ANNEXURE C6

SPECIALIST ASSESSMENTS

- Conceptual Stormwater Management Plan

aurecon

ENVIRONMENTAL IMPACT ASSESSMENT PROCESS: PROPOSED PHOTOVOLTAIC (SOLAR) ENERGY FACILITIES ON HOEKPLAAS FARM NEAR COPPERTON, NORTHERN CAPE

Conceptual Stormwater Management Plan - Hoekplaas Farm

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Document prepared by:

Aurecon South Africa (Pty Ltd)

PO BOX 494
Cape Town
8000

T *27 21 526 9400
F *27 21 526 9500
E capetown@aurecongroup.com
W www.aurecongroup.com

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Author signature		Approver signature	
Name	NJ Walker Pr.Sci.Nat	Name	F. Nagdi
Title	Hydrologist	Title	Technical Director

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1. Background

Mulilo Renewable Energy (Pty) Ltd (Mulilo) proposes to construct ten 75 MW alternating current (AC) photovoltaic (PV) solar energy plants on the farm Hoekplaas (Remainder of Farm No. 146), near Copperton in the Northern Cape. The location of the farm and its extent is presented in Figure 1. Mulilo is proposing a similar project for Klipgats Pan Farm, which is located south of Copperton and east of the Hoekplaas Farm. 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 Hoekplaas Farm and Klipgats Pan 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. .

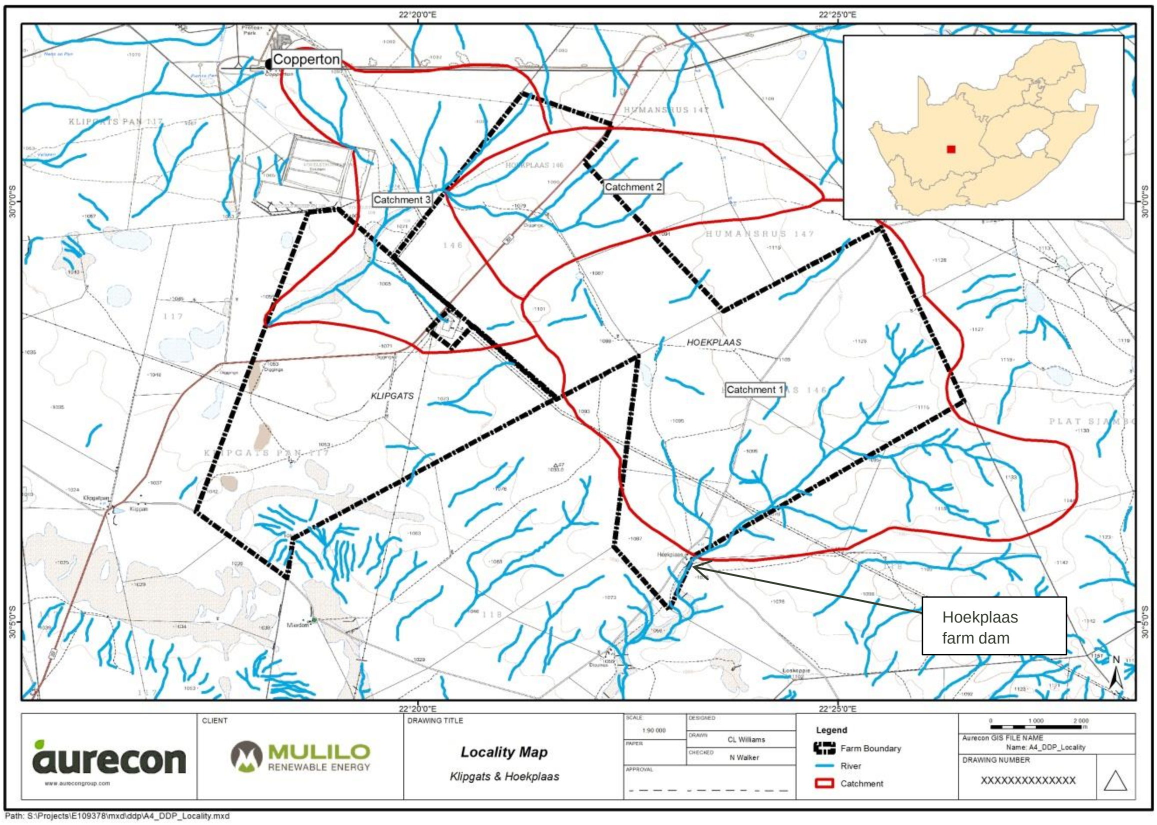

Figure 1: Location of the Hoekplaas Farm (Remainder of Farm No. 146), and Klipgats Farm, near Copperton in the Northern Cape

2. Terms of Reference

The development of a Conceptual Stormwater Management Report for the planned PV facility at Hoekplaas Farm is necessary to mitigate any adverse effects of the proposed developments 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 two 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 1:5 and 1:20 year flood. The pre- and post-development flood peaks were determined for Catchments 1 and 2 (Figure 1). The layout Alternatives are described in Section **Error! Reference source not found.** with the envisaged land alterations detailed in Section 5. The 1:20 year flood peak was ascertained using the Rational Method (Section 6).

As mentioned in Section 1, there is a proposed solar energy facility on the nearby Klipgats Pan Farm. Part of this Study is to consider the impact of the Hoekplaas Farm facility on the Klipgats Pan Farm and also the cumulative effects of the two facilities.

The pre- and post-development runoff was determined for each of the PV blocks. Only 20m contours are currently available for the site so a “typical” drainage layout with the direction of flow for each PV 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 should be developed when a detailed topographic survey for the site is available.

4. Description of Layout Alternatives and site characteristics

The Department of Environmental Affairs and Development Planning’s (DEA&DP) guidelines state that “every Environmental Impact Assessment (EIA) process must identify and investigate alternatives, with feasible and reasonable alternatives to be comparatively assessed.” The alternatives for Hoekplaas 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 Hoekplaas Farm and Klipgats Pan Farm are shown in Figure 2 and Figure 3.

4.1 Layout Alternatives

4.1.1 Layout Alternative 1

This alternative consists of the ten proposed 75MW PV facilities and associated infrastructure referred to as PV1[1], PV2, PV3, PV4, PV5, PV6, PV7, PV8, PV9 and PV10. It should be noted that not all of the PV facilities will necessarily be constructed. These layouts take cognisance of the 75MW Department of Environment's cap and the environmentally sensitive areas as identified by Aurecon (2013). The layout for Alternative 1 is shown in Figure 2 and the footprint area of each PV facility is given in Table 1.

Table 1: Area of Hoekplaas Farm PV facilities for Alternative 1

Name	Area (ha)
PV1	170
PV2	233
PV3	301
PV4	217
PV5	350
PV6	240
PV7	210
PV8	212
PV9	256
PV10	249

[1] Received Environmental Authorisation in January 2013

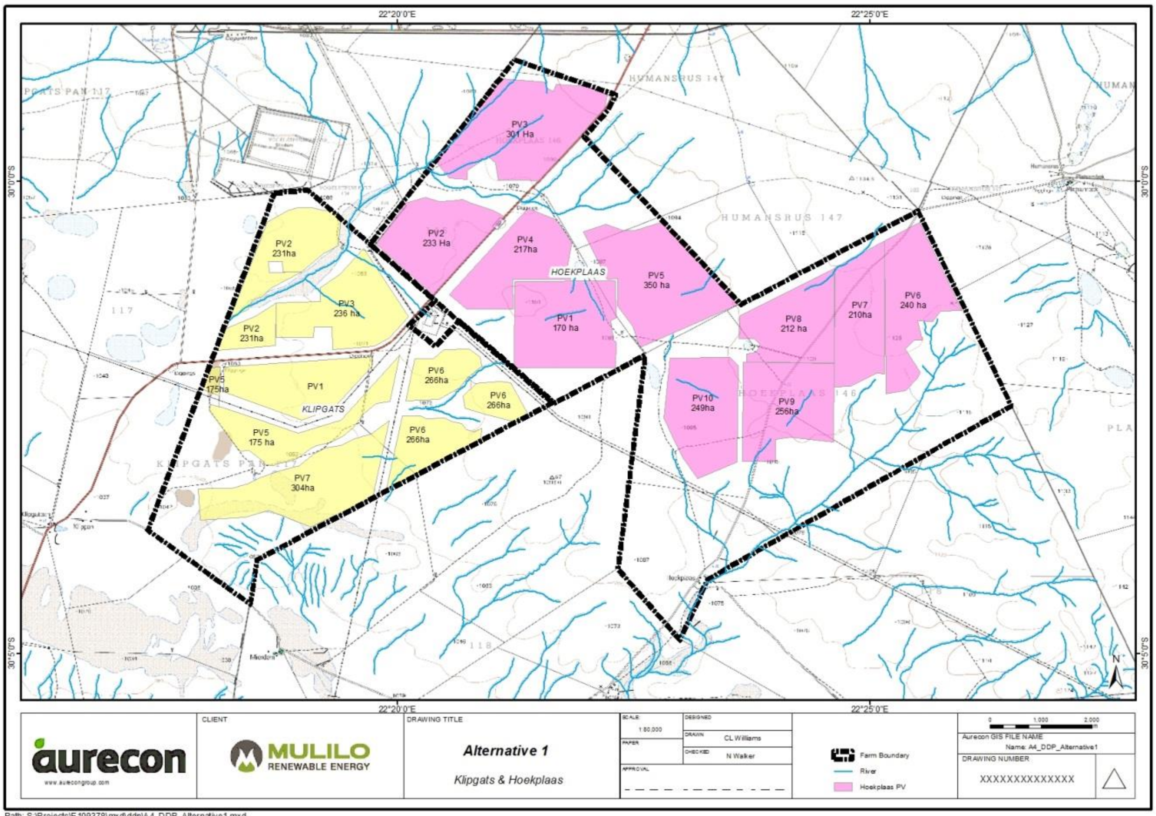

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Figure 2: Layout of Alternative 1 for both Hoekplaas Farm and Klipgats Farm

4.1.2 Layout Alternative 2

This alternative consists of one 500MW PV facility (PV2A), one 225MW facility (PV3A) and 290MW facility (PV4A) (Figure 3). The area of each PV block is given in Table 2. The layout for these was developed by extending and combining some of the proposed 75MW facilities. This alternative is not limited to the Department of Environment’s 75MW cap per project.

Table 2: Area of Hoekplaas Dam Farm PV blocks for Alternative 2

Name	Area (ha)
PV2A	1300
PV3A	662
PV4A	810

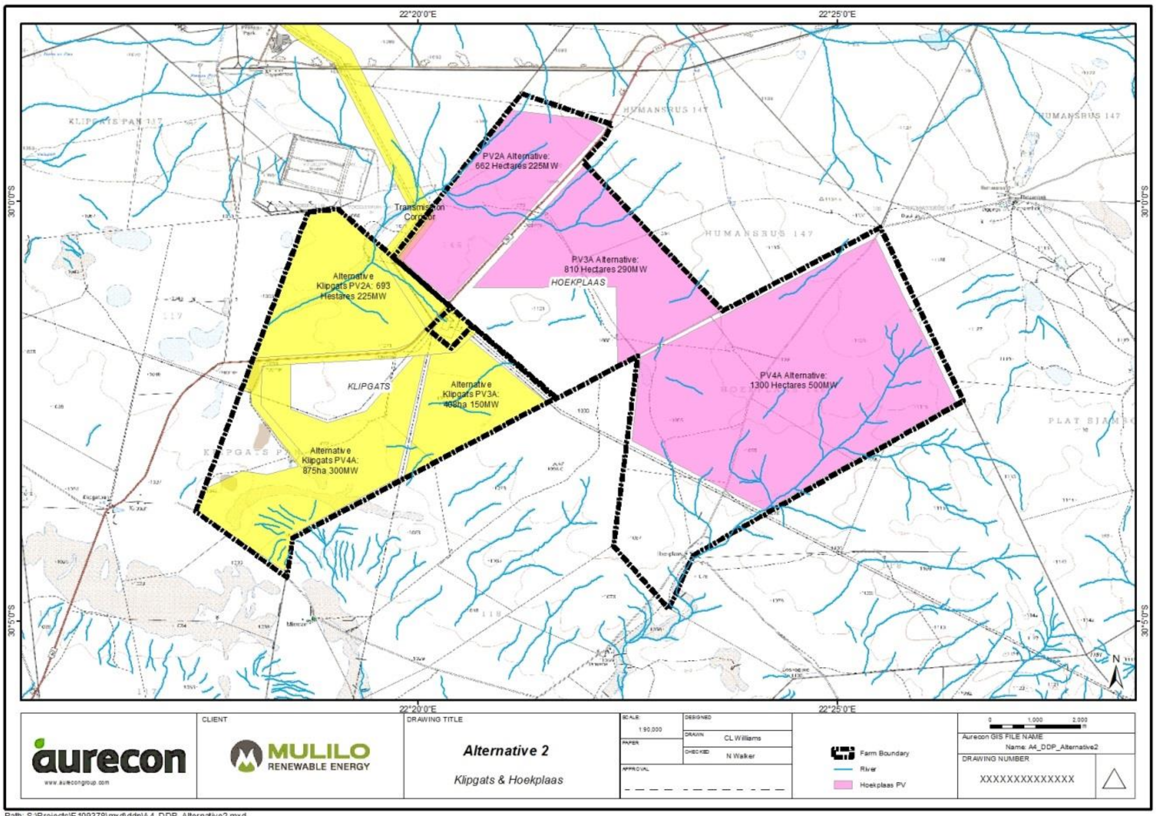

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Figure 3: Layout of Alternative 2 for both Hoekplaas Farm and Klipgats Farm

4.2 Climate and Land Use

The study area has a Mean Annual Precipitation (MAP) of just below 200 mm. Figure 4 shows the annual precipitation for a gauge at Uitsig (1931-1999) approximately 20km from site. The study area has a semi-arid climate with a rainfall regime confined to summer months (Figure 5).

The average catchment slope for Catchment 1, 2 and 3 is 1%. The current land use is grazing land (Figure 6) while the soils within the project area have been deemed unsuitable for arable agriculture (SiVest, 2013).

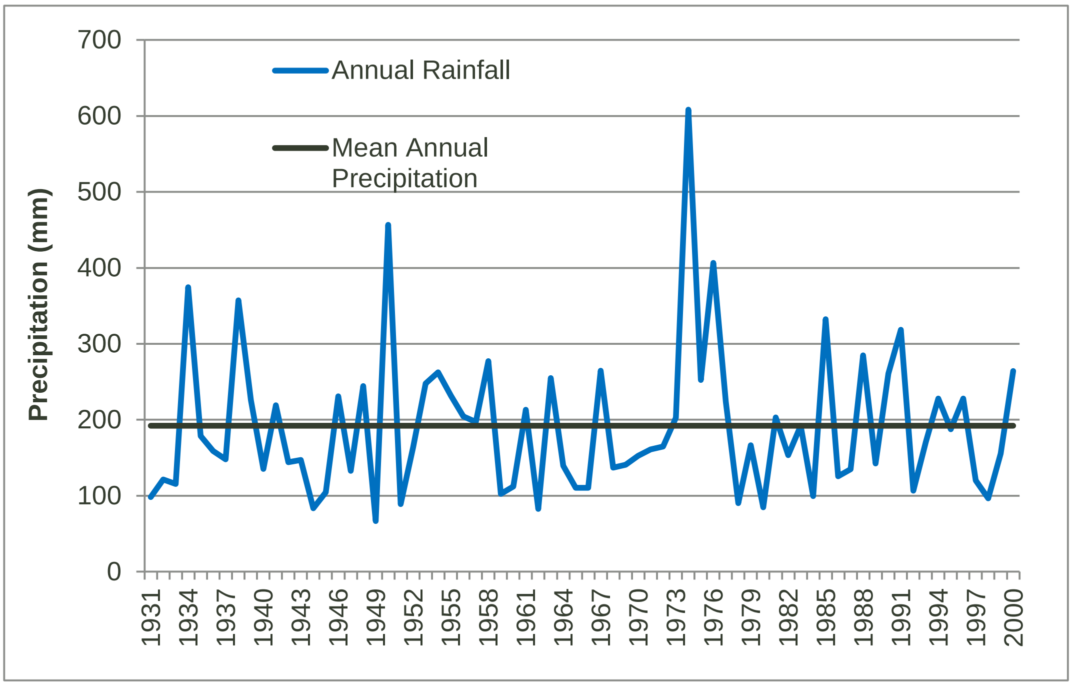


Figure 4: Annual precipitation for Uitsig (rainfall station 0224208 W)

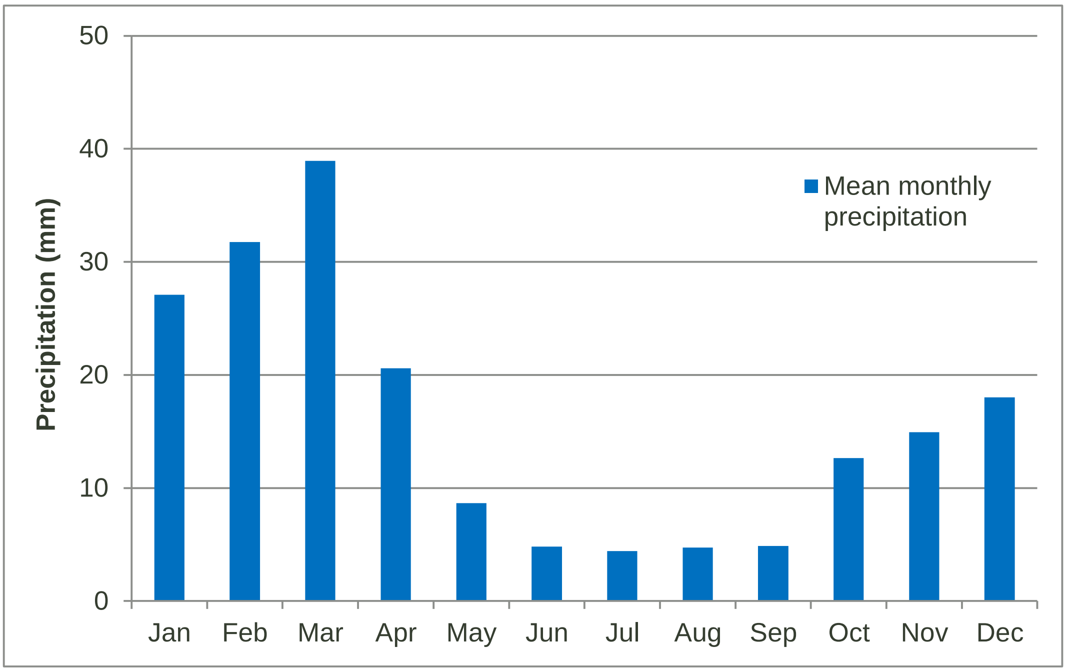


Figure 5: Mean monthly precipitation for Uitsig (rainfall station 0224208 W)

Figure 6: Grazing land at Hoekplaas Farm

4.3 Drainage Characteristics

There is a well-defined ephemeral watercourse to the south-east of the farm (Figure 7). This watercourse is in Catchment 1 (Figure 1) and is the catchment for the Hoekplaas Farm Dam which has a catchment area of 54.18km^2. Two endorheic pans on Hoekplaas have been previously identified (Mackenzie, 2013). Two other ephemeral pans, immediately west of PV 8 and PV10 are also considered important for ground water recharge. Figure 8 shows the pan immediately west of PV8.

There is a large borrow pit adjacent to the R357, shown in Figure 9, approximately 2.6km from the Kronos sub-station which appears to have impact on the ephemeral watercourse that crosses the R357 close by. The water course drains from the Hoekplaas Farm through the Klipgats Pan Farm and exits the farm boundary to supply the several pans.

Figure 7: Ephemeral watercourse on Hoekplaas Farm

Figure 8: Pan at Hoekplaas Dam

Figure 9: Large Borrow Pit on R357 approximately 2.6km from the Kronos sub-station

5. Proposed Physical Land Alterations

It is anticipated that the existing vegetation cover at the site will be removed. The proposed development would include the:

- construction of gravel access lanes;
- possible grading of the site;
- foundations and tracking equipment for numerous solar panels;
- site boundary fence;
- transmission lines; and
- local drainage channels and possibly stormwater attenuation facilities.

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 8. 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).

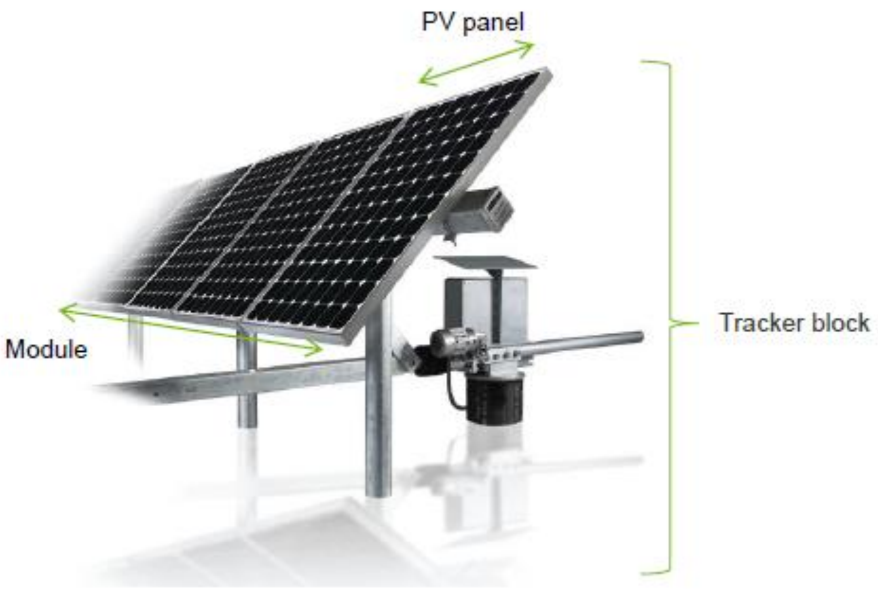


Figure 10: Single axis tracking system (image courtesy of Mulilo)

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.

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 RI. The 5-year runoff has been used to assess storm drainage on the PV Sites 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 external drainage (1:20 year) and internal drainage (1:5 year) were undertaken using the Rational Method. For Catchment 1 where the flow of runoff has a possible impact on the Hoekplaas Farmhouse and farmworker dwellings the SCS method was used as a check. Parameters for Catchments 1 and a combined catchment 2 and 3 are summarised in Table 3.

Table 3: Catchment Parameters for Catchments 1 and combined 2 and 3

Catchment Parameter	Catchment 1	Combined Catchments 2 and 3
Catchment Area (km^2)	54.18	36.11
Longest Water Course (km)	9.77	12.57
Centroid of Catchment (km)	4.80	6.84
Average Catchment Slope (%)	0.82	0.70
Slope Watercourse 10:85 Method (m/m)	0.006	0.005
1 day point rainfall (mm) 20 year RI	47	47
1 day point rainfall (mm) 5 year RI	58	58

6.1 Design Rainfall

For a deterministic design flood approach (i.e. the Rational Method and SCS) 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 SCS method is designed for a critical design storm duration of 24 hours.

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

Catchment parameters used in the flood estimation are presented in Table 3. The Rational Method and the SCS approach were originally developed for small catchments and are widely used internationally. Both approaches have 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 and 2 is different for the 2 alternatives. The C-values given in Table 5 are for the PV facilities 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-Values for the 1:20 year RI for Catchments 1 and combined 2 and 3

C-value	Catchment 1	Combined Catchment 2 and 3
C-Value pre-development	0.16	0.16
C-Value Alternative 1	0.27	0.20
C-Value Alternative 2	0.31	0.24
Time of concentration (hrs)	2.69	3.27

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

Alternative	C-Value pre-development	C-Value post-development
1	0.14	0.29
2	0.14	0.29

6.2.2 SCS Method

The SCS was used as a conceptually different alternative to the Rational Method. The SCS approach yields a full design flood hydrograph. The flood response of the catchment is represented by two quasi-physical parameters: Curve Number (CN), which is a function of soil group, land-use, vegetation cover, and antecedent soil moisture conditions; and Lag Time, which is a function of average catchment slope, length of the longest watercourse and CN. Soil groups are classified according to Binomial Classification System for Southern Africa (Soil Group A – D), which has a strong texture and depth basis (Schmidt and Schulze, 1987b).

A soil survey of each of the sites found the dominating soils to be a combination of rocky soils, such as Mispah and Glenrosa Forms, and shallow duplex soils such as Swartland (SiVEST, 2012 and 2013). These soils are categorised as Soil Group C in the Bionomial Classification system. For the purposes of the EIA investigation an assumption was made that these soils are characteristic of the catchments in which they are found. Therefore, in determining the CN for the SCS 100% soil group C was assumed.

The original SCS basin lag equation was used in this study as the original equation has been shown in verification studies to be applicable to catchments in more arid areas, limited vegetation and shallow soils (Schmidt and Schulze, 1987a). The parameters used in the SCS method are presented in Table 6.

Table 6: SCS parameters

Parameter	Catchment 1
SCS curve number pre-development	78
SCS curve number Alternative 1	85.5
SCS curve number Alternative 2	87
Basin lag pre-development (mins)	320
Basin lag Alternative 1 (mins)	253
Basin lag Alternative 2 (mins)	240

The SCS approach requires a rainfall hyetograph as input. For this Study the 24-hour rainfall hyetograph based on the South African-derived "Storm Type II Distribution" was employed (Schmidt and Schulze, 1987b).

7. Stormwater Assessment

7.1 Flood Peaks Estimates

The direction of flow through the different PV facilities is presented in Figure 11. The ephemeral watercourse situated in Catchment 1 takes the flow in the direction of the Hoekplaas farm house where there is a dam that has been breached in a previous high flow.

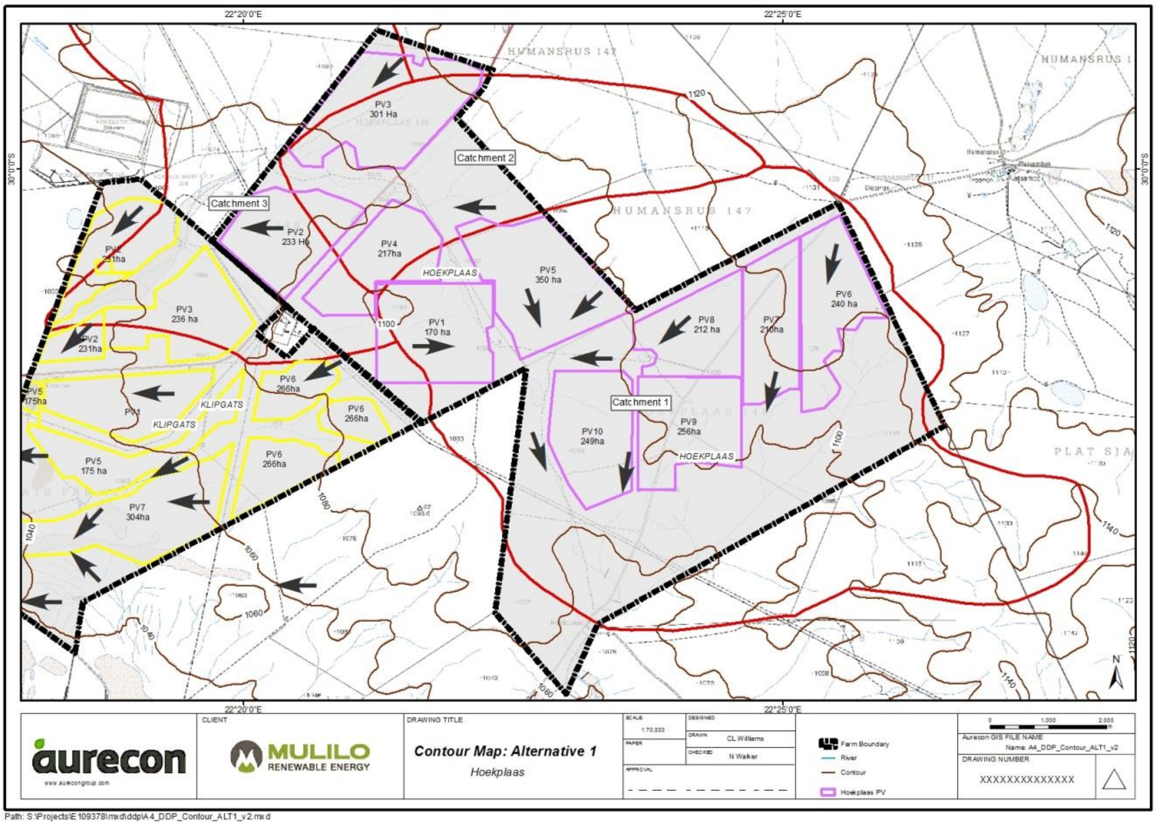


Figure 11: Direction of flow (pre-development) through Hoekplaas Farm

The flood peaks for Catchment 1 for the different conditions are summarised in Table 7. Alternative 1 increased the 1:20 year peak flow of Catchment 1 by 64% while Alternative 2 increased the peak by 86%. Mitigation for both Alternatives would be required to reduce the flood peak to pre-development levels. At this stage it appears likely that attenuation ponds will be required.

The flood peaks for combined Catchment 2 and 3 is presented in Table 8. Alternative 1 increased the 1:20 year peak flow of Catchment 1 by 17% while Alternative 2 increased the peak by 32%. Mitigation for both Alternatives would be required in the form of multiple stormwater outlets and energy dissipaters. The major concern with the developments in terms of stormwater is the increased likelihood of 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 site of Alternative 1 and 2 are summarised in Tables 9 and 10 respectively.

Table 7: 1:20 year Flood Peak Estimates for Catchment 1

Condition	Catchment 1 Rational Method	Catchment 1 SCS
Pre-development flood peak (m^3/s)	36.6	31.9
Alternative 1 flood peak (m^3/s)	60.1	59.2
Alternative 2 flood peak (m^3/s)	68.4	67.8

Table 8: 1:20 year Flood Peak Estimates for combined Catchment 2 and 3

Condition	Catchment 2 and 3 (Rational Method)
Pre-development flood peak (m^3/s)	20.9
Alternative 1 flood peak (m^3/s)	26.1
Alternative 2 flood peak (m^3/s)	30.6

Table 9: 1:5 year peak flows for the PV sites for Alternative 1

Catchment	1: 5 year peak pre-development (m^3/s)	1: 5 year peak post-development (m^3/s)
PV1	6.1	12.5
PV2	3.9	8.0
PV3	2.9	6.0
PV4	3.0	6.1
PV5	3.1	10.2

Catchment	1: 5 year peak pre-development (m^3/s)	1: 5 year peak post-development (m^3/s)
PV6	2.9	5.9
PV7	2.9	3.8
PV8	3.1	6.3
PV9	4.0	8.1
PV10	2.9	6.5

Table 10: 1:5 year peak flows for the PV sites for Alternative 2

Catchment	1: 5 year peak pre-development (m^3/s)	1: 5 year peak post-development (m^3/s)
PV2A	10.7	21.9
PV3A	7.2	14.6
PV4A	4.0	8.1

7.2 Discussion and proposed measures to alleviate drainage problems

There is an increased 1:20 year flood peak for Catchment 1 (64% for Alternative 1 and 86% Alternative 2). At the downstream end of Catchment 1 Hoekplaas farm the watercourse feeds into a dam. The dam wall is approximately 2.5 m high and has been damaged by a previous flood event (see Figure 12), where the dam wall meets the spillway. The farm worker dwelling and the Hoekplaas farmhouse have been previously inundated with flood waters in the farm worker dwelling estimated at 0.5m deep. As a consequence the increase in flood peak should be reduced to pre-development levels before the runoff leaves the PV facilities which could be achieved by using attenuation ponds. The pre-developed Hoekplaas farmhouse and other dwelling are at risk from flooding therefore it is recommended that during the formulation of a detailed stormwater management plan that Mulilo Renewable Energy (Pty) Ltd discuss with the landowner the flood risk implications pre- and post-development. Possible measures to manage flood risk which would require further investigation are:

- the determination of a 1:100 year floodline for Hoekplaas farm house and other dwelling using a detailed survey
- improve the capacity of the spillway channel
- protect the housing with a berm

Figure 12: Hoekplaas farm dam wall

When a detailed survey for the site is available, the catchment area of the two endorheic pans identified by the freshwater specialist should be delineated and the PV facilities should be placed outside of their catchment areas. No stormwater should be directed into the endorheic pans due to the ecological changes it may facilitate within these sensitive areas i.e. if there is increased runoff into the pans, the pans would stay wetter for longer causing the composition of the plant species to change.

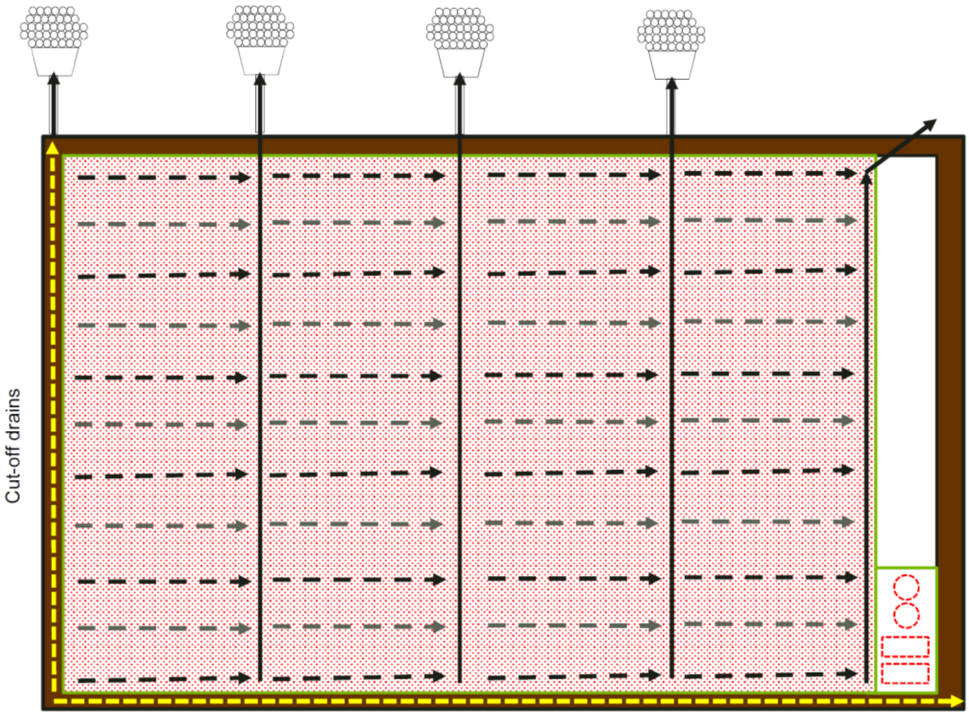
Two other ephemeral pans, which have been deemed not as ecologically sensitive as the above mentioned endorheic pans, immediately west of PV8 and PV10 and located within a drainage line, are also considered important for ground water recharge and should be incorporated into the PV internal drainage system, so that stormwater is directed into them rather than away from them. However, during the construction phase stormwater should not be directed into the pans. Mulilo intends on using water only (i.e. no detergent) to clean the solar panels during the operational phase.

The expected 1:5 year runoff from the PV facilities of Alternative 1 are summarised in Table 9. It is not recommended that the internal drainage system concentrate the flow from a large area (200ha+) to one outlet. This would cause erosion and change the hydrology at the PV facilities from overland flow to channelled flow and prevent water from entering the pans in a natural manner. Instead the area should be sub-divided into smaller sub-catchments (which will distribute the runoff) and have multiple outlets from the site. A schematic of this is shown in Figure 13. Concrete aprons (see Figure 14) with rip-rap no less than 12m long should be used at the multiple outlets. This would prevent erosion, assist in moving the runoff from channelled flow back to overland flow and would dissipate energy. A summary of the mitigation measures for each Alternative are presented in Table 11.

The section of the R357 that passes through the project site currently has no culverts. A cut off drain from PV4 could be used to prevent increased runoff from crossing the road. This runoff should be directed to natural drainage channels across the road by installing suitably sized culverts.

Table 11: Summary of mitigation measure for the increased runoff

Location	Impact	Mitigation
Catchment 1 - Hoekplaas farmhouse	Increase in peak runoff by Alternative 1 (64%) and Alternative 2 (86%)	Use of multiple apron outlets at the exit of the PV site and attenuation ponds.
R357 (length of the road that goes through the project area).	Increase in runoff from PV4	Cut-off drain and insertion of culverts under road R357 (currently no culverts).
Each PV facility	Change in hydrology from overland flow to channel flow	Use of multiple apron outlets at the exit of the PV site.
Catchment 2 and 3	Increase in runoff from PVs. Alternative 1 (17%) and Alternative 2 (32%)	Use of multiple apron outlets at the exit of the PV site.



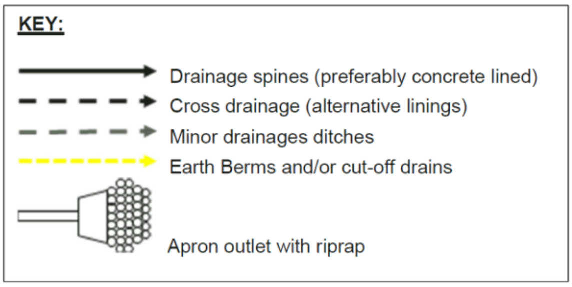


Figure 13: A typical drainage scheme

The topography would determine the actual placement of drainage spines (indicated as solid lines in Figure 13) and as such a detailed survey is required to correctly place the drainage spines. Cross drainage in the form of v-drains should be provided (indicated as dashed lines in Figure 13) to intercept overland flow and to direct this to the spines. The cross drainage would also assist with erosion control. These v-drains can take the form of road side drains and should be lower than the surrounding area to intercept flows. The channels can be compacted earth channels but would require maintenance on a regular basis and after each rainfall event due to possible scouring. 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.

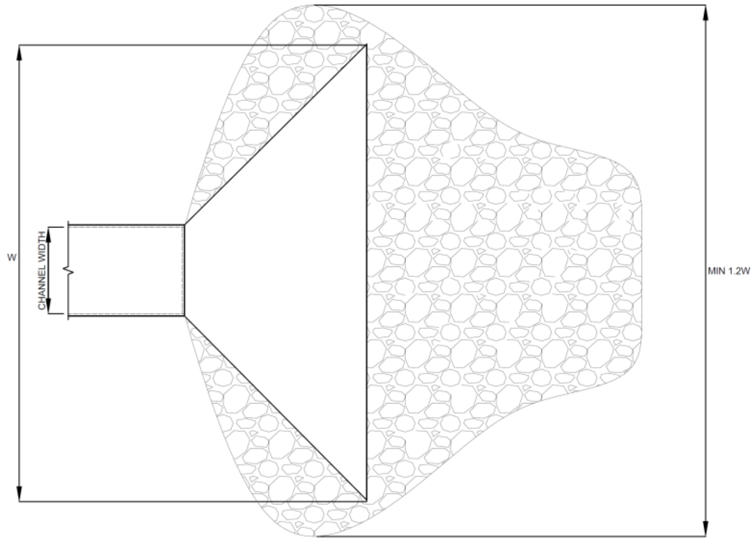


Figure 14: A plan view of a drainage channel to concrete apron to rip-rap (after Caltrans, 2003)

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 with graded gravel and a 38mm gravel capping. Erosion protection in the form of rip-rap with average diameters of 200 mm would be required at the drain outfalls from the solar facilities for a distance of no less than 12 m (Figure 13).

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 would typically be at least 300 mm deep and v-shaped as described above.

The proposed developments include the construction of additional internal gravel roads. 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 therefore 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 would 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 (replaced after 3 months or when needed) 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 15). Suspended solids carried by overland flow would be intercepted. These are erosion barriers placed at intervals of 25-50 m apart in the drainage paths which would intercept suspended solids from entering the natural drainage paths.
- Packed stone (also known as rip-rap) should 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 would 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 would 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.

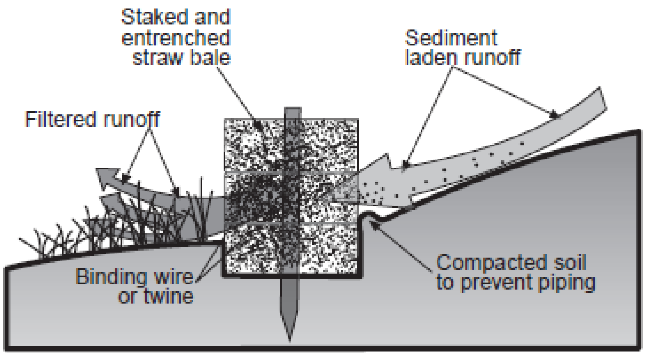


Figure 15: Cross-sectional view of an installed straw bale (Broz *et al.*, 2003)

9. Summary and Recommendations

The study indicates that there would be an increase in runoff due to the proposed development. Both Alternative 1 and 2 increase stormwater (1:5 year and 1:20 year peaks) at the site but this increased runoff can be mitigated. The PV facilities of Alternative 1 are placed clear of any natural drainage lines across the farm and therefore is the preferred option in regard to stormwater. The increased runoff and erosion potential can be mitigated by using multiple stormwater outlets and energy dissipaters. Particular attention needs to be given during the detailed design process to manage the flood risk of Hoekplaas Farmhouse and associated dwellings.

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 crossings and other infrastructure.

When a detailed survey for the site is available the catchment area of the two endorheic pans identified by the freshwater specialist should be delineated and the PV facilities should be place outside of their catchment area.

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Aurecon South Africa (Pty Ltd)
PO BOX 494
Cape Town
8000

T *27 21 526 9400
F *27 21 526 9500
E capetown@aurecongroup.com
W www.aurecongroup.com

Aurecon offices are located in:
Angola, Australia, Botswana, China, Ethiopia, Ghana, Hong Kong, Indonesia, Lesotho, Libya, Malawi, Mozambique, Namibia, New Zealand, Nigeria, Philippines, Qatar, Singapore, South Africa, Swaziland, Tanzania, Thailand, Uganda, United Arab Emirates, Vietnam.