



BALLENGEICH COLLIERY

PRELIMINARY CIVIL DESIGN REPORT

FOR

ACID MINE DRAINAGE

PASSIVE TREATMENT DESIGN

Revision 00

February 2023

The logo for Kangra Coal features the word "KANGRA" in a large, bold, blue, sans-serif font, with "COAL" in a smaller, blue, sans-serif font below it, all enclosed within a blue rectangular border.	The logo for Bhekani (Pty) Ltd features a stylized circular emblem composed of four overlapping segments in blue, orange, yellow, and green. To the right of the emblem, the text "BHEKHANI (PTY) LTD" is written in a bold, blue, sans-serif font, with "Sustainable Solutions" in a smaller, orange, italicized font below it.
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1 INTRODUCTION

Bhekani (Pty) Ltd has been appointed by Kangra Coal (Pty) Ltd (Kangra) to conduct a civil infrastructure design for Acid Mine Drainage to provide additional input into the Water Use License of the Ballengeich Mine (Ballengeich).

2 PROJECT LOCATION

The project is located in Ballengeich which is at the confluence of the Horn River and Ngagane River approximately 15 km south of Newcastle in the province of KwaZulu-Natal in South Africa. The site is found in the Thukela Water Management Area (WMA 7) and on the border of Quaternary Catchments V31F and V31G. The Ballengeich Mine complex is situated at the confluence of the Horn and Ngagane Rivers to the west and the eastern side is bordered by the N11 (see Figure 1).

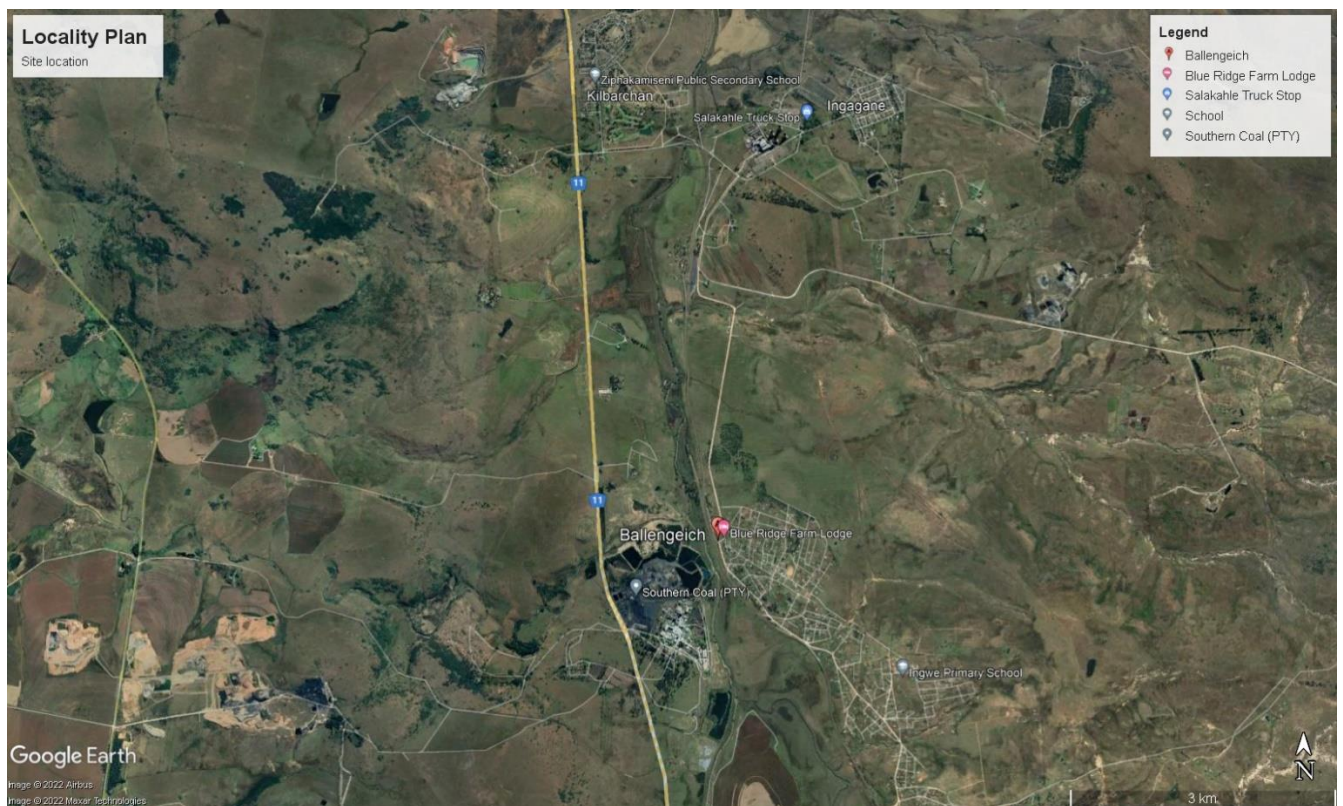


Figure 1: Locality Map

3 PROJECT BACKGROUND

Kangra: Coal (Pty) Ltd has an approved Mining Right issued by the Department of Mineral Resources for coal mining activities on portion 19 (Remaining Extent) of the farm Ballengeich 3299 HS. The project area is characterized by several defunct mining activities that ceased during the early 1990's. Kangra Coal is the current owner of Ballengeich Colliery.

3.1 Scope of work

The current situation at Ballengeich Colliery is that RQO's are exceeded for several variables (SO₄, TDS, Alkalinity, Cl, Na) and that the concentration of selected variables resulted in a significant increase of >40% when compared to the upstream values. The impact on water quality will increase the cost for the Newcastle Water Treatment Plant when water abstracted from the Ngagane River is treated for potable supply. The Ngagane River is earmarked as the receptor for a waste discharge, but the impact is rated as moderate subject to the condition that the AMD to be discharged is treated. In order to allow for a discharge, the AMD needs to be neutralised by applying passive waste water treatment technology. Active treatment options are not considered as it is seen as too expensive for the scale of mining envisaged for the Ballengeich Colliery Operation.

Kangra: Coal (Pty) Ltd is in need for water treatment following a DWS Directive section 19 of the National Water Act, 1998 (Act 36 of 1998) to address the impacts of Acid Mine Drainage on the Horn River. Kangra has inherited a settling pond system consisting of 7 ponds that are seeping into the Horn River. Passive and self-sustainable treatment options will be preferred. Kangra is looking for the civil engineering designs for the passive sustainable treatment option to deal with the pollution problem.

Bhekani Pty Ltd was appointed to design Acid Mine Drainage infrastructure to accommodate the effluent produced from the Ballengeich Colliery site. According to (BPG H4: Water treatment), Water treatment may be required to improve the quality of the water to such an extent that it can be reused by the mine or other users. Water treatment may also be required as a final step to render water suitable for discharge in accordance with the conditions of a water use authorization, catchment management objectives, reserve requirements and/or downstream user requirements.

The discharge of the neutralised AMD will be subject to a Water Use License Authorisation for the following section 21 water uses:

- Section 21(c,i)
- Section 21(f)
- Section 21(g)
- Section 21(j)

4 LEGISLATION

It is necessary to consider the relevant legislation and policies for different aspects of Water Management. This paragraph summarizes the main legislation and policies that are applicable to this study. It should be noted that this is not an all-inclusive list; however, all applicable legislation and policies are adhered to. The legislative aspects are addressed in the following categories:

The legal requirements applicable are given in the list below:

- IWULA requirements;
- Best Practice Guidelines – H4: Water Treatment;
- National Water Act;
- Regulation GN 704.

5 ENVIRONMENTAL DESCRIPTION

The Ballengeich Mine is mainly drained by the Horn River (from west to east) which flows into the Ngagane River (south to north) (see Figure 2). The Horn River and the Ngagane River are classified as perennial streams. They are largely controlled by precipitation and groundwater baseflow in the area. In addition, the Ngagane River also receives flow from the upstream located Chelmsford Dam.

The Ballengeich Mine falls within Thukela Water Management Area (WMA), the Horn River falls within Quaternary Catchment V31F and the Ngagane River downstream of the Chelmsford Dam falls within Quaternary Catchment V31G. A portion of the non-perennial Mbazo Stream, however, flows through the northern under- ground mining area.



Figure 2: Ballengeich Mine Infrastructure Overview

5.1 Regional Climate

The climate at the Ballengeich Mine is described as warm and humid with a Koppen-Geiger climate classification of Cfb (warm temperate, fully humid and warm summers). The vegetation biome that dominates this area is Eastern Mountain grassland Invalid. The climate data used in this study were obtained from the WR 2012 Study (WRC, 2015) and Design Rainfall Estimation software (Schulze & Smithers, 2002) for Ballengeich Rainfall Station (0370863_W). The evaporation was calculated for Evaporation Zone 30C within which the study area falls. The MAP of 858 mm and MAE 1 785 mm (Symons Pan) are projected for the area around Ballengeich Mine

5.2 Rainfall and evaporation

The average rainfall per year at the Ballengeich Rainfall Station (0370863_W) is 858.5 mm and the Mean Annual Evaporation (Based on S-pan data) is 1785.9mm. The higher rainfall months occur from October to March during spring/summer.

Table 1: Average monthly rainfall depth for the Ballengeich rainfall record (0370863_W) and evaporation depths (from WR90)

Month	Average rainfall (mm)	Average evaporation (mm)
October	81	177
November	106	182.2
December	148.5	201.7
January	164.5	206.8
February	120.3	173.5
March	88.8	155.2
April	45.1	116.3
May	14.1	97.4
June	12	83
July	10.7	95.8
August	28.6	131.6
September	39	166.7
Annual Total	858.5	1785.8

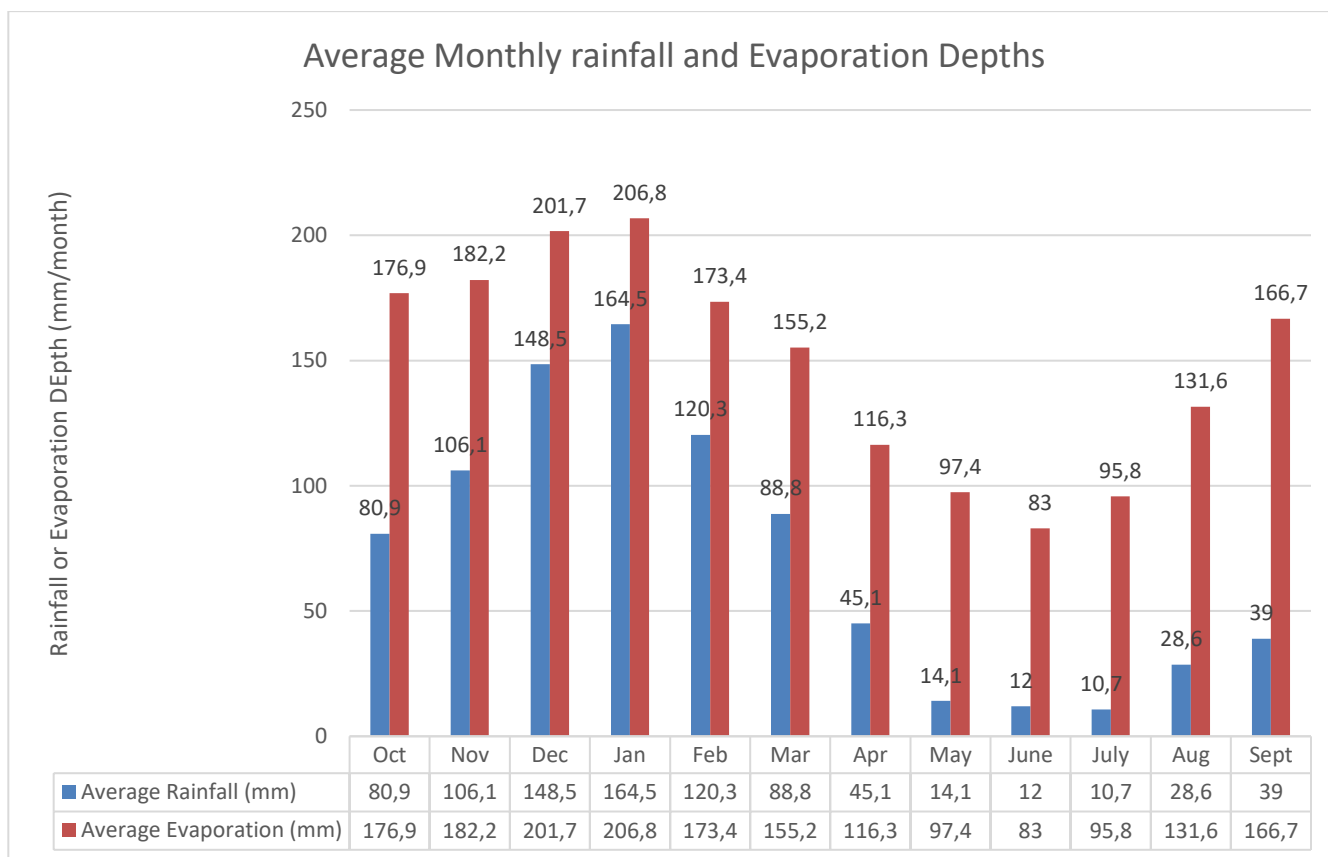


Figure 5.2-1: Mean Monthly Rainfall and Evaporation

6 STUDIES DONE BY OTHERS

Kangra Coal (Pty) Ltd (hereafter referred to as Kangra) appointed consultants to carry out specialists' studies. The information from these studies was used to inform the preferred treatment method for the AMD.

6.1 Characteristics of the AMD

A hydrological assessment of Ballengeich mine was conducted in 2016 by GCS water and environmental consultants. The study by GCS investigated the water quality of the AMD and its impacts on the Ngagane and Horn River. A water quality assessment was undertaken at ten existing monitoring points in Ballengeich, and water quality parameters tested and analyzed include Electric Conductivity (EC), Sulphate (SO₄), pH and Aluminium (Al). These water quality indicators were analyzed against Water Quality Objectives (WQO) defined the 2015 IWWMP and recommendations from DWS. In the Upper Horn River, a possible impact maybe ascribed to decant/seepage from the old underground workings into the river see Figure 4. The following AMD characteristics were derived from the study:

Table 2: AMD Discharge properties

Variable (mg/l)	AMD Discharge
Total Dissolved solids	7260
Total Alkalinity	152
Chloride	143
Sulphate	3902
Sodium	841
Potassium	29
Calcium	435
Magnesium	411
Aluminum	0.1
Iron	189
Manganese	4.0

6.2 Groundwater and surface water protection

The study conducted by GCS was conducted to provide input into the Integrated Water Use License (IWUL) of the Ballengeich Colliery (Ballengeich). The following recommendations were made:

- In order to mitigate associated flood risk and ensure compliance with General Notice 704 (GN704) of the South African National Water Act (36 of 1998), flood protection berms should be elevated to a minimum of 1185 mamsl along the Horn River and 1184 mamsl along the Ngagane River at the site in question;
- It is recommended that flood lines be recalculated if construction is proposed for the area, as the existing flood lines are indicative and can be used for planning purposes only.

To reduce the risk of ground water contamination, the proposed wetlands shall be lined.

6.3 AMD Assimilative Capacity

M2 Environmental Connections (Pty) Ltd (hereafter referred to as Menco) was appointed by Kangra to conduct a specialist study for the determination of the assimilative capacity of the Horn and Ngagane rivers for the pollution stemming from uncontrolled seepage and decants to determine whether it can be treated before decanting into the environment to reduce further degradation of the natural water resources to unacceptable levels.

The approach is based on the assimilative capacity of the receiving water resources whereby the Waste Load as determined by means of mass balance modelling was used to determine the impact of the treated water on downstream water uses. The study revealed sufficient assimilative capacity in the Ngagane River system to ensure that the Present Ecological Status (PES) of Class C for the catchment will not be detrimentally impacted.

With the implementation of a passive treatment option linked to a Water Use License Authorization, the long-term impacts from AMD could be effectively mitigated at a cost-effective method. All potential concerns as raised by Regulatory Authorities as well as Interested and Affected Parties could be adequately addressed with the concomitant impact mitigation to acceptable levels (low to moderate) by implementing the following treatment options:

- Installation of open limestone trenches;
- Construction of an Anoxic Limestone Drain.
- Implementation of successive alkaline reducing system;
- Implementation of oxidation pond;
- Implementation of an aerobic constructed wetland;

The treatment design methodology and proposed treatment train is presented in figures below. **Error! Reference source not found.**

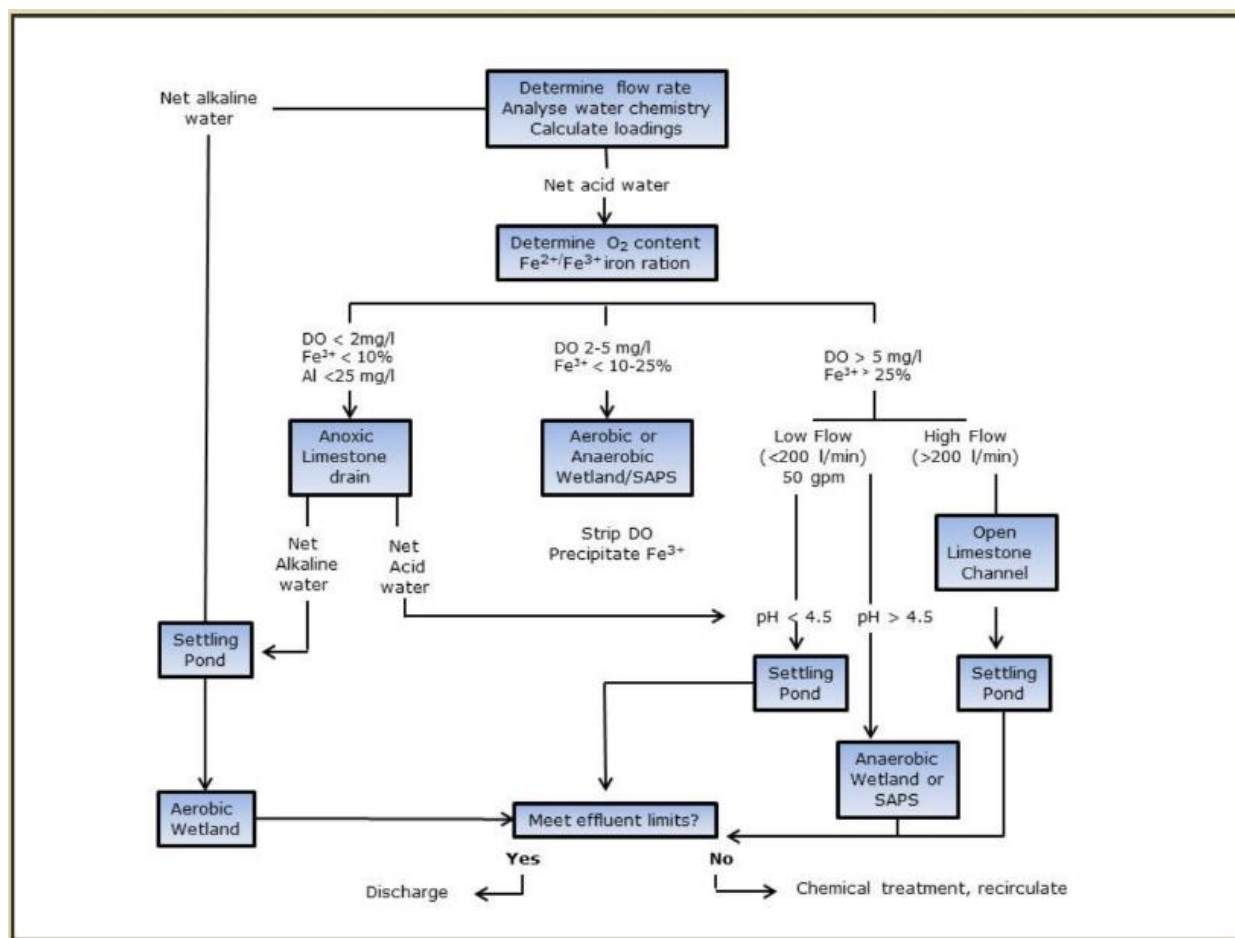


Figure 4 Design Methodology (Adapted from Menco and GCS)

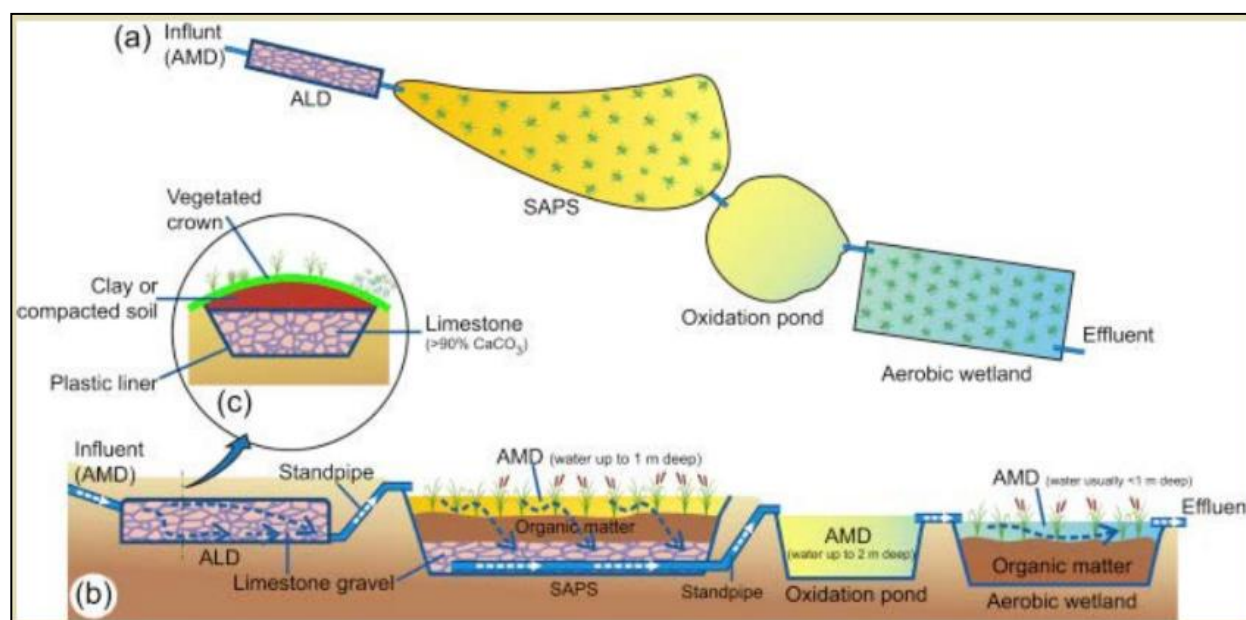


Figure 5: Proposed treatment train

7 ACID MINE DRAINAGE TREATMENT DESIGN

The mixing of AMD with natural rivers and lakes can cause severe degradation in the quality of the natural water bodies. Neutralization is generally the first step in treatment of acid mine water. The choice between active and passive water treatment technologies depends very much on the period in the mine's life-cycle. Passive treatment systems do not require continuous chemical inputs but take the advantage of naturally occurring chemical and biological processes to treat the acid mine drainage. Active treatment systems require the continuous or semi continuous input of energy and/or reagents.

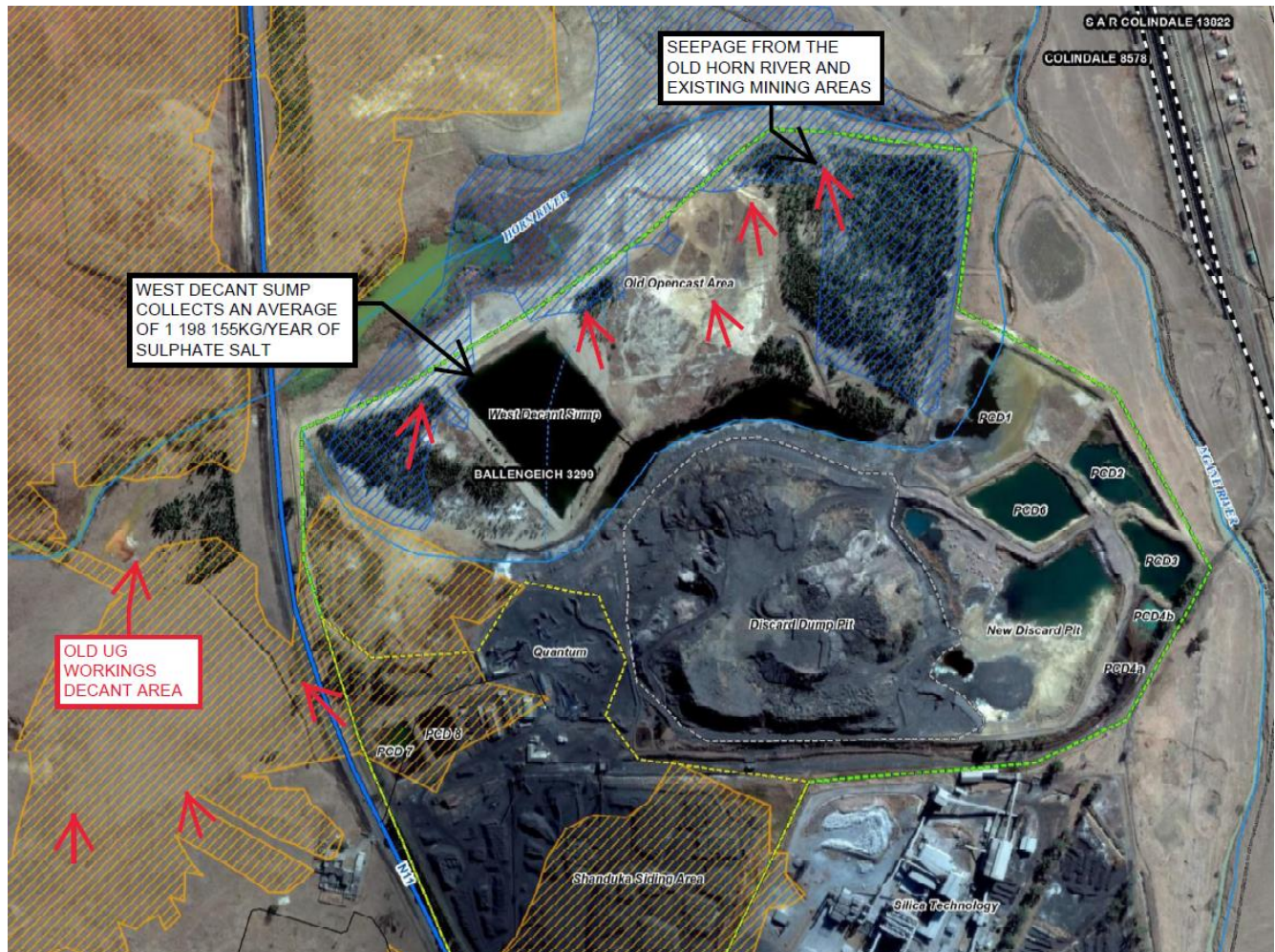


Figure 4: Ballengeich Mine Pollution Sources

At Ballengeich Mine, AMD is generated in various areas as shown in Figure 4 shown above, a combination of treatment methods was adopted to ensure that all AMD is treated. The source control principal was used to determine the layout of the AMD treatment, this is to ensure that the effluent it treated before it gets into the Rivers. The main pollution sources are :

1. Old underground workings decanting effluent water into the horn river
2. Effluent discharge into West decant sump and seepage from the old horn river into the Ngagane and Horn River.

7.1 Proposed AMD Treatment

Passive treatment systems are the preferred option for treating the AMD due to the low cost and low maintenance requirements. Passive treatment systems provide a controlled environment for natural chemical and biological reactions to occur that treat acid mine drainage. There are several types of passive treatment systems which can be used on their own or in sequence to optimize the treatment. The proposed AMD treatment system will be composed of a series of passive treatment systems as shown in the figure below. The treatment system will start with an Anoxic Limestone drain (ALD) which will be followed by a successive alkalinity producing systems (SAPS) which will discharge into an oxidation pond connected to an anaerobic wetland which will be the last process unit before the water is discharged into the river. See appendix for the proposed layout of the proposed treatment options.

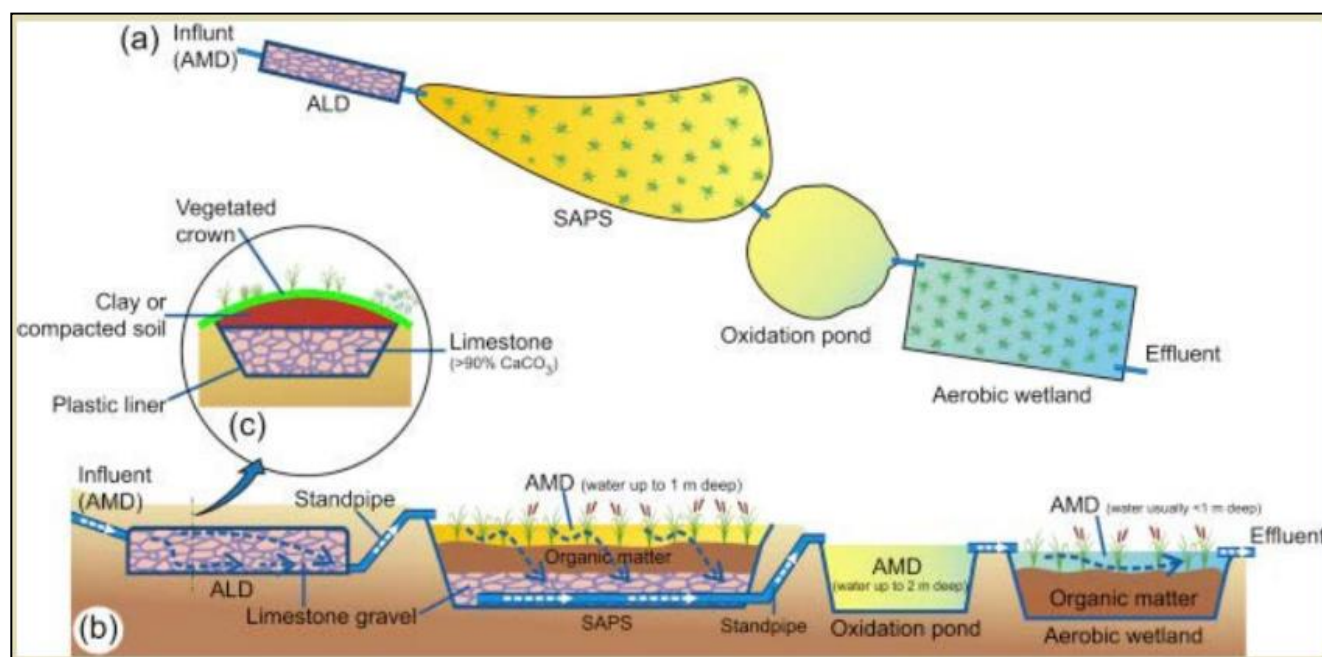


Figure 7: Passive treatment system

The passive treatment options chosen for the treatment of the AMD have the following roles to improve the water quality before discharge:

Table 3: Functions of Passive treatment options

Treatment Option	Role in treatment process
Anoxic Limestone drain (ALD)	To neutralise acidic (low pH) water by generating alkalinity.
Successive alkalinity producing systems (SAPS)	To neutralise acidic (low pH) water by generating alkalinity.
Oxidation pond	To remove metals from metal-bearing mine waters.
Aerobic wetland	Removal as metal hydroxides, metal co-precipitates and/or plant uptake

Treatment of Old UG Workings

The proposed AMD treatment will be constructed in two areas. The full treatment train (ALD to SAPS to Oxidation Pond and Aerobic wetland) will be constructed to treat effluent from the decanting of old underground workings. 6 hectares of land is available in this area for treatment of effluent from underground workings.

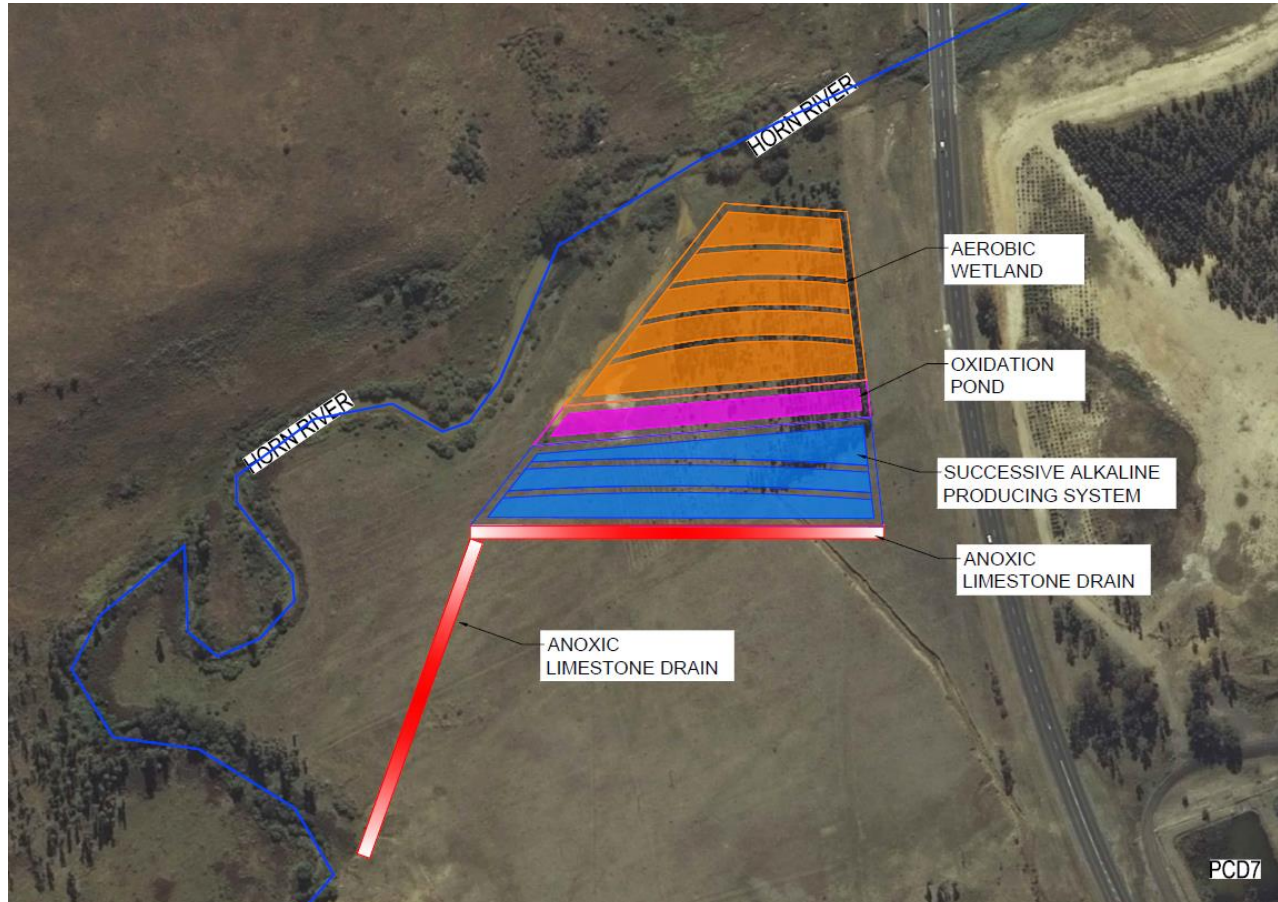


Figure 8: Area with underground workings to receive full treatment train

Treatment of Effluent from West Decant Sump

According to the hydrogeological assessment, an average of 1 198 155 kg/annum of sulphate salt ends up in the West Decant Sump on the Ballengeich Mine and this salt load may discharge/seep into the Horn River or transpire through the surrounding tree area. Due to the space available between the West Decant Sump and the Horn river, two treatment methods will be constructed to treat effluent from Old open cast workings and Unger ground workings to prevent further degradation of the Horn river. An Anoxic limestone drain will be constructed after the west decant along with an Aerobic wetland which will treat all seepage water from the Old Horn River and the existing pollution control dams. A stormwater berm will be constructed along the Ngagane river to ensure that there is no spillage of the 1:100-year storm into the Ngagane river.



Figure 9: West Decant Sump area to be treated with ALD and cut off Aerobic Wetland along Horn River boundary

7.2 Anoxic Limestone drain (ALD)

An Anoxic Limestone Drain (ALD) is a passive treatment system that is typically used to treat net-acidic, anoxic mine drainage of low to moderate flow with low to moderate acidity (range) and dissolved metals. The ALD is constructed to intercept subsurface mine water flows and prevent/ minimise exposure to atmospheric oxygen. Keeping oxygen out of the water prevents oxidation of metals and armoring of the limestone. The sole purpose of an ALD is to provide alkalinity through the limestone dissolution process. The increase in alkalinity helps reduce the acidity of the AMD . Retaining carbon dioxide in the drain can improve limestone dissolution and thus alkalinity generation.

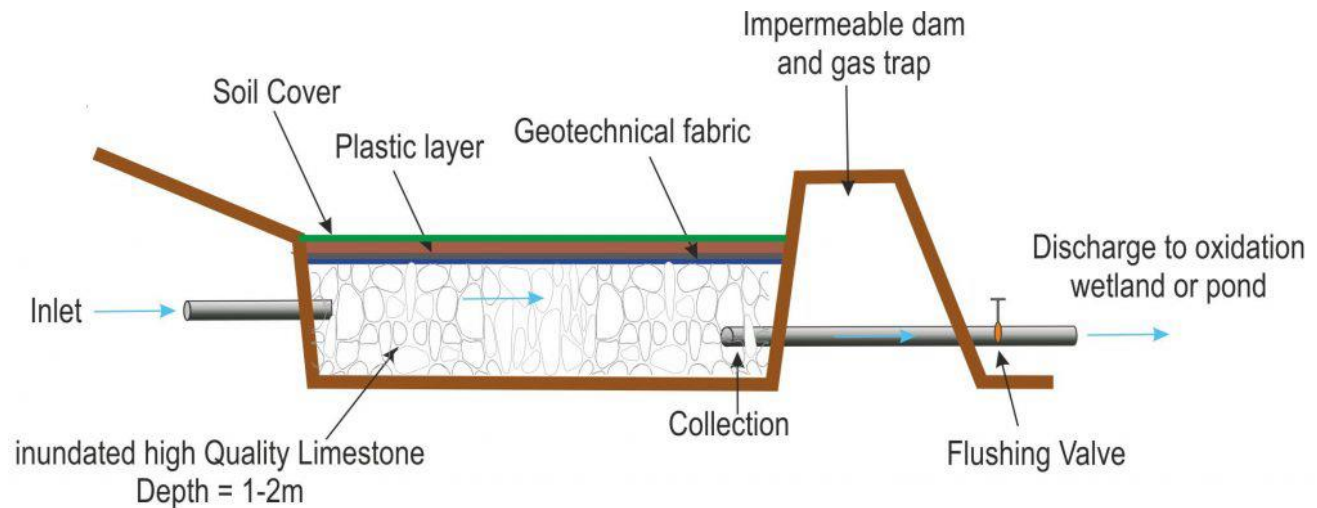


Figure 10: Typical section of Anoxic Limestone drainage system

An ALD is essentially a buried trench or basin filled with limestone overlain by a soil cover. The trench can be rectangular in shape with vertical side walls or can be constructed as an inverted trapezoidal prism (basin). The limestone is wrapped like a “burrito” in a synthetic liner to prevent water leaking, minimize the introduction of air and to prevent the surrounding soil from migrating into the limestone layer. An influent pipe transports water into one end or side of the ALD and an effluent pipe discharges water from the opposite downstream end or side. The effluent pipe carries water to the surface and is positioned at an elevation to ensure the limestone layer remains fully submerged and anoxic (minimal or no headspace within the ALD).

The ALD will meet the following design requirements.

- Shallow in depth (1-2m)
- Limestone layer 1-2m thick
- 0.6m compacted impermeable soil cover

The ALD will be sized based on the following.

- Minimum retention time 14hours
- Limestone aggregate porosity 50% (8-25cm)

The bulk void volume needed V_v (m³) to store 14 hours of water is calculated as follows.

$$V_v = Q_d \cdot t$$

Where?

Q_d = Design flow per day for the system (m³/d)

T = Retention time (hours)

The minimum active part of the ALD can be calculated as follows:

$$V_t = \frac{V_v}{n_e}$$

Where

V_t = Minimum total volume

V_v = bulk volume needed

n_e = bulk volume needed

The mass of limestone required to construct the ALD can be calculated as follows:

$$M = \frac{Q \cdot V_L \cdot t_r}{V_v} + \frac{Q \cdot C \cdot T}{x}$$

Where

To calculate the first bracketed term:

Q = water flow rate; ρ = limestone density; t = design retention time (14hrs); and V = bulk void volume of the limestone gravel, expressed as a percent of total volume.

To calculate the second bracketed term:

Q = influent flow rate; C = expected rate of alkalinity generation, expressed on an mg-CaCO₃/L per unit time basis; T = the design lifetime; and x = the CaCO₃ content of the limestone, for which 90% or greater is recommended.

The ALD for the site will have the following properties listed below. for the ALD layout.

Table 4: Anoxic Limestone Drain (ALD) Design

Parameters	Value
Area	600m ²
Depth	2.70m
Clay Layer	600mm
Geotextile ling	2 mm thick smooth HDPE lining, complying with SANS 10409 and A4 geotextile
Limestone depth	2000 mm
Incoming flow rate	1000 m ³ /day
Outgoing flowrate	1000 m ³ /day

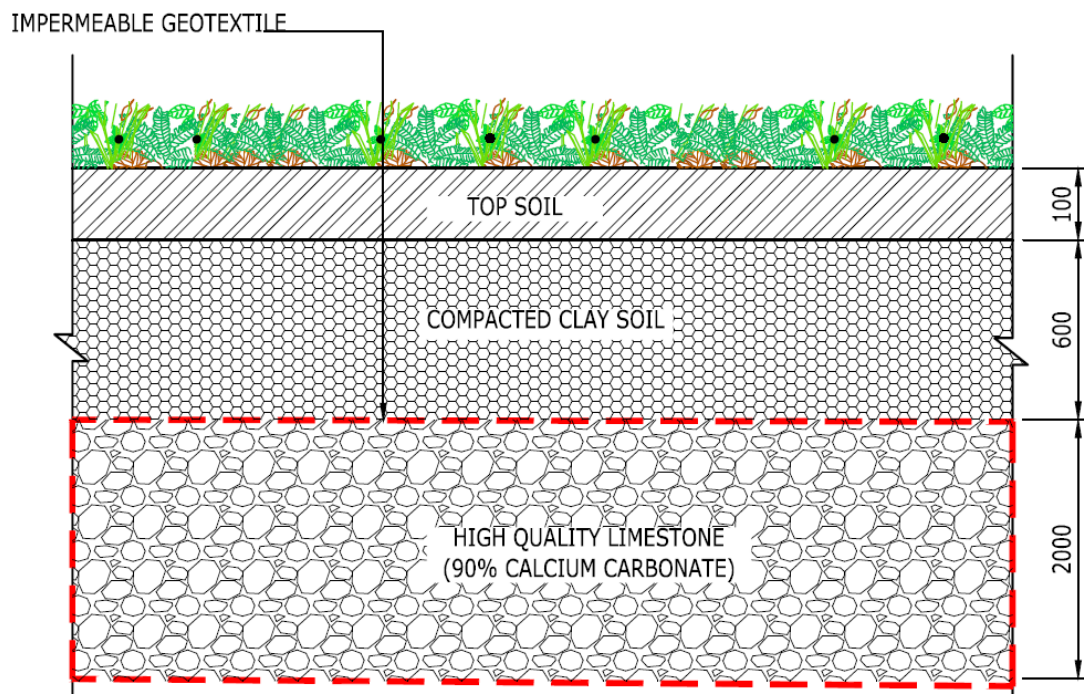


Figure 11: Section through ALD

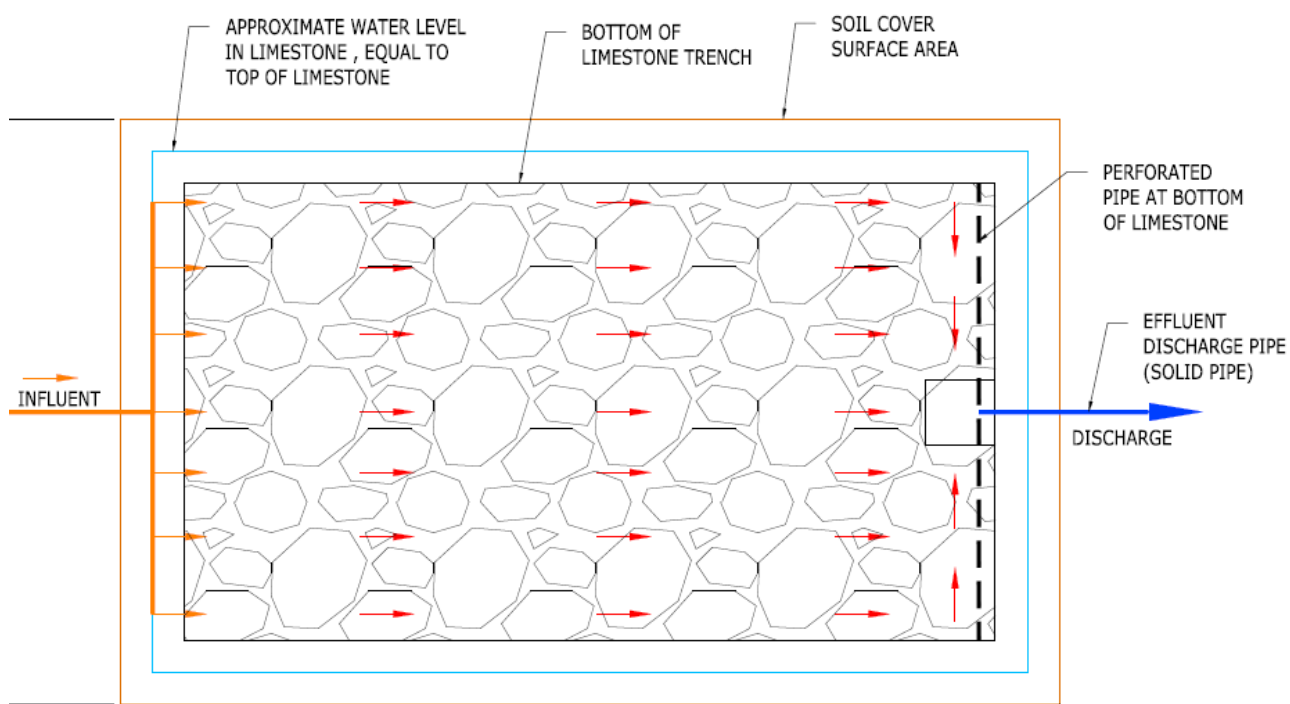


Figure 12: ALD Plan layout

ALD Maintenance

Limestone: The limestone can require maintenance and periodic partial replacement, mostly due to clogging from metal precipitate. Therefore, the default recommendation in AMD Treatment is to replace 50% of the limestone every 10 years.

Liner: Often liners are destroyed, especially synthetic, while conducting maintenance on passive treatment systems, if the equipment operator is inexperienced with passive systems. Thus, AMD Treatment recommends planning to replace a portion of the liner while the Limestone is being replaced. The default assumption is to replace 50% of the Limestone every 10 years, so the same assumptions are recommended for Liner recapitalization.

Pipe: Piping is often exposed at the surface and can become damaged by vandalism, falling trees, and other factors. AMD Treatment assumes 50% of the piping will require replacement after 25 years of service.

7.3 Successive Alkaline Producing System (SAPS)

The SAPS systems combine ALD and compost wetland systems with vertical flow of water. First the acidic water flows through the low hydraulic conductivity compost part of the SAPS, where dissolved oxygen is consumed, and ferric iron (Fe^{3+}) reduced to ferrous iron (Fe^{2+}). As a result, the water becomes anoxic and will flow through the anoxic layer of limestone resulting in alkaline water without any iron precipitating on the limestone. The removal capacity of SAPS system is approximately 10 g acidity /m²/d and estimated lifetime 20-30 years. The area-adjusted contaminant removal rate was derived by Hedin et al. (1994a) for systems that must meet regulatory standards a value of 10 g/m²/d for iron, and 0.5 g/m²/d for manganese is recommended. The effluent discharged from Ballengeich has a design loading of 1000 m³/d and 189 mg/L iron and 4.0 mg/L manganese. The minimum required area is 18 900 m². Schematic of the system is presented in figure 5 below. The proposed SAPS systems will be as follows:

Table 5: Successive alkaline producing system design

Parameters	Value
Retention time	15 hours
Standing water height	1.0m
Compost layer thickness	0.6m
Limestone depth	2000 mm
Incoming flow rate	1000 m ³ /day
Outgoing flowrate	1000 m ³ /day



Figure 13: The schematic picture of an anaerobic wetland. © GTK

7.4 Sedimentation/Oxidation Pond

Oxidation ponds, also called lagoons or stabilization ponds, are large, shallow ponds designed to treat wastewater through the interaction of sunlight, bacteria, and algae. Algae grow using energy from the sun and carbon dioxide and inorganic compounds released by bacteria in water. During the process of photosynthesis, the algae release oxygen needed by aerobic bacteria. Mechanical aerators are sometimes installed to supply yet more oxygen, thereby reducing the required size of the pond. The sedimentation/oxidation pond is designed based on a 24-hour retention time at the design flow of 1000 m³/day, a water depth of 1500 mm and 600 mm freeboard. The pond shall feature the following:

- total surface area: 670 m²;
- flow distributing inlets;
- maximum length to breadth ratio of 3:1;
- side slopes of 1:2;
- scour valves for desludging;
- No. of ponds: at least two ponds are proposed;
- HDPE lining constructed to the same detail as the aerobic wetland above.

7.5 Aerobic wetland

Aerobic wetlands are relatively shallow, either constructed or natural ponds that are filled with flooded gravel, soil and organic substrate for plant growth. The cells are usually 30 cm deep or less, lined with impermeable sediments and water flows above the substrate. Constructed aerobic wetlands are based on aeration of the water to be treated, resulting in the transformation of dissolved Fe to the solid phase via oxidation. Thus, aerobic wetland treatment is very effective in treating Iron-rich mine waters, yet they have commonly limited capability to neutralize acidity. In addition, commonly accompanying manganese requires specific conditions for removal: circum-neutral to basic pH and Fe^{2+} will be oxidized to prevent manganese from reducing. In its most general form, the sizing formula may be written as follows (Younger et al. 2002):

$$A = Q_d * \left[\frac{C_i - C_t}{R_A} \right]$$

where,

A = the required wetland area (m^2)

R_A = area-adjusted contaminant removal rate ($\text{g}/\text{m}^2/\text{d}$)

C_i = mean daily influent contaminant concentration (mg/L)

C_t = concentration of contaminant in final discharge (mg/L)

Q_d = mean daily flowrate (m^3/d)

The area-adjusted contaminant removal rate was derived by Hedin et al. (1994a). For systems that must meet regulatory standards a value of $10 \text{ g}/\text{m}^2/\text{d}$ for iron, and $0.5 \text{ g}/\text{m}^2/\text{d}$ for manganese is recommended. At a design loading of $1000 \text{ m}^3/\text{d}$ and $189 \text{ mg}/\text{L}$ iron and $4.0 \text{ mg}/\text{L}$ manganese the minim required area is $18\,900 \text{ m}^2$. For enhanced performance a combination of free water surface wetland and vertical flow wetland is proposed. Schematics of the two system are shown below.

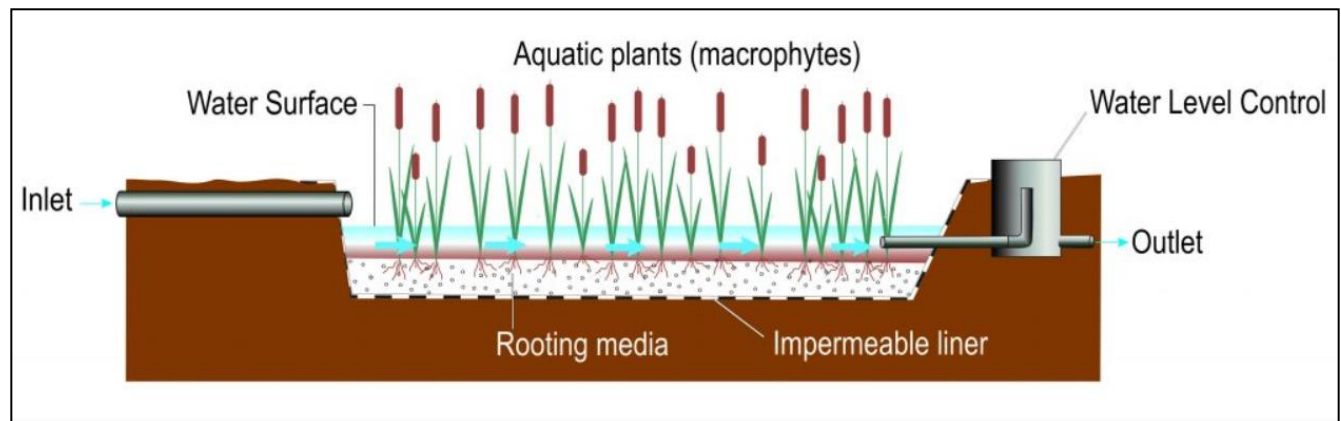


Figure 14: Free water surface wetland. (Modified from Wildeman et al. 1993, Kadlec & Wallace 2008, © GTK 2014)

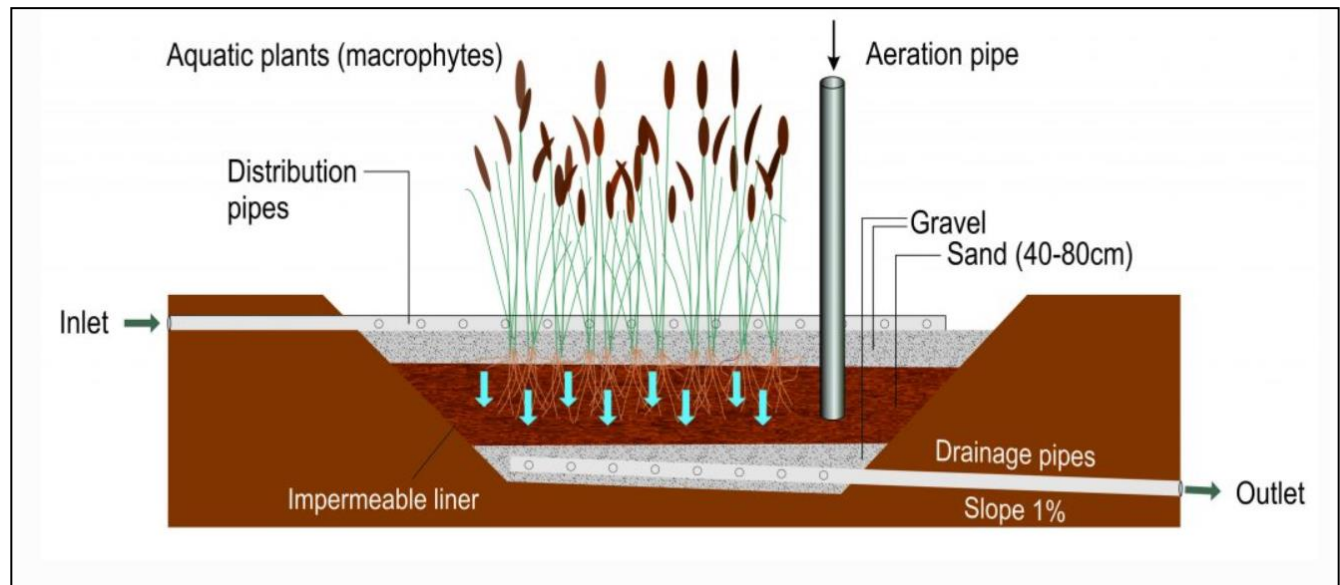


Figure 15: Vertical flow wetland. (Modified from Vymazal 2010, © GTK 2014)

The proposed wetlands will have the following properties:

- Soil depth to be 400 mm. Important aspects of soil quality are as follows:
 - It does not contain excessive large stones or other sharp objects, which may puncture pond liners and impede plant growth;
 - The soil is not contaminated. The best way to ensure this is to ensure a reliable analysis is made of it;
 - It contains sufficient nutrients, in appropriate proportions, to support reed growth;
- The depth of water above soil surface will be 1 m plus 600 mm freeboard;
- Aquatic plants typically reeds are to be planted at a density of 3-4/m²;
- Flow distributing inlets;
- maximum length to breadth ratio of 3:1;
- side slopes of 1:2;
- The subgrade shall be prepared with a 150 mm G7 sand layer with maximum particle size of 3 mm. A 2 mm thick smooth HDPE lining, complying with SANS 10409, overlaying A4 geotextile with the anchor trench detailed below, is proposed.

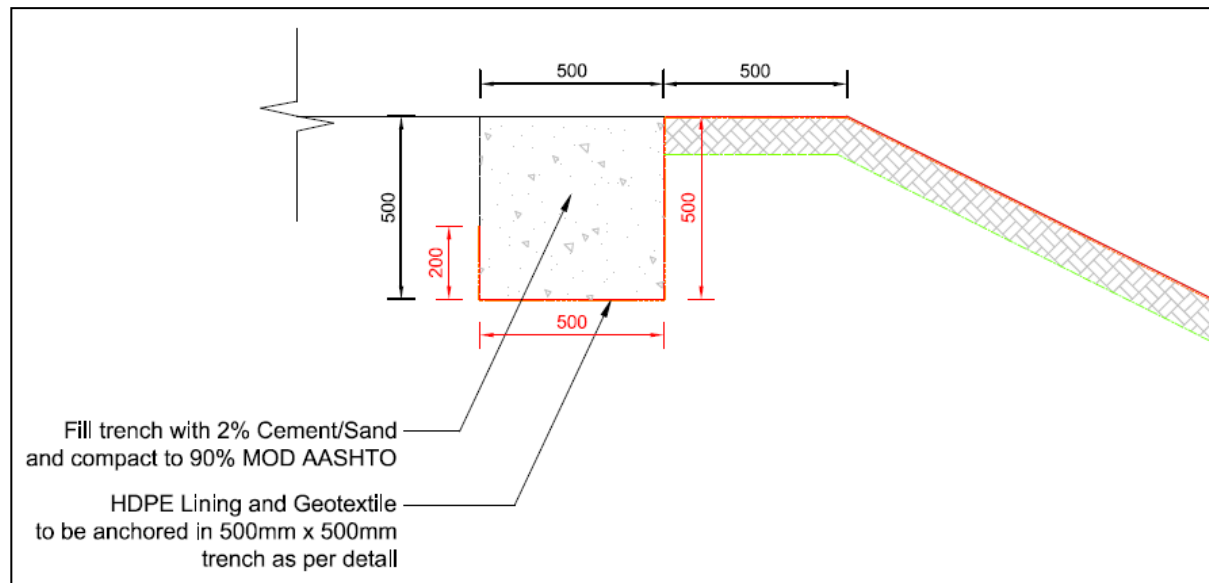


Figure 16: Geotextile Anchoring detail

8 MOTIVATION

The use of “natural systems” is proposed due to their simplicity of operation and low maintenance requirements. The implementation of various passive treatment systems in series enhances the treatment capacity of natural treatment to acceptable quality according to (BPG H4: Water treatment). The advantages and disadvantages of natural treatment systems are listed below:

Pro's:

- Civil works limited to earthworks and HDPE linings, no major structures required.
- Totally natural system, no external energy input required.
- No electricity required for operation.
- Limited chemicals required for operation – only disinfectant required.
- Very low maintenance costs, no mechanical or electrical equipment required.
- Very low operational costs, limited supervision and operator input required.
- Will continue working even if severely neglected.
- Provides a good quality effluent that complies with General Limit values if not overloaded.
- Scenically attractive and provides a good habitat for birds.
- Long life expectancy, in excess of 30 years

Con's

- Large footprint, significantly more land required than for conventional type plants
- Sensitive to effective pre-treatment, requires good screening and primary settlement to avoid solids blocking the reed bed growth media or primary ponds filling up with solids.
- Reeds need to be cut and harvested on an annual basis
- Requires expert design and construction.
- Sensitive to toxins entering the plant with wastewater, plants and active bacteria may die.
- Odours can be problematic due to anaerobic nature of some ponds, exude hydrogen sulphide.
- Requires secure fencing as deep ponds pose a risk for drowning if open to the public.
- Primary anaerobic ponds need to be desludged once every 5 to 7 years due to accumulation of non-biodegradable solids on pond floor over time.
- Initial capital costs higher than for conventional systems of same capacity due to large footprint.

Given the above comparison of options and positive and negative aspects of the proposed system, we recommend the use of the horizontal Reed Bed to augment the quality of the Treated Effluent. The advantages and improvement in water quality will over time far outweigh the negative impact of an inferior quality water disposed of in the environment.

9 CONCLUSION

This report has been drafted to assist Kangra Coal (Pty) Ltd in obtaining rights to a water use license. The report presents the design methodology, calculations and layouts of the acid Mine drainage treatment system proposed for the Ballengeich Colliery. The feasibility of the AMD treatment design is presented while summarizing the implementation highlighting the following:

- Compliance with Regulation GN704 as well as IWULA requirements
- Responsible usage of water as a scarce commodity
- Prevent pollution to the environment.

10 REFERENCES

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11 APPENDICES

Appendix A: Passive treatment layout.

Appendix A: Preliminary Passive treatment layout.

