3 ALTERNATIVES ASSESSMENT

The alternatives assessment was undertaken by the lead consultants in conjunction with the client, the April 2011 Mine Plan having been issued as the base plan from which to conduct the impact assessment and finalisation of the sustainable mine plan.

Figures 2 - shows the most recent mine plan proposal with the positioning of the infrastructure open pits and waste stockpile footprints (April 2011).

As part of the overall assessment to the area of concern, it was important that the specialist studies inform 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 significant in terms of long term sustainability and affective mitigation would be the

i) Placement of the proposed support and process infrastructure on the less sensitive and most easily rehabilitated soils;
ii) Reducing of the total area that is going to be disturbed to a minimum,
iii) The storage of utilizable soil (Soils >500mm in depth),
iv) The conservation of these materials (erosion by wind and water and retention of the seed pool) and
v) The utilization of the soils at closure to re-establish the cover to the processing plant site, explosives magazine, haulage ways, access routes etc.

It is well understood and documented that the more highly sensitive and balanced biodiversity and ecology that has been mapped and reported for this area is dependent on the unique soils and pedogenisis that has developed, with the calcrete layer in particular forming an integral part of the system.

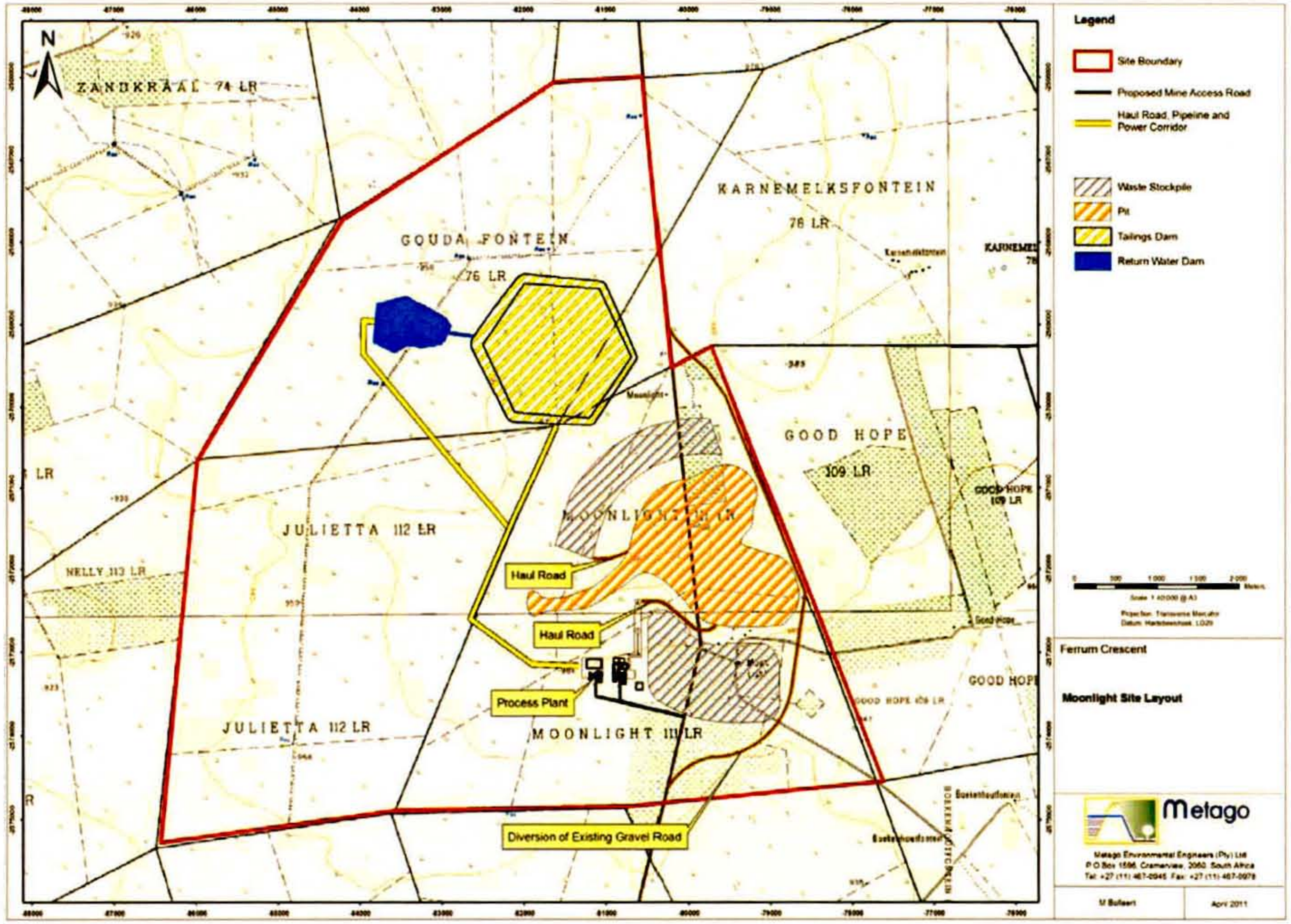
An understanding of the functionality of this layer, the importance of preserving the material at the time of materials stripping and its storage are all considered important elements to the impact assessment and management plan being proposed.

These aspects will need more investigation.

Based on the April 2011 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 latter part of April 2011 on the final positions of the process facilities and waste stockpile footprints and used as the basis for the impact assessment.

The impact on the soils and land capability of the proposed mining development are table in the following sections (Section 4 – Impact Assessment and Section 5 – Management Programme) and are based on the Mine Plan tabled April 2011 (Refer to Figure 3).

Figure 3 Proposed Mine Plan



4. IMPACT ASSESSMENT

The impact assessment has been undertaken for the proposed mining and its related infrastructure and includes the proposed open cast mining and support infrastructure.

The potential impacts of the open pit mining and the development of the processing and support infrastructure (Offices, Processing Plant, Workshops and Waste Stockpile) 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 used 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 Impact Assessment

4.2.1 Construction Phase

Issue - ***Loss of utilizable resource (sterilization and erosion), compaction and contamination or salinization.***

The construction phase will require:

- The stripping of all utilizable soil (Top 150mm to 500mm depending on activity);
- The preparation (levelling and compaction) of lay-down areas, foundations and pad footprint areas for stockpiling of utilizable soil removed from the footprint to the open cast mining area, the waste stockpile and tailings dam facility, the stormwater control dam(s), and the foundations for the Processing Plant and related support infrastructure (Offices, Workshops etc) - Refer to Figure 2 - Mine Plan;
- The clearing, stripping and stockpiling from the construction of all access and haulage roads, water supply and electrical power supply servitudes - linear infrastructure;
- The use of heavy machinery over unprotected soils;
- The creation of dust and loss of materials to wind and water erosion, and
- The possible contamination of the soils by chemical and hydrocarbons spills (dust and dirty water runoff);

The noted (baseline study) differences in the texture of the various soils, the soil depth variations, composition of the "C" horizon (hard rock versus calcrete), wetness of subsoil's and the structure of the different soil groupings is of significance to the impact assessment and the sensitivity that is assigned to the different soil groups and land capability ratings.

The difference in the significance of the expected impacts based on soil form or group alone will have an influence on the management recommendations and mitigation methods employed.

The assessment is confined to the project footprint and its immediate surroundings, and as such the "spatial scale is regarded as "Low" or "Localised".

The support infrastructure designed for the Moonlight Iron Ore project includes large and heavy structures with deep founding excavations (water dams) which will entail the removal of significant quantities of soil, and possibly the complete removal of soil and soft overburden in places were the foundations for the larger structures are to be excavated.

The haulage and conveyencing routes will require that heavy vehicles and loads are moved along these routes, requiring strong and stabilized foundations with moderate to deep excavation and engineering of the sub base. The access roads and general service ways will require less engineering and will not be as invasive on the natural materials. These soils will all however be sterilized and lost from the system for the life of the operation.

A number of temporary facilities will be used primarily for the construction phase of the project and possibly into the early stages of the operation. These will be available for rehabilitation if not needed into the operational phase.

The structures to be used in the contractor's camp are assumed to comprise prefabricated and portable infrastructure with light concrete slabs as foundations, chemical toilets and a soak away system for grey water, and groundwater as the water supply method. These will be easily demolished and rehabilitation undertaken with relative ease.

A number of site specific baseline (existing environment) conditions need mention here if the relative significance of the activities being planned are to be understood. Of importance are:

- ***The underlying calcrete layer (barrier layer), and its function as a barrier to soil water loss down the profile. This will in almost all cases (deep foundations or facilities (dams etc)) be destroyed and possibly removed from the system;***
- ***All/any pan structures that classify as wetlands are considered to be ecologically sensitive and important and should be considered as "No Go" areas (require additional ecological inputs in classify wetland areas);***

These conditions have had a bearing on the ratings assigned to the overall impact statement, as loss of these features will have a definite localised negative impact that is of significance to the biodiversity balance and possible functionality. The calcrete horizon acts as a barrier to surface and soil water infiltration. This feature within the vadose zone is considered important for the biodiversity balance of this sensitive environment, as it is possibly responsible for soil water and surface water being retained in a position close to surface were it can be used.

Impact Significance

The loss of the utilization of the soil resource will impact the land use practice of moderate intensity wildlife grazing and the commercial hunting that is the major activity on these lands at present. These activities are perceived to be of great economic benefit to the local economy and land owners.

The construction of the Process Plant and its support activities (Waste Stockpile and Water Control/Management Facilities) will if un-managed and without mitigation:

- Have a definite negative impact on the environment due to the loss of the soil resource;
- Have the potential for contamination (hydrocarbon and reagent chemical spills, raw materials and spillage of product), compaction of working/laydown areas and the waste storage facility footprints and soil stockpiles and the potential for erosion (wind and water – dust and suspended solids) over unprotected areas;
- Have a moderate negative intensity potential rating based on the confined (limited to footprint of impact) and compact nature of the infrastructure for the relative size of the project.
- Continue throughout the construction phase and into the operational phase;
- Is reversible (can be broken down and rehabilitated), but is in place for a significant period of time (Life of mine) and
- Is confined to the site only.

However, with management, the loss, degree of contamination, compaction and erosion of this primary resource can be mitigated and reduced to a level that is more acceptable.

The reduction in the significance of the impact can be achieved by:

- Limiting the area of impact to as small a footprint as possible, inclusive of waste management facilities, resource stockpiles and the length of servitudes, access and haulage ways and conveyencing systems wherever possible;
- Construction of the facility and associated infrastructure on the less sensitive soil groups;

- An awareness of the length of time that the resource will need to be stored and managed (life of the mining venture and potentially beyond – use of the facility to process additional mining ventures after the life of the Moonlight Project);
- The development and inclusion of soil management as part of the housekeeping operations, and the independent auditing of the management;
- Effective soil stripping during the less windy months when the soils are less susceptible to erosion;
- Separation of the utilizable soils and calcrete base materials from each other and from the soft overburden;
- Effective cladding of the berms and soil, calcrete stockpiles/heaps with vegetation or large rock fragments, and the minimising of the height of storage facilities to 15m and soil berms to 1,5m wherever possible;
- Restriction of vehicle movement over unprotected or sensitive areas, this will reduce compaction;
- Soil amelioration (cultivation) to enhance the oxygenation and growing capability (germination) of natural regeneration and/or seed within the stockpiled soils (maintain the soils viability during storage) and areas of concurrent rehabilitation.

It is evident that, failure to manage the impacts on this important resource (soil) will result in the total loss of this resource, with a resultant much higher significance rating.

Residual Impact (Post Mitigation)

The above management procedures will likely reduce the significance of the impacts to moderate in the medium term.

Table 4.2.1 Construction Phase Impact Significance

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

4.2.2 Operational Phase

Issue ***Loss of utilizable resource (Sterilization and erosion), compaction, de-nutrification and contamination or salinization.***

The operation phase of the proposed mining and processing of the raw product will see the impact of transportation of reagents and additives into the complex, and final product being transported to the markets. The potential for spillage and contamination of the in-situ and stockpiled materials due to dirty water run-off and/or contaminated dust deposition/dispersion, the de-nutrification of the stockpiled soils due to excessive through flow of rain water on unconsolidated and poorly protected soils, and the flushing of the soil nutrient pool by rainfall on unprotected soils is probable if un-managed. In addition, the potential for compaction of the in-situ materials by uncontrolled vehicle movement and the loss of the soil resource from the environment (down-wind and downstream) of soil by wind and water erosion over un-protected ground will need to be considered.

In summary, the mining operation and associated process activities will result in:

- The sterilization of the soil resource on which the facilities are constructed. This will be an on-going loss for the duration of the operation;
- The creation of dust and the possible loss (erosion) of utilizable soil down-wind and/or downstream;
- The compaction of the in-situ and stored soils and the potential loss of utilizable materials from the system;
- The contamination of the soils by dirty water run-off and or spillage of hydrocarbons from vehicle and machinery or from dust and emissions from the process;
- Contamination of soils by use of dirty water for road wetting (dust suppression) and irrigation of the stockpile vegetation;
- Potential contamination of soils by chemical spills of reagents being transported to site;
- Contamination of soil resource by dust and emission fallout;
- Sterilization and loss of soil nutrient pool, organic carbon stores and fertility of stored soils;
- Impact on soil structure and soil water balance.

Un-managed soil stockpiles and soil that is left uncovered/unprotected will be lost to wind and water erosion, will lose the all-important, albeit poor nutrient content and organic carbon stores (fertility) and will be prone to compaction.

The rehabilitation of the temporary infrastructure that was used during the start-up and construction phase will result in an improvement (positive impact) by reducing the area of disturbance.

Impact Significance

The result of the mining and process operations on the soil resource will have a negative intensity potential that is moderate to low, that will last for the life of the operation (reversible if rehabilitated) and be confined to the immediate site or immediate vicinity.

In the un-managed scenario the frequency is likely to be continuous resulting in a significance rating of medium to high.

It is inevitable that some of the soils will be lost during the operational phase if they are not well managed and a mitigation plan is not made part of the general management schedule.

The impacts on the soils during the operational phase (stockpiled, peripheral soils and downstream (wind and water) materials) may be mitigated with management procedures including:

- Minimisation of the area that can potentially be impacted (eroded, compacted, sterilized or de-nutrified);
- Timeous replacement of the soils so as to minimise/reduce the area of affect and disturbance;
- Effective soil cover and adequate protection from wind (dust) and dirty water contamination - vegetate and/or rock cladding;
- Regular servicing of all vehicles in well-constructed and bunded areas;
- Regular cleaning and maintenance of all haulage ways, conveyencing routes and service 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 on all areas that become available for rehabilitation (temporary servitudes), and
- Soil amelioration (rehabilitated and stockpiled) 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.

It will be necessary as part of the development plan to maintain the integrity of the stored soils, so that they are available for rehabilitation at decommissioning and closure. If the soil quantities and qualities are (utilizable soils) managed through the operational phase, rehabilitation costs will be reduced and natural attenuation will more easily and readily take effect and a sustainable "End Land Use" achieved.

Residual Impact (Post Mitigation)

In the long term (Life of the operation) and if implemented correctly, the above mitigation measures will reduce the impact on the utilizable soil reserves (erosion, contamination, sterilization) to a significance rating of low to medium.

However, if the soils are not retained/stored and managed, and a workable management plan is not implemented the residual impact will definitely incur additional costs and result in the impacting of secondary areas (Borrow Pits etc) in order to obtain cover materials etc.

Table 4.2.2a Operational Phase - Impact Significance

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

4.2.3 Decommissioning & Closure Phase

Issue: ***Net loss of soil volumes and utilization potential due to change in material status (Physical and Chemical) and loss of nutrient base.***

The impacts on the soil resource during the decommissioning and closure phase are both positive and negative, with:

- The loss of the soils original nutrient store and organic carbon by leaching of the soils while in storage;
- Erosion and de-oxygenation of materials while stockpiled;
- Compaction and dust contamination due to vehicle movement while rehabilitating the area;
- Erosion due to slope stabilization and re-vegetation of disturbed areas;
- Contamination of replaced soils by use of dirty water for plant watering and dust suppression on roadways;
- Hydrocarbon or chemical spillage from contractor and supply vehicles.
- An improvement (positive impacts) due to the reduction in areas of disturbance and return of soil utilization potential, uncovering of areas of storage and rehabilitation of compacted materials.

Impact Significance

The impact will remain the net loss of the soil resource if no intervention or mitigating strategy is implemented. The intensity potential will remain moderate and negative for all of the activities if there is no active management (rehabilitation and intervention) in the decommissioning phase, and closure will not be possible. This will result in an irreversible impact that is continuous.

However, with interventions and well planned management, there will be medium to medium high intensity potential as the soils are replaced and fertilization of the soils is implemented after removal of the infrastructure.

Ongoing rehabilitation during the operational (temporary infrastructure used during exploration and construction phase) and decommissioning phases will bring about a net long-term improvement on the impact on the soils, albeit that the land capability will likely be reduced to wilderness status.

The intensity potential of the initial activities during rehabilitation and closure will be medium/moderate and negative due to the necessity for vehicle movement while removing the demolished infrastructure and rehabilitating the operational footprint(s). Dust will potentially be generated and soil will probably be contaminated, compacted and eroded to differing extents depending on the degree of management implemented.

The net improvement on the impacts of rehabilitation on the area are the reduction in the footprint of disturbance, the amelioration of the affected soils and oxygenation of the growing medium, the stabilizing of slopes and the revegetation of disturbed areas.

Residual Impacts (Post Mitigation)

On closure of the mining operation and its associated processing activities the long-term negative impact on the soils will be reduced from a significance ranking of moderate to low if the management plan set out in the Environmental Management Programme is effectively implemented.

Re-creation of the calcrete layer effect (Barrier) will require both environmental as well as engineering inputs. This conclusion supposes that the utilizable soils will be available (had been 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.

Table 4.2.3a Decommissioning and Closure Phase – Impact Significance

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

At closure (obtaining of certificate of closure from authorities) the residual impact should, if all rehabilitation and management efforts have been complied with, result in a net improvement (positive) impact, with the area being returned to a land capability of low intensity grazing or wilderness status (similar to the original land capability prior to development), and the use of the land being returned to that of wildlife management (current land use).

5. SOIL AND LAND MANAGEMENT PLAN

In accordance with the IFC Performance Principles and the concept of sustainability, it is incumbent on any developer to not only assess and understand the possible impacts that a development might cause, but to also propose, table, implement and monitor the management measures that will aid in minimising the impact and were possible mitigate the effects.

The management of the natural resources (soils and land capability) have been assessed on a phase by phase basis (construction, operation and decommissioning/closure) in keeping with the impact assessment (EIA) philosophy, while the Management Plan (EMP) has been designed as a ***working plan and utilization guide*** for soil and land management.

The results tabled are based on the site specific 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.

The plan gives recommendations on the stripping and handling of the soils throughout the life of the development along with recommendations for the utilization of the soils for rehabilitation at closure. It has been assumed that all infrastructure will be removed and that the areas affected will be returned to as close as possible their pre-construction state (topographic levels, wilderness/conservation or low intensity grazing (wildlife) status – Refer to the Chamber of Mines Land Classification System (Refer to Section 2 - Table 2.2.1 of the Baseline Study).

The concept of stripping and storage of all "Utilizable" soil is recommended as a minimum requirement and as part of the overall Soil Utilization philosophy.

In terms of the "Minimum Requirements", usable or utilizable 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 forms of soil encountered in a project area and the type of project being considered. It does not differentiate between topsoil (orthic horizon) and other subsoil horizons necessarily.

The following soil utilization guidelines **(all be they generic)** should be adhered to wherever possible:

- Over areas of open cast mining and/or deep excavation (borrow pit excavations and deep foundations where the majority or all of the soil profile is to be impacted) *strip all usable soil* as defined (700mm) in terms of the soil classification and stockpile as berms or low, terraced dumps. The ***deep sandy*** loams (Refer to Figure 2.1.2b) should be stockpiled separately from the ***shallow rocky*** materials and in-situ derived materials, which in turn should be stored separately from the ***structured*** soils and any calcrete material.
- Once the utilizable soil has been removed and stockpiled, the soft overburden must be removed and stored as a separate unit, as a defined dump of less than 15m in height preferably. Protect from contamination and erosion by the propagation of a vegetative cover with adequate drainage to manage surface runoff, or if not possible, then rock cladding of the sandy materials will help to reduce erosion, retain water and help with the natural re-generation of vegetative growth over time.

  At *rehabilitation* replace the soft overburden followed by the calcrete material, compact the calcrete in place, followed by the replacement of the utilizable soil to the predetermined appropriate soil depths.

This should be followed by the final landscaping and topographic contouring of the aspect and attitude to achieve a free draining landscape as close as possible to the pre-mining/construction land form.

- Over areas planned for less invasive Structures (Offices, Workshops etc) and any material stockpile or storage, *strip the top 500 mm* of usable soil over all affected areas including terraces and *strip remaining usable soil and calcrete (if present in profile)* where founding conditions require further soil removal.

  Store the soil in stockpiles or berms of not more than 1.5 m around infrastructure area ready for closure rehabilitation purposes. Stockpile hydromorphic (wet) soils separately from the dry materials, and the "calcrete" separately from all other materials.

  Protect all stockpiles from water and wind erosion (loss of materials) and contamination by dust and runoff water. Clad stockpiles with larger rock or vegetate the stored materials.

  At closure/rehabilitation, remove all large boulders and gravel from the rehabilitated landscape and place at the base/bottom of the open foundations or borrow areas or rehabilitation profile so that they do not interfere with the tillage and cultivation of the final surface. Remove foundations to a maximum depth of 1m. Replace soil to appropriate soil depths, and over disturbed areas and in appropriate topographic position to achieve pre-development land capability and land form where possible.

- Over the area of Tailings Dam, Waste Stockpiles and all Heavy Vehicle Haulage Roads and Major Access Routes, *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 separately from the dry and friable materials.

  Before *rehabilitation* remove all gravel and other rocky material and recycle as construction material or place in open voids. Remove foundations to a maximum depth of 1m. Replace soil to appropriate soil depths and in appropriate topographic position so as to achieve pre-construction land capability. Protect the stored materials from erosion and contamination using vegetation or rock cladding.

- Over areas to be utilized for General Access Roads (light delivery vehicles), Laydown Pads and any Conveyencing servitudes (Above ground pipelines and power line servitudes) *strip the top 150 mm* of usable soil over all affected areas and stockpile in longitudinal stockpile or berms upslope of the facilities. Protect from erosion and contamination.

5.1 Construction Phase

The construction methods and final "End Land Use" are important in deciding if the utilizable soils need to be stripped and retained, and ultimately how much of the materials will be needed for the rehabilitation (stripping volumes). Failure to remove and store the ***utilizable*** materials will result in the permanent loss of the growth medium. Making provision for retention of utilizable material for the decommissioning and/or during rehabilitation will not only save significant costs at closure, but will ensure that additional impacts to the environment do not occur.

The depths of utilizable materials vary between 100mm and greater than 1,500mm. However, due to the shallow soil depths on the more rocky areas/slopes, albeit that these are a small percentage of the overall area, it is recommended that sufficient materials are removed from the areas were the soil depths are present and do exist, so that the shallow areas can be adequately rehabilitated at closure.

For the open cast mining area it is recommended that at least 500mm of soil should be stripped, with 750mm wherever possible. The majority of the area confirmed as low sensitivity and or outside of the "No Go" zones are sufficiently similar that they can be stored as one stockpile. The sensitive soils and wet based materials should not be impacted.

Table 5.1 describes the proposed utilization of the soils during the construction phase.

Table 5.1 Construction Phase – Soil Utilization 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 removed and stockpiled separately from the lower "B" horizon, with the calcrete layer being seperated from the soft/decomposed rock, and wet based soils seperated from the dry soils if they are to be impacted.
		Stripping	The "Utilizable" soil will be stripped to a depth of 750mm or until hard rock/calcrete is encountered. These soils will be stockpiled together with any vegetation cover present (only large vegetation to be removed prior to stripping). The total stripped depth should be 750mm, wherever 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. All stockpiles will be founded on stabilized and well engineered "pads" (compacted and well drained footprint).
		Designation of Areas	Soils stockpiles will be demarcated, and clearly marked to identify both the soil type and the intended area of rehabilitation.

This "Soil Utilization Plan" is intimately linked to the "development plan", and it should be understood that if the plan of construction changes, these recommendations will probably have to change as well.

5.2 Operational Phase

The operational phase will see very little change in the development requirements, with the footprint of disturbance remaining constant, albeit that the temporary infrastructure might become redundant and rehabilitation of these features might be possible.

Maintenance and care of the soil and land resources will be the main management activity and objective required during the operational phase. Management of material loss, compaction and contamination are the main issues of consideration. Table 5.2 details recommendations for the care and maintenance of the resource during the operational phase.

The semi-arid to arid climate and unique character of the soils in these areas require that the site specific and unique natural phenomena should be used to the advantage of the project.

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, and it is important that the sensitive and highly sensitive materials are avoided wherever possible.

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, with the soil water (near surface water) held within the profile by the calcrete layer believed to be integral to the success of the overall biodiversity balance.

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 and berms will be promoted (e.g. by means of watering and/or fertilisation), or a system of rock cladding will be employed. 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 and berm 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 - refer to Appendix 1) 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.
		Waste	Only inert waste rock material will be placed on the soil stockpiles if the vegetative growth is impractical or not viable (due to lack of water for irrigation etc.). This will aid in protecting the stockpiles from wind and water erosion until the natural vegetative cover can take effect.
		Vehicles	Equipment, human and animal movement on the soil stockpiles will be limited to avoid topsoil compaction and subsequent damage to the soils and seedbank.

5.3 Decommissioning and Closure

The decommissioning and closure phase will see:

- The removal of all infrastructure;
- The demolishing of all concrete slabs and ripping of any hard surfaces;
- The backfilling of any open voids and deep foundations and the reconstruction of the required barrier layer (compaction) wherever feasible and possible;
- Topdressing of the disturbed and backfilled areas with the stored "utilizable" soil ready for re-vegetation;
- Fertilization and stabilization of the backfilled materials and final cover materials (soil and vegetation) and
- The landscaping of the replaced soils to be free draining.

There will be a net improvement (positive) impact on the soil and land capability environments 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 (as close as possible to the original state).

Table 5.3 is a summary of the proposed management and mitigation actions recommended.

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 to 750mm) removed during the construction phase, must be redistributed in a manner that achieves an approximate uniform stable thickness consistent with the approved post development end land use (Conservation land capability and/or 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 and stockpiled soils will be analysed to determine the nutrient status and chemistry 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 of at an appropriate, permitted, off-site waste facility.

5.4 Monitoring and Maintenance

Nutrient requirements reported herein are based on the monitoring and sampling of the soils at the time of the baseline survey. These values will definitely alter during the storage stage and will need to be re-evaluated before being used during rehabilitation. Ongoing evaluation of the nutrient status of the growth medium will be needed throughout the life of the project and into the rehabilitation phase.

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

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

Soils should be sampled and analysed for the following parameters:

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

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) – Refer to Appendix 1;
- 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 and practical;
- 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;

6. CONCLUSIONS

The Moonlight Iron Ore Project is planned as a long term open cast mining development, with a full and modern processing and beneficiation infrastructure inclusive of the support waste management facilities, access and haulage ways and power and water reticulation.

The survey area is characterised by a variety of sensitive to highly sensitive soils that vary from extremes of moderate to deep sandy soils with low clay contents, low soil water storage ability, a high erosion index, and low nutrient stores, to moderately clay rich and structured materials that have better than average soil water holding characteristics and a better land capability rating.

The sandy loams are moderately easy to work in a range of climatic condition, while the sandy clay loams are generally difficult to work and store/stockpile if handled or worked on in a wet state.

Of greater significance, but of much smaller spatial extent are the shallow calcrete and ferricrete based sandy clay and clay loams that are associated with the pans and clay rich materials. These are again, difficult to work in the wet state, and are susceptible to chemical erosion if left unprotected. These soils are important in terms of their water holding capabilities and their ability to restrict the vertical infiltration of surface water (barrier layer).

The presence of the disconformable evaporite layer at varying depths is characteristic of a significantly large proportion of the area of study (as noted from the soil test pit exposures) and when combined with the semi-arid to arid climate and the resultant complexity of soil formation and/or deposition, a variety of soil forms and families is the result.

The relatively much younger and generally deeper red sands that cover a large portion of the study area are known to be underlain by evaporites of varying thickness and composition/density, with a much smaller but more significant portion of the area being characterised by calcrete (evaporite) pans that are the result of the calcrete layer being present at surface.

A variety of ephemeral pan like structures are present across the study area, the result of retained soil water or possibly perched water within the vadose zone, believed to be caused by the restriction of vertical infiltration and low permeability of the calcrete layer (Refer to Appendix 2 - Calcrete Geotech Classification) at the base of the soil profile. This potential barrier to water infiltration and resultant storage zone is of significance to the overall biodiversity balance of these areas and groups of soils.

The mechanisms at work in the creation of the evaporite and the ability to recreate this important layer will need to be investigated in more detail as part of the rehabilitation design.

Based on the proposed development plans tabled, all of the soil forms mapped will be affected or impacted to some degree. This impact assessment has mapped the areas of greatest significance based on the soil sensitivities and land capabilities.

In all cases tabled, the infrastructure (Offices, Plant, Tailings Dam and Waste Storage) and its support facilities will impact to a greater or lesser extent on the sensitive to highly sensitive soil environment, all of which are integrally linked to the present sensitive bio-systems (wet soils and pan structures).

The sensitivity of the soils mapped 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 rated as wilderness or at best low intensity grazing on the more sensitive soils, and arable on the less sensitive sandy loams. However, 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, all of which will require that a soil depth of at least 500mm (Grazing Land Potential) is re-instated across the landscape.

The findings of the soil and land capability specialist studies conclude that:

- There is a highly variable depth characteristics from small areas of rocky outcrop and calcrete exposure to deeper in-situ derived soils associated with the evaporite (calcrete) layer that underlies the soils disconformably, to deep sands;
- Generally moderate to very low clay content soils with low reserves of organic carbon 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);
- There is a calcrete layer that forms an impermeable barrier to sub surface water infiltration, resulting in added soil water stores and the potential for perched waters within the vadose zone, the sub horizontal movement of soil water along palaeochannels associated with the disconformable land surface, and a restrictive barrier that has ramifications to the overall biodiversity balance if disturbed;
- In general, sensitive soils that will require better than average management.
- Moderate to high effects and impacts on the highly sensitive soils associated with the proposed process plant and associated infrastructure in the southern central portion of the site and the area under the proposed TSF and RWD;
- Moderate to high impacts on the soils and land capability due to the loss in resource on the soils that will be effected by the construction and operation of the Open Pit mining area (bench mining) and its associated support infrastructure;
- A moderate to low significance rating due to the potential for contamination, compaction and erosion of materials during the construction phase predominantly, with a lower significance during the operational phase and into the decommissioning and closure of the facilities.
- All of the impacts except for the overall loss of the resource under the waste stockpiles will be managed and mitigated to differing degrees as the processing facilities come to the end of their life and rehabilitation is possible.

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APPENDIX 1

VETIVER GRASS ARTICLE

THE VETIVER SYSTEM
A PROVEN SOLUTION

The Vetiver Network International - www.vetiver.org

VETIVER GRASS
A HEDGE AGAINST EROSION

The Vetiver Network International - www.vetiver.org


Malaysia - highway stabilization


India - beach stabilization


Fiji - 2m high vetiver created terrace


Ethiopia - soil conservation


Cambodia - river bank stabilization


Australia - wastewater treatment

The problems we face are growing at a pace that challenges our ability to solve them

- Soil loss results in physical, chemical, and biological degradation and loss of ability to produce food.
- Land slides, unstable slopes and flooding destroy agricultural land and valuable infrastructure.
- Siltation of drains, lakes, reservoirs, and rivers reduce storage capacity and can result in flooding.
- Overuse and misuse of large areas of land, and contamination by toxic runoff from mine dumps, landfills, feedlots, salinization, etc... require extensive reclamation programs.
- Water polluted by mineral or organic sediments as well as the pollutants mentioned above detrimentally affect drinking water supplies, fresh and saltwater fisheries, and coral reefs.
- Decreased groundwater recharge in watersheds results in local water shortages.
- Inattention to site stabilization and maintenance results in infrastructure failure and losses.

Solutions are often too complex or costly given existing resources and capacity

- The complexity and high cost of engineering and structural designs; ambitious and impracticable environmental protection and remedial practices - often due to over demanding design engineers and supervisors - and unnecessary high-end quality control measures; as well as, amongst others, bureaucratic accounting and bidding procedures.
- Low potential for sustainability due to lack of funds for maintenance, unsuitability to local conditions/capacity, or need for continuous subsidies to maintain effectiveness.

Many of these problems share a common solution in THE VETIVER SYSTEM

The Vetiver System (VS)

- Consists of a simple vegetative barrier (a hedge) comprising upright, rigid, dense, and deeply-rooted clump grass, that slows runoff, allowing sediments to stay on site, eventually forming natural terraces.
- Vetiver grass is already found in more than 120 countries throughout the tropics and sub-tropics.
- It has been used for more than a century in many Asian, African, and Caribbean countries as a traditional "soil binding" technology.
- Today, the VS is used for soil and moisture conservation, bioengineering, and for bioremediation.

It is not weedy or invasive

- Hedges are propagated and established vegetatively. **Analyses show that recommended cultivars of *Chrysopogon zizanioides* (south India type) are sterile and are not invasive.**

Deep, tough roots

- Vetiver's deep, massive fibrous root system can reach down to two to three meters in the first year.
- This massive root system is likened to "*living nails*", binding the soil together.
- The measured maximum resistance of vetiver roots in soils is equivalent to one-sixth that of mild steel (75 Mpa); stronger than most tree roots; improves soil shear strength by as much as 39%.
- The fibrous mat of roots strengthens earthen structures and removes many contaminants from soil and soil water.
- Closely planted slips grow into dense hedgerows with a deep, tough root systems. They can withstand inundation, and effectively reduce flow velocities, forming excellent filters that prevent soil loss.

PLANT -- VETIVER GRASS -- *Vetiveria zizanioides L (Nash) recently reclassified* ***Chrysopogon zizanioides L (Roberty)***


Chrysopogon zizanioides L (Roberty) previously named Vetiveria zizanioides L (Nash) common name: ***Vetiver Grass***


Planting slip


Tissue cultivation of vetiver grass


6 month vetiver root grown in Senegal


Cross section through a two year old hedgerow. Note sediment build up over original top soil (brown line)


Longitudinal section through hedgerow


Newly planted vetiver hedgerow


Large differences occur between the roots of vetiver grass species and cultivars. Compare *C. zizanioides* (upper) with *C. nemoralis* (lower)


Indian vetiver nursery of containerized plants


Planting containerized vetiver on steep highway fill slope in Malaysia


Vetiver inflorescence. In many cases vetiver never flowers, but when it does, it produces rather beautiful non-fertile flowers

WHY VETIVER GRASS

For a plant to be useful for agriculture and biological engineering, and be accepted as safe, it should have as many as possible of the following characteristics:

- Its seed should be sterile, and the plant should not spread by stolons or rhizomes, and therefore not escape and become a weed.
- Its crown should be below the surface so it can resist fire, over grazing, and trampling by livestock.
- It should be capable of forming a dense, ground level, permanent hedge, as an effective filter, preventing soil loss from runoff. Apparently only clones will grow 'into' each other to form such a hedge.
- [illegible] should be perennial and permanent, capable of surviving as a dense hedge for decades, but only [illegible]wing where we plant it.
- [illegible]hould have stiff erect stems that can, at minimum, withstand flowing water of 1 foot (30 cm) depth that is moving at 1 foot per second (0.3 meters/second).
- It should exhibit xerophytic and hydrophytic characteristics if it is to survive the extremes of nature. Vetiver grass, once established, is little affected and highly tolerant of droughts or floods.
- It should have a deep penetrating root system, capable of withstanding tunnelling and cracking characteristics of soils, and should the potential to penetrate vertically below the plant to at least three meters.
- It should be capable of growing in extreme soil types, regardless of nutrient status, pH, sodicity, acid sulphate or salinity, and toxic minerals. This includes sands, shales, gravels, mine tailings, and even more toxic soils.
- It should be capable of developing new roots from nodes when buried by trapped sediment, and continue to grow upward with the rising surface level, forming natural terraces.
- It should not compete with the crop plants it is protecting.
- **it should not be a host (or intermediate host) for undesirable pests or diseases of any other plants.**
- It should be capable of growing in a wide range of climates -- from 300 mm of rainfall to over 6,000 mm -- from air temperatures of -15° C (where the soil does not freeze) to more than 55° C. It should be able to withstand long and sustained droughts (>6 months).
- It should be cheap and easy to establish as a hedge and easily maintained by the user at little cost.
- It should be easily removed when no longer required.

Vetiver Grass cultivars used around the world for essential oil production, originating from south India, have all these characteristics.


Dense crown of a vetiver grass clump from which roots and shoots emerge


After a fire vetiver hedge remains vertical and quickly recovers with new growth


Erosion sediment trapped by a vetiver hedgerow in Madagascar.


Closely spaced (15 cm between plants at planting) hedgerow at left assures a properly dense hedge

Very dense and very effective vetiver hedgerow

VS FOR AGRICULTURE

- **On-farm** - in modern and traditional agriculture VS is used to trap sediments, control runoff, increase soil moisture recharge, and stabilize soils during intense rainfall and floods. There is only minimal competition with adjacent perennial and annual crops for moisture or nutrients. VS is used for wind erosion control, forage, and pest control.
- **On-farm** - VS protects rural structures such as roads, ponds, drains, canals and building sites. Also used for land and gully rehabilitation.
- **Off-farm** - VS plays a vital role in watershed protection at large scales - slowing down and spreading rainfall runoff, recharging groundwater reserves, reducing siltation of drainage systems, lakes and ponds, reducing agrochemical loading into groundwater and watercourses, and for rehabilitation of misused land.






Top left: Vetiver hedgerows protecting farm crops on steep slopes in the highlands of N.E. Thailand

Top center: Vetiver hedgerow on Darling Downs, Australia, used to reduce erosive power of flooding on flat land -- as a result more land can be cropped each year

Top right: Farmers from Gundalpet, India, have used vetiver for centuries to reduce soil loss, conserve moisture, provide forage, and increase groundwater recharge

Bottom left: Vetiver hedgerow used to protect crops from high winds in Pintang Island, China

Bottom center: Vetiver used to stabilize a farm road in Malaysia

Bottom right: A irrigation drain/canal stabilized by vetiver hedgerow

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VS FOR BIO-ENGINEERING

- For the stabilization and protection of infrastructure (roads, railroads, and building sites) VS is proven effective, efficient, and low cost when compared to other 'hard' engineering alternatives using cement, rock, and steel. Vetiver grass roots have an Mpa of 75 (1/6 the strength of mild steel) and will improve soil shear strength at a depth of 0.5 meters by as much as 39%. VS costs from 55% to 85% less than traditional engineering systems. **For successful applications cultivars of *Chrysopogon zizanioides* originally from south India should be used**. These cultivars are of the same genotype as Monto and Sunshine, and are **non-invasive.** They have a more massive root structure than non sterile *C.zizanioides* accessions from north India, Africa (*C.nigratana*) and Thailand (*C.nemoralis*)



The KEY to successful VS applications for infrastructure is the availability of large quantities of good quality vetiver planting material. Above, from left to right, are nurseries from Senegal (containerized), China (bare rooted) and Thailand (from in vitro plantlets)

Venezuela - rehabilitation of bauxite mine tailings. The soils are very acid and prone to slippage. High levels of fertilizer assure good growth

China - expressway stabilization. This cut was prone to massive slip. Stabilization with VS has given complete protection

China - unstable highway fill prior to VS treatment. Road stability was so bad in untreated state that major lateral cracks in the pavement occurred

China - same fill less than a year later. After another two years this fill became fully forested. Untreated cut in background

Spain - unstable and eroding highway fill treated with VS. Untreated eroded fill on right. VS grows well under low rainfall Mediterranean climate

Vietnam: the Ho Chi Minh Highway has been [illegible] with vetiver grass. The batters and fills [illegible]e and withstand cyclonic rainfall events

Vietnam - Ho Chi Minh Highway - with and without vetiver stabilization

Thailand - a gas pipeline was laid through tropical forest. On steep slopes the right of way was stabilized with vetiver - native plants regenerated

Disaster mitigation - this railroad in Madagascar was closed down by frequent cyclone damage. Stabilization with vetiver was vital in its rehabilitation

Congo D.R. - huge gullies that destroy urban areas and houses can be rehabilitated and stabilized using the Vetiver System.

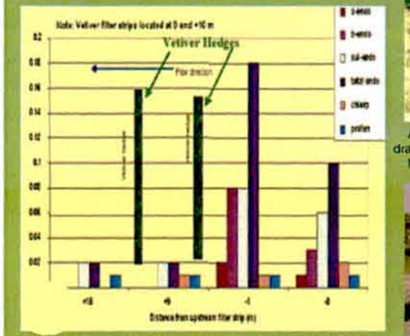
VS FOR WATER RELATED APPLICATIONS

- VS protects ponds, reservoirs, and rivers banks from erosion caused by wave action, it strengthens earthen dams against collapse, and it reduces maintenance costs and ensures the integrity of dam walls, canal and river banks, and drains.
- VS improves groundwater recharge through improved infiltration and reduced rainfall runoff, and the quality of water by removing sediments and chemicals.

Venezuela - Vetiver withstands flooding for long periods. This grass was flooded for 8 months. Vetiver one month after flood receded

China - VS used to stabilize a small river bank located behind hedge allowing the safe production of crops

Vietnam - Vetiver is increasingly used to stabilize the banks of fishponds and to purify pond water



Australia - schematic of research results showing dramatic drop of pesticide levels as pesticide laden water moves through vetiver hedges from right to left. (Green columns = hedges - all other columns pesticide levels)

Australia - VS protects the right hand bank of a drain cut through acid sulphate soils of Queensland. Note left hand bank is devoid of any vegetation

China - partially submerged vetiver grass used to stabilize the draw-down slope of a reservoir in Guangdong Province

Australia - this river bank and bridge abutment have been stabilized with vetiver. Vetiver is an excellent interface for concrete and soil

Zimbabwe - a fast flowing stream protected from stream bank erosion using VS application

Cambodia - This very large bank on the Mekong River has been under continuous erosion. The land owner with assistance from TVNI is stabilizing using vetiver hedgerows.

Cambodia - the bank in the previous image has been reshaped and planted with vetiver hedgerows. Very good growth seven months after planting.

Vietnam - cyclone damage to sea dykes is a major problem. VS has been applied successfully for disaster mitigation

Vietnam - the left hand bank of the canal has been reshaped and stabilized with vetiver, the right bank has yet to be treated.

VS FOR BIO-REMEDIATION

- Onsite and offsite pollution control from wastes and contaminants is a breakthrough application of VS for environmental protection. Vetiver is being used to rehabilitate a large copper mine in China, coal mines in Indonesia, diamond mine spoils in South Africa, to control erosion and leachate from municipal landfills in China.... and more.
- Research has clearly established vetiver's tolerance to extremely high levels of Al, Mn, As, Cd, Cr, Ni, Cu, Pb, Hg, Se, and Zn.
- Vetiver has been used to reclaim soils and increase site productivity in places that were previously believed to be totally unproductive.

Vetiver grass will remove phosphate and nitrate from polluted water. The beaker on the left is before treatment; on the right 4 days later 90% P and 94% N removed

Australia - VS used as a buffer to absorb seeping sewage from this holiday camp site thus reducing runoff and smells

Australia - VS used to stabilize a gold slimes waste area. The hedges reduce the incidence of wind-blown, cyanide-polluted dust

Australia - VS used hydroponically on a pig effluent pond to reduce high levels of phosphate and nitrate

VS FOR OTHER USES

- In disaster mitigation and vulnerability reduction, VS has a crucial role to play.... *"The storms were terrible. [Afterward there were] landslides, roads destroyed, agricultural lands washed away; but, where there were vetiver barriers, everything seemed normal"*. (pers. comm. Mr. E. Mas, USDA/NRCS after Hurricane George, Puerto Rico)
- For handicrafts, perfumes, and medicinal purposes.
- For paper making, mulch, thatch, reinforcing bricks, biofuel, pest control, carbon sequestering, and many other uses.

Thailand - a selection of handicrafts, including handbags, vases, lamp shades, book covers, hats and other crafts from vetiver grass leaves and stems

Zimbabwe - a nicely thatched meeting house using vetiver grass thatch. The thatch will last three times as many years due to its resistance to insects and fungus attack

ACT NOW! **Contact TVNI for additional technical information.**

The Vetiver Network International
709 Briar Rd., Bellingham, WA 98225 USA

Tel/Fax: (001) 360-671-5985
E-mail: coordinator@vetiver.org

Home Page: http//www.vetiver.org
Vetiver Clients Gallery: http://picasaweb.google.com/VetiverClients
Vetiver Picture Gallery:http://picasaweb.google.com/VetiverNetwork
Blog: http://vetivernetinternational.blogspot.com

The Vetiver Network (TVNI) is a nonprofit foundation under United States code 501 (c) (3). It is a volunteer organization that promotes the use of the Vetiver System through dissemination of information and networking worldwide. TVN has helped established over 25 regional and country-based affiliated networks.

Contact your local vetiver network at:

FOR SUCCESSFULL VETIVER SYSTEMS APPLICATION ONLY USE CULTIVARS OF *CHRYSOPOGON ZIZANIOIDES* WITH CHARACTERISTICS OF SOUTH INDIAN GENOTYPES - SUCH AS SUNSHINE, MONTO, KARNATAKA, FIJI, MADUPATTY. THESE NOT ONLY HAVE GOOD ROOT SYSTEMS, BUT ARE KNOWN TO BE NON-INVASIVE AND ARE EXTENSIVELY RESEARCHED

APPENDIX 2

GEOTECHNICAL CLASSIFICATION OF CALCRETE

Geological Society, London, Special Publications

A Geotechnical classification of calcretes and other pedocretes

F. Netterberg and J. H. Caiger

Geological Society, London, Special Publications 1983; v. 11; p. 235-243
doi:10.1144/GSL.SP.1983.011.01.23

A geotechnical classification of calcretes and other pedocretes

F. Netterberg & J. H. Caiger

SUMMARY: Authigenic calcareous accumulations within regoliths can be simply classified for geotechnical purposes as calcareous soils, calcified soils, powder calcretes, nodular calcretes, honeycomb calcretes, hardpan calcretes, and calcrete boulders and cobbles. Each of these categories represents a particular stage in the growth or weathering of a calcrete horizon and possesses a significantly different range of geotechnical properties. A similar classification can be applied to other pedocretes.

Development of the arid and semi-arid zones has increasingly involved the use of non-traditional materials such as calcretes for construction and foundation materials. Such exploitation has often revealed inadequacies in certain geotechnical procedures developed in temperate zones as well as the necessity for studies on these materials. This paper outlines a simple, descriptive classification suitable for geotechnical use on calcretes and similar materials based on approximately 20 years of personal experience of both the authors with these materials. The classification is the latest of several earlier studies (Caiger 1964; Netterberg 1967, 1969a, 1971), and largely represents a very condensed and simplified geotechnical version of one of them (Netterberg 1980) embracing all the known morphogenetic forms of calcrete formation and weathering processes. Although based largely upon southern African experience, perusal of the literature, together with the authors' limited experience in Australia, Israel and Texas, suggests that this classification is applicable to calcretes everywhere and, with minor modifications, to other pedocretes such as ferricretes and silcretes.

Necessity for and requirements of a calcrete classification

The necessity for a calcrete classification stems from the inability of temperate zone soil classifications of the Casagrande (British Standards Institute (BSI) 1957; Bureau of Reclamation 1974; American Society for Testing and Materials (ASTM) 1980) and American Association of State Highway and Transportation Officials (AASHTO) (1978) types adequately to describe and predict the engineering performance of materials composed of cemented particles of clay, silt, sand, etc. or almost pure carbonate, and ranging in consistency from loose silt to very strong rock and in thickness from millimetres to 100 m. Some of these materials are not rock, but they do not slake or soften greatly in water, and when excavated and broken down during compaction, they behave as soils. Only then can they be said to possess a particle size distribution and Atterberg limits. Descriptive methods intended for use on undisturbed material such as those of the ASTM (1980b), BSI (1957, 1972), Geological Society (1970, 1977a,b), Jennings, Brink & Williams (1973), and the Core Logging Committee (1978) are better in this respect, but often require lengthy descriptions to convey an adequate picture. As calcretes frequently present unusual geotechnical properties and performance, it is necessary to distinguish them from other materials (Netterberg 1969a, 1971, 1980, 1982; Horta 1980).

A calcrete classification suitable for geotechnical use should be of both geological and engineering significance, and must be applicable in the field by relatively untrained personnel, as well as satisfying certain other requirements (Netterberg 1969a, 1980). Previous calcrete classifications (reviewed by Netterberg 1980) appear to be either too simple for modern use or too complicated for geotechnical use. The most recent (Horta 1980) only considers calcrete gravels and sands.

Definitions

The extensive calcrete literature has been reviewed in recent years by Netterberg (1969a), Goudie (1973) and Reeves (1976). It is clear that the terms 'calcrete' and 'caliche' have been applied to almost any material of almost any consistency and carbonate content formed by the *in situ* cementation and/or replacement of regolith material by (dominantly) calcium carbonate precipitated from the soil water or ground water. Calcified cave soils, spring tufas, aeolianites, and beachrocks are usually excluded, largely for the sake of convention, although they could be included for geotechnical purposes. The term 'calcrete' has also been used in more restricted senses for indurated materials only or for materials containing more than about 50% $CaCO_3$ equivalent, i.e. the lower limit for the term 'limestone'. This somewhat conflicting usage is accommodated here by the use of the unqualified term 'calcrete' for the widest usages only and the application of qualifying adjectives when more restricted use is intended. In the more restricted usage, calcretes generally possess more than about 50% $CaCO_3$ equivalent and, with one exception, are also indurated, more or less in accordance with the recommendation of the Speciality Session on Pedogenic Materials (1976).

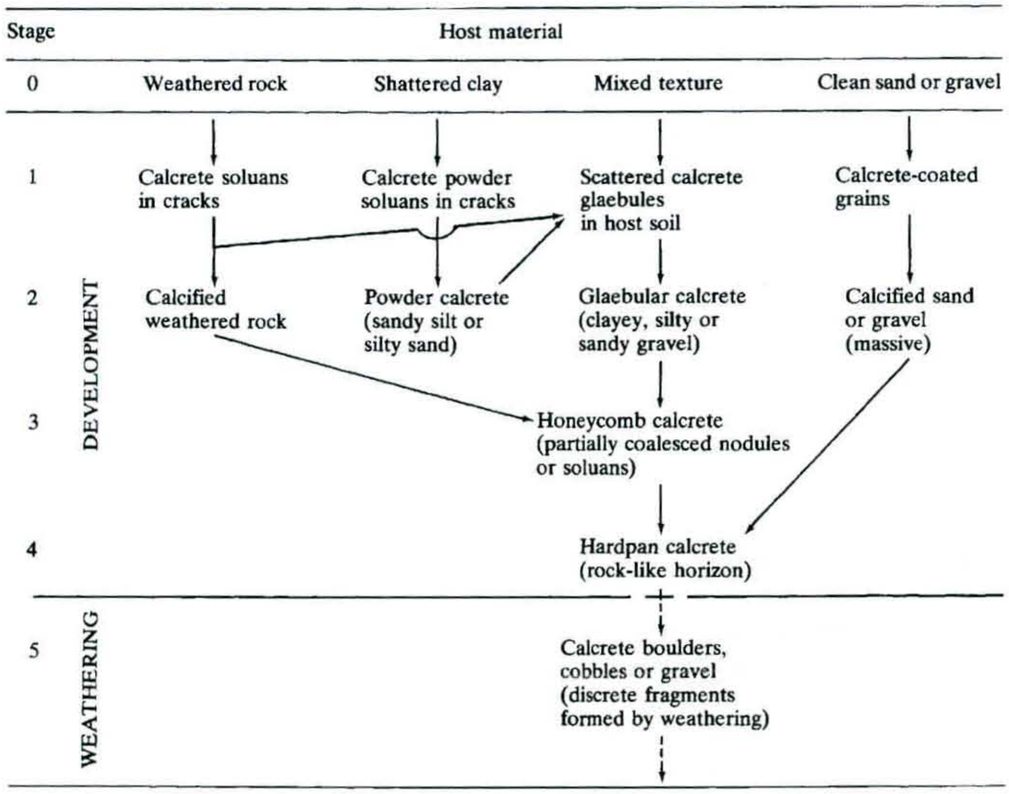
The term 'soil' is used here in its wide engineering sense for practically any geological material which the engineer does not classify as rock, which requires blasting for excavation.

The classification

Basis of the classification

The classification suggested here is a simple, morphogenetic one based upon secondary (chemical) structure and sequence of development. It employs a combined geological and engineering approach, in its simplest form consisting of a genetic term such as 'calcrete', 'calcified', 'ferricrete', 'ferruginised', etc., plus a traditional engineering soil or rock term such as 'sand', 'gravel', etc., e.g. 'calcified sand', 'calcrete gravel', 'calcrete rock', as recommended by the Speciality Session on Pedogenic Materials (1976). This scheme is not dissimilar to that of Fookes & Higginbottom (1975) for the geotechnical classification of near-shore carbonate sediments. As material is often classified simply as 'rock' (requires blasting or consists of large boulders), 'hard' (requires pneumatic tools) and 'soft' (other materials) for

TABLE 1. *Stages in the development and weathering of calcretes (Netterberg 1969b, 1980)*



excavation payment purposes, the addition of such terms would represent the final descriptor in the simplest form of the classification. However, it is often necessary to use the classification together with more detailed geotechnical descriptive and particle size-plasticity classifications. The applicability and modifications required of such classifications have been considered (Netterberg 1969a, 1980, 1982; Horta 1980). Horta's (1980) suggestion of adding calcrete gravels and sands and gypcrete sands to Casagrande-type classifications should be taken even further.

Calcretes are thus classified simply into calcareous soils, calcified soils, powder calcretes, nodular calcretes, honeycomb calcretes, hardpan calcretes, and calcrete boulders and cobbles. As calcretes form more or less in this sequence (Table 1) (Netterberg 1969a,b, 1980; Goudie 1973) this classification should cover all the basic forms possible. Each of the forms listed in Table 1 represents an easily recognizable stage of growth or weathering and possesses a significantly different range of geotechnical properties. Possible correlations between this and other classifications have been discussed by Netterberg (1980). Calcrete profile log symbols have also been suggested by him, as well as a standard method for describing calcrete profiles.

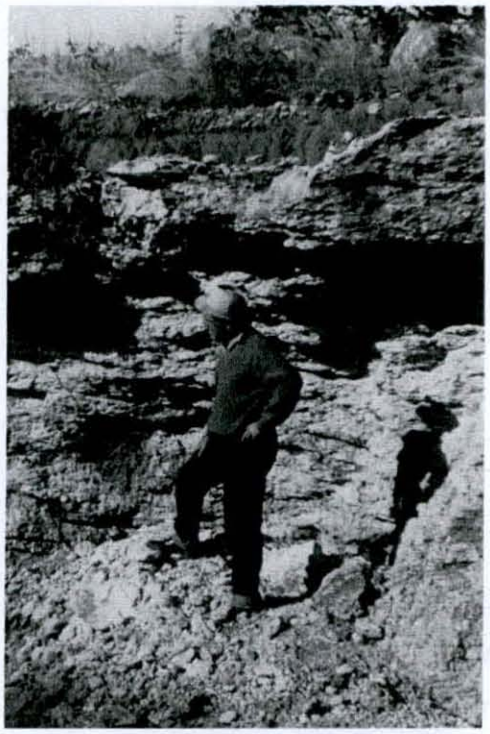


FIG. 1. Pseudobedded calcified alluvial sand (Netterberg 1980) with slight overlying hardpan development.

Calcareous soil

Calcareous soils (further described as sand, gravel, etc.) are soils with little or no cementation or development of carbonate concentrations such as nodules, but which effervesce with dilute hydrochloric acid. As, apart from ion exchange effects, the geotechnical properties of the original host soil have not been significantly altered by the carbonate (usually only 1–10% $CaCO_3$ equivalent), it is probably not necessary to distinguish this category (Stage 1, Table 1) unless the presence of even small amounts of carbonate are of significance to the works in question.

Calcified soil

A calcified soil (further described as sand, gravel, etc.) is a soil horizon (mass) cemented by carbonate usually to a firm of stiff consistency. Although often just friable, it does not usually slake in water. The carbonate is usually evenly distributed throughout the horizon as in calcified sands (Fig. 1) and gravels, but may occur as fissure-fillings as in calcified weathered rocks, although nodules are few. The amount of carbonate (usually 10–50% $CaCO_3$ by mass) is sufficient to have significantly altered the geotechnical properties of the original soil. Calcified soils can generally be dug with a pick or a face shovel (although particularly well-cemented gravels may require more drastic methods) and compacted with rollers to yield sandly or gravelly pavement layer material. Only after excavation and processing can most calcified soils be said to possess a particle size distribution, which is very dependent on the type and amount of such processing. Most aeolianites could be classified as calcified sands with some calcrete hardpan horizons.

Powder calcrete (calcrete silt or calcrete sand)

Powder calcretes are chiefly composed of loose silt-sized and fine sand-sized carbonate with few or no visible host soil particles or calcrete nodules. Any nodules present are generally weak and friable. Powder calcrete horizons are occasionally cemented to a consistency of up to stiff but break down on working (Fig. 2). Carbonate contents often

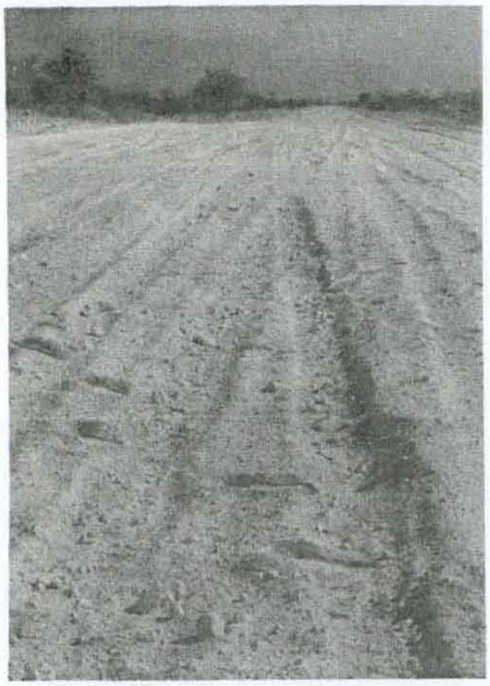


FIG. 2. Unsuccessful use of powder calcrete as gravel road material.

exceed 70% $CaCO_3$ equivalent. Powder calcretes may develop into nodular calcretes, from which they are distinguished by having more than 75% of particles by mass finer than 2 mm (Fig. 3) or a grading modulus of less than 1.5. (The grading modulus (Kleyn 1955) is the sum of the cumulative mass percentages retained on each of the 2.00, 0.425 and 0.075 mm sieves divided by 100. A minimum value of 1.5 is often specified for rural road sub-bases in southern Africa.) Most powder calcretes also possess more than 55% finer than 0.425 mm. Many powder calcrete possess sub-base California bearing ratios (CBR). However, they are generally troublesome materials to compact and best avoided (Von Solms 1976).

Powder calcretes can also be called calcrete silt or calcrete sand (*not* silty calcrete or sandy calcrete), but the use of the term 'powder calcrete' may be more appropriate for use by unsophisticated road workers, and Fig. 3 actually represents the limiting particle-size distributions of powder and nodular calcretes visually classified in the field.

Nodular calcrete (calcrete gravel or calcrete sand)

Nodular calcretes are natural mixtures of silt-sized to gravel-sized particles of carbonate-cemented host soil particles in a matrix of usually calcareous soil (Fig. 4). More than 25% of the particles by mass are coarser than 2 mm (Fig. 3) or the grading modulus has a minimum value of 1.5. The overall consistency of the horizon is generally loose, but the nodules may vary from firm and friable to very strong. Calcrete nodules vary in shape and texture from nearly spherical and smooth, through botryoidal to irregular and rough, while platy, elongated

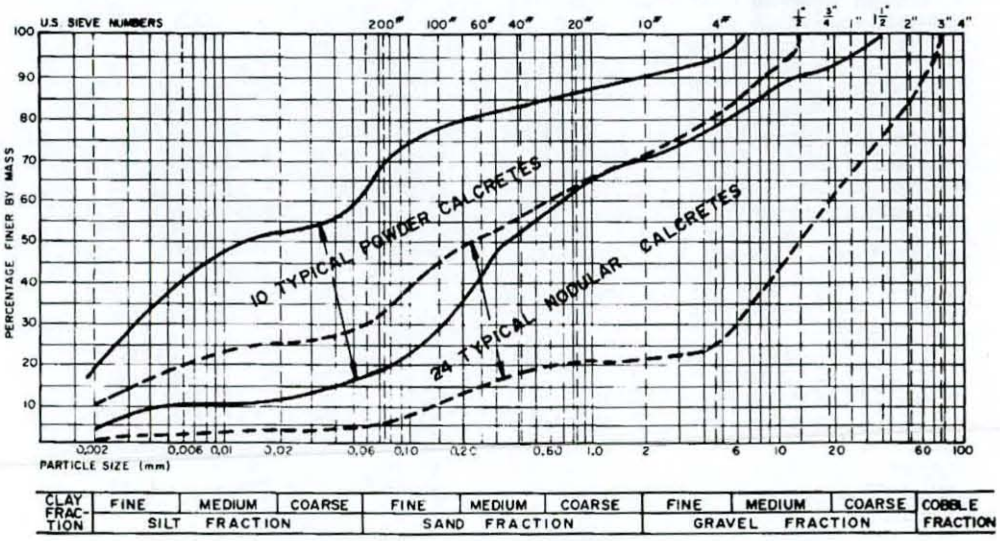


FIG. 3. Grading envelopes of typical powder and nodular calcretes.

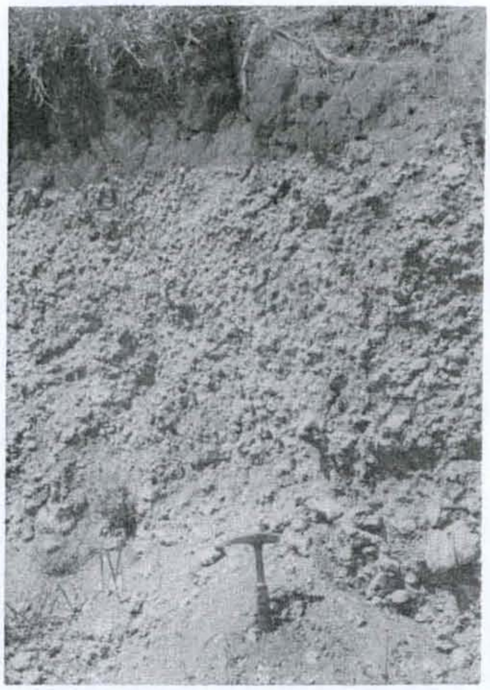


FIG. 4. Nodular calcrete (Netterberg 1980). Calcrete cobble in lower right hand corner is a weathering relic of an older hardpan calcrete and not a nodule.

and cylindroidal forms also occasionally occur. The maximum size of individual or compound nodules very rarely exceeds 50 or 60 mm. Nodular calcretes can usually be scraper-loaded or bulldozed without ripping, and compacted to produce a good pavement layer material. Most calcretes display gap gradings by mass (Fig. 3) even after compaction. These are at least partly due to variations in particle bulk density with size and disappear or are reduced if gradings are calculated on a volumetric basis (Netterberg 1969a, 1971). The best nodular calcretes have properties comparable to those of graded crushed stone.

Geologically, the best term for nodular calcretes is really 'glaebular calcretes' (Brewer 1964). However, since calcrete glaebules other than nodules are rare (Netterberg 1969a, 1980), use of the more common term for geotechnical purposes seems sensible. Similarly, other non-glaebular, secondary structures such as pedotubules and small crotovinas can also be included under the term 'nodular calcrete' for geotechnical purposes.

Geotechnically, the best term for nodular calcrete is 'calcrete gravel'. However, many materials called nodular calcretes by field personnel classify as calcrete 'sands' according to a Casagrande type of classification (e.g. BSI 1957; ASTM 1980a) (Fig. 3). For this reason, as well as the one that, with experience, it is easy to estimate in the field when a material has a grading modulus of 1.5 or more and is thus potential road sub-base or base material, the term 'nodular calcrete' has been retained, especially at a less sophisticated level. Proper geotechnical descriptions should, however, also use the terms 'calcrete gravel' etc. as estimated by the usual criteria for the Casagrande-type classification employed.

Honeycomb calcrete

As the nodules in a nodular calcrete grow larger and more numerous, they may become partially cemented together to form a honeycomb calcrete (Fig. 5). A honeycomb calcrete is thus a stiff to very hard, open, honeycomb-textured calcrete horizon with the interstitial voids often filled with loose or soft soil. Both the voids and the individual nodules seldom exceed a diameter of about 30 mm, and are usually interconnected. Honeycomb calcretes can usually be ripped and grid-rolled to yield an excellent pavement base comparable to or even better than graded crushed stone in quality.

Another less common type of honeycomb calcrete can be formed from carbonate fissure-fillings in a weathered rock to result in a box-work structure. In both forms the soil filling the voids may be quite plastic.

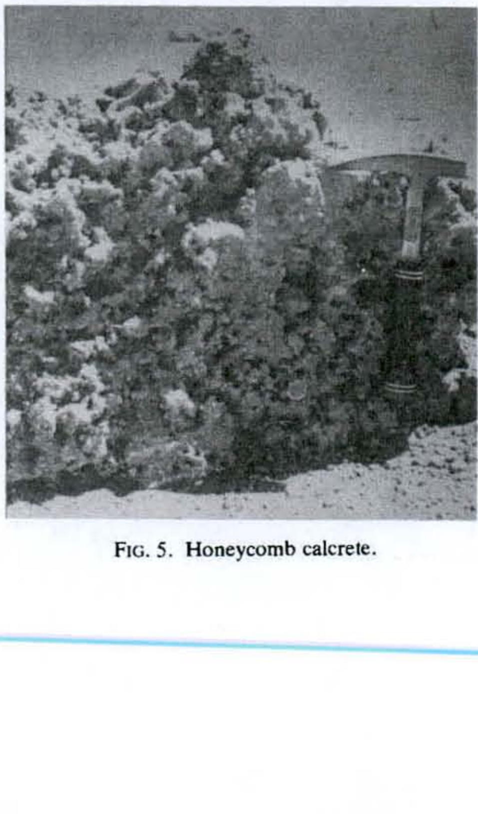


FIG. 5. Honeycomb calcrete.

Although honeycomb (and boulder) calcretes can be geologically regarded as forms of hardpan, their geotechnical properties are sufficiently different to warrant classifying them separately.

Hardpan calcrete

A hardpan calcrete (Fig. 6) is formed when most of the voids in a honeycomb calcrete become cemented or the upper part of a calcified soil horizon becomes more heavily cemented than the rest of the horizon (Table 1). It is a usually stiff to very strong, relatively massive and impermeable, sheetlike horizon which normally overlies a weaker material such as nodular or powder calcrete or calcified soil. Hardpans may vary from millimetres to several metres in thickness, although individual horizons more than 500 mm in thickness are not common. They may be sandy or gravelly or nearly pure limestone, and may be nearly structureless, or pseudobedded, tufaceous, jointed, veined, brecciated or laminated, and may contain voids of various kinds. Many are capped with a thin, very hard laminated 'rind'.

Many calcrete hardpans can be ripped and grid-rolled to yield a good to excellent pave-

TABLE 2. *Summary of some properties of calcretes in comparison with calcareous and calcified soils*

Material type	Total carbonate[a] as $CaCO_3$ %	Grading modulus[b]	Classification: AASHTO M 145–73 (1978) Group	Classification: AASHTO M 145–73 (1978) Index	Classification: BSI CP 2001 (1957)	Mod. AASHO soaked CBR[b] %	<0.425 mm: PI[a,b,c] %	<0.425 mm: Electric. conductivity[a,b,c,d] Sm^{-1} at 25° C
Calcareous soil	1–10?[b]	Variable	Variable	Variable	Variable	Variable	Variable	Variable
Calcified sand	10?–50	1.0–1.8?	A–1–b to A–2–7	0–2	GF, GP, SU, SF	25?–100	NP–20	0.02–0.23
Calcified gravel	10?–50	>1.8?	A–1–a to A–1–b	0–1?	GF to GW?	>80?	<8?	<0.1?
Powder calcrete	70–99	0.4–1.5	A–2–4 to A–7–5	0–13	ML to GF	25?–70?	SP–22	0.1–2.1
Nodular calcrete	50–75	1.5–2.3	A–1–a to A–6	0–3	GF, GP, GU	40–>120	NP–25	0.02–0.74
Honey-comb calcrete	70–90	>2.0	Rock?	–	– (Hard, h or Rock, r)[i]	>100	SP–16	0.01–0.1?
Hardpan calcrete	50–99	>1.5?	Rock?	–	(Hard, h or Rock, r)[i]	10?–>100	NP–7	0.01–0.06
Calcrete boulders and cobbles	50–99	>2.0	Boulders	–	Boulders and cobbles[i] (B)	>100	NP–3	0.01–0.02

[a]Without the soil between calcrete boulders and cobbles.
[b]After excavation and rolling or crushing in the case of hardpans, honeycombs, boulders, calcified gravels and some calcified sands.
[c]On the fines produced in the Los Angeles Abrasion test in the case of honeycombs, hardpans and boulders.
[d]Saturated paste method (Netterberg 1970).

ment layer material. Those which require blasting and crushing are probably best described as 'calcrete rock'. Such materials may occasionally be several metres thick.

Calcrete boulders and cobbles

Calcrete hardpans weather to boulders, cobbles and smaller fragments, usually in a matrix of non- or only slightly calcareous soil (Fig. 7). The shape and sphericity of the fragments vary from subrounded and subspherical to subangular and blocky, depending upon whether dissolution or disintegration was the dominant mode of weathering. Such fragments are generally strong to very strong and are often confused with nodules, from which they can usually be distinguished by their greater strength, sphericity and size, lower grain/matrix ratios, sharper and smoother boundaries, and a frequent partial or complete skin of laminated rind. Significant amounts of gravel-sized fragments have not been observed.

Calcrete boulders and cobbles are relatively useless as pavement materials. In their natural state they are usually too coarse and gap-graded for uses other than as fill, and are generally uneconomic to crush. However, in parts of

TABLE 2 (Continued)

Natural or crushed aggregate					Whole mass *in situ*			
		APT[e]						
ACV %	10% FACT kN	AFV[e] %	APV[e] %	Mohs hardness[f]	Overall consistency[g]	Seismic velocity m sec^{-1}	Workability	Usual max. thickness m
Variable	Variable	Variable	Variable	Variable	Variable	300–900?	Variable	Variable
35? – 55?	18? – 70?	70? – 95?	20? – 50?	2–3	Med. dense —dense or firm–stiff	600? – 1200	Bulldoze, shovel, or rip and grid-roll	5
25? – 35?	70? – 135?	90? – 100?	50? – 90?	≥3?	Med. dense —very dense or firm to very stiff	1200 – 2450?	Rip and grid-roll or blast and crush	10
33? – 55	18 – 90?	25 – 95	5 – 65	2–3	Loose – stiff	400 – 1070	Bulldoze, shovel, or scraper	5
20 – 57	9 – 178	0 – 100	0 – 90	1–5	Loose – med. dense	600 – 900	Bulldoze, shovel, or scraper	5
16 – 35	80? – 205	90? – 100	60? – 100	3–6	Stiff – very stiff	900 – 1200	Rip and grid-roll	1
19 – 53	27 – 196	75? – 100	30? – 100	2–6	Stiff—very strong	900 – 4500	Rip and grid-roll or blast and crush	1, rarely 10
20 – 33	98 – 205	95? – 100	70? – 100	3.5 – 5	Very stiff—very strong	Erratic	Rip and crush	1

[e]APT = Aggregate Pliers Test; AFV = Aggregate Fingers Value; APV = Aggregate Pliers Value (Netterberg 1969a, 1978)
[f]Of the carbonate or silicified carbonate cement (aggregate or mass).
[g]According to methods of BSI (1957, 1972) and Geological Society (1977b).
[h]Up to 50% when many nodules present.
[i]Suggested term and symbol.

FIG. 6. Hardpan calcrete overlying nodular calcrete (Netterberg 1980).

Australia they are gathered by means of 'rock pickers' and crushed with travelling 'rock busters' for base coarse.

Geotechnical properties

The geotechnical properties of calcretes (Netterberg 1969a, 1971, 1982; Reeves 1976; Weinert 1980) depend largely upon the nature of the original host soil (e.g. whether it was sand or clay) and the extent to which it has been cemented and/or replaced by carbonate. They thus vary from those of soil to those of rock (limestone), improving in a general fashion with the stage of development (Table 2).

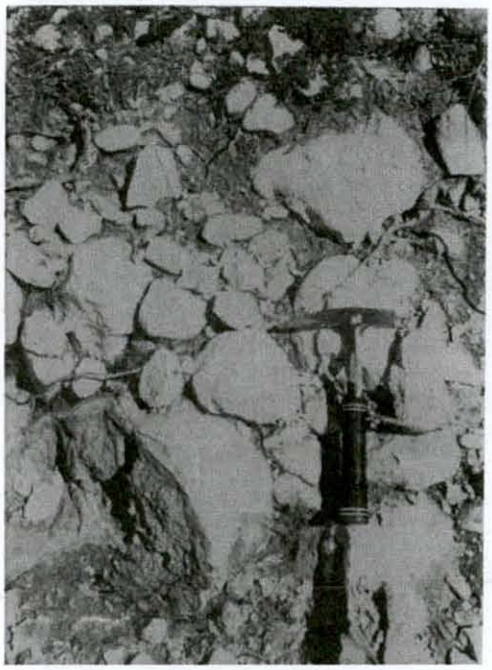


FIG. 7. Calcrete boulders and cobbles.

Application to other pedocretes

Like calcretes, other pedocretes such as ferricrete and silcrete are also simply soils which have been cemented and/or replaced to a varying degree by (in this case) iron oxides and amorphous silica respectively. They therefore pass through similar stages of growth and weathering and, with minor modifications, a similar classification can be applied to them (Netterberg 1975, 1976; Weinert 1980).

Classification for other purposes

With minor modifications and amplifications the scheme suggested here should be suitable for most purposes (Netterberg 1980).

Conclusions

Traditional geotechnical classifications developed for temperate zone materials require modification and amplification in order to adequately describe the non-traditional materials of other areas. In particular, an indication of the type of geological material (e.g. calcrete, weathered dolerite, ferricrete, etc.) is essential.

Authigenic calcareous accumulations in the regolith can be simply classified for geotechnical purposes into calcareous soils, calcified soils, powder calcretes, nodular calcretes, honeycomb calcretes, hardpan calcretes, and calcrete boulders and cobbles. Each of these categories represents an easily recognizable stage in the growth or weathering of a calcrete horizon and possesses a significantly different range of geotechnical properties. A similar classification scheme can be applied to other pedocretes such as ferricretes and silcretes.

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F. NETTERBERG, National Institute for Transport and Road Research, PO Box 395, Pretoria 0001, South Africa.

J. H. CAIGER, Van Wyk & Louw Inc., Consulting Engineers, PO Box 905, Pretoria 0001, South Africa.

APPENDIX H: BIODIVERSITY STUDY

Specialist report prepared by Ecorex CC, April 2011

TURQUOISE MOON

MOONLIGHT PROJECT

BIODIVERSITY STUDY & IMPACT ASSESSMENT

April 2011

Prepared for: METAGO Environmental Engineers (Pty) Ltd

PO Box 1596

Cramerview 2060

Prepared by: ECOREX Consulting Ecologists CC

PO Box 57

White River 1240

Authors: Warren McCleland (ECOREX), Pete Hawkes (AfriBugs)

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Abbreviations

AFI	Associated Flora Index
EIA	Environmental Impact Assessment
EMPR	Environmental Management Plan Report
IBA	Important Bird Areas
NEMBA	National Environment Management: Biodiversity Act (No.10 of 2004)
NFA	National Forests Act (No.38 of 1998)
SANBI	South African National Biodiversity Institute

Terminology

Abundance	Refers to the number of individuals of a particular species within a given community.
Alien	Introduced from elsewhere: neither endemic nor indigenous. Exotic.

Biodiversity	The structural, functional and compositional attributes of an area, ranging from genes to landscapes.
Exotic	Introduced from elsewhere: neither endemic nor indigenous. Alien.
Riparian	Pertaining to the river bank.
Species diversity	When using this term we are referring to beta-diversity, which is defined as the degree of change in species composition of communities along a gradient.
Species richness	Refers to the number of species in a given community, also known as alpha-diversity.

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Dr Ansie Dippenaar-Schoeman (Agricultural Research Institute) – mygalomorph spiders
James du G. Harrison (Transvaal Museum) – ground beetles
Ian Engelbrecht (Gauteng Deptartment of Agriculture, Conservation and Environment) – scorpions.
Dr Fernando Fernandéz (National University of Colombia) – ant identification

Declaration of Independence

We declare that we have been appointed as independent consulting ecologists with no affiliation with or vested financial interests in the proponent, other than for work performed under the Environmental Impact Assessment Regulations, 2006. We have no conflicting interests in the undertaking of this activity and have no interests in secondary developments resulting from the authorisation of this project. Remuneration for our services by the proponent is not linked to approval by any decision-making authority responsible for authorising this development.

W.L.McCleland *19 April 2011*

P.G.Hawkes *19 April 2011*

1. INTRODUCTION

1.1 Background

Turquoise Moon Trading 157 (Pty) Ltd (Turquoise Moon) has interests in an iron ore prospect near the village of Marnitz, about 60 km north of Lephalale, Limpopo Province. The iron ore prospect covers an area known as the Moonlight project area, which comprises the farms Moonlight 111 LR, Gouda Fontein 886 (previously known as Gouda Fontein 76 LR) and Julietta 112 LR. Turquoise Moon intends to develop an open-cast iron ore mine in the project area.

Metago Environmental Engineers (Pty) Ltd was appointed to manage the environmental impact assessment process and approached ECOREX Consulting Ecologists CC to co-ordinate the biodiversity component of the project. The biodiversity study comprised flora and vertebrate fauna (ECOREX), and invertebrate fauna (AfriBugs).

Project Description

The proposed operation will entail the following:

- Open-cast Mine;
- Tailings Storage Facility;
- Return Water Dam;
- Water Rock Stockpile;
- Transport routes – haul road to service the pit, and an access road to administration offices;
- Administration Offices.

The study area within which the impact footprint will be located is approximately 4 700 ha. The projected life-time of the mine will be approximately 30 years.

1.2 Objectives

The key objective of this study was to describe the Present Ecological State and the Conservation Importance of the terrestrial and aquatic habitats represented within the study area, and on this basis to conduct an assessment of the potential impacts of the mining project.

1.3 Study Team

Warren McCleland – Terrestrial Ecologist. Warren is the owner and director of ECOREX Consulting Ecologists CC, a consultancy of flora and vertebrate fauna specialists based in White River, Mpumalanga. He has been involved in specialist biodiversity assessments for a wide range of developments, particularly mining, throughout Southern and South-central Africa over the past 14 years. Countries of work experience outside of South Africa include Democratic Republic of the Congo, Zambia, Malawi, Mozambique, Namibia and Swaziland. Warren is the co-author of the highly acclaimed "Field Guide to the Trees & Shrubs of Mpumalanga & Kruger National Park" published in 2002, and is currently working on a field guide to the wildflowers of Mpumalanga.

Pete Hawkes – Entomologist. Pete is the founder director of AfriBugs CC, an independent consultancy that specialises in the invertebrate biodiversity and impact assessments, as well as biomonitoring. He has a BSc (Hons.) in Entomology from Rhodes University. Pete has undertaken numerous environmental assessments in South Africa, and was involved in biodiversity studies in the Eastern Arc Mountains in Tanzania. He is a member of the SA Council for Natural Scientific Professions (No 400411/04).

Anthony Emery – GIS. Anthony is the founder director of Emross, an independent consultancy that specialises in biodiversity mapping and conservation planning. He has a MSc in Conservation Biology from the University of Cape Town. Anthony has 14 years' experience in conservation planning and project management. He specialises in the mapping of biodiversity at the ecosystems, communities and species scales. He also has experience and expertise in modelling of species distributions and the identification of threats to biodiversity, as well as setting conservation targets, prioritising areas in terms of biodiversity, transformation and threats, and determining the irreplacibility of land. He has managed and run projects on behalf of South African National Biodiversity Institute and the Department of Water Affairs and Forestry.

2. TERMS OF REFERENCE

- Conduct a desktop review of previous studies and relevant literature pertaining to the study area.
- Conduct a full biodiversity baseline assessment of terrestrial ecosystems within the study area. No perennial drainage systems or extensive pan systems were located within the study area and hence no aquatic ecology assessment was undertaken.
- Assess the potential impacts of current and potential future mining activities on terrestrial ecosystems.
- Recommend mitigation measures for impacts of high and medium significance.

3. STUDY AREA

3.1 Location

The Moonlight Project is located on the farms Moonlight 111 LR, Gouda Fontein 886 (previously known as Gouda Fontein 76 LR) and Julietta 112 LR, which are about 60 km north of Lephalale and just south of the village of Marnitz, Limpopo Province (Figure 1).

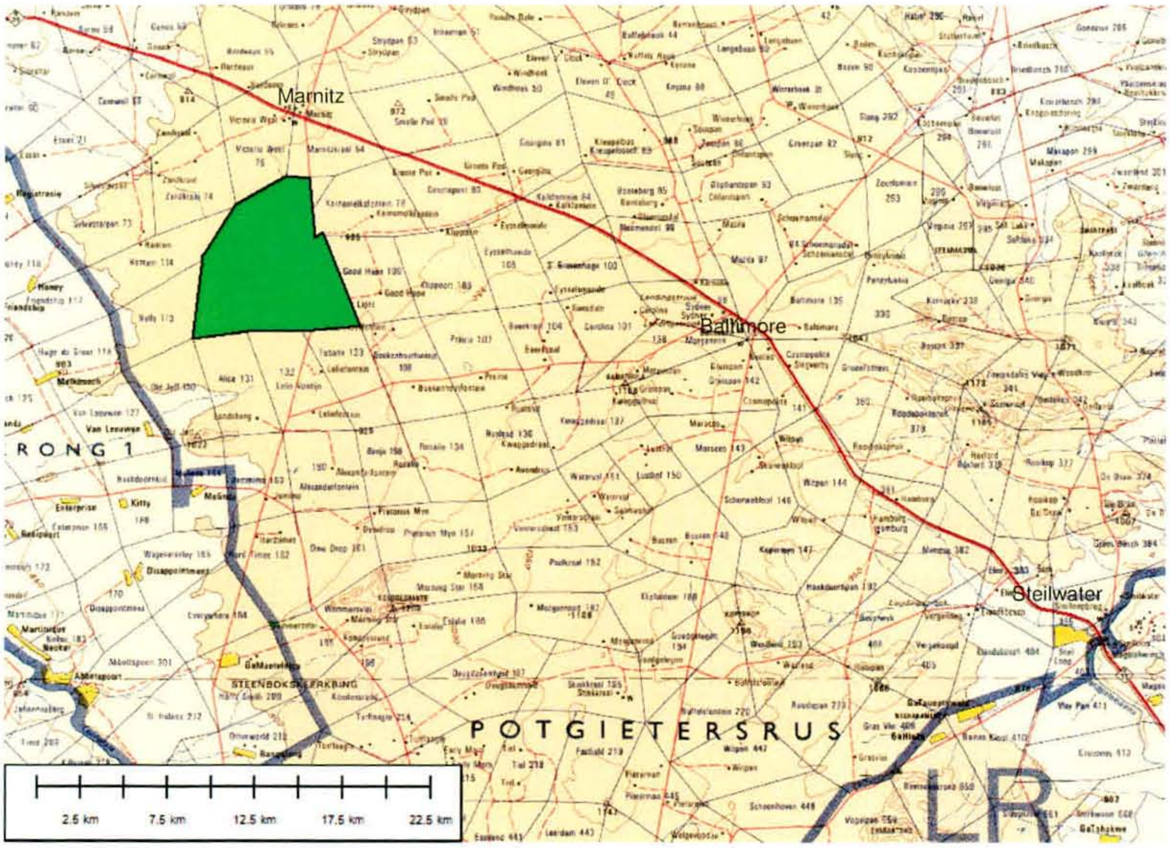

Figure 1. Location of Study Area

3.2 Physiography

Regionally the site falls within the Polokwane Plateau which is flat. Altitudes in the Moonlight area range between 940 to 984 metres above mean sea level (mamsl). Near Moonlight, the Palala Granite inselberg and the Koedoesrand formation in the south and the Waterberg Group towards the east form the main topographical features (Metago, 2011).

3.3 Geology

The Moonlight deposit is situated within the Central Zone of the Limpopo Mobile Belt of the Beit Bridge Complex (ultramafic, mafic and pelitic gneisses) (Metago, 2011). Within the study area this geology is mostly overlain by sand and calcrete, with doleritic outcrops occurring in a few areas.

3.4 Soils

Much of the study area is dominated by Hutton soils of varying depth, while the calcrete ridges are dominated by Coega soils.

3.5 Landuse

Most cultivation within the Moonlight project area has taken place on the farm Moonlight 111 LR, while Gouda Fontein 886 (previously known as Gouda Fontein 76 LR) and Julietta 112 LR have not been cultivated. Land use outside of cultivated areas is livestock farming (mostly cattle) and game farming.

3.6 Sampling Sites

Nine vegetation sampling quadrats and numerous vegetation transects were used to assess the terrestrial ecosystems within the study area. Sampling sites were located along a gradient of landform types and vegetation communities. Photographs of the sampling sites are shown in Appendix 3.

4. METHODS

Fieldwork in this project took place during the 2010 / 2011 rain season. This was timed to coincide with flowering times of most plants and the peak periods of activity of fauna.

4.1 Flora

Desktop

Vegetation communities were identified prior to fieldwork using the most current aerial images. These communities were ground-truthed during the field visits. Potentially occurring plant species of conservation concern were derived from species lists for the quarter-degree grids 2328 AA and AC in the PRECIS database of the South African National Biodiversity Institute (SANBI). We follow Raimondo *et al.* (2009) in considering species of conservation concern to be those that have been assigned threat status (Vulnerable, Endangered or Critically Endangered), those are classified as Near Threatened or Declining, and those that are currently Data Deficient.

Fieldwork

The study area was visited over five days during the rain season (December 2010). Representative meandering transects were surveyed on foot in each vegetation community that was identified during the desktop phase. These transects were placed over landscape gradients that contained the highest number of microhabitats in order to maximize species detection and thus produce fairly comprehensive lists for each community (Appendix 1). In addition, nine quadrats measuring 10 x 10 metres ($100m^2$) were placed in the various vegetation communities in order to get a measure of species richness per $100m^2$ (Appendices 2 and 3). Cover-abundance was estimated for each species in each quadrat according to the Braun-Blanquet method (after Kent & Coker, 1992):

Value	Braun-Blanquet cover
+	< 1%
1	1 – 5%
2	6 – 25%
3	26 – 50 %
4	51 – 75%
5	76 – 100%

The locations of plant species of conservation concern were recorded using a Garmin 60CSx GPS and these localities were used to highlight where sensitive plant assemblages occurred. Plants not identified to species level were collected and dried in a plant press for identification back at the office. Type specimen images at *www.aluka.org* and specimens at the Lydenburg Herbarium (LYD) were used to confirm as many specimens as possible.

4.2 Fauna

4.2.1 Mammals

Desktop

Friedmann & Daly (2004) and Van Cakenberghe *et al.* (2006) were used to compile a list of potentially occurring threatened mammal species (Appendix 5).

Fieldwork

Mammals were recorded incidentally during bird and vegetation surveys through direct observation or recording evidence such as spoor and droppings. Observations were also made during a night drive in December 2010. In order to sample small mammals, especially rodents, three traplines were laid on the farm Julietta 112 LR. Fifteen baited Willan traps were placed in each trapline and traps were checked each morning. Traps were baited with a mixture of peanut butter, sunflower oil and rolled oats. Anecdotal accounts of large mammal sightings made by the farm manager on Gouda Fontein 886 LR (Andries van der Merwe) were used to supplement the list.

4.2.2 Birds

Desktop

Barnes (2000), Harrison *et al.* 1997 and data from the current second Southern African Bird Atlas Project (SABAP2) were used to compile a list of potentially occurring Red Data birds (Appendix 5). The list of potential Red Data species was used to direct the fieldwork strategy for bird surveys.

Fieldwork

Timed-species counts (Pomeroy & Tengecho, 1986) were used along line transects and at various stationary points to survey the bird assemblages within the project area. Each vegetation community was sampled and a species list generated within each community. All birds seen and heard were recorded on a field sheet in 10-minute segments per vegetation community. Sampling took place in December 2010 during the first few hours of each day (07h00-10h00); this was to maximise the most productive sampling periods for birds.

4.2.3 Reptiles & Frogs

Desktop

Jacobsen (1989), Minter *et al.* (2004) and data from the South African Reptile Conservation Assessment (SARCA) (accessed at http://sarca.adu.org.za), were used to compile a list of potentially occurring threatened reptiles and frogs (Appendix 5).

Fieldwork

Reptiles were surveyed through active searching of potential habitat. This included sitting motionlessly at rocky outcrops and waiting for lizards to come out and sun themselves, as well as turning over rocks and logs and searching crevices on rocky outcrops. A number of reptile species were unearthed by the team of entomologists and collected for identification. Frogs were sampled through actively searching suitable habitat and catching frogs by hand, and through recording frog calls at man-made dam sites during the night.

4.2.4 Selected Invertebrates

At present, only a few invertebrate groups are well enough known for evaluation of their conservation status to have reached a level where they can be meaningfully included in species-level assessments of the conservation value of proposed development or mining sites. Thus, while other groups may be better-suited to broader-level biodiversity assessments and monitoring of impacts and rehabilitation, assessment of potential environmental impacts on invertebrate populations in South Africa continues to be based largely on the well-known groups such as butterflies, dragonflies and damselflies, scorpions and certain spider and beetle families. Limpopo Province does not at present have formal requirements for invertebrate surveys but in general those formulated by the Mpumalanga Tourism and Parks Agency (MTPA 2006) for developments in Mpumalanga are applied in Limpopo. The MTPA requirements indicate that in addition to the taxa listed above, groups such as ants, termites and leafhoppers should be surveyed in a quantified manner to provide a statistically valid baseline biodiversity assessment for monitoring of rehabilitation (Mpumalanga Tourism and Parks Agency, 2006). The survey carried out at the Moonlight site should therefore ideally have included both evaluation of the likelihood of rare or threatened species being present on the site, with surveys to confirm their presence or absence, and assessments of diversity within selected invertebrate indicator groups to provide baselines for monitoring. However, the latter surveys are time-consuming and add significantly to the overall cost of the assessment, so it was proposed to exclude these initially, on the understanding that if the project is approved, monitoring baseline surveys would be required before any development of the site is undertaken.

Only 13 Red-Listed invertebrate species are known to occur in Limpopo Province, and all of these are butterflies (9) or dragonflies / damselfiles (4). However, the brevity of this list is largely due to the paucity of data on the conservation status of invertebrate species and additional groups that also include species of concern in South Africa were therefore also considered. The invertebrate groups investigated were thus scorpions (Arachnida: Scorpiones), trapdoor and baboon spiders (Arachnida: Araneae: Mygalomorphae), dragonflies and damselflies (Odonata), ground beetles (Coleoptera: Carabidae) and butterflies (Lepidoptera: Papilionoidea and Hesperiodea). The assessment thus covers all invertebrate taxa including currently Red Data listed and protected species in the province. It should be borne in mind that while the conservation importance assessment may be largely confined to these relatively well-documented groups, a far greater number of invertebrate species belonging to less studied taxa will be present in the study area, and these may include many species that are rare or threatened.

Desktop

The potential for Red Data and other invertebrate species of concern (e.g. certain baboon and trapdoor spiders, scorpions, beetles, cicadas, dragonflies, damselflies and butterflies) was determined by reference to the literature and by consultation with relevant experts.

Lists of species of conservation concern (endemic, protected, and IUCN or nationally Red-Listed) within each of the selected groups that might be expected to occur within the project area were drawn up with reference to information drawn from the following literature sources and experts: scorpions (Leeming, 2003; Prendini, 2001; Prendini, 2006; I.Engelbrecht pers.comm.); trapdoor and baboon spiders (Dippenaar-Schoeman, 2002; Dr A.Dippenaar-Schoeman pers.comm.; Dr S.Foord pers.comm.; R.Gallon pers.comm.; A.Leroy pers.comm.); dragonflies and damselflies (Samways, 2006; Samways & Taylor, 2004; Tarboton & Tarboton, 2002; Tarboton & Tarboton, 2005); cicadas and leafhoppers (M.Stiller pers.comm.); ground beetles (Basilewsky, 1977; Peringuey, 1896; Werner, 2000; J.du G.Harrison pers.comm.); butterflies (Woodhall, 2005; Henning, Terblanche & Ball 2009, G.Henning pers.comm.; Prof M.Williams pers.comm.); ants (Social Insects Specialist Group 1996).

Species from each of the groups discussed below that are both of conservation concern and considered as potentially occurring at the Moonlight site are listed in Appendix 7.

Fieldwork

The field survey was aimed at confirming presence/absence of species of conservation concern and as far as possible assessing the local suitability of key groups as indicators for monitoring of impacts and rehabilitation progress. Sampling was carried out using the methods describe below at several sites, with the aim of spending approximately one full day sampling each of the main habitat types identified within the study area.

- **Trapdoor and Baboon spiders**: active searching and collecting by hand (including digging, rock turning, etc) was used to confirm presence/absence of mygalomorph spider species of conservation concern.
- **Scorpions**: active searching and collecting by hand (including digging, rock turning, etc) was used to confirm presence/absence of scorpion species of conservation concern. Night searching with the aid of ultraviolet light, which is considered to be the most effective and environmentally friendly means of surveying scorpion species (Leeming, 2003; Lowe et al., 2003) was also carried out in selected areas of each main habitat type identified during the field survey.
- **Dragonflies and damselflies**: presence of Red Data species was checked by active searching and specimens were collected by netting. Searches for these species were concentrated in small man-made dams.
- **Ground beetles**: active searching and collecting by hand (including digging, rock turning, etc) was used to confirm presence/absence of beetle species of conservation concern. Abundance and diversity of *Dromica*, a protected tiger beetle genus, was lower than expected during the December 2010 field survey, so an additional site visit in January 2011 was carried out to obtain additional data on this group.
- **Butterflies**: presence of Red Data species was checked by active searching and voucher specimens were collected by netting. Special attention was paid to identifying any areas which might provide suitable habitat for Edge's Copper (*Erikssonia edgei*) or the Regular Woolly Legs butterfly (*Lachnocnema regularis regularis*).
- **Ants**: sampling was carried out ad hoc by hand collecting during the field surveys, but no standardised or quantified sampling was carried out.

The above sampling was carried out in the Moonlight study area by a team of two during a six-day field visit carried out from 30 November to 5 December 2010 and a two-day field visit carried out on 19-20 January 2011. The areas surveyed are indicated in Figure 2. No specific surveys were carried out for groups such as cicadas in which no conservation-important species were predicted for the site, but the possibility of unknown or unexpected species was kept in mind during the surveys and an eye was kept out for unusual invertebrates of any kind.

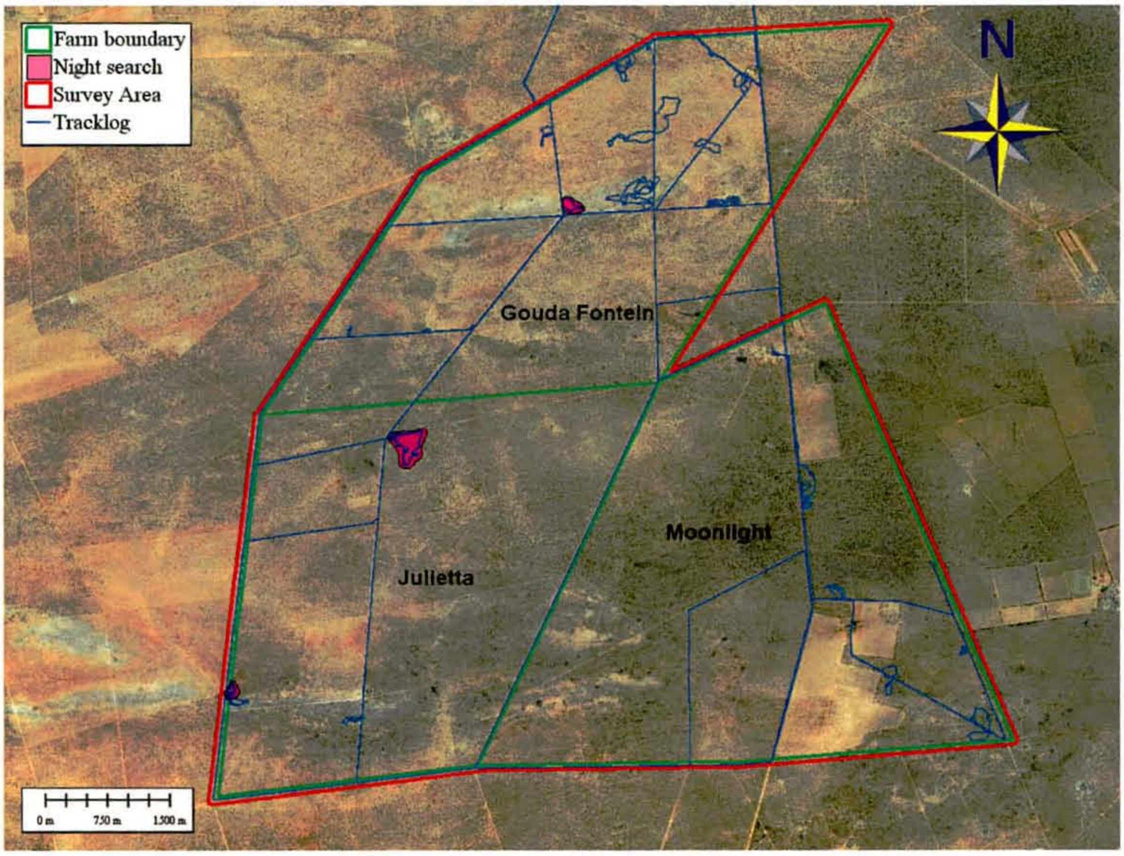

Figure 2. Routes followed during field surveys in the Moonlight project area

Specimens collected for evaluation of presence/absence of species of conservation concern were identified by reference to available literature and confirmed by relevant experts.

The invertebrate importance of each vegetation type was assessed by assigning a probability of occurrence of each conservation-significant invertebrate species in each vegetation/habitat type (see Appendix 7) and then multiplying this probability by a value assigned to the conservation importance of each species (see Appendix 8). The sum of these products for each habitat unit was then calculated and an overall importance rating assigned following a scale of Low (score 0-10), Medium (10-20), High (20-30) and Very High (30+).

4.2.6 Conservation Importance

The floristic conservation importance of each vegetation community was ascertained in terms of an Associated Flora Index (AFI), after Deall (2003), modified to recognise higher values for the threat categories of Vulnerable, Endangered and Critically Endangered. This index is derived from the summation of the species-status scores of constituent species. Such scores are assigned to plant species of conservation concern[1], plant species that are protected under national and provincial legislation, and species that are endemic to a particular area; these scores are then weighted in relation to local abundance and levels of importance (Table 1). Each vegetation community is then weighted according to whether it is representative of a threatened vegetation type as follows:

- Vulnerable vegetation types = weighting of 1.2
- Endangered vegetation types = weighting of 1.5
- Critically Endangered vegetation types = weighting of 1.8

The final weighted AFI score indicates the importance of that vegetation community for plant species of conservation concern (Table 2). Thus, an objective basis for assessing the significance of impacts on different vegetation communities at the local scale is derived.

[1] We follow Raimondo et al. (2009) in considering species of conservation concern to be threatened species (with a status of Vulnerable, Endangered or Critically Endangered), those that are Near Threatened or Declining, and those that are Data Deficient

Table 1. Species-status scores in relation to conservation importance and local abundance.

Conservation Importance	Local abundance[2]		
	Rare (+)	Frequent (1)	Abundant (2)
Red Data species (Critically Endangered)	6	7	8
Red Data species (Endangered)	5	6	7
Red Data species (Vulnerable)	4	5	6
Red Data species (DD, NT, LC)	3	4	5
Endemic species (En)	2	3	4
Protected species (Pr)	1	2	3

Table 2. Significance of AFI Scores

AFI Score	Significance
>30	High
26-30	High-Medium
21-25	Medium-High
16-20	Medium
11-15	Medium-Low
6-10	Low-Medium
0-5	Low

The vertebrate importance of each vegetation type was assessed by assigning a probability of occurrence of each threatened vertebrate species in each vegetation/habitat type and then multiplying this probability by a value assigned to the conservation importance of each species (Table 3; Appendix 5). The sum of these products for each habitat unit was then calculated and an overall importance rating assigned following a scale of Low (score 0-10), Medium (10-20), High (20-30) and Very High (30+).

By integrating assessments of the floristic and faunal values of the different vegetation communities, an assessment of conservation importance was made and used for impact assessment. Conservation importance values were then mapped as an aid to development planning (Figure 9).

[2] Based on the Braun-Blanquet cover-abundance scale

Table 3. Framework of criteria used for assessing conservation importance of fauna.

Red Data Status	Breeding / Foraging								Foraging Only							
	Local Endemic		Regional Endemic		National Endemic		Global		Local Endemic		Regional Endemic		National Endemic		Global	
	Prot	NonProt	Prot	NonProt	Prot	NonProt	Prot	NonProt	Prot	NonProt	Prot	NonProt	Prot	NonProt	Prot	NonProt
CR, EN	Very High	Very High	Very High	Very High	Very High	Very High	Very High	Very High	High	High	High	High	High	High	High	High
VU	Very High	High	Very High	High	High	High	High	High	High	Medium	High	Medium	Medium	Medium	Medium	Medium
NT, DD	High	Medium	High	Medium	Medium	Medium	Medium	Medium	Medium	Low	Medium	Low	Low	Low	Low	Low
LC, None	High	Medium	Medium	Low	Medium	Low	Medium	Low	Medium	Low	Low	Very Low	Low	Very Low	Low	None

Values for assessment calculations: None = 0, Very Low = 1, Low = 2, Medium = 3, High = 4, Very High = 5.

4.3 Assumptions, Limitations and Knowledge Gaps

4.3.1 Overlooked Species

- The floristic assessment was based on a single field survey during the rain season, which was considered appropriate for the purposes of locating species of conservation concern. However, a number of species that flower in early or late summer may have been overlooked. Certain plant species, particularly geophytes, will only flower in seasons when conditions are optimal and may thus remain undetected over several seasons. Other plant species may be overlooked because of very small size and / or extreme rarity. A sampling strategy will always represent merely a subset of the true diversity of the study area.
- No survey can cover all invertebrate species present, so the biodiversity estimates provided represent only a few indicator taxa; it is possible that diversity in other groups follows a significantly different pattern from these and hence re-establishment of the selected taxa is not a guarantee that rehabilitation has been equally successful for all invertebrates. A far greater number of invertebrate species belonging to less studied taxa will be present in the study area, and these may include many species that are rare or threatened. No quantified baseline surveys of indicator groups were carried out, although data to inform selection of information groups for future reference was gathered, on the understanding that such surveys will be carried out prior to development of the site if the project proceeds.
- A single early/mid-summer invertebrate survey, with a brief follow-up just after mid-summer, was carried out; this was considered adequate for the taxa of conservation importance predicted for the site.
- Experience has shown that obtaining sufficient data on scorpions, mygalomorph spiders and ground beetles to allow their meaningful inclusion in a monitoring programme is extremely time-consuming; these groups were therefore omitted from the quantified survey component of the field work and only surveyed for on the basis of checking for presence of protected and / or rare species.

4.3.2 Lack of Data for Invertebrate Groups

Assessment of the importance of the study area for invertebrates is hampered by the lack of detailed knowledge on most invertebrate species and groups. The assessment in this report is thus based primarily on 1) a desktop assessment of the likelihood of occurrence of species of known conservation significance, and 2) adjustment of these probabilities where confirmation of presence or absence of individual species on the site and/or within specific habitat types was obtained during the field survey. Due to seasonal constraints, for some species such confirmation was not possible during the field survey carried out.

5. BIODIVERSITY BASELINE DESCRIPTION

5.1 Flora

5.1.1 Regional Context

National Vegetation Types

The Moonlight study area is indicated as being situated within Roodeberg Bushveld, at the junction with Limpopo Sweet Bushveld (Mucina & Rutherford, 2006). Boundaries between similar vegetation types are rarely clearly defined, and it is likely that elements of Limpopo Sweet Bushveld are represented in the Moonlight project area. These two vegetation types are described in more detail below:

i. Roodeberg Bushveld

This vegetation type is endemic to north-western Limpopo Province, occurring from Marken and Villa Nora in the south to Blouberg Mountain in the north-east and Swartwater in the north-west, with an altitudinal range of 850 – 1 100 masl. Topography is mostly level to undulating plains, with scattered low hills. Vegetation structure is short closed woodland to tall open woodland, with a poorly developed grass layer.

Dominant trees are Black Monkey Thorn *Acacia burkei,* Knob-thorn *Acacia nigrescens,* Splendid Thorn *Acacia robusta,* Blue Thorn *Acacia erubescens,* Black Thorn *Acacia mellifera* subsp. *detinens,* Scented Thorn *Acacia nilotica,* Umbrella Thorn *Acacia tortilis,* Red Bushwillow *Combretum apiculatum* and White Syringa *Kirkia acuminata.* The shrub layer is dominated by Sickle-bush *Dichrostachys cinerea* and Velvet Raisin *Grewia flava.* The most common grasses are *Aristida canescens, Chloris virgata, Digitaria eriantha, Enneapogon cenchroides, Eragrostis rigidior, Panicum maximum* and *Urochloa mossambicense.*

Roodeberg Bushveld has a conservation status of **Least Threatened** because of a fairly low level of transformation (18%), much vegetation being informally conserved through game ranching, and since almost 9% this vegetation type is formally protected (Mucina & Rutherford, 2006).

ii. Limpopo Sweet Bushveld

This vegetation type occurs in Limpopo Province and neighbouring Botswana, stretching from the lower reaches of the Crocodile and Marico Rivers around Makoppa and Derdepoort, along the Limpopo valley through Lephalale (Ellisras) and Tom Burke, to the Usuthu border post in the north. The altitudinal range is 700 – 1 000 masl. This vegetation type is mostly represented to the west of the study area, although elements are highly likely to be represented in the western parts of the study area. Topography is mostly level plains. Vegetation structure is short open woodland, with dense, impenetrable thickets in disturbed areas.

Dominant trees are Splendid Thorn *Acacia robusta,* Blue Thorn *Acacia erubescens,* Blade Thorn *Acacia fleckii,* Scented Thorn *Acacia nilotica,* Three-hook Thorn *Acacia senegal* var. *rostrata,* Worm-cure Albizia *Albizia anthelmintica,* Shepherd's Tree *Boscia albitrunca* and Red Bushwillow *Combretum apiculatum.* The shrub layer is dominated by Trumpet Thorn *Catophractes alexandri, Acacia tenuispina,* Sickle-bush *Dichrostachys cinerea, Phaeoptilum spinosum* and Wild Pomegranate *Rhigozum obovatum.* The most common grasses are *Digitaria eriantha, Enneapogon cenchroides, Eragrostis lehmanniana, Panicum coloratum* and *Schmidtia pappophoroides.* The Central Bushveld endemic herb, *Piaranthus atrosanguineus*, is endemic to this vegetation type.

Limpopo Sweet Bushveld has a conservation status of **Least Threatened** because of a very low level of transformation (5%), even though very little of this vegetation type is formally protected (Mucina & Rutherford, 2006).

Threatened Ecosystems

The Moonlight project area is not situated within any threatened terrestrial ecosystems as listed in Notice 1477 of Government Gazette No. 32689 (6 November 2009)[1].

Centres of Plant Endemism

The study area is not situated within any centre of plant endemism. The closest centre of endemism is the Soutpansberg Centre, an aggregated centre comprising the Soutpansberg and Blouberg Mountain massifs (Van Wyk & Smith, 2001). Blouberg Mountain is situated about 65 km east of the study area and none of its endemics are likely to occur in the study area.

5.1.2 Vegetation Communities

Six broad vegetation communities were identified within the study area on the basis of distinctive vegetation structure (grassland, woodland, thicket, etc), floristic composition (dominant and diagnostic species) and position in the landscape (midslopes, terrace, crest, etc). Nature of the soils as determined by parent material appeared to be a significant driver

[1] SANBI & DEAT, 2009

of vegetation communities in the project area, as well as anthropogenic drivers such as overstocking of livestock, leading to overgrazing and subsequent dominance by woody species. The vegetation communities are described in detail below:

1) ***Combretum apiculatum* Closed Woodland (Figure 3)**

This vegetation community occurs on or near to dolerite outcrops, and is most well represented on the farm Moonlight 111 LR (Figure 7). *Combretum apiculatum* Closed Woodland covers 323 ha which equates to 6% of the area surveyed. Rock cover is moderate to high, with many scattered boulders present.

Vegetation structure is Short Closed Woodland (*sensu* Edwards, 1983). This vegetation community is characterised by dominance by deciduous, broad-leaved trees, with a sparse shrub understory and sparse to dense grass sward. Red Bushwillow *Combretum apiculatum* is consistently dominant at every site, with African Chestnut *Sterculia rogersii,* False Marula *Lannea schweinfurthii* var. *stuhlmannii* and Velvet Corkwood *Commiphora mollis* being co-dominant at some sites. Other common trees and woody shrubs are Sickle-bush *Dichrostachys cinerea* subsp. *africana,* Silver Raisin *Grewia monticola,* Large Sourplum *Ximenia caffra* and Black Monkey Orange *Strychnos madagascariense.* Scattered understory shrubs and herbaceous plants include *Hibiscus lunariifolius, Melhania burchellii, Blepharis* cf. *subvolubilis, Tephrosia rhodesica, Indigofera* spp. and *Ruellia cordata.* The dominant grass is *Panicum maximum,* with other common species including *Panicum coloratum, Aristida vestita, Pogonarthria squarrosa, Eragrostis lehmanniana* and *Eragrostis chloromelas.*

Four smaller vegetation associations were identified within this community, but were not distinguishable on satellite imagery:

- ***Acacia senegal – Combretum apiculatum* Closed Woodland**: found on Hutton soils of average depth (c.300 mm); possibly an ecotonal association between this community and *Acacia senegal – Terminalia prunioides* Closed Woodland / Thicket in the west-central part of the study area.
- ***Combretum apiculatum* Open to Closed Woodland**: found on shallow Mispah and Hutton soils, often where dolerite outcrops are present; this is the typical association defining this community; *Combretum apiculatum* always strongly dominant.
- ***Commiphora mollis - Combretum apiculatum* Open to Closed Woodland**: encountered at numerous areas of deeper Hutton soils a bit further from the dolerite outcrops than the above association.

- ***Commiphora pyracanthoides* – *Combretum apiculatum* Closed Woodland / Thicket**: restricted to the south-eastern part of this community; is lower and more dense than the other associations; associated with Hutton soils of moderate depth.

A total of 82 species (44% of the entire list) was recorded from *Combretum apiculatum* Woodland (Appendix 1) with no species of conservation concern being recorded[1]. Thirty species (41% of the community species list) appear to be confined to this vegetation community within the study area, a remarkably high fidelity level. Two species occurring in this vegetation community are protected under the National Forest Act (No.84 of 1998), namely Shepherd's Tree *Boscia albitrunca* and Marula *Sclerocarya birrea* subsp. *cafra*. However, both occur in small numbers and the resultant AFI score is only 3, which reflects Low importance for flora of conservation concern (Table 4). Only one invasive alien species was recorded, namely *Solanum elaegnifolium*, which was confined to road edges and other disturbed areas within this community. A number of small temporary pan-like structures were located in this community, although no wetland-associated flora were encountered, indicating the ephemeral nature of these structures. The lack of diagnostic and associated flora meant that no separate description of the panlike structures could be compiled.

Combretum apiculatum Closed Woodland is not that representative of Roodeberg Bushveld (Mucina & Rutherford, 2006) and is not considered to be threatened.

[1] We follow the terminology of Raimondo *et al.* (2009); Species of conservation concern are those that are important for South Africa's conservation decision-making processes and comprise all threatened species (those facing a high risk of extinction, in the categories Critically Endangered, Endangered or Vulnerable), as well as those with a status of Data Deficient, Near Threatened, Critically Rare, Rare and Declining.

Figure 3. ***Combretum apiculatum*** **Closed Woodland, near Quadrat 8 (Moonlight 111 LR)**

2) ***Acacia senegal var. leiorachis – Terminalia prunioides* Closed Woodland / Thicket (Figure 4)**

This vegetation community is strongly associated with calcrete (shallow Coega soils) and is often on low ridges that are orientated west-east (Figure 7). *Acacia senegal – Terminalia prunioides* Closed Woodland / Thicket covers 456 ha which equates to 8.5% of the area surveyed. Rock cover is often high and is dominated by weathered calcrete.

Vegetation structure is Short Closed Woodland to Tall Thicket (*sensu* Edwards, 1983). This vegetation community is characterised by dominance of the distinctive tall, slender variety of Slender Three-hook Thorn *Acacia senegal*, with Purple=pod Cluster-leaf *Terminalia prunioides* often present and occasionally co-dominant. Other common trees and woody shrubs are Black Thorn *Acacia mellifera,* Sickle-bush *Dichrostachys cinerea* subsp. *africana,* Common Corkwood *Commiphora pyracanthoides,* Smelly Shepherd's Tree *Boscia foetida,* Three-hook Thorn *Acacia senegal var. rostrata, Lycium schizocalyx* and White-berry Bush *Flueggea virosa.* Dwarf shrubs and herbaceous plants include *Barleria prionitis, Asparagus cooperi, Blepharis* cf. *subvolubilis, Indigofera heterotricha* and *Ruellia cordata.* Common grasses are *Enneapogon cenchroides, Enneapogon desveauxii, Melinis repens, Setaria spacelata* and *Eragrostis lehmanniana.*

Three smaller vegetation associations were identified within this community, but were not distinguishable on satellite imagery:

- ***Acacia senegal - Acacia mellifera - Boscia foetida* Closed Woodland**
- ***Acacia senegal - Acacia nigrescens* Closed Woodland or Thicket**
- ***Acacia senegal - Terminalia prunioides - Commiphora mollis* Closed Woodland or Thicket**: this is the typical association defining this community.

A total of 86 species (46% of the entire list) was recorded from *Acacia senegal – Terminalia prunioides* Closed Woodland / Thicket (Appendix 1) with no species of conservation concern being recorded[1]. Twenty species (30% of the community species list) appear to be confined to this vegetation community within the study area, which represents moderately high fidelity.

[1] We follow the terminology of Raimondo *et al.* (2009); Species of conservation concern are those that are important for South Africa's conservation decision-making processes and comprise all threatened species (those facing a high risk of extinction, in the categories Critically Endangered, Endangered or Vulnerable), as well as those with a status of Data Deficient, Near Threatened, Critically Rare, Rare and Declining.

Acacia senegal – Terminalia prunioides Closed Woodland / Thicket has elements of both Roodeberg Bushveld and Limpopo Sweet Bushveld, but is not that representative of either (Mucina & Rutherford, 2006) and is not considered to be threatened. Only one invasive alien species was recorded, namely *Solanum elaegnifolium*, which was confined to road edges and other disturbed areas within this community. A number of small temporary pan-like structures were located in this community, although no wetland-associated flora were encountered, indicating the ephemeral nature of these structures. The lack of diagnostic and associated flora meant that no separate description of these pan-like structures could be compiled.

Figure 4. *Acacia senegal* var. *leiorachis* – *Terminalia prunioides* Closed Woodland

3) ***Sclerocarya birrea* – *Boscia albitrunca* - *Acacia tortilis* Open to Closed Woodland Mosaic (Figure 5)**

This is a fairly complex mosaic of vegetation associations occurring on deep reddish brown sands on plains across the project area (Figure 7). *Sclerocarya – Boscia - Acacia* Open to Closed Woodland covers just under 3 900 ha which equates to 73% of the area surveyed. Rock cover is mostly low. Soils are mostly Hutton and Plooysburg forms and vary in depth from 80 – 100 mm (Plooysburg) and from 250 - 1 500 mm (Hutton).

Vegetation structure is very variable, depending on a combination of edaphic factors (e.g. soil depth) and anthropogenic factors (e.g. overstocking leading to overgrazing). Structure varies from Short Sparse Woodland to Short Closed Woodland (*sensu* Edwards, 1983). Structurally distinct vegetation boundaries often follow farm portion boundaries, highlighting the importance of anthropogenic influences in vegetation community dynamics in the study area.

Twelve vegetation associations could be identified based on structural and floristic differences. These can be broadly divided into two groups, namely Sparse Woodland / Wooded Grassland associations and Open to Closed Woodland associations:

Sparse Woodland / Wooded Grassland associations

These vegetation associations are most prevalent in the north of the study area, particularly on the farm Gouda Fontein 886 LR. At least eight associations could be identified:

- *Sclerocarya birrea-Acacia nigrescens-Acacia tortilis* Sparse Woodland
- *Sclerocarya birrea-Acacia nigrescens-Boscia albitrunca* Sparse Woodland
- *Sclerocarya birrea-Commiphora mollis-Dichrostachys cinerea* Sparse Woodland
- *Sclerocarya birrea-Acacia tortilis* Sparse Woodland
- *Acacia tortilis-Acacia senegal* Sparse to Open Woodland
- *Acacia tortilis-Boscia albitrunca* Sparse to Open Woodland
- *Grewia flava* Open Shrubland – this association is similar to *Sclerocarya birrea - Acacia nigrescens - Acacia tortilis*, but differs through dominance of *Grewia flava* in the shrub layer and more widely scattered trees; *Boscia albitrunca* is also quite prominent in places.
- *Acacia senegal* Open Woodland

Open to Closed Woodland Associations

- *Acacia tortilis* Closed Woodland
- *Acacia nigrescens* Closed Woodland
- *Sclerocarya birrea – Acacia nigrescens* Closed Woodland
- *Acacia senegal* Closed Woodland

Consistent species, i.e. species that are consistently present throughout the different associations are Marula *Sclerocarya birrea* subsp. *cafra,* Umbrella Thorn *Acacia tortilis,* Knob Thorn *Acacia nigrescens* and Shepherd's Tree *Boscia albitrunca* in the canopy, and Velvet Raisin *Grewia flava,* Sickle-bush *Dichrostachys cinerea* subsp. *africana* and Common Corkwood *Commiphora pyracanthoides.* Twenty-seven grass species were recorded in these vegetation associations, of which the most common were *Aristida congesta, Brachiaria deflexa, Enneapogon scoparia, Eragrostis lehmanniana, Eragrostis rigidior, Schmidtia pappophoroides* and *Stipagrostis uniplumis.*

A total of 107 species (57% of the entire list) was recorded from the different associations with this Open to Closed Woodland Mosaic (Appendix 1). Twenty-four species (27% of the community species list) appear to be confined to this vegetation community within the study area, a lower fidelity level than the other vegetation communities in the study area. No species of conservation concern were recorded[1] and only two protected tree species were confirmed (*Boscia albitrunca* and *Sclerocarya birrea* subsp. *cafra*). Both of these are protected under the National Forest Act (No.84 of 1998). Both occur as dominant species and the resultant AFI score is thus 6, which reflects Low-Medium importance for flora of conservation concern (Table 4). Only two invasive alien species were recorded, namely *Cereus jamacaru* and *Solanum elaegnifolium*, both of which were found in disturbed areas within this community, such as road verges. A number of small temporary pan-like structures were located in this community, although no wetland-associated flora were encountered, indicating the ephemeral nature of these structures. The lack of diagnostic and associated flora meant that no separate description of these pan-like structures could be compiled.

Sclerocarya – Boscia - Acacia Open to Closed Woodland Mosaic is representative of Roodeberg Bushveld (Mucina & Rutherford, 2006), which is not considered to be threatened.

[1] We follow the terminology of Raimondo *et al.* (2009); Species of conservation concern are those that are important for South Africa's conservation decision-making processes and comprise all threatened species (those facing a high risk of extinction, in the categories Critically Endangered, Endangered or Vulnerable), as well as those with a status of Data Deficient, Near Threatened, Critically Rare, Rare and Declining.

Acacia nigrescens Closed Woodland

Sclerocarya-Acacia-Commiphora Open to Closed Woodland

Sclerocarya birrea – Acacia tortilis Sparse Woodland

Grewia flava Open Shrubland

Figure 5. Various vegetation associations within *Sclerocarya – Boscia - Acacia* Open to Closed Woodland Mosaic

4) ***Commiphora spp. – Grewia flava* Open to Closed Woodland (Figure 6)**

This vegetation community occurs in the south-eastern corner of the project area (Figure 7) and merges with both *Combretum apiculatum* Closed Woodland and *Sclerocarya – Boscia – Acacia tortilis* Open to Closed Woodland Mosaic, so that the boundaries are sometimes difficult to discern in the field. *Commiphora - Grewia* Open to Closed Woodland covers just under 300 ha which equates to 5.6% of the area surveyed. Rock cover is low to moderate.

Vegetation structure is Short Open to Closed Woodland to Closed Shrubland (*sensu* Edwards, 1983). This vegetation community is characterised by dominance of short, dense shrubs and scattered taller trees. Common Corkwood *Commiphora pyracanthoides* and Velvet Raisin *Grewia flava* are dominant in the understory, while Sickle-bush *Dichrostachys cinerea* subsp. *africana* is co-dominant in places. Common trees are Velvet Corkwood *Commiphora mollis,* Tall Common Corkwood *Commiphora glandulosa,* Knob Thorn *Acacia nigrescens,* Smelly Shepherd's Tree *Boscia foetida* and Purple-pod Cluster-leaf *Terminalia prunioides.* Dominant grasses are *Eragrostis chloromelas*, *Eragrostis rigidior* and *Pogonarthria squarrosa.*

Three smaller vegetation associations were identified within this community, but were not distinguishable on satellite imagery:

- ***Commiphora mollis - Commiphora pyracanthoides - Grewia flava* Open to Closed Woodland**: found on shallowish to fairly deep Hutton soils; this is the typical association defining this community.
- ***Commiphora pyracanthoides - Acacia* spp. Open to Closed Woodland**: found at one site on fairly deep (c. 500 mm) Clovelly soils on Moonlight 111 LR.
- ***Commiphora pyracanthoides - Grewia flava* Shrubland**: found on fairly deep soils near some calcrete outcropping in the extreme south-east of the study area.

A total of 69 species (37% of the entire list) was recorded from *Commiphora* spp. – *Grewia flava* Open to Closed Woodland (Appendix 1) with no species of conservation concern being recorded[1]. Two species occurring in this vegetation community are protected under the National Forest Act (No.84 of 1998), namely *Boscia albitrunca* and *Sclerocarya birrea* subsp. *cafra.* However, both occur in small numbers and the resultant AFI score is only 3, which reflects Low importance for flora of conservation concern (Table 4). Only seven species

[1] We follow the terminology of Raimondo *et al.* (2009); Species of conservation concern are those that are important for South Africa's conservation decision-making processes and comprise all threatened species (those facing a high risk of extinction, in the categories Critically Endangered, Endangered or Vulnerable), as well as those with a status of Data Deficient, Near Threatened, Critically Rare, Rare and Declining.

(12.5% of the community species list) appear to be confined to this vegetation community within the study area, a low fidelity level that reflects how strong affinities are with adjacent vegetation communities. Only two invasive alien species were recorded, namely *Cereus jamacaru* and *Solanum elaegnifolium*, both of which were found in disturbed areas within this community, such as road verges.

This vegetation is moderately representative of Roodeberg Bushveld (Mucina & Rutherford, 2006), which is not considered to be threatened.

Figure 6. *Commiphora spp. – Grewia flava* Closed Woodland, near Quadrat 3 (Moonlight 111 LR)

5) ***Acacia tortilis – Dichrostachys cinerea* Old Lands**

This vegetation community is typical of old cultivated lands that have been left fallow for many years. The Umbrella Thorn *Acacia tortilis* and Sickle-bush *Dichrostachys cinerea* are dominant throughout, and a dense grass sward is dominated by grass species that typically colonise disturbed areas. This community did not have species of conservation importance and is unlikely to provide habitat for such species.

6) **Transformed Areas**

A few scattered homesteads, farm dams and ploughed lands are collectively referred to as Transformed Areas in this study. These areas have low conservation value within the study area and were not surveyed.

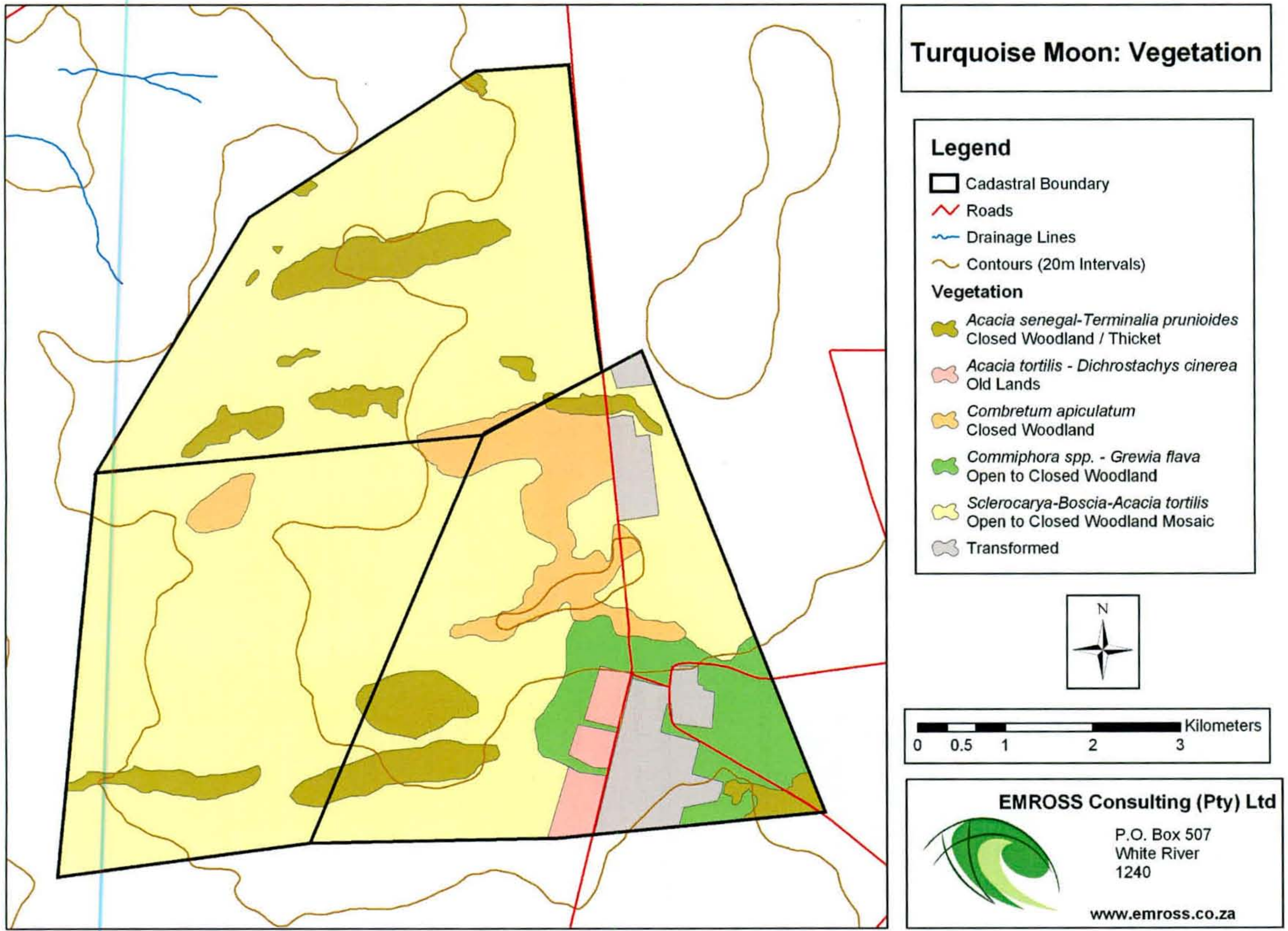

Figure 7. Vegetation Communities on Moonlight

5.1.3 Potentially Occurring Flora of Conservation Concern

Seven plant species of conservation concern[1] have been confirmed within the quarter-degree grids 2328AA and 2328AC and surrounding grids (Table 5), none of which was located during fieldwork. Only one of these is threatened, namely *Marsilea farinosa* subsp. *arrecta*, which is classified as Vulnerable. Limited habitat for this species is present in the study area, but it is also easily overlooked because of its very small size; the likelihood of occurrence is considered Low. Six species of conservation concern that are not considered threatened potentially occur. Two of these have a Moderate likelihood of occurrence because of the presence of suitable habitat and known nearby records. Transvaal Saffron *Elaeodendron transvaalense* is classified as Near Threatened and Camel Thorn *Acacia erioloba* as Declining. Neither of these distinctive trees was located during fieldwork, but it is still possible that some specimens may have been overlooked because of the size of the study area. Four species have a Low likelihood of occurrence because of lack of suitable habitat and / or distance from nearest known records. Details regarding habitat and likelihood of occurrence are given in Table 5.

Table 4. Associated Floral Index Scores for Protected Species in the Moonlight Study Area

Species	Protective Legislation	*Acacia senegal-Terminalia prunioides* Closed Woodland / Thicket	*Sclerocarya-Boscia-Acacia tortilis* Open to Closed Woodland Mosaic	*Commiphora spp. - Grewia flava* Open to Closed Woodland	*Combretum apiculatum* Closed Woodland	*Acacia-Dichrostachys* Old Lands
Boscia albitrunca	NFA	0	3	2	1	0
Sclerocarya birrea subsp. *cafra*	NFA	0	3	2	2	0
AFI Score		0	6	4	3	0
AFI Significance		**Low**	**Low-Med**	**Low**	**Low**	**Very Low**

NFA = National Forest Act

[1] We follow the terminology of Raimondo *et al.* (2009); Species of conservation concern are those that are important for South Africa's conservation decision-making processes and comprise all threatened species (those facing a high risk of extinction, in the categories Critically Endangered, Endangered or Vulnerable), as well as those with a status of Data Deficient, Near Threatened, Critically Rare, Rare and Declining.

Table 5. Plant species of conservation concern potentially occurring in the Moonlight study area

Species	Red Data Status	Habitat	Likelihood	Reason
Marsilea farinosa subsp. *arrecta*	Vulnerable	Dry sandy river beds, seasonally flooded vleis or pans, along rivers and streams	Low	Limited habitat present
Elaeodendron transvaalense	Near Threatened	Savannah or bushveld, often on termite mounds	Moderate	Suitable habitat
Panicum dewinteri	Near Threatened	Quartzite ridges in open woodland	Low	Lack of suitable habitat
Adenia fruticosa subsp. *simplicifolia*	Rare	Tall *Terminalia* woodland on basalt, gneiss, granite and pegmatite	Low	Lack of suitable habitat
Euphorbia louwii	Rare	Sandstone ridges in open woodland	Low	Limited habitat; nearest records from 2328CA
Euphorbia waterbergensis	Rare	Quartzite ridges and outcrops in mixed bushveld	Low	Lack of suitable habitat
Acacia erioloba	Declining	Savannah with deep, sandy soils	Moderate	Suitable habitat

5.2 Vertebrate Fauna

5.2.1 Mammals

Twenty-three mammal species were confirmed to occur within the study area, based on fieldwork and discussions with the farm manager on Gouda Fontein (Andries van der Merwe) (Appendix 4). Five of these are species of conservation concern:

- Leopard – confirmed through anecdotal accounts; this is the only threatened species confirmed to occur in the study area; it has been allocated a status of Vulnerable under NEMBA; probably only moves through and is not resident.
- Spotted Hyaena - confirmed through anecdotal accounts; has a national status of Near Threatened; probably only moves through the study area and is not resident.
- Brown Hyaena – confirmed through anecdotal accounts; has a national status of Near Threatened; probably resident in the study area.
- Serval – confirmed through anecdotal accounts; has a national status of Near Threatened; probably resident in the study area.
- Bushveld Elephant Shrew – a single individual caught in a Willan trap at Trapline 3 (S23.21471 E28.19026) in *Acacia – Boscia* open woodland, 02.12.2010; has a status of Data Deficient.

The savanna biome, in which the study area is situated, has high mammal diversity and a high number of Red Data species, but a disproportionately low number of endemics. An estimated 26 mammal species of conservation concern potentially occur within the project area (Appendix 5). Only four of these are threatened, namely Pangolin, Botswana Long-eared Bat, Peak-saddle Horseshoe Bat and Leopard, all of which have a status of Vulnerable[1]. While the Pangolin has a moderate likelihood of occurring, the likelihood of two bats occurring is difficult to predict. Botswana Long-eared Bat is only known from a few specimens in South Africa, most of which were collected in the Waterberg Mountains in Limpopo Province[2]. Its roosting and feeding habits are not known, and thus it is impossible to say whether habitats in the study area are suitable or not. Peak-saddle Horseshoe Bat has been collected in the Wonderkop Nature Reserve[3], a provincial conservation area situated about 30 km east of the Moonlight study area (Transvaal Museum specimen

[1] Friedman & Daly, 2004; Leopard assessed under NEMBA
[2] Van Cakenberghe *et al.*, 2009
[3] Van Cakenberghe *et al.*, 2009

no.46645). However, this species requires caves or mine adits as roosting habitat, neither of which are present in the study area. So this species probably only has a low likelihood of occurrence. Leopard has been confirmed through anecdotal accounts of local residents. The remaining species of conservation concern either have a status of Near Threatened (11 species) or Data Deficient (10 species). These are species that either could soon qualify for threatened status or for which not enough data are available for an assessment of status to be made. Seven of the Near Threatened species and one Data Deficient species are bats, all of which would possibly forage over the study areas, but would be unlikely to roost. Nine species are either rodents or small insectivores, of which one is Near Threatened (South African Hedgehog) and the rest are Data Deficient. One of these, Bushveld Elephant Shrew, was confirmed during fieldwork. The remaining five species are carnivores, four of which are Near Threatened (Brown Hyaena, Spotted Hyaena, Serval, Honey Badger) and one Data Deficient (African Weasel). Both hyaenas and Serval were confirmed through anecdotal accounts from local residents.

No vegetation community appears to be more important than any other for mammals of conservation concern. The confirmed occurrence of five of these species (one of which is Vulnerable), gives all untransformed vegetation a **Medium-High** importance.

5.2.2 Birds

A total of 94 bird species was confirmed to occur within the study area during fieldwork (Appendix 4). Two of these have a national Red Data status of Vulnerable:

- White-backed Vulture - a flock of several birds seen soaring over the study area in December 2010.
- Bateleur – several solitary birds seen soaring over the study area over several days in December 2010.

Two other species of conservation concern that were confirmed to occur are European Roller and Red-billed Oxpecker, both of which have a conservation status of Near Threatened. European Roller was found to be fairly common in open to sparse woodland, particularly in the northern half of the study area, while a pair of oxpeckers was observed on a telephone pole at a farmhouse near the centre of the study area.

Two biome-restricted assemblages as described by Barnes (1998) are represented in the study area:

- *Kalahari – Highveld Transition*: this assemblage occurs in north-western South Africa at the interface between the Kalahari and Highveld regions; three species (Barred Wren-Warbler, Burchell's Sandgrouse and Kalahari Scrub-Robin) were confirmed during fieldwork.
- *Zambezian*: this assemblage is best represented north of South Africa, in the miombo woodlands of Zimbabwe, Zambia, Malawi, Angola and Mozambique; two widespread and common members of this assemblage were confirmed during fieldwork (White-throated Robin-Chat and White-bellied Sunbird).

Data accessed from the South African Bird Atlas Project (SABAP2) website (http://sabap2.adu.org.za) were used to compile a list of potentially occurring species of conservation concern (Appendix 5). Eight species in addition to those above are listed as having been recorded on nearby properties. Six of these are threatened (Vulnerable). Three of these are unlikely to breed within the study area, either because of lack of suitable breeding sites (Cape Vulture) or distance from nearest known breeding areas (Lappet-faced Vulture and Hooded Vulture). The three remaining species potentially breed and forage in the study area and have a High likelihood of occurrence (Tawny Eagle, Martial Eagle and Kori Bustard). Two Near Threatened birds of prey have a High likelihood of occurring (Lanner Falcon, Secretarybird).

No Important Bird Areas have been described for the vicinity of the study area. The nearest is the Blouberg Mountain IBA, about 65 km north-east of the property (Barnes, 1998).

The more open vegetation associations in the north of the study area appear to be more important for birds of conservation concern. However, nine of the 12 species are birds of prey that can forage widely over a range of vegetation types, making any of the vegetation communities potentially important. The confirmed occurrence of four of these species (two of which are Vulnerable), gives the *Sclerocarya-Boscia-Acacia* Open to Closed Woodland Mosaic vegetation a **Medium-High** importance and the other communities **Medium** importance.

5.2.3 Reptiles

Ten reptile species were confirmed to occur within the study area during fieldwork (Appendix 4). Most of these are widespread species occurring throughout the savannah biome in South Africa, such as Flap-neck Chamaeleon, Leopard Tortoise, Common Dwarf Gecko and

Yellow-throated Plated Lizard. However, two species with restricted ranges in northern South Africa were also confirmed to occur:

- Variegated Skink (*Trachylepis variegata*) – this widespread Western and Northern Cape species only just enters northern South Africa along the Botswana border; a single specimen was captured and photographed along a calcrete ridge on Julietta 112 LR (Appendix 6).
- Kalahari Dwarf Worm-Lizard (*Zygaspis quadrifrons*) – this rarely seen fossorial species was unearthed by entomologists digging for scorpions in *Acacia senegal – Terminalia prunioides* Closed Woodland (Appendix 6).

Only one threatened reptile potentially occurs in the study area, namely Southern African Python, which is classified as Vulnerable. This species has a High likelihood of occurring in the study area. The lack of reptiles of conservation concern results in the untransformed habitats being rated as Low importance for reptiles of conservation concern.

5.2.4 Frogs

Six frog species were confirmed to occur within the study area during fieldwork (Appendix 4). Most of these are widespread species occurring throughout the savannah biome in South Africa, such as Bubbling Kassina, Foam-nest Frog and Bushveld Rain Frog. However, two species with more restricted ranges in northern South Africa were also confirmed to occur:

- Southern Ornate Frog (*Hildebrandtia ornata*) – this species occurs most widely in Kruger National Park and follows the Limpopo River along the Zimbabwe and Botswana borders, occurring marginally into north-western parts of Limpopo Province. The photographic record in the Moonlight study area (Appendix 6), appears to represent a new locality for this species (Minter et al., 2004). Two specimens were captured and photographed at a small man-made dam in *Combretum apiculatum* Closed Woodland on Moonlight 111 LR (Appendix 6).
- African Bullfrog (*Pyxicephalus edulis*) – this species occurs mostly in the eastern Lowveld and scattered localities along the Limpopo Valley and other parts of north-western Limpopo Province. A single individual was captured and photographed at a small muddy roadside pool in *Combretum apiculatum* Closed Woodland on Moonlight 111 LR (Appendix 6).