Eskom	Scope of Work	Generation

Title: **Kriel Power Station Chemical Supply for Cooling Water and Ash Water Return/Supply Systems Scope of Work**

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Compiled by	**Functional Responsibility**	**Authorised by**
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Date: 2024-04-08	Date: 2024-04-08	Date: 2024/04/08

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TABLES

1. INTRODUCTION

Kriel Power Station (PS) is situated in Kriel, Mpumalanga. It comprises of six (6) five hundred (500) megawatt (MW) units. The station uses primary inputs of coal and water to produce electricity for supply to the country. It is a wet-cooled station, in that the primary means of condensing low-pressure steam from the low-pressure turbine uses water, which is cooled, in an open evaporative natural draft-cooling tower.

Kriel PS utilises lime softening for hardness removal. The lime softening is conducted on a side-stream treatment, meaning approximately 10% of the total volume of the CW system is treated through the process on a continuous basis. The CW system is split into two operating systems, one servicing Units 1-3 termed the South side and the other servicing Units 4-6 termed the North side. The cooling water circuits operate independently of each other with their own treatment systems.

The lime treatment systems on each CW circuit include the lime treatment plant that was originally installed with the power station and a new lime treatment plant which was installed in 2019. There are currently challenges that are experienced on both the original and the new lime treatment plants, which affects availability of the lime treatment plants. In addition, chemicals are dosed to control microbiological growth and scale formation in the system, and there are no long-term contracts in place to manage the consistent supply of these chemicals. This results in inadequate control of microbiological growth and scale within the system.

All the impacts explained in the previous paragraph results in reducing the efficiency of the condenser, which results in load losses experienced on the station.

Kriel PS also operates a wet ashing system where the ash is disposed off in a slurry on ash dams. Once the ash has settled in the dam, the ash water (supernatant) is decanted via penstocks in the ash dam and pumped back to the power station to be reused to slurry the ash from the boilers. The ash water that is returned (termed ash water return) is highly scaling. Chemicals are dosed to prevent the scaling of these ash water return lines.

2. SUPPORTING CLAUSES

2.1 SCOPE

The scope covers the supply and surveillance of treatment chemicals for cooling water chemistry control and ash water return/supply systems. This will include monitoring and technical support.

2.1.1 Purpose

The purpose is to ensure that the correct dosing and surveillance regime is followed for cooling water chemistry control to comply with the Cooling Water Standard and that scale formation is controlled on the ash water return/supply systems.

2.1.2 Applicability

This document shall apply to Kriel Power Station.

2.2 NORMATIVE/INFORMATIVE REFERENCES

Parties using this document shall apply the most recent edition of the documents listed in the following paragraphs.

2.2.1 Normative

[1] ISO 9001 Quality Management Systems.

[2] 240-55864767: Chemistry and Microbiological Standard for Cooling Water

[3] 240-123919938 - Legionella Control and Management Standard

2.2.2 Informative

[4] Not applicable.

2.3 DEFINITIONS

2.3.1 Disclosure Classification

Controlled disclosure: controlled disclosure to external parties (either enforced by law, or discretionary).

2.4 ABBREVIATIONS

Abbreviation	Description
COC	Cycles of Concentration
CW	Cooling Water
CFU	Colony Forming Unit
Ml	Megalitre
m^3/s	Meter cubed per second
PS	Power Station

2.5 ROLES AND RESPONSIBILITIES

Contract Manager

- Is required to use this document as the basis for the works information developed for the specific station.
- Is responsible to ensure the products/services are as per the quality control specification.
- Is responsible to ensure all the terms of the contract scope of work are adhered to.
- Is responsible for the drafting of the procurement request and scope of work for the contract.

System Engineer

- Is required to assist in the compilation of the scope of work for the supply of the chemicals contract.
- Evaluate and review any proposed optimisation interventions to ensure that it complies with the design base.
- Is responsible for following the engineering change management process when there are changes to the design base.

Corporate Microbiology Consultant

- Is responsible to provide guidance and support during compilation of the Scope of Work for the supply of microbiology treatment chemicals.
- Is responsible for participating in the technical evaluation of all the tenders received.

Chemical Services Manager of the Power Station

- Is responsible for facilitating and participating in the technical evaluation of all the tenders received.
- Is responsible for managing the successful contractor after contract award to ensure they meet the requirements of the contract

Chemical supplier

- Is responsible for monitoring and optimisation of the chemical treatment program proposed to achieve compliance to the KPIs as stipulated in Appendix A.
- Is responsible for supply and dosing of contracted chemicals to maintain the required concentrations in the main CW circuit.
- Is responsible to notify the chemical services staff timeously of contingency treatment requirements.

2.6 PROCESS FOR MONITORING

Stakeholders must review the technical specifications before the request is issued to market by Procurement. These stakeholders will conduct the technical evaluation of the tenders once received. The tenderer appointed shall be monitored as per the KPIs in Appendix A.

2.7 RELATED/SUPPORTING DOCUMENTS

Not applicable.

3. SCOPE OF WORK

3.1 SYSTEM INFORMATION

- North System Volume ~ 40.76 Ml
- South System Volume ~ 40.76 Ml
- Blowdown Volume: System limited due to constraints on ash system, performed when an opportunity arises. There are leaks that can be approximated to a blowdown but are not quantifiable.
- Target Raw Water Makeup per day ~ 45 Ml on North and 45 Ml on South. There are situations in which these values may be exceeded, causing cooling tower ponds to overflow.
- Recovery streams are continuously recovered into the cooling tower ponds, except when the recovery water quality located in Appendix B is exceeded as per the specifications in Appendix A. There is a project in place to move the recovery streams to the cooling water clarifiers.
    - Vaal Pan to north cooling towers ~ 346 m^3/h
    - Vaal Pan to south cooling towers ~ 486 m^3/h
    - Coal stockyard to south cooling towers ~ 414 m^3/h
- Cycles of Concentration target is approximately between 15 – 20 based on potassium as per the specifications in Appendix A.
- Cooling Water recirculating water temperature ranges: Cold Duct ~26°C – 35°C, Hot Duct ~ 41°C - 48°C, however, maximum temperatures in the hot duct of around 60°C have been experienced in the past.
- The condenser tube metal temperature will vary depending on how dirty the condenser is. It will also vary significantly over the length of the tube since the water heats up as it flows down the tube. In addition, winter, summer, day night, etc. leads to temperature variations. Thus, the skin temperature will not be constant, however it may range between a minimum of 40 °C to approximately 52 °C. This is the tube wall temperature on the water side (inside).
- The pH of the system is operated between 8.1 and 8.6, per specifications provided in Appendix A.

    - There is no additional pH control required for the system.

3.2 CURRENT SYSTEM DESCRIPTION

- Kriel has two (2) CW systems – The North side and South side CW system, which are independent of each other.
    - Each CW system has two (2) cooling towers supplying cooling water to (3) operating units.
    - Each side has side-stream treatment involving lime treatment.
    - There are two lime treatment plants, a new lime treatment plant and an old lime treatment plant.
        - Due to maintenance challenges being experienced, the new lime treatment plants are not operational, resulting in reliance on the old lime treatment plants.
    - The process flow for the old lime treatment plants are as follows:
        - The feed to the plant is approximately 10% (between 1224 m^3/h and 1404 m^3/h per side) of the concentrated cooling water.
        - The concentrated cooling water is dosed with flocculant and coagulant to remove suspended solids. The dosing rate for these are currently determined by an external contractor and is monitored monthly.
        - The dosed water is then mixed with lime (calcium hydroxide) slurry from the lime dilution tanks to remove hardness and alkalinity in the two (2) lime plant clarifiers. The dosing rate for this is varied based on the flow and hardness and alkalinity ingress into the cooling system and is done to ensure the pH is approximately 10.2, and to ensure the relation 2P = M is valid.
        - The lime treated concentrated cooling water then overflows into the cooling tower ponds.
        - Cooling tower blowdowns are performed when 90% of the limiting parameter is reached on that cooling water circuit, to ensure that cycled salts are removed from the cooling water system, to prevent non-compliance with the KPIs as per Appendix A.
        - It should be noted that there currently exist constraints on the ash system, which is the effluent sink for cooling tower blowdowns.
        - This results in an inability to perform cooling tower blowdowns when the ash dams are full.
- The raw water make-up used for the cooling water systems feeds directly to the cooling tower ponds.
    - Due to constraints on the raw water system, Kriel is required to feed a mixture of water from the Usutu and Usutu-Vaal scheme. The Usutu-Vaal scheme refers to water being supplied from the Grootdraai dam or the Vaal dam via the Matla PS reservoir,
        - This can vary as a 100% Usutu water makeup,
        - 100% Usutu-Vaal water makeup
        - Normal scenarios of 60% Usutu/40% Usutu-Vaal
        - However, depending on the system constraints primarily from the Department of Water and Sanitation, it will be required to manage water at any ratio between Usutu

and Usutu-Vaal and is either 100% Usutu or blended with Vaal Scheme water to 60% Usutu/ 40% Vaal.

- There are also waste recovery streams into the cooling tower ponds from the following systems, flowrates indicated in 3.1:
  - Vaal Pan recovery to the North side
  - Vaal Pan recovery to the South side and
  - Coal Stockyard to the South side.
  - Due to oil leaks, ash line leaks, and recovery of water containing coal particles into the recovery dams, there may be the presence of oil, ash, and coal particles within these recovery streams.

- If the lime treatment plants on either side are unavailable, there exists sulfuric acid (98%) dosing plants on each side.
  - The sulfuric acid dosing system contains a sulfuric acid tank near the lime treatment plants, and gravity feeds sulfuric acid into the cooling tower centre-well on either side.
  - Sulfuric acid dosing is done primarily for alkalinity removal, and dosed at a rate that the pH of the bulk concentrated cooling water in the system does not fall out of the range of 8.1 – 8.6, for compliance with the KPIs as per Appendix A.
  - When sulfuric acid is dosed, it should be noted that blowdown volumes increased significantly because COC management is required based on SO_4 limits as per KPI in Appendix A.
    - This poses a risk as the ash system which sinks cooling tower blowdown is severely constrained and may overflow ash dams resulting in an environmental contravention.
- There is currently a crystal modifier dosed into the cooling tower centre-well to allow for higher operation of hardness and alkalinity parameters.
- The cooling water is circulated at a maximum flowrate of 14.36 m^3/s (South CW system) or 13 m^3/s (North CW system), through the condensers and back to the cooling towers. The flowrate is dependent on the number of CW pumps running (max 6 pumps per system), which is dependent on the number of operating units on-load.

3.3 MATERIALS OF CONSTRUCTION IN CW SYSTEM

- Concrete structures (Class C)
- Carbon steel piping
- Titanium condenser tubes
- Superferritic Stainless Steel condenser tubes
- Duplex Stainless Steel condenser tubes
- Brass piping/tubes
- Polypropylene cooling tower fills

3.4 POSSIBLE DOSING POINTS

- Centre well
- Suction of AWR/AWS pumps

3.5 CURRENT CHEMICALS USED

- Lime (70% Calcium hydroxide)
- Antiscalant
- Flocculant and Coagulant
- Sulfuric acid (98%)
- Corrosion inhibitor/Antiscalant
- Biocides/Biodispersant

3.6 DETAILED REQUIREMENTS

- Chosen suppliers will be required to model the system based on the information provided and propose an optimised chemical dosing regimen for the control of microbiological growth, scaling, fouling and corrosion under the various scenarios within the CW system. The following scenarios must be modelled as a minimum:
  - 100% raw water makeup using Usuthu water.
  - 100% raw water makeup using Grootdraai dam water.
  - 100% raw water makeup using Vaal dam water.
  - Raw water makeup with the following blend ratio - 60% Usutu/40% Grootdraai dam water.
  - Raw water makeup with the following blend ratio - 60% Usutu/40% Vaal dam water.
  - X% raw water makeup with recovered water streams as indicated in Section 3.1.
- If additional information is required by the supplier that is not indicated in this document, it is the suppliers' responsibility to request this information. The results of the modelling performed by the Contractor must be submitted as part of the tender returnable.
- The supplier will ensure that the proposed chemical dosing regimen does not negatively impact the integrity of the materials of construction within the CW system as per Section 3.3.
- Based on the challenges with the system, the supplier can propose what they can achieve within 6-month period based on their chemical dosing proposal. The supplier will be measured as per the KPIs in Appendix A.
- The proposed chemical dosing regimen will maintain microbiological control within the KPIs for microbiological control as per Appendix A. Oxidising and non-oxidising biocides may be considered for the dosing regimen.
- The proposed chemical dosing regimen will maintain scaling, fouling and corrosion control (as monitored using corrosion coupons) within the KPIs as per Appendix A.
  - The supplier may consider the impact of not dosing sulfuric acid in the event of lime plant unavailability and may propose alternatives to sulfuric acid dosing to manage the alkalinity.
    - Full design requirements for any alternatives are required.

        - All detailed calculations/case studies indicating results.
        - Dosing system required.
        - CAPEX
        - OPEX
        - Impact on COC
        - Blowdown volume requirement
    - However, the supplier is to keep in mind the KPIs and ensure that no negative impact will be experienced due to the alternatives proposed.
- Suppliers will be required to complete power station induction training to operate on the PS.
- All Eskom SHEQ (in-full) policies are to be followed when the supplier is on Eskom sites.
- The supplier is expected to supply, install, and maintain all necessary equipment (chemical dosing stations, monitoring equipment, etc.) to ensure the KPIs as per Appendix A are met/exceeded. Optimal dosing and measuring points should be identified. Any equipment will be owned by the supplier, in that it will be rented by Eskom Kriel PS.
- All necessary safety requirements should be enforced during design, installation, chemical dosing, inspection, and maintenance activities. A HAZOP will be required for the system that will be installed.
- Appropriate product storage facilities should be identified and utilised for the compliant chemical storage as per regulations. All chemical dosing tanks/drums shall be bunded correctly as per SANS 310.
- All drums/tanks of chemicals proposed must be labelled with the name, use and safety information of the chemical. An SDS must be located at these chemical drums/tanks. Contact names must be available in the event of a chemical spill.
- Safety Data Sheets (SDS) and Certificates of Composition must be submitted with each delivery. These must not be older than 5 years and should be valid as per Global Harmonised System of Classification and Labelling (GHS) requirements. Eskom reserves the right to test the products submitted. Please note that ALL chemical ingredients utilised in the chemical products must be provided so that the impact to downstream treatment process can be assessed.
- The Supplier must conduct a minimum weekly plant visits to ensure chemical tank/drum levels are monitored and chemical dosing systems are fully functional. These tank levels and any issues observed during plant visits must be communicated to the Project Manager/Chemical Services for record purposes.
- Note that remote monitoring of the system is NOT permitted, unless compliant with Eskom’s Information Security – IT/OT and Third-Party Remote Access Standard (32-373)
- Equipment failures must be rectified by the supplier within 24 hours of being notified of the problem.
- The supplier must install or utilise on-line equipment for monitoring of sessile bacteria proliferation and biofilm formation on the North and South side. This equipment must be readily inspectable without the need for interruption of any systems. The tenderer shall evaluate the CW system and propose areas in which this equipment can be installed.
- Fouling, scaling, and corrosion of all metallurgies indicated below shall be monitored on the North and South side using a corrosion coupon rack designed and operated as per ASTM D2688-15 and ASTM G1-03. The tenderer shall evaluate the CW system and propose areas in which the corrosion coupon rack can be installed. The following requirements are applicable:

- The coupon rack must be installed on the hot duct (T2) of each cooling water side.
- The coupon rack must have rotameter installed for flow measurement and all isolation valves for maintenance.
- Coupon rack sizing must be planned for multi-metal coupon installation, and multi-metals must be supplied as per below. There must also be several coupons installed to trend the scaling/fouling/corrosion occurrence over time, corresponding to analysis on a rolling period every 30-days.
  - Carbon Steel coupons – 90-day exposure at 1 m/s
  - Brass coupons – 180-day exposure at 1 m/s
- Non-metal coupon rack is preferred.
- The supplier must provide a detailed design of the coupon rack system as per Eskom's ECM procedure. Labelling and plant coding must be included as per procedure. The operating and maintenance procedure must be provided.
- Supplier must be present for the installation and monthly recovery and replacement of coupons as well as coupon analysis that will be done onsite the same day.
- An agreed upon heat exchanger monitoring program must be put in place for both parties and reported in the monthly report. This must be stipulated in the proposal.
- Measurements, photos of before and after with comments to be included in monthly report. Analysis to be done by Eskom laboratory personnel and results to be confirmed by both parties.
- In the event of excess scale and/or fouling experienced on the coupons, the tenderer must perform analysis of the deposits and provide the information in a report to the Employer.
- The KPIs shall be as per Appendix A.

- The tenderer may propose advanced online monitoring of fouling, scaling, and corrosion in addition to coupon analysis. This will not replace the coupon monitoring system as specified above.
- The supplier will be notified on any changes in makeup water quality to the cooling water system, seasonal variations in the cooling water system or the recovery of different effluents, which may affect the water quality in the cooling water system upon request.
- The supplier must propose a sampling regime with clear justification of how the proposed sampling regime will ensure that the KPIs as per Appendix A are met. The samples must be submitted to an accredited (SANAS) microbiology laboratory.
  - The total aerobic, total anaerobic, hydrogen sulphide producing bacteria and chlorophyll A (as per the CW standard), in both planktonic and sessile conditions must be measured to prove the efficacy of proposed dosing regimen.
- The supplier must consider the dosing of oil dispersant due to the risk of fats, oil, and grease present in the CW system. The supplier must sample and analyse the cooling water to provide information on the effectiveness of oil control. The supplier must sample for oil presence, given that both fuel oil and lube oil is used at the station.
- The supplier must propose a dosing regime for the control of scale formation in the ash water return system piping. The supplier must sample and analyse the ash water to provide effectiveness of scale control. All necessary components to ensure the proposed dosing regimen is carried out shall be supplied by the supplier.
  - Additionally, the supplier must provide a coupon monitoring system to monitor the

effectiveness of the chemical dosing regime, as per ASTM D2688-15 and ASTM G1-03.

- The coupon rack must have rotameter installed for flow measurement and all isolation valves for maintenance.
- Coupon rack sizing must be planned for multi-metal coupon installation, and multi-metals must be supplied as per below. There must also be several coupons installed to trend the scaling/fouling/corrosion occurrence over time, corresponding to analysis on a rolling period every 30-days.
  - Carbon Steel coupons – 90-day exposure at 1 m/s
- Non-metal coupon rack is preferred.
- The supplier must provide a detailed design of the coupon rack system as per Eskom's ECM procedure. Labelling and plant coding must be included as per procedure. The operating and maintenance procedure must be provided.
- Supplier must be present for the installation and monthly recovery and replacement of coupons as well as coupon analysis that will be done onsite the same day.
- Measurements, photos of before and after with comments to be included in monthly report. Analysis to be done by Eskom laboratory personnel and results to be confirmed by both parties.
- In the event of excess scale and/or fouling experienced on the coupons, the tenderer must perform analysis of the deposits and provide the information in a report to the Employer.
- The KPIs shall be as per Appendix A.

- The supplier must analyse for *Legionella* at an accredited (SANAS) lab, according to the ISO methodology, on a quarterly basis. The *Legionella* count must be below 10 000 CFU/L. Refer to [3] for additional information on management of legionella. The supplier will be held responsible for compliance with the Legionella limits in the KPIs for microbiological control as per Appendix A.
- The supplier will provide a minimum of weekly feedback to the chemistry staff of the PS on the status of the dosing regimen.
  - The supplier will submit a report on the dosing regimen and performance to the KPIs to the chemistry staff.
  - This will include the performance of the chemical treatment program compared to the KPIs.
  - Chemical product consumption against forecasted consumption, including explanations of deviations.
  - Problems/concerns experienced/observed on the Cooling System during the chemical treatment program.
  - Steps to be taken to address issues experienced on the cooling system.
  - Trending of data must be included in the reports for all analysis conducted. Investigations must be conducted on outliers/system upsets or trends continuing away from the target operating values and the reasons for this must be provided in the reports. The supplier must include the action plan with detailed tasks required to correct / prevent these deviations. The data must be trended for the week of operation as well as since the commencement of the contract.
  - All data must be saved on Eskom's LIMS system. The trends and analytical information must be provided to Eskom in its editable version for data storage.

4. AUTHORISATION

This document has been seen and accepted by:

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5. REVISIONS

Date	Rev.	Compiler	Remarks
November 2023	0.1	J Pillay	Draft Document
March 2024	1	J Pillay	Final Document for Authorisation

6. DEVELOPMENT TEAM

The following people were involved in the development of this document:

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7. ACKNOWLEDGEMENTS

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APPENDIX A: KEY PERFORMANCE INDICATORS

Table 1: KPIs

Hardness & Alkalinity KPIs	
Parameter	**Limit**
Calcium Carbonate Precipitation Potential (mg/kg as $CaCO_3$) (Modelled using STASOFT V using sample temperature (Hot duct temperature in this SOW))	10 – 30 without crystal modifier 10 – 45 with crystal modifier
Chloride (mg/kg as Cl)	400
Calcium (mg/kg as $CaCO_3$, titration method)	200 - 500
M-alkalinity (mg/kg as $CaCO_3$)	80 – 120 without crystal modifier 120 – 160 with crystal modifier
Sodium (mg/kg as Na)	500 (Also consider sulfate limit)
P-alkalinity (mg/kg as $CaCO_3$)	7.5
Potassium (mg/kg as K)	- (CoC is based on Potassium)
pH	8.1 - 8.6 8.3 (target)
Phosphate (mg/kg as PO_4)	0.5
Silica (mg/kg as SiO_2)	150 (ensuring $MgxSiO_2 < 25000$)
Sulfate (mg/kg as SO_4)	1000 if Na < 250 ppm, 750 if Na > 250 ppm
Microbiological KPIs	
Hydrogen Sulfide Producers (Planktonic) (CFUs/ml)	50 (limit/target)
Hydrogen Sulfide Producers (Sessile) (CFU/cm^2)	100
Chlorophyll A (Planktonic) (µg/kg)	25
Legionella (Planktonic) (CFU/l)	10000 (limit) 100 (target)
Total Aerobic Bacteria (Planktonic) (CFU/ml)	10^5
Total Aerobic Bacteria (Sessile) (CFU/cm^2)	10^6
Total Anaerobic Bacteria (Planktonic) (CFU/ml)	10^4
Total Anaerobic Bacteria (Sessile) (CFU/ cm^2)	10^5
Corrosion/Fouling/Scaling KPIs	
Corrosion Rate (mm/annum) (Steel)	0.2
Corrosion Rate (mm/annum) (Brass)	0.02
Fouling Rate (mg/dm^2/day) (Carbon Steel)	20

Fouling Rate (mg/dm^2/day) (Brass)	2
Scaling Rate (mg/dm^2/day) (Carbon Steel)	1.5
Scaling Rate (mg/dm^2/day) (Brass)	0.15
Lime Treatment Clarifier Outlet	
Parameter	**Limit**
M-alkalinity (mg/kg CaCO3)	Minimum 50% removal across clarifier
pH	10.2
Reaction zone M-alkalinity	2P=M
Turbidity (NTU)	15 (limit) 5 (target)

Table 2: Current Monitoring Frequencies

Hardness & Alkalinity Frequencies	
Parameter	**Frequency**
Calcium Carbonate Precipitation Potential (mg/kg as $CaCO_3$)	Daily
Chloride (mg/kg as Cl)	3 times per week
Calcium (mg/kg as $CaCO_3$, titration method)	Daily
M-alkalinity (mg/kg as $CaCO_3$)	Every 8 hours or once per shift
Sodium (mg/kg as Na)	3 times per week
P-alkalinity (mg/kg as $CaCO_3$)	Daily
Potassium (mg/kg as K)	Weekly
pH	Every 8 hours or once per shift
Phosphate (mg/kg as PO_4)	Weekly
Silica (mg/kg as SiO_2)	Once per week with lime plant/Daily without lime plant
Sulfate (mg/kg as SO_4)	3 times per week
Microbiological Frequencies	
Hydrogen Sulfide Producers (Planktonic) (CFUs/ml)	Minimum Monthly
Hydrogen Sulfide Producers (Sessile) (CFU/cm^2)	Minimum Quarterly
Chlorophyll A (Planktonic) (µg/kg)	In the event of algal bloom
Legionella (Planktonic) (CFU/l)	Quarterly
Total Aerobic Bacteria (Planktonic) (CFU/ml)	Minimum monthly
Total Aerobic Bacteria (Sessile) (CFU/cm^2)	Minimum Quarterly
Total Anaerobic Bacteria (Planktonic) (CFU/ml)	Minimum Monthly
Total Anaerobic Bacteria (Sessile) (CFU/ cm^2)	Minimum Quarterly
Lime Treatment Clarifier Outlet Frequencies	

Parameter	Frequency
M-alkalinity (mg/kg $CaCO_3$)	6 times daily
pH	6 times daily
Reaction zone M-alkalinity	6 times daily
Turbidity (NTU)	6 times daily

APPENDIX B: MAKEUP WATER QUALITIES

** 95th percentile conductivity data set refers to the set of analysis that relates to nearest conductivity value to the 95th percentile conductivity value.*

Table 3: Usutu Qualities (2022/01 – 2024/02)

Parameter	Median	Average	95th Percentile	95th Percentile Conductivity Data Set*
Chloride (mg/kg)	4.69	4.71	5.50	5.06
Calcium (ppm CaCO3)	9.94	10.49	14.46	14.30
Magnesium (ppm CaCO3)	9.04	9.76	13.60	13.60
Potassium (mg/kg)	1.94	1.99	2.38	1.85
Conductivity @ 25°C (µS/cm)	66.95	70.08	91.49	90.30
M-alkalinity (ppm as CaCO3)	16.20	19.32	29.60	26.10
Sodium (mg/kg)	3.92	4.19	4.88	4.83
Oxygen Absorbed (mg/kg)	5.20	5.01	7.00	-
pH	6.79	6.82	7.15	6.83
Silica (mg/kg)	0.21	0.29	0.78	-
Sulfate (mg/kg)	5.94	6.55	9.21	9.21
TOC (ppm)	5.28	6.06	5.82	-
Turbidity (NTU)	2.94	2.95	3.98	1.76

Table 4: Vaal Qualities (2022/01 – 2024/02)

Parameter	Median	Average	95th Percentile	95th Percentile Conductivity Data Set
Chloride (mg/kg)	5.93	6.93	12.2	9.74
Fluoride (mg/kg)	0.12	0.44	0.26	0.17
Calcium (ppm CaCO3)	18.45	22.25	46.14	46
Magnesium (ppm CaCO3)	18.95	22.88	50.33	51.4
Potassium (mg/kg)	2.47	2.67	4.06	3.97
Conductivity @ 25°C (µS/cm)	112.5	134.83	277	276
M-alkalinity (ppm as CaCO3)	31.85	37.64	77.9	75.8
Sodium (mg/kg)	7.12	8.32	16.7	16.7
Nitrate (mg/kg)	0.05	0.11	0.39	0.27
pH	7.08	7.11	7.72	7.28
Silica (mg/kg)	0.99	0.99	1.621	1.03
Sulfate (mg/kg)	11.5	16.66	39.34	41.1
Turbidity (NTU)	9.015	14.64	45.21	25.4

Table 5: Vaal Pan Recovery Qualities (2022/01 – 2024/02)

Heading 3	Median	Average	95th Percentile	95th Conductivity Data Set
Chloride (mg/kg)	111	110.74	138.6	137
Chemical Oxygen Demand (mg/kg)	78.5	78.2	98.1	99

Fluorine (mg/kg)	0.89	2.36	2.69	0.77
Calcium (ppm CaCO3)	158	162.08	210	170
Magnesium (ppm CaCO3)	164	181.59	213.4	197
Potassium (mg/kg)	42	44.52	52	49
Conductivity @ 25°C (µS/cm)	1572	1576.17	1817.7	1827
M-alkalinity (ppm as CaCO3)	122.3	127.11	153.66	130.3
Sodium (mg/kg)	193	185.06	225	225
Nitrate (mg/kg)	0.55	1.31	2.632	0.91
P-alkalinity (mg/kg CaCO3)	8.7	9.79	17.14	9.8
pH	8.43	8.38	8.89	8.61
Silica (mg/kg)	3.435	14.65	44.25	
Sulfate (mg/kg)	450	445.43	547.05	554
Turbidity (NTU)	3.95	4.62	8.84	3.88

Table 6: Coal Stockyard Recovery Qualities

Parameter	Single Data Set
Chloride (mg/kg)	254
Fluorine (mg/kg)	1.1
Calcium (ppm CaCO3)	293
Magnesium (ppm CaCO3)	164
Potassium (mg/kg)	94
Conductivity @ 25°C (µS/cm)	3170
M-alkalinity (ppm as CaCO3)	70.4
Sodium (mg/kg)	479
Nitrate (mg/kg)	0.27
pH	7.94
Sulfate (mg/kg)	1098
Turbidity (NTU)	3.6

APPENDIX C: SUPPLEMENTARY WATER QUALITIES

Table 7: Cooling Water North Recirculating Water Qualities (2022/01 – 2024/02)

Parameter	Median	Average	95th Percentile	95th Percentile Conductivity Data Set
Calcium Carbonate Precipitation Potential (mg/kg CaCO3)	46.80	46.11	94.66	77.00
Chloride (mg/kg)	229.00	227.49	344.20	326.00
Chemical Oxygen Demand (mg/kg)	199.00	199.67	246.50	
Fluorine (mg/kg)	1.70	6.53	9.85	4.62
Calcium (mg/kg CaCO3)	293.00	309.95	495.00	350.00
Magnesium (mg/kg CaCO3)	325.00	338.89	631.00	789.00
Total Hardness (mg/kg CaCO3)	627.00	649.60	1063.00	1139.00
Potassium (mg/kg)	85.30	85.50	129.00	117.00
Conductivity (µS/cm)	2840.00	2832.27	3930.00	3980.00
M-alkalinity (mg/kg CaCO3)	164.70	166.28	264.16	257.40
Sodium (mg/kg)	366.00	365.80	548.00	525.00
Ammonia (mg/kg)	0.00	13.38	7.05	
Nitrate (mg/kg)	2.26	4.42	8.81	3.51
P-alkalinity (mg/kg CaCO3)	9.20	10.68	22.10	15.60
pH	8.59	8.53	8.85	8.44
Silica (mg/kg)	13.00	13.99	26.50	34.00
Sulfate (mg/kg)	849.50	859.49	1308.70	1321.00
Total Suspended Solids (mg/kg)	38.17	55.28	161.46	
Turbidity (NTU)	30.00	38.44	123.00	45.20

Table 8: Cooling Water South Recirculating Water Qualities (2022/01 – 2024/02)

Parameter	Median	Average	95th Percentile	95th Percentile Conductivity Data Set
Calcium Carbonate Precipitation Potential (mg/kg CaCO3)	39.05	41.45	86.21	60.10
Chloride (mg/kg)	233.00	236.46	373.80	354.00
Chemical Oxygen Demand (mg/kg)	135.00	136.00	190.80	
Fluorine (mg/kg)	1.57	5.27	7.56	4.79
Calcium (mg/kg CaCO3)	329.00	344.76	573.25	413.00
Magnesium (mg/kg CaCO3)	304.00	335.69	637.00	653.00
Total Hardness (mg/kg CaCO3)	649.50	680.73	1109.75	1066.00
Potassium (mg/kg)	91.00	92.14	142.00	141.00

Conductivity (µS/cm)	3050.00	2986.02	4180.00	4210.00
M-alkalinity (mg/kg CaCO3)	153.80	161.65	255.16	174.30
Sodium (mg/kg)	393.00	397.53	635.65	608.00
Ammonia (mg/kg)	0.00	1.80	5.28	
Nitrate (mg/kg)	3.46	4.14	9.55	8.30
P-alkalinity (mg/kg CaCO3)	6.70	8.87	21.30	12.10
pH	8.50	8.47	8.77	8.62
Silica (mg/kg)	15.00	15.79	29.00	10.00
Sulfate (mg/kg)	950.00	938.35	1464.00	1282.00
Total Suspended Solids (mg/kg)	34.14	38.45	65.64	
Turbidity (NTU)	30.00	33.78	78.40	32.50

Table 9: Cooling Water North East Clarifier Outlet (2022/01 – 2024/02)

Parameter	Median	Average	95th Percentile
M-alkalinity (mg/kg CaCO3)	128.4	140.79	261.51
P-alkalinity (mg/kg CaCO3)	14.6	17.78	43.3
pH	8.75	8.98	10.21
Turbidity (NTU)	10.1	11.1	22.8

Table 10: Cooling Water North West Clarifier Outlet (2022/01 – 2024/02)

Parameter	Median	Average	95th Percentile
M-alkalinity (mg/kg CaCO3)	126.20	138.35	262.00
P-alkalinity (mg/kg CaCO3)	15.20	19.11	44.80
pH	8.75	9.00	10.25
Turbidity (NTU)	9.70	10.91	21.50

Table 11: Cooling Water South East Clarifier Outlet (2022/01 – 2024/02)

Parameter	Median	Average	95th Percentile
M-alkalinity (mg/kg CaCO3)	114	130.89	244.7
P-alkalinity (mg/kg CaCO3)	15.8	22.04	57.59
pH	8.89	9.03	10.54
Turbidity (NTU)	7.96	9.45	19.3

Table 12: Cooling Water South West Clarifier Outlet (2022/01 – 2024/02)

Parameter	Median	Average	95th Percentile
M-alkalinity (mg/kg CaCO3)	115.1	130.15	244.48
P-alkalinity (mg/kg CaCO3)	15.9	24.37	64.76
pH	8.89	9.31	10.62
Turbidity (NTU)	7.6	9.07	18.7