ENVIRONMENTAL IMPACT ASSESSMENT PROCESS: PROPOSED PHOTOVOLTAIC (SOLAR) ENERGY FACILITIES ON DU PLESSIS DAM FARM NEAR DE AAR NORTHERN CAPE

Conceptual Stormwater Management Plan – Du Plessis Dam Farm

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1. Background

Mulilo Renewable Energy (Pty) Ltd (Mulilo) proposes to construct three separate solar energy facilities, on Du Plessis Dam Farm (Remainder of Farm 179), near De Aar in the Northern Cape. Each of the three proposed facilities would have a maximum generation capacity of 75MW Alternating Current (AC) through photovoltaic (PV) technology. The location of the farm and its extent is presented in Figure 1. Mulilo is proposing a similar project for Badenhorst Dam Farm, which is located south-east of De Aar. As both of these projects are located within the same project area, they are shown in Figure 1. Aurecon South Africa (Pty) Ltd was requested to produce separate Conceptual Stormwater Management Reports for both Du Plessis Dam Farm and Badenhorst Dam Farm. This report focuses on Du Plessis Dam Farm. The proposed development includes, but is not limited to gravel access lanes, grading of the site and foundations and equipment for numerous solar panels, water supply infrastructure and on-site buildings.

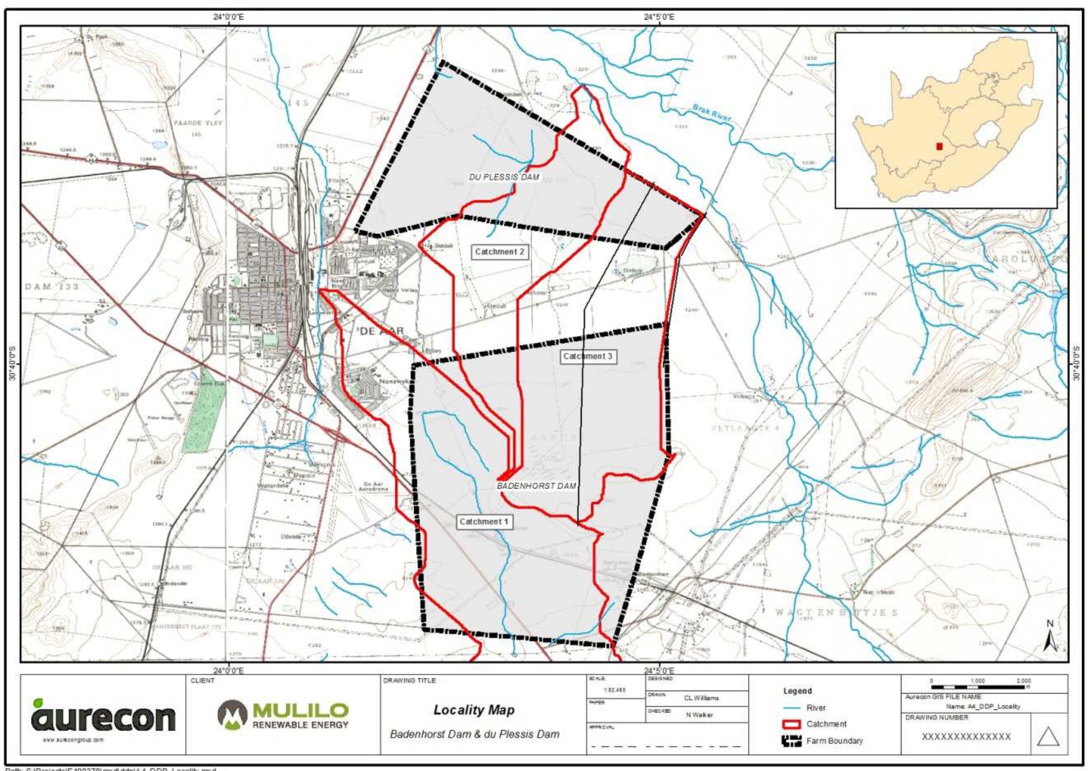

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Figure 1: Location of the Du Plessis Dam Farm (Remainder of Farm 179) and Badenhorst Dam Farm, near De Aar in the Northern Cape.

2. Terms of Reference

The development of a Conceptual Stormwater Management Report for the planned photo-voltaic (PV) facility at Du Plessis Farm Dam is necessary to mitigate any adverse effects of the proposed development in relation to local stormwater runoff. To this end, pre- and post-development stormwater runoff from the sites will be assessed and recommendations made to mitigate and / or accommodate increased and concentrated runoff for a range of storm Recurrence Intervals (RI), typically 1:5 year and 1:20 year. The 1:20 year RI is considered adequate for rural stormwater assessment.

3. Approach to the Study

Two alternatives for the development of the site are proposed. The layout of these alternatives overlaps 2 different catchments. Therefore the effect on stormwater runoff needs to consider the increase in runoff of each alternative as it impacts on each catchment.

A comparison of layout Alternatives 1 and 2 in regard to the impact on the runoff was conducted for the 1:20 year flood. The pre- and post-development flood peaks were determined for Catchments 2 and 3 (Figure 1). The layout Alternatives are described in Section **Error! Reference source not found.** with the land alterations detailed in Section 5. The 1:20 year and 1:5 year flood peak was ascertained using the Rational Method (Section 6).

As mentioned in Section 1, there is a proposed PV facility on the upstream Badenhorst Dam Farm. Part of this Study is to consider the impact of the Badenhorst facility on the Du Plessis Farm and also the cumulative effects of the two facilities.

The pre- and post-development runoff was determined for each of the PV facilities. Only 20m contours are currently available for the site so a “typical” drainage layout with the direction of flow for each PV facility is presented in Section 7 with erosion control measures discussed in Section 8.

This information has been based on the limited information available (e.g. SRTM 90m Digital Elevation Model). A detailed drainage layout will need be developed when a detailed topographic survey for the site is available.

4. Description of Layout Alternatives and site characteristics

4.1 Layout Alternatives

The DEA&DP 2013 guidelines state that “every EIA process must identify and investigate alternatives, with feasible and reasonable alternatives to be comparatively assessed.” The alternatives for Du Plessis Dam Farm are termed Alternative 1 and 2 are described in Sections 4.1.1 and 4.1.2. The layouts for the Alternatives at both Du Plessis Dam Farm and Badenhorst Dam Farm are shown in Figure 2 and Figure 3.

4.1.1 Layout Alternative 1

The preferred alternative consists of the three proposed 75MW PV facilities and associated infrastructure (referred to as PV2, PV3 and PV4). These layouts take cognisance of the 75MW Department of Energy (DoE) cap and the environmentally sensitive areas as identified by Aurecon (2012).The layout for Alternative 1 is shown in Figure 2 with the areas given in Table 1.

Table 1 Du Plessis Dam Farm PV blocks for Alternative 1

Name	Area (ha)
PV2	169
PV3	212
PV4	374

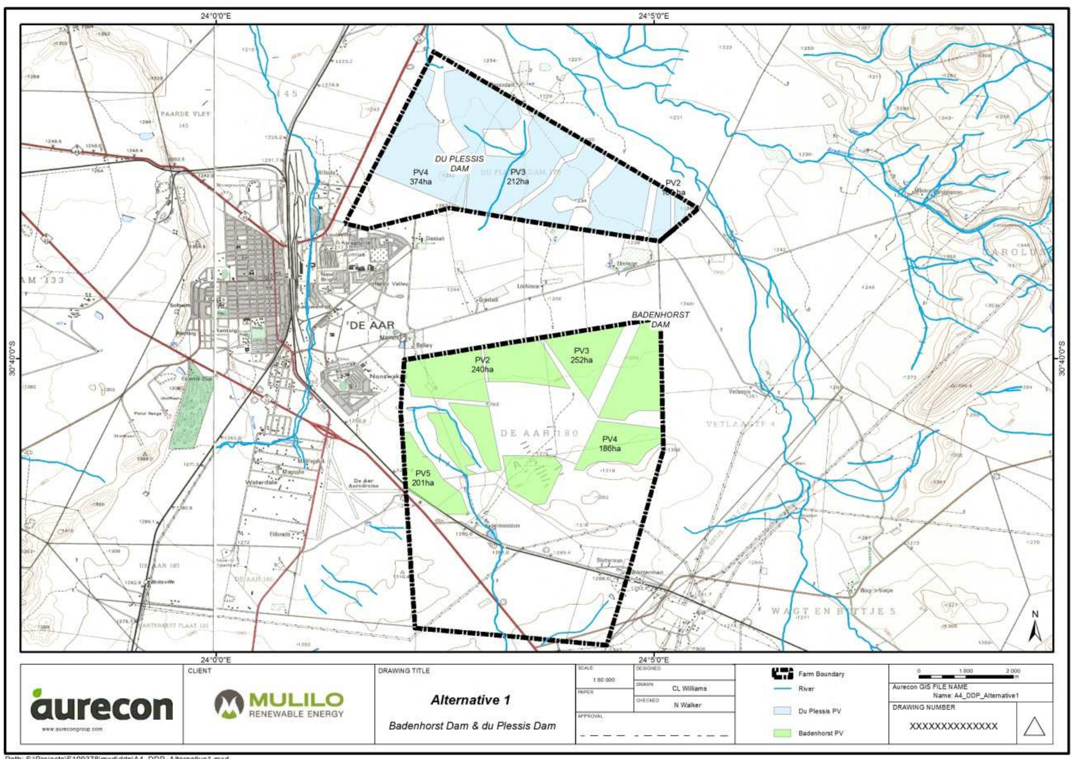

Figure 2: Layout of Alternative 1 for both Badenhorst Dam Farm and Du Plessis Dam Farm

4.1.2 Layout Alternative 2

This alternative consists of one 400MW PV facility. The layout for this alternative was developed by extending and combining the proposed 75MW facilities. This alternative is thus not limited to the DOE's 75MW cap per project. By increasing the capacity it has the benefit of utilising industries at scale thereby reducing associated development and construction costs which reduces lending rates and essentially lowers the tariff of electricity sold. The layout of extended PV2 more or less overlaps with the Alternative 1 layouts. The details of Alternative 2 are shown in Figure 3 and Table2.

Table 2: Du Plessis Dam Farm PV blocks for Alternative 2

Name	Area (ha)
PV2	1000

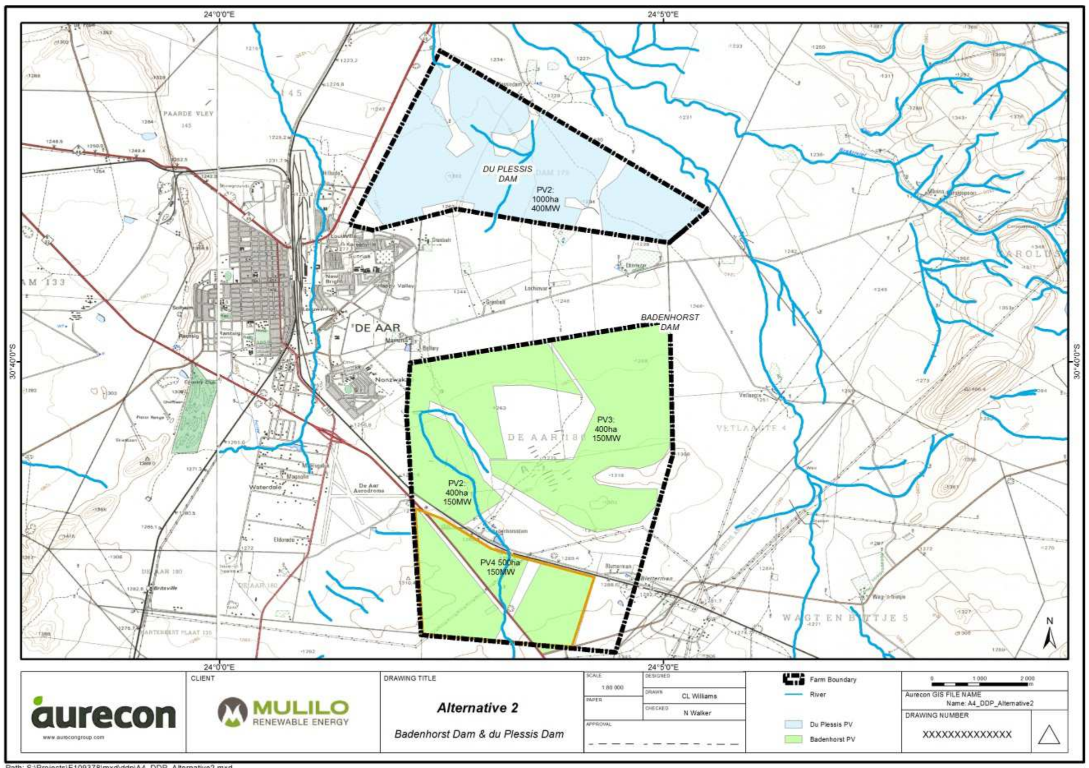

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Figure 3: Layout of Alternative 2 for both Badenhorst Dam Farm and Du Plessis Dam Farm

4.2 Climate and Land Use

The study area has a Mean Annual Precipitation (MAP) of around 300 mm. Figure 4 shows the annual precipitation for a gauge in De Aar (1921-1999). The study area has a semi-arid climate with a rainfall regime confined to summer and early autumn (Figure 5)

The site has an average catchment slope in the region of 2% (Aurecon, 2012). The current land use is grazing land (Figure 6). The soils are considered unsuitable for arable agriculture (SiVest, and 2013).

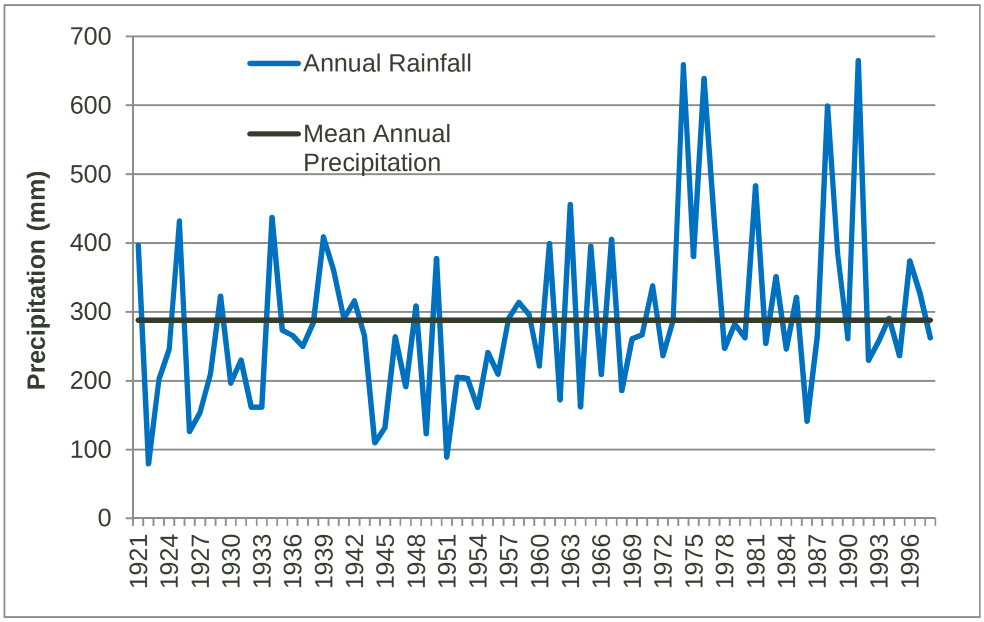

Figure 4: Annual precipitation for De Aar (rainfall station 0170009 A)

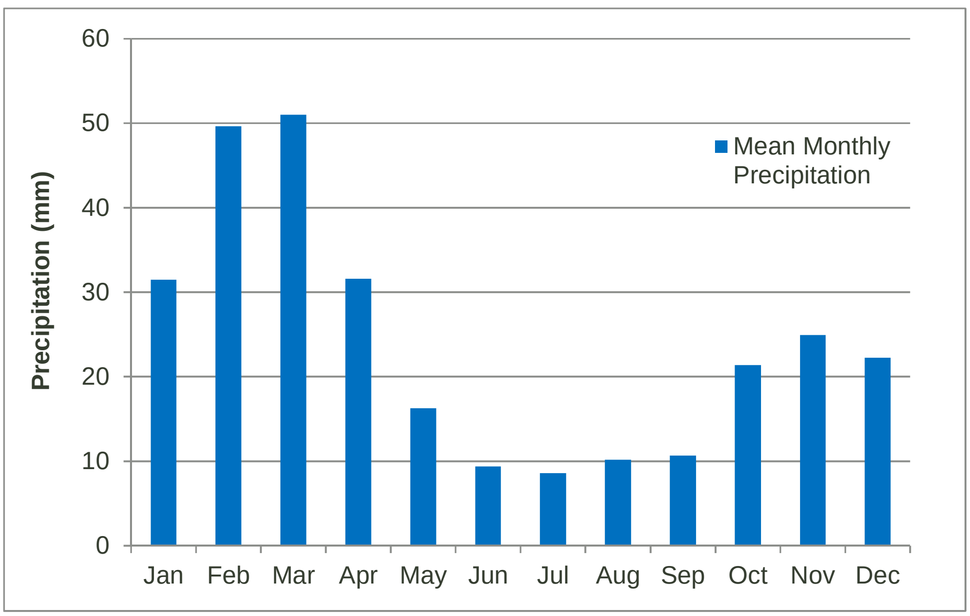

Figure 5: Mean monthly precipitation for De Aar (rainfall station 0170009 A)

4.3 Drainage Characteristics

There is an ephemeral tributary of the Brak River to the north of the Du Plessis Dam Farm. An indicative 1:100 year floodline was determined previously for this watercourse (Aurecon, 2012). It is recommended that after the site has been surveyed the 1:100 year floodline should be re-determined before the PV facility areas are finalised. There two drainage lines that begin on the higher ground in the west of the site. In addition, there are four other drainage lines in the eastern side of the farm which are not well defined and carry runoff from outside of the site boundary. These drainage lines have been previously identified by Belcher (2012 and 2013). The preliminary design of Layout Alternative 1 has taken the identified drainage lines into consideration and all PV facilities are outside of the buffer zones identified for the drainage channels.

Figure 6: Grazing land at Du Plessis Dam Farm

5. Proposed Physical Land Alterations

The proposed PV development will include the:

- construction of gravel access lanes;
- possible grading of the site;
- foundations and tracking equipment for numerous solar panels; and

- site boundary fence; and
- local drainage channels.

The proposed PV panels are approximately 2m wide and 1m long. These panels are arranged into modules that are durable and can last up to 25 years due to the sturdiness of the structure and few moving parts. The PV modules (which will include a number of PV panels) will be physically mounted to a galvanized steel rotation tube, single axis tracking system to ensure ground connection from the module frames to the structure. The PV modules, fixed to the tracking system, are arranged into tracker blocks as indicated in Figure 7. These tracker blocks will be uniformly aligned to facilitate efficient sun-tracking.The dimensions of a tracker block range between 88m and 113m in an east to west direction and 35m to 38m in a north-south direction (Mulilo, 2013).

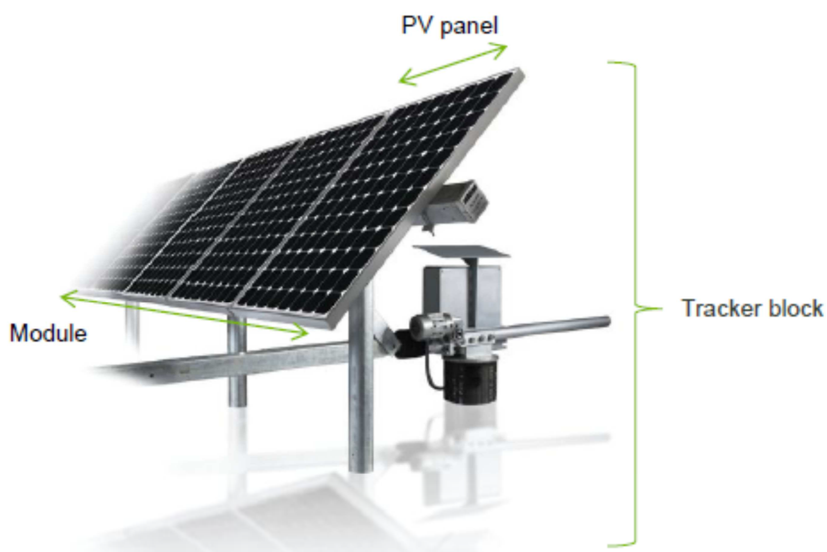

Figure 7: Single axis tracking system (image courtesy of Mulilo)

The supports of the frame will be fixed on top of steel piles. Since there is existence of rock at shallow depths, it is likely that the steel piles would be embedded into concrete piles. However, the final design of the foundations will depend on the geotechnical conditions of the site which will be determined at a later stage.

With the solar panels being impervious, rainwater will land on the panels and run off directly onto the ground below the individual panels. Some erosion may occur beneath each solar panel as well as downstream of panels as runoff is incremented and concentrated due to the site layout and topography. V-drains should be provided to intercept and convey the runoff.

6. Methods for Flood Peak Estimation

The potential flood risks have been assessed by analysing storm runoff generated by storms of 5-year and 20-year recurrence interval. The 5-year runoff has been used to assess storm drainage on the individual PV blocks while the 20-year runoff has been used to assess the risks associated with external drainage paths and stormwater control measures. The analyses for the internal drainage (1:5 year) and external drainage (1:20 year) were undertaken using the Rational Method. Parameters for Catchments 2 and 3 are summarised in Table 3.

Table 3: Catchment Parameters for Catchments 2 and 3

Catchment Parameter	Catchment 2	Catchment 3
Catchment Area (km^2)	10.65	16.16
Longest Water Course (km)	10.83	7.50
Centroid of Catchment (km)	4.54	3.97
Average Catchment Slope (%)	1.13	1.12
Slope Watercourse 10:85 Method (m/m)	0.005	0.005
1 day point rainfall (mm) 20 year RI	73	73
1 day point rainfall (mm) 5 year RI	61	61

6.1 Design Rainfall

For a deterministic design flood approach (i.e. the Rational Method) a crucial input is the design rainfall. The design rainfall is associated with a particular recurrence interval and critical storm duration. For the Rational Method, the critical design storm duration is usually set equal to the "Time of Concentration" (T_c).

The design point rainfall for the 1:5 and 1:20 year RI (Table 3) was obtained from the Smithers and Schulze (2002) database. The design point rainfall depths were converted to 24-hour point rainfall using Adamson's (1981) conversion factor of 1.11. The 24-hour design point rainfall depths were then converted into their respective duration rainfall depths by applying the Adamson (1981) sub-daily ratios for the summer rainfall region (R1). To convert the 24-hour point rainfall values to areal rainfall for each catchment, an Areal Reduction Factor (ARF) was applied based on the curves developed by Alexander (1990).

6.2 Runoff Determination

The ESRI GIS-tool, Arc Hydro 1.4, was used to automate the generation of the river networks and delineation of the associated catchment boundaries from the SRTM 90m Digital Elevation Model.

Catchment parameters are presented in Table 3. The Rational Method was originally developed for small catchments and is widely used internationally. This approach has been extensively enhanced by research conducted in South Africa.

6.2.1 Rational Method

The Rational Method is represented by the following relationship:

$$Q = \frac{CIA}{3.6}$$

Q = design flood peak (m^3/s)

C= runoff coefficient (dimensionless)

I = average rainfall intensity over catchment (mm/hour)

A = effective area of catchment (km^2)

3.6 = conversion factor

The Rational Method yields a design flood peak only (i.e. no hydrograph). The flood response of the catchment is expressed by two quasi-physical parameters: Runoff Coefficient (C), which is a function of average catchment slope, permeability, land-use, MAP, RI and Time of Concentration (T_c), which is a function of the length of the longest watercourse and the average slope of that watercourse. This Study utilised the C-value guide derived by the Department of Water Affairs (Alexander, 1990). For the 1:20 year RI the C-value was adjusted by 0.75 (Table 4) and for the 1:5 year RI the C-value was adjusted by 0.65 (Table 5). The C-value or runoff coefficient can change if the land use changes. There is a difference in the C-value for two alternatives (post-development) as the percentage of impervious surface in Catchments 1, 2 and 3 is different for the 2 alternatives. The C-values given in Table 5 are for the PV facility only and not the wider catchment, as the percentage of impervious surface is the same implying that the C-values remain the same.

Table 4: C-Value for the 1:20 year RI for Catchments 2 and 3

C-value (Runoff coefficient)	Catchment 2	Catchment 3
C-Value pre-development	0.16	0.16
C-Value Alternative 1 Du Plessis PV only	0.22	0.24
C-Value Alternative 1 Du Plessis and Badenhorst PVs	0.28	0.29
C-Value Alternative 2 Du Plessis only	0.27	0.24

C-value (Runoff coefficient)	Catchment 2	Catchment 3
C-Value Alternative 2 and Du Plessis and Badenhorst PVs	0.32	0.33
Time of concentration pre-development (hrs)	3.61 (overland flow)	3.04 (overland flow)
Time of concentration post-development (hrs)	3.19	2.41

Table 5 C-Value for the 1:5 year RI for the PV facilities only Alternatives

Catchment	C-Value pre-development	C-Value post-development
Alternative 1	0.14	0.23
Alternative 2	0.14	0.23

7. Stormwater Assessment

7.1 Flood Peaks Estimates

The direction of flow through the different PV facilities is presented in Figure 8. The direction of flow is predominately towards the ephemeral tributary of the Brak River. Catchments 2 and 3 (see Figure 1) bring flow from the Badenhorst Dam Farm in the upper part of the catchment.

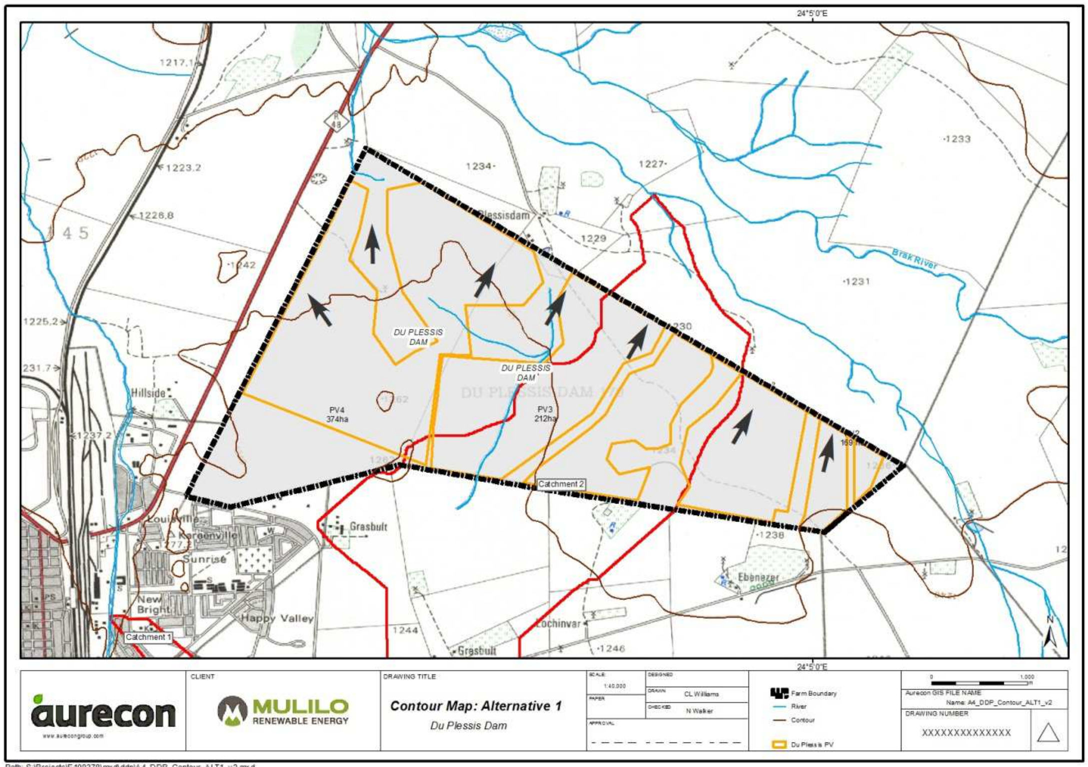

Figure 8: Direction of flow (pre-development) through Du Plessis Dam Farm

The flood peaks for Catchment 2 and 3 are presented in Table 6. The development, for both Alternative 1 and 2, in Catchments 2 and 3 causes the hydrology of site to change from predominately overland flow in the upper reaches to channelled flow. As a consequence of the change in hydrology the 1:20 year peak flow is increased as the velocity of runoff in the defined channels is higher than for overland flow. Mitigation measures are discussed in Section 7.2. The major concern with the development in terms of stormwater is the increased likelihood erosion locally around the panels as well in the wider catchment. Erosion control measures are discussed in Section 7.2 and Section 8. The expected 1:5 year runoff from the individual PV sites of Alternative 1 and 2 are summarised in Table 7.

Table 6: The 1:20 year Flood Peak Estimates for Catchments 2 and 3

Condition	Catchment 2	Catchment 3
Pre-development flood peak (m^3/s)	7.3	12.8
Alternative 1 flood peak (m^3/s)	11.1	22.4
Alternative 1 and Badenhorst section flood peak (m^3/s)	13.9	26.8
Alternative 2 flood peak (m^3/s)	13.2	22.2
Alternative 2 and Badenhorst section flood peak (m^3/s)	16.0	31.3

Table 7: 1:5 year peak flows for individual PV facilities of Alternative 1 and 2

Catchment	1: 5 year peak pre-development (m^3/s)	1: 5 year peak post-development (m^3/s)
Alternative 1 PV2	4.8	9.8
Alternative 1 PV3	5.0	10.3
Alternative 1 PV4	8.0	16.4
Alternative 2 PV4	19.3	31.7

7.2 Discussion and proposed measures to alleviate drainage problems

The expected 1:5 year runoff from the PV facilities of Alternative 1 are summarised in Table 7. It is not recommended that the internal drainage system concentrate the flow from a large area (200ha+) to one outlet. This will cause erosion and change the hydrology of the area from overland flow to channelled flow. Instead the area should be sub-divided into smaller sub-catchments (which will distributed the runoff) and have multiple outlets from the site. A schematic of this is shown in Figure 9. Concrete aprons with rip rap no less than 12m long should be used at the multiple outlets (Figure 10). This will prevent erosion, assist in moving the runoff from channelled flow back to overland flow and will dissipate energy. A summary of the mitigation measures for each Alternative are presented in Table 8.

The runoff from the Du Plessis site should in the most part should be directed to the tributary of the Brak River to the north of the site which follows the pre-development flow across the site. The runoff from the western side of the site (PV4 Alternative 1) should be directed away from the R48 north towards the Brak River. Should localised drainage within this area be a concern during the design phase, attenuation ponds may be required. The Brak River has a confluence with a tributary north of the site and the Brak River then flows under the R48. The Brak River has catchment of 2090 km^2 at this point with a 1:100 year flood peak of 1060 m^3/s. The increased runoff from the Du Plessis Dam Farm PV facilities and the Badenhorst Dam Farm PV facilities would not significantly impact the high flows in the Brak River.

Table 8: Summary of mitigation measure for the increased runoff

Condition	Impact	Mitigation
Catchment 2 Alternatives 1 and 2	Change in hydrology from overland flow to channel flow	Use of multiple apron outlets at the exit of the PV site.
Catchment 3 Alternatives 1 and 2	Change in hydrology from overland flow to channel flow	Use of multiple apron outlets at the exit of the PV sites and possible attenuation ponds on Badenhorst Dam Farm.
Alternatives 1 and 2 on the western side of the site	Increased flow towards the R48	Use of multiple apron outlets at the exit of the PV sites and possible attenuation ponds.

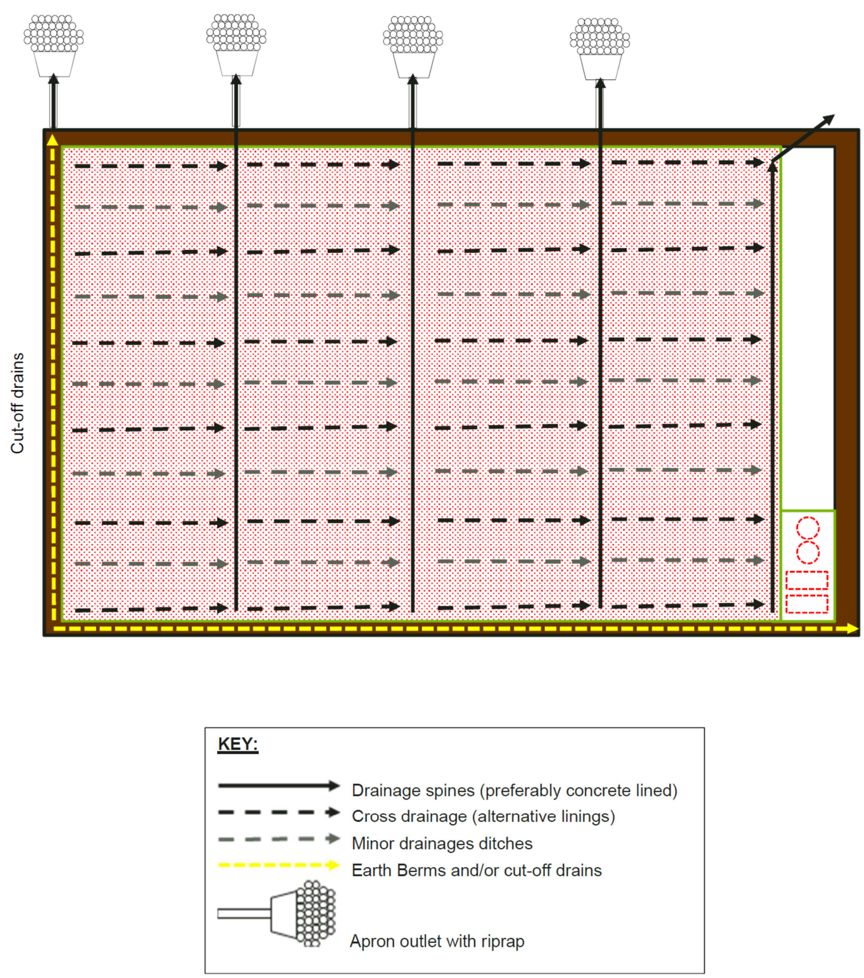

Figure 9: A typical drainage scheme

The topography will determine the actual placement of drainage spines (solid lines Figure 9) and as such detailed survey is therefore required to place the drainage spines. Cross drainage in the form of v-drains should be provided (indicated as dashed lines in Figure 9) to intercept overland flow and to direct this to the spines. The cross drainage will also assist with erosion control. These v-drains can take the form of road side drains and must be lower than the surrounding area to intercept flows. The channels can be compacted earth channels but will require maintenance on a regular basis and after each rainfall event due to possible scouring. Although more expensive, the construction of a concrete lined system is advised. A typical channel size is 300 mm deep, v-shaped. This could, for example, have a left side slope of 1:1 and right side slope of 1:3 when water enters the channel from the right side and flows down the channel. The general slope of the surrounding ground would be right to left.

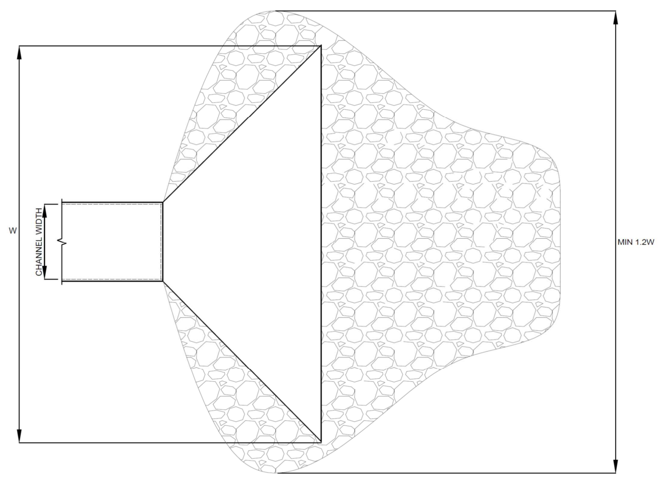

Figure 10: A plan view of a drainage channel to concrete apron to rip rap (after Caltrans, 2003).

Erosion around concrete plinths and supporting structures is a concern and is dependent on the erodibility of the material. It is recommended that the surfaces around plinths be compacted well graded gravel with a 38mm gravel capping. Erosion protection in the form of rip rap with average diameters of 200mm is required at the drain outfalls from the solar facility for a distance of no less than 12m (Figure 10).

Cut-off drains should be provided along the outside boundaries of the PV sites that receive overland flow from areas upstream. The cut-off drains will typically be at least 300 mm deep and v-shaped as described above.

There are planned gravel access roads for the site. Drainage is an important consideration of gravel road design. Any standing water on the road can quickly lead to erosion even with light traffic. The gravel roads should have the following:

- a crowned driving surface,

- a shoulder area that slopes directly away from the edge of the driving surface, and
- a ditch.

Where the roads intersect drainage lines a suitably sized culvert should be used. It is important that ditches and culverts be kept clear from obstructions.

8. Erosion and Abatement during Construction

Due to the disturbances associated with construction activities it can be expected that soil erosion will occur, resulting in an increased loading of suspended solids into receiving waters. To mitigate the following measures should be taken, both as erosion prevention and control measure:

- Straw barriers should be installed in drainage paths to act as a check dam, i.e. to reduce velocity, and as a sediment trap during construction (Figure 11). Suspended solids carried by overland flow will be intercepted. These are erosion barriers placed at intervals of 25-50 m apart in the drainage paths which will intercept suspended solids from entering the natural drainage paths.
- Packed stone (also known as rip-rap) must be placed as liners for channel spines. These comprise packed stones with an average diameter of 100 mm, packed in the channels as lining material to control flow velocities and hence erosion.
- Earth cut-off channels at boundaries of the facility. These will assist in directing flow away from the site and reduce the possibility of flooding from runoff origination from outside the site.
- Provide erosion protection at channel outfalls and positions of high flow concentration. These comprise packed stones with an average diameter of 200 mm, packed in the drainage path to control flow velocities and hence erosion.

The sediment and erosion control measures should remain in place until construction is complete. The above noted sediment traps will require regular monitoring during construction and reinstatement as necessary. The measures, listed above, and this report should form part of the Environmental Management Plan compiled for this project.

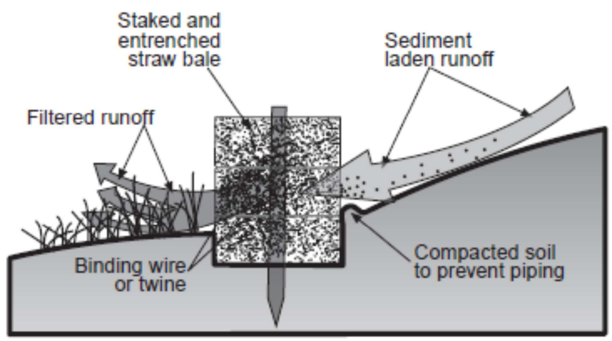

Figure 11: Cross-sectional view of an installed straw bale (Broz *et al.*, 2003)

9. Summary and Recommendations

The study indicates that there will be increases in runoff due to the proposed developments. The flood peak estimations showed that Alternative 1 is the preferred option in regard to stormwater, as it causes a smaller increases in runoff. Also the PV facilities of Alternative 1 are placed clear of any natural drainage lines across the farm. The increased runoff and erosion potential for Alternative 1 can be mitigated by using multiple stormwater outlets and energy dissipaters. However it should be noted that once a detailed survey and design of the stormwater infrastructure has been undertaken there may be a need for on-site attenuation of the flood peak for the volume that exceeds the predevelopment flow especially where increased runoff in the downstream watercourse could impact downstream dwellings, sensitive ecological areas, road and railway crossings and other infrastructure.

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