Flood Frequency Analysis: Rational Method Department of Water Affairs application

Flood Frequency Analysis: Rational Method

Project	= BOKAMOSO ENEGY PV DEVELOPMENT
Analysed by	= CAS COETZER
Name of river	= BOKAMOSO ENEGY PV DEVELOPMENT
Description of site	= MATJESSPRUIT 145: LEEUDORINGSTAD
Date	= 5/30/2016
Area of catchment	= 3.622 km²
Dolomitic area	= 0.0 %
Mean annual rainfall (MAR)	= 520.00 mm
Length of longest watercourse	= 3.12 km
Flow of water	= Overland flow
Height difference	= 30.0 m
Value of r for over land flow	= Sparse grass (r=0,3)
Rainfall region	= Coastal
Area distribution	= Rural: 50 %, Urban: 50 %, Lakes: 0 %

Catchment description - Urban area (%)

Lawns		Residential and industry		Business	
Sandy, flat (<2%)	1	Houses	0	City centre	0
Sandy, steep (>7%)	9	Flats	0	Suburban	0
Heavy soil, flat (<2%)	1	Light industry	0	Streets	80
Heavy soil, steep (>7%)	9	Heavy industry	0	Maximum flood	0

Catchment description - Rural area (%)

Surface slopes	Permeability	Vegetation

Lakes and pans	**0**	**Very permeable**	**0**	**Thick bush & forests**	**0**
Flat area	**100**	**Permeable**	**0**	**Light bush & cultivated land**	**0**
Hilly	**0**	**Semi-permeable**	**55**	**Grasslands**	**55**
Steep areas	**0**	**Impermeable**	**45**	**Bare**	**45**

Average slope = 0.00962 m/m

Time of concentration = 1.73 h

Run-off factor

Rural - C1 = 0.431

Urban - C2 = 0.812

Lakes - C3 = 0.000

Combined - C = 0.622

The HRU, Report 2/78, Depth-Duration-Frequency diagram was used to determine the point rainfall.

Return Period (years)	Time of concentration (hours)	Point rainfall (mm)	ARF (%)	Average intensity (mm/h)	Factor Ft	Runoff coefficient (%)	Peak flow (m^3/s)
1:2	1.73	20.8	99.9	12.0	0.75	56.8	6.840
1:5	1.73	28.3	99.8	16.3	0.80	57.9	9.487
1:10	1.73	35.8	99.8	20.6	0.85	58.9	12.22
1:20	1.73	44.2	99.7	25.4	0.90	60.0	15.36
1:50	1.73	57.4	99.7	33.1	0.95	61.1	20.31
1:100	1.73	70.7	99.6	40.6	1.00	62.2	25.42

Run-off coefficient percentage includes adjustment saturation factors (Ft) for steep and impermeable catchments

Flood Frequency Analysis: Alternative Rational Method

Project	**= BOKAMOSO ENEGY PV DEVELOPMENT**
Analysed by	**= CAS COETZER**
Name of river	**= BOKAMOSO ENEGY PV DEVELOPMENT**
Description of site	**= MATJESSPRUIT 145: LEEUDORINGSTAD**
Date	**= 5/30/2016**
Area of catchment	**= 3.622 km²**
Dolomitic area	**= 0.0 %**
Length of longest watercourse	**= 3.12 km**
Flow of water	**= Overland flow**
Height difference	**= 30.0 m**
Value of r for over land flow	**= Sparse grass (r=0,3)**
Area distribution	**= Rural: 50 %, Urban: 50 %, Lakes: 0 %**

Catchment description - Urban area (%)

Lawns		Residential and industry		Business	
Sandy, flat (<2%)	1	Houses	0	City centre	0
Sandy, steep (>7%)	9	Flats	0	Suburban	0
Heavy soil, flat (<2%)	1	Light industry	0	Streets	80
Heavy soil, steep (>7%)	9	Heavy industry	0	Maximum flood	0

Catchment description - Rural area (%)

Surface slopes		Permeability		Vegetation	
Lakes and pans	0	Very permeable	0	Thick bush & forests	0
Flat area	100	Permeable	0	Light bush & cultivated land	0
Hilly	0	Semi-permeable	55	Grasslands	55
Steep areas	0	Impermeable	45	Bare	45

Days on which thunder was heard = 60 days/year

Weather Services station number = 399241

Weather Services station location = LEEUKOP

Mean annual precipitation (MAP) = 520 mm

Duration	2	5	10	20	50	100	200
1 day	54	73	88	103	125	143	163
2 days	67	95	116	138	170	198	228
3 days	74	105	128	153	190	220	253
7 days	95	139	173	210	263	308	358

The modified recalibrated Hershfield relationship was used to determine point rainfall.

Average slope = 0.00962 m/m

Time of concentration = 1.73 h

Run-off factor

Rural - C1 = 0.431

Urban - C2 = 0.812

Lakes - C3 = 0.000

Combined - C = 0.622

Return period (years)	Time of concentration (hours)	Point rainfall (mm)	ARF (%)	Average intensity (mm/h)	Factor Ft	Runoff coefficient (%)	Peak flow (m^3/s)
1:2	1.73	31.00	100.0	17.89	0.75	56.8	10.22
1:5	1.73	52.29	100.0	30.19	0.80	57.9	17.57
1:10	1.73	68.40	100.0	39.49	0.85	58.9	23.41
1:20	1.73	84.51	100.0	48.79	0.90	60.0	29.45
1:50	1.73	105.80	100.0	61.08	0.95	61.1	37.54
1:100	1.73	121.91	100.0	70.38	1.00	62.2	44.01
1:200	1.73	138.02	100.0	79.68	1.00	62.2	49.83

Run-off coefficient percentage includes adjustment saturation factors (Ft) for steep and impermeable catchments

Flood frequency analysis: Standard Design Flood method

Project name	**= BOKAMOSO ENEGY PV DEVELOPMENT**
Analysed by	**= CAS COETZER**
Name of river	**= BOKAMOSO ENEGY PV DEVELOPMENT**
Description of site	**= MATJESSPRUIT 145: LEEUDORINGSTAD**
Date	**= 5/30/2016**
Catchment characteristics:	
Area of catchment	**= 3.622 km²**
Length of longest watercourse	**= 3.12 km**
1085 height difference	**= 30 m**
Average slope	**= 0.0128 m/m**
Drainage basin characteristics:	
Drainage basin number	**= 7**
Mean annual daily max rain	**= 49 mm**
Days on which thunder was heard	**= 39 days**
Runoff coefficient C2	**= 15 %**
Runoff coefficient C100	**= 60 %**
Basin mean annual precipitation	**= 510 mm**
Basin mean annual evaporation	**= 1700 mm**
Basin evaporation index MAE/MAP	**= 3.33**

RAINFALL DATA

The rainfall data in the table below are derived from two sources. The daily rainfall is from the Department of Water Affair's publication TR102 for the representative site. The modified Hershfield equation is used for durations up to four hours. Linear interpolation is used for values between 4 hours and one day.

Weather Services station ex TR102 = 328726 @ OLIVINE

Point mean annual precipitation = 510 mm

Dur:	RP =2	5	10	20	50	100	200
.25 h	14	24	32	39	49	57	64
.50 h	19	32	41	51	64	74	84
1 h	23	39	51	63	79	91	103
2 h	27	46	61	75	94	108	122
4 h	32	54	70	87	109	125	142
1 day	49	68	82	96	118	137	157
2 days	62	87	107	128	158	184	213
3 days	68	94	115	136	167	193	221
7 days	84	118	144	172	211	243	279

CAUTION. The time of concentration is less than one hour.
Runoff coefficients C2 = 15 % C100 = 60 %

Return period (years)	Time of concentration (hours)	Point precipitation (mm)	ARF (%)	Catchment precipitation (mm)	Runoff coefficient (%)	Peak flow (m^3/s)
1:2	0.85	22.1	100.0	22.1	15.0	3.923
1:5	0.85	37.4	100.0	37.4	31.2	13.78
1:10	0.85	48.9	100.0	48.9	39.7	22.92
1:20	0.85	60.4	100.0	60.4	46.7	33.28
1:50	0.85	75.6	100.0	75.6	54.6	48.74
1:100	0.85	87.1	100.0	87.1	60.0	61.72
1:200	0.85	98.6	100.0	98.6	64.8	75.50

Empirical methods Midgley and Pitman as well as Kovács Method

Project = **BOKAMOSO ENEGY PV DEVELOPMENT**
Analysed by = **CAS COETZER**
Name of river = **BOKAMOSO ENEGY PV DEVELOPMENT**
Description of site = **MATJESSPRUIT 145: LEEUDORINGSTAD**
Date = **5/30/2016**

Area of catchment = **3.622 km²**
Length of longest watercourse = **3.12 km**
Height difference along equal-area slope = **25.0 m**
Distance to catchment centroid = **1.6 km**
Dolomitic area = **0.0 %**
Mean annual rainfall = **520.0 mm**
Veld type = **1**
Kovács region = **K4(K = 4.6)**
Catchment parameter with regard to reaction time = **0.065**

Peak discharges by means of an empirical method developed by **Midgley and Pitman**

Return period (years)	KT constant	Peak flow (m^3/s)
1:10	0.17	4.175
1:20	0.23	5.649
1:50	0.32	7.859
1:100	0.40	9.824

This RMF calculation includes a transition zone adjustment in the case of small catchments.

Regional maximum flood: 163.1 m^3/s

Kovács Method

Q50(RMF): 67.84 m^3/s (based on QT/QRMF relationship for **Kovács** regions)
Q100(RMF): 85.45 m^3/s (based on QT/QRMF relationship for Kovács regions)
Q200(RMF): 102.58 m^3/s (based on QT/QRMF relationship for Kovács regions)

The following equivalent maxima make no transition zone adjustments for small catchments.

Equivalent southern African maximum
K-factor 5.6: 532 m^3/s

Equivalent world maxima
K-factor 6.0: 1056 m^3/s
K-factor 6.3: 1765 m^3/s

HERBST ALGORITHM DEVELOPED AT THE DEPARTMENT OF WATER AFFAIRS

$Q_T = C_{HERBST} A^{0,46} P^{0,93} (1+(K_T * C_V)/100)$

With:

C_{HEBST} = Coefficent of variation

A = Catchment area in km^2

P = Mean annual precipitation

K_T = Frequency factor

For this situation:

Coefficent of variation	=	170.1
Catchment area	=	3.62 km^2
Mean annual precipitatio	=	520 mm
Frequency factor	=	4.3
Recurrance interval	=	100 year

Q_T : 67 m^3/s

HRU ALGORITHM DEVELOPED AT THE
THE WITS UNIVERSITY

$Q_T = 0{,}0377\ K_T P A^{0,8} (S^{0,5}/(LL_C))^{0,2}$

With:

K_T = Constant dependant on veld zone and T

A = Catchment area in km^2

P = Mean annual precipitation mm

S = Slope of the longest water course in m/m

L = Length of the longest stream in km

L_c = Distance to the centroid of the catchment in km

For this situation:

K_T	=	1.200	
A	=	3.62	km^2
P	=	520	mm
S	=	0.0096	
L	=	3.12	km
L_c	=	3.6	km

Recurrance interval = 100 year

Q_T = 26 m^3/s

TEN NOORT STEPHENSON ALGORITHM DEVELOPED AT WITS UNIVERSITY

$Q_T = (a_3P + b_3)T^{b2}A^{b1}$

With:

T = Recurrence interval in years

A = Catchment area in km^2

P = Mean annual precipitation mm

b_1 = Coefficient dependant on veld zone, region and P

b_2 = Coefficient dependant on veld zone, region and P

b_3 = Coefficient dependant on veld zone, region and P

a_3 = Coefficient dependant on veld zone, region and P

For this situation:

T	=	100	year
A	=	3.62	km^2
P	=	520	mm
a_3	=	0.0012	
b_1	=	0.69	
b_2	=	0.49	
b_3	=	-0.18	
Q_T	**=**	**19**	**m^3/s**

UNIT HYDROGRAPH METHOD

$Q = Q_P \times d_e \times F_m =$ Peak flood in m^3/s

With:

Q_P = Peak flood of the 1 hour synthetic hydrograph
$= K_U \times (A / T_L)$

A = Catchment area in km^2

$T_L = C_T [L \times L_C / (S^{0.5})]^{0.36}$ = Basin lag in hour

C_T = Constant depending on the sone

L = Length of the longest stream in km

L_C = Distance to catchment centroid in km

S = Average slope along longest stream

P = Mean annual precipitation

K_U = Constant depending on the sone

d_e = Percentage of storm run-off x d_g

d_g = d x a in mm

d = Design raifall depth in mm

a = Area reduction factor

i = Rainfall intensity mm/hour

and,

F_m = ***Highest ordinate obtained with the S-curve transformation***

For this situation:

A	=	3.62	km^2
T_L	=	1.76	hour
C_T	=	0.32	
L	=	3.12	km
L_C	=	3.6	km
S	=	0.0096	m/m
P	=	520	mm
K_U	=	0.386	
d_g	=	90	mm
d	=	55.8	mm
a	=	1	
i	=	94.508	mm/hour
F_m	=	1	

T	=	100	year
Q_P	=	0.7923	m^3/s
d_e	=	55.8	mm

Q = 44.21 m^3/s