Byevanger Dam: Hydrological and Yield Analysis (J11J)

Report

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Table of Contents

1 INTRODUCTION 1
2 OBJECTIVES 1
3 MODELS AND DATA 4
4 METHODOLOGY 6
4.1 Representative long-term hydrology 6
4.2 Yield determination 7
4.3 Incremental Buffels River Present-day simulation 8
4.4 Impact of the dam on EWR. 8
5 RESULTS 8
5.1 Representative hydrology 8
5.2 Yield Determination 9
5.3 Incremental Buffels River Present-day simulation 10
5.4 Impact on EWR compliance 11
6 CONCLUSIONS 12
7 REFERENCES 14

APPENDICES

APPENDIX A: Calibration of the Floriskraal Dam (J1R003) catchment hydrology
APPENDIX B: Incremental Buffels River Present-Day Simulation
APPENDIX C: EWR Requirements and compliance

BYEVANGER DAM: HYDROLOGICAL AND YIELD ANALYSIS (J11J)

1 INTRODUCTION

A hydrological and water resources assessment was requested in support of WULA and NEMA applications for the constructed Byevanger Dam. This irrigation dam is in quaternary catchment J11J, on an unnamed tributary of the Groot River (also known as the Buffels River) in the Western Cape Province. The Groot River is in an arid area with catchment Mean Annual Precipitation (MAP) varying between 167 to 308 mm/a. The catchment is relatively developed with mostly farm dam, irrigation activities and a few large reservoirs such as Floriskraal Dam, as well as substantial groundwater use. **Figure 1** shows the catchment area for Byevanger dam in relation to major rivers, dams and flow gauging stations. **Figure 2** shows the part of J11J catchment and position of Byevanger Dam (-33.480239°S, 21.060235°E) in relation to the Groot River and related irrigation activities.

The Recommended Ecological Category of the Groot River in J11was set as a Class C for water quantity in a recent Government Gazetted Classification of Significant Water Resources Study undertaken by the Department of Water and Sanitation (see EWR 1 site in **Figure 1**). Resource Quality objectives were set for both J11H and J11J. To determine any impact of the constructed dam on the Ecological Water Requirements (EWR) for the Groot River, the entire Study Area's (see **Figure 1**) hydrology had to be evaluated and improved.

This document provides a brief description of the tasks undertaken to assess the yield of the dam, the improvement of water supply to the Client (viability) and any impacts on the EWR.

2 OBJECTIVES

The hydrological and water resource assessment aimed at the following:

- Developing a representative long-term monthly hydrological timeseries as inflow to the Byevanger Dam, and for the Buffels River downstream of the constructed dam.
- Determining the long-term historical and stochastic yield of the dams in the area.

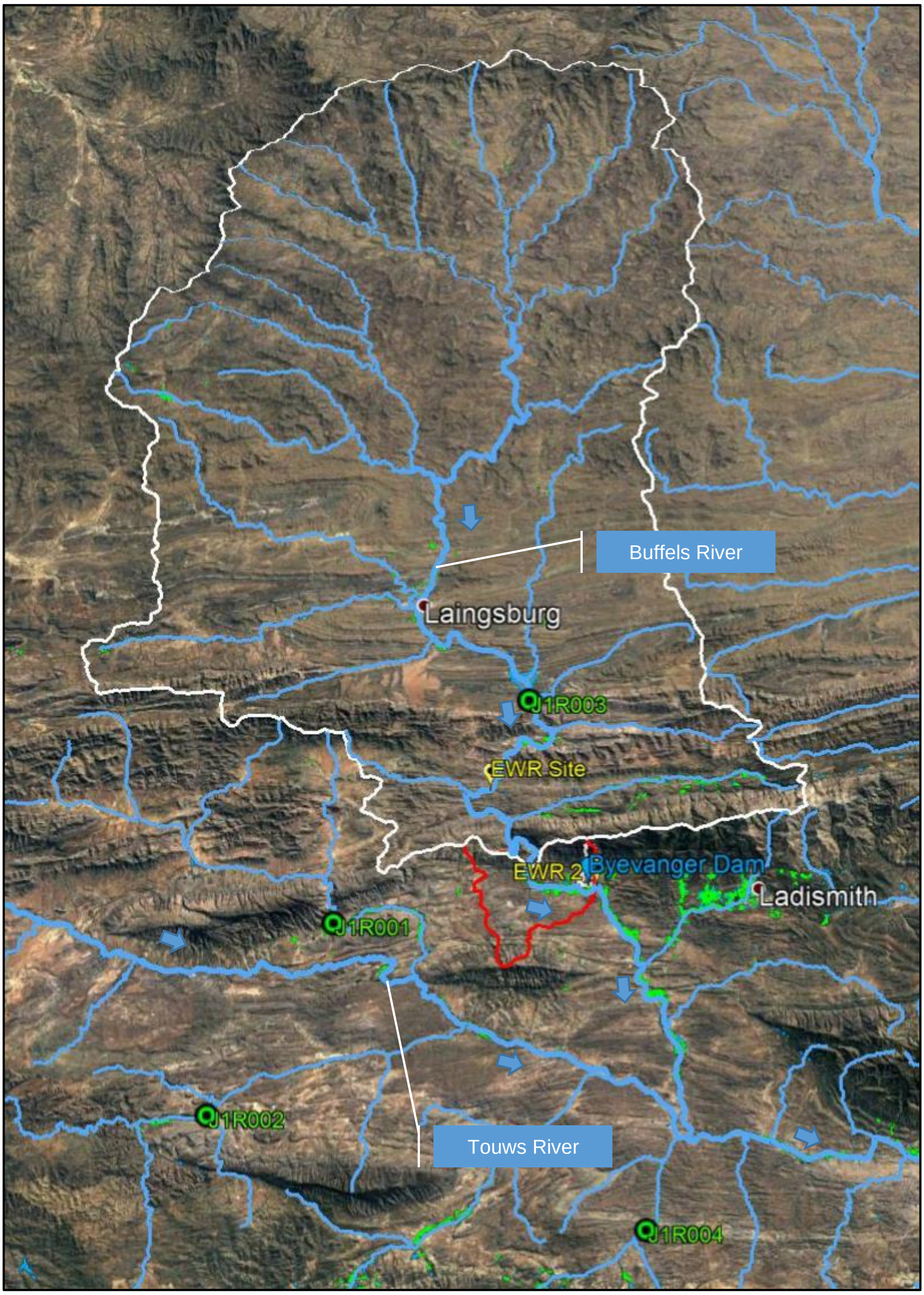

Figure 1: Map of Buffels and Groot Rivers catchment indicating the study area in white outline and the localised study area in red outline (blue arrows = flow direction; green circles = streamflow gauging stations or dam monitoring sites – J1R001 = Prinsrivier Dam; J1R003 = Floriskraal Dam; J1R002 Bellair Dam, J1R004 = Miertjieskraal Dam, green areas – irrigated fields, red area = Client's localised runoff catchment)

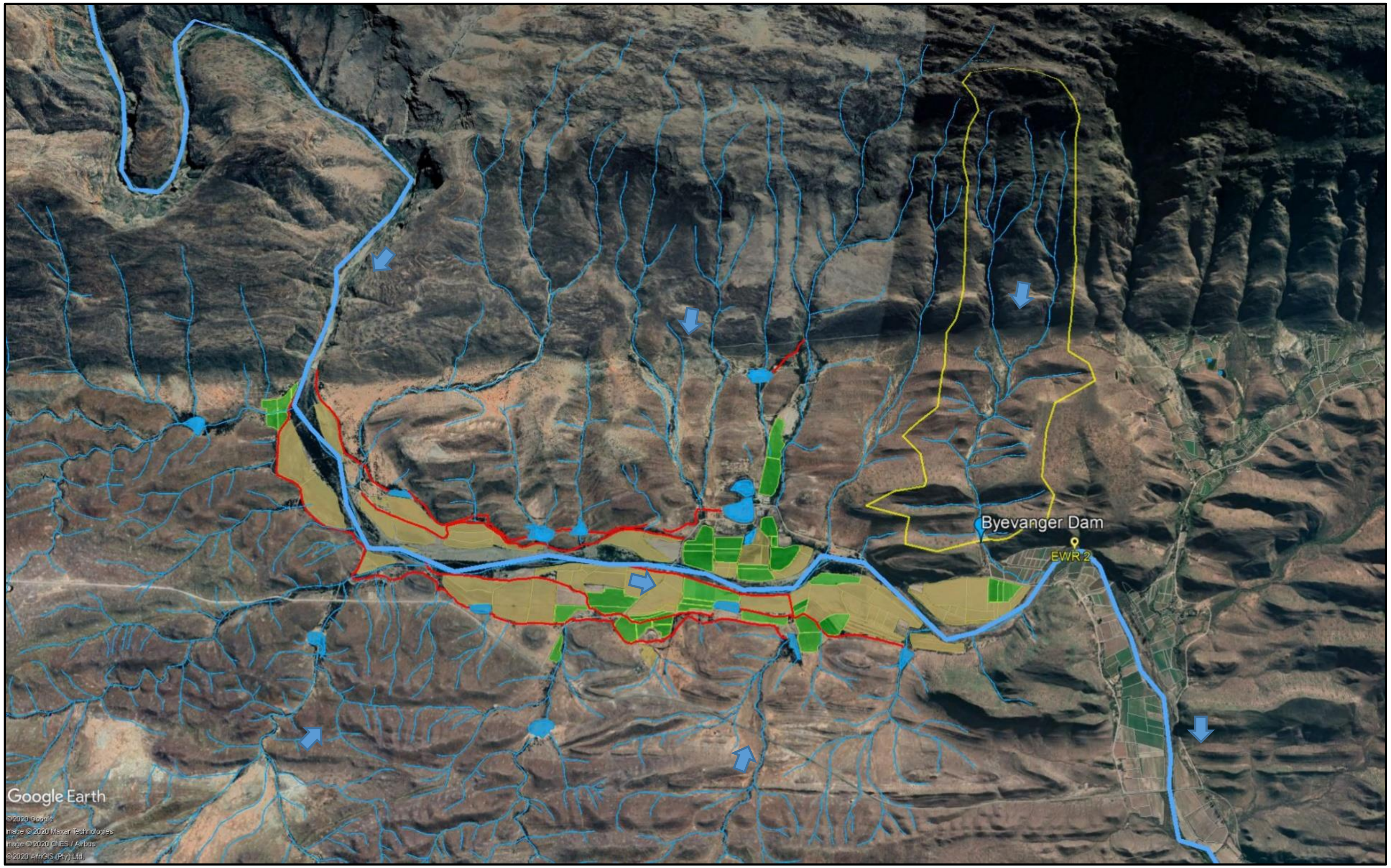

Figure 2: Byevanger Dam location on the tributary of the Buffels River. (Yellow Outline = Byevanger Dam catchment, blue polygons = existing farm and balancing dams, beige highlight = Client's fields with grazing crops, green highlight = Client's higher valued crop fields, red lines = canals, blue arrows= flow direction).

- Assessing the impact of the new dam on water supply to the Client's water requirements
- Assess the impact of the dam on a desktop confidence level quantity component of the Reserve (EWR requirements).

3 MODELS AND DATA

The data and mathematical model configurations of the Water Resources of South Africa 2012 (WR2012) Study from the Water Research Commission (WRC, 2015) were used as basis for the hydrological simulations done during this analysis. The WR2012 Study provides long-term (1920 – 2009) monthly time-step simulated streamflow timeseries for approximately 2000 catchments throughout South Africa. The timeseries represent the volume of water that was likely be produced at the outlet of each of the 2000 catchments every month from October 1920 to September 2010. The data is generated by a rainfall-runoff model (WRSM2000-Pitman Model) that can convert long-term monthly rainfall data into equivalent streamflow. This is done after the rainfall-runoff model has been calibrated against historic streamflow gauging stations data throughout the country.

The Pitman model also considers all land-and -water uses upstream of the flow gauging stations to estimate the reduction in streamflow due to human development over time. Once the model is calibrated, what-if scenarios can be developed, such as pre-dam and post-dam impacts downstream flows, or importantly, what Present-Day (PD) scenario flow conditions would be over the long-term. PD scenario conditions is the flow in the river if all upstream water – and land-use development have been at the same level from the start to the end of the simulation period. This makes the rainfall-runoff model a powerful tool for long-term water resources planning. The PD scenario therefore represents how current reservoirs and water supply would have behaved historically over a 89-year monthly simulation.

The Water Resources Yield Model (WRYM) is like the Pitman model but allows for the calculation of the Historic and Stochastic Firm Yield of reservoirs under different scenarios (mostly Present-Day conditions). The Historic Firm Yield (HFY) is defined as the maximum fixed volume per annum that can be abstracted from the dam or water resource over the totals simulation period, without a failure in supply in any of the years or months. This means that in the driest part of the record the dam would just touch the minimum operating or dead storage level (see **Figure 3** below).

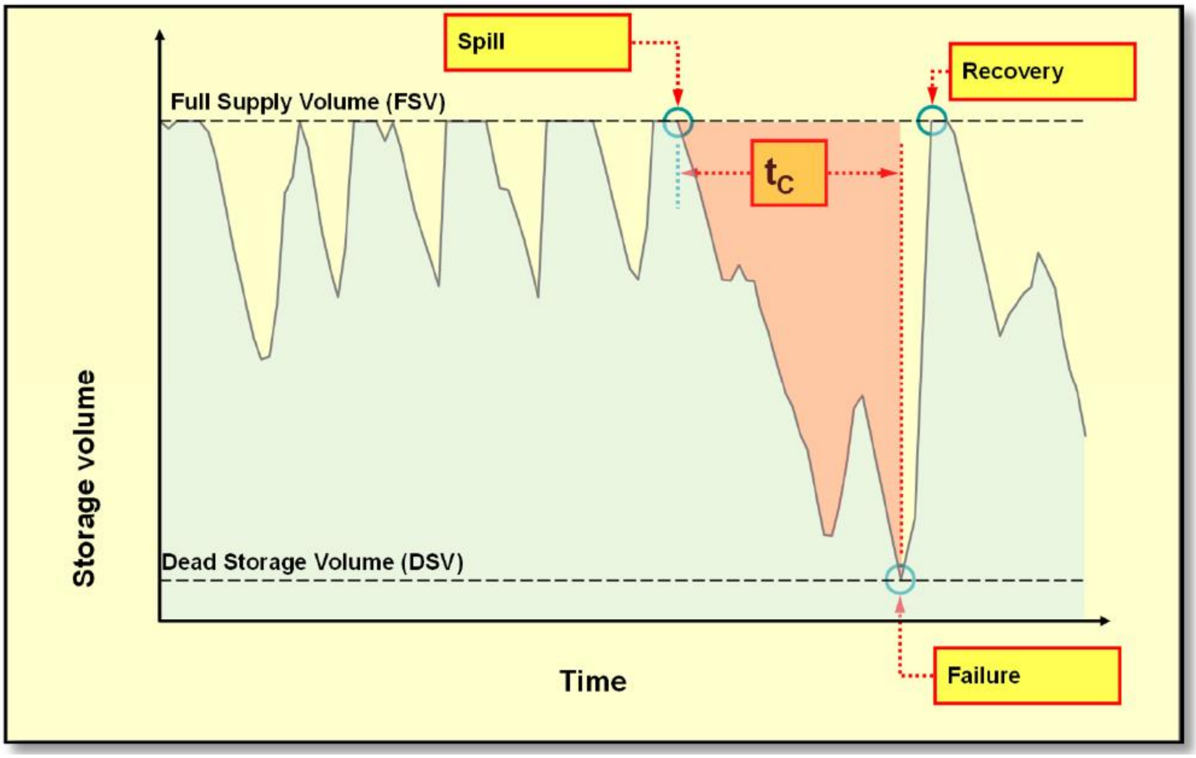

Figure 3: Historic Firm Yield storage graph

When the fixed annual draft imposed on the dam is just slightly increased to above the historic firm yield, the dam will reach the dead storage in the driest year resulting in a failure to supply 100% of the draft imposed on the dam. The period from when the dam last spilled before it entered the dry period until it reached the driest year or failure in supply, is referred to as the critical period of the dam. Recovery of the system after the failure that occurred is important and is defined as the first time of spilling after the failure occurrence. If the dam or system did not recover after the failure it means that it is not the end of the critical period yet and will most probably result in a reduced historic firm yield. Stochastic Firm yield is a statistical method of determining the risk-based assured yield of the dam to estimate the return period (1 in 100 years etc) of failure of the dam for a specific draft on the dam.

In order to determine the most accurate yields and most representative historic streamflow in the rivers and water volumes in dams, the water and land-use data for all the models were extensively updated, which included the following:

- Monthly varying irrigation requirements: Irrigated fields, crops and irrigation application types and efficiencies were obtained from the 2017 areal survey done for the whole of the Western Cape by the Department of Agriculture of the Western Cape Government. The field areas were checked against historical Google-Earth images. Crop and irrigation methods were used in SAPWAT to calculate the long-term median crop water requirements, given the field's position and therefore climatic conditions. SAPWAT (WRC, 2016) is also a Water Research Commission software product that does daily water balance calculations over a 50-year period location given specific climatic conditions.
- Domestic water use: The Department of Water and Sanitation's (DWS) so called All Towns Water Reconciliation Studies were used to obtain estimated surface and groundwater water use for Laingsburg and Matjiesfontein.
- Dams: all farm dam capacities were derived from their Google Earth digitised full supply surface areas. Known area-capacity relationships for larger dams and other known formulas were used to calculate the approximate farm dam capacities for the whole are. This was checked against the DWS Dam Safety database data for dams in the area.
- Measured stream flow: **Figure 1** shows the only usable stream data available in the area. All the sites are large dams which DWS monitors on an ongoing basis. Dam content volume, river releases, spills, rainfall and evaporation timeseries are used to calculate the monthly inflow to the dams (called dam balances), against which the models can be calibrated. These dam balances are notoriously bad in measuring low flows.

All the models, detailed datasets and GIS information used during this assessment are available at request by the Client. This report will not attempt to capture all the data sets that went into the simulation models but focus on the methodology and the simulation results.

4 METHODOLOGY

4.1 REPRESENTATIVE LONG-TERM HYDROLOGY

The hydrological models and land- and water-use data for the whole Buffels River just beyond the Client's property were updated by extending the rainfall data to

September 2019 to include the most recent drought. Since there are no measured flows downstream of the Byevanger Dam, a process of calibration parameter transfer was done to the localised catchment. Calibration parameters are variables that changes how the rainfall-runoff models calculate the relationship between rainfall and the amount of runoff that reaches the stream. These variables are adjusted by comparing the fit between simulated streamflow model output against the historic observed streamflow.

In areas where there is no observed streamflow, the calibration parameters of close by catchments with similar climatic conditions can be used for the non-measured catchment areas. The following sets of calibration parameters were used to generate hydrology runoff for the catchments downstream from Floriskraal Dam and for Byevangers Dam with:

- Floriskraal Dam (J1R003): The hydrology for the whole catchment was updated and improved and re-calibrated against the dam's inflow record. **Appendix A** provides some of the information used in this process and the calibration results and network diagram for the Pitman model.
- Prinsrivier Dam (J1R001): The calibration done for the WR2012 study was slightly adjusted and used in the comparison.
- Miertjieskrall Dam (J1R004): The calibration done for the WR2012 study was slightly adjusted and used in the comparison.
- WR2012: The WR2012 Study has regionalised parameters for the areas downstream of J1R003 which was also considered.

The parameters from the different sources were used with the local climatic parameters to simulate the natural runoff for the area and values were compared to decide on the parameter set that would best represent the study area.

4.2 YIELD DETERMINATION

The WRYM and the hydrology generate from the previous task was used to calculate the historical firm yield (HFY) and the stochastic yield for Floriskraal, Byevanger and other high-runoff dams on the Client's property for comparison purposes.

4.3 INCREMENTAL BUFFELS RIVER PRESENT-DAY SIMULATION

The incremental catchment downstream from Floriskraal Dam up to the EWR site selected downstream from Byevangers Dam (see **Figure 2**) was simulated for Present-Day conditions, with and without the dam, to assess typical water balances for the area. This was done excluding the Buffelsriver Irrigation Board scheme water supply from Floriskraal Dam, to estimate the long-term annual average water balance in supplying crops on the Client's property before and after the dam, and to generate worst case scenario flows for the EWR assessment.

4.4 IMPACT OF THE DAM ON EWR.

The Present-Day flows after Byevanger Dam generated in the previous step is evaluated against a Desktop EWR generated from information contained in the Resource Quality Objectives published by DWS for the Breed-Gouritz Water Management Area.

5 RESULTS

5.1 REPRESENTATIVE HYDROLOGY

After the detailed calibration of the Pitman model for Floriskraal Dam, it was hoped that the calibration parameters would provide the best representative hydrology for the quaternary catchment J11H (incremental catchment between Client's property and Floriskraal Dam, and J11J (of which the Client's property is situated in the upper 113 km^2 of the catchment). **Table 1** provides the results of the catchments' natural runoff for the different source sets of parameters.

Table 1: Comparison of natural runoff for different source calibration parameters

Quaternary Catchment	Source	Area (km^2)	Evaporation (mm/a)	Rainfall (mm/a)	1920-2009 WR2012 Mm^3/a	1930 - 2018 This Study Mm^3/a	1920-2009 WR2012 mm/a	1930 – 2018 This Study mm/a
J11H	WR2012	651	2080	240	1.43	1.76	2	3
J11H	J1R003	651	2080	240	1.43	3.98	2	6
J11H	J1R004	651	2080	240	1.43	5.41	2	8
J11H	J1R001	651	2080	240	1.43	2.56	2	4
J11J	WR2012	450	1915	304	2.27	2.76	5	6
J11J	J1R003	450	1915	304	2.27	6.1	5	14
J11J	J1R004	450	1915	304	2.27	7.71	5	17
J11J	J1R001	450	1915	304	2.27	3.87	5	9

Comparing the last two columns shows that the unit runoff generated by all the other sources produces significantly higher runoff than what is generated by the regionalised WR2012 parameter. For mainly this reason, and to err on the conservative side, it was decided to stick to the regionalised WR2012 parameters for the yield and water balance calculations. **Table 2** summarises the natural timeseries statistics used in the following steps.

Table 2: Natural hydrology statistics for the catchments downstream from Floriskraal Dam

Catchment Number	Description	Area km²	Evaporation mm/a	Rainfall mm/a	Natural Runoff Mm³/a	Natural Runoff mm/a
J11H	Incremental catchment between Client and Floriskraal Dam	651.0	2080	240	1.77	2.7
J11J1	Byevangers Dam catchment	5.5	1915	401	0.08	14.5
J11J2	Higher runoff dams in the northern mountainous parts of the Client's property	16.2	1915	391	0.22	13.6
J11J3	Incremental catchment of remainder of rivers flowing through the Client's property	101.4	1915	241	0.27	2.7

5.2 Yield Determination

Using the hydrology in **Table 2**, the historical and stochastic yields of the dams in the study area were determined and presented in **Table 3.**

Table 3: Dam yields in the study area.

Dam	Source	Volume Mm³	Yields (Mm³/a) HFY	1:200	1:100	1:50	1:20	1:10
Floriskraal	BGCMA	50.30	4.700	3.950	4.940	6.150	8.050	8.290
	This Study	44.67	2.940	2.471	3.722	5.068	6.362	7.019
Byevanger Dam	This Study	0.15	0.017	0.011	0.014	0.017	0.023	0.025
Existing Higher Runoff dams	This Study	0.15	0.017	0.011	0.015	0.018	0.023	0.026

Table 3 shows that the yield for Floriskraal Dam compares well with the recently completed Breede Gouritz Catchment Management Strategy (BGCMA, 2017), although this study's results are significantly lower. The reason for this is that the BGCMA's analysis included a bigger dam volume – the indicated dam volume for this analysis is the projected current dam volume based on the dam's historic measured capacity reduction trends due to siltation after major flooding events. This analysis showed that the 1:20 yield of Floriskraal Dam (failure of on averaged1 in every 5 years), which is appropriate for irrigation purposes, is 6.3 million m³ per annum. This is 2.6 times smaller the annual scheme's allocated quotas of 16.8 million m³ per annum. Historical

release records from the dam show that since 1990, 15.0 million m^3 per annum and more could only be supplied 15 out of 29 years (51,2%), of which 2016 -2018 is the lowest supply since the dam balance monitoring started in 1957. The releases from Floriskraal Dam will continue to decline as the dam's capacity shrinks and upstream water uses continues to grow, especially on the Buffels river just upstream and downstream from Laingsburg.

Byevangers Dam's yield is basically the same as the Client's other 5 dams combines to the north of the Buffels River which lay in the same mountainous, higher runoff area. It is however expected that the dam will be used far beyond its safe yield values.

5.3 INCREMENTAL BUFFELS RIVER PRESENT-DAY SIMULATION

This scenario in the Pitman model had the following characteristics:

- It presented the Present-Day conditions in the incremental catchment between Floriskraal Dam and the EWR site just downstream from Byevanger Dam.
- No inflow from Floriskraal Dam is simulated except for the PD pipeline releases to the irrigators just downstream from the dam. The other releases from the dam is not included to assess how much of current irrigation water requirements can be supported from local surface water resources alone, with the remainder to be supported by either Floriskraal Dam or groundwater.
- High valued crop water requirements with their application efficiency is simulated to first get their water supply from all the farm dams.
- Grazing crops such as Lucern is modelled to get most of their water from catchment runoff
- Conditions are simulated pre- and post-dam.

Appendix B provides the network diagram as well as some irrigation information used in this analysis. **Table 4** provides as summary of the long-term annual average water balance for the incremental Buffels River catchment. From **Table 4** it is seen that Byevangers dam will increase the supply of irrigation water from farms dams to higher valued crops with 26% over the long-term and could reduce the dependence on Floriskraal Scheme water for high valued crops by 12% if the same full allocation of groundwater is still abstracted.

Table 4: Summary of the long-term annual average water balance for the incremental Buffels River catchment, excluding releases from Floriskraal Dam.

Area	RR	Total area (km2)	Requirement without drought reduction or quotas (Mm^3/a)	Requirement with drought reduction and quotas (Mm^3/a)	PD Local catchment supply (Mm^3/a)	PD Shortfall (Mm^3/a)	Possible shortfall supply from Scheme (Mm^3/a)	Potential ground-water supply (
Upstream river irrigation (scheme and non-scheme)	RR5	2.09	2.53	2.30	0.57	1.73	1.12[1]	0.61
Klein Swartberg Rivier high valued crops	RR4	2.41	1.91	1.91	0.07	1.83	0.00	1.83
Client's high valued crops from dams	RR24	1.08	0.78	0.78	0.19	0.59	0.46	0.13
Client's grazing from run of river and balancing dams	RR25	3.03	6.23	4.57	0.64	3.93	2.36[2]	1.00
Balance after Byevanger dam								
Client's high valued crops from dams	RR24	1.08	0.78	0.78	0.24	0.54	0.41	0.13
Client's grazing from run of river and balancing dams	RR25	3.03	6.23	4.57	0.62	3.95	2.37[2]	1.00

Notes:

(1) -Only 65% of shortfall to be supplied from scheme, rest is located on Klein Swartbergrivier

(2) Only 60% of shortfall to be supplied from scheme, since this is grazing crops which are assumed to be irrigated at lower reliability.

5.4 IMPACT ON EWR COMPLIANCE

The compliance to EWR is measured based on monthly EWR supply duration relationships. The Desktop EWR is specified as a supply duration relationship for each month. This means that a certain amount of flow or more must be supplied at the EWR site for the indicated % of time. Under normal conditions, lower flows occur (or is exceeded) for a larger percentage of time in a stream than higher flows. Very high flows (such as floods) only occur seldom (say less than 10% of the time). The WRYM timeseries output is expressed in terms of monthly supply duration charts for the simulation period, as illustrated in **Figure 4**.

The Present-Day flows simulated in the Buffels River downstream from Byevanger Dam, under the scenario conditions as described in **Section 5.4**, were assessed against the Ecological Water Requirements using the WRYM model. The analysis included the constructed Byevanger Dam. **Appendix C** provides the output from the Desktop EWR analysis as well as the compliance graphs tested against a maintenance low and high flow scenario.

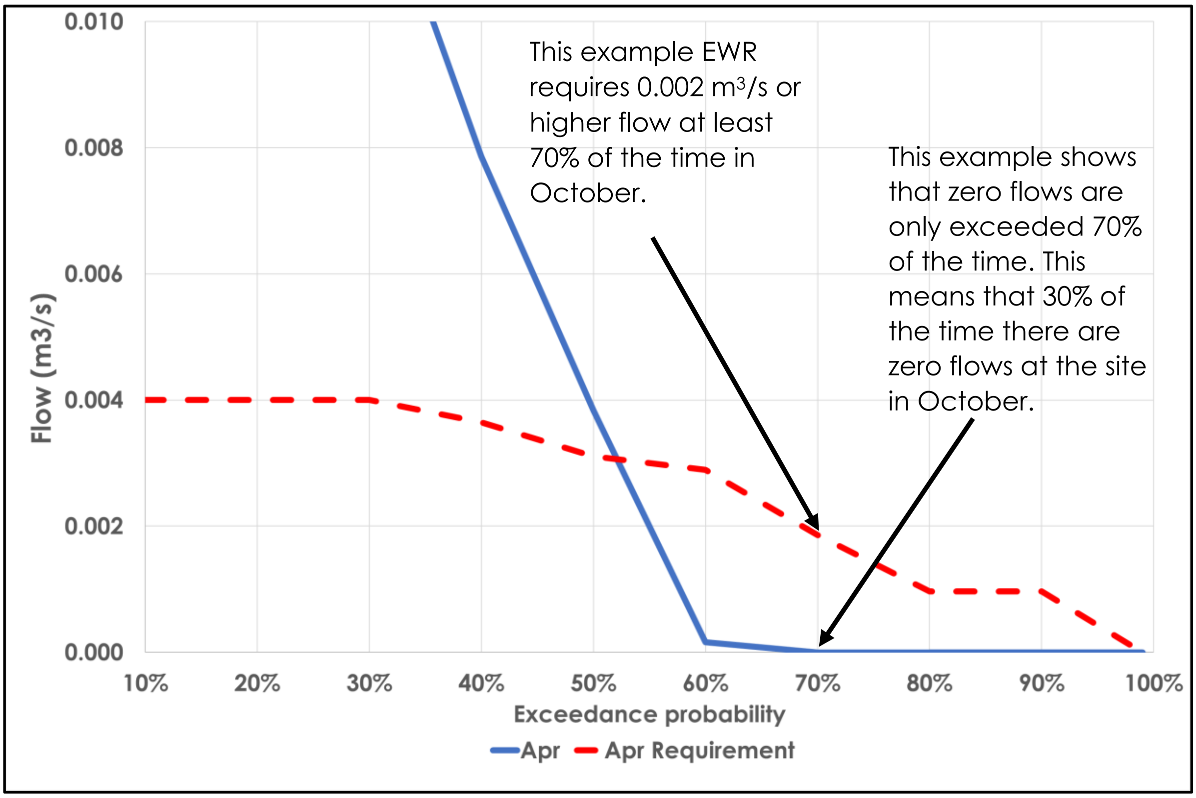

Figure 4: Example of EWR supply duration relationship
(red line = EWR requirement for April; blue line = simulated EWR supply)

The generated Desktop EWR shows that no flow conditions are required between 30% to 50% of the time depending on the month of the year. **Figure C-3** in **Appendix C** shows the resulting EWR compliance graph per calendar month with Byevanger Dam included in the Present-Day, no Floriskraal Dam support scenario. The analysis showed that the EWR requirements are met or exceeded for all lower flow conditions (up to flows that occur 40% of the time). Failures in meeting the higher flows are due to this scenario not including any spills or releases from Floriskraal Dam. The higher flows can only be met by Floriskraal Dam's releases and spills and is not dependant on the flows from the incremental downstream catchments.

6 CONCLUSIONS

During this analysis extensive rainfall-runoff and water resources systems modelling were done to create representative long-term streamflow simulations at and downstream of the constructed Byevangers Dam. The WRSM2000/Pitman model and the WRYM model were extensively updated and improved for the 4803 km^2 arid study area. Irrigation activities in the whole study area were digitised from Google Earth satellite images, both from current and historic images. The Western Cape Government's 2017 crop survey data and the SAPWAT application were used to determine crop requirements and estimated application efficiency for irrigation activities throughout the study area.

Since there are no streamflow measurements downstream from Floriskraal Dam, the hydrology of the Floriskraal dam was recalibrated for a simulation period up to September 2019. Calibration parameter transfer was used to simulate flows downstream from Floriskraal Dam and for the inflow to Byevangers Dam. Comparison of parameters showed that the regionalised WR2012 parameters generated the lowest inflow and these parameters were further used to be conservative in estimating the yield of the Byevanger and other dams on the Client's property.

The analysis showed that the Byevangers Dam will have a 1:20 reliable yield of only 23 000 m^3/a to 25 000 m^3/a, however it is expected that the dam actual water use will be far higher than this. This is approximately the same yield as the combined yield of 5 other dams on the northern parts of the property where Byevanger Dam is also situated. The long-term water balance simulation showed that Byevangers dam will increase the Client's supply of irrigation water from farms dams to higher valued crops with 26% and could reduce the dependence on Floriskraal Scheme water for high valued crops by 12% if the same full allocation of groundwater is still abstracted. At the same time the analysis showed that the supply from Floriskraal dam is likely to decrease over time due to reduced capacity and higher upstream water use.

A Desktop EWR assessment showed that with Byevangers Dam in place that the low-flow water requirements are still met while the higher flows are met for most months. Since the EWR analysis did not include possible releases or spills from Floriskraal dam, it is expected that the EWR requirements will be fully complied with or exceeded once these releases are considered.

7 REFERENCES

Breede-Gouritz Catchment Management Agency (BGCMA) (2017) Development of a Catchment Management Strategy for the Breede-Gouritz Water management Area: Reconciliation Strategy Report, Worcester, South Africa

Dent M. C., Lynch S. D. & Schulze R. E., (1987) *Mapping Mean Annual and Other Rainfall Statistics Over Southern Africa*, University of Natal

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APPENDIX A: CALIBRATION OF THE FLORISKRAAL DAM (J1R003) CATCHMENT HYDROLOGY

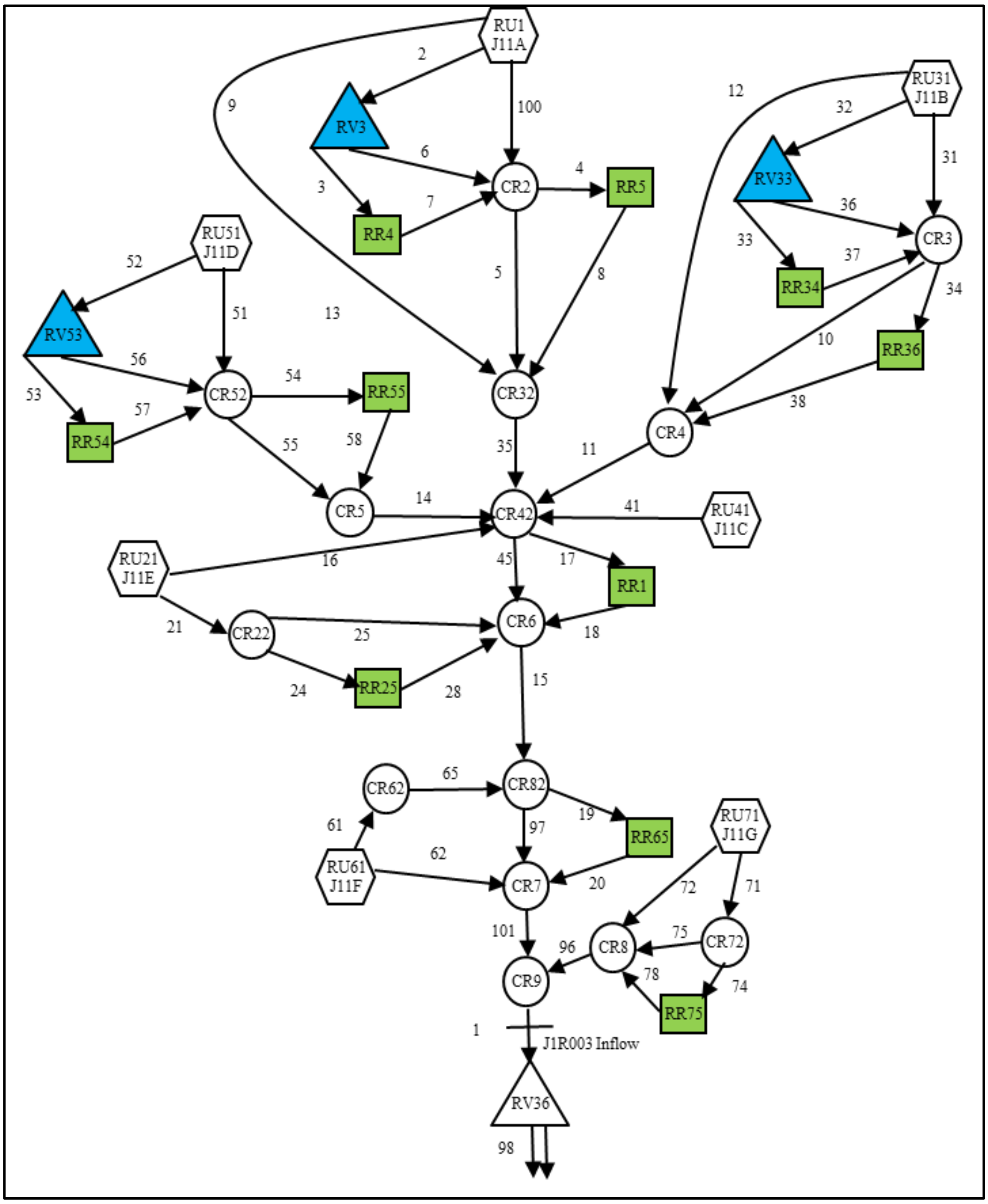

Figure A-1: Network diagram for Floriskraal Dam

Table A-1: Areas of irrigation per quaternary catchment (km²) – all shortfall in supply was place as a groundwater demand on the model

Area	2018	2003	1990	1970	1945	1920
J11A Dams	0.33	0.33	0.28	0.24	0.00	0.00
J11A Rivers	0.16	0.16	0.14	0.12	0.00	0.00
J11B Dams	0.11	0.11	0.09	0.08	0.00	0.00
J11B Rivers	0.17	0.17	0.14	0.12	0.00	0.00
J11D Dams	1.59	1.59	1.35	1.15	0.00	0.00
J11D Rivers	0.06	0.06	0.05	0.04	0.00	0.00
J11E1 Rivers	0.31	0.44	0.38	0.32	0.00	0.00
J11E2 Rivers	0.54	0.37	0.32	0.27	0.00	0.00
J11F Rivers	0.62	0.62	0.53	0.45	0.00	0.00
J11G Rivers	0.13	0.13	0.11	0.09	0.00	0.00

Table A-2: Full supply areas and capacity of farm dams

Area	Year	2018	2003	1990	1970	1945	1920
J11A	Area (km²)	0.32	0.32	0.27	0.27	0.00	0.00
	Capacity (million m³)	0.36	0.36	0.30	0.26	0.00	0.00
J11B	Area (km²)	0.10	0.10	0.09	0.07	0.00	0.00
	Capacity (million m³)	0.11	0.11	0.09	0.08	0.00	0.00
J11D	Area (km²)	0.53	0.53	0.45	0.39	0.00	0.00
	Capacity (million m³)	0.55	0.55	0.47	0.40	0.00	0.00

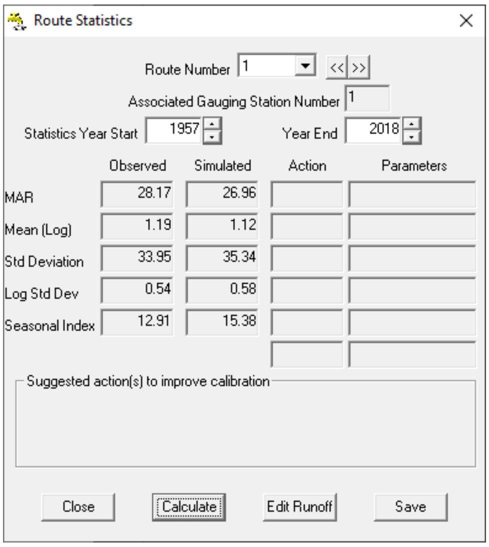

Figure A-2: Calibration Statistics

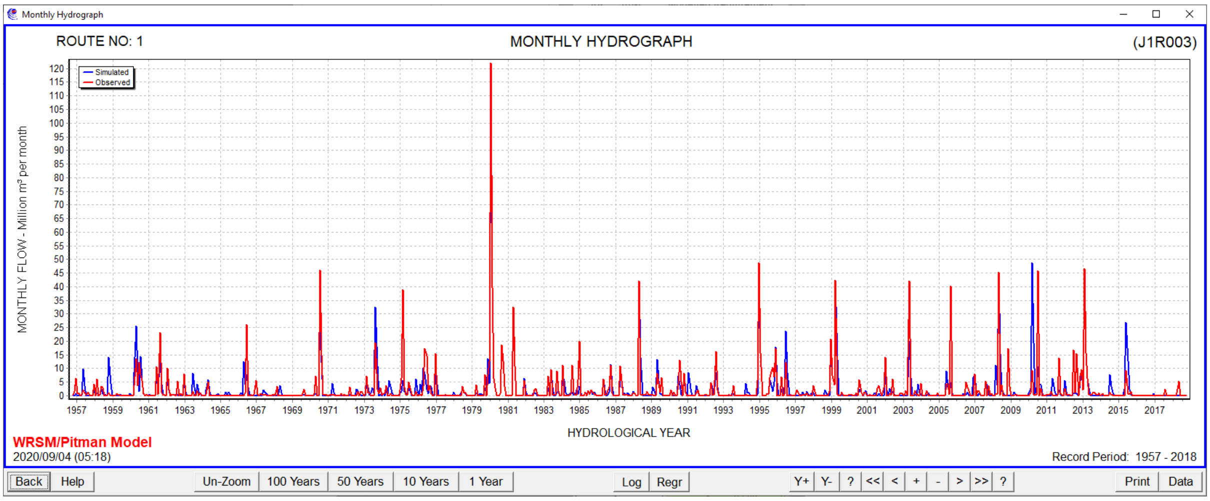

Figure A-3: Monthly Hydrograph comparison

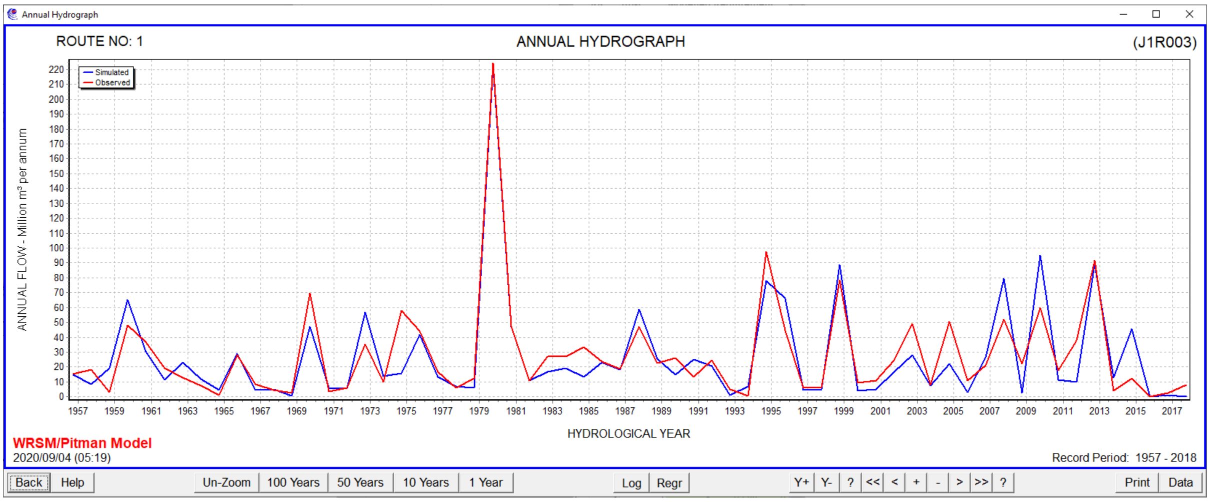

Figure A-4: Annual Hydrograph comparison

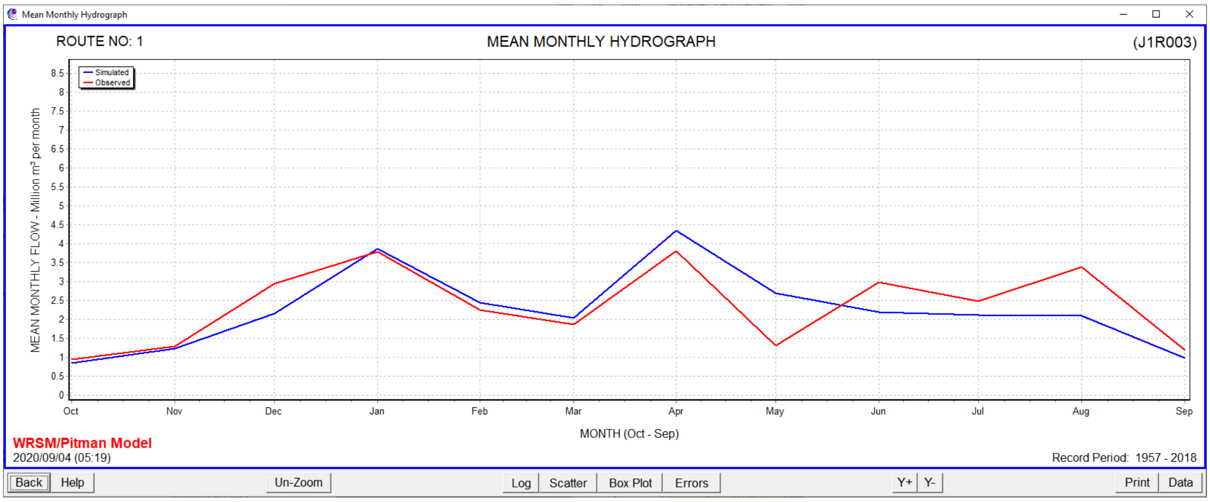

Figure A-5: Mean Monthly Hydrograph comparison

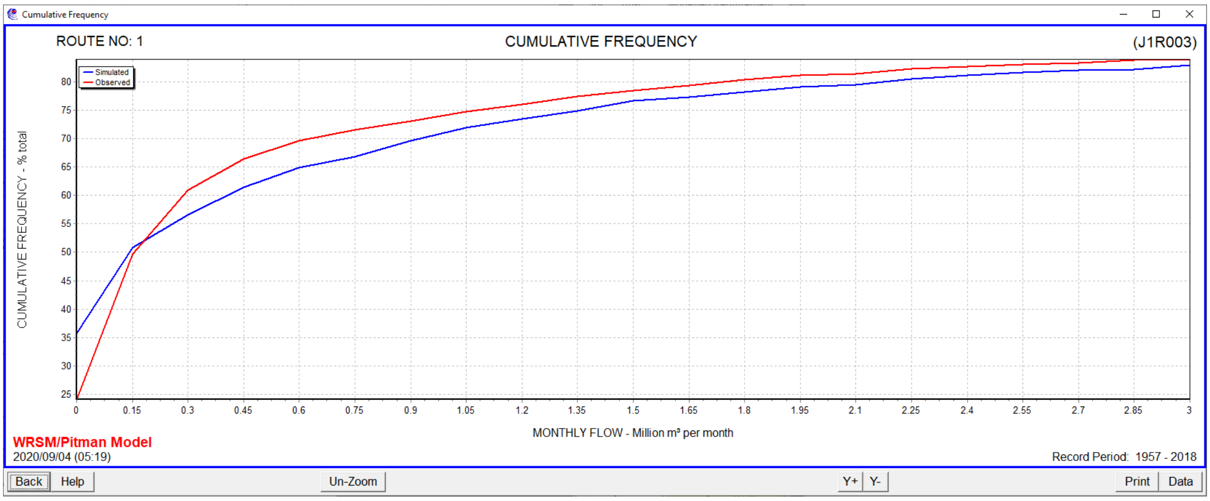

Figure A-6: Cumulative flow frequency comparison

APPENDIX B: INCREMENTAL BUFFELS RIVER PRESENT-DAY SIMULATION

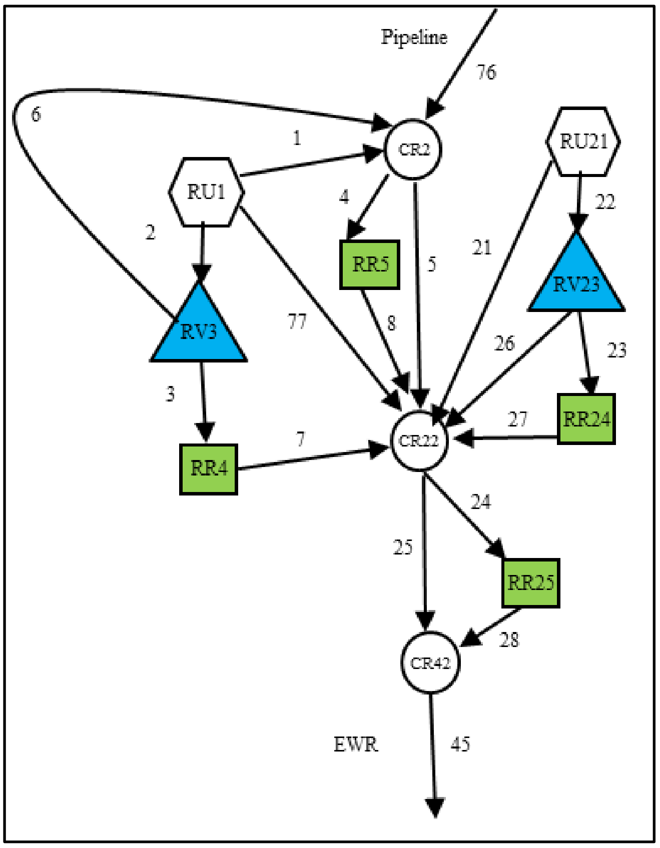

Figure B-1: Network Diagram for this scenario

Table B-1: Crops, areas (km²) and irrigation methods

Client - High valued crops (RR23)	Sprinkler	Drip	Crop Total	
Almond nuts	0.00	0.26	0.26	
Figs	0.00	0.07	0.07	
Olives	0.00	0.02	0.02	
Onions	0.09	0.04	0.13	
Plums	0.00	0.11	0.11	
Pomegranate	0.00	0.25	0.25	
Wine grapes	0.00	0.24	0.24	
Total per irrigation method	0.09	0.99	1.08	
Client – Grazing crops (RR25)	Sprinkler	Flood	Floppy	Crop Total
Lucerne/Medics	0.05	2.58	0.14	2.85
Small grain grazing	0.03	0.10	0.05	0.18
Total per irrigation method	0.08	2.68	0.19	3.03
Buffels IB upstream of Client (RR5)	Sprinkler	Drip	Pivot	Crop Total
Apricot	0.00	0.11	0.00	0.11
Lucerne/Medics	0.30	0.00	0.00	0.30
Nectarine	0.00	0.01	0.00	0.01
Olives	0.00	0.07	0.00	0.07
Onions	0.00	0.00	0.03	0.03
Other fruit	0.00	0.03	0.00	0.03
Peach	0.00	0.11	0.00	0.11
Pecan nuts	0.00	0.05	0.00	0.05
Planted pastures	0.38	0.00	0.00	0.38
Plums	0.00	0.01	0.00	0.01
Prickly pear	0.00	0.00	0.00	0.00
Table grapes	0.00	0.03	0.00	0.03
Wine grapes	0.00	0.22	0.00	0.22
Total per irrigation method	0.68	0.65	0.03	1.36
Klein Swartberg Rivier - High valued crops (RR4)	Sprinkler	Drip	Dragline	Crop Total
Almond nuts	0.00	0.01	0.00	0.01
Apricot	0.00	0.67	0.00	0.67
Carrots	0.37	0.02	0.01	0.40
Nectarine	0.00	0.10	0.00	0.10
Olives	0.00	0.12	0.00	0.12
Onions	0.22	0.02	0.00	0.25
Other nuts	0.00	0.01	0.00	0.01
Peach	0.00	0.52	0.00	0.52
Pear	0.00	0.11	0.00	0.11
Pecan nuts	0.00	0.01	0.00	0.01
Plums	0.00	0.11	0.00	0.11
Spring onions	0.00	0.02	0.00	0.02
Table grapes	0.00	0.07	0.00	0.07

Total per irrigation method	0.60	1.80	0.01	2.41
Klein Swartberg Rivier – grazing (RR5)	Sprinkler	Flood	Dragline	Crop Total
Lucerne/Medics	0.51	0.06	0.03	0.60
Planted pastures	0.09	0.00	0.00	0.09
Small grain grazing	0.03	0.00	0.00	0.03
Total per irrigation method	0.63	0.06	0.03	0.73

Table B-1: Crops requirements (mm/month), irrigation application efficiency, return flows and quotas

RR	Area (km2)	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Eff	Return Flow (fraction)	Quota Mm3/a
RR5	1.36	127	130	142	148	117	103	61	35	17	25	38	64	0.85	0.09	3.18
	0.73	162	192	206	214	174	154	82	30	10	30	43	93	0.74		
Tot	2.09	139	152	165	171	137	121	68	33	14	27	39	74	0.81		
RR4	2.41	90	113	156	168	142	94	18	9	5	8	12	28	0.90	0.05	3.66
RR24	1.08	74	119	184	181	122	68	26	11	5	5	9	24	0.93	0.04	1.64
RR25	3.03	179	229	260	269	219	186	92	26	4	28	39	97	0.67	0.17	4.61

APPENDIX C: EWR Requirements and compliance

Table C-1: Desktop EWR Results (Tab)

Desktop Version 2, Printed on 2020/08/28
Summary of IFR estimate for: J11J Generic Name
Determination based on defined BBM Table with site specific assurance rules.

Annual Flows (Mill. cu. m or index values):

MAR	=	32.395
S.Dev.	=	41.797
CV	=	1.290
Q75	=	0.060
Q75/MMF	=	0.022
BFI Index	=	0.161
CV(JJA+JFM) Index	=	6.050

ERC = D

Total IFR	=	4.792 (14.79 %MAR)
Maint. Lowflow	=	0.287 (0.89 %MAR)
Drought Lowflow	=	0.008 (0.02 %MAR)
Maint. Highflow	=	4.505 (13.91 %MAR)

Monthly Distributions (cu.m./s)
Distribution Type : E.Karoo

Month	Natural Flows			Modified Flows (IFR)			
				Low flows		High Flows	Total Flows
	Mean	SD	CV	Maint.	Drought	Maint.	Maint.
Oct	0.378	0.849	0.838	0.007	0.000	0.206	0.213
Nov	0.684	1.445	0.815	0.008	0.000	0.656	0.664
Dec	0.903	2.505	1.036	0.008	0.000	0.206	0.214
Jan	1.167	5.195	1.662	0.007	0.000	0.635	0.642
Feb	1.146	3.464	1.249	0.007	0.000	0.000	0.007
Mar	0.981	2.179	0.830	0.009	0.000	0.000	0.009
Apr	1.510	3.720	0.951	0.010	0.000	0.000	0.010
May	1.062	2.591	0.911	0.011	0.000	0.000	0.011
Jun	1.766	6.532	1.427	0.012	0.000	0.000	0.012
Jul	1.224	3.091	0.943	0.011	0.000	0.000	0.011
Aug	1.006	2.241	0.832	0.011	0.000	0.000	0.011
Sep	0.524	1.168	0.860	0.008	0.003	0.000	0.008

Table C-2: Desktop EWR Results (RuI)

Desktop Version 2, Printed on 2020/08/28
Summary of IFR rule curves for : J11J Generic Name
Determination based on defined BBM Table with site specific assurance rules.
Regional Type : E.Karoo   ERC = D

Data are given in m^3/s mean monthly flow

	% Points									
Month	10%	20%	30%	40%	50%	60%	70%	80%	90%	99%
Oct	0.317	0.221	0.110	0.050	0.030	0.024	0.019	0.012	0.004	0.000
Nov	0.994	0.729	0.378	0.171	0.092	0.048	0.023	0.010	0.000	0.000
Dec	0.330	0.253	0.145	0.069	0.036	0.026	0.023	0.007	0.000	0.000
Jan	0.988	0.793	0.281	0.144	0.050	0.022	0.007	0.001	0.000	0.000
Feb	0.015	0.011	0.006	0.002	0.001	0.000	0.000	0.000	0.000	0.000
Mar	0.018	0.013	0.006	0.002	0.001	0.000	0.000	0.000	0.000	0.000
Apr	0.020	0.014	0.006	0.002	0.001	0.000	0.000	0.000	0.000	0.000
May	0.022	0.015	0.007	0.002	0.001	0.000	0.000	0.000	0.000	0.000
Jun	0.024	0.015	0.006	0.002	0.001	0.000	0.000	0.000	0.000	0.000
Jul	0.021	0.013	0.005	0.001	0.000	0.000	0.000	0.000	0.000	0.000
Aug	0.022	0.014	0.006	0.002	0.001	0.000	0.000	0.000	0.000	0.000
Sep	0.016	0.012	0.007	0.004	0.003	0.003	0.003	0.003	0.003	0.000

Reserve flows without High Flows

Oct	0.014	0.010	0.004	0.001	0.000	0.000	0.000	0.000	0.000	0.000
Nov	0.016	0.012	0.006	0.002	0.001	0.000	0.000	0.000	0.000	0.000
Dec	0.017	0.013	0.007	0.003	0.001	0.000	0.000	0.000	0.000	0.000
Jan	0.015	0.012	0.007	0.003	0.001	0.000	0.000	0.000	0.000	0.000
Feb	0.015	0.011	0.006	0.002	0.001	0.000	0.000	0.000	0.000	0.000
Mar	0.018	0.013	0.006	0.002	0.001	0.000	0.000	0.000	0.000	0.000
Apr	0.020	0.014	0.006	0.002	0.001	0.000	0.000	0.000	0.000	0.000
May	0.022	0.015	0.007	0.002	0.001	0.000	0.000	0.000	0.000	0.000
Jun	0.024	0.015	0.006	0.002	0.001	0.000	0.000	0.000	0.000	0.000
Jul	0.021	0.013	0.005	0.001	0.000	0.000	0.000	0.000	0.000	0.000
Aug	0.022	0.014	0.006	0.002	0.001	0.000	0.000	0.000	0.000	0.000
Sep	0.016	0.012	0.007	0.004	0.003	0.003	0.003	0.003	0.003	0.000

Natural Duration curves

Oct	1.204	0.355	0.205	0.110	0.070	0.034	0.019	0.012	0.004	0.000
Nov	2.583	0.741	0.378	0.171	0.092	0.048	0.023	0.010	0.000	0.000
Dec	2.279	0.949	0.489	0.192	0.098	0.037	0.024	0.007	0.000	0.000
Jan	2.688	0.793	0.281	0.144	0.050	0.022	0.007	0.001	0.000	0.000
Feb	2.426	1.025	0.342	0.128	0.043	0.025	0.012	0.001	0.000	0.000
Mar	2.743	1.466	0.778	0.367	0.160	0.087	0.034	0.019	0.004	0.000
Apr	3.016	1.436	0.666	0.486	0.306	0.184	0.042	0.018	0.001	0.000
May	2.899	1.033	0.605	0.401	0.206	0.159	0.063	0.031	0.004	0.000
Jun	3.392	1.313	0.656	0.413	0.231	0.170	0.098	0.058	0.019	0.000
Jul	2.274	1.203	0.682	0.423	0.258	0.172	0.097	0.049	0.015	0.000
Aug	2.137	1.138	0.614	0.383	0.228	0.177	0.090	0.052	0.017	0.000
Sep	1.564	0.528	0.302	0.191	0.105	0.063	0.036	0.015	0.004	0.000

Figure C-3: Present Day EWR compliance graphs