HYDROLOGICAL ASSESSMENT, STORM WATER MANAGEMENT & EROSION CONTROL PLAN

FOR THE PROPOSED DEVELOPMENT OF THE 325 MW OYA WIND ENERGY FACILITY AND ASSOCIATED INFRASTRUCTURE, WITZENBERG & KAROO HOOGLANDLOCAL MUNICIPALITY
CAPE WINELANDS & NAMAKWA DISTRICT MUNICIPALITY
WESTERN CAPE & NORTHERN CAPE

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FINAL REPORT

Acronyms

SWMP	Storm Water Management Plan
DEDTEA	Department of Economic Development, Tourism and Environmental Affairs
DWS	Department of Water and Sanitation
EIA	Environmental Impact Assessment
UPD	Utility Programme for Drainage

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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	PhD, Hydrology	Kudusberg Wind Farm (Pty) Ltd	Date: 20/10/2020
Nick Davis Isikhungusethu Environmental Services	Design & GIS	BSc, BSc Hon, MSc Hydrology	Kudusberg Wind Farm (Pty) Ltd	Date: 20/10/2020

<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

Kudusberg Wind Farm (Pty) Ltd has proposed to develop a Wind Energy Facility (WEF) with a maximum generation capacity of 325 MW (herein after referred to as "Oya WEF"), approximately 45 km south-west of Sutherland spanning between the Northern and Western Cape Provinces. The proposed WEF is located within the Witzenberg and Karoo Hoogland Local Municipalities, which fall within the Cape Winelands and Namakwa District Municipalities respectively. The site is referred to as Oya WEF here after.

The proposed project falls entirely within the Renewable Energy Zone (REDZ) 2 (i.e. Komsberg REDZ), that was Gazetted in February 2018 by the Minister of Environmental Affairs (GN 114). In terms of the National Environmental Management Act (Act 107 of 1998, as amended) (NEMA) and the 2014 NEMA EIA Regulations promulgated in Government Gazette 40772 and Government Notice (GN) R326, R327, R325 and R324 on 7 April 2017, wind and solar PV projects located within a REDZs are subject to a Basic Assessment (BA) and reduced decision-making period by the authorities. A Basic Assessment (BA) Process in terms of Appendix 1 of the Environmental Impact Assessment (EIA) Regulations (2014, as amended) has therefore been undertaken for the proposed project. The competent authority for this BA is the national Department of Environmental Affairs.

The proposed WEF consists of the following:

- Wind Turbines (3 – 6.5 MW):
  - Up to 56 turbines (140 m tall hub, rotor diameter of 180 m and blade length of 90 m)
  - Concrete foundation (30x30x5m)
  - Crane pad (25.2 ha each)
- Collector Substation:
  - 33/132 kV of 2.25 ha
  - Transformer at each turbine (between 2x2 m – 10x10 m)
  - Underground 33 kV cabling
  - Overhead 33 kV at valley crossings
- Operations and Maintenance Building (1 ha)
- Construction Camp (12.6 ha)
- Access Roads:
  - Roads up to 12 m wide including stormwater control (82.44 ha partially existing)
  - Turn areas with a 50 m radius
- Other Infrastructure:
  - Wind measuring equipment (anemometers/wind sentry)
  - Fencing around the camp
  - Stormwater channels and culverts

As part of the specialist requirements and Water Use License (WUL), a flood and storm water assessment is required. This is in part due to the potential presence of watercourse features on site and the partially impervious nature of the proposed activity (infrastructure and roads). 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 focus of the flood assessment would be on where access roads or any related WEF infrastructure traverse or encroach on a watercourse. The SWMP and erosion control plan focuses on the infrastructure footprint areas and access roads. The location of the Oya WEF site can be seen in Figure 2.

The proposed energy facility will be located on the following properties:

FARM DESCRIPTION	21-DIGIT SURVEYOR GENERAL (SG) CODE
Western Cape	
Portion 1 of 156 Gats Rivier Farm	C01900000000015600001
Portion 2 of 156 Gats Rivier Farm	C01900000000015600002
Remainder of 156 Gats Rivier Farm	C01900000000015600000
Portion 1 of 157 Riet Fontein Farm	C01900000000015700001
Portion 1 of 158 Amandelboom Farm	C01900000000015800001
Remainder of 158 Amandelboom Farm	C01900000000015800000
Portion 1 of 159 Oliviers Berg Farm	C01900000000015900001
Remainder of 159 Oliviers Berg Farm	C01900000000015900000
Portion 2 of 157 Riet Fontein Farm	C01900000000015700002
Remainder of 161 Muishond Rivier Farm	C01900000000016100000
Remainder of 395 Klipbanks Fontein Farm	C01900000000039500000
Northern Cape	
Portion 4 of 193 Urias Gat Farm	C07200000000019300004
Portion 6 of 193 Urias Gat Farm	C07200000000019300006
Remainder of 193 Urias Gat Farm	C07200000000019300000
Remainder of 194 Matjes Fontein Farm	C07200000000019400000
Remainder of 196 Karree Kloof Farm	C07200000000019600000
Road Access	
Portion 169 of Zeekoegat Farm	C07200000000016900000
Portion 1 of 170 Roodeheuvel Farm	C07200000000017000001
Rem of 170 Roodeheuvel Farm	C07200000000017000000
Rem of 190 Wind Heuvel Farm	C07200000000019000000
Portion 1 of 190 Wind Heuvel Farm	C07200000000019000001
Portion 5 of 193 Urias Gat Farm	C07200000000019300005
Rem of 171 Vink Kuil Farm	C07200000000017100000
Alkant Rem/220 Farm	C07200000000022000000
Portion 1 of 174 Lange Huis Farm	C07200000000017400001

1.2 Impact of Wind Energy Farms 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).
- 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.

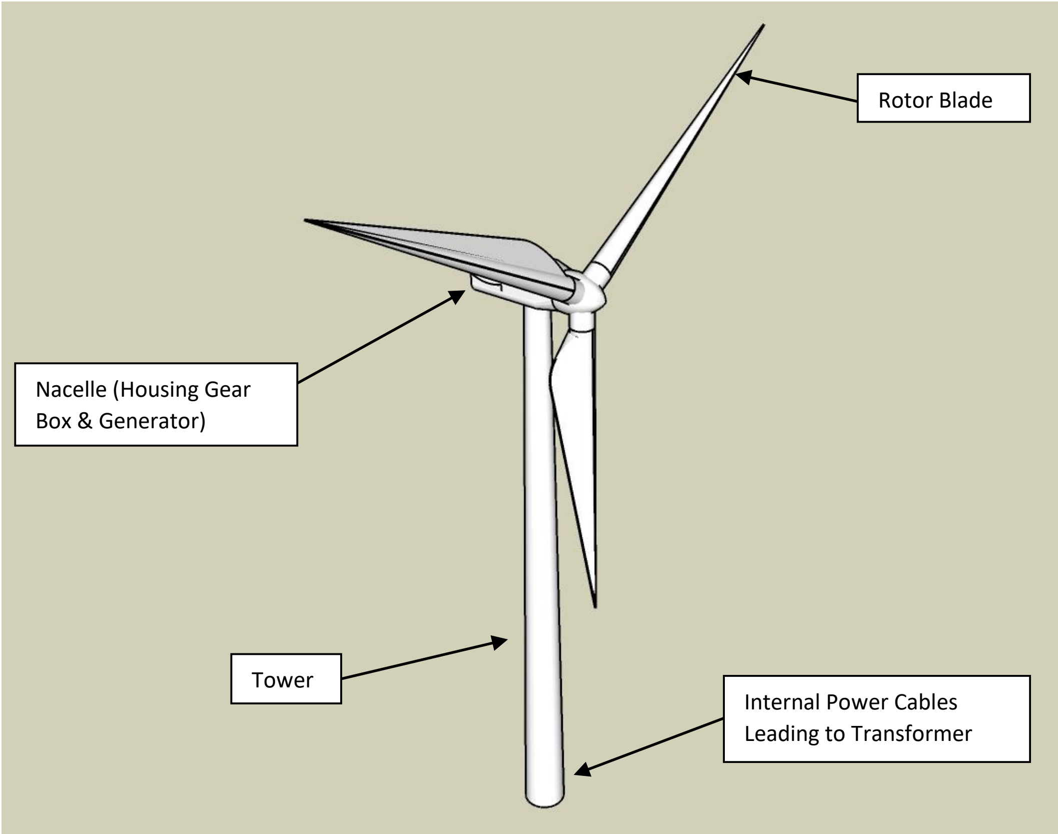


Figure 1 Typical design of a wind turbine (Suzlon model)

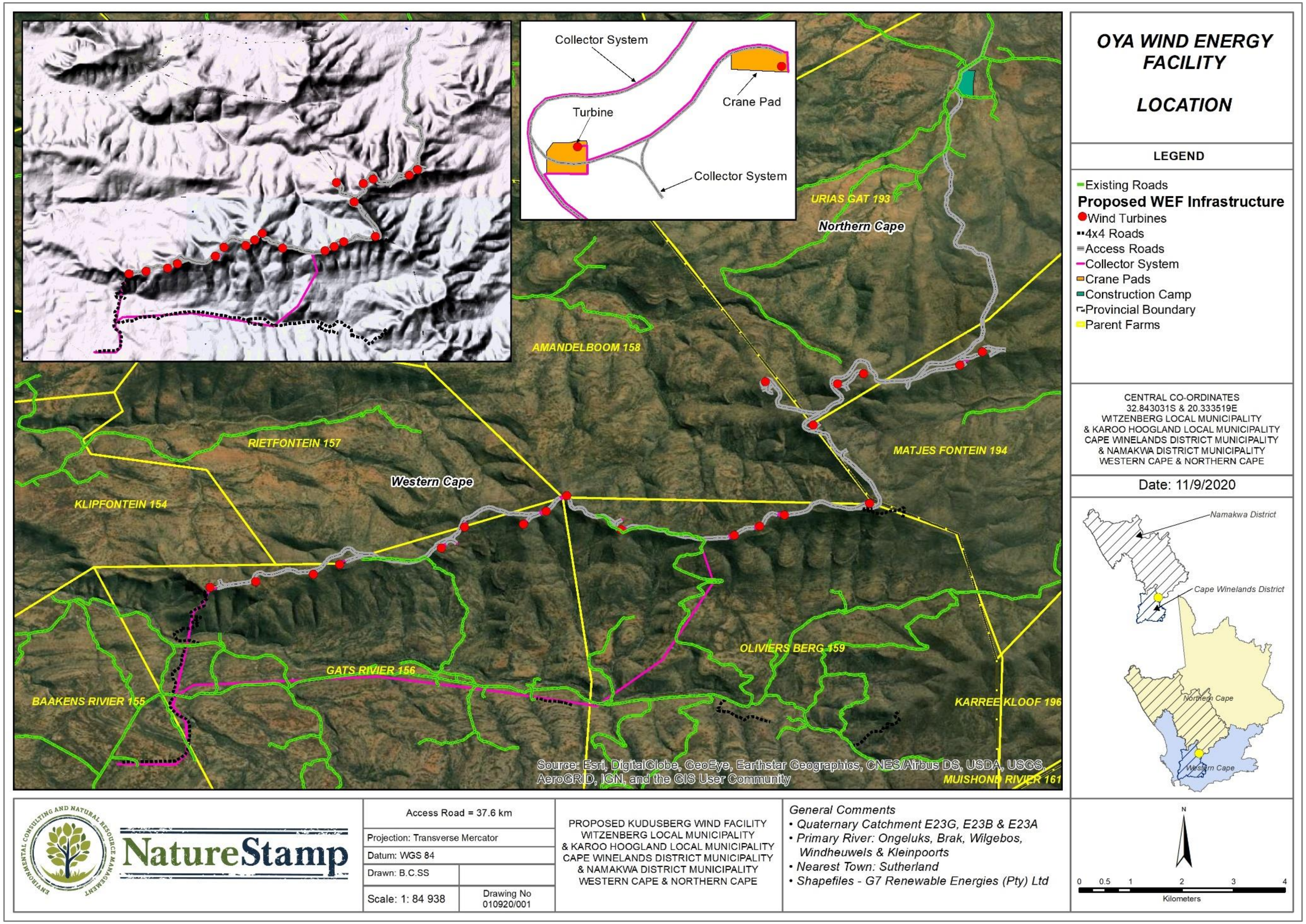


Figure 2 Locality map of the proposed Oya WEF

1.3 Terms of reference

NatureStamp has been appointed to compile a flood assessment, storm water management plan (SWMP) for the WEF and existing roads. The SWMP is in accordance with Government Notice 704 (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 year return period);
  b. Determination of the capability of proposed structures; and
  c. Recommendation of mitigation options and improvements.

- 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.

- Water balance assessment:
  a. analysing climate data from the SAWS and other databases using nearby rainfall stations (input or known data);
  b. determining any water demands and water outputs; and
  c. determining whether water in the system is clean or contaminated.
  d. 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.
  e. 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 IWWMP and help the land owners to manage their water appropriately.

- 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.

2. STUDY SITE

The site is located along the catchment divide of Quaternary Catchments E23G, E23B and E23A, falling under the Olifants/Doorn Management Area (WMA). The proposed WEF area sits on the plateau of Roggeveld mountain range that is almost entirely natural excepts for some small structures and gravel roads.

The proposed WEF 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, it was previously used for low intensity grazing however the properties are no longer actively used for agricultural activities, likely due to limited water.

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 Gatsrivier (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**

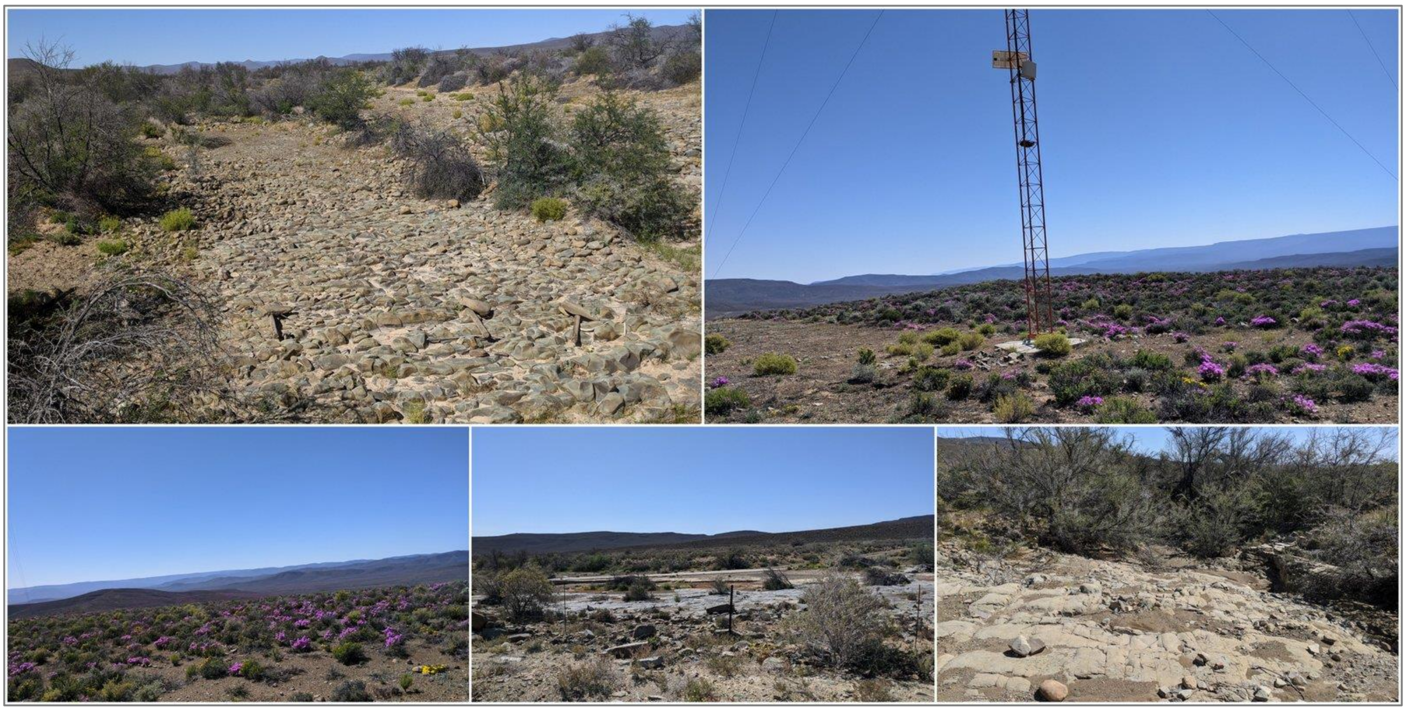


Figure 3 General setting of the proposed Oya WEF site

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 Government Notice 704 (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).

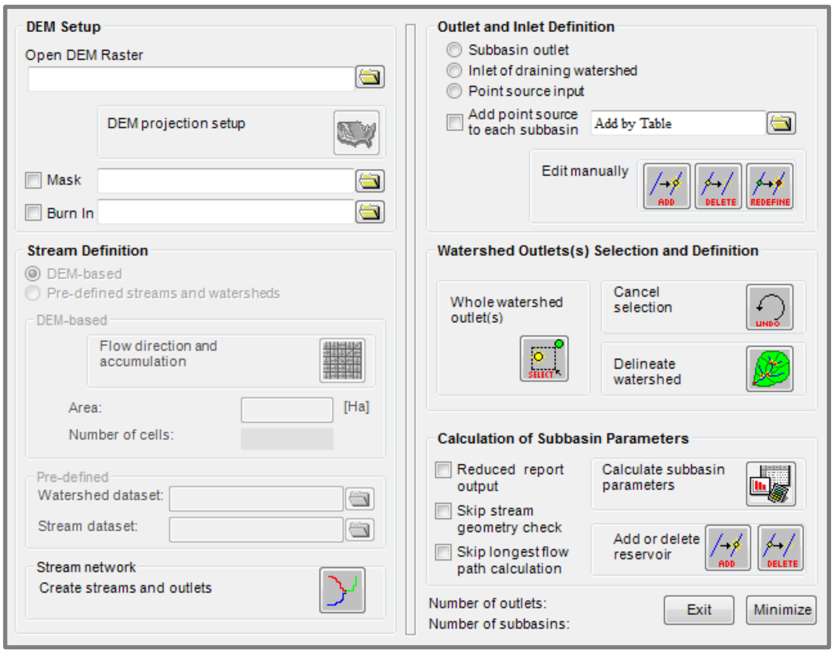


Figure 4 Soil Water Assessment Tool (*SWAT*) watershed delineation tool for sub-catchment delineation and stream network creation

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 km^2. 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.

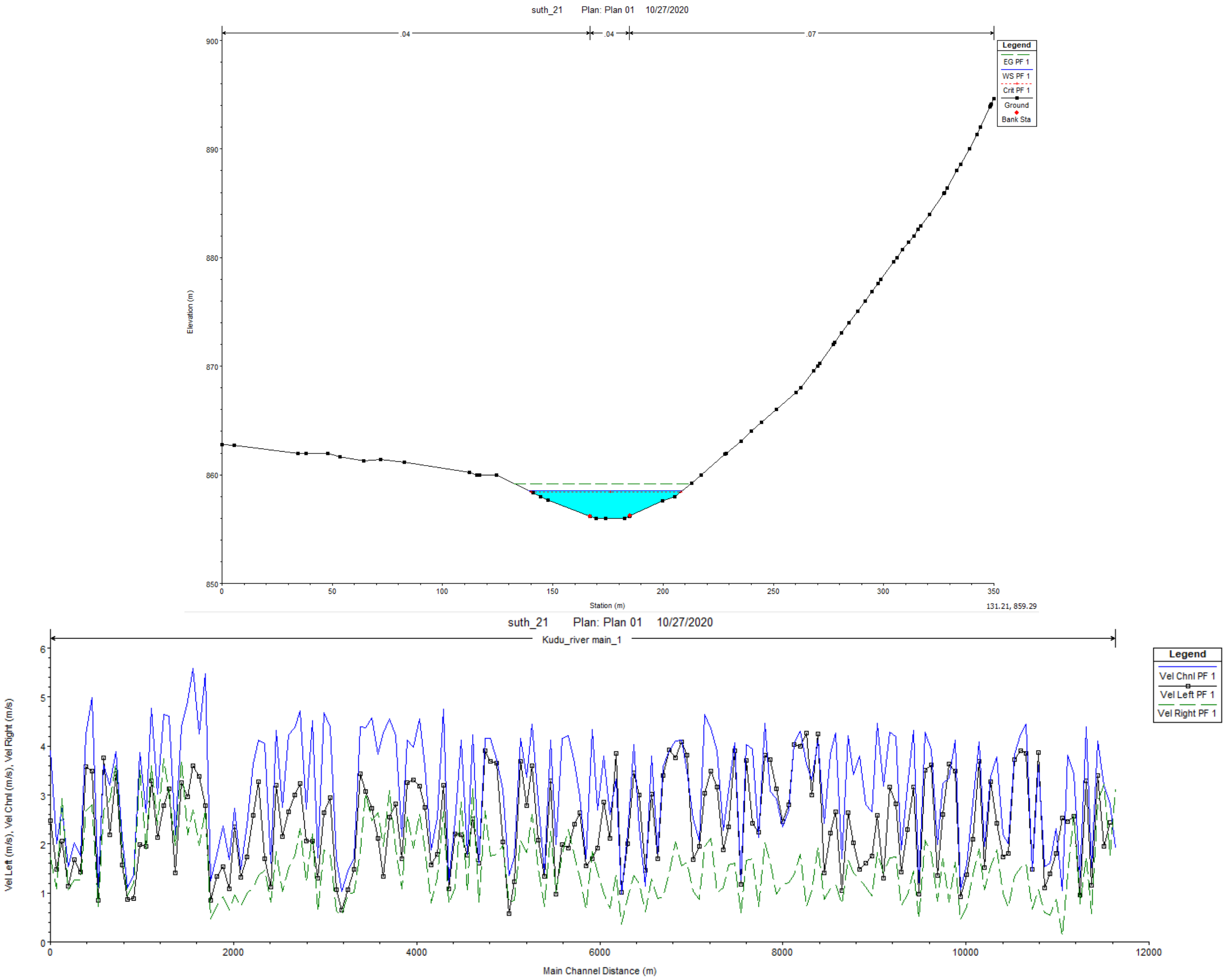


Figure 5 Channel cross sections and channel velocities developed for the relevant sections of the Ongeluks tributary

At each profile, a unique peak flow was calculated for each return period. 15 different volumes (linked to the 15 unique profiles) were calculated using either flow or design rainfall calculations.

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.

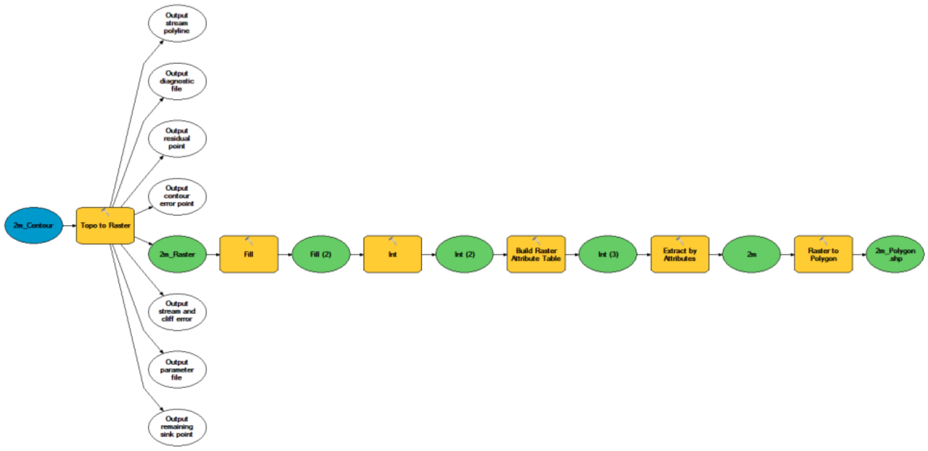


Figure 6 GIS model for flood generation in small channels

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 recommendations that the 1:50 year return design for a 30-minute storm was is used as a typical event to design for. The areas of the proposed infrastructure can be seen in Table 4.

Table 4 Activity/Infrastructure areas

Activity/Infrastructure	Impervious	Area
Access Roads and culverts	Yes	338 830 m^2
4x4 Roads	Partial	134 844 m^2
Construction Camp & Operations Building	Yes	125 773 m^2
Crane Pads incl. turbine and substation	Yes	114 755 m^2
Collector System	No	119 863 m^2

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 general 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 Ongeluks tributary (and its 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. More information is available from the Freshwater Ecological Report (du Preez *et al*., 2020).

Only small artificial FEPA dams were identified within the study site.

5.1.2 Terrain, Soils, Geology & Vegetation

Contour lines (2 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 moun-tain 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 scat-tered 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, skel-etal soils. Region is classified as Fc land type (to a large extent), with Ib land type 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 (21st - 22nd September) 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.

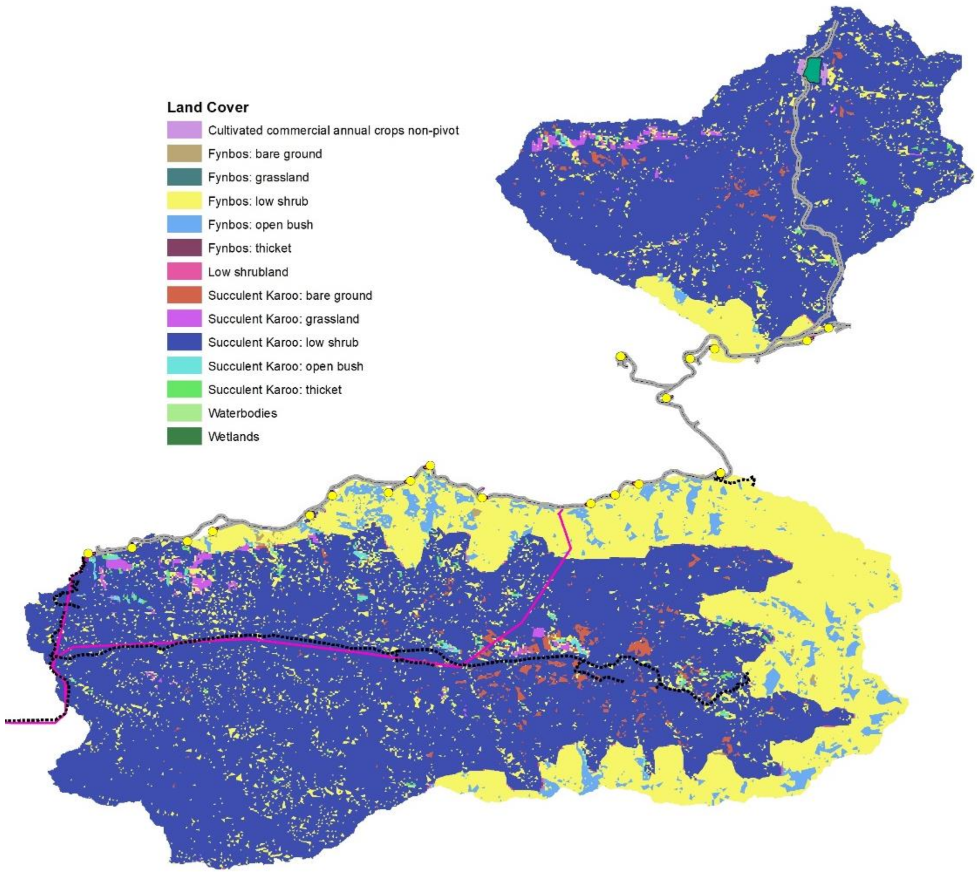


Figure 7 Land cover for the Oya WEF catchment area

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

Land Use	Area (ha)	Percentage
Cultivated/Commercial	8.71	0.07
Fynbos: bare ground	13.02	0.11
Fynbos: grassland	2.93	0.02
Fynbos: low shrub	2833.95	23.87
Fynbos: open bush	325.76	2.74
Fynbos: thicket	0.36	0.00
Low Shrubland	12.07	0.10
Succulent Karoo: bare ground	147.83	1.25
Succulent Karoo: grassland	85.38	0.72
Succulent Karoo: low shrub	8354.77	70.38
Succulent Karoo: open bush	40.90	0.34
Succulent Karoo: thicket	44.63	0.38
Waterbodies	0.63	0.01
Wetlands	0.39	0.00

The catchment was divided into sub-catchments based on connections between tributaries (Figure 8). This was undertaken using the Soil Water Assessment Tool (SWAT). The catchment area of Oya 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.

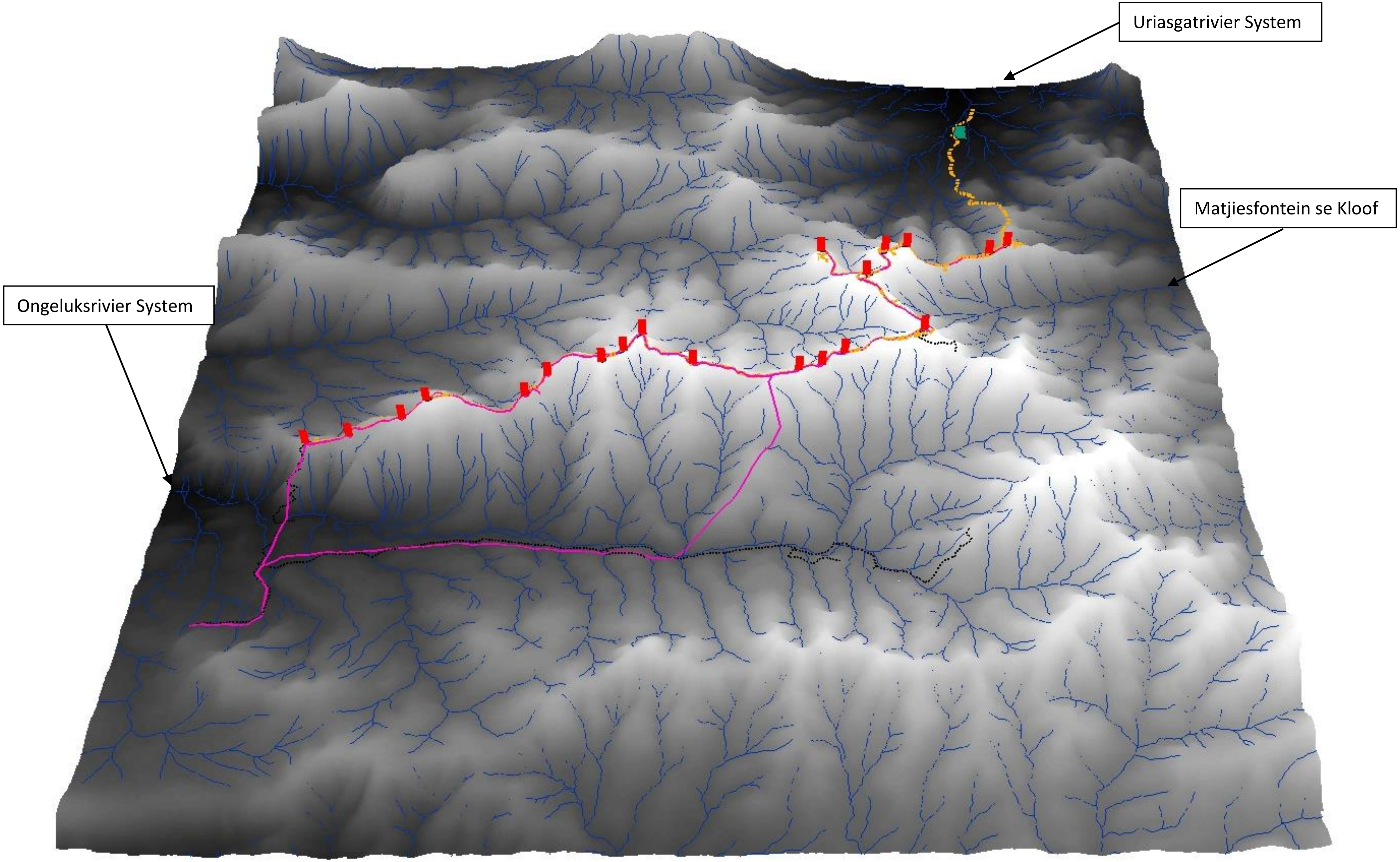


Figure 8 Terrain model for the catchment associated with the proposed Oya WEF

5.2 Climate Analysis

The long term annual rainfall data (Station 0044765 W – 35 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 9 – Lynch, 2003; Climate Forecast System Reanalysis (CFSR)). Some inconsistencies were identified in this record (e.g. some missing data in the early1900s 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)
0044134 W	315	314	120	16.7	82.5	836	Nooitgedag
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)
0066027 W	259	259	120	56.5	43.1	1372	Dumure

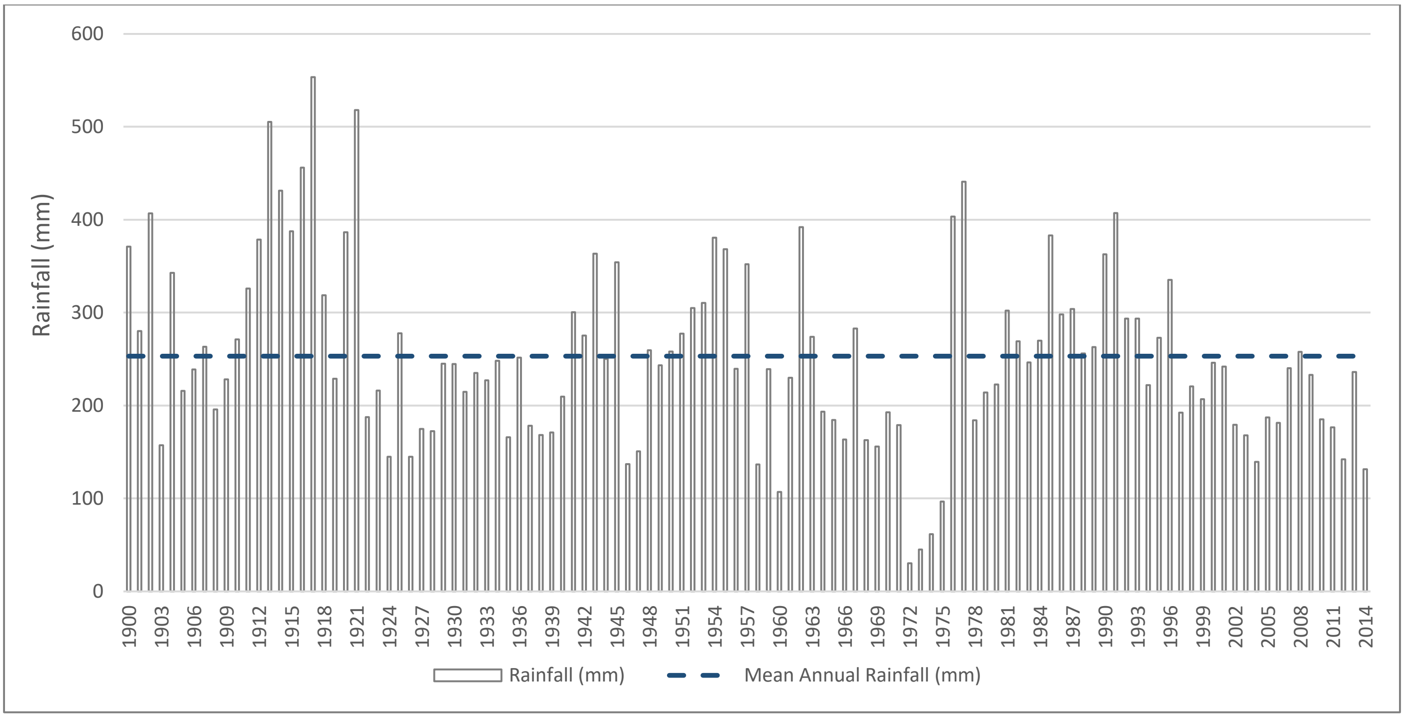


Figure 9 Long-term annual rainfall (annual in blue) near the proposed Oya WEF

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 Oya 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)

5.5 Design Peak Discharge

The design runoff results obtained for the 1:20, 1:50 and 1:100 year flood events for the various river reaches are summarized in Table 7. 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 would discharge a total of 172.9 $m^3.s^{-1}$ (Table 8).

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

Peak Discharge ($m^3.s^{-1}$)	Return Period						
	2	5	10	20	50	100	200
Rational	147.472	231.040	303.977	388.220	510.776	626.142	723.227
SDF	23.75	76.19	124.41	178.73	259.43	327.00	398.58
SCS-SA	42.6	96.9	146.7	210.6	314.5	411.1	522.7

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 11), whereas the area with negative results illustrated the dry areas not inundated by the flood. Inundation can be seen along the watercourse (Figure 11). Further results are provided in Annexure B, C and D.

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

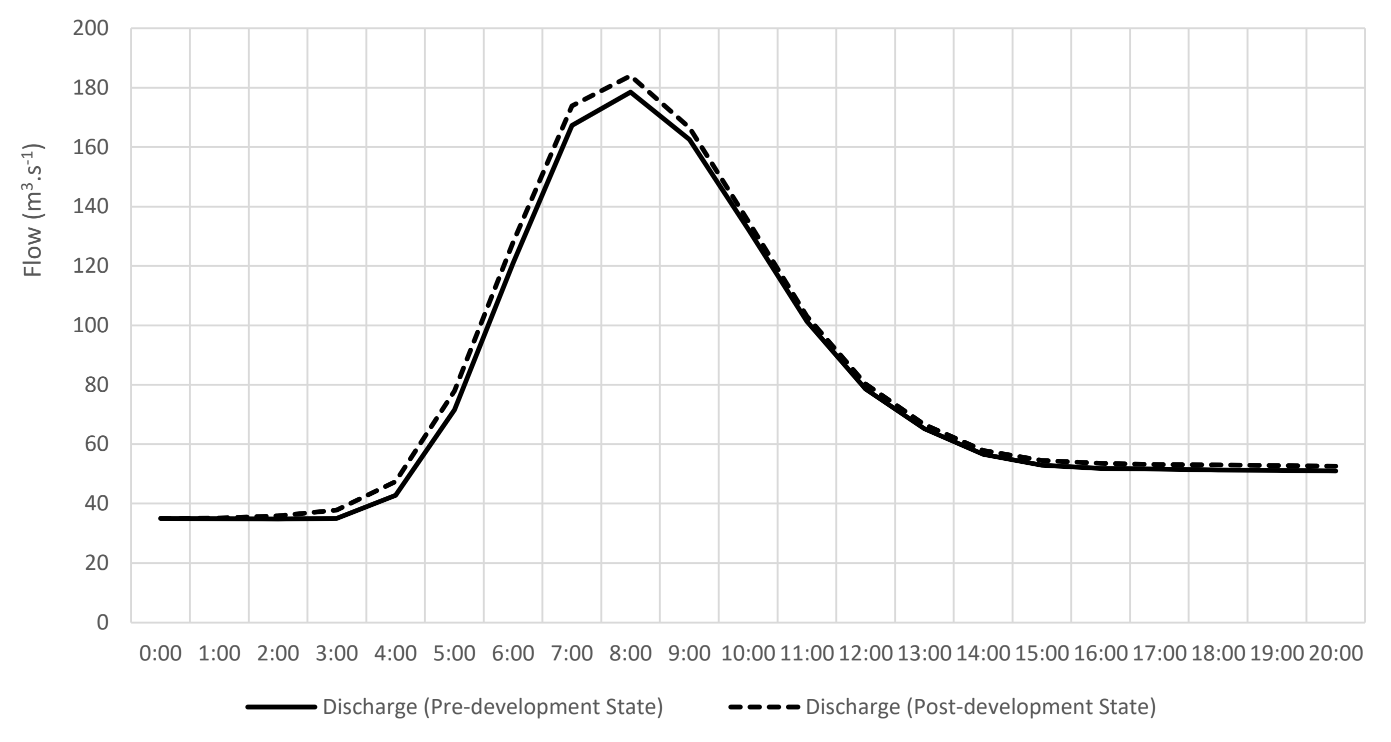


Figure 10 Pre- and post-development 1:50 year hydrograph for the proposed Oya WEF

Through the flood analysis, it is clear that the proposed infrastructure (Construction camp, crane pads and offsite 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. 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 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 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.

The location of the existing boreholes that would potentially be used on site were confirmed. Of the boreholes identified, the most suitably located would be the Urias Gat de List borehole as it is outside of the 1:100 year flood extent and in close proximity to proposed infrastructure (Table 9 and Figure 11).

Table 9 Existing boreholes in relation to the proposed Oya WEF

Borehole	X- Coordinate	Y-Coordinate	Within 100 Year Flood (Y/N)
RE/159, Oliviers Berg, Hendrik Visser	20.30307600000	-32.89324100000	N
1/156, Gats Rivier, Hendrik Visser	20.24179300000	-32.88989600000	N
1/157, Rietfontein Spitskop Trust	20.23319166700	-32.84999722200	N/A
2/157, Rietfontein Spitskop Trust	20.26139722200	-32.84602777800	N/A
1/159, Oliviers Berg, P U Uys	20.33695477300	-32.89072418500	N
6/196 Urias Gat De List borehole	20.37005670700	-32.79803754800	N
1/190 Wind Heuvel De List Trust borehole	20.32240102800	-32.77290353700	Y

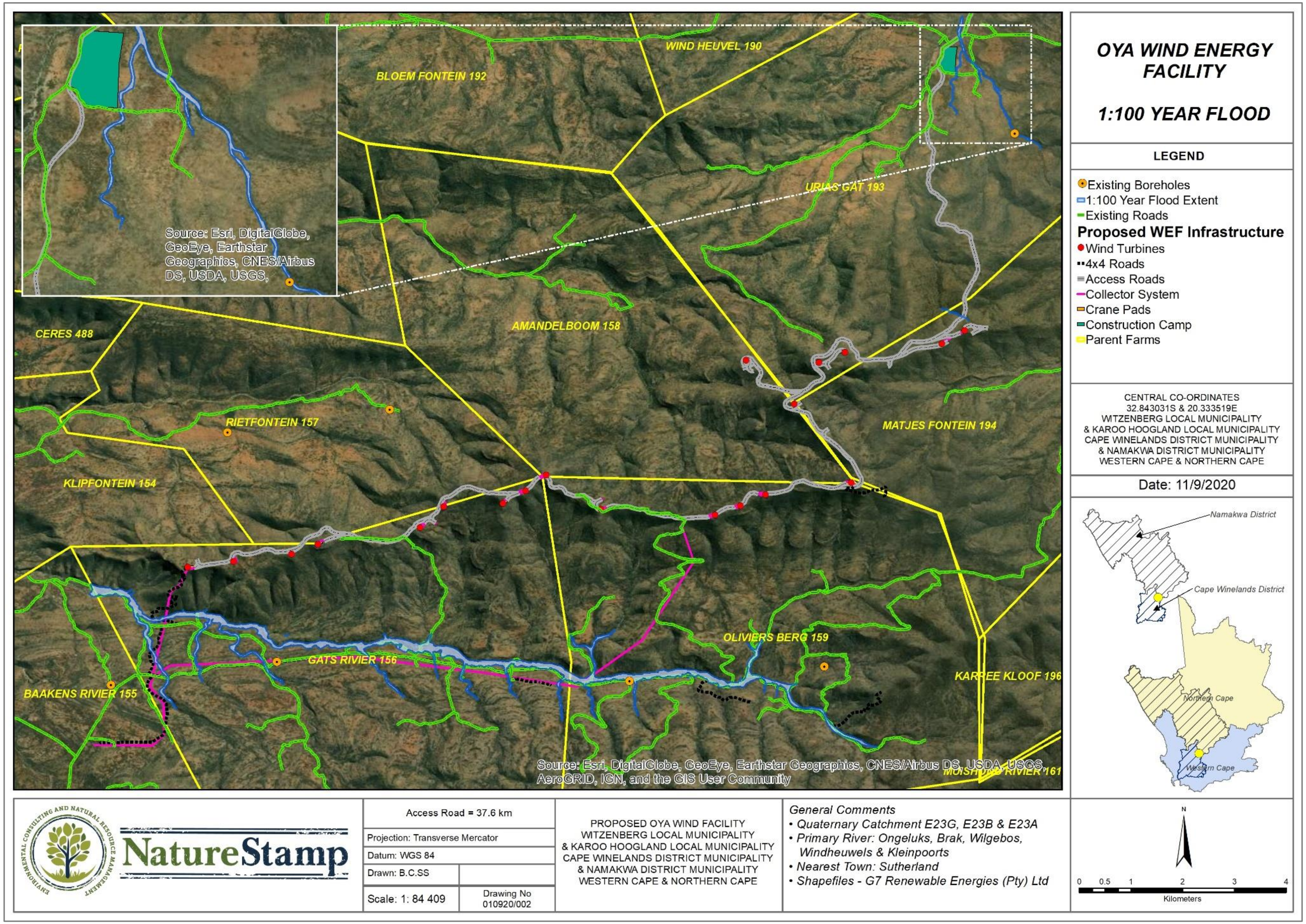


Figure 11 Steady state analysis of the 1:100 year flood event for the proposed Oya WEF

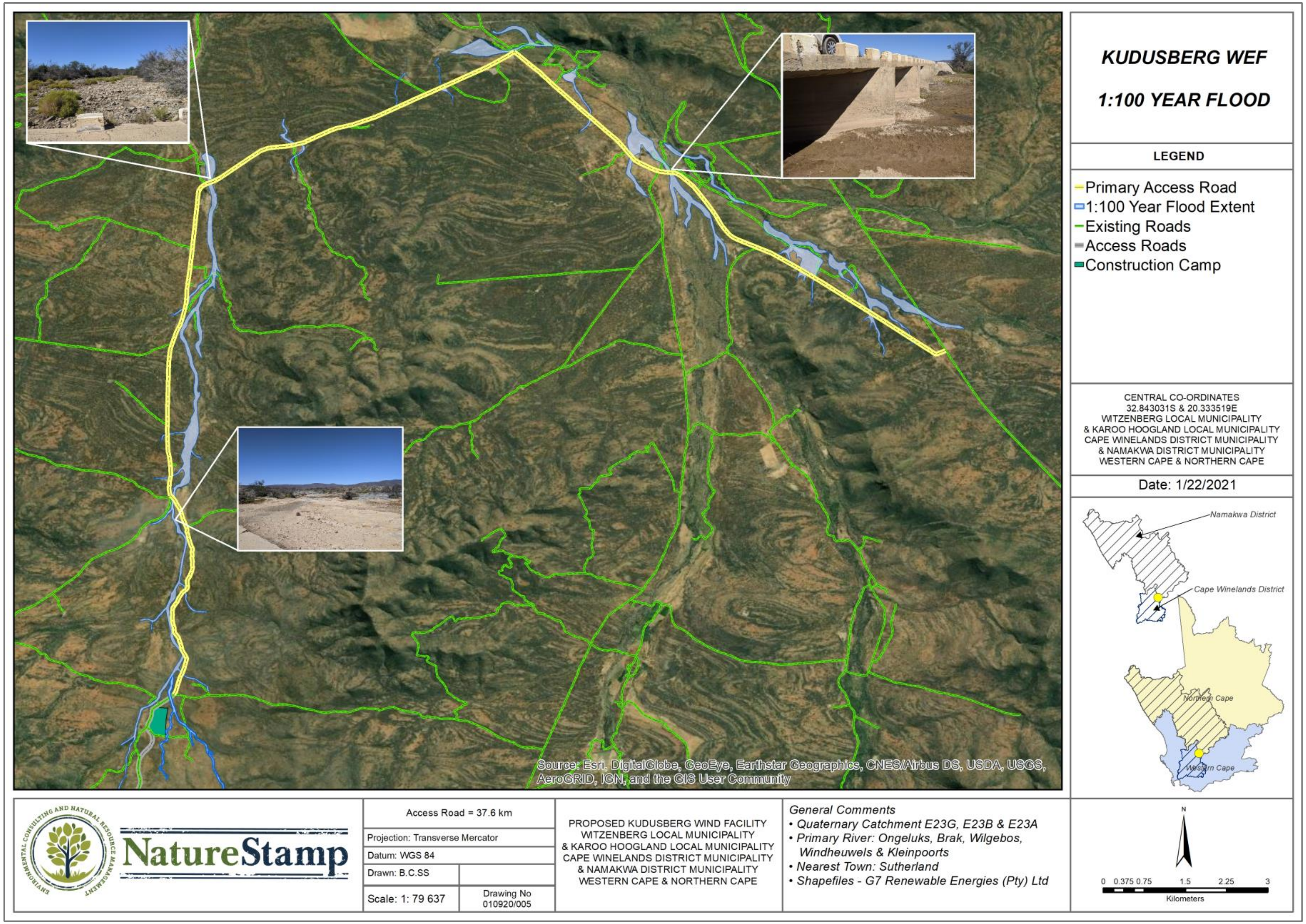


Figure 12 Steady state analysis of the 1:100 year flood event for the proposed Oya WEF primary access roads

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, showing 85.4mm/h. Peak flows shows an 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 10 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. During such a storm event, the depth of flow on the surfaces would be **24.06 mm**.

The results show that each cut-off drain could handle **0.126 $m^3.s^{-1}$** after which water would exceed the channel and flows would not be attenuated. As such, if a cutoff 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

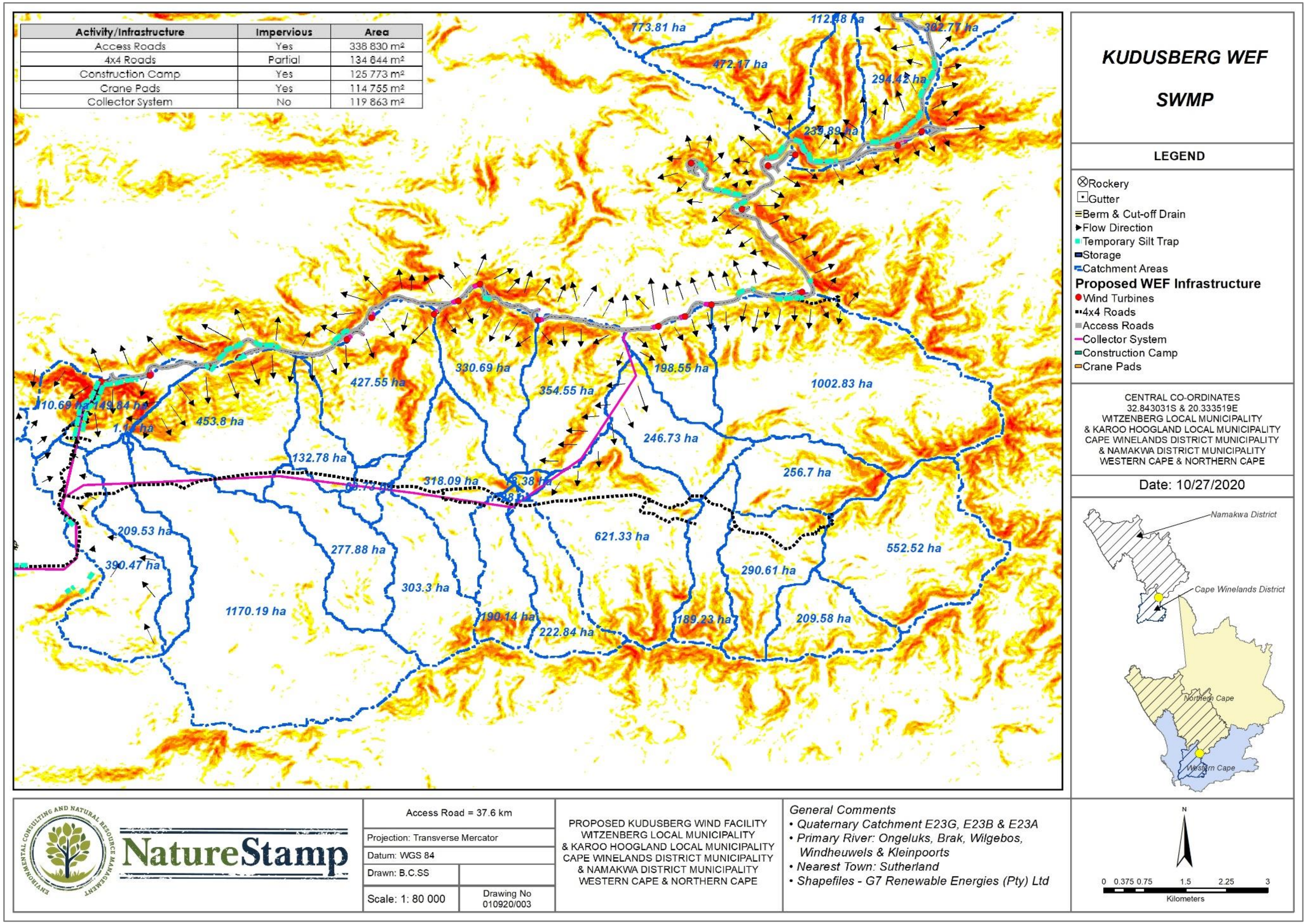
- Cut-off drains as per the design recommendations must be installed to facilitate the control of surface water runoff velocities from roads (250 mm depth, variable width depending on site/existing road conditions);
- Any erosion caused from excess discharge adjacent to road and/or crane pad areas must 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 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 13 Existing lay-down area and turbine for the nearby Perdekraal site

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 14 & 15.

All runoff under the development footprint can and should be contained and managed within the site boundary of each crane pad. 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. Underground cabling areas should also be completely rehabilitated once complete. Guidelines should be followed based on the wetland/riparian assessments and rehabilitation plan.



Activity/Infrastructure	Impervious	Area
Access Roads	Yes	338 830 m²
4x4 Roads	Partial	134 844 m²
Construction Camp	Yes	125 773 m²
Crane Pads	Yes	114 755 m²
Collector System	No	119 863 m²

Figure 14 Storm water management plan for linear servitudes showing high risk area in red

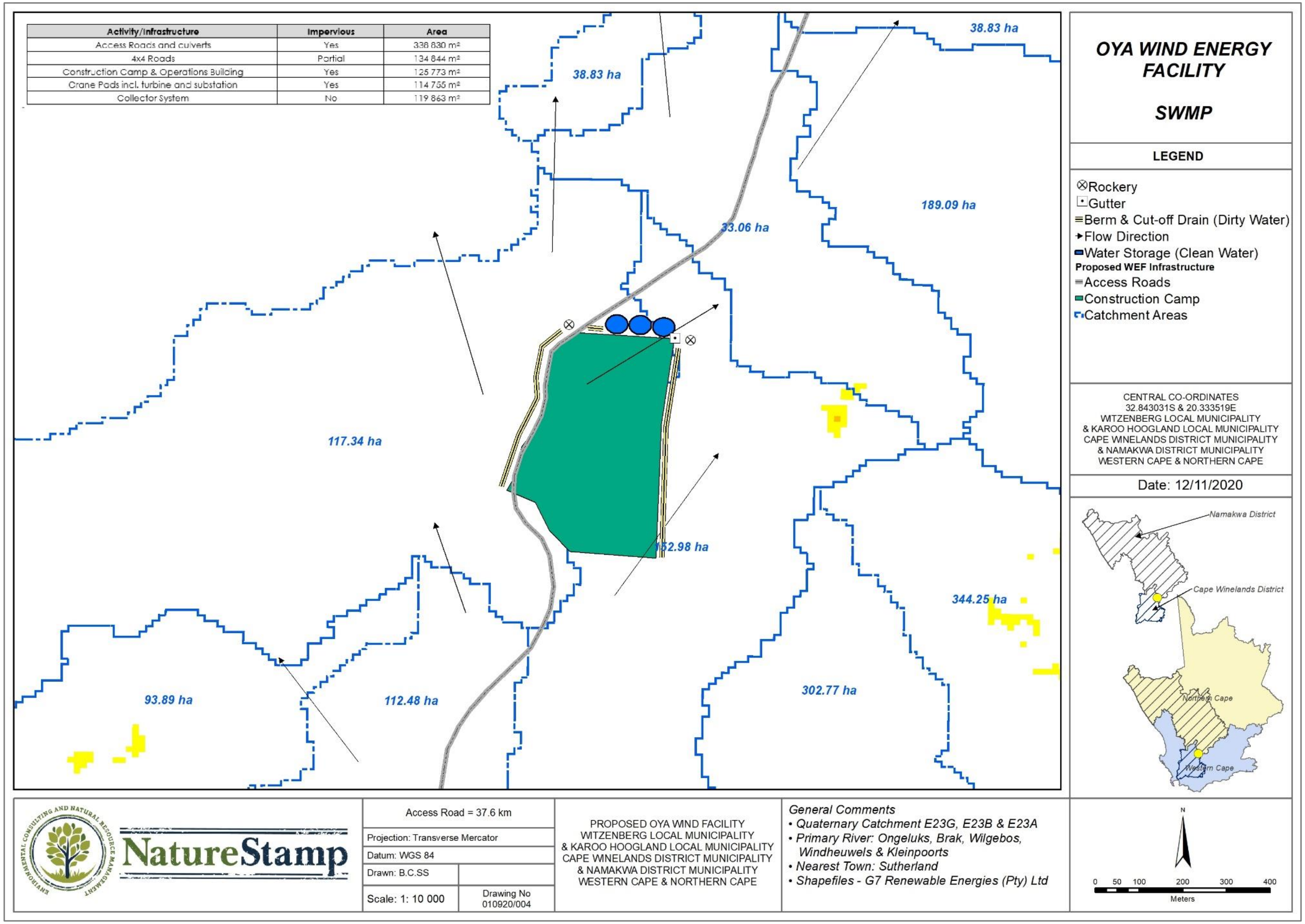
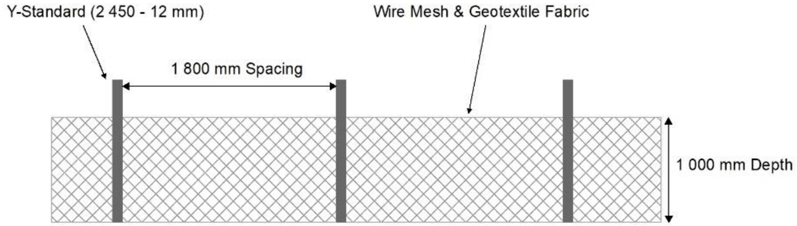
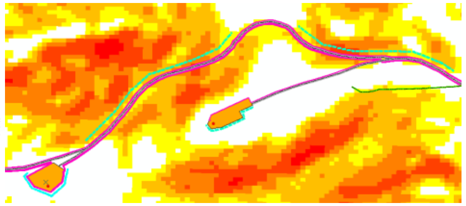
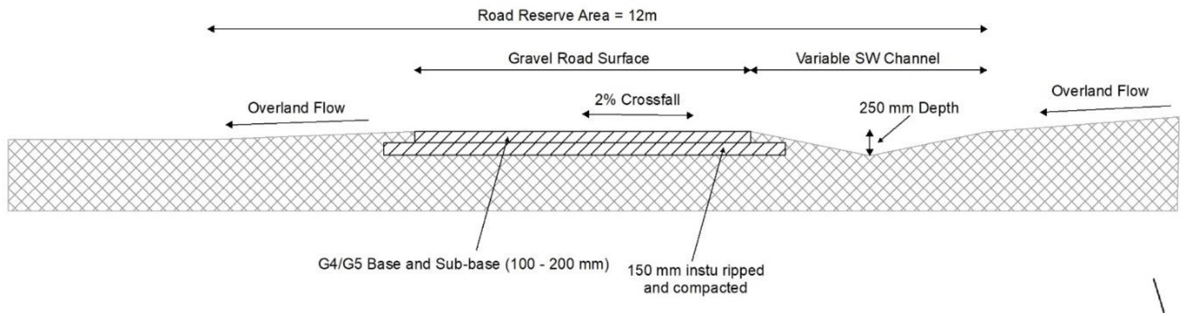


Figure 15 Storm water management plan for infrastructure showing high risk area in yellow/red

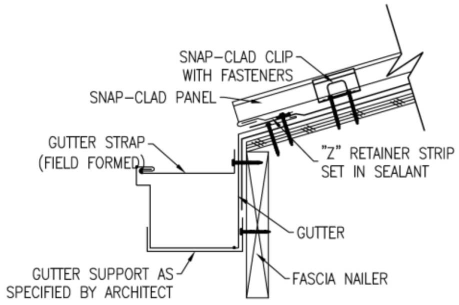
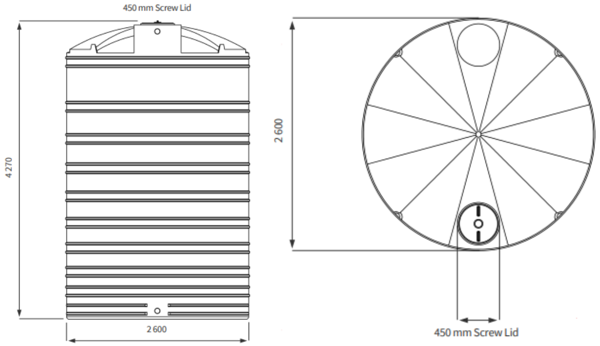
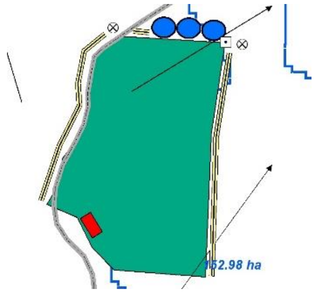
Table 10 Intervention measures per unit at Oya

<table>
<tr><th>Unit</th><th>Activity/Risk</th><th>Severity</th><th>Intervention</th></tr>
<tr><td colspan="4">Preliminary Stage</td></tr>
<tr><td>Access Roads</td><td>Route planning</td><td>Low</td><td>• Ensure watercourse crossings are kept to a minimum;
• Ensure steep slopes are avoided where possible;
• Ensure existing roads are used where possible.</td></tr>
<tr><td>Crane Pads</td><td>Site planning</td><td>Low</td><td>• Ensure sites are flat;
• Ensure sites are away from watercourses;
• Ensure the bearing capacity and bed rock is stable for foundations and platform weight.</td></tr>
<tr><td>Collector System</td><td>Route planning</td><td>Low</td><td>• Ensure watercourse crossings are kept to a minimum;</td></tr>
<tr><td colspan="4">Construction Stage</td></tr>
<tr><td>Access Roads</td><td>Expansion of gravel roads to between 8 to 12 meters. Grading of roads.

Risk of erosion and sedimentation</td><td>Moderate</td><td>• 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;</td></tr>
</table>

			• 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.
Crane Pads	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 (20 000 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. 
Collector System	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°.
Crane Pads	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.
Collector System	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 Potential Spill Scenarios

Due to the nature of the activity, there is a chance of potential spills occurring on site (equipment etc.). This is largely due to the fuel based generation facility, storage and battery storage. 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. The potential for contamination from battery storage or fuel generation.

3. 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.

5.11 Mitigation Measures and Recommendations (Spill Management Plan)

The Oya WEF and road grading should employ best stormwater management practises, as outlined below –

- Construction should take place during the dry season wherever possible. Construction should stop during heavy rains.
- Vegetation clearing should be limited as much as possible and plants rescued for rehabilitation.
- Directing clean stormwater towards natural drainage lines, contours and dispersing over grassed, flat areas (preferably the existing watercourses).
- Vehicles and equipment must be kept outside of watercourse buffers (du Preez *et al*., 2020) and flood lines.
- Vehicles and equipment must be kept clean and serviced off site.
- Staff/workers on-site must be educated on identifying potential erosion areas and best practice guidelines.
- Energy dissipating measures with regards to stormwater management should be installed where necessary to prevent soil erosion.
- The engineer or contactor must ensure that only clean stormwater runoff enters the environment.
- Drainage should be controlled to ensure that runoff from the project area does not culminate in off-site pollution, flooding or result in any damage to properties downstream, of any stormwater discharge points.
- Infrastructure must have the following:
    - Completely lined infrastructure (concrete bunded area), with the capacity to contain 120% of the total amount of petrochemicals stored within a specific tank. This excludes partially pervious areas that do not store chemicals;
    - Spills must be completely removed from the site unless an oil separator is installed;
    - Valves / taps to contain or release any spillage collected from storage tanks; and
    - Fire extinguisher equipment installed within each facility.

Furthermore, 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 DEDTEA and DWS.

5.12 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/m^2 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 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).

5.13 Water Balance

5.13.1 WR2012 Analysis (Sami, 2016)

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 4.86 million m^3 for the E23G catchment area of 747 km^2, 16.58 million m^3 for the E23A catchment area of 762 km^2 and 16.58 million m^3 for the E23B catchment area of 705 km^2

Table 11 WR2012 data relevant to the Oya 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)
E23G	747	747	23B	1810	1810	E2B	190	3.2	4.97	4.86	-2.2
E23A	762	762	15B	1895	1895	E2A	254	7.70	15.22	16.58	8.9
E23B	705	705	15B	1870	1870	E2A	240	5.90	15.22	16.58	8.9

5.13.2 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 16 & 17). 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.
- Storage facilities (20 000 L tanks x 3) 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.

Oya WEF Conceptual Water Balance

ANNUAL

IN			OUT	
From: Borehole Abstraction/Storage	5,592.00 m^3/yr	Storage for Staff drinking/wastewater Usage & Maintenance	To: Wastewater (removed from site) & Human Consumption	31,756 m^3/yr
From: External (Trucked in)	95,262.90 m^3/yr			
From: Rainwater Storage	5,000 m^3/yr		To: Channel Discharge (excess from construc activities)	74,098 m^3/yr
From: Runoff from Crane Pads	29,113 m^3/yr	Crane Pads, Construction Camp & Roads	To: Channel Discharge	102,888 m^3/yr
From: Runoff from Construction Camp	31,909 m^3/yr		To: Infiltration	44,095 m^3/yr
From: Runoff from Access Roads/Servitudes	85,961 m^3/yr			
TOTAL	**252,838 m^3/yr**		**TOTAL**	**252,838 m^3/yr**

KEY	
Measured Values	(green)
Calculated Values	(yellow)
Assumed Values	(red)

Figure 16 Annual water balance for the construction of the proposed Oya WEF

Oya WEF Conceptual Water Balance

ANNUAL

IN			OUT	
From: Borehole Abstraction/Storage	5,592.00 m^3/yr	Storage for Staff drinking/wastewater Usage & Maintenance	To: Wastewater (removed from site) & Human Consumption	3,178 m^3/yr
From: External (Trucked in)	- m^3/yr			
From: Rainwater Storage	5,000 m^3/yr		To: Channel Discharge (excess from storage facilities)	7,414 m^3/yr
From: Runoff from Crane Pads	29,113 m^3/yr	Crane Pads, Maintenance buildings	To: Channel Discharge	88,986 m^3/yr
From: Runoff from Maintenance Structures	12,048 m^3/yr		To: Infiltration	38,137 m^3/yr
From: Runoff from Access Roads/Servitudes	85,961 m^3/yr			
TOTAL	**137,715 m^3/yr**		**TOTAL**	**137,715 m^3/yr**

KEY	
Measured Values	(green)
Calculated Values	(yellow)
Assumed Values	(red)

Figure 17 Annual water balance for the operation of the proposed Oya WEF

6. CONCLUSION

The work undertaken for this report provides information on the flood and storm water components for the proposed Oya WEF facility. The areas associated with the development are relatively small. 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. Additionally, the boreholes identified on site are outside of the 1:100 year flood line and would be at very low risk of inundation/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.

Through the SWMP, dirty water was identified as water containing sediments around cleared areas during construction and potential spills/leaks from chemical storage areas. 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 vehicle. However, should this happen, effluent 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.

Water requirements and usage on-site is low as shown in the water balance. The site requires 100 854 m^3/annum during construction and 5 592 m^3/annum during operation.

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 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. These audits should continue for two years after the start of the operation phase. Focus should be placed on maintaining the integrity of the watercourse and the impact the development may have on soil structure.

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ANNEXURE A Design Rainfall Values for Oya 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 (°)	Latitude (')	Longitude (°)	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 (°)	Latitude (')	Longitude (°)	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 Oya WEF

Description of Catchment	**Ongeluks/Gatsrivier**						
River detail	**Ongeluks/Gatsrivier**						
Calculated by	**B. Scott-Shaw**			**Date**		**10-Oct-20**	
Physical characteristics							
Size of catchment (A)		**87**	km²	Rainfall Region			
Longest Watercourse		**16.5**	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*			
					Latitude:	*29°38'*	
				Tc =	*Longitude:*	*30°17'*	
				2.27521115			
3.4 Hours	2.3 Hours						
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	0.578 5
Adjusted for dolomitic areas, C_{1D} ($= C_1(1-D_{\%})+C_1D_{\%}(\Sigma(D_{factor} \times C_{s\%}))$)	0.5785	0.578 5	0.5785	0.5785	0.5785	0.578 5	0.578 5

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

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

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} ($= C_{1D} \times F_t$)	0.433875	0.4628	0.491725	0.52065	0.549575	0.5785	0.5785
Combined run-off coeffiecient C_T ($= \alpha C_{1T} + \beta C_2 + \gamma C_3$)	0.433875	0.4628	0.491725	0.52065	0.549575	0.5785	0.5785
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 ($= P_{iT} \times ARF_T$)	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),	147.472	231.040	303.977	388.220	510.776	626.142	723.227

ANNEXURE C SDF Method for the Oya WEF

Description of catchment	Ongeluks/Gatsrivier		
River detail	Ongeluks Tributary		
Calculated by	BCSS	**Date**	10 October 2020

Physical characteristics

Size of catchment (A)	87	km²	Time of Concentration (T_C)	$T_c = \left(\frac{0,87 L^2}{1000 S_{av}}\right)^{0,385}$	2.28	hours
Longest watercourse (L)	16.5	km				
Average slope (S_{av})	0.028	m/m				
SDF basin (0)#	19		Time of concentration, t (= 60 T_C)		137	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)	9.83	16.58	21.69	26.80	33.55	38.66	43.77

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), $Q_T = 0.278 \times C_T I_T A$	23.75	76.19	124.41	178.73	259.43	327.00	398.58

ANNEXURE D SCS Results for the Oya WEF

```
CATCHMENT NAME                      :  Ongeluks
 PROJECT NO                         :  Oya WEF
 RUN NO                             :  1
 TOTAL CATCHMENT AREA (km^2)        :  87.00
 STORM INTENSITY DISTRIBUTION TYPE :  2
 CATCHMENT LAG TIME (h)             :  1.42
 COEFFICIENT OF INITIAL ABSTRACTION:  0.10

 CURVE NUMBERS:           Initial    Final
   Sub-catchment 1         79        73.2
   Sub-catchment 2         79        75.4
   Sub-catchment 3         75        71.8
   Sub-catchment 4         82        75.7

 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                  7.2   15.6   23.3   33.2   49.2   64.1   81.3
   Sub-catchment 2                  8.3   17.5   25.7   36.2   52.9   68.3   86.0
   Sub-catchment 3                  6.5   14.5   21.9   31.5   47.1   61.6   78.4
   Sub-catchment 4                  8.5   17.7   26.0   36.6   53.4   68.9   86.7

 TOTAL RUNOFF DEPTH (mm)            7.7   16.4   24.4   34.6   50.9   66.0   83.4

 DESIGN STORMFLOW VOLUME
 (millions m^3)
   Sub-catchment 1                  0.2    0.4    0.5    0.8    1.2    1.5    1.9
   Sub-catchment 2                  0.2    0.3    0.5    0.7    1.1    1.4    1.7
   Sub-catchment 3                  0.1    0.3    0.4    0.5    0.8    1.1    1.4
   Sub-catchment 4                  0.2    0.5    0.7    1.0    1.4    1.8    2.3

 TOTAL STORMFLOW VOLUME             0.7    1.4    2.1    3.0    4.4    5.7    7.3
 (millions m^3)

 COMPUTED CURVE NUMBER             74.2   74.2   74.2   74.2   74.2   74.2   74.2

 PEAK DISCHARGE (m^3/s)            42.6   96.9  146.7  210.6  314.5  411.1  522.7


 *******************************************************************
RETURN PERIOD (years)   =      2
DESIGN RAINFALL   (mm)  =     39
STORM DISTRIBUTION TYPE =      2
CURVE NUMBER (computed) =   74.2
LAG TIME (h)            =    1.4
PEAK DISCHARGE (m^3/s)  =  42.56
 *******************************************************************
    TIME                 DISCHARGE
  (minutes)       (cubic metres/sec)      (litres/sec)

     650.              0.000                 0.
     666.              0.016                16.
     681.              0.084                84.
     697.              0.290               290.
     712.              0.976               976.
     728.              5.555              5555.
     743.             11.638             11638.
     759.             18.552             18552.
     774.             25.996             25996.
     790.             33.692             33692.
     805.             41.056             41056.
     821.             42.564             42564.
     837.             41.965             41965.
     852.             40.324             40324.
     868.             37.980             37980.
     883.             35.105             35105.
     899.             31.802             31802.
     914.             28.146             28146.
     930.             24.210             24210.
     945.             20.081             20081.
     961.             15.993             15993.
     976.             14.013             14013.
     992.             12.740             12740.
    1007.             11.780             11780.
    1023.             11.010             11010.
    1039.             10.369             10369.
    1054.              9.823              9823.
    1070.              9.349              9349.
    1085.              8.933              8933.
    1101.              8.564              8564.
    1116.              8.232              8232.
    1132.              7.933              7933.
```

1147.	7.660	7660.
1163.	7.411	7411.
1178.	7.183	7183.
1194.	6.971	6971.
1209.	6.776	6776.
1225.	6.594	6594.
1241.	6.424	6424.
1256.	6.265	6265.
1272.	6.116	6116.
1287.	5.975	5975.
1303.	5.843	5843.
1318.	5.718	5718.
1334.	5.600	5600.
1349.	5.488	5488.
1365.	5.381	5381.
1380.	5.280	5280.
1396.	5.183	5183.
1411.	5.091	5091.
1427.	5.003	5003.
1443.	4.904	4904.
1458.	4.717	4717.
1474.	4.443	4443.
1489.	4.083	4083.
1505.	3.639	3639.
1520.	3.111	3111.
1536.	2.524	2524.
1551.	2.001	2001.
1567.	1.541	1541.
1582.	1.143	1143.
1598.	0.805	805.
1613.	0.528	528.
1629.	0.310	310.
1645.	0.150	150.
1660.	0.047	47.

```
 ******************************************************************
RETURN PERIOD (years)   =      5
DESIGN RAINFALL   (mm)  =     56
STORM DISTRIBUTION TYPE =      2
CURVE NUMBER (computed) =   74.2
LAG TIME (h)            =    1.4
PEAK DISCHARGE (m^3/s)  =  96.91
 ******************************************************************
```

TIME (minutes)	DISCHARGE (cubic metres/sec)	(litres/sec)
557.	0.000	0.
572.	0.007	7.
588.	0.034	34.
603.	0.096	96.
619.	0.216	216.
635.	0.423	423.
650.	0.758	758.
666.	1.276	1276.
681.	2.070	2070.
697.	3.358	3358.
712.	6.003	6003.
728.	17.403	17403.
743.	31.694	31694.
759.	47.403	47403.
774.	63.844	63844.
790.	80.336	80336.
805.	95.371	95371.
821.	96.911	96911.
837.	94.085	94085.
852.	89.156	89156.
868.	82.848	82848.
883.	75.528	75528.
899.	67.432	67432.
914.	58.737	58737.
930.	49.611	49611.
945.	40.275	40275.
961.	31.324	31324.
976.	27.263	27263.
992.	24.684	24684.
1007.	22.749	22749.
1023.	21.203	21203.
1039.	19.920	19920.
1054.	18.831	18831.
1070.	17.888	17888.
1085.	17.061	17061.
1101.	16.327	16327.
1116.	15.670	15670.
1132.	15.078	15078.
1147.	14.540	14540.
1163.	14.049	14049.
1178.	13.598	13598.

1194.	13.183	13183.
1209.	12.798	12798.
1225.	12.440	12440.
1241.	12.107	12107.
1256.	11.796	11796.
1272.	11.504	11504.
1287.	11.229	11229.
1303.	10.971	10971.
1318.	10.727	10727.
1334.	10.496	10496.
1349.	10.278	10278.
1365.	10.070	10070.
1380.	9.873	9873.
1396.	9.685	9685.
1411.	9.506	9506.
1427.	9.334	9334.
1443.	9.143	9143.
1458.	8.789	8789.
1474.	8.275	8275.
1489.	7.602	7602.
1505.	6.772	6772.
1520.	5.788	5788.
1536.	4.694	4694.
1551.	3.721	3721.
1567.	2.864	2864.
1582.	2.124	2124.
1598.	1.497	1497.
1613.	0.981	981.
1629.	0.576	576.
1645.	0.278	278.
1660.	0.087	87.

```
 ******************************************************************
RETURN PERIOD (years)   =     10
DESIGN RAINFALL   (mm)  =     69
STORM DISTRIBUTION TYPE =      2
CURVE NUMBER (computed) =   74.2
LAG TIME (h)            =    1.4
PEAK DISCHARGE (m^3/s)  = 146.73
 ******************************************************************
```

TIME (minutes)	DISCHARGE (cubic metres/sec)	(litres/sec)
495.	0.000	0.
510.	0.006	6.
526.	0.029	29.
541.	0.081	81.
557.	0.178	178.
572.	0.338	338.
588.	0.584	584.
603.	0.936	936.
619.	1.412	1412.
635.	2.043	2043.
650.	2.876	2876.
666.	3.992	3992.
681.	5.540	5540.
697.	7.876	7876.
712.	12.366	12366.
728.	30.007	30007.
743.	51.707	51707.
759.	75.287	75287.
774.	99.713	99713.
790.	123.934	123934.
805.	145.576	145576.
821.	146.731	146731.
837.	141.558	141558.
852.	133.383	133383.
868.	123.265	123265.
883.	111.743	111743.
899.	99.165	99165.
914.	85.798	85798.
930.	71.897	71897.
945.	57.808	57808.
961.	44.469	44469.
976.	38.585	38585.
992.	34.866	34866.
1007.	32.084	32084.
1023.	29.865	29865.
1039.	28.026	28026.
1054.	26.466	26466.
1070.	25.117	25117.
1085.	23.935	23935.
1101.	22.888	22888.
1116.	21.951	21951.
1132.	21.106	21106.
1147.	20.340	20340.
1163.	19.640	19640.

1178.	18.999	18999.
1194.	18.408	18408.
1209.	17.861	17861.
1225.	17.353	17353.
1241.	16.880	16880.
1256.	16.438	16438.
1272.	16.023	16023.
1287.	15.634	15634.
1303.	15.268	15268.
1318.	14.922	14922.
1334.	14.595	14595.
1349.	14.285	14285.
1365.	13.991	13991.
1380.	13.712	13712.
1396.	13.446	13446.
1411.	13.193	13193.
1427.	12.951	12951.
1443.	12.681	12681.
1458.	12.187	12187.
1474.	11.471	11471.
1489.	10.536	10536.
1505.	9.384	9384.
1520.	8.019	8019.
1536.	6.503	6503.
1551.	5.154	5154.
1567.	3.968	3968.
1582.	2.941	2941.
1598.	2.073	2073.
1613.	1.359	1359.
1629.	0.797	797.
1645.	0.385	385.
1660.	0.120	120.

```
*******************************************************************
RETURN PERIOD (years)   =     20
DESIGN RAINFALL   (mm)  =     84
STORM DISTRIBUTION TYPE =      2
CURVE NUMBER (computed) =   74.2
LAG TIME (h)            =    1.4
PEAK DISCHARGE (m^3/s)  = 210.60
*******************************************************************
```

TIME (minutes)	DISCHARGE (cubic metres/sec)	(litres/sec)
448.	0.004	4.
464.	0.022	22.
479.	0.066	66.
495.	0.150	150.
510.	0.289	289.
526.	0.501	501.
541.	0.801	801.
557.	1.196	1196.
572.	1.698	1698.
588.	2.321	2321.
603.	3.086	3086.
619.	4.024	4024.
635.	5.180	5180.
650.	6.626	6626.
666.	8.483	8483.
681.	10.983	10983.
697.	14.659	14659.
712.	21.546	21546.
728.	47.208	47208.
743.	78.368	78368.
759.	111.953	111953.
774.	146.482	146482.
790.	180.415	180415.
805.	210.234	210234.
821.	210.596	210596.
837.	202.185	202185.
852.	189.668	189668.
868.	174.523	174523.
883.	157.506	157506.
899.	139.103	139103.
914.	119.696	119696.
930.	99.654	99654.
945.	79.488	79488.
961.	60.584	60584.
976.	52.430	52430.
992.	47.300	47300.
1007.	43.471	43471.
1023.	40.419	40419.
1039.	37.895	37895.
1054.	35.754	35754.
1070.	33.906	33906.
1085.	32.287	32287.
1101.	30.853	30853.

1116.	29.572	29572.
1132.	28.418	28418.
1147.	27.371	27371.
1163.	26.416	26416.
1178.	25.540	25540.
1194.	24.733	24733.
1209.	23.988	23988.
1225.	23.295	23295.
1241.	22.651	22651.
1256.	22.048	22048.
1272.	21.484	21484.
1287.	20.955	20955.
1303.	20.456	20456.
1318.	19.986	19986.
1334.	19.541	19541.
1349.	19.121	19121.
1365.	18.721	18721.
1380.	18.342	18342.
1396.	17.981	17981.
1411.	17.637	17637.
1427.	17.309	17309.
1443.	16.944	16944.
1458.	16.279	16279.
1474.	15.320	15320.
1489.	14.069	14069.
1505.	12.529	12529.
1520.	10.705	10705.
1536.	8.681	8681.
1551.	6.879	6879.
1567.	5.295	5295.
1582.	3.925	3925.
1598.	2.766	2766.
1613.	1.813	1813.
1629.	1.063	1063.
1645.	0.513	513.
1660.	0.160	160.

```
 *******************************************************************
RETURN PERIOD (years)   =     50
DESIGN RAINFALL   (mm)  =    106
STORM DISTRIBUTION TYPE =      2
CURVE NUMBER (computed) =   74.2
LAG TIME (h)            =    1.4
PEAK DISCHARGE (m^3/s)  = 314.55
 *******************************************************************
```

TIME (minutes)	DISCHARGE (cubic metres/sec)	(litres/sec)
370.	0.000	0.
386.	0.008	8.
401.	0.035	35.
417.	0.094	94.
433.	0.202	202.
448.	0.373	373.
464.	0.626	626.
479.	0.970	970.
495.	1.407	1407.
510.	1.944	1944.
526.	2.586	2586.
541.	3.342	3342.
557.	4.224	4224.
572.	5.250	5250.
588.	6.442	6442.
603.	7.834	7834.
619.	9.473	9473.
635.	11.436	11436.
650.	13.844	13844.
666.	16.896	16896.
681.	20.961	20961.
697.	26.877	26877.
712.	37.773	37773.
728.	76.437	76437.
743.	122.784	122784.
759.	172.331	172331.
774.	222.875	222875.
790.	272.079	272079.
805.	314.548	314548.
821.	313.156	313156.
837.	299.186	299186.
852.	279.413	279413.
868.	255.972	255972.
883.	229.957	229957.
899.	202.079	202079.
914.	172.898	172898.
930.	142.970	142970.
945.	113.075	113075.

961.	85.334	85334.
976.	73.647	73647.
992.	66.327	66327.
1007.	60.876	60876.
1023.	56.538	56538.
1039.	52.955	52955.
1054.	49.919	49919.
1070.	47.299	47299.
1085.	45.007	45007.
1101.	42.979	42979.
1116.	41.167	41167.
1132.	39.536	39536.
1147.	38.058	38058.
1163.	36.710	36710.
1178.	35.474	35474.
1194.	34.337	34337.
1209.	33.286	33286.
1225.	32.311	32311.
1241.	31.403	31403.
1256.	30.555	30555.
1272.	29.762	29762.
1287.	29.017	29017.
1303.	28.316	28316.
1318.	27.655	27655.
1334.	27.030	27030.
1349.	26.439	26439.
1365.	25.878	25878.
1380.	25.346	25346.
1396.	24.839	24839.
1411.	24.357	24357.
1427.	23.896	23896.
1443.	23.386	23386.
1458.	22.463	22463.
1474.	21.135	21135.
1489.	19.405	19405.
1505.	17.278	17278.
1520.	14.761	14761.
1536.	11.969	11969.
1551.	9.483	9483.
1567.	7.299	7299.
1582.	5.410	5410.
1598.	3.812	3812.
1613.	2.498	2498.
1629.	1.465	1465.
1645.	0.707	707.
1660.	0.220	220.

```
******************************************************************
RETURN PERIOD (years)   =    100
DESIGN RAINFALL   (mm)  =    125
STORM DISTRIBUTION TYPE =      2
CURVE NUMBER (computed) =   74.2
LAG TIME (h)            =    1.4
PEAK DISCHARGE (m^3/s)  = 411.10
******************************************************************
```

TIME (minutes)	DISCHARGE (cubic metres/sec)	(litres/sec)
339.	0.006	6.
355.	0.031	31.
370.	0.091	91.
386.	0.202	202.
401.	0.380	380.
417.	0.646	646.
433.	1.010	1010.
448.	1.474	1474.
464.	2.040	2040.
479.	2.711	2711.
495.	3.492	3492.
510.	4.388	4388.
526.	5.408	5408.
541.	6.564	6564.
557.	7.872	7872.
572.	9.355	9355.
588.	11.047	11047.
603.	13.001	13001.
619.	15.291	15291.
635.	18.023	18023.
650.	21.361	21361.
666.	25.574	25574.
681.	31.158	31158.
697.	39.236	39236.
712.	53.962	53962.
728.	104.698	104698.
743.	165.035	165035.
759.	229.204	229204.
774.	294.338	294338.

790.	357.356	357356.
805.	411.104	411104.
821.	407.724	407724.
837.	388.353	388353.
852.	361.673	361673.
868.	330.414	330414.
883.	295.975	295975.
899.	259.270	259270.
914.	221.026	221026.
930.	181.969	181969.
945.	143.131	143131.
961.	107.324	107324.
976.	92.465	92465.
992.	83.185	83185.
1007.	76.284	76284.
1023.	70.798	70798.
1039.	66.269	66269.
1054.	62.435	62435.
1070.	59.129	59129.
1085.	56.237	56237.
1101.	53.680	53680.
1116.	51.396	51396.
1132.	49.341	49341.
1147.	47.479	47479.
1163.	45.781	45781.
1178.	44.227	44227.
1194.	42.796	42796.
1209.	41.473	41473.
1225.	40.247	40247.
1241.	39.105	39105.
1256.	38.040	38040.
1272.	37.042	37042.
1287.	36.106	36106.
1303.	35.226	35226.
1318.	34.396	34396.
1334.	33.612	33612.
1349.	32.870	32870.
1365.	32.166	32166.
1380.	31.498	31498.
1396.	30.862	30862.
1411.	30.257	30257.
1427.	29.679	29679.
1443.	29.040	29040.
1458.	27.890	27890.
1474.	26.238	26238.
1489.	24.088	24088.
1505.	21.446	21446.
1520.	18.320	18320.
1536.	14.853	14853.
1551.	11.768	11768.
1567.	9.057	9057.
1582.	6.713	6713.
1598.	4.729	4729.
1613.	3.099	3099.
1629.	1.817	1817.
1645.	0.877	877.
1660.	0.273	273.

```
 ******************************************************************
RETURN PERIOD (years)   =    200
DESIGN RAINFALL   (mm)  =    146
STORM DISTRIBUTION TYPE =      2
CURVE NUMBER (computed) =   74.2
LAG TIME (h)            =    1.4
PEAK DISCHARGE (m^3/s)  = 522.70
 ******************************************************************
```

TIME (minutes)	DISCHARGE (cubic metres/sec)	(litres/sec)
293.	0.001	1.
308.	0.016	16.
324.	0.062	62.
339.	0.156	156.
355.	0.317	317.
370.	0.565	565.
386.	0.922	922.
401.	1.391	1391.
417.	1.972	1972.
433.	2.664	2664.
448.	3.470	3470.
464.	4.391	4391.
479.	5.430	5430.
495.	6.594	6594.
510.	7.890	7890.
526.	9.330	9330.
541.	10.927	10927.
557.	12.712	12712.

572.	14.723	14723.
588.	17.012	17012.
603.	19.647	19647.
619.	22.726	22726.
635.	26.387	26387.
650.	30.846	30846.
666.	36.452	36452.
681.	43.853	43853.
697.	54.504	54504.
712.	73.757	73757.
728.	138.469	138469.
743.	214.903	214903.
759.	295.827	295827.
774.	377.606	377606.
790.	456.298	456298.
805.	522.699	522699.
821.	516.711	516711.
837.	490.880	490880.
852.	456.057	456057.
868.	415.645	415645.
883.	371.391	371391.
899.	324.441	324441.
914.	275.710	275710.
930.	226.126	226126.
945.	177.012	177012.
961.	131.986	131986.
976.	113.544	113544.
992.	102.056	102056.
1007.	93.522	93522.
1023.	86.744	86744.
1039.	81.152	81152.
1054.	76.421	76421.
1070.	72.343	72343.
1085.	68.778	68778.
1101.	65.626	65626.
1116.	62.813	62813.
1132.	60.281	60281.
1147.	57.989	57989.
1163.	55.900	55900.
1178.	53.987	53987.
1194.	52.226	52226.
1209.	50.600	50600.
1225.	49.092	49092.
1241.	47.689	47689.
1256.	46.379	46379.
1272.	45.154	45154.
1287.	44.004	44004.
1303.	42.922	42922.
1318.	41.903	41903.
1334.	40.940	40940.
1349.	40.029	40029.
1365.	39.166	39166.
1380.	38.346	38346.
1396.	37.566	37566.
1411.	36.823	36823.
1427.	36.115	36115.
1443.	35.332	35332.
1458.	33.929	33929.
1474.	31.916	31916.
1489.	29.297	29297.
1505.	26.081	26081.
1520.	22.278	22278.
1536.	18.062	18062.
1551.	14.310	14310.
1567.	11.013	11013.
1582.	8.162	8162.
1598.	5.750	5750.
1613.	3.768	3768.
1629.	2.209	2209.
1645.	1.066	1066.
1660.	0.332	332.

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