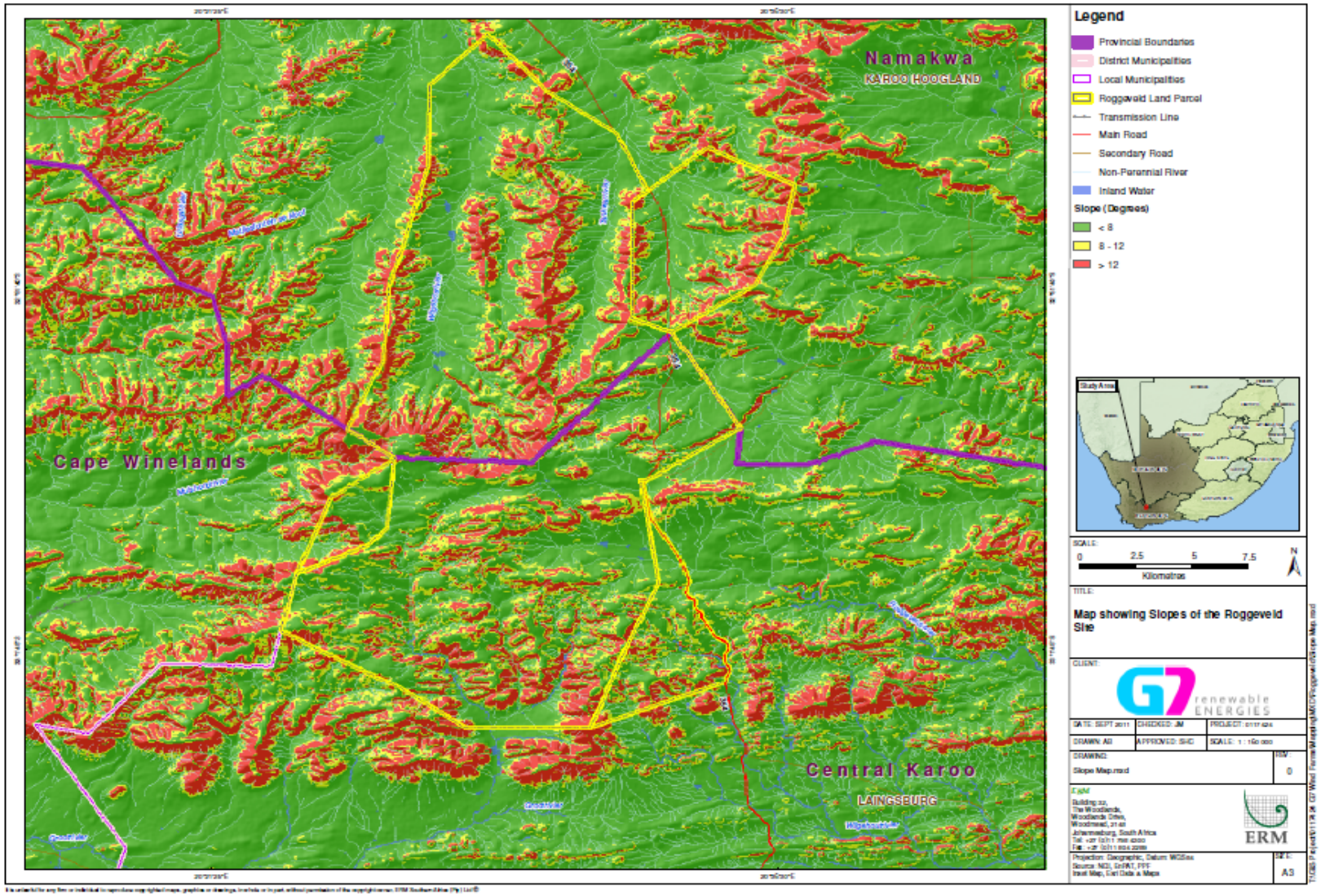
Topography

The highest point within the site is 1,450 m above sea level. The site area and surrounds feature a network of numerous hills, mountains and ridges, interspersed by valleys below the high ground, which are located at approximately 700 - 1,000 m above sea level. The dominant orientation of the ridges within the site area is north-south. A wider, open valley with undulating hills lies to the east of the site at approximately 1,000 – 1,200 m above sea level. *Figure 10.1* below shows the slope and general topography of the site.

Figure 10.1 Slope and topography of the Roggeveld site



Geology and Soils
The site is underlain by the Adelaide Subgroup which forms part of the lower Beaufort Group and is Permian in age. This subgroup consists of fine grained sandstone and course arkose, alternating with green and brownish-red mudstone. Jurassic aged dolerite intrusions in the form of dykes and sills are also associated with this Subgroup.

Surface Water and Groundwater
The aquifer beneath the site is classified as a fractured aquifer which has a groundwater yield potential of between 0.5 to 2.0 l/s and electrical connectivity values vary between 20 to 795 mS/m. The aquifer is fractured and groundwater is associated with joints and fractures of dolerite contact zones with country rock, decomposed dolerite and zones of semi-weathered dolerite. The Department of Water Affairs and Forestry (1) classifies the regional aquifer as a major aquifer with moderate vulnerability (likelihood of contaminants reaching a receptor) and low susceptibility (potential significance of contaminants reaching a receptor).

Within the site area there are numerous small non-perennial watercourses that flow from areas of high ground into and along valleys within the site. Tributaries of two perennial rivers, the Wilgebosrivier and Furrowrivier flow from within the site area to beyond in the north and south of the site respectively. Other perennial watercourses that are located in the areas surrounding the site include the following:

- Kereekloofrivier (approximately 2 km west of site)
- Matjiesfontein se Kloof (approximately 5 km west of the site)
- Roggeveldrivier (approximately 5 km east of the site)

Given the size of the site and varied topography it is likely that the site is located within a number of different watersheds. Within the site area and beyond there are a number of farm dams. To the east of the site, topography maps show a number of waterbodies which may be dams or non-perennial pans.

10.1 IMPACTS ON SOILS, HYDROLOGY AND HYDROGEOLOGY

This chapter discusses the potential impacts the proposed Roggeveld Windfarm may have on soils, surface- and groundwater. The potential impacts are assessed for the entire lifecycle of the project and mitigation measures to reduce the impacts are outlined below.

The project may impact the soils, surface water and groundwater in the area and these potential impacts are summarised in *Table 100.1*.

Table 100.1 Impact Characteristics: Impacts on Soils, Surface Water and Groundwater

Summary	Construction	Operation	Decommissioning

Summary	Construction	Operation	Decommissioning
Project Aspect/ Activity	• Soil compaction, removal of topsoil and erosion associated with site clearance and preparation, road construction, laydown and assembly area etc. • Impact on surface water and groundwater resulting from fuel, oils or cement spills • Increase in sediment load in drainage channels and surface water bodies as a result of erosion	• Soil erosion around cleared areas and roads • Impact on surface water and groundwater resulting from fuel and oil spills • Increase of sediment load in drainage channels and surface water bodies as a result of erosion • Reduction of groundwater recharge due to sealed surfaces	• Impact on surface- and groundwater resulting from fuel and oil spills during removal of equipment • Reduced soil erosion and compaction and sediment loads after rehabilitation. • Increased groundwater recharge after rehabilitation
Impact Type	• Direct	• Direct	• Direct
Receptors Affected	• Soils on site underlying construction areas, turbines, roads etc. • Surface and groundwater quality at or near the site	• Soils in the vicinity of cleared areas or roads and turbines • Surface and groundwater quality at or near the site	• Soils on site • Surface and groundwater quality at or near the site

A detailed list of the expected activities to take place during the lifetime of the project and the nature of the potential impact is presented in *Table 100.2*.

Table 100.2 Interaction and Nature of the Potential Impacts between Project Activities and Receiving Environment

Project Activities	Impact					
	Soil Erosion	Soil Compaction	Soil Contamination	Surface Water Quality	Groundwater Quantity	Groundwater Quality
Pre-construction and Construction						
Vegetation Clearance						
Erection of Fencing						
Construction of Access Roads						
Construction of Site Office and Storage Facilities						
Levelling of Hard Standing Areas						
Laying of Turbine Foundations						
Laying of Underground Cables						
Stringing of Overhead Transmission Lines						
Substation Construction						
Wind Turbines Delivery and Erection						
Operation						
Wind Farm Operation						
Use of Access Tracks						
Use of Buildings						
Site Maintenance						
Decommissioning						
Removal of Wind Turbines						
Removal of Foundations						
Removal of Access Roads						
Removal of Underground and Overhead Cables						
Site Restoration & Rehabilitation						

Key: Red box indicates a potential negative impact, green box a potential positive impact and white box no interaction between the project and resource or receptor.

10.2 LOSS OF TOPSOIL, SOIL COMPACTION AND EROSION

10.2.1 Impact Description and Assessment

Construction Phase Impacts

Preparation of the site for the establishment of turbines, underground cables, access roads, lay-down areas, substation site and operation and maintenance building during the construction phase will result in vegetation clearance, removal of topsoil and subsoil to varying depths and soil compaction.

It is planned to erect a total of 250 wind turbines. The area required to establish one wind turbine tower includes a 20 x20m excavation and a 5x5m patch for the concrete foundation of the turbine, a compacted gravel hard standing lay down area of 2,500m^2 and an electrical transformer. The deepest excavations will be for turbine foundation which will extend up to 3m depth.

The substation will incorporate an area of approximately 6000m^2 in size and will be a single storey building accompanied by offices, storage and ablution facilities. Site access roads that are developed will be up to 12m wide with drainage trenches adjacent to the road. The total area required is relatively small, approximately 65ha, which is roughly 0.2% of the total size of the site.

Areas cleared of vegetation in preparation for the establishment of the Wind Farm are prone to erosion by wind or rain. The vegetation cover is the most important physical factor influencing soil erosion. An intact cover reduces impact from rain-drops on the soil, slows down surface run-off, filters sediment and binds the soil together for more stability. However, the intensity of potential erosion is also influenced by precipitation which is generally low in this arid region with an annual rainfall of 250mm.

In addition, although the area directly affected may be small, the effects of potential soil erosion and increased sediment load in surface runoff may extend to other areas onsite if appropriate controls are not in place.

Compaction of soils results in lower permeability resulting in decreased infiltration and increased runoff. Permanent removal of the topsoil horizon changes the soil profile which may inhibit rehabilitation which may, in turn, increase the erosion potential of the soil.

Soils may be impacted as a result of spills or leaks of fuels, oils and lubricants from construction vehicles or storage tanks. These impacts are dependent on the size of the spill and the speed with which it is addressed and cleaned up. The likelihood of a spill is also associated with the volume of product that may be stored onsite. Usually, above ground storage tanks for diesel and varying amounts of hydraulic oils, transformer oil and used oils will be required onsite during the construction phase.

Box 100.1 Construction Impact: Loss of Topsoil, Soil Compaction and Soil Erosion

Nature: The loss of topsoil, changes in the soil profile through compaction, potential soil erosion and contamination will have a **negative direct** impact on the soils of the site.

Impact Magnitude –Medium

- **Extent:** The extent of the impact is **local** since the impacts are predominantly limited to the boundaries of the site but may extend beyond the site.
- **Duration:** The duration would be **long-term** since although removal of topsoil and compaction will occur largely during the construction phase, the effect may continue through the project lifecycle.
- **Intensity:** The intensity is **medium** since although topsoil removal and soil compaction may be limited to specific areas of the site, potential erosion may affect a larger area.

Likelihood – There is a **medium** likelihood that this impact will occur.

IMPACT SIGNIFICANCE (PRE-MITIGATION) – MEDIUM (-VE)

Degree of Confidence: The degree of confidence is **medium**.

Operational Phase Impacts

Soil erosion caused by storm water or surface water runoff may occur during the operational phase as a result of additional impervious surfaces onsite resulting in increased runoff. And, although the disturbance associated with the construction phase is over, unless measures are undertaken loss of topsoil may continue during the operational phase of the project. No additional topsoil clearing is anticipated during routine operation and maintenance of the facility. Soil compaction may occur during the operational phase if heavy vehicles leave the roads and hard standing areas.

Soil contamination associated with leaks and spills are reduced during the operation phase since only limited on-site storage of hydrocarbons will take place and site activities will be reduced.

Box 100.2 Operational Impact: Loss of Topsoil, Soil Compaction and Soil Erosion

Nature: Routine operational and maintenance activities may result in a **negative direct** impact on the soils of the site.

Impact Magnitude –Low

- **Extent:** The extent of the impact is **local,** the impacts are predominantly limited to the site boundaries but may extend to the immediate vicinity of the site.
- **Duration:** The duration would be **long-term** as the soils may be affected at least until the project stops.
- **Intensity:** The intensity is **low** since the impact will be limited to areas that are already disturbed or to areas in close proximity.

Likelihood – There is a **medium** likelihood that these impacts will occur.

IMPACT SIGNIFICANCE (PRE-MITIGATION) – LOW (-VE)

Degree of Confidence: The degree of confidence is **medium**.

Decommissioning

Once the facility has reached the end of its life the wind turbines may be refurbished or replaced to continue operating as a power generating facility, or the facility can be closed and decommissioned. If decommissioned, all the components of the wind farm would be removed and the site would be rehabilitated.

Removal of site equipment including turbines, buildings, underground cables and access roads, will induce more disturbance to the site and have a potential for soil contamination as a result of spills or leaks of fuels, oils and lubricants from construction vehicles or storage tanks if managed inappropriately. This impact would be **negative direct** and the significance would be **low**.

However, the concrete foundations of the turbines may be removed to below ground level and would be covered with topsoil and be replanted to allow a return to agricultural land use (cultivation and grazing) which could have a **positive direct** impact on the soils on site.

10.2.2 Mitigating Loss of Topsoil, Soil Compaction and Erosion

Mitigation measures are possible to address the majority of the potential impacts outlined above in order to contribute to reducing the significance of the residual impacts associated with loss of topsoil, soil compaction and erosion to an acceptable level.

Proposed mitigation measures are detailed below for each of the project phases and will be further detailed in the Environmental Management Plan (EMP) to ensure mitigation measures are followed.

Construction Phase

- Restrict removal of vegetation and soil cover to those areas necessary for the development;
- Implement soil conservation measures such as stockpiling top soil for remediation of disturbed areas;
- Stockpiles should be vegetated or appropriately covered to reduce soil loss as a result of wind or water to prevent erosion;
- Proper drainage controls such as culverts and cut-off trenches discharging into drainage channels present on site should be used to ensure proper management of surface water runoff to prevent erosion;
- Disturbed areas should be rehabilitated as soon as possible to prevent erosion;
- Work areas should be clearly defined and demarcated, where necessary, to avoid unnecessary disturbance of areas outside the development footprint;
- Fuel, oil and used oil storage areas should have appropriate secondary containment (i.e. bunds);
- Spill containment and clean up kits should be available on site and clean-up from any spill should be appropriately contained and disposed of;

- Construction vehicles and equipment should be serviced regularly and provided with drip trays if required; and
- Construction vehicles should remain on designated and prepared roads.

Operational Phase

The following mitigation measures are proposed to be implemented during the operational phase:

- Laydown or infrastructure assembly areas which should not be required during the operational phase of the facility should be re-vegetated with indigenous vegetation to prevent erosion;
- Bi-annual monitoring of erosion in the vicinity of roads, turbines and other hard-standing surfaces should be conducted before and after the rainy season to ensure erosion sites can be identified early and remedied; and
- Establishing an Environmental Management System (EMS) to monitor compliance, check quality controls and ensure the EMP is being followed.

Decommissioning Phase

The following mitigation measures are proposed to be implemented during the decommissioning phase:

- Work areas should be clearly defined and demarcated, where necessary, to avoid unnecessary disturbance or areas outside the development footprint;
- Fuel, oil and used oil storage areas should have appropriate secondary containment (i.e. bunds);
- Spill containment and clean up kits should be available onsite and clean-up from any spill should be appropriately contained and disposed of; and
- Construction vehicles and equipment should be serviced regularly and provided with drip trays, if required.

10.2.3 Residual Impact

The implementation of construction, operational and decommissioning phase mitigation will contribute to reducing the significance of the residual impacts associated with loss of topsoil, soil compaction and erosion to low (see *Table 100.3*).

Table 100.3 Pre- and Post-Mitigation Significance: Loss of topsoil, soil compaction and erosion

Phase	Significance (Pre-mitigation)	Residual Impact Significance
Construction	**MEDIUM (-VE)**	**LOW (-VE)**
Operation	**LOW (-VE)**	**LOW (-VE)**
Decommissioning	**LOW (-VE)**	**LOW (-VE)**

10.3 IMPACT ON SURFACE WATER AND GROUNDWATER

10.3.1 Impact Description and Assessment

Construction Phase Impacts

Soil compaction and vegetation clearance may increase the intensity and volume of surface water runoff as a result of a decrease in water infiltration recharging the groundwater. This may impact the non-perennial drainage channels on site by exacerbating erosion features and increasing the sediment load of the water entering these channels when they are flowing.

Surface- and groundwater may be impacted as a result of run-off and infiltration of contaminants associated with spills or leaks of fuels, oils and lubricants from construction vehicles or storage tanks. These impacts are dependent on the size of the spill and the speed with which it is addressed and cleaned up as well as the vulnerability and susceptibility of the aquifer (least vulnerability [1] and low susceptibility [2]). The likelihood of a spill is also associated with the volume of product that may be stored on site. Usually, above ground storage tanks for diesel and varying amounts of hydraulic oils, transformer oil and used oils will be required on site during the construction phase.

Box 100.3 Construction Impact: Impact on Surface and Groundwater

Nature: Surface and groundwater impacts resulting from soil compaction, increased sediment load or through leaks or spills would result in a **negative direct** impact.

Impact Magnitude –Low

- **Extent:** The extent of the impact is **local** since the impacts are limited predominantly to the boundaries of the site or in the vicinity of the site.
- **Duration:** The duration for water quality impacts would be **short or long-term** depending on the size or nature of the spill and **long-term** for impacts from soil compaction.
- **Intensity:** The intensity is **low** since runoff is expected to be low and the quantity of dangerous goods stored onsite will be relatively small.

Likelihood – There is a **medium** likelihood that this impact will occur.

IMPACT SIGNIFICANCE (PRE-MITIGATION) – LOW (-VE)

Degree of Confidence: The degree of confidence is **medium**.

(1) [1] Tendency or likelihood for contaminants to reach a specified position in the groundwater system after introduction at some location above the uppermost aquifer.

(2) [2] Qualitative measure of the relative ease with which a groundwater body can be potentially contaminated by anthropogenic activities and includes both aquifer vulnerability and the relative importance of the aquifer in terms of its classification.

Operational Phase Impacts

Soil erosion caused by storm water or surface water runoff may occur during the operational phase and result in an increase in the sediment load of onsite drainage channels.

Surface- and groundwater impacts associated with leaks and spills are reduced during the operation phase since only reduced on-site storage of hydrocarbons will take place and site activities will be reduced.

Due to sealed surfaces, compacted soil (access roads and lay down areas) and turbines covering parts of the site, recharge to groundwater from rainfall is expected to be reduced on site.

Box 100.4 Operational Impact: Impact on Surface- and Groundwater

Nature: Increased sediment loads in drainage channels, spills and leaks during routine operational and maintenance activities and reduced groundwater recharge may result in a **negative direct** impact on surface- and groundwater.

Impact Magnitude –Low

- **Extent:** The extent of the impact is **local** since the impacts are limited predominantly to the boundaries of the site or in the vicinity of the site.
- **Duration:** The duration for contamination would be **short to long-term** depending on the size of the spill. The duration for increased sediment loads and reduced groundwater recharge would be **long-term**.
- **Intensity:** The intensity is **low** since the size of a spill is likely to be small given the limited volume of product to be stored onsite. Intensity for increased sediment load will be **medium** and for reduced groundwater recharge **low** since the natural groundwater recharge from rainfall in the area is low.

Likelihood – There is a **medium** likelihood that this impact will occur.

IMPACT SIGNIFICANCE (PRE-MITIGATION) – LOW (-VE)

Degree of Confidence: The degree of confidence is **medium**.

Decommissioning

Removal of site equipment including turbines, buildings, underground cables and access roads, would have a potential for surface- and groundwater contamination related to run-off and infiltration of contaminants as a result of spills or leaks of fuels, oils and lubricants from construction vehicles or storage tanks if managed inappropriately. This impact would be **negative direct** and the significance would be **low**.

However, the rehabilitation of the entire site would reduce erosion and therefore decrease sediment loads in surface water courses on site. Groundwater recharge would increase as a result of reduction of sealed surfaces and rehabilitated soils. In general, decommissioning would have a

positive direct impact on surface- and groundwater if managed appropriately.

10.3.2 Mitigating Impacts on Surface and Groundwater

Construction Phase

- Soil stockpiles should be protected from wind or water erosion through placement, vegetation or appropriate covering;
- Proper drainage controls such as culverts, cut-off trenches should be used to ensure proper management of surface water runoff to prevent erosion;
- Cleared or disturbed areas should be rehabilitated as soon as possible to prevent erosion;
- Fuel, oil and used oil storage areas should have appropriate secondary containment (i.e. bunds);
- Spill containment and clean up kits should be available onsite and clean-up from any spill should be appropriately contained and disposed of; and
- Construction vehicles and equipment should be serviced regularly and provided with drip trays, if required.

Operational Phase

The following mitigation measures are proposed to be implemented during the operational phase:

- Fuel, oil and used oil storage areas should have appropriate secondary containment (i.e. bunds);
- Areas disturbed during construction should be re-vegetated with indigenous vegetation to prevent erosion; and
- Establishing an Environmental Management System (EMS) to monitor compliance, check quality controls and ensure the EMP is being followed.

Decommissioning Phase

The following mitigation measures are proposed to be implemented during the decommissioning phase:

- Work areas should be clearly defined and demarcated, where necessary, to avoid unnecessary disturbance or areas outside the development footprint;
- Fuel, oil and used oil storage areas should have appropriate secondary containment (i.e. bunds);
- Spill containment and clean up kits should be available onsite and clean-up from any spill should be appropriately contained and disposed of; and
- Construction vehicles and equipment should be serviced regularly and provided with drip trays, if required.

10.3.3 Residual Impact

It is not anticipated that any major watercourses or water bodies will be directly impacted by the proposed development and the project is not

expected to require large water-inputs during construction or operation (*Table 100.4*).

Table 100.4 Pre- and Post-Mitigation Significance: Impacts on Surface and Groundwater

Phase	Significance (Pre-mitigation)	Residual Impact Significance
Construction	**LOW (-VE)**	**LOW (-VE)**
Operation	**LOW (-VE)**	**LOW (-VE)**
Decommissioning	**LOW (-VE)**	**LOW (-VE)**