HOWBILL FARMING

HYDROLOGICAL AND ENVIRONMENTAL WATER REQUIREMENTS STUDY FOR THE KLEINVLEI DAM & RIVER DIVERSION

Prepared by Gerald Howard & Bruce Paxton

January 2020

Freshwater Research Centre
www.frcsa.org.za
Office 23, ImhoffFarm
Kommetjie Rd
Kommetjie, 7975
Cape Town
South Africa
+

HYDROLOGICAL AND ENVIRONMENTAL WATER REQUIREMENTS STUDY FOR THE KLEINVLEI DAM & RIVER DIVERSION

Document title	:	HYDROLOGICAL AND ENVIRONMENTAL WATER REQUIREMENTS STUDY FOR THE KLEINVLEI DAM AND RIVER DIVERSION
Consultant		Freshwater Research Centre (FRC), Office 23, Imhoff Farm, Kommetjie Rd, Kommetjie, 7975, Cape Town, Office: +27 (0) 21 783 0155
Author/s :		Mr Gerald Howard (Hydrologist, Cape Town South Africa), Dr Bruce Paxton (FRC, Cape Town, South Africa)
Status of report :		Final Report
Report date :		11 January 2020

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

EXECUTIVE SUMMARY

1. Project Overview

This report presents the findings of a hydrological and Environmental Water Requirements (EWR) assessment undertaken by the Freshwater Research Centre on behalf of Howbill Farming (Pty) Ltd, Ceres, South Africa for their proposed Kleinvlei Dam located in Quaternary catchment E21D in the Koue Bokkeveld. This is a supplementary study for the Water Use Licence Application. The proposed dam will have a storage capacity of 235 000 m^3 (0.235 Mm^3) and is intended to receive water from its own catchment, as well as from a supplementary diversion on the Houdenbeks River.

2.1 Hydrology: Approach and Methodology

The Water Resources Simulation Model (WRSM2012) was used to generate monthly inflows at the Proposed Dam Site as well as the Diversion Site. This suite of software includes the Pitman Model (a rainfall-runoff model) as well as a Reservoir Simulation Model, Irrigation Demand Model and other functionality such as wetland simulation and river channel bed losses.

Adjustments to the original WR2012 model for catchment E21D

(i) The original WR2012 configuration consisted of a single runoff module that routed **50% of the total quaternary catchment flow through farm dams and the other 50% directly to the catchment outlet**. However, upon review of the existing dam configuration in the catchment it was determined that this was inaccurate since it was apparent that a far greater proportion of the runoff was being routed through farm dams. The configuration was changed so that **95% of the catchment runoff is routed through farm dams**. This is considered more accurate and is also conservative given current levels of water resource development and the passage of runoff through in the catchment.

(ii) An additional change to the original WR2012 model included **reducing the irrigation return flows from 10% to zero**. This results in zero flow being generated in the dry summer months which is again conservative. Only surplus winter flow is therefore available which is believed to better reflect the current scenario.

(iii) Other improvements to the configuration included **incorporating two runoff modules, one for the high MAP area and one for the low MAP area**. This is necessary as accurate flows are required in the mountainous areas.

3. Environmental Water Requirements (EWR)

Using the modified and updated hydrology described above, the Desktop Method Reserve Method (Hughes et al. 2003) was then used to determine the EWR for a C/D class river. The EWRs were then subtracted from the relevant monthly current-day flow record to determine the available flow at each site. An analysis was undertaken to determine what percentage of the EWR is met. The analysis at the Diversion Site on the Houdenbeks River indicates that the Total Flows EWR is met 23% of the time under the current-day scenario. The remaining months are only met by the Low Flow EWR 49 % of the time.

3.1 Available Flows

The WR2012 software was used to generate current-day flows at the Diversion Site. This included routing 95% of all runoff through a simulated farm dam that supplies an irrigation demand. The EWR identified above was then deducted from the present-day flow to create a monthly time series of available flow.

Results show that the available mean annual runoff (MAR) at the Proposed Dam is 0.749 Mm^3 and the Diversion Site is 5.59 Mm^3 for the full modelling period (1937 to 2018) (**Table 3.3**). Note that these are mean figures, i.e. flows that are likely to occur in an average year. Refer to the yield analysis for a more detailed assessment.

Table 3.3 Hydrological statistics at the Proposed Dam Site and Diversion Site – including flow available for abstraction. Note that these are mean figures and only likely to occur in an average year.

	Proposed Dam Site	Diversion Site
Natural MAR (Mm3)	0.882	16.50
EWR (Mm3)	0.133	1.24
Total Farm Dam Capacity (Mm3)	-	12.20
Water Use (Mm3)	-	9.66
Available MAR (Mm3)	0.749	5.59

4. Kleinvlei Dam Yield

The yield is also referred to as the assurance yield. An 80% assurance yield is considered appropriate for irrigation. A yield with an 80 % assurance means that a yield of a certain magnitude can be achieved 80% of the time, or eight years out of ten. This means that 80% of the time the annual yield will be higher. The yield results show that there is an 80% assurance yield of approximately 0.175 Mm^3/annum if the proposed Kleinvlei Dam relies on inflow from the upstream catchment only. Supplementary pumping from the Diversion Site increases the 80% assurance yield to 0.205 Mm^3/annum using a pumping rate of 10 l/s and 0.210 Mm^3/annum using a pumping rate of 25 l/s. Further increases in pumping capacity have no benefit.

5. EWR Implementation & monitoring

The mean monthly EWR in m^3/s required at the Diversion Site on the Houdenbeks River is presented in **Table 5.1**. This can be supplied by any combination of dams upstream, operating rules for other diversions, or from the proposed Kleinvlei Dam. We recommend, however that a bottom release be incorporated into the dam during the construction phase should EWR releases be required.

Table 5.1 Required mean monthly EWR (m^3/s) at the diversion site.

Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total
0.016	0.008	0.003	0.000	0.000	0.000	0.000	0.013	0.029	0.021	0.051	0.021	0.161

However, the release of a variable EWR as defined in **Table 5.1** is not currently feasible as these releases would simply be stored in downstream on-channel dams. The EWR can only therefore be effective in the context of broader catchment-wide water management plan that includes Quaternary catchments E21A, E21B and E21E. This plan should include a strategy to provide the EWR to catchments downstream of the developed area which would require coordinated releases by individual landowners and take into consideration the volume of water required to fill and flush pools in the Riet River gorge towards the end of winter. The plan should take into consideration the following:

- The EWR is required for a short period during the winter/high flow season;
- The EWR must be apportioned between all upstream landowners;
- The total EWR requirement should be determined (for example 0.161 m3/s in **Table 5.1**) and this assigned each location/landowner

- If the winter flow is enough to meet the EWR requirement in the gorge, i.e. all dams are spilling, no EWR releases are required;
- If there is no spill, coordinated EWR releases should be made

The water management plan should include monitoring to ensure that EWR flow targets are met in an adaptive management context. The implementation of the EWR, i.e. the adherence to operating rules, depends on access to regular and reliable flow records. River flows should be monitored at strategic points throughout the catchment. At these monitoring points, a rated section should be established to convert water levels to volumes. Operating rules will need to be regularly reviewed and if necessary, adjusted in the light of monitoring data.

6. Conclusion

The hydrological conditions in the catchment are strongly seasonal with practically no summer flows. In addition, there is a large variability in annual flows. This analysis is based on an EWR requirement that is fully met in the Proposed Dam catchment. However, due to highly developed nature of the Diversion Site catchment the Low Flow EWR can only be met 49 % of the time. The analysis therefore only includes pumping at the Diversion Site during months when flow exceeds the required EWR.

The variable nature of flow results in a 100% assurance yield that is very low. Generally, an 80% assurance yield is considered appropriate for irrigation. The proposed Kleinvlei Dam with a capacity of 0.235 Mm^3 can supply an 80% assurance yield of 0.175 Mm^3/annum from its own catchment. This can be increased to 0.205 Mm^3/annum using a supplementary diversion from the Houdenbeks River with a pumping capacity of 10 l/s.

1. Project Overview & Terms of Reference

This report presents the findings of a hydrological and Environmental Water Requirements (EWR) assessment undertaken by the Freshwater Research Centre on behalf of Howbill Farming (Pty) Ltd, Ceres, South Africa for their proposed Kleinvlei Dam located in Quaternary catchment E21D in the Koue Bokkeveld. This is a supplementary study for the Water Use Licence Application. The proposed dam will have a storage capacity of 235 000 m^3 (0.235 Mm^3) and is intended to receive water from its own catchment, as well as from a supplementary diversion on the Houdenbeks River.

The following is a summary of tasks required to generate hydrological flows for the EWR determination and for quantifying the required supplementary diversion.

(i) Re-establish the ACRU Model configuration of the Koue-Bokkeveld*.

(ii) Generate flows at both sites and the appropriate sub-catchments and generate daily flows at the proposed dam site as well as the diversion site where abstractions might be required.

(iii) Establish the environmental flows (using the monthly inflow record) at both the proposed dam site and abstraction site.

(iv) Quantify the proposed dam inflow and assess the additional transfers required.

(v) Report Writing

Study Team: Mr Gerald Howard – hydrological modelling

Dr Bruce Paxton (FRC) – project lead and reporting, flow data collection, E-flows assessment

*We initially proposed using the ACRU model for the hydrology but upon closer inspection found that it had not been configured for the Houdenbeks River, we opted therefore to use the Pitman model.

2. Hydrology

The proposed Kleinvlie Dam is located in Quaternary catchment E21D in the upper reaches of the Houdenbeks River (**Figure 2.1**) in the Kouebokkeveld management unit of the Olifants-Doring catchment (Primary catchment E, Water Management Area 17). The total runoff into the dam consists of inflow to the proposed dam from its own catchment, as well as a supplementary diversion from the Houdenbecks River. **Figure 2.2** shows the location of the proposed Kleinvlei Dam and upstream catchment area as well as the catchment area upstream of the proposed Diversion Site.

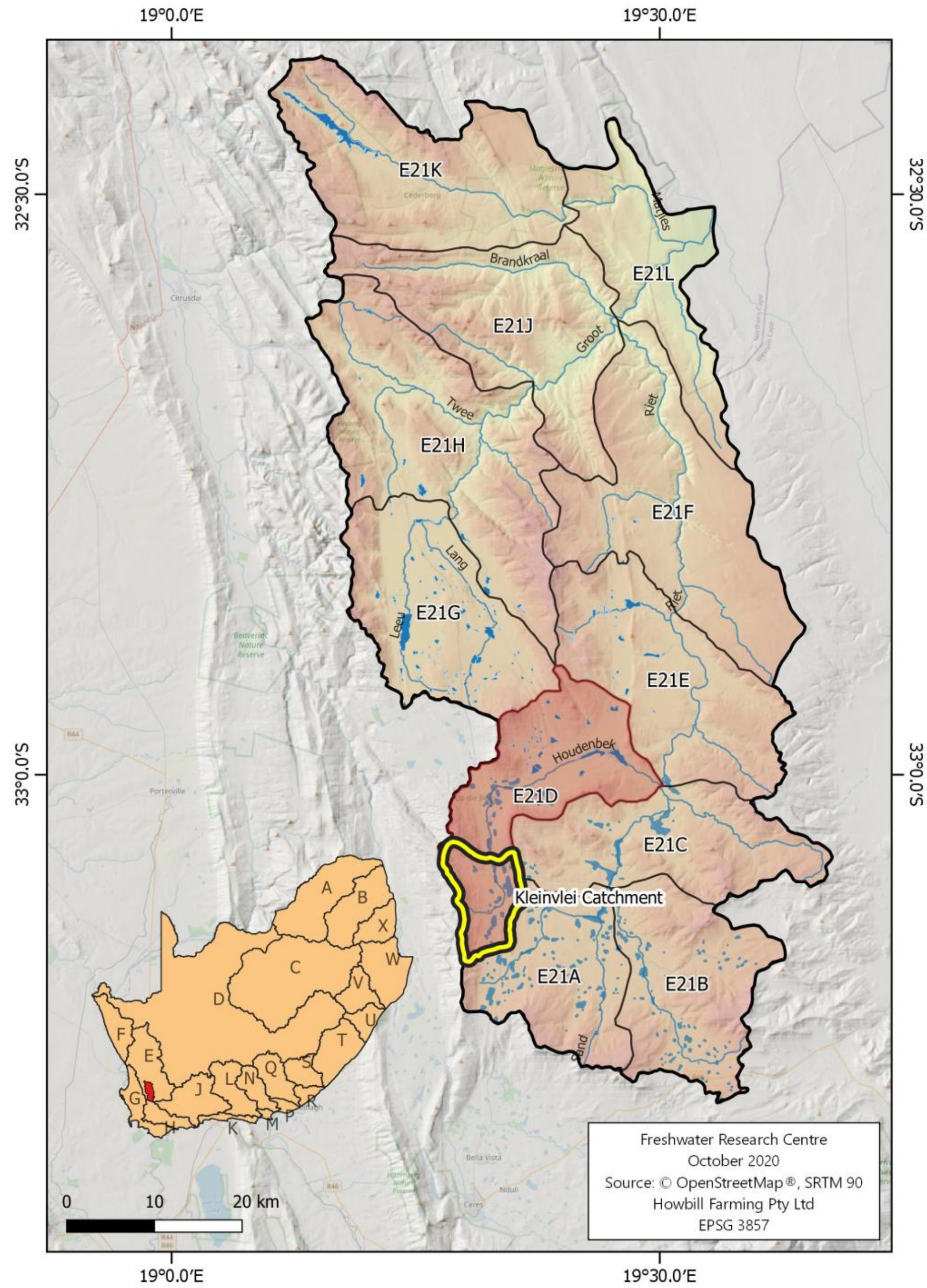

Figure 2.1 Location of catchment E21D is the Koue Bokkeveld management unit of the Olifants-Doring River, Western Cape, South Africa (Primary catchment E, WMA 17, inset) The Kleinvlei Diversion catchment is shown in yellow.

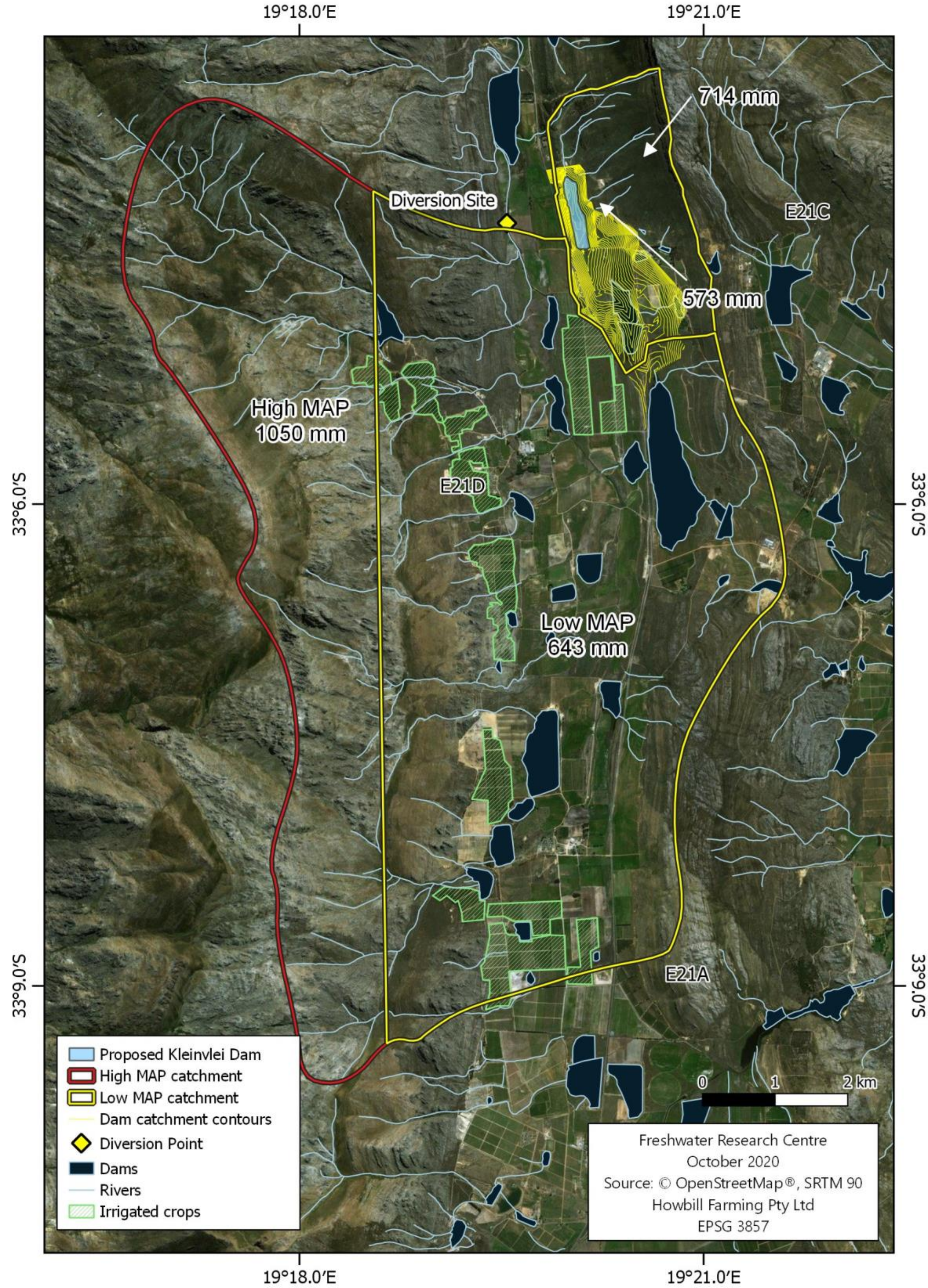

Figure 2.2 Location of the proposed Kleinvlei Dam and supplementary Diversion Site with catchment boundaries delineated for each. High Mean Annual Runoff (MAP) and Low MAP areas are shown as well as the Kleinvlei Dam catchment and irrigated crops.

2.1 Approach and methodology

The methodology is summarised below:

- The Water Resources Simulation Model (WRSM2012) was used to simulate monthly flows.
- The configuration for the model was improved to ensure a more realistic proportion of catchment runoff flows into the simulated farm dam. Catchment Mean Annual Precipitation (MAP) was updated and a more appropriate catchment rainfall was used. In addition, the relevant farm dam capacity and irrigation demand was determined.
- The Environmental Water Requirement (EWR) for both the proposed dam catchment and diversion catchment was determined using the Desktop Method. Available monthly flows at each location were generated by accounting for the EWR as well as current water-use.
- Daily flows were generated at the Diversion Site by disaggregating the simulated monthly flows using the daily observed record at gauging station E2H007 on the Leeu River.
- A diversion function determines the daily volume of supplementary water for different diversion capacities.
- The yield from the proposed dam is presented for a range of options

2.2 Water Resources Simulation Model (WRSM2012)

The Water Resources Simulation Model (WRSM2012) was used to generate monthly inflows at the Proposed Dam Site as well as the Diversion Site. This suite of software includes the Pitman Model (a rainfall-runoff model) as well as a Reservoir Simulation Model, Irrigation Demand Model and other functionality such as wetland simulation and river channel bed losses.

2.2.1 Adjustments to the original WR2012 model for catchment E21D

(iv) The original WR2012 configuration consisted of a single runoff module that routed **50% of the total quaternary catchment flow through farm dams and the other 50% directly to the catchment outlet**. However, upon review of the existing dam configuration in the catchment it was determined that this was inaccurate since it was apparent that a far greater proportion of the runoff was being routed through farm dams. The configuration was changed so that **95% of the catchment runoff is routed through farm dams**. This is considered more accurate and is also conservative given current levels of water resource development and the passage of runoff through in the catchment.

(v) An additional change to the original WR2012 model included **reducing the irrigation return flows from 10% to zero**. This results in zero flow being generated in the dry summer months which is again conservative. Only surplus winter flow is therefore available which is believed to better reflect the current scenario.

(vi) Other improvements to the configuration included **incorporating two runoff modules, one for the high MAP area and one for the low MAP area**. This is necessary as accurate flows are required in the mountainous areas.

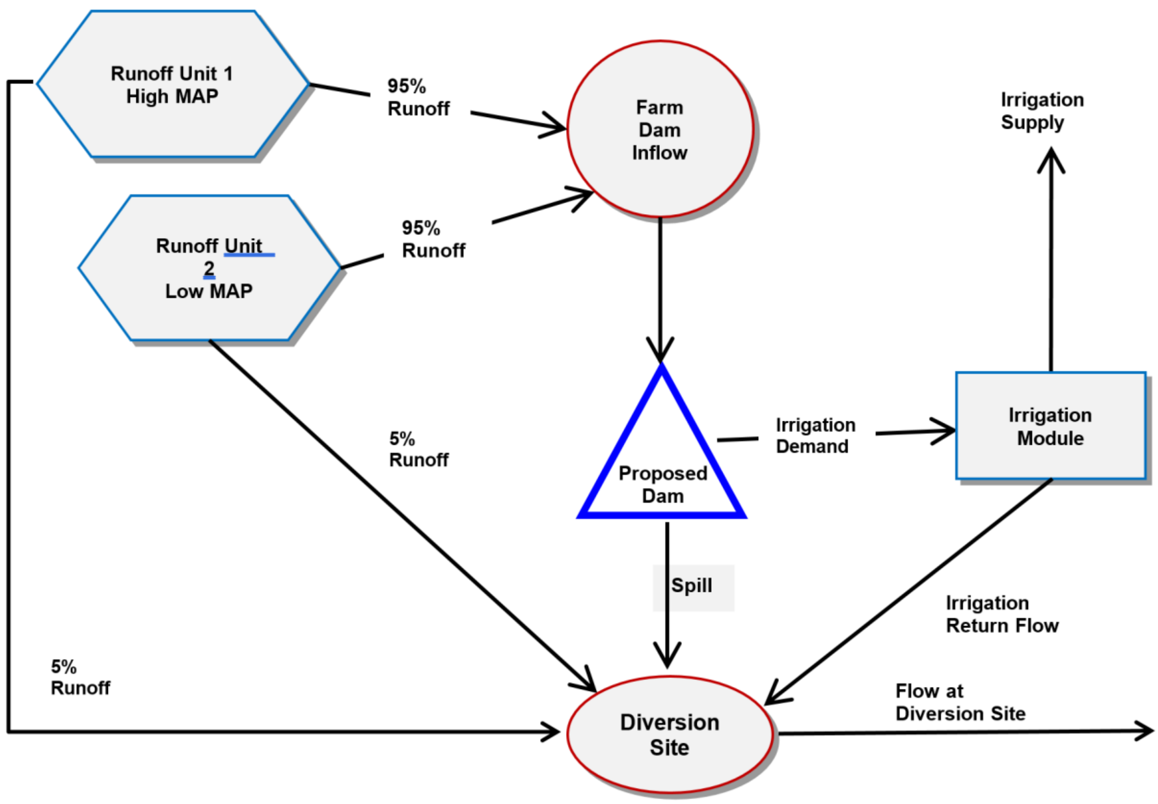

Figure 2.3 Configuration diagram of the Pitman model for the proposed dam catchment.

The Pitman Model Parameters obtained from the WRSM2012 were left unchanged. These are shown in Table 2.1. These parameters are derived from calibration in nearby catchments and are smoothed to identify regional parameters. They can therefore be used without re-calibrating the Pitman Model.

Table 2.1 Pitman Model parameters.

Power in the soil moisture / subsurface flow equation...........(POW)	2.00	
Power in the soil moisture recharge equation......................(GPOW)		
Soil moisture state where no subsurface flow occurs.................(SL)	0.00	mm
No recharge occurs below a storage of...............................(HGSL)		mm
Soil moisture storage capacity in mm ....(ST)	250.00	mm
Subsurface flow at full soil moisture capacity ....(FT)	50.00	mm/month
Maximum groundwater flow in mm/month ....(GW)	0.00	mm/month
Maximum soil moisture recharge ....(HGGW)		mm/month
Min. catchment absorption rate in mm/month .... (ZMIN)	0.00	mm/month
Max. catchment absorption rate in mm/month ....(ZMAX)	600.00	mm/month
Interception storage in mm ....(PI)	1.50	mm
Forest Factor (automatic in SFR modules)................................(FF)	1.00	
Lag of flow (excluding groundwater) ....(TL)	0.25	
Lag of groundwater flow ....(GL)	0.00	
Coefficient in the evaporation / soil moisture equation ....(R)	0.00	

2.3 Climate data

2.3.1 Evaporation

The S-pan mean monthly evaporation is available in the WRSM2012 Pitman Model and Reservoir Simulation Model. Mean monthly A-pan evaporation is required to determine crop water demands and is available in the WRSM2012 Irrigation Module. S-pan and A-pan evaporation is listed in Table 2.2.

Table 2.2 S-pan and A-pan evaporation (mm).

	Oct	Nov	Dec	Jan	Feb	Mar	Apl	May	Jun	Jul	Aug	Sep
S-pan	144	201	247	251	207	191	117	67	44	42	59	93
A-pan	183	255	314	319	263	243	149	85	55	54	75	118

2.3.2 Mean Annual Precipitation (MAP)

The Pitman Model uses catchment MAP to differentiate high and low runoff zones. Figure 2 shows the raster-based MAP grid that is available on the WR2012 website. Each individual grid has a MAP. These were averaged to obtain high and low catchment MAP. For the Proposed Dam catchment, the average catchment MAP was determined using the two relevant grid MAPs.

2.3.3 Point Rainfall Data

Monthly rainfall data is required in the Pitman Model. Three sources were considered. Firstly, the monthly catchment rainfall time series used in the WR2012 configuration. Secondly, the satellite-based daily global rainfall database (CHIRPS). A third source of long-term monthly rainfall data at De Keur (1937-2017) was made available. De Keur is located approximately 10km north of the study area at a similar altitude.

The monthly time series of quaternary catchment rainfall used in the WR2012 configuration was rejected as this includes rainfall data from several rainfall stations located a large distance from the study area. A comparison of monthly CHIRPS based data with De Keur indicated that CHIRPS does not compare well so the CHIRPS data was also rejected.

Monthly rainfall data from the De Keur rainfall station was therefore used to determine the catchment rainfall. The monthly data is presented in Appendix A.

2.4 Water-use

Water-use requirements in the WR2012 hydrological model are based on irrigation abstractions from farm dams. Adaptions to the WR2012 configuration were made to determine the capacity of all farm dams and irrigation requirements upstream of the diversion site.

2.4.1 Farm Dams

Google Earth was used to identify all farm dams in the upper Houdenbeks catchment. The location of all farm dams is shown in Figure 2.2.

For modelling purposes all farm dams are treated as a single larger dam, known as a "dummy dam". In the WR2012 configuration the "dummy dam" area and capacity for quaternary catchment E21D are presented in Table 3. This information was used to determine the capacity of the "dummy dam" upstream of the diversion site.

Firstly, the surface area of each individual farm dam upstream of the diversion site was digitised and summed (1.60 km^2). The capacity of the "dummy" farm dam was then determined using the same surface area/capacity relationship for the quaternary catchment and is presented in **Table 2.3**. This information was compared to the Cape Farm Mapper data. Although the Cape Farm Mapper indicated a lower surface area of 1.24 km^2, using a larger "dummy farm" dam is conservative in terms of available water.

Table 2.3 Dummy Farm Dam Surface Area (km^2) and Capacity (Mm^3)

	Quaternary Catchment E21D	Diversion Site	Cape Farm Mapper
Surface Area (km2)	7.43	1.60	1.24
Capacity (Mm3)	56.16	12.20	9.37

2.4.1 Water Demand

In the WR2012 configuration the total irrigation demand on the "dummy" farm dam is determined using numerous variables which include:

- Total irrigation area
- Mean monthly A-Pan evaporation
- Composite crop factors (these represent the average crop factors for all the different crops in quaternary catchment E21D
- Effective rainfall (75%)

Google Earth was used to digitize the total area of irrigated crops upstream of the diversion site. Identified irrigated fields (coloured green) are shown in Figure 3. The digitized irrigation area of 7.3 km2 was compared to the irrigated area of 4.6 km2 derived from Cape Farm Mapper. The higher number was used as it yields a more conservative estimate.

2.5 Observed Flow Records at E2H007 (Leeu River)

The daily observed flow record at E2H007 was used to dis-aggregate monthly model flows. Daily flows are only available from 1980 to 2018. The record contains very little missing data and patching was only required in 2 months. The record is considered accurate and the flow regime closely resembles flow in the Houdenbecks River. The adjacent Leeu and Houdenbecks Rivers have similar rainfall and are both developed with numerous farm dams and similar irrigation water-use. It can therefore be assumed with a high degree of confidence that the flow record at E2H007 can be used to dis-aggregate monthly model flows upstream of the diversion site.

2.6 Hydrological Modelling

The hydrological modelling component consists of simulating natural flows which are used to determine the EWR requirement and then using present day water-use and the EWR requirement to generate a monthly time series of available water.

3. Environmental Water Requirements (EWR)

Using the data discussed in the previous sections, the WRSM2012 model was used to generate natural flows for both the proposed Kleinvlei Dam Catchment as well as the Diversion Site Catchment. The Desktop Method Reserve Method (Hughes et al. 2003) was then used to determine the EWR. Table 3.1 and Table 3.2 shows the EWR requirement at the Kleinvlei Dam Site and the Diversion Site respectively. The EWR used is the mean monthly flow listed under the column Total Flows in Table 3.1 and Table 3.2, as well as mean monthly flow listed under the Low Flow columns during dry months when natural flows are less than the Total Flows' EWR. Section 3.1 describes how the EWR is subtracted from the relevant monthly current-day flow record to determine the available flow at each site. An analysis was undertaken to determine what percentage of the EWR is met. Results show that the Total Flows EWR is met 90% of the time at the Proposed Dam Site and that the remaining months can fully meet the Low Flow EWR. The analysis at the Diversion Site on the Houdenbeks River indicates that the Total Flows EWR is met 23% of the time under the current-day scenario. The remaining months are only met by the Low Flow EWR 49 % of the time.

Table 3.1 EWR at the proposed Kleinvlei Dam site. Ecological Category = C/D. Distribution Type: W Cape(wet)

Natural Flows (Mm3)		Modified Flows (Mm3)			
		Low Flows		High Flows	Total Flows
Month	Mean	Maint.	Drought	Maint.	Maint.
Oct	0.084	0.008	0.005	0.007	0.015
Nov	0.039	0.006	0.003	0.001	0.007
Dec	0.014	0.003	0.000	0.000	0.003
Jan	0.003	0.001	0.000	0.000	0.001
Feb	0.001	0.000	0.000	0.000	0.000
Mar	0.001	0.000	0.000	0.000	0.000
Apr	0.009	0.000	0.000	0.000	0.000
May	0.058	0.002	0.000	0.008	0.010
Jun	0.132	0.005	0.000	0.018	0.024
Jul	0.185	0.008	0.004	0.010	0.018
Aug	0.204	0.010	0.006	0.033	0.043
Sep	0.151	0.010	0.005	0.010	0.020

3.1 Available Flow

Natural flows were generated by the WR2012 software to determine the EWR. The natural inflows to the proposed Kleinvlei Dam were used to determine the available flow as there is no water-use in the catchment upstream of the proposed Kleinvlei dam. The EWR identified in Section 3 was deducted from the natural flow to create a monthly time series of available flow.

The WR2012 software was used to generate current-day flows at the Diversion Site. This included routing 95% of all runoff through a simulated farm dam that supplies an irrigation demand. The EWR identified in Section 3 was then deducted from the present-day flow to create a monthly time series of available flow.

Table 3.2 EWR at the Diversion Site. Ecological Category = C/D. Distribution Type: W Cape(wet)

Natural Flows (Mm3)		Modified Flows (Mm3)			
		Low Flows		High Flows	Total Flows
Month	Mean	Maint.	Drought	Maint.	Maint.
Oct	1.313	0.179	0.111	0.092	0.272
Nov	0.626	0.126	0.078	0.014	0.14
Dec	0.246	0.055	0.035	0	0.055
Jan	0.082	0.022	0	0	0.022
Feb	0.037	0.01	0	0	0.01
Mar	0.058	0.009	0	0	0.009
Apr	0.228	0.016	0	0	0.016
May	1.213	0.06	0.01	0.159	0.219
Jun	2.717	0.136	0.07	0.353	0.489
Jul	3.598	0.198	0.1	0.173	0.372
Aug	3.811	0.24	0.149	0.572	0.812
Sep	2.573	0.22	0.136	0.173	0.393

The procedure to account for the EWR was as follows:

- If the current-day flow is higher than the EWR Total maintenance flows, this water becomes available for abstraction;
- If the current-day flow is lower than the EWR Total maintenance flows the EWR Drought Flows are used;
- The residual flow (current-day minus EWR drought flow) is available for abstraction;
- If the current-day flow is less than the EWR Drought flow then no water is available for abstraction.

The available monthly inflows to the proposed Kleinvlei Dam as well as at the Diversion Site are presented in **Appendix B** and **Appendix C** respectively and hydrological statistics for both sites are provided in **Table 3.3**. Results show that the available mean annual runoff (MAR) at the Proposed Dam is 0.749 Mm^3 and the Diversion Site is 5.59 Mm^3 for the full modelling period (1937 to 2018). Note that these are mean figures, i.e. flows that are likely to occur in an average year. Refer to the yield analysis for a more detailed assessment.

Table 3.3 Hydrological statistics at the Proposed Dam Site and Diversion Site – including flow available for abstraction. Note that these are mean figures and only likely to occur in an average year.

	Proposed Dam Site	Diversion Site
Natural MAR (Mm^3)	0.882	16.50
EWR (Mm^3)	0.133	1.24
Total Farm Dam Capacity (Mm^3)	-	12.20
Water Use (Mm^3)	-	9.66
Available MAR (Mm^3)	0.749	5.59

4. Kleinvlei Dam Yield

A yield analysis was undertaken to obtain an indication of the expected yield from the proposed Kleinvlei Dam with a capacity of 0.235 Mm^3. Firstly, the yield of the Kleinvlei Dam was determined based on runoff from the upstream catchment only. Then the yield of the Kleinvlei Dam was determined based on upstream runoff and supplementary water diverted from the Diversion Site. Several pumping capacities were used to generate a time series of diverted flow at the Diversion Site. This required converting the monthly time series of available flow at the Diversion Site to daily flow. This was achieved using the daily flow pattern at E2H007. Pumping rates of 10 l/s, 25 l/s and 50l/s were used.

The yield analysis was undertaken for the period 1980 to 2017 which is the period for which daily diversion data is available. This statistical analysis identifies the yield that is achieved for selected number of failure years (years in which the dam is not filled). The yield is also referred to as the assurance yield. A yield with an 80 % assurance means that a yield of a certain magnitude can be achieved 80% of the time, or eight years out of ten. This means that 80% of the time the annual yield will be higher.

In the analysis, an irrigation demand distribution is assumed, and the software increases the demand until the number of required failure years is achieved. Table 4.1 shows the demand distribution which was based on the composite crop factors and A-Pan evaporation used in the WRSM2012 configuration.

Table 4.1 Demand distribution used to determine yield.

	Oct	Nov	Dec	Jan	Feb	Mar	Apl	May	Jun	Jul	Aug	Sep	Total
Composite Crop Factors	0.45	0.49	0.47	0.48	0.63	0.55	0.38	0.28	0.23	0.25	0.27	0.39	n/a
A-pan (mm)	183	255	314	319	263	243	149	85	55	54	75	118	2113
Irrig Demand (mm)	82	125	148	153	166	134	57	24	13	14	20	46	980
Distribution	0.084	0.127	0.151	0.156	0.169	0.136	0.058	0.024	0.013	0.014	0.021	0.047	1.000

The yield results are shown in Figure 4.1 to Figure 4.4. Results show that there is an 80% assurance yield of approximately 0.175 Mm^3/annum if the proposed Kleinvlei Dam relies on inflow from the upstream catchment only. Supplementary pumping from the Diversion Site increases the 80% assurance yield to 0.205 Mm^3/annum using a pumping rate of 10 l/s and 0.210 Mm^3/annum using a pumping rate of 25 l/s. Further increases in pumping capacity have no benefit.

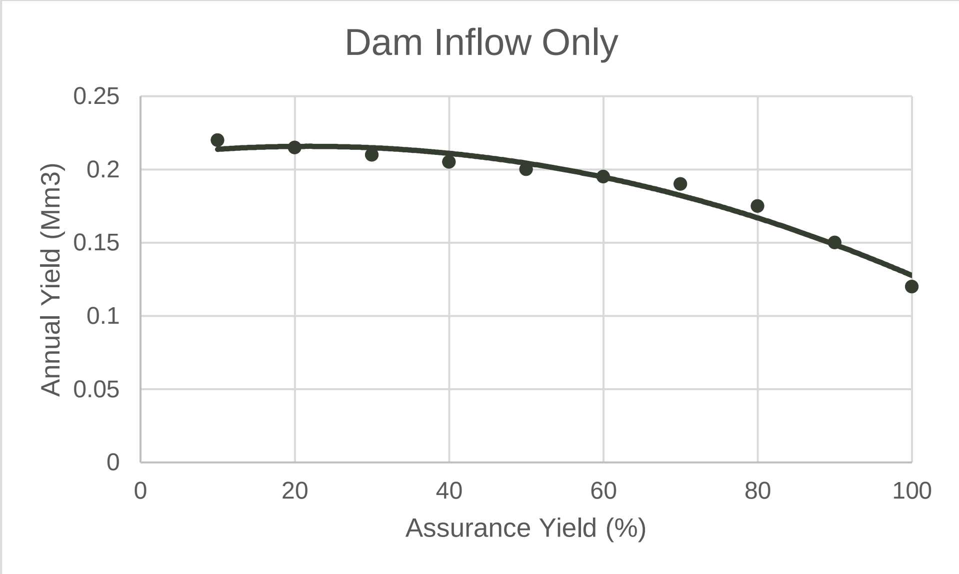

Figure 4.1 Proposed Dam yield (Mm^3/ann) based on upstream inflow only.

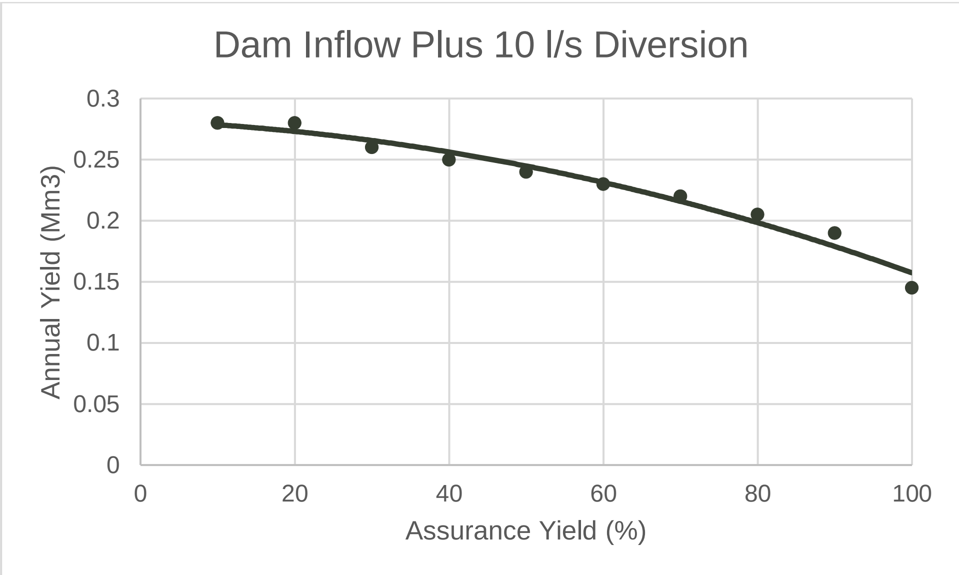

Figure 4.2 Proposed Dam yield (Mm^3/ann) using upstream inflow and diversion with a pumping capacity of 10 l/s.

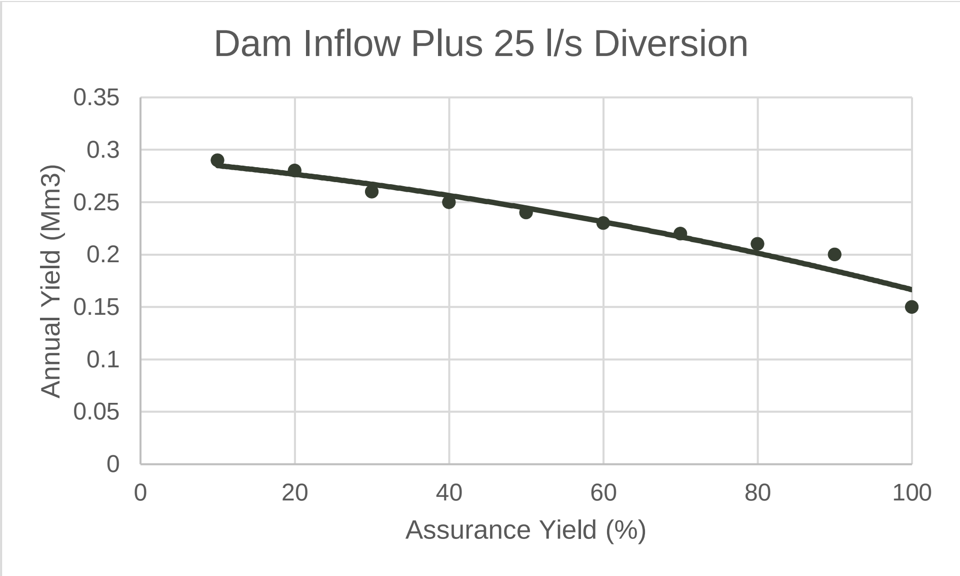

Figure 4.3 Proposed Dam yield (Mm³/ann) using upstream inflow and diversion with a pumping capacity of 25 l/s.

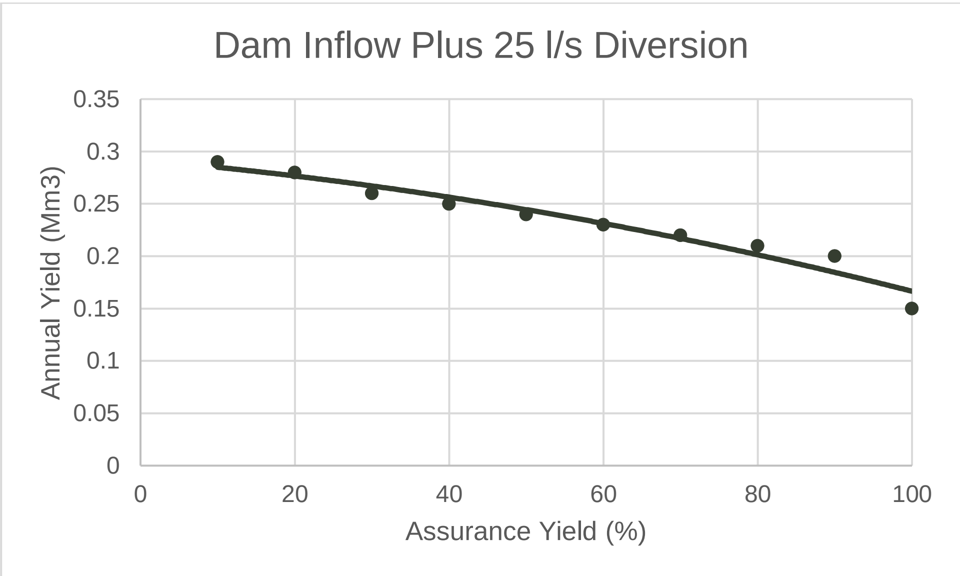

Figure 4.4 Proposed Dam yield (Mm³/ann) using upstream inflow and diversion with a pumping capacity of 50 l/s.

5. EWR Implementation and monitoring

The mean monthly EWR in m^3/s required at the Diversion Site on the Houdenbeks River is presented in **Table 5.1**. This can be supplied by any combination of dams upstream, operating rules for other diversions, or from the proposed Kleinvlei Dam. We recommend, however that a bottom release be incorporated into the dam during the construction phase should EWR releases be required.

Table 5.1 Required mean monthly EWR (m^3/s) at the diversion site.

Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total
0.016	0.008	0.003	0.000	0.000	0.000	0.000	0.013	0.029	0.021	0.051	0.021	**0.161**

However, the release of a variable EWR as defined in **Table 5.1** is not currently feasible as these releases would simply be stored in downstream on-channel dams. The EWR can only therefore be effective in the context of broader catchment-wide water management plan that includes Quaternary catchments E21A, E21B and E21E. This plan should include a strategy to provide the EWR to catchments downstream of the developed agricultural area which would require coordinated releases by individual landowners and take into consideration the volume of water required to fill and flush pools in the Riet River gorge towards the end of winter. The plan should take into consideration the following:

- The EWR is required for a short period during the winter/high flow season;
- The EWR must be apportioned between all upstream landowners;
- The total EWR requirement should be determined (for example 0.161 m^3/s in **Table 5.1**) and this assigned each location/landowner
- If the winter flow is enough to meet the EWR requirement in the gorge, i.e. all dams are spilling, no EWR releases are required;
- If there is no spill, coordinated EWR releases should be made

The water management plan should include monitoring to ensure that EWR flow targets are met in an adaptive management context. The implementation of the EWR, i.e. the adherence to operating rules, depends on access to regular and reliable flow records. River flows should be monitored at strategic points throughout the catchment. At these monitoring points, a rated section should be established to convert water levels to volumes. Operating rules will need to be regularly reviewed and if necessary, adjusted in the light of monitoring data.

6. Conclusion

The hydrological conditions in the catchment are strongly seasonal with practically no summer flows. In addition, there is a large variability in annual flows. This analysis is based on an EWR requirement that is fully met in the Proposed Dam catchment. However, due to highly developed nature of the Diversion Site catchment the Low Flow EWR can only be met 49 % of the time. The analysis therefore only includes pumping at the Diversion Site during months when flow exceeds the required EWR.

The variable nature of flow results in a 100% assurance yield that is very low. Generally, an 80% assurance yield is considered appropriate for irrigation. The proposed Kleinvlei Dam with a capacity of 0.235 Mm^3 can supply an 80% assurance yield of 0.175 Mm^3/annum from its own catchment. This can be increased to 0.205 Mm^3/annum using a supplementary diversion from the Houdenbeks River with a pumping capacity of 10 l/s.

7. Literature cited

Hughes DA, Hannart P, Watkins D. 2003. Continuous baseflow separation from time series of daily and monthly streamflow data. *Water Sa* 29: 43-48.

Appendix A De Keur monthly rainfall

Table A-1 De Keur Monthly Rainfall (mm)

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	ANN
1937	32	0	31	55	0	6	29	114	49	80	56	88	**540**
1938	5	12	0	8	29	46	96	0	124	48	25	0	**392**
1939	17	0	0	6	43	22	78	36	86	42	53	41	**423**
1940	20	78	0	59	0	0	78	198	210	140	93	96	**972**
1941	75	0	0	0	0	0	10	103	289	105	23	5	**608**
1942	48	0	18	33	9	40	40	13	107	133	211	54	**705**
1943	28	60	0	13	0	34	14	81	152	134	75	58	**649**
1944	33	14	13	0	0	14	39	128	193	121	154	0	**708**
1945	18	4	7	0	0	0	76	62	30	84	49	166	**495**
1946	52	9	10	0	0	32	0	65	48	85	183	56	**539**
1947	64	0	0	0	19	50	38	79	92	8	134	159	**641**
1948	51	3	0	4	0	0	50	32	73	114	89	65	**481**
1949	20	100	9	0	0	7	103	25	37	0	130	65	**495**
1950	54	60	32	0	0	0	54	47	181	36	83	19	**566**
1951	50	63	0	0	26	7	7	106	62	174	77	112	**683**
1952	42	47	11	0	0	63	204	111	36	96	137	2	**748**
1953	8	44	33	3	0	17	54	208	56	94	241	54	**813**
1954	29	8	23	0	45	29	33	12	119	231	156	0	**686**
1955	64	35	47	0	13	18	8	46	132	105	114	17	**598**
1956	0	0	16	0	92	7	17	115	236	39	190	98	**808**
1957	0	7	0	0	39	0	0	113	31	76	0	16	**281**
1958	41	28	0	0	15	9	42	303	20	73	32	9	**572**
1959	66	0	0	0	0	12	49	46	79	11	10	26	**299**
1960	7	0	40	20	13	4	16	54	123	75	39	78	**468**
1961	0	0	0	0	0	18	21	15	286	174	97	35	**645**
1962	154	23	0	13	0	0	26	8	100	273	105	70	**771**
1963	18	19	0	0	61	12	0	32	161	101	38	12	**454**
1964	16	46	0	0	0	0	0	52	23	54	19	13	**222**
1965	10	11	35	0	0	70	31	16	133	47	106	38	**497**
1966	2	1	4	10	33	0	55	69	234	39	37	35	**518**
1967	29	46	2	5	2	2	80	155	89	69	105	5	**587**
1968	82	13	116	6	6	9	34	9	35	61	18	78	**467**
1969	94	9	2	0	21	0	0	87	171	93	108	59	**643**
1970	21	8	8	9	8	20	14	36	108	97	111	5	**445**
1971	9	2	1	19	5	11	55	85	61	56	15	34	**353**
1972	18	1	53	0	0	34	5	36	22	53	209	49	**481**
1973	20	0	31	0	13	9	0	89	179	278	63	41	**721**
1974	50	38	6	20	9	8	76	203	44	83	92	12	**640**
1975	66	21	3	14	10	28	67	25	227	51	92	31	**634**
1976	26	137	101	15	20	9	106	323	204	189	143	40	**1314**
1977	25	32	24	18	3	42	35	48	10	162	11	44	**454**
1978	16	12	117	14	28	3	7	71	147	78	62	75	**630**
1979	42	2	0	35	12	3	29	101	82	85	22	12	**425**
1980	21	131	25	50	0	18	18	14	49	191	144	118	**779**
1981	22	15	13	34	0	55	49	40	44	22	96	12	**401**
1982	71	6	23	0	22	37	15	198	177	30	130	41	**750**
1983	5	11	4	3	6	132	35	272	19	43	103	203	**833**

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	ANN
1984	95	0	58	65	19	120	57	79	138	125	138	56	950
1985	16	4	40	5	4	31	30	71	129	80	134	46	589
1986	6	16	0	10	10	4	52	178	116	95	93	70	649
1987	6	0	31	0	0	25	83	41	111	48	93	76	515
1988	11	2	20	3	13	57	48	29	127	84	158	85	638
1989	22	24	3	1	36	19	129	122	101	129	33	3	620
1990	1	10	21	22	4	13	22	93	171	220	82	121	779
1991	62	9	0	0	23	30	37	51	203	102	92	25	633
1992	118	30	30	3	9	7	129	139	96	343	39	8	949
1993	5	5	23	3	0	5	40	8	177	46	13	143	464
1994	31	2	11	0	3	32	2	76	75	51	84	28	393
1995	76	15	55	0	16	3	0	48	220	142	125	182	880
1996	62	87	32	0	0	48	23	48	259	18	104	0	681
1997	0	0	0	20	0	4	18	241	52	84	32	27	476
1998	29	43	16	2	12	0	51	61	101	95	233	113	755
1999	0	0	0	9	7	31	9	73	105	163	73	149	619
2000	0	48	4	0	24	0	60	132	66	295	223	128	981
2001	78	32	4	73	28	4	35	179	56	253	118	35	893
2002	54	27	29	4	0	24	25	17	10	22	226	98	536
2003	77	0	44	16	0	3	90	4	119	105	107	33	597
2004	55	10	0	21	0	7	114	66	146	128	180	49	774
2005	13	0	0	3	0	5	88	275	100	42	113	26	663
2006	20	76	12	0	13	26	88	115	408	221	95	6	1078
2007	14	56	43	10	50	6	4	154	177	373	159	246	1290
2008	7	107	3	3	49	0	111	211	287	81	106	40	1002
2009	14	146	2	0	48	10	15	260	124	48	76	46	788
2010	45	44	40	0	10	20	40	230	268	19	105	47	866
2011	37	31	23	41	1	16	75	41	184	69	243	57	817
2012	15	0	46	5	19	0	139	67	272	116	241	127	1046
2013	26	61	0	84	0	70	39	181	216	163	152	21	1012
2014	0	50	0	9	2	26	0	21	130	101	44	8	390
2015	10	11	5	49	0	48	126	15	133	151	83	63	693
2016	4	4	0	10	11	0	16	0	173	16	22	5	260
2017	27	17	0	0	4	12	59	104	160	76	104	77	638
AVG	33	26	18	12	12	20	46	93	128	105	101	57	651

Appendix B Available Inflow

Table B-1 Available Inflow to the Kleinvlei Dam

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Ann
1937	0.03	0.01	0.01	0.01	0.00	0.00	0.00	0.02	0.02	0.04	0.04	0.08	**0.25**
1938	0.06	0.02	0.01	0.00	0.00	0.00	0.02	0.01	0.04	0.05	0.03	0.02	**0.25**
1939	0.01	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.02	0.03	0.02	0.04	**0.13**
1940	0.03	0.02	0.01	0.01	0.00	0.00	0.01	0.14	0.32	0.39	0.22	0.17	**1.31**
1941	0.13	0.05	0.02	0.00	0.00	0.00	0.00	0.01	0.35	0.26	0.12	0.07	**1.00**
1942	0.04	0.01	0.01	0.00	0.00	0.00	0.01	0.00	0.02	0.09	0.35	0.21	**0.73**
1943	0.09	0.04	0.02	0.00	0.00	0.00	0.00	0.01	0.08	0.15	0.13	0.12	**0.63**
1944	0.08	0.03	0.01	0.00	0.00	0.00	0.00	0.04	0.17	0.24	0.35	0.17	**1.08**
1945	0.06	0.01	0.01	0.00	0.00	0.00	0.01	0.01	0.02	0.03	0.02	0.14	**0.30**
1946	0.11	0.04	0.01	0.00	0.00	0.00	0.00	0.00	0.02	0.02	0.14	0.14	**0.47**
1947	0.09	0.04	0.01	0.00	0.00	0.00	0.01	0.01	0.03	0.04	0.07	0.18	**0.47**
1948	0.14	0.05	0.01	0.00	0.00	0.00	0.00	0.00	0.02	0.05	0.07	0.09	**0.42**
1949	0.06	0.05	0.03	0.01	0.00	0.00	0.02	0.01	0.02	0.00	0.03	0.06	**0.28**
1950	0.06	0.03	0.02	0.01	0.00	0.00	0.00	0.00	0.11	0.09	0.06	0.07	**0.44**
1951	0.05	0.03	0.02	0.00	0.00	0.00	0.00	0.02	0.02	0.14	0.13	0.15	**0.55**
1952	0.11	0.05	0.02	0.00	0.00	0.01	0.15	0.12	0.08	0.10	0.15	0.12	**0.90**
1953	0.05	0.02	0.01	0.00	0.00	0.00	0.01	0.15	0.10	0.10	0.47	0.25	**1.15**
1954	0.09	0.03	0.01	0.00	0.00	0.00	0.00	0.00	0.02	0.25	0.38	0.18	**0.95**
1955	0.07	0.03	0.02	0.01	0.00	0.00	0.00	0.00	0.04	0.08	0.11	0.10	**0.45**
1956	0.05	0.01	0.01	0.00	0.02	0.01	0.00	0.03	0.25	0.17	0.31	0.23	**1.08**
1957	0.10	0.03	0.01	0.00	0.00	0.00	0.00	0.02	0.01	0.03	0.01	0.01	**0.21**
1958	0.01	0.00	0.01	0.00	0.00	0.00	0.00	0.37	0.17	0.07	0.05	0.04	**0.71**
1959	0.04	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.02	0.00	**0.09**
1960	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.06	0.04	0.07	**0.20**
1961	0.05	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.31	0.32	0.21	0.14	**1.03**
1962	0.16	0.08	0.02	0.00	0.00	0.00	0.00	0.00	0.02	0.32	0.23	0.15	**0.97**
1963	0.09	0.03	0.01	0.00	0.01	0.00	0.00	0.00	0.06	0.09	0.07	0.06	**0.41**
1964	0.03	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.01	0.00	**0.06**
1965	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.00	0.04	0.05	0.06	0.08	**0.25**
1966	0.05	0.01	0.00	0.00	0.00	0.00	0.00	0.01	0.22	0.15	0.07	0.06	**0.56**
1967	0.04	0.02	0.01	0.00	0.00	0.00	0.01	0.08	0.08	0.09	0.11	0.10	**0.53**
1968	0.07	0.03	0.04	0.02	0.00	0.00	0.00	0.00	0.01	0.00	0.01	0.02	**0.19**
1969	0.05	0.03	0.01	0.00	0.00	0.00	0.00	0.00	0.10	0.12	0.13	0.13	**0.56**
1970	0.08	0.03	0.01	0.00	0.00	0.00	0.00	0.00	0.02	0.05	0.09	0.08	**0.35**
1971	0.04	0.01	0.00	0.00	0.00	0.00	0.00	0.01	0.02	0.04	0.01	0.02	**0.14**
1972	0.02	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.15	0.12	**0.30**
1973	0.06	0.02	0.01	0.00	0.00	0.00	0.00	0.01	0.11	0.56	0.27	0.12	**1.15**
1974	0.08	0.03	0.02	0.00	0.00	0.00	0.01	0.15	0.10	0.09	0.10	0.09	**0.66**
1975	0.06	0.03	0.01	0.00	0.00	0.00	0.01	0.00	0.19	0.14	0.09	0.09	**0.61**
1976	0.06	0.07	0.07	0.02	0.01	0.00	0.03	0.45	0.53	0.57	0.41	0.18	**2.39**
1977	0.08	0.03	0.01	0.00	0.00	0.00	0.00	0.00	0.01	0.08	0.05	0.04	**0.29**
1978	0.03	0.01	0.04	0.02	0.00	0.00	0.00	0.00	0.06	0.08	0.07	0.09	**0.39**
1979	0.07	0.03	0.01	0.00	0.00	0.00	0.00	0.02	0.03	0.06	0.04	0.04	**0.29**
1980	0.02	0.05	0.03	0.01	0.00	0.00	0.00	0.00	0.01	0.12	0.16	0.19	**0.58**
1981	0.12	0.04	0.01	0.00	0.00	0.00	0.01	0.00	0.02	0.01	0.01	0.03	**0.24**
1982	0.04	0.02	0.01	0.00	0.00	0.00	0.00	0.13	0.20	0.15	0.14	0.13	**0.81**
1983	0.07	0.02	0.01	0.00	0.00	0.04	0.03	0.31	0.16	0.07	0.07	0.30	**1.07**

1984	0.20	0.07	0.03	0.02	0.01	0.04	0.03	0.03	0.09	0.16	0.29	0.18	**1.14**
1985	0.08	0.03	0.01	0.00	0.00	0.00	0.00	0.00	0.05	0.08	0.13	0.13	**0.50**
1986	0.07	0.02	0.01	0.00	0.00	0.00	0.00	0.10	0.11	0.13	0.14	0.14	**0.71**
1987	0.09	0.02	0.01	0.00	0.00	0.00	0.01	0.01	0.04	0.05	0.06	0.09	**0.37**
1988	0.07	0.02	0.01	0.00	0.00	0.00	0.01	0.00	0.04	0.07	0.15	0.17	**0.53**
1989	0.10	0.04	0.01	0.00	0.00	0.00	0.04	0.07	0.09	0.16	0.12	0.08	**0.70**
1990	0.03	0.01	0.00	0.00	0.00	0.00	0.00	0.01	0.11	0.42	0.24	0.19	**1.00**
1991	0.14	0.05	0.02	0.00	0.00	0.00	0.00	0.00	0.15	0.15	0.13	0.12	**0.75**
1992	0.11	0.06	0.02	0.01	0.00	0.00	0.04	0.08	0.10	0.78	0.34	0.09	**1.62**
1993	0.04	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.08	0.07	0.02	0.10	**0.32**
1994	0.08	0.03	0.01	0.00	0.00	0.00	0.00	0.00	0.01	0.03	0.03	0.05	**0.23**
1995	0.05	0.03	0.02	0.01	0.00	0.00	0.00	0.00	0.17	0.19	0.25	0.40	**1.11**
1996	0.20	0.08	0.04	0.01	0.00	0.00	0.00	0.00	0.26	0.15	0.08	0.08	**0.89**
1997	0.04	0.01	0.00	0.00	0.00	0.00	0.00	0.21	0.11	0.08	0.06	0.05	**0.55**
1998	0.04	0.02	0.01	0.00	0.00	0.00	0.00	0.00	0.03	0.07	0.37	0.27	**0.80**
1999	0.11	0.03	0.01	0.00	0.00	0.00	0.00	0.00	0.03	0.14	0.13	0.21	**0.65**
2000	0.13	0.04	0.02	0.00	0.00	0.00	0.01	0.05	0.05	0.49	0.68	0.36	**1.82**
2001	0.16	0.07	0.02	0.01	0.01	0.00	0.00	0.10	0.07	0.39	0.33	0.16	**1.31**
2002	0.08	0.03	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.16	0.14	**0.42**
2003	0.10	0.04	0.02	0.01	0.00	0.00	0.01	0.00	0.03	0.07	0.10	0.10	**0.47**
2004	0.07	0.03	0.01	0.00	0.00	0.00	0.03	0.03	0.09	0.16	0.41	0.22	**1.04**
2005	0.08	0.02	0.01	0.00	0.00	0.00	0.01	0.31	0.20	0.12	0.12	0.11	**0.97**
2006	0.06	0.03	0.02	0.00	0.00	0.00	0.02	0.05	0.76	0.83	0.33	0.12	**2.21**
2007	0.06	0.02	0.02	0.01	0.01	0.00	0.00	0.06	0.15	0.94	0.64	0.63	**2.53**
2008	0.24	0.07	0.03	0.01	0.00	0.00	0.03	0.18	0.62	0.33	0.20	0.14	**1.84**
2009	0.07	0.09	0.04	0.01	0.00	0.00	0.00	0.25	0.18	0.12	0.10	0.10	**0.95**
2010	0.07	0.03	0.02	0.01	0.00	0.00	0.00	0.19	0.50	0.24	0.12	0.11	**1.28**
2011	0.08	0.03	0.01	0.01	0.00	0.00	0.01	0.01	0.12	0.12	0.46	0.25	**1.09**
2012	0.09	0.03	0.01	0.00	0.00	0.00	0.05	0.04	0.34	0.35	0.62	0.37	**1.89**
2013	0.14	0.05	0.02	0.02	0.01	0.01	0.01	0.11	0.31	0.46	0.41	0.18	**1.72**
2014	0.06	0.02	0.01	0.00	0.00	0.00	0.00	0.00	0.03	0.06	0.05	0.05	**0.27**
2015	0.02	0.00	0.00	0.00	0.00	0.00	0.04	0.03	0.06	0.16	0.15	0.14	**0.59**
2016	0.08	0.02	0.01	0.00	0.00	0.00	0.00	0.00	0.07	0.05	0.03	0.01	**0.26**
2017	0.01	0.00	0.00	0.00	0.00	0.00	0.01	0.02	0.11	0.13	0.13	0.14	**0.54**
2018	0.09	0.03	0.02	0.01	0.00	0.00	0.00	0.00	0.01	0.13	0.10	0.07	**0.45**
Average	**0.07**	**0.03**	**0.01**	**0.00**	**0.00**	**0.00**	**0.01**	**0.05**	**0.11**	**0.17**	**0.16**	**0.13**	**0.75**

Appendix C Available inflow at Diversion

Table C-1 Available inflow at Diversion site

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Ann
1937	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.05	0.00	0.00	0.00	0.00	0.06
1938	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.02	0.02	0.00	0.00	0.00	0.07
1939	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.00	0.00	0.00	0.00	0.02
1940	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.01	0.01	4.65	3.73	2.86	11.27
1941	1.44	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.03	3.77	1.43	0.23	6.92
1942	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.07	1.32	3.19	4.59
1943	0.31	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.08	0.18	0.61	1.54	2.72
1944	0.30	0.00	0.00	0.00	0.00	0.00	0.00	0.07	0.23	1.34	6.04	1.90	9.87
1945	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.00	0.00	0.00	0.12	0.15
1946	0.06	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.15	0.07	0.28
1947	0.01	0.00	0.00	0.00	0.00	0.00	0.01	0.02	0.01	0.00	0.02	0.17	0.25
1948	0.63	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.02	0.01	0.67
1949	0.00	0.00	0.00	0.01	0.00	0.00	0.02	0.02	0.00	0.00	0.00	0.00	0.06
1950	0.00	0.00	0.00	0.01	0.00	0.00	0.01	0.00	0.12	0.05	0.00	0.00	0.19
1951	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.00	0.16	0.09	0.10	0.39
1952	0.10	0.00	0.00	0.01	0.00	0.00	0.21	0.18	0.05	1.88	3.68	1.34	7.45
1953	0.00	0.00	0.00	0.01	0.00	0.00	0.01	0.02	0.09	0.07	7.73	3.74	11.67
1954	0.34	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.05	5.01	2.01	7.41
1955	0.32	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.02	0.06	0.09	0.02	0.52
1956	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.05	0.33	0.20	5.91	4.11	10.60
1957	0.46	0.00	0.00	0.00	0.00	0.00	0.00	0.04	0.00	0.00	0.00	0.00	0.50
1958	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.29	0.17	0.01	0.00	0.00	0.47
1959	0.01	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.02
1960	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.00	0.00	0.02
1961	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.38	0.39	3.86	1.53	6.15
1962	2.87	0.04	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.13	3.55	2.18	8.77
1963	0.29	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.06	0.07	0.00	0.00	0.42
1964	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1965	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.02	0.00	0.01	0.00	0.04
1966	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.02	0.29	0.13	0.00	0.00	0.45
1967	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.13	0.08	0.06	0.07	0.00	0.35
1968	0.33	0.00	0.02	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.35
1969	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.11	0.11	0.10	0.04	0.38
1970	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.06	0.00	0.08
1971	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.03	0.00	0.00	0.00	0.00	0.04
1972	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.13	0.05	0.20
1973	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.13	1.52	4.64	1.23	7.52
1974	0.37	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.09	0.05	1.27	0.82	2.62
1975	0.31	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.24	0.11	0.29	1.04	2.00
1976	0.07	0.78	0.05	0.01	0.00	0.00	0.02	3.92	9.84	9.80	6.90	2.32	33.70
1977	0.12	0.00	0.00	0.01	0.00	0.00	0.01	0.01	0.00	0.05	0.00	0.00	0.20
1978	0.00	0.00	0.01	0.01	0.00	0.00	0.00	0.01	0.06	0.06	0.00	0.00	0.15
1979	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.00	0.02	0.00	0.00	0.05
1980	0.00	0.01	0.02	0.02	0.00	0.00	0.00	0.00	0.00	0.12	0.17	0.16	0.50
1981	0.23	0.00	0.00	0.01	0.00	0.00	0.01	0.01	0.00	0.00	0.00	0.00	0.26
1982	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.20	0.27	0.11	0.81	1.69	3.08
1983	0.06	0.00	0.00	0.00	0.00	0.06	0.02	0.22	1.16	0.97	1.54	6.25	10.28

1984	3.16	0.01	0.00	0.02	0.00	0.05	0.03	0.05	0.11	2.51	5.17	2.45	13.56
1985	0.16	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.04	0.06	0.12	0.83	1.22
1986	0.09	0.00	0.00	0.00	0.00	0.00	0.01	0.16	0.14	0.13	1.97	1.93	4.42
1987	0.14	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.02	0.00	0.00	0.01	0.20
1988	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.03	0.04	0.16	0.67	0.92
1989	0.55	0.00	0.00	0.00	0.00	0.00	0.05	0.11	0.11	1.15	1.66	0.31	3.94
1990	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.13	1.71	4.29	3.50	9.64
1991	1.50	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.18	0.17	1.41	1.19	4.46
1992	1.61	0.01	0.00	0.01	0.00	0.00	0.05	0.13	0.11	11.93	5.13	0.54	19.52
1993	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.09	0.02	0.00	0.03	0.14
1994	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.02
1995	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.20	0.22	0.57	6.92	7.92
1996	2.47	0.16	0.02	0.01	0.00	0.00	0.01	0.00	0.33	0.74	1.73	0.58	6.04
1997	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.09	0.11	0.03	0.00	0.00	0.24
1998	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.00	0.04	1.68	5.16	6.90
1999	0.67	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.17	0.09	3.14	4.08
2000	0.97	0.00	0.00	0.00	0.00	0.00	0.01	0.08	0.03	4.11	11.62	6.29	23.10
2001	2.00	0.01	0.00	0.02	0.00	0.00	0.00	0.16	0.06	4.62	6.00	1.92	14.78
2002	0.44	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.14	0.09	0.68
2003	0.03	0.00	0.00	0.01	0.00	0.00	0.00	0.01	0.01	0.05	0.07	0.02	0.21
2004	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.04	0.10	0.19	5.73	2.98	9.07
2005	0.06	0.00	0.00	0.00	0.00	0.00	0.00	0.23	1.25	1.91	2.54	1.28	7.27
2006	0.04	0.00	0.00	0.01	0.00	0.00	0.01	0.08	8.01	13.96	5.39	1.15	28.65
2007	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.10	0.20	13.62	10.60	10.62	35.14
2008	2.71	0.20	0.01	0.01	0.00	0.00	0.03	0.07	9.33	6.01	3.42	1.67	23.45
2009	0.14	1.06	0.01	0.01	0.00	0.00	0.00	0.15	1.75	1.96	1.64	1.14	7.85
2010	0.26	0.00	0.00	0.01	0.00	0.00	0.00	0.08	5.43	3.76	2.10	1.40	13.03
2011	0.25	0.00	0.00	0.01	0.00	0.00	0.00	0.01	0.14	0.10	6.25	3.75	10.51
2012	0.20	0.00	0.00	0.01	0.00	0.00	0.06	0.06	0.79	6.47	10.26	6.39	24.24
2013	1.19	0.00	0.00	0.01	0.00	0.01	0.00	0.18	2.75	8.19	6.87	2.17	21.37
2014	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.02	0.00	0.00	0.03
2015	0.00	0.00	0.00	0.01	0.00	0.00	0.05	0.04	0.05	0.19	0.12	0.19	0.66
2016	0.05	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.07	0.00	0.00	0.00	0.12
2017	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.04	0.14	0.12	0.09	0.06	0.47
2018	0.44	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.15	0.03	0.00	0.63
Average	0.34	0.03	0.00	0.00	0.00	0.00	0.01	0.09	0.56	1.35	1.90	1.31	5.59