HYDROLOGICAL ASSESSMENT, STORM WATER MANAGEMENT & EROSION CONTROL PLAN

FOR THE PROPOSED KARREEBOSCH WIND ENERGY FACILITY PART 2 AMENDMENT, FINAL LAYOUT & EMPR APPROVAL PROCESS AND BASIC ASSESSMENT PROCESS FOR THE ASSOCIATED GRID INFRASTRUCTURE

KAROO HOOGLAND LOCAL MUNICIPALITY, NAMAKWA DISTRICT MUNICIPALITY, NORTHERN AND WESTERN CAPE PROVINCES

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FINAL REPORT

Acronyms

DEDTEA	Department of Economic Development, Tourism and Environmental Affairs
DWS	Department of Water and Sanitation
ECO	Environmental Control Officer
EIA	Environmental Impact Assessment
GA	General Authorisation
GIS	Geographical Information System
HEC-RAS	Hydrologic Engineering Center's (CEIWR-HEC) River Analysis System
MAP	Mean Annual Precipitation
MAT	Mean Annual Temperature
NFEPA	National Freshwater Priority Area
OHL	Over Head Lines
QC	Quaternary Catchment
SAWS	South African Weather Service
SWAT	Soil & Water Assessment Tool
SWMP	Storm Water Management Plan
UPD	Utility Programme for Drainage
WEF	Wind Energy Facility
WMA	Water Management Area
WULA	Water Use License Application

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Specialist Details & Declaration

This report has been prepared in accordance with Section 13: General Requirements for Environmental Assessment Practitioners (EAPs) and Specialists as well as per Appendix 6 of GNR 982 – Environmental Impact Assessment Regulations and the National Environmental Management Act (NEMA, No. 107 of 1998 as amended 2017) and Government Notice 704 (GN 704). It has been prepared independently of influence or prejudice by any parties.

The details of Specialists are as follows –

Table 1 Details of Specialist

Specialist	Task	Qualification and accreditation	Client	Signature
Bruce Scott-Shaw NatureStamp SACNASP:118673	Fieldwork, modelling & report	BSc, BSc Hon, MSc, PhD, Hydrology	G7 Renewable Energies (Pty) Ltd	Date: 29/07/2022
Nick Davis Isikhungusethu Environmental Services	GIS & Review	BSc, BSc Hon, MSc Hydrology	G7 Renewable Energies (Pty) Ltd	Date: 29/107/2022

<u>Details of Authors:</u>

Bruce is a hydrologist, whose focus is broadly on hydrological perspectives of land use management and climate change. He completed his MSc under Prof. Roland Schulze in the School of Bioresources Engineering and Environmental Hydrology (BEEH) at the University of KwaZulu-Natal, South Africa. Throughout his university career he has mastered numerous models and tools relating to hydrology, soil science and GIS. Some of these include ACRU, SWAT, ArcMap, Idrisi, SEBAL, MatLab and Loggernet. He has some basic programming skills on the Java and CR Basic platforms. Bruce completed his PhD at the Center for Water Resources Research (UKZN), which focused on rehabilitation of alien invaded riparian zones and catchments using indigenous trees. Bruce is currently affiliated to the University of KwaZulu-Natal where he is a post-doctoral student where he runs and calibrates hydrological and soil erosion models. Bruce has presented his research around the world, including the European Science Foundation (Amsterdam, 2010), COP17 (Durban, 2011), World Water Forum (Marseille, 2012), MatLab advanced modelling (Luxembourg, 2013), World Water Week (Singapore, 2014), Forests & Water, British Colombia, (Canada, 2015), World Forestry Congress (Durban, 2015), Society for Ecological Restoration (Brazil, 2017). Conservation Symposium (Howick, South Africa, 2018) and SWAT modelling in Siem Reap (Cambodia, 2019). As a consultant, Bruce is the director and principal hydrologist of NatureStamp (PTY) Ltd. In this capacity he undertakes flood studies, calculates hydrological flows, performs general hydrological modelling, stormwater design, dam designs, wetland assessments, water quality assessments, groundwater studies and soil surveys.

Nicholas Davis is a hydrologist whose focus is broadly on hydrological perspectives of land use management, climate change, estuarine and wetland systems. Throughout his studies and subsequent work at UKZN he has mastered several models and programs such as ACRU, HEC-RAS, ArcMap, QGIS, Indicators of Hydrologic Alteration software (IHA) and Idrisi. He has moderate VBA programming skills, basic UNIX and python programming skills.

1. INTRODUCTION

1.1 Project Background and Description of the Activity

Karreebosch Wind Farm (Pty) Ltd. are undertaking a Part 2 amendment (including final layout and EMPr approval process) for the Karreebosch WEF, which will also supplement the WULA process. In addition, a separate Basic Assessment (BA) process for the associated grid infrastructure (132kV overhead powerline and 33kV/132kV substation) is being undertaken.

As part of the specialist requirements, a Floodline & Hydrological Assessment (including Stormwater Water Management Plan (SWMP)) is required in alignment with Government Notice 704 (GN 704 of the National Water Act). The location and layout of the site can be seen in Figure 1. The hydrological assessment complies with IFC Performance Standards (PSs), Appendix 6 of the NEMA EIA Regulations (2014, as amended) and comply with the DWS WUL/GA reporting requirements in terms of the National Water Act.

The requirement for the hydrological assessment is in part due to the potential presence of watercourse features on site and the impervious nature of the proposed activity. A key component of the investigation will be potential flood areas, accommodation of peak storm events, best practice erosion control and the general impact of the development on downstream surface water resources for water users in the catchment. The proposed infrastructure is as follows:

- Overhead Powerline (OHL)
- Servitudes
- Substations
- Site Access
- Turbines (40)
- Laydown Areas
- Construction Camp

The proposed wind energy facility (WEF) and associated grid infrastructure will be located on the following properties:

Farm Description	21-Digit Surveyor General (SG) Code	Area (ha)
Western Cape Province		
Portion 1 of Farm Bon Espirange No. 73	C04300000000007300001	1916,6474
Farm Aprils Kraal No. 105	C04300000000010500000	559,6837
Remainder of Farm Bon Espirange No. 73	C04300000000007300000	1764,2561
Remainder of Farm Brandvalley No. 75	C04300000000007500000	1981,9465
Northern Cape Province		
Farm Roode Wal No. 187	C07200000000018700000	2457,9713
Remainder of Farm Wilgebosch Rivier No. 188	C07200000000018800000	2898,914
Remainder of Farm Klipbanks Fontein No. 198	C07200000000019800000	1886,6226
Portion 1 of Farm Klipbanks Fontein No. 198	C07200000000019800001	1886,6226
Remainder of Farm Ek Kraal No. 199	C07200000000019900000	1407,4834
Portion 1 of Farm Ek Kraal No. 199	C07200000000019900001	1780,0948
Portion (Nuwe Kraal) of Farm Ek Kraal No. 199	C07200000000019900002	824,9459
Remainder of Farm Karreebosch No. 200	C07200000000020000000	1538,3432
Farm Appels Fontein No. 201	C07200000000020100000	4382,0063
Portion 2 of Farm Standvastigheid No. 210	C07200000000021000002	43,3064
Farm Rietfontein No. 197	C07200000000019700000	5873,6625
Farm Oude Huis No. 195	C07200000000019500000	1638,2716
Portion 1 of Farm Karree Kloof No. 196	C07200000000019600001	1859,8862
Portion 1 of Farm Karreebosch No. 200	C07200000000020000001	1550,7552
Remainder of Farm Standvastigheid No. 210	C07200000000021000000	4716,7192

1.2 Impact of Wind Energy Facilities on Hydrology

Wind Energy Facilities (WEF) in South Africa, which are becoming more abundant, may impact on the distribution of rainfall entering a catchment. The largest impacts are during construction as the size of the turbines require large vehicle/machines to transport to their destination, require deep piled foundations and large temporary storage areas. This results in potential erosion and an increase in stormflow. This is particularly relevant where slopes are steep. Following the construction phase, the impacts of WEFs on the hydrology is relatively low as natural and/or agricultural activities can continue and the disturbed footprint can be allowed to be rehabilitated without further disturbances.

In the context of this report, the following impacts are relevant:

- Change in runoff rates due to impeding structures (excavation and installation of foundations/crane pads for turbines and substation).
- Reduction in surface and groundwater quality through excavation for cables, foundations and crane pads leading to sedimentation and potential spills.
- Increased flood risk due to increased impervious areas.
- Potential erosion around construction areas, impervious surfaces and drip from blades.
- Potential erosion due to the widening of existing roads.

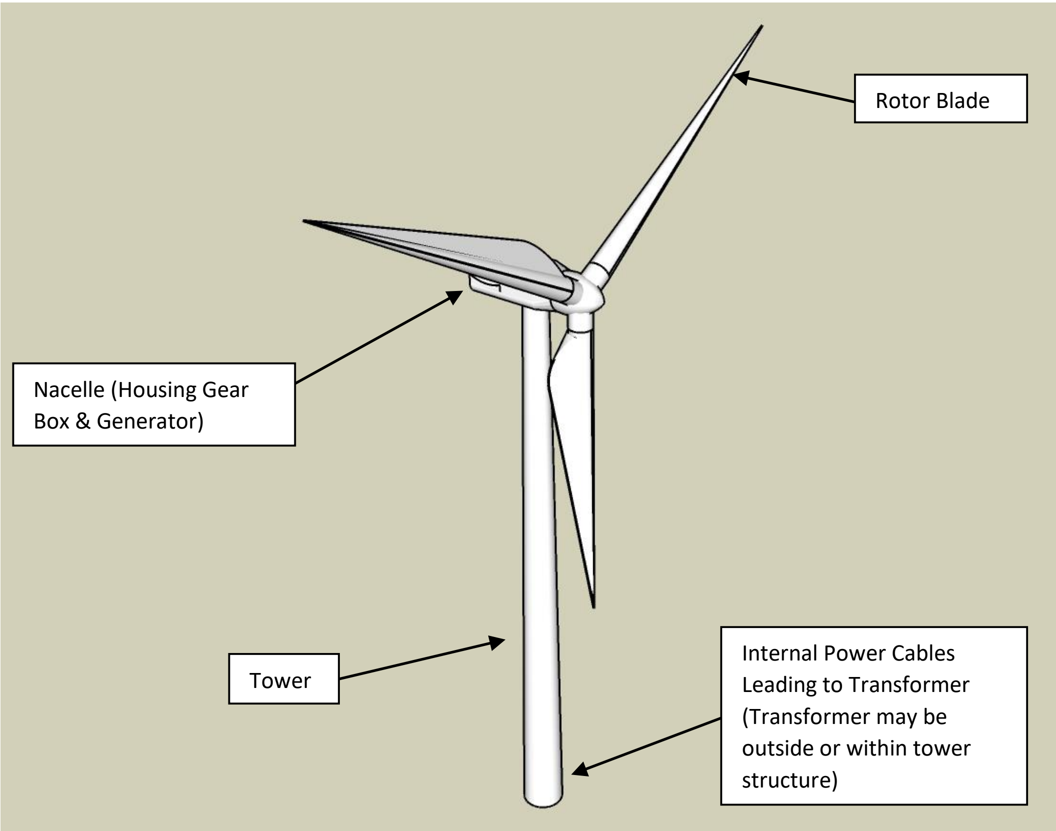


Figure 1 Typical design of a wind turbine (Suzlon model)

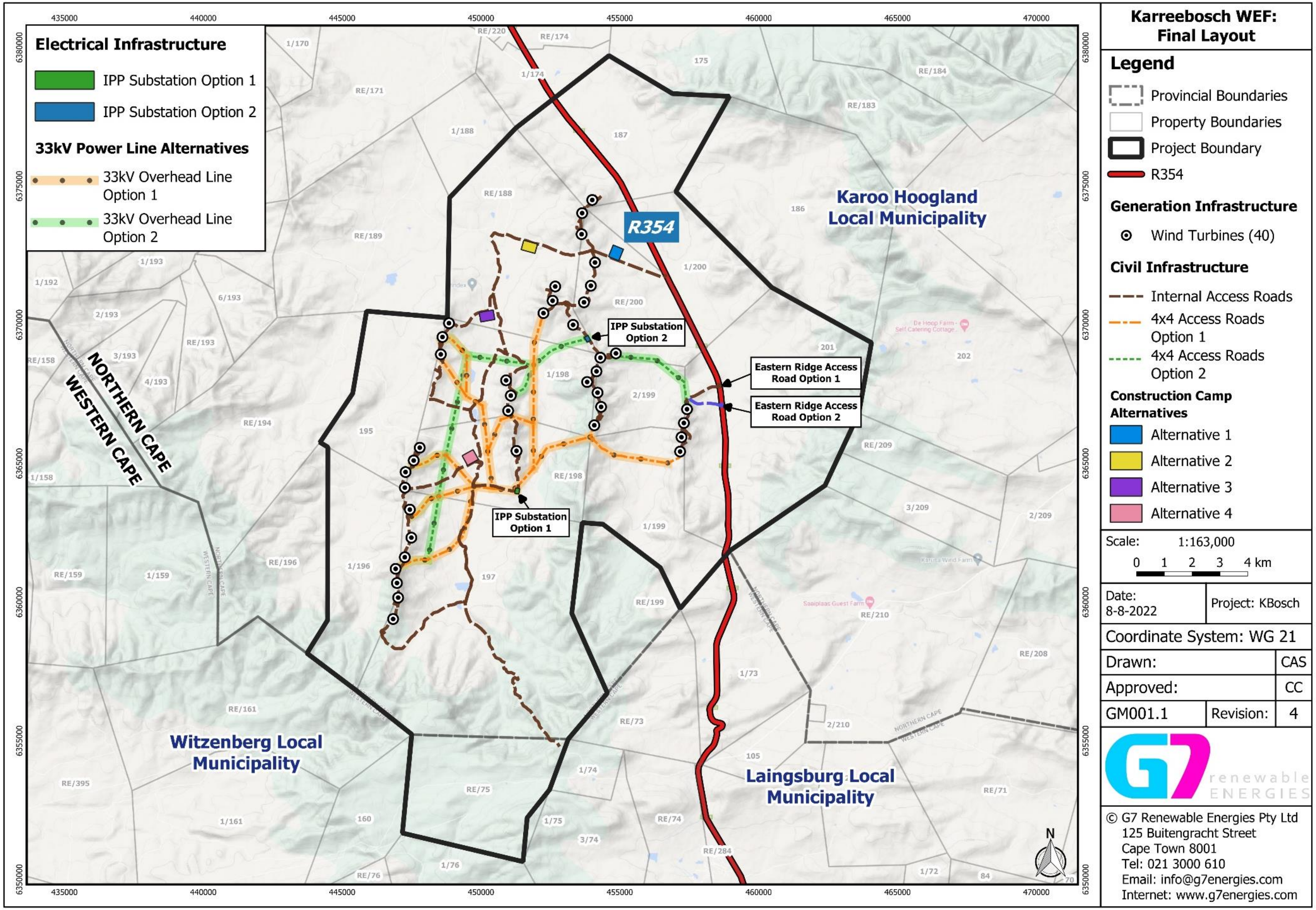


Figure 2 Locality map of the proposed Karreebosch WEF

1.3 Terms of reference

NatureStamp has been appointed to compile a flood assessment, SWMP for the Karreebosch WEF, powerline and substation (including all alternatives proposed) and associated access roads. The SWMP is in accordance with GN 704.

The terms of reference are as follows -

i. **Flood Analysis and SWMP**

- Site hydrological assessment, undertaken by the:
  a. Analysis of surface areas of the site;
  b. Analysis of sensitive areas on site;
  c. Analysis of existing storm water structures on site; and
  d. Determination of areas with clean and dirty water.
- Hydraulic design analysis, illustrated by the:
  a. Determination of the design storm event (1:2, 1:10, 1:50 & 1:100 year return period);
  b. Determination of the capability of proposed structures; and
  c. Recommendation of mitigation options and improvements.
  d. Classify access roads as per SANRAL Drainage Manual. Recommend the design flood frequency for all stormwater infrastructure typically constructed on a WEF (culverts, bridges or drifts for watercourse crossings, road drainage channels etc.).
- Erosion control plan
  a. Compilation of erosion control measures;
  b. Identification of high risk areas, exclusion areas and potential stockpile areas;
  c. Final erosion mitigation measures and rehabilitation objectives.
- Flood Hydrology:
  a. Hydraulic analysis, illustrated by the:
  - Compilation of the river reach model and flood line using HEC-RAS and HEC-geoRAS;
  - Determination of the flood risk and flood hazard throughout the study site; and
  - Recommendation of mitigation options associated with the hydraulic analysis.
  b. Consolidate results in a report with:
  - Flood line maps; and
  - A final flood line report.
- Consolidate results in a report with:
  a. Storm water maps;
  b. CAD storm water drawings and flood extents; and
  c. A storm water management plan and flood report.

ii. **Water balance assessment:**
- analysing climate data from the SAWS and other databases using nearby rainfall stations (input or known data);
- determining any water demands and water outputs; and
- determining whether water in the system is clean or contaminated.
- Development of a static water balance. The information gathered in the desktop assessment and during the site visit will be used to create a process water flow diagram. A series of models will be considered for use in this balance study. The Department of Water Affairs and Forestry, 2006 Best Practice Guideline G2: Water and Salt Balances was followed in this study.
- Produce a water balance study report with recommendations. An average annual water balance will be provided including an average dry and average wet month water balance. A set of recommendations will be provided to assist in the WULA and help the land owners to manage their water appropriately.

iii. **Final Reports:**
- Storm water maps/layouts
- CAD drawings for SW infrastructure and floodlines
- SWMP and Flood report (this report)

2. STUDY SITE

The site is located along the catchment divide of Quaternary Catchment E23A, falling under the Olifants/Doorn Management Area (WMA). The authorized Karreebosch WEF area sits on the plateau of Roggeveld mountain range that is almost entirely natural excepts for some small structures and gravel roads.

The WEF and associated grid infrastructure is in the Witzenberg & Karoo Hooglandlocal Municipality and the Cape Winelands & Namakwa District Municipality. The properties are currently zoned as natural land with some agricultural land use with low agricultural potential, and seasonal grazing still occurs across the site.

Rainfall in the region occurs throughout the year (mostly March to August), with a mean annual precipitation of 253 mm (observed from rainfall station 0044765 W – Lynch, 2003). The reference potential evaporation (ET_o) is approximately 2 490 mm (A-pan equivalent, after Schulze, 2011) and the mean annual evaporation is between 1 800 – 2 000 mm, which exceeds the annual rainfall. This suggests a high evaporative demand and a water limited system. Summers are warm to hot and winters are cold with snow events. The mean annual temperature is approximately 22.5 °C in summer and 8.8 °C in the winter months (Table 2 – Schulze, 2003). The underlying geology of the site is sedimentary Ecca Shale of the Karoo formation (Permian period) and the soils overlain are shallow sandy-clay-loam ranging from Mispah to Glenrosa form in this particular area.

Table 2 Mean monthly rainfall and temperature observed at Karreebosch (derived from historical data)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Ann
Mean Rainfall (mm)	7.4	10.4	18.2	21.4	29.8	43.1	32.9	32.2	19.1	15.9	11.8	11.5	**253.8**
Average Maximum Temperature (°C)	31.9	31.7	28.9	23.9	19.1	15.2	15.2	16.7	20.2	24.2	27.3	30.0	**23.7**
Average Minimum Temperature (°C)	13.7	14.0	12.8	10.5	8.0	5.6	4.8	5.5	6.9	9.0	10.8	12.8	**9.5**

Figure 3 General setting of the proposed Karreebosch WEF and OHPL site

3. METHODOLOGY

The following methodology was followed in order to meet the objectives as detailed in the terms of reference.

Table 3 Data type and source for the hydrological assessment

Data Type	Year	Source/Reference
Aerial Imagery	2013, 2016	Surveyor General
1:50 000 Topographical	2011	Surveyor General
2& 5m Contour	2010	Surveyor General
River Shapefile	2011	NFEPA
Geology Shapefile	2011	Council of Geoscience, 2015/National Groundwater Archive
Land Cover	2015	Department of Environmental Affairs, Republic of South Africa
Water Registration	2013, 2016	WARMS - DWS

*Data will be provided on request

3.1 Catchment Assessment

The pre-development conditions were assessed as follows -

- The vegetation and surface characteristics of the watercourse were assessed for the determination of the Manning's n-values;
- The presence and dimensions of any storm water structures, such as culverts, bridges, drains, berms and gutters that would divert flow during a storm event were noted;
- The overall state of drainage channels, streams and nearby rivers was assessed;
- The slope of the study site as well as evidence of erosion around the site were noted; and
- The elevation throughout the site in order to verify contour data.

In accordance with GN 704, the main objectives of a SWMP were:

1. To accommodate post-development storm events;
2. To keep clean and dirty water separated;
3. To contain any dirty water within a system; and
4. To prevent contamination of clean water.

A range of storm water design events were considered. 2-meter contours obtained from the Surveyor General were obtained and improved using a GPS. Rainfall data was extracted using the rainfall extraction utility tool (Kunz, 2003). Contributing catchment areas were calculated using the derived elevation model.

The critical contributing catchment area was determined for use in both the watershed delineation tool and HEC-HMS and SWAT models. The sub-catchments were delineated using the 5m contour set as an input. This was used to create a Digital Elevation Model (DEM) that was then used as an input to the watershed tool (Figure 4).

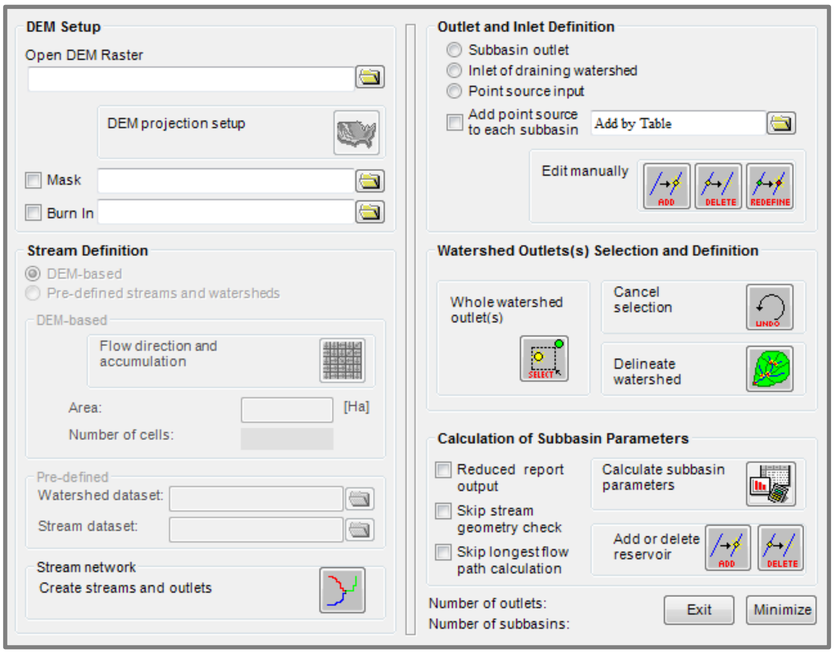


Figure 4 Soil Water Assessment Tool (*SWAT*) watershed delineation tool for sub-catchment delineation and stream network creation

3.2 Design Flood Determination

The peak flows for the 1:5, 1:10, 1:50 and 1:100 flood events were calculated for the catchments using the rational method, the SCS-SA model, the rational method and the Standard Design Flood Method as outlined in the SANRAL Drainage Manual (2013) in areas where flow data was not available. Additionally, an area corrected flow was also calculated using catchments with flow data to compare to the design rainfall/runoff calculations.

The SCS-SA model is a hydrological storm event simulation model suitable ideally for application on catchments that have a contributing catchment of less than 30 km². The model has been used widely both internationally and nationally for the estimation of flood peak discharges and volume (Schulze *et al*., 1992). The type of surface in the drainage basin is also important.

The Rational Method becomes more accurate as the amount of impervious surface, such as pavements and rooftops, increases. As a result, the Rational Method is most often used in urban and suburban areas (ODOT Hydraulics Manual, 2014).

3.3 Flood Line Determination

Modelling of the flood lines was undertaken using the U.S. Army Corps of Engineers' HEC-RAS v4.1 programme, which is commonly used throughout South Africa. Numerous cross sections were created throughout the contributing area (Figure 5). Ineffective areas/hydraulic structures were digitized and included in the model. Land use coverage was used to determine the Manning's n-values in a GIS platform. Each cross section may have had numerous values on either side of the channel depending on the site characteristics. Manning's N-values were obtained from the HEC-RAS Hydraulic Reference Manual (2010) for the channel areas (a value of between 0.03 and 0.04 was used depending on the presence or absence of rock features and debris). Design flood values were used as an input for the relevant reaches.

Given the slope of the catchment and the distance to downstream hydrological infrastructure, some inundation within the study site would occur but not from external features on the watercourse. As such, Normal Depth was selected for the reach boundary conditions. The slope of the channel was used as the value for the backwater calculation of the initial condition. Some inundation structures were included in the cross sections where these were structures present (Figure 6). Varying reach boundary conditions were set for these sites.

Figure 5 provides an overview of one of the impeding structures along the river. A cross-section shows the delineated area with unique station variables at each site.

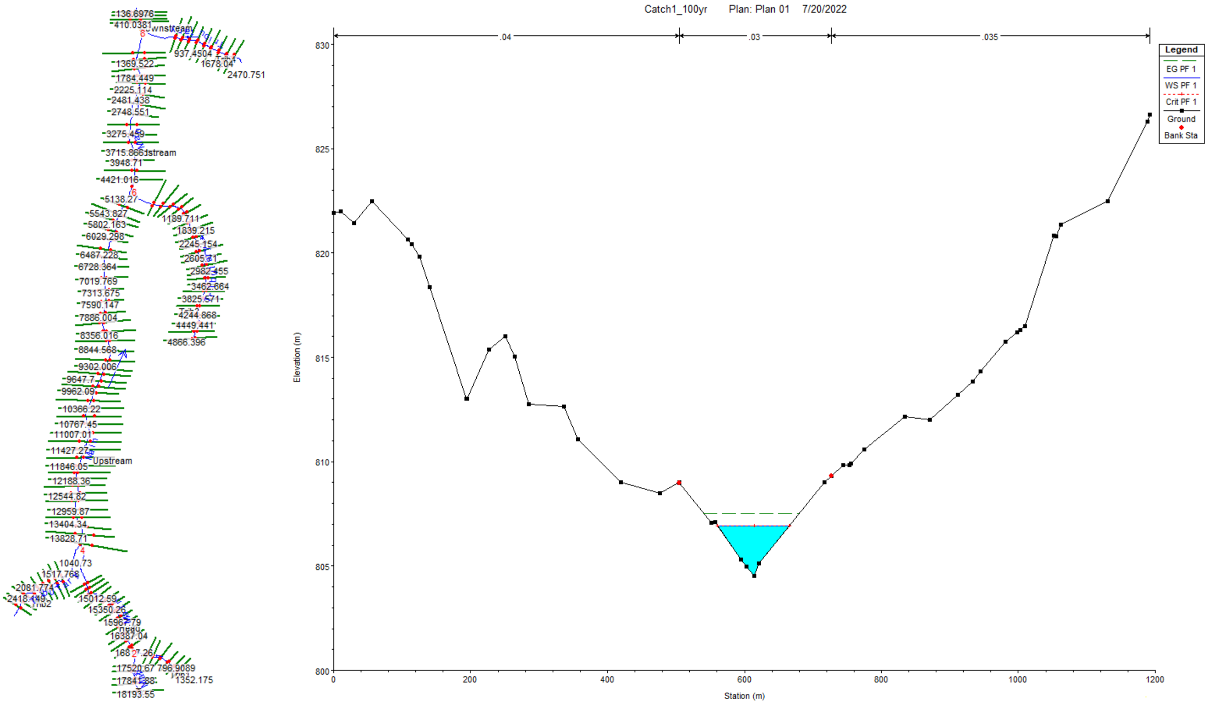


Figure 5 Channel cross sections and channel velocities developed for the relevant sections of the Tankwa tributary

At each profile, a unique peak flow was calculated for each return period. Nine (9) different volumes (linked to the 9 unique profiles) were calculated using either flow or design rainfall calculations. This was undertaken for each catchment.

3.4 Flood Line Determination for Minor Channels

As HEC-RAS and HEC-geoRAS are highly sensitive to the resolution of the terrain data used in the model, small non-perennial channels such as drainage lines are often not captured within the model. In most cases the flood output is not required for such channels as the flood generated would be negligible. However, it is good practice to ensure that all channels or drainage lines are adequately covered. As such, the author has developed a simple model to generate a flood depth through GIS. The model considers the flood generated for nearby smaller catchments and applies and area weighted correction. The model generates a flood height based on this estimation within the existing terrain model. Figure 6 provides a schematic of this model.

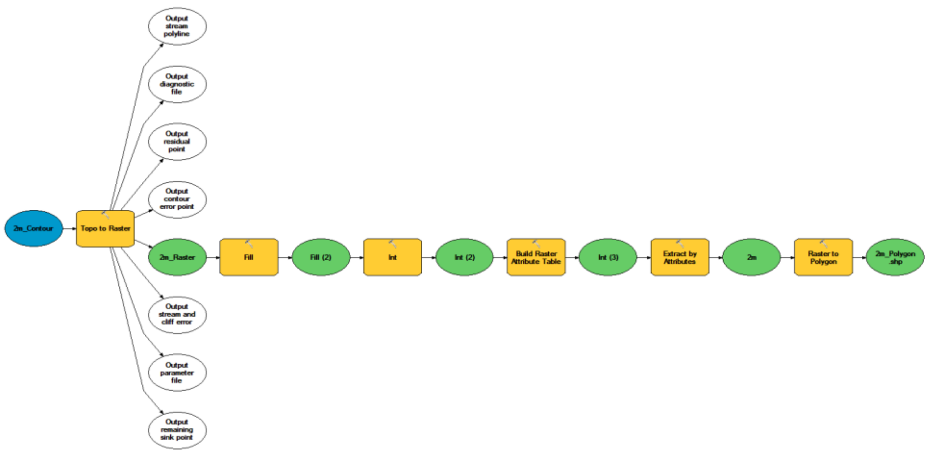


Figure 6 GIS model for flood generation in small channels

3.5 Design Storm Determination

The peak flows for the 1:2, 1:5, 1:10, 1:50 and 1:100 storm events were calculated for the catchments using the rational method as outlined in the SANRAL Drainage Manual (6th Edition, 2013). The type of surface in the drainage basin is an important component in the design calculations. The SANRAL Rational Method becomes more accurate as the amount of impervious surface, such as pavements and rooftops, increases. As a result, the Rational Method is most often used in urban and suburban areas (ODOT Hydraulics Manual, 2014). The Utility Programme for Drainage (Sinotech) was used to run the rational method, determine drainage grid and kerb drainage calculations.

It is recommended for infrastructure that the 1:50 year return design for a 30-minute storm is used as a typical event to design for. The areas of the proposed infrastructure can be seen in Table 4. Roads and culverts were assessed separately and adopt a 1:20 year return period.

Table 4 Activity/Infrastructure areas

Activity/Infrastructure	Impervious	Area
Access Roads, internal roads and culverts (new, widened & 4x4)	Partial	119.82 ha
Powerline access incl. Komsberg (included above)	Partial	41.5 ha
Transformers/Substation	Yes	3.4 ha
Construction Camp & Operations Building	Yes	14 ha
Lay Down Area (incl. Crane Pads Turbine Footprint)	Yes	40.14 ha

3.6 Storm Water Design Principles

The objective of the Stormwater Management Plan is to control runoff flows and prevent detrimental impacts on receiving waters, considering both the quality and quantity of the stormwater runoff. As the existing site has natural impervious areas, steep slopes and shallow soils, the velocity of stormwater runoff would be considered high. However, as the site is located near the catchment divide, there are little to no upper catchment contributions.

Stormwater management design principles to be followed on site include:

- The establishment and maintenance of grass and plants adjacent to newly constructed infrastructure and graded roads.
- Hazardous or environmentally dangerous chemicals kept on site must be kept outside of the 1:00 year flood line and watercourses or appropriately bunded.
- Groundcover should be maintained during construction to ensure erosion protection.
- Flow concentration points should avoid unstable soil areas and/or stockpiles.
- All pollution from the surfaces should not flow directly into water resources.
- Ensure aesthetic designs.

The above-mentioned principles are to be used as a conceptual stormwater management guide.

3.7 Water Balance

There are three methods to consider when undertaking a water and salt balance. These are manual methods, spreadsheet-based models and standalone PC based models (after DWAF, 2006), described as follows:

3.7.1 Manual Calculation

Manual calculations are the simplest option which involves a rapid screening of a site for quick and simple once off results. This approach is more suited to very simple systems where there is a limited level of complexity in the hydrological partitions. This approach does not require any equipment (field or desktop based). However, this approach may not be suitable for moderate to complex systems and could become impractical where larger repetitive calculations are required. This approach does not present the data visually as in some models. Although the water balance of this site is relatively simple, this approach was not used.

3.7.2 Spreadsheet Based Models

Spreadsheet based models are commonly used by specialists as they allow for calculations to be undertaken quickly. These are calculations undertaken in Excel or MATLAB using recognised runoff algorithms. The user of such sheets can easily see the algorithms used in the model and can add or modify the functions according to the user requirement. However, there is a potential for greater user error and editing outputs can be time consuming.

3.7.3 Standalone PC Based or High-End Software

Many software platforms are available to users looking to compile a water and salt balance. Some of the software is specifically designed for this purpose whereas others are more general accounting models. These models can be used for larger and more complex systems. These models/tools are user friendly and can produce data is a logical and aesthetically pleasing format. The input layout can often help the user to understand the water balance process. Furthermore, it is relatively simple to change variables and quickly run scenarios. However, this approach can be confusing if the user is inexperienced and can cost a lot of money for the license. An example of one of the models considered in this study is GoldSim and HEC-HMS.

A water balance was calculated for the existing development using WR2012 data in a spreadsheet-based model and run through HEC-HMS. The output included an annual, wet month and dry month assessment.

4. LIMITATIONS AND ASSUMPTIONS

In order to apply generalized and often rigid design methods or techniques to natural, dynamic environments, a number of assumptions are made. Furthermore, a number of limitations exist when assessing such complex hydrological systems. The following constraints may have affected this assessment:

- Manning's n - values (the channels roughness coefficient) was estimated on site. However, most of these values were informed assumptions as all of the flow on site would be overland flow (limited channels exist within the site).
- There were no sub-surface servitudes identified on site. It was assumed that storm water concentrations points would be undertaken at strategic locations.
- It was assumed that culverts would be partially obstructed by debris.
- It was assumed that the roads are impervious.
- It was assumed that all storm water systems on site were 90 % unblocked.
- It was assumed that all roofs and roads would have standard sized culverts and gutters.
- 2-meter and 5-meter contour interval data and Digital Elevation Models (DEMs) were used in the design flood estimation (development of the elevation model) within the greater catchment area. Within a 500 m radius of the site, a detailed topographical survey was undertaken. Given the flood proposed, this resolution was of sufficient accuracy for the flood line determination.
- Given the setting of the site (numerous rocky outcrops) it was difficult to determine which channels would be fully active in a small flood and which are remnant channels which have since been bypassed. As such, the HEC-geoRAS and HEC-RAS models cannot be used to a very high level of accuracy in certain areas as they are usually used on larger catchment areas.

5. RESULTS AND DISCUSSION

The following results were used as input to the selected models and have been provided here.

5.1 Desktop Assessment

5.1.1 National Freshwater Ecosystem Priority Areas (NFEPA) Project / Assessment

In accordance with the NFEPA guidelines CSIR (2011), the relevant reach of the Tankwa, Wilgebos and Kleinpoorts (and their associated riparian areas) have been classified as a FEPA system (Class C – Moderately Modified), which indicates that this river system is a national freshwater conservation priority but has been disturbed to some extent. Small artificial FEPA dams were identified within the study site. Some natural systems are present but are limited to the riparian areas. A freshwater ecology study has been undertaken by FEN (2022) and should be referred to for the spatial extent of aquatic resources.

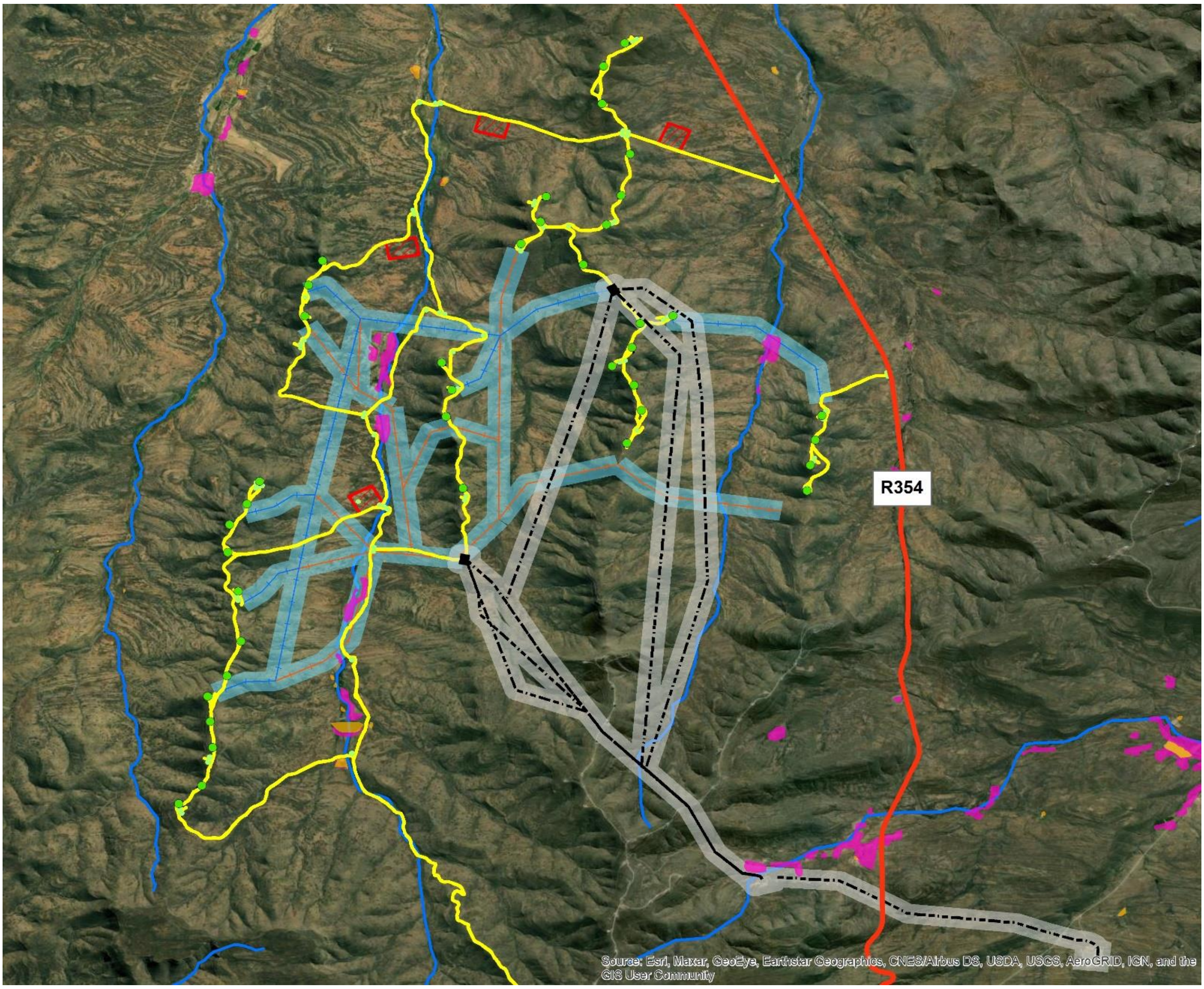


Figure 7 NFEPA rivers (blue), wetlands (pink) and artificial systems (orange) in relation to the proposed Karreebsoch WEF and Grid Infrastructure

5.1.2 Terrain, Soils, Geology & Vegetation

Contour lines (5 meter) were used to calculate the slope of each of the banks. The soils and geology were obtained from GIS layers. Various vegetation databases were used to determine the likely or expected vegetation types (Mucina & Rutherford, 2006; Scott-Shaw & Escott, 2011). A number of recognized databases (*c.f.* Table 4) were utilized in achieving a comprehensive review and allowing any regional or provincial conservation and biodiversity concerns to be highlighted.

Natural vegetation of the area is Koedoesberge-Moordenaars Karoo (SKv 6, Mucina and Rutherford, 2006). This occurs within the Succulent Karoo biome. The desktop analysis revealed that the area is a least threatened area, with the potential for some flagged fauna and flora (e.g. red data species and endangered wildlife) being found from the C-plan, SEA and MINSET databases. However, this does not necessarily mean that rare or endangered species will occur in the area of interest.

- **Distribution:** Western Cape and Northern Cape (smaller portion) Provinces: Koedoesberge and Pienaar se Berg low mountain ranges bordering on southern Tanqua Karoo and separated by the Klein Roggeveld Mountains from the Moordenaars Karoo in the broad area of Laingsburg and Merweville. The unit also includes the Doesberg region east of Laingsburg and piedmonts of the Elandsberg as far as beyond the Gamkapoort Dam at Excelsior (west of Prince Albert).
- **Altitude:** 500–1 250 m (most of the area at 680–1 120 m).
- **Vegetation & Landscape Features:** Slightly undulating to hilly landscape covered by low succulent scrub and dotted by scattered tall shrubs, patches of 'white' grass visible on plains, the most conspicuous dominants being dwarf shrubs of Pteronia, Drosanthemum and Galenia.
- **Geology & Soils:** Mudstone mainly, shale and sandstone of the Adelaide Subgroup (Beaufort Group), accompanied by sandstone, shale and mudstone of the Permian Waterford Formation (Ecca Group) and sandstone and shale of other Ecca Group Formations as well as Dwyka Group diamictites (all of the Karoo Supergroup). This geology gives rise to shallow, skeletal soils. Region is classified as Fc land type (Lime generally present, Glenrosa and Mispah forms), with Ib land type (Rock areas with miscellaneous soils) playing a subordinate role.
- **Climate:** Probability of rain is given for the entire year, but it is higher in winter. MAP slightly above 200 mm. There are two slight rainfall optima: one in March and another spread from May to August. MAT close to 16°C and incidence of frost relatively high (30 days).
- **Conservation:** Least threatened. Target 19%. Only a very small portion enjoying statutory conservation in the Gamkapoort Nature Reserve. Transformed only to a very small extent. No serious alien plant invasions recorded. Erosion is moderate (88%) and only to lesser extent high or very low.

5.1.3 Site Analysis

A detailed site assessment was undertaken through the site visit (12th – 15th of July 2022) and supported by desktop data. This is important as it assisted in determining the Manning's n values (Chow, 1959), that are used to create an additional input spatial file used in HEC-RAS.

The site is almost entirely dominated by low shrub, which was confirmed during the site visit. Basal cover is low resulting in an increase stormflow potential.

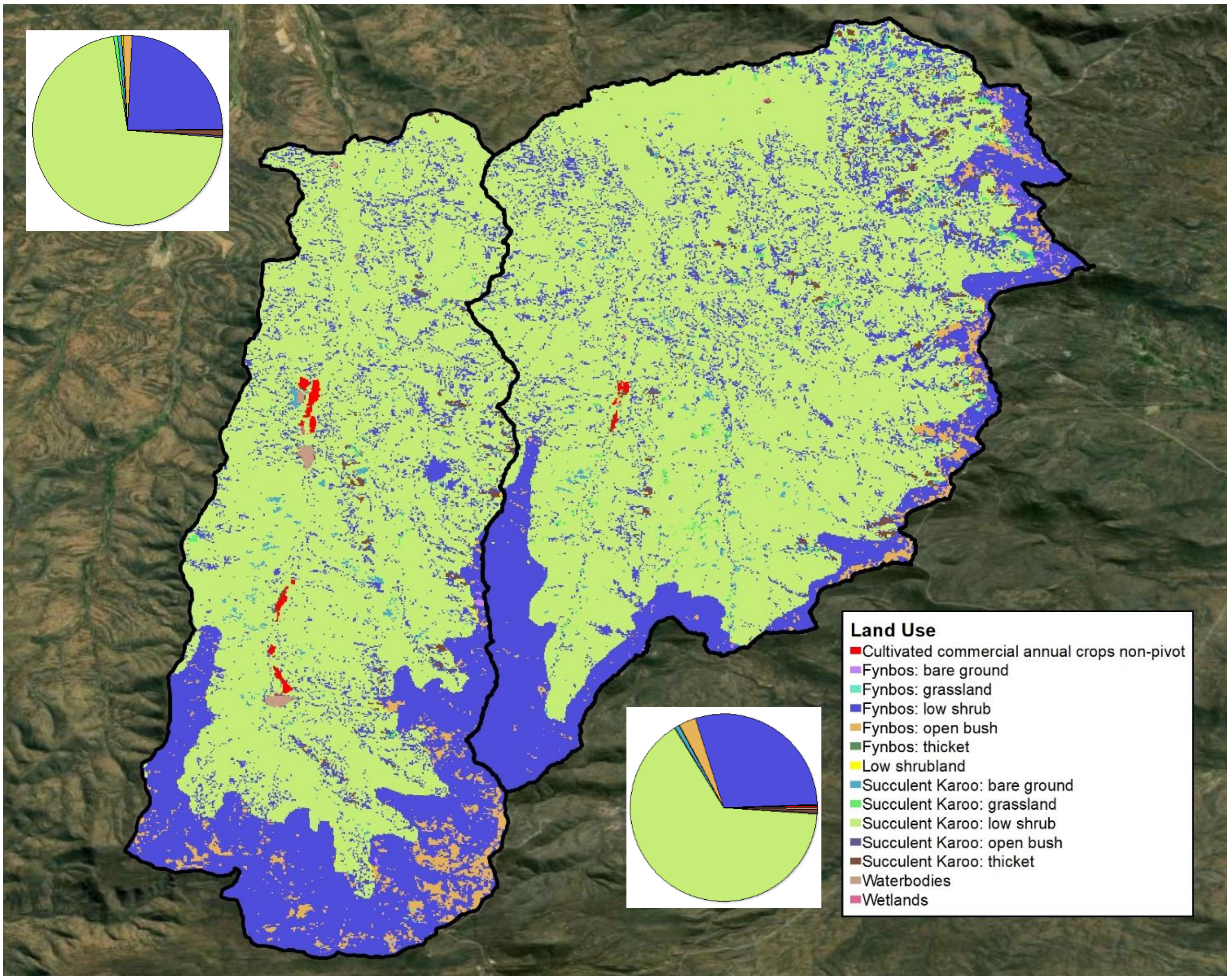


Figure 8 Land cover for the Karreebosch WEF catchment area

Table 5 Catchment land use areas used for modelling the peak discharge

Land Use	Area (ha)	Percentage	Area (ha)	Percentage
Cultivated commercial annual crops non-pivot	9.63	0.06	43.38	0.36
Fynbos: bare ground	18.35	0.12	11.16	0.09
Fynbos: grassland	9.76	0.06	6.26	0.05
Fynbos: low shrub	3712.11	24.01	3545.46	29.31
Fynbos: open bush	241.46	1.56	368.04	3.04
Fynbos: thicket	3.24	0.02	1.26	0.01
Low shrubland	21.07	0.14	17.28	0.14
Mines	1.08	0.01	0.00	0.00
Succulent Karoo: bare ground	104.37	0.67	84.86	0.70
Succulent Karoo: grassland	114.94	0.74	21.22	0.18
Succulent Karoo: low shrub	11036.65	71.38	7864.13	65.02
Succulent Karoo: open bush	44.11	0.29	22.91	0.19
Succulent Karoo: thicket	141.69	0.92	71.31	0.59
Waterbodies	1.44	0.01	32.94	0.27
Wetlands	2.61	0.02	4.79	0.04
Total	**15462.51**	**100**	**12095.00**	**100**

The catchment was divided into sub-catchments based on connections between tributaries (Figure 9). This was undertaken using the Soil Water Assessment Tool (SWAT). The catchment area of Karreebosch is relatively small with all channels on-site being non-perennial in nature and would only have flowing water succeeding moderate to high rainfall events.

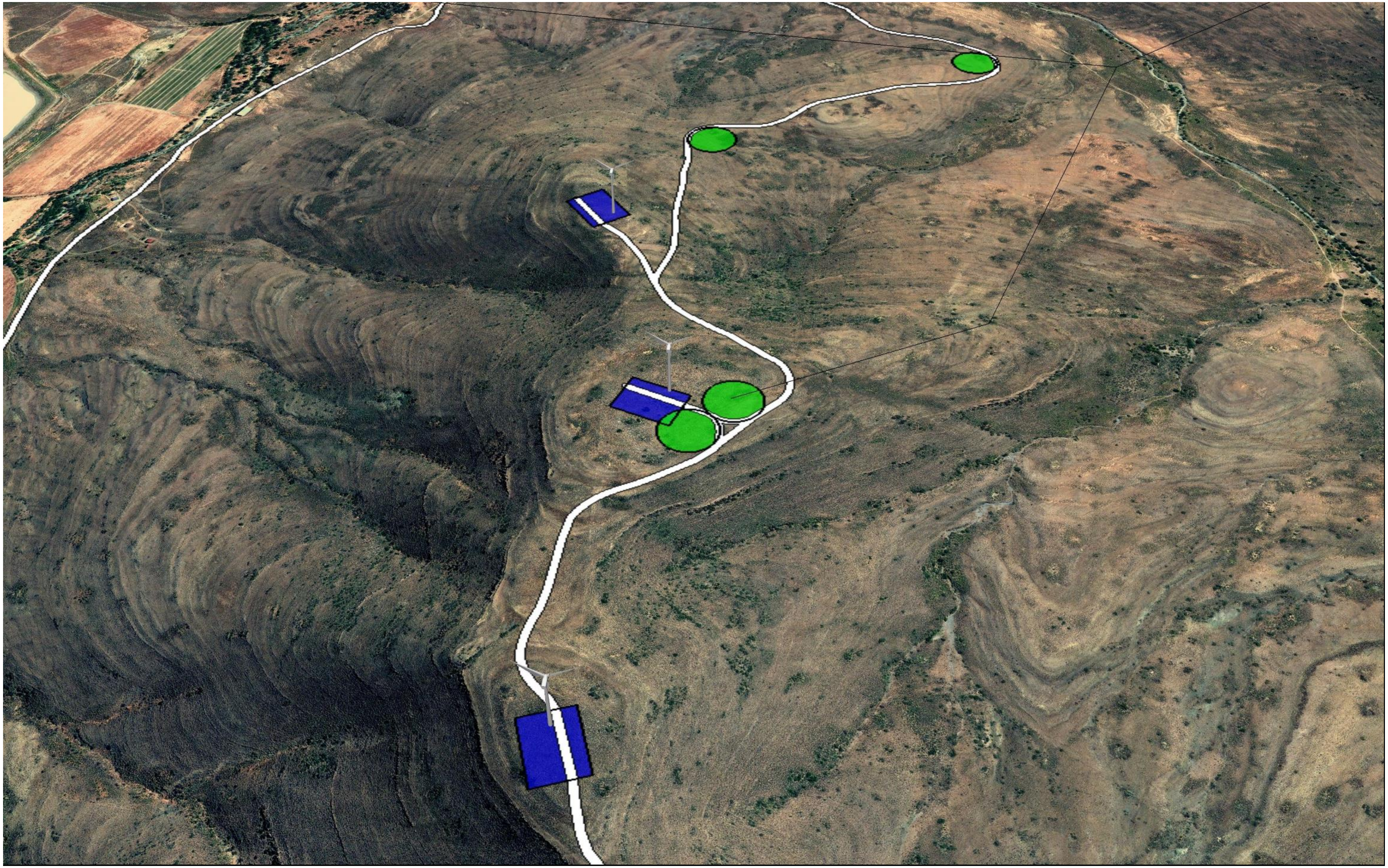


Figure 9 Plateau position of the internal roads/turning circles, laydown areas and turbines at Karreebosch WEF

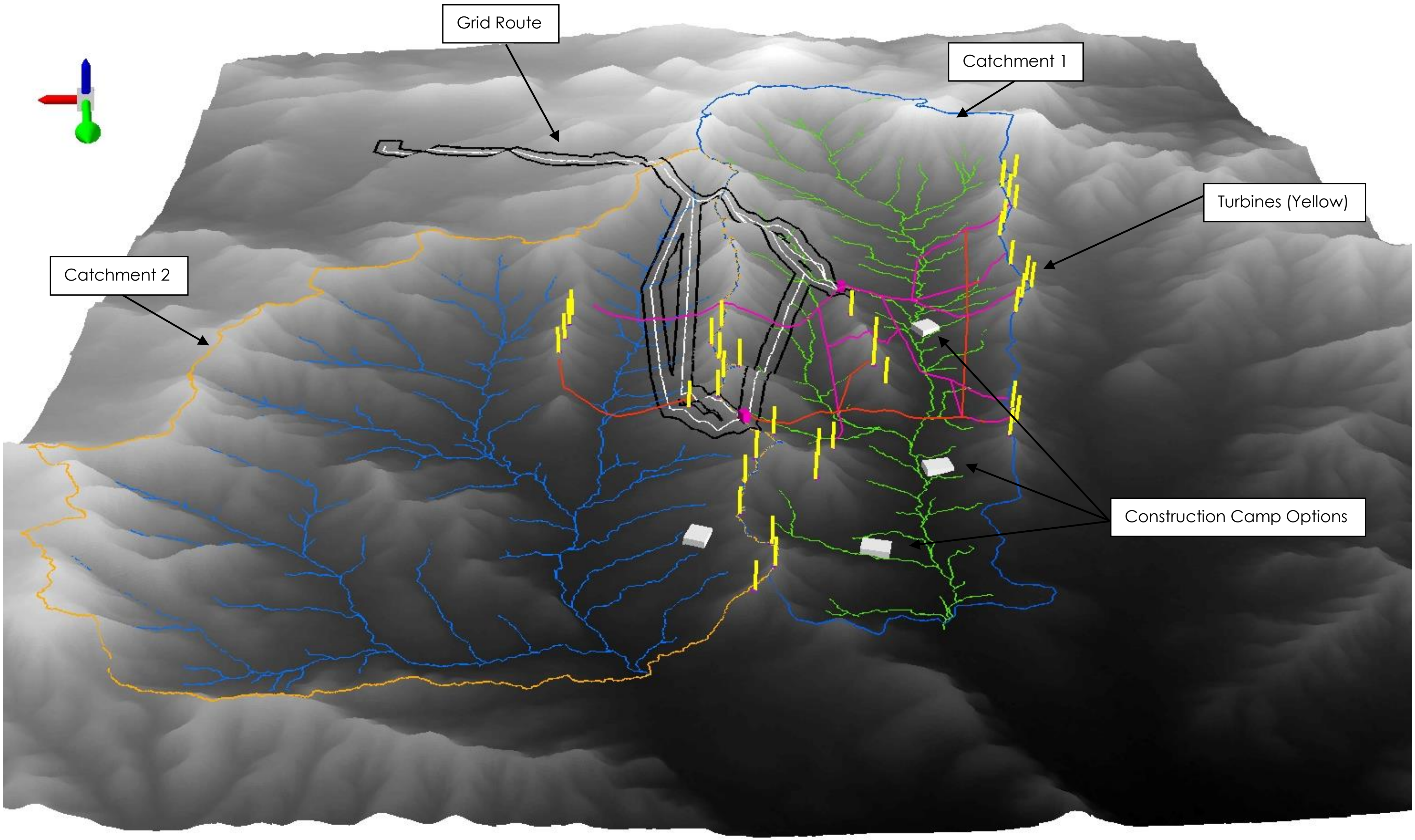


Figure 10 Exaggerated terrain model for the catchment associated with the proposed Karreebosch WEF (north –green arrow)

5.2 Climate Analysis

The long term annual rainfall data (Station 0044765 W – 41 km from the site) as well as design rainfall was sourced for the study area. The long term annual rainfall for numerous stations was extracted using the Daily Rainfall Extraction Utility (Lynch, 2003). Mean Annual Precipitation (MAP) for the study area is approximately 253 mm (Figure 11 – Lynch, 2003; Climate Forecast System Reanalysis (CFSR)). Some inconsistencies were identified in this record (e.g. some missing data in the earlly1900s and some large flood events not being recorded), these were verified using nearby stations and corrected as such. The best rainfall records were synthesized with the more recent data to create a new rainfall record that could be used in the design flood estimation. The station in close proximity, with similar altitude and MAP and a reliable record was selected.

Table 6 Comparison of values from some of the rainfall stations that were assessed during the data analysis

Station No.	Estimated MAP (mm)	Observed MAP (mm)	Years	Reliable	Patched	Altitude (m)	Station Name
004050 W	224	225	122	32.4	32.9	776	Touwsrivier (SAR)
0066027 W	259	259	120	56.5	43.1	1372	Brandvlei
0045134 W	151	151	56	62	34.5	930	Dwars In
0044765 W	252	252	120	58.7	40.5	1067	Pieter Meintjies (SAR)
0044286 W	206	207	122	41.0	58.7	866	Jan De Boers
0045134 W	170	173	120	80.3	19.3	902	Matjiesfontein (SAR)

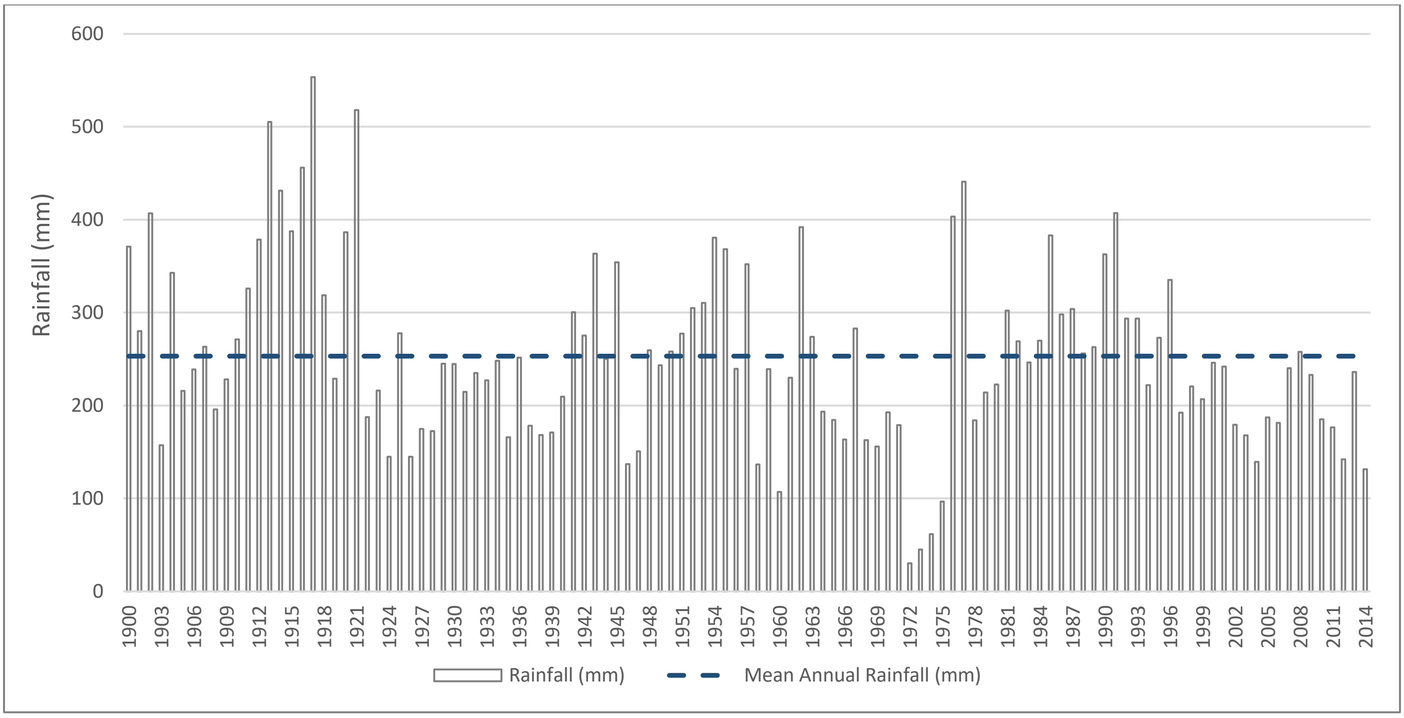


Figure 11 Long-term annual rainfall (annual in blue) near the proposed Karreebosch WEF and associated infrastructure

5.3 Design Rainfall

Design rainfall differs from mean annual rainfall as it is rainfall associated with an events rainfall depth for a specified storm duration and a recurrence interval (frequency of occurrence). The design rainfall used is dependent on the method used to determine the peak discharge. The SCS-SA method uses 1 day-rainfall for various return periods while the Rational and SDF Methods use rainfall intensity linked to the catchments Time of Concentration (Tc) and Storm Duration. The Design Rainfall Estimation (DRE) tool which uses observed rainfall data was included for comparative purposes. The results of the design rainfall assessment have been provided in Annexure A. A summary of these results has been provided in Table 7.

Table 7 Design rainfall for the Karreebosch WEF

Station Name & ID	Obs MAP	Years	Altitude (m)	Design Rainfall (mm)						
				2	5	10	20	50	100	200
Pieter Meintjies - 0044765 W	252	100	1067	32.0	47.0	58.2	70.2	87.5	101.9	117.7

5.4 Hydraulic Structures

An assessment was undertaken on any structures, which was populated in HEC-RAS. According to SANRAL (2016), the discharge capacity of the structures such as culverts would be determined by the following equation:

$$Q_{ideal} = CbH^{1.5}$$

where: Q = Discharge ($m^3.s^{-1}$)
C = Discharge Coefficient
G = Gravitational Constant (9.81 $m.s^{-1}$)
b = Side Width (m)
H = Headwater Depth (m)

The roads throughout the site have been assumed to be class 3 roads. As such, the 1:20 year event should be used in sizing the culverts. This peak event varies throughout the catchment position and whether a major or minor crossing occurs. Thirteen crossing points have been proposed. It is recommended that for major crossings, the proponent utilizes a low level crossing or portal culverts and for minor crossings, the proponent uses pipe culverts. Once the final dimensions of the road and exact crossing points have been determined, the size of each culvert can be calculated.

Using Mannings formula for an open channel ($Q = 1.486/n)AR_h^{2/3}S^{1/2}$), the average discharge capacity of a natural channel adjacent to the road would be **0.41 $m^3.s^{-1}$**.

5.5 Design Peak Discharge

The design runoff results obtained for the 1:2, 1:15, 1:10, 1:20, 1:50 and 1:100 year flood events for the various river reaches are summarized in Table 8. The populated calculation sheets for the rational, SCS and SDF methods can be seen in Annexure B, C & D. The high contrast in values is due to the catchment size limitations of the design approaches. It is expected by the authors that the estimates from the rational and SDF are over designed. This is likely due to smaller catchment areas and rainfall value that may not be representative of the entire catchment. Furthermore, the lack of vegetation and the presence of eroded channels has resulted in a much shorter time of concentration than what would have occurred in past decades. The design values indicate that the larger design events were vastly different between models whereas the smaller more frequent events were similar between models. This is likely due to the recommended catchment areas that these models are designed for. Given the results, the SCS model was considered to be the most appropriate model if design rainfall were to be used. As such, the 1:100 year flood event, which is used in Water Use License Applications would discharge a total of 411.1 and 756.7 $m^3.s^{-1}$ respectively (Table 8).

Table 8 Adopted design peak discharge values ($m^3.s$-1) run through HEC-RAS for the catchment area

Catchment	Peak Discharge ($m^3.s^{-1}$)	Return Period						
		2	5	10	20	50	100	200
1 (119 km^2)	Rational	147.472	231.040	303.977	388.220	510.776	626.142	723.227
	SDF	33.49	107.42	175.39	251.97	365.75	461.00	561.92
	SCS-SA	42.6	96.9	146.7	210.6	314.5	411.1	522.7
2 (153 km^2)	Rational	169.0	284.7	368.1	447.8	653.0	802.2	1047.5
	SDF	38.64	123.94	202.37	290.72	422.00	531.91	648.34
	SCS-SA	97.9	200.2	292.1	407.9	590.5	756.7	946.5

5.6 Hydraulic Modelling

Various hydraulic models were produced in HEC-RAS and exported to HEC-geoRAS by importing river centreline, cross sections, water surfaces and flow data from GIS layers and the hydrologic model. This allowed for inundation mapping and flood line polygons to be generated. The water surface TIN was converted to a GRID, and then actual elevation model was subtracted from the water surface grid. The area with positive results (meaning the water surface is higher than the terrain) illustrated the flood area (Figure 12), whereas the area with negative results illustrated the dry areas not inundated by the flood. Inundation can be seen along the watercourse (Figure 13). Further results are provided in Annexure B, C and D.

Any areas outside of the proposed development footprint were not included in the flood generation model although the contributing catchment area was accurately accounted for.

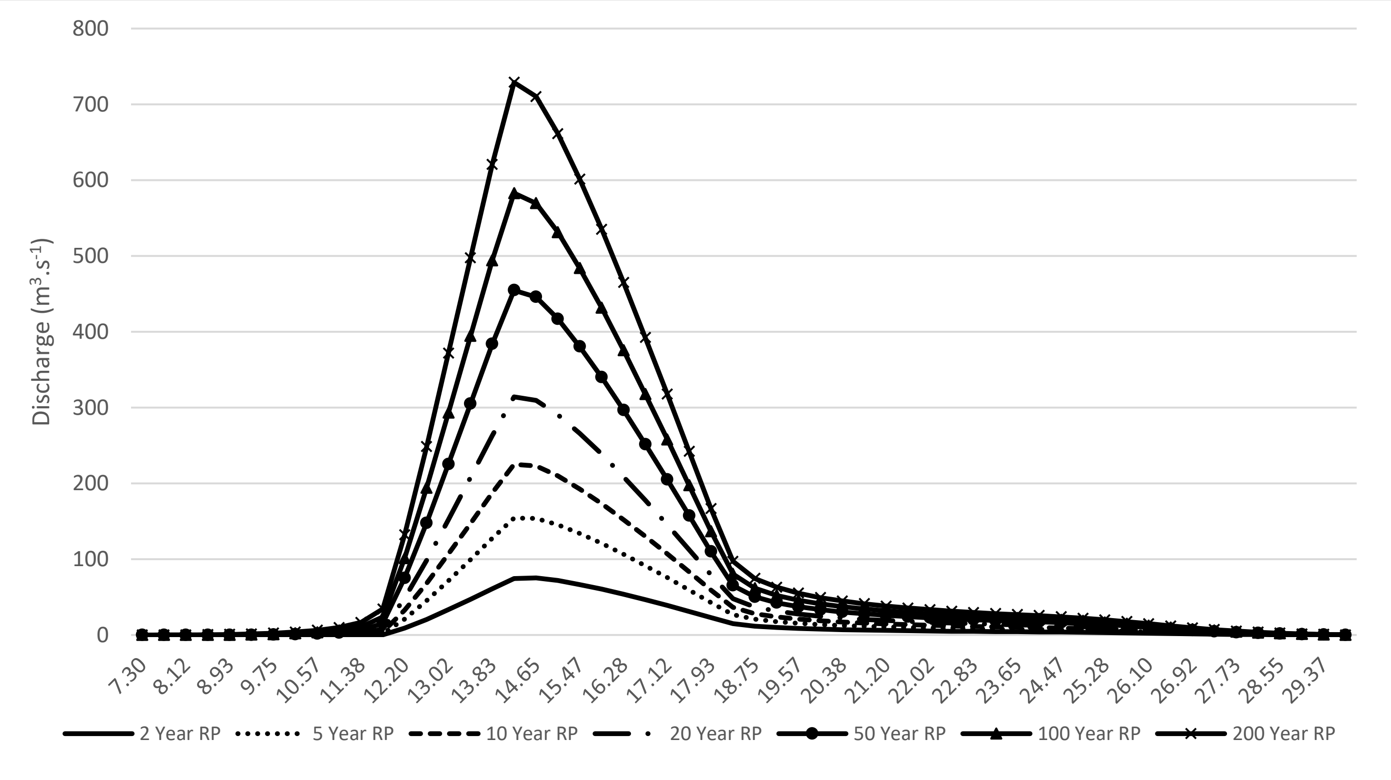


Figure 12 Post-development hydrograph for the proposed Karreebosch WEF and associated grid infrastructure (Catchment 1)

Through the flood analysis, it is clear that the proposed infrastructure (Construction camp, laydowns, OHPL, internal access roads and onsite Substations) will not be at risk of damage through flooding from the channels. This is largely due to the general low rainfall in the area and the small catchments on the site, resulting in less accumulated surface runoff. Additionally, the structures are mostly placed on plateau areas, well outside of the flood extent. The post-development state will result in a very slight increased peak flow due to an increase in impervious structures and a resultant increase in storm flow. This has been accommodated through the storm water management plan. The site is also at increased risk of erosion due to areas of poor basal cover, the increase in hardened surfaces and the steep terrain. This is true for both the pre-development and post-development state. Although the laydown areas and crane pads are on the plateau of the mountain, they do still pose a risk of triggering erosion channels. In similar vein, the roads that traverse up steep slopes need to be secured against erosion.

Ephemeral drainage lines were not an output as the catchment area was too small to derive a meaningful spatial output (although this area was still used as a model input). In such cases, the delineated watercourse and its buffer would be far greater than the derived flood extent.

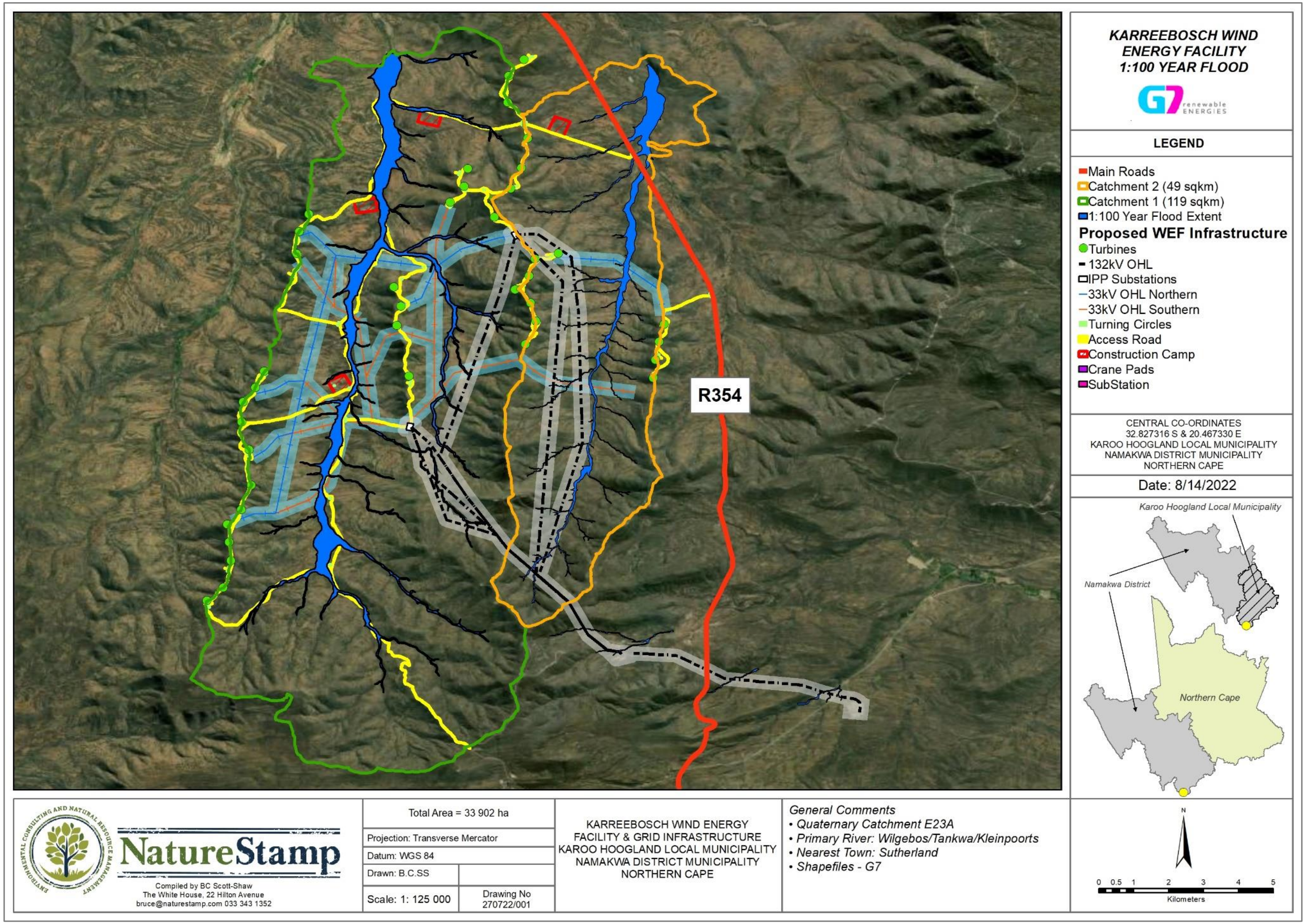


Figure 13 Steady state analysis of the 1:100 year flood event for the proposed Karreebosch WEF and Grid infrastructure

5.7 Design Storm Determination

5.7.1 Rational Method using Surface Drainage Utility

From the rational method, used in the calculation of peak flows and rainfall intensity, based on various basic spatial and descriptive input parameters pertaining to the site in question, average rainfall intensity per hour was calculated for the 2, 5, 10, 20, 50 and 100-year 30 minute, 1 hourly and daily events. The results pertaining to this study are the 1 in 50 year, (for infrastructure). Peak flows shows an average increase in **0.11 m^3/s** for post-development conditions. This is low, mostly as much of the roads are pre-existing. This results in an excess of **0.065 m^3/s** that needs to be attenuated per hectare of impervious surface. These outputs have then been used as inputs for the calculations in the following subsections.

5.7.2 Drainage Grid Calculations

It is assumed that the gravel roads that will be utilized will be of the open drains which are recessed into the ground. Dimensions were assumed as a typical dirt road drain (1 meters in width and recessed below the level of the culvert / kerb by approximately 0.3 meters). New roads were considered in the stormwater calculations. The roads would be between 4 to 12 meters with wide cut-off drains would be placed strategically and increased in high slope areas. Drains were assessed to determine if they could handle certain design events, the following calculation was used (SANRAL Drainage Manual 5th Edition):

$$Q = 1.77 \times A\sqrt{H}$$

Where: Q = Flow Capacity ($m^3.s^{-1}$)
A = Area of inlet (m^2)
H = Submergence (m)

Therefore A = (0.65 * 0.375) = 0.24 m^2
H = 0.2 (assumed for the site)

Drowned conditions were assumed and a blockage coefficient of 0.3 was assumed due to the small amount of debris likely on site. The equation $Q = CFA\sqrt{2gH}$ was used in this setting. Although open drains are being used, the aforementioned calculation was used as a guideline to see if the excess runoff could be accommodated.

The results show that each cut-off drain could handle **0.41 $m^3.s^{-1}$** after which water would exceed the channel and flows would not be attenuated. As such, if a cut-off drain is placed for every 5 ha of contributing area, there would be sufficient flow attenuation. This further shows that the excess flows on site would be accommodated by the proposed drain structures.

5.8 Storm water Control

- Cut-off drains as per the design recommendations must be installed to facilitate the control of surface water runoff velocities from roads (250 mm depth, variable width depending on site/existing road conditions);
- Any erosion caused from excess discharge adjacent to road and/or crane pad areas must be rehabilitated immediately. This would involve re-vegetation, geotextiles or rock gabions. This would be identified by the ECO;
- Stone protection structures, such as gabion baskets, would be required at any steep sections and where intersections occur;
- Runoff around the WEF infrastructure, substations, pylons and construction camps need to be protected by erosion protection and channels to increase infiltration and promote the natural runoff regime. Runoff should not be concentrated at one point. Structures would include rainwater harvesting at the construction camp, berms and cut-off drains along steep road areas and berms around crane pads with cutoff drains with rockeries;
- Storm water discharge should be dispersed across each impervious area. Around such structures, assurance is needed that the ground remains vegetated and protected from erosion. Small rocks from construction should be placed along the edges of impervious areas; and
- Washing of equipment should avoid harmful chemicals.

Figure 14 Existing lay-down area and turbine for the nearby Perdekraal site as a comparative example

5.9 Storm Water Management Structures

The overall aim of the stormwater structures is to attenuate increases in flow due to the development to their predevelopment state. Any excess flow from the proposed development should not be concentrated towards one point. However, the natural flow channels as per the pre-development state should be promoted. The WEF and road grading should have structures as illustrated in Figures 15 and 16.

All runoff under the development footprint can and should be contained and managed within the site boundary of each laydown area. Temporary storm water structures should be put in place if pollution and spills are evident on site. The construction camp should be completely rehabilitated after construction through re-vegetation and erosion control. Guidelines should be followed based on the wetland/riparian assessments and rehabilitation plan. The IPP substation option (Figure 17) are both of low risk as they are situated on the plateau and have little to no catchment area. The substations would need a PCD of 123 m^3 to attenuate potential dirty water on the footprint. Construction camp option one and two are considered suitable due to their proximity to access points, existing roads and contributing catchment areas.

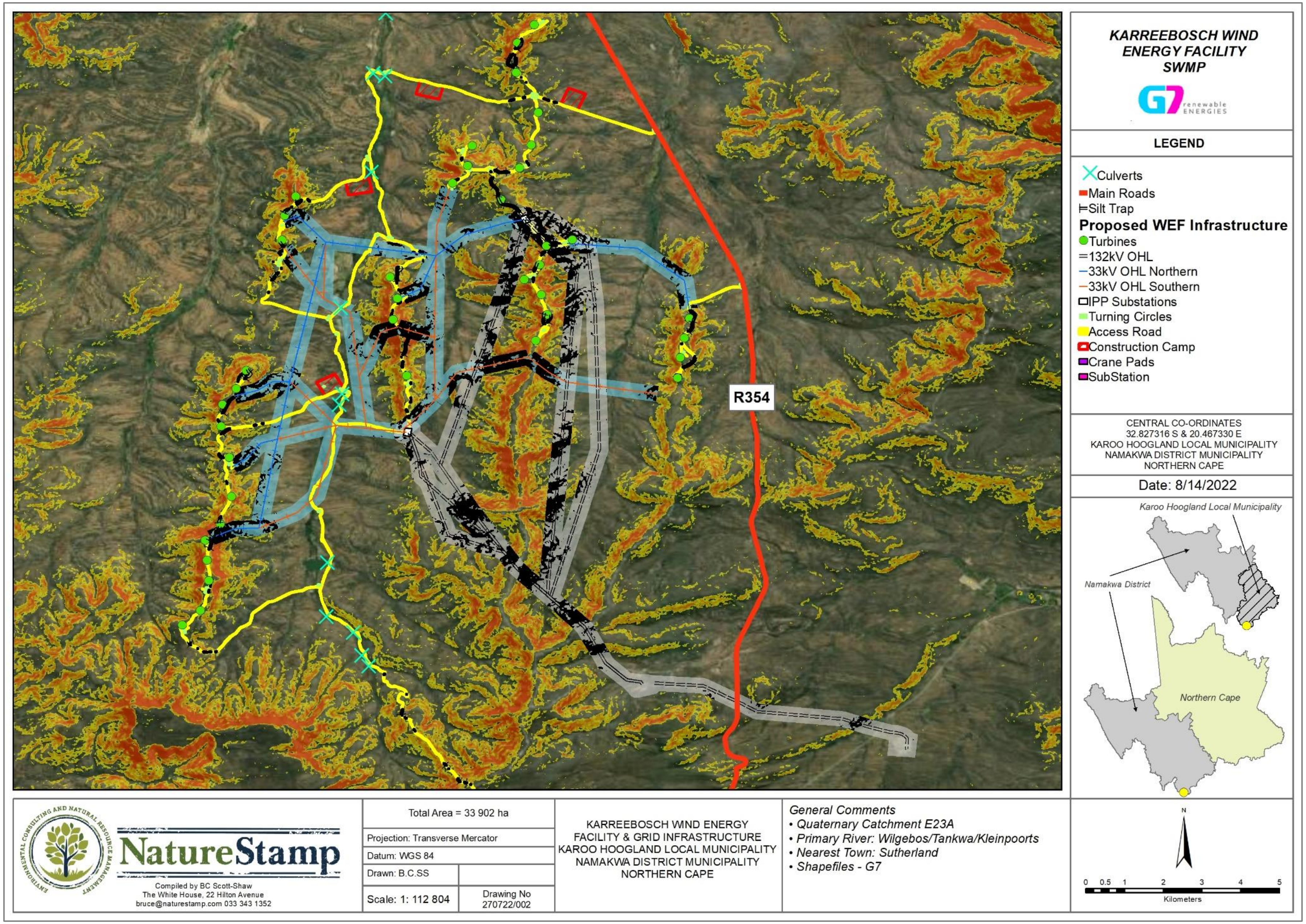


Figure 15 Storm water management plan for linear servitudes showing high risk area in pink and slopes exceeding 12° in red

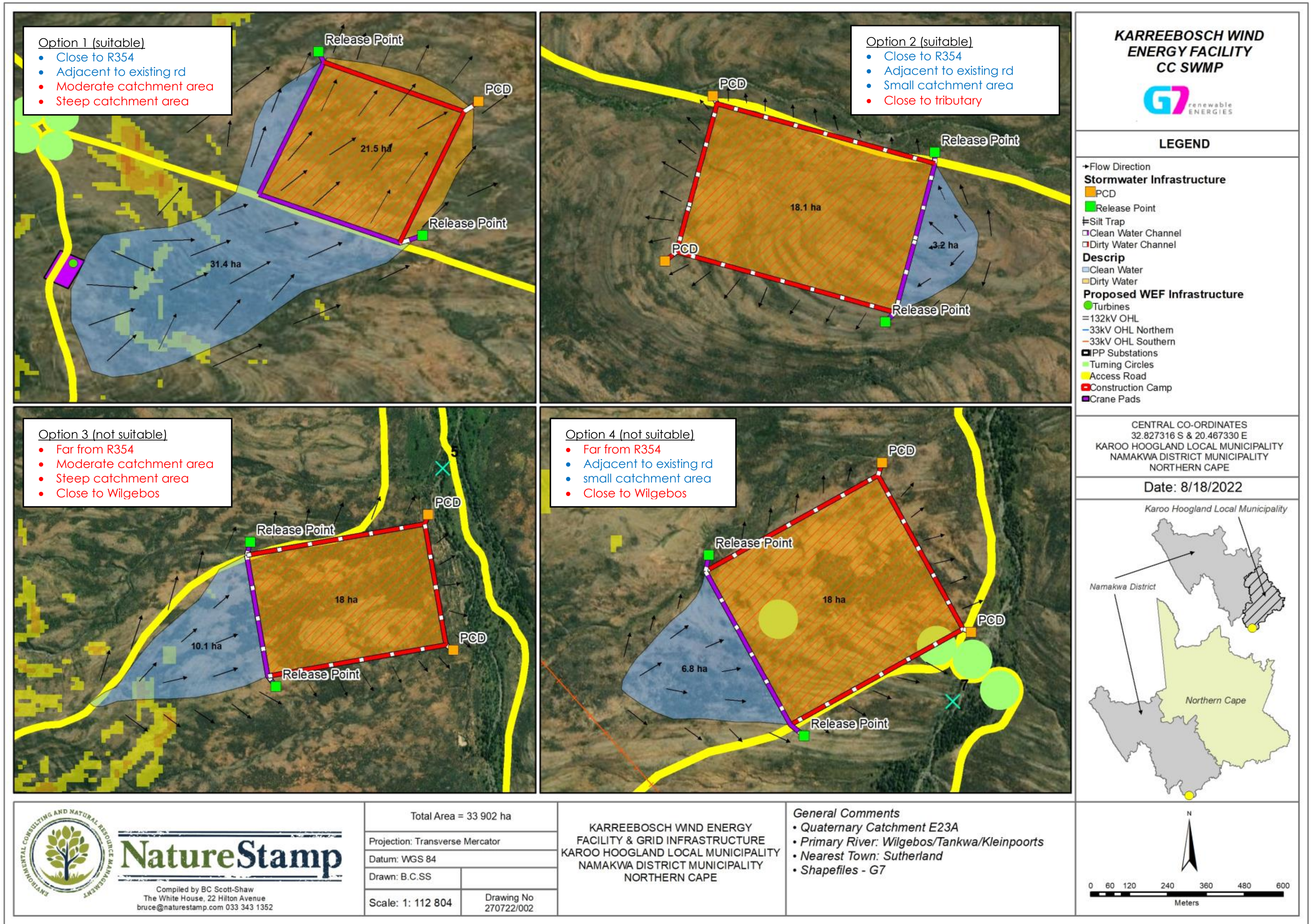


Figure 16 Storm water management plan for construction camp infrastructure showing high risk area in yellow/red

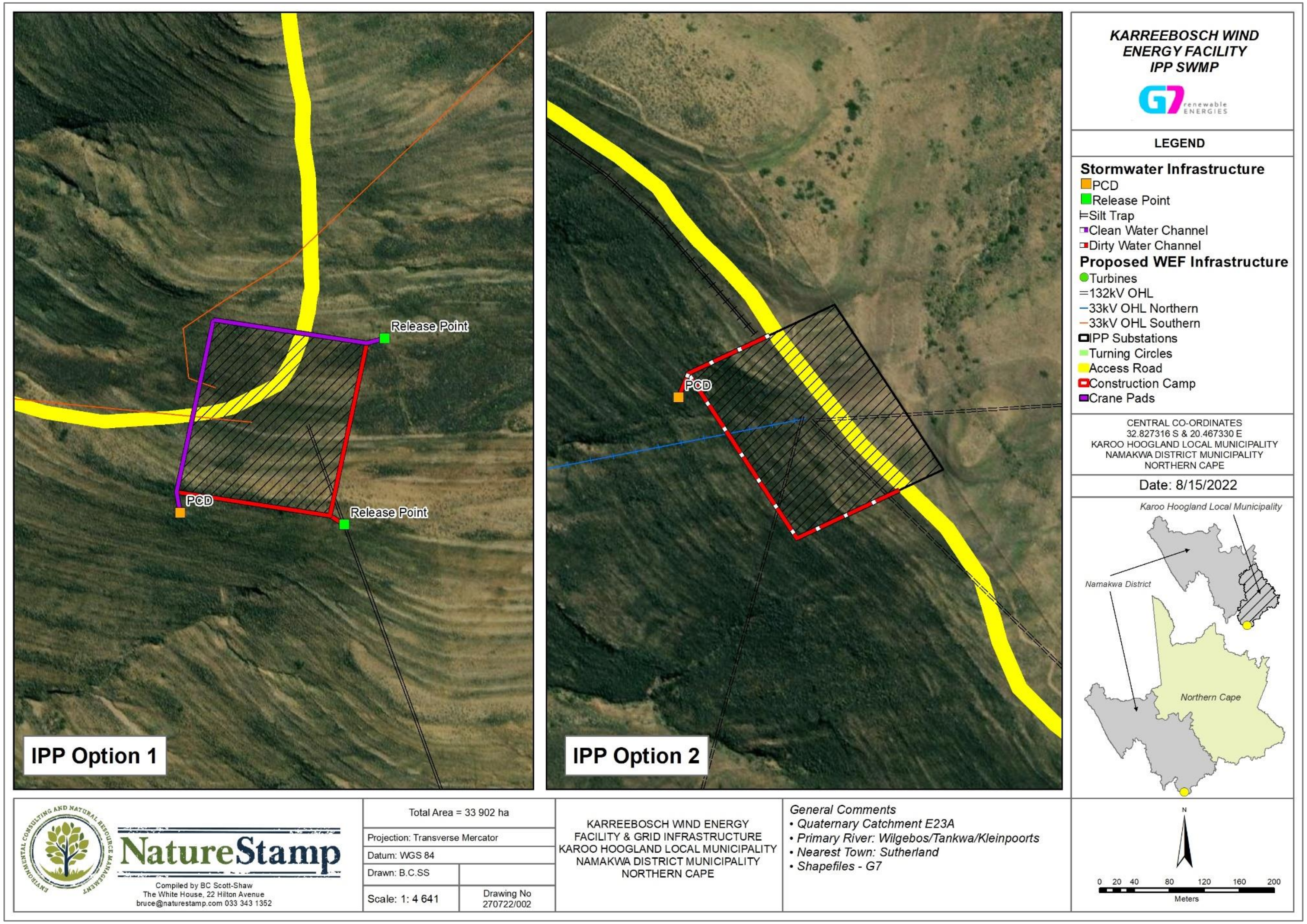
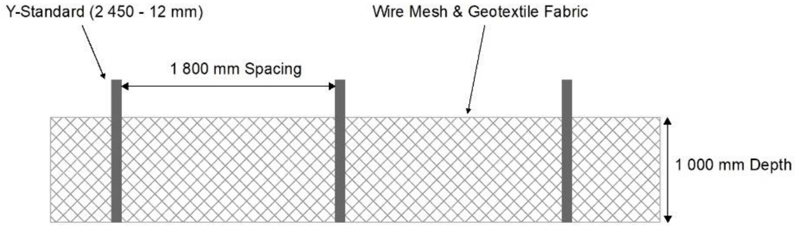
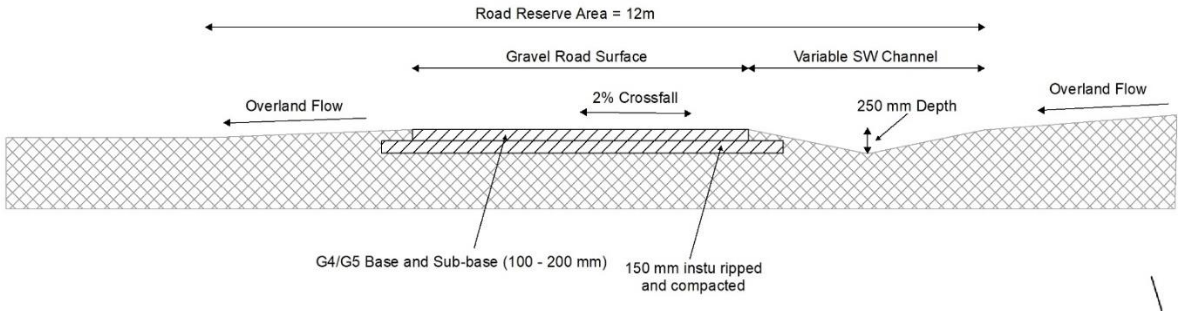
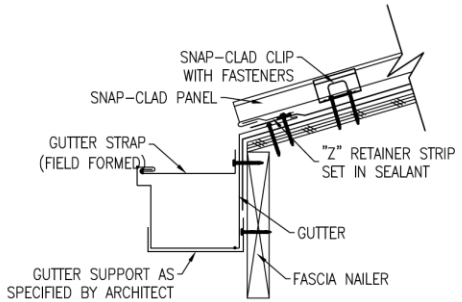
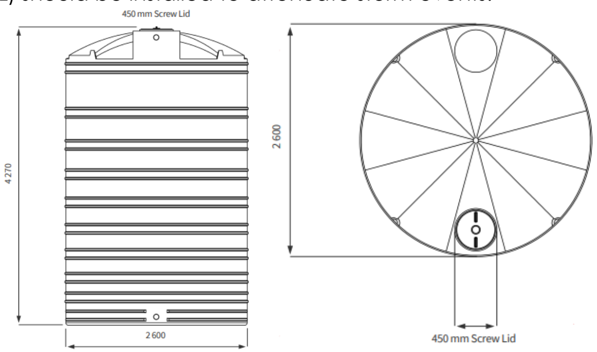


Figure 17 Storm water management plan for IPP substation infrastructure

Table 9 Intervention measures per unit at Karreebosch

Unit	Activity/Risk	Severity	Intervention
Preliminary Stage			
Access Roads	Route planning	Low	• Ensure watercourse crossings are kept to a minimum where possible; • Ensure steep slopes are avoided where possible; • Ensure existing roads are used where possible.
Laydown Areas/Camps	Site planning	Low	• Ensure sites are flat; • Ensure sites are away from watercourses in compliance with the conditions of the WULA; • Ensure the bearing capacity and bed rock is stable for foundations and platform weight.
OHL	Route planning	Low	• Ensure watercourse crossings are kept to a minimum where possible;
Construction Stage			
Access Roads	Expansion of gravel roads to between 8 to 12 meters. Grading of roads. Risk of erosion and sedimentation	Moderate	• Temporary silt traps in any development areas where the slope exceeds 12° (see design and layout in light blue below).  • Storm water runoff be directed to the lower side of the gravel roads. At this point it should then be collected in side drains and disposed of in designated places by means of suitable outlet structures (cut-off drains and rockeries) and berms.  • No dirty water must be directed into watercourses. • Roads should be constructed at-grade to allow for continued flow; • Only include side drains where inundation or damage may occur otherwise the natural flow path would be interrupted; • At crossings, stone protection walls should be constructed on either side to reduce scour; • All storm water runoff be directed to the lower side of the gravel roads. At this point it should then be collected in side drains and disposed of in designated places by means of suitable outlet structures and berms.

Laydown Areas	Contamination from construction activities. Risk of erosion and sedimentation	Moderate	• Compounds, storage and lay-down areas must be clear of all debris, and the area must be level and free draining and have the same bearing capacity and proof testing as the Crane Pad. • No dirty water must be directed into watercourses. • Emergency pumps should be in place to remove any water at the bottom of excavated areas if needed. • Temporary silt traps and berms should be constructed around the footprint (see above)
Construction Camp	Potential pollution from staff. Potential oil spills from vehicles and equipment. Risk of erosion and sedimentation	Moderate	• Drains and berms at concentration points to manage and divert surface flow/ runoff from all structures during operation. • Gutters, downpipes and storage tanks (10 000 L) should be installed to attenuate storm events.  • No dirty water must be directed into watercourses. • Flows must be attenuated and subsequently directed towards natural flow paths. • Effluent from construction staff must be treated on-site otherwise it should be removed from the site. • The calculated attenuation volume required for the entire camp is 943 m3. Some of this could be accommodated within rainwater harvesting structures.
OHL	Disturbance of soil and vegetation from collector footprint.	Low	• Temporary silt traps in any development areas where the slope exceeds 12°. • Revegetation of any disturbed areas. • Underground cabling areas should ensure sub-soil and top-soil are layered as per their natural state. • Steep areas should have additional erosion control measures put in place.
Operation Stage			
Access Roads	Operation of vehicles along roads. Potential erosion channels.	Low	• Undertake a periodic site inspection to verify and inspect the effectiveness and integrity of the storm water run-off control systems. • Immediate rehabilitation should erosion occur. • Temporary silt traps to continue for 1 year during operation in any areas where the slope exceeds 12°.
Laydown Areas/Camps	Increased stormflow from surface Risk of erosion and sedimentation	Low	• Undertake a periodic site inspection to verify and inspect the effectiveness and integrity of the storm water run-off control systems. • Immediate rehabilitation should erosion occur.
OHL	Continued disturbance of soil and vegetation from collector footprint.	Low	• Undertake a periodic site inspection to verify and inspect the effectiveness and integrity of the storm water run-off control systems. • Immediate rehabilitation should erosion occur.

5.10 Water Balance

5.10.1 WR2012 Analysis

The data obtained for the site showed a mean annual evaporation of 1 810 mm, 1 895 mm and 1 870 mm for the three QCs. The naturalized flow mean annual runoff for the greater catchment is 16.58 million m^3 for the E23A catchment area of 762 km^2.

Table 10 WR2012 data relevant to the Karreebosch WEF

								NATURALISED FLOW MARs			
	BASIC INFORMATION							1920 - 1989	1920 - 2004	1920 - 2009	Change in MAR
	Catchment area		S-pan evaporation			Rainfall		MAR (WR90)	MAR (WR2005)	MAR (WR2012)	WR2005 to WR2012
Quaternary	Gross	Net	evap	MAE WR2005	MAE WR90	Rainfall	MAP	Net	Net	Net	(percent)
catchment	(km2)	(km2)	zone	(mm)	(mm)	zone	(mm)	(mcm)	(mcm)	(mcm)	(percent)
E23A	762	762	15B	1895	1895	E2A	254	7.70	15.22	16.58	8.9

5.10.2 Water Balance

Data from the developers was provided to the specialists. This data allowed for an assessment of the proposed structures and the expected water usage/requirements (Figure 18). The proponent requires water for construction activities (concrete mixing etc.), water for staff (potable and ablutions) and water for general maintenance. The key goal of the water balance assessment is to determine the runoff from structures. The greatest runoff was from the access roads as these will be widened to allow for large vehicle access. However, overall, the volumes of water are very small and this is a low intensive water use activity, particularly during operation.

Further details regarding the source of water will be confirmed. This water balance assumes the following:

- Water will be obtained from groundwater abstraction and a small amount from rainwater harvesting.
- The volume required for the construction phase is 45 000 m^3 per annum.
- Storage facilities (10 000 L tanks) have been accounted for and would also act as attenuation structures.
- Clean water would be directed into JoJo tanks from any building infrastructure.
- All sewage will be removed from the site by a suitable waste disposal company.

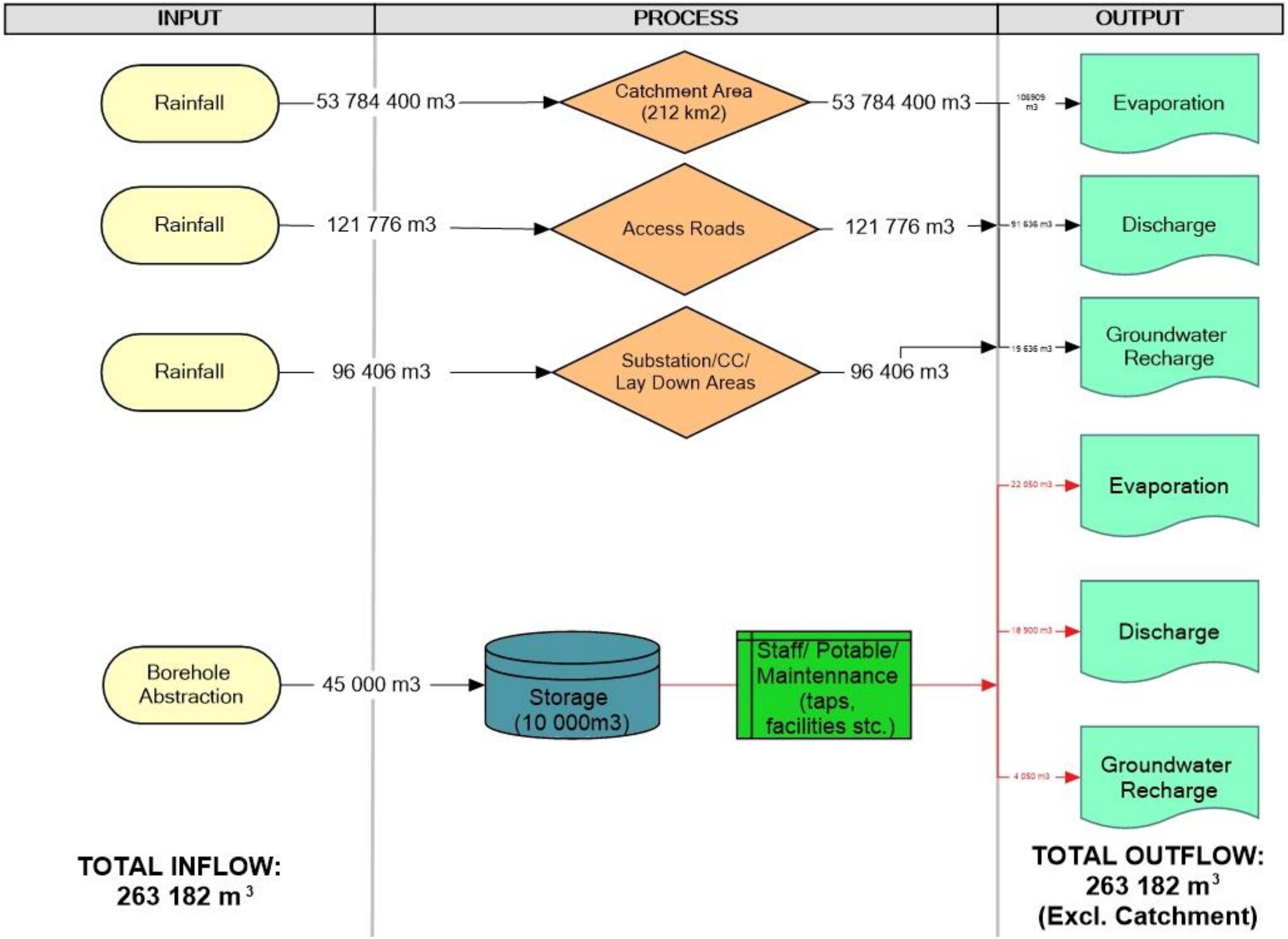


Figure 18 Annual water balance for the construction of the proposed Karreebosch WEF

6. POTENTIAL SURFACE WATER IMPACTS & MITIGATION

The site for the proposed Karreebosch WEF Project and its associated grid infrastructure is mostly natural (succulent Karroo). The primary surrounding impacts are farming areas, asphalt and dirt roads, which cross watercourse areas leading to a loss/disturbance of wetland area and potential pollution of the watercourses. Most of the site is lightly vegetated due to the dry climate.

6.1 Present Impacts

Within and around the Karreebosch WEF footprint, the existing impacts on surface water and respective catchment areas include -

- The clearance of natural habitat for settlements and associated roads;
- Hardened surfaces resulting in a reduction in infiltration;
- Concentrated flow paths from drain outlets/dongas along the roads;
- Historical modification of watercourse systems for agriculture and infrastructure construction; and
- Various servitudes.

In the broader catchment, similar impacts are present as noted for the site proposed for the Karreebosch WEF project. Additional existing impacts on the groundwater resources and respective catchment areas include -

- Infrastructure development within wetland systems (wetland encroachment) or river banks – leading to a direct loss of wetland systems and decrease in groundwater recharge;
- Slight expansion of agricultural areas resulting in an increased water demand and an increase in water pollution;
- Cumulative increases in WEFs within the greater area;
- Unregulated boreholes that may put strain on the limited groundwater resources; and
- Poor or absent sanitation – direct water pollution.

6.2 Potential Impacts During Construction

Some impacts will occur during construction. These include –

- Vegetation clearing (roads, construction camp, substation, lay down areas);
- Enhanced runoff and erosion potential due to open surface areas, spoil/stockpile areas and compacted areas;
- Decrease in water quality due to potential spills/contaminants from vehicles, machinery and cement mixing areas;
- Spread of alien invasive plants, particularly in disturbed areas;
- Loss of wetland area (including aquatic flora and fauna) at crossing points;
- Alteration of flow pattern due to changes in flow paths.

The identified construction impacts have been classified in the form of impact tables (Tables 11 and 12).

Table 11 Increase in surface runoff and general change in hydrology

Issue	Impact on Local Hydrology	
Description of Impact		
o Increase in surface runoff due to hardened surfaces. o Increase in the erosion potential due to concentrated flow paths. o Reduction in infiltration reducing groundwater recharge.		
Type of Impact	Direct	
Nature of Impact	Negative	
Phases	Construction	
Criteria	Without Mitigation	With Mitigation
Intensity	Medium	Medium
Duration	Short-term	Short-term
Extent	Local	Local
Consequence	Medium	Low
Probability	Probable	Possible / frequent
Significance	Low -	Very Low -
Degree to which impact can be reversed	The impact is partially reversible if adequate storm water structures are put in place. Additionally, the construction footprint could be minimised with spoil areas being placed on already disturbed areas and concentration points being allowed to infiltrate appropriately.	
Degree to which impact may cause irreplaceable loss of resources	Without mitigation there would be a net loss groundwater recharge. Additionally, there would be an increase in open soil leading to erosion and loss of soil stability.	
Degree to which impact can be mitigated	There is a reasonable scope for mitigation measures to be effective. A storm water management plan would encourage infiltration and reduce this impact.	
Mitigation actions		
The following measures are recommended:	Ensure the storm water management plan is implemented by an appropriate engineer. Here, the engineer should ensure both natural run-off (that which can be released into the natural landscape with no detrimental effect) and excess artificial run-off generated by the proposed development structures. Other structures that may be considered are semi-permeable surfaces that can absorb artificial run-off but releases a certain amount into the landscape. Energy dissipating structures can also be used.	
Monitoring		
The following monitoring is recommended:	o All impervious surfaces to be monitored to ensure drains etc. are functional. o Ensure all clean water is dissipated towards the natural flow area and all dirty water is directed towards a control structure. o Ensure no sediments are allowed to enter the system.	
Cumulative impacts		
Nature of cumulative impacts	The cumulative impact considers the combined impact of the surrounding linked developments. The site for the project is natural. The cumulative impact would be low due to the significant distances for the type of development, low rainfall and the low impact on surface water resources in the given area.	
Rating of cumulative impacts	Without Mitigation	With Mitigation
	Low -	Very Low -

Table 12 Potential spills from construction areas, storage areas and machinery

Issue	Potential Spills Contaminating Surface Water	
Description of Impact		
o Spills from machinery. o Spills from vehicles. o Spills from cement mixing areas. o Litter from staff. o Increase risk of pollutants being washed into the nearby watercourse systems.		
Type of Impact	Direct	
Nature of Impact	Negative	
Phases	Construction	
Criteria	**Without Mitigation**	**With Mitigation**
Intensity	Medium	Low
Duration	Short-term	Short-term
Extent	Local	Local
Consequence	High	Medium
Probability	Probable	Possible / frequent
Significance	Medium -	Low -
Degree to which impact can be reversed	The impact is partially reversible if spill management plans (including spill kits) are put in place. Staff should be trained on preventing spills. Maintenance must occur in designated areas. Hazardous chemicals need to be bunded.	
Degree to which impact may cause irreplaceable loss of resources	Should hazardous chemicals enter watercourses, long-term damage may occur. This is likely without mitigation.	
Degree to which impact can be mitigated	There is a good scope for mitigation measures to be effective.	
Mitigation actions		
The following measures are recommended:	o Spill prevention kits must be available on site. Eco-friendly alternatives are recommended. o Activities to stop during heavy rainfall periods. o Drip trays to be present and maintenance only to occur in designated lined areas.	
Monitoring		
The following monitoring is recommended:	o The ECO must confirm all designated maintenance areas. o Basic water quality to be checked in the event of a spill and monitored. o The ECO must audit any likely pollution areas regularly.	
Cumulative impacts		
Nature of cumulative impacts	The cumulative impact would be low due to the lack of open surface water and the low rainfall. Cumulative impacts could occur without mitigation.	
Rating of cumulative impacts	**Without Mitigation**	**With Mitigation**
	Medium -	Very Low -

6.3 Potential Impacts During Operation

Some impacts will occur during operation. These include –

- Enhanced runoff and erosion potential due to an increase in impervious and compacted areas leading to more surface water discharge, particularly during extreme events; and
- Decrease in water quality due to potential spills/contaminants from maintenance vehicles, infrastructure and equipment.

The identified operation impacts have been classified in the form of impact tables (Tables 13 and 14) which addresses both water quality and quantity. Although infrequent, rainfall events exceeding 80 mm in a day have occurred here. As such, these events need to be accommodated to match the pre-development state and ensure the continued hydrological patterns.

Table 13 Impact on local hydrology during operation

Issue	Impact on Local Hydrology	
Description of Impact		
o Increase in surface runoff due to impervious surfaces. o Increase in the erosion potential due to concentrated flow paths. o Reduction in infiltration. o Increase risk of pollutants being washed into the system.		
Type of Impact	Direct	
Nature of Impact	Negative	
Phases	Operation	
Criteria	**Without Mitigation**	**With Mitigation**
Intensity	Medium	Low
Duration	Short-term	Short-term
Extent	Local	Local
Consequence	Medium	Low
Probability	Probable	Possible / frequent
Significance	Low -	Very Low -
Degree to which impact can be reversed	The impact is partially reversible if adequate long-term storm water structures are put in place. Discharge should match pre-development state.	
Degree to which impact may cause irreplaceable loss of resources	Without mitigation there would be an increase in erosion which would cause irreplaceable damage to the ecosystem and future loss in infiltration.	
Degree to which impact can be mitigated	There is a reasonable scope for mitigation measures to be effective. A storm water management plan must be followed.	
Mitigation actions		
The following measures are recommended:	Ensure the storm water management plan is implemented by an appropriate engineer. Here, the engineer should ensure both natural run-off (that which can be released into the natural landscape with no detrimental effect) and excess artificial run-off generated by the proposed operation structures. Other structures that may be considered are semi-permeable surfaces that can absorb artificial run-off but releases a certain amount into the landscape. Energy dissipating structures can also be used. Clean and dirty water must be separated.	
Monitoring		
The following monitoring is recommended:	o All impervious surfaces to be monitored to ensure drains etc. are functional. o Ensure all clean water is dissipated towards the natural flow area and all dirty water is directed towards a control structure. o Ensure no sediments are allowed to enter the system.	
Cumulative impacts		
Nature of cumulative impacts	The cumulative impact would be low due the limited rainfall. The structures have a relatively low impact on surface water in the given area.	
Rating of cumulative impacts	**Without Mitigation**	**With Mitigation**
	Low -	Very Low -

Table 14 Impact on surface water quality during operation

Issue	Potential Spills	
Description of Impact		
o Spills from maintenance equipment. o Spills from maintenance vehicles. o Litter from staff. o Spills from the hydrogen plant/refueling plant.		
Type of Impact	Direct	
Nature of Impact	Negative	
Phases	Operation	
Criteria	**Without Mitigation**	**With Mitigation**
Intensity	Medium	Low
Duration	Short-term	Short-term
Extent	Local	Local
Consequence	Medium	Low
Probability	Probable	Possible / frequent
Significance	Low -	Very Low -
Degree to which impact can be reversed	The impact is partially reversible if spill management plans (including spill kits) are put in place. Staff must be trained on preventing spills. Maintenance must occur in designated areas. Hazardous chemicals need to be bunded. Spills must be prevented from entering the sub-surface.	
Degree to which impact may cause irreplaceable loss of resources	Should hazardous chemicals enter the unsaturated zone, long-term damage may occur. This is likely without mitigation.	
Degree to which impact can be mitigated	There is a good scope for mitigation measures to be effective.	
Mitigation actions		
The following measures are recommended:	o Spill prevention kits must be available on site. Eco-friendly alternatives are recommended. o Activities/maintenance to stop during heavy rainfall periods. o Drip trays to be present and maintenance must only occur in designated lined areas.	
Monitoring		
The following monitoring is recommended:	o The ECO must confirm all designated maintenance areas. o Basic water quality to be checked in the event of s spill. o The ECO must audit any likely pollution areas regularly.	
Cumulative impacts		
Nature of cumulative impacts	The cumulative impact would be low due to the significant distances away from surface users and the overall low impact. Cumulative impacts could occur without mitigation.	
Rating of cumulative impacts	**Without Mitigation**	**With Mitigation**
	Low -	Very Low -

Table 15 Impact of the 'No-Go' alternative

Issue	No Go Alternative	
Description of Impact		
o Impact accrued due to the development not proceeding. o The natural environment would subsequently not change. o Pre-existing impacts would continue with a slight projected increase in impacts. o Due to water and financial constraints, landowners are likely to construct more water pipelines to increase availability and distribution.		
Type of Impact	Direct	
Nature of Impact	Negative	
Phases	Planning	
Criteria	**Without Mitigation**	**With Mitigation**
Intensity	Low	N/A
Duration	Long-term	
Extent	Local	
Consequence	Low	
Probability	Probable	
Significance	Low -	
Degree to which impact can be reversed	The impact is reversible if future activities follow best practice guidelines.	
Degree to which impact may cause irreplaceable loss of resources	Not applicable.	
Degree to which impact can be mitigated	Not applicable.	
Mitigation actions		
The following measures are recommended:	Not applicable.	
Monitoring		
The following monitoring is recommended:	Not applicable.	
Cumulative impacts		
Nature of cumulative impacts	The cumulative impact would be low/negligible.	
Rating of cumulative impacts	**Without Mitigation**	**With Mitigation**
	Very Low -	N/A

6.4 Potential Cumulative Impacts

In relation to an activity, cumulative impact "means the past, current and reasonably foreseeable future impact of an activity, considered together with the impact of activities associated with that activity, that in itself may not be significant, but may be significant when added to the existing and reasonably foreseeable impacts eventuating from similar or diverse activities" (NEMA EIA Reg GN R982 of 2014). It is important to consider the bigger picture where numerous small impacts can lead to greater cumulative impacts. The recommended mitigation measures are aligned with the identified construction and operation impacts. Key mitigation measures would be to minimize Stormwater runoff, share construction access roads, utilize the same spoil areas and utilize water efficiently.

The South African government gazetted[1] eight (8) areas earmarked for renewable energy development in South Africa. These areas are known as Renewable Energy Development Zones (REDZ) and this project falls within the Komsberg REDZ.

These existing surrounding projects of varying approval status are listed below. Given the site's location within the Komsberg REDZ, it is considered to be located within the renewable energy hub that is developing in this focus area. From a hydrological perspective, due to the low rainfall and suggested mitigation measures, the proposed development would have a **low negative impact**.

[1] Government Notice 114 of 16 February 2018.

1. 140MW Rietrug Wind Energy Facility Near Sutherland, Northern Cape Province.(EA Ref:12/12/20/1782/1/AM5)
2. 140MW Sutherland 1 Wind Energy Facility near Sutherland, Northern Cape and Western Cape Provinces. (EA Ref:12/12/20/1782/2/AM6)
3. 140 MW Sutherland 2 Wind Energy Facility near Sutherland, Northern Cape Provinces.(EA Ref: 12/12/20/1782/3/AM3)
4. 150MW Perdekraal (West) Wind Energy Facility, Western Cape Province.(EA Ref: 12/12/20/1783/1/AM5)
5. 147MW Perdekraal (East) Wind Energy Facility, Western Cape Province. (EA Ref:12/12/20/1783/2/AM5)
6. 140MW Roggeveld Phase 1 Wind Farm, North of Matjiesfontein, Northern Cape and Western Cape Provinces. (EA Ref:12/12/20/1988/1/AM6)
7. 140 MW Karusa Wind Energy Facility,Phase 1, Karoo Hoogland Municipality, Northern Cape Province. (EA Ref:12/12/20/2370/1/AM6)
8. 140MW Soetwater Wind Farm Phase 2, Karoo Hoogland Municipality, Northern Cape Province. (EA Ref:12/12/20/2370/2/AM6)
9. 140MW Great Karoo Wind Energy Facility Phase 3, Karoo Hoogland Municipality, Northern Cape Province.(EA Ref: 12/12/20/2370/3/AM5)
10. 310MW Pienaarspoort Wind Energy Facility Phase 1, Witzenberg local Municipality, Western Cape Province.(EA Ref: 14/1/1/16/3/3/1/2318)
11. 360MW Pienaarspoort Wind Energy Facility Phase 2, Witzenberg local Municipality, Western Cape Province.(EA Ref:14/12/16/3/3/1/2441)
12. 226MW Kudusberg Wind Energy Facility between Matjiesfontein and Sutherland in Western and Northern Cape Provinces. (EA Ref:14/12/16/3/3/1/1976/1/AM3)
13. 325WM Rondekop Wind Energy Facility between Matjiesfontein and Sutherland in Western and Northern Cape Provinces (14/12/16/3/3/1115)
14. 183MW Rietkloof Wind Energy Facility near Matjiesfontein in the Western Cape Province. (14/12/16/3/3/1/1977/AM3)
15. 200 MW Esizayo Wind Energy Facility Expansion near Laingsburg, Western Cape.(EA Ref:14/12/16/3/3/1/2542)
16. Oya Energy Facility located near Laingsburg, Western and Northern Cape Provinces.(EA Ref:14/12/16/3/3/2/2009/AM1)
17. 140MW Gunsfontein Wind Energy Facility Karoo Hoogland Municipality, Northern Cape Province.(EA Ref:14/12/16/3/3/2/826)
18. 275MW Komsberg West near Laingsburg, Western Cape Provinces. (14/12/16/3/3/2/856/AM4)
19. 275 Komsberg East near Laingsburg, Western Cape Provinces. (14/12/16/3/3/2/857/AM4)
20. 140MW Brandvalley Wind Energy Facility, within the Laingsburg and Witzenberg Local Municipalities in the Western and Northern Cape Province. (EA Ref:14/12/16/3/3/2/900/AM2)
21. 140 MW Maralla East Wind Energy Facility, Namakwa and Central Karoo District Municipalities, Western and Northern Cape Provinces. (14/12/16/3/3/2/962/AM1
22. 140 MW Maralla West Wind Energy Facility, Karoo Hoogland local Municipality, Northern Cape Province.(EA Ref: 14/12/16/3/3/2/963/AM1)
23. 140MW Esizayo Wind Farm, Laingsburg Local Municipality Western Cape Province. (EA Ref:14/12/16/3/3/2/967/AM3)
24. 10MW Inca Photovoltaic Facility near Sutherland, Northern Cape Province.(EA Ref:12/12/20/2235)

6.5 Impacts associated with Climate Change Projections

The following potential impacts may arise as a result of climatic changes in the future, which would possibly affect the Karreebosch Facility drainage areas and surrounding environment:

- Increase in extreme weather events such as powerful rain/thunderstorms, strong winds, intense heat waves, severe coldness and increased lightning strikes.

- This would likely cause flooding within the watercourses, which could damage the surrounding environment.
- The risk of contamination of watercourses would increase due to significantly greater volumes of runoff, which may lead to disease outbreaks and human health problems.
- Alien vegetation uses more water than indigenous vegetation, therefore reducing natural water supplies / choking natural watercourses. Alien plants have the ability to overpower indigenous vegetation and becoming overgrown within rivers and streams.

7. ENVIRONMENTAL MANAGEMENT PROGRAMME (EMPr) INPUT

The objectives of the EMPr is to ensure that any impacts remain at a low risk/sensitivity.

Table 16 Rehabilitation actions for inclusion into the EMPr

Objective	Action	Timing
Manage Surface Water Usage	1. Recycle water where possible	With immediate effect (Construction & Operation)
	2. Ensure storm water structures promote infiltration	With immediate effect (Construction)
Ensure surface and groundwater quality is not impacted upon	3. In the event of a spill, implement a spill contingency plan and monitor surface water for 6 months if spill is not contained.	Construction and Operation
Manage stormwater from the roads and infrastructure areas	4. Ensure appropriate storm water infrastructure is installed to dissipate flow and direct away from concentrated paths.	During winter months
	5. Ensure drip trays are used under vehicles/machinery and that impervious floor surfaces are constructed to ensure chemicals and waste do not enter the sub-surface.	With immediate effect throughout construction.
Manage spills during construction	6. Ensure drip trays are used under vehicles/machinery and erosion control measures are implemented. 7. Ensure a spill contingency plan is put into place.	With immediate effect ECO to check every 2 months
Manage watercourse areas	8. Ensure wetland buffers are marked so that activities do not occur near them. 9. Remove alien species and manage indigenous species as per the vegetation component.	With immediate effect and ongoing
Manage spills during operation	10. Completely lined infrastructure (concrete bunded area), with the capacity to contain 110% of the total amount of chemicals stored within any construction area. 11. Spills must be completely removed from the site. 12. Fire extinguisher equipment installed within permanent structures. 13. Ensure air circulation to prevent the build up of chemicals. 14. Implement the storm-water management plan and ensure appropriate water diversion systems are put in place. 15. Compile (and adhere to) a procedure for the safe handling of chemicals. 16. Compile an emergency response plan and implement should an emergency occur. 17. Ensure that spill kits (if appropriate) are available on site for clean-up of spills and leaks. 18. Drip-trays or containment measures must be placed under equipment that poses a risk when not in use. 19. Immediately clean up spills and dispose of contaminated soil at a licensed waste disposal facility. 20. Dispose of waste appropriately to prevent pollution of soil and groundwater. 21. On-site maintenance to be done over appropriate drip trays/containment measures and any hazardous substances must be disposed of appropriately. 22. Record and report all fuel, oil, hydraulic fluid or electrolyte spills to the PM / Engineer / ERP so that appropriate clean-up measures can be implemented.	With immediate effect/Ongoing

7.1 Potential Spill Scenarios

Due to the nature of the activity, there is a chance of potential spills occurring on site (equipment etc.). The potential spill scenarios are outlined as follows:

1. Spills and leaks from vehicles. These incidents are likely to be the smallest and least concerning spills to take place on site. Regular removal of spills and leaks should be undertaken on-site. Eco-friendly detergents should be used.
2. A storm or flood event occurs during construction, resulting in structures being exceeded. All activities should stop and a spill management plan be executed. Furthermore, erosion control actions should be initiated.

7.2 Mitigation Measures and Recommendations (Spill Management Plan)

As guided by the DWS, the following soil erosion measures would be put into place –

- Erosion control measures should be put in place to minimize erosion along the construction areas. Extra precautions must be taken in areas where the soils are deemed to be highly erodible.
- Soil erosion onsite should be prevented at all times, i.e. post- construction activities.
- Erosion measures should be implemented in areas prone to erosion such as near water supply points, edges of slopes etc. These measures could include the use of sand bags, hessian sheets, retention or replacement of vegetation if applicable and in accordance with the EMPR and the biodiversity impact assessment.

- Where the land has been disturbed during construction, it must be rehabilitated and re-vegetated back to its original state after construction.
- Stockpiling of soil or any other material used during the construction phase must not be allowed on or near slopes, near a watercourse or water body. This is to prevent pollution of the impediment of surface runoff (further details are provided in the EMPr).

In order to reduce the potential impact of spills on site the following must be adhered to:

- Emergency numbers are provided on site – e.g. Spilltech, fire department, ambulance, etc.;
- Spill cleaning kits such as a Drizit kit are available on site;
- All chemicals on site are recorded in the inventory of hazardous substances;
- Equipment, machinery and vehicles are regularly checked and maintained in good order;
- Machinery and equipment maintenance is undertaken in designated areas;
- Drip trays are to be placed underneath machinery and equipment during maintenance;

In the instance of a spill on site the following procedure must be followed:

1. Locate the source of the spill;
2. Stop the spill and prevent further spreading;
3. The appropriate oil sponge, absorbent or spill kit (e.g. DriZit) can then be used to clean and remove the spilled substance(s);
4. Spills from trucks/tractors must be contained within a concreted site area and prevented from spreading;
5. Spilled petrochemicals can then be cleaned up and removed using the appropriate oil sponge, absorbent or spill kit (e.g. DriZit);
6. The spill must be reported to the site manager / supervisor and ECO;
7. Depending on the significance of the spill, the incident may also need to be reported to the DEA&DP (WC), DAEARD&LR (NC) and DWS.

7.3 Erosion Control Plan

There is an overlap between the storm water management and erosion control. The erosion control is particularly relevant during construction and at certain locations during operation. The removal of vegetation also leaves the site at a higher risk.

- Immediately rehabilitate eroded areas:
  - Install protective structures, e.g. geotextiles;
  - Ensure the slope remains gentle and stable;
  - Use vegetation plugs, rock packs or gabions where erosion is visible;
  - Immediately revegetate the area.
- Ensure that steeper areas are avoided and that the vegetation remains at these sites.
- Continual erosion monitoring should occur by a trained staff member.

The site should take into account the following erosion control mechanisms:

- Geotextiles;
- Gabion baskets;
- Soil binding chemicals;
- Hydroseeding techniques;
- Vegetation plugs;
- mulch

To ensure rehabilitation is effective, it is vital that the working area is managed correctly during the construction phase. An important part of this management will be that careful preservation and management of soil stockpiles should be implemented from the start of the site. The following points have been provided for use with the rehabilitation actions:

- Top- and subsoil stockpiles (used for road levelling and bank lifting) must not be stockpiled within 100m or within the 1:100 year floodplain of a watercourse.

- Naturally occurring vegetation removed by site clearance operations may be grubbed in with the topsoil for stockpiling.
- The topsoil shall not be buried or rendered in any other way inappropriate for rehabilitation use.
- Topsoil stripping (in widening and realignment areas) shall not occur in wet weather and during stripping and stockpiling, the topsoil shall not be subject to a compaction force greater than 1 500kg/m² and shall not be pushed for more than 50m.
- Topsoil shall also only be handled twice, once to strip and stockpile, and secondly to replace, level, shape and scarify if necessary.
- Top soil stockpiles must be protected against erosion and a record kept of all top soil quantities and should there be shortfalls of topsoil required for rehabilitation, adequate replacement material from commercial sources should be obtained as approved by the Engineer (preferably from areas identified with sourced excess topsoil).
- Equally, excess topsoil shall be landscaped and stabilized in accordance to the requirements of the Engineer and in consultation with the Contractor's Land Rehabilitation Specialist.
- Topsoil stockpiles should not be stockpiled for longer than 6 months if possible. If this can't be avoided, the stockpiles will need to be enriched or upgraded prior to rehabilitation. The Contractor shall consult with the Engineer with regards to matching preconstruction conditions or existing adjacent conditions.
- All stockpiles left for extended periods of time shall be stabilized using approved vegetation cover or other erosion control measures.
- Any excess subsoil must be removed from the road fringe once back filling is completed, and spoiled at an agreed spoil site (spoil sites to be agreed between landowner, ECO and Engineer).

8. CONCLUSION

The work undertaken for this report provides information on the flood and storm water components for the proposed Karreebosch WEF facility and associated grid infrastructure. The areas associated with the development are relatively small in contrast to the catchment area. However, the contributing catchment area is large as the development is distributed along a catchment divide. The site has existing roads. The site has a low vegetation cover and an undulating terrain indicating that it is at higher risk of erosion. As such, it essential that storm water and erosion control measures are strictly adhered to. Pollution control measures should also be appropriately implemented for the construction and operational phase. Temporary silt traps must be placed as recommended in this SWMP during construction. Additional structures such as cut-off drains, natural rockeries, rainwater harvesting and storage have been recommended for the operation of the site. Roads that cross watercourses require open drains and natural rockeries.

The flood component showed that the proposed infrastructure is not at risk of flood damage. The overall risk to watercourses is moderate during construction but low during operation, assuming that control measures and rehabilitation is adhered to and successful. It has been recommended that a low level crossing or portal culverts be adopted for major crossing points while pipe culverts be adopted for minor crossing points. At each crossing, the catchment area varies. The 1:20 year return period should be used in the design. Once the final dimensions and layout of the roads have been determined and the proponent's choice of culvert option has been determined, the size of each culvert can be determined. A typical trapezoidal drainage channel along the road areas will be able to accommodate 0.41 $m^3.s^{-1}$. The SCS-SA model was adopted in determining the peak values due to the catchment size and the natural state of the catchments.

Through the SWMP, dirty water was identified as water containing sediments around cleared areas during construction and potential spills/leaks from chemical storage areas. For the storm water component, the 1:50 year return period, 30-minute storm event was used in the design calculations. During construction, water would be attenuated, passed through silt traps and rockeries to allow for the sediments to be contained. Potential spills would be contained within lined structures on site and removed. All sewage would be removed from the site. As such, there is no risk of effluent contamination apart from minor spills from the removal by vehicles. However, should this happen, waste would be removed from site and the spill contained. Clean water would be attenuated and directed into storage tanks or natural flow paths during operation. Of the four construction camp options, site 1 and 2 are suitable while site 3 and 4 are not suitable.

Water requirements and usage on-site is low as shown in the water balance. The site requires 45 000 m^3/annum during construction and approximately 1 000 m^3/annum during operation. Should this 45 000 m^3 be required on one farm portion, a WUL would be required.

Regular checks should be made by the ECO and site manager. These measures should also be incorporated into the EMPr. Monitoring and follow up assessments are essential to maintaining the overall state and continued management of the watercourse system. **Monthly audits** should be undertaken by the ECO during construction and reports submitted identifying potential/existing erosion areas should they occur. Should any erosion areas be identified, the erosion control plan should be immediately implemented. Operational audits should continue for two years but occur every four months. Focus should be placed on maintaining the integrity of the watercourse and the impact the development may have on soil structure.

9. REFERENCES

1. BAILEY, AK & PITMAN, WV. (2015)WATER RESOURCES OF SOUTH AFRICA 2012 STUDY (WR2012). WRC Report K5/2143/1
2. Department of Water Affairs and Forestry, 2006. Best Practice Guideline G2: Water and Salt Balances.
3. Drainage Manual, The South African Roads Agency Limited (SANRAL), 6th edition, 2013
4. Drainage Manual, The South African Roads Agency Limited (SANRAL), 5th edition, 2006
5. DWA (2010) Department of Water Affairs, Hydrological Information System. http://www.gov.za/Hydrology/ (Accessed 15 July 2010).
6. Kovacs, Z.P; Du Plessis, D.B; Bracher, P.R; Dunn, P and Mallory, G.C.L. 1985. Documentation of the 1984 Demoina Floods. TR122. Department of Water Affairs.
7. Lynch, SD. 2003: Development of a Raster Database of Annual, Monthly and Daily Rainfall for Southern Africa, WRC Report No. 1156/1/03, Water Research Commision, Pretoria, RSA.
8. Schulze, R.E. (2003). Development of a Database of Gridded Daily Temperatures for Southern Africa. University of Natal, Pietermaritzburg, School of Bioresources Engineering and Environmental Hydrology. ACRUcons Report, 41. pp 82.
9. Schulze, RE. (2011) Atlas of Climate Change and the South African Industrial Sector: A 2010 Perspective. Department of Agriculture, Forestry and Fisheries, Pretoria, RSA. pp 387.
10. Schulze, RE. (2012) Climate Change and the South African Water Sector: Where from? Where now? Where to in future? University of KwaZulu-Natal, Pietermaritzburg Campus, South Africa.
11. US Army Corps of Engineers, HEC-GeoRAS version 4.3.93 for ArcGIS 9.3
12. US Army Corps of Engineers, HEC-RAS version 4.1
13. Visual SCS-SA, R.E. Schulze, E.J. Schmidt and J.C. Smithers, University of Natal
14. WR2012 SAMI Groundwater module: Verification Studies, Default Parameters and Calibration Guide (WRC Report No. TT 687/16

ANNEXURE A Design Rainfall Values for Karreebosch WEF

Design Rainfall in South Africa: Ver 3 (July 2012)

User selection has the following criteria:

Coordinates: Latitude: 32 degrees 54 minutes; Longitude: 20 degreess 10 minutes

Durations requested: 5 m, 10 m, 15 m, 30 m, 45 m, 1 h, 2 h, 4 h, 6 h, 8 h, 10 h, 24 h, 1 d

Return Periods requested: 2 yr, 5 yr, 10 yr, 20 yr, 50 yr, 100 yr, 200 yr

Block Size requested: 0 minutes

Data extracted from Daily Rainfall Estimate Database File

The six closest stations are listed

Station Name	SAWS Number	Distance (km)	Record (Years)	Latitude (°)	(')	Longitude (°)	(')	MAP (mm)	Altitude (m)	Duration (m/h/d)	Return Period (years) 2	2L	2U	5	5L	5U	10	10L	10U	20	20L	20U	50	50L	50U	100	100L	100U	200	200L	200U
DUMURE	0066027_W	36.4	73	32	57	20	30	340	1341	1 d	35.1	34.9	35.2	51.5	51.2	51.7	63.8	63.2	64.3	76.8	75.8	77.9	95.8	93.3	98.1	111.6	107.6	115.7	129.0	123.1	135.1
JAN-DE-BOERS	0044286_W	39.8	49	33	16	20	8	269	866	1 d	29.3	29.2	29.4	43.0	42.8	43.2	53.2	52.8	53.7	64.2	63.3	65.1	80.0	77.9	81.9	93.2	89.8	96.6	107.7	102.8	112.8
SPES BONA	0043516_W	45.1	67	33	6	19	48	127	619	1 d	20.1	20.0	20.2	29.4	29.3	29.6	36.5	36.2	36.8	44.0	43.4	44.6	54.8	53.4	56.2	63.9	61.6	66.2	73.8	70.4	77.3
PIETER MEINTJIES (SAR)	0044765_W	47.5	75	33	15	20	26	264	1064	1 d	32.0	31.9	32.2	47.0	46.8	47.2	58.2	57.7	58.7	70.2	69.2	71.2	87.5	85.2	89.6	101.9	98.2	105.6	117.7	112.4	123.3
DWARS-IN-DIE-WEG	0045184_W	48.5	80	33	4	20	35	159	998	1 d	25.9	25.8	26.0	38.0	37.9	38.2	47.1	46.7	47.6	56.8	56.0	57.6	70.8	69.0	72.6	82.5	79.5	85.5	95.4	91.0	99.9
TOUWSRIVIER (SAR)	0044050_W	49.0	99	33	20	20	2	223	774	1 d	29.1	29.0	29.2	42.7	42.5	42.9	52.9	52.5	53.4	63.8	62.9	64.7	79.5	77.5	81.4	92.6	89.3	96.0	107.0	102.2	112.1

Gridded values of all points within the specified block

Latitude (°)	(')	Longitude (°)	(')	MAP (mm)	Altitude (m)	Duration (m/h/d)	Return Period (years) 2	2L	2U	5	5L	5U	10	10L	10U	20	20L	20U	50	50L	50U	100	100L	100U	200	200L	200U
32	54	20	10	270	933	5 m	6.7	5.9	7.6	9.9	8.7	11.1	12.3	10.8	13.8	14.8	12.9	16.7	18.4	15.9	21.0	21.5	18.3	24.8	24.8	21.0	29.0
						10 m	9.8	8.5	11.0	14.3	12.5	16.2	17.7	15.4	20.2	21.4	18.4	24.4	26.7	22.7	30.8	31.1	26.2	36.3	35.9	29.9	42.3
						15 m	12.1	10.5	13.8	17.8	15.3	20.2	22.0	18.9	25.2	26.5	22.7	30.5	33.1	28.0	38.4	38.6	32.2	45.3	44.5	36.9	52.9
						30 m	15.4	13.3	17.6	22.6	19.5	25.8	28.1	24.0	32.2	33.8	28.8	39.0	42.2	35.5	49.1	49.1	40.9	57.8	56.8	46.8	67.5
						45 m	17.8	15.3	20.3	26.1	22.4	29.8	32.3	27.6	37.1	39.0	33.1	45.0	48.6	40.8	56.6	56.6	47.0	66.7	65.4	53.8	77.9
						1 h	19.7	16.9	22.5	28.9	24.7	33.0	35.8	30.5	41.1	43.1	36.6	49.8	53.7	45.1	62.7	62.6	51.9	73.9	72.3	59.4	86.3
						2 h	25.1	21.4	28.7	36.8	31.4	42.2	45.6	38.8	52.5	54.9	46.5	63.6	68.4	57.2	80.1	79.8	66.0	94.4	92.2	75.5	110.2
						4 h	29.0	23.6	34.4	42.6	34.6	50.5	52.8	42.7	62.9	63.6	51.2	76.2	79.3	63.1	95.9	92.4	72.7	113.0	106.8	83.2	132.0
						6 h	31.7	25.0	38.3	46.5	36.6	56.1	57.6	45.2	69.8	69.4	54.2	84.6	86.5	66.7	106.6	100.8	76.9	125.6	116.4	88.0	146.7
						8 h	33.7	26.0	41.2	49.4	38.1	60.5	61.2	47.1	75.3	73.7	56.4	91.2	91.9	69.5	114.8	107.1	80.1	135.4	123.8	91.7	158.1
						10 h	35.3	26.8	43.7	51.8	39.3	64.1	64.2	48.6	79.8	77.3	58.2	96.7	96.4	71.7	121.7	112.4	82.6	143.4	129.8	94.6	167.5
						24 h	42.5	30.3	54.9	62.4	44.5	80.5	77.3	54.9	100.2	93.2	65.8	121.4	116.2	81.1	152.8	135.4	93.4	180.1	156.4	106.9	210.3
						1 d	33.8	24.1	43.6	49.5	35.3	63.9	61.4	43.6	79.5	74.0	52.3	96.4	92.2	64.3	121.3	107.5	74.2	143.0	124.2	84.9	167.0

ANNEXURE B Rational Method for Karreebosch WEF

Description of Catchment	**Ongeluks/Tankwa River**		
River detail	**Ongeluks/Tankwa River**		
Calculated by	**B. Scott-Shaw**	**Date**	**10-Oct-22**

Physical characteristics

Size of catchment (A)	**119**	km²	Rainfall Region		
Longest Watercourse	**22.1**	km	**Area Distribution Factors**		
Average slope (S_{av})	**0.028**	m/m	Rural (α)	Urban (β)	Lakes (γ)
Dolomite Area ($D_{\%}$)	**0**	%	**1**	**0**	**0**
Mean Annual Rainfall (MAR)	**253**	mm			
Catchment Characteristics	**Steep/impermeable**	%			
r - look up from Table 3C.3	**Medium grass cover**	0.4			

Rural (1)				**Urban** (2)			
Surface Slope	**%**	**Factor**	**C_s**	**Description**	**%**	**Factor**	**C_2**
Vleis and Pans	5	0.05	0.003	**Lawns**			
Flat Areas	15	0.11	0.017	Sandy, flat (<2%)		0.075	-
Hilly	65	0.2	0.130	Sandy, steep (>7%)		0.175	-
Steep Areas	15	0.3	0.045	Heavy soil, flat (<2%)		0.15	-
Total	100	-	0.194	Heavy soil, steep (>7%)		0.3	-
Permeability	**%**	**Factor**	**C_p**	**Residential Areas**			
Very Permeable	0	0.05	-	Houses		0.4	-
Permeable	35	0.1	0.035	Flats		0.6	-
Semi-permeable	55	0.2	0.110	**Industry**			
Impermeable	10	0.3	0.030	Light industry		0.65	-
Total	100	-	0.175	Heavy Industry		0.75	-
Vegetation	**%**	**Factor**	**C_v**	**Business**			
Thick bush and plantation	0	0.05	-	City Centre		0.825	-
Light bush and farm-lands	42	0.15	0.063	Suburban		0.6	-
Grasslands	55	0.25	0.138	Streets		0.825	-
No Vegetation	3	0.3	0.009	Maximum flood		1.00	-
Total	100	-	0.210	Total	0	-	0.000

Time of concentration (T_c)	**Defined Watercourse**	Notes:
Overland flow	Defined watercourse	*Pre-development Run-off*

$$T_c = 0.604\left(\frac{rL}{\sqrt{S_{av}}}\right)^{0.467}$$

$$T_c = \left(\frac{0{,}87L^2}{1000S_{av}}\right)^{0.385}$$

Overland flow		Defined watercourse	
3.4	Hours	2.3	Hours

Latitude: *29°38'*

Longitude: *30°17'*

Tc = *2.27521115*

Run-off coefficient

Return period (years), T	**2**	**5**	**10**	**20**	**50**	**100**	**Max**
Run-off coefficient, C_1 ($C_1 = C_s + C_p + C_v$)	0.579	0.579	0.579	0.579	0.579	0.579	0.5785
Adjusted for dolomitic areas, C_{1D} ($= C_1(1-D_{\%})+C_1D_{\%}(\Sigma(D_{factor} \times C_{s\%}))$)	0.5785	0.5785	0.5785	0.5785	0.5785	0.5785	0.5785

Adjustment factor for initial saturation, F_t	0.75	0.8	0.85	0.9	0.95	1	1
Adjusted run-off coefficient, C_{1T} (= C_{1D} x F_t)	0.4338 75	0.462 8	0.49172 5	0.52065	0.5495 75	0.578 5	0.578 5
Combined run-off coeffiecient C_T (= $\alpha C_{1T} + \beta C_2 + \gamma C_3$)	0.4338 75	0.462 8	0.49172 5	0.52065	0.5495 75	0.578 5	0.578 5
Rainfall							
Return period (years), T	**2**	**5**	**10**	**20**	**50**	**100**	**Max**
Point Rainfall (mm), P_T	32.0	47.0	58.2	70.2	87.5	101.9	117.7
Point Intensity (mm/hour), P_{iT} (=P_T/T_C)	14.1	20.7	25.6	30.9	38.5	44.8	51.7
Area Reduction Factor (%), ARF_T	**100**	**100**	**100**	**100**	**100**	**100**	**100**
Average Intensity (mm/hour), I_T (= P_{iT} x ARF_T)	14.1	20.7	25.6	30.9	38.5	44.8	51.7
Return period (years), T	**2**	**5**	**10**	**20**	**50**	**100**	**Max**
Peak flow (m^3/s),	147.47 2	231.0 40	303.977	388.220	510.77 6	626.1 42	723.2 27

ANNEXURE C SDF Method for the Karreebosch WEF

Description of catchment	**Karreebosch**						
River detail	**Tankwa Tributary**						
Calculated by	**BCSS**			**Date**	**21 July 2022**		
Physical characteristics							
Size of catchment (A)	**153**	km²	Time of Concentration (T_C)	$T_c = \left(\frac{0{,}87\,L^2}{1000\,S_{av}}\right)^{0{,}385}$	**2.46**	hours	
Longest watercourse (L)	**24.4**	km					
Average slope (S_{av})	**0.05**	m/m					
SDF basin (0)#	**19**		Time of concentration, t (= 60 T_C)		**148**	minutes	
2-year return period rainfall (M)	**34**	mm	Days of thunder per year (R)		**16**	days/year	
TR102 n-day rainfall data							
Weather Service station	**Letjiesbos**		Mean annual precipitation (MAP)		**160**	mm	
Weather Service station number	**69 483**		Coordinates				

Duration (days)	Return period (years)						
	2	5	10	20	50	100	200
1	**34**	**55**	**72**	**92**	**124**	**152**	**185**
2	**38**	**64**	**87**	**112**	**153**	**190**	**233**
3	**40**	**68**	**93**	**121**	**166**	**206**	**254**
7	**45**	**79**	**110**	**145**	**202**	**254**	**315**

Rainfall							
Return period (years), T	2	5	10	20	50	100	200
Point precipitation depth (mm) $P_{t,T}$	**22.36**	**37.73**	**49.35**	**60.97**	**76.34**	**87.96**	**99.58**
Area reduction factor (%), ARF (= (90000-12800lnA+9830lnt)$^{0.4}$)	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**
Average intensity (mm/hour), I_T (= $P_{t,T}$ x ARF / T_C)	**9.09**	**15.34**	**20.06**	**24.79**	**31.03**	**35.76**	**40.48**

Run-off coefficients							
Calibration factors	C_2 (2-year return period) (%)		**10**	C_{100} (100-year return period) (%)			**35**
Return period (years)	2	5	10	20	50	100	200
Return period factors (Y_T)	0	0.84	1.28	1.64	2.05	2.33	2.58
Run-off coefficient (C_T), $C_T = \frac{C_2}{100} + \left(\frac{Y_T}{2{,}33}\right)\left(\frac{C_{100}}{100} - \frac{C_2}{100}\right)$	**0.10**	**0.19**	**0.24**	**0.28**	**0.32**	**0.35**	**0.38**
Peak flow (m³/s), Q_T = 0.278 x $C_T I_T A$	**38.64**	**123.94**	**202.37**	**290.72**	**422.00**	**531.91**	**648.34**

ANNEXURE D SCS Results for the Karreebosch WEF

CATCHMENT NAME : Karreebosc

PROJECT NO : 1

RUN NO : 1

TOTAL CATCHMENT AREA (km^2) : 153.00

STORM INTENSITY DISTRIBUTION TYPE : 3

CATCHMENT LAG TIME (h) : 2.22

COEFFICIENT OF INITIAL ABSTRACTION: 0.10

CURVE NUMBERS:	Initial	Final
Sub-catchment 1	79	79.0
Sub-catchment 2	79	79.0

RETURN PERIOD (YEARS)	2	5	10	20	50	100	200
DESIGN DAILY RAINFALL DEPTH (mm)	39	56	69	84	106	125	146
DESIGN STORMFLOW DEPTH (mm)							
Sub-catchment 1	10.4	20.8	29.9	41.2	59.1	75.3	93.8
Sub-catchment 2	10.4	20.8	29.9	41.2	59.1	75.3	93.8
TOTAL RUNOFF DEPTH (mm)	10.4	20.8	29.9	41.2	59.1	75.3	93.8
DESIGN STORMFLOW VOLUME (millions m^3)							
Sub-catchment 1	1.1	2.2	3.2	4.4	6.2	7.9	9.9
Sub-catchment 2	0.5	1.0	1.4	2.0	2.8	3.6	4.4
TOTAL STORMFLOW VOLUME (millions m^3)	1.6	3.2	4.6	6.3	9.0	11.5	14.3
COMPUTED CURVE NUMBER	79.0	79.0	79.0	79.0	79.0	79.0	79.0
PEAK DISCHARGE (m^3/s)	97.9	200.2	292.1	407.9	590.5	756.7	946.5

ANNEXURE E **Surface drainage calculations**

Utility Programs for Drainage
Surface drainage calculations

Sinotech

Project:	**Sutherland**
Designer:	**ND/BCSS**
Date:	**14 October 2020**
Description:	**Gravel roads at Sutherland WEFs site**
Filename:	**E:\Work\2020\Sutherland_Raod_surafce Calcs\Sutherland.sdp**

Printed: 27 October 2020 **Page 1**

SURFACE DRAINAGE CALCULATIONS

DEPTH OF FLOW ON ROAD SURFACE

INPUT DATA

Road crossfall (n1):	0.1 %
Road gradient (n2):	15 %
Width of road way (w):	10 m
Rainfall intensity (I):	85.4 mm/h

RESULTS

Slope of flow path (Sf):	15.00 %
Length of flow path (lf):	1500.03 m
Flow depth of water (d):	24.06 mm
Comments:	The flow depth is greater than 6.0 mm.

Calculated using Utility Programs for Drainage 1.1.0