POLICY BRIEF

March 2025
The WRC operates in terms of the Water Research Act (Act 34 of 1971) and its mandate is to support water research and development as well as the building of a sustainable water research capacity in South Africa.

Guidelines for rehabilitating mined land to irrigable standard

A Water Research Commission (WRC) funded project has developed a new guideline to provide support for the successful rehabilitation of mined land to meet irrigable standards; the assessment of the irrigation potential of rehabilitated mine land, and the remediation of sub-optimal areas in irrigated rehabilitated mined land.

Introduction

Managing or treating large volumes of mine water is expensive, and irrigation may be a beneficial, cost-effective option to consider. This enhances food security, and can improve livelihoods of nearby communities, especially post-closure, thereby supporting the Just Energy Transition.

Suitable rehabilitated mined land in close proximity to such waters could be ideal for irrigation, as off-site environmental impacts are expected to be minimal and manageable if return flows accumulate in old pit voids and are contained. However, due to physical limitations, rehabilitated land is generally less favourable than unmined land for crop production.

Technical Guidelines for Irrigation with Mine-Affected Waters (**WRC report no. TT 855/2/21**) and *Guidance for attaining regulatory approval of irrigation as a large-scale sustainable use of mine water* (**WRC report no. TT 837/20**), have been developed to facilitate informed decision-making and to promote the sustainability of this practice. Additionally, *Land Rehabilitation Guidelines for Surface Coal Mines* (LaRSSA 2019) provide guidance on how to rehabilitate mined land. However, guidance is required on how to rehabilitate mined land to irrigable and not just arable standards. Such guidelines should also contain procedures for the assessment of irrigability of rehabilitated land and offer recommendations for remediation of sub-optimal rehabilitated areas.

The *Guidelines for Rehabilitating Mined Land to Irrigable Standard* presented here exclusively consider physical land and soil characteristics, as it is assumed that chemical limitations to crop production, such as soil fertility, are easier to address than physical limitations.

Mine water is often of poor quality, requiring uniform irrigation application to reduce the risk of salinisation in irrigated fields. Due to the high risk of emitter blockage, mine water is unsuitable for micro-irrigation systems. Therefore, these guidelines assume that overhead centre-pivot irrigation, will be the preferred method for using mine water.

These proposed guidelines expand on the LaRSSA 2019 guidelines, and are presented in three sections; SECTION A outlines the requirements for rehabilitation of mined land to irrigable standard, SECTION B presents the assessment of irrigation potential of rehabilitated mined land, and SECTION C recommends remediation approaches for areas of sub-optimal irrigability in rehabilitated mined land.

Although the development of all three sections have been guided by established and recognised practices or standards, the development of the Rehab Irrigation Suitability (RIS) assessment model presented in section B, is novel, and is the main section that will be discussed here.

Approach

These guidelines stress the need to carefully follow the LaRSSA 2019 mine land rehabilitation guidelines to improve the chances of rehabilitating land to irrigable standard. This requires correct placement of suitable soil materials to sufficient depth, and the minimisation of compaction. Factors rendering rehabilitated mined land unsuitable for irrigation include poor surface drainage due to subsidence and low infiltrability, causing ponding, and poor internal profile drainage, causing water logging and salinisation.

WATER RESEARCH COMMISSION

Developing the Rehab Irrigation Suitability (RIS) model

The Rehab Irrigation Suitability (RIS) assessment procedure was developed by integrating the evaluation criteria of physical land and soil factors from commonly used quantitative land suitability models which evaluate the suitability of natural land for irrigation, including the Storie Index and the Parametric Model.

The RIS model evaluates six physical land and soil factors that often render rehabilitated mined land unfit for irrigation. These include: position in the landscape (PL); slope (S); depressions (Dep); infiltrability (IB); permeability or drainage rate (Perm) and water holding capacity (WHC).

Due to the expected high spatial variability of rehabilitated mined land, a 50 x 50 m sampling grid is advised at which to evaluate each of the six parameters in the desired sampling area. In-field measurements are compared to parameter-specific criteria and rated from "Ideal" to "Unacceptable". The overall irrigability class (Table 1) of an area is determined by the factor expected to most limit sustainable production. This classification system was adapted from the *Irrigation Water Quality Decision Support System* (IrrigWQ-DSS) (TT 727/17), as it was considered simple, intuitive, and suitable for these guidelines.

Table 1: Irrigability classes of the Rehab Irrigation Suitability (RIS) model.

Irrigability class	Description
Ideal	High irrigation potential
Acceptable	Irrigable, with occasional yield penalty expected
Tolerable	Irrigable, but continuous yield penalty expected
Unacceptable	Serious yield limitations, irrigation not recommended

The importance of each of the six assessment factors as well as their respective assessment criteria are presented.

Position in the landscape (PL)

Areas intended for irrigation should not be situated in low-lying areas such as floodplains, which may become waterlogged and unproductive due to surface flooding after heavy rainfall. Furthermore, infiltration, erosion and sedimentation vary based on slope position. Consequently, irrigated areas on slopes, especially those situated on backslope and toeslope regions (Figure 1) may require up-slope drainage channels to prevent surface flow, erosion and sediment deposition, which may compromise the irrigated area.

Ideally, the summit is the preferred area for irrigation, as it is expected to have more suitable infiltration, minimal sedimentation and erosion risks, subsequently requiring minimal, if any controls to reduce off-site environmental impacts.

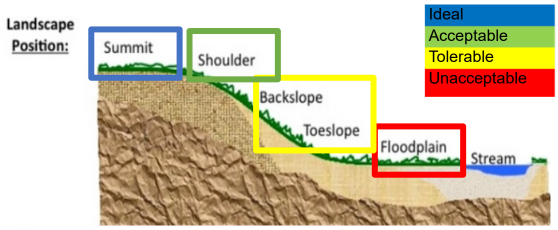


Figure 1: Illustration of different slope positions.

Slope gradient (S)

When irrigating field crops with mine waters which are often saline, fields should be relatively flat (< 2%) to promote uniform distribution of irrigation water. However, the LaRSSA (2019) guidelines recommend a minimum slope of 1% to ensure effective surface drainage, preventing waterlogging and maintaining productivity in areas where subsidence or depressions may form.

Table 2 presents the RIS assessment criteria of slope gradient (%), which was adapted from the Storie Index and the Parametric Model. Moderate slopes (8-12%) were considered 'Tolerable' and steep slopes (>12%) 'Unacceptable'. These steeper slopes pose a higher risk of erosion and surface runoff.

Table 2: Assessment criteria of slope gradient (%).

Slope gradient (%)			
Ideal	Acceptable	Tolerable	Unacceptable
<2%	2 – 8%	8 – 12%	>12%

Micro-relief or depressions (Dep)

Micro-relief is typically not of concern after land levelling, however, incorrectly constructed rehabilitated land is susceptible to secondary subsidence. The resettling of replaced material results in the formation of depressions which are often poorly drained, prone to waterlogging and salt build-up, making them unproductive under irrigation.

The risk of a depression becoming unproductive will depend on the likelihood of ponding, which is influenced by run-on, surface drainage or runoff, infiltrability and permeability. Determining both the presence of depressions, as well as the severity of ponding (Table 3), aids in better evaluating the potential risk of a depressed area becoming unproductive.

Table 3: Assessment criteria of the occurrence and severity of depressions within a rehabilitated landscape.

Occurrence and severity of depression			
Ideal	Acceptable	Tolerable	Unacceptable
No depression	Slight depression	Medium depression	Large depression

Slight depression – Low risk of ponding and limited expected loss of productivity.
Medium depression – Moderate risk of ponding which may result in loss of productivity.
Large depression – High risk of ponding, where irrigation will most likely be unsuccessful.

Infiltrability (IB)
Surface soil texture, surface compaction and soil crusting will influence infiltrability, the potential rate at which water can enter the soil profile. It is important that only the top 5 cm of the profile is assessed for infiltrability. The measured hydraulic conductivity ranges for Infiltrability assessment criteria (Table 4), were based on the ***South African Irrigation Institute's*** (SABI) ideal surface infiltration rates of greater than 150 mm/h, specifically for centre pivot irrigation.

Permeability (Perm)
Permeability or internal drainage, on the other hand, is the rate water can pass through the profile and beyond the rooting zone. Poor permeability may be due to restrictive layers within the rehabilitated profile such as compacted material and stratified layers with textural contrasts (Rethman 2006). For profile permeability, textural changes down the profile are assessed, with the lowest permeability class considered the limiting layer.

For Permeability (Table 5), the minimum natural soil drainage rates of greater than 2.5 mm/h recommended by the *Technical Guidelines for irrigation Suitability Land Classification* of which were adjusted to rates exceeding 5 mm/h, to ensure free draining rehabilitated land irrigated with poor quality mine waters.

Table 4: Assessment criteria for infiltrability of the surface.

Infiltrability (mm/h)				
	Ideal	Acceptable	Tolerable	Unacceptable
Hydraulic conductivity (mm/h)	> 150 mm/h	60 – 150 mm/h	5 – 60 mm/h	< 5 mm/h
Soil texture (% clay)	Coarse sand (< 5%)	Loamy sand, sandy loam (5 – 20%)	Loam*, silt loam*, silt*, sandy clay loam, clay loam, silty clay loam, sandy clay* (20 – 40%)	Silty clay, clay (> 40%)

Note: * indicates soil textures which do not strictly correlate with the clay % range specified per class.
Description: "Ideal" – Very rapid, "Acceptable" – rapid, "Tolerable" – moderate, "Unacceptable" – slow

Table 5: Assessment criteria of permeability of the most limiting layer.

Permeability in mm/h of limiting layer				
	Ideal	Acceptable	Tolerable	Unacceptable
Hydraulic conductivity (mm/h)	> 50 mm/h	20 – 50 mm/h	5 – 20 mm/h	< 5 mm/h
Soil texture (% clay)	Sand, loamy sand, sandy loam* (< 10%)	Loam*, silt loam*, Sandy clay* (10 – 20%)	Silt*, clay loam, silty clay loam, sandy clay loam, (20 – 40%)	Silty clay, clay (> 40%)
Note: * indicates soil textures which do not strictly correlate with the clay % range specified.				

Using permeameters to measure hydraulic conductivity is time-consuming. A more convenient, albeit less accurate approach, involves estimating hydraulic conductivity from soil texture (Table 5). The LaRSSA 2019 guidelines assess bulk densities of various soil textures to identify levels that restrict root penetration, using this as a proxy for compaction induced impermeability.

Water holding capacity (WHC)

Water holding capacity depends on effective soil depth and the soil's ability to retain water. An approximation of WHC is often only related to effective soil depth. However, the WHC of a specific soil will be largely influenced by its soil texture. Sandy soils can often hold only 40 mm available water per metre soil, while clayey soils easily hold 150 mm/m. Therefore, sandy soils need to be deeper than clayey soils to hold the equivalent amount of water.

Despite irrigated agriculture relying less on rainfall than is the case for dryland production, the profile still requires enough soil material over spoil to store sufficient water for the crop between irrigation cycles, as well as to reduce the risk of crop water stress during periods when breakdowns occur.

Plant Available Water (PAW) is the water held between field capacity (FC) and wilting point (WP). FC is the upper limit where drainage is negligible, while WP is the lower limit, below which plants cannot extract water. As a rule of thumb, for optimal production under irrigation, no more than half of PAW should be depleted. This is known as Readily Available Water (RAW). Approximate PAW and RAW requirements for various irrigability classes assume that a full cover crop under hot, dry conditions, should be able to sustain optimal growth with a weekly irrigation interval. From these PAW and RAW thresholds, together with available water contents of specific soil textures (% clay), one can predict the irrigation potential class from effective soil depth and texture, as seen in Table 6.

Table 6: Soil depths (m) of different texture materials (% clay) to meet specific irrigability class requirements for provision of Readily Available Water.

Soil depth (m) relative to % clay						
	% Clay				Available Water (mm)	
	< 5%	5 – 10%	10 – 20%	20 – 40%	PAW	RAW
Ideal	> 2.5 m	> 1.25 m	> 0.80 m	> 0.66 m	> 100	> 50
Acceptable	1.5 – 2.5 m	0.75 – 1.25 m	0.5 – 0.80 m	0.4 – 0.66 m	60 – 100	30 – 50
Tolerable	0.75 – 1.5 m	0.37 – 0.75 m	0.25 – 0.5 m	0.2 – 0.4 m	30 – 60	15 – 30
Unacceptable	< 0.75 m	< 0.37 m	< 0.25 m	< 0.2 m	< 30	< 15
Assuming the profile is irrigated to field capacity, under hot dry conditions with a full canopy cover: **Ideal:** Profile can provide readily available water to the crop for a week without irrigation **Acceptable:** Crop should remain productive for at least 5 – 7 days before irrigation is needed **Tolerable:** Full cover crop will need irrigation every 3 to 5 days in hot dry weather **Unacceptable:** Profile will need to be irrigated at intervals of less than 3 days in hot dry weather						

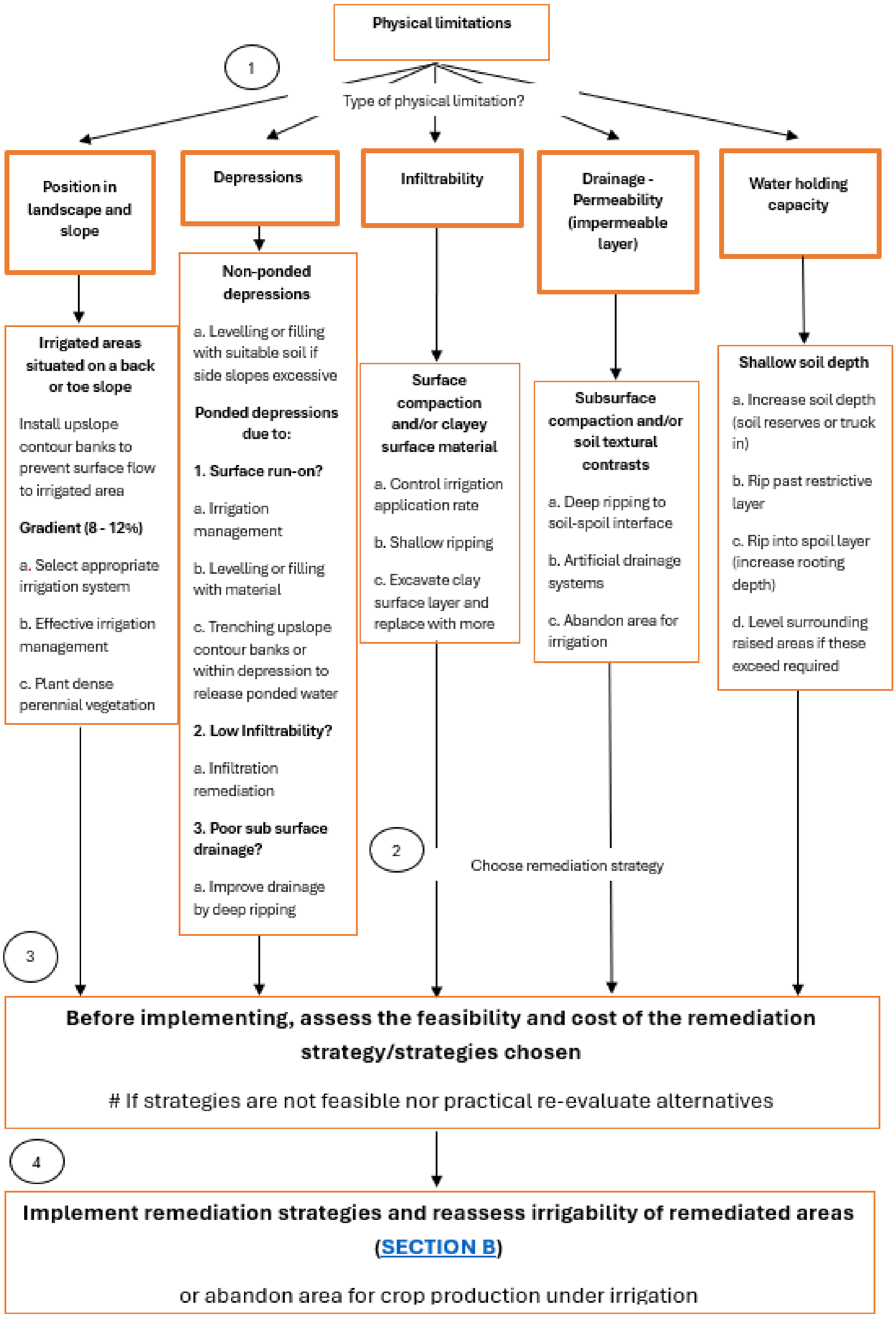
Although not included here, rehabilitated areas, may have underlying spoil material that is permeable, uncompacted and chemically suitable for root growth. This can contribute significantly to PAW, and is especially important for profiles with limited soil cover.

Remediation strategies to improve the irrigability of sub-optimal rehabilitated mined land

The guideline's final section recommends remediation actions to improve rehabilitated land with low or unsuitable irrigation potential, as identified by the RIS model. Common remediation strategies are highlighted in the tree diagram below.

Table 7: Remedial recommendations to improve sub-optimal rehabilitated mined land.

Type of physical limitation	Remedial action recommendations
Position in landscape and slope	Levelling slopes greater than 12% is impractical, while slopes of 8–12% need proper irrigation systems, management, and dense perennial ground cover. Gentler slopes (2–8%), especially those with poor infiltration and erosion risks (areas on backslope to toeslope regions), may require contour ridging and upslope drainage to manage run-on and runoff and prevent sediment accumulation.
Depressions	Determine whether ponding is due to surface run-on, poor infiltration or poor drainage. If ponded due to poor infiltration and drainage, refer to respective sections. If filling and reshaping are not feasible, consider creating an outflow for excess water to drain, ensuring erosion is avoided.
Infiltrability	Soil infiltration issues caused by crusting, compaction, or clayey surfaces can be improved by adding organic matter to low-carbon soils, gypsum to sodic soils, and shallow cultivation or ripping to enhance structure and water retention. Ensure irrigation rates meet the soil's infiltration capacity, while impermeable clay material should be removed and replaced with permeable material.
Drainage -Permeability (impermeable layer)	Poor drainage from impermeable layers can be addressed by deep ripping into the soil-spoil interface or installing artificial drainage systems. If these are infeasible, alternative options include planting on ridges or using waterlogging-tolerant species like tall fescue.
Water holding capacity	For areas with restrictive subsurface layers or shallow soil, deep ripping beyond the restrictive layer or 300 mm past the soil-spoil interface enhances root and water movement. If ineffective, additional soil may be required and levelled.



The decision tree above guides the user in determining the potential limitation(s) of sub-optimal irrigable areas and recommend applicable remediation strategies.

Application

Rehabilitating mined land to an irrigable standard from the outset is ideal, allowing for strategic site selection and suitable soil placement. However, many mines that need to manage water surplus have already rehabilitated land to different standards and must assess its suitability for irrigation using mine water. These guidelines present the six-factor Rehab Irrigation Suitability (RIS) model.

To illustrate how the Rehab Irrigation Suitability (RIS) index is assigned, an example is given. Once a sampling point has been evaluated, the assessor would have scored (circled in black) all six parameters, as indicated in Figure 2.

After completing the assessment for each of the sampling points on the 50 x 50 m grid, each sample location will be allocated an irrigability class, Ideal, Acceptable, Tolerable or Unacceptable.

The assigned irrigability classes can be displayed as digital maps for each of the six factors assessed or as an overall Irrigation Potential/RIS map (Figure 3) for a rehabilitated area. This map will identify suboptimal areas requiring remediation or, if the extent of area not suitable for irrigation or cost of remediation is too great, for locating areas more suitable for irrigation.

Sample no: E 12			Co-ordinates: 25°47'26.09"S 29°46'8.86"E	
Land Characteristic	Ideal	Acceptable	Tolerable	Unacceptable
Position in the landscape	Summit	Between Shoulder and Backslope	Between Backslope and Toeslope	Floodplain
Slope (%)	< 2%	2 – 8%	8 – 12%	> 12%
Depression	No depression	Slight depression	Medium depression	Large depression
Infiltrability (mm/h)	> 150	60 – 150	5 – 60	< 5
Soil surface texture (% clay)	Coarse sand (< 5%)	Loamy sand, sandy loam (5 – 20%)	Loam*, silt loam*, silt*, sandy clay loam, clay loam, silty clay loam, sandy clay* (20 – 40%)	Silty clay, clay (> 40%)
Permeability (mm/h)	> 50	20 – 50	5 – 20	< 5
Soil texture (% clay)	Sand, loamy sand, sandy loam (< 10%)	Loam*, silt loam*, sandy loam* (10 – 20%)	Silt*, clay loam, silty clay loam, sandy clay loam (20 – 40%)	Silty clay, clay (> 40%)
WHC/PAW	> 100 mm	60 – 100 mm	30 – 60 mm	< 30 mm

Augured depths (cm)	Layer thickness (m)	Textural estimate (% clay)	PAW (mm water)	
0 – 30 cm	0.3 m	Clay loam (20 - 40%)	150 mm/m x 0.3 = 45 mm	
30 – 55 cm	0.25 m	Silt loam (10 - 20 %)	120 mm /m x 0.25 = 30 mm	
55 – 80 cm	0.25 m	Sandy clay loam (20 - 40 %)	150 mm/m x 0.25 = 37 mm	
Total depth	0.8 m	Cumulative PAW	112 mm	WHC class: Ideal

RIS index	PL/S/Dep/IB/Perm/WHC	Irrigability class	Unacceptable

Figure 2: An illustration of how the RIS index is assigned.

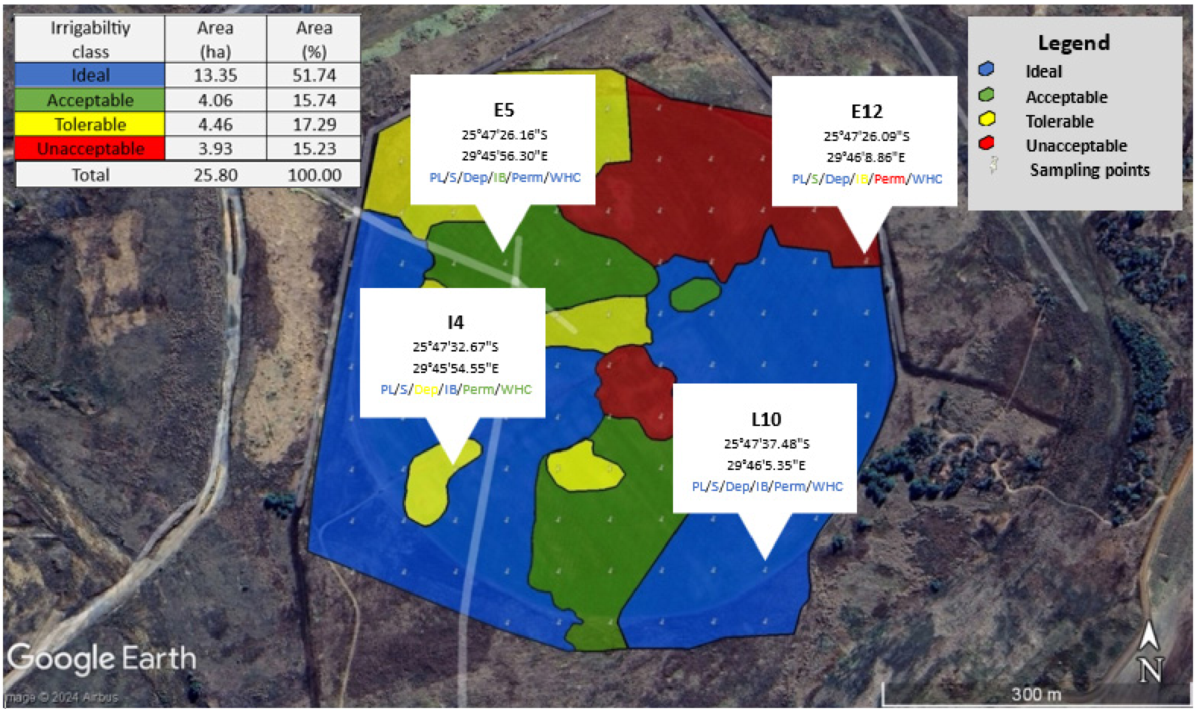


Figure 3: Example of a Rehab Irrigation Suitability (RIS) map.

Conclusion

These draft guidelines aim to support the rehabilitation of open-cast mined land to irrigable standards, assess irrigation potential, assist with site selection, and offer guidance on improving sub-optimal sites for sustainable irrigation. Future fieldwork will assess the guidelines' validity and practicality, allowing for necessary refinements.

Related project:
Guidelines for rehabilitating mined land to irrigable standard (**WRC project no. C2021/2023-00555**). For more information, contact WRC research manager, Dr John Ngoni Zvimba, email: johnz@wrc.org.za.