Cooling Tower Wastewater Treatment Design Report

BOC Limited - Kooragang Island

16 November 2016

working with the environment

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1 Introduction

1.1 BOC Limited Kooragang Island

BOC Limited - Kooragang Island, herein referred to as BOC Kooragang, owns and operates a gas facility for the production and supply of gas products located at 9 Egret Street Kooragang, New South Wales. The facility operates 24 hours per day, 7 days per week. BOC Kooragang holds NSW Environmental Protection Authority (EPA) Environmental Protection Licence (EPL) 20165. The Scheduled Activities in the EPL include dangerous goods production, general chemicals storage and chemical storage waste generation.

1.2 Background

BOC Kooragang currently possess two (2) cooling towers onsite. Currently the cooling tower blowdown (waste) water continues to two (2) 10,000 litre capacity storage tanks, totalling a capacity of 20,000 litres storage onsite. The wastewater is collected by an approved waste contractor approximately once per week.

BOC Kooragang are researching the possibility of utilising the cooling tower wastewater for irrigation purposes in specific grassed areas of the site. Water quality analysis performed in August 2016 showed that the wastewater contains fluoride concentrations which are above the applicable guideline limits.

In order to research the possibility of utilising the cooling tower wastewater onsite MJM Environmental (MJM) was engaged by BOC Kooragang to undertake a treatment options assessment. In order to verify key process design parameters for the treatment options assessment, a bench-scale jar testing investigation was completed to trial current defluoridation techniques including coagulation and pH precipitation. The results of the investigation showed these methods were ineffective in removing the high levels of fluoride.

In October 2016 MJM carried out a pilot plant trial at the BOC Kooragang site. The objective of the trial was to determine the effectiveness of activated alumina (AA) media adsorption for removing fluoride from the cooling tower blowdown wastewater. Two trials were conducted which included AA adsorption with pH correction and AA adsorption without pH correction.

As a result of the trials it was found that AA adsorption was effective in removing the fluoride to below the recommended irrigation threshold limits. It was also found that pH correction was not required with a maximum fluoride removal of 99% achieved with AA adsorption without pH correction.

It was recommended that BOC Kooragang proceed with a treatment design based on the results of the pilot trial. This report details the treatment design for the cooling tower blowdown wastewater.

1.3 Project Objectives

BOC has engaged MJM Environmental to complete a treatment design for the cooling tower blowdown wastewater based on the results of the pilot trial.

The scope of works for the project includes the following:

- Overview of current wastewater storage system
- Review of wastewater quality
- Development of treatment design
- Approximation of capital costs, operating costs and life cycle cost estimates
- Recommendation

2 Site Identification

BOC Kooragang operates a gas facility located at 9 Egret Street Kooragang, New South Wales. The plant vicinity map and location of the cooling towers and wastewater storage tanks are shown in Figure 2-1 and Figure 2-2.

Figure 2-1: BOC Limited Kooragang and vicinity (Spatial Information Exchange [SIXMaps] 2016)

Figure 2-2: Location of BOC Limited's cooling towers and wastewater tanks

The BOC Kooragang office and plant has, on average, three (3) staff members onsite during normal operating hours. The office and plant contains one kitchen, and toilets. BOC Kooragang does not have access to Hunter Water's sewer system. Onsite treatment of amenity wastewater (toilets and sinks) is performed by an onsite septic wastewater treatment system, which is managed using an approved contractor.

3 Assessment of Current Wastewater Storage System

3.1 Overview of current wastewater storage system

BOC Kooragang currently possess two (2) cooling towers onsite. The cooling tower blowdown (waste) water continues to two (2) 10,000 litre capacity storage tanks, with a total a capacity of 20,000 litres storage onsite. The cooling tower blowdown operates on a time based cycle. The cooling tower process is consistent in wastewater production, therefore changes in the process will not result in an increased volume of wastewater.

The wastewater storage tanks and cooling towers are presented in Figure 3-1 and Figure 3-2. Cooling tower blowdown water of volume 20,000 litres is collected by an approved and licensed waste contractor once a week. The amount of cooling tower blowdown water produced and disposed of is a significant cost to BOC Kooragang’s operations. The direct cost to BOC Kooragang is approximately $40,000 per quarter.

Figure 3-1: Current cooling tower blowdown wastewater storage tanks

Figure 3-2: BOC Kooragang cooling towers

3.2 Current Water Quality Assessment

In order to research the possibility of utilising the cooling tower wastewater for onsite irrigation, MJM was engaged by BOC Kooragang from 2014 to 2016 to undertake wastewater sampling and analysis to obtain baseline data.

The analytes tested are presented in Table 3-1, which are taken from the Australian and New Zealand Environment and Conservation Council (ANZECC) 2000 guidelines. The water sampling analysis results were compared to the ANZECC guidelines presented in *Section 4: Primary Industries - 4.2 Water Quality for irrigation and general water use*.

Table 3-1: Cooling tower wastewater sampling analytes

Analytes		
pH	Herbicides	Iron
Enterococci	Pesticides	Lead
Faecal (thermotolerant) Coliforms	Cadmium	Lithium
Electrical conductivity	Zinc	Manganese
Sodium Absorption Ratio (sodicity)	Aluminium	Mercury
Alkalinity as calcium carbonate	Arsenic	Molybdenum
Chloride	Beryllium	Nickel
Sodium	Boron	Selenium
Fluoride	Chromium VI	Uranium
Nitrogen (total)	Cobalt	Vanadium
Phosphorus	Copper	

Water quality sampling was performed in 2014 to 2016. Three samples (3) were performed in August 2014, one (1) sample in April 2015 and one (1) sample was performed in August 2016.

Sampling was performed in accordance with ANZECC monitoring standards AS/NZS 5667.1:1998 and AS/NZS 5667.11:1998. These procedures include the documentation of the name and location of the sample point, date and time of sample collection, the type of sample point, method of sample collection and sample appearance at the time of collection. The water samples were then transferred into clean plastic bottles provided by a NATA accredited laboratory.

The results for the cooling tower wastewater sampling from 2014 to 2016 are presented in Table 3-2.

Table 3-2: BOC Limited cooling tower wastewater sampling results

Analyte	Units	Result 27/08/2014	Result 03/09/2014	Result 11/09/2014	Result 01/04/2014	Result 18/09/2016	Average	Recommended Irrigation Thresholds [1]
pH	pH Unit	7.85	7.95	7.83	-	8.18	7.95	6 – 9
Enterococci	CFU/100mL	~9	~4	<1	-	~4	~5	-
Faecal (thermo tolerant) Coliforms	CFU/100mL	<1	<1	<1	-	~1	~1	<10,000 [4]
Electrical conductivity	µS/cm	1,670	1,690	1,650	-	1,550	1,640	-
Sodium Absorption Ratio	-	5.2	4.61	4.32	-	4.08	4.55	-
Alkalinity as calcium carbonate (hardness)	mg/L	60	58	68	-	97	71	-
Chemical oxygen demand (COD)	mg/L	-	-	-	50	-	-	-
Suspended solids (SS)	mg/L	-	-	-	13	-	-	-
Chloride	mg/L	294	292	349	-	307	311	-
Sodium	mg/L	223	198	179	-	177	194	-
Fluoride	mg/L	**7.7**	**7.3**	**7.5**	-	**3.5**	**6.5**	1.0[2] 2.0[3]
Nitrogen (total)	mg/L	**11.0**	**10.0**	**8.9**	-	3.8	**8.4**	25 - 125[2] 5[3]
Phosphorus	mg/L	**3.62**	**2.77**	**4.17**	-	**2.13**	**3.17**	0.8 - 12[2] 0.05[3]
Cadmium	mg/L	<0.0001	0.0001	<0.0001	-	<0.0001	0.0001	0.01[2] 0.05[3]
Zinc	mg/L	0.025	0.025	0.018	-	0.012	0.020	2.0[2] 5.0[3]
Aluminium	mg/L	0.04	0.07	0.04	-	0.12	0.07	5.0[2] 20[3]
Arsenic	mg/L	0.003	0.003	0.003	-	0.002	0.003	0.1[2] 2.0[3]
Beryllium	mg/L	<0.001	<0.001	<0.001	-	<0.001	<0.001	0.1[2] 0.5[3]
Boron	mg/L	0.2	0.22	0.17	-	0.18	0.19	0.5[2] 2 – 4[5]
Chromium VI	mg/L	<0.01	<0.01	<0.01	-	<0.01	<0.01	0.1[2] 1.0[3]
Cobalt	mg/L	<0.001	<0.001	<0.001	-	<0.001	<0.001	0.05[2]

Analyte	Units	Result 27/08/2014	Result 03/09/2014	Result 11/09/2014	Result 01/04/2014	Result 18/09/2016	Average	Recommended Irrigation Thresholds [1]
								0.1[3]
Copper	mg/L	0.154	0.136	0.146	-	0.120	0.14	0.2[2] 5.0[3]
Iron	mg/L	0.1	0.1	0.07	-	0.15	0.11	0.2[2] 10[3]
Lead	mg/L	<0.001	<0.001	<0.001	-	<0.001	<0.001	2.0[2] 5.0[3]
Lithium	mg/L	0.005	0.005	0.005	-	0.005	0.005	2.5[2] 2.5[3]
Manganese	mg/L	0.008	0.007	0.007	-	0.003	0.006	0.2[2] 10[3]
Mercury	mg/L	<0.0001	<0.0001	<0.0001	-	<0.0001	<0.0001	0.002[2] 0.002[3]
Molybdenum	mg/L	0.002	0.002	0.002	-	<0.001	0.0016	0.01[2] 0.05[3]
Nickel	mg/L	0.003	0.003	0.003	-	0.012	0.005	0.2[2] 2.0[3]
Selenium	mg/L	<0.01	<0.01	<0.01	-	<0.01	<0.01	0.02[2] 0.05[3]
Uranium	mg/L	<0.001	<0.001	<0.001	-	<0.001	<0.001	0.01[2] 0.1[3]
Vanadium	mg/L	<0.01	<0.01	<0.01	-	<0.01	<0.01	0.1[2] 0.5[3]
Herbicide (Phenoxyacetic Acid Herbicides)								
4-Chlorophenoxy acetic acid	µg/L	<10	<10	<10	-	<10	<10	1,000[6]
2.4-DB	µg/L	<10	<10	<10	-	<10	<10	1,000
Dicamba	µg/L	<10	<10	<10	-	<10	<10	1,000
Mecoprop	µg/L	<10	<10	<10	-	<10	<10	1,000
MCPA	µg/L	<10	<10	<10	-	<10	<10	1,000
2.4-DP	µg/L	<10	<10	<10	-	<10	<10	1,000
2.4-D	µg/L	<10	<10	<10	-	<10	<10	1,000
Triclopyr	µg/L	<10	<10	<10	-	<10	<10	1,000
2.4.5-TP (Silvex)	µg/L	<10	<10	<10	-	<10	<10	1,000
2.4.5-T	µg/L	<10	<10	<10	-	<10	<10	1,000
MCPB	µg/L	<10	<10	<10	-	<10	<10	1,000
Picloram	µg/L	<10	<10	<10	-	<10	<10	1,000
Clopyralid	µg/L	<10	<10	<10	-	<10	<10	1,000
Fluroxypyr	µg/L	<10	<10	<10	-	<10	<10	1,000
2.6-D	µg/L	<10	<10	<10	-	<10	<10	1,000
2.4.6-T	µg/L	<10	<10	<10	-	<10	<10	1,000
Pesticide (Organochlorine Pesticides)								

Analyte	Units	Result 27/08/2014	Result 03/09/2014	Result 11/09/2014	Result 01/04/2014	Result 18/09/2016	Average	Recommended Irrigation Thresholds [1]
alpha-BHC	µg/L	<0.5	<0.5	<0.5	-	<0.5	<0.5	1,000[6]
Hexachlorobenzene (HCB)	µg/L	<0.5	<0.5	<0.5	-	<0.5	<0.5	1,000
beta-BHC	µg/L	<0.5	<0.5	<0.5	-	<0.5	<0.5	1,000
gamma-BHC	µg/L	<0.5	<0.5	<0.5	-	<0.5	<0.5	1,000
delta-BHC	µg/L	<0.5	<0.5	<0.5	-	<0.5	<0.5	1,000
Heptachlor	µg/L	<0.5	<0.5	<0.5	-	<0.5	<0.5	1,000
Aldrin	µg/L	<0.5	<0.5	<0.5	-	<0.5	<0.5	1,000
Heptachlor epoxide	µg/L	<0.5	<0.5	<0.5	-	<0.5	<0.5	1,000
trans-Chlordane	µg/L	<0.5	<0.5	<0.5	-	<0.5	<0.5	1,000
alpha-Endosulfan	µg/L	<0.5	<0.5	<0.5	-	<0.5	<0.5	1,000
cis-Chlordane	µg/L	<0.5	<0.5	<0.5	-	<0.5	<0.5	1,000
Dieldrin	µg/L	<0.5	<0.5	<0.5	-	<0.5	<0.5	1,000
4.4-DDE	µg/L	<0.5	<0.5	<0.5	-	<0.5	<0.5	1,000
Endrin	µg/L	<0.5	<0.5	<0.5	-	<0.5	<0.5	1,000
beta-Endosulfan	µg/L	<0.5	<0.5	<0.5	-	<0.5	<0.5	1,000
4.4-DDD	µg/L	<0.5	<0.5	<0.5	-	<0.5	<0.5	1,000
Endrin aldehyde	µg/L	<0.5	<0.5	<0.5	-	<0.5	<0.5	1,000
Endosulfan sulfate	µg/L	<0.5	<0.5	<0.5	-	<0.5	<0.5	1,000
4.4-DDT	µg/L	<2.0	<2.0	<2.0	-	<2.0	<2.0	1,000
Endrin ketone	µg/L	<0.5	<0.5	<0.5	-	<0.5	<0.5	1,000
Methoxychlor	µg/L	<2.0	<2.0	<2.0	-	<2.0	<2.0	1,000
Pesticide (Organophosphorus Pesticides)								
Dichlorvos	µg/L	<0.5	<0.5	<0.5	-	<0.5	<0.5	1,000
Demeton-S-methyl	µg/L	<0.5	<0.5	<0.5	-	<0.5	<0.5	1,000
Monocrotophos	µg/L	<2.0	<2.0	<2.0	-	<2.0	<2.0	1,000
Dimethoate	µg/L	<0.5	<0.5	<0.5	-	<0.5	<0.5	1,000
Diazinon	µg/L	<0.5	<0.5	<0.5	-	<0.5	<0.5	1,000
Chlorpyrifos-methyl	µg/L	<0.5	<0.5	<0.5	-	<0.5	<0.5	1,000
Parathion-methyl	µg/L	<2.0	<2.0	<2.0	-	<2.0	<2.0	1,000
Malathion	µg/L	<0.5	<0.5	<0.5	-	<0.5	<0.5	1,000
Fenthion	µg/L	<0.5	<0.5	<0.5	-	<0.5	<0.5	1,000
Chlorpyrifos	µg/L	<0.5	<0.5	<0.5	-	<0.5	<0.5	1,000
Parathion	µg/L	<2.0	<2.0	<2.0	-	<2.0	<2.0	1,000
Pirimphos-ethyl	µg/L	<0.5	<0.5	<0.5	-	<0.5	<0.5	1,000
Chlorfenvinphos	µg/L	<0.5	<0.5	<0.5	-	<0.5	<0.5	1,000
Bromophos-ethyl	µg/L	<0.5	<0.5	<0.5	-	<0.5	<0.5	1,000
Fenamiphos	µg/L	<0.5	<0.5	<0.5	-	<0.5	<0.5	1,000
Prothiofos	µg/L	<0.5	<0.5	<0.5	-	<0.5	<0.5	1,000
Ethion	µg/L	<0.5	<0.5	<0.5	-	<0.5	<0.5	1,000
Carbophenothion	µg/L	<0.5	<0.5	<0.5	-	<0.5	<0.5	1,000
Azinphos Methyl	µg/L	<0.5	<0.5	<0.5	-	<0.5	<0.5	1,000

[1] Australian and New Zealand Environment and Conservation Council (ANZECC) 2000 guidelines - *Section 4: Primary Industries - 4.2 Water Quality for irrigation and general water use*.
[2] Short-term trigger value (STV) – The STV is the maximum concentration (mg/L) of contaminant in the irrigation water which can be tolerated for a shorter period of time (20 years).
[3] Long-term trigger value (LTV) – The LTV is the maximum concentration (mg/L) of contaminant in the irrigation water which can be tolerated assuming 100 years of irrigation.
[4] Trigger value chosen for areas with restricted public access.
[5] Trigger value chosen for moderately tolerant crops.
[6] General limit set for herbicides for NSW.

The Short-term Trigger Values (STV) and Long-term Trigger Values (LTV) presented in Table 3-2 are recommendations from the *Australian and New Zealand Environment and Conservation Council (ANZECC) 2000* guidelines (ANZECC guidelines). The guidelines for irrigation were chosen for comparison with the cooling tower wastewater quality.

Table 3-2 shows that Fluoride exceeded the STV and LTV for all three samples with an average of 6.5 mg/L. It is noted that the guidelines state '*the LTV has been set on the assumption that irrigation water could potentially be phytotoxic to sensitive plant or contaminate stock drinking water*'.

Nitrogen (total) was within the STV range, however exceeded the LTV for all three samples with an average of 10.0 mg/L. It is noted that the guidelines state for nitrogen that '*the LTV has been set at a concentration low enough to ensure no decrease in crop yields or quality due to excessive nitrogen concentrations during later flowering and fruiting stages*'.

Phosphorus concentrations for all three samples also exceeded the LTV with an average of 3.52 mg/L. However it is noted that the guidelines state the LTV for phosphorus is set '*to minimise bioclogging of irrigation equipment only*'. It is therefore possible to manage phosphorus levels with routine maintenance of irrigation equipment.

The remaining analytes were compliant with the recommended threshold levels.

Therefore it was identified that Fluoride was the main analyte of concern. Investigations were commenced to provide a treatment option for removal of fluoride from the cooling tower wastewater.

4 Pilot Plant Trial for Removal of Fluoride

In September and October 2016, MJM performed a pilot plant trial for the removal of fluoride using a AA media in a pilot scale filter unit. It was found that the pilot scale filter unit successfully removed fluoride to acceptable levels, and also reduced phosphorus concentrations. Table 4-1 presents the results of the analytes monitored and the pilot trial report.

The study was focused on fluoride removal to meet the ANZECC guidelines for LTV (100 years of irrigation) and therefore analytes were chosen that were of concern for irrigation. Analytes such as metals, herbicides and pesticides were not targeted and therefore not monitored as the concentrations of the analytes were already below the ANZECC guidelines or not detected in the raw water.

Table 4-1: BOC Kooragang pilot trial treated water quality results

Analyte	Units	Treated water quality	Recommended Irrigation Thresholds [1]
pH	pH Unit	7	6 – 9
Electrical conductivity	µS/cm	1,520	-
Sodium Absorption Ratio (SAR)	-	7	-
Chloride	mg/L	300	-
Sodium	mg/L	229	-
Fluoride	mg/L	0.2	1.0[2] 2.0[3]
Nitrogen (total)	mg/L	3	25 - 125[2] 5[3]
Phosphorus	mg/L	0.02	0.8 - 12[2] 0.05[3]

[1] Australian and New Zealand Environment and Conservation Council (ANZECC) 2000 guidelines - *Section 4: Primary Industries - 4.2 Water Quality for irrigation and general water use*.
[2] Short-term trigger value (STV) – The STV is the maximum concentration (mg/L) of contaminant in the irrigation water which can be tolerated for a shorter period of time (20 years).
[3] Long-term trigger value (LTV) – The LTV is the maximum concentration (mg/L) of contaminant in the irrigation water which can be tolerated assuming 100 years of irrigation.

As a result of the trial it was recommended to develop a treatment design based on AA adsorption. The following section presents the proposed treatment design.

5 Wastewater Treatment Design

5.1 Proposed Treatment System

5.1.1 Design Basis

The recommended treatment process is activated alumina media adsorption and onsite irrigation.

The design basis for the preferred treatment option is presented in Table 5-1.

Table 5-1: Treatment option design criteria

Criteria	Unit	Value
Wastewater produced weekly	L	20,000
Raw water fluoride	mg/L	8
Treated water fluoride target	mg/L	<1
Activated alumina fluoride uptake capacity	mg/kg	2,500
Activated alumina density	kg/m³	700
Activated alumina required for 12 months	kg	3,072
	t	3.1

5.1.2 Treatment Process Design

The proposed process configuration will consist of the following:

- Existing 2 X 10 kL cooling tower blowdown storage tanks
- 1 X cooling tower blowdown storage tank submersible pump
- 1 X flow meter
- 2 X open gravity filters
- 1 X 20 kL treated water storage tank
- 1 X treated water storage tank submersible pump
- Irrigation pipework
- Application of effluent to land using a Drip irrigation system

A process and instrumentation diagram is presented in Appendix A. The AA filtration process design is presented in the following table.

Table 5-2: Treatment options design criteria

Criteria	Unit	Value
Activated alumina fluoride uptake capacity	mg/kg	2,500
Activated alumina density	kg/m³	700
Activated alumina required for 12 months	kg	3,072
	t	3.1
Filter media volume required	m³	4.4
Number of Filters	no. off	2
Filter Diameter	m	1.6
Contact time	min	10
Filter Design Flow	m³/h	13.2
Filter Design Flow	L/s	3.7
Time Required to Treat 20 kL	min	91
Mode of Operation	Filters operating in parallel without the need for filter backwashing	

The open gravity filters have been sized to treat the blowdown wastewater produced for a period of 12 months. At the end of 12 months the media will reach its maximum fluoride uptake capacity and will need to be replaced. Preliminary waste classification of the AA used in the pilot trial showed the media can be classified as general solid waste (non-putrescible). However it is recommended that the media be reclassified at the end of 12 months of operation due to the likelihood of elevated fluoride levels which may exceed waste classification guideline limits.

The AA filtered water will be collected in a new 20 kL treated water storage tank.

5.2 Proposed Irrigation Option

5.2.1 Irrigation Pipework Overview

New irrigation pipework will be installed from the gravity filters to an existing underground copper line which runs across the site to the proposed irrigation area. New pipework will then be installed from the existing pipework to the treated water storage tank. A general arrangement diagram showing where the proposed gravity filters and irrigation pipework will be installed is presented in Figure 5-1.

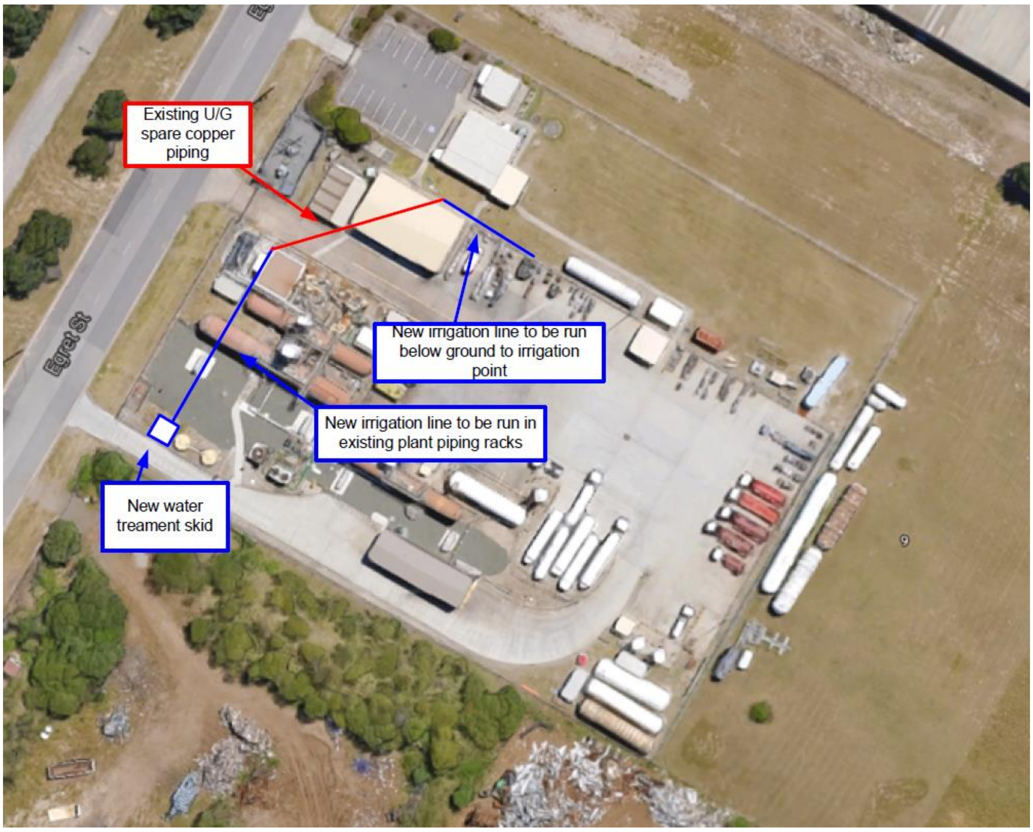


Figure 5-1: Proposed filters and irrigation pipework

5.2.2 Irrigation Area

The proposed irrigation area selected by BOC Kooragang and its approximate dimensions are presented in Figure 5-2.

An Irrigation Options Report has been prepared by MJM for submission to NSW EPA to obtain a licence variation for the proposed irrigation.

The report findings show the proposed irrigation system at the BOC Kooragang site is feasible for the following reasons:

- Water balance calculations show that the estimated percolation rate of the proposed irrigation is well below the typical range of percolation rates for the soil type at the facility. When managed appropriately at the estimated rate of application, is it believed the soil type is therefore able to handle the capacity of the effluent applied based upon percolation rates and unlikely to cause ponding.
- Nitrogen and phosphorus balances performed show that the concentration of these analytes are not limiting factors for irrigation purposes.

Figure 5-2: Proposed irrigation area

A drip irrigation system is proposed to be utilised. Drip irrigation systems provide more operational flexibility and efficiency. Pressurised effluent is discharged through micro-emitters and dripped; this process reduces the risk of aerosol drift and potential odour.

5.3 Cost Estimates

The estimated capital, operating and lifecycle costs for the proposed treatment design are presented in Table 5-3.

Table 5-3: Wastewater treatment design approximate costs

Item	Result
Capital Costs	
Open gravity filter, 2 off	$ 15,120
Treated water storage tank	$ 15,000
Submersible pump, 2 off	$ 2,000
Pipework and valves	$ 10,400
PLC and Scada	$ 5,000
Level sensors, 4 off	$ 16,000
Flowmeter	$ 2,500
Total estimated capital costs including contingency of 20%	**$ 79,224**
Operating Costs	
Activated alumina 3,100 kg at $3.90/kg, includes gravel and sand media	$ 13,250
Annual maintenance cost (assumed 2% of capital cost)	$ 3,220
Total estimated annual operating costs	**$ 14,570**
Net Present Value (NPV) Analysis $NPV = Cap + \sum_{n=0}^{N} \left(\frac{Op}{(1+dr)^n} \right)$	
NPV (1 %)	$ 111,485
NPV (2.5%)	$ 106,952
NPV (4 %)	$103,296

* Prices do not include GST or freight to site, testing or commissioning, design or documentation and are indicative at time of writing.

6 Recommendations

In October 2016 MJM carried out a pilot plant trial at the BOC Kooragang site. The objective of the trial was to determine the effectiveness of AA media adsorption for removing fluoride from the cooling tower blowdown wastewater. The results of the trial showed that AA adsorption was effective in removing the fluoride to below the recommended irrigation threshold limits and it was recommended that a treatment design be developed.

The proposed treatment design consists of AA adsorption and irrigation onsite. Table 6-1 shows an evaluation of the operational and financial criteria for the treatment design.

Table 6-1: Treatment design evaluation

Criteria	Evaluation
Operational Criteria	
Capability of achieving water quality targets (low, medium, high capability)	Medium-High
Plant footprint required (low, medium, high area)	Medium
Technology Risks (low, medium, high risk)	Low
Operational complexity (low, medium, high complexity)	Low
Chemical Handling Risks (low, medium, high risk)	Low
Financials	
Capital Cost	$ 79,224
Annual Operating Cost	$ 14,570
Life Cycle Cost (4%)	$ 103,296

It is recommended BOC Kooragang proceed with the proposed cooling tower blowdown wastewater treatment design.

Appendix A – Process and Instrumentation Diagram

SYMBOL	DESCRIPTION
	GATE VALVE
	GLOBE VALVE
	TELESCOPIC VALVE
	ACTUATING VALVE
	NON RETURN VALVE
	SWING CHECK VALVE
	DIAPHRAGM VALVE
	FLOAT VALVE
	RELIEF VALVE
	ANGLED RELIEF VALVE
	NEEDLE VALVE
	BALL VALVE
	REDUCING VALVE

SYMBOL	DESCRIPTION
	EJECTOR
	BELL MOUTH
	REDUCER
	Y-STRAINER
FI	ROTAMETER
	AERATOR DIFFUSER
	PULSATION DAMPNER
F	ELECTROMAGNETIC FLOWMETER

SYMBOL	DESCRIPTION
	PROCESS FLOW
	INSTRUMENT CONNECTION
	GENERIC SIGNAL
	DATA
	PNEUMATIC
	ELECTRIC
	CAPILLARY TUBE
	HYDRAULIC
	ELECTROMAGNETIC WITH WIRING
	ELECTROMAGNETIC WITH NO WIRING
	FLEXIBLE HOSE

SYMBOL	DESCRIPTION
	GENERAL PUMP
	CENTRIFUGAL PUMP
	PERISTALTIC PUMP
	GENERAL COMPRESSOR
	CENTRIFUGAL FAN
	AXIAL FAN
	SPRAY NOZZLE
	GENERAL FILTER
	STATIC MIXER
	AIR FILTER
	MECHANICAL MIXER

SYMBOL	DESCRIPTION
	INSTRUMENT, FIELD MOUNTED
LSH	INSTRUMENT, REMOTE PANEL MOUNTED, ON FRONT OF PANEL
	INSTRUMENT, LOCAL PANEL MOUNTED, ON FRONT OF PANEL
	STATUS INDICATOR, FIELD MOUNTED
	STATUS INDICATOR, REMOTE PANEL MOUNTED
	STATUS INDICATOR, LOCAL PANEL MOUNTED
	DISPLAY/CONTROL DEVICE, FIELD MOUNTED
	DISPLAY/CONTROL DEVICE, LOCAL PANEL INTERFACE
	DISPLAY/CONTROL DEVICE, REMOTE PANEL INTERFACE
	PROGRAMMABLE LOGIC CONTROL, FIELD MOUNTED
	PROGRAMMABLE LOGIC CONTROL, LOCAL PANEL INTERFACE
	PROGRAMMABLE LOGIC CONTROL, REMOTE PANEL INTERFACE

LETTER	FIRST LETTER	MODIFIER	SUCCEEDING LETTER
A	ANALYSIS		ALARM
B	BURNER, FLAME		STATE OR STATUS DISPLAY
C	CONDUCTIVITY		CONTROL
D	DENSITY	DIFFERENCE	
E	VOLTAGE		SENSING ELEMENT
F	FLOWRATE	RATIO	
G	GAUGE POSITION		GLASS
H	HAND OPERATED		HIGH (ALARM)
I			INDICATING
J		SCAN	
K	TIME		BARRIER
L	LEVEL		LOW (ALARM)
M	MOISTURE/HUMIDITY		
N			
O			
P	PRESSURE/VACUUM		TEST POINT CONNECTION
Q		INTEGRATE/TOTALISE	INTEGRATING OR SUMMATING
R	RADIATION		RECORDING
S	SPEED/FREQUENCY		SWITCHING
T	TEMPERATURE		TRANSMITTING
U	MULTIVARIABLE		MULTIFUNCTION UNIT
V	VIBRATION		VALVE, DAMPENER, LOUVRE OR ACTUATING ELEMENT
W	WEIGHT FORCE		WELLS
X			CATHODE RAY TUBE
Y			RELAY OR COMPUTING RELAY
Z			EMERGENCY/SAFETY ACTING

DRAWING NOTES:

1. ALL PIPING WILL BE UPVC
2. ALL DIMENSIONS IN METRIC UNITS UNLESS OTHERWISE STATED

REV.	DESCRIPTION	DATE	BY
0	FIRST ISSUE	1/11/2016	AB

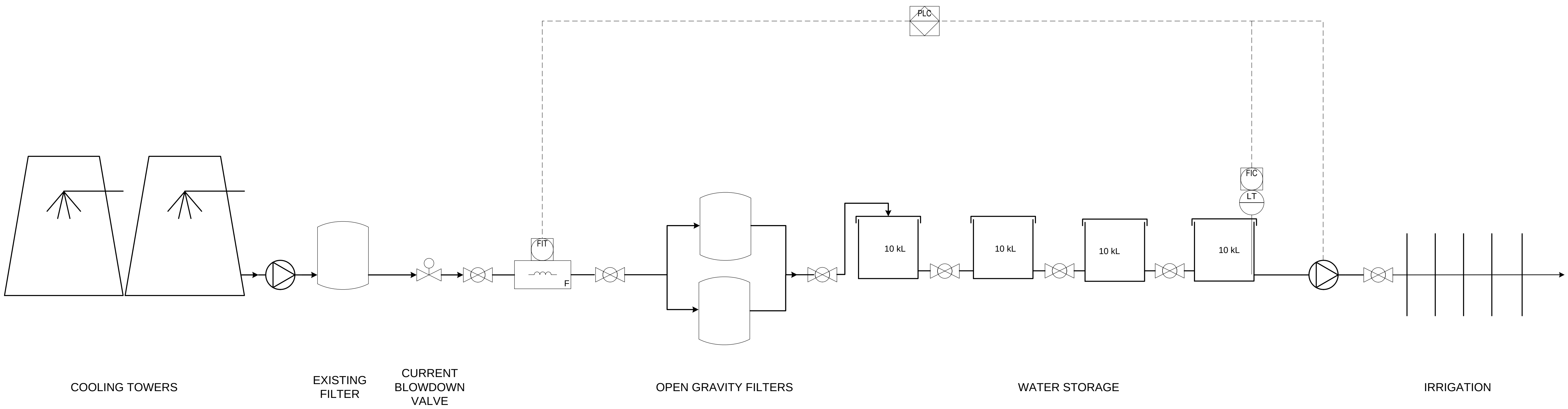
	BY	DATE
DESIGNED	AB	10/2016
DRAWN	AB	10/2016
CHECKED	AM	11/2016

CLIENT: BOC LIMITED

PROJECT: COOLING TOWER WASTEWATER TREATMENT DESIGN

TITLE: TREATMENT PLANT PID

DATE	16/11/2016
SCALE	NTS
JOB NO	034 1612
DWG NO	0



REV.	DESCRIPTION	DATE	BY
1	SECOND ISSUE	9/11/16	DA
0	FIRST ISSUE	1/11/2016	AB
REV.	DESCRIPTION	DATE	BY

DESIGNED	AB	10/2016
DRAWN	AB	10/2016
CHECKED	AM	11/2016
	BY	DATE

CLIENT	BOC LIMITED
PROJECT	COOLING TOWER WASTEWATER TREATMENT DESIGN
TITLE	TREATMENT PLANT PID

DATE	16/11/2016
SCALE	NTS
JOB NO	034 1612
DWG NO	01