A novel and practical approach to identify durable rock for landform rehabilitation at the Mt Arthur Coal Mine

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INTRODUCTION

The Mt Arthur Coal Mine is located approximately 5 km south-west of Muswellbrook, in the Upper Hunter Valley region of New South Wales (Figure 1). The project is scheduled for closure by 2030.

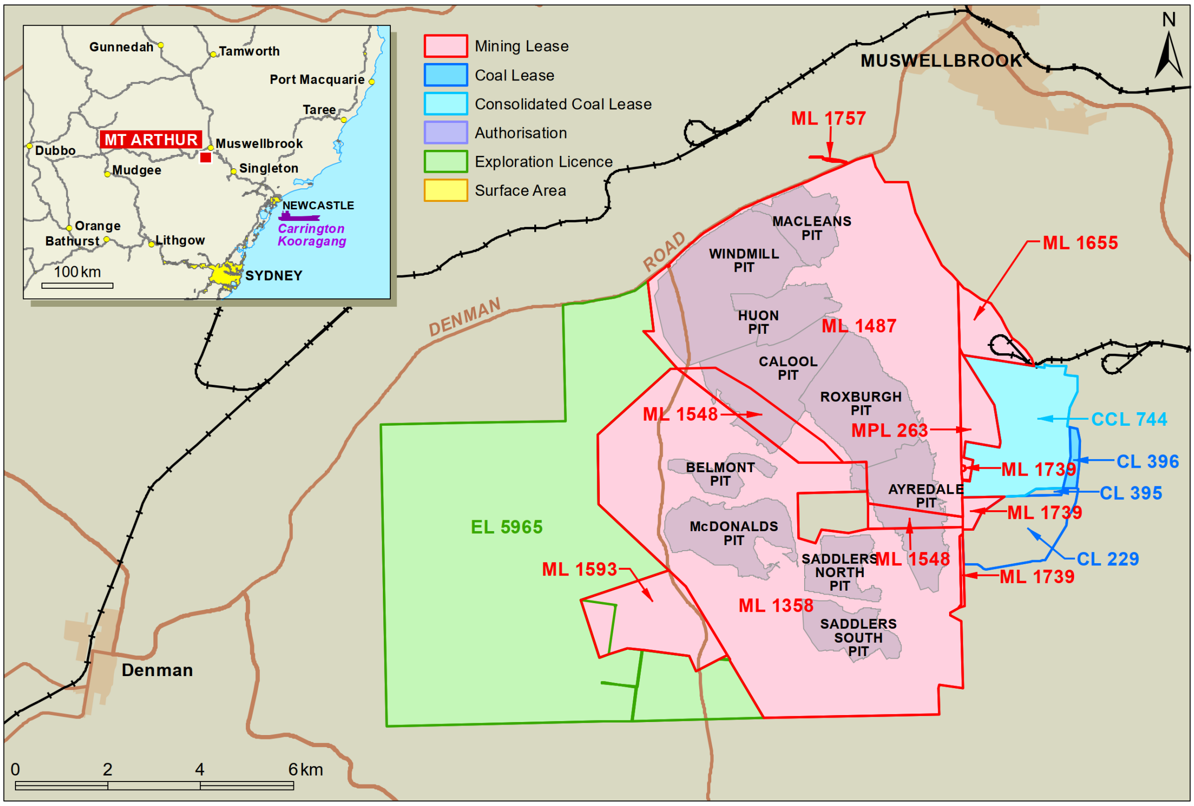

FIG 1 – Location of the Mt Arthur Coal Mine.

Disturbed land at the project will be rehabilitated using innovative geomorphological designs specifically developed for mining landforms. A large volume of durable rock will be required for the construction of the drainage channels that will be incorporated into the final slopes of the rehabilitated landforms.

A preliminary assessment did not identify a suitable source of durable rock on-site for constructing the drainage channels. To address rehabilitation requirements, alternative options were considered including importing rock from off-site sources and fabricating specialised concrete matting off-site. Following the evaluation of these options, a comprehensive and collaborative reassessment of on-site rock resources was conducted to identify a viable source of durable rock suitable for drain construction and other rehabilitation applications.

The reassessment resulted in the discovery of an abundant source of durable rock and the development of a novel and practical approach to its characterisation and identification in the field.

Target rock types

The most abundant and accessible source of durable rock identified on-site was the lower, massive portion of the Woodlands Hill sandstone unit (WHMS). This material comprises massive sandstone that was observed to be consistently hard and durable from all pits and stockpile exposures that were inspected. The upper portion (approximately the upper half) of the Woodlands Hill sandstone unit was observed to be finely laminated and interbedded and not suitable as a source of durable rock.

Whilst less abundant and accessible, a secondary source of potentially durable rock identified on-site was the Warkworth sandstone unit (WWS).

The WHMS will be the focus of this paper given it is the most abundant and accessible source of durable rock on-site.

APPROACH

A practical field procedure was developed for implementation by operational staff. This led to the collection of data over an intensive six-month period. Qualitative and quantitative data were collected from field observations and measurements, and laboratory test work on grab and drill core samples.

The focus of the field procedure was on the novel application of a 'Schmidt hammer' to measure rock strength by conducting a non-destructive rebound test to derive a 'Q-value' (Figure 2). Additional physical data was also collected to evaluate rock strength and durability and to provide context for the Schmidt hammer results. The key parameters that were assessed included point load strength (Figure 3), uniaxial compressive strength (Figure 4), geological-hammer hit, mineralogical composition, rock quality designation (RQD), density, water absorption and as-mined particle size distribution.

FIG 2 – Schmidt hammer.

FIG 3 – Point load test.

FIG 4 – Uniaxial compressive strength test.

A threshold Q-value was ultimately developed for operational staff to distinguish suitable durable rock from non-durable rock. The threshold Q-value was developed from a comprehensive review of the data, collected over the six-month campaign and from collaborative verification by geological, engineering and landform design personnel.

Interpretation

Rock strength classification systems utilising Schmidt hammer, point load strength and uniaxial compressive strength (UCS) results have been developed by several authors including Goudie (2006), Hawley and Cunning (2017), Hoek and Brown (1997), AusIMM (1995) and CIRIA, CUR and CETMEF (2007). The classification system used by Hawley and Cunning (2017) in Guidelines for mine waste dump and stockpile design is applicable for categorising waste rock on the slopes of mining waste rock landforms in Australia.

The classification system presented in Hawley and Cunning (2017) utilises the rating system and UCS thresholds listed by Hoek and Brown (1997). This has been adapted further to include point load index (Hoek and Brown, 1997) and Schmidt hammer results (Goudie, 2006).

The modified rock strength classification system presented in Table 1 was applied to the results to provide context and categorise the waste rock sources.

TABLE 1

Rock strength classification system (modified from Hawley and Cunning, 2017).

Type	UCS	Point Load (Is50)	Adjusted Q-Value
5	>250 MPa	>10 MPa	>70
	100-250	4-10	60-70
4	50-100	2-4	50-60
3	25-50	1-2	45-50
2	5-25	0.1-1	30-45
1	1-5	<0.1	20-30
	<1		<20

FINDINGS

The most prospective target rock type on-site was the WHMS. There are two key sources of the WHMS unit: (i) Roxborough pit and (ii) Saddlers pit. The WHMS from both locations was classified as suitable for drain construction by the landform design team.

Weathered WHMS is exposed along the crest of the Roxborough pit (Figure 5). It was drilled and blasted in preparation for recovery and use as durable rock for drain construction. Fresh WHMS will be mined from the Roxborough pit in the coming years. The blasted rock is comprised of large, massive sandstone fragments up to ~2 m in diameter with a relatively low proportion of fines. These larger fragment sizes are reflective of the way the rock on the pit crest was blasted, with more energy being released at surface than in a pit setting.

FIG 5 – Woodland Hill Massive Sandstone from Roxborough pit.

Fresh WHMS was drilled, blasted, loaded, hauled and dumped in a large stockpile at the Saddlers pit (Figure 6). Whilst a smaller fragment size was observed, this is predominantly due to the rock being blasted within a confined pit setting and then undergoing mechanical handling. The blasted rock is comprised of massive sandstone fragments up to ~1.5 m in diameter with a low proportion of fines.

FIG 6 – Woodland Hill Massive Sandstone from Saddlers pit.

Only the results from the key material parameters are presented in this paper including Schmidt hammer, point load, UCS and mineralogy results.

Schmidt hammer results

Schmidt hammer mean Q-values were obtained for transitional to fresh WHMS from the Roxborough pit (113 results) and Saddlers pit (24 results).

Histograms of the mean Q-values for Roxborough and Saddlers pits are presented in Figures 7 and 8 respectively. The histograms show a bimodal distribution of the mean Q-values, with the highest numbers of results within the ranges of 40–50 (Types 2–3) and 65–70 (Type 5).

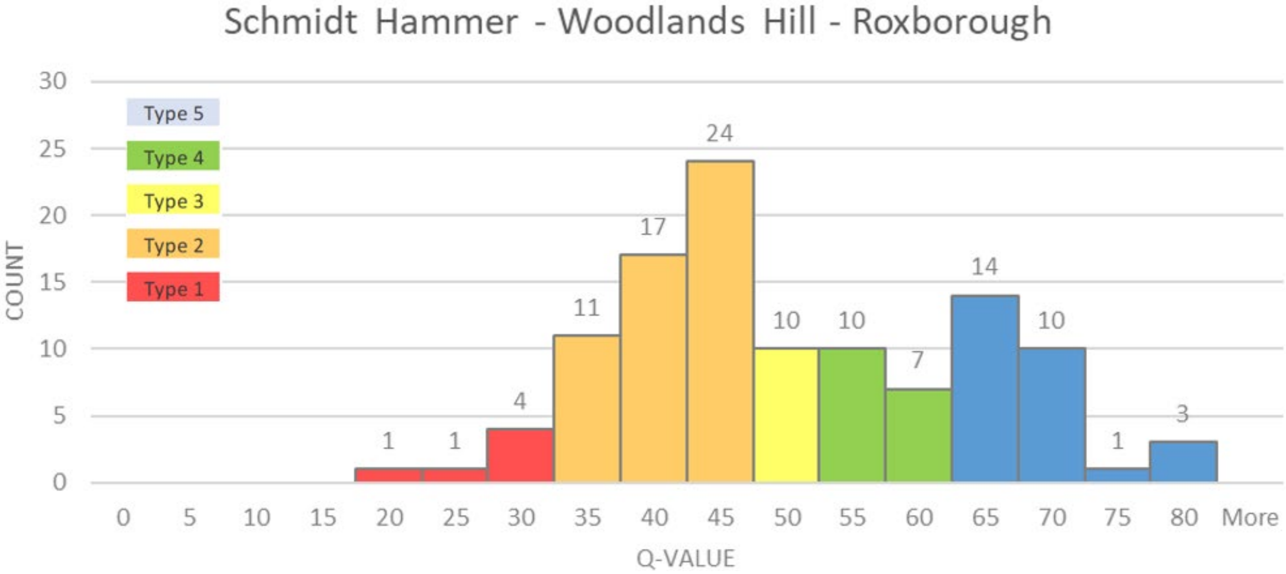

FIG 7 – WHMS mean Q-values for Roxborough pit (colours align with the Hawley and Cunning (2017) classification).

FIG 8 – WHMS mean Q-values for Saddlers pit (colours align with the Hawley and Cunning (2017) classification).

A review of the correlation between the WHMS Schmidt hammer data and the hardness rating assigned by geological hammer hits is presented in Figure 9. The subjective hardness classifications of low, moderate and high, as rated by site personnel, correlate consistently to Q-values of <30 (low), 30–50 (moderate) and >50 (high), and to rock strength Types 1–2 (low), Type 3 (moderate) and Types 4–5 (high). This adds confidence to the use of a geological hammer to quickly and easily rate rock hardness in the field.

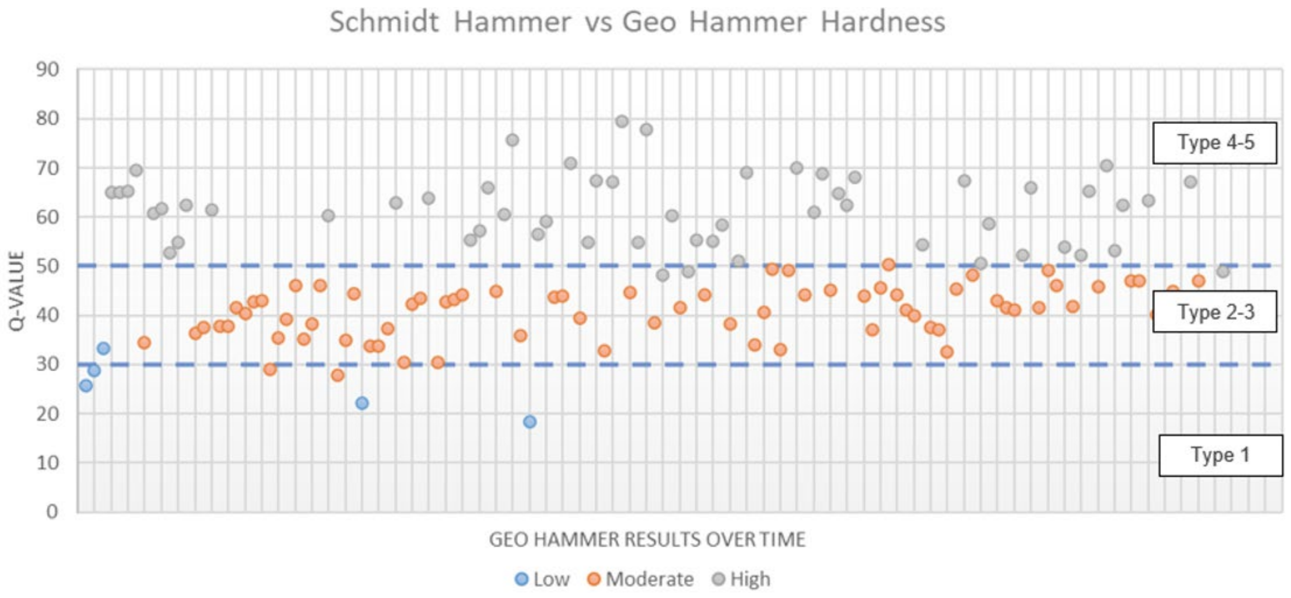

FIG 9 – Correlation of geological hammer hardness ratings with Q-values (Types align with the Hawley and Cunning (2017) classification).

Point load results

From the analysis of the field and drill core samples, point load results were obtained for transitional to fresh WHMS from the Roxborough pit (32 field/5 core) and Saddlers pit (9 field/3 core).

Histograms of the point load results for Roxborough and Saddlers pits are presented in Figures 10 and 11 respectively. Rock strength Types 2–4 are the most prevalent within the point load results, however the results within the Type 5 class can show significantly high point load values (>6 MPa).

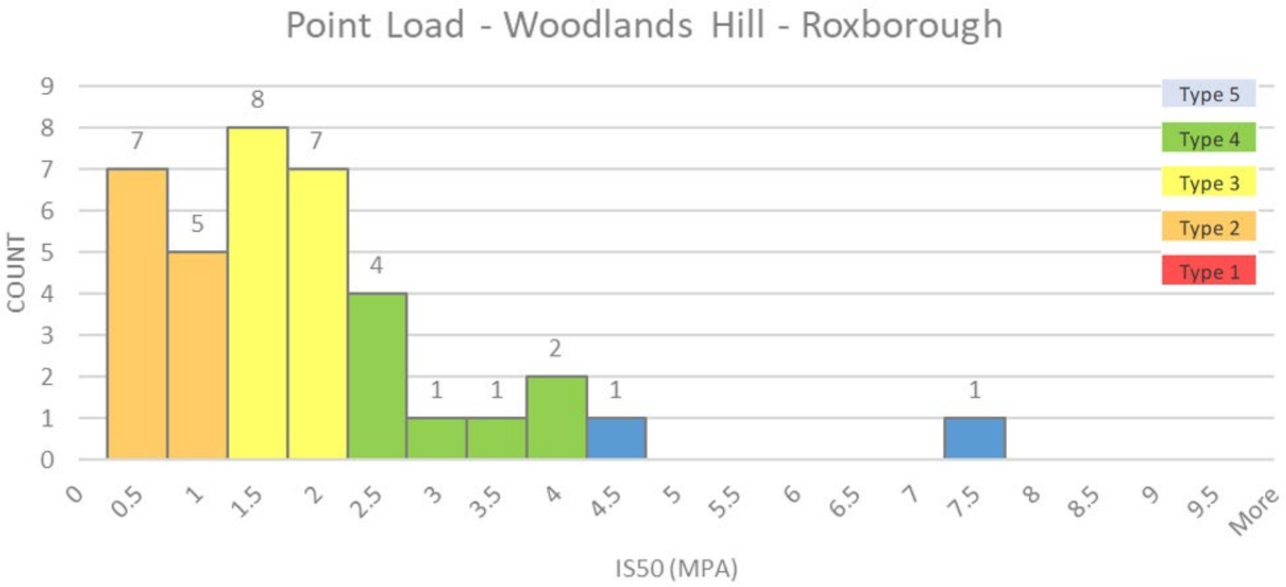

FIG 10 – WHMS point load results for Roxborough Pit.

FIG 11 – WHMS point load results for Saddlers Pit.

UCS results

The UCS data was obtained for transitional to fresh WHMS from the Roxborough pit and Saddlers pit by testing drill core samples.

Histograms of the UCS results for Roxborough and Saddlers pits are presented in Figures 12 and 13 respectively. All UCS results for the drill core samples fall within the Type 3–4 rock strength classes.

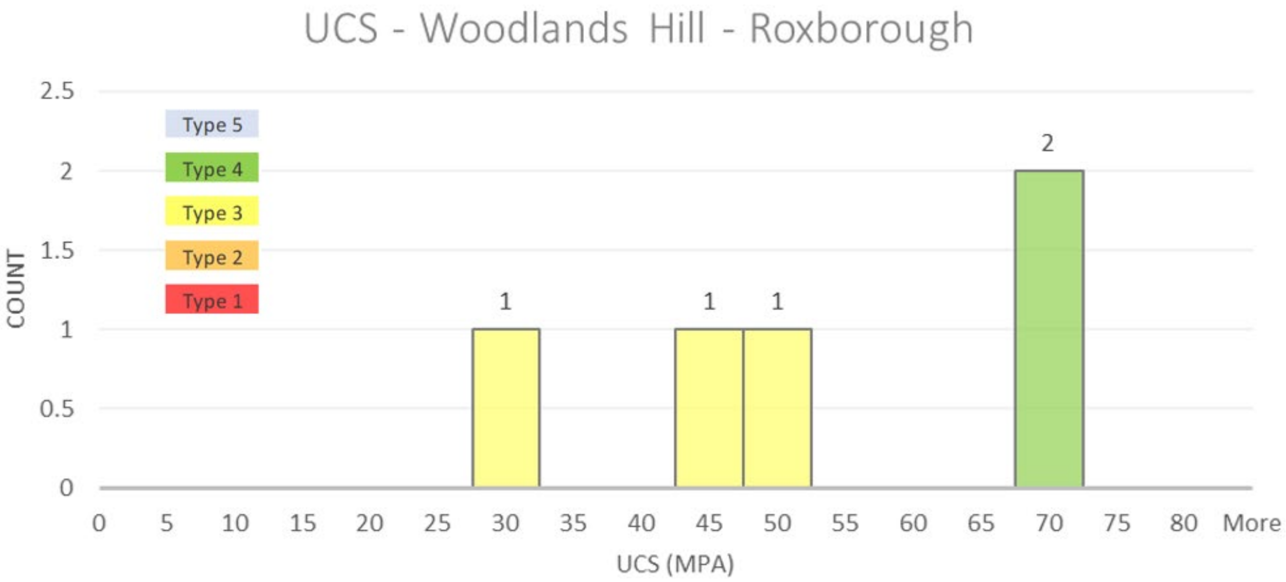

FIG 12 – WHMS UCS results for Roxborough Pit.

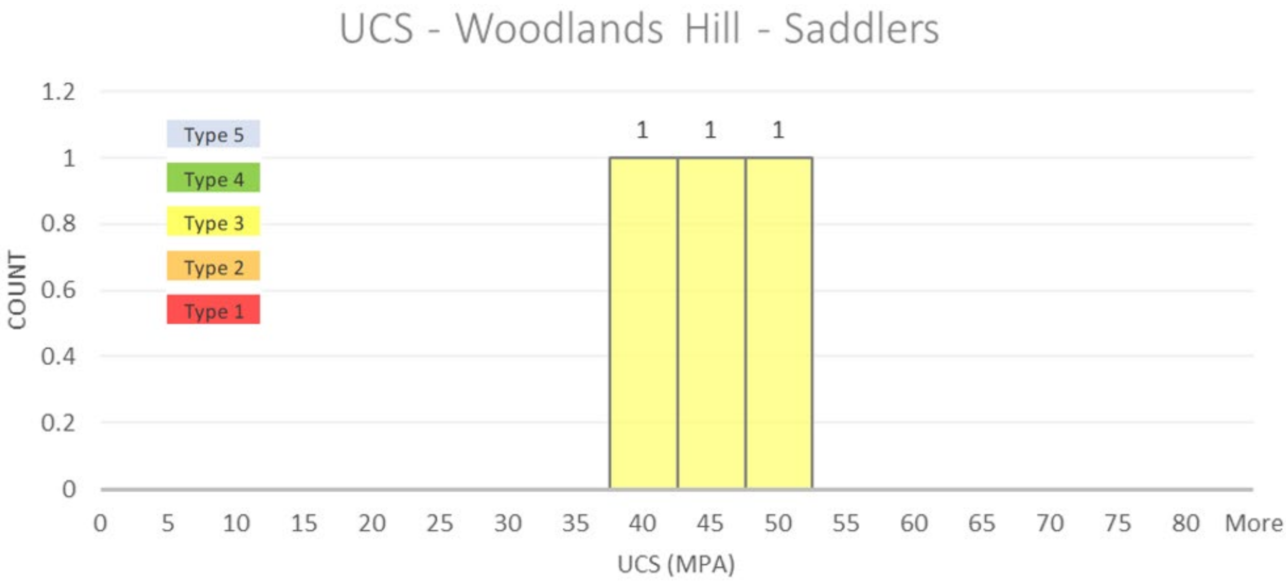

FIG 13 – WHMS UCS results for Saddlers Pit.

Mineralogy results

Mineralogical test work was undertaken on six samples from Roxborough pit and eight samples from Saddlers pit. The samples typically contained dominant quartz grains and a variety of lithic fragments within a matrix of silica, clays and carbonate. All samples were grain-supported, containing >60 per cent sedimentary grains and 6–37 per cent matrix. Photomicrographs of a WHMS sample from Saddlers pit are presented in Figure 14.

Mineral composition provides an indication of rock strength, susceptibility to dissolution and overall erodibility. The dominance of quartz and igneous rock fragments within the tested samples indicates that the granular component of the rocks is both physically and chemically durable. The amount of matrix and the ratio of silica (high durability) to carbonate and clays (low durability) cementing the grains within the sandstones can affect the overall ability of the rocks to resist erosion from weathering, and fragmentation during blasting and mechanical disturbance. When carbonates and clays form a higher proportion of the rock matrix, the durability of the rock structure can be more susceptible to physical and chemical weathering over time, increasing the porosity.

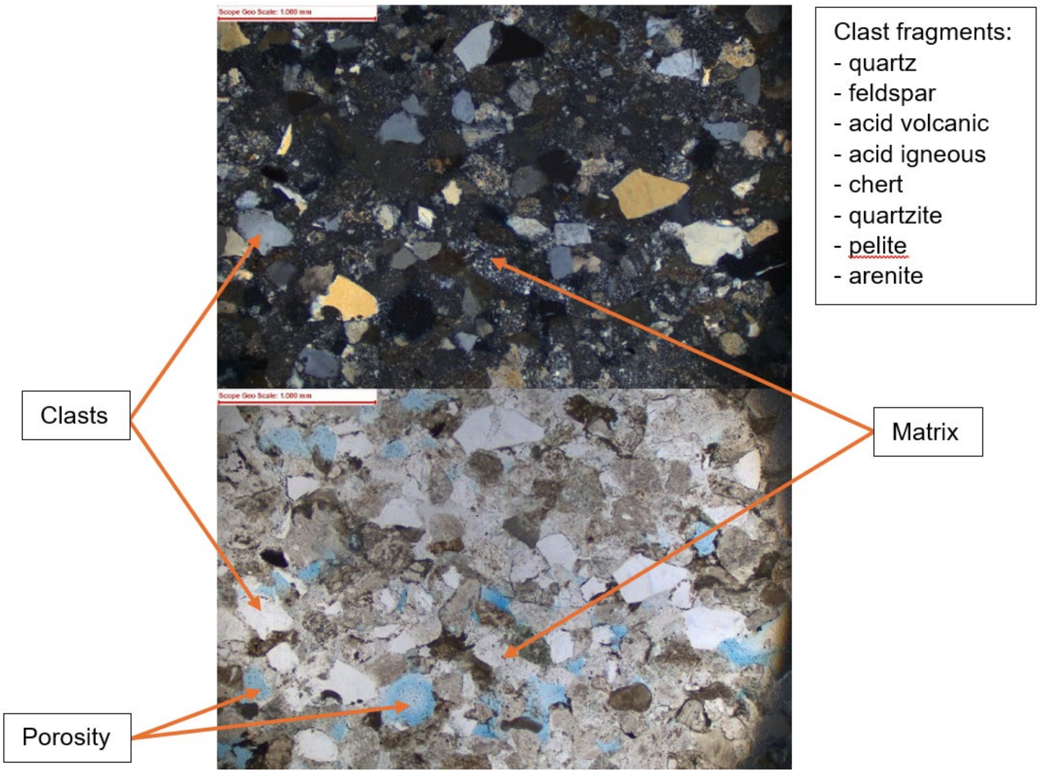

FIG 14 – Photomicrograph of WHMS sample from Saddlers pit.

Inventory

It has been estimated that approximately 1 M BCM of durable rock will be required for rehabilitation purposes on-site. Even with a material recovery factor of 50 per cent, the volume of WHMS available from Roxborough and Saddlers pits (3.3 M BCM) greatly exceeds estimated demand.

CONCLUSION

The WHMS unit is the most abundant, accessible and homogeneous source of durable waste rock available on-site and has been classified as suitable for drain construction by the landform design team.

Results for Schmidt hammer, point load index, UCS, RQD, density, water absorption, porosity and mineralogy were assessed to provide an overall indication of rock strength and durability. A rock strength classification system, modified from Hawley and Cunning (2017), was applied to the results to provide context and help categorise the key waste rock sources.

Importantly, the results showed Schmidt hammer measurements to be a quick and reliable indicator of rock strength in the field.

The Schmidt hammer, point load index, UCS and geological hammer hit results showed that the WHMS from the Roxborough and Saddlers pits was similar in strength:

- The Schmidt hammer results showed a bimodal distribution of mean Q-values with the highest numbers of results between material Types 2–3 (Q-value 40–50) and Type 5 (Q-values 65–70).
- The point load results fell within material Types 2–4 and some within Type 5.
- All UCS results were within the range for material Types 3–4.

From a comprehensive review of the data and from collaborative verification by geological, engineering and landform design personnel, threshold Q-values were developed to distinguish suitable durable rock from non-durable rock in the field:

- Rock strength Type 1 (Q-value <30) material is not suitable for use as durable rock.

- Rock strength Type 2 (Q-value 30–45) material is suitable for general applications where durable rock is required.
- Rock strength Type 3 and above (Q-value >45) material is suitable for applications where the best durable rock is required.

To further develop the data set and improve confidence for defining material thresholds, ongoing data collection will continue.

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