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Flood Line Assessment for the Hekpoort Area

Report

Version - 1

18 November 2019

GladAfrica Group (Pty) Ltd

GCS Project Number: 19-0866

Client Reference: GCS - Hekpoort Flood lines

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LIST OF ACRONYMS

ALOS	Advanced Land Observing Satellite
MIPI	Midgley and Pitman
UHM	Unit Hydrograph Method
WMA	Water Management Area
NWA	National Water Act No. 36 of 1998
RM	Rational Method
SDF	Standard Design Flood
UPD	Utility Programs for Drainage
WUL	Water Use License
DWS	Department of Water and Sanitation

EXECUTIVE SUMMARY

GladAfrica group (Pty) Ltd appointed GCS Water and Environmental Services (Pty) Ltd (GCS) to undertake a specialist flood line assessment study for the Hekpoort area located 15km northeast of Magaliesberg within the Mogole City Local Municipality of the Gauteng Province of South Africa. The site lies within quaternary catchment A21F in the Crocodile (West) and Marico Water Management Area. Magalies River, which runs through the Hekpoort area, was assessed for potential risks posed by floods.

The 1:2, 1:5, 1:10, 1:20 1:50 and 1:100 flood peak volumes were determined in order to determine the flood lines. All the flood lines were mapped, and the results show that the Western-most portion of the development will be submerged if any of the flood events that were modelled occur.

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1 INTRODUCTION

GladAfrica group (Pty) Ltd appointed GCS Water and Environmental Services (Pty) Ltd (GCS) to undertake a specialist flood line assessment study for the Hekpoort area located 15km northeast of Magaliesberg within the Mogole City Local Municipality of the Gauteng province (Figure 1.1). The study area covers portion 79, 91, 96, 321 and 322 of the farm Hekpoort No 504 JQ within quaternary catchment A21F.

The north-western boundary of the areas is located next to the Magalies River (Figure 1.1), therefore this study is aimed at assessing local hydrology, determining likely peak floods and evaluating the flood inundation extent and the potential flood hazard from this river.

The GCS study was limited to the analysis of probable peak floods that are likely to occur in the watercourse that passes through the Hekpoort Area and the flood risk posed by those floods. The GCS study needs to determine that these flood lines do not pose a threat to the Hekpoort area.

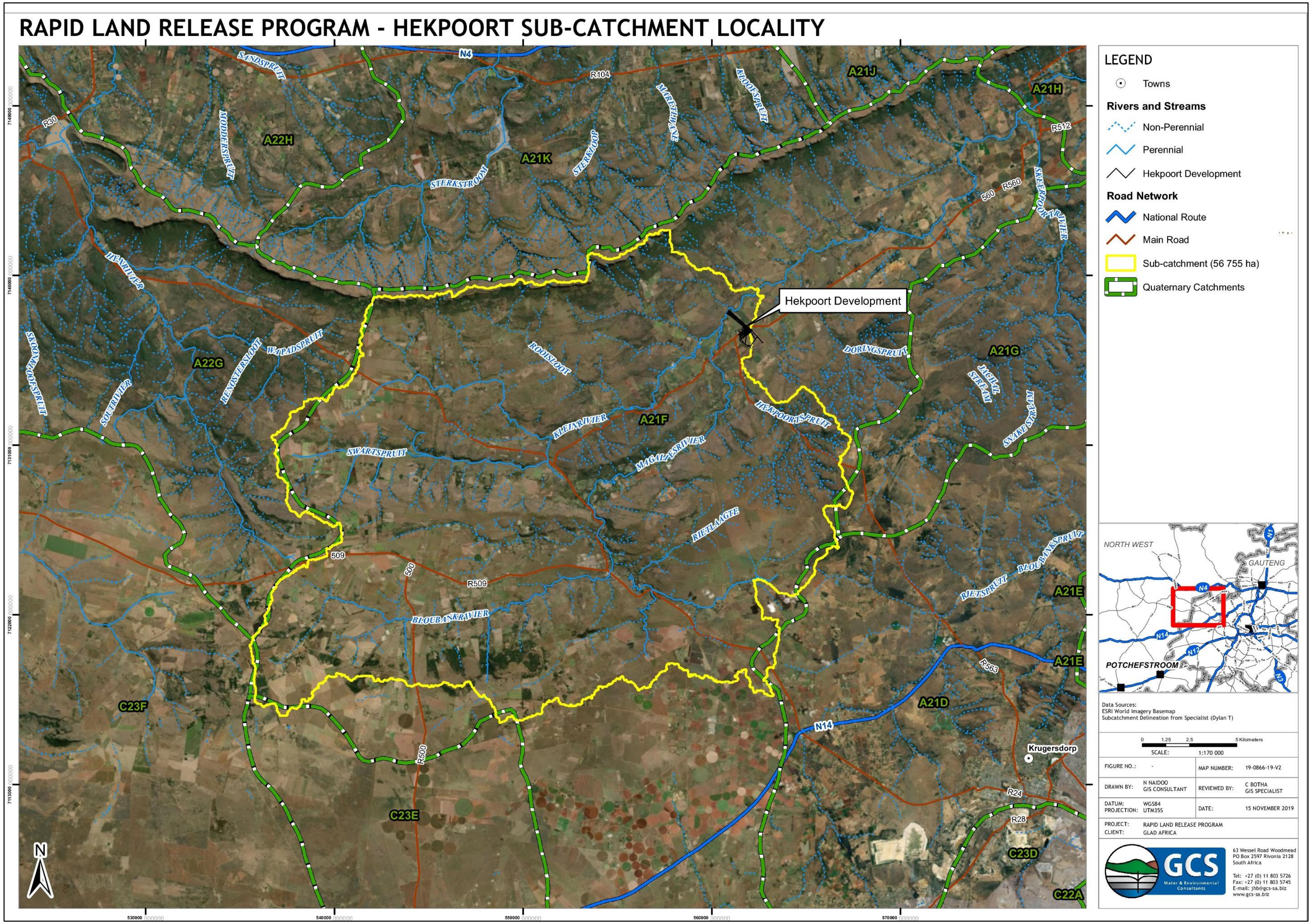

Figure 1.1: Study location

2 SCOPE OF WORK

The following scope of work (SoW) is defined as follows:

1. Project Initiation and Management:
   - Project initiation meeting and project management.
2. Regulations Review
   - Review of existing literature and the applicable regulations and guidelines with regards to the study.
3. Flood line modelling:
   - Catchment delineation and drainage characteristics;
   - Design rainfall depths and calculation of the 1:5, 1:10, 1:20, 1:50 and 1:100-year peak flow volumes;
   - Preparation of river geometric settings file or flood modelling;
   - Setting up the GeoHecRas hydraulic modelling software for river sections to be modelled;
   - Simulation of the 1:2, 1:5, 1:10, 1:20, 1:50 and 1:100-year flood line; and
   - Mapping and analysis of the flood line modelling results.
4. Reporting:
   - A report detailing the results of all the activities listed above will be compiled and this will include conclusions and recommendations.

3 METHODOLOGY

3.1 Literature Review

The magnitude of a flood is dependent on many factors, such as catchment size, slope and rainfall intensity. There are several different methods for determining floods and in general, different methods arrive at different conclusions as to the peak flow rate. The accepted approach is therefore to use several methods and then make a judgment call as to which method is the most applicable to the catchment under consideration.

3.2 Peak Flood Determination and Methods

No statistical flow data was available and therefore three (3) deterministic methods, namely the Rational Method (RM), Unit Hydrograph Method (UHM), the Midgley and Pitman (MIPI) and the Standard Design Flood (SDF), were employed by using the Utility Programmes for Drainage (UPD) software for hydraulic analysis to determine design flood peaks for the delineated river catchments. These methods were chosen as they are suitable for small and medium to large catchment sizes. A short description of the methods to determine flood flows which were used in this study is given below.

3.2.1 Rational Method

The Rational Method was developed in the mid-19th century and is one of the most widely used methods for the calculation of peak flows typically for smaller catchments (<15 square kilometres (km^2). However, it can be used for larger catchments with caution. The formula indicates that Q = CIA, where “I” is the rainfall intensity, A is the upstream runoff area and “C” is the runoff coefficient. “Q” is the peak flow.

3.2.2 Unit Hydrograph Method (UHM)

The UHM is suitable for the determination of flood peaks as well as hydrographs for medium sized rural catchments (15 to 5 000 km^2). The method is mainly based on regional analyses of historical data and is independent of personal judgement. The results are generally reliable, although some natural variability in the hydrological occurrences is lost through the broad regional divisions and the averaged forms of hydrographs. This is especially true in the case of catchments smaller than 100km^2 in size (SANRAL, South African Drainage Manual, 2013).

3.2.3 Empirical Method: Midgely and Pitman (MiPi)

MIPI is an empirical method and is based on correlation between peak flows and some catchment characteristics. Regional parameters are then mapped out for South Africa and the border with Botswana. These methods are mostly suitable for medium to large catchments (SANRAL, South African Drainage Manual, 2013)

3.2.4 Standard Design Flood (SDF)

The Standard Design Flood (SDF) method was developed specifically to address the uncertainty in flood prediction under South African conditions (Alexander, 2002). The runoff coefficient (C) is replaced by a calibrated value based on the subdivision of the country into 26 regions or Water Management Areas (WMAs). The design methodology is slightly different and looks at the probability of a peak flood event occurring at any one of a series of similarly sized catchments in a wider region, while other methods focus on point probabilities (SANRAL, 2013).

3.3 Catchment Description and Delineation

The sub-catchments for the site was delineated using 30 m DEM data downloaded from the ALOS Global Digital Surface Model (Tadono T. , et al., 2014). From this delineation, catchment characteristics, such as: area, slopes and hydraulic parameters of the modelled river sections, were derived. The total surface area of the delineated sub-catchment is approximately 839 km^2 .The delineated water shed does not seem to follow the boundary of the quaternary catchment in the southern portion, however, upon further investigation, using Google Earth Imagery and Digital elevation models, it has been assumed that the delineated watershed is correct.

3.4 Flood Line Modelling

Imagery from the ALOS Global Digital Surface Model was used to derive the hydraulic and river geometry parameters. River cross sections and flow paths were prepared using GeoHECRAS software. Visual assessment of riverbanks from Google Earth Imagery was used to estimate the Manning's roughness coefficients along the river line. The flood lines generated were mapped in Global Mapper and were used to evaluate potential flood risks for the Hekpoort Area.

4 FLOOD LINE DETERMINATION

4.1 Standards and Legislation Framework

Legislation guides the minimum requirements for placement of river abstraction infrastructure in relation to a natural watercourse. The NWA (No. 36 of 1998) (Sections 121 and 144) requires the 1:100-year flood line for new developments on town layout plans. This is confirmed in the Guideline for Human Settlement Planning and Design. Municipalities may, however, stipulate other flood line recurrence intervals.

For any intended water abstraction, the following sections of the NWA must also be considered for a Water Use License (WUL):

- Section 21 (a) taking water from a water resource.

4.2 Modelling Guidelines and Methods

4.2.1 Topographical data

Topographical data, based on 1-arcsecond grid cells (~30m), were obtained from The Japan Aerospace Exploration Agency (JAXA). JAXA releases the global digital surface model (DSM) dataset with a horizontal resolution of approximately 30-meter mesh (1 arcsec) free of charge. The dataset has been compiled with images acquired by the Advanced Land Observing Satellite (ALOS) (Tadono T. , et al., 2014) (Tadono, et al., 2016) (Takaku, Tadono, & Tsutsui, 2014) (Takaku, Tadono, Tsutsui, & Ichikawa, 2016). The total surface area of the delineated sub-catchment is approximately 839 km^2 (Figure 1.1).

4.2.2 Roughness Coefficients

No site visit was conducted; therefore, roughness coefficients were determined via desktop study using Google Earth Imagery. Roughness coefficients represent the surface roughness of the channel and banks and are influenced by the nature of the river systems and surrounding vegetation. A Manning's roughness coefficient of 0.055 was chosen for the left overbank, channel and right overbank roughness. This value represents clean, meandering main channel with some pools, vegetation and stones. The maximum value was chosen as this is the most conservative.

5 RESULTS

5.1 Peak Flow Volumes

Flood peak volumes for the Magalies River in the Hekpoort Area are listed in Table 6.1. The Design Rainfall Estimation Software (Smithers & Schulze, 2002) used data from rainfall stations surrounding the study site to calculate 24-hour design rainfall depths for various return periods. Utility Programs for Drainage software was used to derive peak flows using five different methods and after assessing the results, taking into consideration background knowledge of the methods, a peak flow that best suited all methods was chosen and input into GeoHECRAS (US Army Corps of Engineers, 2018). The assumed correct peak flows (Table 5.1) were chosen taking into consideration the size of the catchment and the best suited and more conservative methods.

Table 5.1: Flow peak volumes calculated for different return periods using different methods

Method	1:2	1:5	1:10	1:20	1:50	1:100
Rational Method	237.68	343.76	460.53	599.99	820.85	1060.57
Alternative Rational Method	237.82	393.67	487.33	588.80	373.30	872.82
Unit Hydrograph Method	112.05	185.23	270.54	378.99	576.14	802.63
Standard Design Flood	88.68	365.32	625.67	822.44	1367.92	1743.84
Empirical Method	-	-	368.21	499.72	692.59	876.70
Assumed Peak Flows	*230*	*350*	*450*	*550*	*850*	*1100*

5.2 Flood Lines

The delineated flood lines for all return periods for the Klein River adjacent to the Hekpoort area are pesented in Figure 5.1. The aerial extent of the flood line reveals that . No devlopments fall within the floodplain, there is significant ponding along the length of the river, and the westerm-most portion of the Hekpoort will be submerged in the event of any of the modelled floods occuring.

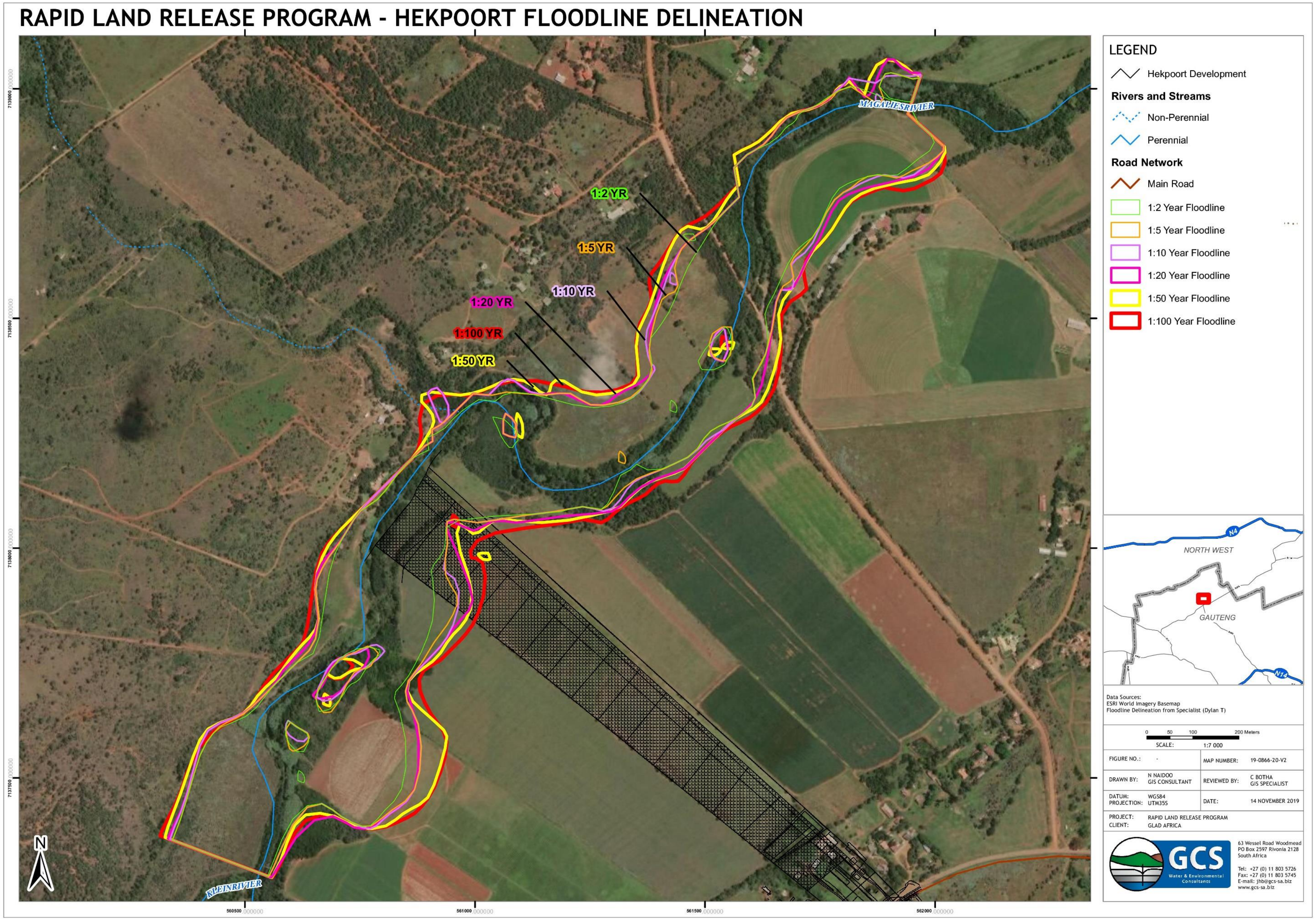

Figure 5.1: Simulated flood lines

6 CONCLUSIONS

Based on the findings of the study, the following conclusions were drawn:

- The Hekpoort Area is located along the Magalies River in the quaternary catchment A21F, with the study site covering portions of the farm Hekpoort No. 504 JQ.
- The total surface area of the delineated sub-catchment is approximately 839 km^2 was used to calculate peak flow volumes for the area.
- Peak flow volumes were calculated using the Rational Method, Alternative Rational Method, Standard Design Flood and Empirical Method (MiPi), and through analysing results of each method, a peak flow of 1100 m^3/s and 850 m^3/s were used to calculate the 1:100-year and 1:50-year flood lines respectively.
- The aerial extent of the flood lines shows that in the event of any of the modelled flood events occurring, the western-most portions of the Hekpoort development along the riverbank will be submerged.

7 RECOMMENDATIONS

From the results of the study, the following recommendations can be made:

- Due to uncertainty of the ALOS30 (30mx30m) topographical survey it is recommended to re-model flood lines with a detailed topographical survey of the riverbeds and any other features that occur within the riverbed.
- No “permanent” facilities should be placed within the 1:100-year flood line according to the NWA section 121 and 144.
- An application to the Department of Water and Sanitation (DWS) must be undertaken for a WUL (Section 21 (a): taking water from a water resource of the NWA) to commence a river abstraction.

9 REFERENCES

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APPENDIX A: CALCULATION OF PEAK FLOWS FOR THE HEKPOORT AREA

Name of project: Gladafrica | **River name:** Klein | **Date:** 7 November 2019

Description of site: | **Designer:** Dylan

Catchment characteristics

Area of catchment	839.89	km²
Length of longest watercourse	43.35	km

Calculate floods for the following return periods: ☑ 1:2 year ☑ 1:5 year ☑ 1:10 year ☑ 1:20 year ☑ 1:50 year ☑ 1:100 year

◉ Defined watercourse ○ Overland flow

Values for "r" if overland flow: Clean soil (r=0,1)

Height difference along 10-85 slope	254.47	m
Area dolomite	5	%
Mean annual rainfall	675	mm

Rainfall region: Inland

Physical characteristics as a percentage of the area of the catchment

Area distribution (%): Rural 90, Urban 10, Lakes 0

Adjustment factor for value of C: ◉ Default factors ○ Factor for flat and permeable catchments

Rural area

Surface slope		Permeability		Vegetation	
Lakes and pans	0	Very permeable	0	Thick bush & forests	5
Flat area	100	Permeable	0	Light bush & cultivated land	80
Hilly	0	Semi-permeable	100	Grasslands	15
Steep areas	0	Impermeable	0	Bare	0

Urban area

		Factor
Lawns		
Sandy, flat (<2%)	0	0.10
Sandy, steep (>7%)	0	0.20
Heavy soil, flat (<2%)	100	0.17
Heavy soil, steep (>7%)	0	0.35
Residential areas		
Houses	0	0.50
Flats	0	0.70
Industry		
Light industry	0	0.80
Heavy industry	0	0.90
Business		
City centre	0	0.70
Suburban	0	0.70
Streets	0	0.95
Maximum flood	0	1.00

View run-off coefficient factors

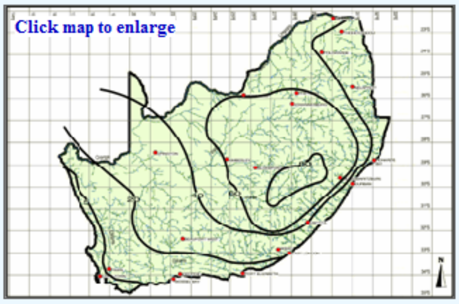
Rational | Alternative Rational | Unit Hydrograph | SDF | Empirical | Statistical | Results

Name of project: Gladafrica | **River name:** Klein | **Date:** 7 November 2019

Description of site: | **Designer:** Dylan

For the Alternative Rational method all the data as required for the Rational method on the previous tab should be entered as well as the data on this tab

Click map to enlarge



Calculate floods for the following return periods: ☑ 1:2 year ☑ 1:5 year ☑ 1:10 year ☑ 1:20 year ☑ 1:50 year ☑ 1:100 year ☑ 1:200 year

Days on which thunder was heard: 60 days/year

MAP data

Duration	2	5	10	20	50	100	200
1 day	45	59	69	79	94	106	119
2 days	59	77	90	104	124	140	157
3 days	67	89	106	124	149	169	191
7 days	85	116	139	163	198	226	256

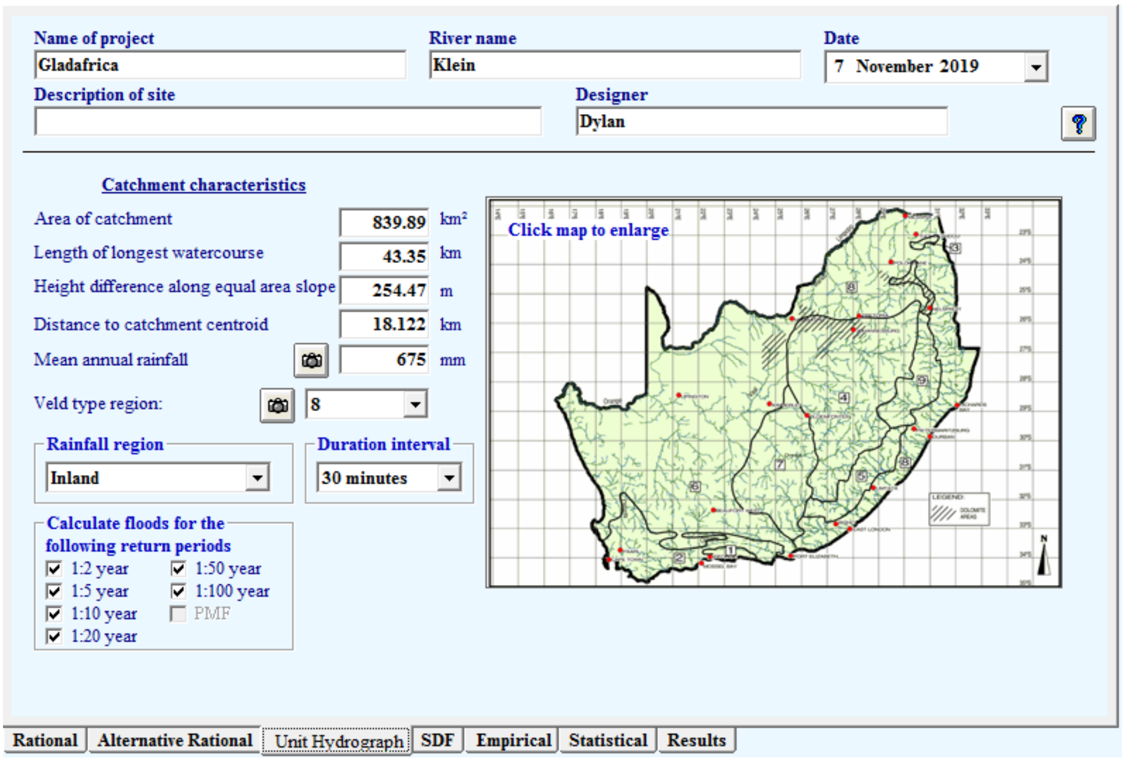
Weather Services station number: 5605

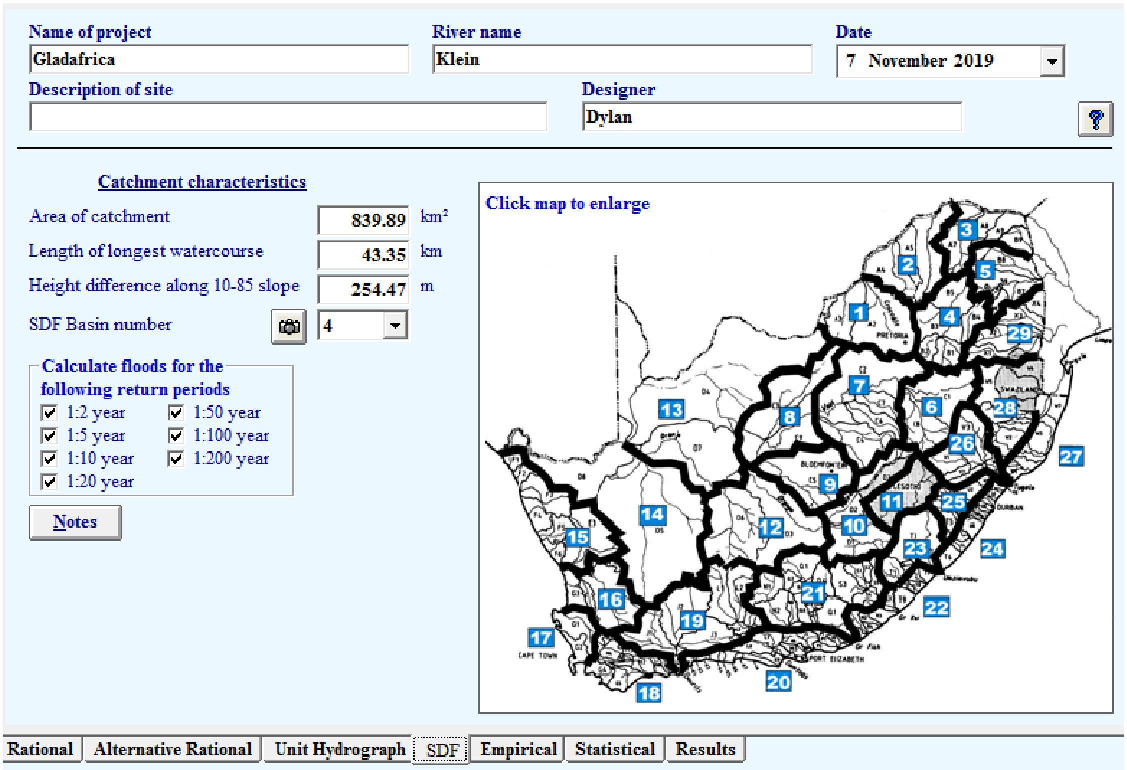
Weather Services station location: SOMERSET WEST

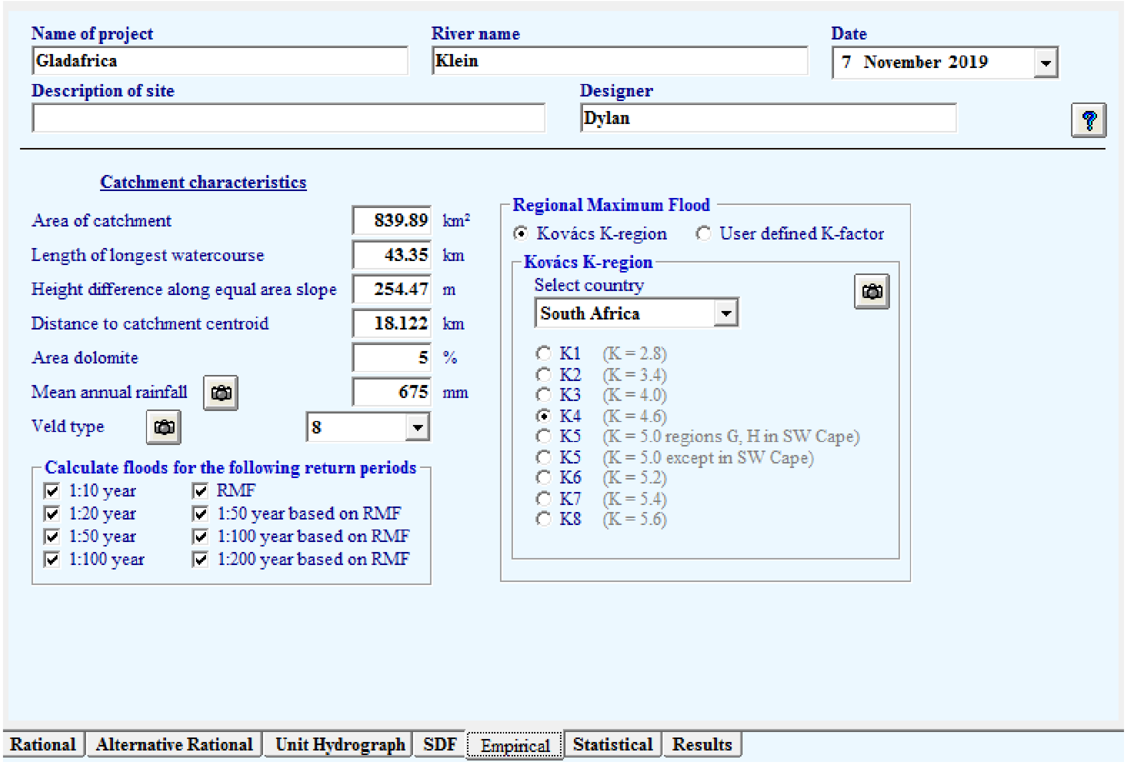
Mean annual precipitation (MAP): 606 mm

View the TR102 Data

Rational | Alternative Rational | Unit Hydrograph | SDF | Empirical | Statistical | Results


Name of project
Gladafrica
River name
Klein
Date
7 November 2019
Description of site
Designer
Dylan
Catchment characteristics
Area of catchment 839.89 km²
Length of longest watercourse 43.35 km
Height difference along equal area slope 254.47 m
Distance to catchment centroid 18.122 km
Mean annual rainfall 675 mm
Veld type region: 8
Rainfall region
Inland
Duration interval
30 minutes
Calculate floods for the following return periods
1:2 year
1:5 year
1:10 year
1:20 year
1:50 year
1:100 year
PMF
Click map to enlarge
Rational
Alternative Rational
Unit Hydrograph
SDF
Empirical
Statistical
Results


Name of project
Gladafrica
River name
Klein
Date
7 November 2019
Description of site
Designer
Dylan
Catchment characteristics
Area of catchment 839.89 km²
Length of longest watercourse 43.35 km
Height difference along 10-85 slope 254.47 m
SDF Basin number 4
Calculate floods for the following return periods
1:2 year
1:5 year
1:10 year
1:20 year
1:50 year
1:100 year
1:200 year
Notes
Click map to enlarge
Rational
Alternative Rational
Unit Hydrograph
SDF
Empirical
Statistical
Results


Name of project
Gladafrica
River name
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Date
7 November 2019
Description of site
Designer
Dylan
Catchment characteristics
Area of catchment 839.89 km²
Length of longest watercourse 43.35 km
Height difference along equal area slope 254.47 m
Distance to catchment centroid 18.122 km
Area dolomite 5 %
Mean annual rainfall 675 mm
Veld type 8
Calculate floods for the following return periods
1:10 year
1:20 year
1:50 year
1:100 year
RMF
1:50 year based on RMF
1:100 year based on RMF
1:200 year based on RMF
Regional Maximum Flood
Kovács K-region
User defined K-factor
Kovács K-region
Select country
South Africa
K1 (K = 2.8)
K2 (K = 3.4)
K3 (K = 4.0)
K4 (K = 4.6)
K5 (K = 5.0 regions G, H in SW Cape)
K5 (K = 5.0 except in SW Cape)
K6 (K = 5.2)
K7 (K = 5.4)
K8 (K = 5.6)
Rational
Alternative Rational
Unit Hydrograph
SDF
Empirical
Statistical
Results