pendragon environmental solutions

Technical Memorandum

To:	Chris Davidson	Date:	28/11/2023
cc:	Alan Tandy	From:	Carel van der Westhuizen
Subject:	Waste Characterisation: Turnberry and St Annes Deposits	Project:	PES23038

Introduction

This memorandum details a technical review of the document: Soilwater Consultants, 2017: Gnaweeda Deposit Waste Characterisation, a report prepared for Doray Minerals Ltd as per your request:

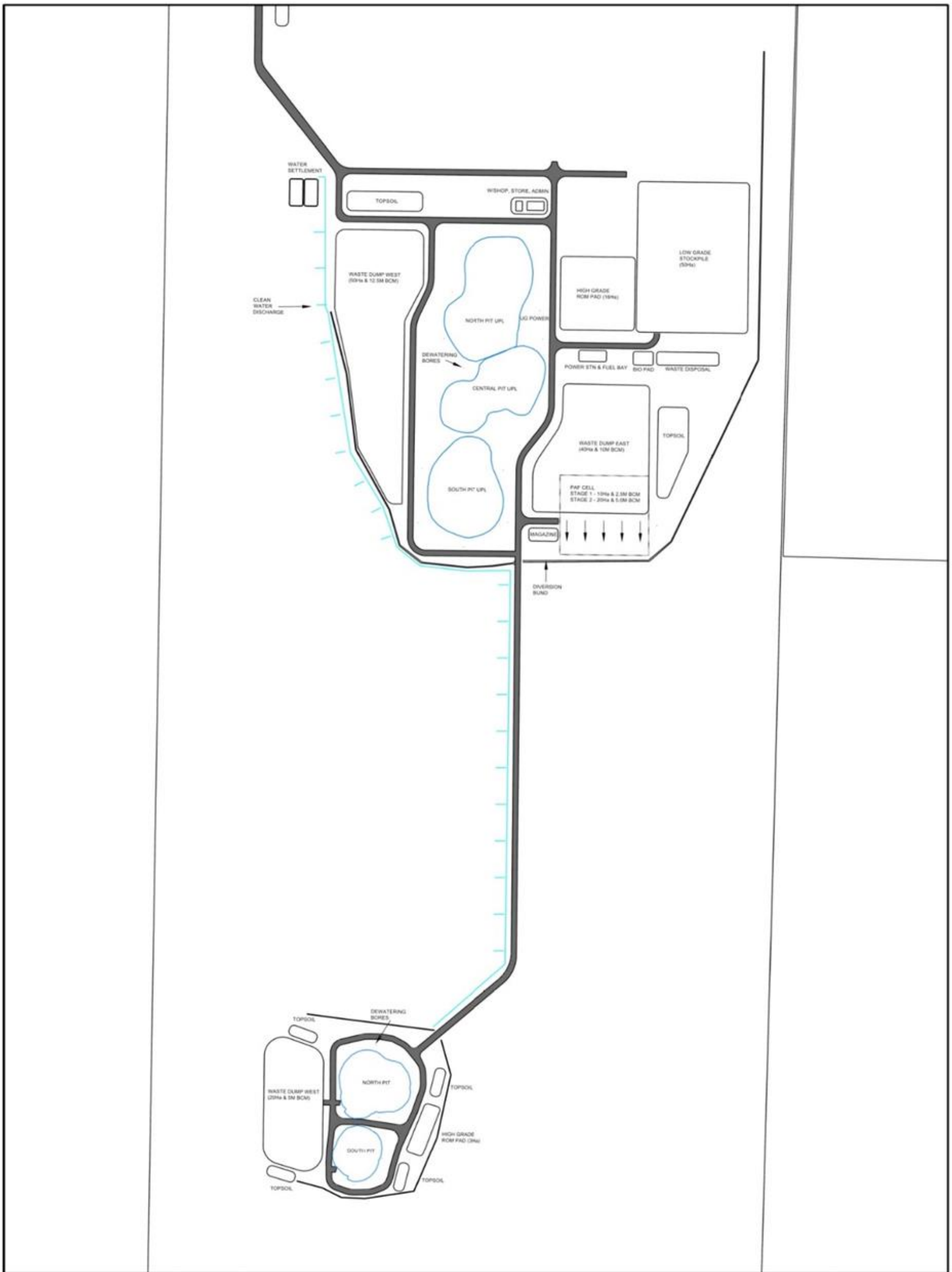
To ensure the entire development envelope, including both North Turnberry and St Annes, is adequately surveyed; we need a short memo explaining your review. We note that the earlier investigation found that the %S in the oxide are not an issue and mining of oxide is not going to present a PAF issue at Turnberry (red rectangle below). We need a review of the SoilWater report to support their findings or otherwise. Then we need assistance with a review of the pXRF data for the St Annes deposit located 3.5km south of Turnberry, the focus of the SoilWater report. Based on the review of %S data for St Annes, hopefully we can form a view on PAF/NAF management. The sulphur detected in the pXRF was very low and was entirely leached from the clays/oxide.

In addition to the above, this document also includes an assessment of the XRF mineralogy and detailed lithological/geological descriptions for the St Annes deposit.

The Gnaweeda deposit (including Turnberry and St Annes collectively) is located approximately 40km north-east of Meekatharra and approximately 15km south-east of the existing Andy Well operations in the Northern Murchison region of Western Australia. The proposed project will comprise the mine site and a haul road corridor to transport ore to the mill at Andy Well or to a third-party mill located off tenure.

The Turnberry and St Annes mining plan involves the excavation of five open pits in oxide/transitional material. The proposed mining landforms are (refer Figure: MGP Stage 1 Design):

Open Pits	High Grade Ore (t)	Low Grade Ore (t)	Ore (BCM)	Waste (t)	Waste (BCM)	Depth (Pit)/ Height (WRL)	Area (ha)
Turnberry North	647,673	89,175	320,369	6,645,791	2,889,474	120	25
Turnberry Central	243,465	42,333	124,260	2,714,564	1,180,245	110	20
Turnberry South	171,564	47,510	95,250	4,566,143	1,985,280	130	20
St Annes North	125,830	28,968	67,303	2,844,868	1,236,899	90	15
St Annes South	70,276	5,003	32,730	1,679,041	730,018	80	10
Other							
Turnberry WRL	batter height 10m with a slope of 20°; berm width 7m					30	90
St Annes WRL						30	25
Turnberry ROM						4	16
St Annes ROM						4	3
Turnberry Low Grade Stockpile						12	50
St Annes Low Grade Stockpile							6



03/11/2023	1	MGP	Meeka Metals
Meeka Metals		MGP Stage 1 Design	1

Waste Rock Landforms will be installed around each pit using non-acid forming material containing no NORM or fibrous material. At closure the WRLs will be covered with non-eroding material.

Approximately 87% of the waste at Turnberry comprises oxide materials, predominantly (84%) transported silts and sands, dolerite, basalt and sediments. All of the waste rocks at St Annes will be oxide comprising predominantly (78%) transported silts and sands, basalt and sediments.

Open Pit	Ore HG	Ore LG	Waste Total	Oxide	Transitional	Fresh
	t	t	t	t	t	t
Turnberry North	647,673	89,175	6,645,791	5,097,487	1,538,559	9,744
Turnberry Central	243,465	42,333	2,714,564	2,625,462	87,813	1,288
Turnberry South	171,564	47,510	4,566,143	4,397,567	168,576	0
Total	**1,062,702**	**179,018**	**13,926,498**	**12,120,516**	**1,794,948**	**11,032**
% of Total	**-**	**-**	**100.0%**	**87.0%**	**12.9%**	**0.1%**
St Annes North	125,830	28,968	2,844,868	2,844,868	0	0
St Annes South	70,276	5,003	1,679,041	1,679,041	0	0
Total	**196,106**	**33,971**	**4,523,910**	**4,523,910**	**0**	**0**
% of Total	**-**	**-**	**100.0%**	**100.0%**	**0.0%**	**0.0%**
Open Pit	**Transported Silts/Sands**	**Dolerite**	**Basalt**	**Sediments**	**Felsic**	**Ultramafic**
	t	t	t	t	t	t
Turnberry North	1,329,158	1,661,448	1,993,737	664,579	664,579	332,290
Turnberry Central	542,913	1,085,826	542,913	407,185	0	135,728
Turnberry South	913,229	684,921	913,229	913,229	913,229	228,307
Total	**2,785,300**	**3,432,195**	**3,449,879**	**1,984,992**	**1,577,808**	**696,325**
% of Total	**20.0%**	**24.6%**	**24.8%**	**14.3%**	**11.3%**	**5.0%**
St Annes North	711,217	0	995,704	568,974	426,730	142,243
St Annes South	419,760	0	419,760	419,760	335,808	83,952
Total	**1,130,977**	**0**	**1,415,464**	**988,734**	**762,538**	**226,195**
% of Total	**25.0%**	**0.0%**	**31.3%**	**21.9%**	**16.9%**	**5.0%**

The Geology at Turnberry and St Annes

The Turnberry and St Annes deposits are located within the greenstone belt comprising a succession of metamorphosed mafic to ultramafic, felsic and metasedimentary rocks, with minor felsic to intermediate intrusives, belonging to the Norie Group within the Murchison Supergroup. The geological package largely comprises of fractionated dolerite with an ultramafic base, basalt, felsic volcaniclastics and porphyry surrounded by a package of siliciclastic sediments and shales. The stratigraphy dips steeply east to sub-vertical with isoclinal folding along a north-north-east axis with a north-north-east trending foliation.

Turnberry

Lithologies at Turnberry are dominated by dolerites with the best mineralisation along a 1.7km north-north-east trending gold anomalous corridor hosted within a magnetic quartz dolerite. This mineralisation style is best developed at Turnberry as it hosts the highest and most consistent grades and widths. Several northwest-southeast structures are interpreted from geophysical imagery to crosscut the stratigraphy and appear to offset both lithology and mineralisation. The area is covered with transported colluvium to a depth of ~10m to 25m and is highly weathered with a depth to fresh rock of approximately 100m.

Mineralisation is broadly defined into three zones, Turnberry North, Central and South (Figure 1).

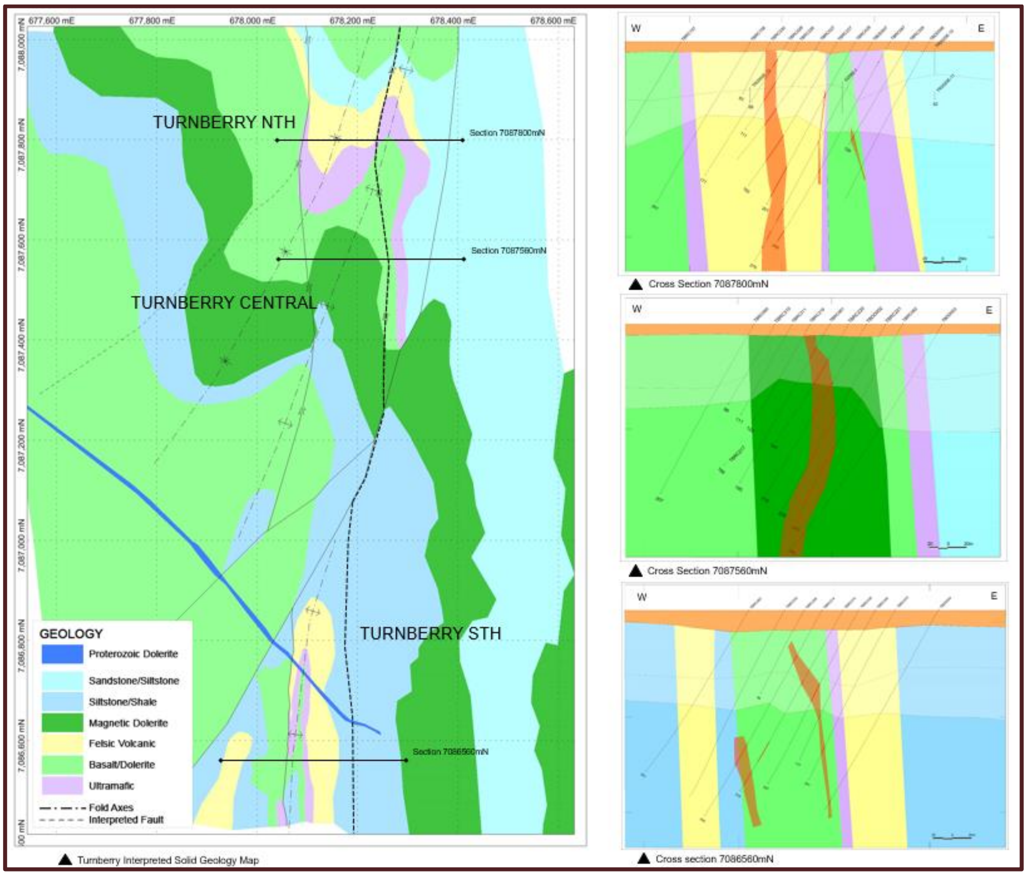


Figure 1: Turnberry Interpreted Geology and Mineralisation.

Figure 2 displays the interpreted geology and sulphur distribution which is predominantly below the bases of the open pits in fresh bedrock (Figures 3 and 4).

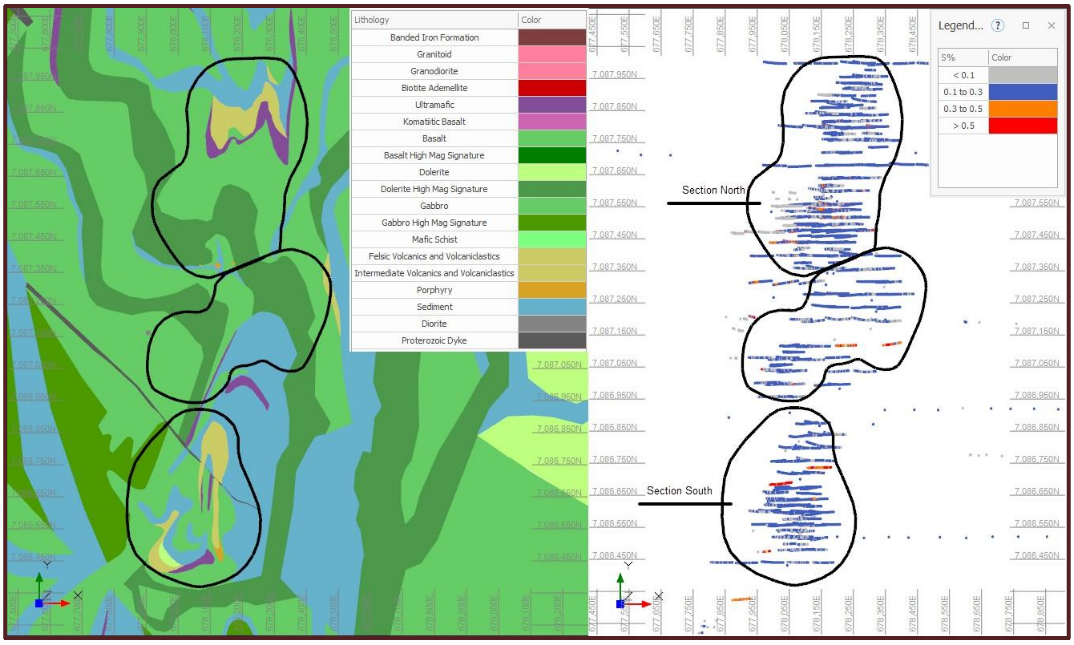


Figure 2: Turnberry Geological Interpretation with Sulfur spatial distribution.

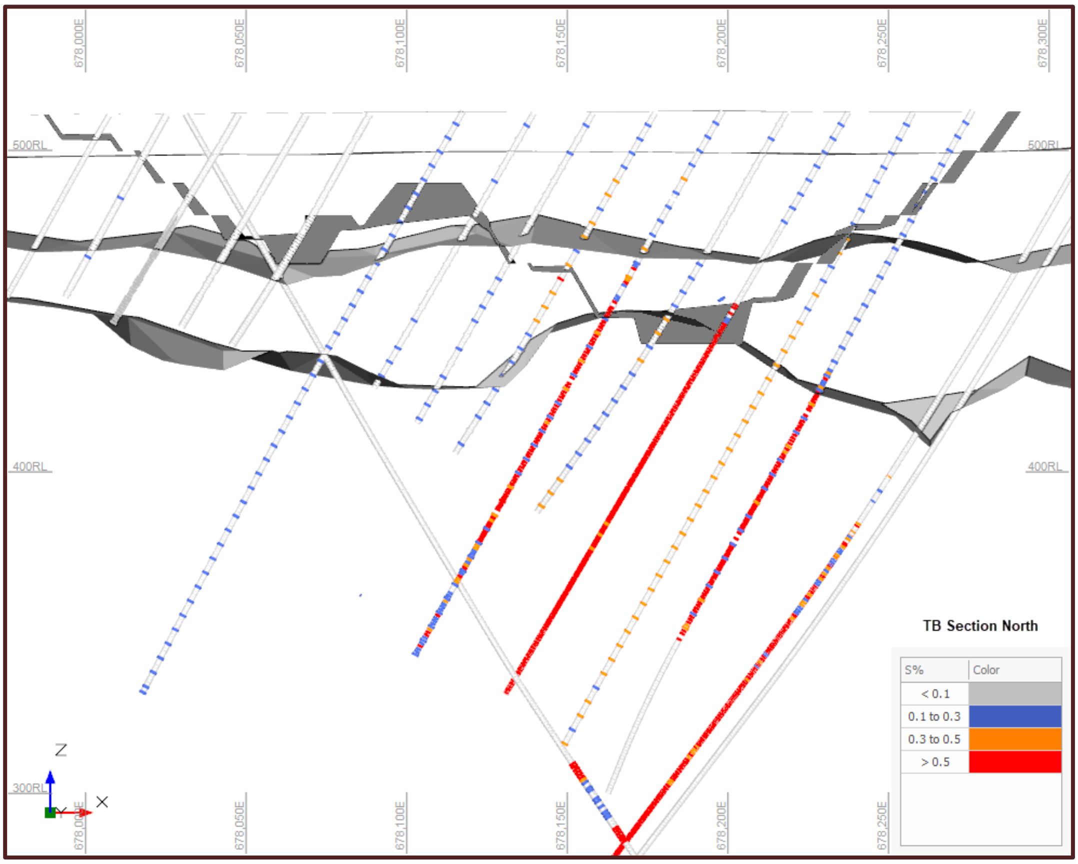


Figure 3: Turnberry North Pit Sulphur Concentrations (elevated in fresh rock only).

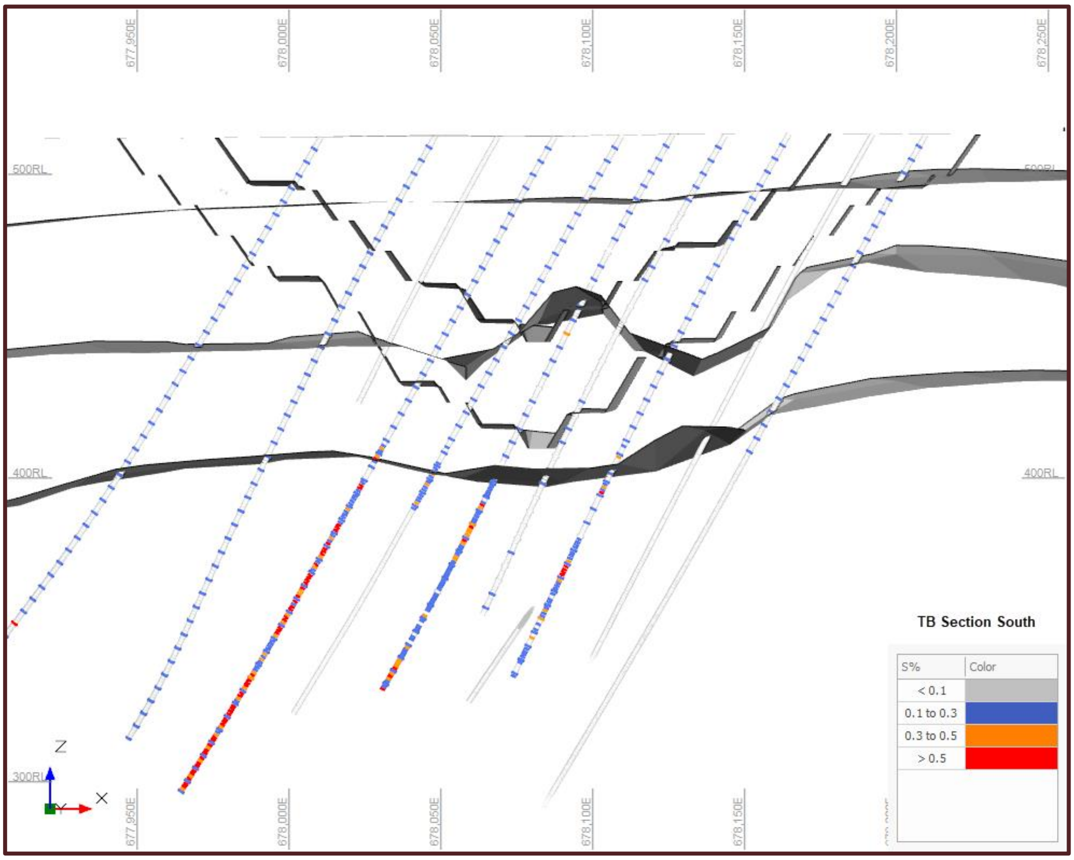


Figure 4: Turnberry South Pit Sulphur Concentrations (elevated in fresh rock only).

St Annes

The local geology and stratigraphy of St Annes, from east to west, comprise of ultramafic metasedimentary rocks, siliciclastic sediments, basalt and felsic volcaniclastics (Figure 5) which is highly weathered with a depth to fresh rock between ~100m and 160m covered with transported colluvium to a depth of ~25m.

Mineralisation is aligned along an 800m north-north-east trending shear divided into the St Annes North and South zones. Figures 6 and 7 indicate that there are no elevated (>0.3%S) Sulphur concentrations within the proposed open pits.

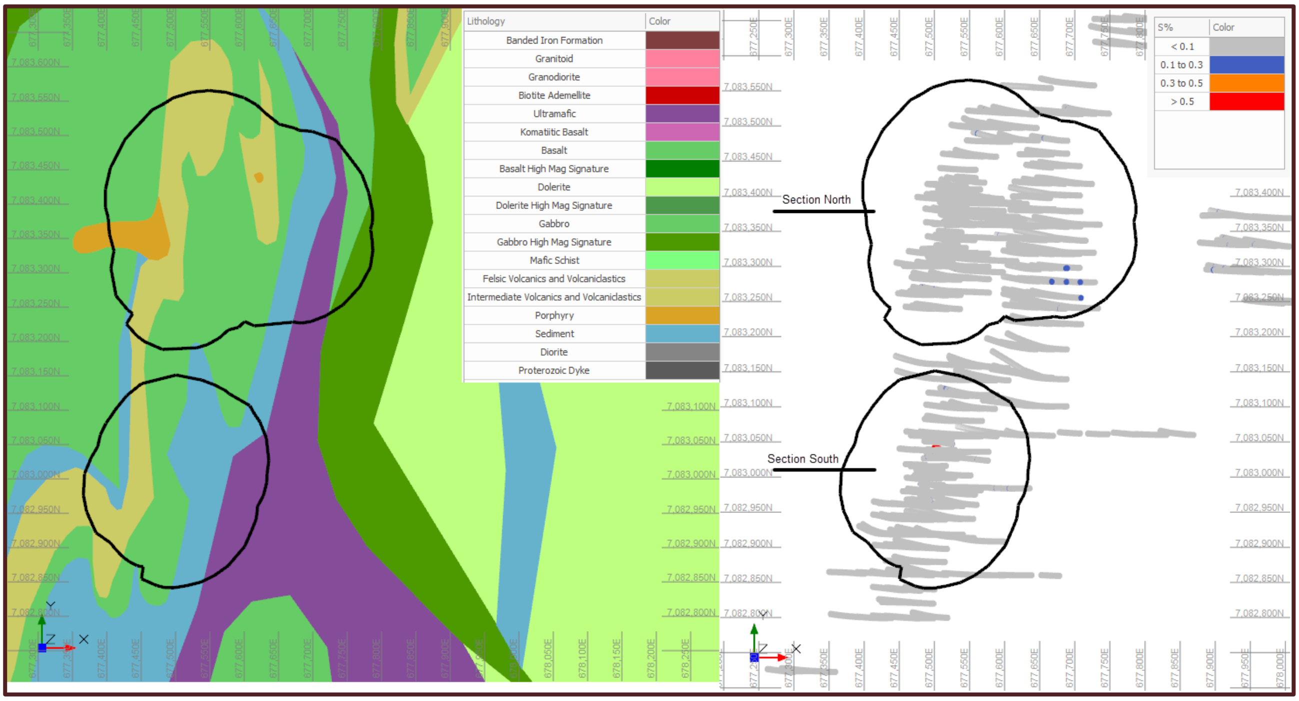


Figure 5: St Anne's Geological Model.

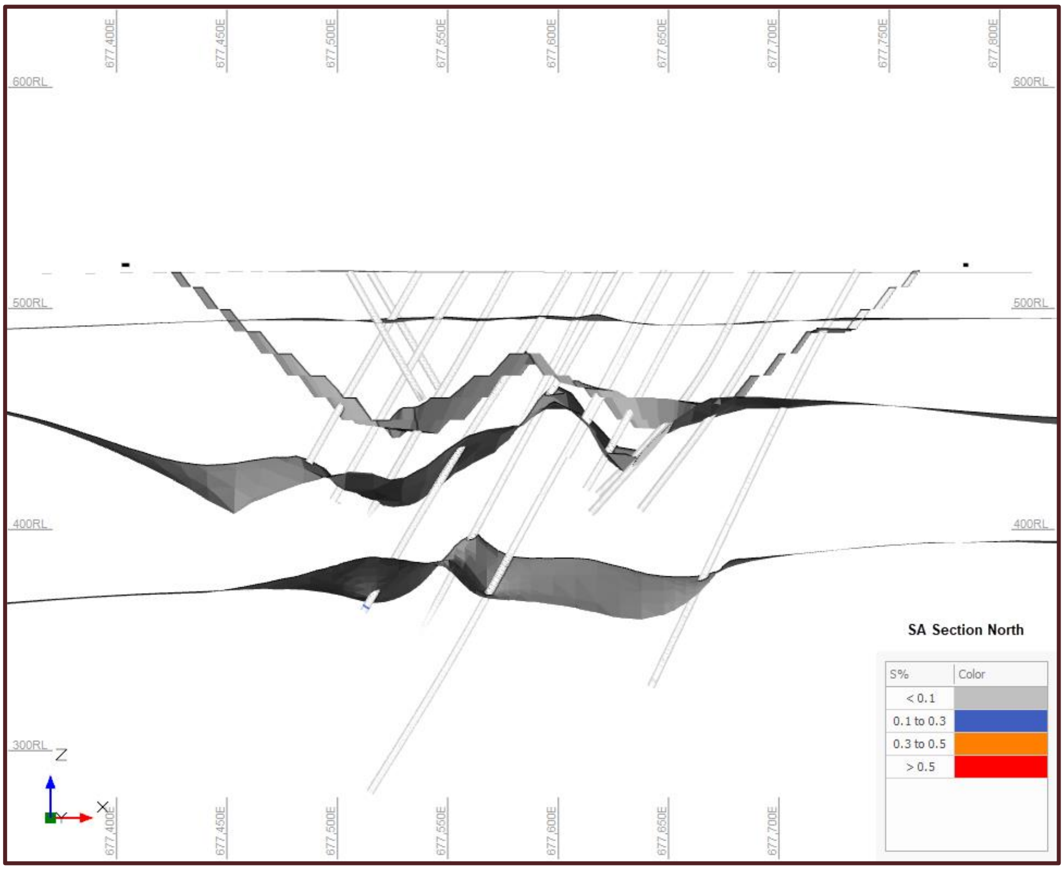


Figure 6: St Annes North Pit Cross Section showing no elevated %S concentrations within the open pit.

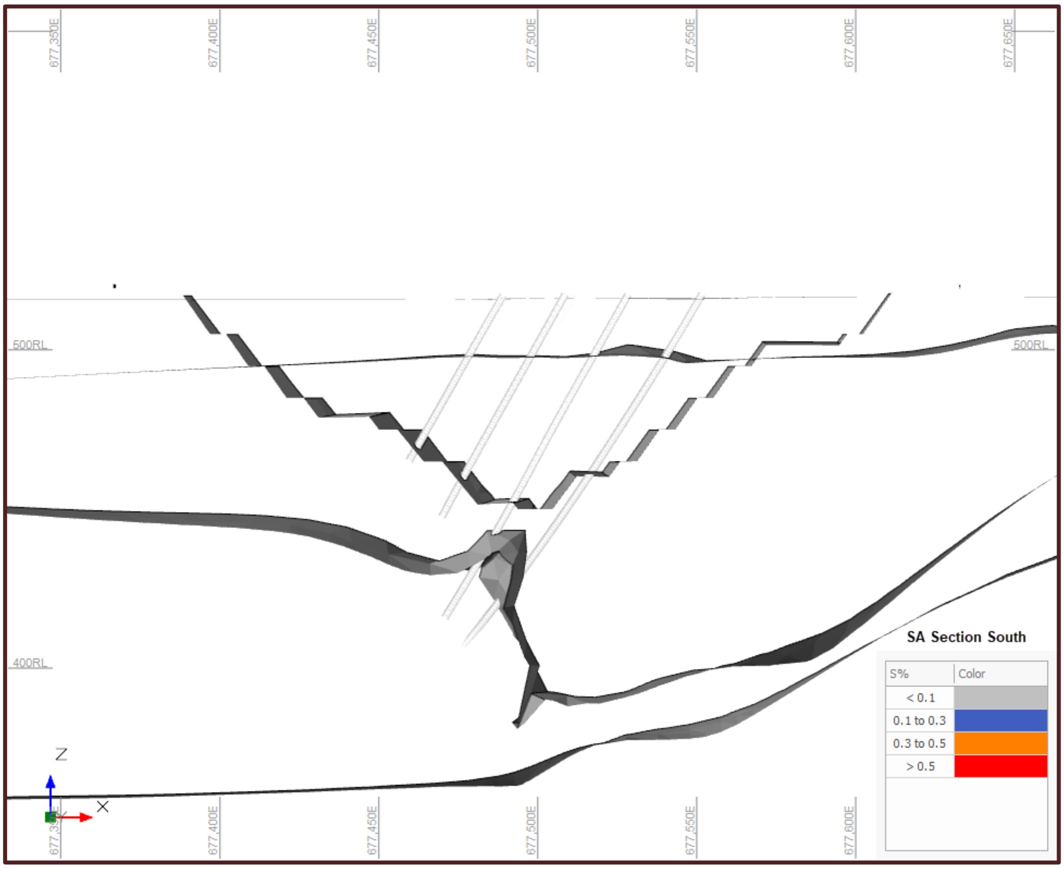


Figure 7: St Annes South Pit Cross Section showing no elevated %S concentrations within the open pit.

Turnberry Waste Characterisation

Soil Water Consultants (SWC) were engaged by Doray Minerals Ltd (Doray) in 2017 to undertake a geochemical characterisation for the proposed Turnberry deposit which is to be mined by three open pits with the excavated waste rock to be placed in an adjacent Waste Rock Landform (WRL; refer Figure MGP Design Stage 1 above). As part of the environmental approvals, this geochemical characterisation was undertaken to identify the presence or absence of potential acid rock (ARD) or metalliferous (MD) drainage materials, highly saline materials and other problematic materials which may impact the surrounding downstream environment if not managed appropriately.

The objectives of this investigation were primarily to:

- Assess the current baseline geochemical conditions.
- Undertake laboratory analytical assessments to identify the environmental risks associated with mining and waste disposal.
- Identify any other potentially problematic characteristics of the wastes that may impact on the stability and sustainability of the WRL.
- Suggest management strategies for the handling and management of the waste rock materials during mining and rehabilitation.

SWC indicated that in 2017 approximately 700 drill holes, some 33,000m of drilling in total, were contained within the Turnberry deposit boundaries to depths between 36m and 374m with samples collected at 1 and 2 m vertical intervals. SWC identified six drillholes (TBRC005, TBRC009, TBRC024, TBRC073 and TBRC141 and TBRC153 to depths between 99m and 153m) as representative of the different geological units and weathering characteristics of the major waste lithologies and selected a total of 298 samples at between 2m and 3m vertical intervals for screen analysis:

The dominant lithologies are basalt (24.0% with 55 samples), gabbro (20.7% with 57 samples), siltstone (12.4% with 27 samples), alluvial and colluvial sediments, clay and lateritic ferricrete (11.0% with 52 samples), followed by felsic volcaniclastics (7% with 47 samples), dolerite (3.5% with 33 samples), carbonate and quartz veins (3.6% with 9 samples) and ultramafic rocks (2.0% with 17 samples).

All the samples selected were subjected to *screen laboratory analysis* to determine their basic chemical characteristics and provide key information on the likelihood of AMD occurrence:

- pH (1:5 soil/water extract): to measure existing acidity and determine if previous oxidation of sulfides has occurred and the potential buffering capacity of the materials.
- EC (1:5 soil/water extract): to measure the level of salinity in the waste materials which may reflect previous oxidation of sulfides.
- pH_{fox}: measures pH following the addition of 30% hydrogen peroxide to rapidly oxidise any sulfides present.

Following the screen analysis and assessment of the analytical results, 20 representative samples were selected for further detailed testing:

- Total S and sulfate-S (SO_4-S).
- Static Net Acid Generation (NAG).
- Acid Neutralising Capacity (ANC).

- Total Inorganic Carbon (TIC).
- Multi-element composition (As, B, Ba, Be, Cd, Co, Cr, Cu, Hg, Mn, Ni, Pb, Se, V and Zn).
- Neutral and acidic static leach testing and metal mobility (As, B, Ba, Be, Cd, Co, Cr, Cu, Hg, Mn, Ni, Pb, Se, V and Zn).

Screening of the samples indicated that:

- pH varies between 3.2 and 9.3 with an average of 7.7 (circum-neutral). The pH depth profiles emphasize the dominance of neutral to alkaline conditions throughout the profile with a general increase in pH with decrease in weathering (increased depth).
- pH_{fox} values vary between 2.7 and 10.2 with an average of 7.2 (circum-neutral).

  The similarity between the majority of the pH and pH_{fox} values (i.e. pH – pH_{fox} <1pH unit), along with the alkaline pH values, indicates that sulfides are unlikely to be widespread within these materials. The exceptions are two zones within drill holes TBRC073 and TBRC153 where the recorded pH_{fox} values are significantly lower than the corresponding pH value indicative of sulfides in interceptions of siltstone and felsic volcanics with a potential to release acid release upon oxidation. However, both these zones correspond to mineralised areas (ore) and therefore will not be stored within the waste landform.
- Electrical Conductivity: salinity is uniformly low varying between 2mS/m and 34mS/m, averaging 6mS/m. The materials are considered non-saline and pose no limitation to rehabilitation. These values also suggest that oxidation of sulfides and subsequent formation of sulfate salts within the material and lithological units are not widespread. There is a slight increase in salinity at the base of TBRC005 which corresponds to the lower pH and pH_{fox} values, suggesting that in this area, partial oxidation of sulfides may have occurred.

Subsequently twenty representative samples were selected for sulphur speciation and subjected to detailed laboratory analysis for Total Sulfur (S) and Sulfate (SO_4) to ascertain what portion of the Total S is in the form of sulfide minerals (such as pyrite, chalcopyrite, etc.) which may release acidity when oxidised representing the main drivers of AMD:

- Total S varies between below the limit of detection (70 % of the samples contained <0.01%S) to 0.57%S; 30% of the samples averaged 0.1%S. Only one sample (felsic volcanics at a depth of 133.5m) exceeded the 0.3% threshold (AMIRA, 2000). Materials with S concentrations below this threshold generally have a low risk of forming AMD regardless of their other mineralogical characteristics (e.g. acid neutralising capacity).
- Most samples reported low concentrations of SO_4-Sulfur, with those samples with detectable concentrations of Total S having the majority of the Total S content in the form of sulfide (S_2).

The acid neutralising capacity (ANC), Total Inorganic Carbon (TIC) and calculated CarbNP ranges and averages for the representative samples are:

Statistical Parameter	Minimum	Maximum	Average
ANC (kg H_2SO_4/t)	1.7	118.0	16.1
TIC (%)	<0.02	1.6	0.3
CarbNP (kg H2SO4/t)	<1.6	133.2	22.4

Most of the samples contain low ANC (<20kg H_2SO_4/t) indicative of the absence of carbonates within the material; only two samples (from clays and ultramafic metasediments) reported considerable ANC values.

Acid Base Accounting (ABA) is the process of comparing the Maximum Potential Acidity (MPA) and

ANC/CarbNP results; the results of this comparison for the 20 representative samples are:

Statistical Parameter	Minimum	Maximum	Average
MPA (Total S)	0.6	17.4	5.2
MPA (S_2-S)	0.2	17.0	5.0
ANC	1.7	118.0	16.1
$NAPP_{Total\ S}$	-109.7	4.1 (one sample: felsic volcanics)	-14.6
All values are in (kg H_2SO_4/t). **MPA is calculated from the measured Total S and assumes that all the S within each sample occurs in the form of iron pyrite (FeS_2) which produces the maximum amount of acidity per molar weight of S of any sulfide species and therefore presents a *worst case* scenario.**			

ABA highlights the absence of sulfide within most of the samples, with only one sample reporting a positive Net Acid Production Potential (NAPP) value which were generally slightly negative due to low acid neutralising capacity and negligible sulfide content. All but one sample has an ANC/MPA ratio >2, denoting the excess buffering capacity in comparison to acid production potential within these samples.

Static NAG testing used in conjunction with the NAPP results allow a geochemical classification of the acid generating potential of a material:

- Non Acid Forming (NAF): materials may have significant acid generating potential but contain sufficient readily available ANC to adequately buffer any acidity formed. A material is classified as NAF when it has a negative NAPP and a final NAGpH≥4.5.
- Potentially Acid Forming (PAF): these materials present a risk of generating acid upon oxidation i.e. when these materials are exposed to atmospheric conditions. A material is classified as PAF when it has a positive NAPP and a final NAGpH<4.5.
- Uncertain (UC): a material is classified as *uncertain* where there is a conflict between the NAPP and NAG test results (i.e. where the NAPP is positive and the NAGpH≥4.5 or vice versa). These materials require further investigation and/or assessment to determine the likely acid generation potential.

Most of the samples fall within the NAF category borderline with the UC zone as they are barren of both buffering and acid generating capacity; only the felsic volcanic (ore) sample classify as PAF.

Element enrichment using the Geochemical Abundance Index (GAI) indicated:

- Elevated Arsenic concentrations likely due to trace arsenopyrite which is a common occurrence within the mineralised areas of hydrothermal gold deposits with the larger concentrations in the mafic and sedimentary samples.
- One sample from dolerite contains elevated levels of Cadmium.

The environmental mobility of metals by static extraction, using the Australian Standard Leaching Procedure (ASLP; AS4439) with both a mild acetic acid (pH 5.0) and a stronger acetic acid solution (pH 2.9) to simulate rainfall (neutral conditions) and acid production (AMD conditions) indicated that:

- The majority of metals are immobile under both leaching conditions with As, Be, Cd, Pb, Se, V and Hg concentrations all below the limit of reporting.
- B, Cr, Co, Cu, Ni and Zn are present in trace concentrations generally increasing by a small margin under acidic conditions.
- Ba and Mn are present in small concentrations within most samples again increasing slightly from neutral to acidic leaching conditions.

- Metal concentrations, when compared with the long-term irrigation water guidelines (ANZECC & ARMCANZ, 2000), are generally well below the guideline values with the exception of Co and Mn which are slightly above the published guidelines in several samples. However, it should be noted that the leach tests produce aggressive leaching environments which are unlikely to be reproduced in the field, however the results show that runoff from the waste landform should be controlled to prevent undue transport of dissolved metals and potential build-up within surrounding soils.

The saline findings of the above materials characterisation include:

- The waste materials possessing neutral to alkaline characteristics, can be used, without restriction, to construct the outer surface of the waste rock landform (WRL). Since the materials are non-saline, root development will not be restricted and therefore the upper regolith materials represent favourable growth medium materials. However, the consistently low salinity is likely to increase structural instability and therefore testing should be undertaken to confirm the materials erosion characteristics prior to placement on the outer surface to avoid stability issues.
- Sulfides are not common within waste materials and are confined to mineralised zones which will be processed as ore.
- Sulfur concentrations were uniformly low with the dominant waste lithologies (felsic volcaniclastics and mafic volcanics) containing low available buffering capacities hence in one sample, a slightly increased sulfur content (0.57%) resulted in the sample being classified as PAF.
- Alluvial clays and ultramafic lithologies contain large buffering capacities due to increased carbonate contents.
- The potential for AMD within the major waste lithology types is low, with the generally low buffering capacity sufficient to neutralise the negligible reported sulfide mineralisation.
- Multi-element composition and leaching tests indicated low concentrations both within solid material and both neutral and acidic static leach tests. Consequently, the development of metalliferous drainage following disturbance of the waste materials is considered to be low.

St Annes Waste Characterisation

To date 244 exploration holes were drilled across the St Annes deposit of which 22SAAC018, 066, 102, 134, 186 and 243 are considered representative of the waste that will result from mining the North and South Pits with the most dominant lithologies to a depth of 90m below surface comprising transported silts and sands (25.0%), basalt (31.3%), metasediments (21.9%) and felsic volcanics (16.9%). A detailed assessment of the XRF database indicated that:

Statistical Parameter	n	Minimum	Maximum	Average	Std.Dev.
Exploration Data Set: %S	23,912	0.000	0.791	0.001	0.012
Representative Bores: %S	474	0.000	0.216	0.001	0.010

Taking due cognisance of the waste characterisation at Turnberry and the XRF data for St Annes, coupled with the homogenous geological environment prevailing at both deposits, it may be concluded that the absence of Sulphur at Turnberry continues southwards across St Annes, averaging <0.001% at the latter. The standard deviation, a measure of how dispersed the data is in relation to the average, is relatively small indicating that the data are clustered tightly around the average value.

The heavy metals and metalloids in the waste rocks in the representative bores at St Annes include:

Statistical Parameter	Average Concentration (C)	Average Crustal Abundance (ACA)	Comment
As	255	1.5	**As enriched; potential to leach**
Ba	168	500	
Ca/Mg	1,828/6,742	41,500/23,300	Absence of Ca and Mg
Cd	0.5	0.1	**C>ACA**
Cr	292	100	**C>ACA**
Cu	76	50	**C>ACA**
Mn	371	950	
Ni	103	80	**C>ACA**
Zn	96	75	**C>ACA**
All concentrations are in mg/kg.			

Similar to Turnberry, it seems that the waste rocks at St Annes is enriched with Arsenic which has the potential to leach should the waste rocks be exposed to large scale infiltration of rain. The data also confirms the absence of Ca and Mg, hence the neutralising capacity of the rocks will be limited. Whilst Cd, Cr, Cu, Ni and Zn exceed their average crustal abundance indexes, the exceedances are insufficient to cause enrichment in terms of their GAI's.

Implications for mining at Turnberry and St Annes

The saline findings of the above materials characterisations concluded:

- Sulfides, hence PAF materials, are absent in the oxide and transitional materials, the target of the current mining plan, with limited and random occurrences at depth in the transitional and fresh rock lithologies. Geological descriptions and laboratory testing also confirmed the absence of naturally occurring radioactive materials (NORM) and/or asbestiform (fibrous) materials.
- The waste materials possess neutral to alkaline and non-saline characteristics and can be used without restriction to construct the outer surfaces of the waste rock landforms (WRL) subject to further investigation and assessment pertaining to stability.
- Sulfur concentrations were uniformly low with the dominant waste lithologies containing low available buffering capacities. However, alluvial clays and ultramafic lithologies contain large buffering capacities due to increased carbonate contents and are to be used in construction PAF cells as a contingency measure.
- The potential for AMD within the major waste lithologies is low, with the generally low buffering capacity sufficient to neutralise the negligible reported sulfide mineralisation.
- Multi-element composition and leaching tests indicated low metal and metalloid concentrations within solid materials and in both the neutral and acidic static leaches. Consequently, the development of metalliferous drainage following disturbance of the waste materials is considered to be low.
- The Turnberry and St Annes deposits are located within the Murchison River Basin and within the Meekatharra subarea of the East Murchison Groundwater Area. There are three aquifer types: surficial calcretes, alluvium and colluvium), sedimentary rock (sandstone and limestone) and fractured rock (granite and greenstone). Groundwater occurs within the weathering profile and in fractures in the bedrock and

associated shear zones, quartz veins and dykes. The depth to groundwater generally ranges between 9m to 13m below surface hence whilst dewatering will be required to facilitate open pit mining, the groundwater level is expected to return to these levels post mining and consequently flood any exposures of potentially acid forming materials at depth.

Recommendations

The consistently low salinity in waste rocks across the area is likely to increase their structural instability hence further investigation and assessment is required to confirm the characteristics of the materials prior to placement on the outer surface to avoid potential instability. These investigations and assessments should be undertaken during mining once sufficient bulk materials are available to facilitate appropriate field trials to inform the final landforms post rehabilitation and closure.

Deeper mining at Turnberry and St Annes, and particularly within the transitional zone at depth and where it transgresses into fresh bedrock, should be subject to further sampling using a waste rock characterisation methodology (standard operating procedure) based on a combination of Total Sulphur (using XRF assays); paste-pH and NAGpH testing as the primary indicators for classifying waste materials:

Material Characterisation Transitional and Fresh Waste Rocks

Type	XRF Assessment	Paste pH Assessment	NAG Assessment		Geochemical Characteristic	Further Assessment
			NAG pH	NAG (kg H_2SO_4/t)		
Type 1	Total S < 0.25%	>4.6	>4.5	0	NAF	-
	Total S>0.25% - <0.30%	>4.6	>4.5	0	NAF	ABA
Type 2	Total S < 0.25%	<4.6	<4.5	≤5kg H_2SO_4 / t	Uncertain/NAF	ABA
	Total S >0.25% - <0.30%	<4.6	<4.5	≤ 5kg H_2SO_4 / t	Uncertain/NAF	ABA
	Total S>0.30% - 0.75%	>4.6	>4.5	≤ 5kg H_2SO_4 / t	Uncertain/PAF	ABA
Type 3	Total S>0.30% - 0.75%	<4.6	<4.5	> 5 kg H_2SO_4 / t	Low PAF	-
Type 4	Total S% >0.75%	<4.6	<4.5	> 5 kg H_2SO_4 / t	High PAF	-
Where uncertain materials are encountered, waste rocks should be subject to further analytical assessment using ABA techniques.						

Consideration should be given to construct PAF cells (internal and/or external to the current planned WRL's) as a contingency measure and flexibility to manage mining wastes appropriately. These cells should at least have:

- The cell containing PAF material should be in the centre and at least 30m away from any side to ensure it is at least 15m from the batter after rehabilitation to achieve a slope of 20^o. For lesser slopes, measurements must increase accordingly.
- No PAF cell should be thicker than 10m in the vertical direction.
- Any active PAF cell faces and/or tip-heads, particularly during infrequent dumping, should be covered with crushed NAF, minimum 2.5m thickness, waste rock as soon as possible.
- The compacted base, sides and cover should be constructed using alluvial clays and ultramafic lithologies contain large buffering capacities at the base and cover and crushed NAF lithologies.

- The minimum base and final cover thicknesses post compaction should be 2.5m. Materials should be placed in layers no thicker than 0.5m to achieve proper and maximum compaction.

References

Meeka Metals, 2023: XRF mineralogical data.

Soilwater Consultants, 2017: Gnaweeda Deposit Waste Characterisation, unpublished report prepared for Doray Minerals Ltd.