Earth Science Solutions

Stonecap Trading 14 (Pty) Ltd

Our Ref: MEE.LHP.S.09.03.020
Your Ref: M009-03 (Order - 1173)

10th October 2010

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Attention: Ms. Joanna Goeller'

Re: Swakop Uranium Husab Uranium Project
Specialist Soils and Land Capability Assessment

Dear Joanna,

In line with the Terms of Reference supplied under your project number M009-03 (Order No. 1170 dated 27th July 2009), and discussions had with the Metago team regarding the soils and land capability assessments required and proposed for the Swakop Uranium Husab Uranium Project, the following draft report detailing the findings of the site investigation, and the results is tabled for your comment.

Should you require any additional information in this regard, please do not hesitate to contact us.

Yours sincerely
Earth Science Solutions (Pty) Ltd

Ian Jones B.Sc.(Geol) Pr.Sci.Nat (400040/08). EAP Certified
Director

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Swakop Uranium Husab Project

SPECIALIST SOILS AND LAND CAPABILITY STUDIES

Draft Report v1.9

Compiled By

ESS Earth Science Solutions

For

metago Environmental Engineers (Pty) Ltd

October 2010

CLIENT: Metago Environmental Engineers (Pty) Ltd
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Client: **Swakop Uranium Husab Project**

Attention: **Joanna Goeller/Brandon Stobart**

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Author	Ian Jones	Director		10th October 2010
Project Director	Brandon Stobart	EAP		
Technical Review	Joanna Goeller	Environmental Scientist		

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Declaration

This specialist report has been compiled in terms of the Namibian Environmental legislation and forms part of the overall impact assessment, both as a standalone document and as supporting information to the overall impact assessment and management plan for the proposed development.

The specialist Pedological and Land Capability studies where managed and signed off by Ian Jones (Pr. Sci Nat 400040/08), an Earth Scientist with 32 years of experience in these fields of expertise.

I declare that both, Ian Jones, and Earth Science Solutions (Pty) Ltd are totally independent in this process, and have no vested interest in the project.

The objectives of the study were to:

- ❖ Provide a permanent record of the present soil resources in the area that are potentially going to be affected by the proposed development and processing/mining related activities,
- ❖ Assess the nature of the site in relation to the overall environment and its present and proposed utilization, and determine the capability of the land in terms of agricultural utilization, and
- ❖ Provide a base plan from which long-term ecological and environmental decisions can be made, impacts of the proposed development can be determined, and mitigation and rehabilitation management plans can be formulated.

The Taxonomic Soil Classification System and a combination of the Canadian Land Inventory System and Chamber of Mines Land Capability Rating Systems were used as the basis for the soils and land capability investigations respectively. These systems are recognized nationally and internationally.

<u>Signed</u>: 10th October 2010 at Nelspruit

Ian Jones B.Sc. (Geol) Pr.Sci.Nat 400040/08, EAP Certified
Director – Earth Science Solutions (Pty) Ltd

EXECUTIVE SUMMARY

Soils and Land Capability Assessment:

The proposed Swakop Uranium Husab Project is planned as open pit mining operation, and is being planned to exploit the resource at depth. The uranium mineralisation is hosted by a series of semi-conformable alkali feldspar granitic and pegmatitic dykes, intruding schists, quartzites and calc-silicate rocks that make up part of the Swakop Uranium Husab Formation. Lithological units including quartz-diopside calc-silicate units and quartz-biotite schists make up additional minor components of the mineralized strata included in the Swakop Uranium Husab South deposit. The mineralized zones are arranged around the limbs of local dome structures cored by amphibole and pyroxene bearing gneiss of the Khan Formation (Nosib Group) – Refer to Figure 2 – Regional Geology.

The proposed mining process will be undertaken using a conventional truck and shovel methodology with bench mining as the basis for the raw materials extraction. There will be no backfill of the open pit structures, and all overburden (soft cover) will be stockpiled as part of the co-disposal of waste rock and tailings. These areas (Tailings and Waste Rock) will be engineered to stable dumps.

The main components of this greenfields project include:

- The completion of the exploration programme;
- The open pit operations associated with Zone 1 and Zone 2;
- The construction of the Co-Disposal (Tailings Storage Facility and Waste Rock Dump)
- The construction of a mine workshop;
- The construction of a Processing Plant/Facility inclusive of a crushing and sizing facility and concentrator section;
- The construction of laydown areas/pads for the utilizable soil stockpiles;
- The construction of access roads and haulage ways/conveyer routes;

In addition, there will be associated facilities and operations servicing the processing facilities including a full and integrated storm water (clean and dirty water) management facility, dust management, and the monitoring of water and dust around areas of soil disturbance and rehabilitation sites.

The study was undertaken on two differing scales and intensity of investigation, with more detail studies undertaken over the areas proposed for open pit mining (Zones 1 and Zone 2), Plant Site and associated facilities, Tailings Storage Facility and Waste Rock Dump, and a semi detailed to reconnaissance scale study of the areas that will be less affected (lower impact) by the project including the access and haulage ways etc.

The powerline and main access route was mapped as an addition to the original scope of work, and has been included as part of a separate and stand alone report.

Of importance to the development of any project is the understanding of the sustainability of the project, and the degree to which the impacts of the operation or development can be mitigated.

An understanding of the baseline conditions is paramount to any operation if rehabilitation is to meet the minimum criteria and obtain a stable and stand alone state at closure.

The findings of the baseline study will be used to not only obtain an understanding of what will need to be removed and what will be stockpiled and saved during the construction and operational phases of the project, but is essential in formulating a plan for the possible reinstatement of materials in closing the project. This is specifically important to the Swakop Uranium Husab situation due to the fine balance in the ecological systems (water, soil, vegetation and their affect on the animal life) that prevail in the desert environment.

Taking this into account, and with an understanding of the impacts that this overall mining plan/method could have on the environment, it was imperative that a full understanding of the environment that is to be disturbed and affected was obtained prior to the implementation of any mining or mining related activities taking place. In addition to the mining to be undertaken, there will be a number of surface features/structures that will impact on the environment (both physical and social), which will need to be assessed and mitigated.

Apart from the more obvious environmental studies (Fauna and Flora, Surface Water etc.) that need to be undertaken prior to the implementation of a new development, it has become increasingly apparent that the soils need to be investigated in detail if a comprehensive base line of information is to be available for future reference and the materials are to be used in a sustainable manner through the operational phase and into rehabilitation. In compliance with the local environmental legislation (still in draft), a comprehensive pedological investigation at various scales (depending on the degree of disturbance to be implemented), coupled with an interpretation, and understanding of the land capability for the area to be disturbed has been undertaken as part of the overall Environmental Impact Assessment, and Environmental Management Programme for the Swakop Uranium Husab South Project.

In general terms, the survey area can be described as being characterised by moderately shallow to shallow and highly sensitive soils that overlie an evaporate layer of varying thickness and density (calcrete) that occurs above the host rock geology. The in-situ soils derived from the host rocks are intricately interspersed with windblown desert sands forming a set of soil forms and families which are unique to this environment (desert) and which will require careful management.

The current land capability is rated as wilderness or very low intensity grazing land on the S.A. Chamber of Mines Guidelines (1991), with conservation/wilderness the preferred land use option for the area.

The unique climatic conditions (low rainfall, high evaporation and coastal fogs) that reach inland as far as the Swakop Uranium Husab project area and the resultant unique pedogenetic characteristics that result from the interaction of these variables, are all important to the ecological cycle and sustainability of the overall eco-system.

Of great importance to the area is the presence and existence of "evaporites", both as a surface capping and as restrictive horizons within the pedological profile ("C" horizon at the base of the soil profile). These features have been highlighted as important to the pre-mining baseline conditions, and will be analysed in more detail as part of the impact and management requirements.

Successful rehabilitation of these sensitive soils and underlying materials will require significant management and engineering input if they are to sustainably support the sensitive vegetative cover and ecosystems that typify the area at present.

It is important that the findings of this specialist study are read in conjunction with the biodiversity studies and ecological baseline assessments if the long term "End Land Use" is to be understood, and a viable rehabilitation plan developed.

In summary, the findings of the soil study for the proposed Swakop Uranium Husab Project are as follows:

The major soil types encountered include those of the orthic phase Augrabies, Prieska, Trawal, Coega, Montagu, Addo, Etosha/Clovelly, Oakleaf, Dundee, Mispah and Glenrosa.

The land capability (soils, climate, ground roughness etc.) ranges from very low intensity (poor quality) grazing lands with no significant economic potential, to highly sensitive wilderness and conservation status lands.

The soils are associated with an evaporite layer (calcrete) either at surface and/or at a moderately shallow depth. These layers are significant to the ecological balance of the desert environment.

Physical Characteristics

- Where present, the evaporite crusting on surface is moderately thin (100mm to 300mm) and is associated with the accumulation of salts that precipitate out from the evaporation of the "sea mist" that falls onto the desert plains along the west coast during the early hours of most days. This very unique system is distinctive to a strip of land that extends inland from the coast for approximately 80km to 100km, and is associated with the cold ocean currents. The effects on, and resulting pedological features that occur as a result of the "mists" have a marked impact on the very sensitive bio-diversity of the area;
- Topsoil clay percentages range from as low as 2% to more than 18% depending on the host/parent geology from which they are derived, and their position in the landscape/topography;
- Subsoil clays that range from less than 06% to 20%;
- Very high infiltration/permeability rates are associated with the sandy loams and gravels of the ephemeral channels (washes) and deeper sands;
- Moderate to high in-situ permeability rates on the more clay rich loams and sandy clay loams associated with the shallow soils and materials associated with the calcrete horizon;
- A significant and impermeable calcrete (evaporite) as the "C" horizon to many of the pedological profiles mapped;
- Moderate to good intake (infiltration) rates, depending on the type of clay present,
- Moderate to poor water holding capacities, and
- Poor to very poor and unsuitable agricultural potential ratings (nutrient status).

The physical characteristics are highly influenced by the parent materials from which the soils are derived, as well as their relative position in the topography, all be it that a significant percentage of the soils that are likely to be disturbed are associated with the desert plains and "outwash" zones (colluvial and/or alluvial deposits) within the alluvial floodplain, all of which are relatively young in pedological age, and are the product of the various geologies that make up the area of study.

The in-situ soils that occur on the desert plains are very sensitive to wind and water erosion, and have a significantly shallower rooting depth (on average) than the alluvial soils, with a large proportion of the site being less than 400mm in depth, and significantly large areas of outcropping geology outside of the outwash valleys.

The structure of the soils varies from very loose and single grained structure for the majority of the alluvial sediments and colluvial derived materials, to apedel, and in isolated instances weak crumby structures on the more silty loams and clay loams that form the in-situ derived materials associated with the host rock (schists) and calcareous subsoils.

The extremely dry and hot environment and associated formation of evaporates at shallow depths has resulted in the accumulation of salts and associated clay minerals as inhibiting and restrictive layers on surface (desert plains) and within the soil profile. In addition, the highly variable size fraction of the materials that make up the soil profile (silt and fine sand inter-layered and bedded with pebbles and cobble size material) of the ephemeral channels is significant in the pedogenisis and resultant variation in soil forms mapped. The Prieska and Augrabies Forms are symptomatic of the arid environment typified by extremely high evaporation rates and low rainfall.

The low organic carbon, moderately low to very low clay contents and relatively shallow/slight topographic gradients associated with the study area (not the mountain ranges of the Khan Valley) and flat to undulating terrain that makes up the study area are responsible for the relatively low erosion indices, while the geological structure and chemical composition of the parent materials result in a complex of transported materials that form the open plain deposits and colluvial/alluvial materials associated with the ephemeral channels (outwashes) and water ways, that make up the complex geomorphology of the site.

While compaction is a concern to be noted and managed in the natural environment, it is of greater consequence to the successful implementation of any rehabilitation plan, but has been assessed as part of the baseline study for the sake of completeness. The variable grain size of the materials will, when mixed and/or disturbed, result in a compaction index that is significantly altered form the natural conditions.

The moderately complex nature of the geology (physical and chemical) and geomorphology of the area added to the attitude (dip and strike) of the lithological units and the extremes of climate (moderate to strong winds and freeze and thaw), all play a significant role in the soil forming process. The grain size variation and distribution (cycles of deposition) are important factors noted in the baseline soil study and profile classification. These factors are noted specifically in terms of their local significance, but more specifically their role in any rehabilitation planning for the future.

Storage of the relatively more nutrient rich “topsoil” and utilizable subsoil will be imperative if any rehabilitation is to be successful, while the “calcrete” (evaporate) layer that has to all intents and purposes formed the underlying impermeable layer and the source of shallow water within the ephemeral channels (washes) will need to be recognised as a fundamental contributor to the success of the ecological balance in the area (accessible water stored in the sands). The occurrence and formation of a relatively thin (<300mm) surface layer or crusting in some places is not well understood, and its function within the ecological and biophysical sustainability is a debate within the specialist fraternity, but is known to be associated with the “mists” that flow in from the cold Atlantic ocean and deposit significant quantities of fresh water to the area. It is believed that the evaporation of these waters leaves salt accumulations on surface – thus forming a crust of calcium and sodium rich salts at surface.

Chemical Characteristics

The chemistry of the soils is typical of the weathered product of the surrounding geology and upstream environs (Feldspathic quartzites, mica schists, calc silicates and red granites), with a mixture of alluvial derived materials that are part of the active outwash environs, with high levels of movement of suspended solids and soluble materials within the profile, with contrasting colluvial derived materials that show accumulation of clays and concentrations of nutrient rich materials.

In terms of the land capability rating, the soils returned lower than average nutrient levels, with slightly better reserves of the basic growth requirements associated with the colluvial and in-situ materials that are more commonly associated with the outwashes.

These soils are characteristically:

- Slightly alkaline in pH, with a range of between 8.10 and 8.75;
- Higher than average amounts of calcium and sodium;
- Lower than required quantities of magnesium and zinc, copper, potassium and aluminium;
- Adequate reserves of phosphorus;
- Extremely low clay contents (<6%), and
- Very low organic carbon (0.07 – 0.17 C%)

As a result, these soils require significant amounts of some nutrients as additives/input if they are to be used as a growing medium (rehabilitation). Grazing of wild animals (game) on a very low stocking density could be considered, and is the primary activity of the area in its natural state.

The impact of development on the soils and the resultant change in the land capability is highly variable due to the very unique differences associated with the outwashes (alluvial), the colluvial derived materials, and the in-situ soils.

Of the total mining/mineral right area (Figure 4 - Red border), only a relatively small proportion of the area will be impacted by the proposed open pit mining development (Zones 1 and 2), with significant areas of the open desert plains being targeted for the co-disposal dump (TSF and WRD), while much smaller areas in close proximity to the mining have been ear marked for the processing facilities, administrative facilities, workshops, concentrator plant and the RoM Stockpiles).

The open pit nature of the proposed mining operation coupled with the sensitive environment in which it is to take place will require extensive and high level management input if the original characteristics of the area are to be engineered at rehabilitation.

The majority of the mining and infrastructure that is planned will impact on the desert plain materials inclusive of the deeper soils that make up the many outwashes and water ways that cross the proposed area of development, with significant areas of outcrop and shallow soils that make up the more resistant lithologies on the site being impacted by the proposed by-product disposal infrastructure. The large footprints of the TSF and WRD will have the largest spatial impact which will be permanent, while the Open Pit mining (Zone 1 and Zone 2) will affect a relatively small area of less sensitive soils.

All of these soils are sensitive to erosion and compaction, and will need to be well managed. However, the variable depth profiles of the materials that occur across the open plain areas that are potentially going to be disturbed, and the resultant depths of utilizable soil that can be stripped and stored makes for complex and difficult management of the natural materials.

In contrast, the colluvial/alluvial derived materials associated with the outwashes and waterways are far more sensitive to disturbance, with some major challenges associated with re-instatement and replacement of the utilizable materials as a result. The proposed disturbance of these soils and water ways (east of mining area) **will definitely have a HIGH negative** impact and affect the overall ecology in the long term.

The variable size fractions combined with the layered nature of many of these material deposits combined with the presence of a prominent calcrete (Calcium Carbonate) layer at the base of the soil profile ("C" Horizon) which is believed to be for the restriction to vertical infiltration of water below the sands and gravels, all make for a complex of natural conditions that are going to be extremely difficult to replicate at closure.

The resultant loss of sub surface water within the gravels will need to be assessed and understood as a function of the ecological balance.

The low levels of organic carbon and relatively low nutrient stores of some important nutrients within the top soils will require that good handling and storage of the resource is managed, with the concept of "**utilizable soil**" storage being adapted as a basic management tool.

The robust nature of most of the vegetation is an advantage to any rehabilitation venture, however, the need for water and nutrients cannot be over emphasised, and management and engineering of the re-instated materials will be difficult but necessary for a successful rehabilitation plan.

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GLOSSARY OF TERMS

Alluvium: Refers to detrital deposits resulting from the operation of modern streams and rivers.
Base status: A qualitative expression of base saturation. See base saturation percentage.
Black turf: Soils included by this lay-term are the more structured and darker soils such as the Bonheim, Rensburg, Arcadia, Milkwood, Mayo, Sterkspruit, and Swartland soil forms.
Buffer capacity: The ability of soil to resist an induced change in pH.
Calcareous: Containing calcium carbonate (calcrete).
Catena: A sequence of soils of similar age, derived from similar parent material, and occurring under similar macroclimatic conditions, but having different characteristics due to variation in relief and drainage.
Clast: An individual constituent, grain or fragment of a sediment or sedimentary rock produced by the physical disintegration of a larger rock mass.
Cohesion: The molecular force of attraction between similar substances. The capacity of sticking together. The cohesion of soil is that part of its shear strength which does not depend upon inter-particle friction. Attraction within a soil structural unit or through the whole soil in apedel soils.
Concretion: A nodule made up of concentric accretions.
Crumb: A soft, porous more or less rounded ped from one to five millimetres in diameter. See structure, soil.
Cutan: Cutans occur on the surfaces of peds or individual particles (sand grains, stones). They consist of material which is usually finer than, and that has an organisation different to the material that makes up the surface on which they occur. They originate through deposition, diffusion or stress. Synonymous with clayskin, clay film, argillan.
Desert Plain: The undulating topography outside of the major river valleys that is impacted by low rainfall (<25cm) and strong winds.
Denitrification: The biochemical reduction of nitrate or nitrite to gaseous nitrogen, either as molecular nitrogen or as an oxide of nitrogen.
Erosion: The group of processes whereby soil or rock material is loosened or dissolved and removed from any part of the earth's surface.
Fertilizer: An organic or inorganic material, natural or synthetic, which can supply one or more of the nutrient elements essential for the growth and reproduction of plants.
Fine sand: (1) A soil separate consisting of particles 0,25-0,1mm in diameter. (2) A soil texture class (see texture) with fine sand plus very fine sand (i.e. 0,25-0,05mm in diameter) more than 60% of the sand fraction.
Fine textured soils: Soils with a texture of sandy clay, silty clay or clay.
Hardpan: A massive material enriched with and strongly cemented by sesquioxides, chiefly iron oxides (known as ferricrete, diagnostic hard plinthite, ironpan, ngubane, ouklip, laterite hardpan), silica (silcrete, dorbank) or lime (diagnostic hardpan carbonate-horizon, calcrete). Ortstein hardpans are cemented by iron oxides and organic matter.
Land capability: The ability of land to meet the needs of one or more uses under defined conditions of management.
Land type: (1) A class of land with specified characteristics. (2) In South Africa it has been used as a map unit denoting land, mapable at 1:250,000 scale, over which there is a marked uniformity of climate, terrain form and soil pattern.
Land use: The use to which land is put.
Mottling: A mottled or variegated pattern of colours is common in many soil horizons. It may be the result of various processes *inter alia* hydromorphy, illuviation, biological activity, and rock weathering in freely drained conditions (i.e.

saprolite). It is described by noting (i) the colour of the matrix and colour or colours of the principal mottles, and (ii) the pattern of the mottling.

The latter is given in terms of abundance (few, common 2 to 20% of the exposed surface, or many), size (fine, medium 5 to 15mm in diameter along the greatest dimension, or coarse), contrast (faint, distinct or prominent), form (circular, elongated-vesicular, or streaky) and the nature of the boundaries of the mottles (sharp, clear or diffuse); of these, abundance, size and contrast are the most important.

Nodule: Bodies of various shapes, sizes and colour that have been hardened to a greater or lesser extent by chemical compounds such as lime, sesquioxides, animal excreta and silica. These may be described in terms of kind (durinodes, gypsum, insect casts, ortstein, iron, manganese, lime, lime-silica, plinthite, salts), abundance (few, less than 20% by volume percentage; common, 20 – 50%; many, more than 50%), hardness (soft, hard meaning barely crushable between thumb and forefinger, indurated) and size (threadlike, fine, medium 2 – 5mm in diameter, coarse).

Overburden: A material which overlies another material difference in a specified respect, but mainly referred to in this document as materials overlying weathered rock

Ped: Individual natural soil aggregate (e.g. block, prism) as contrasted with a clod produced by artificial disturbance.

Pedocutanic, diagnostic B-horizon: The concept embraces B-horizons that have become enriched in clay, presumably by illuviation (an important pedogenic process which involves downward movement of fine materials by, and deposition from, water to give rise to cutanic character) and that have developed moderate or strong blocky structure. In the case of a red pedocutanic B-horizon, the transition to the overlying A-horizon is clear or abrupt.

Pedology: The branch of soil science that treats soils as natural phenomena, including their morphological, physical, chemical, mineralogical and biological properties, their genesis, their classification and their geographical distribution.

Slickenslides: In soils, these are polished or grooved surfaces within the soil resulting from part of the soil mass sliding against adjacent material along a plane which defines the extent of the slickenslides. They occur in clayey materials with a high smectite content.

Sodic soil: Soil with a low soluble salt content and a high exchangeable sodium percentage (usually EST > 15).

Swelling clay: Clay minerals such as the smectites that exhibit interlayer swelling when wetted, or clayey soils which, on account of the presence of swelling clay minerals, swell when wetted and shrink with cracking when dried. The latter are also known as heaving soils.

Texture, soil: The relative proportions of the various size separates in the soil as described by the classes of soil texture shown in the soil texture chart (see diagram on next page). The pure sand, sand, loamy sand, sandy loam and sandy clay loam classes are further subdivided (see diagram) according to the relative percentages of the coarse, medium and fine sand subseparates.

Vertic, diagnostic A-horizon: A-horizons that have both, a high clay content and a predominance of smectitic clay minerals possess the capacity to shrink and swell markedly in response to moisture changes. Such expansive materials have a characteristic appearance: structure is strongly developed, ped faces are shiny, and consistence is highly plastic when moist and sticky when wet.

1. INTRODUCTION AND TERMS OF REFERENCE

Metago Environmental Engineers (Pty) Ltd commissioned Earth Science Solutions (ESS (Pty) Ltd.) to undertake a pedological survey for the Swakop Uranium Husab South Uranium Expansion Project. The initial study commissioned was specifically of the ore body zone (Zone 1 and Zone 2) and possible access routes for power and water, and was undertaken in May of 2009, with additional studies being commissioned and undertaken during January 2010 and March 2010. A total area of approximately 6,420ha was investigated in the course of the studies undertaken, with a variation in the intensity of the study depending on the potential for impact to the site. Areas proposed for open pit mining, and construction of structures that will disturb the soils were looked at in somewhat greater detail, with the powerline route and general mining right area that will have limited or no material impact was studied on a much less intensive basis.

Using this philosophy, the areas of concern were assessed and an understanding of the baseline conditions obtained. The two separate studies have been combined into one report and a single mapping unit, with the open pit mining areas comprising the fixed and well understood impact, while the positioning of the infrastructure, roads, pipelines and co-disposal (waste management and tailings storage) facilities that will be required in terms of the processing and beneficiation of the raw product can be planned and positioned with the environment in mind. A number of scenarios have been looked at, with the most recent alternatives having been used for this discussion.

In light of this position, the baseline study is presented, with a general assessment of possible impacts for the mining activities only. The impacts of the beneficiation infrastructure and support activities and the affects of the waste management facilities will be updated once these have been finalised and the positions in the landscape are known.

The proposed mining project and associated development is planned for an area in the western central region of Namibia, to the east of Swakopmund and north of the Swakop River in an area of desert plains south of the Swakop Uranium Husab South Uranium Mine. The area is accessed via the C28 route that runs from Swakopmund to Windhoek and the access road north through the Swakop River to the area renowned for the large Welwitschia. The area forms part of the Namib Naukluft National Park.

The specialist studies undertaken for the proposed expansion project have been structured so as to satisfy the requirements of the environmental legislation as tabled in the Environmental Management Act, 7 of 2007. Although the proposed EIA regulations have not yet been promulgated, the draft regulations and Namibian Environmental Policy for EIA (1995) have been used as a guideline where relevant. In this regard, a project specific environmental impact assessment (EIA) is required as part of the application for the proposed expansion project.

This specialist study has been written as a standalone document, but should be read as part of the larger EIA and forms a part of the baseline study used in the determination of the impacts as well as informing the environmental management plan (EMP).

To this end, a number of soil parameters were mapped and classified using the standard *Taxonomic Soil Classification System for South Africa (Mac Vicar et al, 2nd edition* 1991) and the S.A. Chamber of Mines Land Classification System of rating.

The objectives of the study were to:

- Survey the areas that are required for open pit mining and the erection of infrastructure;
- Classify the different soil types and produce a soils distribution map;
- Rate the natural land capability of the areas proposed for development;
- Provide a profile of the soils, including the effective depth and occurrence of sub soils;
- Analyze properties and define characteristics of the soil such as nutrient content, chemistry, capability to support ecosystem functionality;
- Assess the cumulative impacts on soils and land capability, and
- Have input, together with Metago, other specialists and the client, into project alternatives and management measures going forward.

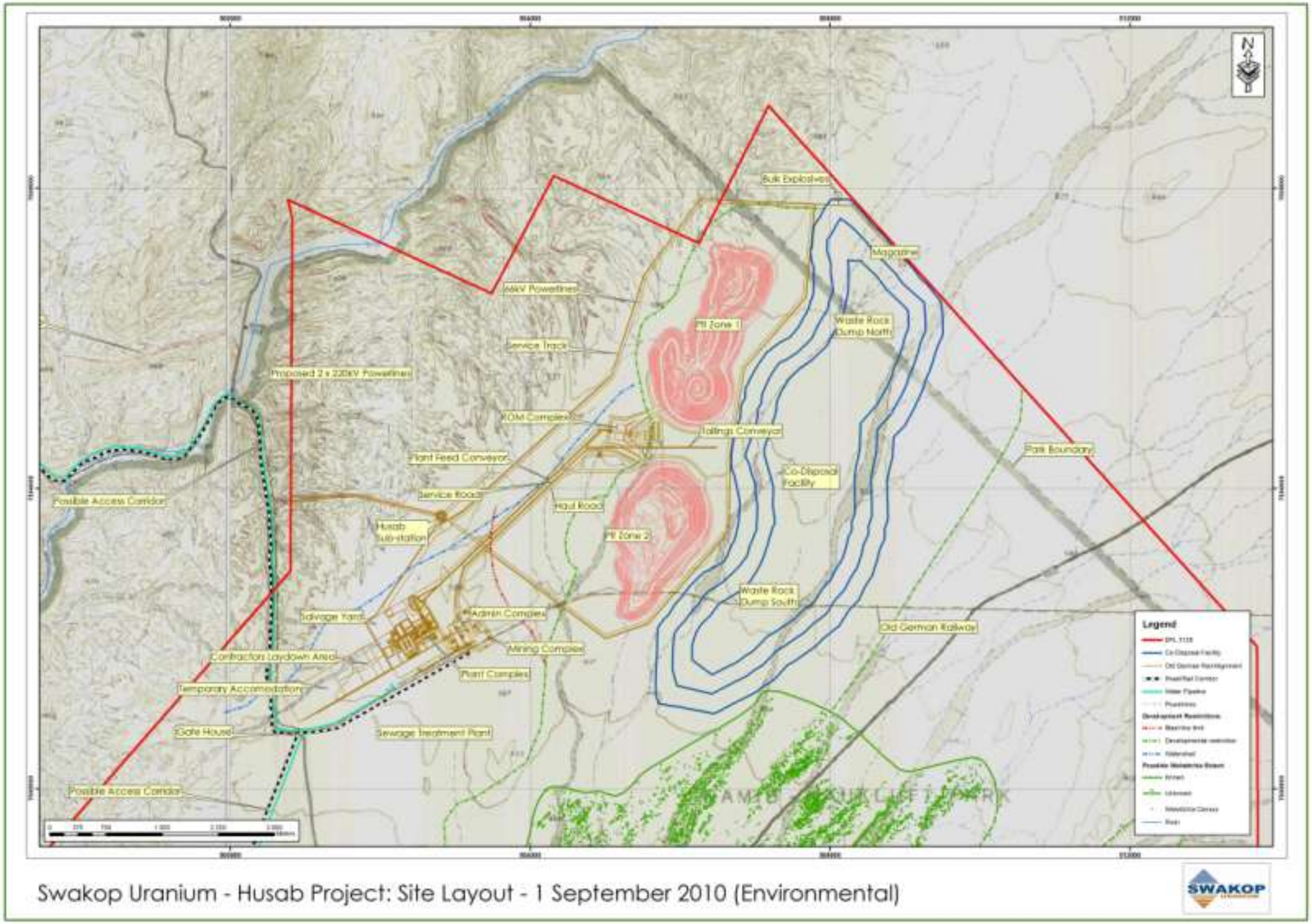
Historically, the area proposed for the expansion project was conservation land managed as part of the Namib Naukluft National Park, with the change to mining lease area in the recent past when the Swakop Uranium Husab South (Husab) Project was initiated.

With the ever-increasing competition for land, it has become imperative that the full scientific facts for any particular site are known, and the effects on the land to be used by any other proposed enterprise must be evaluated, prior to the new activity being implemented.

This document describes the in-field methods used to classify and describe the *in-situ and colluvial/alluvial derived* soils, rates the land capability based on the soils information, climate and topographic variables, and gives details of the pre mining/construction situation as a baseline to the proposed planning. The impact assessment and mitigation scenarios are based on an internationally recognised system with inputs from the results of the site (in-field) survey and an interpretation of the field results.

The findings are based primarily on a pedological survey involving a number of specialists in differing fields of expertise and the interpretation of the resulting data.

Figure 2.1 - Proposed Mining Plan (July 2010)



2.DESCRIPTION OF THE PRE-CONSTRUCTION ENVIRONMENT

2.1Soils

2.1.1Data Collection

Review of published reports and maps

As part of the original ToR the client made available to the project team all published information, inclusive of all available geological and engineering plans, topographic mapping and aerial imagery. The feasibility study and published exploration results in conjunction with the hydrogeological modelling, biodiversity impact assessment and hydrological studies were also obtained as they became available.

This information was invaluable in understanding the project development and philosophy, all be it that additional in depth investigation of the soils and underlying conditions were needed.

The soils and land capability studies have been undertaken in a number of phases, with the baseline assessment for the mining zones and alternative access routes for road, water and power being undertaken initially, followed by additional mapping of the ELP to the south and east over areas that could potentially be used for the beneficiation plant and associated process infrastructure and waste management facilities.

The July 2010 Mine Plan (figure 3) is referenced as the baseline information used for this study, while the different alternatives that were tabled during the study have influenced the outcomes. Based on the sensitivities associated with the soil environ and other environmental issues associated with the region, the mine plan was altered and the alternatives used in refining the best candidate sites for the various infrastructure.

The government survey geological maps and descriptions were used in an understanding of the general lithological setting for the area, and discussions with the local site geologist helped in understanding the possible pedogenic processes that are unique to desert environments.

Little information is/was available at the time of the field mapping on the influence and effects of the evaporites on the local ecological balance and sustainability of the systems that naturally occur. These hard carbonate horizons are common to the environment, and, while these are possibly not of consequence to the mining operation or management of the project from an engineering perspective, they are believed to be of great importance to the biodiversity and systems that make these areas habitable.

The Welwitschia Workshop organised by the client in April 2010 was invaluable in obtaining a firsthand understanding of the desert biodiversity from local experts.

The aerial imagery (Satellite Photographs) supplied by the client is recent and proved to be of great assistance in the mapping of the soil patterns.

The aerial imagery has been used as the base plan onto which all soil and land capability information was mapped. The most recent proposals for the mine planning were used as a measure of the possible positions that the infrastructure and co-disposal facilities might occupy in the landscape and their possible impact on the environment assessed as part of the EIA.

The final positioning of infrastructure will need to be based on a sustainable compromise between the impact on the natural environment and the distance relative to the open pit mining

A number of alternative options had been tabled for the placement of the infrastructure and by-product facilities, with the option of a co-disposal facility being mooted as a feasible compromise and answer to the quantity of material that will need to be stored on a relatively small expanse of land. The final positioning of these will be dependent on the findings of the overall SEIA and associated specialist studies.

Significantly large areas of presently unaffected land will be impacted by the proposed new development, with associated affects on the areas that lie adjacent to and downslope of the proposed development. The sub linear nature of the proposed mining by open pit methods of the desert gravels, sands and underlying host rock lithologies will by its very nature affect the surface washes (colluvial deposits) and waterways, and the soil water (vadose zone water) regime and the in-situ soils.

The groundwater model has assessed the spatial extent of the groundwater draw down around the open pit structures, which will inevitably have an effect on the un-saturated zone above it. The extent and degree of impact is well understood and will have an influence on the ability for surface developments at closure

In addition to the hard copy data and electronically generated files supplied by the client, a meeting with the Swakop Uranium Husab Project geologists on site and the senior management team at the Welwitschia Workshop, interaction with a number of the local ecologists working on Welwitschia in the area (Gobabeb Desert Research Foundation, Bio-Centre Klein Flottbek and Botanical Garden – University of Hamburg, Desert Research Foundation of Namibia, PhD Student – University of Virginia – Dept Environmental Science) and local consultants working in the region have been extremely beneficial to the understanding of local conditions.

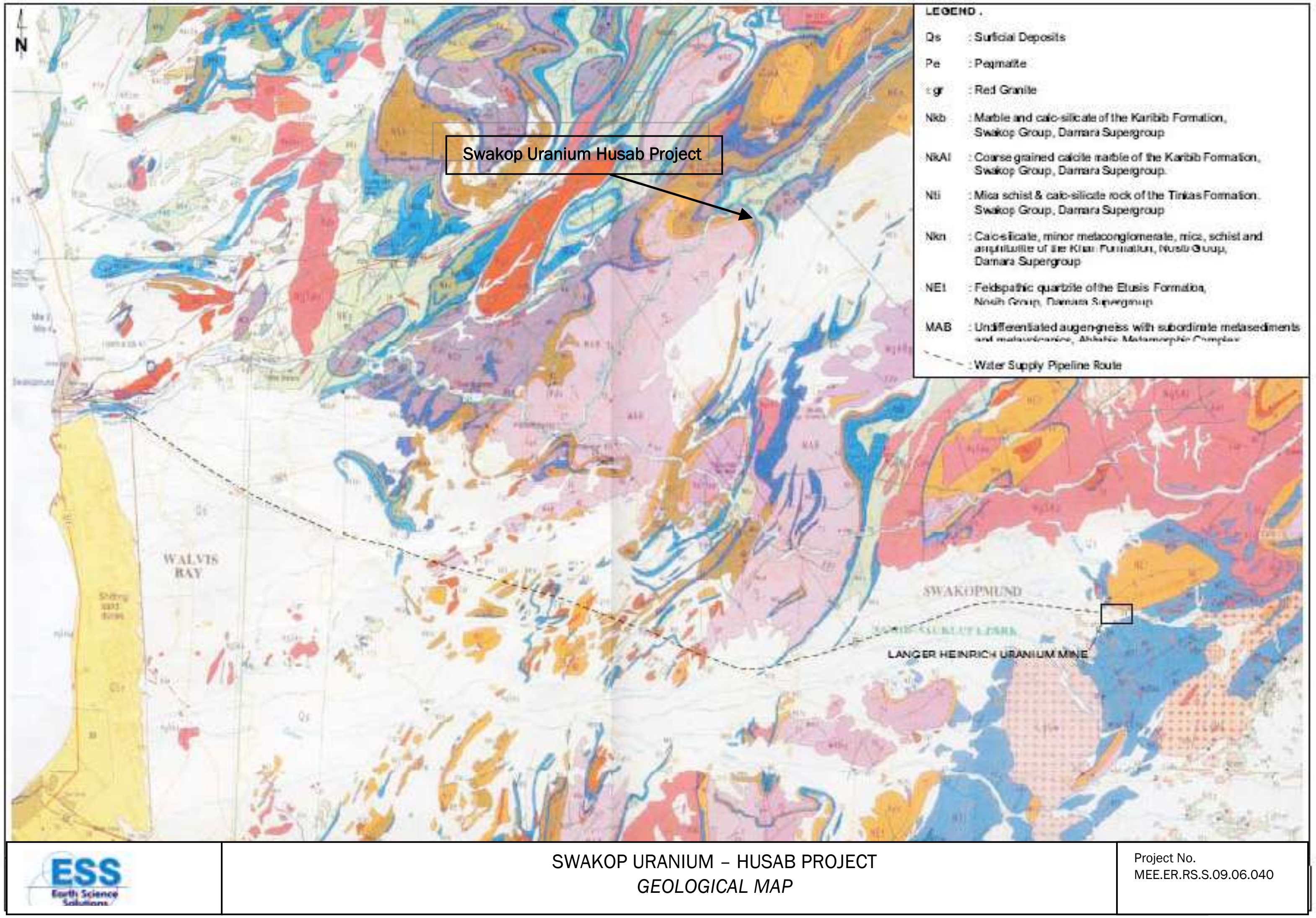
Our thanks is also extended to the environmental manager for their input and assistance.

Of significance to the soils study is the underlying geology, with a moderately complex suite of rocks that make up the overall sequence and which have had a profound effect on the weathered materials. In its simplicity, the area can be described as follows:

The mining is planned to exploit the uranium mineralization which is hosted predominantly by a series of semi-conformable alkali feldspar granitic to pegmatitic dykes intruding schists, quartzites and calc-silicate rocks of the Rössing Formation, while quartz-diopside calc-silicate units and quartz-biotite schists make up minor components of the mineralized inventory in the area of interest. The mineralized zones are arranged around the limbs of local dome structures cored by amphibole and pyroxene bearing gneiss of the Khan Formation (Nossib Group). (Refer to Figure 2.1.1a – Regional Geological Map). Overlying these quartzites are schists comprised of interbedded fine-grained metapelite, metagreywacke and calcsilicate beds.

It is these complexes of lithologies combined with the subtle topographic changes that produce the complex of differing soil polygons mapped Refer to Figure 2.1.1b).

Figure 2.1.1a - Regional Geological Map



Field Work

The reconnaissance pedological study of the site was performed using various different scales of mapping, with the majority of the area being assessed on a reconnaissance base of between 300m and 500m depending on the complexity of the soil patterns noted and the degree of impact that is likely to occur (Open Pit mining or infrastructure). The areas of potential impact by construction and Open Pit mining were assessed in more detail, all be it that the grid base was again varied depending on the degree of complexity and the accessibility to the natural environment.

The surveys were undertaken during August of 2009 and January 2010. In addition to the grid point observations, a representative selection of the soil forms mapped were sampled and analysed to determine their chemistry and physical attributes. The soil mapping was undertaken on a 1:10,000 scale (Refer to Figure 4) orthophotographic base.

A total area of approximately 6,420ha was covered in the course of this study.

The majority of observations used to classify the soils were made using a hand operated bucket auger and Dutch (clay) auger.

Standard mapping procedures and field equipment were used throughout the survey. Initially, geological map of scale 1:250,000 and topocadastral maps at a scale of 1:50,000 were used to provide an overview of the area, while colour imagery at a scale of 1:10,000 was used as the base map for the soil survey.

The fieldwork comprised a site visit during which profiles of the soil were examined and observations made of the differing soil extremes. Relevant information relating to the climate, geology, wetlands and terrain morphology were also considered at this stage, and used in the classification of the soils of the area.

The pedological study was aimed at investigating/logging and classifying the soils within the area of potential disturbance. Terrain information, topography and any other infield data of significance was also recorded, with the objective of identifying and classifying the area in terms of:

- The soil types to be disturbed/rehabilitated;
- The soil physical and chemical properties;
- The soil depth;
- The erodibility of the soils;
- Pre-construction soil utilisation potential, and
- The soil nutrient status.

Soil Profile Identification and Description Procedure

The identification and classification of soil profiles were carried out using the *Taxonomic Soil Classification System (Mac Vicar et al, 2nd edition 1991*)

The Taxonomic Soil Classification System is in essence a very simple system that employs two main categories or levels of classes, an upper level or general level containing Soil Forms, and a lower, more specific level containing Soil Families.

Each of the soil Forms in the classification is a class at the upper level, defined by a unique vertical sequence of diagnostic horizons and materials.

All Forms are subdivided into two or more families, which have in common the properties of the Form, but are differentiated within the Form on the basis of their defined properties.

In this way, standardised soil identification and communication is allowed by use of the names and numbers given to both Form and Family. The procedure adopted in field when classifying the soil profiles is as follows:

i. Demarcate master horizons;
ii. Identify applicable diagnostic horizons by visually noting the physical properties such as:

- ❖ Depth (below surface)
- ❖ Texture (Grain size, roundness etc.)
- ❖ Structure (Controlling clay types)
- ❖ Mottling (Alterations due to continued exposure to wetness)
- ❖ Visible pores (Spacing and packing of peds)
- ❖ Concretions (cohesion of minerals and/or peds)
- ❖ Compaction (from surface)

iii. Determine from i) and ii) the appropriate Soil Form
iv. Establishing provisionally the most likely Soil Family

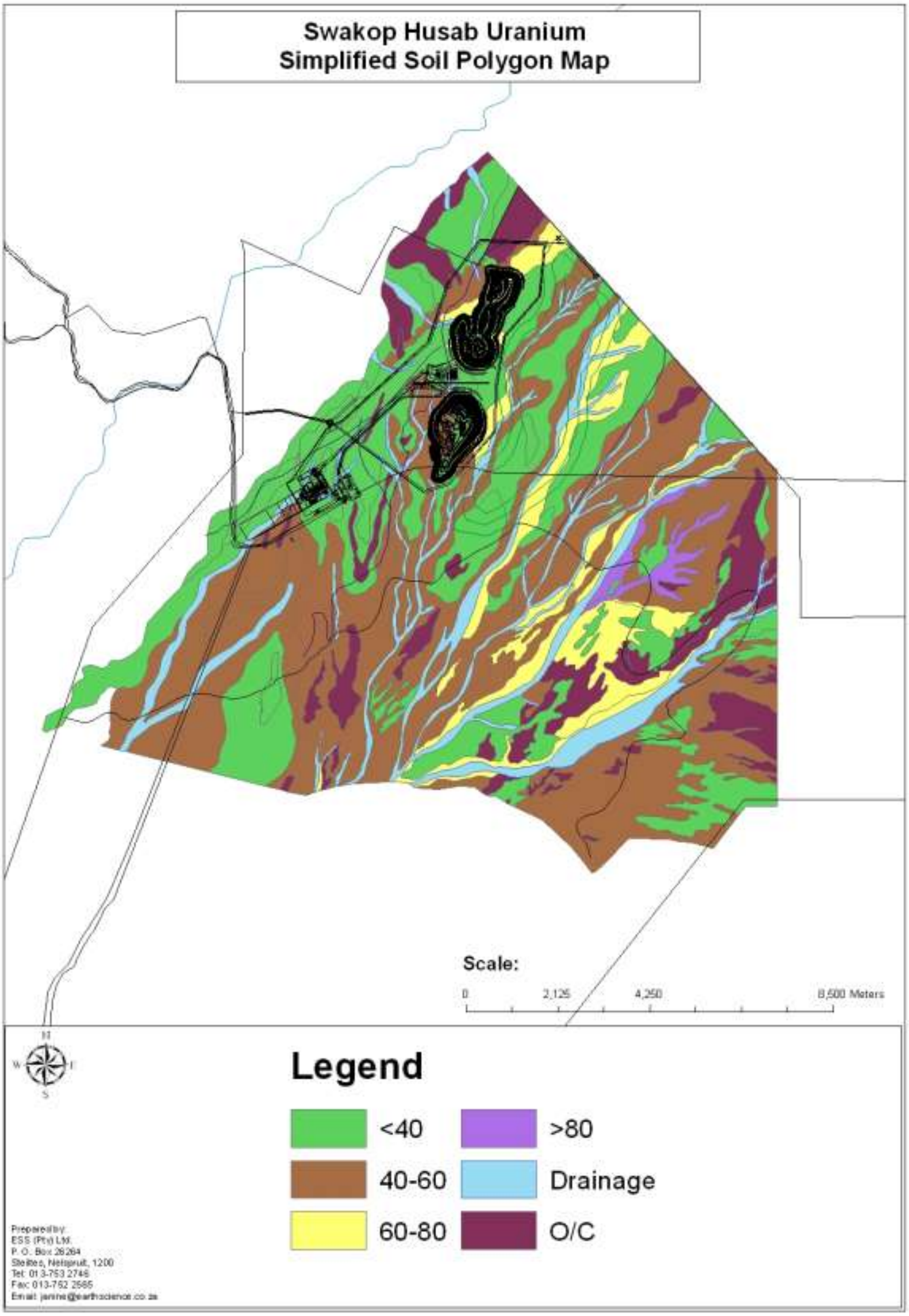
Table 2.1.1 Typical Arrangement of Master Horizons in Soil Profile

SOLUM
(Zone in which the soil forming processes are maximally expressed)

O		O1	Loose leaves and organic debris, largely undecomposed
O		O2	Organic debris, partially decomposed or matted
A		A1	Dark coloured due to admixture of humified organic matter with the mineral fraction
A		A2 or E	Light coloured mineral horizon
A		A3	Transitional to B but more like A than B
G	B	B1	Transitional to A but more like B than A
G	B	B2	Maximum expression of B-horizon character
G	B	B3	Transitional to C
G	C		Unconsolidated material
R			Hard rock

Arrangement of master horizons

Figure 2.1.1b - Soil Polygon Map (simplified)



2.1.2 Description

Soil Forms Identified

The soils encountered can be broadly categorised into three groupings, with those associated with the more mountainous and rocky terrain (little to no soil) associated with the local dome structures cored by amphibole and pyroxene bearing gneiss of the Khan Formation (Nosib Group). Limited areas of these formations are affected by the proposed project. These very shallow and rocky soils are distinctly different and easily distinguished from the much flatter and open desert plains that are comprised of colluvial and alluvial materials associated with and confined to the distinctive outwash/washes that finger across the study area from northeast to south west, the low lying hills that form the ridges between the "wash zones" and comprise shallow soils derived from intrusive schists, quartzites and calc-silicate rocks of the Rössing Formation, and the extensive area of in-situ derived materials associated with the desert plains.

As with any natural system, the transition from one system to another is often complex with multiple facets and variations. However, in simplifying the trends mapped include the following major soil Forms:

- In the "**transition zone**", is a variation of shallow in-situ to colluvial derived materials founded on a hard saprolitic horizon or hard rock associated with the outcropping ridge zones that divide the "ephemeral channels/wash zones" from the very shallow rocky outcrop zones and rugged mountain terrain (shallow <400mm poorly structured (apedel to single grained – Blue Zone on map) that forms the ridge between the project in the south east and the Khan River Valley to the northwest. These soils are generally founded on a hard rock base or lithocutanic horizon, and returned poor vegetative cover for the most part and comprise predominantly outcrop, Mispah and Glenrosa Form soils with pockets of shallow Clovelly and Fernwood Forms within extensive areas of outcrop (Refer to Appendix 2 for Photographs).

  The transition zone comprises predominantly fine grained sandy loams and silty loams that are typically characterised by Glenrosa, Coega, Trawal, Augrabies, Montagu, and Glencoe Forms varying from very shallow and dry orthic phased materials on neocutanic and neocarbonate subsoil horizons, to slightly deeper materials that show distinctive pedogenisis, are comprised of sandy loams and silty loams that returned low to very low clay contents and no structure (single grained). These soils are generally defined by their well sorted character which is distinctive from the stratification of the river sediments (typically, Coega, Trawal, Montagu, Prieska and Augrabies).

- In contrast, the stratified soils that make up the majority of the **"Ephemeral Channels or washes/waterways"** layers or stratified horizons of loose/unconsolidated materials of varying composition, are generally deep (600mm to greater than 800mm – Red and Green Zones on the map), and vary in texture from fine grained silt and sand to pebble and cobble size materials. Radically differing extremes of energy environments would have occurred for these profiles to be present, and are indicative of the extremes of climate that characterise desert environments. In almost all cases mapped, the outwash materials are founded on a hard rock base that comprises either the host lithology (bedrock) or a sequence of evaporite derived sediments of varying consistency (Calcium Carbonate).

This underlying layer is significant to the overall ecological success of the area in its natural state, and forms a potential barrier layer that can potentially hold water close to the surface, but below the sands where it is available to animals and plants, but does not easily evaporate. This situation needs more detailed investigation. Concentration of salts and stores of nutrients within these soils are again a sensitive balance that should be noted. These soils are dominated by the Oakleaf and in places Dundee Forms, with variations from Fernwood to Augrabies and Prieska Forms across the catena.

- The third main grouping of soils are associated with the **"desert Plains",** and are characterised by moderately deep to shallow (400mm to 600mm), silty sands with or without the surface crusting and/or the calcrete "C" horizon. The structure is generally apedel to single grained, and they are often associated with a distinctive tufty (individual tufts) grass cover where the calcrete crust is absent or very thin, and almost baron (un-vegetated) desert sand plains where the crust is present in any thickness (>100mm).

In terms of the Taxonomic Classification the major soil types encountered include those of the orthic phase Clovelly, Oakleaf, Dundee, Mispah, Glenrosa, Augrabies, Coega, Trawal, and Prieska Forms with minor areas of hydromorphic form soils including the Montagu Pinedene and Avalon Forms.

All areas (inclusive of washes/outwashes) included in the study have been captured in a GIS format and mapped according to their soil classification nomenclature and soil depth (decimetres). A simplified map of the relative areas of the differing soil groupings has been tabled in Table 2.1.2 and Figure 2.1.1b - Soil Polygon Map) as a function of the total area surveyed.

Table 2.1.2 Soil Depth Coverage – Mining Lease Area

Soil Depth (cm)	Area
<40	2066.57
40 to 60	1736.17
60 to >80	271.36
Drainage areas	2219.52
Outcrop	125.54
Total	6419.16

2.1.3 Soil Chemical and Physical Characteristics

A suite of representative samples from the differing soil forms/types were taken and sent for analyses for both chemical as well as physical parameters. A select number of samples were submitted, each sample containing a number of sub samples from a particular soil Form or Type, which is representative of the area in question, thus forming a "composite sample", which in turn is representative of the Soil Form rather than a specific point sampled.

2.1.3.1: Soil Chemical Characteristics

Sampling of the soils for nutrient status was confined where possible to areas of undisturbed land. However, some of the better soil and rock exposure, and areas where sampling could be undertaken are associated with the sumps (pit structures) that had been dug as part of the exploration drilling water circulation system (Refer to Appendix 2). These sumps are approximately 1.5m deep, and at the time of survey were concentrated in close proximity to the proposed open pit (Zones 1 and 2). These sites expose the profile from surface to the hard rock or evaporite contact in most cases. Samples were taken at intervals down the profile within the sumps, and where available samples of the disturbed topsoil's were also taken for analysis.

These results are representative indications of the pre-mining conditions, and are at best a reconnaissance representation of the baseline conditions. These results will need to be augmented with additional sampling of materials at depth from other parts of the site. The idea of pits being dug upslope of and within the Welwitschia Fields will help to understand the composition and structure of the soils at depth in these specific areas. In addition, on-going sampling prior to and during the mining operation is proposed, and will give a baseline from which to compare the soil chemical and physical conditions during the rehabilitation process and at closure.

The results of the laboratory analysis returned light textured soils with a pH (KCl) of between 8.1 and 8.7, a base status ranging from 3.2me% to 6.9me% (Eutrophic (slight leaching status) to Mesotrophic (moderate leaching status)), and nutrient levels reflecting generally high levels of calcium and sodium, but deficiencies in the levels of magnesium, potassium, phosphorous, copper, aluminium and zinc, with exceptionally low levels of organic carbon matter and low to very low clay contents (as low as 2%).

The slightly more structured (weak crumby) and associated sandy and silty clay loams returned values that are indicative of the more iron rich materials and more basic lithologies that have contributed to the soils mapped. They are inherently low in potassium reserves, and returned lower levels of zinc and phosphorous.

Growth of vegetation in these mediums will require the addition of nutrients at start up if they are going to be considered for use at closure for rehabilitation. It should be noted that the addition of nutrients in the form of commercial fertilisers are potential pollutants to the riverine and groundwater environment if added in excess.

Table 2.1.3.1 Analytical Soils Results

Results: MEE.ER.RS.S.09.06.040 - Metago Rossing South													
Laboratory Ref		3506	3507	3508	3509	3510	3511	3512	3513	3514	3515	3516	3517
Sample No - Type Area		R 10	R 17	R 26	R 33	R 48	R 76	R 98	R 105	R 116	R 268	R 269	R 270
pH (Water)	pHunit	7.60	8.05	8.10	8.30	8.07	8.40	8.12	8.11	8.10	8.09	8.10	8.11
Res (Conductivity EC)	ohms	350	200	100	1960	430	640	310	815	380	140	370	410
Calcium as Ca	mg/kg	28760	7220	28120	1700	5560	1540	5160	28220	28920	5120	29420	29900
Magnesium as Mg	mg/kg	27	62	59	32	66	27	69	61	21	44	17	24
Potassium as K	mg/kg	63	205	93	37	60	33	73	89	43	117	25	37
Sodium as Na	mg/kg	30	549	504	22	45	18	61	612	28	446	26	108
Phosphorus as P	(Brayl)	5.3	0.3	4.4	2.7	0.2	4.1	1.2	4.1	4.3	3.6	8.1	8.8
Aliminium as Al	mg/kg	3	1	3	1	1	1	1	3	3	2	3	3
Ca/Mg Ratio	%	1065.19	116.45	476.61	53.13	84.24	57.04	74.78	462.62	1377.14	116.36	1730.59	1245.83
Ca+Mg/K Ratio	%	456.94	35.52	303.00	46.81	93.77	47.49	71.63	317.76	673.05	44.14	1177.48	808.76
Zinc as Zn	mg/kg	0.80	1.67	1.62	1.01	0.45	1.61	0.81	0.71	1.34	1.64	0.82	2.51
Copper as Cu	mg/kg	0.72	0.66	0.39	0.62	0.66	0.63	0.56	0.59	0.47	0.58	0.51	0.68
Organic Carbon	%	0.00	0.04	0.00	0.00	0.04	0.00	0.15	0.00	0.00	0.15	0.00	0.00
Org.Mat. As C	%	0.00	0.07	0.00	0.00	0.07	0.00	0.26	0.00	0.00	0.26	0.00	0.00
Sand	%	82	82	86	90	86	92	90	86	80	92	94	96
Silt	%	16	8	12	8	6	6	6	10	18	6	2	2
Clay	%	2	10	2	2	8	2	4	4	2	2	4	2

2.1.3.1.1 Soil acidity/alkalinity

In general, it is accepted that the pH of a soil has a direct influence on plant growth. This may occur in a number of different ways including:

- The direct effect of the hydrogen ion concentration on nutrient uptake;
- Indirectly through the effect on major trace nutrient availability; and by
- Mobilising toxic ions such as aluminium and manganese, which restrict plant growth.

A pH range of between 6 and 7 most readily promotes the availability of plant nutrients to the plant. However, pH values below 3 or above 9, will seriously affect, and reduce the nutrient uptake by a plant.

The dominant soils mapped in this area are slightly alkaline (pH = 8.1 to 8.7), but still generally within the accepted range for good nutrient mobility.

2.1.3.1.2 Soil salinity/sodicity

In addition, to the acidity/alkalinity of a soil, the salinity and/or sodicity are of importance in a soils potential to sustain growth.

Highly saline soils will result in the reduction of plant growth caused by the diversion of plant energy from normal physiological processes, to those involved in the acquisition of water under highly stressed conditions. Salinity levels of <60 mS/m will have no effect on plant growth. From 60 – 120 mS/m salt sensitive plants are affected, and above 120 mS/m growth of all plants is severely affected.

In addition soil salinity may directly influence the effects of particular ions on soil properties. The sodium adsorption ratio (SAR) is an indication of the effect of sodium on the soils. At high levels of exchangeable sodium, certain clay minerals, when saturated with sodium, swell markedly. With the swelling and dispersion of a sodic soil, pore spaces become blocked and infiltration rates and permeability are greatly reduced. The critical SAR for poorly drained (grey coloured) soils is 6, for slowly draining (black swelling as found in this site) clays it is 10 and for well drained, (red and yellow) soils and recent sands, 15.

Generally, the soils mapped in this area are non saline to slightly saline in character returning salinity levels of below 60mS/m as measured in field (portable EC metre) during the field assessment, and between 35 mS/m (350 ohms) on the well sorted sands to 196 mS/m (1960 ohms) on the more clay rich soils associated with the calcrete parent materials, and as measured in the laboratory. However, the soils are prone to sodic/salt development where evaporation has concentrated the salts at surface (thin surface crust/cap) and/or within the soil profile as varying intensities of restrictive layering of calcrete. Of consequence to any development in these climatic conditions and with the soil chemistry present, will be the potential for the salts to be retained within the soil profile over areas that are impacted or disturbed. Exceptionally good water management will be needed as part of the operational plan.

2.1.3.1.3 Soil fertility

The soils mapped returned at best moderate levels of some of the essential nutrients required for plant growth with sufficient stores of calcium and sodium. However, levels of Zn, P, Mg, Al, Cu and K are generally lower than the optimum required.

Significantly large areas of soil with a lower than acceptable level of plant nutrition were mapped across the mineral lease area. These poor conditions for growth were further compounded by the high permeability and low clay and carbon contents of the majority of the soils.

There are no indications of any toxic elements that are likely to limit natural plant growth in the soils mapped within the study area

2.1.3.1.4 Nutrient Storage and Cation Exchange Capacity (CEC)

The potential for a soil to retain and supply nutrients can be assessed by measuring the cation exchange capacity (CEC) of the soils.

The low organic carbon content and very low clays are detrimental to the exchange mechanisms, as it is these elements which naturally provide exchange sites that serve as nutrient stores. These conditions will result in a low retention and supply of nutrients for plant growth.

Low CEC values are an indication of soils lacking organic matter and clay minerals. Typically a soil rich in humus will have a CEC of 300 me/100g (>30 me/%), while a soil low in organic matter and clay may have a CEC of 1-5 me/100g (<5 me/%).

Generally, the CEC values for the soils mapped in the area are low and enhanced due to the low clay contents.

2.1.3.1.5 Soil organic matter

The soils mapped are all extremely low in organic carbon as would be expected for a desert environment. This factor coupled with the moderately low to low clay contents for the majority of the soils mapped will adversely affect the erosion indices for the soils, with a very high index prevailing for the majority of the materials classified.

2.1.3.2 Soil Physical Characteristics

The majority of the soils mapped exhibit apedel to single grained structure, low clay content and a eutrophic leaching character. These conditions are conducive to the formation of evaporites, with extremely low rainfall (<100mm/yr) and high evaporation (1450mm/yr) the driving mechanism. Hard pan calcification at or close to surface (100mm to 500mm) is common due to the precipitation of salts (calcium and magnesium predominantly) as the salt enriched waters evaporate off. These layers are considered to be an extremely important feature of the biosphere and are expected to contribute to the sustainability of the ecological systems in these desert environments.

The surface crusting that is evident over a substantial portion of the western extent of the site is associated with the "sea mist" that blows in from the west, and which deposits sufficient water onto the desert surface on a regular basis (almost daily). These waters take up salts from the surface soils into solution and, as the water is evaporated off during the heat of the day, the salts are left behind as a crust (evaporite layer). This crust can reach many centimetres in thickness (10cm to greater than 30cm), and forms a protective screen to the wind that erodes these desert plain normally

Surface Crusting – Western central Zone

Close-up of Surface Crusting

This layer, although of a similar/same chemical composition to the deeper calcrete layer, have formed by a slightly different mechanism. The deeper and generally much thicker evaporite layers are found more widespread, and are in almost all cases associated with the zones of overland surface flow (outwash zones), where the accumulation of water after rain events dissolves salts from the soils and underlying geology, and through a process of osmosis, the water rises to surface (evaporation) leaving the accumulations of salts which develop into thick layers of calcrete/evaporites over geological time.

Typical Calcrete/Evaporite Profile

Close up of Calcrete in rail Cutting

In addition to the unique characteristics of the area, the normal soil forming processes are at work, with in-situ soils with shallow depth and sandy loam textures characterising the rocky hill slopes and rocky desert, while the colluvial derived soils are characterised by deeper, sandy loams and sandy clay loams that bound on a hard rock or calcrete "C" horizon.

These soils are prone to erosion if the vegetative cover is removed and the topsoil's are disturbed.

In contrast to the colluvial derived materials, the alluvial soils or stratified alluvium is characterised by variable texture, and grain size distribution through the profile, with a mixture of fine and coarse materials occurring in layers, the result of intermittent and variable strength of flood events and changes in the depositional energy of the flood events with time.

The ability for water to easily move through this environment (high permeability), and the high evaporation common to this climate are the driving mechanisms that results in the characteristic evaporite or "calcrete" layers.

The resultant sensitivity of these materials is noted over a large proportion of the overall area that is to be affected by the mining operations and its associated infrastructure.

Heavy traffic (quantities) and the size of the machinery to be employed will have a significant effect on both compaction and erosion of the materials if not well managed

2.1.3.3 Characteristics of different Soil Groups

2.1.3.3.1 The Heavy Clay Rich Soils

The presence of clay rich soils is almost nonexistent in the areas that are to be disturbed with some kaolinite associated with weathering of the calcite/calcium carbonates in the base of the soil profiles. The presence of these weathered clays will need to be identified during the mining process, and where possible, these materials must be stored as separate stockpiles for future use at rehabilitation. These materials will be invaluable in the reconstruction of barrier layers if required, and are the only materials available in the area for this purpose.

Soils derived from the more calcium rich parent materials (calc silicates and hardpan calcrete) that form the hard base to some of the soil profiles, exhibit some degree of structure, with weak crumby and weak blocky structure occurring where weathering of these materials occurs. This saprolitic layer is generally quite thin (<500mm) and underlain by the schists and calc silicates of the local geology.

Intake rates and drainage through these calcrete layers is slow, forming the underlying inhibiting layers to the soil profile.

2.1.3.3.2 Light Textured –Single Grained to Apedal soils

The majority of the soils to be disturbed classify as light textured soils that returned high inflow rates, good to very good drainage characteristics and low to very low water holding characteristics. These are of the more sensitive soils in the area, and will erode if not protected from the affects of wind and water erosion.

The working of these soils as well as the protection during storage (stockpiling) will need to be well managed.

2.1.3.3.3 Shallow soils

The generally shallow rooting depths of the soils that dominate the area (<400mm) are associated with the resistant lithologies/host rock geology, while the deeper soils are associated with the alluvial flood plains/washes and the transitional zone desert plain materials. Shallow soil depths within the wash environment are generally associated with the hard rock geology or a variation of calcrete layers.

2.1.3.4 Soil distribution

The distribution of the soils (Figure 4 Soil Polygon Map) is closely linked to the depositional mechanisms and environment, along with the topography and parent materials from which the soils are derived.

2.1.4 Soil Erosion and Compaction

The resistance to or ease of erosion of a soil is expressed by an erodibility factor (“K”), which is determined from soil texture, permeability, organic matter content and soil structure. The Soil Erodibility Nomograph of (*Wischmeier et al,* 1971) was used to calculate the “K” value.

An index of erosion (I.O.E.) for soils is then determined by multiplying the "K" value by the slope percentage. Erosion problems may be experienced when the Index of Erosion is greater than 2.

The "K" value is used to express the "erodibility" of a particular soil form. Erodibility is defined as the vulnerability or susceptibility of a soil to erosion. It is a function of both the physical characteristics of that soil as well as the treatment of the soil. Erodibility ratings are expressed as:

Resistant	"K" factor = <0.15
Moderate	"K" factor = 0.15-0.35
Erodible	"K" factor = 0.35-0.45
Highly erodible	"K" factor = >0.45

The average "Erosion Indices" for the dominant soil forms on the study site are shown in Table 2.1.4. The majority of the soils mapped can be classified as having a high erodibility index in terms of their clay content (very low), organic carbon (very low) and structure (structureless), which is off set and tempered by the almost flat terrain to an index of moderate.

These factors are enhanced on the more mountainous terrain by the low level of vegetative cover and steepness of the slopes, while the valley environments and desert plains are characterised by low erosion indices due to the flatness of the terrain, the presence of the hardened evaporite layer and the generally better vegetative cover associated with a better soil cover.

The vulnerability of the "B" horizon to erosion once/if the topsoil is removed must not be under estimated.

The concerns around erosion and inter alia compaction, are directly related to the disturbance of the protective vegetation (all be it sparse) cover and topsoil that will be disturbed during any mining or construction operation. Once disturbed, the actions of wind and water are increased. Loss of soil (topsoil and subsoil) is extremely costly to any operation, and is generally only evident at closure or when rehabilitation operations are compromised. The effects in this desert environment will be even greater and of greater consequence to the success of any rehabilitation process.

Well planned management actions during the planning, construction and operational phases will save time and money in the long run, and will have an impact on the ability to successfully "close" an operation once completed.

Table 2.1.4 Erodibility of Differing Soil Forms

Soil Form	Erodibility Index	Index of Erosion (I.O.E.)
Augrabies	Moderate to High	1.40 – 1.65
Prieska/Trawal	Moderate	1.35 – 1.45
Montagu	Moderate to High	0.95 – 1.15
Glenrosa/Mispah	Moderate to High	1.35
Oakleaf	Moderate	0.85 - 0.95

2.2 Pre-Construction Land Capability

2.2.1 Data Collection

Based on a well developed and scientifically founded baseline of information, the South African Chamber of Mines (1991) Land Capability Rating System in conjunction with the Canadian Land Inventory System haves been used as the basis for the land capability study.

Using these systems, the land capability of the study area was classified into four distinctly different and recognisable classes, namely, wetland, arable land, grazing land and wilderness. The criteria for this classification are set out in Table 2.2.1.

Table 2.2.1 Criteria for Pre-Construction Land Capability (S.A. Chamber of Mines 1991)

Criteria for Wetland

Land with organic soils or supporting hygrophilous vegetation where soil and vegetation processes are water determined.

Criteria for Arable land

Land, which does not qualify as a wetland.
The soil is readily permeable to a depth of 750mm.
The soil has a pH value of between 4.0 and 8.4.
The soil has a low salinity and SAR
The soil has less than 10% (by volume) rocks or pedocrete fragments larger than 100mm in the upper 750mm.
Has a slope (in %) and erodibility factor ("K") such that their product is <2.0
Occurs under a climate of crop yields that are at least equal to the current national average for these crops.

Criteria for Grazing land

Land, which does not qualify as wetland or arable land.
Has soil, or soil-like material, permeable to roots of native plants, that is more than 250mm thick and contains less than 50% by volume of rocks or pedocrete fragments larger than 100mm.
Supports, or is capable of supporting, a stand of native or introduced grass species, or other forage plants utilisable by domesticated livestock or game animals on a commercial basis.

Criteria for Wilderness land

Land, which does not qualify as wetland, arable land or grazing land.

2.2.2 Description

The "land capability classification" as described above was used to classify the land units identified during the pedological survey. In summary, of the total area investigated 6,420ha, approximately 95% is considered to be of a wilderness land rating based on the depth of the materials alone, while consideration is given to the possibility and utilization potential of the grazing potential, all be it of a very low intensity grazing land potential. Figures 5 illustrates the distribution of land capability classes.

Arable Land

The very low rainfall of this area (<100mm/a) limits the utilization potential of the study area to very low intensity grazing and wildlife conservation. The land utilization ability to obtain a return on any cropping system will fall short of the national average (a measure used in the Land Capability Rating System – Refer Table 2.2.1 above), and thus negates the idea of even the deep soils being a potential for arable cultivation.

Grazing Land

The areas that classify as grazing land are generally confined to the shallower and transitional zones that are well drained. These soils are generally darker in colour, and are not always free draining to a depth of 750mm, but are capable of sustaining palatable plant species on a sustainable basis, especially since only the subsoil's (at a depth of 500mm) are periodically saturated. In addition, there should be no rocks or pedocrete fragments in the upper horizons of this soil group. If present it will limit the land capability to wilderness land.

Wilderness / Conservation Land

The majority of the area in question classifies as either conservation or wilderness land based on the shallow rocky nature of the materials and the inability of the materials to sustain a crop yield that is at least equal to the current national average.

Wetland

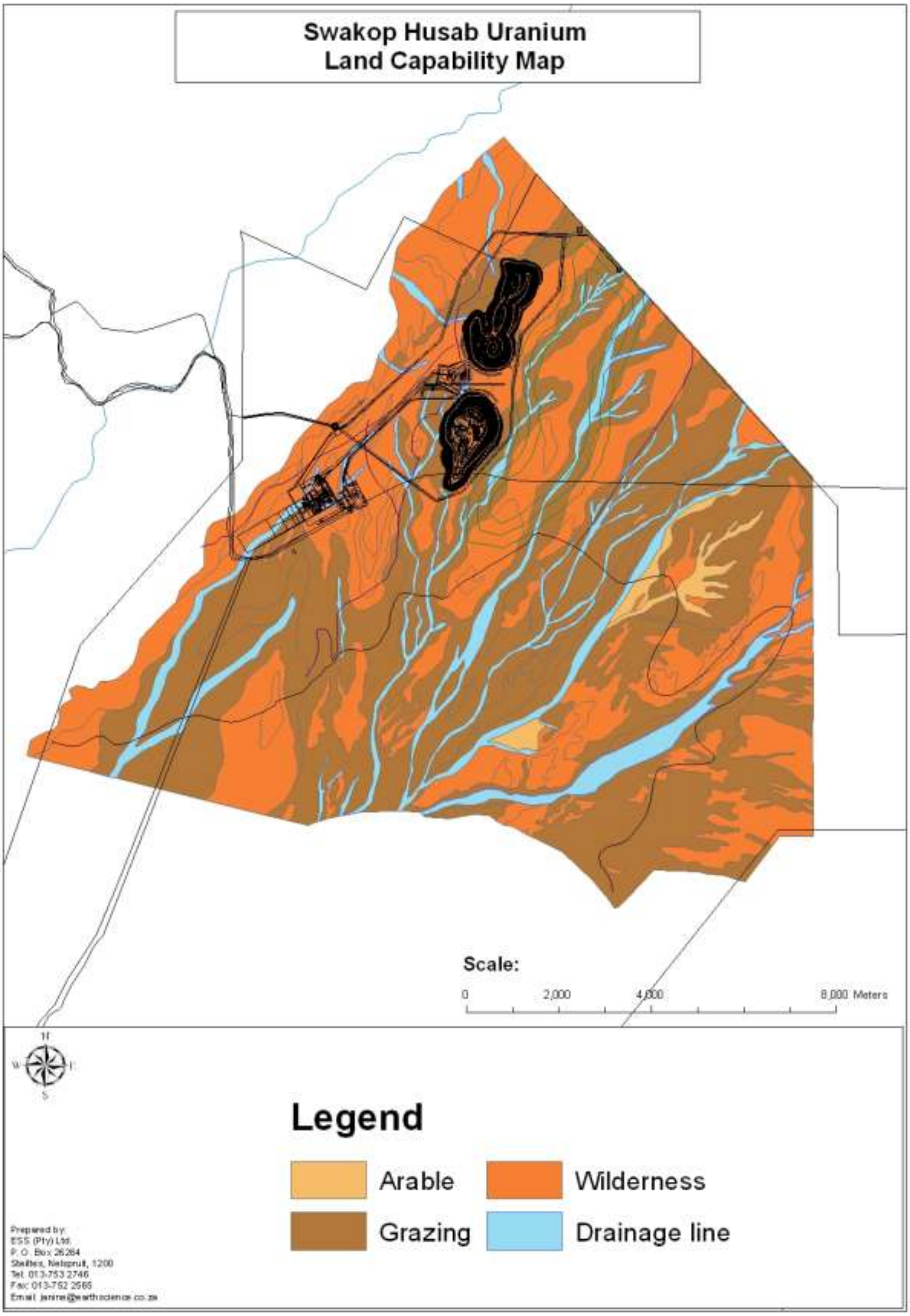
Wetland areas are defined in terms of the wetland delineation guidelines, which use both soil characteristics, the topography as well as vegetation criteria to define the domain limits.

These zones (wetlands) are dominated by hydromorphic soils (wet based) that often show signs of structure, and have plant life (vegetation) that is associated with seasonal wetting or permanent wetting of the soil profile.

The wetland soils are generally characterised by dark grey to black (organic carbon) in the topsoil horizons and are often high in transported clays and show variegated signs of mottling on gleyed backgrounds (pale grey colours) in the subsoil's. Wetland soils occur within the zone of soil water influence.

There are no areas of true wetland (wetness too deep below surface – must be within 500mm of surface) soils present within the study are, with zones of wetness at depths of 700mm and greater having been noted within the wash zones, thus relegating these zones to "Transitional" wetland or moist grassland status.

Figure 2.2.2Land Capability Plan



3 ALTERNATIVES ASSESSMENT

The alternatives assessment has been based on a number of different scenarios that considered the positioning of the infrastructure and mine related facilities in relation to the open pit mining and the environmental (social and bio-physical) sensitivities and the services (Power, water and road network) needs of a project of this size and nature.

All of the scenarios support the same positioning and area of Open Pit mining, with the original positioning of the waste rock dump and the Tailings Storage Facility being consolidated and moved to accommodate and reduce the footprint size in the form of a large co-disposal facility in close proximity to the open pit structure. The mine infrastructure and linear servitudes for water, power and access were also assessed in detail and moved a number of times due to environmental and economic constraints until the best option was decided upon.

Figures 3 - shows the most recent mine plan proposal with the positioning of the infrastructure open pits and co-disposal footprints (July 2010).

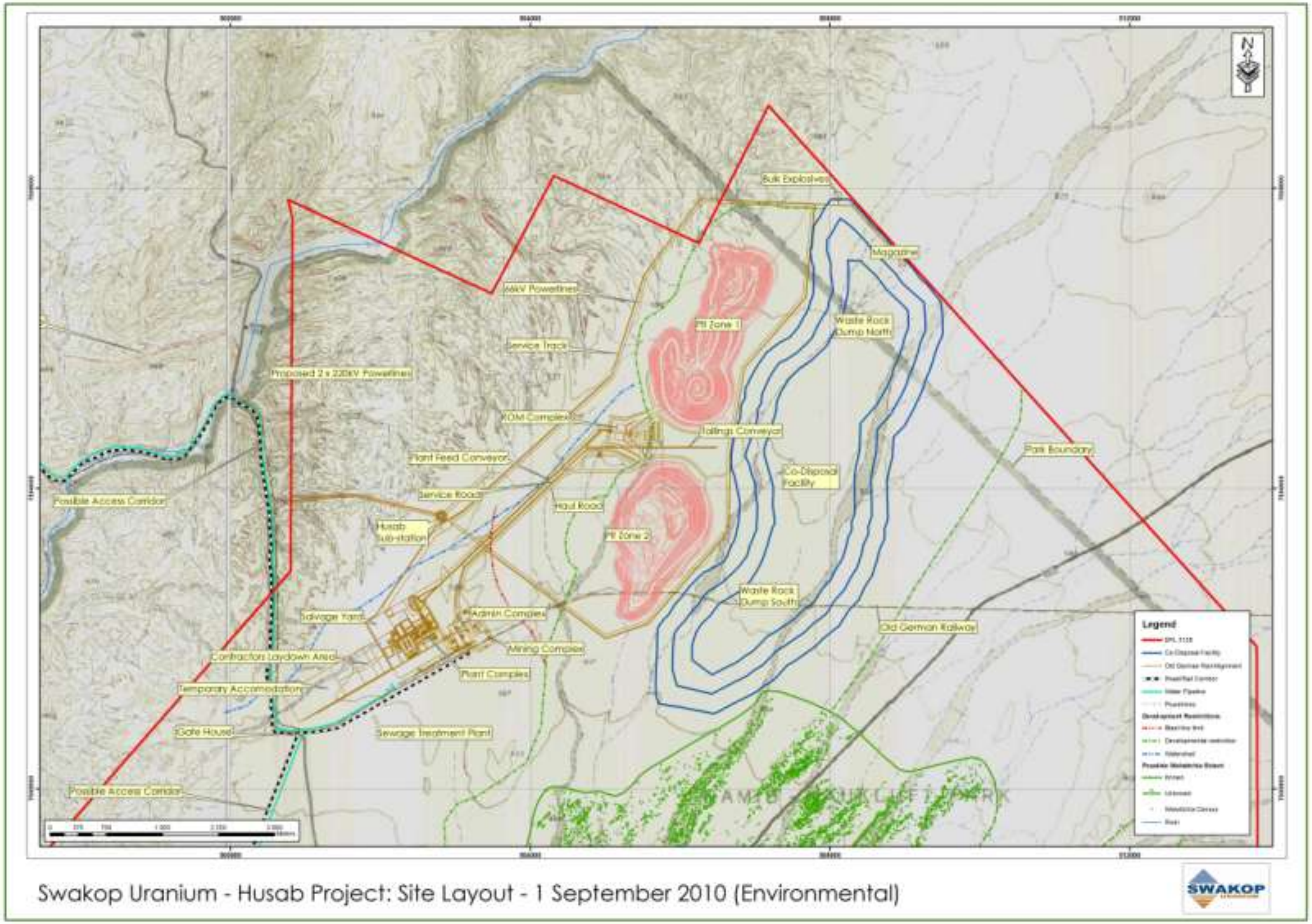
As part of the overall assessment to the area of concern, it was important that the studies informed the project leaders of the best alternative/s for the proposed project. The concerns around the soil and land capability are many and varied. However, the most affective mitigation would be the i) reducing of the total area that is going to be disturbed to a minimum, ii) the storage of utilizable soil (Soils >500mm in depth) and iii) the conservation of these materials (erosion by wind and water and retention of the seed pool) and the utilization of the soils at closure to re-establish the cover to the processing plant site, explosives magazine, haulage ways, access routes etc.

In line with this philosophy and with the study having covered the majority of the area of concern for at least two different options (Early 2009) in the early stages of the study, it was the conclusion of the team leaders and client that none of these options could be considered based on the extensive footprint area that would be impacted and the number and extent of the ephemeral channels that would be disturbed/impacted.

It is well understood and documented that the highly sensitive and balanced biodiversity and ecology that is integrately sustained by the soils was considered to be more important and ultimately would need more investigation. The impacting of the surface washes was ultimately the area of greatest concern, with soil moisture heading the list of most important soil attributes.

With the tabling of the July 2010 Mine Plan, the assessing of the impacts of the proposed facilities and infrastructure on the soils of the area has been undertaken. Additional inputs and field mapping were undertaken during the later part of July 2010 on the repositioning of the process plant and the “co-disposal” dump (Refer to Figure 3).

Figure 3 - July 2010 Draft of Proposed Mining Plan



Swakop Uranium - Husab Project: Site Layout - 1 September 2010 (Environmental)

4. IMPACT ASSESSMENT

The impact assessment has been undertaken for the proposed mining and its related infrastructure that is contained within the mineral rights area or EPL, with a separate EIA being undertaken for the linear servitudes required in for the power, water supply and access to the site that occurs outside of the EPL.

The potential impacts of the open pit mining and the development of the processing and support facilities (Offices, Beneficiation and Concentrator Plant, Workshops and the Co-disposal Facilities) have been assessed and rated according to the system developed by the Lead Consultants using the South African Integrated Environmental Management Information Series (DEAT 2002) and the criteria and methodology developed by Theo Hacking (Hacking 1998).

The Impact Assessment (Hacking) Methodology is as follows:

The "Significance Rating" of an impact is the product of the consequence and the probability, while the consequence is a function of the severity of the impact, its extent and the expected duration (Refer to Table 4 for Criteria for Assessing Impacts).

i.e. Significance = consequence x probability,

Where: Consequence = severity + spatial extent + duration,

The following sections summarise the potential impacts associated with the proposed construction, operation and closure of the mining and its related infrastructure for both the existing operation and the expansion phase.

Table 4 Criteria for Assessing Impacts

Table 3.1: Ccriteria for Assessing Impacts

PART A: DEFINITION AND CRITERIA*		
Definition of SIGNIFICANCE		**Significance = consequence x probability**
Definition of CONSEQUENCE		**Consequence is a function of severity, spatial extent and duration**
Criteria for ranking of the SEVERITY of environmental impacts	**H**	Substantial deterioration (death, illness or injury). Recommended level will often be violated. Vigorous community action. Irreplaceable loss of resources.
	M	Moderate/ measurable deterioration (discomfort). Recommended level will occasionally be violated. Widespread complaints. Noticeable loss of resources.
	L	Minor deterioration (nuisance or minor deterioration). Change not measurable/ will remain in the current range. Recommended level will never be violated. Sporadic complaints. Limited loss of resources.
	L+	Minor improvement. Change not measurable/ will remain in the current range. Recommended level will never be violated. Sporadic complaints.
	M+	Moderate improvement. Will be within or better than the recommended level. No observed reaction.
	H+	Substantial improvement. Will be within or better than the recommended level. Favourable publicity.
Criteria for ranking the DURATION of impacts	**L**	Quickly reversible. Less than the project life. Short term
	M	Reversible over time. Life of the project. Medium term
	H	Permanent. Beyond closure. Long term.
Criteria for ranking the SPATIAL SCALE of impacts	**L**	Localised - Within the site boundary.
	M	Fairly widespread – Beyond the site boundary. Local
	H	Widespread – Far beyond site boundary. Regional/ national

PART B: DETERMINING CONSEQUENCE

			SEVERITY = L		
DURATION	Long term	**H**	**Medium**	**Medium**	**Medium**
	Medium term	**M**	**Low**	**Low**	**Medium**
	Short term	**L**	**Low**	**Low**	**Medium**
			SEVERITY = M		
DURATION	Long term	**H**	**Medium**	**High**	**High**
	Medium term	**M**	**Medium**	**Medium**	**High**
	Short term	**L**	**Low**	**Medium**	**Medium**
			SEVERITY = H		
DURATION	Long term	**H**	**High**	**High**	**High**
	Medium term	**M**	**Medium**	**Medium**	**High**
	Short term	**L**	**Medium**	**Medium**	**High**
			L	**M**	**H**
			Localised Within site boundary Site	Fairly widespread Beyond site boundary Local	Widespread Far beyond site boundary Regional/ national
			SPATIAL SCALE		

PART C: DETERMINING SIGNIFICANCE

PROBABILITY	Definite/ Continuous	**H**	**Medium**	**Medium**	**High**
(of exposure to impacts)	Possible/ frequent	**M**	**Medium**	**Medium**	**High**
	Unlikely/ seldom	**L**	**Low**	**Low**	**Medium**
			L	**M**	**H**
			CONSEQUENCE		

PART D: INTERPRETATION OF SIGNIFICANCE

Significance	**Decision guideline**
High	It would influence the decision regardless of any possible mitigation.
Medium	It should have an influence on the decision unless it is mitigated.
Low	It will not have an influence on the decision.

4.1 Soils

4.1.1 Construction Phase

Issue: **Loss of Utilizable Soil Resource due to – Erosion, Contamination and/or Compaction during construction**

Due to the noticeable differences between the colluvial/alluvial (ephemeral channels) soils that exhibit variations in texture and grain size through the profile, the in-situ desert plains materials that are better sorted, generally more compacted and sometimes associated with a surface (calcrete) capping, and the more rocky ridge slope zones (positive topography – schist and marble ridges of the Khan Formation) that form the divide between the Khan River and the study area, and more locally between the outwash zones, the impacts are highly varied and significantly different across the three zones, with different management and mitigation measures consequently proposed for the different materials.

Construction for Project

Stripping of utilizable soil (Top 500mm were present), preparation (levelling and compaction) of lay-down areas and pad footprint for stockpiling and berms, opening up of foundations and stockpiling of utilizable soil, soft overburden, and the stabilisation of slopes where required. Haulage and access road construction and storage of utilizable soils within the EPL.

Control of dust and loss of materials to wind and water erosion, and protection of materials from contamination (chemical, hydrocarbons and sewage).

The construction phase will impact on all of the proposed mining and developmental activities associated with the mine support infrastructure within the EPL.

Open Pit mining starts during the construction phase with the mining of a bulk sample to determine crushing and screening requirements and specifications, while the building of a contractors camp and office/workshop facilities will pre-empt the construction of the processing facilities and the clearing and construction of the co-disposal facility footprint.

Some of these activities will continue into the operational phase as well, with new areas and extensions to the open pit mining being undertaken throughout the operational phase.

In addition, and were appropriate the “utilizable soils” will need to be stockpiled and maintained in a state where they are available when needed for rehabilitation and closure.

These actions will continue through the construction and into the operational phases, with the materials stripped from the areas of infrastructure, roads and pad footprint construction being best stockpiled as close as possible to these features in the form of berms and heaps upslope of the facilities. The soils from the open pit area should be stored as a series of low level dumps and/or berms as close as possible to the plant infrastructure and associated support structures were it will be available for use at closure.

If the gravels and less well sorted materials associated with the ephemeral channels are to be impacted (eastern slopes of the co-disposal dump) they should be stored and stockpiled separately from the desert plain soils, with all materials being removed as a matter of necessity (engineering of the footprint foundations), a part of the long term stability and sustainability that is proposed as part of the “End Land Use” planning.

Description of Impacts

The loss of the soil resource to the overall environment due to the impact on the soils stripped during the open pit mining activities and the construction of the Co-disposal Facility (Waste Rock Dump and Tailings Storage Facility), Water & Waste Management Facilities, Processing/Beneficiation Plant (Crushing, Screening and Concentration) and support infrastructure (Workshops and Offices) will definitely be High (H) in the medium term_(life of mine) (M) and restricted to the immediate mining area (L) - EPL. The overall loss of the soil resource to the environment if un-mitigated will result in a High (H) Significant Rating.

Disturbance of the surface restrictive layers associated with the relatively more sensitive soils will occur for all founding areas, and particularly those associated with the desert plains that will be impacted, with only the deeper foundations required for the heavier structures and open pit mining areas requiring that the underlying calcrete layer (inhibiting layer and barrier zone) is broken through.

The majority of the support infrastructure is outside of the alluvial washes and are for the most part associated with the moderately shallow to shallow soils of the desert plains environment that are underlain by an evaporite layer or directly by the phyllite host rock geology that dominates the area in the west and north west of the proposed development.

However, the eastern extent of the co-disposal will encroach on substantial areas of out wash alluvials. These areas are extremely sensitive to the ecology of the area, and will need to be considered in terms of the long-term impacts that could occur (Welwitschia Plains)

The variation in soil sensitivity alters only slightly from the shallow colluvial derived materials adjacent to the phyllite outcrop, while the desert plains and deeper alluvial materials are more extreme.

The impact of removing the “utilizable soil” (Top 500mm) will, destroy any surface capping that might be present, will remove all vegetative cover, and will expose any subsoil to erosion and compaction unless well managed and protected.

The moderate to highly sensitive soils (friable soils of the desert plains) will be susceptible to erosion and compaction once disturbed, and will be difficult to manage if left unprotected.

It must be emphasised, that the failure to manage the soils will result in the total loss of this resource, with a resultant **high** significance rating.

Mitigation/Management Actions

With management, the loss of this primary resource can be reduced and mitigated to a level that is more acceptable.

The impacts on the soils may be mitigated with a number of management procedures, including:

- Effective soil stripping during the less windy months when the soils are less susceptible to erosion and compaction. This will assist the stockpiling and natural regeneration of vegetative cover to propagate;

- Effective cladding of the co-disposal facility with waste rock, and the minimising of the height of all stockpiles wherever possible will help to reduce wind erosion and the loss of materials;
- Soil replacement to all areas (temporary) that are not required for the operational phase, and the preparation of a seed bed and/or rock cladding to facilitate the re-vegetation program for these areas will limit potential erodibility during the operational phase and into the rehabilitation and closure phases.
- Soil amelioration (cultivation) to enhance the growing capability of the stockpiled soils so that they can be used for rehabilitation at closure and to maintain the soils viability during storage.
- Soil replacement and the preparation of a seed bed to facilitate the re-vegetation program and to limit potential erodibility during the rehabilitation process.

Care will need to be taken to keep any wet based soils separated from the dry soils, and to keep all stockpiled soils that are in storage, vegetated/covered and protected from contamination and erosion. These soils will be stripped as "Utilizable Soil" the topsoil and upper portion of the subsoil (B2/1 Horizon) and stored in a position that will be convenient for the final rehabilitation of the facilities during the operational and closure phases.

Only if these materials are available can rehabilitation possibly be executed successfully and cost effectively. It is suggested that an average "Utilizable Soil Depth" (USD) of 500mm be stockpiled where present/available.

<u>Residual Impact</u>

The above management procedures will probably reduce the significance of the impacts to Medium in the long term.

However, if the soils are not going to be stripped and retained, then the residual impact will remain as High in the long term.

Management	Severi ty	Duration	Spatial Scale	Consequence	Probability of Occurrence	Significance
Unmanaged	H	M	L	M	H	**H**
Managed	M/H	M	L	M	M	**M**

4.1.2 Operational Phase

Issue: **Loss of Soil Usability**

Operation of Project – Cumulative

Loss of soil utilization - open pit mining – on-going soil stripping, ore processing and the possible contamination by dirty water interaction, acid spillage, dust and/or hydrocarbon spillage, sewage spills, covering of the soils by infrastructure, by-product stockpiles, storage facilities and dumps, compaction by vehicle movement, and erosion and loss of materials due to wind and water interaction with unprotected soils.

Description of Impacts

During the operational phase, all of the construction activities for the infrastructure and major by-product storage structures will have been completed and the crushing and sizing of materials, processing and beneficiation of product will have started and the deposition of the tailings and waste rock in a co-disposal facility will have begun. Continuous opening up of additional mining areas (Open Pits) will also be on-going.

The loss of the soil utilization and the covering of materials for extended periods of time by infrastructure will lead to the compaction and sterilization of the materials for future use. This will definitely result in a High (H) negative impact that will last for the duration of the mining venture within the mining area - EPL. The consequence is moderate (M) with an overall significance of High.

The movement of haulage vehicles, the use of access roads and the on-going additions of tailings and by-products to the co-disposal stockpiles and storage facilities will all impact on the size of area (footprint) to be impacted, and ultimately on the area of soil affected.

Spillage from moving vehicles and conveyers of product, by-product and possibly hydrocarbons, will negatively impact the in-situ materials, while unmanaged dirty water will erode and contaminate the soils that it comes into contact with.

Un-managed soil stockpiles and soil that is left uncovered will be lost to water and wind erosion, and will be prone to compaction if left unprotected.

The preservation of the generally thin evaporite capping will be impossible to retain or protect over areas where the soils will have been stripped, and it will be difficult to re-produce/create this feature during the storage stage.

In contrast, but of similar concern, is the presence of the semi impermeable barrier layer that forms below many of the alluvial gravels and desert plain materials mapped.

This material is believed to be the mechanism/feature that makes it possible for there to be perched water close to surface within the vadose zone. This possibility is to be noted as an extremely important feature needed for the ecological sustainability of these desert plains, and which it is believed has a strong support for the sensitive bio-diversity of the area.

Both of these soils will be impacted upon to differing degrees .and were possible and practical will have been stockpiled for future use during the rehabilitation phase and at closure.

The significance of the impact on these soils during the operational phase will differ both in intensity and duration, with the soils associated with the infrastructure remaining in a stockpile/stored state for the full life of the beneficiation process, while the open pit areas that are not planned to be backfilled will require that their utilizable soil is stored and utilized over sites with limited utilizable soil. These soils might be replaced at a much earlier stage in the mining process.

It is inevitable however, that some of the soils will be lost during the operational phase, and possibly for ever if they are not well managed and a mitigation plan is not tabled.

<u>Mitigation/Management Action</u>

The impacts on the stockpiled and stored soils may be mitigated with management procedures including:

- ❖ Minimisation of the area impacted;
- ❖ Timeous replacement of the soils so as to minimise the area of disturbance;
- ❖ Effective soil cover and protection from wind (dust) and dirty water contamination;
- ❖ Adequate protection from erosion (wind and water);
- ❖ Servicing of all vehicles on a regular basis and in well constructed and bunded areas, well constructed and maintained oil traps and dirty water collection systems;
- ❖ Cleaning of all roadways and haulage ways, drains and storm water control facilities;
- ❖ Containment and management of spillage;
- ❖ Soil replacement and the preparation of a seed bed to facilitate and accelerate the re-vegetation program and to limit potential erosion, and
- ❖ Soil amelioration to enhance the growth capability of the soils and sustain the soils ability to retain oxygen and nutrients, thus sustaining vegetative material during the storage stage;

Of consequence during the operational phase will be the minimising of the area that is being impacted by the mining operation and its related support structures and operations, and maintenance of the integrity of the soils. This will require that the soils are kept free of contamination (dust and dirty water), and stabilized and protected from erosion and compaction. The action of wind on dust generated and the loss of materials downwind will need to be considered, while contamination of the soils used on the roads and workshop areas will need to be managed.

The impacts on the differing materials, is in line with the proposed management plan to handle the areas of impact as one mining area (Open Pit areas and areas of Infrastructural development). It will be necessary early in the development of the mining plan to develop dedicated stockpiles for the various materials, as close to the areas where they will be needed at rehabilitation.

However, if the soils are stripped to a utilizable depth, and replaced as close as possible to their original position in the topography, the chances of nature being able to restore the systems present prior to disturbance will be greater.

More research into the mechanisms that cause the capping phenomena (Calcrete Capping) will be needed, and the exact functioning of the evaporite capping in the ecological balance will need to be better understood if this phenomena is to be recreated as part of the rehabilitation plan.

Specialist studies and long term trials to mimic the conditions under which these phenomena occur will be needed, and should be planned for early in the mining plan.

Residual Impact

In the long term, the above mitigation measures will probably reduce the impact on the utilizable soil reserves to a **Medium** impact.

However, if the soils are not stripped and retained/stored, the residual impact will be **High** in the long term.

Management	Severity	Duration	Spatial Scale	Consequence	Probability	Significance
Unmanaged	H	M	L	M	H	**H**
Managed	M	M	L	M	M	**M**

4.1.3 Decommissioning & Closure Phase

Issue: Net loss of soil potential due to change in materials (Physical and Chemical) and loss of nutrient base.

Decommissioning and Closure – Cumulative

Loss of the soils original nutrient store by leaching, erosion and de-oxygenation while stockpiled. Impact of vehicle movement, dust contamination and erosion during soil replacement and demolishing of infrastructure, slope stabilization and re-vegetation of disturbed areas. Possible contamination by dirty water interaction (use of mine water for irrigation of re-vegetation), dust and/or hydrocarbon spillage from construction vehicles. Positive impacts of reduction in areas of disturbance and return of soil utilization potential, uncovering of areas of storage and rehabilitation of compacted materials.

Description of Impact

The impact will remain the net loss of the soil resource if no intervention or mitigating strategy is implemented. The impact will be **High**, negative and permanent over the area of disturbance, with a relatively high consequence and resultant high significance. Un-managed closure will result in a long term depletion of soil utilization potential.

Management/Mitigation Actions

Ongoing rehabilitation during the decommissioning phase of the project will probably bring about a net long-term positive impact on the soils.

The initial impact during rehabilitation and closure will be high and negative due to the necessity for vehicle movement while rehabilitating the benches and ramp stabilization of the open pit area, moving of softs and soils, the demolishing of storm water controls, dams etc. and the demolishing of buildings and infrastructure. Dust will be generated and soil will be contaminated and eroded.

The positive impacts of rehabilitating an area are the reduction in the area previously disturbed, the amelioration of the affected soils and oxygenation of the growing medium, the stabilizing of slopes, benches and ramps, and revegetation of areas decommissioned with a reduction in areas previously subjected to wind or water erosion.

Residual Impacts

On mine closure the long-term negative impact on the soils will probably be of medium to low significance if the management plan set out in Environmental Plan is effectively implemented to reinstate current soil conditions. If backfilling of the open pit voids is considered the re-creating of a barrier layer should be considered. However, this will require further inputs from environmental and rehabilitation engineers. This conclusion supposes that the utilizable soils will be stripped and stored, and the calcrete layer removed and stored separately.

Chemical amelioration of the soils will possibly have a low but positive impact on the nutrient status (only) of the soils in the medium term.

Management	Severity	Duration	Spatial Scale	Consequence	Probability	Significance
Unmanaged	H	H	L	H	H	**H**
Managed	M+	M	L	M	H	**M/L+**

5. ENVIRONMENTAL MANAGEMENT PLAN

Based on the studies undertaken, it has been possible to assess the impacts that mining and beneficiation could potentially have on the soils and their resultant utilization potential, and has aided in a better understanding of the possible management and mitigation measures that could help to minimise the impacts during the rehabilitation process and develop a more sustainable End Land use and closure plan.

The management and mitigation measures proposed have been tabled for the different stages of the project in line with the impacts identified. The results tabled are based on the soil characterisation and classification in conjunction with the geomorphology (topography, altitude, attitude, climate and ground roughness) of the sites that will be impacted or affected and the resultant utilization change to the environmental management plan (EMP) has been suggested.

The plan caters for the construction, operation and decommissioning stages of the project, and gives recommendations on the stripping and handling of the soils during the construction and operation phases of the project, along with recommendations for the implementation of and rehabilitation during the end of the construction phase (closing of un needed roads etc) and into the operation and ultimately closure of the facility. It is imperative that a full and detailed EMP is implemented if the economics of mine closure are to be understood, and the relative positioning and timings of materials handling are to be aligned with the mining plan.

All alluvial outwash and associated materials that are not going to be mined, but which might be impacted by the proposed co-disposal facility (TSF and WRD), will be impacted permanently, and will require that the “utilizable soil” (Top 500mm) are stripped and stored for possible utilization as rehabilitation top dressing for the various facilities that are going to be demolished and returned to their natural state.

5.1 Construction Phase

<u>Soil Stripping and Handling</u>

In considering any management plan for soils it is imperative that the soil physical and chemical composition is known as these will be important in obtaining a utilizable material at decommissioning and/or during rehabilitation. The method of stockpiling and general handling of the soil will vary depending on the composition, and the reaction to storage will vary depending on the soil characteristics.

The sandy and silty loams (low to very low clay contents) that form the majority of the topsoil materials to be affected, along with the upper portion of the subsoil (B2/1 Horizon) within which the majority of the nutrient store occurs **<u>(Utilizable Soil)</u>** will need be stripped and stockpiled for use at closure.

<u>The concept of stripping and storage of all “Utilizable” soil is recommended as a minimum requirement and as part of the overall Soil Utilization Guidelines.</u>

Table 5.1 – Construction Phase – Soil Conservation Plan

Phase	Step	Factors to Consider	Comments
Construction	Delineation of areas to be stripped		Stripping will only occur where soils are to be disturbed by activities that are described in the design report, and where a clearly defined end rehabilitation use for the stripped soil has been identified.
	Reference to biodiversity action plan		It is recommened that all vegetation is stripped and stored as part of the utilizable soil. However, the requirements for moving and preserving fauna and flora according to the biodiversity action plan should be consulted.
	Stripping and Handling of soils	Handling	Soils will be handled in dry weather conditions so as to cause as little compaction as possible. Utilizable soil (Topsoil and upper portion of subsoil B2/1) must be handled and stockpiled separately from the lower "B" horizon and all softs (decomposed rock).
		Stripping	The "Utilizable" soil will be stripped to a depth of 500mm or until hard rock/calcrete is encountered. These soils will be stockpiled together with any vegetation cover present (only large bushes to be removed prior to stripping). The total stripped depth should be 500mm, where possible.
	Delineation of Stockpiling areas	Location	Stockpiling areas will be identified in close proximity to the source of the soil to limit handling and to promote reuse of soils in the correct areas.
		Designation of Areas	Soils stockpiles will be demarcated, and clearly marked to identify both the soil type and the intended area of rehabilitation.

In terms of the “Minimum Requirements”, usable soil is defined here as ALL soil above an agreed subterranean cut-off depth defined by the project soil scientist, and will vary for different types of soil encountered in a project area. It does not differentiate between topsoil (orthic horizon) and other subsoil horizons.

Soil stripping requirements are set to enable the mining company to achieve post mining land capabilities stipulated by the management plan and are based on pre-mining land capability assessment for the area in question. Pre-mining grazing land capability (As described by the Chamber of Mines Land Classification System – Refer to Section 2.2 – table 2.2.1) is the norm that is aimed for in most situations post mining. However, in this unique, and very sensitive desert environment, although a low intensity grazing land status is tabled as the minimum requirement, it is likely that this grazing land capability will need to be reduced to a wilderness or conservation land capability status i.e. soil less than 300mm deep in some instances.

<u>The following requirements (all be they generic) should be adhered to wherever possible:</u>

- Over areas of OPEN PIT PITS *strip all usable soil* as defined (500mm). Stockpile alluvial soils should be stockpiled separately from the colluvial (shallower) materials, which in turn should be stored separately from the overburden.

  At *rehabilitation* replace soil to appropriate soil depths, and cover areas to achieve an appropriate topographic aspect and attitude to achieve a free draining landscape and as close as possible the pre-mining land capability rating.

- Over area of STRUCTURES (Offices, Workshops, Haul Roads) AND SOFT OVERBURDEN STOCKPILES *strip the top 300 mm* of usable soil over all affected areas including terraces and *strip remaining usable soil* where founding conditions require further soil removal. Store the soil in stockpiles of not more than 1.5 m around infrastructure area for closure rehabilitation purposes. Stockpile hydromorphic soils separately from the dry materials.

For rehabilitation strip all gravel and other material places to form terraces and recycle as construction material or place in open pit. Remove foundations to a maximum depth of 1m. Replace soil to appropriate soil depths, and over areas and in appropriate topographic position to achieve pre-mining land capability and land form.

- Over area of CONSTRUCTION OF TAILINGS STORAGE FACILITIES AND HARD OVERBURDEN STOCKPILES (Co-disposal Facility in this case) *strip usable soil* to a *depth of 750 mm where possible and/or* in areas of *arable soils* and *between 300mm and 500mm* in areas of *soils with grazing land capability.* Stockpile hydromorphic soils and out wash derived soils separately from the dry and friable materials. *For rehabilitation* strip all gravel and other material places to form terraces and recycle as construction material or place in open pit. Remove foundations to a maximum depth of 1m. Replace soil to appropriate soil depths, and over areas and in appropriate topographic position to achieve pre-mining land capability.

- Over areas to be utilized for ACCESS ROADS, LAY-DOWN PADS AND CONVEYOR SERVITUDES *strip the top 150 mm* of usable soil over all affected areas and stockpile in longitudinal stockpile or berms upslope of the facilities and within the mining lease area.

In general, the depths of the topsoil materials that characterise the site are between 100mm and 400mm. However, due to the shallow soil depths on the more rocky slopes outside of the alluvial out wash zones and in some localities associated with the desert plains, and the need to rehabilitate these areas with sufficient materials to induce growth at closure, it is recommended that a minimum of 500mm is stripped from the Plant Site and associated infrastructure areas (Sites with impacts to below the B2/1 level, or foundations that extend into the saprolitic zone (weathered rock)), and 300mm from all roads (Access and Haulage Ways) and founding pads for the soil stockpiles and co-disposal facility, while an additional 300mm is removed from the open pit mining area to make up the quantities required to cover the Plant area with 500mm.

The positioning of these storage facilities will need to be assessed on the basis of the cost of double handling, distances to the point of rehabilitation need, and the potential for use of the materials as storm water management facilities (berms). Suggestions include the use of materials in positions upslope of the mining infrastructure and mining facilities as clean water diversion berms, and/or as stockpiles close to, but outside of the final voids that are to be created by the mining operations. The berms should be kept to height of 1,5m where ever possible, with any residual stockpiles being constructed in a series of 1,5m lifts to a maximum of 20m – preferably 15m (this will be dependent on the visual specialists findings).

Soils removed from areas that require deep foundations, lay-down pads for the co-disposal facility and the processing/beneficiation facility, conveyer routes, dam footprints, all access and haulage roads and their associated support infrastructure must be stockpiled as close as possible to the facilities as is possible without the topsoil becoming contaminated or impacted by the operations.

The vegetated soils should be stripped and stockpiled without the vegetation having been cleared/stripped off wherever practical.

All utilization of the land for any other purpose will need to stop before mining begins.

The base to all of the proposed structures to be constructed should be founded on stabilized materials, the soils having been stripped to below the topsoil contact (100mm to 400mm) and or to 500mm as the depth of utilizable soil.

The stripping and handling of these very sensitive materials during the construction phase or while opening up of the Open pit mining sections is highlighted, because the correct removal, storage and reinstatement of the materials will have a significant effect on the costs and the final success or failure of the rehabilitation plan at closure.

Of importance to the success and long term sustainability of rehabilitating these very sensitive environments will be the replacement of the materials in as close as possible their original position in the topography. Only if the open pit structures or ephemeral channels (that have been impacted) are going to be considered for remediation will it be important to have stored the calcrete horizon and utilizable soil, as these will form the base to any attempt at recreating a barrier layer and the pre mining environment that will have been disturbed or destroyed. This will be no mean feat, as the natural materials that are achieving this function at present have developed under very unique conditions.

This “Soil Utilization Plan” is intimately linked to the mine plan, and it should be understood that if the plan of mining changes, these recommendations will change substantially.

Long term forward planning for the utilization of the materials to their best advantage and the understanding of the final “End Land Use” will need to be well understood if the optimum utilization of the materials is to be achieved. Please refer to the recommendations of materials replacement under the decommissioning and closure plan section.

The consequences of not achieving these goals will need to be assessed and quantified in terms of the long term ecological impacts, and will require the input of the specialist ecologists and engineers in formulating a management plan.

5.2 Operational Phase

<u>Soil Stockpiling and Storage</u>

Based on the findings of the baseline studies the sensitivity of the soil materials across the site (EPL) has been evaluated and site specific recommendations are made that are relevant to the unique conditions that pertain to a desert environment.

Table 5.2– Operational Phase – Soil Conservation Plan

Phase	Step	Factors to Consider	Comments
Operation	Stockpile management	Vegetation establishment and erosion control	Enhanced growth of vegetation on the Soil Stockpiles will be promoted (e.g. by means of watering and/or fertilisation). The purpose of this exercise will be to protect the soils and combat erosion by water and wind.
		Storm Water Control	Stockpiles will be established/engineered with storm water diversion berms in place to prevent run off erosion.
		Stockpile Height and Slope Stability	Soil stockpile heights will be restricted where possible to <1.5m so as to avoid compaction and damage to the soil seed pool. Where stockpiles higher than 1.5m cannot be avoided, these will be benched to a maximum height of 15m. Each bench should ideally be 1.5m high and 2m wide. For storage periods greater than 3 years, vegetative (vetiver hedges and native grass species) or rock cover will be essential, and should be encouraged using fertilization and induced seeding with water and/or the placement of waste rock. The stockpile side slopes should be stabilized at a slope of 1 in 6. This will promote vegetation growth and reduce run-off related erosion. The proposed system of Co-disposal of rock and tailings will help in the stabilization, reduction in erosion and promotion of vegetative cover.
		Waste	No waste material will be placed on the soil stockpiles unless they are >1.5m high in which case waste rock might be needed to clad the soil stockpiles against wind erosion until the vegetative cover can take effect.
		Vehicles	Equipment movement on to of the soil stockpiles will be limited to avoid topsoil compaction and subsequent damage to the soils and seedbank.

It is proposed that the construction of any berms needed and soil storage stockpiles are undertaken in a series of 1,5m lifts if the storage facilities are to be greater than 1,5m high. For soils that are to be stored for any length of time (greater than three years) it is recommended that all utilizable soil should be stockpiled, while the heavier subsoil's and calcrete materials should be stored as separate stores. Storing the soil in this manner will maximize the beneficial properties of each material, and render them available for use at closure in the best position. Separation of these layers at the time of utilizing these soils is a matter for management, as the mixing and dilution of the soil properties is not recommended.

The utilizable soil stockpiled must be adequately protected using either vegetation and/or waste rock as soon after emplacement on the storage pads as possible and maintained throughout the life of mining.

It is imperative, where possible, that the slopes of the stockpile berm facility are constructed to 1:6 or shallower. This will minimize the chances of erosion of the soils and will enhance the growth of vegetation. However, prior to the establishment of vegetation, it is recommended that erosion control measures, such as the planting of Vetiver Grass hedges, or the construction of benches and cut-off drains be included in the stockpile/berm design. These actions will limit the potential for uncontrolled run-off and the subsequent erosion of the unconsolidated soils, while the vegetation is establishing itself. Vetiver is a recognised and certified natural grass specie in South Africa, and after many years of trials and testing has been given a positive record of decision as a non invasive material that can be used as a hedging grass in the development of erosion control. The advantages to the use of Vetiver Grass, is documented in the attached brochure (Refer Appendix 1 - The Vetiver Network International - www.vetiver.org).

Erosion and compaction of the disturbed soils and the management of the stored or stockpiled materials are the main issues that will need to be managed on these sensitive soil forms. This is due to the sensitivity of the soils to mechanical disturbances during/after the removal of surface vegetation and the difficulties in replacing the disturbed materials (Hardpan Calcrete and Calcrete Surface Crusting/Capping). Although limited, the presence of the vegetation aids in the precipitation of the fine coastal mists that blow across the desert plains, and are believed to be responsible for the fine calcrete crusting, while the vegetation in tern binds and stabilises the soils ensuring some stability to the soil profile and soil retention. The enhancement and use of the desert mist will need additional studies, but should be utilized to the advantage of soil stabilization and plant growth. The direction of berm construction might need to be looked at critically in this respect.

These same conditions will need to be emulated if possible as soon after storage/stockpiling and/or rehabilitation of the soils has been undertaken. Although little is known or understood regarding the mechanisms involved in the surface crusting, it is evident that the formation plays a significant role in the stabilization of the desert soils in this area, and has allowed for pedogenetic systems to take effect

Working with or on the differing soil materials (all of which occur within the areas that are to be disturbed) will require better than average management and careful planning if rehabilitation is to be successful. Care in removal and stockpiling or storage of the "Utilizable" soils, and protection of materials which are derived from the "hardpan calcrete" layer is imperative to the success of sustainable rehabilitation in these areas. The sensitivity of the soils is a factor to be considered during the rehabilitation process (Refer to section on Soil Handling and Removal – Construction Phase (5.1) and Mitigation and Management Measures – Decommissioning and Closure Section (5.3)). The soil character is believed to be integral to the success of the biodiversity and ecological systems note in this well balanced environment. Near surface water and the success of the bio-sphere are believed to be very integrately balanced. The interference with this balance will, we believe have a profound effect on the long term sustainability of the overall environment, not least of which is, the presence of the world renowned Welwitschia Fields to the south and south east of the project.

5.3 Decommissioning and Closure

Soil Replacement and Land Preparation

During the decommissioning and closure phase of any mining project there will a number of actions being undertaken or completed. The removal of all infrastructure and the demolishing of concrete slabs, the backfilling of structures such as dams and deep foundations and the compaction of the required barrier layer, and the topdressing of the disturbed and backfilled areas with utilizable soil ready for re-vegetation are all considered part of a successful closure operation.

The order of replacement, fertilization and stabilization of the backfilled materials and final cover materials (soil and vegetation) are all important to the success of the decommissioning plan and final closure.

There will be a positive impact on the environment in general and on the soils in particular as the area of disturbance is reduced, and the soils are returned to a state that can support low intensity wildlife grazing or sustainable conservation.

Table 5.3 – Decommissioning and Closure Phase – Soil Conservation Plan

Phase	Step	Factors to Consider	Comments
Decommissioning & Closure	Rehabilitation of Disturbed land & Restoration of Soil Utilization	Placement of Soils	Stockpiled soil will be used to rehabilitate disturbed sites either ongoing as disturbed areas become available for rehabilitation and/or at closure. The utilizable soil (500mm) removed during the construction phase or while opening up of open cast workings, shall be redistributed in a manner that achieves an approximate uniform stable thickness consistent with the approved postmining land use (Low intensity wildlife grazing), and will attain a free draining surface profile. A minimum layer of 300mm of soil will be replaced.
		Fertilization	A representative sampling of the stripped soils will be analysed to determine the nutrient status of the utilizable materials. As a minimum the following elements will be tested for: EC, CEC, pH, Ca, Mg, K, Na, P, Zn, Clay% and Organic Carbon. These elements provide the basis for determining the fertility of soil. based on the analysis, fertilisers will be applied if necessary.
		Erosion Control	Erosion control measures will be implemented to ensure that the soil is not washed away and that erosion gulleys do not develop prior to vegetation establishment.
	Pollution of Soils	In-situ Remediation	If soil (whether stockpiled or in its undisturbed natural state) is polluted, the first management priority is to treat the pollution by means of in situ bioremediation. The acceptability of this option must be verified by an appropriate soils expert and by the local water authority on a case by case basis, before it is implemented.
		Off site disposal of soils.	If in situ treatment is not possible or acceptable then the polluted soil must be classified according to the Minimum Requirements for the Handling, Classification and Disposal of Hazardous Waste (Local Dept of Water Affairs) and disposed at an appropriate, permitted, off-site waste facility.

Fertilizers and Soil Amendments

For any successful soil amelioration and resultant successful vegetative cover, it is necessary to distinguish between the initial application of nutrients or soil amendments and maintenance dressings. Basal or initial applications are required to correct disorders that might be present in the in-situ material and raise the fertility status of the soil to a suitable level prior to seeding. The initial application of nutrients and stabilisation additives to the disturbed materials is necessary to establish a healthy plant cover as soon as possible. This will prevent erosion. Maintenance dressings are applied for the purpose of keeping up nutrient levels. These applications will be undertaken only if required, and only after additional sample analysis has been undertaken.

Nutrient requirements reported herein are based on the sampling of the soils at the time of the baseline survey and will definitely alter during the storage stage.

The quantities of additives required at any given time during the storage phase or after rehabilitation will potentially change due to physical and chemical processes. The fertilizer requirements should thus be re-evaluated at the time of rehabilitation.

It is recommended that a qualified person (agronomist or plant ecologist) be employed to establish the possible need or not for other additives including organic matter and nutrients that will be applied, prior to the starting of the rehabilitation process.

It will be necessary to re-evaluate the nutrient status of the soils at regular intervals to determine the possibility of needing additional fertilizer applications. In addition, it is important that only small amounts of fertilizer are added on a more frequent basis, rather than adding large quantities in one application.

The following maintenance is recommended:

- ❖ The area must be fenced, and all animals kept off the area until the vegetation is self sustaining;
- ❖ Newly seeded/planted areas must be protected against compaction and erosion (Vetiver hedges etc);
- ❖ Traffic should be limited were possible while the vegetation is establishing itself;
- ❖ Plants should be watered and weeded as required on a regular and managed basis were possible;
- ❖ Check for pests and diseases at least once every two weeks and treat if necessary;
- ❖ Replace unhealthy or dead plant material;
- ❖ Fertilise, hydro seeded and grassed areas soon after germination, and
- ❖ Repair any damage caused by erosion;

Soil Sampling

During the rehabilitation exercise preliminary soil sampling should be carried out to determine the fertilizer requirements more accurately. Additional soil sampling should also be carried out annually until the levels of nutrients, specifically magnesium, phosphorus and potassium, are at the required levels. Once the desired nutritional status has been achieved, it is recommended that the interval between sampling be increased. An annual environmental audit should be undertaken. If growth problems develop, ad hoc, sampling should be carried out to determine the problem.

Sampling should always be carried out at the same time of the year and at least six weeks after the last application of fertilizer.

All of the soil samples should be analysed for the following parameters:

- ❖ pH (H_2O);
- ❖ Electrical conductivity;
- ❖ Calcium mg/kg;
- ❖ Magnesium mg/kg;
- ❖ Potassium mg/kg;
- ❖ Sodium mg/kg;
- ❖ Cation exchange capacity;
- ❖ Phosphorus (Bray I);
- ❖ Zinc mg/kg;
- ❖ Clay% and;
- ❖ Organic matter content (C %)

6. CONCLUSIONS

The Swakop Uranium Husab Project is planned as opencast mining operation, with the construction of processing and beneficiation infrastructure and support waste management facilities – co-disposal facility, access ways, haulage systems and power and water reticulation.

The survey area is characterised by a variety of sensitive to highly sensitive soils that comprise the extremes of shallow Aeolian derived desert plain soils, alluvial wash zones that vary in depth from shallow to deep, and exposed (little vegetation) and rocky hill slopes. The undulating to flat desert plains that host the mineralization contrasts with the sandy/rocky desert environment that host the Khan and Swakop Rivers that form natural boundaries to the study area.

The relatively much younger and generally deeper alluvial derived soils of the ephemeral channels are believed to be underlain by evaporites of varying thickness and composition/density, with significantly large portions of the desert plains returning a similar situation with relatively much shallower soil profiles (generally <400mm). This potential barrier to water infiltration and storage zone is of significance to the overall ecological and biodiversity balance of these areas and zones, and should be investigated in more detail as part of the detailed rehabilitation planning.

It is also apparent, that these layers could be important in the Welwitschia growth patterns, a point that has become more important as the project has evolved.

All of the soil forms noted will be affected or impacted to some degree, with the open pit mining occurring predominantly on the desert plains dominated by shallow gravel's and sandy loams, while the processing and beneficiation facilities are being planned to the west of the open pit structures on the eastern slope of the Khan river ridge on shallow soils and a moderately prominent ephemeral channel, with the co-disposal planned to the east of the mining activities and planned for a footprint that is dominated by desert gravels and sands and a very significant ephemeral channel. This area (co-disposal) comprises a number of shallow desert plain soil forms inter fingered with a prominent and, in the opinion of the specialist study, a very important ephemeral channel (gravels and deeper alluvials), and a generally more varied geomorphology of rock outcrop of schists and marble.

In all cases tabled, the infrastructure and related facilities will impact to a greater or lesser extent on the soil environment, all of which are integrally linked to the ecological well being of the present sensitive bio-systems. The sensitivity of the site in general, and the soils in particular will require better than average management during the construction and operational phases if they are to be useful for rehabilitation during the later stages of the operation and into the closure phase of the project.

The current land capability is listed as wilderness in the majority of the study area, but for successful rehabilitation to take place the site will require well developed and implemented management to stabilise and re-establish the natural elements and obtain a self sustaining and standalone land class unit.

The findings of the studies for the Swakop Uranium Husab Project include:

- Highly variable depth characteristics from the rocky outcrop in the west to deeper alluvial materials associated with the ephemeral channels (wash zones) and a variety of soil depths on the desert plain environment;
- Generally low clay content soils with low carbon contents and resultant high potential erodibility underlain by a variable thickness, and consistency of calcrete;

- Poor nutrient stores in association with high permeability rates in the upper soil horizons and poor water holding characteristics, and impermeable to low permeability on the evaporite layer (calcrete) that underlies the area for the most part;
- Highly variable grain size distribution associated with the alluvial sediments and resultant poor workability index;
- Highly sensitive capping to many of the aeolian desert plain deposits;
- Calcrete layer that forms the impermeable barrier to sub surface water infiltration, particularly within the ephemeral channel environs, a restrictive barrier that has ecological ramifications;
- In general, sensitive soils that will require better than average management.

If these soils are to be disturbed by the mining operation they will require a significant management input to ensure that they can be returned to an end use and stability similar to and/or better than the pre-mining environment.

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APPENDIX 1

VETIVER GRASS ARTICLE

APPENDIX 2

PHOTOGRAPHS