Hydrological Assessment for a Proposed Instream Dam on the Ruiterbos River, Farm 420 and 373, Ruiterbos, Western Cape.

Hydrological Assessment

Prepared For: Eco Route
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Dr. James Dabrowski (Ph.D., Pr.Sci.Nat. Water Resources; SACNASP Reg. No: 114084)

April 2025

EXECUTIVE SUMMARY

Outeniqua Game Farm (the applicant) is in the process of expanding agricultural production on neighbouring Farm 373 (RE/373) and Farm 420 (RE/420) near Ruiterbos, which is located just north of Mossel Bay in the Western Cape. Increased abstraction and storage of water is necessary for the sustainable irrigation of proposed increased crop areas on the farms. The applicant intends to construct an instream dam (on the Ruiterbos River on RE/420) to fulfil this need. A hydrological assessment was required to understand the yield of the catchment area of the dam, determine the size of dam required to meet the irrigation demand of proposed crops and assess the impacts of the operation of the dam on downstream users. The main findings can be summarised as follows:

- The WRSM-Pitman model was used to simulate flows in the Ruiterbos River and was updated with more recent rainfall data to allow simulations up to the 2022 hydrological year. Updated simulations compared favourably to measured flow data at K1H004 on the Brandwag River in quaternary catchment K10D.
- The mean estimated irrigation requirements for crops that will be irrigated from this dam is approximately 180 000 m^3 per annum, with maximum demand reaching up to 215 000 m^3. Considering an existing water entitlement of 80 000 m^3 from the Ruiterbos River, a Water Use License (WUL) would be required to abstract and additional 100 000 m^3 to 135 000 m^3
- A catchment modelling exercise indicates that the mean annual runoff from the catchment area of the dam is approximately 1.24 Mm^3, which is sufficient to meet the irrigation demands of crops.
- Based on a detailed monthly water balance based on weather data covering a 50-year period, a dam size of 150 000 m^3 is expected to provide at least a 95 % assurance of supply.
- There are no additional users on the Ruiterbos River downstream of the proposed dam. Base flows are however likely to reduce and low to zero flow conditions are expected to increase from 40 % of the time to approximately 60 % of the time. This reduction of flow is likely to have a significant impact of aquatic biota in the river.
- According to the WRSM model output, the Ruiterbos River (upstream of the dam) contributes approximately 1.24 Mm^3 (or 9.5 %) of the total mean annual flow volumes measured at K1H004. Based on the 50-year simulation assuming a 150 000 m^3 dam and abstraction for meeting irrigation requirements, mean annual flow simulated at K1H004 would reduce from 11.08 Mm^3 to 10.87 Mm^3 (or 2 %).
- Impacts of this 2 % reduction on flow on downstream users in the Brandwag River and on the Reserve are likely to be negligible.
- The following mitigation measures are recommended:
  - Flow meters must be installed on pumps and records of abstraction volumes must be submitted to BOCMA bi-annually.
  - The EWR for the Ruiterbos River must be determined and an outlet works must be incorporated into the dam design to ensure that the EWR is met. Alternatively, a weir and pipeline must be constructed at the dam inlet to divert baseflows around the dam and into the Ruiterbos River below the dam.

- Authorisation of additional taking of water from the Ruiterbos River must be subject to the surrender of abstraction rights from boreholes on RE/420 and RE/373.

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1 INTRODUCTION

1.1 Project Background

Outeniqua Game Farm (the applicant) is in the process of expanding agricultural production on neighbouring Farm 373 (RE/373) and Farm 420 (RE/420) near Ruiterbos, which is located just north of Mossel Bay in the Western Cape. Increased abstraction and storage of water is necessary for the sustainable irrigation of proposed increased crop areas on the farms. The applicant intends to construct an instream dam (on the Ruiterbos River on RE/420) to fulfil this need. A hydrological assessment was required to understand the yield of the catchment area of the dam and to determine the size of dam required to meet the irrigation demand of proposed crop areas.

1.2 Scope of Work

The scope of work for this report includes the following:

- An assessment of the yield of surface water flows available in the immediate catchment of the dam;
- Estimation of irrigation requirements for the proposed crops and a determination of whether the surface water yield is sufficient to meet these requirements;
- Development of a water balance to estimate the size of the dam required to meet the irrigation requirements; and
- An assessment of the impacts of increased abstraction and storage on downstream users (including the Reserve).

2 CATCHMENT CHARACTERISTICS

2.1 Study Site

The proposed dam is located on the Ruiterbos River on RE/420 and is intended to store water for agricultural activities on this farm and the neighbouring RE/373 – both of which are owned by the applicant. The Ruiterbos River meets the Palmiet River (which drains quaternary catchment K10C) and together form the Brandwag River (Figure 1). A DWS flow gauging station (K1H004) is located further down the Brandwag River, just upstream of an intensive agricultural area. The Brandwag River meets the Moordkuil River at the Klein Brak Estuary. Several, small instream farm dams are located in the upper most reaches of the Ruiterbos River and its catchment, where a mixture of dryland and irrigated pastures are farmed as well as small areas of macadamia and avocado. The properties fall within the Southern Coastal Belt (Ecoregion Level 1: 22) which is located from 0 to 500 m.a.m.s.l. and is characterized by undulating plains and low hills of moderate relief. Terrain throughout the properties consists of flat to gentle sloping plains at higher altitudes, interspersed with very steep valleys along the Ruiterbos River and its tributaries.

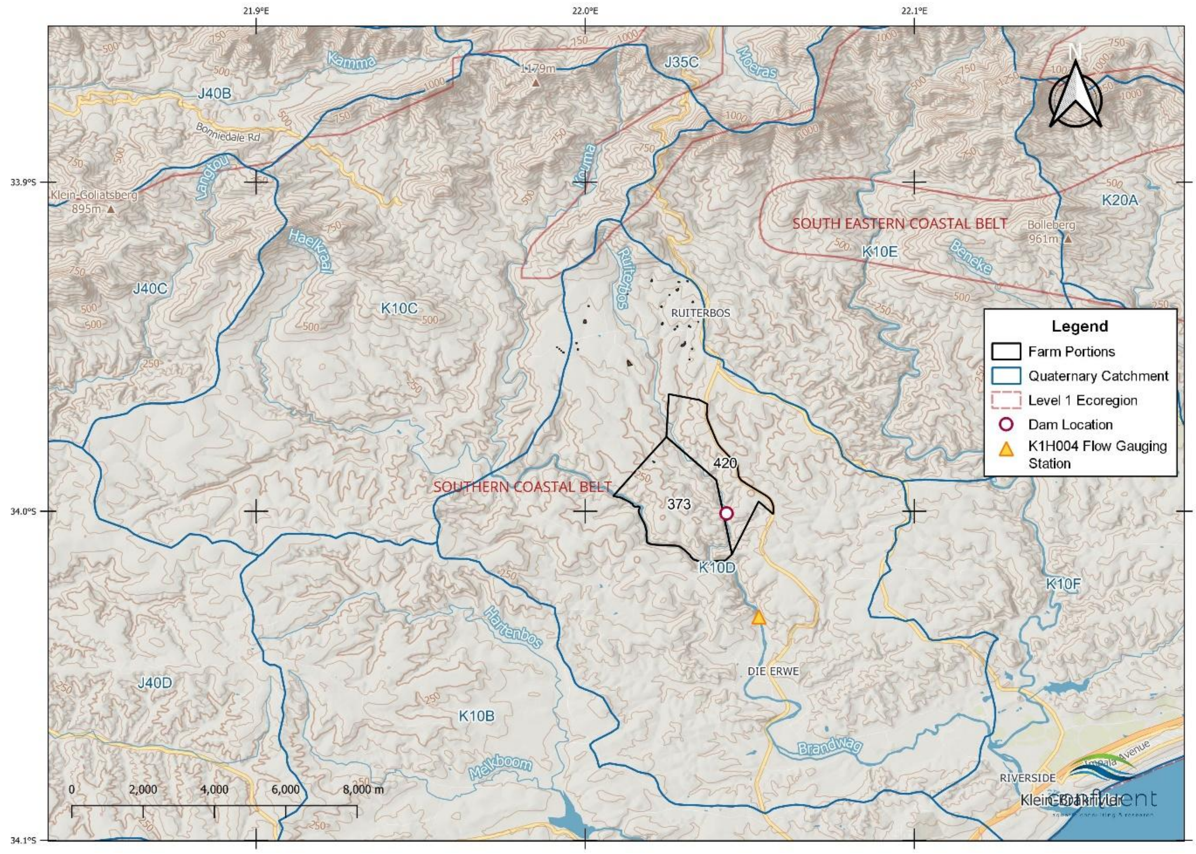

Figure 1: Map indicating the location of RE/373 and RE/420.

2.2 Climate

According to the Koppen climate classification the catchment area is characterised by an ocean-moderated semi-arid climate. The mean annual precipitation (MAP) is relatively low (454 mm per annum - Bailey and Pitman, 2016), with distinct peaks in the transition between summer and autumn (March to April) and winter and spring (August to November) (Figure 2).

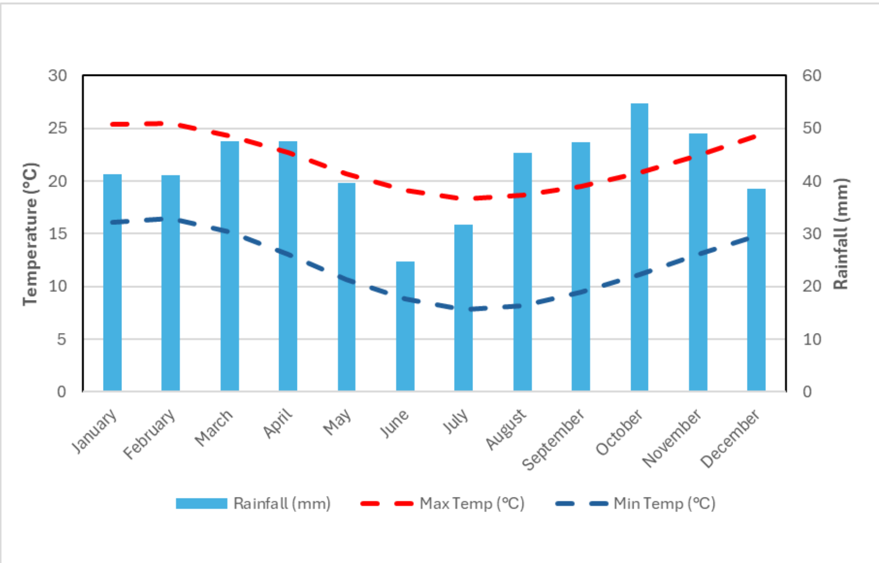

Figure 2: Mean monthly rainfall and temperature for quaternary K10D (Van Heerden and Walker, 2016)

2.3 Existing Water Users

The Reserve is the quantity and quality of the water required to satisfy the basic human needs by securing a basic water supply and to protect the aquatic ecosystem in order to secure ecologically sustainable development and use of the relevant water resource.

The MAR for the entire K10D catchment is 17.9 Mm^3. According to the Reserve Determination for Water Resources of the Breede-Gouritz Water Management Area (GN 2428 of August 2022) the Present Ecological State (PES) and Ecological Importance and Sensitivity (EIS) of the Brandwag River is D (Largely Modified) and High, respectively. Given the High EIS, the Recommended Ecological Category (REC) for the Brandwag River is B (Largely Natural) and Reserve requirements are as follows:

- **Ecological Water Requirement (EWR):** 9 % of MAR (or 1.77 Mm^3)
- **Basic Human Need (BHN):** 0.06 % of MAR (or 0.01 Mm^3).

This implies that 16.12 Mm^3 of water is available for allocation to other users. According to the Department of Water and Sanitation (DWS) Water and Registration Management System (WARMS), 8.3 Mm^3 has been registered for Section 21 (a) water use (mainly irrigation as well as livestock watering). Therefore approximately 7.82 Mm^3 of water is available for allocation. Registered abstraction points of water users are indicated in Figure 3. Water users located downstream of the proposed dam location abstract from the Brandwag River. These water users account for 3.54 Mm^3 of the total annual abstraction from quaternary catchment K10D.

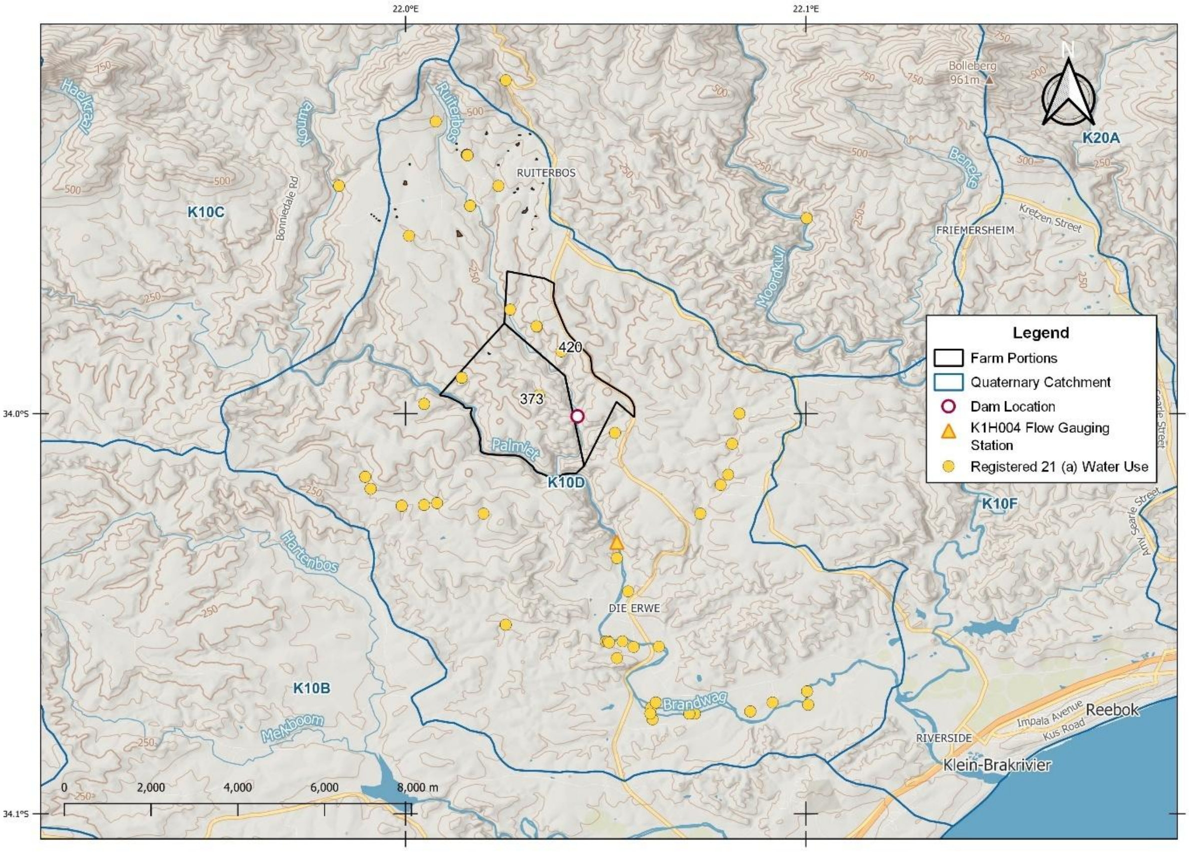

Figure 3: Location of 21 (a) water users in quaternary catchment K10D.

2.4 Existing Lawful Use (ELU)

Each farm has registered (lawful) rights to abstract water from the Palmiet and Ruiterbos rivers, respectively, as well as from boreholes located on each farm (Table 1). According to the applicant, the quality of water abstracted from boreholes is not adequate for irrigation or domestic use purposes. The applicant will therefore surrender the rights to these water sources in favour of increased abstraction from the Ruiterbos River.

Table 1: Registered lawful water uses for Farm 373 and Farm 420.

Property	Water Use	Volume (m^3/annum)
RE/373	21 (a): Taking of groundwater from a borehole for irrigation	117 819
	21 (a): Taking of surface water from the Palmiet River for irrigation	80 000
RE/420	21 (a): Taking of groundwater from a borehole for irrigation	73 425
	21 (a): Taking of surface water from the Ruiterbos River for irrigation	80 000

3 METHODOLOGY

Data and model configurations developed as part of the Water Resources of South Africa 2012 (WR2012) Study (Bailey and Pitman, 2016) were used to estimate hydrological flows originating from the catchment area of the proposed dam. The WR2012 study developed long-term monthly time-step simulated streamflow for most quaternary catchments throughout South Africa. The time-series represent the volume of water discharged from each quaternary catchment over a 90-year time period (i.e. October 1920 to September 2010). The data is produced by the WRSM-Pitman Model which is a rainfall-runoff model that simulates streamflow from long-term monthly rainfall data. As part of the WR2012 study, the outputs of the model were calibrated against real-time measured hydrological data collected from streamflow gauging stations located throughout the country. The WR2012 therefore provides the most comprehensive database of the estimated flow volumes for quaternary catchments throughout the country. The WRSM-Pitman Model modelled all land and water use activities upstream of the flow gauging stations to estimate the reduction in streamflow due to human development over time. The model can therefore be used to simulate Present-Day (PD) flow conditions over the long-term and to assess the impact of additional activities (e.g. construction of a dam) on hydrological flows over the long term. The WRSM-Pitman Model also provides Naturalised streamflow for each quaternary catchment which are the natural pre-development flows that would occur if all anthropogenic influences (i.e. afforestation, mining, abstractions, transfers etc.) are removed from the simulation. The hydrological assessment adopted the following approach:

- Three catchment areas were delineated through a hydrological analysis of a Digital Elevation Model (DEM) for the area (the DEM was obtained from the USGS Earth Explorer website (https://earthexplorer.usgs.gov/):
    - **K1H004:** The entire catchment area contributing flows to the K1H004 flow gauging station. This included the whole of K10C and part of K10D.

  - **OGF U/S:** The catchment area of the Ruiterbos River contributing flows to the OGF Dam.
  - **OGF D/S:** The catchment area contributing flows to the Ruiterbos River downstream of the OGF Dam.

- The calibrated WRSM2000-Pitman model was updated with more recent rainfall data, which extended the period of simulation to the end of the 2022 hydrological year (i.e. September 2023). Rainfall data was obtained from the DWS Hydrology website for meteorological station K1E003. The PD time-series for quaternary catchment K10D was compared to flow data measured at the K1H004 flow gauging station to calibrate the model (if necessary) and ensure that the updated model provided realistic simulations (K1H004 Flow).
- The calibrated WRSM2000-Pitman model simulation for the portion of quaternary catchment K10D contributing flows to K1H004 was downscaled to simulate flows from the Ruiterbos River catchment area upstream of the dam (OGF U/S Flow).
- The calibrated WRSM2000-Pitman model simulation for the portion of quaternary catchment K10D contributing flows to K1H004 was also downscaled to simulate flows from the portion of the Ruiterbos River catchment that falls downstream of the dam (OGF D/S Flow).

3.1 Irrigation Requirements

The SAPWAT 4.0 model was used to estimate irrigation requirements for crops and associated areas specified in Table 2 (59 ha in total). SAPWAT estimates typical monthly water use requirements for a variety of crops over a historical 50-year period (1950 to 2000) using catchment specific weather data. The following assumptions were made in the estimation of irrigation requirements:

- Water requirements were estimated for each crop based on the proposed irrigation method specified in (Table 2);
- The default setting of 75 % was used for water distribution efficiency; and
- Irrigation scheduling was set to take place when readily available water (RAW) reached 70 %.
- Soil was assumed to be a sandy loam.

Table 2: Area of proposed crops requiring irrigation on RE/420 and RE/373.

Crop	Property	Area (ha)	Irrigation Method
Avocado	RE/420	10	Drip
Broccoli	RE/420	3	Drip
Maize	RE/373	23	Centre Pivot Sprinkler
Lucerne	RE/373	23	Centre Pivot Sprinkler

3.2 Assumptions & Limitations

- The WRSM-Pitman model used to estimate hydrology for the Ruiterbos River catchment was calibrated at a quaternary catchment scale. The calibrated model therefore provides an integrated estimate of hydrology based on average rainfall that

- falls over the larger quaternary catchment area, which may not necessarily be representative of the contained catchment area upstream of the proposed dam.
- A proportional or homogenous hydrological response is assumed when downscaling from the quaternary catchment to the scale of the Ruiterbos River. Improvements in the estimation of PD flows would be possible through a site-specific hydrological model that is compared to and calibrated with streamflow measured in the Ruiterbos River.

4 HYDROLOGY

4.1 Catchment Delineation

A map of the delineated catchment areas is provided in Figure 4. The area of each catchment and the percentage of each catchment area that falls within quaternary K10D upstream of K1H004 is provided in Table 3. The percentage area of K10D upstream of K1H004 (51 %) was used to downscale WRSM-Pitman flow estimates modelled for the K10D catchment area contributing to flows at K1H004 in order to estimate flows derived from the Ruiterbos catchment.

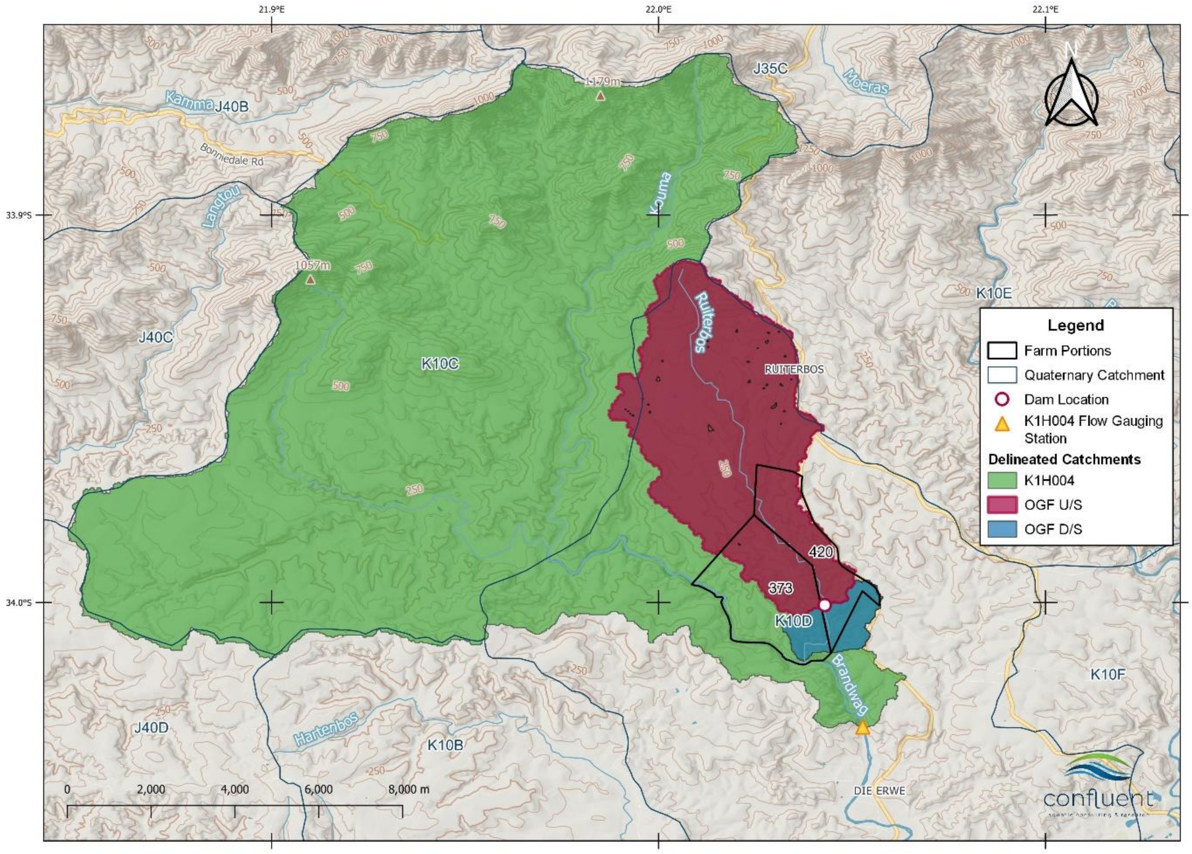

Figure 4: Delineated catchments.

Table 3: Area of delineated catchments.

Catchment	Total Area (km^2)	Area in K10D Upstream of K1H004 (km^2)	Area in K10D Upstream of K1H004 (%)[1]
K1H004	183	26.47	44 %
OGF U/S	31.15	31.15	51 %
OGF D/S	3.01	3.01	5 %

4.2 Quaternary Catchment K10D

Graphs comparing observed and simulated flows at the K1H004 flow gauging station are presented in Figure 5 to Figure 7. These figures present the flow derived from quaternary catchment K10C and the portion of the K10D catchment located upstream of the flow gauging station. Measured annual flow volumes are highly variable ranging from just over 2.5 Mm^3 per annum to almost 60 Mm^3 per annum with a mean annual runoff (MAR) of 13.07 Mm^3. While rain typically does fall throughout the year, results show that runoff is highly seasonal with the majority occurring during spring from August up until November. January through to April typically represents the low flow period.

Simulated flows provide an accurate representation of measured flows at K1H004 as illustrated in Figure 5 to Figure 7 and also in Table 4, which provides summary statistics that compare observed and simulated flows. Most summary statistics for the updated 2022 simulation are within or slightly higher than the guideline for a good fit between observed and simulated flows. The 2022 simulation represents an improved simulation when compared to the calibrated 2009 simulation, when only the Mean (Log) statistic fell within the 'Good Fit' range. These results indicate that the 2022 simulation is suitable for estimating hydrological flows in the ungauged Ruiterbos River catchment using a downscaling approach.

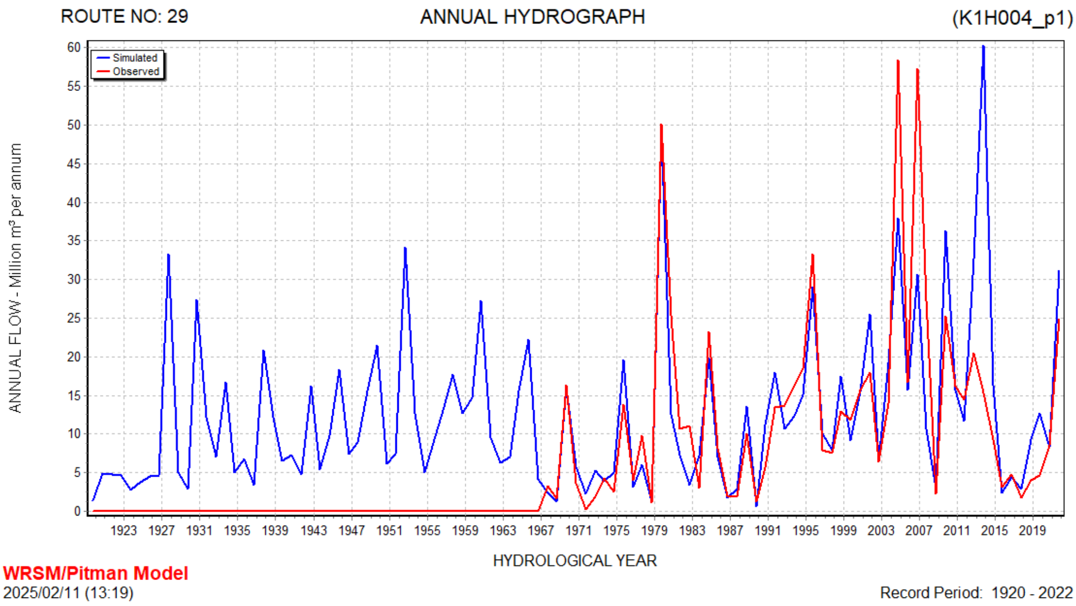

Figure 5: Annual hydrograph for DWS flow gauge station K1H004.

[1] Calculated as a percentage of the total catchment area in of K10D upstream of K1H004 (60.63 km^2).

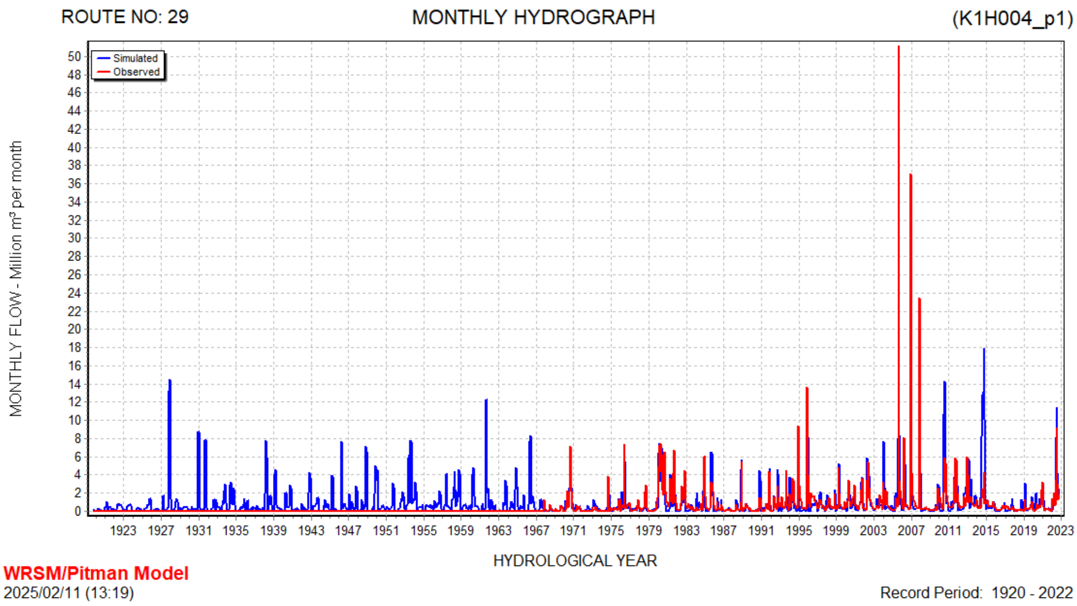

Figure 6: Monthly hydrograph DWS flow gauge station K1H004.

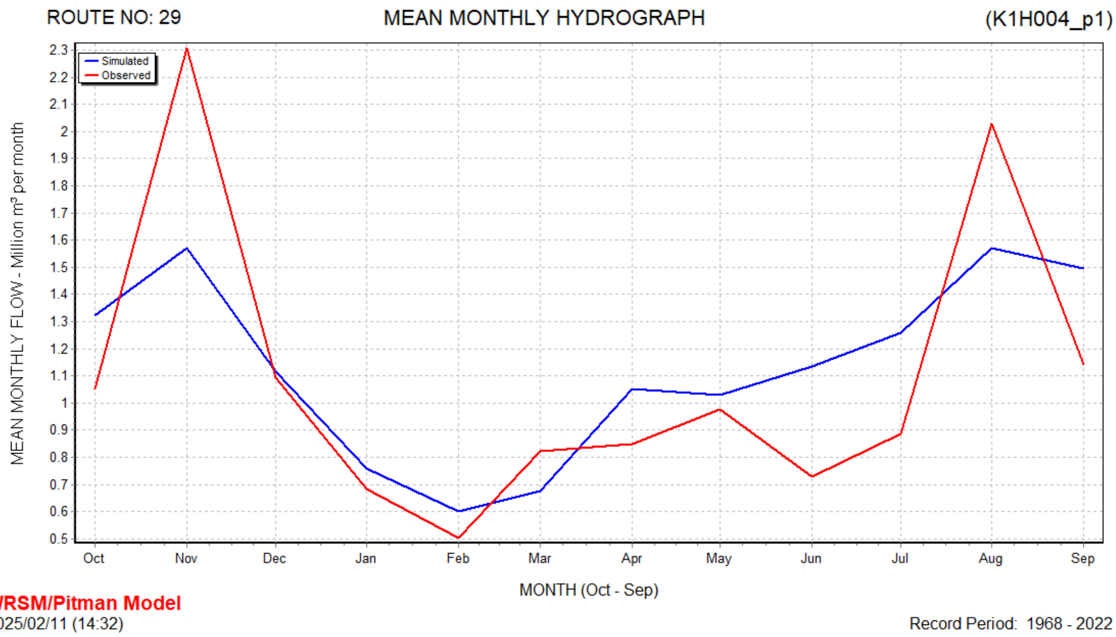

Figure 7: Mean monthly hydrograph for DWS flow gauge station K1H004.

Table 4: Comparison of statistics for observed (Obs.) and simulated (Sim.) flow at K1H004 for simulations ending in the 2009 and 2022 hydrological year[2].

Statistic	2009		2022		Variation between Observed and Simulated		Guideline for 'Good Fit'
	Obs.	Sim.	Obs.	Sim.	2009	2022	
MAR	13.49	11.97	13.07	13.59	11 %	4 %	< 4%
Mean (Log)	0.89	0.90	0.90	0.95	1.1 %	5.5 %	< 4 %
Std Deviation	14.12	10.50	12.93	12.48	26 %	3.4 %	< 6 %
Log Std Deviation	0.51	0.43	0.48	0.44	16 %	8.3 %	< 6 %
Seasonal Index	18.97	12.36	16.65	11.51	34 %	31 %	< 8 %

4.3 OGF Dam Catchment

Mean annual runoff for the Ruiterbos catchment upstream of the dam was estimated using downscaled estimates of flow simulated by the WRSM/2000 for K10D. The percentage area of the OGF Dam catchment that falls within K10D catchment area upstream of K1H004 (i.e. 51 %) was used to downscale WRSM K10D simulations for K1H004 in order to estimate flows into the dam from Ruiterbos River catchment.

As per K1H004, peak high flow periods are from spring to early summer (i.e. August to November) and critical low flow periods are during peak summer (January and February). Table 5 provides basic statistics. From this table it is apparent that the Ruiterbos River does periodically cease flowing 25 % of the time during the summer months (October to March). Simulated mean annual flows from the OGF U/S catchment area are 1.24 Mm^3, which represents approximately 9.5 % of the mean annual flows measured at K1H0004 (13.07 Mm^3).

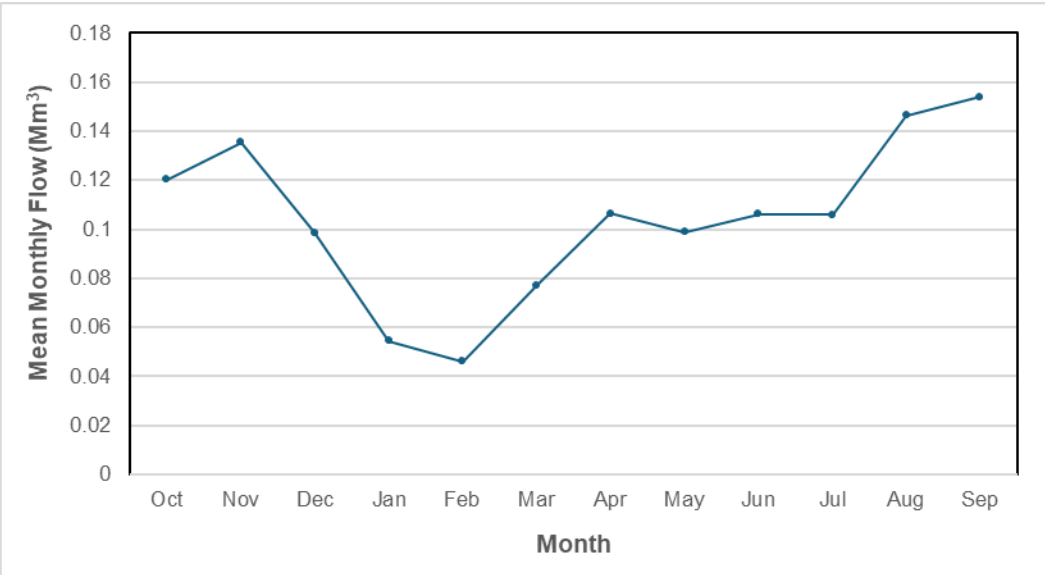

Figure 8: Mean monthly hydrograph for OGF U/S.

[2] Observed and simulated flow time-series are only compared from the 1968 hydrological year, when flows were first measured in

Table 5: Monthly flow statistics for OGF U/S (Mm³).

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	TOTAL
90th Percentile	0.308	0.437	0.273	0.102	0.114	0.192	0.373	0.246	0.193	0.128	0.231	0.301	2.858
75th Percentile	0.175	0.118	0.017	0.010	0.019	0.061	0.123	0.081	0.077	0.091	0.100	0.150	1.445
Median	0.048	0.017	0.002	0.003	0.004	0.006	0.022	0.030	0.045	0.058	0.063	0.062	0.887
25th Percentile	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.010	0.022	0.028	0.025	0.015	0.380
10th Percentile	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.010	0.016	0.011	0.000	0.167
Average	0.120	0.136	0.098	0.055	0.046	0.077	0.107	0.099	0.109	0.109	0.146	0.154	1.242

4.4 Water Requirements Analysis

RE/373 has an authorised abstraction of 80 000 m³ from the Palmiet River. This allocation will be used for irrigation of 10 ha of avocado and 8 ha of maize (Table 6). Water from the Ruiterbos River will be used for irrigation of 15 hectares of maize and 23 ha of lucerne on RE/373 and 3 hectares of broccoli on RE/420. Estimated annual irrigation requirements over a 50-year simulation period (taking rainfall and other weather data for the catchment into account) are presented in Table 7. Average irrigation demand per annum is approximately 180 000 m³ per annum, with maximum demand (90th percentile) increasing up to 214 770 m³ during below average rainfall periods. The applicant currently has an authorised abstraction of 80 000 m³ from the Ruiterbos River. The applicant will therefore need to apply for additional abstraction of between 100 000 m³ and 135 000 m³ in order to meet irrigation demands with a 90 % assurance of supply. Average monthly flows meet average monthly irrigation requirement (Table 8). Median flows are however a more meaningful comparison, since they minimise the influence of extreme events which can give the appearance of much greater or lower flows than typically occur during a month. Median irrigation requirements exceed median monthly flows during the drier summer months and demonstrates the need for a dam to store water during high flow periods such that irrigation demands can be met during low flow periods.

Table 6: Irrigation requirements for proposed crops on RE/373 – abstracted from Palmiet River.

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	TOTAL
Avocado (10 hectares) – RE/373													
90th Percentile	7500	5250	5000	5000	2500	6420	0	0	2500	5000	7500	7500	38430
75th Percentile	7500	5000	2500	2500	2500	4675	0	0	0	2500	5000	7500	31775
Median	5000	2500	2500	0	0	3350	0	0	0	2500	2500	5000	27800
25th Percentile	2500	0	0	0	0	1850	0	0	0	0	2500	2500	20650
10th Percentile	2500	0	0	0	0	1140	0	0	0	0	0	0	18640
Average	4970	2950	2300	1400	1150	3466	2	50	650	2050	3250	4600	26838
Maize (8 hectares) – RE/373													
90th Percentile	9450	7000	7000	5250	3500	3500	3500	3500	5250	7000	10577	6300	51317
75th Percentile	8750	5250	5250	3500	3500	1750	1750	3500	3500	5250	9152.5	5600	49665
Median	7000	5250	3500	1750	1750	1750	1750	1750	3500	3500	7560	4200	43330
25th Percentile	5687.5	3500	3500	1750	0	0	0	1750	1750	1750	5845	2800	38885
10th Percentile	4900	1750	1750	0	0	0	0	0	0	1750	5068	1960	37296
Average	6769	4305	3960.6	2380	1890	1470	1575	2310	2695	3815	7379.4	4050.2	42599.2
TOTAL CROPS													
90th Percentile	17020	12075	10425	8500	6000	8905	3500	3500	6000	10250	14508	13870	88727
75th Percentile	15900	10250	9500	6000	6000	6437.5	1750	3500	5250	7750	12687.5	12400	80537.5
Median	12000	7750	6000	2625	1750	5200	1750	1750	3500	6000	10935	9200	71305
25th Percentile	9150	3687.5	3500	1750	0	2100	0	1750	1750	3500	8435	5475	60952.5
10th Percentile	7400	1750	1750	0	0	1280	0	0	0	1750	7696	2660	57942
Average	11739	7255	6260.6	3780	3040	4936	1577	2360	3345	5865	10629.4	8650.2	69437.2

Table 7: Irrigation requirements for proposed crops on RE/373 and RE/420 – abstracted from Ruiterbos River

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	TOTAL
Maize (15 hectares) – RE/373													
90th Percentile	20250	15000	15000	11250	7500	7500	7500	7500	11250	15000	22680	13500	109995
75th Percentile	18750	11250	11250	7500	7500	3750	3750	7500	7500	11250	19650	12000	106500
Median	15000	11250	7500	3750	3750	3750	3750	3750	7500	7500	16200	9000	94050
25th Percentile	12750	7500	7500	3750	5	0	0	3750	3750	3750	12750	6000	84338
10th Percentile	10500	3750	3750	0	0	0	0	0	7	3750	10860	4200	80670
Average	**14801**	**9413**	**8648**	**5204**	**4133**	**3214**	**3444**	**5051**	**5893**	**8342**	**16136**	**8847**	**95066**
Lucerne (23 hectares) – RE/373													
90th Percentile	4600	6900	11500	17250	11500	11500	11500	11500	17250	17250	18860	0	88688
75th Percentile	2300	5750	5750	11500	11500	5750	11500	11500	11500	11500	13110	0	79695
Median	0	0	5750	5750	5750	5750	5750	5750	11500	5750	8050	0	70840
25th Percentile	0	0	0	0	5750	0	5750	5750	5750	10	4600	0	55603
10th Percentile	0	0	0	0	0	0	0	0	5750	0	2760	0	46575
Average	**1526**	**2699**	**4577**	**6454**	**6924**	**4577**	**6454**	**7628**	**9623**	**7510**	**9571**	**0**	**68947**
Broccoli (3 hectares – 2 rotations per year) – RE/420													
90th Percentile	2550	3750	3762	2250	1500	1500	1500	1500	2250	2250	2460	0	18678
75th Percentile	2400	3750	3390	1500	1500	750	1500	1500	1500	1500	1710	0	17265
Median	1800	3000	3000	750	750	750	750	750	1500	750	1050	0	15495
25th Percentile	1650	2250	2430	390	750	0	750	750	750	10	600	0	13635
10th Percentile	750	1500	1764	0	0	0	0	0	750	0	360	0	12141
Average	**1867**	**2878**	**2920**	**909**	**903**	**597**	**842**	**995**	**1255**	**980**	**1249**	**0**	**15714**
TOTAL CROPS													
90th Percentile	26220	24450	26500	27000	20500	16750	20500	20500	30750	34500	43610	13500	214770
75th Percentile	22050	20750	20990	20500	20500	10250	16750	20500	20500	24250	33510	12000	203303
Median	18300	13250	16250	10310	10250	10250	10250	14000	16750	17750	25650	9000	172645
25th Percentile	14550	9750	10140	3750	6500	3750	6500	10250	10250	7500	20800	6000	158205
10th Percentile	12090	6750	5514	265	0	0	0	6	6500	3750	14878	4200	142188
Average	**18194**	**14990**	**16144**	**12567**	**11959**	**8388**	**10740**	**13674**	**16771**	**16832**	**26955**	**8847**	**179727**

Table 8: Mean montly irrigation requirements compared to estimated mean monthly flow (m^3).

Month	Mean Monthly Flow	Mean Monthly Irrigation Requirement	Median Monthly Flow	Median Monthly Irrigation Requirement
January	36 524	18 194	4 064	18 300
February	47 453	14 990	5 961	13 250
March	43 693	16 144	5 419	16 250
April	90 242	12 567	10 839	10 310
May	118 874	11 959	26 554	10 250
June	94 837	8 388	49 315	10 250
July	70 078	10 740	62 322	10 250
August	149 493	13 674	67 470	14 000
September	151 175	16 771	40 374	16 750
October	108 465	16 832	12 464	17 750
November	117 926	26 955	10 568	25 650
December	53 911	8 847	2 981	9 000

4.5 Water Balance & Dam Sizing

A detailed monthly time-series water balance was compiled to determine the volume of storage that is required to ensure assurance of supply covering the full range of expected climatic conditions over a 50-year period. The SAPWAT model was used to produce monthly irrigation requirements using weather data (supplied with the model) covering the period from 1950 to 2000 (i.e. a 50-year period). The water balance estimated the dam volume at the end of each month taking the following into consideration:

- Three different maximum storage volumes were simulated (200 000, 150 000 and 100 000 m^3). The maximum storage volume was defined such that the stored volume at the end of each month could not exceed this volume;
- The starting balance at each month comprised of the volume of stored water from the preceding month, and incoming monthly surface water flows (i.e. from the furrow and the immediate catchment area of the dam) and the monthly supply from the borehole (which is also stored in the dam);
- The monthly time series of flows into the dam from the catchment was derived using the output of WRSM-Pitman model for the Ruiterbos River (OGF U/S);
- The balance at the end of each month was calculated by subtracting the evaporative loss from the dam and the irrigation requirement for the month from the starting balance;
- The evaporative loss for each month was estimated based on the monthly evaporation and the surface area of the dam. The surface area was estimated for each month according to the following equation (Murray, 2004):

$$A = A_{max}(V/V_{max})^{0.6}$$

Where:

A = surface area (m^2) to be determined a volume V;

A_{max} = surface area (m^2) at maximum capacity

V = volume (m^3) for which A is to be determined

V_{max} = volume (m^3) at maximum capacity

The objective of the monthly time series water balance is to ensure that there is sufficient storage so as to ensure assurance of supply (i.e. zero deficit) for at least 95 % of the time. Negative monthly balances imply that irrigation demands for the month exceed the total volume of water stored for the month. Dam sizing simulations are presented in Figure 9 to Figure 11 and can be summarised as follows (see also Table 9):

- A dam storage volume of 100 000 m^3 results in 44 deficit months and a 92.4 % assurance of supply.
- A dam storage volume of 150 000 m^3 results in 15 deficit months and a 97.4 % assurance of supply.
- A dam storage volume of 200 000 m^3 results in 6 deficit months and a 99 % assurance of supply.

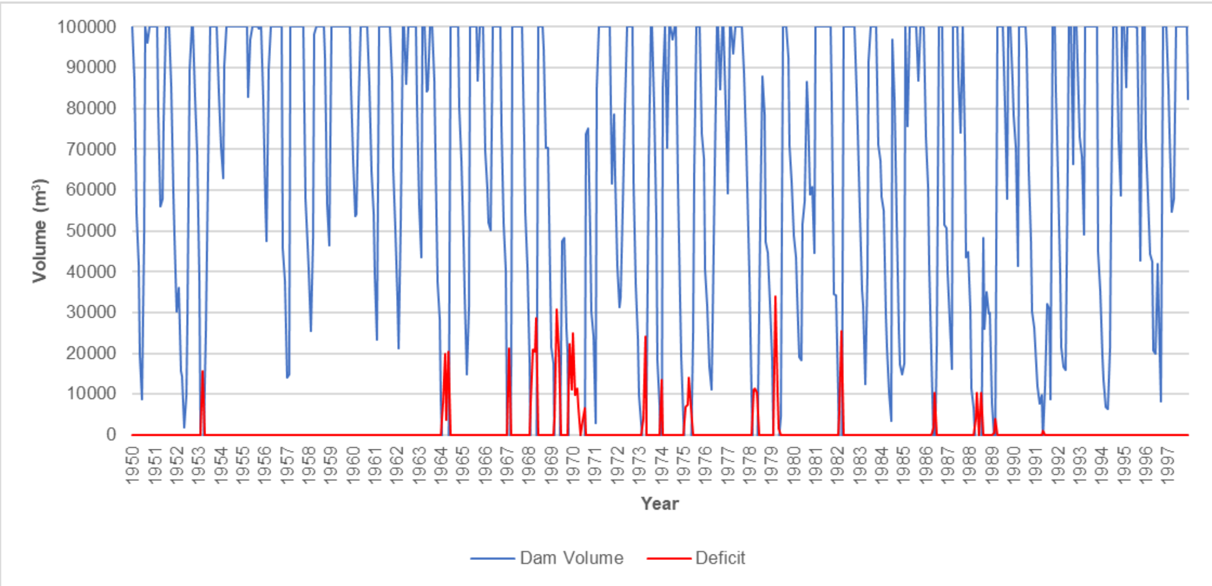

Figure 9: 50-year simulation with a 100 000 m^3 dam

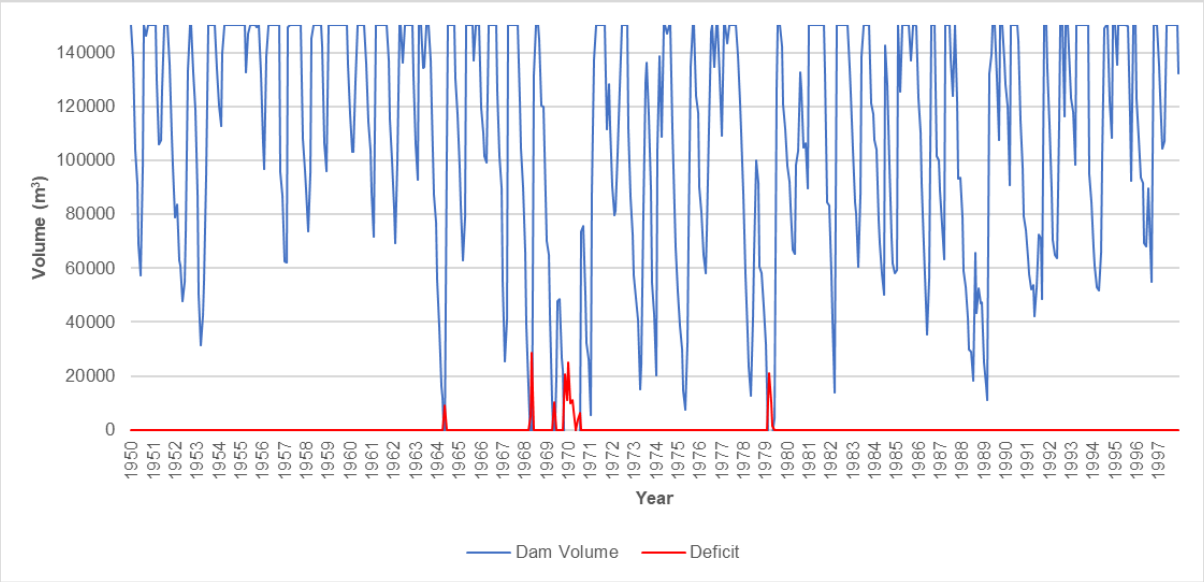

Figure 10: 50-year simulation with a 150 000 m³ dam.

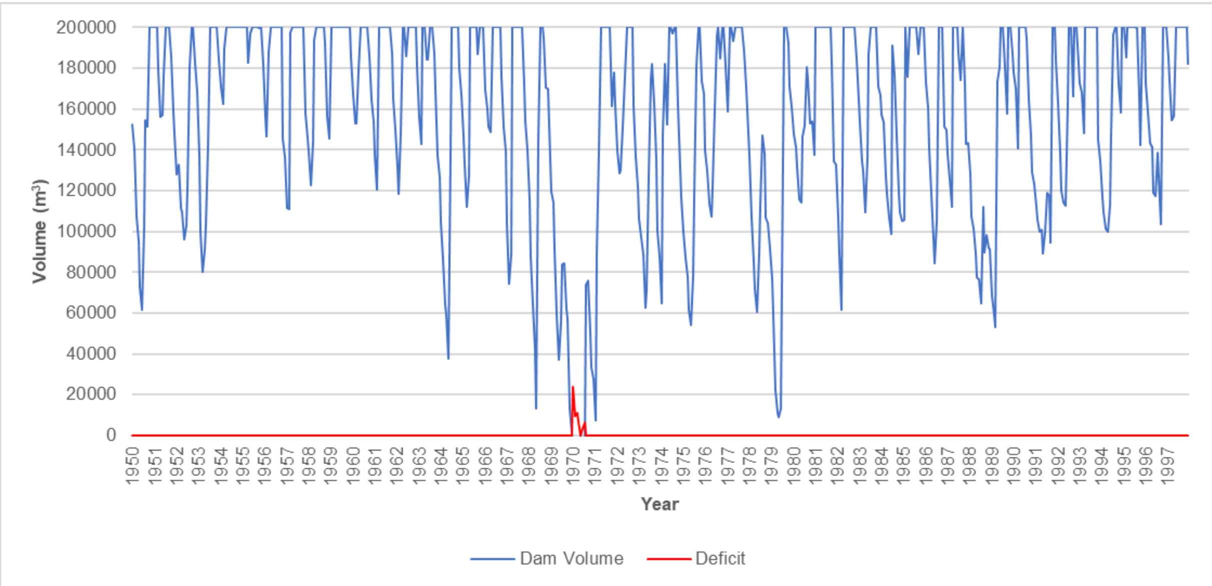

Figure 11: 50-year simulation with a 200 000 m³ dam.

Table 9: Summary of irrigation deficit for different dam sizes.

Dam Size	No. of Deficit Months	No. of Deficit Months (% of total)	Average Monthly Deficit (% of irrigation demand)	Maximum Monthly Deficit (% of irrigation demand)
100 000	44	7.6	72	100
150 000	15	2.6	68	100
200 000	6	1.0	88	100

5 IMPACT OF DAM ON DOWNSTREAM USERS

5.1 Ruiterbos River

There are no additional water users on the Ruiterbos River downstream of the proposed dam and increased abstraction will therefore not affect any users that abstract water from the Ruiterbos River. The most important impact is on the ecological flows in the river and on base flows in particular. Currently dry river conditions (with minimal base flow or zero flow) occur approximately 40 % of the time (Ruiterbos-Pre). For all dam sizes, modelled flows (Ruiterbos-Post) indicate that that these low flow conditions will increase to approximately 60 % of the time (see Figure 12).

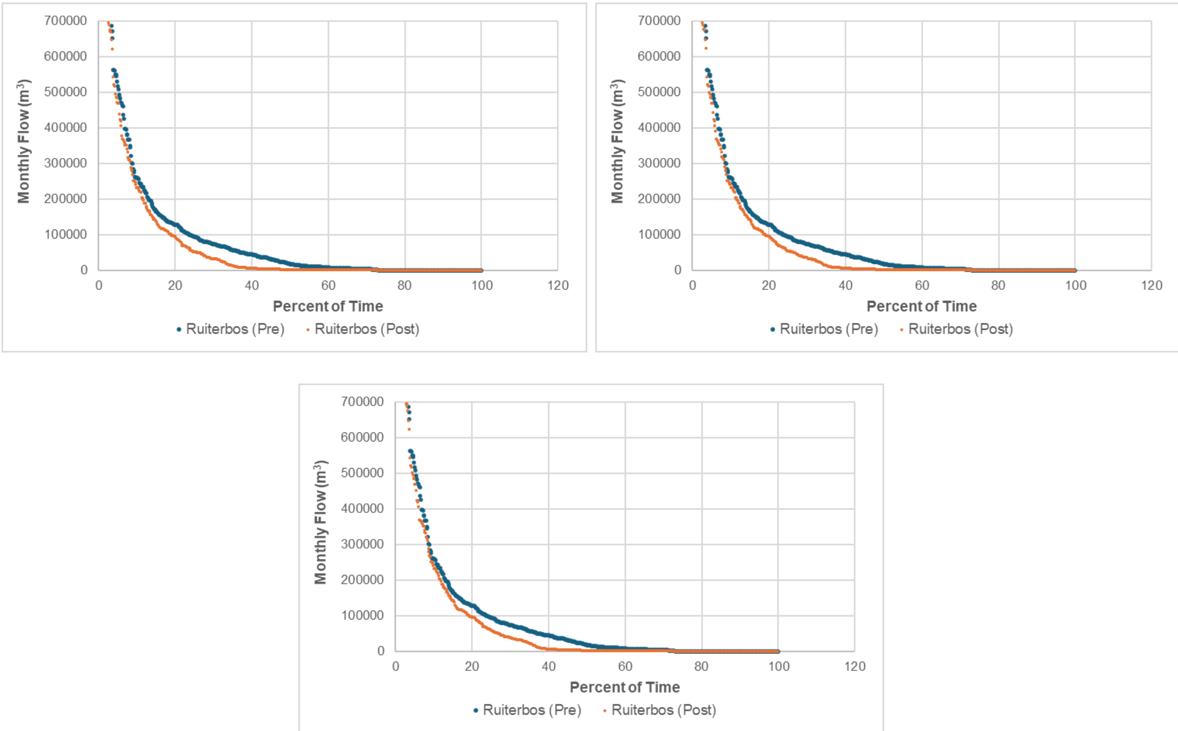

Figure 12: Flow duration curves illustrating the effect of different dam sizes on flow in the Ruiterbos River below the proposed dam.

5.1.1 Impact Mitigation

- Flow meters must be installed on pumps and records of abstraction volumes must be submitted to BOCMA bi-annually.
- The EWR for the Ruiterbos River must be determined and an outlet works must be incorporated into the dam design to ensure that the EWR is met. Alternatively, a weir and pipeline must be constructed at the dam inlet to divert baseflows around the dam and into the Ruiterbos River below the dam.
- Authorisation of additional taking of water from the Ruiterbos River must be subject to the surrender of abstraction rights from boreholes on RE/420 and RE/373.

5.2 Water Users in the Brandwag River

According to the 50-year simulation period, MAR at K1H004 is expected to reduce from to 11.08 Mm^3 to 10.87 Mm^3 which is considered minimal. According to the WARMS database, water users downstream of the applicant are registered to abstract a total of 3.54 Mm^3 per annum. The reduction in MAR caused by the storage and increased abstraction from the Ruiterbos River is therefore unlikely to have any significant impact on downstream users.

5.3 Reserve for the Brandwag River

Based on a volume of 7.82 Mm^3 that remains unallocated, the additional abstraction of 100 000 m^3 to 135 000 m^3 per annum will ensure that sufficient water remains in the system to meet reserve requirements of 1.78 Mm^3 per annum.

6 CONCLUSION

This report summarises the hydrological yields to a proposed instream dam located on the Ruiterbos River on RE/420. The main findings can be summarised as follows:

- The WRSM/Pitman model was updated with more recent rainfall data to allow simulations up to the 2022 hydrological year. Updated simulations compared favourably to measured flow data at K1H004 on the Brandwag River in quaternary catchment K10D.
- The mean estimated irrigation requirements for crops that will be irrigated from this dam is approximately 180 000 m^3 per annum, with maximum demand reaching up to 215 000 m^3. Considering an existing water entitlement of 80 000 m^3 from the Ruiterbos River, a Water Use License (WUL) would be required to abstract and additional 100 000 m^3 to 135 000 m^3
- A catchment modelling exercise indicates that the mean annual runoff from the catchment area of the dam is approximately 1.24 Mm^3, which is sufficient to meet the irrigation demands of crops.
- Based on a detailed monthly water balance based on weather data covering a 50-year period, a dam size of 150 000 m^3 is expected to provide at least a 95 % assurance of supply.
- There are no additional users on the Ruiterbos River downstream of the proposed dam. Base flows are however likely to reduce and low to zero flow conditions are expected to increase from 40 % of the time to approximately 60 % of the time. This reduction of flow is likely to have a significant impact of aquatic biota in the river.
- According to the WRSM model output, the Ruiterbos River (upstream of the dam) contributes approximately 1.24 Mm^3 (or 9.5 %) of the total mean annual flow volumes measured at K1H004. Based on the 50-year simulation assuming a 150 000 m^3 dam and abstraction for meeting irrigation requirements, mean annual flow simulated at K1H004 would reduce from 11.08 Mm^3 to 10.87 Mm^3 (or 2 %).
- Impacts of this 2 % reduction on flow on downstream users in the Brandwag River and on the Reserve are likely to be negligible.
- The following mitigation measures are recommended:
    - Flow meters must be installed on pumps and records of abstraction volumes must be submitted to BOCMA bi-annually.
    - The EWR for the Ruiterbos River must be determined and an outlet works must be incorporated into the dam design to ensure that the EWR is met. Alternatively, a weir and pipeline must be constructed at the dam inlet to divert baseflows around the dam and into the Ruiterbos River below the dam.

- Authorisation of additional taking of water from the Ruiterbos River must be subject to the surrender of abstraction rights from boreholes on RE/420 and RE/423.

7 REFERENCES

Bailey AK and Pitman WV (2016). Water Resources of South Africa, 2012 Study (WR2012). WRC Report No. TT 683/16, Water Research Commission, Pretoria.

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