FLOOD ASSESSMENT

FOR THE PROPOSED UPGRADE OF THE ROCKY DRIFT WWTW,

MBOMBELA LOCAL MUNICIPALITY, EHLANZENI DISTRICT, MPUMALANGA

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November 2020
FINAL REPORT

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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	Design, GIS & report	BSc, BSc Hon, MSc, PhD Hydrology	SLR Consulting (Africa) (Pty) Ltd	Date: 01/11/2020
Nick Davis Isikhungusethu Environmental Services	Design & GIS	BSc, BSc Hon, MSc Hydrology	SLR Consulting (Africa) (Pty) Ltd	Date: 03/11/2020

<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

The project area is located approximately 12km north of the city of Nelspruit, Mbombela Municipality, Mpumalanga Province (Figure 2). The project area is located in the X22F quaternary catchment, within the Inkomati-Usuthu Water Management Area (Husted, 2017). There are two small watercourses that the proposed sewer pipeline would traverse. A previous study was undertaken by JG Afrika (2017) but did not cover the recent addition of the bulk sewer line.

The dimensions of the proposed and existing infrastructure are as follows-

- Proposed 500mm uPVC Bulk Sewer Pipe; and
- Existing 160 Ø Bulk Sewer Pipeline to be upgraded to 500 Ø and realigned.

The key requirements for this study are as follows:

1. Hydrology calculation: catchment delineation, flow peak analysis.
2. Hydraulic calculation: floodline modelling & profile, determination of flood level.
3. Mapping: plot flood lines.
4. Reporting (report & drawing in pdf format, flood lines plot in dwg/dxf format).

The coordinates for the development are:
25.367471 S & 30.970472 E.

The typical site setting can be seen in Figure 1 with the layout of the proposed development and associated infrastructure in Figure 2.

Figure 1 Typical setting of the drainage lines and surrounds at Rocky Drift

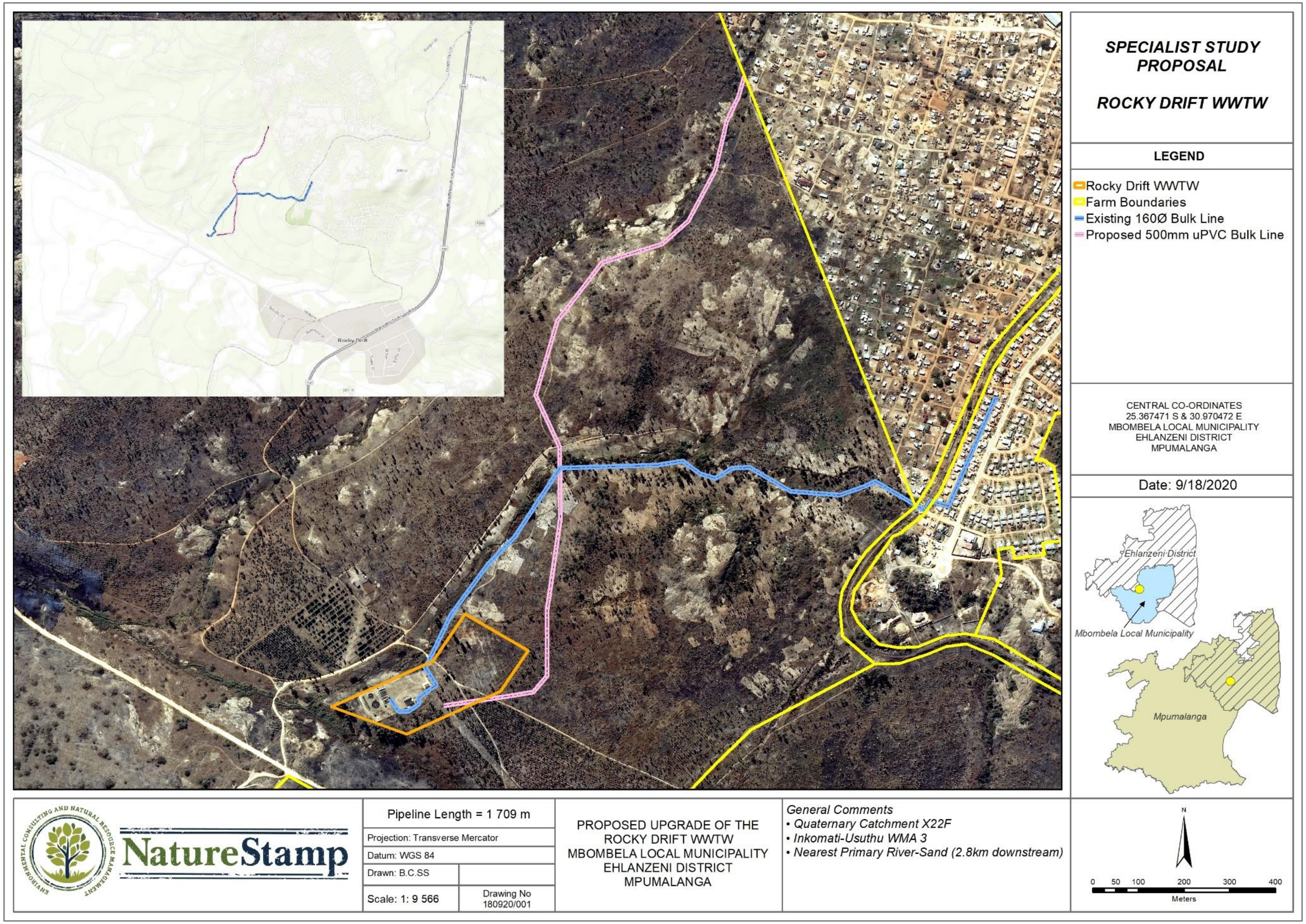

Figure 2 Locality map of the proposed Rocky Drift expansion

1.2 Terms of reference

NatureStamp has been appointed to conduct a 1:2, 1:5. 1:10, 1:20, 1:50 and 1:100 year flood line assessment of any significant stream or river system that may impact on the development.

The terms of reference are as follows -

i. Hydrological assessment, undertaken by the:

   a. Analysis of rainfall data available;
   b. Analysis of streamflow data available;
   c. Determination of the catchment characteristics;
   d. Determination of the Manning's n-values;
   e. Analysis of the river reach network; and
   f. Estimation of the design flood.

ii. Hydraulic analysis, illustrated by the:

   a. Compilation of the river reach model and flood line using HEC-RAS and HEC-geoRAS;
   b. Determination of the flood risk and flood hazard throughout the study site; and
   c. Recommendation of mitigation options associated with the hydraulic analysis.

iii. Consolidate results in a report with:

   a. Flood line maps; and
   b. A final flood line report.

1.3 Gauged versus Ungauged Catchments

Flood hydrology assessments can be limited if the information available is scant. In the Rocky Drift area (which has experienced a recent severe drought) most of the smaller tributaries (excluding large rivers) do not flow all year round as they have done in the past. This can be explained by changes in land use through intensification and increased areas under crops or commercial forests, an increase in water extraction (irrigation, dams, industrial needs and human needs), cyclic drought and climate change. Much of the flow in these rivers is not always accurately recorded by weirs. When a flood hydrology assessment is undertaken, depending on the data available, either gauged or ungauged catchments can be assessed. Gauged data are the most accurate approach assuming that the data quality is reliable and over a long period of time. In the absence of such data, an ungauged catchment is assessed using observed rainfall. This data (assuming it is of good quality) is used as an input to a rainfall-runoff model. The design flood is determined using a statistical analysis of the rainfall and the catchment characteristics.

In large catchment areas the antecedent moisture content is important for 1:100 year flood events. If the catchment is very dry before such an event, dams may fill up first from the flood waters and part of the rainfall may infiltrate, resulting in a reduced flow through the system, whereas a saturated catchment would result in a shorter lag time and a larger flow volume in the channel. This can lead to a difference in a simulated flood using design rainfall (ungauged) and a flood using observed streamflow (gauged). Furthermore, the large flood events are often poorly recorded in weirs due to poor maintenance and overtopping.

For the study area, no streamflow data was available, as such, a detailed rainfall assessment was undertaken to determine the design rainfall-runoff events.

2. STUDY SITE

2.1 Catchment

The site is located 12 km north of Nelspruit in Mpumalanga. The existing development area sits within Quaternary Catchment (QC) X22F of the Crocodile River catchment (Inkomati-Usuthu).

The site sits on a non-perennial tributary of the Sand, approximately 2.44 km to the north. The site has been significantly modified for settlements, brick/granite factories and agricultural activities. According to desktop information (DWS, 2017), the activities in the area and local land uses have impacted the aquatic system, which have rendered the system as moderately modified. The associated watercourse is predominantly representative of a wetland system, but a site was selected for the analysis of water (in situ) and to collect a water sample. However, this study assessed the reach of the watercourse adjacent to the WwTW (JG Afrika, 2017).

According to Mucina and Rutherford (2006), the area is dominated by Legogote Sour Bushveld (SVi 9), which falls under the lowveld Savanna (SV) bioregion. The vegetation type has been classified as 'endangered', and 1.6 % receives formal protection. Of the remaining 50 % only a small percentage is statutorily protected in reserves.

Rainfall is not variable throughout the small catchment area (9 km^2) with 720 mm occurring during an average year at the site (Table 2). Temperatures range from an average of 19.3 °C [41 – 9.6 °C max range] in the summer to 14 °C [30.9 – -3.3 °C min range] in the winter months. The soils within the property boundary range from Mispah, to Hutton and Clovelly forms, which dominate most of the site. Some Oakleaf forms occur within the wetland edges. The underlying geological formation is intrusive Mpuluzi Granite of the Archaean Eon and the Swazian Era.

Table 2 Mean monthly rainfall and temperature observed near Rocky Drift(derived from historical data)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Mean Rainfall (mm)	139.4	107.8	88.4	41.8	15.0	7.0	9.8	7.1	21.6	60.3	100.4	121.9	**720.6**
Mean Temperature (°C)	23.2	23.0	22.1	19.6	16.7	14.1	14.1	15.9	18.7	20.0	21.1	22.5	**19.3**

The site is largely modified. However, contributing catchment area of 9.1 km^2 is partially vegetated with sandy soils allowing a moderate infiltration rate. The steep drainage lines would have a quick response to a storm event although they are highly invaded with alien plant species.

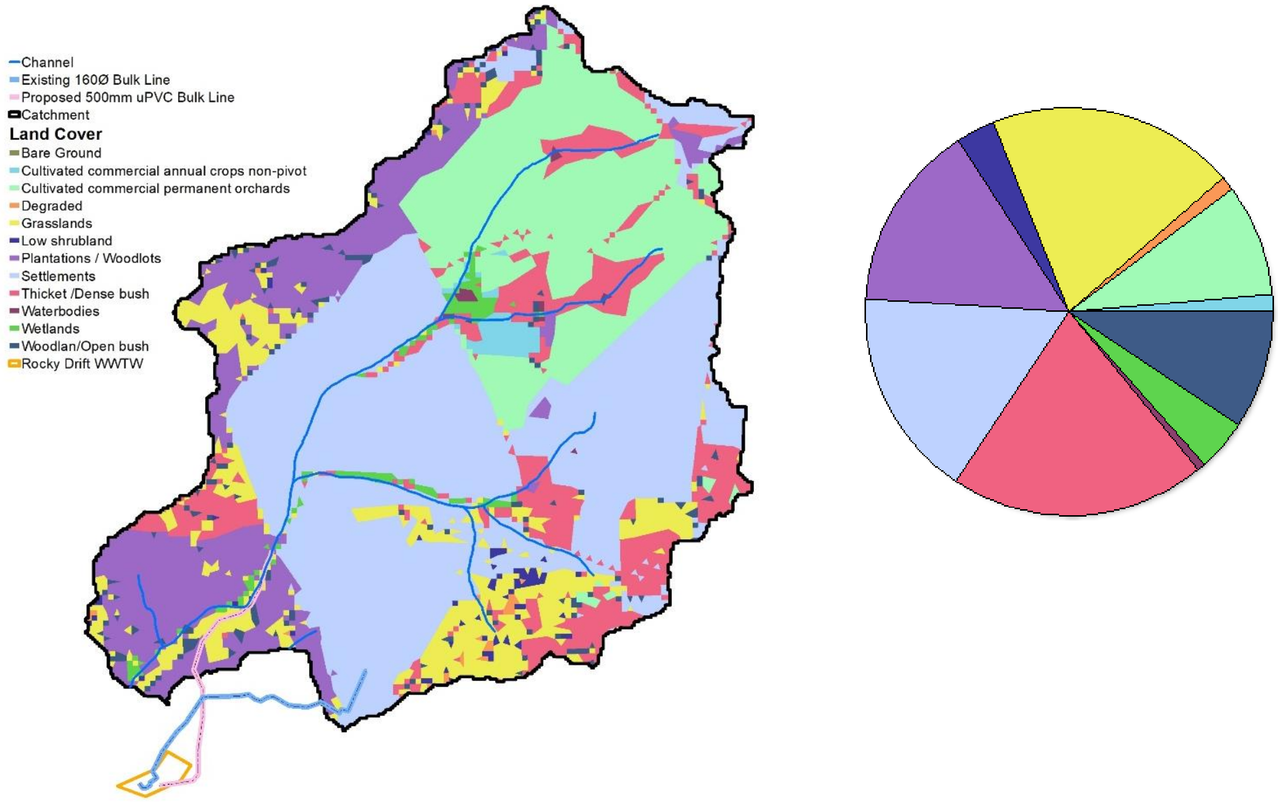

Figure 3 land cover for the contributing catchment of Rocky Drift

Table 3 Land cover area for the contributing catchment area

Land Cover	Area (ha)	Percentage
Bare Ground	0.10	0.01
Cultivated commercial annual crops non-pivot	8.52	0.93
Cultivated commercial permanent orchards	167.51	18.34
Degraded	2.17	0.24
Grasslands	89.18	9.76
Low shrubland	5.67	0.62
Plantations / Woodlots	133.93	14.66
Settlements	372.22	40.75
Thicket /Dense bush	105.60	11.56
Waterbodies	1.65	0.18
Wetlands	11.75	1.29
Woodland/Open bush	15.21	1.67
Total	**913.51**	**100**

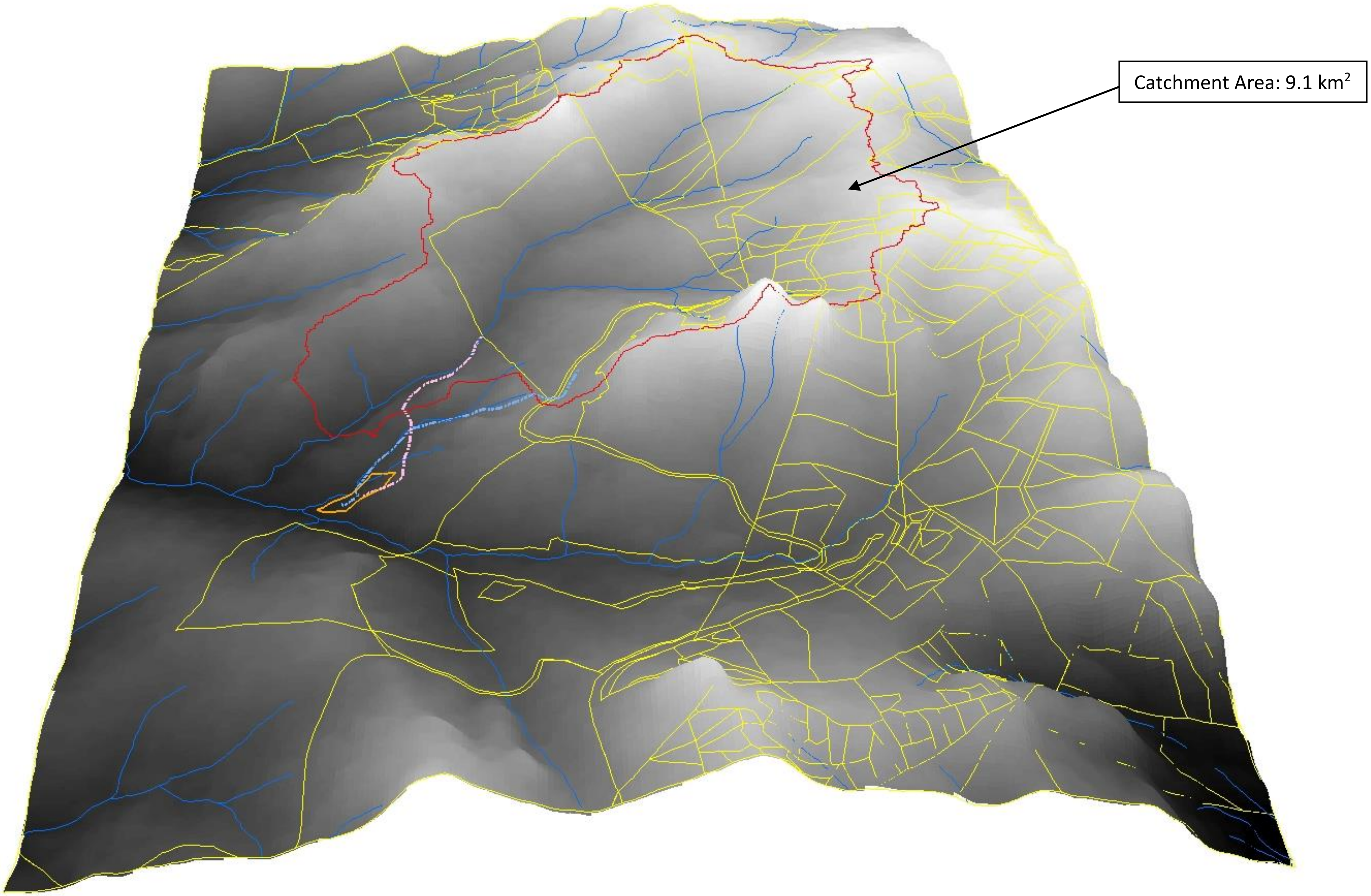

Figure 4 Exaggerated terrain model for the contributing catchment of Rocky Drift

3. METHODOLOGY

The following methodology was followed in order to meet the objectives as detailed in the terms of reference. The assessment of these systems considered the following databases where relevant:

Table 4 Data type and source for the Rocky Drift assessment

Data Type	Year	Source/Reference
Aerial Imagery	2013, 2016 & 2018	Surveyor General
1:50 000 Topographical	2011	Surveyor General
2m Contour	2010	Surveyor General/Msunduzi EMF
River Shapefile	2011	EKZNW
Geology Shapefile	2011	Durban Geological Sheets/National Groundwater Archive
Land Cover	2014 & Current	EKZNW & Site Assessment
Water Registration	2015	WARMS - DWS

*Data will be provided on request

3.1 Site Visit

A site visit was conducted by Bruce Scott-Shaw is of NatureStamp on the 19th October 2020. A pre-development condition was assumed. The current condition was assessed as follows -

- The vegetation characteristics of the watercourse were assessed for the determination of the Manning's n-values;
- The presence and dimensions of any crossings, such as culverts and bridges, that would act as a barrier to a flood event and that may be damaged during the occurrence of such an event were noted;
- The overall state of drainage channels, streams and rivers was assessed;
- The slope of the study site as well as evidence of flood damage and erosion around the site were noted;
- The state of existing gauging stations (nearby) was assessed to determine if the structure is accurately recording streamflow (e.g. evidence of under cutting or damaged features); and
- The elevation at the channel level and property level in order to verify contour data.

The watercourse systems were not flowing at the time of the site visit. As a result of low-flow conditions, a river profile analysis was possible using a high accuracy GPS.

3.2 Critical Catchment Delineation and River Reach Analysis

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 2m 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 5). Data collected during the site visit and from available databases were used as inputs to the models (Figure 6).

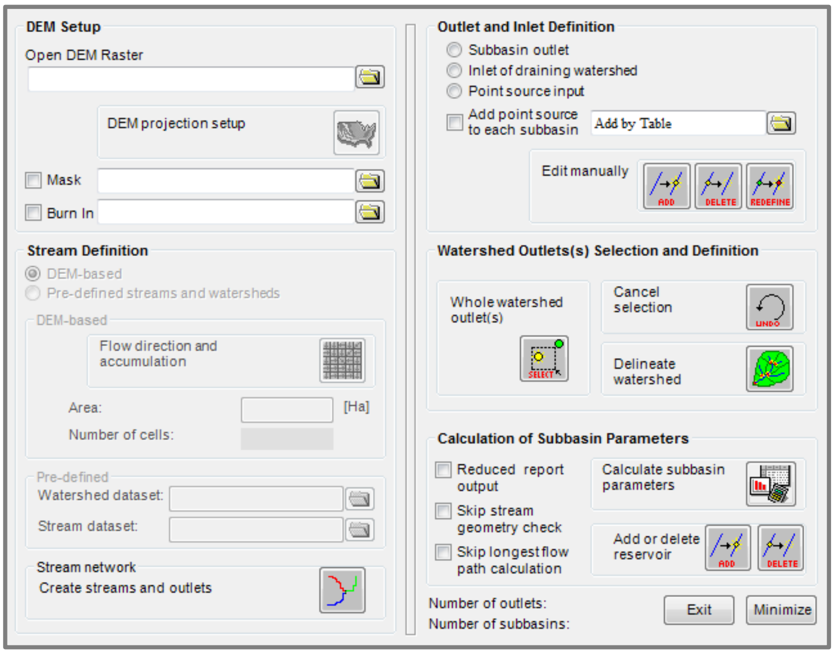

Figure 5 Soil Water Assessment Tool (*SWAT*) watershed delineation tool for sub-catchment delineation and stream network creation

3.3 Design Flood Determination

The peak flows for the 1:2, 1:5, 1:10, 1:20, 1:50 and 1:100 flood events were calculated for the catchments using the rational method, the SCS-SA model and the Standard Design Flood Method as outlined in the SANRAL Drainage Manual (2013). The SCS-SA model is a hydrological storm event simulation model suitable ideally for application on catchments that have a contributing catchment of less than 30 km². The model has been used widely both internationally and nationally for the estimation of flood peak discharges and volume (Schulze *et al*., 1992). The type of surface in the drainage basin is also important. The Rational Method becomes more accurate as the amount of impervious surface, such as pavements and rooftops, increases. The Rational Method is most often used in urban and suburban areas (ODOT Hydraulics Manual, 2014). Given the land use and catchment size, the SCS method was adopted as the most appropriate model.

3.4 Flood Line Determination

Modelling of the flood lines was undertaken using the U.S. Army Corps of Engineers' HEC-RAS v5.05 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, no inundation within the study site would occur 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 there were structures present (Figure 6).

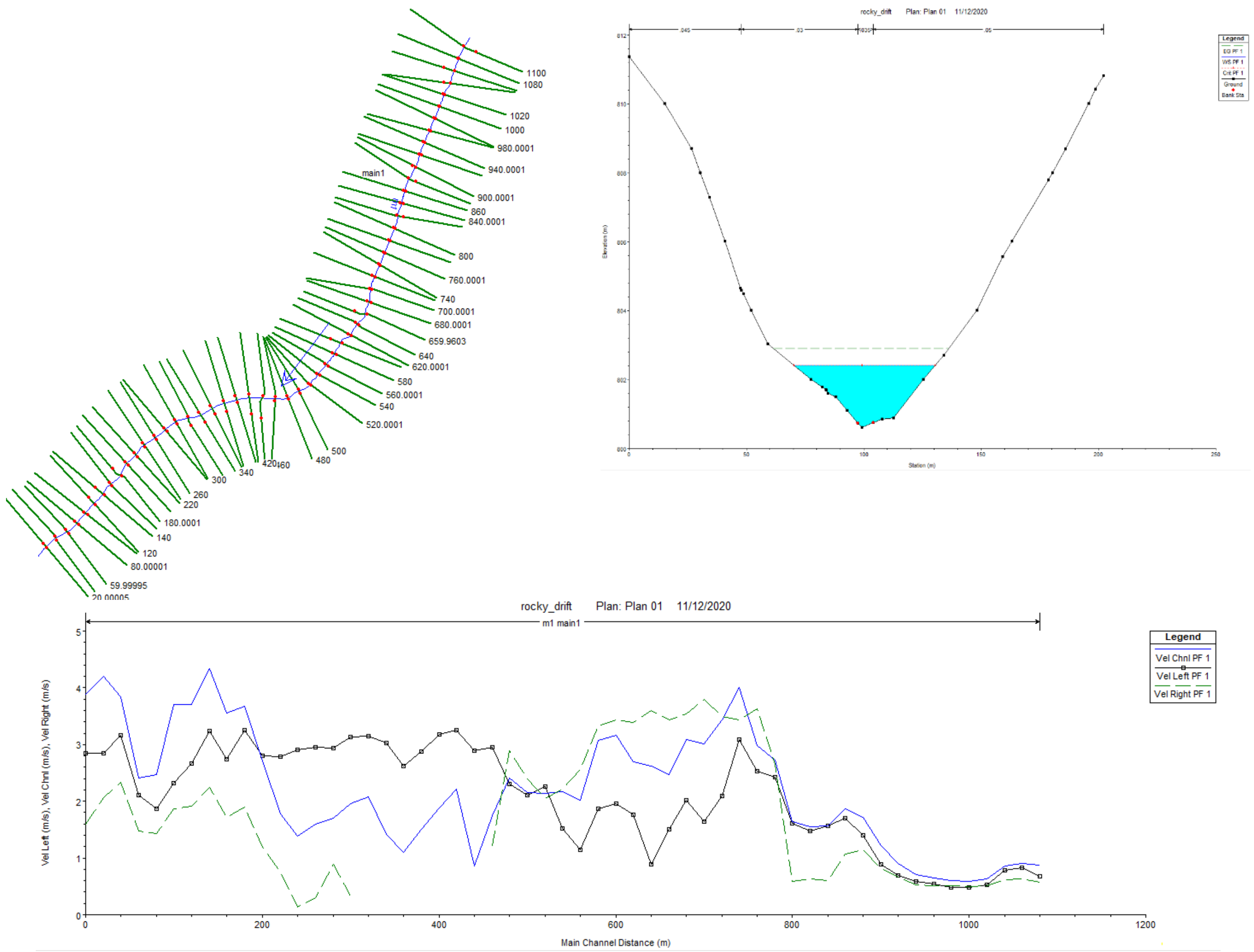

Figure 6 Longitudinal profile and channel cross sections developed for a section of the drainage channel

3.5 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 a GIS interface. 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 7 provides a schematic of this model.

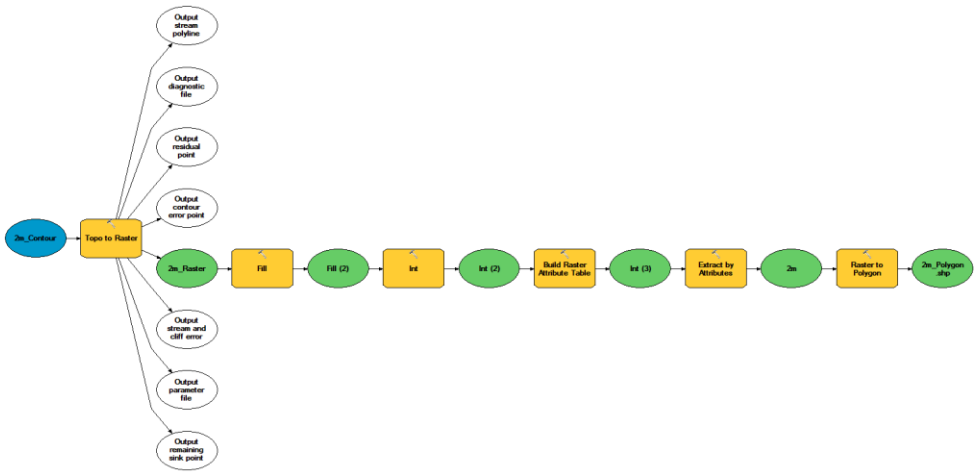

Figure 7 GIS model for flood generation in small channels

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. However, n- values in areas outside of the study area were estimated using a desktop approach due to the extent of the catchment.

- 2 meter contour interval data and Digital Elevation Models (DEMs) were used in the design flood estimation (development of the elevation model). Within a 1 km radius of the site, a detailed topographical survey was undertaken. Given the desktop flood proposed, this resolution was considered to be of sufficient accuracy for the flood line determination.

- Given the setting of the site (no flow during the site visit) it was difficult to determine which channels would be fully active in a flood and which are remnant channels which have since been bypassed.

5. RESULTS AND DISCUSSION

A detailed desktop assessment was undertaken for the site.

5.1 Desktop Assessment

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

In accordance with the NFEPA guidelines, the relevant reach of the Sand tributary (and its associated riparian areas) has not been classified as a FEPA, which indicates that this river system is a not national freshwater conservation priority. However, the Sand river (2.87 km downstream) has been classified as a Class C (Moderately Modified) NFEPA system.

FEPA wetlands were not identified within the study site. The nearest FEPA wetland is 3.05 km away. The layer codes for River FEPAs and associated sub-quaternary catchments, Fish Support Areas and associated sub-quaternary catchments and Upstream Management Areas.

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 obtained from national databases and site samples. 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 were utilized in achieving a comprehensive review, and allowing any regional or provincial conservation and biodiversity concerns to be highlighted.

This site is dominated by Legogote Sour Bushveld (SVl 9, Mucina and Rutherford, 2006). This occurs within the lowveld savanna biome. The desktop analysis revealed that the area is endangered, 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. The following information was collected for the vegetation unit SVl 9 (Mucina & Rutherford, 2006). The characteristics of this grassland are described as:

- The vegetation type occurs on gently to moderately sloping upper pediment slopes with dense woodland including many medium to large shrubs often dominated Parinari curatellifolia and Bauhinia galpinii with Hyperthelia dissolute and Panicum maximum in the undergrowth.
- Short thicket dominated by Acacia ataxacantha occurs on less rocky sites.
- Exposed granite outcrops have low vegetation cover, typically with Englerophytum magalismontanum, Aloe petricola and Myrothamnus flabellifolia.
- It has been greatly transformed, mainly by plantations and also cultivated areas and urban development.
- Scattered alien plants include Lantana camara, Psidium guajava and Solanum mauritianum.
- Important taxa includes:
    - Tall trees: *Pterocarpus angolensis (d), Sclerocarya birrea subsp. caffra (d);*
    - small trees: *Acacia davyi (d), A. sieberiana var. woodii (d), Combertum zeyheri (d), Erythrina latissima (d), Parinari curatellifolia (d), Terminalia sericea (d), Trichilia emetica (d), Verononia amygdalina (d), Acacia caffra, Antidesma venosum, Erythroxylum emarginatum, Faurea rochetiana, F. saligna, Ficus burikei, F. glumosa, F. glumosa, F. ingens, F. petersii, Heteropyxis natalensis, Peltophorum africanum, Piliostigma thonningii, Pterocarpus rotundifolius, Schotia brachypetala;*
    - succulent tree: *Euphorbia ingens;*
    - tall shrubs: *Diospyros lycioides subsp. sericea, Erythroxylum delagoense, Olea europaea subsp. africana, Pachystigma macrocalyx, Pseudarthria hookeri var. hookeri, Rhus pentheri;*
    - low shrubs: *Diospyros galpinii (d), Flemingia grahamiana (d), Agathisanthemum bojeri, Eriosema psoraleoides, Gymnosporia heterophylla, Hemizygia punctata, Indigofera filipes, Myrothamnus flabellifolius, Rhus rogersii; succulent shrubs: Aloe petricola, Euphorbia vandermerwei, Huernia kirkii;*
    - woody climbers: *Acacia ataxacantha (d), Bauhinia galpinii (d), Helinus intergrifolius, Sphedamnocarpus pruriens subsp. Pruriens;*
    - graminoids: *Bothriochloa bladhii (d), Cymbopogon caesius (d), C. nardus (d), Hyparrhenia cymbaria (d), H. poecilotricha (d), Hyperthelia dissolute (d), Panicum maximum (d), Andropogon schirensis, Paspalum scrobiculatum, Schizachyrium sanguineum;*

- herbs: *Gerbera ambigua, G. viridifolia, Hemizygia persimilis, Hibiscus sidiformis, Ocimum gratissimum, Waltheria indica; succulent herbs: Orbea carnosa subsp. carnosa, Stapelia gigantean; and geophytic herbs: Gladiolus hollandii, Hypoxis rigidula.*
- Endemic Taxon: Succulent herb: *Aloe simii.*

5.1.3 Desktop Hydrological Assessment

A detailed assessment of the climate was undertaken. Rainfall stations were considered based on their proximity to the site, altitude and length/reliability of the data record. The long term mean annual rainfall of the site that was used in the design was 712 mm (Figure 8).

Table 5 Comparison of values from some of the rainfall stations that were assessed during the data analysis

Station No.	Estimated MAP (mm)	Years	Reliable	Altitude (m)	Station Name
0555799 W	935	96	7.9	807	Heidelberg
0555837 A	708	96	51.6	660	Nelspruit Res
0555837 W	708	96	52.3	660	Nelspruit
0555866 W	632	96	21.3	756	Friedenheim
0555889 W	851	96	14.4	934	Dipgate
05556020 W	852	96	34.3	962	Witrivier (Pol)

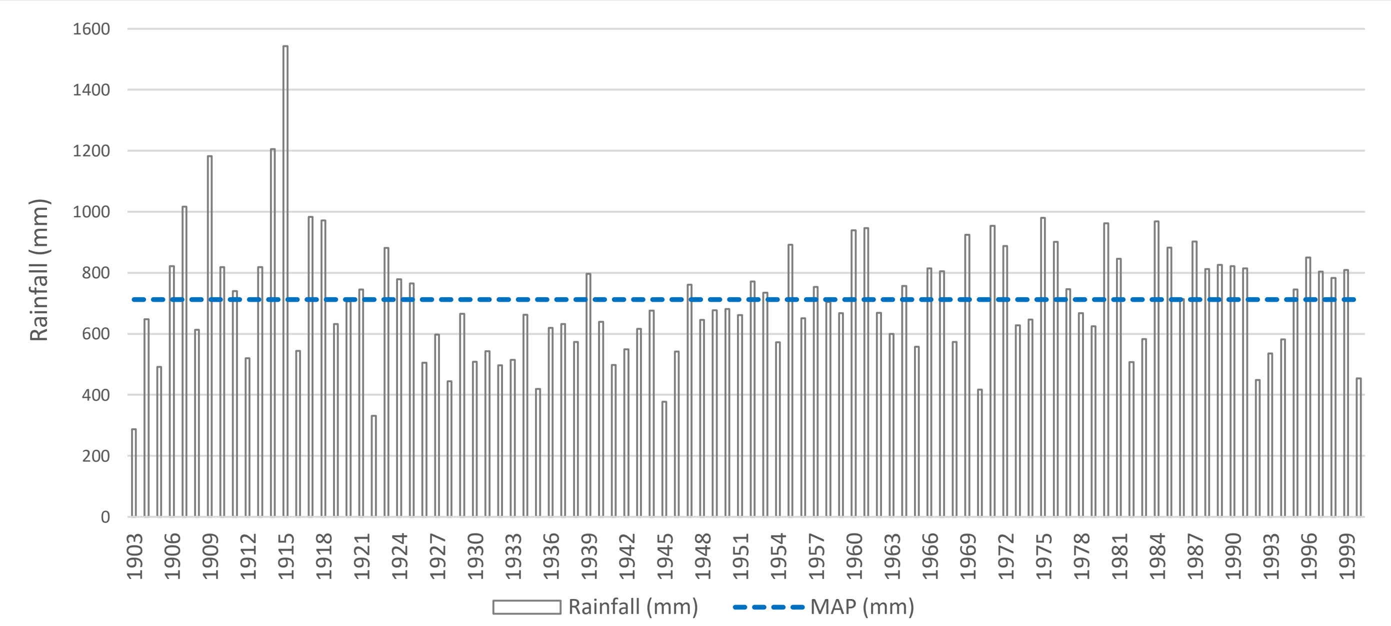

Figure 8 Long term synthesized annual rainfall values with the mean annual precipitation indicated in blue

4.1 Hydraulic Structures

An assessment was undertaken on the small channel obstructions. These were modelled as ineffective areas. According to SANRAL (2016), the discharge capacity of the Rocky Drift obstruction areas 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)

4.2 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 use 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 has been included for comparison.

The results of the design rainfall analysis are summarised below:

Table 6 Comparison between the various one day design rainfall estimation techniques available for the study site

Return Period	Design Rainfall Depth (mm)			
	SDF	DRE	SCS-SA	Rational
10 Year Return Period	72.36	106.8	136	106.8
50 Year Return Period	111.93	156.6	210	156.6
100 Year Return Period	128.97	181.6	249	181.6

4.3 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, SDF and SCS 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 (the area is known for localised storm events). 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, based on the small catchment area.

Table 7 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	69.210	100.101	126.201	157.919	216.849	278.725	321.240
SDF	14.61	45.37	73.56	105.24	152.23	191.52	233.11
SCS-SA	**28.4**	**50.7**	**70.8**	**93.4**	**129.8**	**162.2**	**199.3**

4.1 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 10), whereas the area with negative results illustrated the dry areas not inundated by the flood. Inundation can be seen along the watercourse (Figure 10). Further results are provided in Annexure B, C and D.

No comparison between pre and post development peak flows was undertaken for this assessment. Once the proposed development is finalised, stormwater management interventions should ensure that post-development flows do not exceed pre-development flows.

The 1:100 year flood lines (Figure 9) indicated that a small section of the proposed bulk line would be inundated during such an event. However, given the layout of the site, the inundation risk is low (Figure 11). The flood hydrograph shows a quick response and a short lag time (Figure 9). There is also a significant difference between return periods due to the exponential increase in stormflow under such conditions, largely due to the settlement areas.

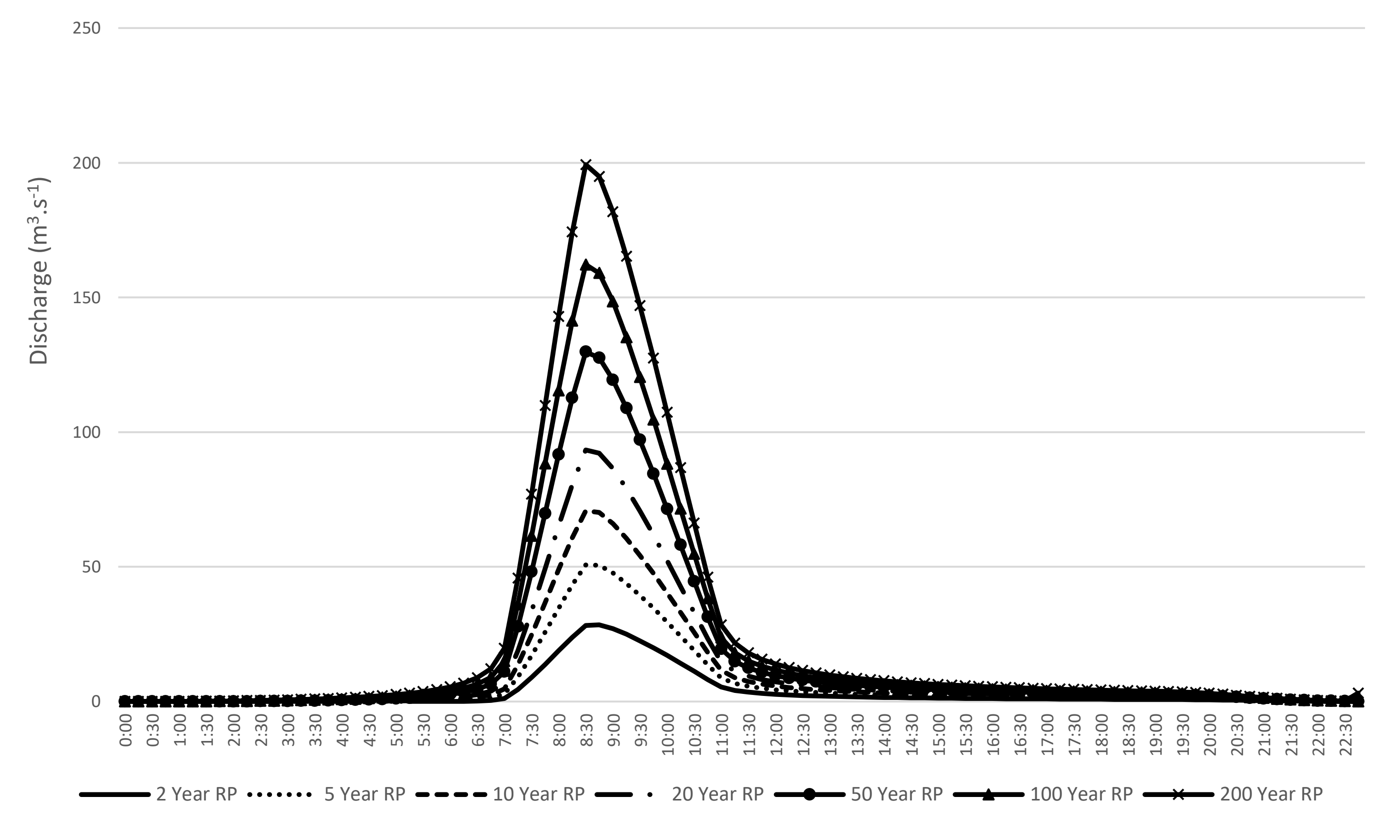

Figure 9 Flood hydrograph as determined by the SCS method

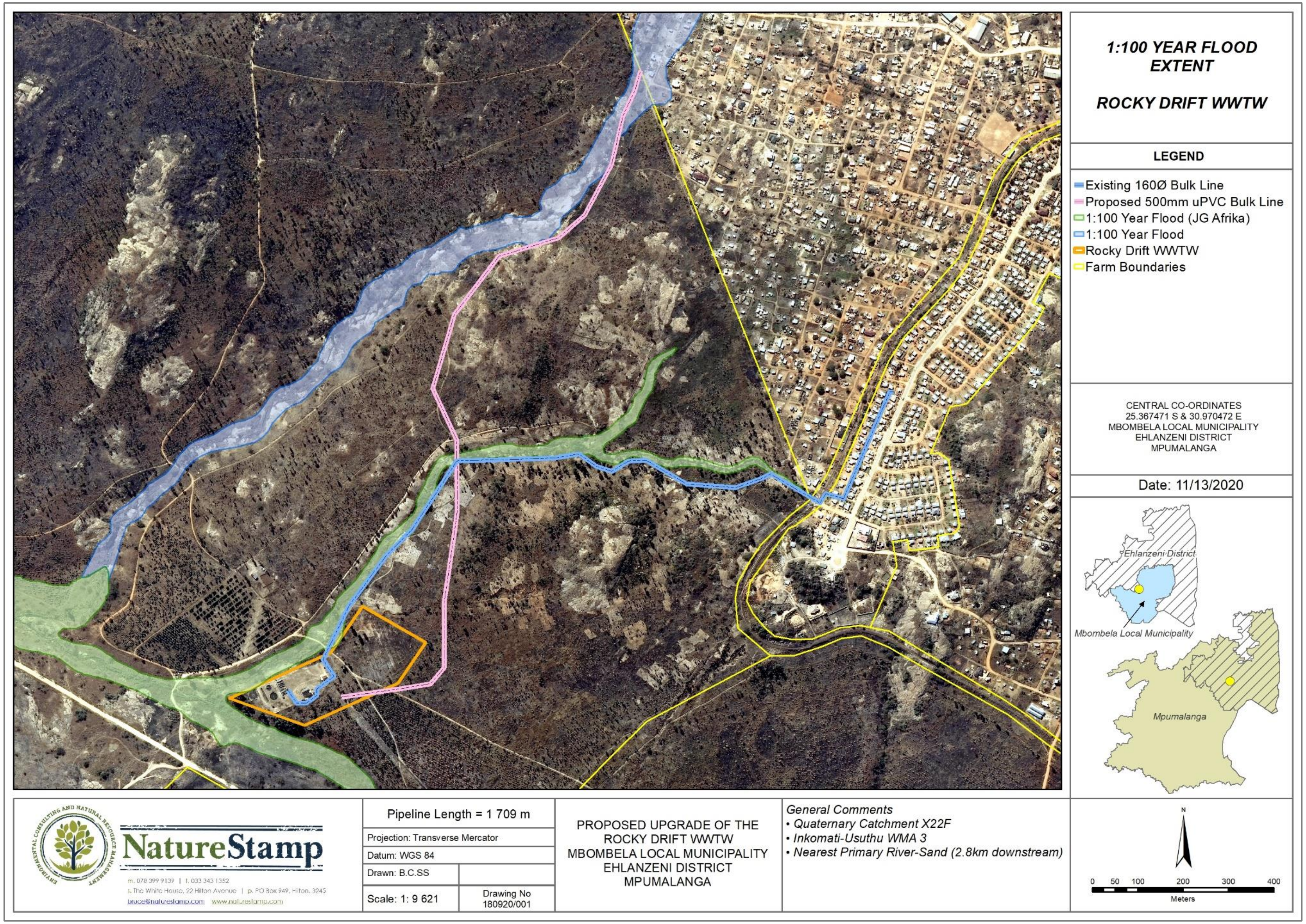

Figure 10 1:100 year flood extent for the Rocky Drift drainage channels

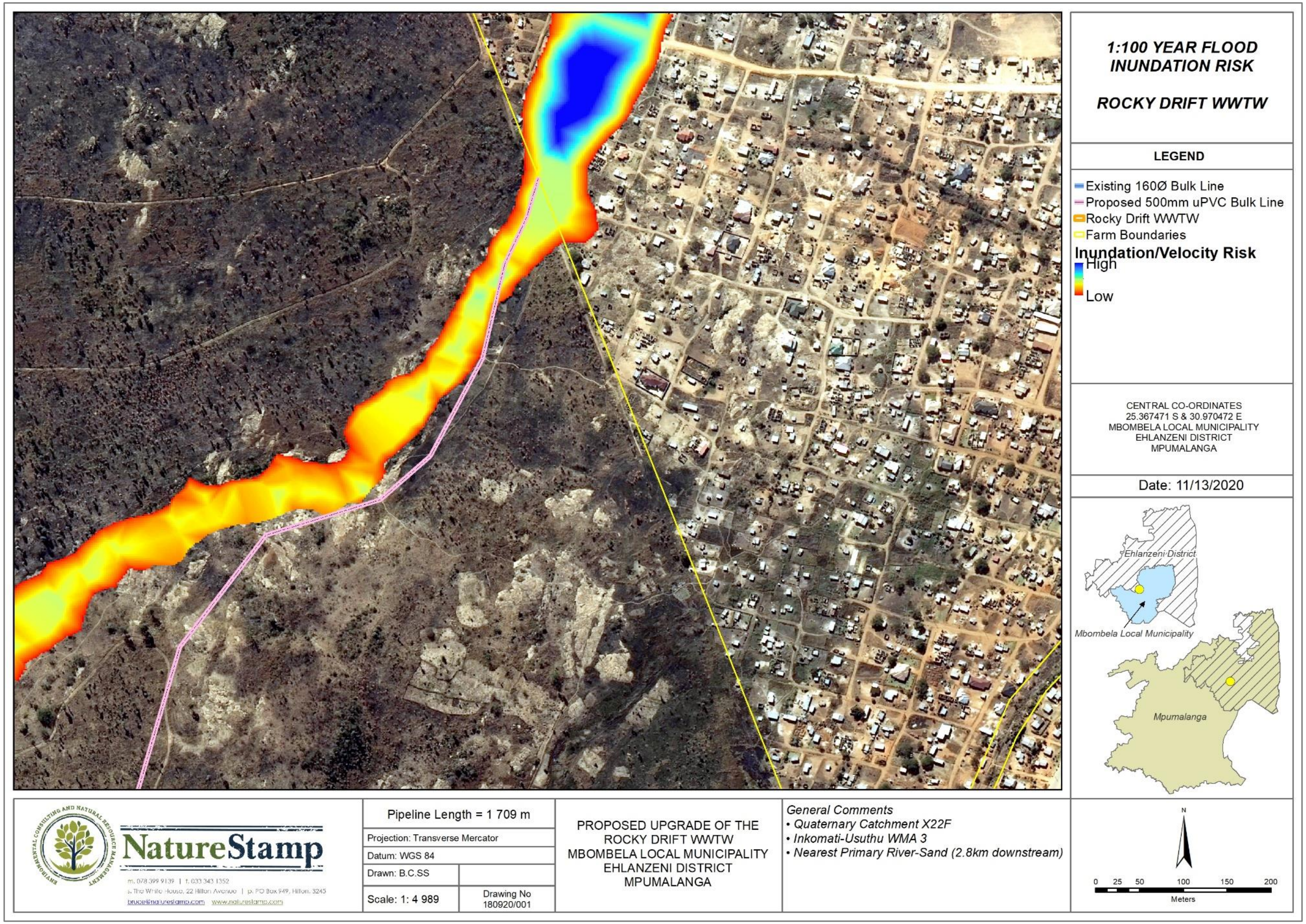

Figure 11 Flood risk map for the Rocky Drift drainage channels

6. CONCLUSION

The assessment of Rocky Drift site has taken cognisance of watercourses and associated crossings that may impact on the inundation areas. The catchment has been heavily transformed through settlements (largely illegal) and agriculture. The site visit identified many illegal plots that have recently been cleared and levelled. These plots cross the proposed bulk line and are steadily changing the flood response of the catchment. This is a big concern for the area and should be addressed through the municipalities.

Flow volumes below the site and at other nearby gauges were not usable for the site, resulting in design rainfall being utilised to obtain the flood event. The resultant flood extent shows that most of the proposed infrastructure is outside of the flood extent, except for the channel crossings and the northern extent of the bulk line. Downstream users would not be at increased risk due to the small footprint and the small size of the catchment. However, there may be an increased risk of contamination through leaks although the contaminants are already entering the watercourse.

The findings and recommendations are:

1. The nearby watercourses are in a modified condition due to historical and present modifications. Similarly, the wetlands are in a moderate to poor condition but do function reasonably in attenuating peak flows.
2. The crossing points are partially blocked by debris indicating a slight risk of damage in the event of a flood.
3. Strict adherence to best practice guidelines, spill management and erosion control must be undertaken during any construction and operation.
4. Regular maintenance of culverts and road crossings on the site must be undertaken to ensure that the flood risk is not increased due to blockages by debris.
5. The risk of the site is low due to the very small catchment area. However, the risk should still be managed through general maintenance.
6. The northern channel would experience a 162.2 $m^3.s^{-1}$ discharge during a 100 year flood event.

7. REFERENCES

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3. Lynch, SD. 2003: Development of a Raster Database of Annual, Monthly and Daily Rainfall for Southern Africa, WRC Report No. 1156/1/03, Water Research Commision, Pretoria, RSA.
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ANNEXURE A Design Rainfall

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

User selection has the following criteria:
Coordinates: Latitude: 25 degrees 21 minutes; Longitude: 30 degreess 59 minutes
Durations requested: 30 m, 1 h, 2 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 Distance Record Latitude Longitude MAP Altitude Duration Return Period (years)
Number (km) (Years) (°) (') (°) (') (mm) (m) (m/h/d) 2 2L 2U 5 5L 5U 10 10L 10U 20 20L 20U 50 50L 50U 100
100L 100U 200 200L 200U

WITRIVIER (POL) 0556020_W 5.1 96 25 19 31 1 930 893 1 d 63.3 63.0 63.6 88.0 87.6 88.4 106.8 105.9 107.9 127.0 125.2 128.9 156.6 153.3
161.1 181.6 177.3 188.7 209.3 203.4 220.3
LOCHABAR 0555797_W 8.0 53 25 17 30 57 914 900 1 d 69.2 68.8 69.5 96.2 95.7 96.7 116.8 115.7 118.0 138.9 136.9 140.9 171.2
167.6 176.1 198.5 193.9 206.2 228.8 222.3 240.8
THE KNOLL 0556143_W 9.2 53 25 22 31 4 772 771 1 d 74.1 73.7 74.5 103.1 102.6 103.5 125.1 124.0 126.4 148.8 146.6 151.0 183.4
179.6 188.6 212.7 207.7 220.9 245.1 238.1 258.0
JATINGA 0556110_W 9.7 58 25 19 31 4 868 800 1 d 75.1 74.7 75.4 104.4 103.9 104.9 126.7 125.5 128.0 150.7 148.5 152.9 185.7 181.8
191.0 215.4 210.3 223.7 248.2 241.2 261.3
UMGENYANA 0556141_W 10.8 36 25 21 31 5 870 860 1 d 70.3 69.9 70.6 97.8 97.3 98.2 118.7 117.6 119.9 141.1 139.1 143.2 174.0
170.4 179.0 201.8 197.0 209.6 232.5 225.9 244.8
NELSPRUIT RES. 0555837_A 10.9 87 25 27 30 58 750 648 1 d 59.0 58.6 59.2 81.9 81.6 82.3 99.5 98.6 100.5 118.3 116.6 120.1 145.8 142.8
150.0 169.1 165.1 175.7 194.9 189.4 205.2

Gridded values of all points within the specified block
Latitude Longitude MAP Altitude Duration Return Period (years)
(°) (') (°) (') (mm) (m) (m/h/d) 2 2L 2U 5 5L 5U 10 10L 10U 20 20L 20U 50 50L 50U 100 100L 100U 200 200L 200U

25 21 30 59 906 865 30 m 25.5 19.4 31.5 35.4 27.0 43.8 43.0 32.6 53.5 51.1 38.6 63.9 63.0 47.3 79.8 73.1 54.7 93.5 84.2 62.7 109.1
1 h 36.0 28.5 43.4 50.0 39.7 60.4 60.7 48.0 73.7 72.2 56.7 88.0 89.0 69.5 110.0 103.3 80.4 128.8 119.0 92.2 150.4
2 h 50.9 41.9 59.8 70.7 58.3 83.2 85.9 70.5 101.5 102.1 83.4 121.3 125.8 102.2 151.6 146.0 118.1 177.5 168.2 135.5 207.3
24 h 91.1 77.3 105.0 126.7 107.5 146.0 153.8 130.0 178.2 182.9 153.8 212.9 225.4 188.3 266.0 261.5 217.8 311.5 301.3 249.7
363.8
1 d 75.6 64.1 87.1 105.1 89.2 121.1 127.6 107.8 147.8 151.7 127.6 176.6 187.0 156.2 220.7 216.9 180.7 258.4 249.9 207.2 301.8

ANNEXURE B Rational Method Results

Description of Catchment	**Sand**		
River detail	**Sand Tributary**		
Calculated by	**B. Scott-Shaw**	**Date**	**20/09/2020**

Physical characteristics						
Size of catchment (A)	**9.1**	km²	Rainfall Region			
Longest Watercourse	**5.5**	km	**Area Distribution Factors**			
Average slope (S_{av})	**0.04**	m/m	Rural (α)	Urban (β)	Lakes(γ)	
Dolomite Area ($D_{\%}$)	**0**	%	**0.6**	**0.4**	**0**	
Mean Annual Rainfall (MAR)	**830**	mm				
Catchment Characteristics	**Flat/permeable**	%				
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	**60**	0.11	0.066	Sandy, flat (<2%)		0.075	-
Hilly	**30**	0.2	0.060	Sandy, steep (>7%)		0.175	-
Steep Areas	**5**	0.3	0.015	Heavy soil, flat (<2%)		0.15	-
Total	100	-	0.144	Heavy soil, steep (>7%)		0.3	-
Permeability	**%**	**Factor**	**C_p**	**Residential Areas**			
Very Permeable	**5**	0.05	0.003	Houses	**65**	0.4	0.260
Permeable	**55**	0.1	0.055	Flats		0.6	-
Semi-permeable	**35**	0.2	0.070	**Industry**			
Impermeable	**5**	0.3	0.015	Light industry		0.65	-
Total	100	-	0.143	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	**35**	0.825	0.289
No Vegetation	**3**	0.3	0.009	Maximum flood		1.00	-
Total	100	-	0.210	Total	100	-	0.549

Time of concentration (T_c)	**Defined Watercourse**	Notes:	
Overland flow	Defined watercourse	*Pre-development Run-off*	
			Latitude: *29°38'*
$$T_c = 0.604\left(\frac{rL}{\sqrt{S_{av}}}\right)^{0.467}$$	$$T_c = \left(\frac{0,87L^2}{1000 S_{av}}\right)^{0.385}$$	*Tc =* *0.851140 17*	*Longitude:* *30°17'*
1.9 Hours	0.9 Hours		

Run-off coefficient							
Return period (years), T	**2**	**5**	**10**	**20**	**50**	**100**	**Max**
Run-off coefficient, C_1 ($C_1 = C_s + C_p + C_v$)	0.496	0.496	0.496	0.496	0.496	0.496	0.4955
Adjusted for dolomitic areas, C_{1D} (= $C_1(1-D_{\%})+C_1D_{\%}(\Sigma(D_{factor} \times C_{s\%}))$)	0.4955	0.4955	0.4955	0.4955	0.4955	0.4955	0.4955
Adjustment factor for initial saturation, F_t	0.5	0.55	0.6	0.67	0.83	1	1
Adjusted run-off coefficient, C_{1T}	0.24775	0.272525	0.2973	0.331985	0.411265	0.4955	0.4955

(= C_{1D} x F_t)							
Combined run-off coeffiecient C_T (= $\alpha C_{1T} + \beta C_2 + \gamma C_3$)	0.3681 5	0.38301 5	0.39788	0.418691	0.46625 9	0.516 8	0.5168
Rainfall							
Return period (years), T	**2**	**5**	**10**	**20**	**50**	**100**	**Max**
Point Rainfall (mm), P_T	**63.3**	**88.0**	**106.8**	**127.0**	**156.6**	**181.6**	**209.3**
Point Intensity (mm/hour), P_{iT} (= P_T/T_C)	74.4	103.4	125.5	149.2	184.0	213.4	245.9
Area Reduction Factor (%), ARF_T	**100**	**100**	**100**	**100**	**100**	**100**	**100**
Average Intensity (mm/hour), I_T (= P_{iT} x ARF_T)	74.4	103.4	125.5	149.2	184.0	213.4	245.9
Return period (years), T	**2**	**5**	**10**	**20**	**50**	**100**	**Max**
Peak flow (m^3/s),	69.210	100.101	126.201	157.919	216.849	278.7 25	321.24 0

ANNEXURE C SDF Method Results

Description of catchment	**Sand**		
River detail	**Sand Tributary**		
Calculated by	**BCSS**	**Date**	**27 October 2020**

Physical characteristics

Size of catchment (A)	9.1	km^2	Time of Concentration (T_C) $T_c = \left(\frac{0,87 L^2}{1000 S_{av}} \right)^{0,385}$	0.85	hours
Longest watercourse (L)	5.5	km			
Average slope (S_{av})	0.04	m/m			
SDF basin (0)#	29		Time of concentration, t (= 60 T_C)	51	minutes
2-year return period rainfall (M)	66	mm	Days of thunder per year (R)	11	days/year

TR102 n-day rainfall data

Weather Service station	Mayfern	Mean annual precipitation (MAP)	740	mm
Weather Service station number	556 088	Coordinates		

Duration (days)	Return period (years)						
	2	5	10	20	50	100	200
1	66	93	113	135	168	196	227
2	78	108	130	154	189	218	250
3	89	125	153	183	227	265	306
7	113	159	194	232	286	331	380

Rainfall

Return period (years), T	2	5	10	20	50	100	200
Point precipitation depth (mm) $P_{t,T}$	32.79	55.32	72.36	89.40	111.93	128.97	146.02
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)	38.53	65.00	85.02	105.04	131.51	151.53	171.55

Run-off coefficients

Calibration factors	C_2 (2-year return period) (%)	15	C_{100} (100-year return period) (%)	50

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), $C_T = \frac{C_2}{100} + \left(\frac{Y_T}{2,33}\right)\left(\frac{C_{100}}{100} - \frac{C_2}{100}\right)$	0.15	0.28	0.34	0.40	0.46	0.50	0.54
Peak flow (m^3/s), $Q_T = 0.278 \times C_T I_T A$	14.61	45.37	73.56	105.24	152.23	191.52	233.11

ANNEXURE D SCS Method Results

```
CATCHMENT NAME                    :  Sand
 PROJECT NO                       :  Rocky
 RUN NO                           :  1
 TOTAL CATCHMENT AREA (km^2)      :  9.10
 STORM INTENSITY DISTRIBUTION TYPE :  3
 CATCHMENT LAG TIME (h)           :  1.37
 COEFFICIENT OF INITIAL ABSTRACTION:  0.10

 CURVE NUMBERS:            Initial    Final
   Sub-catchment 1          88        88.0
   Sub-catchment 2          69        69.0

 RETURN PERIOD (YEARS)                2      5     10     20     50    100    200

 DESIGN DAILY RAINFALL DEPTH (mm)    76    109    136    165    210    249    293

 DESIGN STORMFLOW DEPTH (mm)
   Sub-catchment 1                 49.1   79.5  105.1  133.0  176.9  215.2  258.6
   Sub-catchment 2                 23.3   45.0   65.0   88.1  126.1  160.5  200.4

 TOTAL RUNOFF DEPTH (mm)           32.6   57.4   79.4  104.3  144.4  180.2  221.3

 DESIGN STORMFLOW VOLUME
 (millions m^3)
   Sub-catchment 1                  0.2    0.3    0.3    0.4    0.6    0.7    0.8
   Sub-catchment 2                  0.1    0.3    0.4    0.5    0.7    0.9    1.2

 TOTAL STORMFLOW VOLUME             0.3    0.5    0.7    0.9    1.3    1.6    2.0
 (millions m^3)

 COMPUTED CURVE NUMBER             77.1   76.6   76.4   76.2   75.9   75.8   75.7

 PEAK DISCHARGE (m^3/s)            28.4   50.7   70.8   93.4  129.8  162.2  199.3


 *******************************************************************
RETURN PERIOD (years)   =       2
DESIGN RAINFALL   (mm)  =      76
STORM DISTRIBUTION TYPE =       3
CURVE NUMBER (computed) =    77.1
LAG TIME (h)            =     1.4
PEAK DISCHARGE (m^3/s)  =   28.41
 *******************************************************************
    TIME                        DISCHARGE
  (minutes)       (cubic metres/sec)      (litres/sec)

     608.              0.000                   0.
     623.              0.003                   3.
     638.              0.012                  12.
     653.              0.033                  33.
     668.              0.078                  78.
     683.              0.173                 173.
     698.              0.386                 386.
     713.              1.048                1048.
     727.              4.471                4471.
     742.              8.898                8898.
     757.             13.744               13744.
     772.             18.784               18784.
     787.             23.811               23811.
     802.             28.268               28268.
     817.             28.414               28414.
     832.             26.999               26999.
     847.             24.953               24953.
     861.             22.549               22549.
     876.             19.911               19911.
     891.             17.107               17107.
     906.             14.184               14184.
     921.             11.183               11183.
     936.              8.165                8165.
     951.              5.343                5343.
     966.              4.116                4116.
     981.              3.453                3453.
     995.              3.008                3008.
    1010.              2.680                2680.
    1025.              2.424                2424.
    1040.              2.218                2218.
    1055.              2.047                2047.
    1070.              1.903                1903.
    1085.              1.779                1779.
    1100.              1.672                1672.
    1115.              1.577                1577.
    1130.              1.494                1494.
    1144.              1.419                1419.
    1159.              1.353                1353.
    1174.              1.292                1292.
    1189.              1.237                1237.
    1204.              1.187                1187.
    1219.              1.141                1141.
    1234.              1.099                1099.
    1249.              1.059                1059.
    1264.              1.023                1023.
    1278.              0.990                 990.
    1293.              0.958                 958.
    1308.              0.929                 929.
    1323.              0.901                 901.
    1338.              0.875                 875.
    1353.              0.851                 851.
    1368.              0.828                 828.
    1383.              0.807                 807.
    1398.              0.786                 786.
    1412.              0.767                 767.
```

1427.	0.748	748.
1442.	0.729	729.
1457.	0.697	697.
1472.	0.654	654.
1487.	0.599	599.
1502.	0.532	532.
1517.	0.454	454.
1532.	0.367	367.
1546.	0.291	291.
1561.	0.223	223.
1576.	0.165	165.
1591.	0.116	116.
1606.	0.076	76.
1621.	0.045	45.
1636.	0.022	22.
1651.	0.007	7.

****
RETURN PERIOD (years) = 5
DESIGN RAINFALL (mm) = 109
STORM DISTRIBUTION TYPE = 3
CURVE NUMBER (computed) = 76.6
LAG TIME (h) = 1.4
PEAK DISCHARGE (m^3/s) = 50.74
****

TIME (minutes)	DISCHARGE (cubic metres/sec)	(litres/sec)
534.	0.000	0.
549.	0.002	2.
564.	0.007	7.
579.	0.018	18.
593.	0.037	37.
608.	0.070	70.
623.	0.122	122.
638.	0.200	200.
653.	0.318	318.
668.	0.498	498.
683.	0.792	792.
698.	1.340	1340.
713.	2.784	2784.
727.	9.113	9113.
742.	17.084	17084.
757.	25.697	25697.
772.	34.552	34552.
787.	43.257	43257.
802.	50.736	50736.
817.	50.525	50525.
832.	47.704	47704.
847.	43.846	43846.
861.	39.410	39410.
876.	34.600	34600.
891.	29.532	29532.
906.	24.290	24290.
921.	18.949	18949.
936.	13.629	13629.
951.	8.742	8742.
966.	6.704	6704.
981.	5.614	5614.
995.	4.884	4884.
1010.	4.347	4347.
1025.	3.929	3929.
1040.	3.592	3592.
1055.	3.313	3313.
1070.	3.078	3078.
1085.	2.876	2876.
1100.	2.702	2702.
1115.	2.548	2548.
1130.	2.413	2413.
1144.	2.291	2291.
1159.	2.183	2183.
1174.	2.084	2084.
1189.	1.995	1995.
1204.	1.914	1914.
1219.	1.839	1839.
1234.	1.770	1770.
1249.	1.707	1707.
1264.	1.648	1648.
1278.	1.593	1593.
1293.	1.543	1543.
1308.	1.495	1495.
1323.	1.450	1450.
1338.	1.409	1409.
1353.	1.369	1369.
1368.	1.332	1332.
1383.	1.297	1297.
1398.	1.264	1264.
1412.	1.233	1233.
1427.	1.203	1203.
1442.	1.171	1171.
1457.	1.121	1121.
1472.	1.051	1051.
1487.	0.962	962.
1502.	0.854	854.
1517.	0.728	728.
1532.	0.590	590.
1546.	0.467	467.
1561.	0.359	359.
1576.	0.266	266.
1591.	0.187	187.
1606.	0.122	122.
1621.	0.072	72.
1636.	0.035	35.
1651.	0.011	11.

```
 *****************************************************************
RETURN PERIOD (years)   =     10
DESIGN RAINFALL   (mm)  =    136
STORM DISTRIBUTION TYPE =      3
CURVE NUMBER (computed) =   76.4
LAG TIME (h)            =    1.4
PEAK DISCHARGE (m^3/s)  =  70.79
 *****************************************************************
```

TIME (minutes)	DISCHARGE (cubic metres/sec)	(litres/sec)
474.	0.000	0.
489.	0.001	1.
504.	0.004	4.
519.	0.010	10.
534.	0.023	23.
549.	0.043	43.
564.	0.075	75.
579.	0.121	121.
593.	0.185	185.
608.	0.271	271.
623.	0.386	386.
638.	0.543	543.
653.	0.760	760.
668.	1.075	1075.
683.	1.565	1565.
698.	2.441	2441.
713.	4.636	4636.
727.	13.585	13585.
742.	24.709	24709.
757.	36.650	36650.
772.	48.853	48853.
787.	60.753	60753.
802.	70.794	70794.
817.	70.159	70159.
832.	66.019	66019.
847.	60.504	60504.
861.	54.226	54226.
876.	47.460	47460.
891.	40.365	40365.
906.	33.055	33055.
921.	25.637	25637.
936.	18.287	18287.
951.	11.602	11602.
966.	8.877	8877.
981.	7.426	7426.
995.	6.456	6456.
1010.	5.743	5743.
1025.	5.188	5188.
1040.	4.741	4741.
1055.	4.372	4372.
1070.	4.061	4061.
1085.	3.794	3794.
1100.	3.562	3562.
1115.	3.359	3359.
1130.	3.180	3180.
1144.	3.020	3020.
1159.	2.876	2876.
1174.	2.746	2746.
1189.	2.628	2628.
1204.	2.520	2520.
1219.	2.422	2422.
1234.	2.331	2331.
1249.	2.247	2247.
1264.	2.169	2169.
1278.	2.097	2097.
1293.	2.030	2030.
1308.	1.967	1967.
1323.	1.908	1908.
1338.	1.853	1853.
1353.	1.801	1801.
1368.	1.752	1752.
1383.	1.706	1706.
1398.	1.662	1662.
1412.	1.621	1621.
1427.	1.582	1582.
1442.	1.540	1540.
1457.	1.473	1473.
1472.	1.381	1381.
1487.	1.264	1264.
1502.	1.123	1123.
1517.	0.957	957.
1532.	0.775	775.
1546.	0.613	613.
1561.	0.471	471.
1576.	0.349	349.
1591.	0.246	246.
1606.	0.161	161.
1621.	0.094	94.
1636.	0.046	46.
1651.	0.014	14.

```
 *****************************************************************
RETURN PERIOD (years)   =     20
DESIGN RAINFALL   (mm)  =    165
STORM DISTRIBUTION TYPE =      3
CURVE NUMBER (computed) =   76.2
LAG TIME (h)            =    1.4
PEAK DISCHARGE (m^3/s)  =  93.39
 *****************************************************************
```

TIME (minutes)	DISCHARGE (cubic metres/sec)	(litres/sec)
430.	0.000	0.

445.	0.001	1.
459.	0.004	4.
474.	0.012	12.
489.	0.025	25.
504.	0.045	45.
519.	0.077	77.
534.	0.120	120.
549.	0.177	177.
564.	0.251	251.
579.	0.344	344.
593.	0.461	461.
608.	0.610	610.
623.	0.801	801.
638.	1.051	1051.
653.	1.387	1387.
668.	1.864	1864.
683.	2.591	2591.
698.	3.861	3861.
713.	6.943	6943.
727.	18.866	18866.
742.	33.536	33536.
757.	49.202	49202.
772.	65.133	65133.
787.	80.567	80567.
802.	93.391	93391.
817.	92.199	92199.
832.	86.530	86530.
847.	79.118	79118.
861.	70.745	70745.
876.	61.765	61765.
891.	52.382	52382.
906.	42.743	42743.
921.	32.997	32997.
936.	23.380	23380.
951.	14.703	14703.
966.	11.229	11229.
981.	9.387	9387.
995.	8.157	8157.
1010.	7.252	7252.
1025.	6.550	6550.
1040.	5.985	5985.
1055.	5.517	5517.
1070.	5.123	5123.
1085.	4.786	4786.
1100.	4.493	4493.
1115.	4.236	4236.
1130.	4.009	4009.
1144.	3.807	3807.
1159.	3.625	3625.
1174.	3.461	3461.
1189.	3.312	3312.
1204.	3.176	3176.
1219.	3.051	3051.
1234.	2.936	2936.
1249.	2.830	2830.
1264.	2.732	2732.
1278.	2.641	2641.
1293.	2.556	2556.
1308.	2.477	2477.
1323.	2.403	2403.
1338.	2.333	2333.
1353.	2.267	2267.
1368.	2.206	2206.
1383.	2.147	2147.
1398.	2.092	2092.
1412.	2.040	2040.
1427.	1.991	1991.
1442.	1.938	1938.
1457.	1.854	1854.
1472.	1.738	1738.
1487.	1.591	1591.
1502.	1.413	1413.
1517.	1.205	1205.
1532.	0.975	975.
1546.	0.772	772.
1561.	0.593	593.
1576.	0.439	439.
1591.	0.309	309.
1606.	0.202	202.
1621.	0.119	119.
1636.	0.057	57.
1651.	0.018	18.

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 *******************************************************************
RETURN PERIOD (years)    =      50
DESIGN RAINFALL    (mm)  =     210
STORM DISTRIBUTION TYPE =       3
CURVE NUMBER (computed) =    75.9
LAG TIME (h)             =     1.4
PEAK DISCHARGE (m^3/s)   = 129.81
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```

TIME (minutes)	DISCHARGE (cubic metres/sec)	(litres/sec)
370.	0.000	0.
385.	0.001	1.
400.	0.004	4.
415.	0.012	12.
430.	0.025	25.
445.	0.046	46.
459.	0.077	77.
474.	0.119	119.
489.	0.173	173.
504.	0.241	241.
519.	0.323	323.

534.	0.423	423.
549.	0.542	542.
564.	0.685	685.
579.	0.857	857.
593.	1.065	1065.
608.	1.321	1321.
623.	1.640	1640.
638.	2.049	2049.
653.	2.594	2594.
668.	3.354	3354.
683.	4.496	4496.
698.	6.452	6452.
713.	11.037	11037.
727.	27.782	27782.
742.	48.154	48154.
757.	69.780	69780.
772.	91.646	91646.
787.	112.663	112663.
802.	129.808	129808.
817.	127.605	127605.
832.	119.405	119405.
847.	108.891	108891.
861.	97.114	97114.
876.	84.548	84548.
891.	71.470	71470.
906.	58.086	58086.
921.	44.603	44603.
936.	31.365	31365.
951.	19.533	19533.
966.	14.890	14890.
981.	12.436	12436.
995.	10.801	10801.
1010.	9.599	9599.
1025.	8.667	8667.
1040.	7.916	7916.
1055.	7.296	7296.
1070.	6.774	6774.
1085.	6.326	6326.
1100.	5.938	5938.
1115.	5.598	5598.
1130.	5.297	5297.
1144.	5.029	5029.
1159.	4.788	4788.
1174.	4.571	4571.
1189.	4.373	4373.
1204.	4.193	4193.
1219.	4.028	4028.
1234.	3.876	3876.
1249.	3.736	3736.
1264.	3.606	3606.
1278.	3.486	3486.
1293.	3.373	3373.
1308.	3.268	3268.
1323.	3.170	3170.
1338.	3.078	3078.
1353.	2.991	2991.
1368.	2.910	2910.
1383.	2.833	2833.
1398.	2.760	2760.
1412.	2.691	2691.
1427.	2.625	2625.
1442.	2.556	2556.
1457.	2.444	2444.
1472.	2.291	2291.
1487.	2.097	2097.
1502.	1.863	1863.
1517.	1.588	1588.
1532.	1.286	1286.
1546.	1.017	1017.
1561.	0.782	782.
1576.	0.579	579.
1591.	0.407	407.
1606.	0.267	267.
1621.	0.156	156.
1636.	0.076	76.
1651.	0.024	24.

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******************************************************************
RETURN PERIOD (years)   =    100
DESIGN RAINFALL   (mm)  =    249
STORM DISTRIBUTION TYPE =      3
CURVE NUMBER (computed) =   75.8
LAG TIME (h)            =    1.4
PEAK DISCHARGE (m^3/s)  = 162.19
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TIME (minutes)	DISCHARGE (cubic metres/sec)	(litres/sec)
340.	0.001	1.
355.	0.003	3.
370.	0.010	10.
385.	0.022	22.
400.	0.041	41.
415.	0.071	71.
430.	0.112	112.
445.	0.165	165.
459.	0.231	231.
474.	0.311	311.
489.	0.405	405.
504.	0.516	516.
519.	0.646	646.
534.	0.798	798.
549.	0.974	974.
564.	1.181	1181.
579.	1.425	1425.

593.	1.717	1717.
608.	2.074	2074.
623.	2.517	2517.
638.	3.083	3083.
653.	3.830	3830.
668.	4.863	4863.
683.	6.402	6402.
698.	9.005	9005.
713.	14.978	14978.
727.	36.028	36028.
742.	61.457	61457.
757.	88.347	88347.
772.	115.431	115431.
787.	141.326	141326.
802.	162.189	162189.
817.	159.006	159006.
832.	148.509	148509.
847.	135.206	135206.
861.	120.382	120382.
876.	104.616	104616.
891.	88.249	88249.
906.	71.537	71537.
921.	54.745	54745.
936.	38.313	38313.
951.	23.716	23716.
966.	18.058	18058.
981.	15.075	15075.
995.	13.088	13088.
1010.	11.630	11630.
1025.	10.498	10498.
1040.	9.587	9587.
1055.	8.835	8835.
1070.	8.201	8201.
1085.	7.658	7658.
1100.	7.188	7188.
1115.	6.776	6776.
1130.	6.411	6411.
1144.	6.086	6086.
1159.	5.794	5794.
1174.	5.530	5530.
1189.	5.291	5291.
1204.	5.073	5073.
1219.	4.873	4873.
1234.	4.689	4689.
1249.	4.519	4519.
1264.	4.362	4362.
1278.	4.216	4216.
1293.	4.080	4080.
1308.	3.953	3953.
1323.	3.834	3834.
1338.	3.722	3722.
1353.	3.617	3617.
1368.	3.518	3518.
1383.	3.425	3425.
1398.	3.336	3336.
1412.	3.253	3253.
1427.	3.174	3174.
1442.	3.090	3090.
1457.	2.955	2955.
1472.	2.770	2770.
1487.	2.535	2535.
1502.	2.251	2251.
1517.	1.920	1920.
1532.	1.554	1554.
1546.	1.230	1230.
1561.	0.945	945.
1576.	0.700	700.
1591.	0.492	492.
1606.	0.322	322.
1621.	0.189	189.
1636.	0.091	91.
1651.	0.029	29.

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RETURN PERIOD (years)   =    200
DESIGN RAINFALL   (mm)  =    293
STORM DISTRIBUTION TYPE =      3
CURVE NUMBER (computed) =   75.7
LAG TIME (h)            =    1.4
PEAK DISCHARGE (m^3/s)  = 199.26
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TIME (minutes)	DISCHARGE (cubic metres/sec)	(litres/sec)
296.	0.000	0.
310.	0.002	2.
325.	0.006	6.
340.	0.016	16.
355.	0.033	33.
370.	0.059	59.
385.	0.097	97.
400.	0.148	148.
415.	0.212	212.
430.	0.290	290.
445.	0.382	382.
459.	0.490	490.
474.	0.613	613.
489.	0.755	755.
504.	0.917	917.
519.	1.102	1102.
534.	1.314	1314.
549.	1.557	1557.
564.	1.840	1840.
579.	2.174	2174.
593.	2.571	2571.

608.	3.054	3054.
623.	3.650	3650.
638.	4.407	4407.
653.	5.400	5400.
668.	6.766	6766.
683.	8.782	8782.
698.	12.156	12156.
713.	19.761	19761.
727.	45.748	45748.
742.	76.951	76951.
757.	109.833	109833.
772.	142.839	142839.
787.	174.243	174243.
802.	199.262	199262.
817.	194.894	194894.
832.	181.730	181730.
847.	165.209	165209.
861.	146.880	146880.
876.	127.441	127441.
891.	107.306	107306.
906.	86.790	86790.
921.	66.222	66222.
936.	46.154	46154.
951.	28.422	28422.
966.	21.621	21621.
981.	18.043	18043.
995.	15.661	15661.
1010.	13.913	13913.
1025.	12.557	12557.
1040.	11.466	11466.
1055.	10.565	10565.
1070.	9.806	9806.
1085.	9.157	9157.
1100.	8.593	8593.
1115.	8.100	8100.
1130.	7.663	7663.
1144.	7.274	7274.
1159.	6.925	6925.
1174.	6.610	6610.
1189.	6.323	6323.
1204.	6.062	6062.
1219.	5.823	5823.
1234.	5.603	5603.
1249.	5.400	5400.
1264.	5.212	5212.
1278.	5.037	5037.
1293.	4.874	4874.
1308.	4.722	4722.
1323.	4.580	4580.
1338.	4.446	4446.
1353.	4.321	4321.
1368.	4.202	4202.
1383.	4.091	4091.
1398.	3.985	3985.
1412.	3.885	3885.
1427.	3.790	3790.
1442.	3.690	3690.
1457.	3.529	3529.
1472.	3.308	3308.
1487.	3.027	3027.
1502.	2.689	2689.
1517.	2.293	2293.
1532.	1.856	1856.
1546.	1.468	1468.
1561.	1.129	1129.
1576.	0.835	835.
1591.	0.588	588.
1606.	0.385	385.
1621.	0.226	226.
1636.	0.109	109.
1651.	0.034	34.