bed of briquettes, contacting the entire bottom of the bed evenly. The chlorinated solution flows to the lower reservoir where it is continuously mixed. The accuracy and consistency of the resulting solution concentration far exceeds that achieved by an erosion feeder. Consequently, operator dosage adjustment is minimal.



Data source: Arizona test facility

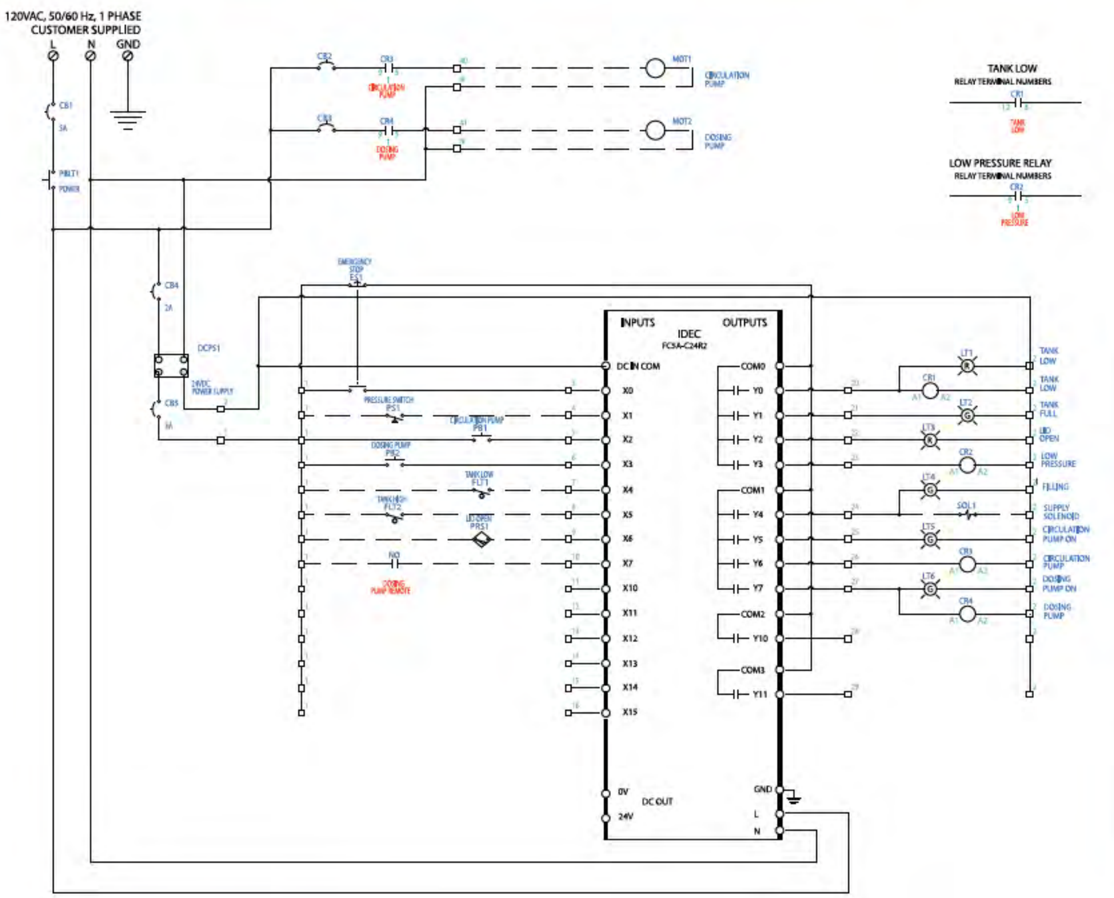


Product Stewardship

Protecting Health, Safety, and Environment
Product Stewardship

Arch is committed to maintaining and improving our leadership in Product Stewardship – from manufacture, marketing, distribution, use, recycling and disposal. Successful implementation includes educating all involved of their responsibilities to address society's interest in a healthy environment and in products that can be used safely. We are each responsible for providing a safe workplace, and all who use and handle products must follow safe and environmentally sound practices.

Electronics Panel and PLC Information



120/240VAC, 50/60Hz, 15/10A, 1 Phase

4 Normally Open Contacts for Remote Interface. 1 Dry Contact for Remote Start of Dosing Pump

24VDC Control Power

PLC with 14 Input/10 outputs

6 Inputs and 2 Outputs Available for Systems Integration

8 BUTTONS / INDICATORS

- E-STOP: Push-Button emergency stop for the unit. Turns OFF every function.
- OFF/ON Indicator: Push-Button to turn the unit ON or OFF.
- CIRCULATION PUMP: Circulation pump is interlocked with TANK LOW and will not operate if TANK LOW alarm is activated. Lamp flashes is circulation pump pressure drops below 5 psi. Push-Button to turn ON or OFF.
- DOSING PUMP: Chemical dosing pump is interlocked to the system. Will not pump if LOW CHLORINE SOLUTION alarm is activated. Remote or manual start capability. Push-Button to turn ON or OFF.
- LID OPEN: Prevents the unit from operating if lid is opened.
- FILLING: Indicates that the solenoid is energized and unit is making solution.
- TANK FULL: The high float is engaged and tank is full of chlorinated solution.
- TANK LOW: Solution inside tank is low, alarm condition.

Constant Chlor® Plus Briquettes

Constant Chlor® Plus Briquettes are designed for use in the **Constant Chlor® Plus MC4-50 feeding system.** The briquettes provide chlorine solution for use in many applications including treatment of surface and groundwater for municipal drinking water use, industrial process water as well as pre- and post-harvest food safety.

These patented, pillow-shaped briquettes contain a scale inhibitor designed to reduce maintenance and improve reliability of the feeder system.

FEATURES

- Dry Solid Product
    - Longer shelf life than liquid bleach
    - Occupies much less space than liquid bleach
    - Less hazardous than liquid bleach or gas chlorine
    - Easier to handle than liquid bleach or gas chlorine

SCALE INHIBITED

- Patented formulation
- Reduces maintenance of equipment

REGULATORY

- EPA No. 1258-1179
- NSF Standard 60, Drinking Water Additives
- Meets AWWA Standard B300

PROPERTIES

• Available Chlorine (wt%)	65% minimum
• Scale Inhibitor (wt%)	0.5%
• Weight	0.25 oz. (7 grams)
• Dimensions	1-1/4 in. X 3/4 in. X 1/2 in.
• Appearance	Pillow Shaped Briquettes

PACKAGING

Constant Chlor® Plus Dry Chlorinator Briquettes are available in 50 lb. plastic pails

Arch also produces **Dry Tec® FG Briquettes** (Food Grade) for use with **the Constant Chlor® Plus MC4-50 feeder. Dry Tec® FG** contains an anti scale formulation for food industry applications.

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MULTIPORT VALVES

Heavy duty construction

Constructed from heavy duty ABS and GFPP, Waterco Multiport valves are designed for maximum performance and working pressures.

- 6-position multiple valve positions
- Top and Side Mount configurations
- Rated at 400 kPa

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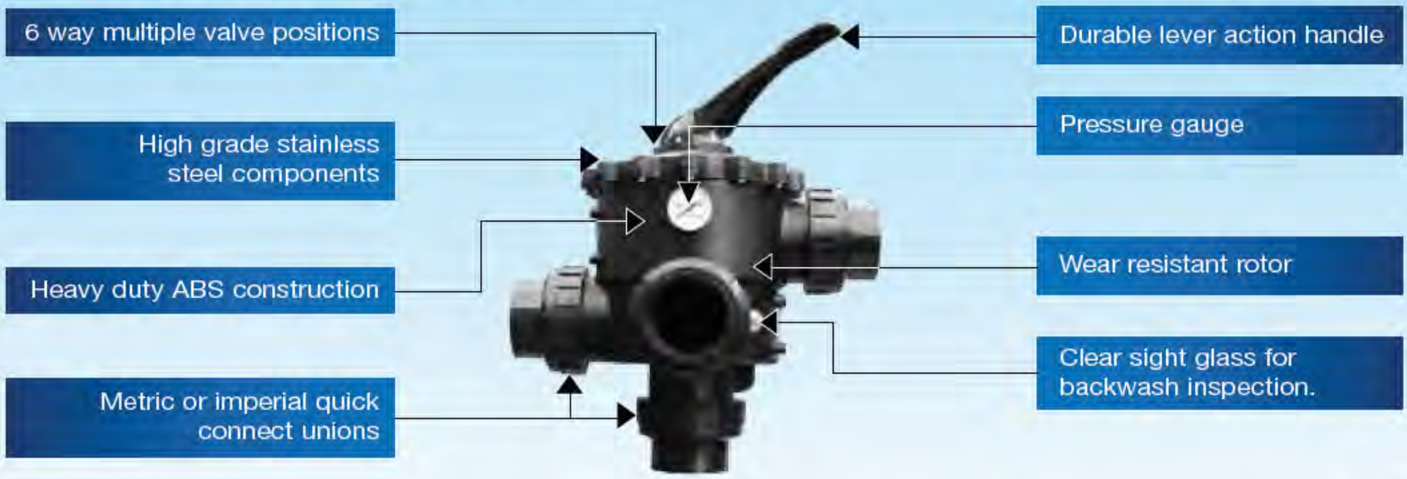
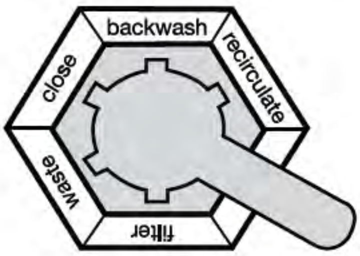
Waterco's entire range of Multiport valves are engineered to withstand a working pressure of up to 400 kPa (58 psi) with a test pressure of 600 kPa (87 psi).



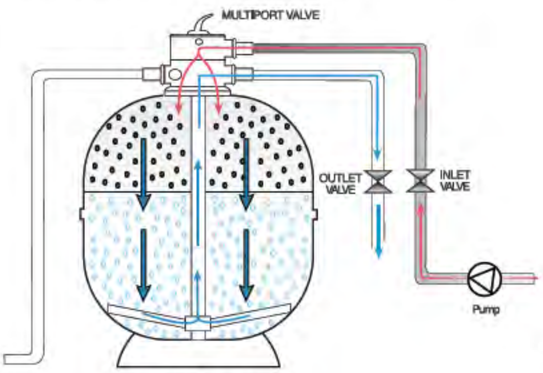
	Max flow rate	Body	Lid	Handle	Rotor	Hardware	Union Nut	Union Tail
40mm MPV	320	ABS	ABS	ABS	GF Noryl	SS304	ABS	PVC
50mm MPV	510	ABS	ABS	ABS	GF Noryl	SS304	ABS	PVC
65mm MPV	780	ABS	GFPP	ABS	GF Noryl	SS304	ABS	PVC
80mm MPV	1080	GFPP	GFPP	ABS	GF Noryl	SS304	ABS	PVC



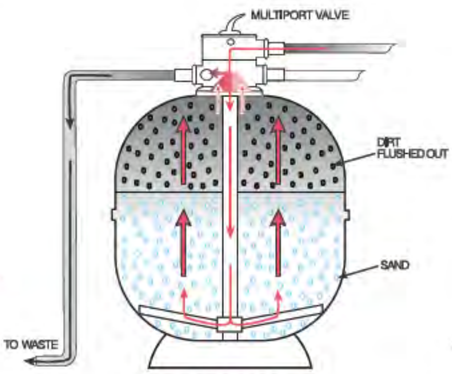
MULTIPORT VALVE MAIN FUNCTIONS

Filter	-	downward flow through the filter bed to outlet
Backwash	-	upward flow through the filter bed to waste
Rinse	-	downward flow through the filter bed to waste
Waste	-	bypass the filter bed to waste
Re-circulate	-	bypass the filter bed to outlet
Closed	-	no flow to the filter

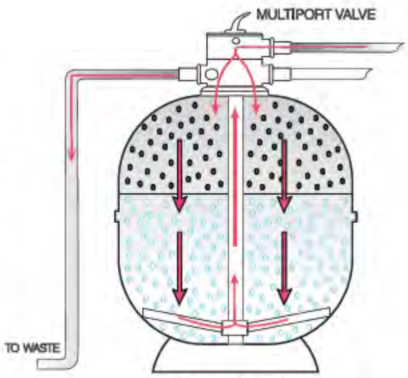
Cleansing a filter simply requires shifting the Multiport lever from the "filter" position to the "backwash" position, which reverses the flow of water in the filter, flushing the filter bed.



Filter Mode



Backwash Mode



Rinse Mode

Warranty

Waterco Multiport valves are covered by 1 year warranty.

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Constant Chlor® Plus

Dry Calcium Hypochlorite Briquettes

Designed for use in the Constant Chlor® Plus Chlorinator, **Constant Chlor® Plus Briquettes** provide the perfect chlorine solution for use in many applications including the treatment of surface and groundwater for municipal drinking water use, as well as the treatment of wastewater effluent.

THE BENEFITS ARE CLEAR

- Longer shelf life than liquid bleach
- Effective alternative to chlorine gas and liquid bleach
- Cost effective for all municipal and water treatment applications
- Easier and safer to transport and use than liquid bleach
- Dry chemical does not leak
- Small pillow-shaped briquettes provide an optimum spray bed pack resulting in outstanding solution consistency

PATENTED PILLOW-SHAPED BRIQUETTES

DELIVER UNPARALLELED CONSISTENT RESULTS

Constant Chlor® plus

Constant Chlor® Plus Calcium Hypochlorite Briquettes

Constant Chlor® Plus Briquettes provide the perfect chlorine solution for use in many applications, including the treatment of surface and groundwater for municipal drinking water use, as well as the treatment of wastewater effluent.

These patented, pillow-shaped briquettes contain a scale inhibitor designed to reduce maintenance and improve reliability of the feeder system.

Designed for use in the Constant Chlor® Plus Chlorinator

FEATURES

- Dry Solid Product
  - Longer shelf life than liquid bleach
  - Occupies much less space than liquid bleach
  - Less hazardous than liquid bleach
  - Easier to handle than liquid bleach
- Scale Inhibited
  - Patented formulation
  - Reduces maintenance of equipment

TYPICAL PROPERTIES

• Available Chlorine (wt%)	66%
• Scale Inhibitor (wt%)	0.5%
• Weight	0.25 oz. (7.0 grams)
• Dimensions	1-1/4 in. X 3/4 in. X 1/2 in. (approx 35mm X 19mm X 13mm)
• Appearance	Pillow Shaped Briquettes

REGULATORY

- EPA No. 1258-1179
- NSF Standard 60, Drinking Water Additives
- Meets AWWA Standard B300

PACKAGING

Constant Chlor® Plus Dry Chlorinator Briquettes are available in 50 lb. plastic pails

ONCE YOU'VE TRIED OUR BRIQUETTES, YOU'LL KNOW HOW TO ACHIEVE THE BEST RESULTS CONSISTENTLY

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MICRON
W & WD FILTERS

Deep Bed Sand Filters

Micron W & WD filters are designed with filter depths of 600mm to 1000mm providing enhanced indepth filtration and increased dirt retention capacity. Combining filter housing and various filter media Micron W & WD filters can be fitted in configurations to provide multi-stage comprehensive water conditioning.

www.waterco.com

Proven Durability

Waterco Micron filters are known throughout the industry for their impressive performance and reliability.

Manufactured from the highest grade of non corrosive materials and employing the latest in fibreglass winding technology, Micron filters are built for many years of trouble free operation.

Technologically Advanced

Micron filters consist of a blow moulded inner shell of fibreglass reinforced polyester resin strengthened with multiple layers of continuous strands of fibreglass filament.

Micron filters are wound with precision by Waterco's digital filament winding machines, for refined consistency and superior quality.

Easy Maintenance

Cleansing the filter simply requires shifting the Multiport Valve lever from the "filter" position to the "backwash" position, which reverses the flow of water in the filter, flushing out the trapped dirt from filter bed.

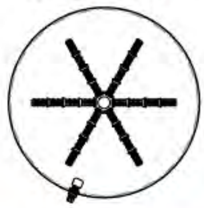
Model No:	MPV Size	Filter Bed Depth	Filter Bed Area	Filtration Flow Rates 36m³/hr/m²	Filtration Flow Rates 36m³/hr/m²	Backwash Flow Rates 40m³/hr/m²	Backwash Flow Rates 40m³/hr/m²	Filter Bed Volume	Sand 16/30	Zeoplus
	(mm)	(mm)	(m^2)	lpm	m^3/hr	lpm	m^3/hr	(litre)	(kg)	(kg)
W250	40	600	0.05	30	1.8	33	2	41	60	49
W300	40	600	0.07	42	2.5	47	2.8	58	85	70
W350	40	600	0.10	60	3.6	67	4	79	115	95
W400	40	600	0.13	78	4.7	87	5.2	79	115	95
W500	40	600	0.20	120	7.2	133	8	123	180	148
W600	40	600	0.28	168	10.1	187	11.2	175	255	210
W700	40	600	0.38	228	13.7	253	15.2	240	350	288

Model No:	MPV Size	Filter Bed Depth	Filter Bed Area	Filtration Flow Rates 36m³/hr/m²	Filtration Flow Rates 36m³/hr/m²	Backwash Flow Rates 40m³/hr/m²	Backwash Flow Rates 40m³/hr/m²	Filter Bed Volume	Sand 16/30	Zeoplus
	(mm)	(mm)	(m^2)	lpm	m^3/hr	lpm	m^3/hr	(litre)	(kg)	(kg)
WD300	40	1000	0.07	42	2.5	47	2.8	86	125	103
WD350	40	1000	0.10	60	3.6	67	4	116	170	140
WD400	40	1000	0.13	78	4.7	87	5.2	129	188	155
WD500	40	1000	0.20	120	7.2	133	8	199	290	238
WD600	40	1000	0.28	168	10.1	187	11.2	288	420	345
WD700	40	1000	0.38	228	13.7	253	15.2	394	575	473

All filters are able to sustain a temperature of 50°C and have a max working pressure of 600kPa.

***Based on 36m³/hr/m²**

Conventional lateral configuration in W & WD Series applies to models 400 to 700 only

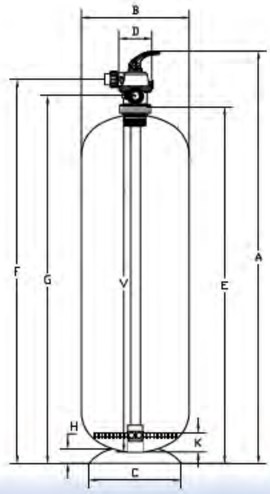


'W' Series Deep Bed Filters									
Model	A	B	C	D	E	F	G	H	V
W250	1385	268	304	160	1119	1252	1172	162	955
W300	1366	322	346	160	1100	1233	1153	175	955
W350	1397	366	355	160	1130	1262	1183	63	1010
W400	1377	416	355	160	1100	1242	1163	63	995
W500	1415	518	443	160	1148	1280	1201	69	1014
W600	1402	620	540	160	1135	1267	1188	88	992
W700	1407	720	540	160	1140	1272	1193	88	1015

***sizes in mm**

'WD' Series Deep Bed Filters									
Model	A	B	C	D	E	F	G	H	V
WD300	1977	315	301	160	1710	1841	1762	75	1590
WD350	1997	366	356	160	1730	1861	1782	63	1612
WD400	1987	416	356	160	1720	1851	1772	63	1595
WD500	2009	518	443	160	1742	1873	1794	69	1600
WD600	1997	620	540	160	1730	1861	1782	88	1582
WD700	2002	720	540	160	1735	1866	1787	88	1622

***sizes in mm**



Warranty

Product	Full Warranty	Pro-rata Warranty
1. Residential Applications • W250 / W300 • Other W/WD	 5 years 2 years	 Not applicable 3 years
2. Commercial Applications	2 years	Not applicable

*** Please refer to Waterco's warranty terms and conditions.**

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Document Status

Revision	Author	Reviewer		Approved for Issue		
		Name	Signature	Name	Signature	Date
A	C Lai	N Johnston		C Lai		17/10/18
0	C Lai	K Northcott		C Lai	Calvin Lai	14/02/19

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FOI 190204
Document 3

Department of the Environment and Energy

Australian Antarctic Division

Potable Water Treatment Strategy
Mawson Station

February 2019

Executive summary

The Department of the Environment and Energy, Australian Antarctic Division (AAD) is responsible for providing safe potable water supply to expeditioners working and living at Mawson station in Antarctica. The AAD have engaged GHD to;

- review water quality test results that previously have indicated the presence of metals exceeding health guideline values,
- identify problems in the water supply systems, and
- provide advice on options for solving and/or managing these problems.

The review of the water supply infrastructure and water quality at Mawson station has indicated that sedimentation observed in the potable water storage tanks is most likely caused by a combination of soft water and microbiologically induced corrosion (MIC). This corrosion and iron-rich sediment build-up in the storage tanks is a major source of iron and suspended solids contamination in the water supply system. Exposure of metallic piping (and possible older pipework containing trace lead levels) to the naturally soft and corrosive melt water is a major source of metals contamination in the drinking water.

To correct the corrosiveness of Mawson's water, calcium and alkalinity must be added. The microbiologically induced corrosion (MIC) also needs to be addressed, with key contributing factors including a lack of a persistent disinfectant, warm water, presence of organic carbon, and stagnant flow. Thirdly, dirty water events that have occurred at Mawson are attributed to resuspension of corrosion products in the storage tanks being drawn into the ring main (as well as biofilms being dislodged) by the high flows generated when exercising the fire water pumps.

Measures explored to address each of the above-mentioned water quality issues included:

- pH and alkalinity adjustment through chemical dosing
- Disinfection of the water supply to prevent bacteria and biofilm (and hence MIC)
- Filtration to remove suspended solids (as a result of corroding tanks and pipework) from the water supply

GHD investigated a short term and a long term solution to the water quality issues at Mawson station. The suggested short term solution includes:

- Remove all sediment from existing storage tanks
- Minimise further corrosion in existing storage tanks through pH/alkalinity adjustment
- Remove all corrosion products / biofilm from existing pipes (scour and flush)
- Provide filtration to minimise future dirty water events
- Add a persistent disinfectant to control future biofilm growth (chlorinated water supply)
- Deal with stagnant sections of pipe (flush before use policy)

However, GHD's conclusions and recommendations from this investigation is for the AAD to focus on the Long Term Solution now. That is; replace the corroding water storage tanks, scour and flush the pipework, and fast-track replacement of metallic pipework with non-metallic plumbing as much as practicable. This should avoid the need for pH and alkalinity correction, as there will be minimal exposed metal in the system and hence no corrosion. Removal of corrosion by-products from the system should negate the need for filtration, as the source water is already low in sediment. Implementation of a long-term disinfection solution is recommended. However, this would only be for biofilm control and not for primary health considerations..

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Appendices

1. Introduction

1.1 Purpose of this report

The Department of the Environment and Energy, Australian Antarctic Division (AAD) is responsible for providing safe potable water supply to communities working and living on its Antarctic stations at Casey, Davis and Mawson. As the water supply at each of the stations are low in mineral content, hardness and alkalinity, AAD staff have reported extensive corrosion in the pipes and storage systems at all three stations. Furthermore, water quality test results indicate the presence of metals at some of the sample points, where levels of lead and nickel exceeded the health guideline values specified in the Australian Drinking Water Guidelines 2011.

AAD have engaged GHD to review these test results, identify problems in the water supply systems, and provide advice on options for solving and/or managing these problems.

This report for Mawson Station summarises the findings of a Stage 1 desktop review of the test results and existing water supply system, options available to solve or manage the problems identified, and provide concept sizing of the recommended solution.

1.2 Scope and limitations

This report has been prepared by GHD for the Department of the Environment and Energy, Australian Antarctic Division (the Client), and may only be used and relied on by Department of the Environment and Energy for the purpose agreed between GHD and the Client as set out in Section 1.1 of this report. GHD otherwise disclaims responsibility to any person other than the Client arising in connection with this report. GHD also excludes implied warranties and conditions, to the extent legally permissible.

The services undertaken by GHD in connection with preparing this report were limited to those specifically detailed in the report and are subject to the scope limitations set out in the report.

The opinions, conclusions and any recommendations in this report are based on conditions encountered and information reviewed at the date of preparation of the report. GHD has no responsibility or obligation to update this report to account for events or changes occurring subsequent to the date that the report was prepared.

GHD has prepared this report on the basis of information provided by the Client, which GHD has not independently verified or checked beyond the agreed scope of work. GHD does not accept liability in connection with such unverified information, including errors and omissions in the report which were caused by errors or omissions in that information.

The opinions, conclusions and any recommendations in this report are also based on assumptions made by GHD described in Section 1.3 of this report. GHD disclaims liability arising from any of the assumptions being incorrect.

1.3 Assumptions

GHD has not had the opportunity to attend site to visually inspect and validate information provided about the existing water supply system, or to understand potential site constraints for mitigation solutions GHD has suggested and recommended. GHD relies on AAD staff to validate our understanding of the system and our interpretation of the data provided, and that AAD will assess site condition (space, electrical infrastructure, constructability, etc) and inform GHD if they believe site condition prohibits GHD’s recommended solution or result in severe OH&S issues.

2. Existing system overview

2.1 Existing water supply infrastructure

Drinking water for Mawson Station is sourced from a melt cavern, recharged from snow melt, located behind the Pump House. The water is pumped via a Melt Bell, and treated by a calcite filter prior to being sent to three indoor 90kL Service/Storage Tanks. The current configuration of the tanks is that Tank 1 is reserved as a dedicated fire water tank, with Tanks 2 and 3 used to provide potable water for station. Mawson has two melt bells situated in different locations in winter and summer months. In summer months, the melt bell is closer to the gantry and Pump House taking water from shallower section of the lake. In winter months the bell is situated around 3-9 metres further out from the summer position. This utilises the deeper section of the melt lake.

Water temperature as it enters the tanks is around 2 – 2.5 degrees C, but as the Tank House is heated, water temperature rises to approximately 18 degrees C over time.

The water is filtered in two stages prior to being pumped to a combined potable and fire services circulating ring main reticulation system. The ring main is a combined potable / fire supply line and serves to supply potable water to all cold and hot water taps as well as the fire sprinklers within the buildings. Under normal operation the water recirculates and is maintained by both pressurising and recirculation pumps. If the fire hydrants / fire sprinkler system is required, the ring main is closed and water is fed to meet fire water demand in the opposing direction.

There is no disinfection provided in the Mawson potable water supply.

Materials of construction of the major infrastructure are:

- Outside Tank House to Melt Bell – copper with HDPE insulation
- Inside Tank House to Water Storage Tanks - copper
- Water Storage Tanks – cast iron with bitumen lining. Bitumen lining has deteriorated and is exposing the cast iron tank to the water. Tank floor was grouted with mass repair mortar then sealed with Hydrepoxy (approximately 2011)
- Ring main – HDPE. Flow is continuously circulated.
- From ring main to hot and cold water taps (internal building hydraulics) – copper. Flow is stagnant until someone uses the hot or cold water tap.
- From ring main to fire sprinkler lines – copper to alarm valve, then galvanised steel. Flow is stagnant.
- Fire sprinkler lines (in buildings) – steel (unsure if galvanised or not). Flow is stagnant

A schematic diagram of Mawson's water supply system is provided in Appendix A.

2.2 Water demands

Mawson Station is home for up to 60 expeditioners and scientists over the summer months and about 15 expeditioners over the long winter months.

The summer months are spent pumping the lower melt lake in order to maintain storages to service the expanded summer population. At times of peak demand, water may be pumped from the upper melt lake, transferred into either the lower melt lake or directly into the internal 90 kL storage tanks. During winter, whilst the population is smaller, pumping continues on a daily basis.

AAD estimates the annual water consumption at Mawson to be approximately 0.1 ML. Summer demand averages about 25 to 40 kL per week, with a peak day of about 5.2 kL. Winter demand averages about 15 to 22 kL per week, with a peak day of about 2.8 kL. Most of the usage is understood to be in the kitchen, brewing, humidifiers and water production.

2.3 Review of water quality

2.3.1 Iron

AAD staff reports extensive corrosion observed in the three water storage tanks, resulting in a build-up of sludge (iron corrosion products) on the tank floors. The sludge is drawn into the ring main and is accumulating in the ring main. Under normal recirculating flow the sludge is relatively undisturbed, but when the fire system is operated (at a higher flow rate and in a reversed direction), this sediment is disturbed and mobilised. Once the ring main is placed back into normal operation, water contaminated with the mobilised sediment is introduced to the point of use.

The corrosion observed in the tanks is believed to be caused by a combination of soft water and microbiologically induced corrosion (MIC). Having the calcite filter at the inlet to the tank did not appear to correct the corrosiveness of the water. A review of January 2018 water quality data provided by AAD clearly shows that the water within the tanks is still soft and corrosive (LSI is still -3.76 in tank 1 and alkalinity marginally improved to 10 mg/L from 3 mg/L in the raw water sample). With such soft water, a protective layer of calcium carbonate cannot form on the exposed cast iron surfaces, leaving the natural corrosion process unchecked. In addition, since the water is not disinfected, iron bacteria has proliferated, accelerating the corrosion process due to MIC (inferred from findings at Davis Station - ALS Report No. 62408-1-1Eng, 10 July 2018).

2.3.2 Other metals

Water quality testing during January 2017 found lead levels close to or slightly exceeding the health guidelines in a number of cold water taps (Green Store bathroom and Aeronomy kitchenette). Lead was not detected in samples from the water tanks, site services potable water reticulation, or taps across various other buildings. The test results indicate that the source of this lead is through contact with older pipework which contains traces of lead and is localised to these buildings.

Review of the January 2018 metals result shows high levels of nickel at one of the sample sites (0.153 mg/L in STR_18). The exceedance of nickel was found in the science building kitchenette cold tap but was absent after the tap was flushed. It was suspected that this metal was entering the water supply due to localised dissolution of nickel from the plumbing materials (pipes or tap fittings) at the sample point.Water samples from all of the other tested locations were within health guideline values.
It appears that soft water in combination with MIC (due to a lack of disinfection), is the cause of leaching of metals from metallic pipework that contains copper / lead / nickel. As the melt water is naturally soft, all metallic piping in the system exposed to this water are at risk of corrosion. Piping with long detention time or stagnant water is the most at risk, such as taps that are rarely used, or the copper / galvanised steel connecting pipe between the HDPE ring main and the fire sprinkler main.

2.3.3 Other water quality risks

The potential for algae to bloom in source water for Mawson Station, resulting in contamination of water tanks and the supply system, is unknown. However, the propensity for this, the conditions that would trigger it, and the possible impacts including toxins production, are currently being investigated. An item is included in the Improvement Plan in the Drinking Water Quality Management Plan dated 29 June 2018.

This water quality risk has not been considered in this water treatment strategy report.

3. Causes and mitigation options

3.1 Corrosive water

Metals, when submerged in freshwater, can suffer from several types of corrosion (i.e. seawater related chloride corrosion is not considered here). Uniform corrosion can occur when there are dissimilar metals in contact with each other, such as when copper piping is connected to mild steel. Pitting, or concentration cell corrosion, can occur when the oxygen concentration near a pipe wall is different to the bulk water, such as under deposits.

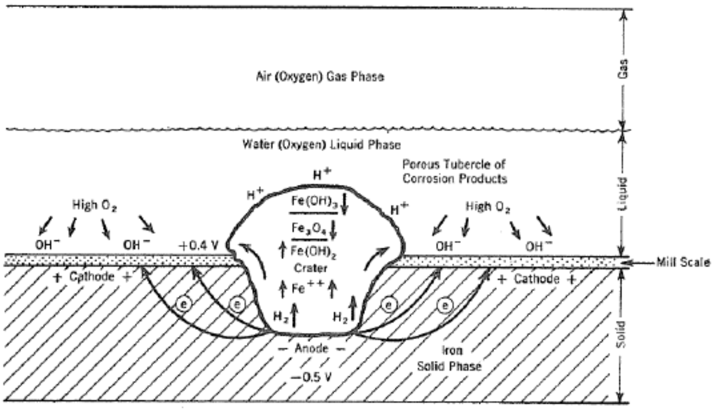


Figure 1 Pitting of iron by tuberculation and oxygen concentration cells (by Obrecht and Pourbaix)

Figure 1 shows pitting of iron and formation of tuberculation due to oxygen concentration cell and this appear to be the principal corrosion mechanism occurring in the storage tanks at Mawson based on previous reports and discussions with AAD.

Freshwater can help slow this form of corrosion (but not uniform corrosion due to dissimilar metals) by depositing a layer of calcium carbonate on the metal surface. However, the source of water at Mawson, being from melting ice, is too low in calcium and alkalinity to deposit a protective calcium carbonate film to slow the natural corrosion of exposed metals. Such water is termed corrosive water. In contact with concrete material, freshwater with low calcium content also has a tendency to leach calcium from the cement, weakening their structure. Fortunately, the grouting of the tank floor was sealed with a protective epoxy, protecting the repaired tank floor from the effect of the corrosive water.

To correct the corrosiveness of Mawson's water, calcium and alkalinity must be added such that the water has a tendency to deposit calcium carbonate. This tendency for deposition of calcium carbonate can be measured by the Langelier Saturation Index (LSI) of the water. A positive LSI indicates a propensity to deposit calcium carbonate, while a negative LSI indicates a tendency to leach calcium from cement. At LSI equal to zero, the water is said to be saturated with respect to calcium carbonate and is neither corrosive nor scaling. As excessively high LSI can mean excessive scaling of pipes and appurtenances by calcium deposit, typical target is a LSI of between -0.3 and +0.3.

Common chemicals used that can add calcium and/or alkalinity are compared in Table 1 below.

Table 1 Chemicals for addition of calcium / alkalinity

Chemical	Advantages	Disadvantages
Calcite ($CaCO_3$)	Stable natural chemical, simple to use, suitable for small and remote sites. Adds both calcium and carbonate alkalinity. Difficult to overdose.	Slow dissolving, particularly in cold water.
Hydrated lime (CaOH)	Faster reaction	Difficult to handle. Adds impurity. Only adds calcium but no carbonate alkalinity. Typically used in conjunction with carbon dioxide to add carbonate alkalinity which

Chemical	Advantages	Disadvantages
		adds complexity to the system (i.e. liquid CO_2 in pressurized tanks).
Calcium chloride (CaCl)	Easy to handle and dissolves quickly.	Only adds calcium but no carbonate alkalinity.
Soda ash ($NaHCO_3$)	Reacts quickly	Only adds carbonate alkalinity but not calcium.

Hydrated lime is a commonly used chemical in water treatment for pH adjustment and addition of calcium. However, it has significant handling issues including being hydroscopic, is dusty, and causes scaling in dosing equipment and dosing lines that requires significant maintenance to maintain operations.

Adding both calcium chloride and soda ash is a possible solution to add both calcium and carbonate alkalinity to the water, however, the use of two chemicals increases the cost of chemicals significantly.

Only calcite can add both calcium and carbonate in a simple filter arrangement. The chemical is stable and is easy to handle. Calcite is therefore the recommended chemical to address the corrosiveness of the water at Mawson.

AAD should note that by adding sufficient calcite to reach a target LSI of between -0.3 and +0.3 would raise the water pH to between 9 and 10 (according to ADWG extreme pH which may adversely affect health lay <4 and >11). However, water with high pH may have an unpleasant taste, and the high pH can also impart a soapy feel to the water. Fish placed in high pH water can also be affected adversely (e.g. if fish tanks were being maintained at the station). To avoid high pH water, carbon dioxide would need to be added to lower the pH without removing the carbonate alkalinity added by the calcite. However, this would add complexity to the system, and is not recommended, noting that the existing system is already adding calcite without pH correction.

The use of corrosion inhibitors such as inorganic phosphates or sodium silicates was also considered but discarded. This is because care must be taken with the use of such chemicals since they are added to the water and are therefore consumed together with the drinking water. Dosage of such chemicals therefore must be carefully controlled to avoid over-dosing, and the chemical must be sourced from reputable manufacturers who can demonstrate compliance with relevant standards for chemicals used in drinking water treatment. The cost of such chemicals is typically higher than calcite, and moreover, the use of phosphate based corrosion inhibitors would result in an increase in phosphate load to the on-site wastewater treatment system.

3.2 Microbiologically induced corrosion

Microbial action can sometime accelerate the rate of natural corrosion that occurs in water systems. The mechanism of such microbiologically induced corrosion (MIC) is not well understood, but contributing factors include a lack of a persistent disinfectant, warm water, presence of organic carbon, and stagnant flow.

The water supply system at Mawson has many of the contributing factors listed above, such as a lack of disinfection and stagnant flow where biofilm can proliferate over time. Biofilm are complex structures that once formed cannot be removed by disinfectant level normally found in drinking water. Therefore, the biofilm that has formed must first be removed (e.g. by scouring and superchlorination) and a persistent disinfectant added to the water to moderate their growth to minimise future risk of MIC and biofilm related dirty water events.

Common disinfection options are compared in Table 2 below.

Table 2 Disinfection options

Option	Advantages	Disadvantages
Ultraviolet light (UV)	UV systems require relatively low maintenance and do not require the addition of chemicals.	High doses of UV is required for bacteria and does not provide a disinfection residual.
Ozone	A strong disinfectant that is effective against most microbial.	Specialised equipment is required to generate ozone on site (ozone cannot be stored). Ozone does not provide a disinfection residual, and the gas is pungent and can be dangerous.
Chlorine gas	A strong disinfectant that is effective against bacteria and viruses.	Specialised equipment is required handle the gas. Chlorine gas is dangerous
Sodium hypochlorite (liquid)	Easy to handle and use. 12% sodium hypochlorite is relatively safe.	Relatively short shelf life. Degrades to form chlorite ion, which is undesirable in drinking water.
Sodium hypochlorite (on-site generation)	A weak, 0.8% sodium hypochlorite is generated on site from high quality salt and electricity. Resolves degradation issues associated with 12% sodium hypochlorite. Only need to transport and store potable grade salt.	Relatively more maintenance compared to 12% sodium hypochlorite or calcium hypochlorite option due to maintenance of the electrolytic cells.
Calcium hypochlorite (solid)	Easy to handle and use. Available as dry briquettes with long shelf life.	Slow dissolving.

To effectively manage the risk of MIC, an option that provides a persistent disinfectant in the water is necessary. UV and ozone are both ruled out on this basis. Chlorine gas is a dangerous gas and 12% sodium hypochlorite has a short shelf life. Both are not suitable for a simple system in a remote location. The water quality issue associated with degradation of 12% sodium hypochlorite can be resolved with an on-site generation system, which can generate 0.8% sodium hypochlorite on demand, or the use of a calcium hypochlorite tablet system. An on-site generation system requires slightly more maintenance than a calcium hypochlorite system due to the need to maintain the specialised electrolytic cells that are the heart of an on-site generation system, whereas the calcium hypochlorite involves simple dosing pumps only that are simple to maintain. Calcium hypochlorite is therefore recommended (chemical datasheet is provided in Appendix B).

The provision of a persistent disinfectant is expected to be effective for controlling MIC in the main recirculating loop where flow is continuous. However, in stagnant lines, such as those servicing taps that are rarely used, the disinfectant would lose its effect over time and biofilm would again take hold. The only mitigation for possible dissolved heavy metals in these taps served by stagnant lines is to implement a “flush before use” policy at the station.

3.3 Dirty water events

It is understood that dirty water events that have occurred were due to iron corrosion products in the storage tanks being drawn into the ring main as well as biofilms in the ring main being dislodged by the high flows generated when exercising the fire water pumps.

Biofilms, as discussed in Section 3.2 above, must first be removed and a persistent disinfectant added to the water to moderate their future growth. This should address future dirty water events caused by a build-up of biofilms in the ring main.

In term of iron corrosion products, AAD advised that, due to the confined space nature and multiple cross-bracing design of the existing storage tanks, it would be unsafe and impractical to sand-blast their interior to remove all existing iron corrosion and tubercules and prevent future corrosion by epoxy coating the interior. AAD has already made provisions to replace the storage tanks in the near future. GHD recommends that the future tanks be constructed from corrosion resistant materials, such as epoxy coated concrete or steel panels, glass-fused to steel panels, or fibreglass An alternative option for corrosion resistant tanks is to look to plastic tanks or framed water bladder tanks. As these essentially have no exposed metal components, they will not corrode. They can be supplied as food grade and are reasonably temperature resistant (both hot and cold) upon selection of the appropriate materials of construction. Whilst the plastic and bladder style tanks would be expected to be substantially cheaper to purchase, they will not necessarily have the same expected service life as for glass-fused steel or fibreglass. Hence cost of replacement would need to be factored in. The suitability of the materials of construction for transportation, both from an extreme cold and wear and tear perspective, would need to be considered.

In the short term, corrosion of the existing tanks is expected to continue, and a method to remove the iron corrosion products from the water is required to minimise the risk of future dirty water events associated with operations of the fire water pumps.

Existing mitigations implemented includes the use of bag filter (5 micron), a JPF screen filter (100 micron), and point-of-use cartridge filters (5 micron). These filters are not appropriate technologies for this application because they operate as “strainers”, which are effective only if the particle size being removed is larger than the openings of the filters. As the iron corrosion products are very fine and there is no chemical being added to coagulate them to form larger particles, the iron corrosion products would simply pass through the filters under pressure.

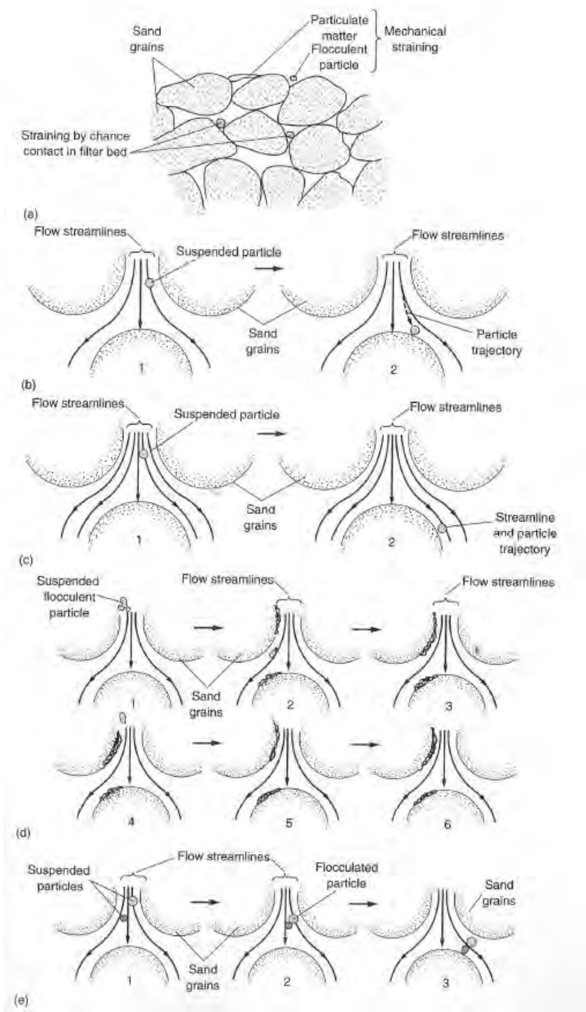


Figure 2 Depth filtration mechanism (by Metcalf & Eddy)

GHD recommends the use of granular media filters (e.g sand filters) for this duty. This is because granular media filters operate in “depth” filtration mode where particles are trapped within the interstices of the granular media via various mechanisms that are not dependent on size. Some of these removal mechanisms within a granular media filter are straining, sedimentation, interception, adhesion, and by flocculation as shown in Figure 2. The use of granular media filters is expected to perform better than the existing strainer type filters and these existing filters can be removed from service. The down side of granular media filtration is the filters do require periodic backwashing to maintain filtration capacity and performance. The disposal of the backwash water would need to be considered in the process augmentation.

Size and arrangement of the recommended granular media filters are discussed in Section 4.2 below.

It is possible to source cartridge filters with smaller nominal micron removal ratings. These can be sourced either as melt blown polypropylene, pleated cartridges either manufactured from polypropylene or a mixture of thermally bonded microglass fibers and cellulose infused with ceramic. These filters also operate (to a lesser extent than granular media) as a form of depth filtration. The benefit of these is the simplicity of their operation, change-out instead of backwashing requirement and the AAD staff familiarity with the existing bag and cartridge filter operation. The negatives of this option is the change-out cost of these particular cartridge filters, which can be of the order of $700 and upwards per cartridge. They may not be able to reliably filter to the same micron level (e.g. less than 0.5 micron) as granular media is able to do.

3.4 Short term management solution

In summary, the following short term management solution is recommended.

Table 3 Short term management solution

Steps	Recommendations	Comments
1. Remove all iron corrosion products from existing storage tanks	• Pressure clean with high pressure cleaner	• Removing all corrosion product from the tanks will minimise future dirty water events.
2. Minimise further corrosion in existing storage tanks	• Correct LSI of stored water with calcite	• Refer to Section 4.1 for configuration options and Section 4.3 for sizing of calcite filter.
3. Remove all corrosion products / biofilm from existing pipes	• Flushing and pigging • Superchlorination	• Removing all corrosion products / slimes from pipes will minimise future dirty water events. • There may be a period of dirty water events after the clean as new slimes are establish and dead slimes are removed.
4. Provide filtration to minimise future dirty water events	• Granular media filters are recommended as the most robust option.	• Refer to Section 4.2 for sizing.
5. Add a persistent disinfectant to control future biofilm growth	• Calcium hypochlorite dosing	• Refer to Section 4.4 for sizing
6. Dealing with stagnant sections of pipe	• Implement a “flush before use” policy at rarely used taps	• Stagnant sections of pipe will remain at risk of MIC. • Flush before use will minimise potential exposure to heavy metals from the drinking water.

3.5 Long term solution

In the longer term, it is understood that AAD plans to replace the existing cast iron storage tanks. GHD recommends that the future tanks be constructed from corrosion resistant materials, such as epoxy coated concrete or steel panels, glass-fused to steel panels, or fibreglass, or (where practical) possibly food grade HDPE or framed bladder tanks using flexible polymer materials. The suitability of the material for the extreme temperatures of Antarctica during transportation and operations must also be confirmed. Additionally, copper piping, which are potential source of copper and lead in the water, could be replaced with non-metallic materials as the opportunity arises.

Once the water network becomes largely non-metallic, the need for continuous calcite and granular media filters could be reassessed. The dosing of a persistent disinfectant could also be reduced or ceased, but would need to be balanced against the need to control biofilm, which could still give rise to dirty water events if their growth becomes excessive.

Table 4 Long term solution

Steps	Recommendation	Comments
1. Replace cast iron storage tanks with corrosion resistant tanks	• Common options are glass lined steel panel tanks, steel or concrete tanks with epoxy coating, FRP. HDPE (where practical) • Choice of material must also be suitable for the extreme temperature that could be encountered in Antarctica.	• Epoxy coating will have limited life and will require re-coating in the future. • If concrete tank without epoxy coating is used, will need to ensure the LSI of the stored water is not corrosive to the concrete.
2. Replace stagnant sections of pipes with non-metallic materials such as HDPE.	• Any non-metallic plumbing must meet the latest requirements of the Building Code of Australia.	• Replacement of stagnant sections of pipe with non-metallic material will remove the risk of potential exposure to heavy metals from the drinking water.
3. Periodic flushing of pipes	• Flushing and pigging • Superchlorination	• Periodic removal of slimes from pipes may still be required to prevent dirty water events. • There may be a period of dirty water events after the clean as new slimes are establish and dead slimes are removed.

4. Treatment configuration and sizing

The preceding sections confirmed the need in the short term to:

- Correct the corrosive nature of the water stored in the water tanks by the use of a calcite filter,
- Filter the water to remove iron corrosion products by the use of granular media filters, and
- Dose calcium hypochlorite into the water to control the growth of biofilm.

This section describes the configuration options and the sizing of major equipment.

4.1 Treatment configuration options

Three alternative treatment configurations were considered for Mawson:

1. Provide calcite filter on the inlet to the water storage tanks.
2. Provide calcite filter on a recirculating loop from the existing ring main back to the water storage tanks.
3. Provide calcite filter on a new recirculating loop from the suction main of the fire supply pumps back to the water storage tanks.

In all options, the current practice of isolating Tank 1 for fire fighting should be discontinued, as this encourages stagnant water in the tank and can results in high level of metals in the water when the fire pumps are tested.

Option 1 was eliminated because the water from the melt bell is still very cold (2 – 2.5 deg C) and this would have an adverse affect on the performance of the calcite filter (dissolution rate would be very slow). Compounding this problem is that a calcite filter on the inlet treats the incoming water once only, which mean a very large calcite filter is necessary to provide the required contact time to overcome the slow dissolution rate and correct the corrosiveness of the water.

Option 2 and 3 has the calcite filter on a recirculating loop downstream of the water storage tanks. In this configuration, not only is the water temperature higher due to detention in the tanks, but the recirculating loop means that the calcite would have multiple opportunities to treat the water, eventually reaching calcium carbonate saturation (i.e. LSI ~ 0). Such multi-pass calcite treatment is therefore recommended.

In Option 2, an analysis of the existing system was conducted to assess the capacity of the existing pressuring pump to supply the flow of the recirculating loop. Figure 3 below is a plot of the pressure pump's (LOWARA SV1603F30T) operating range at various speeds. The Grundfos recirculating pump does not affect this hydraulic analysis since its function is only to provide a recirculating flow and there is no "loss" in the recirculating system.

AAD advised that the pressure pumps are operated to maintain pressure between 31 m and 34.7 m. These settings are superimposed onto the pump curves below and it shows that the pressure pump (variable speed) is continuously changing speed to meet water demand while still maintaining system pressure at appropriate level.

During low demands, water consumption ranges from zero to probably up to 3 m^3/h (assuming conservatively that the peak day usage is all consumed within 1 hour), suggesting that the pressure pump would probably operate at a speed around 39 Hz to supply the instantaneous demand.

As demand increases, water consumption may increase to probably up to 5.3 m^3/h (again conservatively assuming all the peak day's usage is all consumed within 1 hour), suggesting that the pressure pump would probably operate at a speed up to around 41 Hz (may be slightly higher in short bursts if there is coincidence of usage) to meet supply.

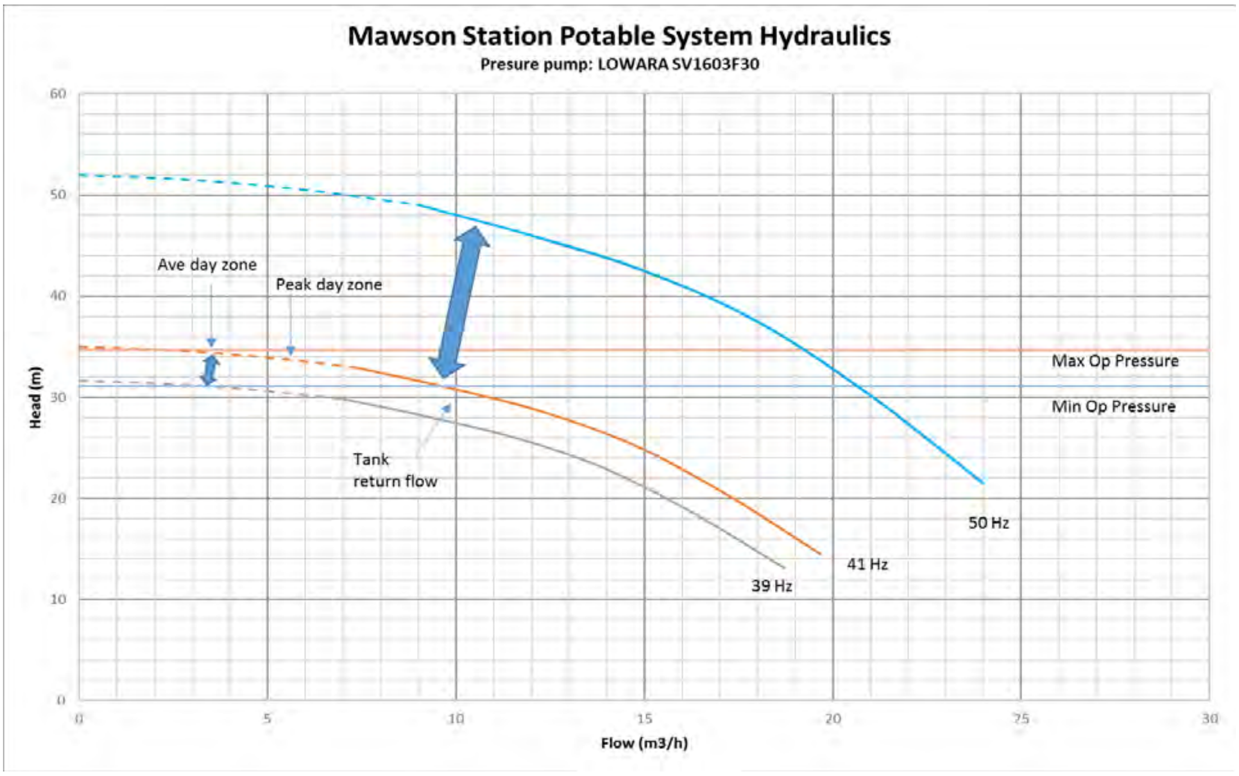


Figure 3 Existing potable system hydraulics

The above analysis is indicating that the existing pressure pump is adequately sized and should be able to supply a CONTINUOUS tank return flow of say 10 m^3/h. This tank return rate would allow the peak day's volume to be treated by a calcite filter at least once in 1.5 hour, and turnover of the entire tank volume of 270 m^3 in 27 hours.

Based on this analysis, a recirculating flow rate of 10 m^3/h is recommended.

Configuration for Option 2 is shown in Figure 4 below. A bleed line sized for 10 m^3/h with a pressure sustaining valve (PSV) would be created on the new recirculating main. This PSV will be set with an upstream pressure same as the pressure pump setpoint. As a PSV opens when the upstream pressure is above the setpoint, the PSV will allow a continuous flow back to the tanks as long as the pressure pump is able to maintain a pressure between above the setpoint in the existing ring main. If instantaneous demand in the system is such that the pressure pump is unable to maintain pressure, the PSV would close, temporarily stopping the tank return flow, so that normal demand can be met by the existing pressure pump. This tank return flow would pass through the granular media filters (to protect the calcite filter from fouling), the calcite filter to correct the LSI of the water, and three return lines each with an adjustable control valve to spread the flow evenly back into each tank. In effect, this bleed line would act as a "demand" on the pressure pump, even when there is a backwash on the granular media filter, and would make the pressure pump operate continuously at a higher speed (around 44 Hz) than it currently does. The advantage of this option is that it avoids the need for a new set of recirculating pumps, however, there is still a potential for iron corrosion products to accumulate in the storage tank floors and be drawn into the ring main when the fire supply pumps are operated.

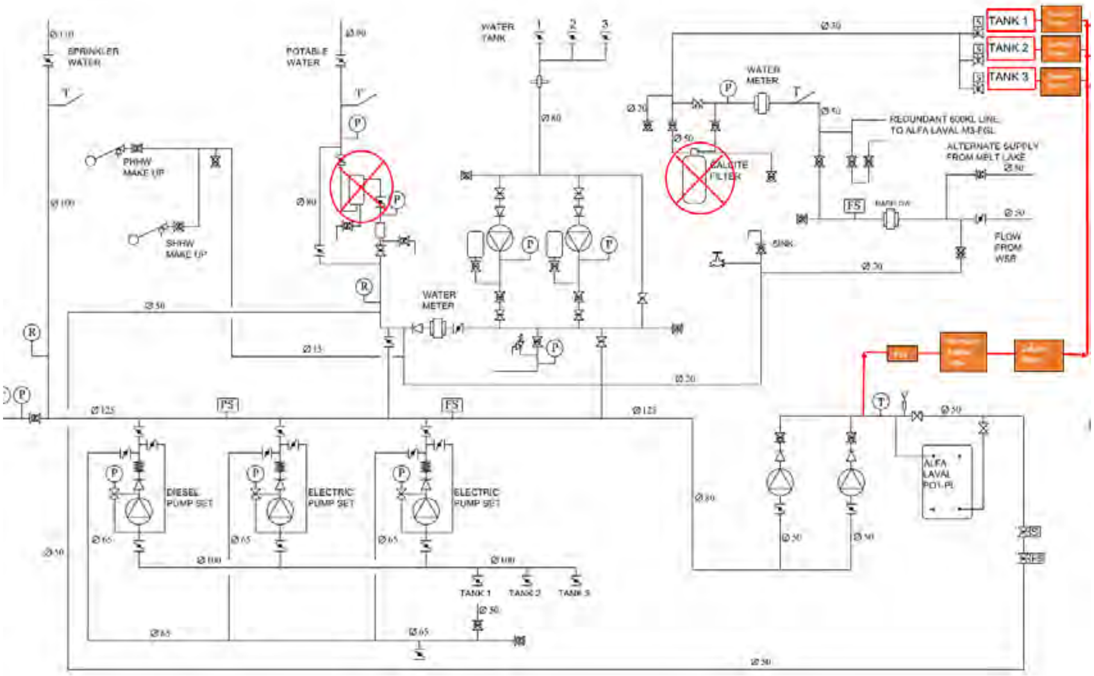


Figure 4 Schematic of recirculation loop from existing ring main

Option 3 (shown in Figure 5 below) addresses the deficiency of option 2 above by configuring the new recirculating loop from the suction main of the fire supply pumps (or from the tank's drain valves if these are appropriately sized), which, since it is drawn from the base of the storage tanks, increases the potential for removing iron corrosion products accumulating in the tanks via the proposed granular media filters. While this option requires a new set of recirculating pumps (10 m^3/h capacity), it resolves the issue of future dirty water events better and is therefore recommended.

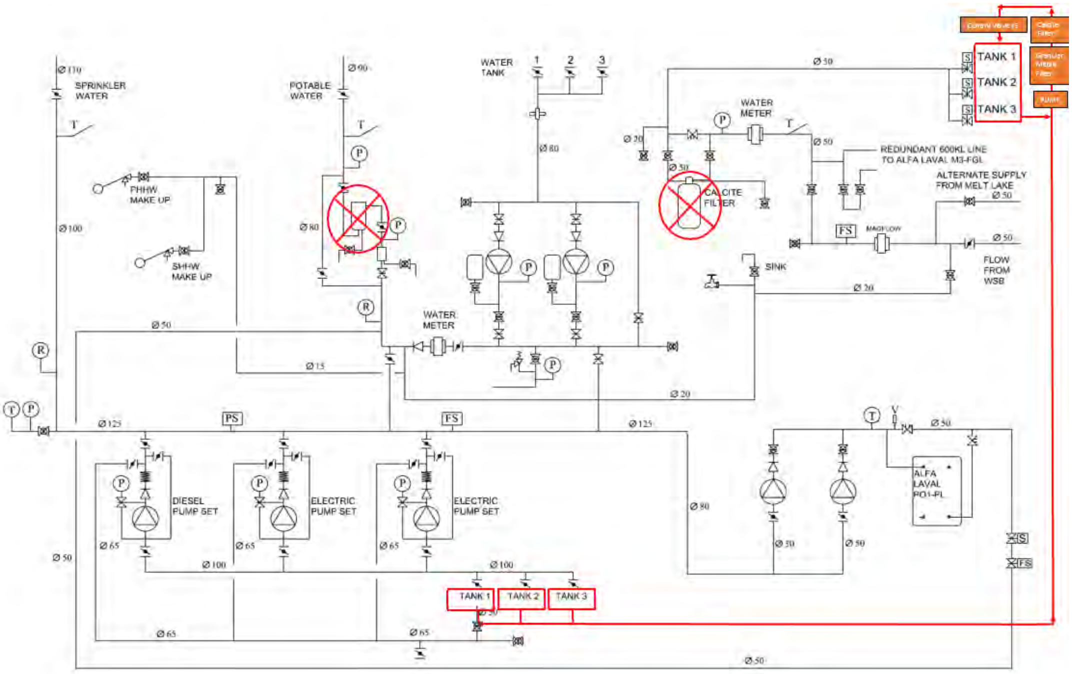


Figure 5 Schematic of recirculation loop from suction main (fire pumps)

Sizing of individual elements of the scheme is provided in the sections below.

4.2 Granular media filters

4.2.1 Filter types

Granular media filters can be configured as open gravity filters or as pressure filters contained in fibreglass pressure vessels. Open gravity filters are the choice for large plants but for smaller installations such as Mawson, pressure filters offer simpler backwashing arrangement and installation.

Due to the size and remoteness of the installation, pressure filters are recommended for Mawson.

Figure 6 Typical pressure filter (courtesy of Waterco)

4.2.2 Filter media selection

Commercially available filter media that is suitable for Mawson are:

- Silica sand (S.G. of 2.65)
- Filter coal (S.G. of 1.4 to 1.5)
- Glass beads (S.G. of 1.55 to 1.65)

The main selection criteria are cost, durability, inertness, particle size (and size distribution), and specific gravity (for backwashing consideration). Of the three filter media listed above, silica sand has the highest specific gravity and therefore would require the highest backwash rate to effectively fluidise the bed to remove trapped particles when backwashing. When used in a pressure filter arrangement, where backwash flow is normally provided by the inflow, the use of the heavier silica sand effectively limits the size of the filter that can be used (so that a suitable backwash rate can be achieved). For this reason, the use of the lighter media such as the filter coal or the glass beads is preferred.

Durability, inertness and particle size distribution requirements for filter media are specified in the American Water Works Association standard B100, and this standard would apply to filter coal. Waterco supplies a glass beads media (Glass Pearls) with their range of pressure filters with a specification shown in Figure 7. The inertness and durability of glass means that such filter media would also be acceptable.

Technical Specifications	
Filtration Media	Glass Pearl
Effective Size (mm)	0.61
Uniformity Coefficient	1.21
Bulk Density	1.61
Mohs Hardness	7.0

Chemical Compositions	
Silicon dioxide (SiO2)	70.00 - 75.00%
Sodium oxide (Na2O)	12.00 - 15.00%
Calcium oxide (CaO)	7.00 - 12.00%
Magnesium oxide (MgO)	approx. 5.00%
Aluminium oxide (AL2O3)	approx. 2.50%
Potassium oxide (K2O)	approx. 1.50%

Figure 7 Glass pearl filter media (courtesy of Waterco)

The effective size and uniformity coefficient for the Glass Pearls are shown as 0.61 and 1.21 respectively. This media size and distribution is suitable for small scale pressure filters and would also apply if filter coal is used.

4.2.3 Filter size and arrangement

Critical parameters for a successful and robust filter design are:

- Filtration rate: expressed in m/h (equivalent to m3/m2/h), it is a measure of how quickly the water will travel through the media bed.
- Filter depth: should be proportional to filtration rate, since detention time in the filter bed increases particle removal by the various removal mechanisms that exist in a filter bed.

Based on a recirculating flow of 10 m^3/h, the filtration rates and detention times achievable for a range of standard pressure filters (datasheet from supplier is provided in Appendix B) are shown in Table 5 below.

Table 5 Granular media filter size range

Filter dia (mm)	Filter Area (m^2)	Filter depth (mm)	Filtration rate (m/h) and detention time (min)			Backwash rate (m/h)
			1 filter	2 filters	3 filters	1 filter
500	0.20	500	50 (0.6)	25 (1.2)	16.7 (1.8)	50
600	0.28	500	35.7 (0.8)	17.9 (1.7)	11.9 (2.5)	35.7
750	0.44	500	22.7 (1.3)	11.4 (2.6)	7.6 (4.0)	22.7
900	0.64	500	15.6 (1.9)	7.8 (3.8)	5.2 (5.8)	15.6

Filter size should also be cognisant of the backwash rate achievable by the inflow (without providing a separate backwash pump). Appropriate backwash rate is a function of water temperature, filter media size and distribution, and specific gravity, and is shown by Figure 8 for 20 degree (for lower water temperature, the required rate is reduced due to viscosity of the water). For the preferred filter media, appropriate backwash rate is about 0.38 m/min (or 22.8 m/h).

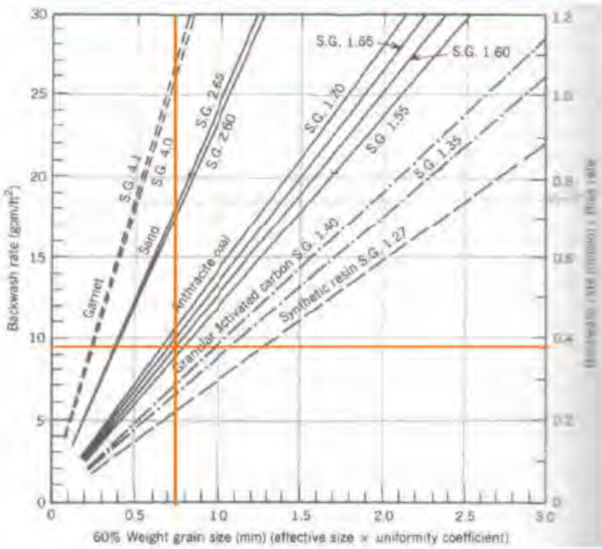


Figure 8 Granular media backwash rates

Suitable filter size and arrangement is therefore 3 x DN750, which enables a suitable backwash rate (when washing one filter at a time) while providing adequate detention time that maximises particle removal. Having larger filters may improve particle removal but is at the expense of poorer backwash rate.

3 x DN750 pressure filters are therefore recommended.

4.2.4 Operations and maintenance

It is expected that the filters will be manually operated. In normal operations, all three filters would be filtering unless there is a fault in which case the faulty filter will be manually isolated. Reasonable performance is expected even with two filters and hence a standby filter is not recommended.

The only maintenance required is to backwash the filters periodically, which can be activated manually via a multiport valve (datasheet from supplier is provided in Appendix B) supplied with the filter. The function of this multiport valve is shown in Figure 9 below. To achieve the required backwash rate, the operator would manually close the other two filters while backwashing the third. Each backwash is expected to take around 2 to 4 minutes and all three filters would be backwashed sequentially.

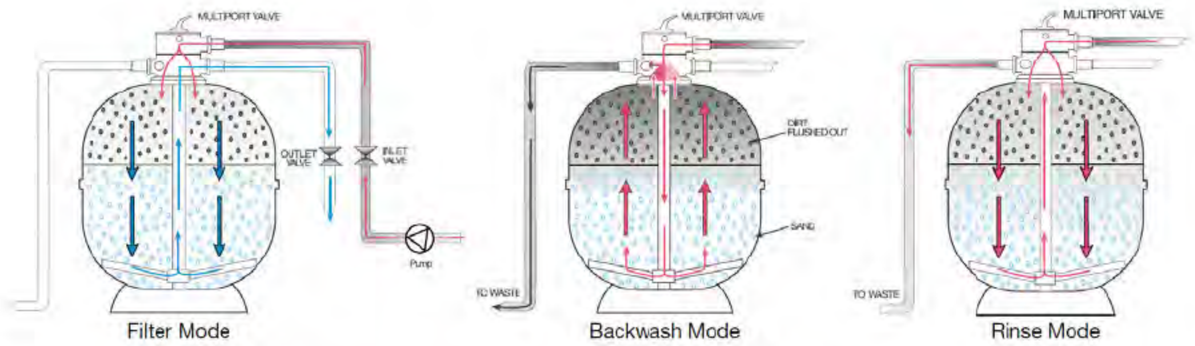


Figure 9 Backwashing of pressure filters using multiport valve (courtesy of Waterco)

Backwash waste would need to be managed on site. It should be suitable to send the backwash waste to the on-site wastewater treatment facility for disposal, subject to an analysis of the hydraulic capacity of the treatment facility. A temporary holding tank may be necessary to hold back the backwash waste and release it at a reduced rate to the treatment facility.

4.3 Calcite contactor

4.3.1 Calcite media

As this is a drinking water system, the calcite media used must conform to recognised standards for chemicals used in the drinking water industry. There is currently no Australian Standards for calcite. We therefore recommend that the calcite media to conform to:

- *British Standard EN 1018:2013+A1:2015 Chemicals used for treatment of water intended for human consumption - Calcium carbonate*

4.3.2 Contactor size and arrangement

British Standard EN 1018 states typical size range for calcium carbonate as 1 to 3 mm, with a bulk density of between 1 kg/L to 1.5 kg/L. In size, they are therefore similar to sand and are typically arranged in similar fashion as sand filters. To avoid the need for re-pumping after the calcite contactor, the use of pressure vessels to house the calcite, similar to that of a sand filter above, is appropriate.

A single contactor arrangement would be acceptable, as there should be no need to backwash the calcite in normal operations (although backwashing would be provided by the multiport valve similar to the granular media filters above, which could be used to occasionally flush out any residual calcite in the contactor if required).

There are two sizing criteria for sizing calcite contactors:

1. That it is sufficiently sized to retain the water in the contactors long enough to dissolve the calcium carbonate for the water to reach the target LSI.

2. That it is sufficiently sized to hydraulically pass the design flow without excessive headloss.

At the design flow rate of 10 m^3/h, a single DN600 pressure filter (Waterco W600, datasheet from supplier provided in Appendix B) would be suitable. The filter would be supplied with calcite rather than sand, but with the multiport valve for isolation and backwash if required.

Model No:	MPV Size	Filter Bed Depth	Filter Bed Area	Filtration Flow Rates		Backwash Flow Rates		Filter Bed Volume	Sand 16/30	Zeoplus
				36m³/hr/m²	36m³/hr/m²	40m³/hr/m²	40m³/hr/m²			
	(mm)	(mm)	(m²)	lpm	m³/hr	lpm	m³/hr	(litre)	(kg)	(kg)
W250	40	600	0.05	30	1.8	33	2	41	60	49
W300	40	600	0.07	42	2.5	47	2.8	58	85	70
W350	40	600	0.10	60	3.6	67	4	79	115	95
W400	40	600	0.13	78	4.7	87	5.2	79	115	95
W500	40	600	0.20	120	7.2	133	8	123	180	148
W600	40	600	0.28	168	10.1	187	11.2	175	255	210
W700	40	600	0.38	228	13.7	253	15.2	240	350	288

Figure 10 Small pressure filter range (courtesy of Waterco)

Rate of dissolution of calcite is a function of:

- Initial water quality – TDS, calcium, alkalinity, and pH
- Water temperature

A limestone bed contactor model developed by the State Health Department of Santa Rosa was used to assess the adequacy of the calcite contactor sized based on hydraulic consideration above. The result is shown in the figure below and it shows that it would require 2.4 minutes for the water to reach the theoretical calcium carbonate saturation point (LSI ~ 0). As the contactor sized above has a media depth of 600 mm, it would take approximately three passes through the calcite contactor for the water to reach this theoretical saturation point, which is acceptable.

Limestone Bed Contactor

Corrosion Control and Treatment Process Analysis Program - Version 1.02

Step 1	Initial Water Characteristics			
Enter initial water characteristics based on laboratory analysis.				
System Name:	Mawson Station			
Source Point:	Melting ice			
Date of Sample:	February 13, 2017			
TDS =	20	mg/L	0.50	mMols/L, Ionic Strength
Total Calcium =	0.05	mg/L Ca^2	0.12	mg/L as $CaCO_3$
Total Alkalinity =	6.0	mg/L as $CaCO_3$		
pH =	8.45	field pH is recommended		
Water Temperature =	12.0	°C (temp. at which pH was analyzed)		
Field Water Temperature =	12.0	°C (operating temperature at facility)		
$CaCO_3$ Solubility Product, pKsp =	-8.453	at 20°C, program default		
Do you want to change the Solubility Product of $CaCO_3$?		○ Yes	◉ No	
User $CaCO_3$ Solubility Product, pKsp =	-8.721		No data entry is required.	
Relative Temperature for pKsp =	20.0	°C		
Enter Pre -Treatment Dosage for Lowering pH.				
Carbon Dioxide (CO_2) +/-	0.0	mg/L	0.00	mg/L as $CaCO_3$

Step 2	Initial Results (Before Limestone Addition)			
Theoretical initial water characteristics after temperature correction.				
pH =	8.45		31.3	uS/cm (Electrical Conductivity)
Total Alkalinity =	0.12	meq/L		
Acidity =	5.9	mg/L as $CaCO_3$		
Carbon Dioxide (CO_2) =	0.05	mg/L as $CO_{2(aq)}$	0.700	mg/L, Atmospheric equilibrium $CO_{2(aq)}$
DIC =	11.9	mg/L as $CaCO_3$	1.43	mg/L as C, dissolved inorganic carbon
Langelier Index, Calcite =	-3.49	Tendency to dissolve CaCO3 (for steel and cast iron piping)		
CCPP =	-8.6	mg/L as $CaCO_3$, Calcium Carbonate Precipitation Potential		
$B_{H20} + B_{CO3}$ =	0.005	mM/pH, Buffer intensity from water and carbonate species		
$CaCO_3$, pKsp =	-8.418	12.0 °C, temperature		
Copper II =	0.02	mg/L; Cupric Hydroxide, light blue/blue-green		
U.S. EPA Guidance recommend that the initial water characteristic meet the following parameters when considering limestone contactor:				
pH <= 7.2	Condition not met			
DIC < 10 mg/L as C	Condition met			
Calcium < 20 mg/L Ca	Condition met			

Step 3	Limestone Bed Contactor Parameters			
Enter parameters for contactor and chemical addition.				
Superficial Velocity =	14.7	gpm/ft²	59.98	cm/min
Limestone Particle Diameter =	0.3	cm, (0.3 to 3.2 cm)		
Limestone Porosity, ε =	0.42			
Sphericity (roundness), χ =	0.80	range: 0.4 - 0.8		
$CaCO_3$ (Limestone) =	8.6	mg/L		
You may enter "Target pH" to determine Limestone concentration and depth of contactor.				
Target pH =	10.00	Target pH		

Program Overview

Step 4	Results (After Chemical Addition of Limestone)					
pH =	9.98	pH of water after chemical addition				
Total Alkalinity =	14.6	mg/L as $CaCO_3$	0.29	meq/L		
Total Calcium =	3.49	mg/L Ca^2	8.7	mg/L as $CaCO_3$		
Carbon Dioxide (CO_2) =	0.00	mg/L as $CO_{2(aq)}$	0.00	mg/L as C		
DIC =	20.5	mg/L as $CaCO_3$	2.46	mg/L C, dissolved inorganic carbon		
Langelier Index, Calcite =	0.00	Tendency to dissolve CaCO3 (for steel and cast iron piping)				
CCPP =	0.0	mg/L as $CaCO_3$, Calcium Carbonate Precipitation Potential				
$B_{H20} + B_{CO3}$ =	0.091	mM/pH, Buffer intensity from water and carbonate species				
Copper II =	0.01	mg/L; Cupric Hydroxide, light blue/blue-green				
Depth of Contactor =	4.76	feet	57.1	inches	145	cm
Empty Bed Contact Time =	2.4	minutes				
Limestone Dissolved =	71.7	pounds per million ga lons of water treated	32.6	Kg/MG		

Figure 11 Calcite contactor model - Mawson

The above model also shows that the theoretical consumption of calcite when treating this water is 32.6 kg per million gallon of water treated. At Mawson, where the annual water consumption is expected to be about 1 million litres (0.3 million gallon), the calcite filter above, with 175 L of bed volume, should last well over 10 years.

4.3.3 Operations and maintenance

As the proposed design includes a set of granular media filters upstream of the calcite contactor, no significant maintenance is expected to be required other than periodic inspections.

Since the calcite bed is gradually being dissolved into the water, its bed volume will diminish, and time to reach target LSI would increase. The rate of dissolution of calcite should therefore be monitored and the bed topped up regularly.

Calcite media conforming to the nominated British Standard should have a high purity of > 97% calcium carbonate. Hence, accumulation of inert within the contactor should be minor. If required, the contactor could be backwashed using the multiport valve to flush out and remove any residual calcite.

4.4 Calcium hypochlorite dosing unit

4.4.1 Recommended hypochlorite dose

The Australian Drinking Water Guidelines (ADWG) is the authoritative source of guidance document for drinking water quality in Australia. In the document, the ADWG emphasizes the importance of maintaining adequate disinfection residual throughout the distribution network to provide protection against accidental backflow, and inhibit biofilm growth. A free chlorine residual of at least 0.2 mg/L is considered desirable in ADWG.

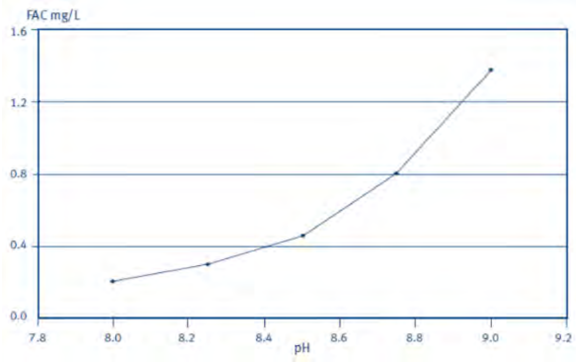


Figure 12 Equivalent free available chlorine vs pH (NZ Drinking Water Guidelines)

When calcium hypochlorite dissolves in water, it forms hypochlorous acid (HOCl) and hypochlorite ion (OCl^-). Hypochlorous acid is a very effective bactericide but hypochlorite ion is not. The percentage of hypochlorous acid versus hypochlorite ion is dependent on the water pH. To achieve adequate disinfection, the goal is therefore to achieve at least 0.2 mg/L of hypochlorous acid, which means, at the higher water pH that will be at Mawson, an equivalent chlorine dose of around 2 mg/L would be required (as shown in Figure 12).

Some users of this water may object to this level of chlorine due to perception of taste and odour. Some latitude is possible for this system to reduce the chlorine dose as there is no primary disinfection required (no foreseeable harmful bacteria or viruses). A goal of the operator of the system is therefore to balance the need to minimise microbial activities in the system (which contributes to possible MIC) with the desires of the users.

4.4.2 Dosing equipment selection

There are currently two types of dosing equipment in the market for dosing calcium hypochlorite. The erosion type has a storage reservoir of calcium hypochlorite briquettes, where the water is piped through for treatment. The movement of water through the briquettes erodes and dissolves the calcium hypochlorite, resulting in disinfection. The advantage of such a system is its simple design, with very little moving parts to maintain. However, the control of chlorine dose in such a system relies on the flow rate of the water through the briquettes, which is difficult to control, resulting in variations in the level of disinfection (an example is shown Figure 13 below).

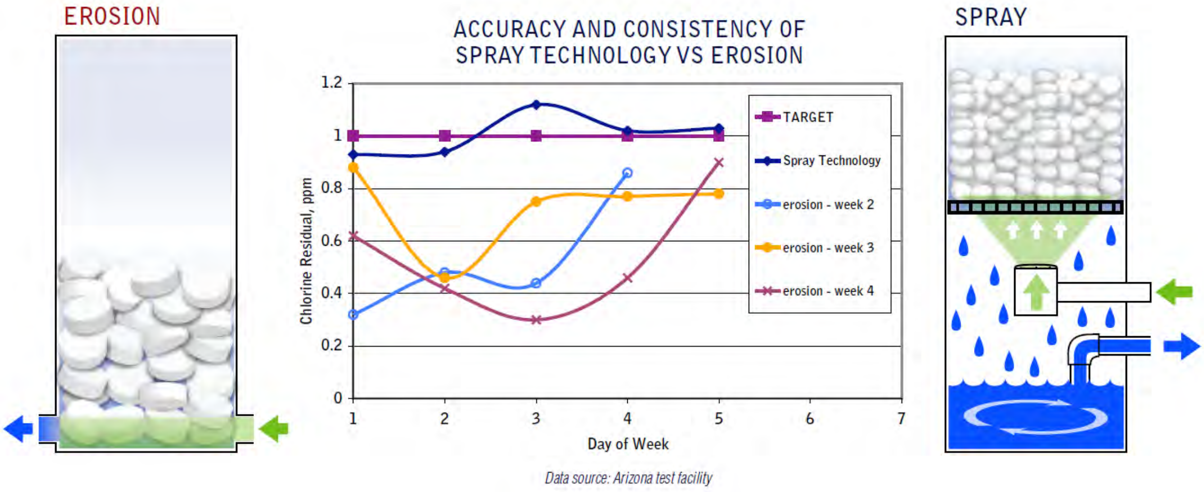


Figure 13 Consistency of chlorine dose with erosion vs spray type equipment (courtesy of Hydromet)

An alternative design in the market sprays a portion of the water to be treated upward into a bed of briquettes, creating a solution of hypochlorite with about 1.5 to 1.8% available chlorine. This solution is then metered out via a chemical dosing pump to disinfect the entire volume of the water to be treated. A residual chlorine analyser would be used to provide feedback control of the chemical dosing pump to provide targeted dosing of hypochlorite. This alternative design has more moving parts to maintain but the system allows a more accurate control of chlorine dosing and is therefore recommended.

The Constant Chlor® Plus Model MC4-50 calcium hypochlorite dosing system manufactured by Arch Chemicals (local Australian distributor is Hydramet) is one such spray type dosing equipment suitable for Mawson (datasheet from supplier is provided in Appendix B). This unit stores approximately 30 kg of calcium hypochlorite briquettes, which is sufficient for over 8 years based on annual water consumption of about 0.1 ML at the nominated dose rate.

4.4.3 Operations and maintenance

The supplier of the dosing unit will have a list of recommended operations and maintenance tasks associated with their equipment. One of the common issues with these systems is scaling due to their use with hard water. As calcium hypochlorite is dissolved in the water, it increases the water pH, which in hard water, can result in precipitation of calcium carbonate. However, as the water at Mawson is soft, this issue is unlikely to cause major problem.

The only other operations and maintenance task is periodic top up of calcium hypochlorite briquettes, and maintenance of the dosing pump and residual chlorine analyser.

4.5 Recirculation pump

A 10 m^3/h centrifugal pump is required for the recommended treatment configuration option. However, an appropriate discharge pressure of the pump can only be determined on site with knowledge of the required static lift and friction loss of the system. Adequate pressure allowance would also be required to overcome increasing friction loss in the granular media filters as iron corrosion products accumulates. This pressure allowance would be sought from the suppliers of the pressure filters.

Variable speed pumping is recommended to ensure target flow is maintained as headloss increases in the system. The three throttling valves at the storage tanks would be adjusted to provide even distribution of the return flow and the necessary back pressure for the pump to deliver 10 m^3/hr at commissioning. As headloss increases to an unacceptable level, or at regular time interval whichever comes first, the granular media filters should be backwashed to restore flow.

A flow meter should be provided on the discharge of the recirculating pump for commissioning and control of pump speed during operations.

4.6 Approximate space requirement

Based on the sizes of equipment nominated above, a space of approximately 5 m x 2 m has been estimated. A conceptual layout for the major equipment is shown in Figure 14 below, however, the most appropriate layout must be determine by AAD based on actual site constraints with consideration of access for operations and maintenance.

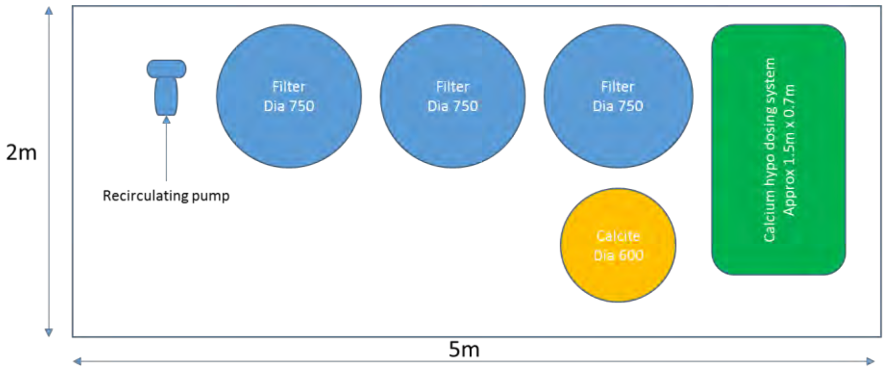


Figure 14 Concept layout of treatment option

5. Conclusions & recommendations

In response to reports of extensive corrosion in the steel pipes and storage systems at Mawson station, and water quality test results indicating the presence of elevated metals at various sample points, To the AAD have engaged GHD to;

- review water quality test results that previously have indicated the presence of metals exceeding health guideline values,
- identify problems in the water supply systems, and
- provide advice on options for solving and/or managing these problems.

The review of the water supply infrastructure and water quality at Mawson station has indicated that corrosion observed in the potable water storage tanks is most likely caused by a combination of soft water and microbiologically induced corrosion (MIC). This corrosion and iron-rich sediment build-up in the storage tanks is a major source of iron and suspended solids contamination in the water supply system.

Localised exposure of metallic piping and joints to the naturally soft and corrosive potable water supply is a source of metals contamination in the drinking water.

To correct the corrosiveness of Mawson's water, calcium and alkalinity must be added such that the water has a tendency to deposit calcium carbonate. Common chemicals used that can add calcium and/or alkalinity include calcite, hydrated lime, soda ash and calcium chloride. The best option for this application is a calcite filter as it can add calcium and carbonate in a single simple filter arrangement.

The microbiologically induced corrosion (MIC) also needs to be addressed, with key contributing factors including a lack of a persistent disinfectant, warm water, presence of organic carbon, and stagnant flow. The provision of a persistent disinfectant is expected to be effective for controlling MIC in the main recirculating loop where flow is continuous. For the purpose of disinfection, calcium hypochlorite dosing is recommended, as it involves a simple dosing pump arrangement that is relatively easy to maintain.

However, in stagnant lines, such as those servicing taps that are rarely used, the disinfectant would lose its effect over time and biofilm would again take hold. The only mitigation for possible dissolved heavy metals in these taps served by stagnant lines is to implement a "flush before use" policy at the station.

Finally, dirty water events that have occurred at Mawson are attributed to iron corrosion products in the storage tanks being drawn into the ring main (as well as biofilms being dislodged) by the high flows generated when exercising the fire water pumps. There is filtration available onsite that has had mixed success. Alternative options include depth filtration, either using a cartridge filter system or via granular media filtration. The granular media filtration option is expected to have the most consistent performance in terms of solids removal.

GHD investigated a short term and a long term solution to the water quality issues at Mawson station.

The recommendation for the short term solution involves:

- Removal of all iron corrosion products (where practical) from existing storage tanks
- Minimising further corrosion in existing storage tanks through pH/alkalinity adjustment
- Removal of all corrosion products / biofilm from existing pipes (scour and flush)
- Provision of filtration to minimise future dirty water events

- Addition of a persistent disinfectant to control future biofilm growth (chlorinated water supply)
- Dealing with stagnant sections of pipe (flush before use policy)

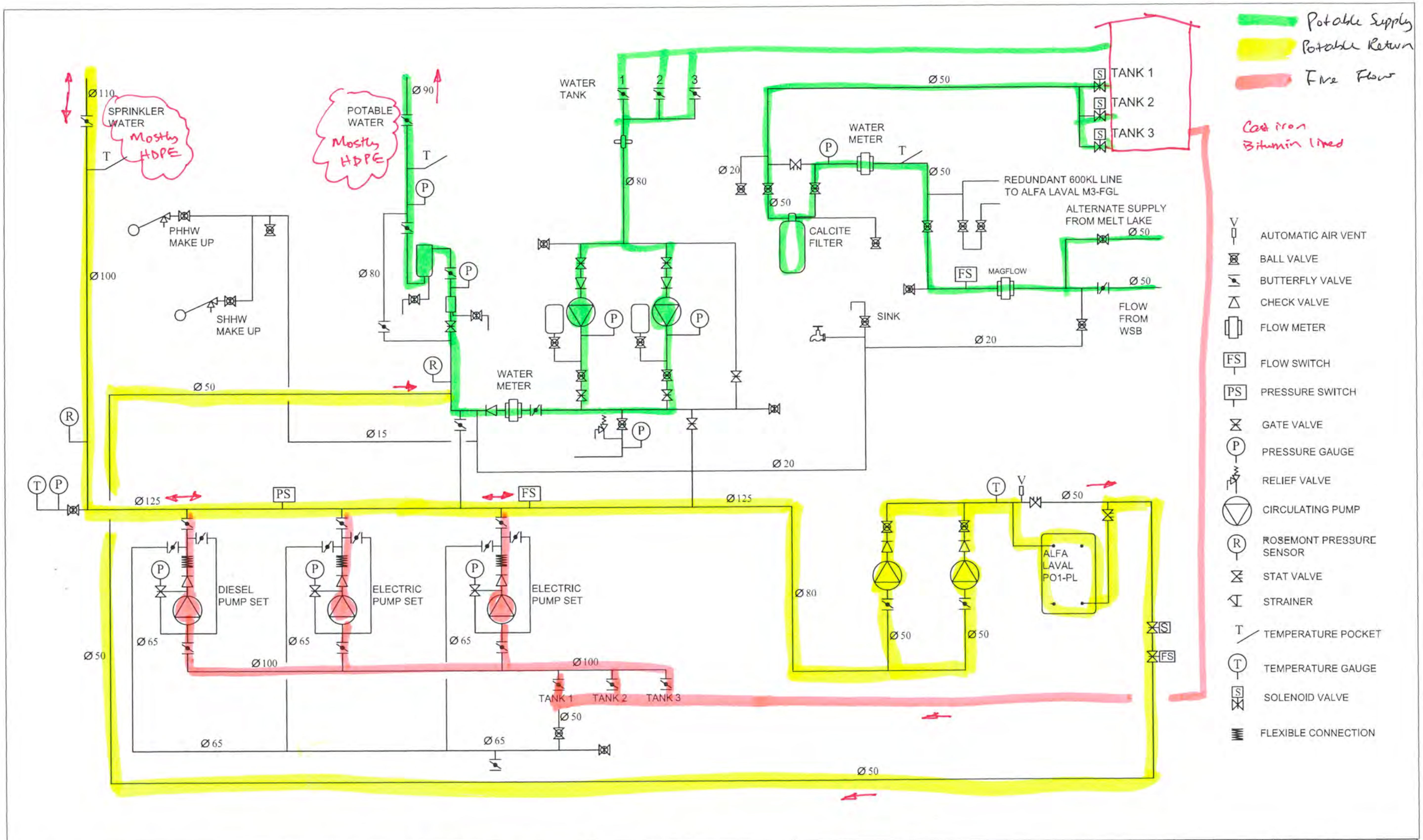
The recommendation for the long term solution involves:

- Replacement of the corroding water storage tanks with those manufactured from corrosion-resistant materials of construction
- Scour and flush all station pipework to remove existing corrosion products and biofilm
- Fast-track replacement of metallic pipework with non-metallic plumbing as much as practicable.
- Implementation of a permanent disinfection system to prevent further biofilm growth

However, GHD's final conclusion and recommendation from this investigation is for the AAD to focus on the Long Term Solution now. This should avoid the need for pH and alkalinity correction, as there will be minimal exposed metal in the system and hence no corrosion. Removal of corrosion by-products from the system should negate the need for extra filtration, as the source water is already low in solids. Implementation of a long-term disinfection solution is recommended. However, this would only be for biofilm control and not for primary health considerations.

Appendices

Appendix A - System schematic



1	For Construction	16/08/2016	
	REVISION	DATE	APPD

Drawn: Cal Young
Checked:
Approved:
Enquiries:
Scale:
Date of Issue:
Date for Revision:

Australian Government
Department of the Environment and Water Resources
Australian Antarctic Division

MAWSON
TANK HOUSE
POTABLE WATER AND FIRE
PIPING SCHEMATIC

Drawing No.
Sheet No.
Maximo Location
L1207
Original Dwg.Size A3

Appendix B – Supplier's datasheets

GLASS PEARLS

Superior filter media

Waterco's Glass Pearls deliver outstanding water clarity.

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SAVE TIME, WATER AND ENERGY

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Purity. Safety. Clarity.

Waterco's Glass Pearls are manufactured from 100% pure glass and offer much finer filtration than conventional filter media.

SUPERIOR PURITY

Whereas other filter media may contain a variety of contaminants, Waterco's Glass Pearls are chemically inert for superior purity. In fact, Glass Pearls have been independently lab tested for leaching contaminants and found to be well within Australian Drinking Water Guidelines.

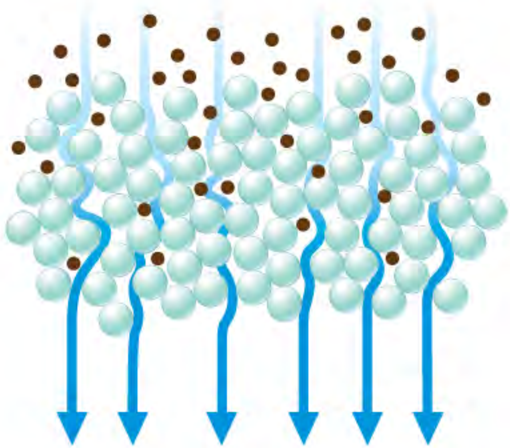
Their superior purity greatly reduces its initial backwashing requirements, prior to commissioning a filter, enabling a rapid start up of media filters.

SAFE

Glass Pearls are safe to handle & safe to service in comparison to other glass media options as crushed glass. Glass Pearls are spherical and do not have sharp edges, making them really safe to use. And if there's ever a failure, of the filter's laterals and Glass Pearls flow into the swimming pool, they pose no risk of injury to swimmers.

SUPERIOR DEPTH FILTRATION

Glass Pearls operate on the basis of “depth filtration”; dirt is driven through the filter bed and trapped in minute spaces between the particles of filter media allowing the cleansed water to pass through.



Conventional media such as sand is crushed and sieved; they generally have an irregular structure and a larger variation in particle size. A conventional media filter bed is more porous and unable to trap fine particles.

Glass Pearls are man-made to specific geometrical shapes providing an extremely narrow particle size range of 0.6mm to 0.8mm, enabling the creation of a dense homogeneous filter media bed, capable of filtering particles down to 3 microns. A micron is equivalent to one millionth of a metre.

Glass Pearl Media

Sand Media

BULK DENSITY

The chart below demonstrates that Glass Pearls have a higher bulk density than crushed glass and sand.

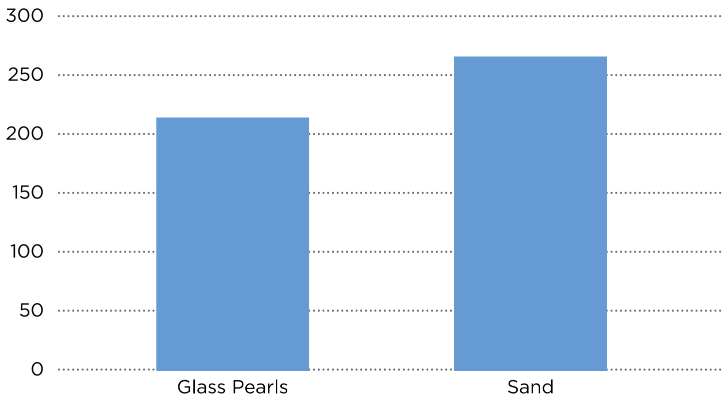
Media	Bulk density, g/cm3
Glass Pearls	1.61
Sand	1.47
Crushed Glass	1.33

Bulk density is a measure of mass per volume.

SAVE WATER

The water saving ability of Glass Pearls are due to their spherical smooth shape, as this result in a low coefficient of friction. After each backwash, Glass Pearls are effectively cleansed of their trapped contaminants.

Glass Pearls require up to 20% less backwash water than sand, saving time and water.

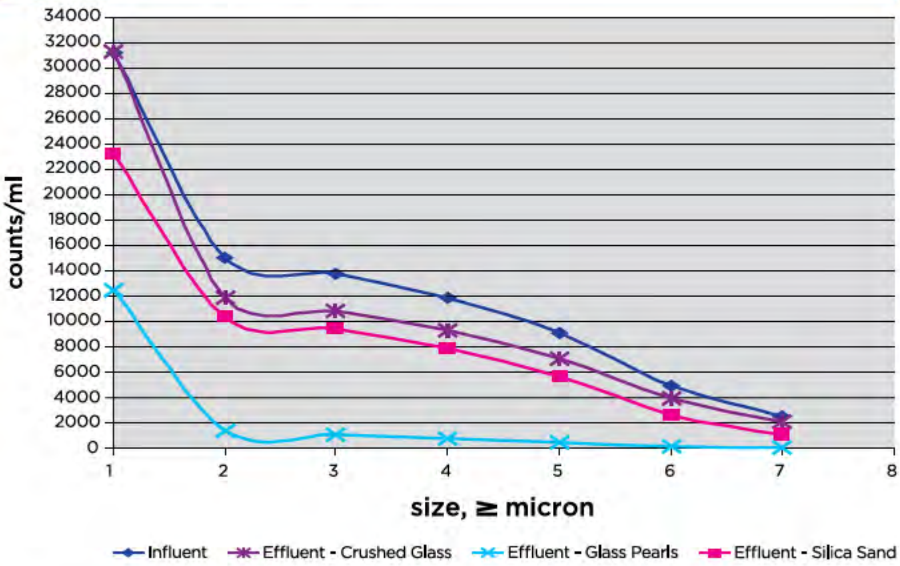


Glass Pearls required 215 litres to successfully backwash a Waterco S600 Media Filter, whereas sand required 266 litres.

Waterco Glass Pearls have been evaluated by TUV SUD PSB and are suitable for both domestic and commercial swimming pools, aquaculture, water treatment and industrial applications.

TUV test reports can be made available upon request.

Particle Count Comparison



Technical Specifications

Filtration Media	Glass Pearl
Effective Size (mm)	0.61
Uniformity Coefficient	1.21
Bulk Density	1.61
Mohs Hardness	7.0

Chemical Compositions

Silicon dioxide (SiO_2)	70.00 – 75.00%
Sodium oxide (Na_2O)	12.00 – 15.00%
Calcium oxide (CaO)	7.00 – 12.00%
Magnesium oxide (MgO)	approx. 5.00%
Aluminium oxide (AL_2O_3)	approx. 2.50%
Potassium oxide (K_2O)	approx. 1.50%

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The smarter way to water quality

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DELIVERS UNPARALLELED CONSISTENT RESULTS

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The Constant Chlor® Plus MC4-50 Dry Calcium Hypochlorite Feeding System

Designed via feedback from actual field users, **The Constant Chlor® Plus MC4-50 dry calcium hypochlorite feeding system** prepares and automatically delivers a consistently accurate dose of liquid available chlorine for disinfection applications. This feeding system can supply up to 50 pounds of AvCL/day on a sustained basis without the storage and handling issues associated with liquid bleach or chlorine gas.

With the ability to stand alone or be integrated with other process and control equipment, this highly customizable feeder uses NSF Standard 60 listed **Constant Chlor® Plus dry calcium hypochlorite briquettes** and patented spray technology to produce fresh liquid chlorine solution as needed. The reservoir is filled and volume maintained via an electronically controlled spray manifold where it is continually circulated to maintain unparalleled solution consistency.

FEATURES

- Unit constructed of high impact HDPE; all wetted areas, internal fittings and level controls constructed of suitable plastics or other non-metallic material
- Utilizes patented spray technology
- Patent-pending mixing mechanism within solution reservoir
- SCADA compatible
- Automatic solution tank refill
- Mechanical overflow-prevention valve
- Large 62 lb. capacity briquette hopper
- Delivers up to 50 lbs. AvCL per day
- Skid mounted with secondary containment
- Area for pump mount

BENEFITS

- Compatible with all types of pumps including positive displacement pumps
- Customizable, convenient and easy to use
- Effective, safer, easier & less expensive alternative to gas and liquid bleach
- Reduced regulatory compliance required including eligibility for Material of Trade (MOT) exceptions for transport
- Efficiencies in bulk storage and man hours
- Consistent and reliable chlorine solutions
- Operates at normal atmospheric pressure and is readily serviceable for refilling and cleaning while in operation
- Eliminates metering pump air locks due to off-gassing
- Eliminates transfer spills
- Minimizes man hours for maintenance and shut downs
- Pre-plumbed and skid mounted for ease of installation
- Internal mixing mechanism enables sustainable homogeneous solution and prevents solids build-up
- Option for pre-treatment

Specifications

Chlorine Delivery Rate*	1.0 - 50.0 lb. AvCl/day with 70° F inlet water temp.	Dry Chemical Capacity	62 lbs.
		Site Requirements:	
Discharge Pressure Range	50 - 150 psig	Inlet Water	1.0 gpm @ 50 - 150 psig
Water Inlet Size	1/2 inch, FNPT	Electrical	20 amp @ 120V/1ph/60Hz
Solution Outlet (Injector) Size......	1/2 inch, MNPT	Operating Temperature	40° - 105° F

Delivery rate is dependant on the dosing pump size

Municipal Applications

Arch Chemicals, Inc. provides municipalities across the country with products that meet the toughest regulations and standards including NSF/ANSI 61 for our feeding equipment and NSF 60 for **Constant Chlor® Plus Briquettes**, allowing the public to rest easy about the quality of their water supply.

- Remote Well Sites
- Booster Stations
- Waste Water
- Reclaimed Water
- Surface Water Treatment Plants
- Ground Water Treatment Plants

Potable Water

- Provides hypochlorination to disinfect water supplies in smaller communities
- Requires low initial investment
- Maintains economical operating costs

Private Water Supplies

- Sanitizes wells, natural springs, cisterns and storage tanks by destroying microbes
- Purifies by destroying harmful organic matter

Other Water Treatments

- Controls slime and maximizes cooling efficiency in cooling towers, ponds and reservoirs of power plants
- Controls growth of slime in commercial air conditioning systems, improving cooling efficiency and eliminating unpleasant odors
- Destroys disease-producing organisms in raw or treated sewage
- Keeps decomposing septic sewage odors and masonry disintegration in check by "up sewer hypochlorination"

Patented Spray Technology

Patented Spray Technology + Constant Chlor® Plus Briquettes = Consistently Accurate Hypochlorite Solution

How it Works

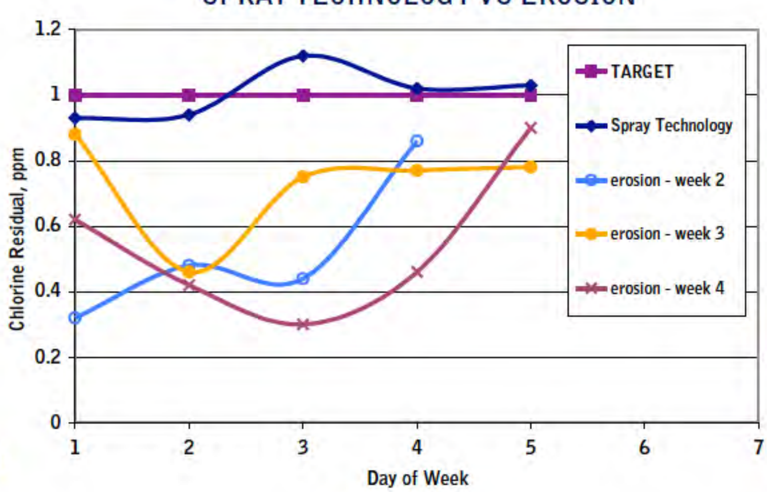
Markedly different from erosion feeders currently on the market, the **Constant Chlor® Plus MC4-50 feed system** injects supply water into the unit by spraying upward into a bed of briquettes; **this short intermittent spray cycle contacts the entire bottom of the bed evenly, not just the material resting on the grid.**

Specifically designed for use in the Constant Chlor® Plus Spray Technology feed systems, the briquettes are relatively small, smooth and "pillow shaped", for maintaining optimum packing in the spray bed.

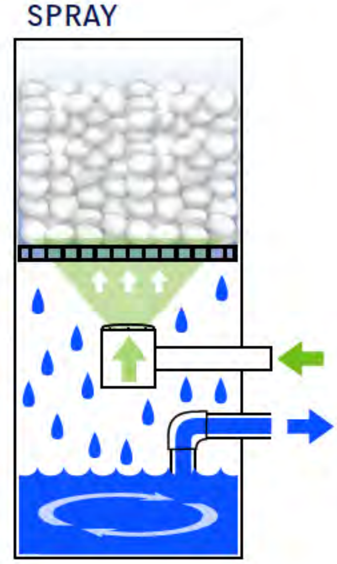
Maintaining a well-packed bed of briquettes significantly reduces the potential for large voids in the spray surface that can result in inconsistent residual concentration in the final solution.

The hypochlorite solution produced by the unit's spray cycle is collected in a 13-gallon solution tank, where the total volume is slowly and continuously mixed, further enhancing concentration consistency.

Unlike an erosion feeder, the Constant Chlor® Plus MC4-50 feeder sprays upward to a well packed bed of briquettes, contacting the entire bottom of the bed evenly. The chlorinated solution flows to the lower reservoir where it is continuously mixed. The accuracy and consistency of the resulting solution concentration far exceeds that achieved by an erosion feeder. Consequently, operator dosage adjustment is minimal.



Data source: Arizona test facility

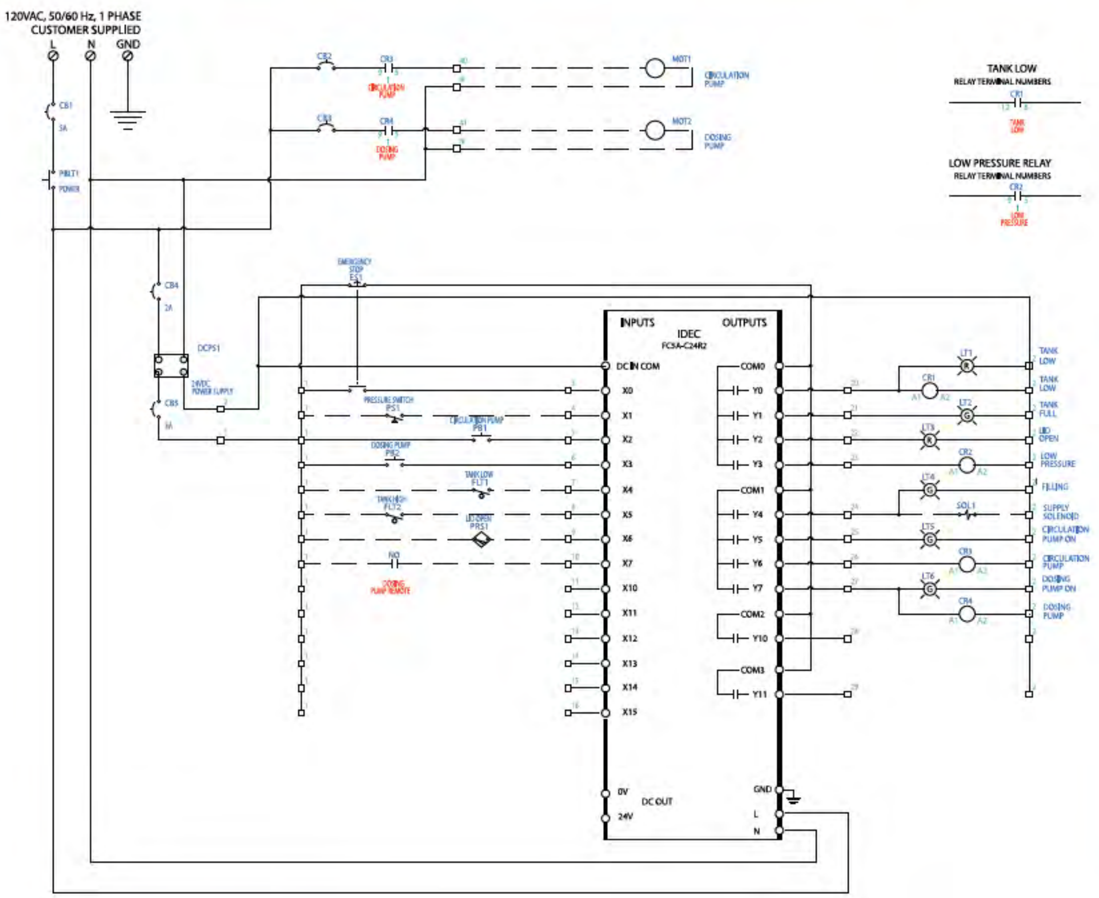


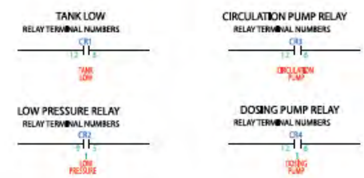
Product Stewardship

Protecting Health, Safety, and Environment
Product Stewardship

Arch is committed to maintaining and improving our leadership in Product Stewardship – from manufacture, marketing, distribution, use, recycling and disposal. Successful implementation includes educating all involved of their responsibilities to address society's interest in a healthy environment and in products that can be used safely. We are each responsible for providing a safe workplace, and all who use and handle products must follow safe and environmentally sound practices.

Electronics Panel and PLC Information





120/240VAC, 50/60Hz, 15/10A, 1 Phase

4 Normally Open Contacts for Remote Interface. 1 Dry Contact for Remote Start of Dosing Pump

24VDC Control Power

PLC with 14 Input/10 outputs

6 Inputs and 2 Outputs Available for Systems Integration

8 BUTTONS / INDICATORS

- E-STOP: Push-Button emergency stop for the unit. Turns OFF every function.
- OFF/ON Indicator: Push-Button to turn the unit ON or OFF.
- CIRCULATION PUMP: Circulation pump is interlocked with TANK LOW and will not operate if TANK LOW alarm is activated. Lamp flashes is circulation pump pressure drops below 5 psi. Push-Button to turn ON or OFF.
- DOSING PUMP: Chemical dosing pump is interlocked to the system. Will not pump if LOW CHLORINE SOLUTION alarm is activated. Remote or manual start capability. Push-Button to turn ON or OFF.
- LID OPEN: Prevents the unit from operating if lid is opened.
- FILLING: Indicates that the solenoid is energized and unit is making solution.
- TANK FULL: The high float is engaged and tank is full of chlorinated solution.
- TANK LOW: Solution inside tank is low, alarm condition.

Constant Chlor® Plus Briquettes

Constant Chlor® Plus Briquettes are designed for use in the **Constant Chlor® Plus MC4-50 feeding system.** The briquettes provide chlorine solution for use in many applications including treatment of surface and groundwater for municipal drinking water use, industrial process water as well as pre- and post-harvest food safety.

These patented, pillow-shaped briquettes contain a scale inhibitor designed to reduce maintenance and improve reliability of the feeder system.

FEATURES

- Dry Solid Product
  - Longer shelf life than liquid bleach
  - Occupies much less space than liquid bleach
  - Less hazardous than liquid bleach or gas chlorine
  - Easier to handle than liquid bleach or gas chlorine

SCALE INHIBITED

- Patented formulation
- Reduces maintenance of equipment

REGULATORY

- EPA No. 1258-1179
- NSF Standard 60, Drinking Water Additives
- Meets AWWA Standard B300

PROPERTIES

• Available Chlorine (wt%)	65% minimum
• Scale Inhibitor (wt%)	0.5%
• Weight	0.25 oz. (7 grams)
• Dimensions	1-1/4 in. X 3/4 in. X 1/2 in.
• Appearance	Pillow Shaped Briquettes

PACKAGING

Constant Chlor® Plus Dry Chlorinator Briquettes are available in 50 lb. plastic pails

Arch also produces **Dry Tec® FG Briquettes** (Food Grade) for use with **the Constant Chlor® Plus MC4-50 feeder. Dry Tec® FG** contains an anti scale formulation for food industry applications.

Hydramet

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hydraqld@hydramet.com.au

 #49769 2M 6/10

MC4-50 Feeding System

Dry Calcium Hypochlorite For Municipal Applications

The smarter way to water quality

PATENTED SPRAY TECHNOLOGY

DELIVERS UNPARALLELED CONSISTENT RESULTS

Constant Chlor® plus

The Constant Chlor® Plus MC4-50 Dry Calcium Hypochlorite Feeding System

Designed via feedback from actual field users, **The Constant Chlor® Plus MC4-50 dry calcium hypochlorite feeding system** prepares and automatically delivers a consistently accurate dose of liquid available chlorine for disinfection applications. This feeding system can supply up to 50 pounds of AvCL/day on a sustained basis without the storage and handling issues associated with liquid bleach or chlorine gas.

With the ability to stand alone or be integrated with other process and control equipment, this highly customizable feeder uses NSF Standard 60 listed **Constant Chlor® Plus dry calcium hypochlorite briquettes** and patented spray technology to produce fresh liquid chlorine solution as needed. The reservoir is filled and volume maintained via an electronically controlled spray manifold where it is continually circulated to maintain unparalleled solution consistency.

FEATURES

- Unit constructed of high impact HDPE; all wetted areas, internal fittings and level controls constructed of suitable plastics or other non-metallic material
- Utilizes patented spray technology
- Patent-pending mixing mechanism within solution reservoir
- SCADA compatible
- Automatic solution tank refill
- Mechanical overflow-prevention valve
- Large 62 lb. capacity briquette hopper
- Delivers up to 50 lbs. AvCL per day
- Skid mounted with secondary containment
- Area for pump mount

BENEFITS

- Compatible with all types of pumps including positive displacement pumps
- Customizable, convenient and easy to use
- Effective, safer, easier & less expensive alternative to gas and liquid bleach
- Reduced regulatory compliance required including eligibility for Material of Trade (MOT) exceptions for transport
- Efficiencies in bulk storage and man hours
- Consistent and reliable chlorine solutions
- Operates at normal atmospheric pressure and is readily serviceable for refilling and cleaning while in operation
- Eliminates metering pump air locks due to off-gassing
- Eliminates transfer spills
- Minimizes man hours for maintenance and shut downs
- Pre-plumbed and skid mounted for ease of installation
- Internal mixing mechanism enables sustainable homogeneous solution and prevents solids build-up
- Option for pre-treatment

Specifications

Chlorine Delivery Rate*	1.0 - 50.0 lb. AvCl/day with 70° F inlet water temp.	Dry Chemical Capacity	62 lbs.
Discharge Pressure Range	50 - 150 psig	Site Requirements:	
Water Inlet Size	1/2 inch, FNPT	Inlet Water	1.0 gpm @ 50 - 150 psig
Solution Outlet (Injector) Size	1/2 inch, MNPT	Electrical	20 amp @ 120V/1ph/60Hz
		Operating Temperature	40° - 105° F

Delivery rate is dependant on the dosing pump size

Municipal Applications

Arch Chemicals, Inc. provides municipalities across the country with products that meet the toughest regulations and standards including NSF/ANSI 61 for our feeding equipment and NSF 60 for **Constant Chlor® Plus Briquettes**, allowing the public to rest easy about the quality of their water supply.

- Remote Well Sites
- Booster Stations
- Waste Water
- Reclaimed Water
- Surface Water Treatment Plants
- Ground Water Treatment Plants

Potable Water

- Provides hypochlorination to disinfect water supplies in smaller communities
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- Maintains economical operating costs

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- Sanitizes wells, natural springs, cisterns and storage tanks by destroying microbes
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- Controls slime and maximizes cooling efficiency in cooling towers, ponds and reservoirs of power plants
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Patented Spray Technology

Patented Spray Technology + Constant Chlor® Plus Briquettes = Consistently Accurate Hypochlorite Solution

How it Works

Markedly different from erosion feeders currently on the market, the **Constant Chlor® Plus MC4-50 feed system** injects supply water into the unit by spraying upward into a bed of briquettes; **this short intermittent spray cycle contacts the entire bottom of the bed evenly, not just the material resting on the grid.**

Specifically designed for use in the Constant Chlor® Plus Spray Technology feed systems, the briquettes are relatively small, smooth and "pillow shaped", for maintaining optimum packing in the spray bed.

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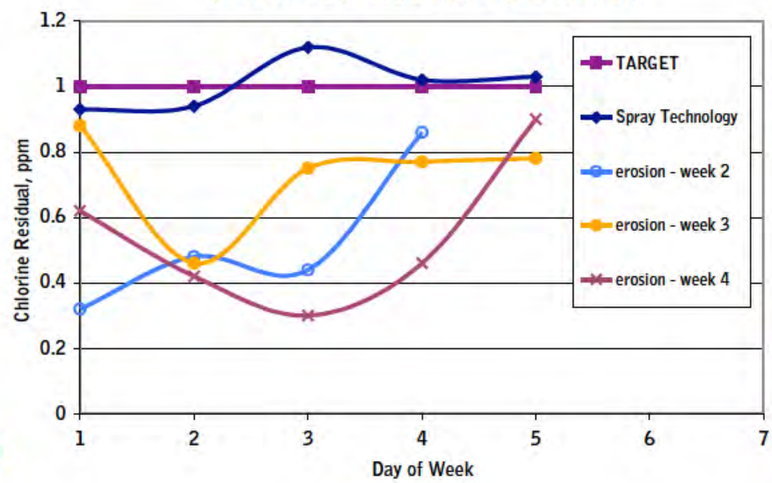
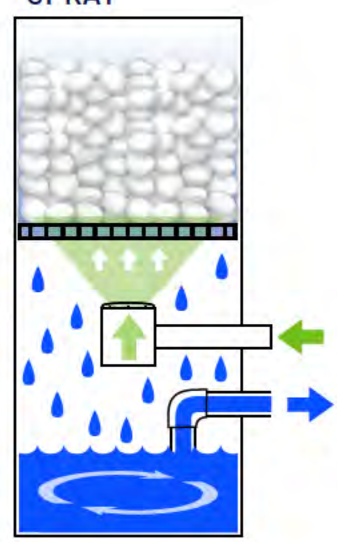
EROSION

ACCURACY AND CONSISTENCY OF SPRAY TECHNOLOGY VS EROSION



Data source: Arizona test facility

SPRAY



Product Stewardship

Protecting Health, Safety, and Environment
Product Stewardship

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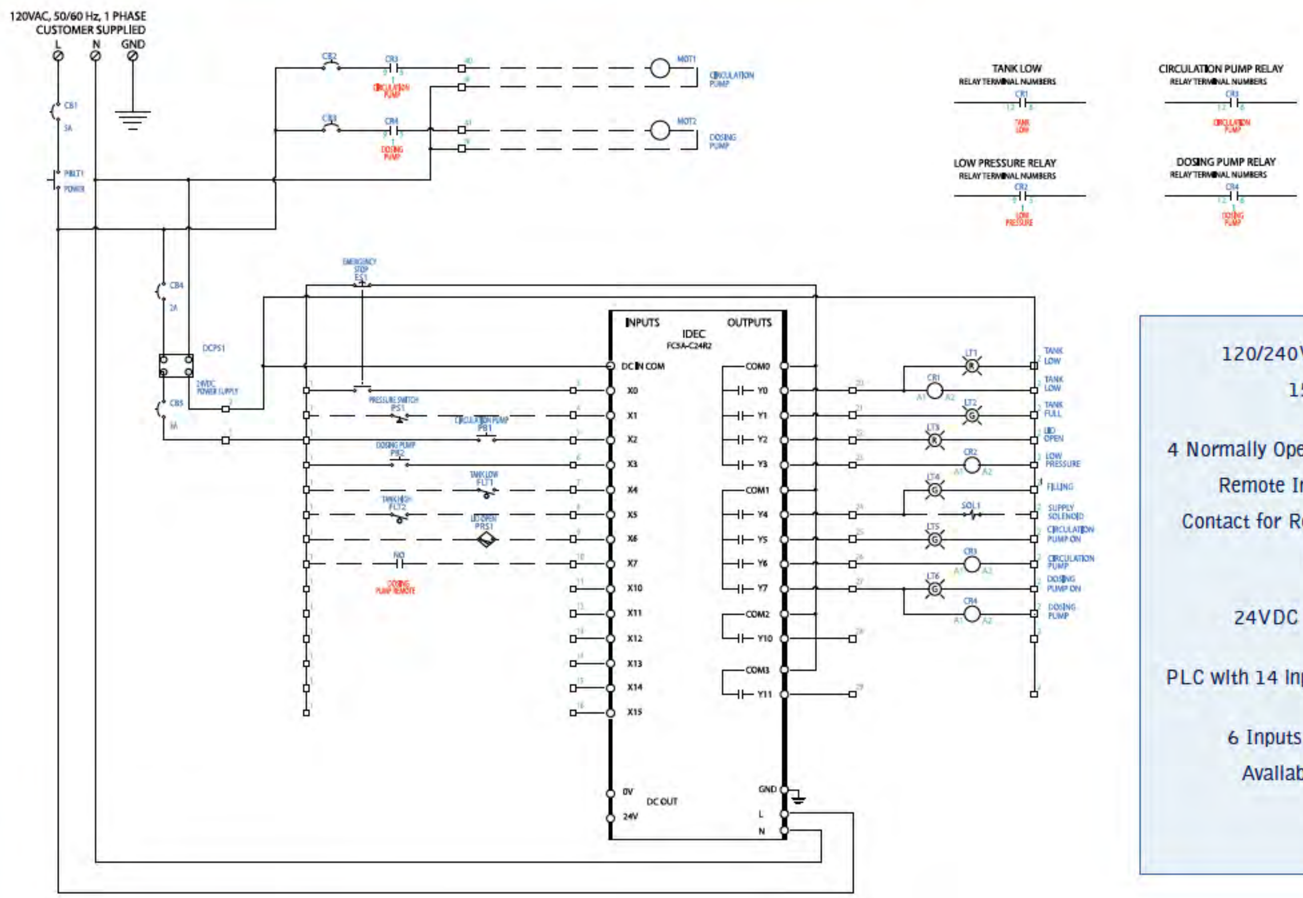
Electronics Panel and PLC Information



120/240VAC, 50/60Hz, 15/10A, 1 Phase

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- FILLING: Indicates that the solenoid is energized and unit is making solution.
- TANK FULL: The high float is engaged and tank is full of chlorinated solution.
- TANK LOW: Solution inside tank is low, alarm condition.

Constant Chlor® Plus Briquettes

Constant Chlor® Plus Briquettes are designed for use in the **Constant Chlor® Plus MC4-50 feeding system.** The briquettes provide chlorine solution for use in many applications including treatment of surface and groundwater for municipal drinking water use, industrial process water as well as pre- and post-harvest food safety.

These patented, pillow-shaped briquettes contain a scale inhibitor designed to reduce maintenance and improve reliability of the feeder system.

FEATURES

- Dry Solid Product
  - Longer shelf life than liquid bleach
  - Occupies much less space than liquid bleach
  - Less hazardous than liquid bleach or gas chlorine
  - Easier to handle than liquid bleach or gas chlorine

SCALE INHIBITED

- Patented formulation
- Reduces maintenance of equipment

REGULATORY

- EPA No. 1258-1179
- NSF Standard 60, Drinking Water Additives
- Meets AWWA Standard B300

PROPERTIES

• Available Chlorine (wt%)	65% minimum
• Scale Inhibitor (wt%)	0.5%
• Weight	0.25 oz. (7 grams)
• Dimensions	1-1/4 in. X 3/4 in. X 1/2 in.
• Appearance	Pillow Shaped Briquettes

PACKAGING

Constant Chlor® Plus Dry Chlorinator Briquettes are available in 50 lb. plastic pails

Arch also produces **Dry Tec® FG Briquettes** (Food Grade) for use with **the Constant Chlor® Plus MC4-50 feeder. Dry Tec® FG** contains an anti scale formulation for food industry applications.

Hydramet

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hydrasa@hydramet.com.au

VIC & TAS
(03) 9325 3900
hydravic@hydramet.com.au

NSW & ACT
(02) 4350 8200
hydransw@hydramet.com.au

QLD
(07) 3802 9500
hydraqld@hydramet.com.au

 #49769 2M 6/10

WATERCO
water, the liquid of life

MULTIPORT VALVES

Heavy duty construction

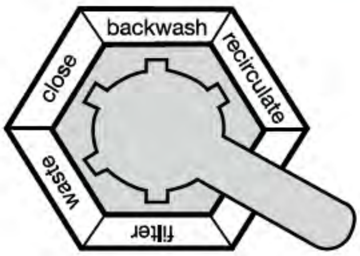
Constructed from heavy duty ABS and GFPP, Waterco Multiport valves are designed for maximum performance and working pressures.

- 6-position multiple valve positions
- Top and Side Mount configurations
- Rated at 400 kPa

www.waterco.com

Waterco's entire range of Multiport valves are engineered to withstand a working pressure of up to 400 kPa (58 psi) with a test pressure of 600 kPa (87 psi).

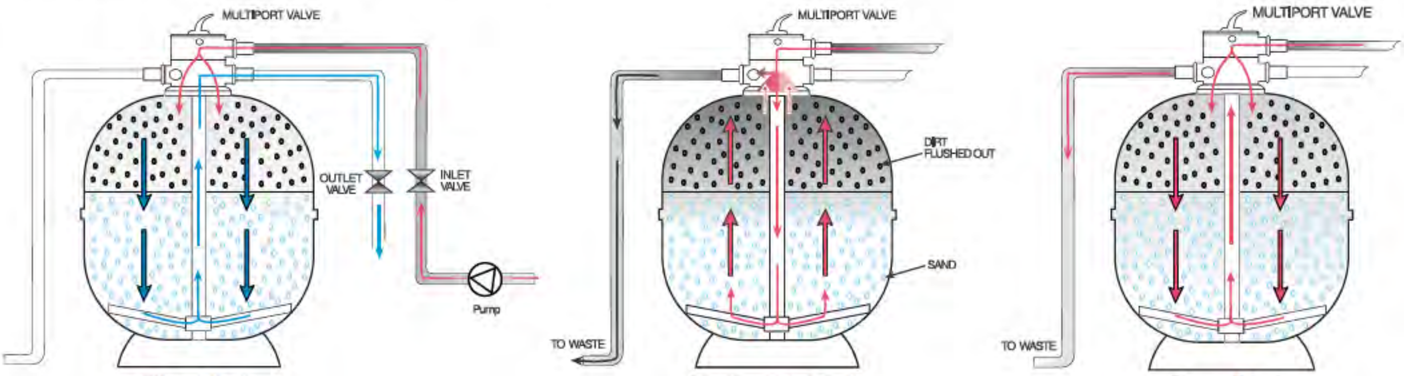
	Max flow rate	Body	Lid	Handle	Rotor	Hardware	Union Nut	Union Tail
40mm MPV	320	ABS	ABS	ABS	GF Noryl	SS304	ABS	PVC
50mm MPV	510	ABS	ABS	ABS	GF Noryl	SS304	ABS	PVC
65mm MPV	780	ABS	GFPP	ABS	GF Noryl	SS304	ABS	PVC
80mm MPV	1080	GFPP	GFPP	ABS	GF Noryl	SS304	ABS	PVC



MULTIPORT VALVE MAIN FUNCTIONS

Filter	-	downward flow through the filter bed to outlet
Backwash	-	upward flow through the filter bed to waste
Rinse	-	downward flow through the filter bed to waste
Waste	-	bypass the filter bed to waste
Re-circulate	-	bypass the filter bed to outlet
Closed	-	no flow to the filter

Cleansing a filter simply requires shifting the Multiport lever from the "filter" position to the "backwash" position, which reverses the flow of water in the filter, flushing the filter bed.



Filter Mode　　Backwash Mode　　Rinse Mode

Warranty
Waterco Multiport valves are covered by 1 year warranty.

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VIC/TAS - Melbourne
Tel: +61 3 9764 1211
WA - Perth
Tel: +61 8 9273 1900
SA/NT - Adelaide
Tel: +61 8 8244 6000
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Waterco (C) Limited
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Jakarta, Indonesia
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Waterco France
SAINT PRIEST, France.
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WATERCO
water, the liquid of life

SPASA AUSTRALIAN MEMBER

Constant Chlor® Plus

Dry Calcium Hypochlorite Briquettes

Designed for use in the Constant Chlor® Plus Chlorinator, **Constant Chlor® Plus Briquettes** provide the perfect chlorine solution for use in many applications including the treatment of surface and groundwater for municipal drinking water use, as well as the treatment of wastewater effluent.

THE BENEFITS ARE CLEAR

- Longer shelf life than liquid bleach
- Effective alternative to chlorine gas and liquid bleach
- Cost effective for all municipal and water treatment applications
- Easier and safer to transport and use than liquid bleach
- Dry chemical does not leak
- Small pillow-shaped briquettes provide an optimum spray bed pack resulting in outstanding solution consistency

PATENTED PILLOW-SHAPED BRIQUETTES

DELIVER UNPARALLELED CONSISTENT RESULTS

Constant Chlor® plus

Constant Chlor® Plus Calcium Hypochlorite Briquettes

Constant Chlor® Plus Briquettes provide the perfect chlorine solution for use in many applications, including the treatment of surface and groundwater for municipal drinking water use, as well as the treatment of wastewater effluent.

These patented, pillow-shaped briquettes contain a scale inhibitor designed to reduce maintenance and improve reliability of the feeder system.

Designed for use in the Constant Chlor® Plus Chlorinator

FEATURES

- Dry Solid Product
  - Longer shelf life than liquid bleach
  - Occupies much less space than liquid bleach
  - Less hazardous than liquid bleach
  - Easier to handle than liquid bleach
- Scale Inhibited
  - Patented formulation
  - Reduces maintenance of equipment

TYPICAL PROPERTIES

• Available Chlorine (wt%)	66%
• Scale Inhibitor (wt%)	0.5%
• Weight	0.25 oz. (7.0 grams)
• Dimensions	1-1/4 in. X 3/4 in. X 1/2 in. (approx 35mm X 19mm X 13mm)
• Appearance	Pillow Shaped Briquettes

REGULATORY

- EPA No. 1258-1179
- NSF Standard 60, Drinking Water Additives
- Meets AWWA Standard B300

PACKAGING

Constant Chlor® Plus Dry Chlorinator Briquettes are available in 50 lb. plastic pails

ONCE YOU'VE TRIED OUR BRIQUETTES, YOU'LL KNOW HOW TO ACHIEVE THE BEST RESULTS CONSISTENTLY

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#49602

WATERCO
water, the liquid of life

MICRON
W & WD FILTERS

Deep Bed Sand Filters

Micron W & WD filters are designed with filter depths of 600mm to 1000mm providing enhanced indepth filtration and increased dirt retention capacity. Combining filter housing and various filter media Micron W & WD filters can be fitted in configurations to provide multi-stage comprehensive water conditioning.

www.waterco.com

Proven Durability

Waterco Micron filters are known throughout the industry for their impressive performance and reliability.

Manufactured from the highest grade of non corrosive materials and employing the latest in fibreglass winding technology, Micron filters are built for many years of trouble free operation.

Technologically Advanced

Micron filters consist of a blow moulded inner shell of fibreglass reinforced polyester resin strengthened with multiple layers of continuous strands of fibreglass filament.

Micron filters are wound with precision by Waterco's digital filament winding machines, for refined consistency and superior quality.

Easy Maintenance

Cleansing the filter simply requires shifting the Multiport Valve lever from the "filter" position to the "backwash" position, which reverses the flow of water in the filter, flushing out the trapped dirt from filter bed.

Model No:	MPV Size	Filter Bed Depth	Filter Bed Area	Filtration Flow Rates 36m³/hr/m²	Filtration Flow Rates 36m³/hr/m²	Backwash Flow Rates 40m³/hr/m²	Backwash Flow Rates 40m³/hr/m²	Filter Bed Volume	Sand 16/30	Zeoplus
	(mm)	(mm)	(m^2)	lpm	m^3/hr	lpm	m^3/hr	(litre)	(kg)	(kg)
W250	40	600	0.05	30	1.8	33	2	41	60	49
W300	40	600	0.07	42	2.5	47	2.8	58	85	70
W350	40	600	0.10	60	3.6	67	4	79	115	95
W400	40	600	0.13	78	4.7	87	5.2	79	115	95
W500	40	600	0.20	120	7.2	133	8	123	180	148
W600	40	600	0.28	168	10.1	187	11.2	175	255	210
W700	40	600	0.38	228	13.7	253	15.2	240	350	288

Model No:	MPV Size	Filter Bed Depth	Filter Bed Area	Filtration Flow Rates 36m³/hr/m²	Filtration Flow Rates 36m³/hr/m²	Backwash Flow Rates 40m³/hr/m²	Backwash Flow Rates 40m³/hr/m²	Filter Bed Volume	Sand 16/30	Zeoplus
	(mm)	(mm)	(m^2)	lpm	m^3/hr	lpm	m^3/hr	(litre)	(kg)	(kg)
WD300	40	1000	0.07	42	2.5	47	2.8	86	125	103
WD350	40	1000	0.10	60	3.6	67	4	116	170	140
WD400	40	1000	0.13	78	4.7	87	5.2	129	188	155
WD500	40	1000	0.20	120	7.2	133	8	199	290	238
WD600	40	1000	0.28	168	10.1	187	11.2	288	420	345
WD700	40	1000	0.38	228	13.7	253	15.2	394	575	473

All filters are able to sustain a temperature of 50°C and have a max working pressure of 600kPa.

*Based on 36m³/hr/m²

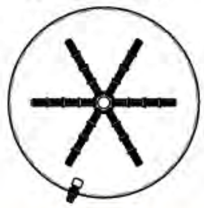
'W' Series Deep Bed Filters									
Model	A	B	C	D	E	F	G	H	V
W250	1385	268	304	160	1119	1252	1172	162	955
W300	1366	322	346	160	1100	1233	1153	175	955
W350	1397	366	355	160	1130	1262	1183	63	1010
W400	1377	416	355	160	1100	1242	1163	63	995
W500	1415	518	443	160	1148	1280	1201	69	1014
W600	1402	620	540	160	1135	1267	1188	88	992
W700	1407	720	540	160	1140	1272	1193	88	1015

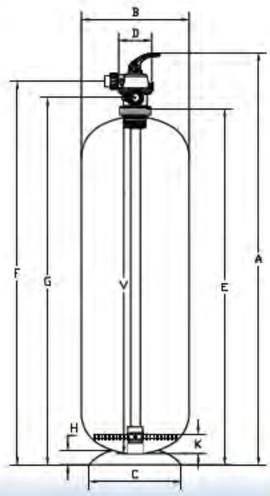
*sizes in mm

'WD' Series Deep Bed Filters									
Model	A	B	C	D	E	F	G	H	V
WD300	1977	315	301	160	1710	1841	1762	75	1590
WD350	1997	366	356	160	1730	1861	1782	63	1612
WD400	1987	416	356	160	1720	1851	1772	63	1595
WD500	2009	518	443	160	1742	1873	1794	69	1600
WD600	1997	620	540	160	1730	1861	1782	88	1582
WD700	2002	720	540	160	1735	1866	1787	88	1622

*sizes in mm

Conventional lateral configuration in W & WD Series applies to models 400 to 700 only





Warranty

Product	Full Warranty	Pro-rata Warranty
1. Residential Applications • W250 / W300 • Other W/WD	 5 years 2 years	 Not applicable 3 years
2. Commercial Applications	2 years	Not applicable

* Please refer to Waterco's warranty terms and conditions.

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Department of the Environment and Energy

Australian Antarctic Division

Potable Water Treatment Strategy
Davis Station

February 2019

Executive summary

The Department of the Environment and Energy, Australian Antarctic Division (AAD) is responsible for providing safe potable water supply to expeditioners working and living at Davis station in Antarctica. The AAD have engaged GHD to;

- review water quality test results that previously have indicated the presence of metals exceeding health guideline values,
- identify problems in the water supply systems, and
- provide advice on options for solving and/or managing these problems.

The review of the water supply infrastructure and water quality at Davis station has indicated that sedimentation observed in the potable water storage tanks is most likely caused by a combination of soft water and microbiologically induced corrosion (MIC). This corrosion and iron-rich sediment build-up in the storage tanks is a major source of iron and suspended solids contamination in the water supply system. Exposure of metallic piping (and possible lead joints) to the naturally soft and corrosive melt water is a major source of metals contamination in the drinking water.

To correct the corrosiveness of Davis' water, calcium and alkalinity must be added. The microbiologically induced corrosion (MIC) also needs to be addressed, with key contributing factors including a lack of a persistent disinfectant, warm water, presence of organic carbon, and stagnant flow. Thirdly, dirty water events that have occurred at Davis are attributed to resuspension of corrosion products in the storage tanks being drawn into the ring main (as well as biofilms being dislodged) by the high flows generated when exercising the fire water pumps.

Measures explored to address each of the above-mentioned water quality issues included:

- pH and alkalinity adjustment through chemical dosing
- Disinfection of the water supply to prevent bacteria and biofilm (and hence MIC)
- Filtration to remove suspended solids (as a result of corroding tanks and pipework) from the water supply

GHD investigated a short term and a long term solution to the water quality issues at Davis station. The suggested short term solution includes:

- Remove all sediment from existing storage tanks
- Minimise further corrosion in existing storage tanks through pH/alkalinity adjustment
- Remove all corrosion products / biofilm from existing pipes (scour and flush)
- Provide filtration to minimise future dirty water events
- Add a persistent disinfectant to control future biofilm growth (chlorinated water supply)
- Deal with stagnant sections of pipe (flush before use policy)

However, GHD's conclusions and recommendations from this investigation is for the AAD to focus on the Long Term Solution now. That is; replace the corroding water storage tanks, scour and flush the pipework, and fast-track replacement of metallic pipework with non-metallic plumbing as much as practicable. This should avoid the need for pH and alkalinity correction, as there will be minimal exposed metal in the system and hence no corrosion. Removal of corrosion by-products from the system should negate the need for filtration, as the source water is already passed through a UF/RO system and is low in sediment. Implementation of a long-term disinfection solution is recommended. However, this would only be for biofilm control and not for primary health considerations.

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1. Introduction

1.1 Purpose of this report

The Department of the Environment and Energy, Australian Antarctic Division (AAD) is responsible for providing safe potable water supply to communities working and living on its Antarctic stations at Casey, Davis and Mawson. As the water supply at each of the stations are low in mineral content, hardness and alkalinity, AAD staff have reported extensive corrosion in the steel pipes and storage systems at all three stations. Furthermore, water quality test results indicate the presence of metals at some of the sample points, where levels of lead, nickel and mercury exceeded the health guideline values specified in the Australian Drinking Water Guidelines 2011.

AAD have engaged GHD to review these test results, identify problems in the water supply systems, and provide advice on options for solving and/or managing these problems.

This report for Davis Station summarises the findings of a Stage 1 desktop review of the test results and existing water supply system, options available to solve or manage the problems identified, and provide concept sizing of the recommended solution.

1.2 Scope and limitations

This report has been prepared by GHD for the Department of the Environment and Energy, Australian Antarctic Division (the Client), and may only be used and relied on by Department of the Environment and Energy for the purpose agreed between GHD and the Client as set out in Section 1.1 of this report. GHD otherwise disclaims responsibility to any person other than the Client arising in connection with this report. GHD also excludes implied warranties and conditions, to the extent legally permissible.

The services undertaken by GHD in connection with preparing this report were limited to those specifically detailed in the report and are subject to the scope limitations set out in the report.

The opinions, conclusions and any recommendations in this report are based on conditions encountered and information reviewed at the date of preparation of the report. GHD has no responsibility or obligation to update this report to account for events or changes occurring subsequent to the date that the report was prepared.

GHD has prepared this report on the basis of information provided by the Client, which GHD has not independently verified or checked beyond the agreed scope of work. GHD does not accept liability in connection with such unverified information, including errors and omissions in the report which were caused by errors or omissions in that information.

The opinions, conclusions and any recommendations in this report are also based on assumptions made by GHD described in Section 1.3 of this report. GHD disclaims liability arising from any of the assumptions being incorrect.

1.3 Assumptions

GHD has not had the opportunity to attend site to visually inspect and validate information provided about the existing water supply system, or to understand potential site constraints for mitigation solutions GHD has suggested and recommended. GHD relies on AAD staff to validate our understanding of the system and our interpretation of the data provided, and that AAD will assess site condition (space, electrical infrastructure, constructability, etc) and inform GHD if they believe site condition prohibits GHD’s recommended solution or result in severe OH&S issues.

2. Existing system overview

2.1 Existing water supply infrastructure

Drinking water for Davis Station is drawn from a surface water catchment; a saline tarn, which is a small water body high in salt, frozen during the winter months. Feed saline water is processed through a combined ultrafiltration system and a reverse osmosis desalination plant. All waste water (brine) produced is then pumped back into the tarn for re-use. The water produced by these plants is pumped to two 600 kL outdoor tanks for storage. The summer months are spent filling these tanks progressively to ensure that winter water supply demands can be met, as the tarn is only pumped during the summer months.

The treated potable water is pumped via a calcite filter into four indoor smaller Service Tanks 2x50 kL and 2x65 kL for distribution and consumption. The high-level potable water outlets on these tanks enable 30kL or 40kL per tank of effective storage. Thus, a total working potable storage volume of 140kL is available. The remaining volume are reserved for fire fighting, which is accessed by dedicated fire pumps via low level outlets on the tanks. Water temperature can be quite cool in the two outdoor tanks (a measurement of 12 degrees C was recorded by AAD staff), but once inside the Service Tanks, water temperature rises to approximately 18 degrees C over time as the room is heated.

The treated water is supplied to buildings on the station via a recirculating ring main, on which a UV disinfection unit has been installed. The ring main is a combined potable / fire supply line and serves to supply potable water to all cold and hot water taps as well as the fire sprinklers within the buildings. Under normal operation the water recirculates and is maintained by both pressurising and recirculation pumps. If the fire hydrants / fire sprinkler system are required, the ring main is closed and the fire pumps are activated to meet fire water demand in the opposing direction.

Materials of construction of the major infrastructure are:

- Outside Storage Tanks - steel panels (with liner inside that separates the water from the steel panels)
- Inside Service Tanks - cast iron with a bituminous lining. Bitumen lining has deteriorated and is exposing the cast iron tank to the water. Tank floors have been repaired with mass repair mortar and sealed with Hydrepoxy (approximately 2008)
- Ring main – HDPE. Flow is continuously circulated.
- From ring main to hot and cold water taps (internal building hydraulics) – copper. Flow is stagnant until someone uses the hot or cold water tap.
- From ring main to fire sprinkler lines – copper to alarm valve, then galvanised steel. Flow is stagnant.
- Fire sprinkler lines (in buildings) – steel (unsure if galvanised or not). Flow is stagnant

A schematic diagram of Davis water supply system is provided in Appendix A.

2.2 Water demands

The Davis Station is home for up to 100 expeditioners and scientists over the summer months and up to 20 expeditioners over the long winter months.

The summer months are spent pumping the tarn water in order to maintain storages to service also for winter months, when lake is frozen and pumping is not possible. The period after station changeover at the first voyage of the year (typically mid-November) but before water production can begin (typically late-December) is a period of a diminishing storage supply as the water production cannot start until the tarn melts. This pose a risk to the station, affecting availability of drinking water for the community.

AAD estimates the annual water consumption at Davis to be approximately up to 2.4 ML/year. Summer demand averages about 10 to 11 kL per week, with a peak day of about 11 kL. Winter demand averages about 2.5 to 3 kL per week, with a peak day of about 3 kL. Most of the usage is understood to be in the kitchen, humidifiers, water production and waste water treatment.

2.3 Review of water quality

2.3.1 Iron

AAD staff reports extensive corrosion is observed in the four indoor water Service Tanks, resulting in a build-up of sludge (iron corrosion products) on the tank floors. This corrosion can be illustrated by plotting the iron level in the water through the process from the tarn to the Service Tanks, as shown in Figure 1, that highlights the dramatic increase in particulate iron in the storage tanks compared to that in the 2x600 kL storage (after the UF/RO treatment). Interestingly, in 2018 accumulation of particulate iron was also found in the outside storage (600 kL) tanks, previously absent in 2017. The source of this iron should be investigated, as it may indicate a possible leak in the internal liners resulting in corrosion of the steel panels.

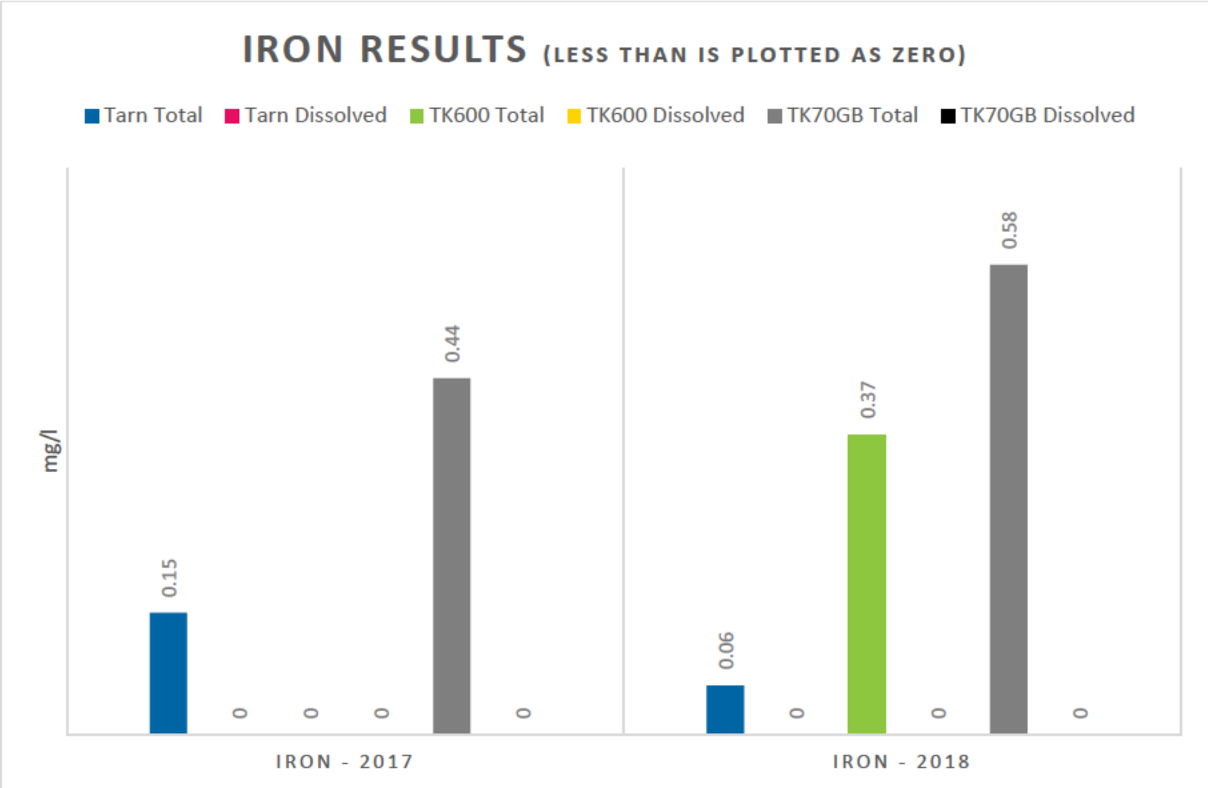


Figure 1 Iron data from tarn to service tanks

The sludge accumulated in the Service Tanks is drawn into the ring main via the low level outlets when the fire pumps are exercised. Under normal recirculating flow, the sludge is relatively undisturbed, but when the fire system is operated (at a higher flow rate and in a reverse direction), this sediment is disturbed and mobilised. Once the ring main is placed back into normal operation, water contaminated with the mobilised sediment is introduced at the point of use.

Review of LSI, alkalinity, and hardness (a measure of calcium) data confirms that the water post RO is corrosive, with low LSI (mostly between -3 to -4), low alkalinity (mostly 7 – 10 mg/L), and low hardness (mostly 20 to 30 mg/L). There is no evidence of the calcite filter adding any significant calcium carbonate to the water, as reflected by the low alkalinity and hardness. Possible reasons for this ineffectiveness are many, including under-sizing of the once-through calcite filter, low water temperature from the outdoor tanks, or fouling of the calcite media by iron corrosion products (at least since 2018).

The corrosion observed in the tanks is believed to be caused by a combination of soft water and microbiologically induced corrosion (MIC). With such soft water, a protective layer of calcium carbonate cannot form on the exposed cast iron surfaces, leaving the natural corrosion process unchecked. In addition, since the water is not disinfected, iron bacteria has proliferated, accelerating the corrosion process due to MIC (ALS Report No. 62408-1-1Eng, 10 July 2018).

2.3.2 Other metals

Water quality test results from samples collected during in February 2017 and February 2018 indicated the presence of metals at some of the sample points. Table 1 summarises the samples where levels of lead, nickel and mercury showed a slight exceedance of the health guideline values specified in the Australian Drinking Water Guidelines 2011. Water samples from all of the other tested locations were within health guideline values.

Table 1 Metals sampling data

	Lead [mg/L]	Nickel [mg/L]	Mercury [mg/L]
ADWG health guideline value	0.01	0.02	0.001
Location (Feb 2017)			
Main powerhouse sink tap (non-flushed)	0.013	0.191	None detected
Main powerhouse sink tap (after 1 minute flush)	0.003	0.011	None detected
Brewery wash-up sink hot tap (non-flushed)	0.038	0.014	0.0012
Brewery wash-up sink hot tap (after 1 minute flush)	0.025	0.009	0.0011
Location (Feb 2018)			
Sample DVS_SCI_218 (non-flushed)	0.002	0.023	Not available
Sample DVS_SCI_218 (flushed)	0.002	0.005	Not available

AAD believes that, for cold water taps, lead and nickel is being leached from the local plumbing fittings, most likely due to the combination of soft water and MIC. In the Sleeping and Medical Quarters, the AAD suspects that metals may be present in water from all hot taps and are entering the building's hot water supply due to contact with metallic parts of the hot water heating system.

Analysis of the data by GHD supports the suspicion that the metals are from local plumbing rather than from the tanks or ring main. Metals result from the two sampling periods along the process train from the tarn to the storage tanks are shown in Figure 2 and Figure 3. These charts show that there is very little (if any) lead in the source water and nickel was below detection after the UF / RO plant. Sampling and testing formercury was carried out for the tarn and in the storage tanks in 2017 (but not in 2018) and results were below detection limit.

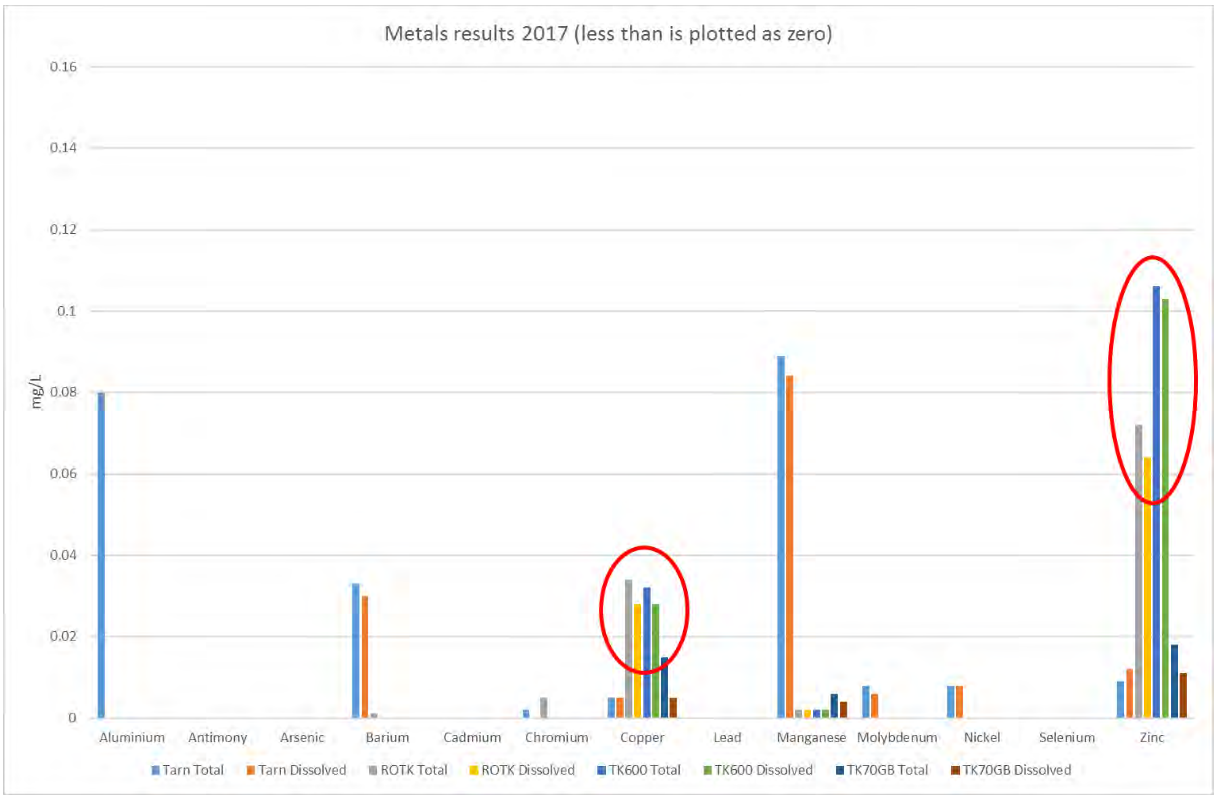


Figure 2 Metals data from tarn to service tanks (2017 Samples)

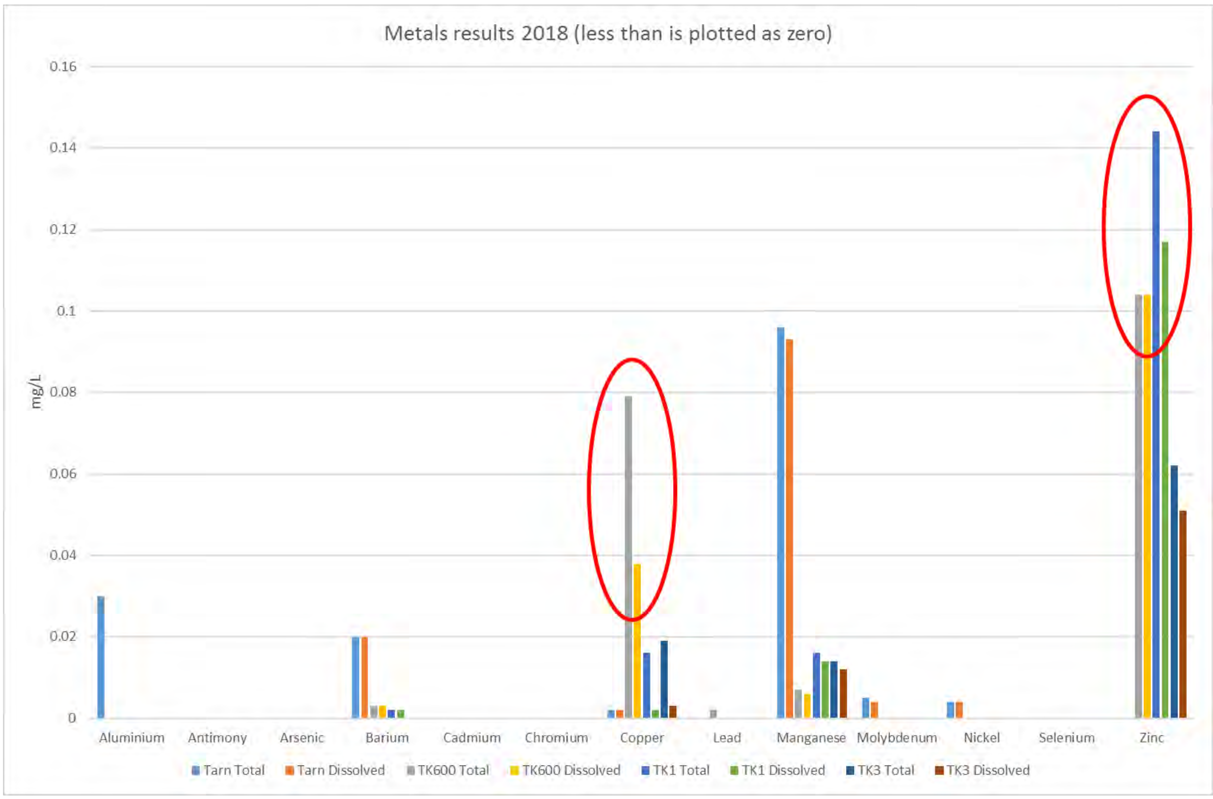


Figure 3 Metals data from tarn to service tanks (2018 Samples)

It is worth mentioning, that following the UF / RO plant, levels of zinc and copper were mildly elevated, although the levels detected are well below the ADWG. There is insufficient data to determine the source of this increase.

Metallic pipework and plumbing such as copper, lead joints, galvanised coating and the likes appears to be the source of elevated lead, nickel, and mercury in the water (since these were not detected in the storage tanks). As the RO treated water is soft, all metallic piping in the system exposed to this water are at risk of corrosion. Piping with long detention time or stagnant water is the most at risk, such as taps that are rarely used, or the copper / galvanised steel connecting pipe between the HDPE ring main and the fire sprinkler main.

2.3.3 Other water quality risks

When salinity levels reach unacceptable levels, or water levels in the tarn fail to be replenished as recorded by annual lake level measurements, the tarn needs to be topped up with sea water. This water is pumped from under the sea ice during the winter months. Recharging of the tarn is undertaken in winter to reduce the likelihood of pumping marine algae into the tarn, which is more active during summer.

According to the Davis Drinking Water Quality Management Plan (dated 29 June 2018), there was no algal bloom observed in saline tarn, however preventive measures and controls are in place to detect possible algae activity. The propensity for algae bloom, the condition that would trigger it, and the possible impacts including algal toxin production, are currently being investigated. This water quality risk has not been considered in this water treatment strategy report.

3. Causes and mitigation options

3.1 Corrosive water

Metals, when submerged in freshwater, can suffer from several types of corrosion (i.e. seawater related chloride corrosion is not considered here). Uniform corrosion can occur when there are dissimilar metals in contact with each other, such as when copper piping is connected to mild steel. Pitting, or concentration cell corrosion, can occur when the oxygen concentration near a pipe wall is different to the bulk water, such as under deposits.

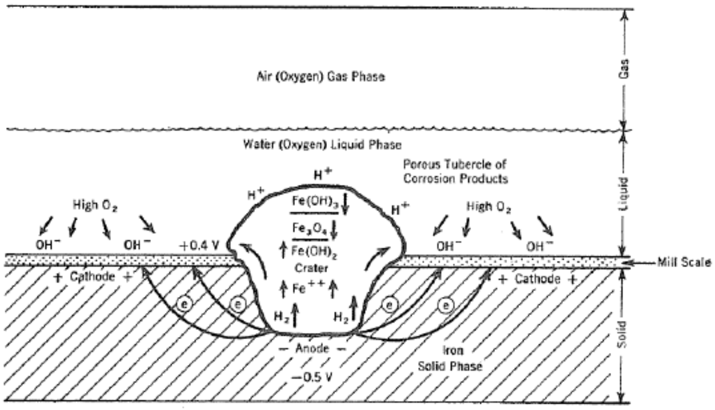


Figure 4 Pitting of iron by tuberculation and oxygen concentration cells (by Obrecht and Pourbaix)

Figure 4 shows pitting of iron and formation of tuberculation due to oxygen concentration cell and this appear to be the principal corrosion mechanism occurring in the storage tanks at Davis based on previous reports and discussions with AAD.

Freshwater can help slow this form of corrosion (but not uniform corrosion due to dissimilar metals) by depositing a layer of calcium carbonate on the metal surface.

However, RO water at Davis, deprived of minerals, is too low in calcium and alkalinity to deposit a protective calcium carbonate film to slow the natural corrosion of exposed metals. Such water is termed corrosive water. In contact with concrete material, freshwater with low calcium content also has a tendency to leach calcium from the cement, weakening their structure. Fortunately, the grouting of the tank floor was sealed with a protective epoxy, protecting the repaired tank floor from the effect of the corrosive water.

To correct the corrosiveness of Davis water, calcium and alkalinity must be added such that the water has a tendency to deposit calcium carbonate. This tendency for deposition of calcium carbonate can be measured by the Langelier Saturation Index (LSI) of the water. A positive LSI indicates a propensity to deposit calcium carbonate, while a negative LSI indicates a tendency to leach calcium from cement. At LSI equal to zero, the water is said to be saturated with respect to calcium carbonate and is neither corrosive nor scaling. As excessively high LSI can mean excessive scaling of pipes and appurtenances by calcium deposit, typical target is a LSI of between -0.3 and +0.3.

Common chemicals used that can add calcium and/or alkalinity are compared in Table 2 below.

Table 2 Chemicals for addition of calcium / alkalinity

Chemical	Advantages	Disadvantages
Calcite ($CaCO_3$)	Stable natural chemical, simple to use, suitable for small and remote sites. Adds both calcium and carbonate alkalinity. Difficult to overdose.	Slow dissolving, particularly in cold water.
Hydrated lime (CaOH)	Faster reaction	Difficult to handle. Adds impurity. Only adds calcium but no carbonate alkalinity. Typically used in conjunction with carbon dioxide to add carbonate alkalinity which

Chemical	Advantages	Disadvantages
		adds complexity to the system (i.e. liquid CO_2 in pressurized tanks).
Calcium chloride (CaCl)	Easy to handle and dissolves quickly.	Only adds calcium but no carbonate alkalinity.
Soda ash ($NaHCO_3$)	Reacts quickly	Only adds carbonate alkalinity but not calcium.

Hydrated lime is a commonly used chemical in water treatment for pH adjustment and addition of calcium. However, it has significant handling issues including being hydroscopic, is dusty, and causes scaling in dosing equipment and dosing lines that requires significant maintenance to maintain operations.

Adding both calcium chloride and soda ash is a possible solution to add both calcium and carbonate alkalinity to the water, however, the use of two chemicals increases the cost of chemicals significantly.

Only calcite can add both calcium and carbonate in a simple filter arrangement. The chemical is stable and is easy to handle. Calcite is therefore the recommended chemical to address the corrosiveness of the water at Davis.

AAD should note that by adding sufficient calcite to reach a target LSI of between -0.3 and +0.3 would raise the water pH to between 9 and 10. Water with high pH may have an unpleasant taste, and the high pH can also impart a soapy feel to the water. Fish placed in high pH water can also be affected adversely (e.g. if fish tanks were being maintained at the station). To avoid high pH water, carbon dioxide would need to be added to lower the pH without removing the carbonate alkalinity added by the calcite. However, this would add complexity to the system, and is not recommended, noting that the existing system is already adding calcite without pH correction.

The use of corrosion inhibitors such as inorganic phosphates or sodium silicates was also considered but discarded. This is because care must be taken with the use of such chemicals since they are added to the water and are therefore consumed together with the drinking water. Dosage of such chemicals therefore must be carefully controlled to avoid over-dosing, and the chemical must be sourced from reputable manufacturers who can demonstrate compliance with relevant standards for chemicals used in drinking water treatment. The cost of such chemical is typically higher than calcite, and moreover, the use of phosphate based corrosion inhibitors would result in an increase in phosphate load to the on-site wastewater treatment system.

3.2 Microbiologically induced corrosion

Microbial action can sometime accelerate the rate of natural corrosion that occurs in water systems. The mechanism of such microbiologically induced corrosion (MIC) is not well understood, but contributing factors include a lack of a persistent disinfectant, warm water, presence of organic carbon, and stagnant flow.

The water supply system at Davis has many of the contributing factors listed above, such as a lack of long lasting disinfection and stagnant flow where biofilm can proliferate over time. Biofilm are complex structures that once formed cannot be removed by disinfectant level normally found in drinking water. Therefore, the biofilm that has formed must first be removed (e.g. by scouring and superchlorination) and a persistent disinfectant added to the water to moderate their growth to minimise future risk of MIC and biofilm related dirty water events.

Common disinfection options are compared in Table 3 below.

Table 3 Disinfection options

Option	Advantages	Disadvantages
Ultraviolet light (UV)	UV systems require relatively low maintenance and do not require the addition of chemicals.	High doses of UV is required for bacteria and does not provide a disinfection residual.
Ozone	A strong disinfectant that is effective against most microbial.	Specialised equipment is required to generate ozone on site (ozone cannot be stored). Ozone does not provide a disinfection residual, and the gas is pungent and can be dangerous.
Chlorine gas	A strong disinfectant that is effective against bacteria and viruses.	Specialised equipment is required handle the gas. Chlorine gas is dangerous
Sodium hypochlorite (liquid)	Easy to handle and use. 12% sodium hypochlorite is relatively safe.	Relatively short shelf life. Degrades to form chlorite ion, which is undesirable in drinking water.
Sodium hypochlorite (on-site generation)	A weak, 0.8% sodium hypochlorite is generated on site from high quality salt and electricity. Resolves degradation issues associated with 12% sodium hypochlorite. Only need to transport and store potable grade salt.	Relatively more maintenance compared to 12% sodium hypochlorite or calcium hypochlorite option due to maintenance of the electrolytic cells.
Calcium hypochlorite (solid)	Easy to handle and use. Available as dry briquettes with long shelf life.	Slow dissolving.

To effectively manage the risk of MIC, an option that provides a persistent disinfectant in the water is necessary. UV and ozone are both ruled out on this basis. Chlorine gas is a dangerous gas and 12% sodium hypochlorite has a short shelf life. Both are not suitable for a simple system in a remote location. The water quality issue associated with degradation of 12% sodium hypochlorite can be resolved with an on-site generation system, which can generate 0.8% sodium hypochlorite on demand, or the use of a calcium hypochlorite tablet system. An on-site generation system requires slightly more maintenance than a calcium hypochlorite system due to the need to maintain the specialised electrolytic cells that are the heart of an on-site generation system, whereas the calcium hypochlorite involves simple dosing pumps only that are simple to maintain. Calcium hypochlorite is therefore recommended (chemical datasheet is provided in Appendix B).

The provision of a persistent disinfectant is expected to be effective for controlling MIC in the main recirculating loop where flow is continuous. However, in stagnant lines, such as those servicing taps that are rarely used, the disinfectant would lose its effect over time and biofilm would again take hold. The only mitigation for possible dissolved heavy metals in these taps served by stagnant lines is to implement a “flush before use” policy at the station.

3.3 Dirty water events

It is understood that dirty water events that have occurred were due to iron corrosion products in the storage tanks being drawn into the ring main as well as biofilms in the ring main being dislodged by the high flows generated when exercising the fire water pumps.

Biofilms, as discussed in Section 3.2 above, must first be removed and a persistent disinfectant added to the water to moderate their future growth. This should address future dirty water events caused by a build-up of biofilms in the ring main.

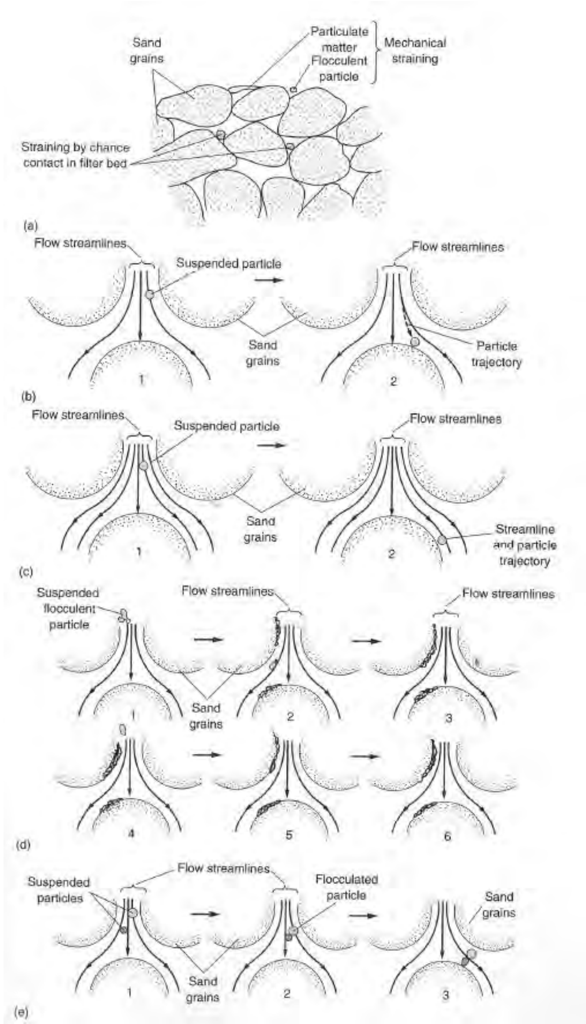


Figure 5 Depth filtration mechanism (by Metcalf & Eddy)

In term of iron corrosion products, AAD advised that, due to the confined space nature and multiple cross-bracing design of the existing storage tanks, it would be unsafe and impractical to sand-blast their interior to remove all existing iron corrosion and tubercules and prevent future corrosion by epoxy coating the interior. AAD has already made provisions to replace the storage tanks in the near future. GHD recommends that the future tanks be constructed from corrosion resistant materials, such as epoxy coated concrete or steel panels, glass-fused to steel panels, or fibreglass. An alternative option for corrosion resistant tanks is to look to plastic tanks or framed water bladder tanks. As these essentially have no exposed metal components, they will not corrode. They can be supplied as food grade and are reasonably temperature resistant (both hot and cold) upon selection of the appropriate materials of construction. Whilst the plastic and bladder style tanks would be expected to be substantially cheaper to purchase, they will not necessarily have the same expected service life as for glass-fused steel or fibreglass. Hence cost of replacement would need to be factored in. As mentioned previously, the suitability of the materials of construction for transportation, both from an extreme cold and wear and tear perspective, would need to be considered.

In the short term, corrosion of the existing tanks is expected to continue, and a method to remove the iron corrosion products from the water is required to minimise the risk of future dirty water events associated with operations of the fire water pumps.

Existing mitigations implemented include the use of twin bag filters (5 and 10 micron), and series of point-of-use cartridge filters (0.5, 5, 10 and 20 micron). These filters are not appropriate technologies for this application because they operate as “strainers”, which are effective only if the particle size being removed is larger than the openings of the filters. As the iron corrosion products are very fine and there is no chemical being added to coagulate them to form larger particles, the iron corrosion products would simply pass through the filters under pressure.

GHD recommends the use of granular media filters (e.g sand filters) for this duty. This is because granular media filters operate in "depth" filtration mode where particles are trapped within the interstices of the granular media via various mechanisms that are not dependent on size. Some of these removal mechanisms within a granular media filter are straining, sedimentation, interception, adhesion, and by flocculation as shown in Figure 5. The use of granular media filters is expected to perform better than the existing strainer type filters and these existing filters can be removed from service. The down side of granular media filtration is the filters do require periodic backwashing to maintain filtration capacity and performance. The disposal of the backwash water would need to be considered in the process augmentation.

Size and arrangement of the recommended granular media filters are discussed in Section 4.2 below.

It is possible to source cartridge filters with smaller nominal micron removal ratings. These can be sourced either as melt blown polypropylene, pleated cartridges either manufactured from polypropylene or a mixture of thermally bonded microglass fibers and cellulose infused with ceramic. These filters also operate (to a lesser extent than granular media) as a form of depth filtration. The benefit of these is the simplicity of their operation, change-out instead of backwashing requirement and the AAD staff familiarity with the existing bag and cartridge filter operation. The negatives of this option is the change-out cost of these particular cartridge filters, which can be of the order of $700 and upwards per cartridge. They may not be able to reliably filter to the same micron level (e.g. less than 0.5 micron) as granular media is able to do.

3.4 Short term management solution

In summary, the following short term management solution is recommended.

Table 4 Short term management solution

Steps	Recommendations	Comments
1. Remove all iron corrosion products from existing storage tanks	• Pressure clean with high pressure cleaner	• Removing all corrosion product from the tanks will minimise future dirty water events.
2. Minimise further corrosion in existing storage tanks	• Correct LSI of stored water with calcite	• Refer to Section 4.1 for configuration options and Section 4.3 for sizing of calcite filter.
3. Remove all corrosion products / biofilm from existing pipes	• Flushing and pigging • Superchlorination	• Removing all corrosion products / slimes from pipes will minimise future dirty water events. • There may be a period of dirty water events after the clean as new slimes are establish and dead slimes are removed.
4. Provide filtration to minimise future dirty water events	• Granular media filters are recommended as the most robust option.	• Refer to Section 4.2 for sizing.
5. Add a persistent disinfectant to control future biofilm growth	• Calcium hypochlorite dosing	• Refer to Section 4.4 for sizing
6. Dealing with stagnant sections of pipe	• Implement a "flush before use" policy at rarely used taps	• Stagnant sections of pipe will remain at risk of MIC. • Flush before use will minimise potential exposure to heavy metals from the drinking water.

3.5 Long term solution

In the longer term, it is understood that AAD plans to replace the existing cast iron storage tanks. GHD recommends that the future tanks be constructed from corrosion resistant materials, such as epoxy coated concrete or steel panels, glass-fused to steel panels, fibreglass, or (where practical) possibly food grade HDPE or framed bladder tanks using flexible polymer materials. The suitability of the material for the extreme temperatures of Antarctica during transportation and operations must also be confirmed). Additionally, copper and other metallic piping, which are potential source of copper, lead, nickel and mercury in the water, could be replaced with non-metallic materials as the opportunity arises.

Once the water network becomes largely non-metallic, the need for continuous calcite and granular media filters could be reassessed. The dosing of a persistent disinfectant could also be reduced or ceased, but would need to be balanced against the need to control biofilm, which could still give rise to dirty water events if growth becomes excessive.

Table 5 Long term solution

Steps	Recommendation	Comments
1. Replace cast iron storage tanks with corrosion resistant tanks	• Common options are glass lined steel panel tanks, steel or concrete tanks with epoxy coating, FRP, HDPE where possible. • Choice of material must also be suitable for the extreme temperature that could be encountered in Antarctica.	• Epoxy coating will have limited life and will require re-coating in the future. • If concrete tank without epoxy coating is used, will need to ensure the LSI of the stored water is not corrosive to the concrete.
2. Replace stagnant sections of pipes with non-metallic materials such as HDPE.	• Any non-metallic plumbing must meet the latest requirements of the Building Code of Australia.	• Replacement of stagnant sections of pipe with non-metallic material will remove the risk of potential exposure to heavy metals from the drinking water.
3. Periodic flushing of pipes	• Flushing and pigging • Superchlorination	• Periodic removal of slimes from pipes may still be required to prevent dirty water events. • There may be a period of dirty water events after the clean as new slimes are establish and dead slimes are removed.

4. Treatment configuration and sizing

The preceding sections confirmed the need in the short term to:

- Correct the corrosive nature of the water stored in the water tanks by the use of a calcite filter,
- Filter the water to remove iron corrosion products by the use of granular media filters, and
- Dose calcium hypochlorite into the water to control the growth of biofilm.

This section describes the configuration options and the sizing of major equipment.

4.1 Treatment configuration options

Three alternative treatment configurations were considered for Davis:

1. Provide calcite filter on the inlet to the Water Service Tanks.
2. Provide calcite filter on a recirculating loop from the existing ring main back to the Water Service Tanks.
3. Provide calcite filter on a new recirculating loop from the suction main of the fire supply pumps back to the Water Service Tanks.

Option 1 was eliminated because the water from the Outside Storage Tanks is very cold (12 deg C was measured by AAD) and this would have an adverse affect on the performance of the calcite filter (dissolution rate would be very slow). Compounding this problem is that a calcite filter on the inlet treats the incoming water once only, which mean a very large calcite filter is necessary to provide the required contact time to overcome the slow dissolution rate and correct the corrosiveness of the water.

Option 2 and 3 has the calcite filter on a recirculating loop downstream of the Water Service Tanks. In this configuration, not only is the water temperature higher due to detention in the tanks, but the recirculating loop means that the calcite would have multiple opportunities to treat the water, eventually reaching calcium carbonate saturation (i.e. LSI = 0). Such multi-pass calcite treatment is therefore recommended.

In Option 2, an analysis of the existing system was conducted to assess the capacity of the existing pressuring pump to supply the flow of the recirculating loop. Figure 6 below is a plot of the pressure pump's (LOWARA SV1603F30T) operating range at various speeds. The Grundfos recirculating pump does not affect this hydraulic analysis since its function is only to provide a recirculating flow and there is no "loss" in the recirculating system.

AAD advised that the pressure pumps are operated to achieve a pressure of 3 bars and are set to turn on at 2.8 bars. These settings are superimposed onto the pump curves below and it shows that the pressure pump (variable speed) is continuously changing speed to meet water demand while maintaining system pressure.

During low demands, water consumption ranges from zero to probably up to 10 m^3/h (assuming conservatively that the peak day usage is all consumed within 1 hour), suggesting that the pressure pump would probably operate at a speed of between 38 Hz to say about 41 Hz to supply the instantaneous demand.

As demand increases, water consumption may increase to probably up to 12 m^3/h (again conservatively assuming all the peak day's usage is all consumed within 1 hour), suggesting that the pressure pump would probably operate at a speed up to around 42 Hz (may be slightly higher in short bursts if there is coincidence of usage) to meet supply.

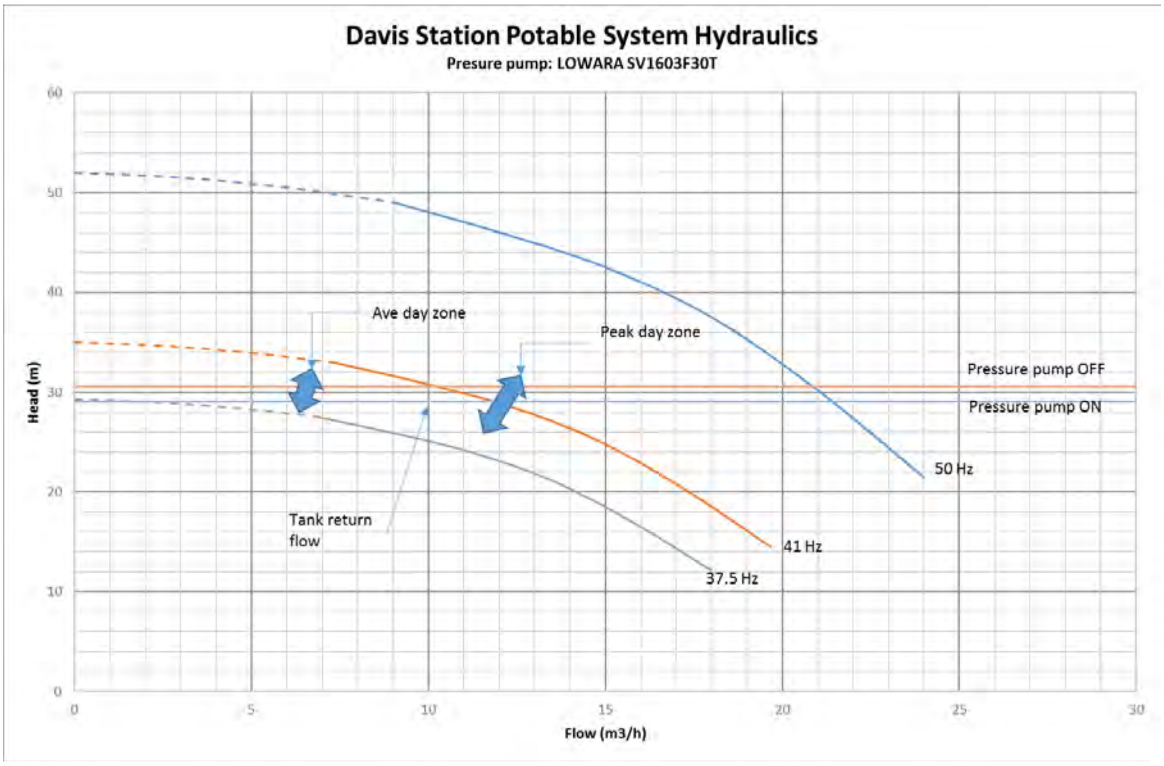


Figure 6 Existing potable system hydraulics

The above analysis is indicating that the existing pressure pump is adequately sized and should be able to supply a CONTINUOUS tank return flow of say 10 m^3/h. This tank return rate would allow the peak day's volume to be treated by a calcite filter at least once in 1.5 hour, and turnover of the entire tank volume of 230 m^3 in 23 hours.

Based on this analysis, a recirculating flow rate of 10 m^3/h is recommended.

Configuration for Option 2 is shown in Figure 7 below. A bleed line sized for 10 m^3/h with a pressure sustaining valve (PSV) would be created on the new recirculating main. This PSV will be set with an upstream pressure same as the pressure pump setpoint (about 30 m). As a PSV opens when the upstream pressure is above the setpoint, the PSV will allow a continuous flow back to the tanks as long as the pressure pump is able to maintain a pressure of 30 m in the existing ring main. If instantaneous demand in the system is such that the pressure pump is unable to maintain pressure, the PSV would close, temporarily stopping the tank return flow, so that normal demand can be met by the existing pressure pump. This tank return flow would pass through the granular media filters (to protect the calcite filter from fouling), the calcite filter to correct the LSI of the water, and four return lines each with an adjustable control valve to spread the flow evenly back into each tank. In effect, this bleed line would act as a "demand" on the pressure pump, even when there is a backwash on the granular media filter, and would make the pressure pump operate continuously at a higher speed (around 41 Hz) than it currently does. The advantage of this option is that it avoids the need for a new set of recirculating pumps, however, there is still a potential for iron corrosion products to accumulate in the storage tank floors and be drawn into the ring main when the fire supply pumps are operated.

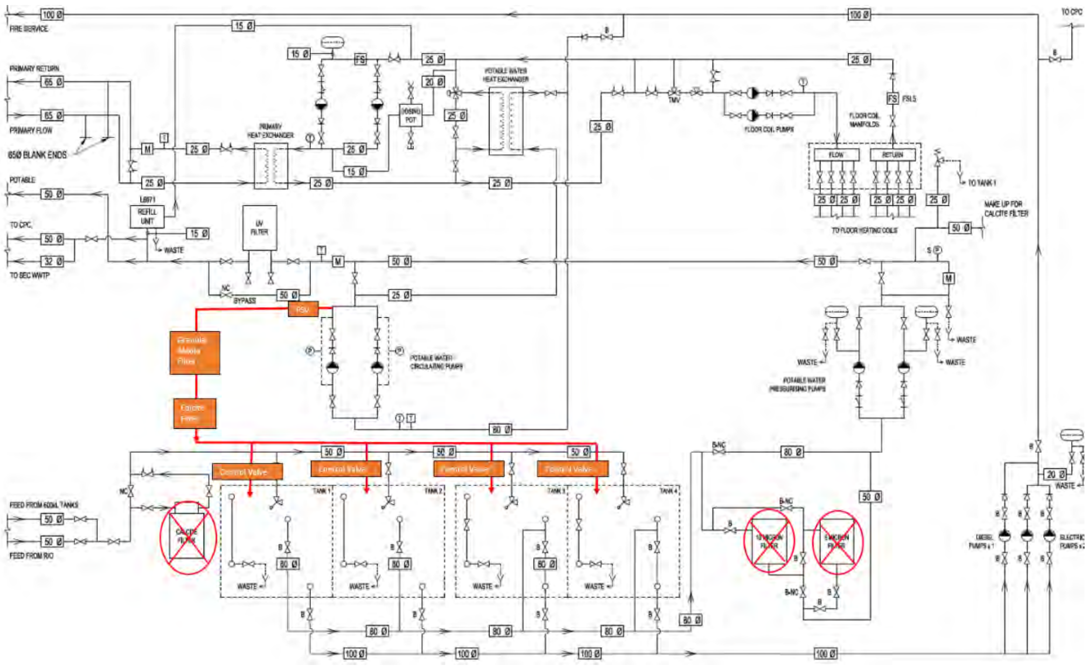


Figure 7 Schematic of recirculation loop from existing ring main

Option 3 (shown in Figure 8 below) addresses the deficiency of option 2 above by configuring the new recirculating loop from the suction main of the fire supply pumps (or from the tank's drain valves if appropriately sized), which, since it is drawn from the base of the storage tanks, increases the potential for removing iron corrosion products accumulating in the tanks via the proposed granular media filters. While this option requires a new set of recirculating pumps (10 m^3/h capacity), it resolves the issue of future dirty water events better and is therefore recommended.

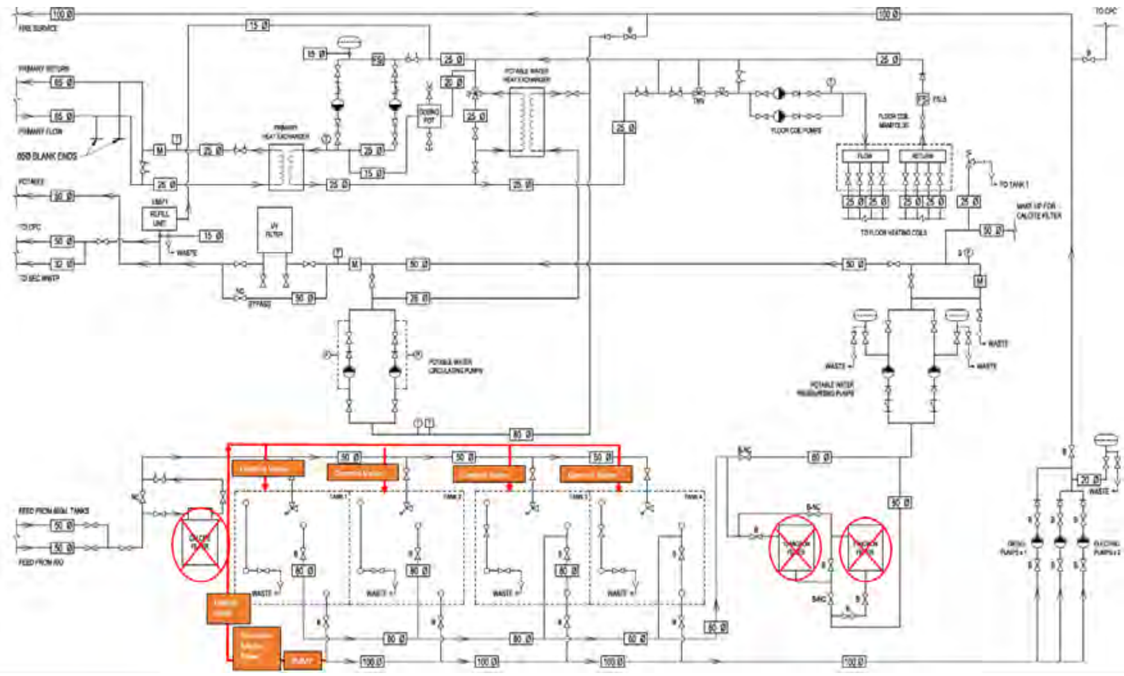


Figure 8 Schematic of recirculation loop from suction main (fire pumps)

Sizing of individual elements of the scheme is provided in the sections below.

4.2 Granular media filters

4.2.1 Filter types

Granular media filters can be configured as open gravity filters or as pressure filters contained in fibreglass pressure vessels. Open gravity filters are the choice for large plants but for smaller installations such as Davis, pressure filters offer simpler backwashing arrangement and installation.

Due to the size and remoteness of the installation, pressure filters are recommended for Davis.

Figure 9 Typical pressure filter (courtesy of Waterco)

4.2.2 Filter media selection

Commercially available filter media that is suitable for Davis are:

- Silica sand (S.G. of 2.65)
- Filter coal (S.G. of 1.4 to 1.5)
- Glass beads (S.G. of 1.55 to 1.65)

The main selection criteria are cost, durability, inertness, particle size (and size distribution), and specific gravity (for backwashing consideration). Of the three filter media listed above, silica sand has the highest specific gravity and therefore would require the highest backwash rate to effectively fluidise the bed to remove trapped particles when backwashing. When used in a pressure filter arrangement, where backwash flow is normally provided by the inflow, the use of the heavier silica sand effectively limits the size of the filter that can be used (so that a suitable backwash rate can be achieved). For this reason, the use of the lighter media such as the filter coal or the glass beads is preferred.

Durability, inertness and particle size distribution requirements for filter media are specified in the American Water Works Association standard B100, and this standard would apply to filter coal. Waterco supplies a glass beads media (Glass Pearls) with their range of pressure filters with a specification shown in Figure 10. The inertness and durability of glass means that such filter media would also be acceptable.

Technical Specifications	
Filtration Media	Glass Pearl
Effective Size (mm)	0.61
Uniformity Coefficient	1.21
Bulk Density	1.61
Mohs Hardness	7.0

Chemical Compositions	
Silicon dioxide (SiO2)	70.00 - 75.00%
Sodium oxide (Na2O)	12.00 - 15.00%
Calcium oxide (CaO)	7.00 - 12.00%
Magnesium oxide (MgO)	approx. 5.00%
Aluminium oxide (AL2O3)	approx. 2.50%
Potassium oxide (K2O)	approx. 1.50%

Figure 10 Glass pearl filter media (courtesy of Waterco)

The effective size and uniformity coefficient for the Glass Pearls are shown as 0.61 and 1.21 respectively. This media size and distribution is suitable for small scale pressure filters and would also apply if filter coal is used.

4.2.3 Filter size and arrangement

Critical parameters for a successful and robust filter design are:

- Filtration rate: expressed in m/h (equivalent to $m^3/m^2/h$), it is a measure of how quickly the water will travel through the media bed.
- Filter depth: should be proportional to filtration rate, since detention time in the filter bed increases particle removal by the various removal mechanisms that exist in a filter bed.

Based on a recirculating flow of 10 m^3/h, the filtration rates and detention times achievable for a range of standard pressure filters (datasheet from supplier is provided in Appendix B) are shown in Table 6 below.

Table 6 Granular media filter size range

Filter dia (mm)	Filter Area (m^2)	Filter depth (mm)	Filtration rate (m/h) and detention time (min)			Backwash rate (m/h)
			1 filter	2 filters	3 filters	1 filter
500	0.20	500	50 (0.6)	25 (1.2)	16.7 (1.8)	50
600	0.28	500	35.7 (0.8)	17.9 (1.7)	11.9 (2.5)	35.7
750	0.44	500	22.7 (1.3)	11.4 (2.6)	7.6 (4.0)	22.7
900	0.64	500	15.6 (1.9)	7.8 (3.8)	5.2 (5.8)	15.6

Filter size should also be cognisant of the backwash rate achievable by the inflow (without providing a separate backwash pump). Appropriate backwash rate is a function of water temperature, filter media size and distribution, and specific gravity, and is shown by Figure 11 for 20 degree (for lower water temperature, the required rate is reduced due to viscosity of the water). For the preferred filter media, appropriate backwash rate is about 0.38 m/min (or 22.8 m/h).

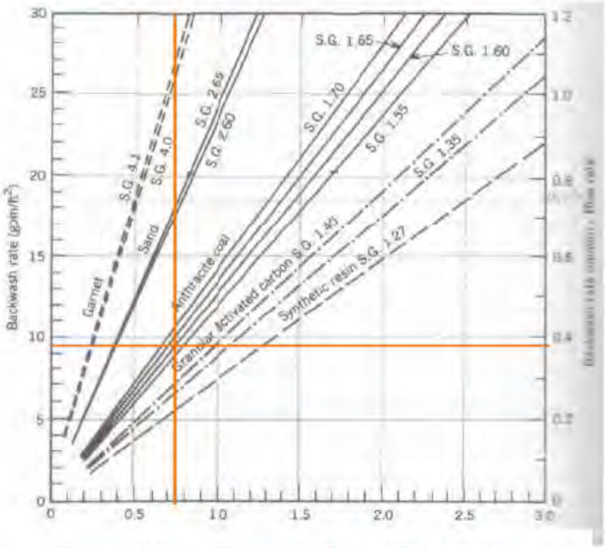


Figure 11 Granular Media Backwash Rates

Suitable filter size and arrangement is therefore 3 x DN750, which enables a suitable backwash rate (when washing one filter at a time) while providing adequate detention time that maximises particle removal. Having larger filters may improve particle removal but is at the expense of poorer backwash rate.

3 x DN750 pressure filters are therefore recommended.

4.2.4 Operations and maintenance

It is expected that the filters will be manually operated. In normal operations, all three filters would be filtering unless there is a fault in which case the faulty filter will be manually isolated. Reasonable performance is expected even with two filters and hence a standby filter is not recommended.

The only maintenance required is to backwash the filters periodically, which can be activated manually via a multiport valve (datasheet from supplier is provided in Appendix B) supplied with the filter. The function of this multiport valve is shown in Figure 12 below. To achieve the required backwash rate, the operator would manually close the other two filters while backwashing the third. Each backwash is expected to take around 2 to 4 minutes and all three filters would be backwashed sequentially.

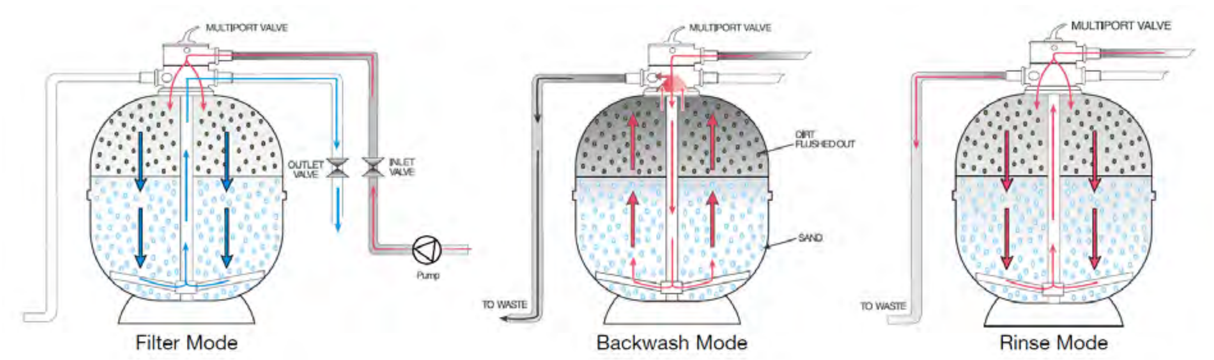


Figure 12 Backwashing of pressure filters using multiport valve (courtesy of Waterco)

Backwash waste would need to be managed on site. It should be suitable to send the backwash waste to the on-site wastewater treatment facility for disposal, subject to an analysis of the hydraulic capacity of the treatment facility. A temporary holding tank may be necessary to hold back the backwash waste and release it at a reduced rate to the treatment facility.

4.3 Calcite contactor

4.3.1 Calcite media

As this is a drinking water system, the calcite media used must conform to recognised standards for chemicals used in the drinking water industry. There is currently no Australian Standards for calcite. We therefore recommend that the calcite media to conform to:

- *British Standard EN 1018:2013+A1:2015 Chemicals used for treatment of water intended for human consumption - Calcium carbonate*

4.3.2 Contactor size and arrangement

British Standard EN 1018 states typical size range for calcium carbonate as 1 to 3 mm, with a bulk density of between 1 kg/L to 1.5 kg/L. In size, they are therefore similar to sand and are typically arranged in similar fashion as sand filters. To avoid the need for re-pumping after the calcite contactor, the use of pressure vessels to house the calcite, similar to that of a sand filter above, is appropriate.

A single contactor arrangement would be acceptable, as there should be no need to backwash the calcite in normal operations (although backwashing would be provided by the multiport valve similar to the granular media filters above, which could be used to occasionally flush out any residual calcite in the contactor if required).

There are two sizing criteria for sizing calcite contactors:

1. That it is sufficiently sized to retain the water in the contactors long enough to dissolve the calcium carbonate for the water to reach the target LSI.
2. That it is sufficiently sized to hydraulically pass the design flow without excessive headloss.

At the design flow rate of 10 m^3/h, a single DN600 pressure filter (Waterco W600, datasheet from supplier provided in Appendix B) would be suitable. The filter would be supplied with calcite rather than sand, but with the multiport valve for isolation and backwash if required.

Model No:	MPV Size	Filter Bed Depth	Filter Bed Area	Filtration Flow Rates 36m³/hr/m²	Filtration Flow Rates 36m³/hr/m²	Backwash Flow Rates 40m³/hr/m²	Backwash Flow Rates 40m³/hr/m²	Filter Bed Volume	Sand 16/30	Zeoplus
	(mm)	(mm)	(m²)	lpm	m³/hr	lpm	m³/hr	(litre)	(kg)	(kg)
W250	40	600	0.05	30	1.8	33	2	41	60	49
W300	40	600	0.07	42	2.5	47	2.8	58	85	70
W350	40	600	0.10	60	3.6	67	4	79	115	95
W400	40	600	0.13	78	4.7	87	5.2	79	115	95
W500	40	600	0.20	120	7.2	133	8	123	180	148
W600	40	600	0.28	168	10.1	187	11.2	175	255	210
W700	40	600	0.38	228	13.7	253	15.2	240	350	288

Figure 13 Small pressure filter range (curtesy of Waterco)

Rate of dissolution of calcite is a function of:

- Initial water quality – TDS, calcium, alkalinity, and pH
- Water temperature

A limestone bed contactor model developed by the State Health Department of Santa Rosa was used to assess the adequacy of the calcite contactor sized based on hydraulic consideration above. The result is shown in the figure below and it shows that it would require 2.2 minutes for the water to reach the theoretical calcium carbonate saturation point (LSI ~ 0). As the contactor sized above has a media depth of 600 mm, it would take approximately three passes through the calcite contactor for the water to reach this theoretical saturation point, which is acceptable.

Limestone Bed Contactor

Corrosion Control and Treatment Process Analysis Program - Version 1.02

Step 1	Initial Water Characteristics			
Enter initial water characteristics based on laboratory analysis.				
System Name:	Davis Station			
Source Point:	RO treated water			
Date of Sample:	February 8, 2018			
TDS =	136	mg/L	3.40	mMols/L, Ionic Strength
Total Calcium =	0.5	mg/L Ca^2	1.25	mg/L as $CaCO_3$
Total Alkalinity =	6.0	mg/L as $CaCO_3$		
pH =	7.92	field pH is recommended		
Water Temperature =	12.0	°C (temp. at which pH was analyzed)		
Field Water Temperature =	12.0	°C (operating temperature at facility)		
$CaCO_3$ Solubility Product, pKsp =	-8.453	at 20°C, program default		
Do you want to change the Solubility Product of $CaCO_3$?		○ Yes	◉ No	
User $CaCO_3$ Solubility Product, pKsp =	-8.721	No data entry is required.		
Relative Temperature for pKsp =	20.0	°C		
Enter Pre -Treatment Dosage for Lowering pH.				
Carbon Dioxide (CO_2) +/-	0.0	mg/L	0.00	mg/L as $CaCO_3$

Step 2	Initial Results (Before Limestone Addition)			
Theoretical initial water characteristics after temperature correction.				
pH =	7.92		212.5	uS/cm (Electrical Conductivity)
Total Alkalinity =	0.12	meq/L		
Acidity =	6.3	mg/L as $CaCO_3$		
Carbon Dioxide (CO_2) =	0.16	mg/L as $CO_{2(aq)}$	0.700	mg/L, Atmospheric equilibrium $CO_{2(aq)}$
DIC =	12.3	mg/L as $CaCO_3$	1.48	mg/L as C, dissolved inorganic carbon
Langelier Index, Calcite =	-3.09	Tendency to dissolve CaCO3 (for steel and cast iron piping)		
CCPP =	-9.4	mg/L as $CaCO_3$, Calcium Carbonate Precipitation Potential		
$B_{H20} + B_{CO3}$ =	0.009	mM/pH, Buffer intensity from water and carbonate species		
$CaCO_3$, pKsp =	-8.418	12.0 °C, temperature		
Copper II =	0.07	mg/L; Cupric Hydroxide, light blue/blue-green		
U.S. EPA Guidance recommend that the initial water characteristic meet the following parameters when considering limestone contactor:				
pH <= 7.2		Condition not met		
DIC < 10 mg/L as C		Condition met		
Calcium < 20 mg/L Ca		Condition met		

Step 3	Limestone Bed Contactor Parameters			
Enter parameters for contactor and chemical addition.				
Superficial Velocity =	14.7	gpm/ft²	59.90	cm/min
Limestone Particle Diameter =	0.3	cm, (0.3 to 3.2 cm)		
Limestone Porosity, ε =	0.42			
Sphericity (roundness), χ =	0.80	range: 0.4 - 0.8		
$CaCO_3$ (Limestone) =	9.4	mg/L		
You may enter "Target pH" to determine Limestone concentration and depth of contactor.				
Target pH =	10.00	Target pH		

Program Overview

Step 4	Results (After Chemical Addition of Limestone)			
pH =	9.95	pH of water after chemical addition		
Total Alkalinity =	15.4	mg/L as $CaCO_3$	0.31	meq/L
Total Calcium =	4.26	mg/L Ca^2	10.6	mg/L as $CaCO_3$
Carbon Dioxide (CO_2) =	0.00	mg/L as $CO_{2(aq)}$	0.00	mg/L as C
DIC =	21.7	mg/L as $CaCO_3$	2.60	mg/L C, dissolved inorganic carbon
Langelier Index, Calcite =	0.00	Tendency to dissolve CaCO3 (for steel and cast iron piping)		
CCPP =	0.0	mg/L as $CaCO_3$, Calcium Carbonate Precipitation Potential		
$B_{H20} + B_{CO3}$ =	0.098	mM/pH, Buffer intensity from water and carbonate species		
Copper II =	0.01	mg/L; Cupric Hydroxide, light blue/blue-green		
Depth of Contactor =	4.39	feet	52.7 inches	134 cm
Empty Bed Contact Time =	2.2	minutes		
Limestone Dissolved =	78.4	pounds per million ga lons of water treated	35.6	Kg/MG

Figure 14 Calcite contactor model - Davis

The above model also shows that the theoretical consumption of calcite when treating this water is 36 kg per million gallon of water treated. At Davis, where the annual water consumption is expected to be about 2.4 million litres (0.6 million gallon), the calcite filter above, with 175 L of bed volume, should last between 8 to 10 years.

4.3.3 Operations and maintenance

As the proposed design includes a set of granular media filters upstream of the calcite contactor, no significant maintenance is expected to be required other than periodic inspections.

Since the calcite bed is gradually being dissolved into the water, its bed volume will diminish, and time to reach target LSI would increase. The rate of dissolution of calcite should therefore be monitored and the bed topped up regularly.

Calcite media conforming to the nominated British Standard should have a high purity of > 97% calcium carbonate. Hence, accumulation of inert within the contactor should be minor. If required, the contactor could be backwashed using the multiport valve to flush out and remove any residual calcite.

4.4 Calcium hypochlorite dosing unit

4.4.1 Recommended hypochlorite dose

The Australian Drinking Water Guidelines (ADWG) is the authoritative source of guidance document for drinking water quality in Australia. In the document, the ADWG emphasizes the importance of maintaining adequate disinfection residual throughout the distribution network to provide protection against accidental backflow, and inhibit biofilm growth. A free chlorine residual of at least 0.2 mg/L is considered desirable in ADWG.

When calcium hypochlorite dissolves in water, it forms hypochlorous acid (HOCl) and hypochlorite ion (OCl^-). Hypochlorous acid is a very effective bactericide but hypochlorite ion is not. The percentage of hypochlorous acid versus hypochlorite ion is dependent on the water pH. To achieve adequate disinfection, the goal is therefore to achieve at least 0.2 mg/L of hypochlorous acid, which means, at the higher water pH that will be at Davis, an equivalent chlorine dose of around 2 mg/L would be required (as shown in Figure 15).

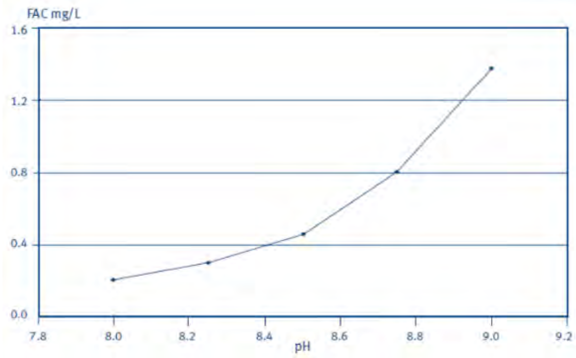


Figure 15 Equivalent free available chlorine vs pH (NZ Drinking Water Guidelines)

Some users of this water may object to this level of chlorine due to perception of taste and odour. Some latitude is possible for this system to reduce the chlorine dose as there is no primary disinfection required (no foreseeable harmful bacteria or viruses). A goal of the operator of the system is therefore to balance the need to minimise microbial activities in the system (which contributes to possible MIC) with the desires of the users.

4.4.2 Dosing equipment selection

There are currently two types of dosing equipment in the market for dosing calcium hypochlorite. The erosion type has a storage reservoir of calcium hypochlorite briquettes, where the water is piped through for treatment. The movement of water through the briquettes erodes and dissolves the calcium hypochlorite, resulting in disinfection. The advantage of such a system is its simple design, with very little moving parts to maintain. However, the control of chlorine dose in such a system relies on the flow rate of the water through the briquettes, which is difficult to control, resulting in variations in the level of disinfection (an example is shown Figure 16 below).

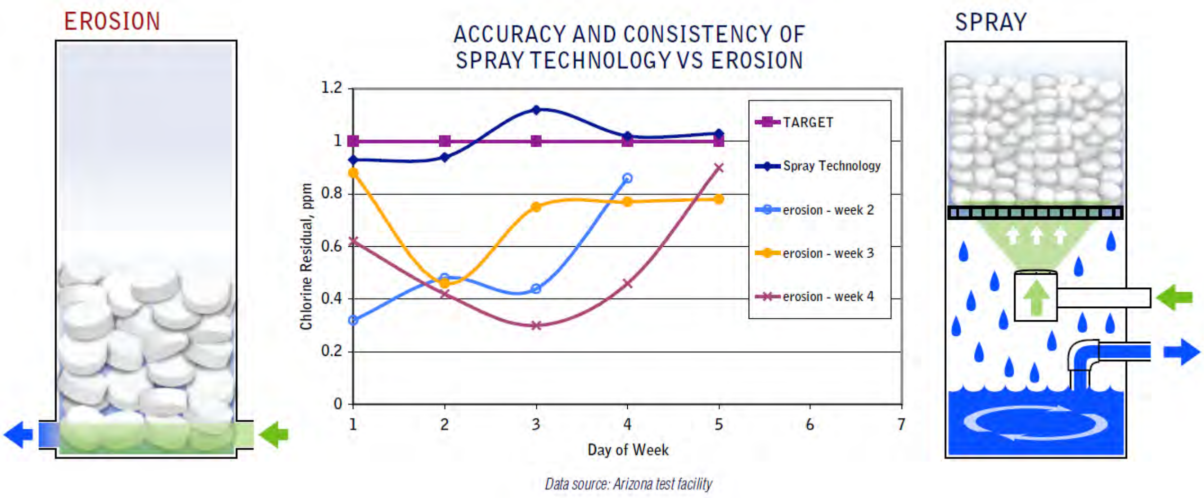


Figure 16 Consistency of chlorine dose with erosion vs spray type equipment (courtesy of Hydromet)

An alternative design in the market sprays a portion of the water to be treated upward into a bed of briquettes, creating a solution of hypochlorite with about 1.5 to 1.8% available chlorine. This solution is then metered out via a chemical dosing pump to disinfect the entire volume of the water to be treated. A residual chlorine analyser would be used to provide feedback control of the chemical dosing pump to provide targeted dosing of hypochlorite. This alternative design has more moving parts to maintain but the system allows a more accurate control of chlorine dosing and is therefore recommended.

The Constant Chlor® Plus Model MC4-50 calcium hypochlorite dosing system manufactured by Arch Chemicals (local Australian distributor is Hydramet) is one such spray type dosing equipment suitable for Davis (datasheet from supplier is provided in Appendix B). This unit stores approximately 30 kg of calcium hypochlorite briquettes, which is sufficient for about 4 years based on annual water consumption of about 2.4 ML at the nominated dose rate.

4.4.3 Operations and maintenance

The supplier of the dosing unit will have a list of recommended operations and maintenance tasks associated with their equipment. One of the common issues with these systems is scaling due to their use with hard water. As calcium hypochlorite is dissolved in the water, it increases the water pH, which in hard water, can result in precipitation of calcium carbonate. However, as the water at Davis is soft, this issue is unlikely to cause major problem.

The only other operations and maintenance task is periodic top up of calcium hypochlorite briquettes, and maintenance of the dosing pump and residual chlorine analyser.

4.5 Recirculation pump

A 10 m^3/h centrifugal pump is required for the recommended treatment configuration option. However, an appropriate discharge pressure of the pump can only be determined on site with knowledge of the required static lift and friction loss of the system. Adequate pressure allowance would also be required to overcome increasing friction loss in the granular media filters as iron corrosion products accumulates. This pressure allowance would be sought from the suppliers of the pressure filters.

Variable speed pumping is recommended to ensure target flow is maintained as headloss increases in the system. The three throttling valves at the storage tanks would be adjusted to provide even distribution of the return flow and the necessary back pressure for the pump to deliver 10 m^3/hr at commissioning. As headloss increases to an unacceptable level, or at regular time interval whichever comes first, the granular media filters should be backwashed to restore flow.

A flow meter should be provided on the discharge of the recirculating pump for commissioning and control of pump speed during operations.

4.6 Approximate space requirement

Based on the sizes of equipment nominated above, a space of approximately 5 m x 2 m has been estimated. A conceptual layout for the major equipment is shown in Figure 17 below, however, the most appropriate layout must be determine by AAD based on actual site constraints with consideration of access for operations and maintenance.

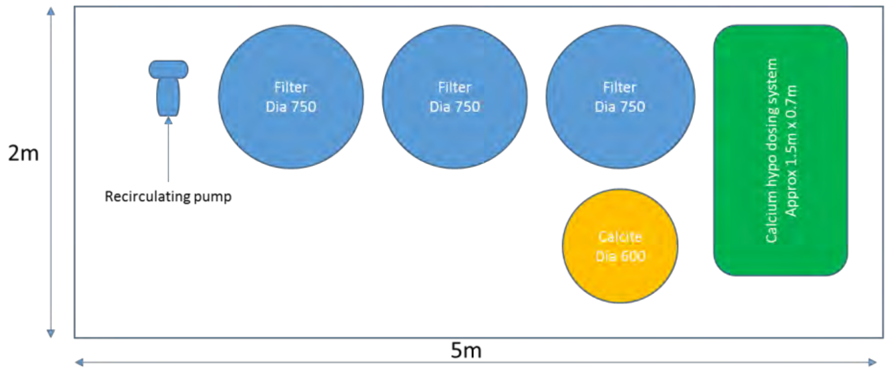


Figure 17 Concept layout of treatment option

5. Conclusions & recommendations

In response to reports of extensive corrosion in the steel pipes and storage systems at Davis station, and water quality test results indicating the presence of elevated metals at various sample points, To the AAD have engaged GHD to;

- review water quality test results that previously have indicated the presence of metals exceeding health guideline values,
- identify problems in the water supply systems, and
- provide advice on options for solving and/or managing these problems.

The review of the water supply infrastructure and water quality at Davis station has indicated that corrosion observed in the potable water storage tanks is most likely caused by a combination of soft water and microbiologically induced corrosion (MIC). This corrosion and iron-rich sediment build-up in the storage tanks is a major source of iron and suspended solids contamination in the water supply system.

Exposure of metallic piping and joints to the naturally soft and corrosive potable water supply is a major source of metals contamination in the drinking water.

To correct the corrosiveness of Davis' water, calcium and alkalinity must be added such that the water has a tendency to deposit calcium carbonate. Common chemicals used that can add calcium and/or alkalinity include calcite, hydrated lime, soda ash and calcium chloride. The best option for this application is a calcite filter as it can add calcium and carbonate in a single simple filter arrangement.

The microbiologically induced corrosion (MIC) also needs to be addressed, with key contributing factors including a lack of a persistent disinfectant, warm water, presence of organic carbon, and stagnant flow. The provision of a persistent disinfectant is expected to be effective for controlling MIC in the main recirculating loop where flow is continuous. For the purpose of disinfection, calcium hypochlorite dosing is recommended, as it involves a simple dosing pump arrangement that is relatively easy to maintain.

However, in stagnant lines, such as those servicing taps that are rarely used, the disinfectant would lose its effect over time and biofilm would again take hold. The only mitigation for possible dissolved heavy metals in these taps served by stagnant lines is to implement a "flush before use" policy at the station.

Finally, dirty water events that have occurred at Davis are attributed to iron corrosion products in the storage tanks being drawn into the ring main (as well as biofilms being dislodged) by the high flows generated when exercising the fire water pumps. To date a combination of bag and cartridge filters have been used with mixed success. Alternative options include depth filtration, either using a cartridge filter system or via granular media filtration. The granular media filtration option is expected to have the most consistent performance in terms of solids removal.

GHD investigated a short term and a long term solution to the water quality issues at Davis station.

The recommendation for the short term solution involves:

- Removal of all iron corrosion products (where practical) from existing storage tanks
- Minimising further corrosion in existing storage tanks through pH/alkalinity adjustment
- Removal of all corrosion products / biofilm from existing pipes (scour and flush)
- Provision of filtration to minimise future dirty water events

- Addition of a persistent disinfectant to control future biofilm growth (chlorinated water supply)
- Dealing with stagnant sections of pipe (flush before use policy)

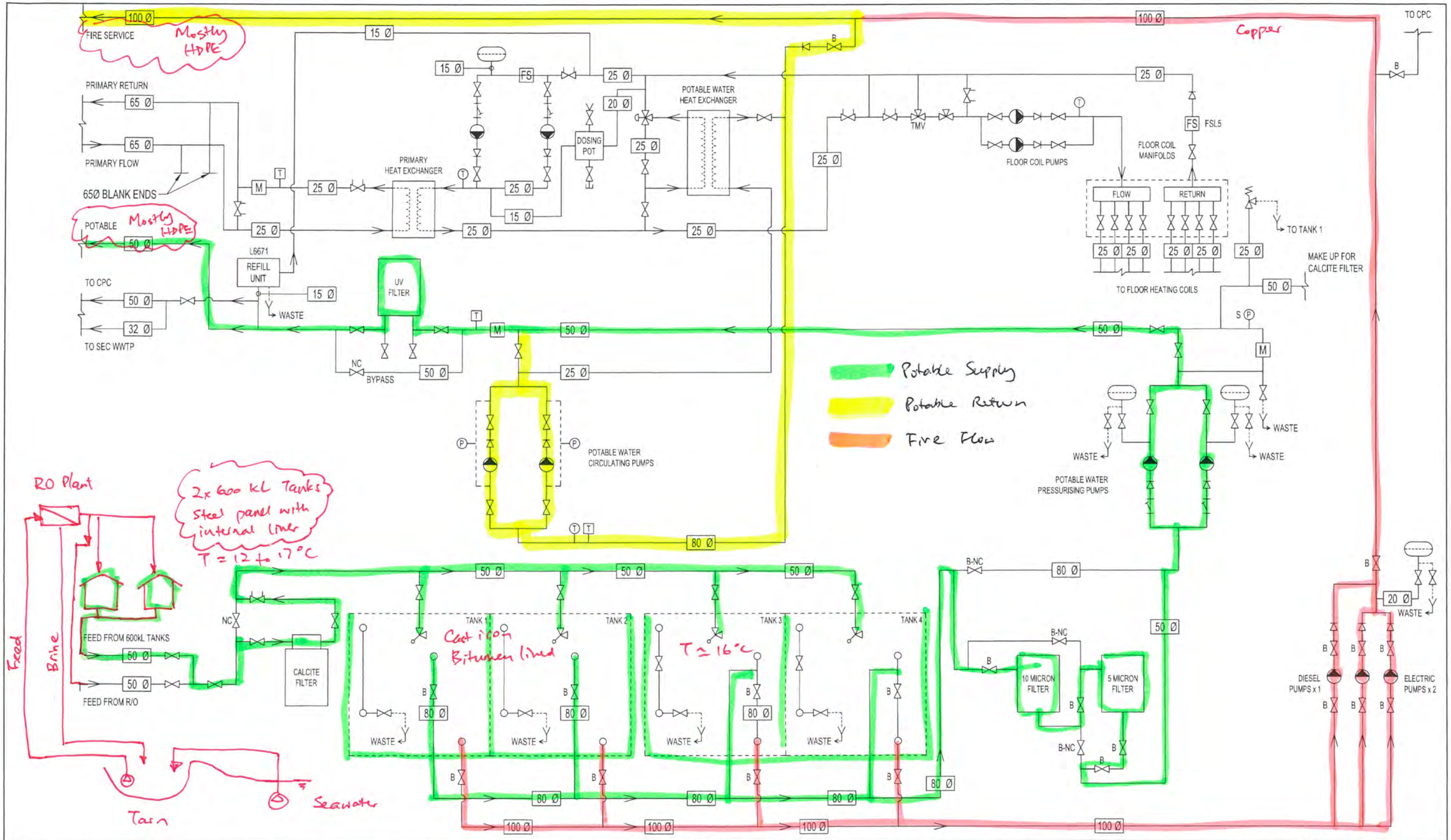
The recommendation for the long term solution involves:

- Replacement of the corroding water storage tanks with those manufactured from corrosion-resistant materials of construction
- Scour and flush all station pipework to remove existing corrosion products and biofilm
- Fast-track replacement of metallic pipework with non-metallic plumbing as much as practicable.
- Implementation of a permanent disinfection system to prevent further biofilm growth

However, GHD’s final conclusion and recommendation from this investigation is for the AAD to focus on the Long Term Solution now. This should avoid the need for pH and alkalinity correction, as there will be minimal exposed metal in the system and hence no corrosion. Removal of corrosion by-products from the system should negate the need for extra filtration, as the source water has already passed through a UF/RO system. Implementation of a long-term disinfection solution is recommended. However, this would only be for biofilm control and not for primary health considerations.

Appendices

Appendix A – System schematic



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	REVISION	DATE	APPD
0	AS INSTALLED	21/06/18	T.PRICE

Drawn: J.B.R
Checked: T.PRICE
Approved:
Enquiries:
Scale: N.T.S
Date of Issue:
Date for Revision:

Australian Government
Department of the Environment and Energy
Australian Antarctic Division

DAVIS STATION TANKHOUSE

WATER SCHEMATIC

Drawing No. L1127-H-SCH
Sheet No. 01/1
Maximo Location
Original Dwg.Size A3

Appendix B – Supplier's datasheets

GLASS PEARLS

Superior filter media

Waterco's Glass Pearls deliver
outstanding water clarity.

enviropro
SAVE TIME, WATER AND ENERGY

SAVE TIME SAVE WATER SAVE MONEY

WATERCO
water, the liquid of life

www.waterco.com


Purity. Safety. Clarity.

Waterco's Glass Pearls are manufactured from 100% pure glass and offer much finer filtration than conventional filter media.

SUPERIOR PURITY

Whereas other filter media may contain a variety of contaminants, Waterco's Glass Pearls are chemically inert for superior purity. In fact, Glass Pearls have been independently lab tested for leaching contaminants and found to be well within Australian Drinking Water Guidelines.

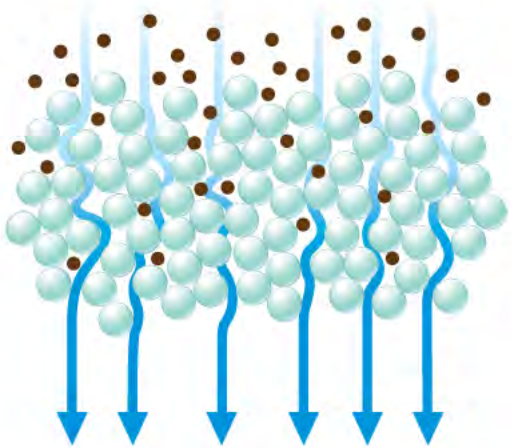
Their superior purity greatly reduces its initial backwashing requirements, prior to commissioning a filter, enabling a rapid start up of media filters.

SAFE

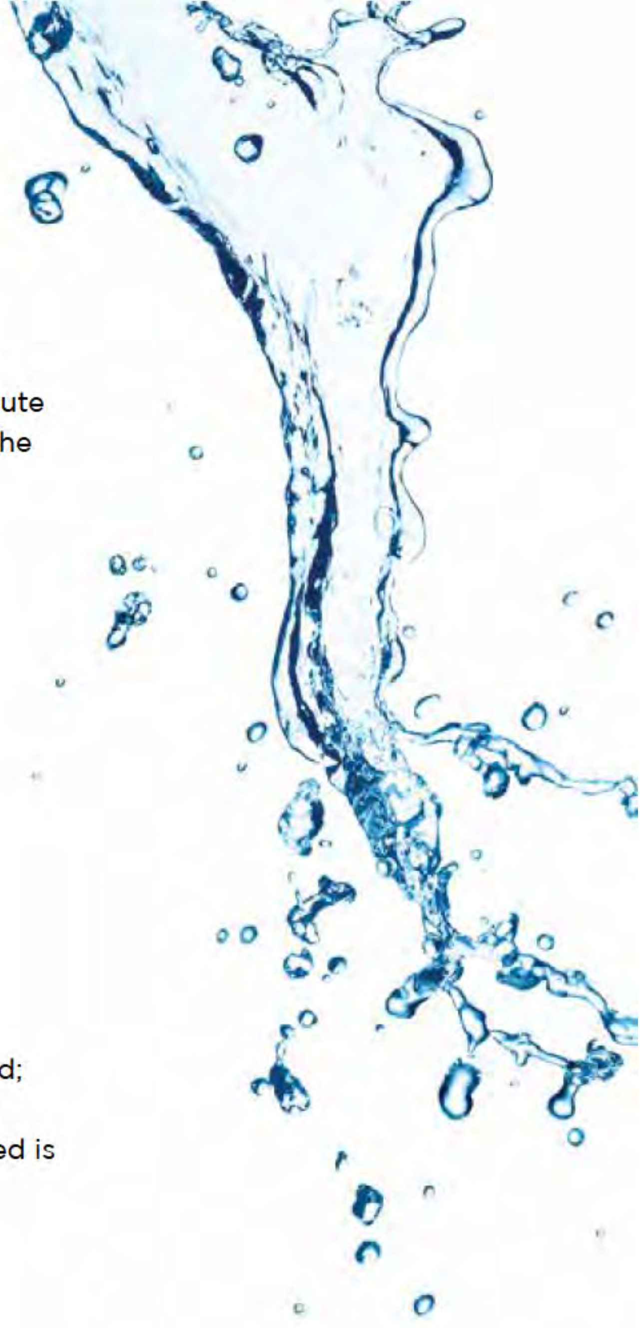
Glass Pearls are safe to handle & safe to service in comparison to other glass media options as crushed glass. Glass Pearls are spherical and do not have sharp edges, making them really safe to use. And if there's ever a failure, of the filter's laterals and Glass Pearls flow into the swimming pool, they pose no risk of injury to swimmers.

SUPERIOR DEPTH FILTRATION

Glass Pearls operate on the basis of "depth filtration"; dirt is driven through the filter bed and trapped in minute spaces between the particles of filter media allowing the cleansed water to pass through.



Conventional media such as sand is crushed and sieved; they generally have an irregular structure and a larger variation in particle size. A conventional media filter bed is more porous and unable to trap fine particles.



Glass Pearls are man-made to specific geometrical shapes providing an extremely narrow particle size range of 0.6mm to 0.8mm, enabling the creation of a dense homogeneous filter media bed, capable of filtering particles down to 3 microns. A micron is equivalent to one millionth of a metre.

Glass Pearl Media

Sand Media

BULK DENSITY

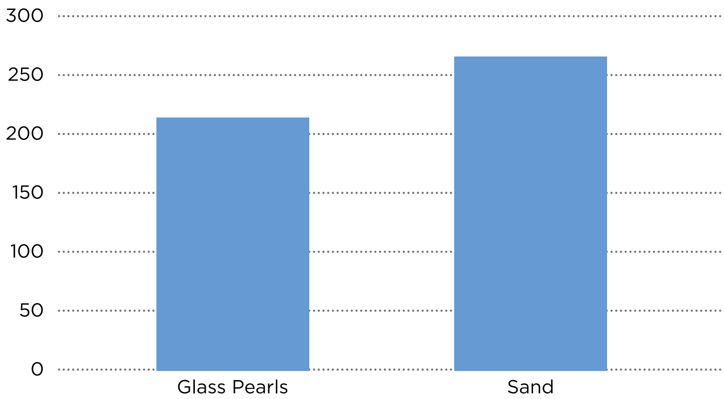
The chart below demonstrates that Glass Pearls have a higher bulk density than crushed glass and sand.

Media	Bulk density, g/cm3
Glass Pearls	1.61
Sand	1.47
Crushed Glass	1.33
Bulk density is a measure of mass per volume.	

SAVE WATER

The water saving ability of Glass Pearls are due to their spherical smooth shape, as this result in a low coefficient of friction. After each backwash, Glass Pearls are effectively cleansed of their trapped contaminants.

Glass Pearls require up to 20% less backwash water than sand, saving time and water.

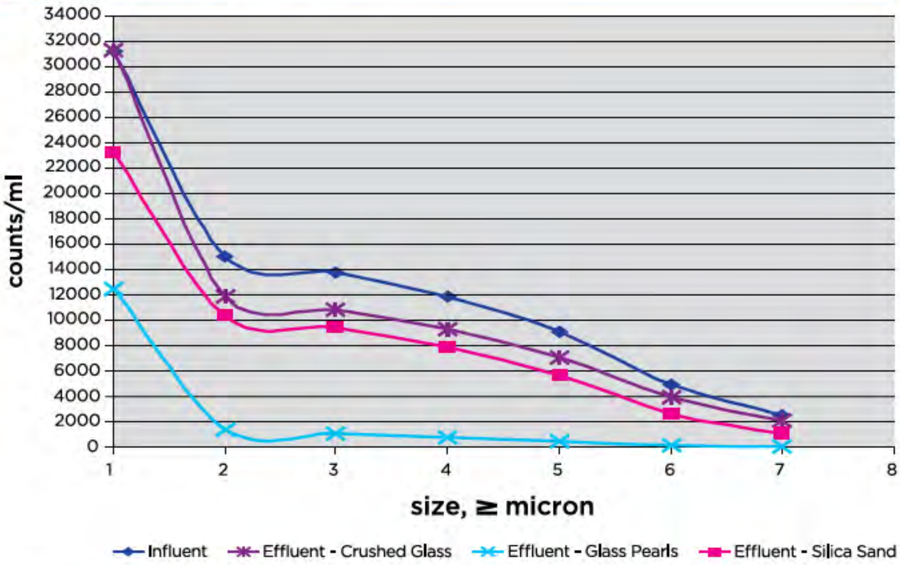


Glass Pearls required 215 litres to successfully backwash a Waterco S600 Media Filter, whereas sand required 266 litres.

Waterco Glass Pearls have been evaluated by TUV SUD PSB and are suitable for both domestic and commercial swimming pools, aquaculture, water treatment and industrial applications.

TUV test reports can be made available upon request.

Particle Count Comparison



Technical Specifications

Filtration Media	Glass Pearl
Effective Size (mm)	0.61
Uniformity Coefficient	1.21
Bulk Density	1.61
Mohs Hardness	7.0

Chemical Compositions

Silicon dioxide (SiO2)	70.00 – 75.00%
Sodium oxide (Na2O)	12.00 – 15.00%
Calcium oxide (CaO)	7.00 – 12.00%
Magnesium oxide (MgO)	approx. 5.00%
Aluminium oxide (AL2O3)	approx. 2.50%
Potassium oxide (K2O)	approx. 1.50%

CONTACT WATERCO

Waterco's head office is situated in Sydney, Australia with international offices, manufacturing plants and warehouses located in Australia, New Zealand, Malaysia, Indonesia, Singapore, China, the US, Canada, France and the UK.

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ZZB1469 04/14

MC4-50 Feeding System

Dry Calcium Hypochlorite For Municipal Applications

The smarter way to water quality

PATENTED SPRAY TECHNOLOGY

DELIVERS UNPARALLELED CONSISTENT RESULTS

Constant Chlor® plus

The Constant Chlor® Plus MC4-50 Dry Calcium Hypochlorite Feeding System

Designed via feedback from actual field users, **The Constant Chlor® Plus MC4-50 dry calcium hypochlorite feeding system** prepares and automatically delivers a consistently accurate dose of liquid available chlorine for disinfection applications. This feeding system can supply up to 50 pounds of AvCL/day on a sustained basis without the storage and handling issues associated with liquid bleach or chlorine gas.

With the ability to stand alone or be integrated with other process and control equipment, this highly customizable feeder uses NSF Standard 60 listed **Constant Chlor® Plus dry calcium hypochlorite briquettes** and patented spray technology to produce fresh liquid chlorine solution as needed. The reservoir is filled and volume maintained via an electronically controlled spray manifold where it is continually circulated to maintain unparalleled solution consistency.

FEATURES

- Unit constructed of high impact HDPE; all wetted areas, internal fittings and level controls constructed of suitable plastics or other non-metallic material
- Utilizes patented spray technology
- Patent-pending mixing mechanism within solution reservoir
- SCADA compatible
- Automatic solution tank refill
- Mechanical overflow-prevention valve
- Large 62 lb. capacity briquette hopper
- Delivers up to 50 lbs. AvCL per day
- Skid mounted with secondary containment
- Area for pump mount

BENEFITS

- Compatible with all types of pumps including positive displacement pumps
- Customizable, convenient and easy to use
- Effective, safer, easier & less expensive alternative to gas and liquid bleach
- Reduced regulatory compliance required including eligibility for Material of Trade (MOT) exceptions for transport
- Efficiencies in bulk storage and man hours
- Consistent and reliable chlorine solutions
- Operates at normal atmospheric pressure and is readily serviceable for refilling and cleaning while in operation
- Eliminates metering pump air locks due to off-gassing
- Eliminates transfer spills
- Minimizes man hours for maintenance and shut downs
- Pre-plumbed and skid mounted for ease of installation
- Internal mixing mechanism enables sustainable homogeneous solution and prevents solids build-up
- Option for pre-treatment

Specifications

Chlorine Delivery Rate*	1.0 - 50.0 lb. AvCl/day with 70° F inlet water temp.	Dry Chemical Capacity	62 lbs.
		Site Requirements:	
Discharge Pressure Range	50 - 150 psig	Inlet Water	1.0 gpm @ 50 - 150 psig
Water Inlet Size	1/2 inch, FNPT	Electrical	20 amp @ 120V/1ph/60Hz
Solution Outlet (Injector) Size	1/2 inch, MNPT	Operating Temperature	40° - 105° F

**Delivery rate is dependant on the dosing pump size*

Municipal Applications

Arch Chemicals, Inc. provides municipalities across the country with products that meet the toughest regulations and standards including NSF/ANSI 61 for our feeding equipment and NSF 60 for **Constant Chlor® Plus Briquettes**, allowing the public to rest easy about the quality of their water supply.

- Remote Well Sites
- Booster Stations
- Waste Water
- Reclaimed Water
- Surface Water Treatment Plants
- Ground Water Treatment Plants

Potable Water

- Provides hypochlorination to disinfect water supplies in smaller communities
- Requires low initial investment
- Maintains economical operating costs

Private Water Supplies

- Sanitizes wells, natural springs, cisterns and storage tanks by destroying microbes
- Purifies by destroying harmful organic matter

Other Water Treatments

- Controls slime and maximizes cooling efficiency in cooling towers, ponds and reservoirs of power plants
- Controls growth of slime in commercial air conditioning systems, improving cooling efficiency and eliminating unpleasant odors
- Destroys disease-producing organisms in raw or treated sewage
- Keeps decomposing septic sewage odors and masonry disintegration in check by "up sewer hypochlorination"

Patented Spray Technology

Patented Spray Technology + Constant Chlor® Plus Briquettes = Consistently Accurate Hypochlorite Solution

How it Works

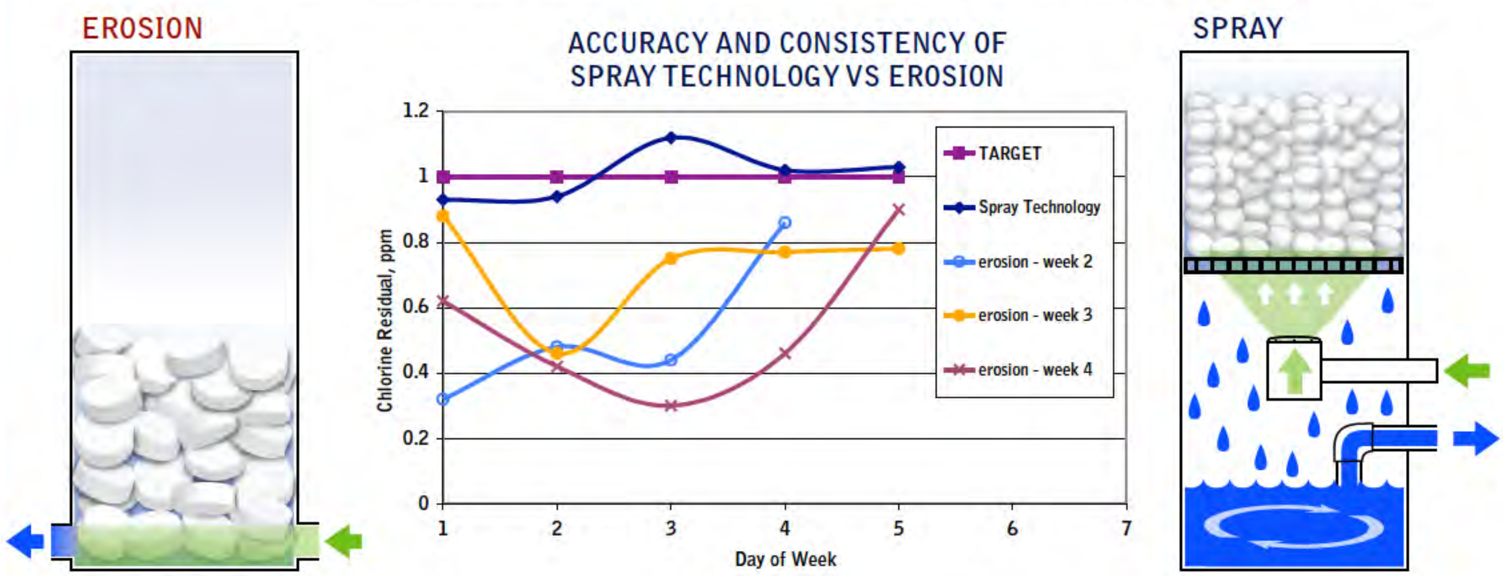
Markedly different from erosion feeders currently on the market, the **Constant Chlor® Plus MC4-50 feed system** injects supply water into the unit by spraying upward into a bed of briquettes; **this short intermittent spray cycle contacts the entire bottom of the bed evenly, not just the material resting on the grid.**

Specifically designed for use in the Constant Chlor® Plus Spray Technology feed systems, the briquettes are relatively small, smooth and "pillow shaped", for maintaining optimum packing in the spray bed.

Maintaining a well-packed bed of briquettes significantly reduces the potential for large voids in the spray surface that can result in inconsistent residual concentration in the final solution.

The hypochlorite solution produced by the unit's spray cycle is collected in a 13-gallon solution tank, where the total volume is slowly and continuously mixed, further enhancing concentration consistency.

Unlike an erosion feeder, the Constant Chlor® Plus MC4-50 feeder sprays upward to a well packed bed of briquettes, contacting the entire bottom of the bed evenly. The chlorinated solution flows to the lower reservoir where it is continuously mixed. The accuracy and consistency of the resulting solution concentration far exceeds that achieved by an erosion feeder. Consequently, operator dosage adjustment is minimal.



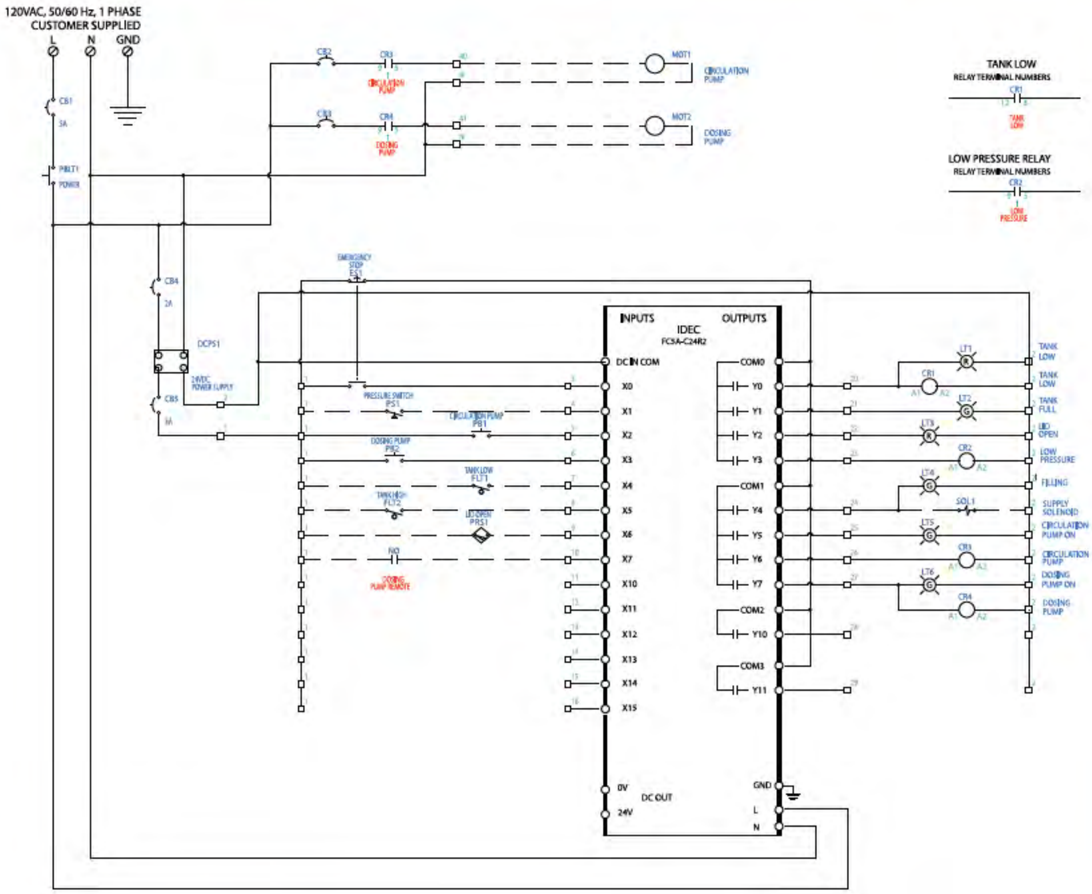
Data source: Arizona test facility

Product Stewardship

Protecting Health, Safety, and Environment — Product Stewardship

Arch is committed to maintaining and improving our leadership in Product Stewardship – from manufacture, marketing, distribution, use, recycling and disposal. Successful implementation includes educating all involved of their responsibilities to address society's interest in a healthy environment and in products that can be used safely. We are each responsible for providing a safe workplace, and all who use and handle products must follow safe and environmentally sound practices.

Electronics Panel and PLC Information



120/240VAC, 50/60Hz, 15/10A, 1 Phase

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24VDC Control Power

PLC with 14 input/10 outputs

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Constant Chlor® Plus Briquettes

Constant Chlor® Plus Briquettes are designed for use in the **Constant Chlor® Plus MC4-50 feeding system.** The briquettes provide chlorine solution for use in many applications including treatment of surface and groundwater for municipal drinking water use, industrial process water as well as pre- and post-harvest food safety.

These patented, pillow-shaped briquettes contain a scale inhibitor designed to reduce maintenance and improve reliability of the feeder system.

FEATURES

- Dry Solid Product
  - Longer shelf life than liquid bleach
  - Occupies much less space than liquid bleach
  - Less hazardous than liquid bleach or gas chlorine
  - Easier to handle than liquid bleach or gas chlorine

SCALE INHIBITED

- Patented formulation
- Reduces maintenance of equipment

REGULATORY

- EPA No. 1258-1179
- NSF Standard 60, Drinking Water Additives
- Meets AWWA Standard B300

PROPERTIES

• Available Chlorine (wt%)	65% minimum
• Scale Inhibitor (wt%)	0.5%
• Weight	0.25 oz. (7 grams)
• Dimensions	1-1/4 in. X 3/4 in. X 1/2 in.
• Appearance	Pillow Shaped Briquettes

PACKAGING

Constant Chlor® Plus Dry Chlorinator Briquettes are available in 50 lb. plastic pails

Arch also produces **Dry Tec® FG Briquettes** (Food Grade) for use with **the Constant Chlor® Plus MC4-50 feeder. Dry Tec® FG** contains an anti scale formulation for food industry applications.

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NSW & ACT
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QLD
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hydraqld@hydramet.com.au

 #49769 2M 6/10

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- Area for pump mount

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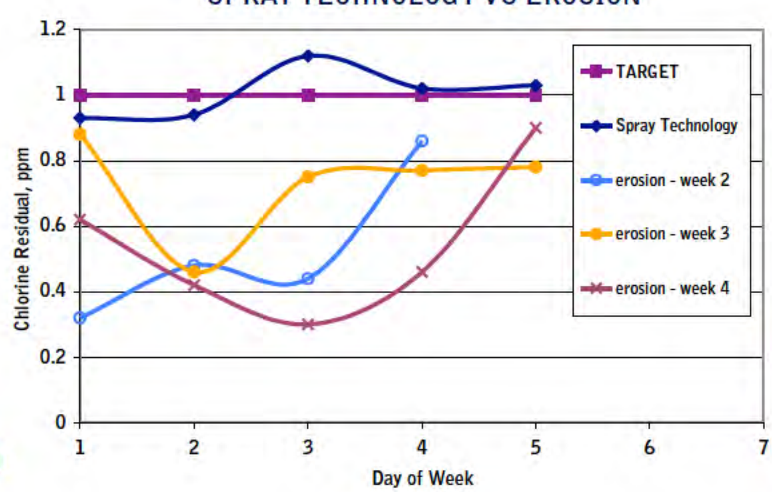

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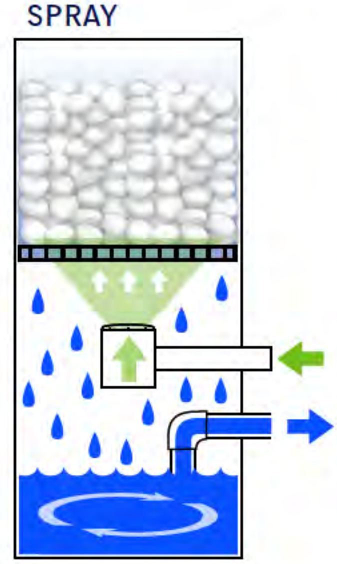

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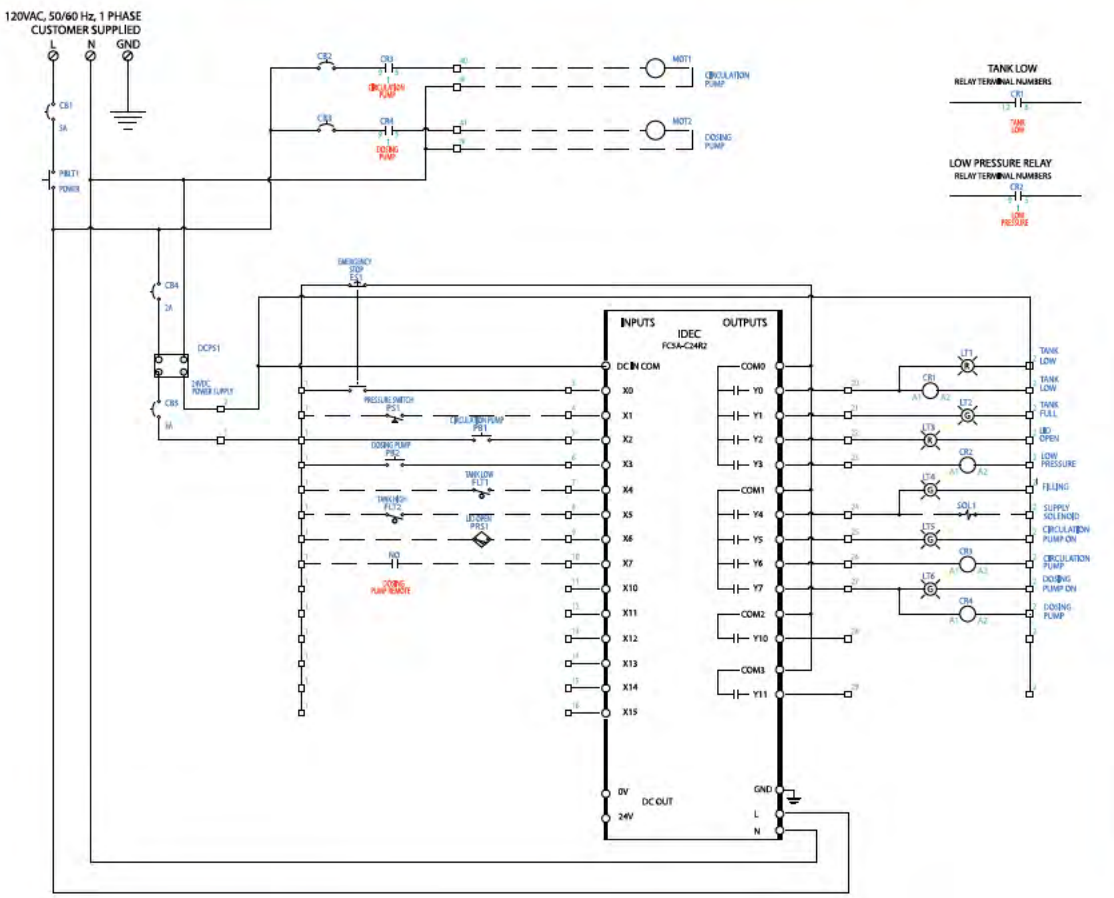

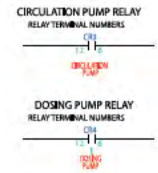

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MULTIPORT VALVES

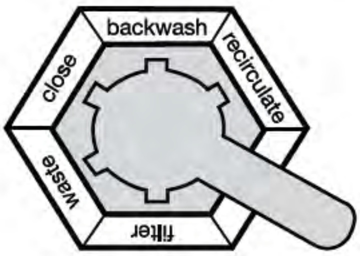
Heavy duty construction

Constructed from heavy duty ABS and GFPP, Waterco Multiport valves are designed for maximum performance and working pressures.

- 6-position multiple valve positions
- Top and Side Mount configurations
- Rated at 400 kPa

Waterco's entire range of Multiport valves are engineered to withstand a working pressure of up to 400 kPa (58 psi) with a test pressure of 600 kPa (87 psi).

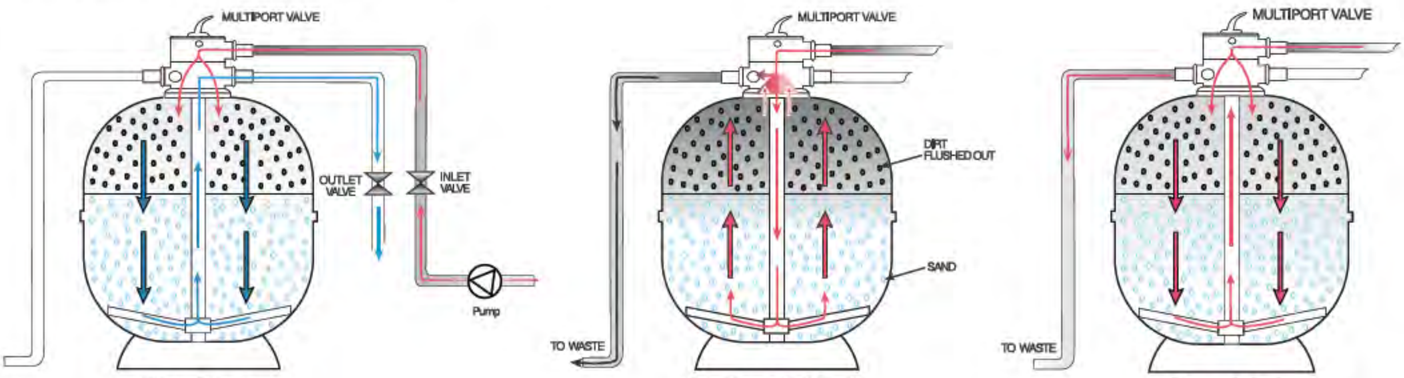
	Max flow rate	Body	Lid	Handle	Rotor	Hardware	Union Nut	Union Tail
40mm MPV	320	ABS	ABS	ABS	GF Noryl	SS304	ABS	PVC
50mm MPV	510	ABS	ABS	ABS	GF Noryl	SS304	ABS	PVC
65mm MPV	780	ABS	GFPP	ABS	GF Noryl	SS304	ABS	PVC
80mm MPV	1080	GFPP	GFPP	ABS	GF Noryl	SS304	ABS	PVC



MULTIPORT VALVE MAIN FUNCTIONS

Filter	-	downward flow through the filter bed to outlet
Backwash	-	upward flow through the filter bed to waste
Rinse	-	downward flow through the filter bed to waste
Waste	-	bypass the filter bed to waste
Re-circulate	-	bypass the filter bed to outlet
Closed	-	no flow to the filter

Cleansing a filter simply requires shifting the Multiport lever from the "filter" position to the "backwash" position, which reverses the flow of water in the filter, flushing the filter bed.



Filter Mode

Backwash Mode

Rinse Mode

Warranty
Waterco Multiport valves are covered by 1 year warranty.

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Constant Chlor® Plus

Dry Calcium Hypochlorite Briquettes

Designed for use in the Constant Chlor® Plus Chlorinator, **Constant Chlor® Plus Briquettes** provide the perfect chlorine solution for use in many applications including the treatment of surface and groundwater for municipal drinking water use, as well as the treatment of wastewater effluent.

THE BENEFITS ARE CLEAR

- Longer shelf life than liquid bleach
- Effective alternative to chlorine gas and liquid bleach
- Cost effective for all municipal and water treatment applications
- Easier and safer to transport and use than liquid bleach
- Dry chemical does not leak
- Small pillow-shaped briquettes provide an optimum spray bed pack resulting in outstanding solution consistency

PATENTED PILLOW-SHAPED BRIQUETTES

DELIVER UNPARALLELED CONSISTENT RESULTS

Constant Chlor® plus

Constant Chlor® Plus Calcium Hypochlorite Briquettes

Constant Chlor® Plus Briquettes provide the perfect chlorine solution for use in many applications, including the treatment of surface and groundwater for municipal drinking water use, as well as the treatment of wastewater effluent.

Designed for use in the Constant Chlor® Plus Chlorinator

These patented, pillow-shaped briquettes contain a scale inhibitor designed to reduce maintenance and improve reliability of the feeder system.

FEATURES

- Dry Solid Product
  - Longer shelf life than liquid bleach
  - Occupies much less space than liquid bleach
  - Less hazardous than liquid bleach
  - Easier to handle than liquid bleach
- Scale Inhibited
  - Patented formulation
  - Reduces maintenance of equipment

TYPICAL PROPERTIES

• Available Chlorine (wt%)	66%
• Scale Inhibitor (wt%)	0.5%
• Weight	0.25 oz. (7.0 grams)
• Dimensions	1-1/4 In. X 3/4 In. X 1/2 In. (approx 35mm X 19mm X 13mm)
• Appearance	Pillow Shaped Briquettes

REGULATORY

- EPA No. 1258-1179
- NSF Standard 60, Drinking Water Additives
- Meets AWWA Standard B300

PACKAGING

Constant Chlor® Plus Dry Chlorinator Briquettes are available in 50 lb. plastic pails

ONCE YOU'VE TRIED OUR BRIQUETTES, YOU'LL KNOW HOW TO ACHIEVE THE BEST RESULTS CONSISTENTLY

Hydramet

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WATERCO
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MICRON
W & WD FILTERS

Deep Bed Sand Filters

Micron W & WD filters are designed with filter depths of 600mm to 1000mm providing enhanced indepth filtration and increased dirt retention capacity. Combining filter housing and various filter media Micron W & WD filters can be fitted in configurations to provide multi-stage comprehensive water conditioning.

www.waterco.com

Proven Durability

Waterco Micron filters are known throughout the industry for their impressive performance and reliability.

Manufactured from the highest grade of non corrosive materials and employing the latest in fibreglass winding technology, Micron filters are built for many years of trouble free operation.

Technologically Advanced

Micron filters consist of a blow moulded inner shell of fibreglass reinforced polyester resin strengthened with multiple layers of continuous strands of fibreglass filament.

Micron filters are wound with precision by Waterco's digital filament winding machines, for refined consistency and superior quality.

Easy Maintenance

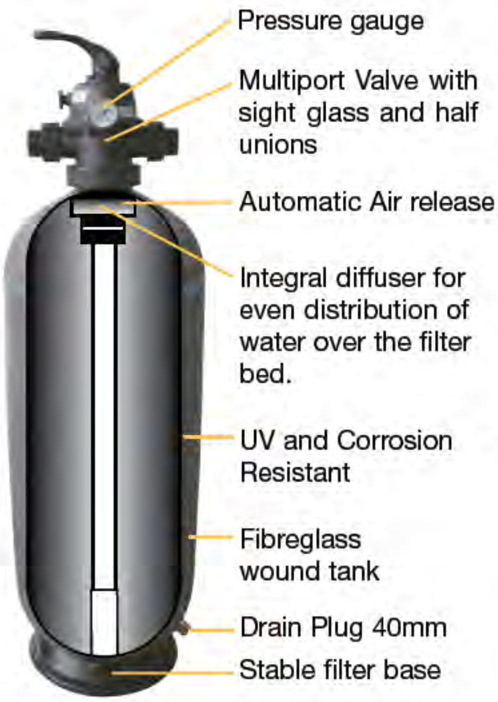
Cleansing the filter simply requires shifting the Multiport Valve lever from the "filter" position to the "backwash" position, which reverses the flow of water in the filter, flushing out the trapped dirt from filter bed.

Model No:	MPV Size	Filter Bed Depth	Filter Bed Area	Filtration Flow Rates 36m³/hr/m²	Filtration Flow Rates 36m³/hr/m²	Backwash Flow Rates 40m³/hr/m²	Backwash Flow Rates 40m³/hr/m²	Filter Bed Volume	Sand 16/30	Zeoplus
	(mm)	(mm)	(m²)	lpm	m³/hr	lpm	m³/hr	(litre)	(kg)	(kg)
W250	40	600	0.05	30	1.8	33	2	41	60	49
W300	40	600	0.07	42	2.5	47	2.8	58	85	70
W350	40	600	0.10	60	3.6	67	4	79	115	95
W400	40	600	0.13	78	4.7	87	5.2	79	115	95
W500	40	600	0.20	120	7.2	133	8	123	180	148
W600	40	600	0.28	168	10.1	187	11.2	175	255	210
W700	40	600	0.38	228	13.7	253	15.2	240	350	288

Model No:	MPV Size	Filter Bed Depth	Filter Bed Area	Filtration Flow Rates 36m³/hr/m²	Filtration Flow Rates 36m³/hr/m²	Backwash Flow Rates 40m³/hr/m²	Backwash Flow Rates 40m³/hr/m²	Filter Bed Volume	Sand 16/30	Zeoplus
	(mm)	(mm)	(m²)	lpm	m³/hr	lpm	m³/hr	(litre)	(kg)	(kg)
WD300	40	1000	0.07	42	2.5	47	2.8	86	125	103
WD350	40	1000	0.10	60	3.6	67	4	116	170	140
WD400	40	1000	0.13	78	4.7	87	5.2	129	188	155
WD500	40	1000	0.20	120	7.2	133	8	199	290	238
WD600	40	1000	0.28	168	10.1	187	11.2	288	420	345
WD700	40	1000	0.38	228	13.7	253	15.2	394	575	473

All filters are able to sustain a temperature of 50°C and have a max working pressure of 600kPa.

*Based on 36m³/hr/m²



'W' Series Deep Bed Filters

Model	A	B	C	D	E	F	G	H	V
W250	1385	268	304	160	1119	1252	1172	162	955
W300	1366	322	346	160	1100	1233	1153	175	955
W350	1397	366	355	160	1130	1262	1183	63	1010
W400	1377	416	355	160	1100	1242	1163	63	995
W500	1415	518	443	160	1148	1280	1201	69	1014
W600	1402	620	540	160	1135	1267	1188	88	992
W700	1407	720	540	160	1140	1272	1193	88	1015

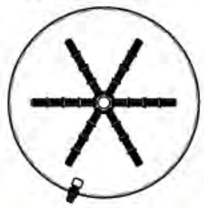
*sizes in mm

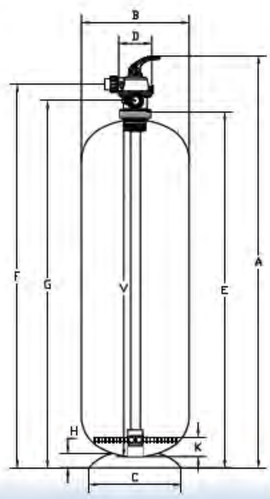
'WD' Series Deep Bed Filters

Model	A	B	C	D	E	F	G	H	V
WD300	1977	315	301	160	1710	1841	1762	75	1590
WD350	1997	366	356	160	1730	1861	1782	63	1612
WD400	1987	416	356	160	1720	1851	1772	63	1595
WD500	2009	518	443	160	1742	1873	1794	69	1600
WD600	1997	620	540	160	1730	1861	1782	88	1582
WD700	2002	720	540	160	1735	1866	1787	88	1622

*sizes in mm

Conventional lateral configuration in W & WD Series applies to models 400 to 700 only





Warranty

Product	Full Warranty	Pro-rata Warranty
1. Residential Applications • W250 / W300 • Other W/WD	 5 years 2 years	 Not applicable 3 years
2. Commercial Applications	2 years	Not applicable

*** Please refer to Waterco's warranty terms and conditions.**

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Document Status

Revision	Author	Reviewer		Approved for Issue		
		Name	Signature	Name	Signature	Date
A	C Lai	N Johnston		C Lai		17/10/18
0	C Lai	K Northcott		C Lai	Calvin Lai	14/02/19

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