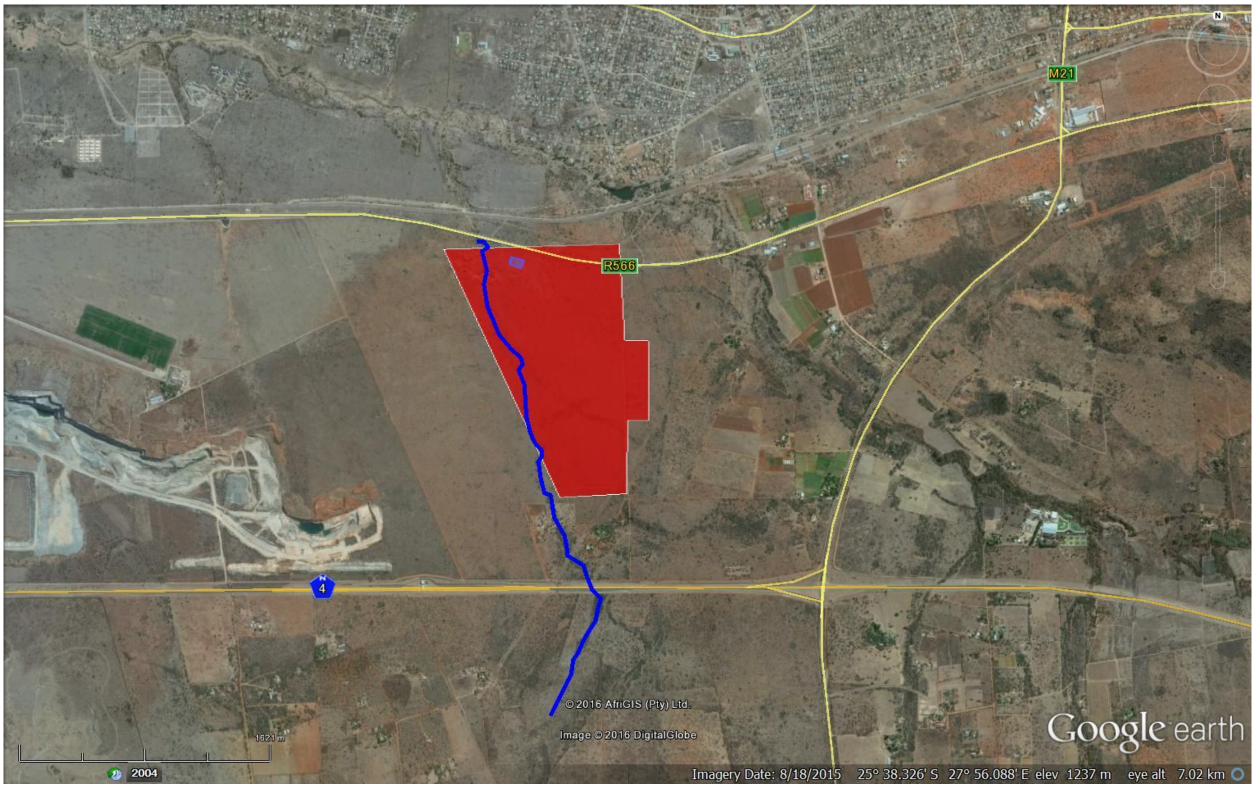
DETERMINATION OF 1:100 YEAR FLOOD LINES AND STORMWATER MANAGEMENT PLAN AND DESIGN OF SMALLER STRUCTURES: DE WILDT PV PLANT



SunEdison®

Water TECHNOLOGY CWT

Cas Coetzer Consultant in Water Technology
BSc Eng(Civ)(Pret) PrEng MECSA MSAICE
BSc Ing(Siv)(Pret) PrIng LECSA LSAISI

TEL (012) 3311033
FAX (012) 3311033
CEL 083 230 8752

EMAIL cas52@mweb.co.za

CLIENT: Business Development SunEdison Energy

CONSULTING ENG: CWT Consulting

REPORT NO ***CWT 342016***

DATE: ***28 April 2016***

DETERMINATION OF 1:100 YEAR FLOOD LINES AND STORMWATER MANAGEMENT PLAN AND DESIGN OF SMALLER STRUCTURES: DE WILDT PV PLANT

CLIENT	Business Development SunEdison Energy
Company	SunEdison
Contact Person	Eric Khumalo / Mr Tsunduka Hatlane
Adress	4th Floor Global House 28 Sturdee and Jellicoe Avenue. Rosebank Johannesburg South Africa 2196
Tel No.	+27 10 595 7006
Cell	
Fax No.	
E-mail	ekhumalo@sunedison.com tsunduka@phakipersonnel.co.za hluke@phakanani.co.za

CONTENTS

ADDENDA

ADDENDUM	1	Flood lines
ADDENDUM	2	Layout of the flood line sections
ADDENDUM	3	Flood level calculations
ADDENDUM	4	Cross sections
ADDENDUM	5	Flood peaks in the stream calculations
ADDENDUM	6	Flood peaks generating on the site
ADDENDUM	7	Layout of erosion mitigation structures
ADDENDUM	8	Mitigating measures details

1. INTRODUCTION

CWT Consulting was appointed by ***SunEdison Energy*** to perform a surface flow hydrologic study at the proposed site of the photo voltaic development on a property in the area of De Wildt in the Gauteng Province

The 1:2, 1:10, 1:20, 1:50 & 1:100 year flood peaks and flood volumes were determined.

2. LOCATION

The location of the area is shown below.

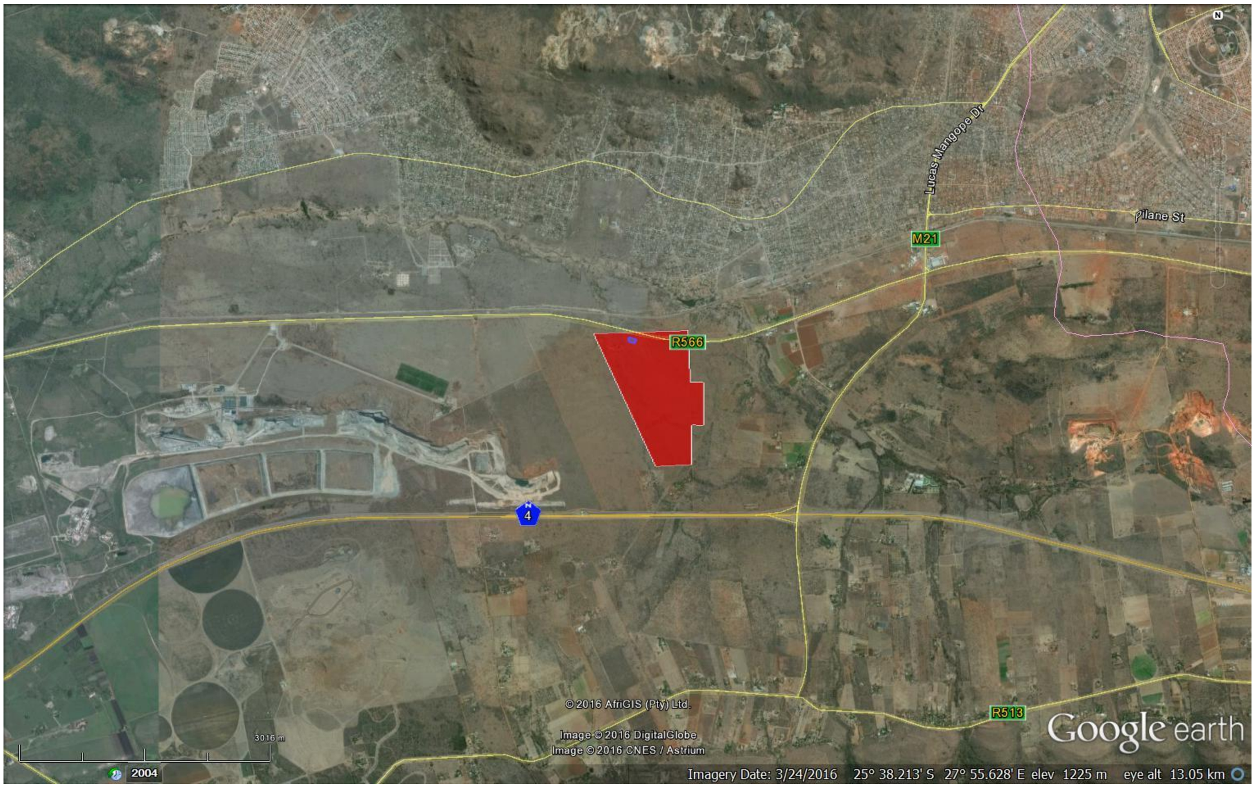


FIGURE 1

3. HYDROLOGY

3.1 Rainfall Data

Catchment MAP (ex HRU quaternary): More than 600 mm

The rainfall data in the table below are derived from three sources. The modified Hershfield equation is used for durations up to four hours.

The daily rainfall is from the Department of Water Affair's publication TR102 adjusted so that TR102 MAP = catchment MAP. Where the equation values exceed the 1-day rainfall, they are reduced to equal to the 1-day rainfall.

Weather Bureau station: **512613 @ HARTEBEESPOORT DAM**
Mean annual precipitation (TR102): **664 mm**

Precipitations in ***mm*** associated with various storm return periods are given in the Table1.

STORM DURATION	**Return Period (RP)**					
	2	**5**	**10**	**20**	**50**	**100**
53 minutes	27 mm	46 mm	60 mm	75 mm	93 mm	108 mm

Table 1

3.2 Catchment characteristics

The catchment area of the stream is shown in Figure 2.

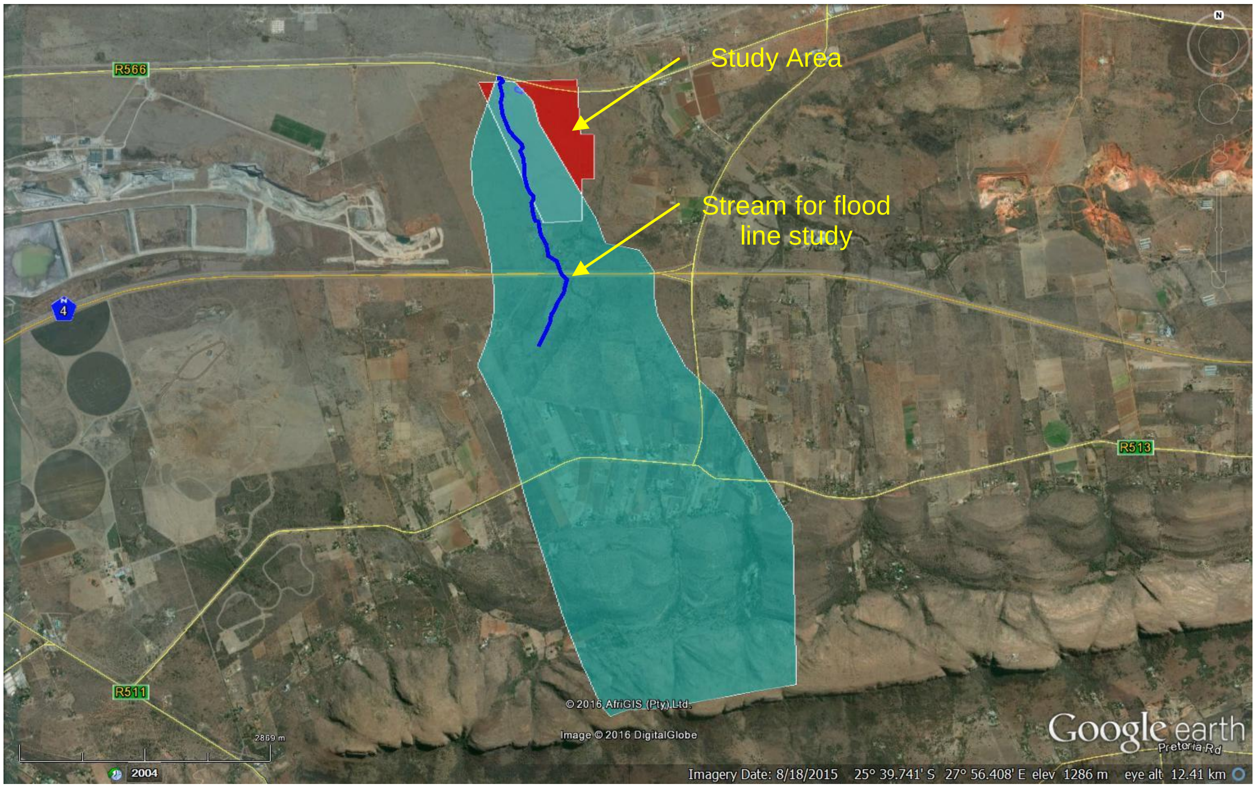


Figure 2

Stream

Area of catchment:	14,68	km²
Length of longest watercourse:	3,50	km
Equal area height difference:	49	m
Distance to catchment centroid:	5,0	km
Time of concentration	53	minutes

3.3 Flood Peak Calculations

3.3.1 The Effect of Dams on the Flood Peaks

The effect of any dam in the catchment was not taken into account because the 1:100 year flood peak will ***not*** be attenuated by a dam with a smaller storage capacity than *6 times the total mean annual runoff* of the catchment draining into the dam.

3.3.2 Methods used to calculate the Flood Peaks

Various different methods were used to calculate the flood hydrology for the catchment as this increases the accuracy of the final flood peak calculation. All the methods used take the following into account:

All factors relating to storm water run-off.

- Evaporation during rain storm (Please read **Addendum A**)
- Wind during rainstorm (Please read **Addendum A**)
- Depth of rainstorm (Please read **Addendum A**)
- Infiltration (Please read **Addendum A**)
- Flow roughness of area. (Please read **Addendum A**)

The following methods were considered:

1. Rational method as implemented by the Department of Water Affairs.
2. Rational method using an alternative implementation.
3. Standard Design Flood (SDF) method as developed at Pretoria University.
4. The Herbst algorithm as developed by the Department of Water Affairs
5. The HRU algorithm

6. Ten Noort & Stephenson algorithms as developed at Wits University.

7. The Unit Hydrograph Method

3.3.3 Most applicable methods for the catchments

Due to the size of the catchment the results obtained from al the methods are deemed to be applicable for this study.

Results of the calculations

The results are listed below. The flows indicated are in cubic meter per second.

Details of the calculations are shown in **Addendum 6**.

Return Period Year	Rational method DWA	Rational method Alterna-tive algorithm	SDF method	Herbst Algo-rithm	HRU Algorithm	Ten Noort & Stephenson algorithms	Unit Hydro-graph
1:50	129	222	131	125	75	42	52
1:100	166	259	166	146	95	60	64

Table 2

3.3.4 Recommended Flood Peaks

The flood peaks were calculated by applying the following algorithm:

$$Q_T = [RMDWA + RMAL + SDF + H] / N$$

With:

- **Q_T** = Flood peak for return period T
- **T** = Return Period
- **RMDWA** = Rational method DWA
- **RMAL** = Rational method Alternative algorithm
- **SDF** = SDF method

H = Herbst Algorithm

N = 4

The recommended flood peaks in cumec (cubic meter per second) at the site are listed in Table 3 below:

Return Period Year	Flood peak in the River
1:50	152
1:100	**184**

Table 3

4. HYDROLOGY FOR ON SITE GENERATED SHEET FLOW

4.1.1 Rainfall Data

Weather Bureau station*:* **512613 @ HARTEBEESPOORT DAM**

Mean annual precipitation (TR102): **664 mm**

4.1.2 Evaporation Data

This site is within the **A21J Tertiary Catchment** and the mean annual s-pan evaporation is 1 700* mm. The mean annual rainfall is 664* mm. This information is available from the Water Research Commission (WRC) Report TT 382/08.

4.2 Catchment characteristics

The study area is shown in Figure 3.

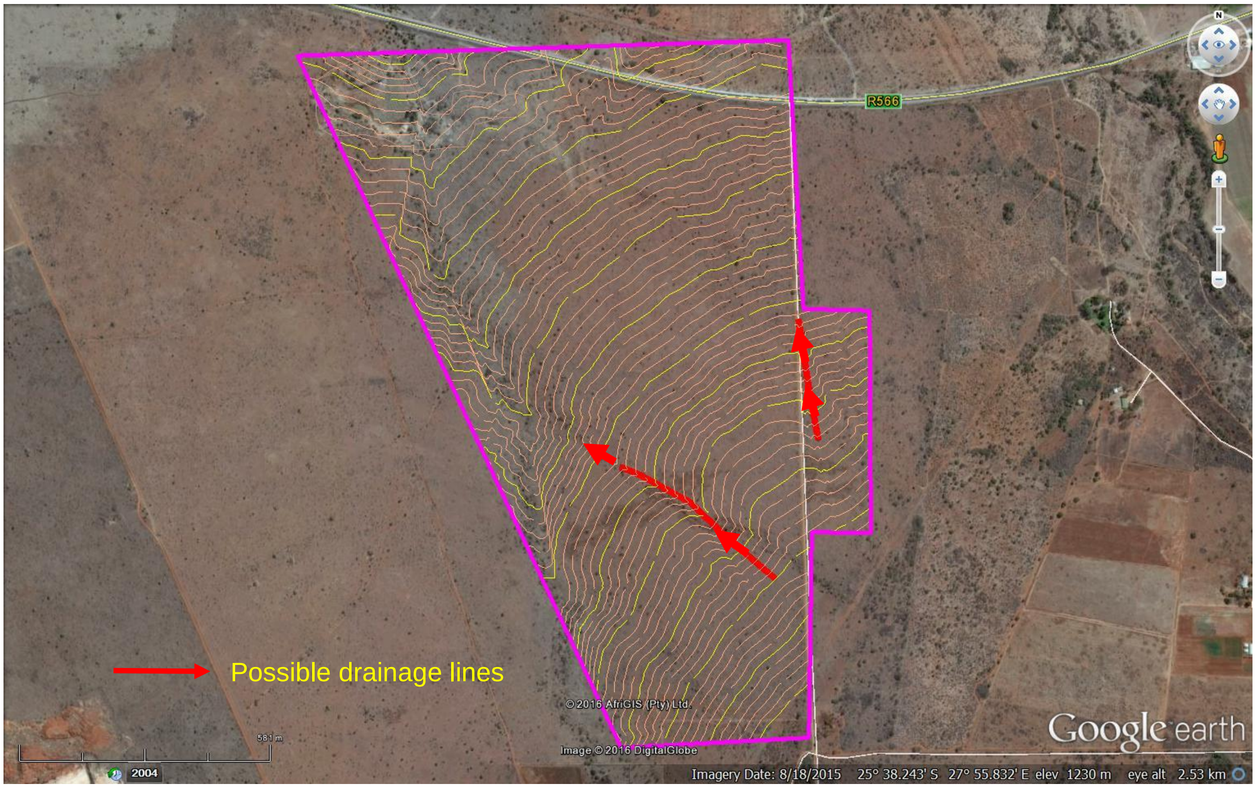


Figure 3

Characteristics

Area of catchment:	1,4	km²
Length of longest watercourse:	1,6	km
Flow of water	Overland Flow	
Equal area height difference:	27,5	m
Average slope	0,01719	m/m
Time of concentration	16,7	minutes

4.3 Flood Peak Calculations

4.3.1 Time of concentration

The catchment area has no defined stream section and therefore ***sheet-flow or overland flow*** will be the flow pattern during a rainstorm. The time of concentration was determined with the Kerby formula.

With: $r = 0,1$ $L = 1,6$ km $h = 27,5$ m $s = 0,01719$ m/m.

Time of concentration: $t_c = 0,604(rL/s^{0,5})^{0,467}$ = **16,7 minutes**.

4.3.2 Volumes of the hydrographs

The volume of the hydrograph is $0,5 \times 4t_c \times Q_T$ m^3 with

T = Return period, t_c in ***seconds.***

4.3.3 Methods used to calculate the Flood Peaks

The Rational method as implemented by the Department of Water Affairs was used because of the relative small size of the area.

Results of the calculations

The results are listed below. The flows indicated are in cubic meter per second.

Details of the calculations are shown in **Addendum 6**.

Return Period Year	Rational method DWA
1:2	6
1:5	9
1:10	13
1:20	16
1:50	23
1:100	29

Table 4

5 Recommended Flood Volumes

The recommended total flood peaks in **m^3/s** and the flood volumes in **m^3** at the site are listed in Table 5 below. The typical length of the storm hydrograph is $4t_c$ = 1002 s.

Return Period Year	Flood peak m^3/s	Flood volume m^3
1:2	6	6012
1:5	9	9018
1:10	13	13026
1:20	16	16032
1:50	23	23046
1:100	29	29058

Table 5

6. THE FLOOD LINES

The 1:100 year flood line is shown in **Addendum 1.** The layout of the sections used to compile the HecRas model is shown in **Addendum 2.** The effect of the road bridge downstream of the property was included in the model. The flow velocities vary between 1m/s to around 4 m/s and the flow state is sub-critical which means that the flood levels are controlled by downstream features such as the road bridge and the existing donga. The flow velocities are such that scouring of the stream banks can be expected.

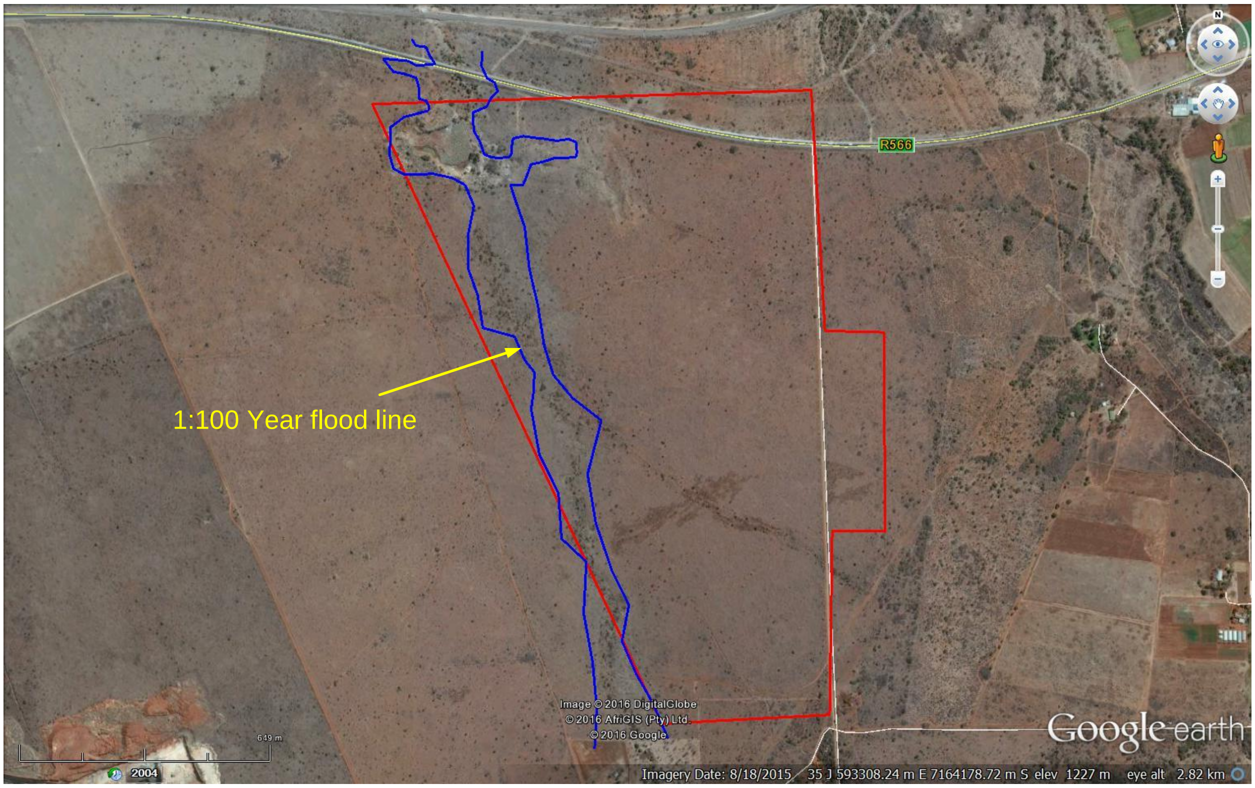


Figure 4

7. ASSESS IMPACT FLOODING EROSION & DEPOSITION OF SILT

7.1 EROSION AND DEPOSITION OF SILT

The soil type at the site can be seen in Figure 5. The soil can be classified as an alluvial sandy loam type (colloidal).

The grass type is NK 37 type and the cover is dense with sparse trees and shrubs.

The clay percentage ranges between 5% and 15%.

Figure 5

The sheet-flow velocities during the various storm return periods were determined. (Table 6.) Flow width is 565 m.

Return period	Sheet-flow depth over the area in m	Sheet-flow velocity over the area in m/s
1:2	0,075	0,07
1:5	0,10	0,11
1:10	0,125	0,15
1:20	0,134	0,2
1:50	0,140	0,27
1:100	0,150	0,34

Table 6

The minimum flow velocity of the storm water over the area for these conditions to cause erosion were determined and summarized in Table 7.

Return period	Minimum flow velocity to cause erosion m/s	Minimum flow velocity to cause deposition of silt m/s	Actual sheet flow velocity over the area m/s
1:2	0,98	0,11	0,07
1:5	1,05	0,14	0,11
1:10	1,1	0,16	0,15
1:20	1,12	0,17	0,2
1:50	1,13	0,17	0,27
1:100	1,14	0,18	0,34

Table 7

From **Table 7** the following conclusions can be made:

1:2 Year Return Period

Deposition of silt may occur for rainfall intensities lower the 1: 2 year return period. No erosion is expected.

1:5 Year Return Period

Deposition of silt may occur for rainfall intensities lower the 1: 5 year return period. No erosion is expected.

1:10 Year Return Period

Deposition of silt will occur for rainfall intensities above the 1: 10 year return period. No erosion is expected.

1:20 Year Return Period

No siltation or erosion is expected.

1:50 Year Return Period

No erosion is expected. No silting is expected.

1:100 Year Return Period

Some erosion may occur.

8. Drag Forces on the legs of the PV stands

Water flowing past a partly or wholly immersed body (legs of PV stands in this case) exerts a force on the body, the component of which in the direction of the flow is known as the *drag force*.

The drag force exerted by the flood water on the legs of the PV stands is a function of the depth of flow, the flow velocity raised to the power of two as well as the density of water (r=1000 kg/m^3). Furthermore a coefficient of drag must also be used for the calculation of the drag.

For this case this coefficient ($\mathbf{C_{DRAG}}$) is 2,2.

The width of a leg was taken as **120 mm** which includes debris around the leg.

The equation to calculate the drag force is:

F_{DRAG} = 0,5 (C_{DRAG} x r x Velocity^2 x Area perpendicular to the flow direction)

The drag forces on the PV stands for floods with the different return periods are as follows:

Return period	Maximum flow velocity m/s	Maximum hydraulic depth m	Flow area immersed m^2	Drag force on four legs Kg
1:2	0,07	0,075	0.009	22
1:5	0,11	0,10	0.012	50
1:10	0,15	0,125	0.015	104
1:20	0,2	0,134	0.01608	157
1:50	0,27	0,140	0.0168	324
1:100	0,34	0,150	0.018	515

Table 8

The biggest expected drag force will be **515 kg** during the 1:100 year rainstorm.

9. Conclusion

1. The PV stands can be erected provided the foundations of the stands are designed to withstand the forces shown on **Table 8.** Please note that the buffer area borders between the drainage paths and the valuable infrastructure are detailed in **Addenda 7 & 8**.

2. The areas should not be backfilled or graded as this will cause more scouring unless the backfill is compacted and covered with vegetation before the first storm run-off.

3. The possible drainage paths must be treated by constructing small flow check structures as detailed in **Addendum 8**.

4. The runoff emanating from the project area eventually drains to the streams and rivers shown in the **Figure 6.**

Positions of existing reservoirs in the area are indicated on Figure 6. No bore holes exist in the area.

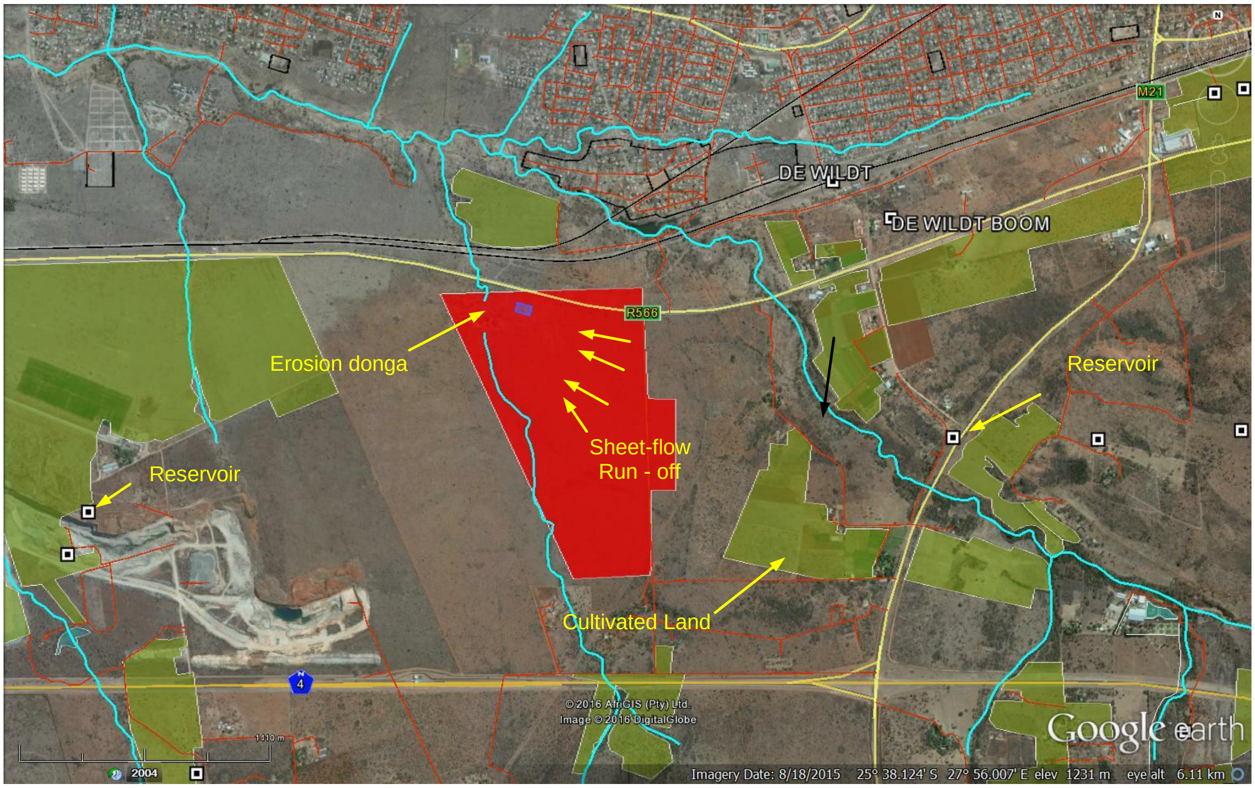


Figure 6

10. REFERENCES

1. *Water Research Commission (WRC) Report TT 382/08.*
2. *Department of Water Affair's publication TR102*
3. *Hydrological Research Unit Report No. 1/72*
4. *PlanetGIS Geographic Information System (GIS) software suite*
5. *National Road Commission: Drainage Handbook.*

C. J. COETZER (Pr Eng)

26 April 2016