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DEPARTMENT OF
WATER AFFAIRS
AND FORESTRY

Feasibility Study for the Raising of Clanwilliam Dam

System Analysis

Final

February 2009

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DIRECTORATE OPTIONS ANALYSIS

FEASIBILITY STUDY FOR THE RAISING OF THE CLANWILLIAM DAM

SYSTEM ANALYSIS

Final

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Department of Water Affairs and Forestry
Directorate Options Analysis

FEASIBILITY STUDY FOR THE RAISING OF THE CLANWILLIAM DAM

APPROVAL

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DWAF Report no.	:	P WMA 17/E10/00/0609
Authors	:	A Sparks, J Cullis, A Brown and Z Sulieman
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STUDY TEAM : **Approved for the Clanwilliam Dam Raising Association by:**

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EXECUTIVE SUMMARY

INTRODUCTION

The Clanwilliam Dam is located on the Olifants River in the Western Cape near the town of Clanwilliam. There is a requirement for a better assurance of supply for agriculture from the Lower Olifants River Government Water Scheme (LORGWS) and demand for further water allocations. There is also pressure to allocate additional water to resource-poor farmers in this area.

In order to comply with current dam safety standards applicable for extreme events, the Department of Water Affairs and Forestry (the DWAF) plans to implement remedial measures in the near future. This presents an opportunity to raise the full supply level (fsl), if the marginal cost of raising, over and above the cost of the strengthening, is economically viable.

The aim of the study was to verify the technical, environmental, social, economic and financial viability of raising the Clanwilliam Dam, at feasibility level. The study also aimed to determine the optimal height for such raising, if found to be viable. Four raising options, namely no raising (0m), and 5m, 10m and 15m raisings were considered.

This report documents the determination of the yield from the system for the various dam raising scenarios, considering the ecological water requirements resulting from the *Olifants/Doring Catchment Ecological Water Requirements Study* (DWAF, 2005).

HYDROLOGY

Streamflow

Because of the severe nature of the drought of 2003 to 2005, which could have changed the reliability of the yield from the dam, the observed streamflow records were used to extend the estimated runoff into the catchment, from 1920 to 2005. These historical streamflows were not naturalised. The hydrological sub-catchments, as determined in previous studies, were retained.

Rainfall

The initial hydrology prepared as part of the Olifants River System Analysis (Sep 1990) used rainfall records available from a number of sources. Subsequently, the Computing Centre for Water Research (CCWR) was disbanded and most of the DWAF's rainfall gauges in the area were closed. This study reviewed data from the available rainfall stations although the intention was not to calibrate the catchments. A large proportion of the rainfall used in the Olifants River System Analysis was based on "public appeal" data that was collected by the CCWR, and now seems to have been lost.

The steep mountain ranges that flank the Olifants River intercept the rainfall and make a major contribution to the runoff from the catchment. However, the rainfall gauges are located near urban and agricultural centres and do not measure the mountain rainfall which must be deduced from rainfall on either side of the mountains. Although the inflow to the Clanwilliam Dam is well represented, the actual runoff in certain reaches is probably under-estimated because the rainfall was underestimated. Rain gauges located in the mountains or at the extremities of the catchment would improve the modelling of the rainfall/runoff relationship in the catchment.

Although the rainfall stations were not used with the Pitman Model to calibrate the catchment, a representative set was used to estimate the relative monthly and annual rainfall upstream of Clanwilliam Dam. The average mean annual precipitation (MAP) at the northern, central and southern portions of the catchment were determined. The values of the northern, central and southern portions were in turn averaged to obtain the monthly rainfall (as a % of MAP) for the catchment upstream of Clanwilliam Dam. This was used to develop a monthly relationship between rainfall and inflow, which could be used to identify outliers in the inflow record.

MODIFICATIONS INTRODUCED IN THIS STUDY

As part of this study the following were updated for the catchment upstream of the Bulshoek Weir:

- Land-use and agricultural demands;
- Dam capacities (farm and government water schemes);
- Extent of alien vegetation;

Agricultural demands

Aerial photographs were used to digitise the areas of crops off aerial photos, and field verification was undertaken. The areas of permanent crops are accurately represented using this approach, but areas of annual crops are difficult to quantify.

The updated estimate of the average irrigation demand upstream of Clanwilliam Dam is 95.7 million m^3/a. The demand from the river and the Clanwilliam Canal, between Clanwilliam Dam and Bulshoek Weir is 21.6 million m^3/a, which includes the observed flow in the canal of 11.6 million m^3/a.

Invasive alien vegetation

Information on the extent of and water use by invasive alien information was updated, based on the latest available information, including the clearing activities of Working for Water upstream of Clanwilliam Dam. For comparative purposes, the areas were condensed to equivalent fully infested areas. The fully cleared area corresponds to 1 004 ha and the remaining infestation to 1 979 ha, which correspond to annual streamflow reductions of about 4.9 and 8.9 million m^3/a respectively. These are significant volumes of water that could be used for other purposes.

Currently, low flows in the river tend to be intercepted by riparian irrigators, so removal of the aliens is not expected to have a significant influence on the yield from Clanwilliam Dam. Infestation was also significantly less for the period from 1935 to 1990, which was used to naturalise the observed streamflow into Clanwilliam Dam. The inflow sequences to Clanwilliam Dam were therefore not adjusted to take account of the updated alien infestation information.

Dam volumes

The updated combined volume of the farm dams upstream of Clanwilliam Dam is 34.3 million m^3. The gross volume of Clanwilliam Dam is 123.7 million m^3 and that of Bulshoek Weir is 5.4 million m^3.

Table E1 shows the gross and net storage capacities for the current Clanwilliam Dam, as well as for the raising options.

Table E1 Capacity of current and raised Clanwilliam Dam

Dam Raising Option	Elevation (m)	Gross storage volume (Mm^3)	Net Storage volume (Mm^3)
0 m	105.25	123.7	121.8
5 m	110.25	186.3	184.4
10 m	115.25	266.0	264.1
15 m	120.25	364.0	362.1

It is estimated that future siltation should not reduce the storage of Clanwilliam Dam by more than 5 million m^3 over the next thirty years, even if the dam is raised by 15 metres.

The yield of farm dams filled from pumping from the main stem of the Olifants River, upstream of Clanwilliam Dam, was estimated as 9.2 million m^3/a.

OPERATION OF THE LORGWS

Upstream of Clanwilliam Dam

Farm dam sizes were restricted to 6 000 m^3/ha/a for the areas falling within the previous Government Water Control Area (GWCA). Under the old Water Act a dam of up to 250 000 m^3 could be constructed in the tributaries outside the GWCA without a special permit.

As soon as the Olifants River starts flowing in winter, the farmers can pump water from the river to their dams and they must stop when the flow in the river is insufficient, normally around the end of October. During summer, the farmers abstract water according to a weekly cycle. The abstraction of water by the upstream users obviously impacts on the water available from the Clanwilliam Dam for downstream irrigators.

Conjunctive operation of Clanwilliam Dam and Bulshoek Weir

Figure E1 charts the annual gross water supply, from 1980 to 2006, to the major consumers. About 27% to 30% of the inflow to the Lower Olifants River and Clanwilliam Canals is lost through seepage and evaporation.

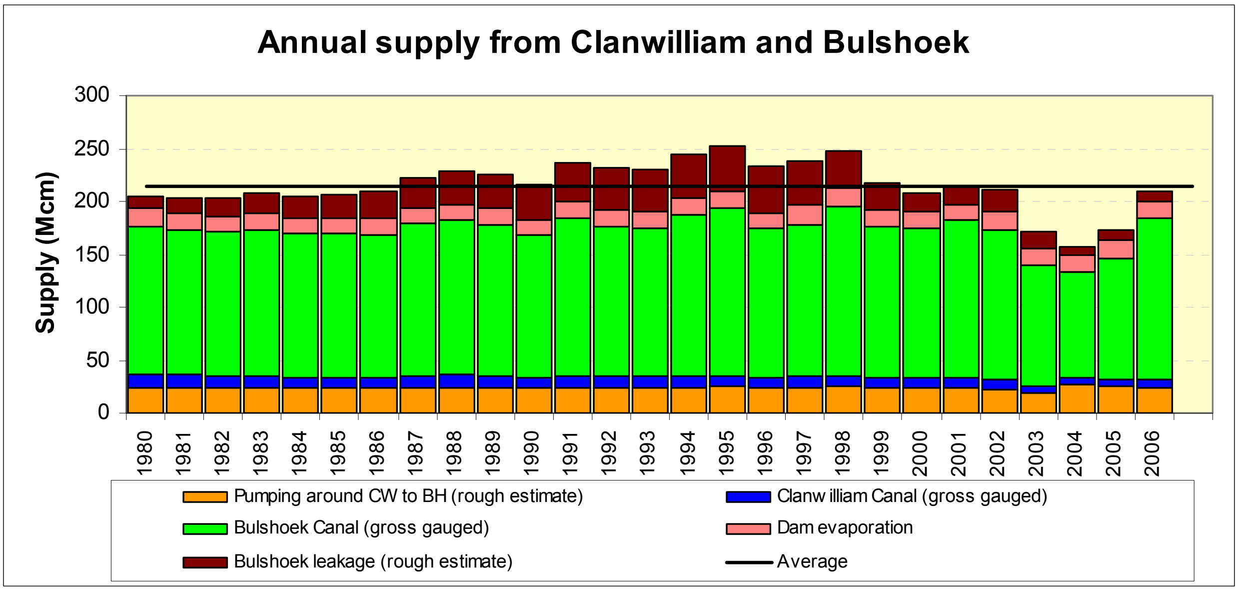

Figure E1 Historical annual supply from Clanwilliam Dam and Bulshoek Weir

Use between Clanwilliam Dam and Bulshoek Weir

The use from pumps along the Jan Dissels and the Olifants Rivers, together with transmission losses along that reach, is 21.6 million m^3/a. It is estimated that leakage from Bulshoek Weir reduced from 1.25 m^3/s down to the current 0.25 m^3/s, as a result of work undertaken by the DWAF's Construction Directorate.

Use from the Lower Olifants River Canal

The LORWUA currently have a theoretical allocation of water from Clanwilliam Dam/Bulshoek Weir of 116 million m^3/a (9 491 ha, each receiving 12 200 m^3/ha). The average inflow to the canal for the period from 1990 to 2006 was 139 million m^3/a, but after deducting losses of 37 million m^3/a (27%) and non-irrigation use of about 9.6 million m^3/a, the remainder left for irrigation is about 92 million m^3/a, about 80% of the theoretical allocation.

Two quotas are used by LORWUA, namely an annual quota of 12 200 m^3/ha and a weekly quota of 325 m^3/ha. LORWUA have limited the capacity of the balancing dams along the canal to 35% of each farmer's allocation. The Ebenhaeser Balancing Dam near the end of the west branch of the Bulshoek Canal has a capacity of 140 000 m^3.

Use downstream of Bulshoek Weir

Irrigators downstream of the Bulshoek Weir requested a concession from the Minister of Water Affairs to use the water leaking from the Weir. In 1963 the Minister granted a concession allowing existing riparian members of the LORGWS to irrigate an additional 10 morgen (8.6 ha) using this water. It was spelt out that this was a temporary concession and that the state could continue with developments upstream in the river without compensating these irrigators in any way. There is however significant uncertainty about the extent of this use, despite a study undertaken by the DWAF to clarify this.

Total return flows from the Lower Olifants River Canal upstream of Lutzville is estimated as approximately 2 m^3/s, of which 0.5 m^3/s were above the confluence with the Doring River. The volume of farm dams downstream of the Bulshoek Weir is relatively small.

Curtailment

The storage of Clanwilliam Dam is currently only about 30% of the present day MAR. The Dam spills almost every year and the allocation for the coming year is dependent not on how much water flowed into the Clanwilliam Dam, but on how late in the season the last rains came. When Clanwilliam Dam stops spilling a portion of the available storage is kept in reserve and the remainder is distributed amongst the various users to meet their requirements until the start of winter, about mid May.

MODELLING OF THE HISTORICAL SYSTEM

Inflows to Clanwilliam Dam were inferred using the "reverse mass balance" method. Inflows were then compared with historical inflow determined in the Olifants River System Analysis (ORSA). For the system analysis the streamflows generated during the original ORSA were retained because, following evaluation, they were deemed to be acceptable. The development of a naturalised set of flows was not requested. The natural MAR of the Olifants River above the Clanwilliam Dam is 356 million m^3.

The historical inflow sequence derived was checked to see how accurately it simulated the historical behaviour of the system. The simulated historical trajectory generally compares very favourably with the actual trajectory. The average supply over the last 25 years was estimated as 174 million m^3/a, although during droughts the supply would have been curtailed.

MEETING ECOLOGICAL WATER REQUIREMENTS

In its natural state the MAR of the Olifants River was 1 055 million m^3/a. During winter about half the streamflows were provided by the Doring River tributary, while during summer the Doring River dried up and the perennial Olifants River provided the estuarine baseflow. Developments in the Olifants River catchment as a whole have reduced the streamflow by 32%.

The proposed dam raising could potentially increase the Dam's storage to 100% of the original inflow. If Clanwilliam Dam is raised then the dam will absorb more of the winter streamflows before it spills and, as a result, the spillage over the dam will be reduced and delayed.

To meet estuarine Reserve flow requirements, releases from Bulshoek Weir could supplement the streamflow at Lutzville, to increase the streamflow to about 1.5 m^3/s. However, proper management is required to ensure that irrigators located downstream do not intercept these ecological releases. In addition to the need for baseflows from the Olifants River, the estuary also requires flood flows during winter. During early winter the Doring River provides these highflows, as the Clanwilliam Dam currently impounds the streamflows in the upper Olifants River until it starts to spill.

Upstream of Clanwilliam Dam

The raising of the Clanwilliam Dam will obviously not impact the reach upstream of the Clanwilliam Dam, but the management of this reach could affect the Clanwilliam Dam. This river reach is in a D ecological Category (EWR Site 1 at Citrusdal).

During the summer months, the naturally perennial Olifants River can be pumped dry, sometimes for up to several weeks. The pumping from boreholes located alongside the river has aggravated the situation. One option to reduce the pumping from the river is to increase the storage of winter water for use in summer. Unless proper controls are in place this might not reduce the summer pumping but will only further reduce the streamflow entering the Clanwilliam Dam.

Between Clanwilliam Dam and Bulshoek Weir

The Dam intercepts winter highflows and releases water for irrigators downstream. During summer, Clanwilliam Dam releases up to 8 m^3/s, significantly more than natural summer baseflow, down to the canal at the Bulshoek Weir. In winter, the Dam releases about 0.5 m^3/s to irrigators, who do not receive accruals from the Jan Dissels River, located just downstream of the Dam. The flow regime is therefore already highly modified, and it cannot be reversed now.

The multilevel outlet works proposed for the raised Clanwilliam Dam will be able to provide the triggers to encourage the spawning of the Clanwilliam Yellow fish. Freshettes released from the Dam for fish spawning could be captured in Bulshoek Weir, and could potentially be released in combination with releases for irrigation.

Between Bulshoek Weir and the Doring River confluence

The environmental flow requirement for the 18 km long reach between the Bulshoek Weir and the confluence with the Doring River could significantly affect the viability of any proposed raising of the Clanwilliam Dam. There was unanimous agreement from the ecologists that the attainment of a D-category at EWR Site 2 in this reach was unrealistic, and a 'residual flow' was instead recommended, to maintain this river reach in a Category E, provided the Doring River remained undammed and thus remain able to provide the bulk of required ecological flows at the estuary.

The principle adopted was that no releases for high flow requirements would be made from Bulshoek Weir for the downstream reach. The option of meeting Drought EWR requirements for the downstream reach for the 0 m raising option, and meeting the Baseflow EWR requirements for the 5, 10 and 15 m raising options was adopted.

Estuary

The present ecological state of the estuary was assessed as a Category C but is worsening. Improved management, reducing the impact of the non-anthropogenic activities, could help to maintain the estuary as a Category C. The baseflows entering the estuary should be maintained above 1.5 m^3/s, providing that such flows would have occurred in the natural undeveloped catchment.

SYSTEM ANALYSIS

Scenarios analysed

Various scenarios were analysed, using the WRYM, to determine the historical yields of the system for the existing (unraised) dam and for three different dam raisings of 5, 10 and 15 m. The scenarios also determined the influence on yield of making releases from Clanwilliam Dam, to meet the EWRs downstream of the Bulshoek Weir and at the estuary.

Flows from the Doring River were assumed to supply the flood requirements at the estuary. A minimum baseflow of 1.5 m^3/s was maintained at the causeway at Lutzville, providing that the baseflow did not exceed natural streamflow. During the peak summer irrigation months, up to 1.2 m^3/s is supplied by return flows from irrigation along the Lower Olifants River Canal. Shortfall in the baseflow was augmented by modelled releases.

Yield

From **Table E2**, when compared to the current system, with a drought EWR implemented (historical firm yield (HFY) of 133 million m^3/a) the increase in HFY is 32, 59 and 73 million m^3/a respectively. When compared to the current system with no EWR implemented (HFY of 149 million m^3/a), the increases in the HFY are 16, 43 and 57 million m^3/a respectively.

Table E2 Yield analysis results

Scenario	Recurrence interval	Absolute yield				Increase in yield wrt current system yield			
		Dam raising				Dam raising			
		0 m	5 m	10 m	15 m	0 m	5 m	10 m	15 m
No EWR	1 in 5 yrs	185	235	274	305	-	50	89	120
	1 : 10	175	219	248	275	-	44	73	100
	1 : 20	169	197	234	263	-	28	65	94
	HFY	149	184	213	227	-	35	64	78
Drought EWR	HFY	**133**	169	199	214	-	36	66	81
Baseflow EWR	1 in 5 yrs	168	213	254	279	-	45	86	111
	1 : 10	161	196	225	254	-	35	64	93
	1 : 20	156	184	213	242	-	28	57	86
	HFY	128	**165**	**192**	**206**	-	37	64	78
Full EWR	1 in 5 yrs	161	203	238	266	-	42	77	105
	1 : 10	154	183	207	239	-	29	53	85
	1 : 20	142	160	195	218	-	18	53	76
	HFY	124	157	172	187	-	33	48	63

The yield for the situation where the baseflow EWR is supplied is shown in **Figure E2**.

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GLOSSARY AND ABBREVIATIONS

ARC	Agricultural Research Council
BAS	Best attained state
CCWR	Computing Centre for Water Research
CWUA	Clanwilliam Water Users' Association
EC	Ecological category
EWR	Ecological water requirements
GWA	Government Water Area
GWCA	Government Water Control Area
ha	Hectare
LORGWS	Lower Olifants River Government Water Scheme
LORWUA	Lower Olifants River Water User Association
MAP	Mean annual precipitation
MAR	Mean annual runoff
Mm^3/a	million cubic metres per annum
m^3	cubic meter (equal to 1 kilolitre or 1 000 litres)
m^3/a	cubic metres per annum
m^3/ha	cubic metres per hectare
m^3/s	cubic metres per second
ORSA	Olifants River System Analysis
PES	Present ecological state
%	percentage
UAW	Unaccounted-for water
WRIMS	Water Resources Information Management System
WRYM	Water resources yield model
WUA	Water user association

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- Freda Jonck for figure showing the extent of the Olifants River (Vanrhynsdorp) Government Water Control Area.
- Harry Swart, Erwin Weidemann and De Wet Oosthuizen for information on the repair of the Bulshoek Barrage.
- Gerrit van Zyl for collecting information on farm dams and irrigation along the Olifants River.
- Abrie Botha for description of the operation of his off-channel dam to minimise salinity impacts.
- Abdul Parker and Nik Wullschleger for information on the concessions downstream of the Bulshoek Barrage.
- Rainfall data provided by Brakfontein Landgoed, Groenkloof, the Baths and Keerom as well as the South African Weather Service (SAWS) and the Agricultural Research Council (ARC).

In particular, the long-term experience and willing assistance of Francois van Heerden and Johan Matthee were invaluable when describing the current operation of the system.

1. INTRODUCTION

The Clanwilliam Dam is located on the Olifants River in the Western Cape near the town of Clanwilliam. There is a requirement for a better assurance of supply for agriculture from the Lower Olifants River Government Water Scheme (LORGWS) and demand for further water allocations. There is also pressure to allocate additional water to resource-poor farmers in this area.

In order to comply with current dam safety standards applicable for extreme events, the Department of Water Affairs and Forestry (the DWAF) plans to implement remedial measures in the near future. This presents an opportunity to raise the full supply level (fsl), if the marginal cost of raising, over and above the cost of the strengthening, is economically viable.

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This report documents the determination of the yield from the system for the various dam raising scenarios, considering the ecological water requirements resulting from the *Olifants/Doring Catchment Ecological Water Requirements Study* (DWAF, 2005).

2. AVAILABLE HYDROLOGICAL DATA

2.1 Previous studies contributing to the current system model

Table 2.1 summarises the contribution of preceding studies to the current system model, including the hydrology, and the irrigation and ecological water requirements.

The hydrology from 1920 to 1990 is based on the streamflow sequences determined in two earlier studies :

- *The Olifants River System Analysis*, and
- *The Olifants/Doring River Basin Study*.

Though it was not intended to recalibrate/extend the hydrology as part of this current study, a serious drought occurred in 2003 to 2005, which could have changed the reliability of the yield from the Dam. To enable the model to simulate the full period from 1920 to 2005, the historical streamflows at three locations were determined using records :

- Clanwilliam Dam
- Doring River
- downstream of the confluence of the Olifants and Doring Rivers.

These historical streamflows were not naturalised.

Table 2.1 Contribution of previous studies to the current system model

Study	Reference	Upper Olifants	Doring	Lower Olifants
Olifants River System Analysis	DWAF (1990)	Calibration of Hydrology (1920-1988) and system analysis	-	-
	DWAF (1994)		Calibration of Hydrology (1920-1990) using data from 1:50 000 topographical maps	
Olifants/Doring River Basin Study	DWAF (1998)	Extension of Hydrology (1920-1990)	Updated land-use data obtained from DWAF. Calibration of Hydrology (1920-1990)	Extension of Hydrology using WR90 (1920-1990)
Olifants/Doring River Basin Study (Phase II)	DWAF (2003)	P4-1 states that "the hydrological records for the Olifants and Doring River Catchments were extended by 10 years from 1989 to 1999". A report detailing this study could not be obtained and a copy of the files used for the system configuration was obtained from Stephen Mallory. In the Clan-dwn.inc file the streamflows for the years starting in Oct 1998 and Oct 1999 are identical. Consequently, the inflow sequences were omitted in favour of historical sequences generated as part of this study.		
Western Cape Olifants/Doring River Irrigation Study	PGWC (2001a)	The draft copy of the main report states that "This yield analysis task was excluded from the WODRIS and done under a separate assignment for the DWAF", Phase II of the Olifants/Doring River Basin Study (see above).		
Olifants Doring Catchment Ecological Water Requirements Study	DWAF (2006); DWAF (2005)	No hydrological analysis – Recommend streamflow requirements at selected sites in the Olifants/Doring including upstream of Clanwilliam Dam, downstream of the Bulshoek Barrage and at the estuary.		
Olifants/Doring Water Management Area : Water Resources Situation Assessment	DWAF (2002)	No hydrological analysis – some synthesis of demands.		
Olifants/Doorn Water Management Area: Internal Strategic Perspective	DWAF (2005a)	No hydrological analysis – some synthesis of demands.		
This study: Feasibility Study for the Raising of Clanwilliam Dam in the Western Cape		Determine historical inflow sequences for the period 1991 to 2005 to check the severity of the 2003 to 2005 drought		

2.2 Groundwater

The contribution of groundwater to irrigation demand was used to reduce the irrigation demands (see **Annexure C**).

2.3 Hydrological summary

In previous studies, the Olifants/Doring catchment was subdivided into reaches by certain key nodes, such as DWAF's dam or streamflow gauges, earlier proposed dam sites and ecological flow monitoring sites (see **Table 2.1**).

Each of these reaches may contain urban, irrigation or ecological water requirements that are supplied via a network of rivers, dams, pipelines and canals according to various precedence rules. The Water Resource Yield Model (WRYM) is a network based monthly timestep model that enables the simulation of complex water resource systems.

2.3.1 Ecological water requirements study

The detailed network diagram for the Present Day System, as used in the previous Ecological Water Requirements Study is presented in **Annexure G.1**.

The various components have also been presented in a more simplified form in **Table 2.2**, using a new row for each reach. The first row corresponds with the headwaters of the Olifants River, in the Agter Witzenberg reach upstream of the proposed Rosendal Dam. The Agter Witzenberg reach was itself subdivided into two portions, the first representing the areas draining into farm dams and the second portion representing the land downstream of farm dams. In Column D, the table first provides the natural inflow for that reach – i.e. the flow from the catchment before any human impacts. From this natural flow the volume of water consumed in the reach is deducted to obtain the incremental inflow from that reach. The water consumed includes:

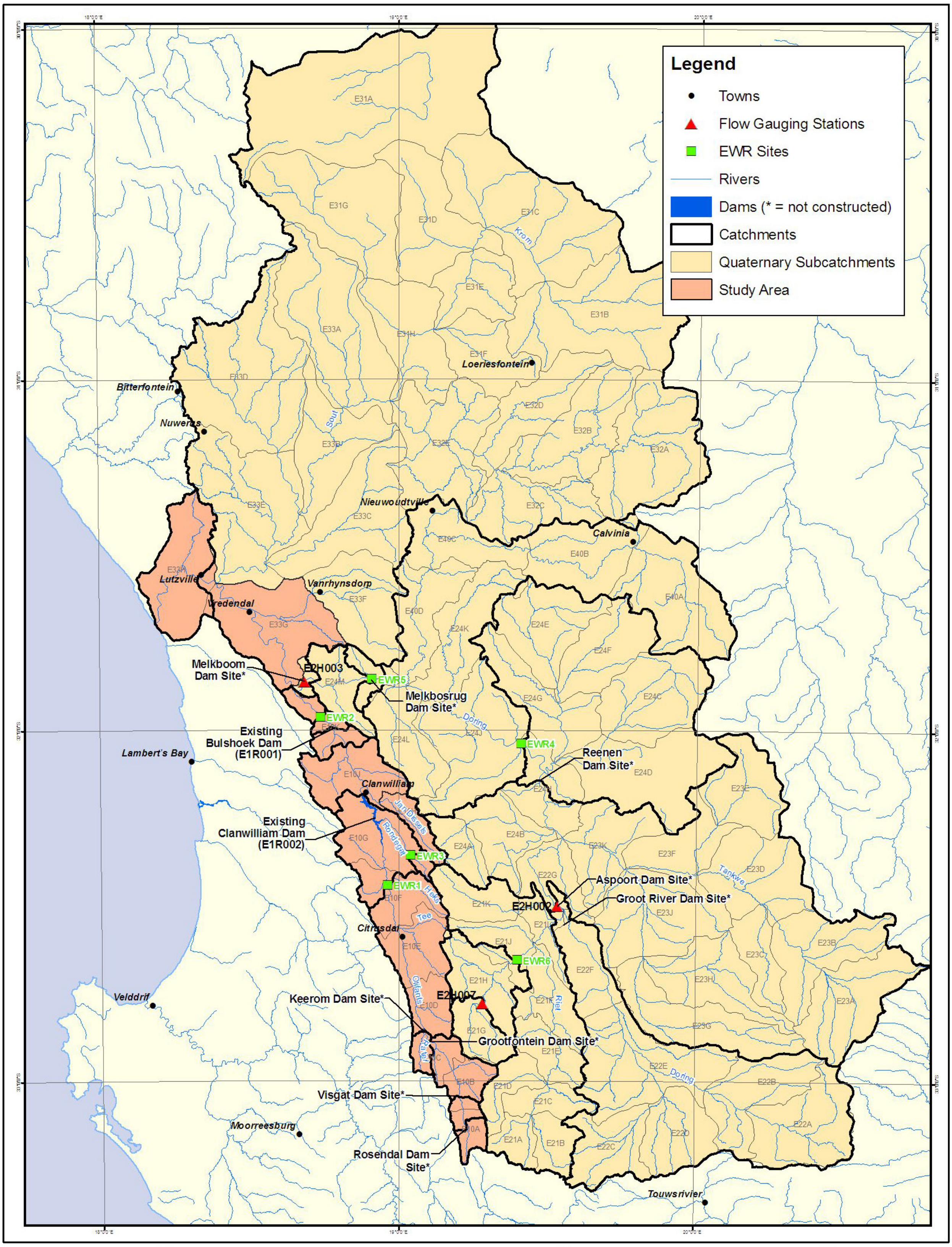
- water supplied to irrigation (from dams [Column E] or from rivers[Column G]), or
- lost to evaporation from dams [Column F],

but excludes "return flows" or unused water returning from irrigation fields [Column H].

If a reach has a negative incremental inflow [Column I] then that reach is a nett consumer of water and uses water from other reaches. The reaches are organised with the upstream reach first. Adding the cumulative inflow from the appropriate preceding reaches to the incremental inflow for the current reach determines the cumulative outflow from the current reach [Column J].

To help with correlating the flows in **Table 2.2** with the schematic in **Annexure G.1** the nodes whose outflow (or inflow) corresponds with the cumulative streamflow have been identified in Column K.

Additional details such as the gross dam capacity and the total demands (as opposed to supply which is constrained by the availability of water) from dams and the river itself, are provided in Columns L, M and N respectively.



Project: CLANWILLIAM DAM RAISING FEASIBILITY STUDY	Scale: 30 15 0 30 Km 1 : 1 100 000	Figure No.: 2.1
Drawing Title: *Sub-catchments in the Olifants/Doring system*	Path: i:/hydro/400415/gis_projects/rep_3/ subcatchments_fig21.mxd	

Figure 2.1 Sub-catchments in the Olifants/Doring system

Table 2.2 Summary of the hydrology used in the Olifants Doring Catchment Ecological Water Requirements Study

Reach			Mass Balance						Additional details					
From	To	Portion	Natural flow	Usage				Incremental present day streamflow	Cumulative present day streamflow	Reference node of channel (ch_) with corresponding cumu8lative flow in scenario 400347/wrym/d7/pd See Annexure G.1	Storage	Demands		
				Dam supply	Dam evaporatio n	Riparian Supply	Return flows				Gross dam capacity	Dam	Riparian	Total
			Mm^3/a	Mm^3/a	Mm^3/a	Mm^3/a	Mm^3/a	Mm^3/a	Mm^3/a		Mm^3	Mm^3/a	Mm^3/a	Mm^3/a
A	B	C	D	E	F	G	H	I=D+E+F+G+H	J	K	L	M	N	O
Agter Witzenberg u/s prop Rosendal Dam		Upstream of farm dams	10.6	-4.4	-0.8	0	0	5.4	5.4	d/s 1	4.5	7.0		7.0
		remainder	20.9	0.0	0.0	0	0	20.9	26.3	d/s 2				
Rosendal	Visgat		32.4	0.0	0.0	0	0	32.4	58.8	d/s 7				
Bo Boschkloof			10.1	-8.1	-0.8	0	0	1.2	59.9	d/s 5	16.0	16.0		16.0
Visgat	Grootfontein		79.4	0.0	0.0	0	0	79.4	139.3	d/s 6				
Grootfontein	Keerom (Ratel River)		13.4	-0.6	-0.9	0	0	11.9	151.2	d/s 13	2.3	0.6		0.6
Keerom	Downstream of Heks River confluence (EWR site 1)	Upstream of farm dams	12.3	-7.0	-1.1	0	0	4.2	155.4		6.4	9.3		36.9
		remainder	141.2	0.0		-18.7	0	122.6	277.9	d/s 10			27.59	
Rondegat River (upstream EWR 3)			7.3	0.0		0	0	7.3	285.2	d/s 64				
Downstream of Heks River	Upstream of Clanwilliam Dam	Upstream of farm dams	8.9	-5.0	-0.9	0	0	3.0	288.2		4.6	6.7		26.7
		remainder	95.0			-15.6		79.3	367.6	d/s 19			19.988	
Elandskloof														
Clanwilliam Dam pumps														
Clanwilliam Dam and canal			0.0	-11.6	-10.5	0		-22.1	345.4	d/s 11	121.4	12.0		12.0
Clanwilliam Dam	Upstream of Bulshoek Barrage		77.4	-27.5	-1.4	0	0	48.5	393.9			27.5		27.5
Bulshoek Barrage				-128.6		0		-128.6	265.4	d/s 13	5.7	137.1		137.1
Doring River			515.4	-87.7	-12.2	-10.3		405.2	405.2	d/s 39	128.0	99.5	34.8	134.2
Bulshoek Barrage	Estuary (excluding Doring River)		30.9			-3.5	17.8	45.2	716.3	ch 164			3.5	3.5
Total	**Total**		**1055.2**	**-280.5**	**-28.6**	**-48.1**	**17.8**	**715.7**	**715.7**		**288.9**	**315.6**	**85.8**	**401.4**

2.3.2 Modifications introduced in this Study

As part of this study, the following were updated for the catchment upstream of the Bulshoek Barrage:

- Agricultural demands
- Dam capacities (farm and Government water schemes)
- Extent of alien vegetation
- Rainfall at Clanwilliam Dam reduced to agree with the observed record at the dam, rather than for the entire catchment.

The new data is summarised in **Table 2.4** and is discussed, if necessary, in more detail below. **Table 2.5**, which is structured similarly to **Table 2.2** above, shows the modified data incorporated into the WRYM.

Agricultural demands

Annexure C contains a review of the irrigation demands upstream of Bulshoek Barrage. Aerial photographs were used to digitise the areas of crops. The areas of permanent crops will be accurately represented using this approach, but areas of annual crops were difficult to quantify.

The area of cultivated/fallow fields does not necessarily give an accurate representation of the areas planted with annual crops such as vegetables. Some fields may support two crops a year whereas some potato fields may only be used once in a four year rotation to avoid a build up of nematodes. Another problem was that the farmers did not necessarily identify which field was used for which crop and instead stated that their farm used water according to their allocation so that a land-use coverage for non-permanent crops could not be created without significant additional work.

The final estimated irrigation demands for the different reaches from **Annexure C** have been summarised in Column D of **Table 2.4**.

A portion of the demands from Keerom to the Hex River confluence are supplied from farm dams and the magnitude of this portion was assumed to be equal to the total volume of these farm dams of 9.5 million m^3 (see Column K of **Table 2.5**).

The demand of 26.7 million m^3/a Column D of **Table 2.4** around Clanwilliam Dam was also subdivided, in this case into the following groups:

- Farm dams upstream of Clanwilliam Dam
- Riparian demands upstream of Clanwilliam Dam
- Elandskloof
- Pumps around Clanwilliam Dam

These demands were apportioned according to the relative irrigation areas to obtain the values in Column K of **Table 2.5.**

The demands of 9.9 and 139.7 million m^3/a for the Clanwilliam and Bulshoek Canals are based on the average recorded historical demands over the last 27 years (see **Table 3.2**). The demand of 21.6 million m^3/a between Clanwilliam and Bulshoek was estimated using the average volume of unaccounted for losses between Clanwilliam and Bulshoek (see discussion of Row J of **Table 3.7** in **Section 3.2.2**).

Alien vegetation

Working for Water is currently busy clearing alien vegetation upstream of Clanwilliam Dam. Their information focuses on the riparian vegetation that has a larger impact than upland vegetation. Not all the areas are fully infested and for comparative purposes, the areas are condensed to equivalent fully infested areas. The fully cleared area corresponds to 1 004 ha and the remaining infestation to 1 979 ha, which correspond to annual streamflow reduction of about 4.9 and 8.9 million m^3/a (see **Annexure D**). These are significant volumes of water that should be used for other purposes.

Currently, low flows in the river tend to be intercepted by riparian irrigators (see **Section 3.1**) so removal of the aliens will not have a significant effect on the yield from the Clanwilliam Dam. Also, the infestation was significantly less for the period from 1935 to 1990 that was used to naturalise the observed streamflow into Clanwilliam Dam so the inflow sequences to Clanwilliam Dam were not adjusted to take account of alien infestations.

Dam volumes

The proposed capacities for the raised Clanwilliam Dam are included in **Table 2.3**. The latest estimates of the private farm and government dams in each reach are summarised in Column F of **Table 2.4**.

The volume of the farm dams upstream of Clanwilliam Dam (Column F of **Table 2.4**) of 34.3 million m^3 are slightly less than those of 39 million m^3 in Table E.2 of DWAF's *Farm Dam Report* (DWAF, 2006) which is included as **Annexure D**) because proposed dams and some dams in the adjoining catchments not upstream of Clanwilliam Dam were excluded.

To help understand the operation of the farm dams in the area, Gerrit van Zyl identified which farm dams are filled using water pumped from the Olifants River (see Column **I** of **Table 2.4**).

The volumes adopted for the Government Water Schemes (Clanwilliam and Bulshoek) were supplied by F Druyts of DWAF (DWAF *Dam Design Report Addendum* (DWAF, 2007).

Although the Gross Full Supply Capacities for Clanwilliam Dam mentioned in DWAF's 2004 dam basin survey and the DWAF *Dam Design Report Addendum* (DWAF, 2007) are both 124 million m^3, the full supply level (FSL) from DWAF's 2004 dam basin survey is RL104.41, as opposed to the RL105.25 from the DWAF *Dam Design Report Addendum*.

Table 2.3 Proposed capacity for Clanwilliam Dam (DWAF, 2007)

Description	RL (m)	Storage (Million m^3)
Current storage	105.25	124
5 m raising	110.25	186
10 m raising	115.25	266
15 m raising	120.25	364

In **Annexure K**, it is estimated that future siltation should not reduce the storage of Clanwilliam Dam by more than 5 million m^3 over the next thirty years, even if the dam is raised 15 metres.

Table 2.4 Additional hydrological data incorporated into the WRYM model

Reach			Demands		Storage			
To	From	Portion	Revised total (1)	Observed demand / losses (5)	Total gross storage (2005) (2)	Dead storage	Nett storage	Portion filled from pumping from the main stem of the Olifants River (3)
			Mm^3/a	Mm^3/a	Mm^3	Mm^3	Mm^3	Mm^3
Column A	**B**	**C**	**D**	**E**	**F**	**G**	**H**	**I**
Agter Witzenberg upstream prop Rosendal Dam		Upstream farm dams	8.7		3.8		3.8	
		Remainder						
Rosendal	Visgat							
Bo Boschkloof			16.0		14.7		14.7	
Visgat	Grootfontein							
Grootfontein	Keerom (Ratel River)		1.4		0.8		0.8	0.5
Keerom	Downstream Hex River confluence (EWR Site 1)	Upstream farm dams	42.8		9.5		9.5	7.9
		Remainder						
Rondegat River (upstream EWR 3)								
Downstream Hex River	Upstream Clanwilliam Dam	Upstream farm dams	26.7		5.5		0.8	0.8
		Remainder						
Elandskloof							4.7	
Clanwilliam Dam pumps								
Clanwilliam Dam and canal (4)					124.0	2.0	122.0	
Clanwilliam Dam	Upstream Bulshoek Barrage			21.6				
Bulshoek Barrage (4)					5.4	0.6	4.8	
Doring River								
Bulshoek Barrage	Estuary (excluding Doring River)							

Flows and Rain20.xls sheet "HydroSummary

1. Table 26.1 of *Review of demands for the Olifants River Catchment upstream of Bulshoek Weir* by James Cullis. The 42.8 is obtained from summing 10.75 and 32.02 in Table 26.1 and the 26.71 is similarly obtained from summing 6.72 and 19.99
2. Coverage of farm dams upstream of Clanwilliam Dam produced by DWAF (2006) (see DWAF, 2006)
3. Dams were identified by Gerrit van Zyl in consultation with irrigators along the Olifants River
4. DWAF (Jan 2007) Updated information on the Feasibility Design of Clanwilliam Dam. Memorandum from F Druyts to Options Analysis (Alan Brown) dated 25 Jan 2007 (Ref 20/2/E100-02/C/1/0) (DWAF, 2007).
5. Estimated using the unaccounted for losses between Clanwilliam Dam and Bulshoek (see **Section 3.2.2**).

Table 2.5 The revised catchment developments incorporated into this study

Reach			Mass Balance					Additional details			
				Usage							
From	To	Portion	Natural inflows	Supply	Evaporation	Return flows	Nett inflow	Cumulative inflow	Reference node or channel (ch-) with corresponding cumulative flow in 400418/ym/v8/ps149 See Annexure Error! Reference source not found.	Apportioned revised demand	Revised nett dam capacities
			Mm³/a	Mm³/a	Mm³/a	Mm³/a	Mm³/a	Mm³/a		Mm³/a	Mm³
Column A	B	C	D	E	F	G	H	I	J	K	L
Agter Witzenberg upstream prop Rosendal Dam		u/s farm dams	10.6	-4.1	-0.5		6.0	6.0	d/s 1	8.7	3.8
		Remainder	20.9	0			20.9	26.9	d/s 2	0.0	
Rosendal	Visgat		32.4	0			32.4	59.3	d/s 7	0.0	
Bo Boschkloof			10.1	-7.9	-0.7		1.5	60.8	d/s 5	16.0	14.7
Visgat	Grootfontein		79.4	0			79.4	140.2	d/s 6		
Grootfontein	Keerom (Ratel River)		13.4	-1.4	-0.3		11.7	151.8	d/s 7	1.4	0.8
Keerom	Downstream Hex River confluence (EWR site 1)	u/s farm dams	12.3	-9.5	-2.5		0.3	152.1		9.5	9.5
		Remainder	141.2	-23.3			117.9	270.1	d/s 10	33.2	
Rondegat River (upstream EWR 3)			7.3	0			7.3	7.3	d/s 64		
Downstream Hex River	Upstream Clanwilliam Dam	u/s farm dams	2.1	-1.2	-0.2		0.7	278.1		2.1	0.8
		Remainder	80.6	-2.9			77.7	355.7		2.9	
Elandskloof			21.2	-8.4			12.8	368.5	d/s 19	17.6	4.7
Clanwilliam Dam pumps			0.0	-4.0			-4.0	364.5		4.0	
Clanwilliam Dam and canal			0.0	-9.7	-14.4		-24.1	340.4	d/s 11	9.9	122.0
Clanwilliam Dam	Upstream Bulshoek Barrage		77.4	-21.5	-2.5		53.5	393.9		21.6	
Bulshoek Barrage			0.0	-138			-138.0	255.9	d/s 13	139.1	4.8
Doring River			515.4	-98.0	-12.2	0.0	405.2	405.2	d/s 57	128.0	134.2
Bulshoek Barrage	Estuary (excluding Doring River)		30.9	-3.5		29.3	56.7	717.8	ch 164	3.5	
Total			1055.2	-333.4	-33.3	29.3	717.8			397.7	295.4

Flows and Rain17.xls sheet "HydroSummary"

2.4 Rainfall

The initial hydrology prepared by BKS as part of the *Olifants River System Analysis* (DWAF, 1990) used rainfall records available from a number of sources :

- DWAF
- Agricultural Research Council (ARC)
- Weather Bureau, and
- Computing Centre for Water Research (CCWR)

Subsequently, the CCWR was disbanded and most of DWAF's rainfall gauges in the area were closed. This study reviewed the available rainfall, even though it was not intended to calibrate the catchments. The available data is summarised in **Table 2.7** and the location of the rain stations is indicated in **Figure 2.2**. A large proportion of the rainfall used in the Olifants River System Analysis was based on "public appeal" data that was collected by the CCWR. This information was stored on the CCWR's UNIX system but no funds were made available to maintain the rainfall database. A cursory check of the data currently available on the CCWR's obsolete Unix system by Mark Horan of the University of KwaZulu-Natal could not locate the public appeal data. The data was also not incorporated into Lynch's database of patched daily rainfall or the DWAF's Water Resource Information System (WRIMS) which houses 13 000 rain stations. Appendix B from the original *Olifants River System Analysis Report* (DWAF, 1990) contains catchment rainfall prepared from combining the different rainfall stations but not the individual rainfall data. The *Physical Characteristics and Present Land-use* report (PGWC, 2001a) mentions that Appendix B contained "statistics" for the CCWR rainfall but the appendix was not supplied with the report.

The steep mountain ranges that flank the Olifants River intercept the rainfall and make a major contribution to the runoff from the catchment. However, the rainfall gauges are located near urban and agricultural centres and do not measure the mountain rainfall which must be deduced from rainfall on either side of the mountains. This problem was experienced in the earlier calibrations that focussed on reconciling the runoff generated by the Pitman Model with the known runoff into the Clanwilliam Dam. Although the inflow to the Clanwilliam Dam is well represented, the actual runoff in certain reaches is probably under-estimated because the rainfall was under-estimated. For instance, **Table 2.5** shows that only about half of the irrigation demands of 16 and 17.6 million m^3/a appear to be supplied in the Bo-Boschkloof and Elandskloof catchments (compare Columns E and K). This is unlikely and is probably due to the inflows/rainfall being under-estimated.

Rain gauges located in the mountains or at the extremities of the catchment would improve the modelling of the rainfall/runoff relationship in the catchment. An effort should be made to collect public appeal data for these and other stations representing rainfall in the more mountainous areas. The stations at Die Berg, Soetfontein and Zoovoorbij may be useful but there may be more suitable gauges in more remote areas. The long period recorded by the gauge of Brakfontein Landgoed is also valuable.

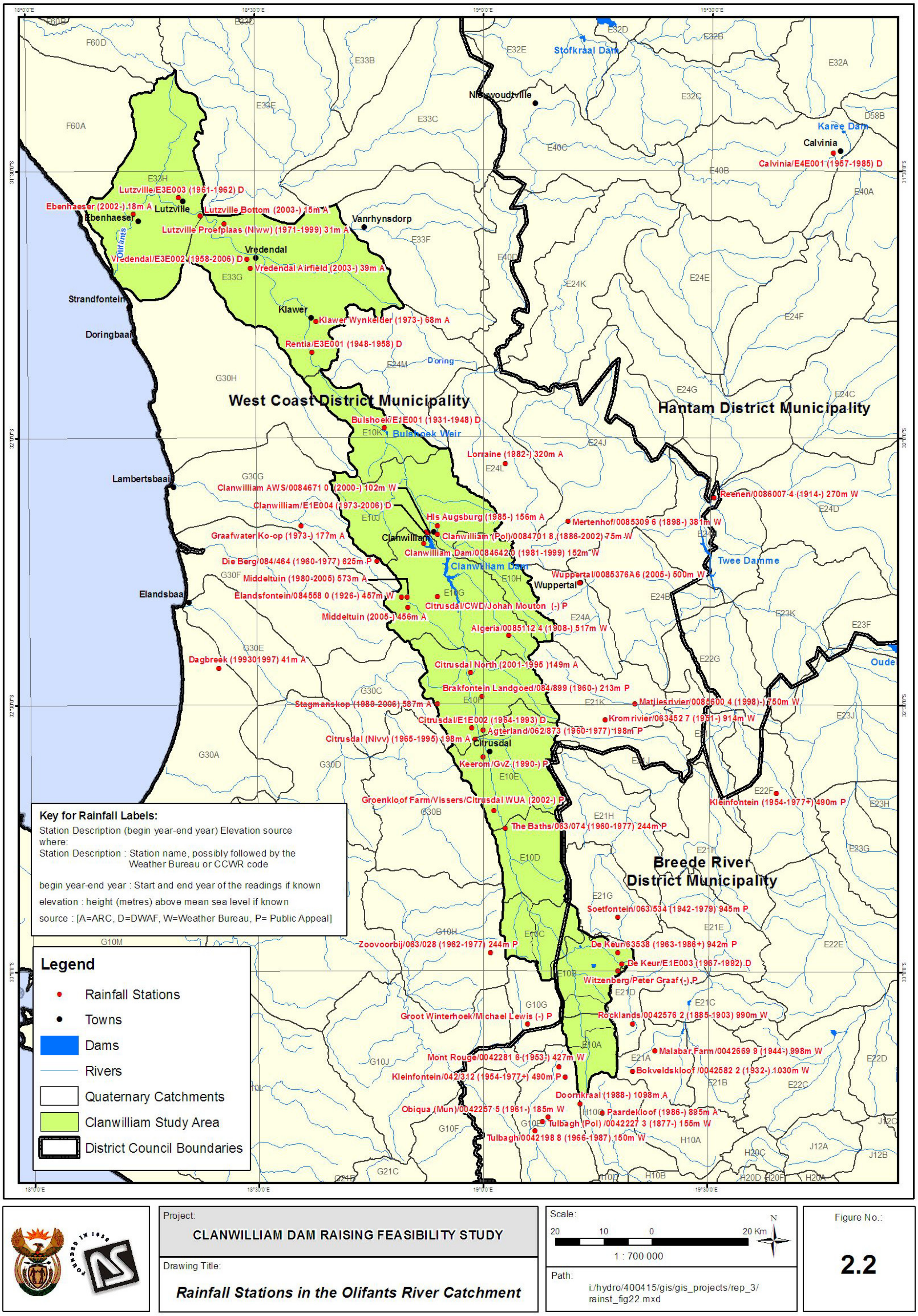


Figure 2.2 Rainfall stations in the Olifants River catchment

Though the rain stations were not used with the Pitman Model to calibrate the catchment, a representative set was used to estimate the relative monthly and annual rainfall upstream of the Clanwilliam Dam. The monthly rainfall at each selected station was expressed as a percentage of its mean annual precipitation (MAP). Thereafter, the average MAP at the northern, central and southern portions of the catchment was determined:

- Northern portion - average of Algeria and Clanwilliam (Pol)
- Central portion - Brakfontein
- Southern portion - average of Bokveldskloof and Tulbach (Pol)

The values of the northern, central and southern portions were in turn averaged to obtain the monthly rainfall (as a %MAP) for the catchment upstream of Clanwilliam Dam.

Table 2.6 Determination of monthly rainfall upstream of Clanwilliam Dam

<table>
<tr><th colspan="2">Preparation of the Clanwilliam rain data</th><th colspan="2">Preparation of the north, central and south rain data</th><th>Rain station (expressed as a percentage of its MAP)</th></tr>
<tr><td rowspan="5">Upstream Clanwilliam Dam (average of the north/central and south rainfall data)</td><td rowspan="5">Patch and Average</td><td rowspan="2">North</td><td rowspan="2">Patch and Average</td><td>Algeria</td></tr>
<tr><td>Clanwilliam (Pol)</td></tr>
<tr><td>Central</td><td></td><td>Brakfontein</td></tr>
<tr><td rowspan="2">South</td><td rowspan="2">Patch and Average</td><td>Bokveldskloof</td></tr>
<tr><td>Tulbach (Pol)</td></tr>
</table>

Table 2.7 Rainfall stations in the Olifants River Catchment

Location	* = Used in 1990	Latitude (decimal degrees)	Longitude (decimal degrees	Source	Reference no	Open	Closed	Elevation (m)	Description
Agricultural Research Council									
Stagmanskop	*	-32.5000	18.9000	A	20127	1989	2006	587	Stagmanskop, Citrusdal
Citrusdal (Nivv)	*	-32.5667	18.9833	A	20019	1965	1995	198	Citrusdal Proefplaas, Citrusdal
Citrusdal North	.	-32.4419	18.9723	A	30462	2001	1995	149	Citrusdal North, Groot Hex Rivier
Ebenhaeser	.	-31.5810	18.2347	A	30400	2002	.	18	Ebenhaeser, Sandveld
Lutzville Bottom	.	-31.5854	18.3808	A	30605	2003	.	15	Lutzville Proefplaas, Lutzville
Vredendal Airfield	.	-31.6838	18.4907	A	30606	2003	.	39	Vredendal Vliegveld, Vredendal
Lutzville Proefplaas (Niww)	.	-31.6000	18.4333	A	20035	1971	1999	31	Lutzville Proefplaas
Dagbreek	.	-32.4333	18.4167	A	21224	1993	1997	41	Dagbreek, Clanwilliam
Graafwater Ko-Op	.	-32.1667	18.6000	A	20069	1973	.	177	Graafwater Ko-Op, Graafwater
Klawer Wynkelder	.	-31.7833	18.6333	A	20073	1973	.	68	Klawer Wynkelder, Klawer
Middeltuin	.	-32.3000	18.8333	A	20124	1980	2005	573	Middeltuin, Clanwilliam
Middeltuin	.	-32.3201	18.8347	A	30718	2005	.	456	Middeltuin, Clanwilliam
Hls Augsburg	.	-32.1667	18.9000	A	20145	1985	.	156	Hls Augsburg, Clanwilliam
Lorraine	.	-32.0500	19.0500	A	20133	1982	.	320	Lorraine, Clanwilliam
Doornkraal	.	-33.2500	19.2167	A	20172	1988	.	1098	Doornkraal
Paardekloof	.	-33.2667	19.2667	A	20152	1986	.	895	Paardekloof
Department of Water Affairs									
Lutzville	.	-31.5500	18.3333	D	E3E003	1961	1962		E3E003, Lutzville
Vredendal	.	-31.6667	18.4833	D	E3E002	1958	2006		E3E002, Vredendal
Rentia	.	-31.8417	18.6250	D	E3E001	1948	1958		E3E001, Rentia
Clanwilliam	.	-32.1792	18.8750	D	E1E004	1973	2006		E1E004, Andriesgrond at Clanwilliam Dam
Citrusdal	.	-32.5458	18.9750	D	E1E002	1964	1993		E1E002, Citrusdal
De Keur	.	-32.9875	19.3083	D	E1E003	1967	1992		E1E003, De Keur at Kouebokkeveld
Calvinia	.	-31.4667	19.7667	D	E4E001	1957	1985		E4E001, Calvinia
Bulshoek	.	-31.9833	18.7833	D	E1E001	1931	1948		E1E001, Bulshoek
South African Weather Services									
Clanwilliam (Pol)	*	-32.18	18.90	W	0084701 8	1886	2002	75	Clanwilliam (Pol)
Clanwilliam Dam	.	-32.20	18.87	W	0084642 0	1981	1999	152	.
Clanwilliam AWS	.	-32.18	18.88	W	0084671 0	2000	.	102	.
Algeria	*	-32.37	19.06	W	0085112 4	1908	.	517	Algeria
Obiqua (Mun)	*	-33.28	19.15	W	0042257 5	1961	.	185	Obiqua (Mun)
Tulbagh	.	-33.30	19.12	W	0042198 8	1966	1987	150	Tulbagh (Pol)
Tulbagh (Pol)	*	-32.285	19.14	W	0042227 3	1877	.	155	.
Rocklands	*	-33.10	19.33	W	0042576 2	1885	1903	990	Rocklands
Bokveldskloof	*	-33.19	19.33	W	0042582 2	1932	.	1030	Bokveldskloof
Malabar Farm	*	-33.15	19.38	W	0042669 9	1944	.	998	Malabar Farm
Reenen	.	-32.11	19.51	W	0086007 4	1914	.	270	.
Wuppertal	.	-32.27	19.21	W	0085376A6	2005	.	500	.
Matjiesrivier	.	-32.50	19.34	W	0085600 4	1998	.	750	.
Mertenhof	.	-32.16	19.19	W	0085309 6	1898	.	381	.
Probably available but not received.									
Elandsfontein	*	-32.30	18.82	W	084558 0	1926	.	457	Elandsfontein
Kromrivier	*	-32.53	19.27	W	063452 7	1951	.	914	Kromrivier
Mont Rouge	*	-33.18	19.17	W	0042281 6	1953	.	427	Remhoogte
Public Appeal									
Received	.	.	.	.	.	.	.	.	.
Brakfontein Landgoed	*	-32.49	19.00	P	084/899	1932	.	213	Brakpan Landgoed
Groenkloof Farm	.	-32.70	19.03	P	.	2002	.		Vissers on Groenkloof Farm near hot water springs
The Baths	*	-32.73	19.05	P	063/074	1960	1977+	244	The Baths(S/W Citrusdal), contact details
Keerom	.	-32.60	19.00	P	GvZ	1990	.	.	Keerom, Citrusdal
Not received	.	.	.	.	.	.	.	.	.
Die Berg	*	-32.23	18.77	P	084/464	1960	1977+	625	Die Berg
Zoovoorbij	*	-32.97	19.02	P	063/028	1962	1977+	244	Zoovoorbij
Soetfontein	*	-32.90	19.30	P	063/534	1942	1979+	945	Soetfontein

Location	* = Used in 1990	Latitude (decimal degrees)	Longitude (decimal degrees	Source	Reference no	Open	Closed	Elevation (m)	Description
Citrusdal/CWD	.	-32.30	18.90	P	.	.	.	.	Johan Mouton Halfway between Citrusdal and Clanwilliam Dam
Witzenberg	.	-33.00	19.30	P	.	.	.	.	Peter Graaff : Witzenberg
Groot Winterhoek	.	-33.10	19.10	P	.	.	.	.	Michael Lewis : Groot Winterhoek
Kleinfontein	*	-33.20	19.18	P	042/312	1954	1977+	490	Kleinfontein
Agterland	*	-32.55	19.00	P	062/873	1960	1977+	198	Agterland
De Keur	*	-32.9667	19.3000	P	63538	1963	1986+	942	De Keur
Kleinfontein	*	-32.67	19.65	P	042/312	1954	1977+	490	Kleinfontein

(1) (P=Public appeal, D=DWAF, W=South African Weather Services, A = ARC)

2.5 Streamflow gauges

The streamflow gauges in the vicinity of the Olifants River are listed in **Table 2.8** and mapped in **Figure 2.3**. The terms of reference did not require that the hydrology of the Olifants River be extended but because of the severe nature of the drought in 2003/5 the observed streamflow records were used to estimate the runoff into the catchment. This entailed estimating the inflow into Clanwilliam Dam, the streamflows in the Doring River and the accruals further downstream. As part of this process some shortcomings in the existing records were identified and these are summarised briefly in **Table 2.9**.

Table 2.8 Streamflow gauges in the vicinity of the Olifants River Catchment

Gauge Name	Location	Lat (decimal)	Long (decimal)	Start	End	Area upstream (km^2)
E1H001	Olifants River at Langkloof	-32.047	18.824	1910	1937	2659
E1H002	Tee River at Thee Rivier	-32.800	19.088	1938	1943	45
E1H003	Noordhoeks River at Misgunst	-32.721	19.067	1938	1943	68
E1H004	Boontjies River at Allendale	-32.631	19.071	1938	1943	61
E1H005	Olifants River at Keerom	-32.853	19.084	1938	1943	532
E1H006	Jan Dissels River at Clanwilliam	-32.212	18.937	1971	2006	160
E1H007	Left canal from Bulshoek Dam at Kromme Valley	-31.995	18.787	1921	2006	
E1H008	Right canal from Clanwilliam Dam at Andriesgrond	-32.184	18.875	1935	2006	
E1H009	Turbine-outlet (right) at Andriesgrond	-32.185	18.875	1939	1991	
E1H010	Right pipeline from Clanwilliam Dam at Andriesgrond	-32.185	18.875			
E1H011	Olifants River at Andriesgrond	-32.185	18.875	1935	1997	2033
E1H012	Tributary of Noordhoeks River at Misgunst	-32.721	19.067	1938	1943	
E1H013	Olifants River at Citrusdal	-32.596	19.008	1992	2006	880.8
E1H014	Pipeline to Leisure Resort at Andriesgrond	-32.185	18.875			
E1H015	Olifants River at Rosendaal	-33.128	19.235	1996	2002	
E1H016	Olifants River at Andriesgrond	-32.184	18.874	2001	2006	
E1H017	Olifant River at Bulshoek Dam	-31.992	18.789	2004	2005	
E2H001	Doring River at Elands Drift	-32.541	19.569	1908	1924	3774
E2H002	Doring River at Elands Drift	-32.503	19.535	1923	2006	6903
E2H003	Doring River at Melkboom	-31.863	18.686	1908	2006	24044
E2H004	Tankwa River at Elandsvlei	-32.321	19.588	1929	1948	6426
E2H005	Little Brak River at Schoor Kraal	-31.932	19.758	1928	1947	85
E2H006	Kruis River at De Kruis	-33.149	19.374	1929	1982	40
E2H007	Leeu River at Leeuw River	-32.780	19.283	1930	2006	265
E2H008	Riet River at De Naauwte	-32.861	19.517	1935	1970	1178
E2H009	Inverdoorn Canal at Uitkomst	-33.296	19.636	1973	2006	
E2H010	Kruis River at Ebenhaeser	-33.115	19.393	1982	2006	76
E2H011	Doring River at Melkboom	-31.860	18.688	1948	1957	24044
E2H012	Right canal from Kruis River at De Kruis	-33.149	19.374	1960	1982	
E2H013	Left canal from Kruis River at De Kruis	-33.149	19.374	1980	1982	
E2H014	Olifants River at Olifants Mond	-31.704	18.190	2001	2006	
E2H015	Olifants River at Lutzville	-31.565	18.331			
E2H016	Olifants River at Lutzville	-31.565	18.331	2002	2004	
E3H001	Troe-Troe River at Farm 256	-31.626	18.695	1982	2006	746
E3H002	Hantams River at Brakke Rivier	-31.222	19.471	1990	2006	1731
E3H003	Olifants River at Lutzville	-31.579	18.358			48146
E3H004	Olifants River at Lutzville	-31.565	18.328	2002	2006	
E4H001	Oorlogskloof at Calvinia	-31.479	19.783			970
E4H002	Pipeline from Karee Dam at Akkeren Dam	-31.428	19.789			
E4H003	Koebee River at Kobe	-31.644	19.059			2416
G1H002	24 Rivers	-33.134	19.060	1951	1960	
G1H028	24 River downstream canal	-33.135	19.061	1972	2007+	
G1H058	24 Rivers canal	-33.139	19.060	1972	2007+	

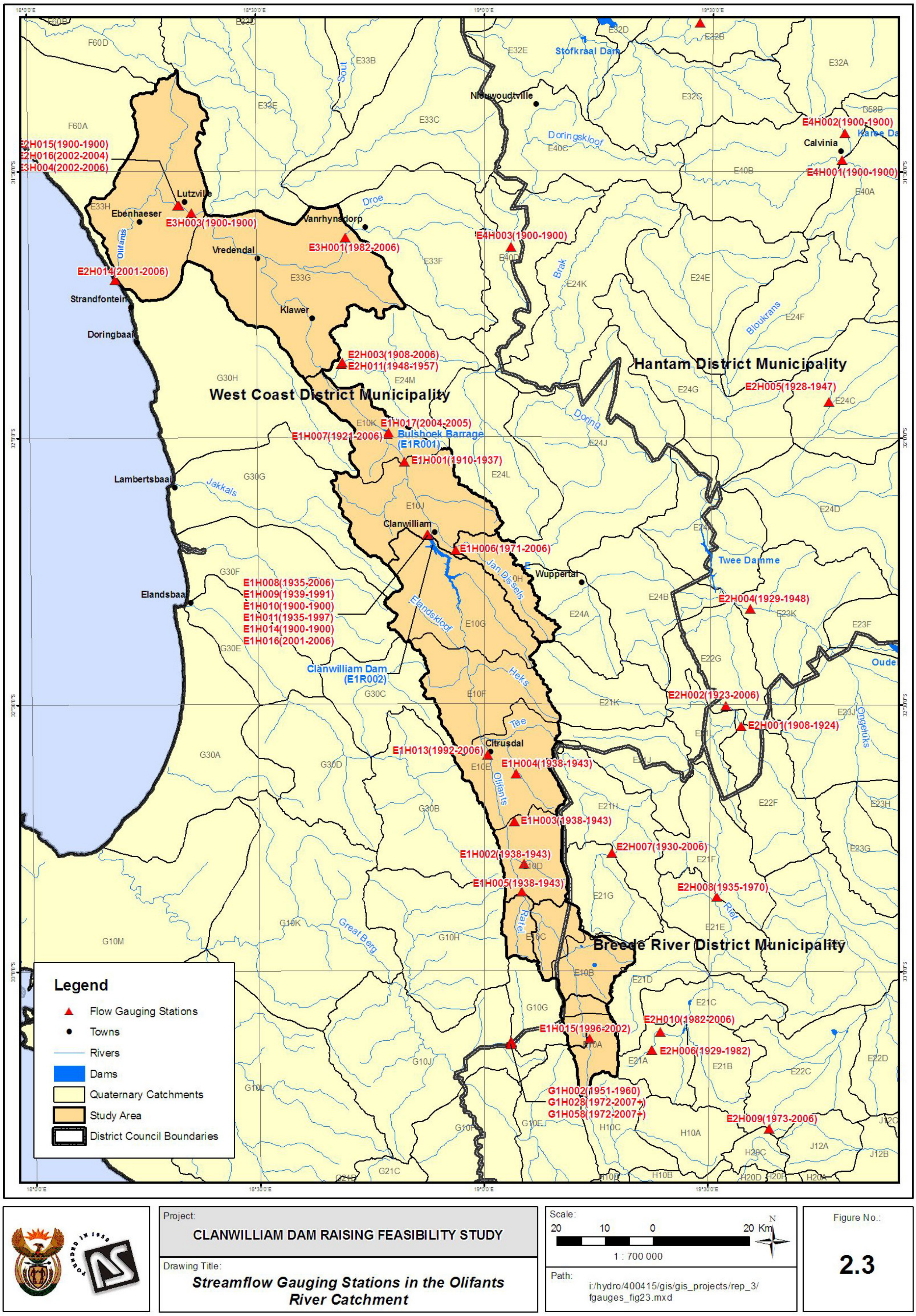


Figure 2.3 Streamflow gauging stations in the Olifants River catchment

Table 2.9 Observations concerning selected gauges in the Olifants/Doring catchment

Code	Description	Comment	Reference
E1H006	Jan Dissels River at Clanwilliam	Reliable. Missing 1971 to 1977	
E1H007	Left canal from Bulshoek Dam at Kromme Valley	Reliable	
E1H008	Right canal from Clanwilliam Dam	Reliable	
E1H009	Turbine-outlet from Clanwilliam Dam		
E1H010	Right pipeline from Clanwilliam Dam		
E1H011	spill/releases from Clanwilliam Dam	Seems unreliable. Too close to dam and does not always match downstream flows. Turbine outlet E1H009 exits below E1H011 and is excluded from this reading	See **Section 2.5.1**
E1H013	Olifants River at Citrusdal	No weir - rated section on a mobile river bed	
E1H016	spill/releases from Clanwilliam Dam	Reliable	
E1H017	Olifants River at Bulshoek	Readings halted until leak through weir foundation fixed	
E2H002	Doring River at Elands Drift	Poor before about 1960	See **Section 2.5.3**
E2H003	Doring River at Melkboom	Reliable	
E3H004	Olifants River at Lutzville	Debris from floods blocks the causeway openings and the pipe for sensing water level. If cleaned at start of summer, the gauge may provide a reasonable reading until the next flood.	See **Section 2.5.2**
G1H002	24 Rivers	Excess flows returned from canal to river at the sandtrap are not measured in the canal G1H058 nor in the river at G1H028	
G1H028	24 River downstream canal		
G1H058	24 Rivers canal		

2.5.1 Gauge E1H011

This gauge measured the spills and most of the releases from the Clanwilliam Dam (with the exception of the hydropower release E1009 which joined the Olifants River downstream of E1H011). The rated capacity of the gauge was frequently exceeded (see **Figure 2.4**) and the measured flows sometimes exceeded the abstractions and increase in storage further downstream at the Bulshoek Barrage (**Figure 2.5**).

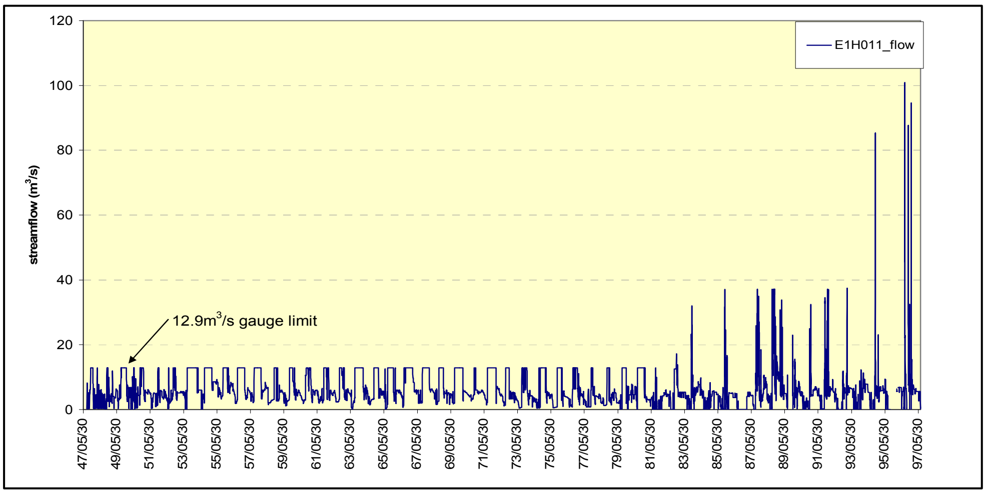


Figure 2.4 Daily record of gauge E1H011 (Clanwilliam Dam releases excluding hydro-power component)

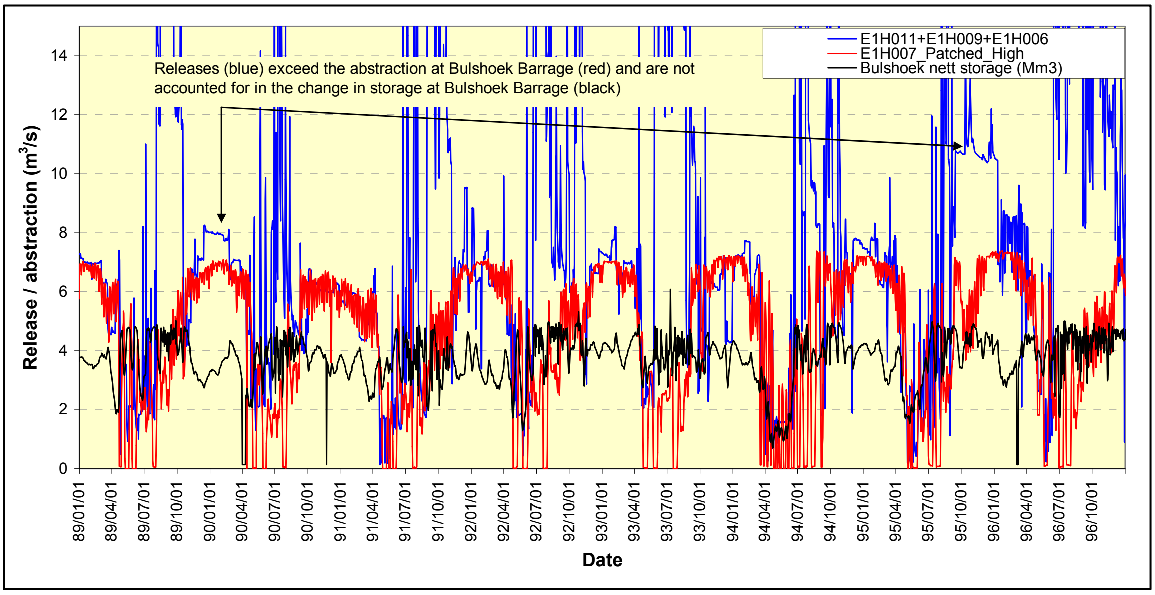


Figure 2.5 Comparison of daily records at gauges E1H011 (Clanwilliam releases) and EH007 (Bulshoek canal abstraction)

2.5.2 Gauge E3H004 : Causeway at Lutzville

Gauge E3H004 measures the flow passing under the causeway at Lutzville. Unfortunately, the floods during winter carry a large amount of debris that block the narrow culverts under the causeway and the narrow pipe used to sense the water level at the causeway. As a result, the flow appears to remain constant after a flood event. However, providing the causeway is cleaned at the end of winter, the gauge does provide a reasonable indication of the flows at the causeway until the next flood, usually at the end of summer. These flows compare favourably with the isolated estimates made by the CSIR in 2004 and by Ninham Shand in 2006.

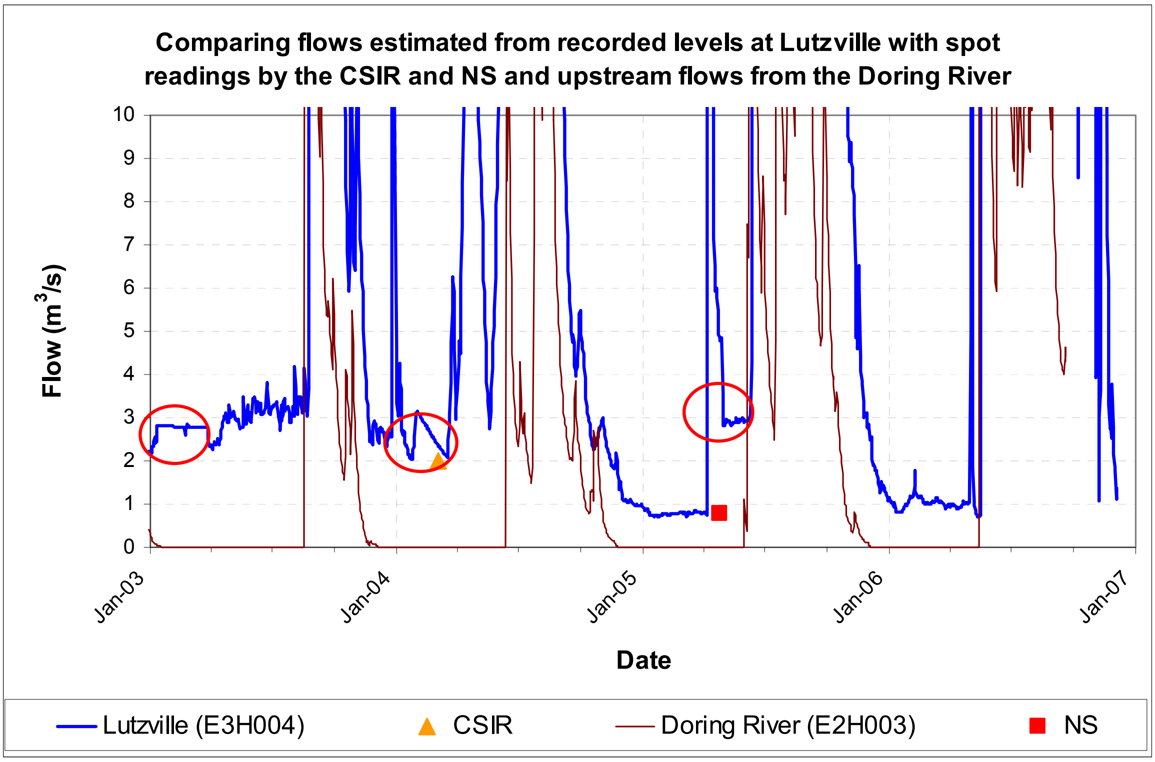


Figure 2.6 E3H004 at Lutzville causeway

2.5.3 Gauge E2H002 : Elandsdrift on the Doring River

Figure 2.7 compares the flows at the Elandsdrift (blue) and Melkboom (red) sites on the Doring River. Prior to 1960, the Elandsdrift flows appear to reach and be capped by the 220 m^3/s level more frequently than later. **Figure 2.8** shows that the relationships between the streamflows at Elandsdrift and Melkboom are similar for the period prior to, and the period after, 1960 and follow the blue and the red trendlines respectively. However, prior to 1960 the relationship is far more erratic as is shown by the wider scatter of the blue dots relative to the red dots. One might surmise that the reading of the gauge was not automated prior to that date but this has not been confirmed. **Figure 2.9**, a cumulative mass plot for gauge E2H002, shows a marked discontinuity or kink around 1960. This indicates that the flows measured at E2H002 decreased after 1960 and that the flows prior to 1960 were probably over-estimated.

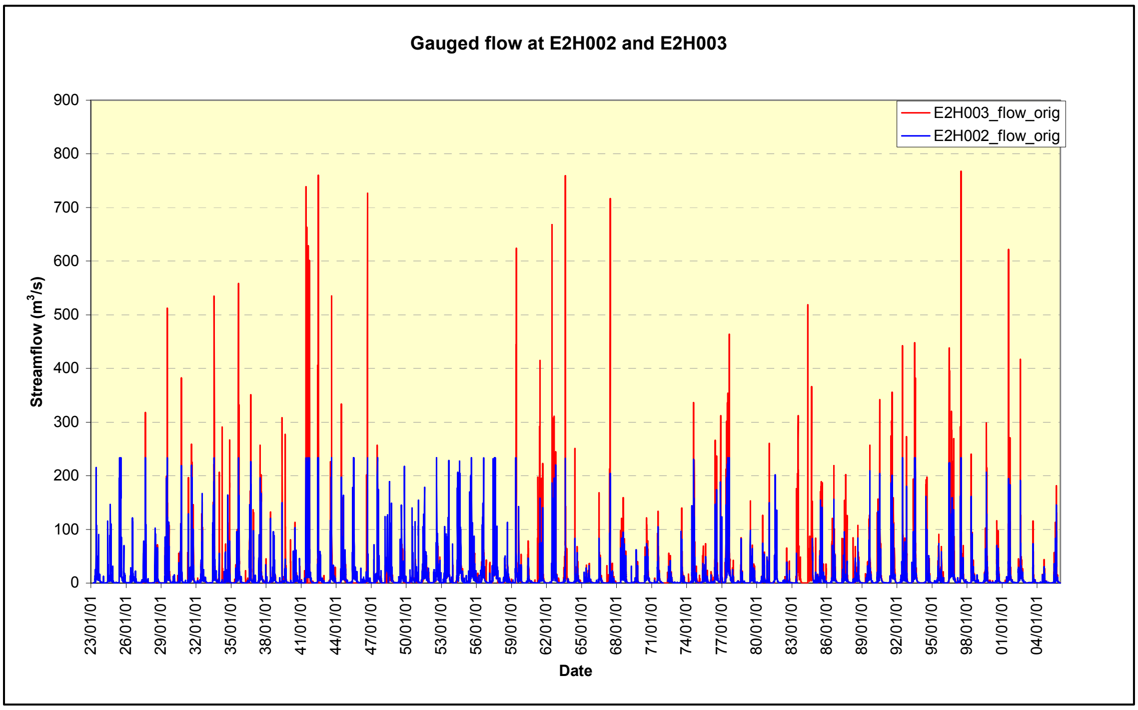


Figure 2.7 Comparison of daily record of gauge E2H002 and E2H003 in the Doring River

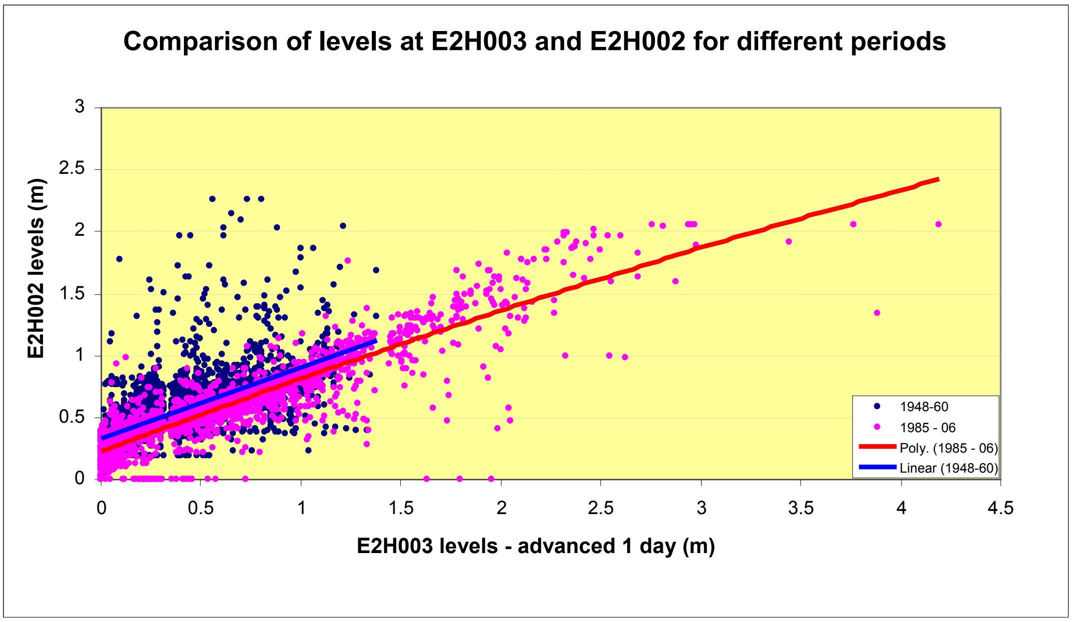


Figure 2.8 Comparison of levels record at gauges E2H002 and E2H003

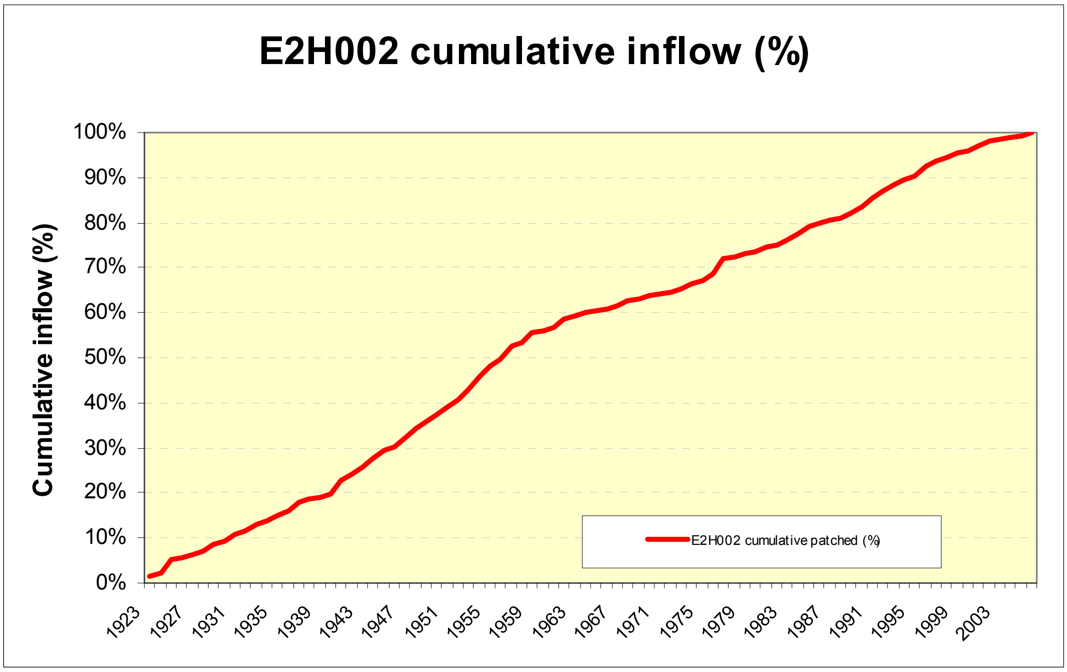


Figure 2.9 Cumulative flows at gauge E2H002

3. CURRENT OPERATION

3.1 Upstream of Clanwilliam Dam

The irrigation upstream of the Clanwilliam Dam cannot be sustained by the summer streamflows of the river alone. Many farmers have constructed off-channel dams to store winter water for use in the dry summer. The abstraction of water by the upstream users obviously impacts on the water available from the Clanwilliam Dam for downstream irrigators.

In the RSA Government Gazette of September 1987 (RSA, 1987), a Government Water Control Area (GWCA) was declared. The allocation of water per scheduled area within the GWA and north of the farm Grootfontein 514 was limited to 12 200 m^3/ha. The allocations of the remaining farms within the GWA (which were located south of Grootfontein 514) were limited to 9 400 m^3/ha.

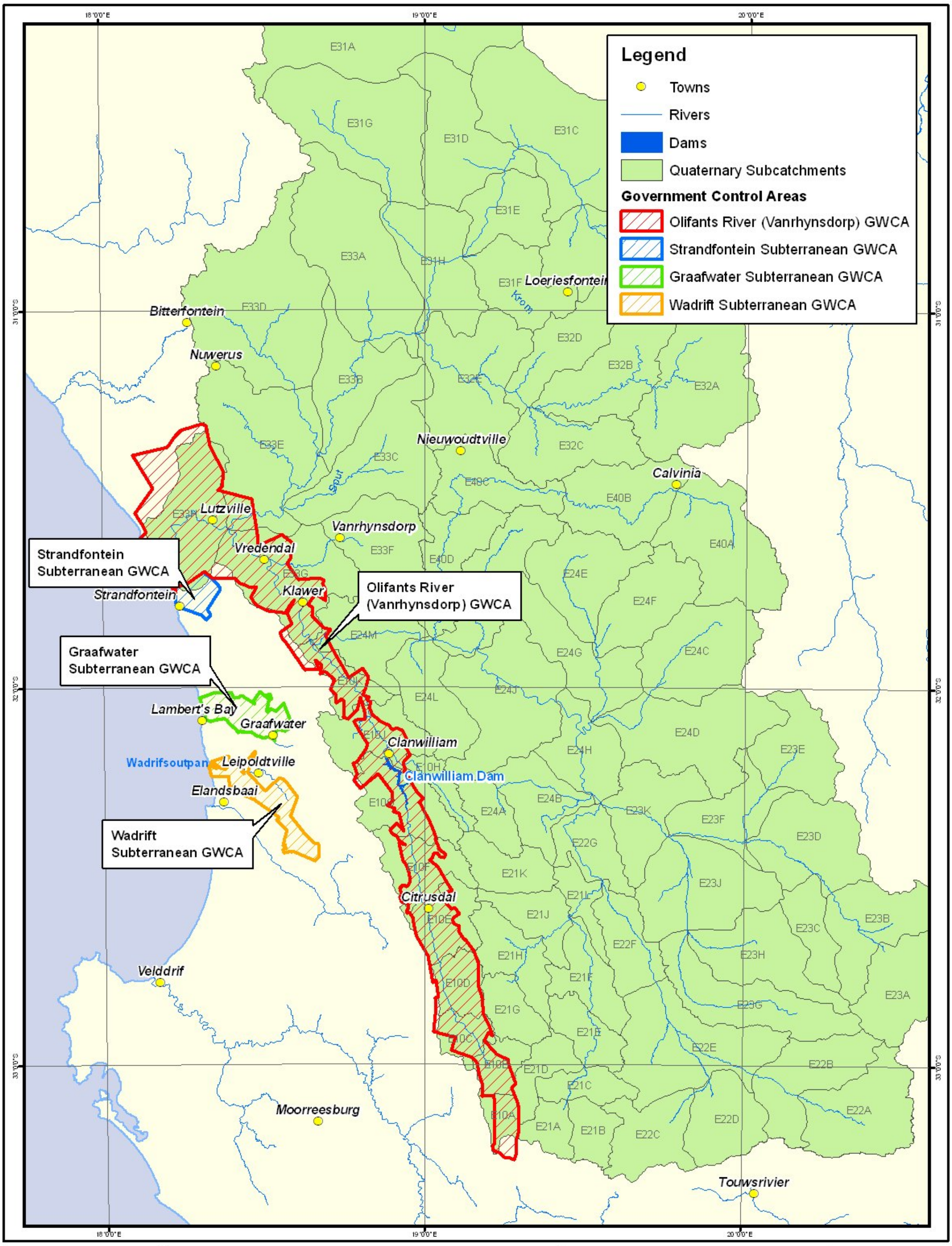
The permitted storage in farm dams above Clanwilliam Dam from these quotas is 6 000 m^3/ha/a for the areas falling within the Government Water Control Area (GWCA) (see **Figure 3.1**). This volume was estimated to be sufficient to irrigate the crops during the summer months when used in conjunction with the streamflows in the river.

Under the previous Water Act, a dam of up to 250 000 m^3 could be constructed in the tributaries outside the GWCA without a special permit which would have to be granted under Section 9b. This procedure has been superseded by the registration and licensing of existing water use being undertaken by DWAF.

As soon as the Olifants River starts flowing in winter, the farmers can pump water from the river for their dams and they must stop when the flow in the river is insufficient, normally around the end of October.

Figure 3.1 also shows three subterranean groundwater control areas at Strandfontein, Graafwater and Wadrift. Coastal towns depended on the groundwater resource and the GWCA was declared to try to prevent over-exploitation that would cause sea water to penetrate into the groundwater.

The Olifants River is perennial and during summer, the farmers abstract water according to a weekly cycle. For instance, the 10 farmers closest to the headwaters might be able to pump from midnight on Sunday to 18:00 on Monday. The farmers would either irrigate their lands or store the water in their dams. The next group of farmers further downstream would then have a turn. The turns would move progressively downstream until all the farmers had had a turn. Each pump is fitted with a water meter that is read monthly or during periods of shortages, weekly. This summer water is shared in proportion to the farmer's scheduled area (pers comm, G van Zyl).



	Project: CLANWILLIAM DAM RAISING FEASIBILITY STUDY	Scale: 25 12.5 0 25 Km — 1 : 1 400 000	Figure No.:
	Drawing Title: ***Olifants River (Vanrhynsdorp) Government Control Areas***	Path: i:/hydro/400415/gis_projects/rep_3/gwca_fig31.mxd	**3.1**

The gauge located at Citrusdal shows the weekly cycle clearly as can be seen by examining the red line (**Figure 3.2** and **Figure 3.3**). The weekly peak flows correspond with periods when the upper irrigators leave water for the lower irrigators. This practice also has some benefit for the ecology as it ensures that pools along the river remain full for fish.

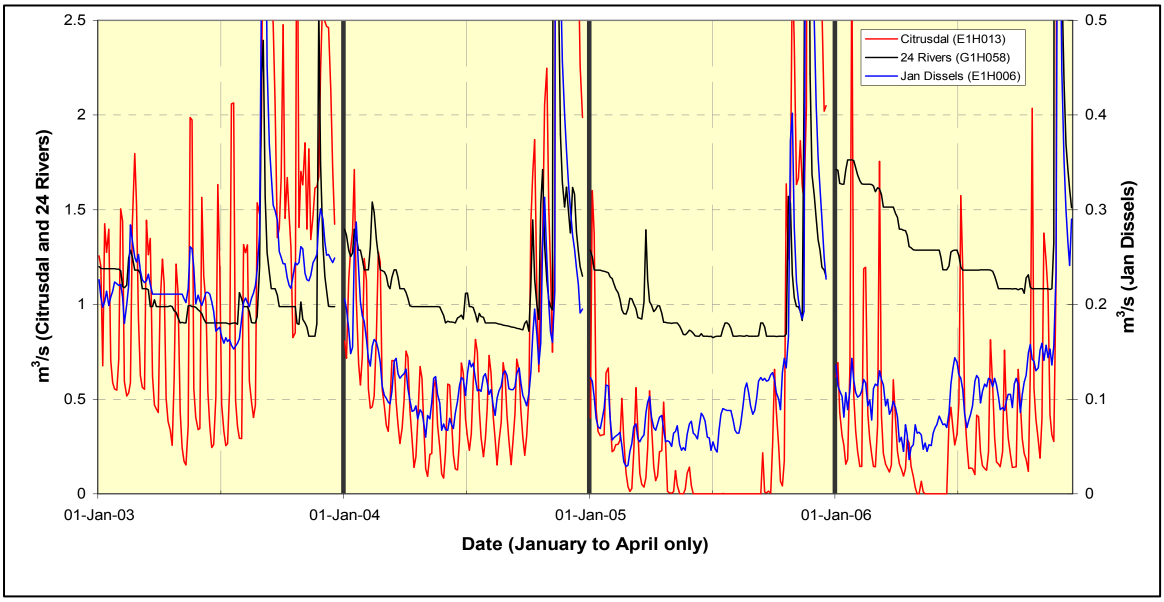


Figure 3.2 Comparing summer streamflows at Citrusdal with those at 24 Rivers and at Jan Dissels River (2003 - 2006)

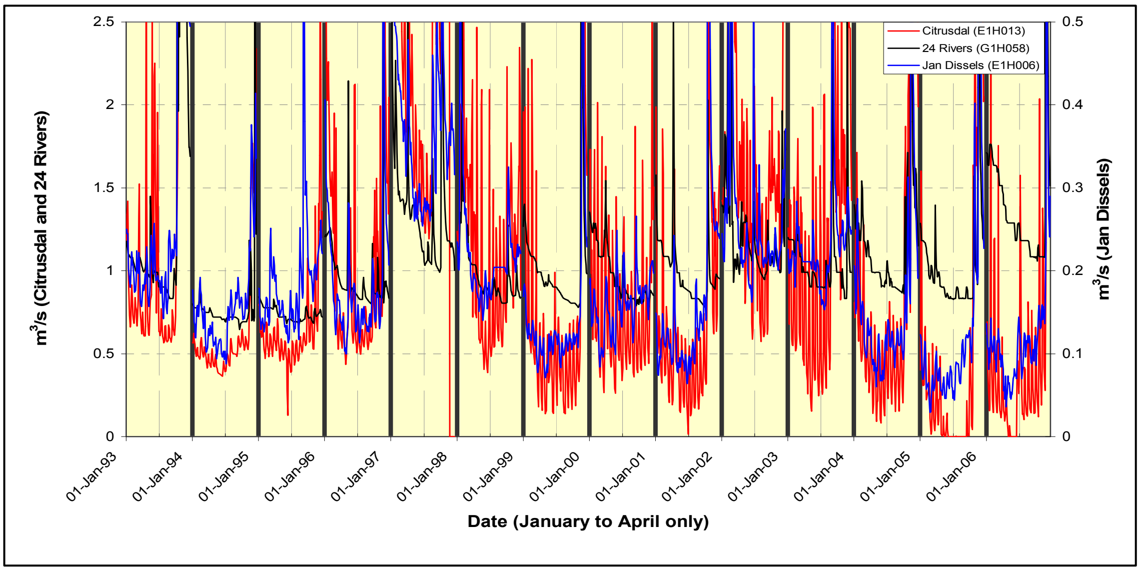


Figure 3.3 Comparing summer streamflows at Citrusdal with those at the 24 Rivers and at the Jan Dissels River

The period shown corresponds with the recent drought in the Olifants River when the Olifants River stopped flowing at the end of summer in 2005. The downstream farmers, such as those just upstream of the Watervalrivier near the turn-off to Algeria, were severely affected and resorted to excavating into the river to extract water for their crops with severe environmental impacts.

For interest, the corresponding flows in the Jan Dissels River (blue line using the rightmost flow axis) and the 24 Rivers (black line corresponding to the leftmost flow axis) have also been plotted. Neither of these records displays the same decrease in flow as the main stem of the

Olifants River. The ratios of the baseflows (from January to March) at Citrusdal (as measured by gauge E1H013) were compared with those in the Jan Dissels River (as measured at gauge e1H006) in **Figure 3.4**. The ratios corresponding to 2004 and 2005 are significantly lower than the other periods and it will be interesting to see if this trend continues in future years. The streamflow in the Jan Dissels River was also compared with the streamflow at the 24 Rivers and it appears that the streamflow may also be decreasing over time, possibly because of the drought but also possibly because of new abstractions upstream of the gauge in the Jan Dissels River (**Figure 3.5**).

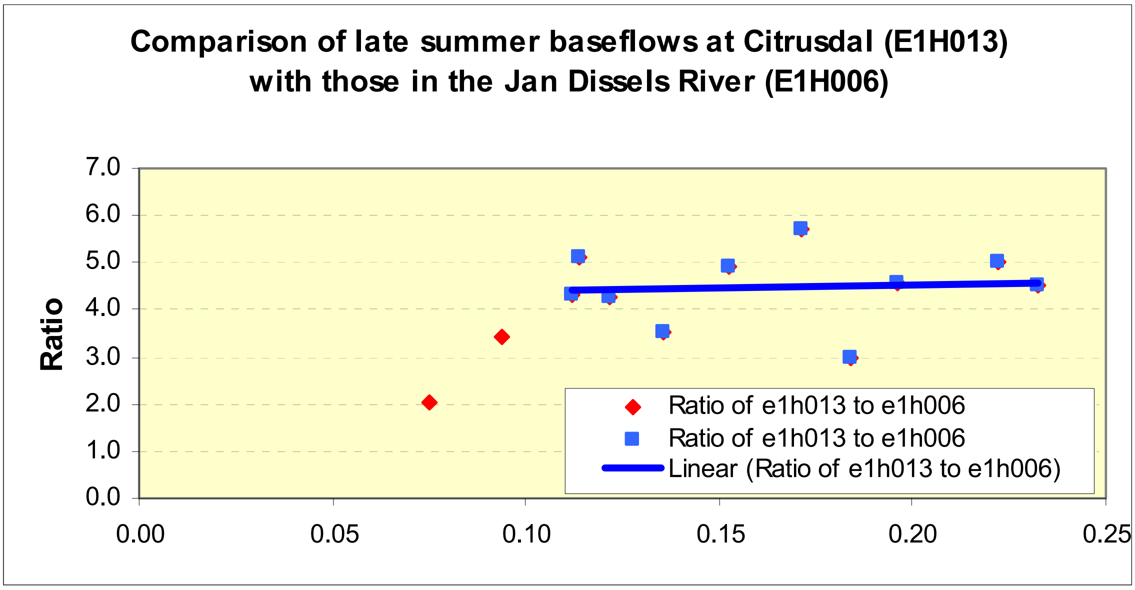


Figure 3.4 Comparison of late summer baseflows (January to March) at Citrusdal and those in the Jan Dissels River

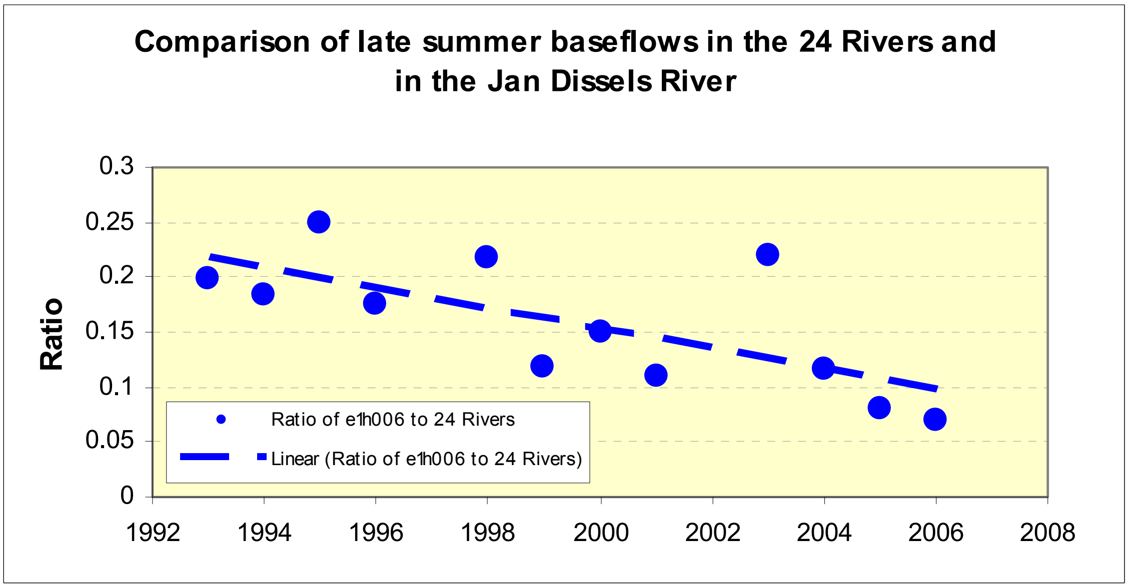


Figure 3.5 Comparison of late summer baseflows (January to March) in the 24 Rivers and in Jan Dissels River

The construction of shallow boreholes adjacent to the river needs to be investigated as these will impact on the streamflow. Water abstracted by these boreholes should be included with the farmer's summer allowance from the Olifants River and if this proves unworkable, then the boreholes should be closed.

3.2 Conjunctive operation of the Clanwilliam Dam and Bulshoek Barrage

3.2.1 Overview

Since about 1935, the Olifants River (Vanrhynsdorp) Government Water Control Area has developed to increase the reliability of the water supply to the irrigators downstream of Clanwilliam despite the increase in consumption in the upper reaches. The Clanwilliam Dam captures a portion of the winter flows of the Olifants River that are later released during summer to the irrigators located further downstream.

Most of the water is released to the Bulshoek Barrage 30 km downstream, from where it is diverted into the Bulshoek Canal. This canal follows the Olifants River for approximately 80 km. For the first 25 km a single canal flows on the left hand bank, but this bifurcates between Trawal and Klawer and one branch crosses over to the right bank. A number of towns (Vredendal, Lutzville, Vanrhynsdorp, Klawer, Ebenhaeser, Strandfontein, Doringbaai), the Namakwa Sands mine and the domestic requirements of farmers along the canal are also supplied from the Bulshoek Canal.

Some water is also released directly from the Clanwilliam Dam into the Clanwilliam Canal which runs for 12 km along the right bank of the Olifants River. The town of Clanwilliam prefers to use the cheaper water from the Jan Dissels River but when the streamflow is inadequate then the shortfall is obtained from the Clanwilliam Canal. A group of irrigators is also located around the Clanwilliam Dam and pump their water directly from the dam. Another group of irrigators is located between the Clanwilliam Dam and the Bulshoek Barrage and pump from the Olifants River or Jan Dissels River to irrigate their crops.

The Clanwilliam Dam was raised in the early 1960s by adding 13 wheel gates to the crest, each 8 metres wide by 3 metres high. The long-term historical supply from the scheme of about 126 million m^3/a is about 84% of the 150 million m^3/a allocated from the Lower Olifants River Water Scheme (LORGWS) as can be seen in Row E of **Table 3.1**.

Table 3.1 also provides a breakdown of the different demand components supplied (Rows A to D) and the losses in the system (Rows F to J). Some of the components such as the flows in the canals, are measured accurately using gauges. Other components, such as the abstractions by the Clanwilliam Water Users' Association (CWUA) (pumps around Clanwilliam Dam and between Clanwilliam and the Bulshoek Barrage), the unaccounted water between Clanwilliam and Bulshoek and the leakage from Bulshoek were only roughly estimated, as explained in **Section 3.2.2**. Together, the unaccounted-for water (UAW) and leakage at Bulshoek were assumed to equal 34 million m^3/a. Errors in their determination will affect the reliability of the yield of the LORGWS.

Figure 3.6 charts the annual water supply from 1980 to 2006 to the major consumers, namely:

- Bulshoek Canal
- Clanwilliam Canal
- Leakage through Bulshoek Barrage
- Net Evaporation from Clanwilliam Dam and the Bulshoek Barrage

- Pumping from Clanwilliam Dam and between Clanwilliam Dam and the Bulshoek Barrage, including abstraction from the Jan Dissels River and water usage by Clanwilliam Municipality and other unaccounted for abstractions

About 27% - 30% of the inflow to the Bulshoek and Clanwilliam Canals is lost through seepage and evaporation. These losses were deducted from the gross canal usage to obtain the net water consumption by agricultural and other users along the canals. **Figure 3.7** charts the net annual water supply from 1980 to 2006 to the major consumers, namely:

- Bulshoek Canal (excluding 27% canal losses)
- Clanwilliam Canal (excluding 30% canal losses)
- Pumping from Clanwilliam Dam down to the Bulshoek Barrage
- Losses

Figure 3.6 and **Figure 3.7** both show the fluctuation in the annual supply depending on the storage in Clanwilliam Dam.

The data used to construct **Figure 3.6** and **Figure 3.7** is provided in **Table 3.2** and **Table 3.3**. According to Row F of **Table 3.3** the consumption from September 2004 to October 2005 was about 71% of the long-term average.

Table 3.1 Average annual supply and allocations from Clanwilliam Dam and Bulshoek Barrage

Component	Row	Supply			Quota				
					Agricultural				
		Agricultural	Urban/ Industrial	Total	Scheduled area	Application rate	Agricultural allocation	Urban / Industrial	Total requirement
		Mm^3/a	Mm^3/a	Mm^3/a	Ha	m^3/ha	Mm^3/a	Mm^3/a	Mm^3/a
Clanwilliam Canal (excluding losses)	A	6.4	0.5[2]	6.9	734	12200	9.0	0.5[3]	9.5
CWUA Pumps around Clanwillaim Dam + Clanwilliam town from Jan Dissels	B	2.6	0.5[2]	3.1	253	12200	3.1	0.5[3]	3.6
CWUA Pumps: Clanwilliam Dam to Bulshoek	C	14		14.0	1315	12200	16.0		16.0
Bulshoek Canal (field edge + urban)	D	97	5.0[1]	101.7	9491	12200	115.8	8.4	120.8
Total Consumption	**E**	**120**	**6.0**	125.7	**11793**		**144**	**9.4**	**150**
Bulshoek + Clanwilliam canal losses	F	41		40.6					
Clanwilliam nett evaporation	G	13		12.8					
Bulshoek nett evaporation	H	3		3.0					
UAW between Clanwilliam and Bulshoek (1)	I	8		7.5					
Leakage from Bulshoek	J	26		25.9					
Total losses	**K**	**90**		**89.8**					
Total usage estimate	**L**	**210**	**6.0**	**215.5**					

1 From personal correspondence with J Matthee (LORWUA) the non-agricultural quota from the Bulshoek Canal is 8.4 million m^3/a. In 2007 about 60% of this allocation was required.
2 According to Appendix 9 in DWAF (2005a) the consumption by Clanwilliam in 1995 was 0.83 million m^3/a and would be constrained to 0;95 million m^3/a by the capacity of the water treatment works. It was assumed that half the demand was supplied from the Clanwilliam Canal and the remainder from the Jan Dissels River.
3 Allocation unknown – current consumption used instead

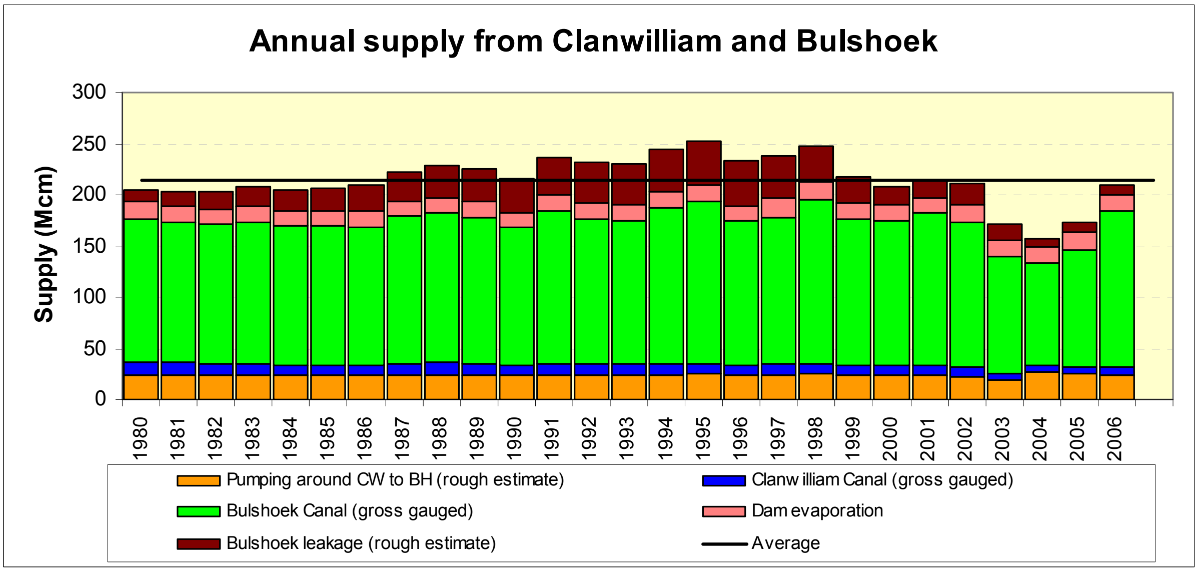


Figure 3.6 **Historical annual supply from Clanwilliam Dam and the Bulshoek Barrage**

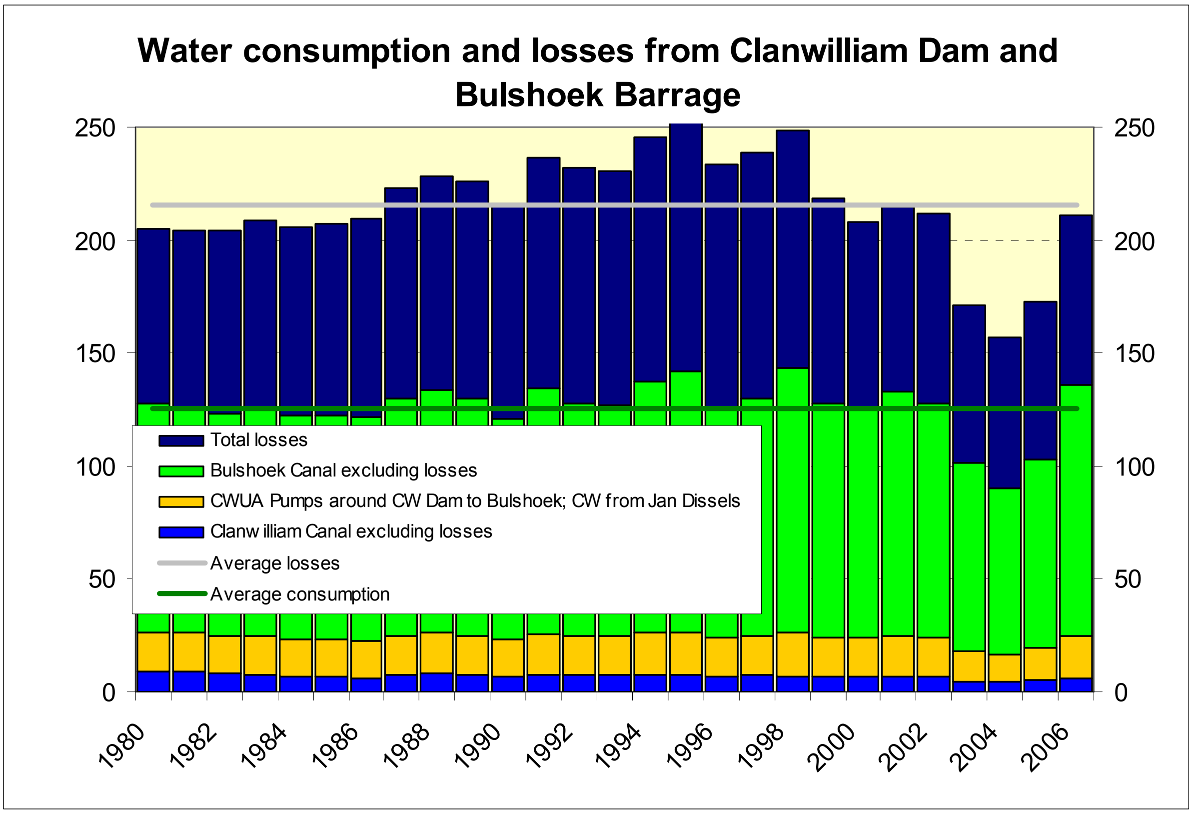


Figure 3.7 **Historical annual water consumption and losses from Clanwilliam Dam and Bulshoek Barrage**

Table 3.2 Gross supply from the Clanwilliam and Bulshoek Dams

Component	Row	Year starting September																											
		1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	Ave
Pumping (and unaccounted for water losses [UAW]) around CW to BH, incl. Clanwilliam Town	a	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	23	20	28	25	24	24.6
Clanwilliam Canal (gross gauged)	b	12	13	11	11	10	9	9	10	12	11	10	11	11	10	11	10	10	10	10	10	9	9	10	6	6	7	9	10
Bulshoek Canal (gross gauged)	c	140	136	135	139	136	136	136	144	147	144	134	149	141	140	152	158	140	143	161	142	141	148	142	114	100	114	152	139
Gross usage (before deducting canal losses)	**d**	**177**	**173**	**171**	**174**	**170**	**170**	**169**	**179**	**184**	**179**	**168**	**184**	**177**	**175**	**188**	**193**	**174**	**179**	**196**	**176**	**175**	**182**	**174**	**140**	**134**	**147**	**185**	**174**
Dam evaporation	e	17	17	16	15	15	14	15	15	14	16	15	16	16	16	16	16	15	19	17	17	15	16	16	15	15	17	16	16
Bulshoek leakage (rough estimate)	f	11	14	17	20	21	23	26	28	31	32	33	36	40	39	42	43	43	41	36	25	18	17	21	16	8	9	10	26
Total supply	**g**	**205**	**204**	**204**	**209**	**206**	**207**	**210**	**223**	**228**	**226**	**216**	**236**	**232**	**230**	**245**	**252**	**233**	**238**	**248**	**218**	**208**	**215**	**211**	**171**	**157**	**173**	**211**	**215.5**

Table 3.3 Nett supply and losses from the Clanwilliam and Bulshoek Dams

Component	Row	Year starting September …																											
		1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	Ave
Clanwilliam Canal (excl. losses)	a	9	9	8	7	7	6	6	7	9	7	7	8	8	7	8	7	7	7	7	7	7	7	7	4	4	5	6	7
CWUA Pumps at CW Dam plus Clanwilliam Town supplied from Jan Dissels River (3)	b	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	2	3	3	3.1
CWUA Pumps: CW Dam to BH	c	14	14	14	14	14	14	14	14	15	14	13	15	14	14	15	16	14	14	16	14	14	15	14	11	10	11	15	14
Bulshoek Canal (excl losses) (2)	d	102	99	99	101	99	99	99	105	107	105	98	109	103	102	111	115	102	105	117	104	103	108	104	83	73	83	111	102
Total usage (excl losses)	**e**	128	125	123	126	122	122	122	130	134	130	121	134	128	127	137	142	126	130	144	128	126	133	128	101	90	103	136	126
Total usage (% average usage)	f	102%	100%	98%	100%	97%	97%	97%	104%	106%	103%	96%	107%	102%	101%	109%	113%	100%	103%	114%	102%	101%	106%	101%	81%	71%	82%	108%	100%
Bulshoek + Clanwilliam canal losses	g	41	41	40	41	39	39	39	42	43	42	39	43	41	41	44	46	41	42	46	41	41	43	41	33	29	33	44	41
Clanwilliam nett evap estimates	h	14	14	13	12	12	11	12	12	11	13	12	13	13	13	13	13	12	16	14	14	12	13	13	12	12	14	13	13
Bulshoek evaporation estimates	i	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
UAW between CW and BH (1)	j	7	8	8	8	8	8	8	7	7	7	8	7	7	8	6	6	8	7	6	7	8	7	6	6	16	11	5	8
Leakage from Bulshoek (less pumping back from 2004/5 summer season))	**k**	11	14	17	20	21	23	26	28	31	32	33	36	40	39	42	43	43	41	36	25	18	17	21	16	8	9	10	26
Total losses	**l**	**77**	**79**	**81**	**83**	**83**	**85**	**88**	**93**	**95**	**96**	**95**	**102**	**104**	**104**	**108**	**111**	**107**	**109**	**105**	**91**	**82**	**82**	**84**	**70**	**67**	**70**	**75**	**90**
Total	**m**	205	204	204	209	206	207	210	223	228	226	216	236	232	230	245	252	233	238	248	218	208	215	211	171	157	173	211	215.5

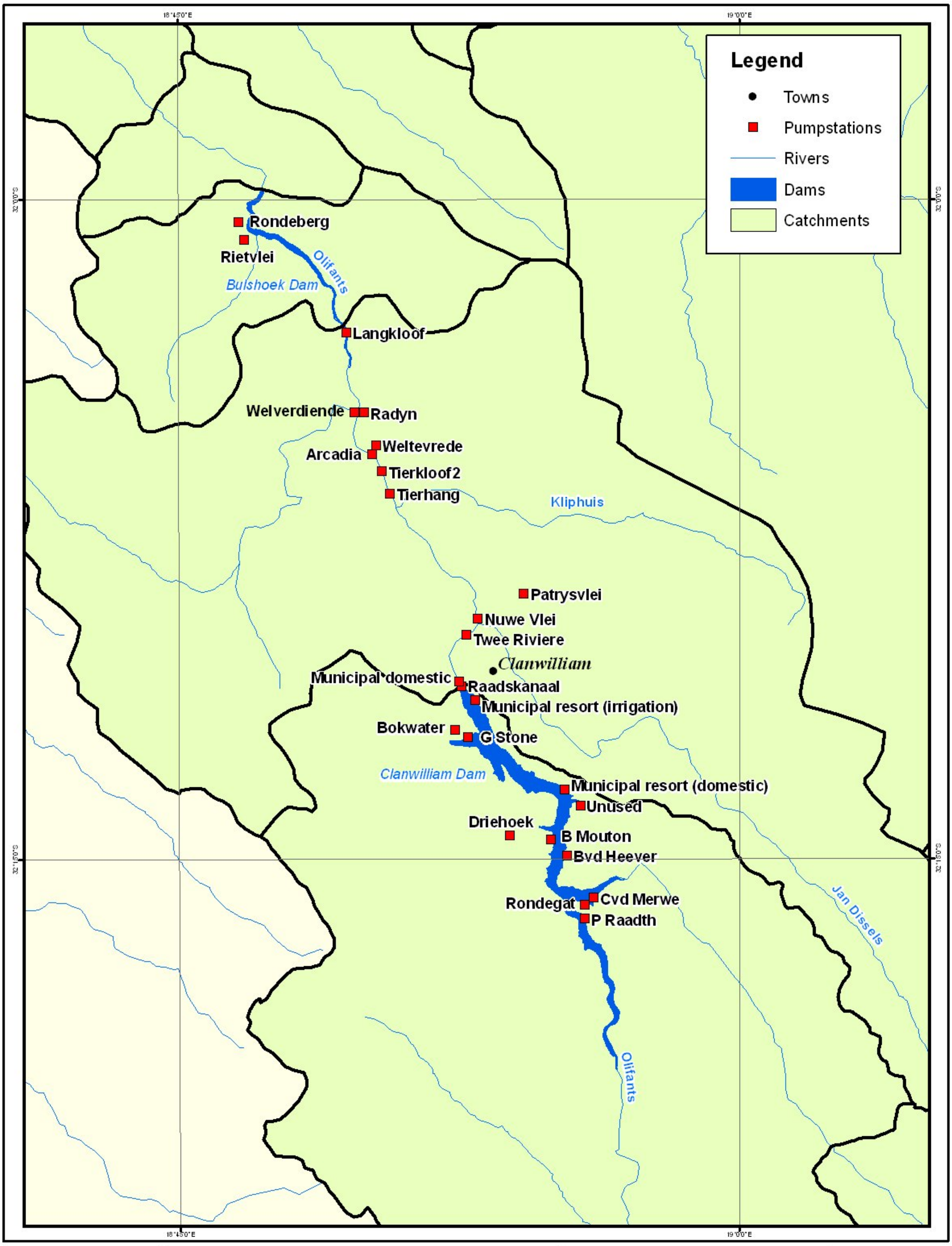
1 include 1.6 Mm^3/a evapo-transpiration
2 From personal correspondence with J Matthee (LORWUA) the non-agricultural quota from the Bulshoek Canal is 8.4 million m^3/a. In 2007 about 60% of this allocation was required.
3 According to Appendix 9 in DWAF (2005a), the consumption by Clanwilliam in1995 was 0.83 million m^3/a and would be constrained to 0;95 million m^3/a by the capacity of the water treatment works

3.2.2 Consumption between Clanwilliam Dam and Bulshoek Barrage and the leaks through Bulshoek Barrage

DWAF has a number of meters on pumps around the Clanwilliam Dam and between Clanwilliam Dam and the Bulshoek Barrage as can be seen in **Table 3.4** and **Figure 3.8**. However, the only records that could be supplied show that the water pumped out upstream and downstream of Clanwilliam Dam at various pump stations (from Bokwater down to Rondeberg in **Table 3.4**) totalled only 4.3 million m^3/a, whereas the allocation is about 19.1 million m^3/a (adding the agricultural allocation for Rows B and C in **Table 3.1**. Because these records seemed unreliable, an alternative approach was used to estimate the consumption between Clanwilliam Dam and Bulshoek Barrage.

Table 3.4 Typical abstraction records from the LORGWS obtained from DWAF for period from 2003/2004 to 2004/2005

Consumer		**Metered consumption (month 1 2003/4 To month 12 2004/5)**		
		m^3/a	**Mm^3/a**	**Mm^3/a**
Upstream of Clanwilliam Dam	CLNMUN1	457311	0.6	0.6
	CLNMUN2	96795		
	CLNMUNWF	60613		
	Bokwater	80083	3.1	4.3
	Driehoek	32029		
	Rondegat	1448		
	Rondegat			
	Raadskanaal	3021752		
Downstream of Clanwilliam Dam	Arcadia	39129	0.8	
	Baksrug1	39277		
	Baksrug2	24319		
	Nuwe Vlei	14642		
	Patrysvlei	83831		
	Radyn 1	87815		
	Radyn2	15733		
	Tierhang	265916		
	Tierkloof1	16716		
	Tierkloof2	3236		
	Twee Riviere	87788		
	Weltevrede	2245		
	Welverd1	78		
	Welverd2	24290		
	Welverd3	2559		
	Welverd4	27494		
	Zandrug1	15576		
	Zandrug2			
	Langkloof	1314	0.4	
	Langkloof (Hilda)	73449		
	Langkloof (Hilda)	25335		
	Langkloof (Hilda)	2156		
	Rietvlei	282665		
	Rondeberg	32652		
	LORWUA	64788231	64.8	64.8
Total			**69.7**	**69.7**



Project:
CLANWILLIAM DAM RAISING FEASIBILITY STUDY

Drawing Title:
Metered abstractions from Clanwilliam Dam to Bulshoek Barrage

Scale: 4 2 0 4 Km
1 : 200 000

Path: i:/hydro/400415/gis_projects/rep_3/farms_pumpst_fig38.mxd

Figure No.: 3.8

The approach adopted was to:

- determine the inflows to the reach between Clanwilliam and Bulshoek using gauge E1H016, and,
- deduct the known supply to the Bulshoek Canal and the increase in storage at the Bulshoek Barrage

The remainder was either leakage/spills/evaporation at the Bulshoek Barrage or consumption/losses between Clanwilliam and Bulshoek. In winter, this remainder would include spillage so the consumption between Clanwilliam and Bulshoek was fixed at 0.5 m^3/s which is an estimate of the minimum release from Clanwilliam Dam to the irrigators between Clanwilliam Dam and Bulshoek Barrage during winter.

The greater the assumed leakage, the less the losses/consumption upstream of the barrage would be. The leakage itself was not measured continuously and has changed significantly recently, when various repairs were made in an effort to minimise the leaks. **Table 3.5** summarises the available information about the leakage. For the purposes of the calculation it was assumed that the leaks for the years starting in September from 2002, 2003, 2004 and 2005 were 0.75, 0.5, 0.25 and 0.25 m^3/s respectively, as the work by DWAF's construction division began to reduce the leakage.

Table 3.5 History of leakage through Bulshoek Barrage

Date	Leak status	Reference
1923+?	Sometime a low flow measuring weir with a rectangular 1.8m wide notch was constructed at the Cascades about 4 km downstream of the Bulshoek Barrage which would measure most of the leakage and return flow from upstream irrigators. The construction date is unknown but the existence of the weir suggests that the leakage has been of concern for a while.	Pers comm. F van Heerden
1963	Minister PK le Roux grants concessions to irrigators from the Bulshoek Canal that are located alongside the river to use the leakage from the Bulshoek Canal, without prejudicing DWAF's right to stop the leak in the future.	Annexure B
1984 to 1994	Progressive increase in leakage from the weir	Pers comm. E Weidemann
26 Jan 1994	Total leakage water from Bulshoek was at some stage estimated to be 1200 l/s of which it was estimated that the leakage through the foundation alone was only about 700 l/s, the rest was from excessive leakage from the crest gates at the time and leakage from the canal.	F van Heerden
1999 - 2001	DWAF Worcester work on foundation which reduced the leakage to about 0.25 m^3/s	E Weidemann
11 Apr 2002	total leakage was estimated to be about 500 l/s	F van Heerden
Nov 2003 to November 2004	Thereafter, from late 2002 to Sep 2003, DWAF: Construction built a new concrete apron to stabilize the foundation. The apron varied from 1 to 4 metres in thickness and steel dowels were used to connect it to the underlying rocks. The apron can also provide a foundation for a further stage of grouting to seal the leakage but the additional grouting to seal the leakage was not done. The gates were refurbished and the leakage was fixed	Pers comm Harry Swart (DWAF construction) / F van Heerden
2005	About 900 m^3/hr (0.25 m^3/s) when Bulshoek Barrage is drawn down increasing to about 1 600 m^3/hr over December when Bulshoek Barrage is maintained at a higher level for recreation. Since 2005 pumps were used in the summer period providing that Bulshoek Barrage was not spilling (i.e. approximately October to March) to return about 800 m^3/hr into the canal above E1H007.	J Matthee (Lorwua)

Table 3.6 summarises the typical calculation to estimate the losses/consumption between Clanwilliam and Bulshoek assuming leakage through Bulshoek of about 0.25 m^3/s. **Table 3.7** summarises the losses/consumption between Clanwilliam and Bulshoek for the years from 2002 to 2005 assuming leakage varying from 1.25 down to 0.25 m^3/s. For each particular year the shaded values were assumed to apply. The estimated consumption during 2004/5 was about 22 (Row J). **Figure 3.9** shows how during summer of 2004/5 the releases from Clanwilliam Dam (blue line) were significantly higher than the abstractions by the Bulshoek Canal (green line). The influence of the leakage from Bulshoek Barrage and the inflows from the Jan Dissels River were negligible at this time.

In 2004/5 the irrigators along the Bulshoek Canal were curtailed to about 60% of their allocation (on average they receive about 84% of their allocation and that in 2004 they were in addition curtailed to about 71% of their average supply). If the irrigators between the Bulshoek and Clanwilliam Canals were similarly curtailed then their supply would be 9.6 million m^3/a (1 315 ha x 12 200 m^3/ha x 60%). Row M of **Table 3.7** compares the estimated consumption between Clanwilliam and Bulshoek with what should have been supplied had the demands between Clanwilliam and Bulshoek been curtailed. These deductions rely on the accuracy of the gauges downstream of Clanwilliam and in the Bulshoek Canal. Because the readings from the meters between the two dams do not represent the true situation, they cannot be used as a check.

The estimated monthly consumptions for the five years starting from September 2002 have been charted in **Figure 3.10**. The timing of the crops varies from year to year, possibly in response to the market demand, as the irrigators between the two dams can access water on demand, simply by intercepting releases to the Bulshoek Barrage. The dashed red line represents the average of the four years charted.

Table 3.6 Typical calculation to estimate the losses between Clanwilliam and Bulshoek Dams

Component	Formulae	Sep 2004	Oct 2004	Nov 2004	Dec 2004	Jan 2005	Feb 2005	Mar 2005	Apr 2005	May 2005	Jun 2005	Jul 2005	Aug 2005	Average (m^3/s) Sep 2004 - Aug 2005	Total (Mm^3/a) Sep 2004 - Aug 2005
Based on daily analysis of the inflows															
Average of E1H016_flow	A	4,0	3,7	5,5	6,9	6,8	6,0	3,7	1,4	1,3	0,4	1,2	57,8	8,30	262
Average of E1H006_flow[1]	B	0,6	0,6	0,2	0,1	0,1	0,1	0,1	0,3	0,6	3,7	2,7	5,3	1,21	38
Average of E1H007_Patched_High	C	3,4	3,4	4,2	5,1	5,2	5,0	3,8	1,4	1,0	1,7	1,5	2,6	3,18	100
Average of leaks (less pumping back to canal) + consumption + spills	D=A+B-C	0,9	0,9	1,5	2,0	1,9	1,3	0,7	0,8	0,7	2,6	1,7	60,6	6,38	201
Manipulation of the monthly totals to estimate the consumption by irrigation															
Simplified Bulshoek leak	F	0,3	0,3	0,3	0,3	0,3	0,3	0,3	0,3	0,3	0,3	0,3	0,3	0,25	8
Deducting Bulshoek leak	G=D-F	0,6	0,7	1,2	1,7	1,7	1,0	0,4	0,6	0,4	2,4	1,5	60,4	6,14	194
Capping winter demand to 0,5 m^3/s	H=0,5 in winter	0,5	0,5	1,2	1,7	1,7	1,0	0,5	0,6	0,5	0,5	0,5	0,5	0,81	25,6

1. E1H006 was not doubled (actual factor about 77/42) to provide the full incremental flow between Clanwilliam Dam and Bulshoek Barrage - i.e. the losses could be under-estimated in winter though the summer flows from the other tributaries are unlikely to reach the Olifants River.

Table 3.7 Inter-relationship of losses between Clanwilliam Dam and Bulshoek Barrage and leakage through Bulshoek Barrage

Leakage	Row	Consumption and losses between Clanwilliam and Bulshoek Dams assuming different rates of leakage through Bulshoek Barrage			
		2002/3	2003	2004	2005
1,25	A	16,3	15,8	16,8	15,8
1,00	B	17,8	15,8	18,2	16,3
0,75	C	19,7	15,9	20,1	17,6
0,50	D	21,7	17,5	22,8	19,5
0,25	E	24,8	19,8	25,6	22,5
consumption for selected (shaded) scenarios	F	19,7	17,5	25,6	22,5
Bulshoek evaporation	G	-2	-2	-2	-2
Nett consumption losses between Clanwilliam and Bulshoek	H	17,7	15,5	23,6	20,5
Evapo-transpiration losses between Clanwilliam and Bulshoek	I	-1,6	-1,6	-1,6	-1,6
Estimated consumption by irrigators between Clanwilliam and Bulshoek (including 500 ha in the Jan Dissels River)	J	16,1	13,9	22,0	18,9
Curtailment factor based on ratio of long-term supply to allocation (**Table 3.1**, Row D) x ratio of annual supply in the particular year to the long-term supply (**Table 3.3**, Row F).	K	84% x 101%	84% x 81%	84% x 71%	84% x 82%
Expected consumption based on factoring allocation by the curtailment of the Bulshoek Canal	L	13,6	10,9	9,6	11,1
Ratio of estimated to expected consumption	M	119%	127%	230%	171%

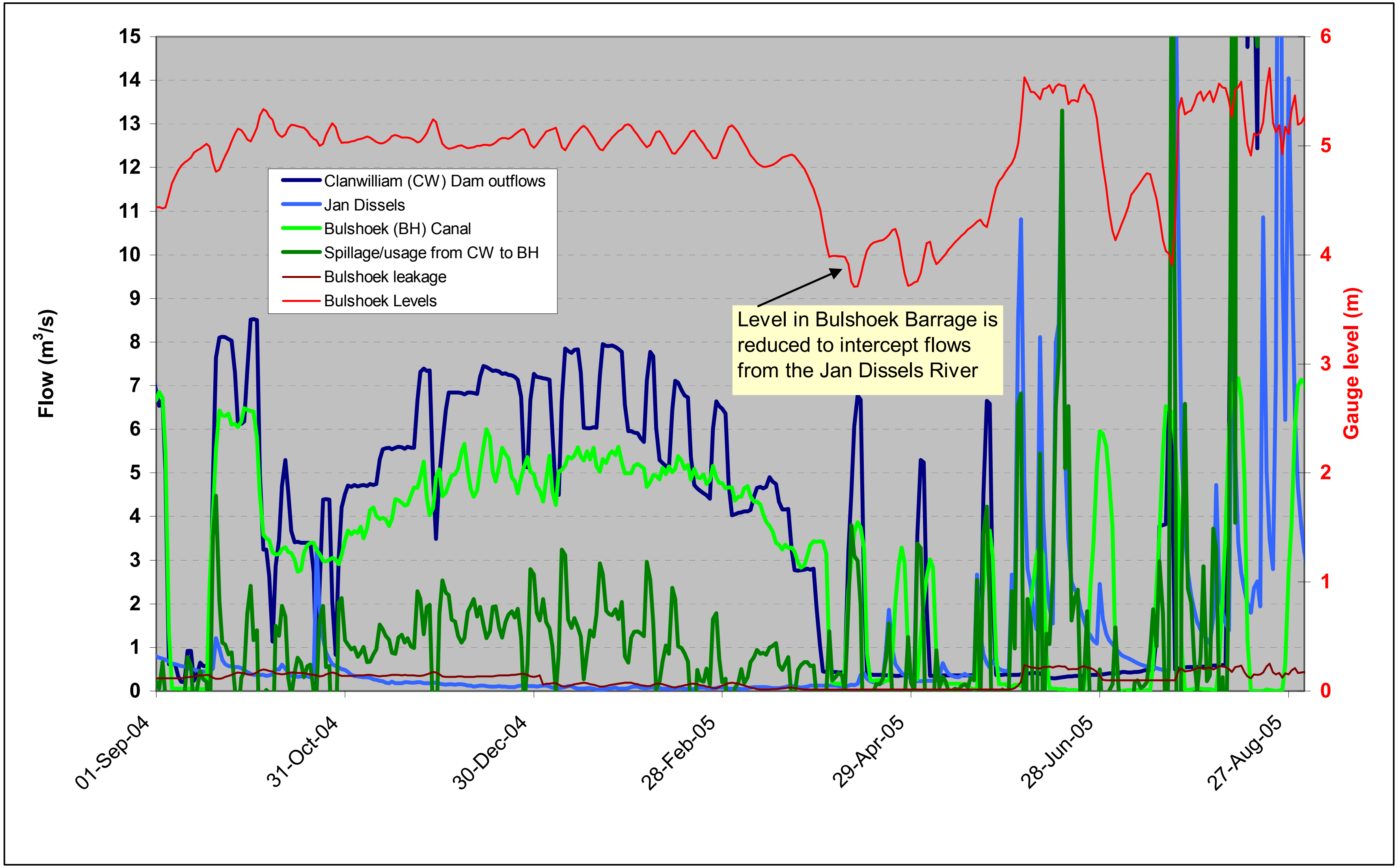


Figure 3.9 Releases and consumption : Clanwilliam Dam to Bulshoek Barrage

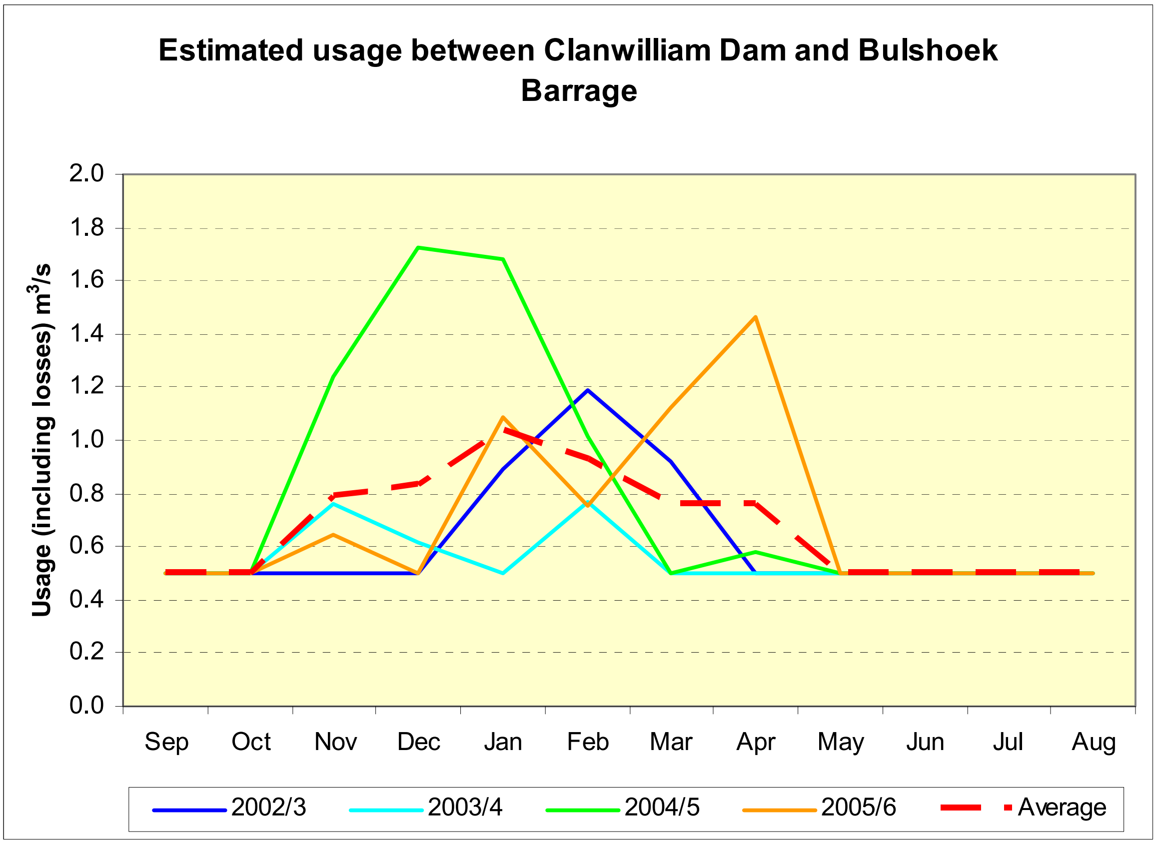


Figure 3.10 Water usage and losses between Clanwilliam Dam and Bulshoek Barrage

For the purposes of the yield analysis, the pumps along the Jan Dissels and the Olifants Rivers, together with transmission losses along that reach, were assumed to total 21.6 million m^3/a, which is similar to the estimated values in Row H of **Table 3.7**. Improved metering of the abstractions by the pumps abstracting from Clanwilliam Dam and the Olifants River would help quantify the unaccounted for water and would help to reduce the demand.

3.2.3 Bulshoek Canal Demands

The Lower Olifants River Water User Association (LORWUA) currently have a theoretical allocation of water from the Clanwilliam/Bulshoek Dams of 116 million m^3/a (9 491 ha each receiving 12 200 m^3/ha). The average inflow to the canal for the period from 1990 to 2006 was 139 million m^3/a, but after deducting losses of 37 million m^3/a (27%) and non-irrigation consumption of about 9.6 million m^3/a, the remainder left for the irrigation is about 92 million m^3/a. This equates to 9 670 m^3/ha or 80% of the theoretical allocation.

All registered irrigation users in the LORWUA are theoretically entitled to 12 200 m^3/ha/yr (this amount was determined on 15 April 1983). Two quotas are used by LORWUA, namely a yearly quota of 12 200 m^3/ha and a weekly quota. The weekly quota, also called maximum abstraction rate, is equal to 325 m^3/ha for all irrigators. No irrigator is allowed to demand more than the maximum extraction rate and no cross-substitution is allowed (i.e. an irrigator is not allowed to receive 200 m^3/ha one week and 450 m^3/ha the next week, because of the limited carrying capacity of the canal (IWMI 2004.).

LORWUA have limited the capacity of the dams receiving water from the canal to 35% of each farmer's allocation, i.e. 35% x 12 200 m^3/ha x farmer's scheduled area (ha). This storage can be used to help balance supply on a daily or weekly basis and also in times of surplus may help the farmer obtain a greater portion of his allocation.

For instance, normally the allocation at the end of winter for the coming summer is less than 8 000 m^3/ha (see **Annexure A**), significantly less than the 12 200 m^3/ha application rate. However, toward the end of winter Clanwilliam Dam may start to spill so that the annual allocation can be revised upward to 12 200 m^3/ha. Irrigators with storage on their land may be able to store this additional portion of their allocation for later use if they are not able to apply the water immediately.

The Ebenhaeser Balancing Dam has a capacity of 140 000 m^3 and was constructed near the end of the west branch of the Bulshoek Canal to help regulate the supply to, and reduce spillage, from the Ebenhaeser Scheme.

At off-peak times the irrigation flows required from the canal are dependent on the cultivation of suitable crop types. For about 17 weeks of the year the canal undergoes maintenance as can be seen in **Table 3.8**. During this period users may experience up to two weeks without water from the canal.

Table 3.8 Typical schedule showing when the three sections of the Bulshoek Canal are closed for maintenance

Start Date	Main	Right bank	Left bank
24-Apr-06	Closed	closed	closed
01-May-06	Closed	closed	closed
08-May-06			
15-May-06	Closed	closed	closed
22-May-06	Closed	closed	closed
29-May-06			
05-Jun-06	Closed	closed	closed
12-Jun-06	Closed	closed	closed
19-Jun-06			
26-Jun-06		closed	
03-Jul-06			closed
10-Jul-06			closed
17-Jul-06		closed	
24-Jul-06		closed	
31-Jul-06			closed
07-Aug-06			closed
14-Aug-06		closed	
21-Aug-06		closed	
28-Aug-06			closed
04-Sep-06			closed
Weeks closed	6	11	12

The Ebenhaeser Balancing Dam at the end of the canal has a capacity of 140 000 m^3.

3.2.4 Minimum operating level

Bulshoek Dam is operated at a level of 4.8 m to 5.1 m where possible, except in winter before Clanwilliam Dam fills when it may be dropped to about 3.8 m to capture flood events. The level of the water in the Bulshoek Barrage is charted in **Figure 3.9** using the red line and the axis on the right hand side of the figure. Note the level was drawn down from about 5.1 m to 3.8 m at the onset of winter and was only allowed to spill once Clanwilliam Dam filled at the end of August 2007.

The following constraints make it difficult to maintain a high level in the Bulshoek Barrage:

- Above about 4.8 m strong southerly winds cause spills over the crest gates.
- In winter, before it is certain that Clanwilliam Dam will fill, maintaining as low a level as possible maximises the volume of streamflow from Jan Dissels River that can be intercepted and used and helps minimise the risk of Clanwilliam Dam not filling. A low level also captures the surplus from releases intended for irrigators downstream of the Clanwilliam Dam, particularly if the Bulshoek Canal is closed for maintenance

The following constraints make it difficult to lower the level too much:

- The irrigators at Langkloof cannot abstract from the dam if it drops below about 4.5 m. Further upstream, Radyn relies on releases from Clanwilliam Dam
- Below about 3.6 m insufficient water may be supplied to the canal
- If the barrage is below 3.8 to 4.0 m, there is a concern that winter floods will silt up the dam basin, reducing the volume for storage and the area available for recreation. A minimum level of 4.8 m has also been suggested though this level is more likely to be adopted once it is clear that Clanwilliam Dam will fill.
- A level below 3.8 to 4.0 m impacts severely on recreational activities (water skiing/fishing).

3.3 Downstream of the Bulshoek Barrage

3.3.1 Bulshoek leakage and flow at Lutzville

During summer, a number of components contribute to the flow in the Olifants River downstream of the Bulshoek Barrage, namely:

- leaks through the Bulshoek Barrage
- Return flows from irrigators alongside the Bulshoek Canal
- Streamflows from the Doring River (normally negligible in summer).

Upstream of Trawal and especially the Doring River confluence, the water quality is acceptable and riparian irrigators have concessions to use the water (this is discussed in more detail in **Section 3.3.2**). **Figure 3.11** illustrates these components.

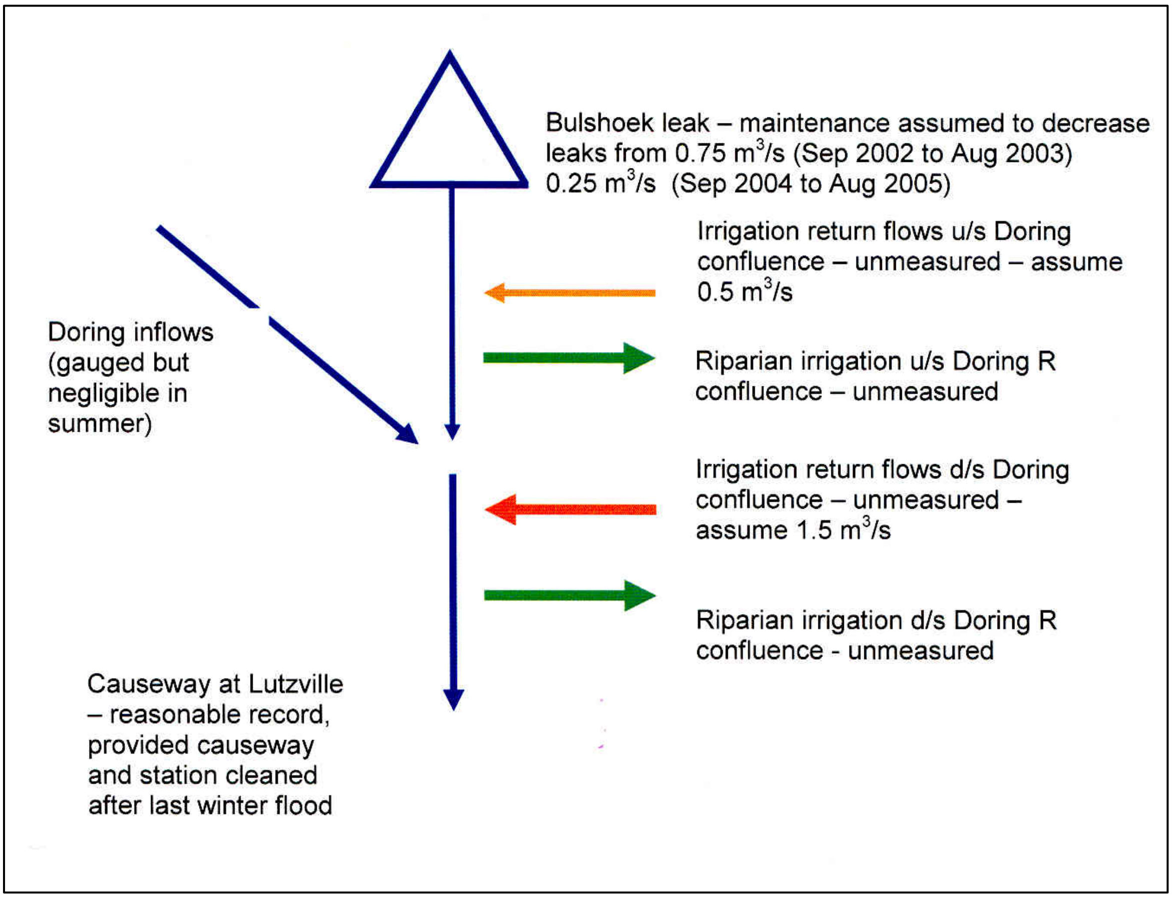


Figure 3.11 Major streamflow components between the Bulshoek Barrage and the causeway at Lutzville in summer

With the exception of the streamflow in the Doring River, and possibly the leak through the Bulshoek Barrage since the LORWUA commenced pumping most of the leakage back into the canal, the components are poorly defined. Based on previous work in **Section 3.2.2** the leaks through Bulshoek were assumed to decrease from 0.75 m^3/s to 0.25 m^3/s from 2002/3 to 2004/5. In 2005, LORWUA commenced pumping the leak back into the Bulshoek Canal that reduced the water available downstream in the Olifants River so that the nett leakage was reduced to zero. The volume abstracted can vary from about 4 million m^3/a to 16 million m^3/a (see Row D in **Table 3.9**). Anecdotal evidence suggests that during the drought from 2003 to 2005, the streamflow in the Olifants River upstream of the confluence with the Doring River reduced to zero. For the purposes of this estimate it was assumed that the total return flows from the Bulshoek Canal upstream of Lutzville were 2 m^3/s, of which 0.5 m^3/s were above the confluence with the Doring River. Subsequent to this analysis it was reported that the main Bulshoek Canal may also have leaked into the Olifants River at a point about 5 km downstream of the Bulshoek Barrage during peak summer flow periods. This leak may have been fixed after 2004 when Element Consulting Engineers completed their investigation into the rehabilitation of the canal (LORWUA, 2004).

Figure 3.12 shows the streamflow recorded at the Lutzville causeway. What is interesting is the sudden decrease in flow from about 2 m^3/s to 1 m^3/s in 2005. This can only be partly explained by the assumed reduction in leakage during 2004, from 0.5 to 0 m^3/s (partly through maintenance work and partly through pumping the remaining leakage back into the Bulshoek Canal). The water shortage in 2004/2005 may have also prompted irrigators to risk taking an additional 0.5 m^3/s from below the confluence with the Doring River. **Table 3.9** attempts to reconcile the estimated inflows and abstractions with the observed streamflow at Lutzville for the four years starting with September 2002 (Row G).

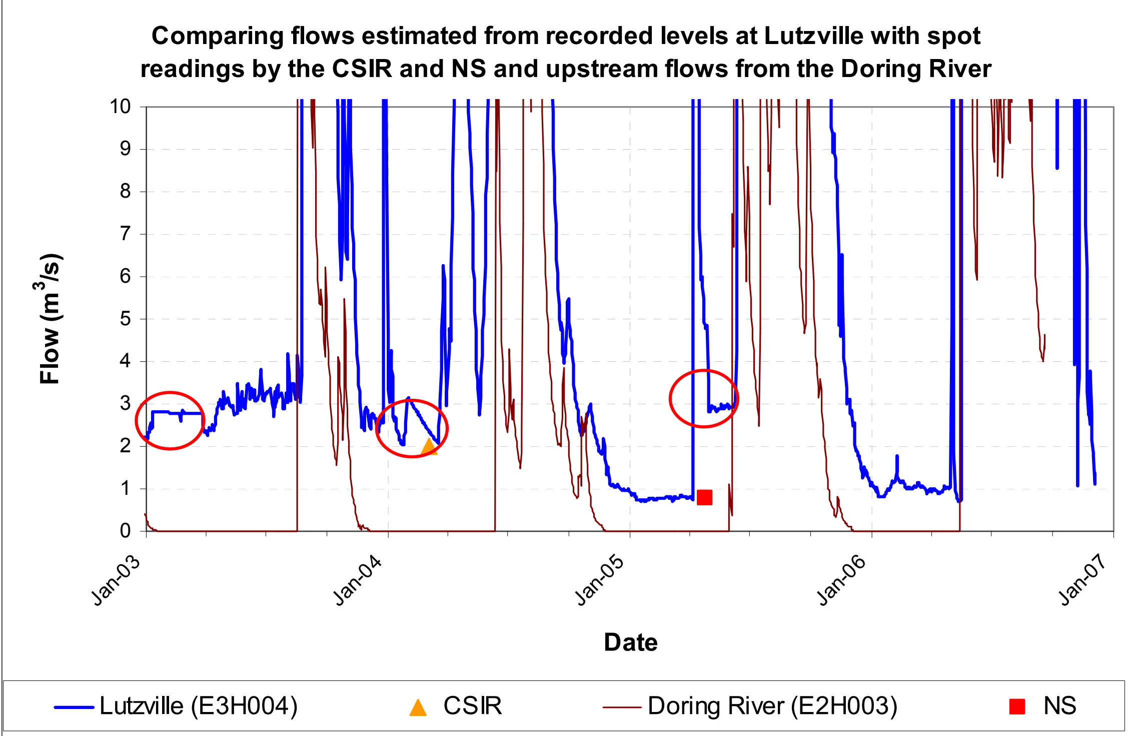


Figure 3.12 Comparing flows estimated from recorded levels at Lutzville with spot readings by the CSIR and NS and upstream flows from the Doring River

Table 3.9 Releases, accruals and consumption for the reach between Bulshoek Barrage and the causeway at Lutzville

Component	Row	Summer (m^3/s)			
		2002/3	2003/4	2004/5	2005/6
Leakage (for selected abstractions in **Table 3.7**)	a	0.75	0.50	0.25	0.25
Pump back to Bulshoek Canal	b	0.00	0.00	-0.25	-0.25
Return flows u/s of Doring River	c	0.50	0.50	0.50	0.50
Return flows u/s Doring River re-used	d	-0.50	-0.50	-0.50	-0.50
Return flows d/s of Doring River (1)	e	1.50	1.50	1.50	1.50
Return flows d/s Doring River re-used	f	0.00	0.00	-0.50	-0.25
Residual flow at Lutzville (E3H004)	g=a-b+c-d+e-f	2.25	2.00	1.00	1.25

(1) Preventing the leaks from the main canal into the Olifants River about 5 km downstream of the Bulshoek Barrage could also have reduced the streamflows at Lutzville

3.3.2 Consumption downstream of Bulshoek Barrage

Irrigators downstream of the Bulshoek Barrage requested a concession from the Minister of Water Affairs to use the water leaking from the barrage. In June 1963 the Minister approved 10 morgen Water Permit Concessions in terms of Section 62 (2) of the Water Act (1957) granted a concession allowing existing riparian members of the LORGWS to irrigate an additional 10 morgen (8.6 ha) using this water. A later letter from the Minister of Water Affairs dated

7 September 1972 (see **Annexure B**) spelt out that this was a temporary concession and that the state could continue with developments upstream in the river without compensating these irrigators in any way:

2.(ii) "Die Staat handhaaf ten alle tye sy reg om die lekkasie in die Bulshoekdam te beëindig en om nuwe opgaring op die Olifantsrivier en die Doornrivier to skep, sonder dat die permit houers enige eis teen die Staat het indien die water wat vir hulle pompe beskikbaar is afneem."

As a result of this proviso the Lower Olifants River Water User Association were able to install a pump downstream of Bulshoek Barrage from 2005 that intercepted and pumped the leakage back into the Olifants River Canal from where it was distributed to the irrigators. Because the irrigators only received the concession if they had rights to water from the Bulshoek Canal this action should not have impacted on their operations as they would have been entitled to water from the Bulshoek Canal.

A current study provisionally estimates the extent of the usage under this concession as follows (pers comm. N J Wullschleger) :

- The total number of persons listed in a DWAF document that could possibly have applied for the 10 morgen (8.6 ha) concession was 439.
- 150 properties responded to our public participation process and completed questionnaires.
- There is to date clear evidence for only 17 concessions (Category A).
- A further 18 cases (Category B) were found which in our assessment are "highly likely" to qualify for a concession.
- Approximately 122 properties are "probably likely" to be able to qualify (Category C).
- Approximately 127 properties have a "low probability" of qualifying (Category D)

Table 3.10 gives an indication of the range in demands downstream of the Bulshoek Barrage assuming different numbers of concessions are valid.

Table 3.10 Dams downstream of Bulshoek Barrage

Component	Unit	Row	Probability of concession being valid			
			Almost certain	Highly likely	Probably likely	Unlikely
Number of concessions	No.	a	17	18	122	127
Ha	Ha	b=a*8.6	146	155	1049	1092
Demand per category	Mm^3	c=b*.0122	2	2	13	13
|Demand for a particular category and above	Mm^3	d	2	4	16	30

3.3.3 Consumption downstream of Bulshoek Barrage

The dams downstream of the Bulshoek Barrage are relatively small in comparison to the Clanwilliam Dam. **Figure 3.11** indicates which dams get their water from the canal and which obtain water from the rivers such as the Olifants, Doring or side streams. The dams of Mr A Botha, Ds Sieberhagen and Van den Heever can store water from both the canal and the Olifants River (pers comm. A Botha). **Figure E1** in **Annexure E** shows the locations of the dams.

Mr Botha's dam is located downstream of the confluence with the Doring River and the river water is only pumped into the dam after the first freshettes have reduced the salinity of the river water. Pumping normally ceases in October/November when the water becomes too saline. Another measure that helps to reduce the salinity, especially in a new dam whose water will be exposed to saline disturbed earth, is to drain the dam completely each year before the start of winter.

The operation of the dams on the Bulshoek Canal is discussed in **Section 3.2.3**.

Table 3.11 Major storage downstream of the Bulshoek Barrage

Registered name	Owner	Capacity (Ml)	Canal	River			Comment
				Side stream	Olifants	Doring	
Zypherfontein	De Wet	1 000			Y	Y	Dam stores water on two properties so allocation is shared
Vleikraal		242		Y			
Vaalwater		210		Y			
Winkelskloof	Stephan/Van Zyl	765					Not yet constructed
Heever	Van den Heever	250		Y	Y		
Bruinklip	Baard	110			Y (West Bank)		
Maleco	Dominee Sieberhagen		Y		Y		
Melkboom	A Botha		Y		Y		
Ebenhaeser balancing dam		140	Y				
Koekenaap canal		129	Y				
Olifantsdrif	Lutouw Landgoed	4 076			Y		Storage exceeds allocation of about 2.3 Mm^3/a
Zoutpansklipheuwel	Dittmer	900			Y		

3.4 Curtailment

Currently the storage of the Clanwilliam Dam is only about 30% of the present day mean annual runoff (MAR). The dam spills almost every year and the allocation for the coming year is dependent not on how much water flowed into the Clanwilliam Dam but on how late in the season the last rains came. When Clanwilliam Dam stops spilling a portion of the available storage is kept in reserve and the remainder is distributed amongst the various consumers to meet their requirements until the start of winter, about mid May.

Annexure A contains a typical allocation decision that allocates each of the irrigators 5 964 m^3 for each of their scheduled hectares over the summer period. If the Clanwilliam Dam is raised, the operating rule will need to be reviewed so that sufficient water is carried over from year to year to increase the reliability of supply.

4. INFLOW TO CLANWILLIAM DAM

4.1 Discussion of Components

The recent drought from 2003 to 2005 impacted severely on irrigation in the region and this study extended the inflow to the dam to include this drought period to see whether the historical firm yield would be affected. A by-product of this effort was the determination of a daily historical streamflow sequence for the period from 1935 to 1962 that could be used to simulate the daily behaviour of the Clanwilliam Dam.

There is no gauge measuring the inflow to the Clanwilliam Dam and the inflows must be inferred using the "reverse mass balance" method. In essence, this method sums the increase in storage and the magnitude of the withdrawals (i.e. abstractions/releases/spills/nett evaporation) from the dam to calculate the inflow.

The measurement of the release and spill components has not always been accurate. The releases from the Dam were measured by gauge E1H011 but the recorded flows seem erroneous at times when compared with the abstraction by the Bulshoek Canal (see **Section 2.5.1**). E1H011 was also located too close to the Dam to measure the high flows accurately and these were initially calculated using the level in the Dam recorded by gauge E1R002 and the formula for the spillway. However, in 1962, the Dam was raised by adding gates to the crest. These gates complicated the calculation of the spill over the Dam as it meant that the spill was not only dependent on the level of the water in the Dam but also on the degree by which each gate had been opened. Gauge E1H011 was discontinued after 1997 and was only replaced in 2001 by the new gauge E1H016 that was further far from the Dam and could measure the spill more accurately. For the period from 1997 to 2001 when there was no gauge downstream of Clanwilliam, the releases were estimated using the water shortfall downstream at the Bulshoek Barrage that would need to be satisfied by a release from Clanwilliam Dam. The shortfall was estimated considering requirements such as the supply to the Bulshoek Canal, leakage through the Bulshoek Barrage, interception by irrigators between Clanwilliam and Bulshoek and the contribution of the Jan Dissels River. The spills were determined using gauges in the Doring River (E2H002) to patch the daily streamflow record. An independent set of spills was also determined using the streamflow in the 24 Rivers (G1H028 and G1H058) to patch the streamflow record. The spills from Clanwilliam Dam were assumed to be the average of the two sets. Obviously if the system were modelled using the Pitman Model (which uses monthly rainfall to simulate monthly runoff) then these flows could possibly also be used to estimate the inflows during months when Clanwilliam Dam spills.

The above legacy meant that different approaches were used to determine the spills and releases from the Clanwilliam Dam in different periods:

- Before 1962 : The spills were determined using the level in Clanwilliam Dam and the spillway equation. The releases were based on meeting the deficit in water requirements downstream.
- Between 1962 and 1997 : The spills were patched using gauges E2H002 and G1H028/G1H058. The releases were assumed to meet any deficit in the water requirements downstream.
- After 1997 : The spills and releases were determined using gauge E1H016

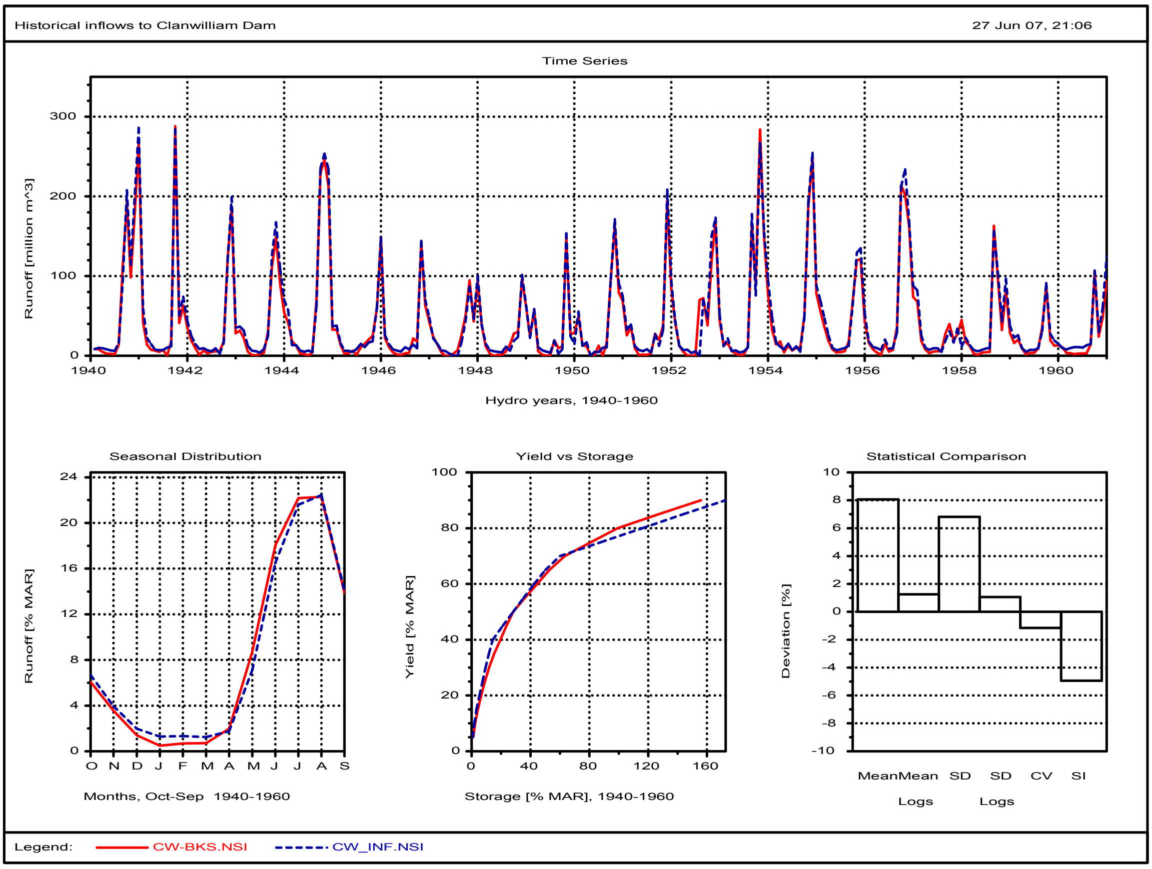
Table 4.1 summarises the methods used to calculate the inflow to Clanwilliam Dam for the three periods. A column is used for each period. The top section indicates the components used for the reverse mass balance calculation and the bottom two sections respectively summarise the methods used to calculate the releases and the spills.

4.2 Checking Inflow

The inflows calculated for the first two periods mentioned in **Table 4.1**, namely 1935-1962 and 1962-2001, were compared with historical inflow determined in the Olifants River System Analysis (ORSA). (Appendix C-10 : (DWAF, 1990)).

In the earlier period the streamflows generated according to **Table 4.1** had 8% more run-off than those from the ORSA and a slightly higher summer inflow as can be seen in **Figure 4.1** in the charts at the bottom right and bottom left respectively.

4.2.1 Before 1962



Ym/h5/inf/cw_bknsa.emf

Figure 4.1 Comparison of the historical streamflows entering Clanwilliam Dam from the System Analysis and from the Dam Raising Study for the period before the construction activities associated with the first raising of Clanwilliam Dam affected spillage estimates

Table 4.1 Components used to estimate the inflows into Clanwilliam Dam

Clanwilliam Dam	Reference	Start year	End year	Records used to estimate inflows for different periods			Remark
				1935-62	1962-2001	2001-07	
Primary components used to estimate the inflows to Clanwilliam Dam							
Storage	E1R002	1935	2007+	√	√	√	
Evaporation	E1E004	1974	2007+	√	√	√	
Abstraction : canal	E1H008	1935	2007+	√	√	√	
Abstraction : pumps	various meters	-	-	√	√	√	No records available
Releases				see Release estimate			
Spills				see Spill estimate			
Release estimate							
Release/spill downstream of Clanwilliam Dam	E1H011	1935	1997				Gauge less accurate than E1H016 and often exceeded - Add HEP releases E1H009
HEP releases bypassing E1H011	E1H009	1939	1991				
Release/spill downstream of Clanwilliam Dam	E1H016	2001	2007+			√	
Jan Dissels	E1H006	1978	2007+	√	√		largely missing 1971-77
Demands between Clanwillam and Bulshoek	various meters			√	√		No records available
Bulshoek Barrage storage	E1R001	1923	2007+				
Bulshoek spill	E1R001						Spills inaccurate because gates installed
Bulshoek Canal demands	E1H007	1921	2007+	√	√		
Bulshoek leakage				√	√		Rough estimate,
Bulshoek evaporation				√	√		
Spill estimate							
Spill	E1R002	1935	1962	√			Use WRYM data prior to 1974
Spill	E1R002	1962	2007+				Spills inaccurate after 1962 because gates installed
Release/spill downstream of Clanwilliam Dam	E1H016	2001	2007+			√	
Gauge downstream of Bulshoek Barrage	E1H017	2004	2005				
Doring River at Elandsdrift	E2H002	1923	1960				flows overestimated before 1960
Doring River at Elandsdrift	E2H002	1960	2007+		√		
Doring River at Melkboom	E2H003	1927	2007+				
24 Rivers	G1H002	1951	1960				
24 River downstream of canal	G1H028	1972	2007+		√		Excess flows returned from canal to river at Sandtrap bypass 24 River gauge and are not measured
24 Rivers canal	G1H058	1972	2007+		√		

In the later period, when this study estimated the spills over Clanwilliam Dam using the gauges in the Doring and the 24 Rivers catchments, the spills were slightly less than those used in the ORSA and the summer baseflows were still more than those from the ORSA. Overall the inflow was about 10% less than from the ORSA but the inflows for the critical period (late 1960s/early 1970s) were very similar because there were few spills during this period. The inflows over the critical periods determine the historical firm yield of the system. Hence the yields for the two streamflow sequences are similar as shown in **Table 4.2**. This table uses the central chart at the bottom of **Figure 4.3** to estimate the historical firm yield of the Clanwilliam Dam for both the ORSA and Dam Raising Feasibility Studies, for both the present day capacity and assuming a 15 m raising. These yields assume:

- no environmental releases
- no contribution from the accruals upstream of the Bulshoek Barrage
- no evaporation losses from the Clanwilliam Dam.
- Ignore impact of later upstream development on the yield from Clanwilliam Dam

As a result the yields derived in **Table 4.2** are about 30 million m^3/a greater than the historical firm yields derived later in **Section 6.2.**

Table 4.2 Estimation of yield from Clanwilliam Dam assuming no environmental releases and no contribution from the accruals upstream of Bulshoek

Component	Row	ORSA	Dam Raising Feasibility Study
MAR	a	363	317
Current Dam Capacity as a percentage of the MAR	b=a/122	34%	38%
Yield as % MAR from **Figure 4.3**	C	50%	58%
Yield (NO EWR releases and no contribution from Bulshoek)	d=a*c	182	184
Proposed dam capacity for a dam raising of 15m (364 Mm^3) as a % of the MAR	e=a/364	100%	115%
Yield as % MAR from **Figure 4.3**	F	70%	81%
Yield (NO EWR releases and no contribution from Bulshoek)	g=a*f	254	257

A double mass plot comparing the inflows to Clanwilliam Dam generated from ORSA and the Dam Raising Feasibility Study for the period 1935 to 1988 is provided in Figure 4.2. This plot confirms that initially the inflows generated by the Dam Raising Study are more than ORSA, but in the later period, they are less. The estimate of the spills using the gauges in the Doring and 24 Rivers appears more conservative than the ORSA spills.

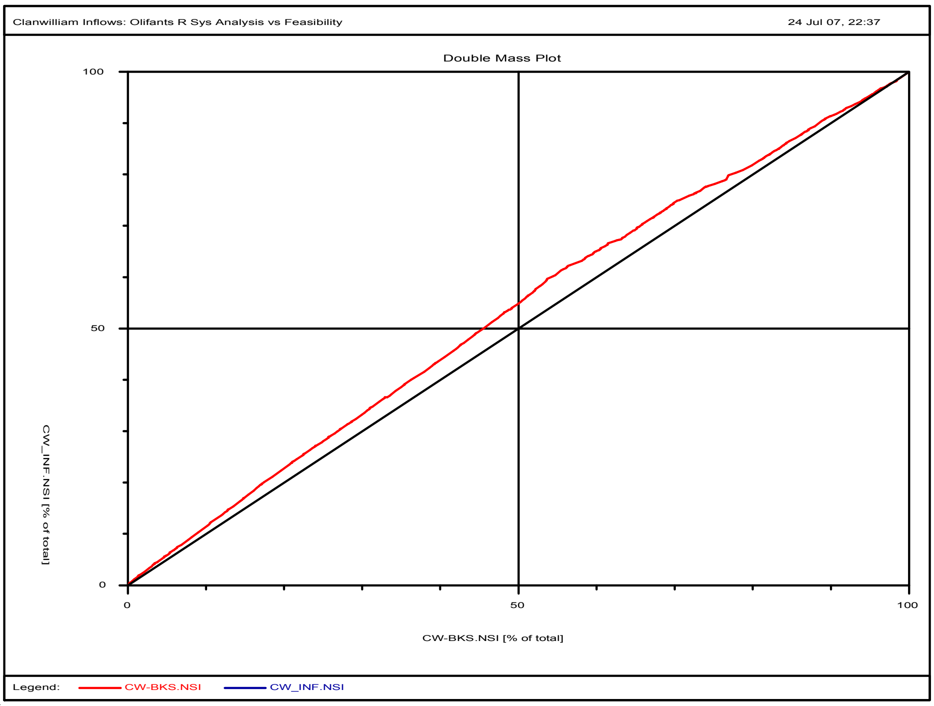
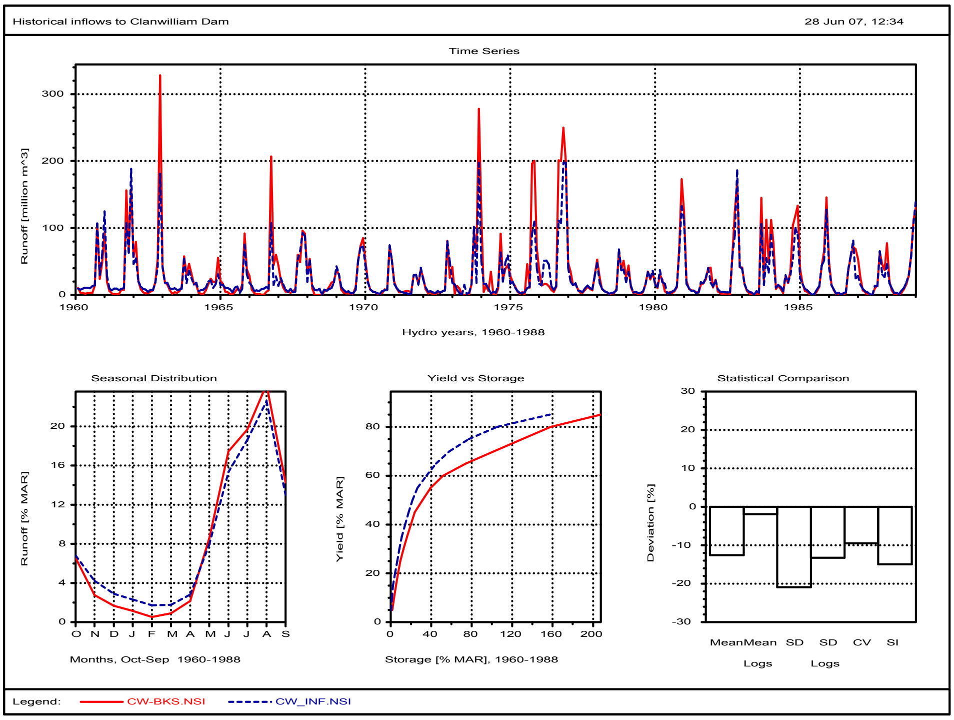


Figure 4.2 Double mass plot comparing the ORSA and feasibility streamflow sequences

4.2.2 1962 to 1990

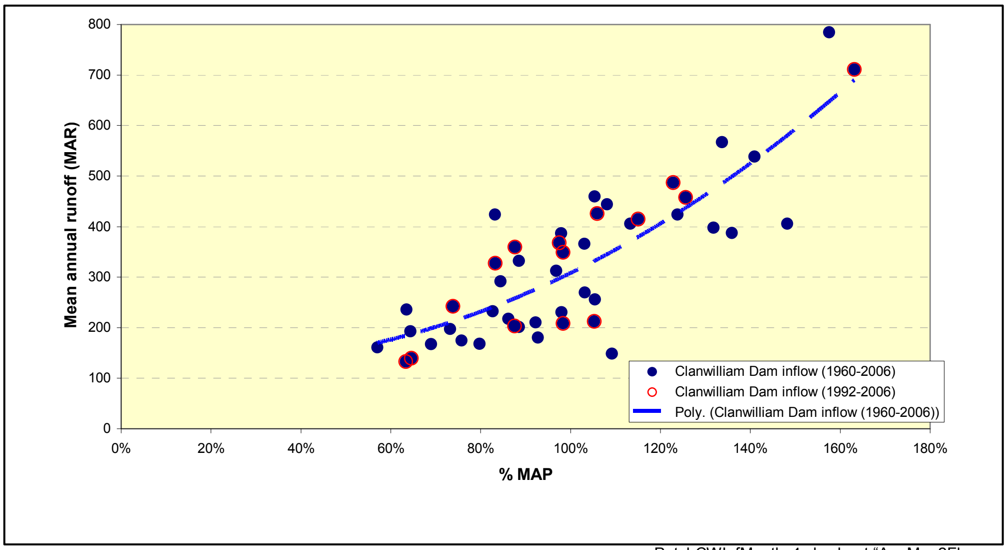


Ym/h5/inf/cw_bknsb.emf

Figure 4.3 Comparison of the historical streamflows entering Clanwilliam Dam from the System Analysis and from the Dam Raising Study for the period after the first raising of Clanwilliam Dam (1968)

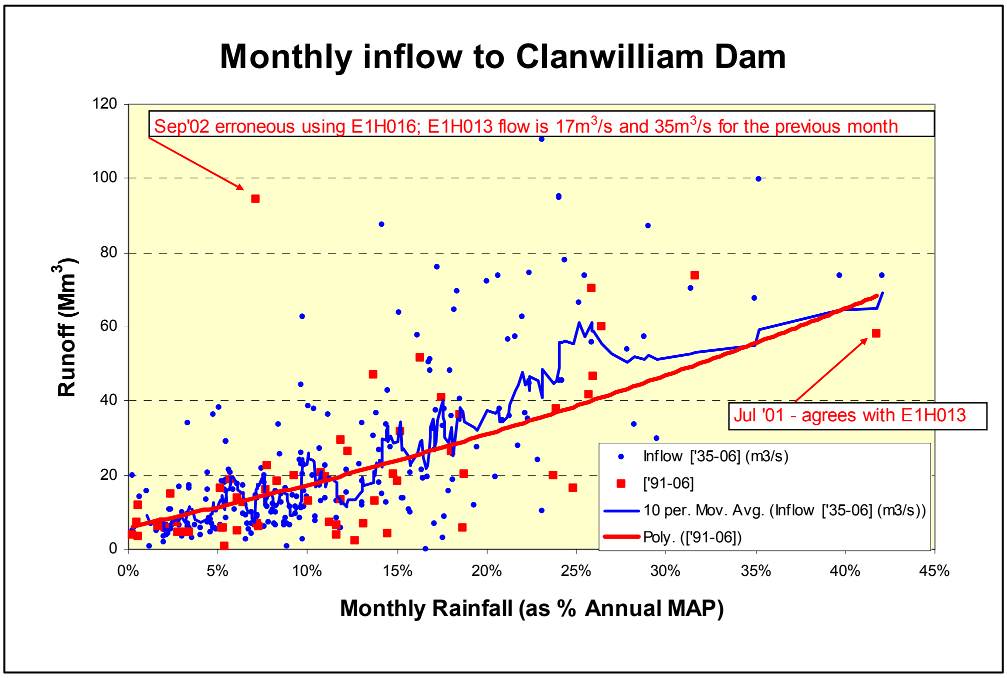
4.2.3 After 1990

For interest, the inflow determined for the period after 1990 was checked to see whether its relationship of runoff to rainfall was consistent with that obtained for the earlier flows. In **Figure 4.4** the long term annual relationship of runoff to the annual precipitation (dashed line through the blue dots), expressed as a % of the MAP, was compared with that for the most recent 15 years (red circles). Both data sets follow the same trend. In **Figure 4.5** the long-term monthly relationship of runoff to the annual precipitation (blue dots), expressed as a % of the MAP, was compared with that for the most recent 15 years (red squares). Again, both data sets follow the same trend.



PatchCWInfMonthv4.xls sheet "AnnMap2Flow

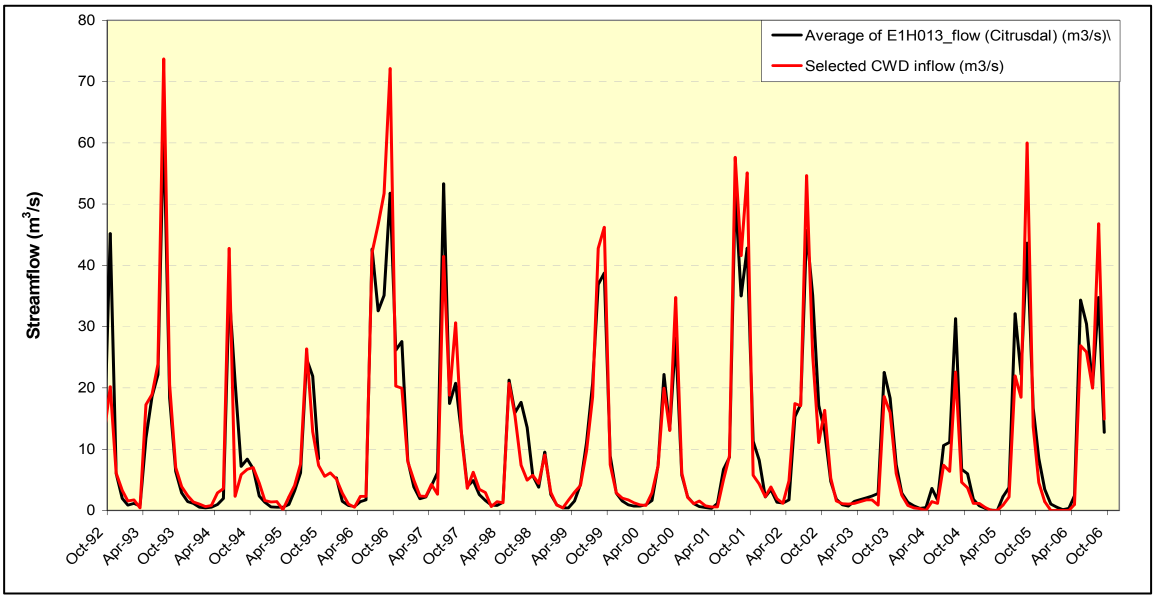
Figure 4.4 Annual inflow to Clanwilliam Dam as % MAP



PatchCWInfMonthv5.xls sheet "MthlyMap2Flow

Figure 4.5 Monthly inflow to Clanwilliam Dam as a function of monthly rainfall

The inflow was also compared with the streamflow measured by the E1H013 gauge at Citrusdal. Surprisingly, even though the E1013 is a rated section with low accuracy, the two flows show similar trends (**Figure 4.6**).



Inflows.xls sheet "CWDInf Pat E1H13"

Figure 4.6 Historical inflow to Clanwilliam Dam

For the system analysis the streamflows generated during the original ORSA were retained. The yield from the two inflow sequences is similar (see **Table 4.2**) and the naturalisation of the Dam Raising Streamflow Sequence was not within the terms of reference for the project.

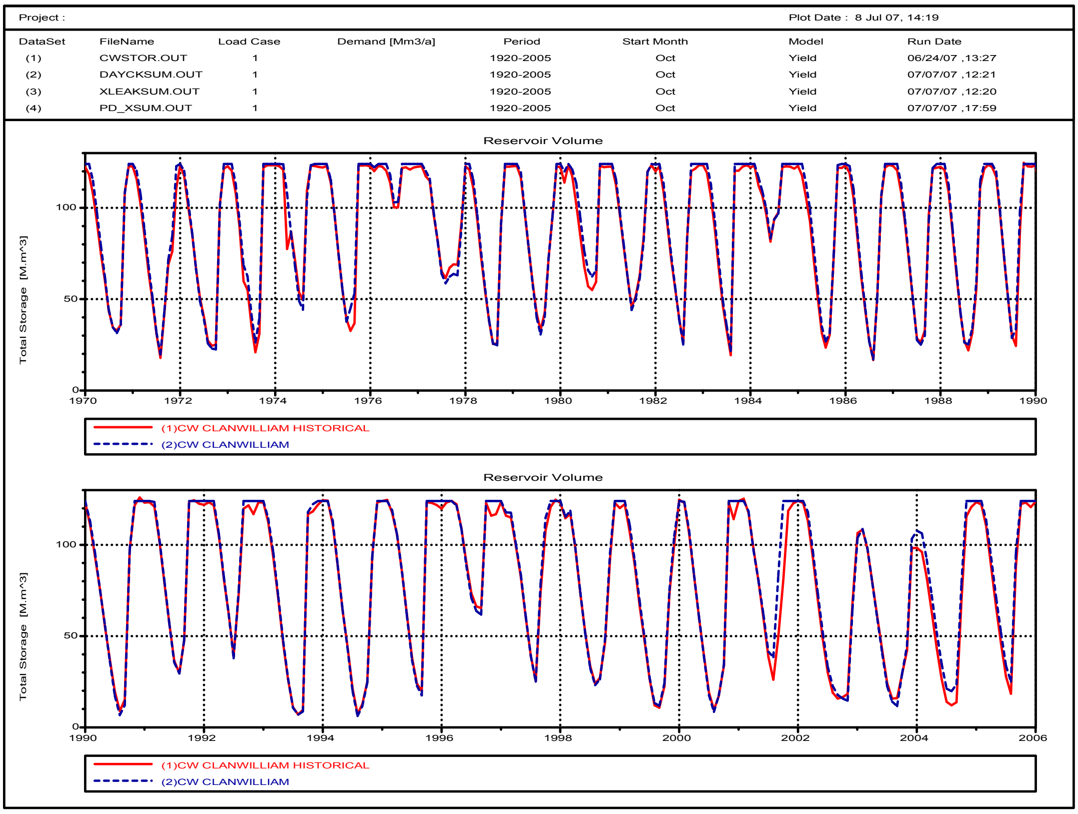
4.3 Modelling historical system

The historical inflow sequence derived in **Section 4.1** was also checked to see how accurately it simulated the historical behaviour of the system. This involved :

- aggregating the daily inflows and demands into monthly sequences
- incorporating these into the Water Resource Yield Model (WRYM)
- comparing the resultant dam trajectory with the historical trajectory.

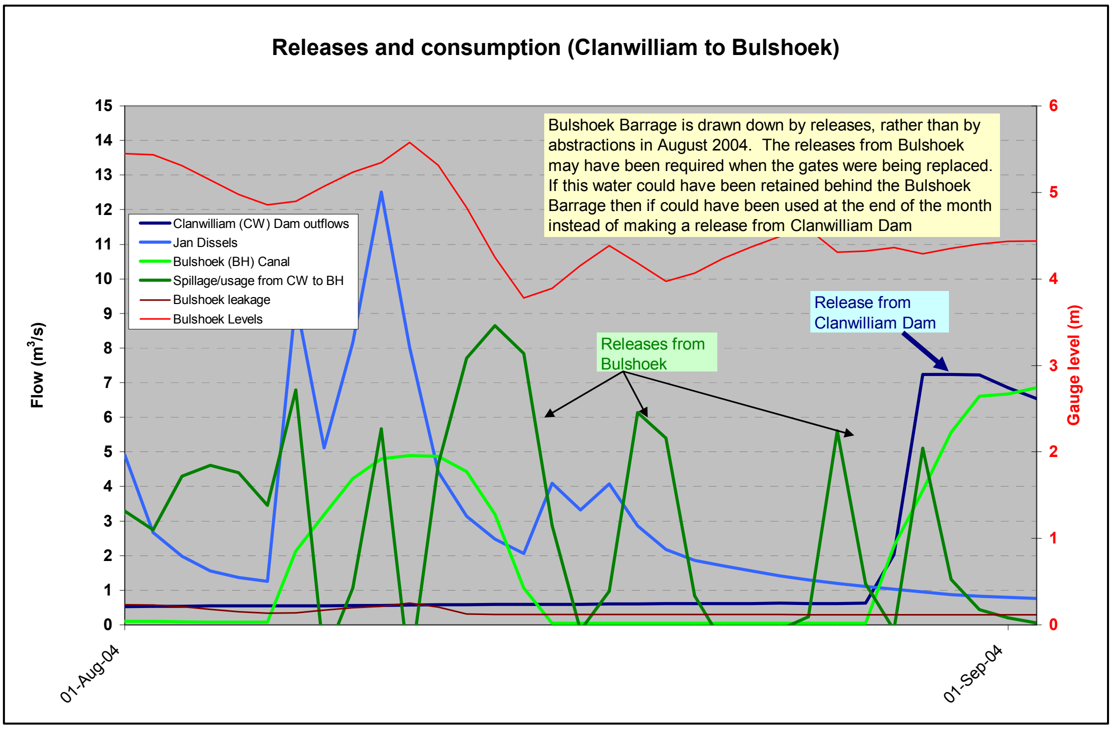
As can be seen in **Figure 4.7**, the simulated historical trajectory (blue) generally compares very favourably with the actual trajectory (red). There appears to be a discrepancy in August 2004, in which the simulated storage is about 10 million m^3 more than the actual and this was investigated in more detail. (Note that the tick marks along the horizontal axis correspond with the start of the hydrological year, so that the tick labelled 2004 actually represents October 2004 not January 2004.) It appears as though three releases (dark green line in **Figure 4.8**) were made in mid-August 2004 to draw down the level of the Bulshoek Barrage (red line using right hand side axis in **Figure 4.8**). Towards the end of the month water was required in the Bulshoek Canal (bright green line in **Figure 4.8**) and because the Barrage had already been drawn down a further release was required from the Clanwilliam Dam (dark blue line in **Figure 4.8**). Had water been held back in the Bulshoek Barrage instead of being released, then the releases from Clanwilliam

Dam would not have been necessary. At this time the Bulshoek Barrage was still being repaired, which may have necessitated the three earlier releases.



ym/v8/out/DAYCK.PLT

Figure 4.7 Observed storage (red) and simulated storage (blue) in Clanwilliam Dam assuming historical abstractions at Bulshoek and Clanwilliam Canals and estimated abstractions between Clanwilliam and Bulshoek and estimated leakage at Bulshoek Barrage



FlowsAndRain17.xls sheet "Clanw2BhoekChartAug 2004

Figure 4.8 Detailed investigation of the operation of Bulshoek Barrage in August 2004

Though reassuring, the favourable comparison does not help to check the assumptions used to determined the inflow to the dam, such as:

- the assumed losses/consumption between Clanwilliam Dam;
- the leakage through the Bulshoek Barrage; and
- the spills over Clanwilliam Dam after the raising of the dam and prior to gauge E1H016 being established (about 1962 to 2000).

For interest, as can be seen in **Figure 4.9**, if the historical leakage downstream of the Bulshoek Barrage were to have been stopped then the simulated (blue) trajectory is about 10 to 20 million m^3 higher than the actual (red) trajectory. If the leakage from the system were over-estimated then this could cause a corresponding over-estimate of the estimated streamflows into the Clanwilliam Dam for the period prior to establishment of gauge E1H016 downstream of the Clanwilliam Dam.

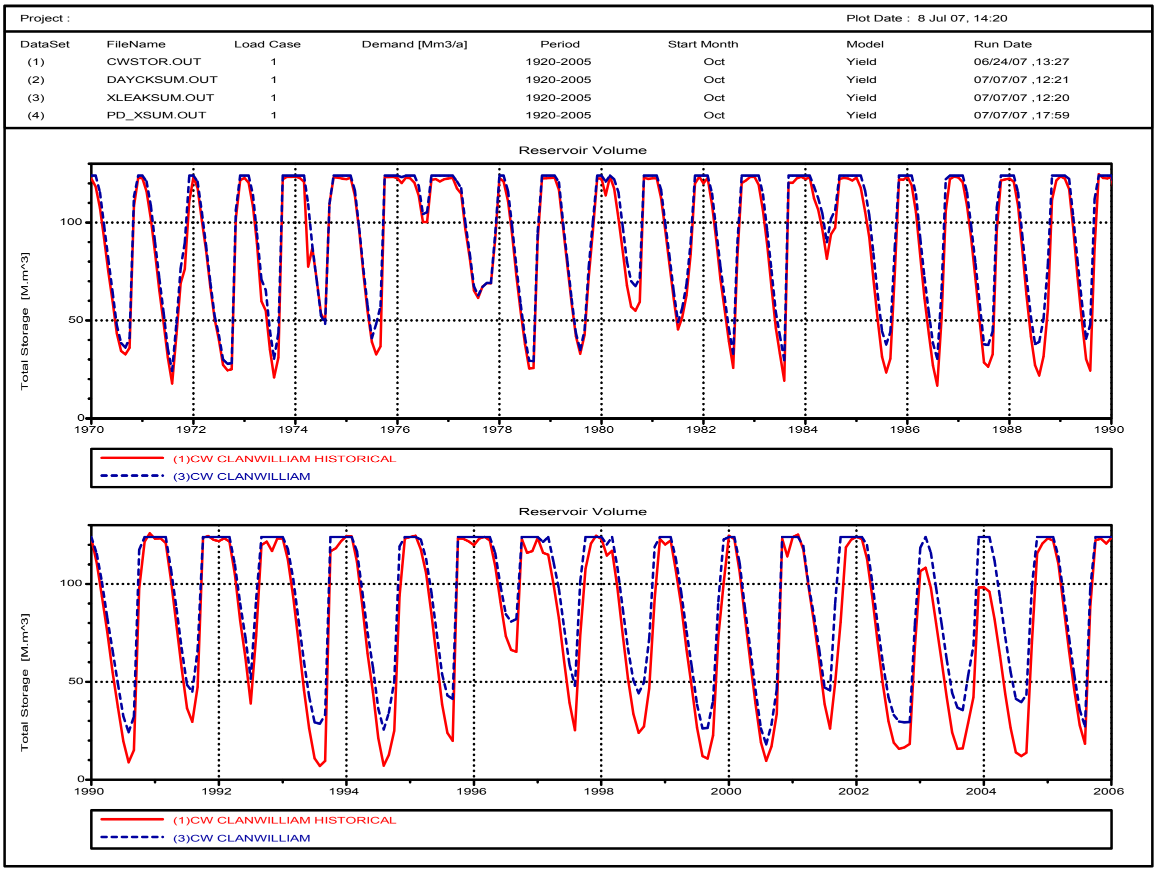


Figure 4.9 Observed storage (red) and simulated storage (blue) assuming historical abstractions at Bulshoek and Clanwilliam Canals and estimated abstractions between Clanwilliam and Bulshoek and no leakage at Bulshoek Barrage

For the purposes of determining the supply from the system under present day conditions the historical inflow sequence needs to be adjusted by increasing the upstream abstraction during the earlier years. The increase over the period from 1970 to 1933 was about 65 m^3/a (DWAF, 1990). Another adjustment made was to fix the leakage at the Bulshoek Barrage, which was reported to be in the order of 1.2 m^3/s (see **Table 3.5**) or about 18 million m^3 over the six summer months. If a constant draft equal to the estimated average supply over the last 25 years is applied to the system then the resultant simulated storage in Clanwilliam Dam differs significantly from the actual historical storage and provides an indication of the sensitivity of the supply from Clanwilliam Dam to these influences. In **Figure 4.10** the simulated storages are initially (in the 1970s) about 20 million m^3/a lower than the actual storages because the simulated storages are created assuming current day developments upstream of the Clanwilliam Dam that reduce the inflow into the dam. However, in the 1990s the simulated storages are about 20 million m^3/a greater than the actual storages because the historical storages would have been drawn down by the leak from Bulshoek, whereas the simulated storages assumed that the leak has been fixed. The average supply over the last 25 years was assumed to be 174 million m^3/a though during droughts the supply would have been curtailed (see Row D of **Table 3.2** for the average and the annual historical water supply volumes).

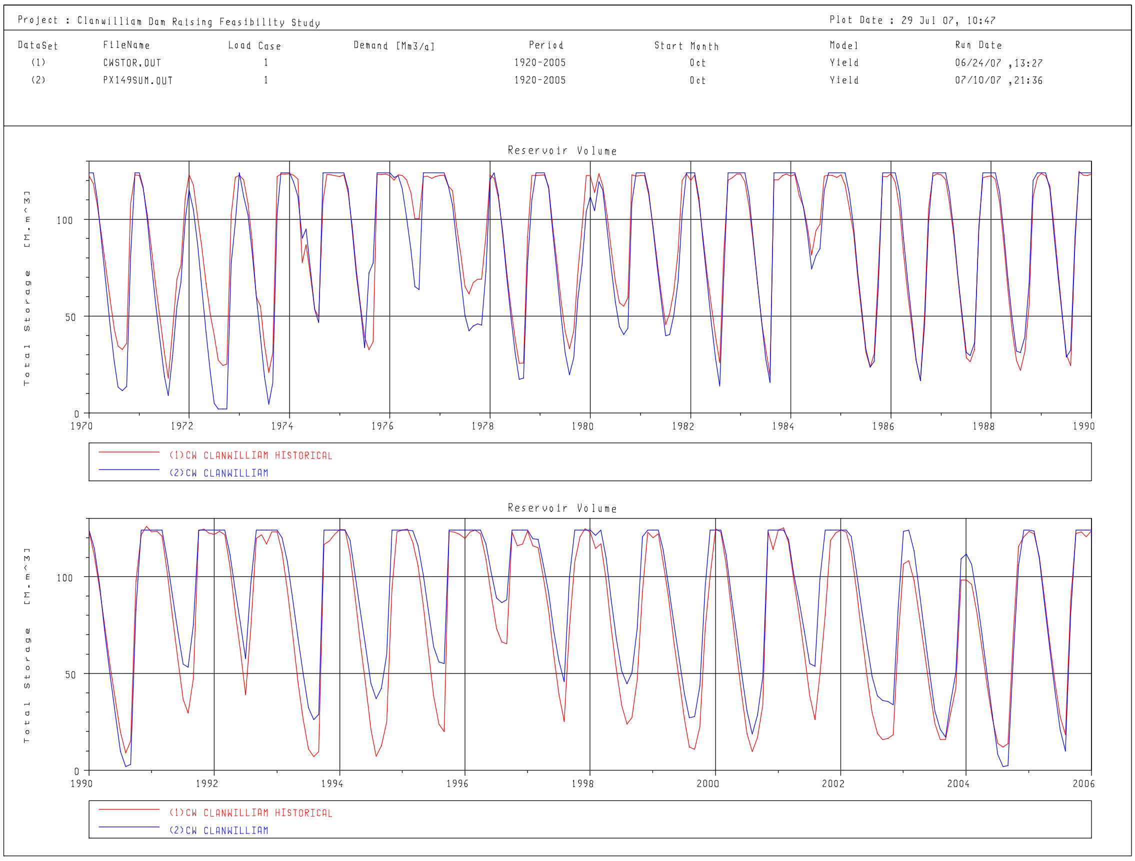


Figure 4.10 **Historical observed storage (red) and simulated storage (blue) assuming present day development levels upstream of Clanwilliam Dam and the average historical supply since 1980 (see Table 4.2) and NO leakage at Bulshoek Barrage**

5. ECOLOGICAL WATER REQUIREMENTS (EWR)

In its natural state the mean annual runoff entering the Atlantic Ocean from the Olifants River would have been about 1 000 million m^3/a (see **Table 2.2**). During winter, about half the streamflows were provided by the Doring River tributary, but during summer the Doring River dried up and the perennial Olifants River provided a baseflow into the estuary. Developments in the Olifants Catchment as a whole have reduced the streamflow by about 30%. The flows in the Doring River tributary have decreased by about 20%, whereas those in the remainder of the catchment have reduced by about 40%, primarily because of the construction of the Clanwilliam Dam. The current capacity of the Clanwilliam Dam is only about 30% of its present day inflow and the proposed raising of the dam may increase the storage up to 100% of the present day inflow.

If Clanwilliam Dam is raised, the dam will absorb more of the winter streamflows before it spills, and as a result, the spillage over the dam will be reduced and delayed.

The streamflows between Clanwilliam Dam and the Bulshoek Barrage are already highly modified to meet the requirements of the scheduled irrigators downstream of the Clanwilliam Dam, which vary from about 8 m^3/s in summer down to 0.5 m^3/s in winter. The multi-level outlet works proposed for the raised Clanwilliam Dam would provide sufficiently warm freshettes to trigger the spawning of the Clanwilliam yellowfish.

It is important to maintain a baseflow in the river downstream of the Bulshoek Barrage, both for the river itself and for the estuary. Historically, some of this baseflow may have been provided by the leak through the Bulshoek Barrage, but irrigators located upstream of the confluence with the Doring River/Trawal intercepted an unknown volume of this leakage. The leak itself has been reduced from a reported value of 1.2 m^3/s down to about 0.25-0.5 m^3/s, and about 0.25 m^3/s of the remaining leakage has been pumped back into the Bulshoek Canal. The effective leakage from 2005 was hence about 0.25 m^3/s.

Historically, the baseflows at the Lutzville causeway have been in the order of 2 m^3/s, decreasing to 0.8 - 1 m^3/s in severe droughts (see **Figure 2.6**). The following measures can contribute toward maintaining this baseflow :

- **Return flows downstream of the Doring River confluence**. It seems as though even during the most severe drought the return flows from the irrigation along the Bulshoek Canal generate a baseflow of about 0.8-1 m^3/s at the Lutzville causeway. These return flows are saline, having total dissolved salts exceeding 2 500 mg/l) and unsuitable for irrigation and hence are left alone.
- **Limiting abstractions upstream of the Doring River confluence**. Anecdotal evidence suggests that irrigators located downstream of the Bulshoek Barrage stopped the Olifants River flowing at the confluence with the Doring River during droughts. Some of these irrigators have a concession to use the leakage from the Bulshoek Barrage but if the leak is fixed and the releases are made for the ecology then this concession could be revoked (see **Section 3.3.2**). More of the return water from irrigators upstream of the confluence would also contribute to the river baseflow.
- **Additional releases from the Bulshoek Barrage**. These releases could supplement the streamflow at Lutzville to increase the streamflow to about 1.5 m^3/s. However, proper management is required to ensure that irrigators located downstream do not intercept these ecological releases. If the freshettes for the Clanwilliam Yellowfish are allowed to

pass through the Bulshoek Barrage as "slug" releases or pulses then the streamflow would be too sporadic to be intercepted by irrigators located lower downstream.

In addition to requiring the baseflows from the Olifants River, the estuary also requires flood flows during winter. During early winter the Doring River provides these high flows as the Clanwilliam Dam impounds the streamflows in the upper Olifants River until it starts to spill. Providing the Doring River continues to provide the flood flows at the estuary it is unnecessary to create a large outlet structure on the Clanwilliam Dam to generate flood flows at the estuary. Even if Clanwilliam Dam is raised the Doring River will continue to contribute toward the high flow requirements of the Olifants River estuary. This means that the outlet capacity required of the Clanwilliam Dam is limited to that dictated by the reaches between Clanwilliam Dam and the confluence with the Doring River, which must essentially be sufficient to trigger the spawning of the Clanwilliam Yellowfish.

The states of selected sites in the catchment are discussed below, together with the possible impact of the raising of the Clanwilliam Dam.

5.1 Upstream of Clanwilliam Dam

The raising of the Clanwilliam Dam will obviously not impact the reach upstream of the Clanwilliam Dam, but the management of this reach could affect the Clanwilliam Dam.

The EWR site selected to evaluate the ecological status of this reach is located on the Olifants River just downstream of the confluence with the Hex River tributary (see **Figure 2.1**). The Present Ecostatus at this site (termed EWR Site 1 in the *Olifants Doring Catchment Ecological Water Requirements Study* – see DWAF, 2006) is a D-category, primarily because of non-flow related impacts, such as:

- bulldozing of the channel,
- cultivation of the alluvial floodplains and
- encroachment of alien and other riparian vegetation.

However, during the summer months, streamflow is an issue as the naturally perennial Olifants River can be pumped dry, sometimes for up to several weeks. The pumping from boreholes located alongside the river has aggravated the situation (see **Section 3.1**).

The most reliable way to increase the level of abstraction possible, and still maintain a D category river, is to reverse the abovementioned impacts by halting illegal practices. Also the volumes pumped from boreholes near the river can be included with the riparian allowance of each farmer or, it this proves impractical, the riparian boreholes can be banned.

One option to reduce the pumping from the river is to increase the storage of winter water for use in summer. Unless proper controls are in place this might not reduce the summer pumping but will only further reduce the streamflow entering the Clanwilliam Dam.

5.2 Downstream of Clanwilliam Dam

The flow regime of the reach between the Clanwilliam Dam and the Bulshoek Barrage is already highly modified. The dam intercepts the winter highflows and releases water for irrigators downstream. During summer, Clanwilliam Dam releases of up to 8 m^3/s, significantly more than natural summer baseflow, down to the canal at the Bulshoek Barrage. In winter, the Clanwilliam Dam releases about 0.5 m^3/s to irrigators located just downstream of the dam who do not receive accruals from the Jan Dissels River (**Figure 3.9**).

However, the multilevel outlet works proposed for the raised Clanwilliam Dam will be able to provide the triggers to encourage the spawning of the Clanwilliam yellowfish, namely:

- freshettes lasting 12 hours with a magnitude between 9 to 17 m^3/s and with a temperature above 19ºC during the period from October to January.
- Subsequent maintenance of the water temperature above 19ºC for about 9 to 20 days after spawning (King, J M, Cambray J A and Impson, N D. 1998).

Previously, these freshettes have been made without any spillage over the Bulshoek Barrage by drawing down the storage level beforehand. However, the Bulshoek Barrage may in turn need to make releases to the estuary during summer. To minimise the use of these releases for irrigation, they could be combined with the freshette releases from Clanwilliam Dam by allowing the freshette releases to spill over the Bulshoek Barrage and allowing them to proceed to the estuary as a series of slug releases, instead of a uniform flow. The freshette releases would need to be timed to deliver sufficient water to the estuary.

5.3 Between Bulshoek Barrage and the Doring River

The environmental flow requirement for the 18 km long reach between the Bulshoek Barrage and the confluence with the Doring River could affect the viability of any proposed raising of the Clanwilliam Dam. The more water flowing in this reach, the less the water that can be used by irrigators upstream. The issue was considered seriously in the *Olifants Doring Catchment Ecological Water Requirements Study*. In this study :

> "There was unanimous agreement from the specialists that the attainment of a D-category at EWR Site 2 was unrealistic, and no such recommendation was made. Instead, a 'residual flow' was recommended to maintain the water quality and vegetation in EWR Reach 2." (DWAF, 2006).

The recommended EWR for this site was to maintain the present ecological state (PES), i.e. a Category E. The key issues pertaining to this EWR site from the *Olifants Doring Catchment Ecological Water Requirements Study* are repeated below :

"The Present Ecostatus is E-category with the deviations from natural, partially driven by flow related issues. These are primarily attenuation of floods and severely-reduced dry season low flows as a result of Clanwilliam Dam and Bulshoek Barrage.

- *Additional impacts include reduced sediment supply, encroachment of reeds and palmiet, and cultivation of flood terraces.*
- *Recent repair work at Bulshoek Barrage has reduced the leaks from the dam, which were in the order of 1 m^3/s in the wet season (Francois van Heerden, DWAF, pers. comm.).*
- *Opportunities for improving the Present Ecostatus through releases from Clanwilliam Dam/Bulshoek Barrage are limited.*
- *At the EWR Workshop an EWR for maintaining a D-category (as per RDM Policy) was determined, however, there was unanimous agreement from the specialists that the risk of the EWR not supporting a D was extremely high as many of the impacts were related to the dam/barrage. Thus, maintenance of a D-category was deemed unrealistic.*
- *The EWR provided here is thus for 'maintenance of PES', viz. E-category.*
- *The EWR to support an E-category was estimated as 51.5 MCM per annum (i.e. 10% nMAR)."*

The EWR requirements for the reach between the Bulshoek Barrage and the confluence of the Olifants and the Doring Rivers are summarised in **Annexure H**.

5.4 Doring River

The raising of the Clanwilliam Dam will reduce the floods entering the estuary and it is assumed that further development in the Doring will be restricted so that floods from the Doring River continue to serve the estuary.

5.5 Estuary

In its natural state, the Olifants River estuary would have half of its winter flows from each of the Doring and the Olifants River and summer baseflows from the naturally perennial Olifants River. Though the current Clanwilliam Dam is only about 30% of the MAR at its site, it does trap the early winter flows and the developments along the Olifants River below the dam modify the summer baseflow.

According to the ecological category (EC) guidelines, the Olifants Estuary, which has been targeted as a Desired Protected Area, should be assigned a Category A, or at least the Best Attainable State (BAS). One development option that might maintain the estuary in a Class B, entailed raising Clanwilliam Dam by 15 metres and making environmental releases. However, the average water supply from this raised dam was 15 million m^3/a less than the supply from the current unraised dam – a scenario unlikely to attract any funding.

The present ecological state of the estuary was assessed as a Class C (DWAF, 2006), which may be worsening due to the low summer baseflows and non-flow related anthropogenic activities such as:

- over-exploitation of fish resources (gill net fisheries); and
- nutrient inputs from agricultural activities

Improved management reducing the impact of the non-anthropogenic activities could help to maintain the estuary as a Class C.

When modelling the yield of the system, the baseflows entering the estuary were maintained above 1.5 m^3/s, providing that such flows would have occurred in the natural undeveloped catchment. This natural baseflow limit was estimated by factoring the streamflow measured at the Jan Dissels gauge E1H006 by 12, an estimate of the ratio of the natural flow at the Jan Dissels to that flowing from the entire Olifants Catchment.

A more complete extract from ecological water requirements study (DWAF, 2006) dealing with the ecological consequences of different runoff scenarios on the Olifants Estuary is repeated in **Annexure I**.

6. IMPACT OF RAISING CLANWILLIAM DAM AND THE EWR ON THE HISTORICAL FIRM YIELD

6.1 Scenarios analysed

Various scenarios were analysed to determine the historical yields of the system for the existing (unraised) dam and for three different dam raisings of 5, 10 and 15 meters. The scenarios also determined the impact of making releases from Clanwilliam Dam to meet certain ecological streamflow water requirements downstream of the Bulshoek Barrage and at the estuary.

The streamflow requirements downstream of the Bulshoek Barrage were only intended to maintain the present ecological status, and the yield for different degrees of environmental releases downstream of the Barrage were investigated:

- no explicit releases,
- drought EWR release
- releases from Bulshoek/Clanwilliam to meet only the baseflow requirement (Class E)
- total flow requirement (Class E)

The Doring River, which contributes about 50% of the winter flow entering the estuary, was assumed to supply the flood requirements at the estuary. A minimum baseflow of 1.5 m^3/s was maintained at the causeway at Lutzville, providing the baseflow did not exceed the natural streamflow at the barrage. During the peak summer irrigation months, up to 1.2 m^3/s of the baseflow was supplied by return flows from the irrigation along the Bulshoek Canal. The shortfall in the baseflow was supplied by releases from the Bulshoek Barrage/Clanwilliam Dam.

6.2 Historical and stochastic yields

The "yield" reported for the Clanwilliam/Bulshoek system in **Table 6.1** and **Figure 6.1** includes the gross supply to the Clanwilliam and Bulshoek Canals and the water pumped out from the Clanwilliam Dam and the Olifants River between Clanwilliam and Bulshoek, including an allowance of 7 million m^3/a for transmission losses between Clanwilliam and Bulshoek. The evaporation from the Clanwilliam Dam and the Bulshoek Barrage are excluded from this yield and it was assumed that the leakage through the Bulshoek Barrage had been stopped. **Table 3.2** gives a breakdown of the historical annual magnitude of these components since 1980. The total average supply was 174 million m^3/a comprising:

- **25 million m^3/a**. Pumping around Clanwilliam Dam and down to Bulshoek Barrage, including unaccounted for transmission losses
- **10 million m^3/a**. Clanwilliam canal
- **139 million m^3/a**. Bulshoek canal

Table 6.1 Yield analysis results derived from historical streamflow sequences

EWR scenario downstream of Bulshoek	Details		Absolute yield				Increase in yield wrt current 122 Mm capacity			
			Dam capacity				Dam capacity			
			122	184	264	362	122	184	264	362
No EWR	Recurrence interval	1 in 5 yrs	185	235	274	305	-	50	89	120
		1 : 10	175	219	248	275	-	44	73	100
		1 : 20	169	197	234	263	-	28	65	94
		HFY	149	184	213	227	-	35	64	78
	Dataset in \hydro\400415\ym\v6		PD	5__	A__	F__				
Class E Drought EWR	Recurrence interval	HFY	133	169	199	214	-	36	66	81
	Dataset in \hydro\400415\ym\v6		0DE	5DE	ADE	FDE				
Class E Baseflow EWR	Recurrence interval	1 in 5 yrs	168	213	254	279	-	45	86	111
		1 : 10	161	196	225	254	-	35	64	93
		1 : 20	156	184	213	242	-	28	57	86
		HFY	128	165	192	206	-	37	64	78
	Dataset in \hydro\400415\ym\v6		0BE	5BE	ABE	FBE				
Full Class E EWR	Recurrence interval	1 in 5 yrs	161	203	238	266	-	42	77	105
		1 : 10	154	183	207	239	-	29	53	85
		1 : 20	142	160	195	218	-	18	53	76
		HFY	124	157	172	187	-	33	48	63
	Dataset in \hydro\400415\ym\v6		OEE	5EE	AEE	FEE				

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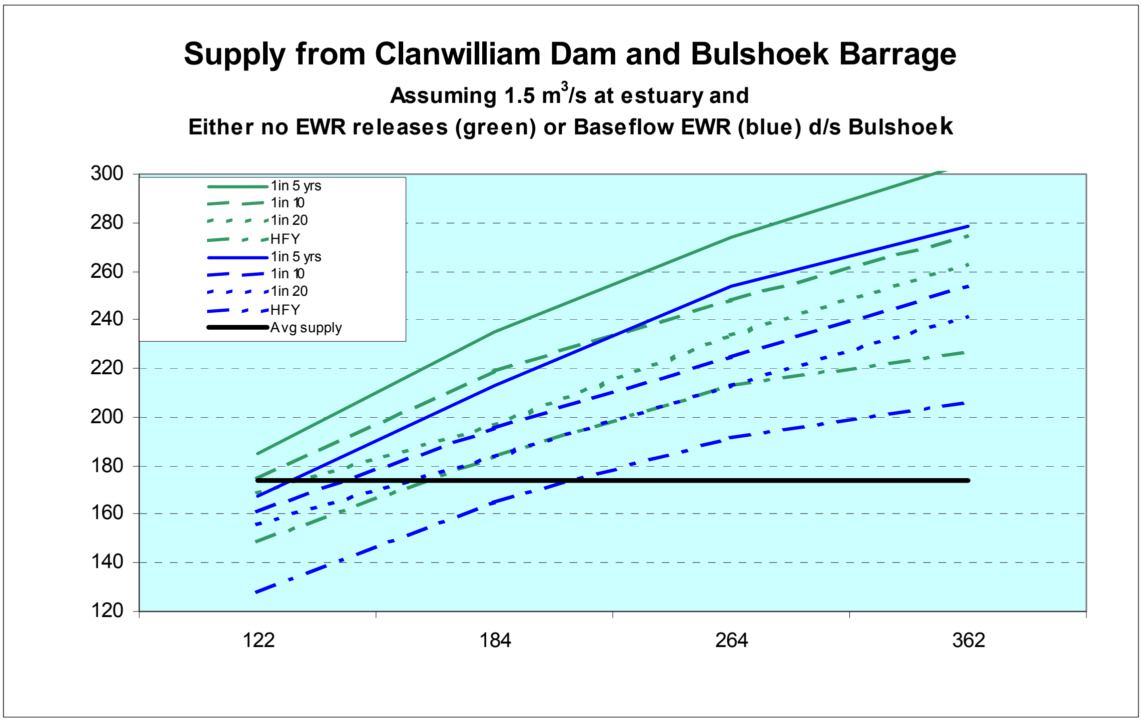


Figure 6.1 Yield analysis results

The long-term supply of 174 million m^3/a is similar to the yield of 1 in 10 year yield of 175 million m^3/a obtained from the current system, i.e. a dam capacity of 122 million m^3 making no EWR releases (see **Table 6.1**). In the past, because of the leakage from the Bulshoek Barrage and greater transmission losses between Clanwilliam and Bulshoek, the actual reliability of the supply would have been less than 1 failure in 10 years. If the Clanwillam Dam is raised by 5, 10 and 15 metres the capacity increases to 184, 264 and 362 million m^3 resulting in increases in the 1 in 10 year yield of 44, 73 and 100 million m^3/a, respectively.

If environmental releases sufficient to provide the Class E baseflow downstream of the Bulshoek Barrage and provide a baseflow of 1.5 m^3/s at Lutzville are made, then the 1 in 10 year yield for the present system reduces by about 14 million m^3/a to 161 million m^3/a and the benefits of increasing the storage capacity of the Clanwilliam Dam are reduced. If the total Class E streamflow downstream of the Barrage is released, then the 1 in 10 year yield reduces by a further 7 million m^3/a to 154 million m^3/a.

The storage trajectories of the Clanwilliam Dam (supplying the Historical Firm Yield and the 1 in 5 year target draft) and the water supply (both monthly and annual) are shown for the current system in **Figure 6.2** and **Figure 6.3** and for Clanwilliam Dam's capacity increased to 362 million m^3 in **Figure 6.4** and **Figure 6.5**.

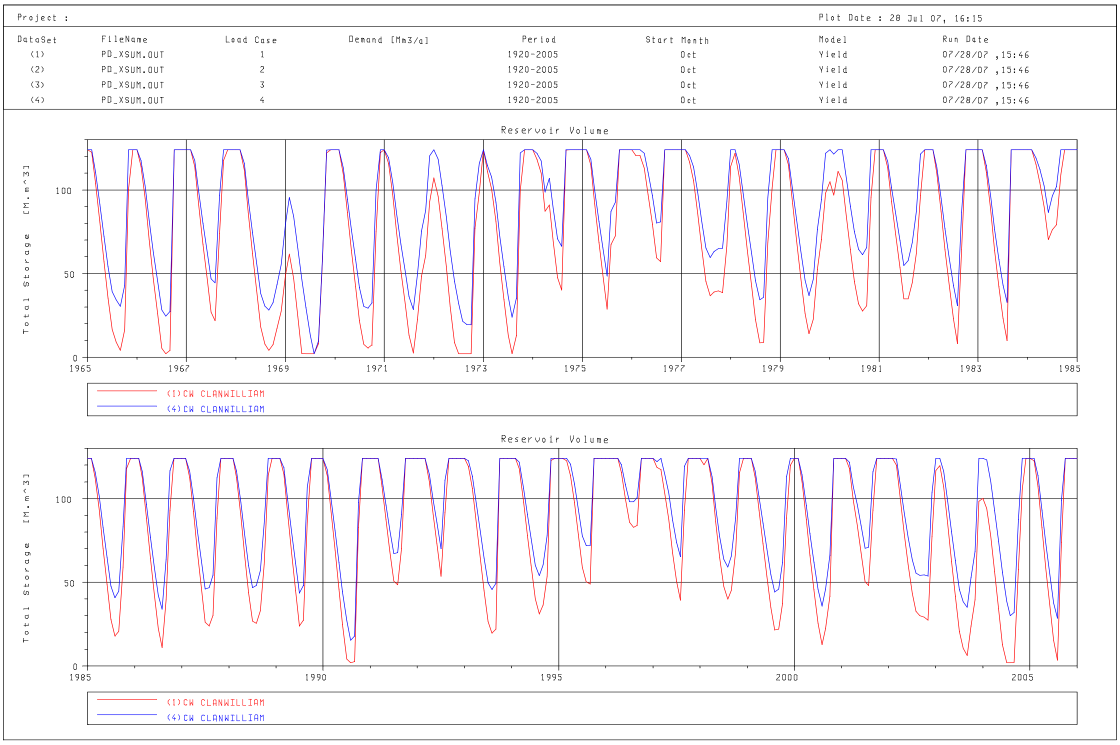


Figure 6.2 Storage for current capacity (124 million m^3) assuming target drafts equal to the historical firm yield (blue) and the 1 in 5 year yield (red)

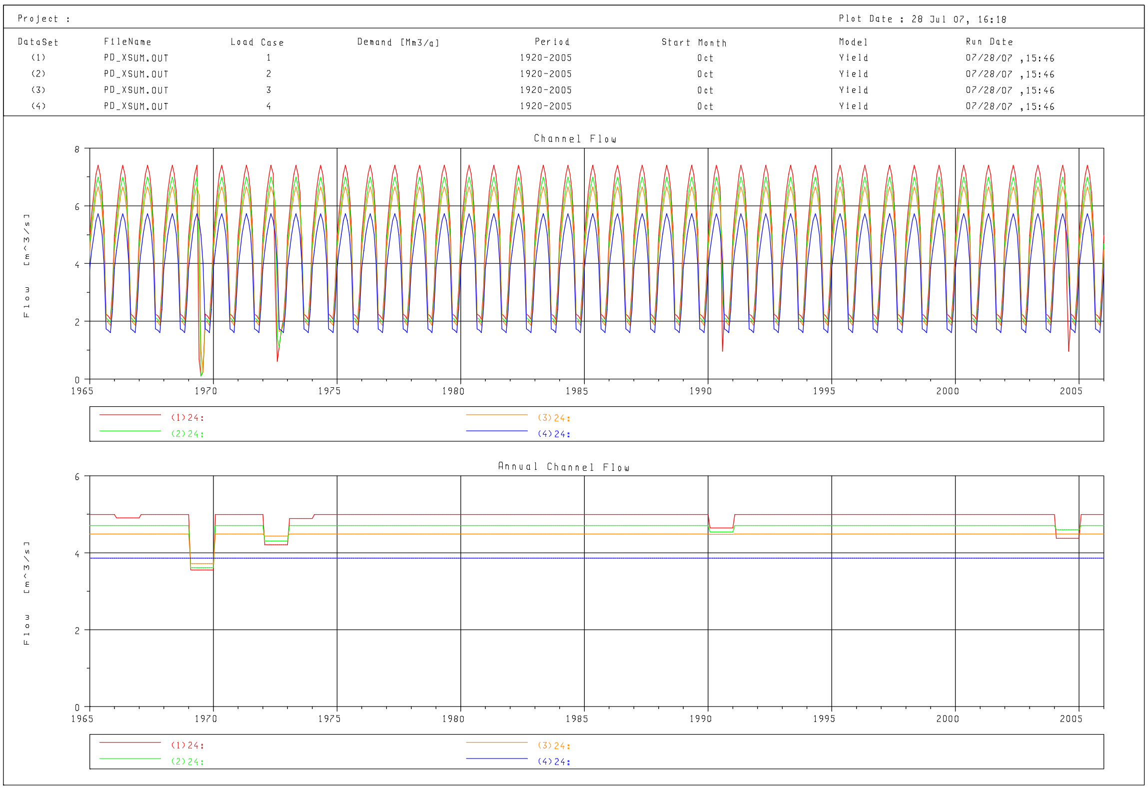


Figure 6.3 Annual supply for current capacity (124 million m³) assuming target drafts equal to the historical firm yield (blue) and the 1 in 20 (orange), 1 in 10 (green) and 1 in 5 (red) year yields

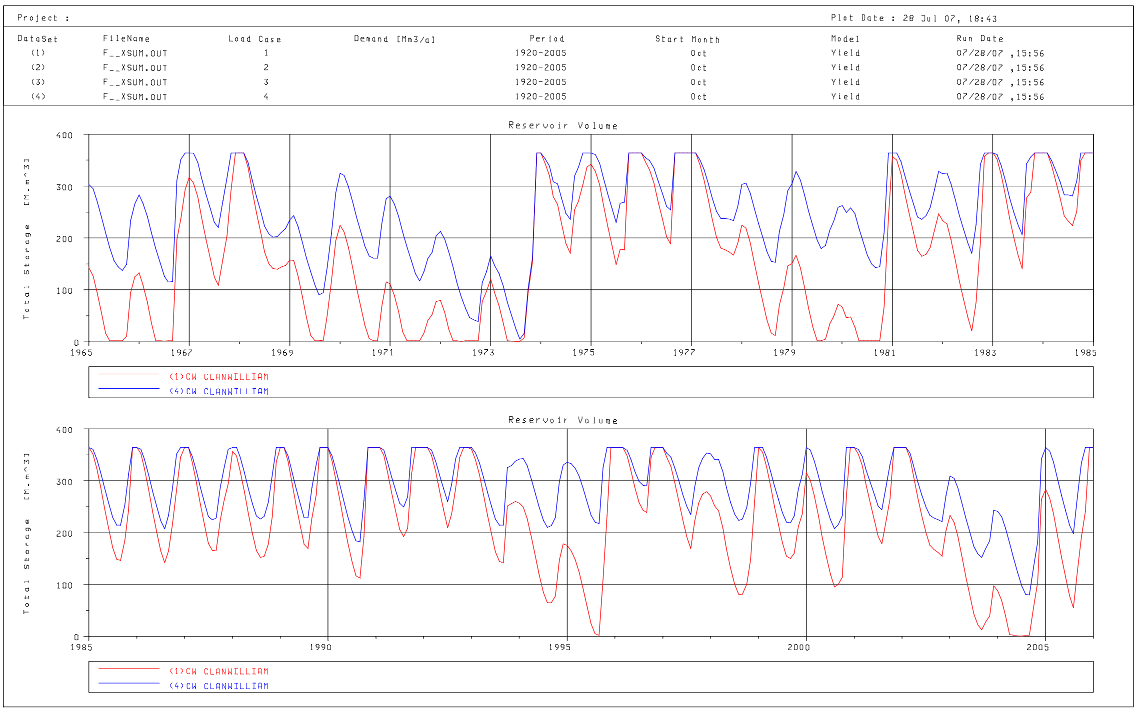


Figure 6.4 Storage for 15 m raising (364 million m³) assuming target drafts equal to the historical firm yield (blue) and the 1 in 5 year yield (red)

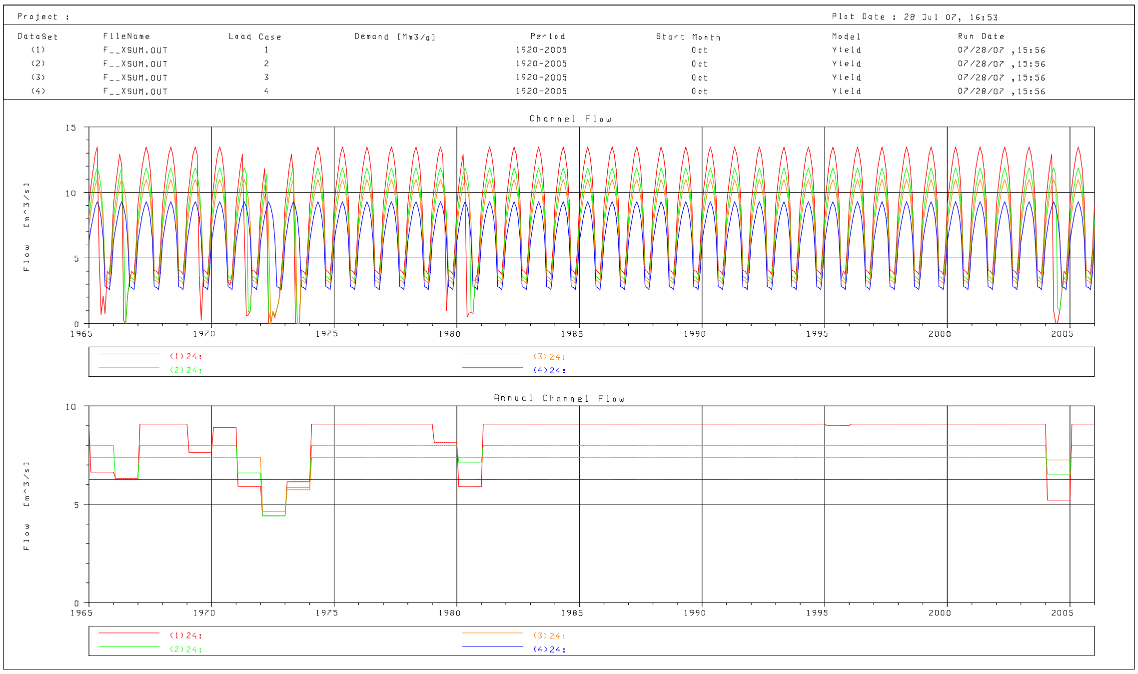


Figure 6.5 Annual supply for 15 m raising (364 million m^3) assuming target drafts equal to the historical firm yield (blue) and the 1 in 20 (orange), 1 in 10 (green) and 1 in 5 (red) year yields

When the dam size is increased, the operation of the Clanwilliam Dam will need be changed from using almost all of the available water each summer to allowing for a carry over from year to year for drought years. If the current system tries to supply the 1 in 10 year yield without carryover then the minimum annual supply during a drought is about 78% of the target supply (see the supply for 1970 – green line in the lower plot of **Figure 6.3**). If the storage is increased to 362 million m^3 and the system still tries to supply the 1 in 10 year yield without carryover then the minimum annual supply during a drought is only 45% of the target supply (see the supply for 1972 – green line in the lower plot of **Figure 6.5**).

The yields for the system were determined for the period from 1920 to 1990. However, check runs were made using three additional historical streamflows for the period from 1991 to 2005, namely :

- Clanwilliam Dam
- Between Clanwilliam and Bulshoek Barrage
- Downstream of Bulshoek Barrage, including the Doring River.

These streamflows incorporated the effects of upstream development (such as abstractions and farm dam interception) and these upstream impacts were not modelled for the extended period. The check runs determined the historical firm yields for the period from 1920 to 2005. The critical period for both the unraised Clanwilliam Dam and 15 meter raising of the Clanwilliam Dam (**Figure 6.2** and **Figure 6.4**) show that the dam is drawn down to empty in the in 1970 and 1974, respectively and not in the period after 2000, so the additional streamflow record does not include the critical period. The impact of the recent drought was exacerbated by the increased upstream development since the 1960s. The estimate of the inflow to Clanwilliam Dam from 2001 should be fairly accurate, as gauge E1H016 had commenced measuring the releases (see **Section 4**).

The yields determined in **Table 6.1** using the historical streamflow sequences were checked using the stochastic streamflow generator, which generates streamflows with the same statistical characteristics as the historical streamflows. This generator helps to check the return period of the historical firm yield and also estimates the yields for return periods exceeding the length of the historical inflow sequence. For the present day scenario the historical firm yield has an annual probability of failure of about 1 in 60 years. For interest, the 1 in 20 year yield of 169 million m^3/a determined using the historical inflow sequences (see **Table 6.1**) is very close to the corresponding 1 in 20 year yield of 167 million m^3/a determined using stochastics (see **Figure 6.6**).

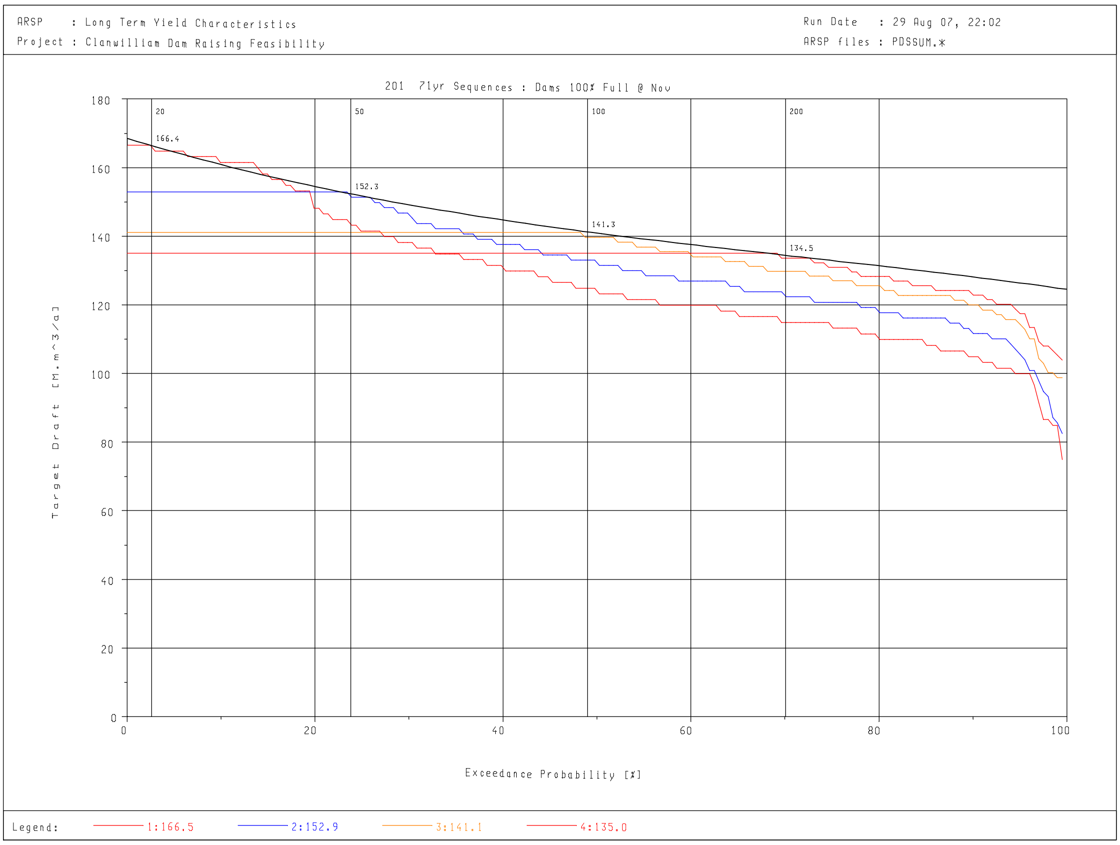


Figure 6.6 LTCC for present day system (Scenario PD)

The stochastic yields were also determined for the scenario assuming that Clanwilliam Dam is raised 15 metres and a baseflow environmental requirement is released from Bulshoek Barrage (see **Figure 6.7**). The historical firm yield appears to have a high reliability, an annual probability of failure in excess of 1 in 100 years. However, if one looks more closely and uses the long-term characteristic curves (LTCC) to estimate the 1 in 70 year yield then this yield of about 21 million m^3/a is only about 6 million m^3/a more than the historical firm yield. However, the 1 in 20 year yield from the historical and stochastic inflow sequences are close, 242 and 249 million m^3/a, respectively.

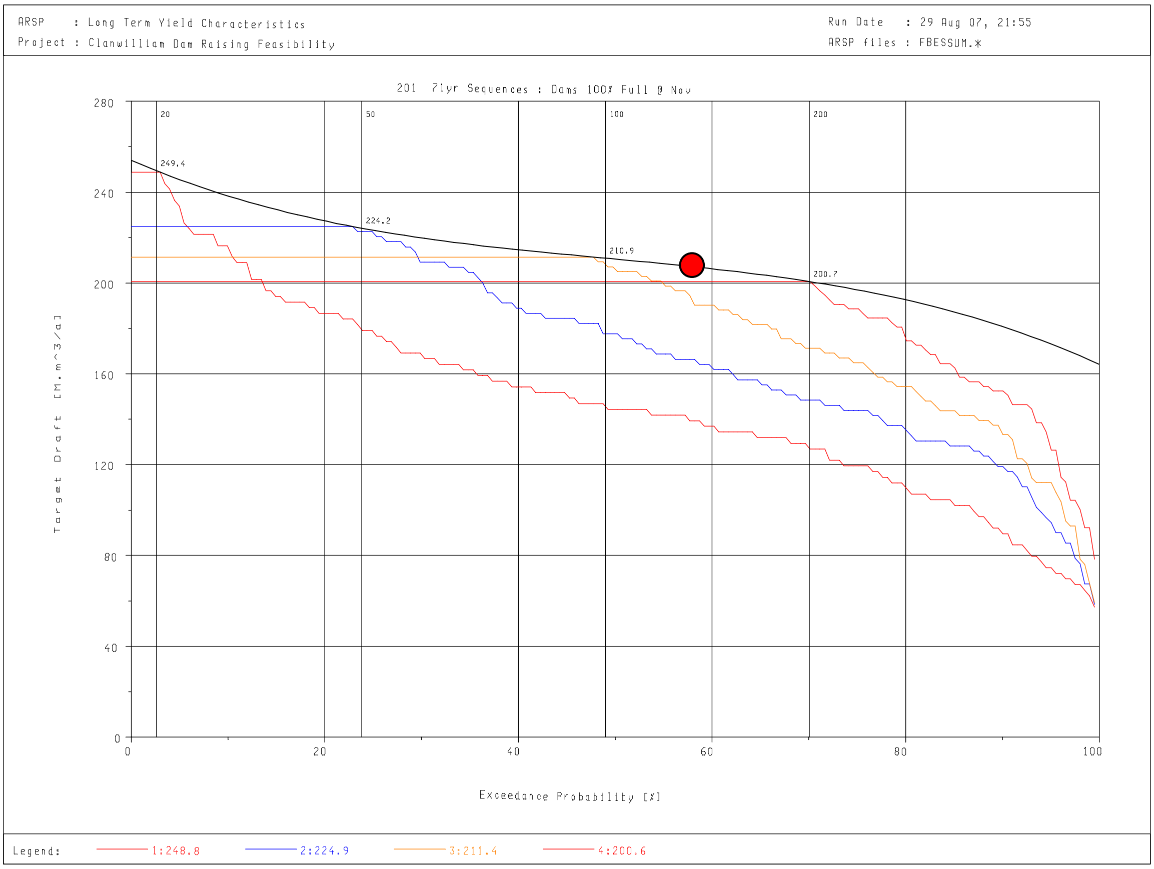


Figure 6.7 LTCC for Clanwilliam Dam raised by 15 m and baseflow releases downstream of Bulshoek Barrage (Scenario FBE)

6.3 EWR supplied for different scenarios

The Olifants Doring Catchment Ecological Water Requirements Study (DWAF, 2006) has already analysed the impact of different Ecological Water Requirements (EWR) scenarios on the estuary.

The study concluded that if Clanwilliam Dam were to be raised that improved management would help to maintain the estuary as a Class C. The management would have to reduce the following :

- over-exploitation of fish resources (gill net fisheries), and,
- nutrient inputs from agricultural activities

The Ecological Water Requirements Study did not analyse the reach immediately downstream of the Bulshoek Barrage, which is therefore covered in more detail in this section. The yield of the existing system is very sensitive to the EWR requirements downstream of the Bulshoek Barrage. Unregulated floods from the Jan Dissels and, later in winter, spills over Clanwilliam Dam will supply a portion of these EWR requirements. The portion of the EWR requirement explicitly supplied from the Bulshoek Barrage can vary from:

- No EWR requirement
- Drought EWR requirement
- Baseflow EWR requirement
- Total EWR requirement

The historical firm yields associated with these scenarios are 149, 133, 128 and 124 million m^3/a, respectively (see **Table 6.1**). If Clanwilliam Dam is raised then the contribution of the spills over the dam to the streamflow below Bulshoek Barrage will diminish, which would mean that the explicit releases from the Bulshoek Barrage might need to be increased.

The motivation of the EWR requirement downstream of the Bulshoek Barrage is to maintain the present ecological state (PES), which in the case of this reach was a Class E, through the provision of a residual flow. The main change in the streamflows downstream of Bulshoek Barrage is the reduction in the leakage through the barrage from about 1.2 m^3/s to about 0.25 m^3/s. Irrigators who obtained concessions to use this leakage when the leaks from the Barrage to the estuary were seen as a waste of water could have used a significant portion of this leakage (see **Section 3.3.2**). In **Table 3.9** the consumption between the Bulshoek Barrage and the Doring River was guessed at 0.5 m^3/s (with extremely low confidence because of the lack of metering). Stopping these temporary concessions allowing riparian irrigators downstream of Bulshoek to pump water from the Olifants River could also help ensure that releases from the Bulshoek Barrage and the return flows/releases for the estuary/leaks from the Bulshoek Canal benefit the environment.

Figure 6.8 shows the streamflow downstream of the Bulshoek Barrage, assuming that Clanwilliam Dam is not raised. The streamflows are split into four seasons/quarters, namely February to April (pink), May to July (red), August to October (blue) and February to April (green). For each of the quarters the total Class E requirement (thick solid lines) and baseflow requirement (thin solid lines – sometimes overlain and masked by the thick lines) are compared with the streamflow obtained from releases equal to the Class E EWR baseflow plus unregulated spills (dashed line). Note that in early winter (May to July), the supplied streamflow (dashed red line) is less that the total EWR requirement for about 40% of the time (solid red line). However, as expected, it does exceed the baseflow EWR requirement (light red line) all the time. Later in winter (August to October) the streamflows exceed the total EWR requirement.

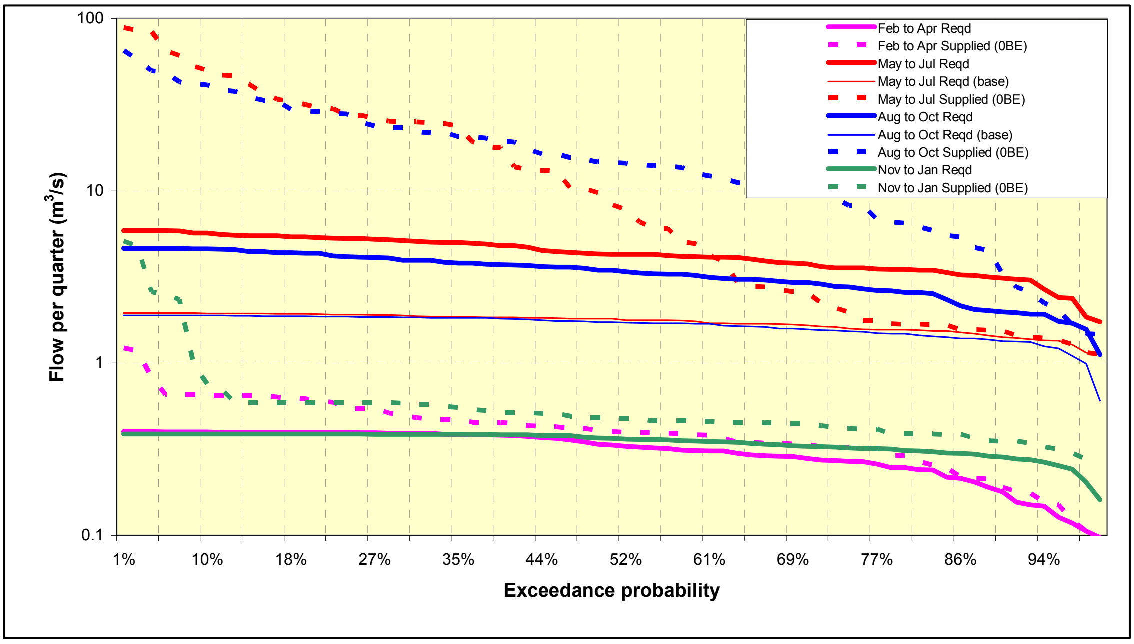


Figure 6.8 **Streamflow downstream of Bulshoek Barrage assuming that Clanwilliam Dam is not raised. Comparing total Class E requirement (thick solid) and baseflow requirement (thin solid) with the streamflow obtained from releases equal to the Class E EWR baseflow plus unregulated spills (dashed)**

Figure 6.9, **Figure 6.10**, **Figure 6.11** and **Figure 6.12** show the streamflow downstream of Bulshoek for the different seasons separately so that the impacts of raising Clanwilliam Dam by 0, 5, 10 and 15 metres can be evaluated. **Figure 6.10** shows the streamflows for the quarter from May to July. The raising of Clanwilliam by 15 meters means that the total flow requirements at the site are satisfied 40% of the time instead of 60% of the time if Clanwilliam Dam is not raised. **Figure 6.11** shows the streamflows for the quarter from August to October and the raising of the Clanwilliam Dam means that the regulated flows need to be augmented by baseflow releases up to 30% of the time.

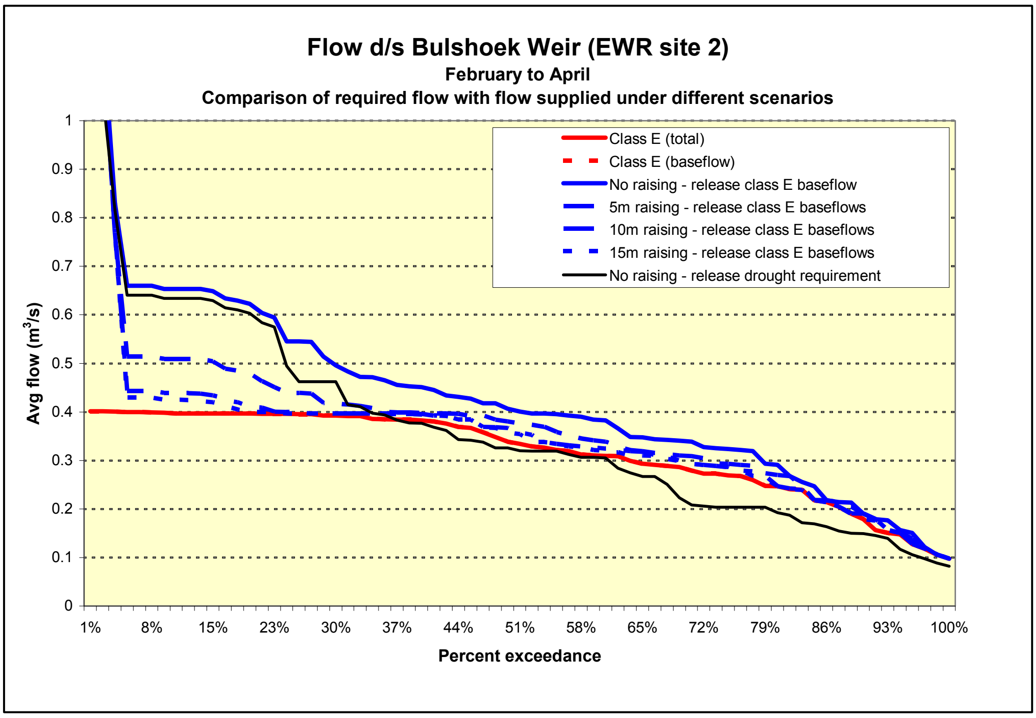


Figure 6.9 Flow downstream of Bulshoek Barrage for different scenarios (May to July)

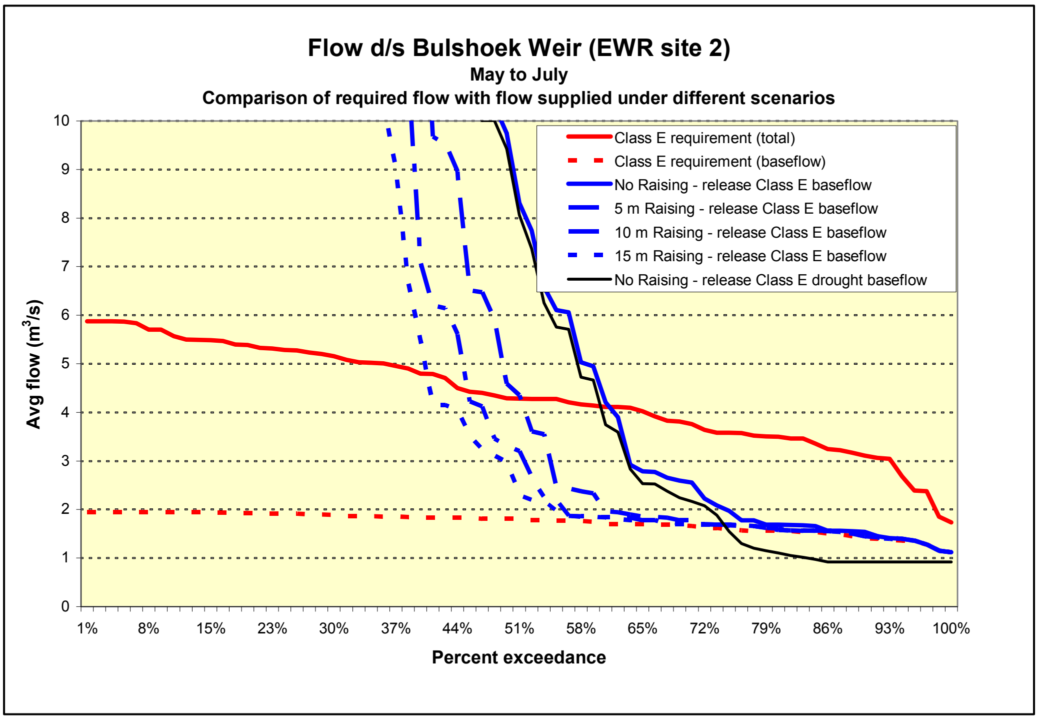


Figure 6.10 Flow downstream of Bulshoek Barrage for different scenarios (May to July)

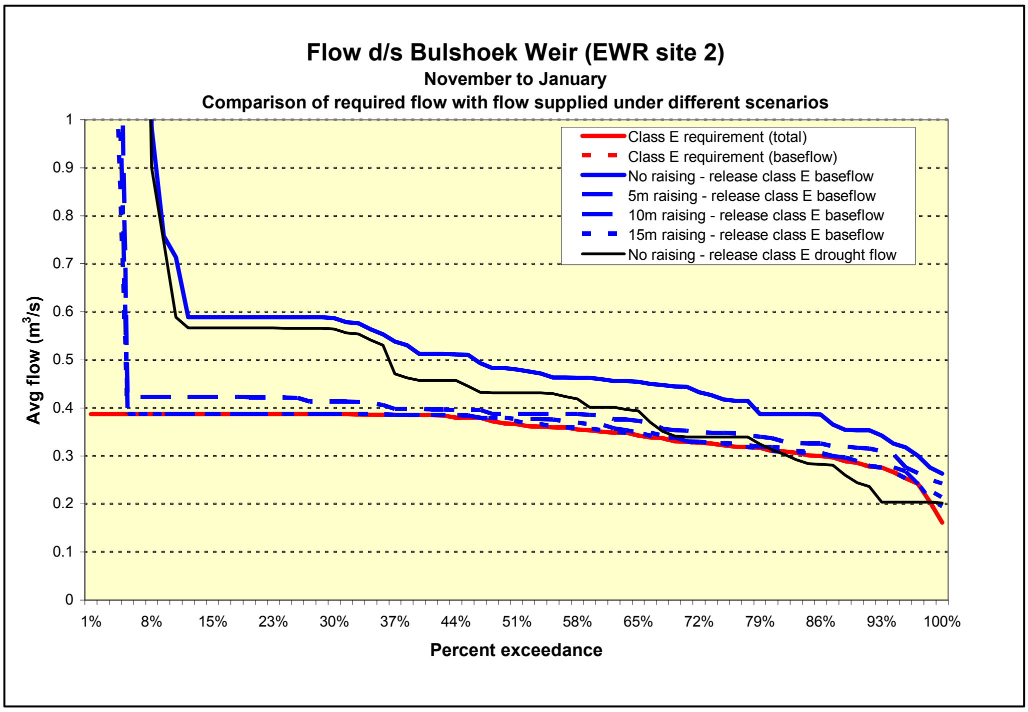


Figure 6.11 Flow downstream of Bulshoek Barrage for different scenarios (August to September)

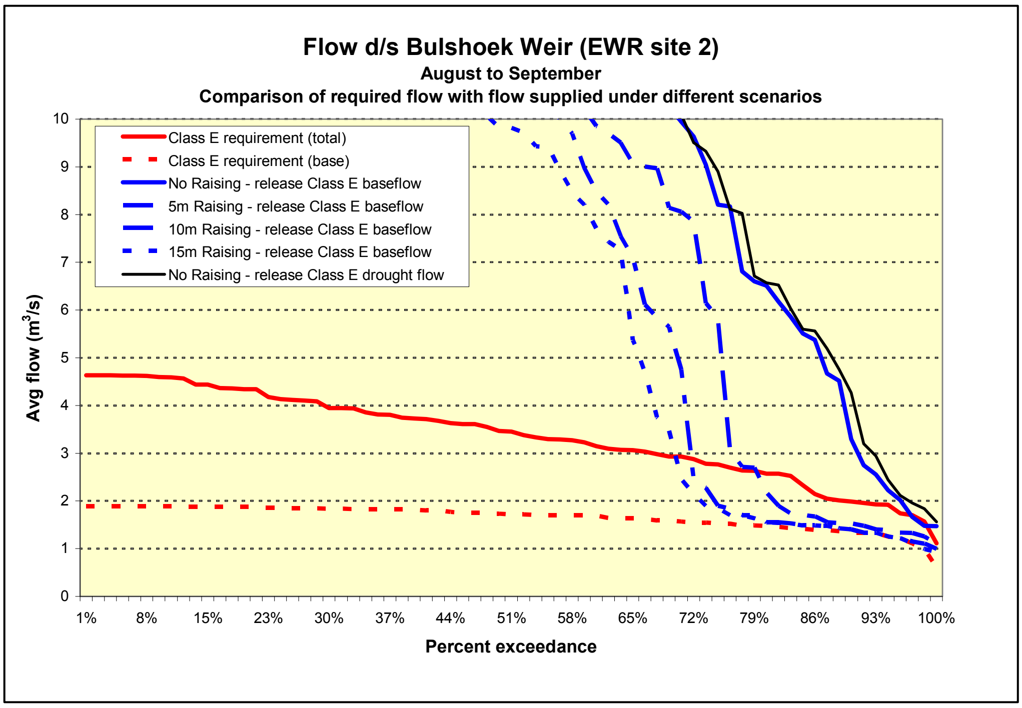


Figure 6.12 Flow downstream of Bulshoek Barrage for different scenarios (November to January)

The scenarios releasing the baseflow EWR from the Bulshoek Barrage were closer to the historical situation when the Bulshoek Barrage was leaking water than the scenarios meeting the total EWR requirements downstream of the Bulshoek Barrage. For raisings of 5, 10 and 15 meters, the yields from the scenarios providing the Class E baseflow were adopted for the financial analysis, while the yields from the scenario providing the drought baseflow was used for the current unraised dam. This approach increased the yield of the unraised dam and therefore decreased the incremental advantage of the dam raising scenarios.

A separate analysis comparing the streamflow downstream of Bulshoek Barrage with the environmental requirements was performed by Southern Waters (see **Annexure O**). The streamflows were compared with the maintenance flows given in Table 5-1 of the Annexure which requires that the average flows be about 5.5 million m^3/a (2 m^3/s) in May and June. This requirement is less onerous than the total flow requirement represented by the red flow duration curves in **Figure 6.10**. Southern Waters concluded that the streamflow downstream of Bulshoek Barrage should be able to meet the reserve.

7. THE YIELD OF PUMP STATIONS UPSTREAM OF CLANWILLIAM DAM

During summer the Olifants River streamflows are insufficient to sustain the irrigation requirements and the river can be pumped dry, with severe impacts on the environment and on the bottommost irrigators (see **Section 3.1**). One possible solution is to construct additional off-channel dams upstream of the Clanwilliam Dam to store the winter flows. These dams would provide a portion of the water requirements during summer and would lessen the summer abstractions from the Olifants River itself. In addition to their cost, these dams could reduce the yield available at Clanwilliam Dam as is discussed below.

The daily historical streamflows to Clanwilliam Dam (developed in **Section 4**) were used to estimate the average abstraction rate from the Olifants River for various capacities of pumps located immediately upstream of the Clanwilliam Dam assuming no environmental releases were made. Because this sequence is a historical sequence the earlier streamflows may over-estimate the available water and more weight should be given to the later period, though during winter the irrigation requirements are low and the capacity of the farm dams upstream of the Clanwilliam Dam is about 34 million m^3, about 10% of the present day inflow (see **Table 2.5**).

Any irrigator would have to select sufficient annual crops that can be curtailed because during the drought of the 1968 calendar year the annual volume pumped into the off-channel dams would have reduced significantly, to about 36% of the normal volume for a 2 m^3/s pump station capacity. This volume would still be subject to evaporation losses.

Figure 7.1 shows that for a capacity of about 4 m^3/s, the pump would operate at close to its capacity for a considerable portion of the time. In 1968, however, the average winter abstraction would have dropped by 66% to only 1.3 m^3/s. A larger 20 m^3/s pump station would have experienced more severe problems in 1968 and would only have been able to pump an average of 3 m^3/s or 15% of its capacity. Farmers would have to include sufficient annual crops in their crop mix to accommodate curtailments of this magnitude.

This information is presented differently in **Figure 7.2** where the pumping rates have been ranked in descending order. **Figure 7.2** can be used to determine how much can be pumped for a given annual risk of failure. For instance, to determine the average winter pumping rate for a 4 m^3/s pump station with a risk of failure of 1 in 10 note where the gridline corresponding to the 90% exceedance (this corresponds to a 1 in 10 year annual risk of failure) crosses the purple line representing the 4 m^3/s pump capacity. The average pump rate is 3.6 m^3/s or 90% of the pump capacity.

Figure 7.2 can also be scaled to estimate the pumping rates at pump stations located further upstream. For instance, if the streamflow at a particular site were half that entering the Clanwilliam Dam then one can deduce that a pump station of 2 m^3/s (half of the 4 m^3/s considered at the Clanwilliam Dam) would also operate at the same capacity as a 4 m^3/s pump station located just upstream of the dam, i.e. 90% of its capacity with a 1 in 10 year annual risk of failure.

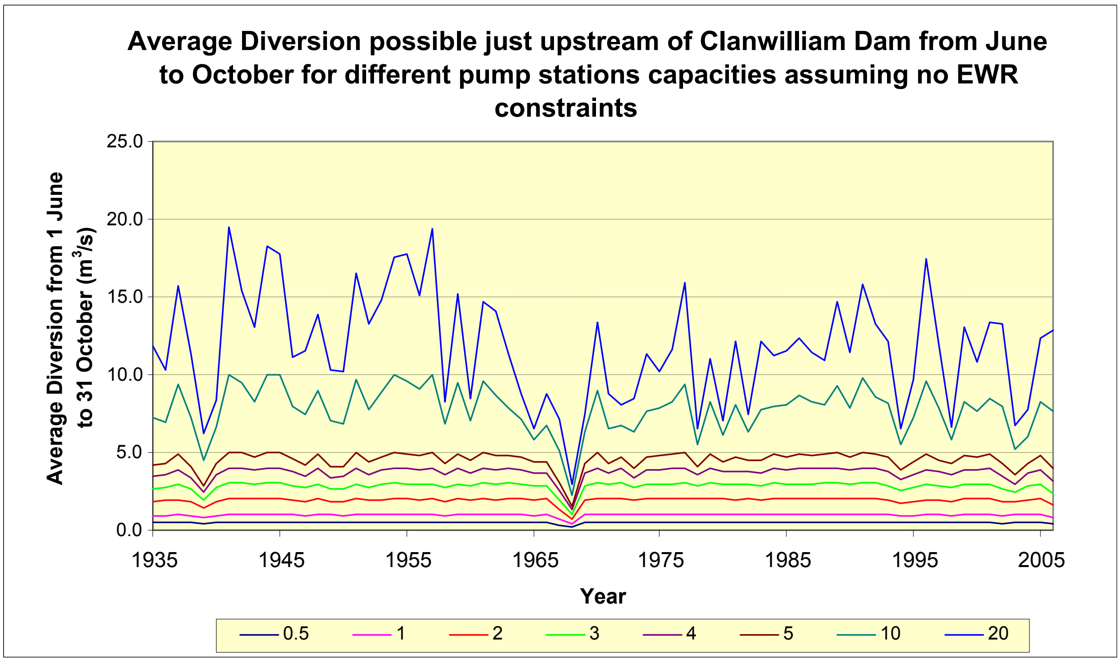


Figure 7.1 Average diversion possible just upstream of Clanwilliam Dam from June to October for different pump stations capacities assuming no EWR constraints

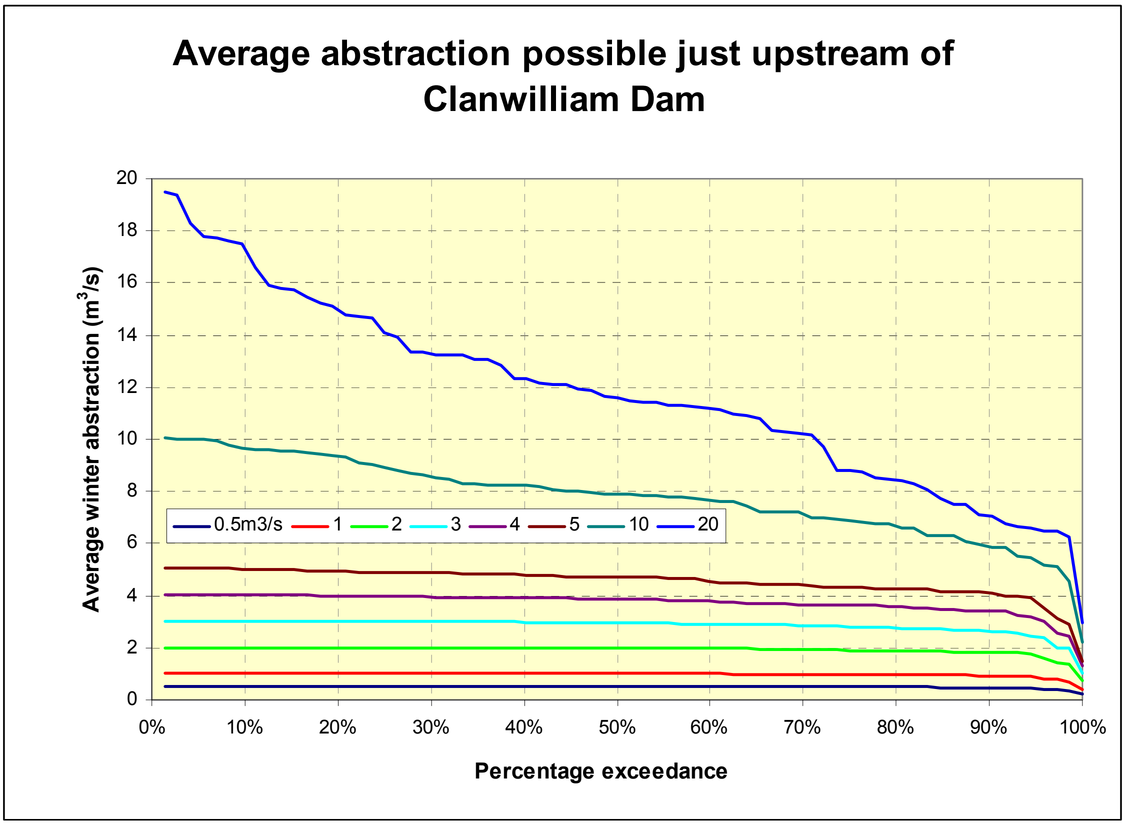


Figure 7.2 Average abstraction possible just upstream of Clanwilliam Dam

From the above, a 2 m^3/s pump station located on the Olifants River and accessing about half the inflow to the Clanwilliam Dam would be able to operate at almost full capacity for most winters (June to October), and fill a dam of 26 million m^3. If Clanwilliam Dam were raised to 264 million m^3 and this additional dam were also constructed upstream then one could argue that one now has a system with a storage of 290 million m^3, which would have a 1 in 10 year yield of about 232 million m^3/a, about 7 million m^3/a more than the 1 in 10 year yield of 225 million m^3/a of the raised Clanwilliam Dam by itself. **Figure 7.3**, (based on **Figure 6.1**), shows the 1 in 10 year supply for a range of sizes of Clanwilliam Dam if releases are made to meet the baseflow requirements downstream of the dam and has been annotated to help identify the increase in yield associated with this increase in dam size. However, the additional dam would supply about 26 million m^3/a on average to users upstream of the Clanwilliam Dam so that the yield measured at the Clanwilliam Dam would be 26 million m^3/a less than 232 million m^3/a or 206 million m^3/a. This means that the additional 26 million m^3 farm dam upstream of the Clanwilliam Dam reduced the yield at Clanwilliam Dam from 225 million m^3/a to 206 million m^3/a, or by about ¾ of the additional capacity of the farm dam.

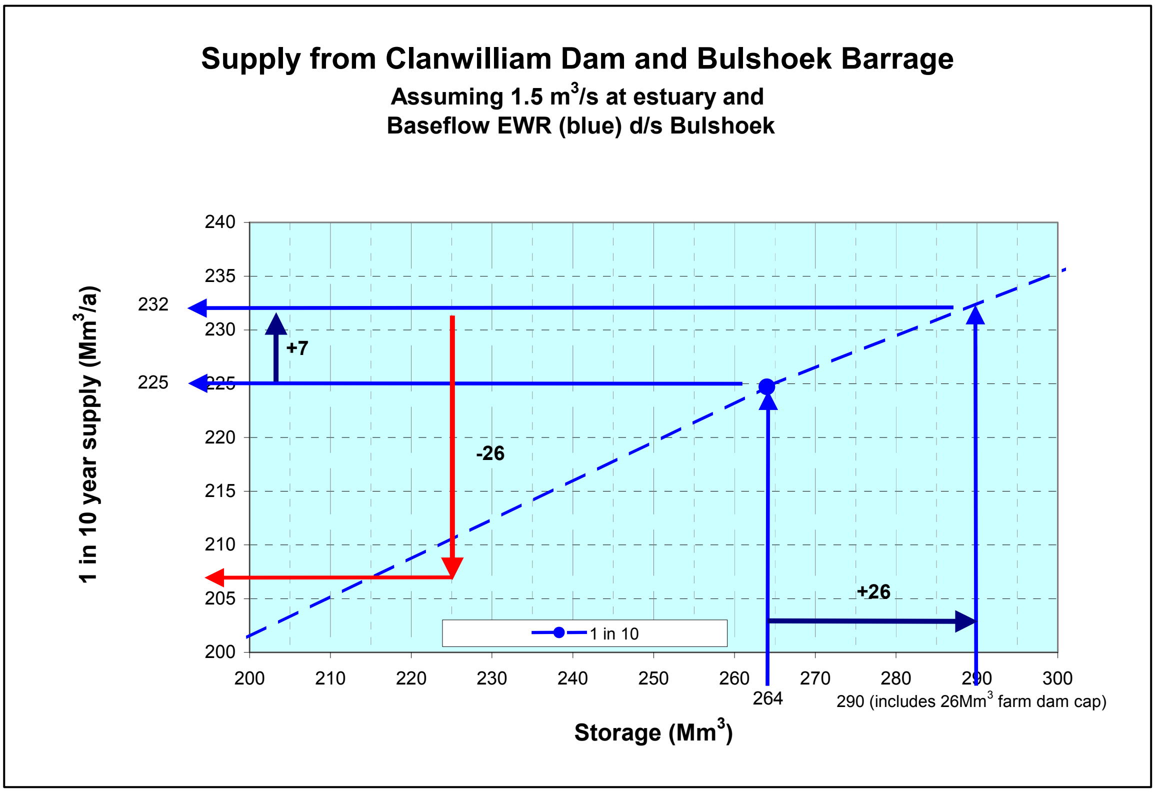


Figure 7.3 **Yield analysis results**

8. IMPACT ON THE FLOW AT THE ESTUARY

To simplify the modelling of the impact of changing the operation and capacity of the Clanwilliam Dam on the estuary, the present day streamflows from the WRYM were accumulated into three components:

- the inflows into the Clanwilliam Dam
- the accruals between Clanwilliam and Bulshoek
- the accruals downstream of Bulshoek, including the Doring River

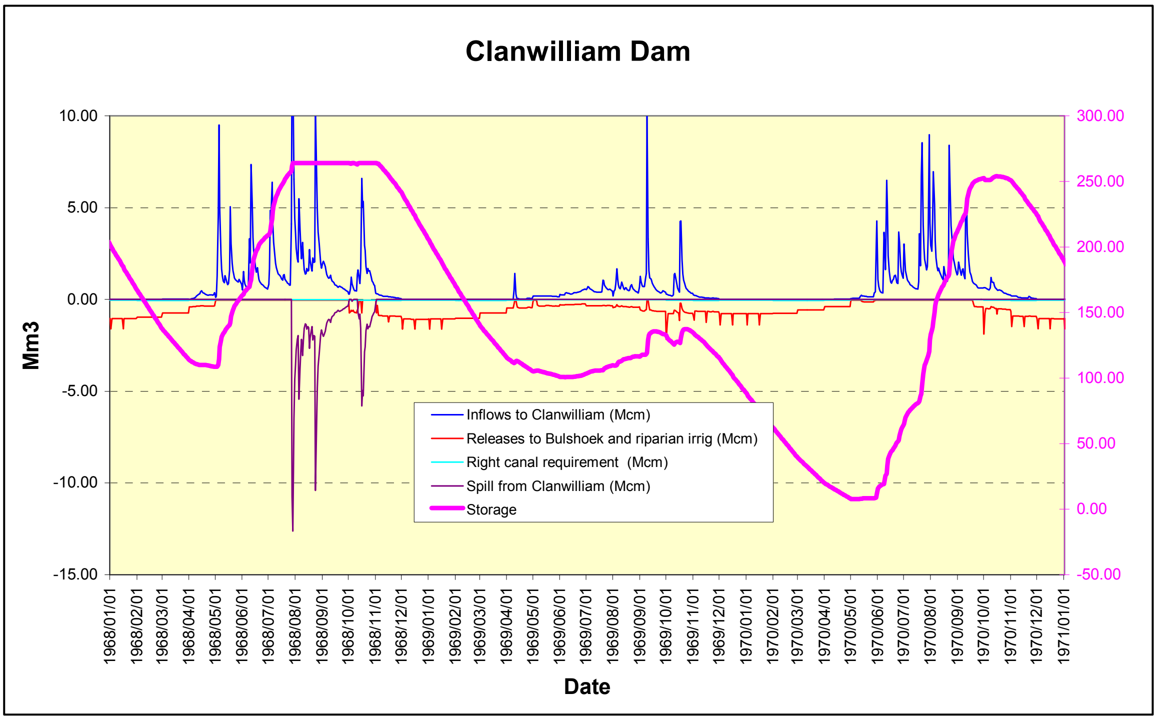
These monthly flows were disaggregated into daily flows using the following daily sequences:

- The daily streamflow sequences into Clanwilliam Dam (**Section 4**),
- Gauge E1H006 in the Jan Dissels River
- Gauge E1H002 on the Doring River just upstream of confluence with the Olifants River

A spreadsheet model was used to simulate the inflows, releases and storage at the Clanwilliam Dam and the Bulshoek Barrage. The model included:

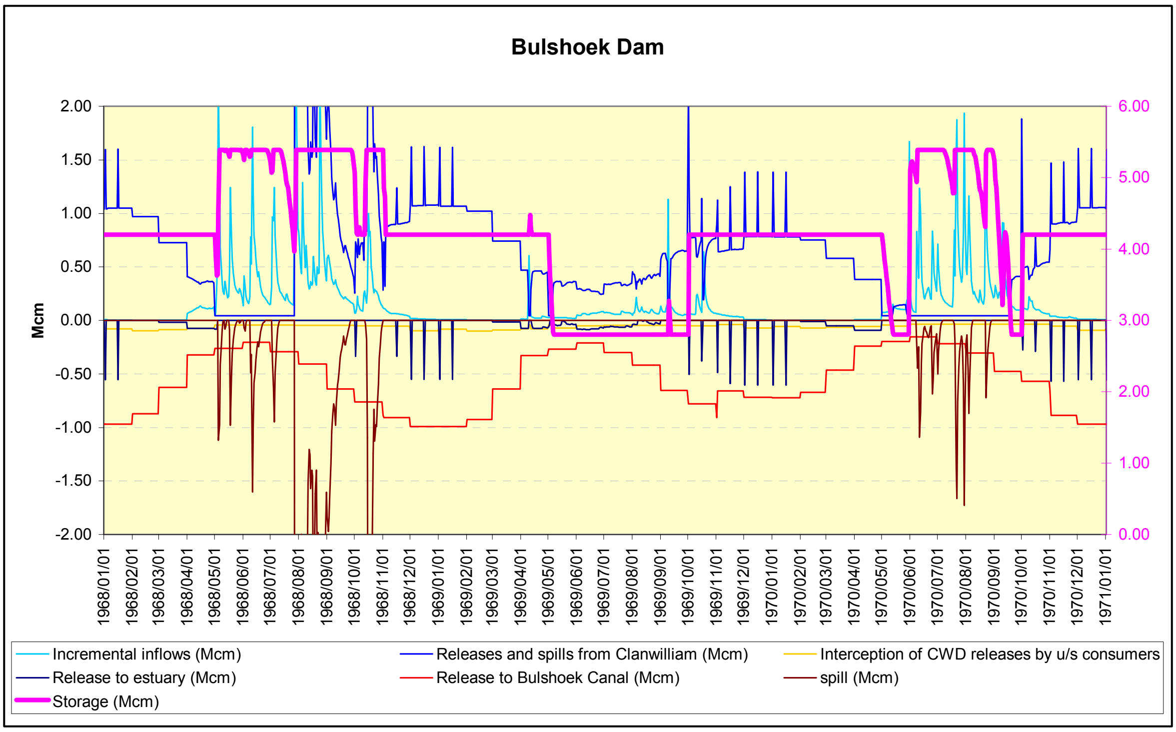
- Irrigation along the Clanwilliam and Bulshoek Canals and between Clanwilliam and Bulshoek
- Environmental pulse releases from Clanwilliam Dam to Bulshoek to trigger spawning of the Yellowfish from October to January.
- Return flows from the irrigation along the Bulshoek canal to the estuary
- Releases from Bulshoek Barrage to augment the return flows from the irrigation along the Bulshoek Canal to maintain an average of about 1.5m^3/s flowing into the estuary

Evaporation and rainfall on the surface of the Bulshoek and Calnwilliam Dams was not modelled. **Figure 8.1** and **Figure 8.2** show the modelled inflows, outflows and storage at the Clanwilliam Dam and the Bulshoek Barrage, respectively. The pulse releases to trigger spawning of the Clanwilliam Yellowfish appear as pulses on top of the releases made for irrigation. In practice, a pulse can also be achieved by first throttling back on the releases to irrigation from Clanwilliam Dam so that the Bulshoek irrigators obtain their water by drawing down the storage in the Bulshoek Barrage. The pulse release is then made but because this pulse is superimposed on a reduced baseflow the peak flows are also reduced and should be less than 20 m^3/s. The baseflow releases to the estuary are also shown as pulses, corresponding to the pulses released from the Clanwilliam Dam, mainly to reduce interception by irrigators downstream of the Bulshoek Barrage. If uniform releases are preferred then the pulse release from Clanwilliam Dam can be retained by the Bulshoek Barrage and released more gradually.



DailySystem14 sheet ClanwilliamPlot

Figure 8.1 Simulated daily inflows (Mm^3/day), outflows and storage of the Clanwilliam Dam

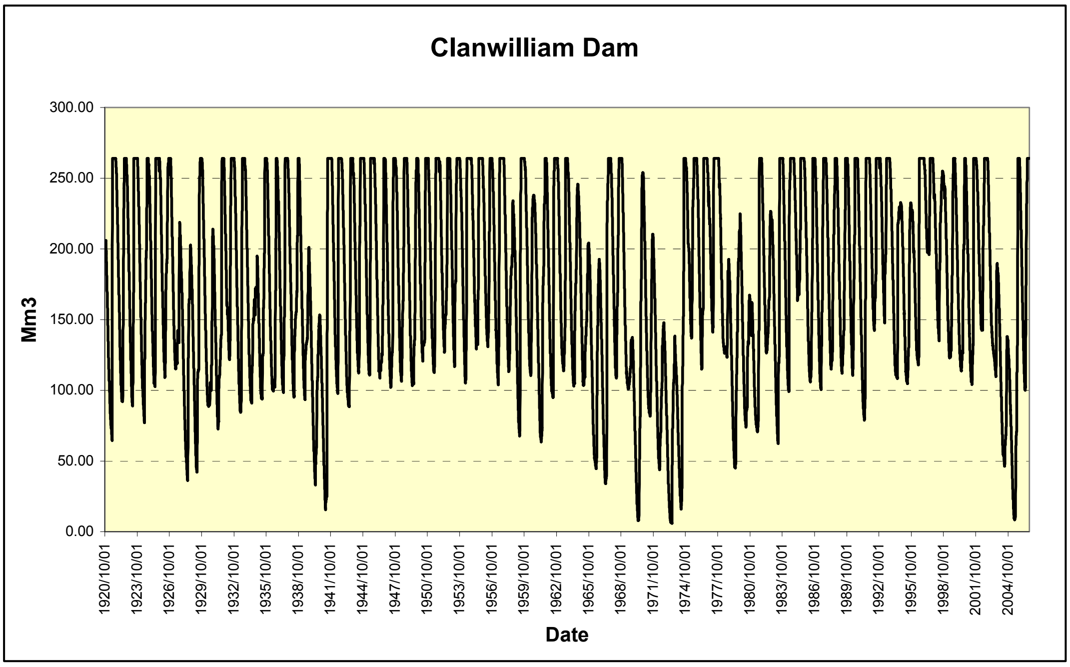


DailySystem14 sheet BulshoekPlot

Figure 8.2 Simulated daily inflows (Mm^3/day), outflows and storage of the Bulshoek Dam

The period covered (1968-1970) was dry and the figures show how the irrigation supply was reduced in 1969 (when compared to 1968) to avoid the dam emptying. The curtailment rule was coarse and was not intended for management of the system but to stop the system completely emptying midway through summer, which would halt the return flows to the estuary unrealistically abruptly.

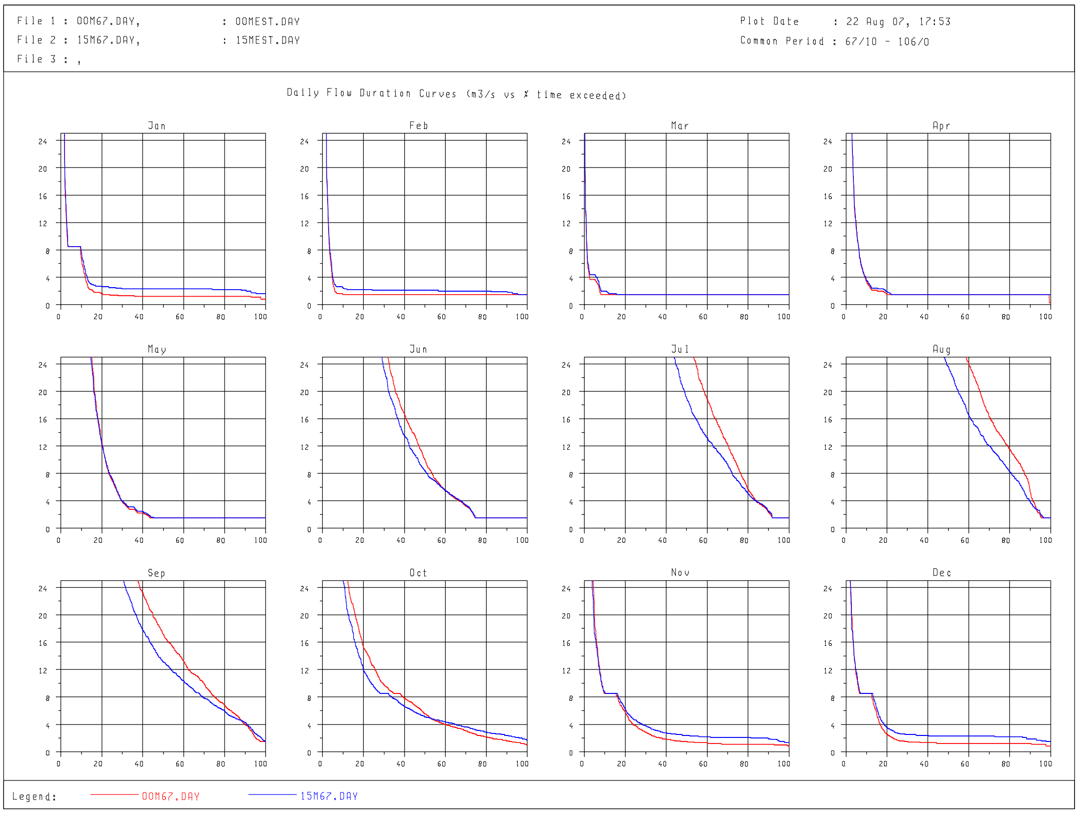
Figure 8.3 shows that the curtailment rule achieved this objective and prevented the dam emptying for extended periods.



DailySystem14 sheet ClanwilliamPlot(2)

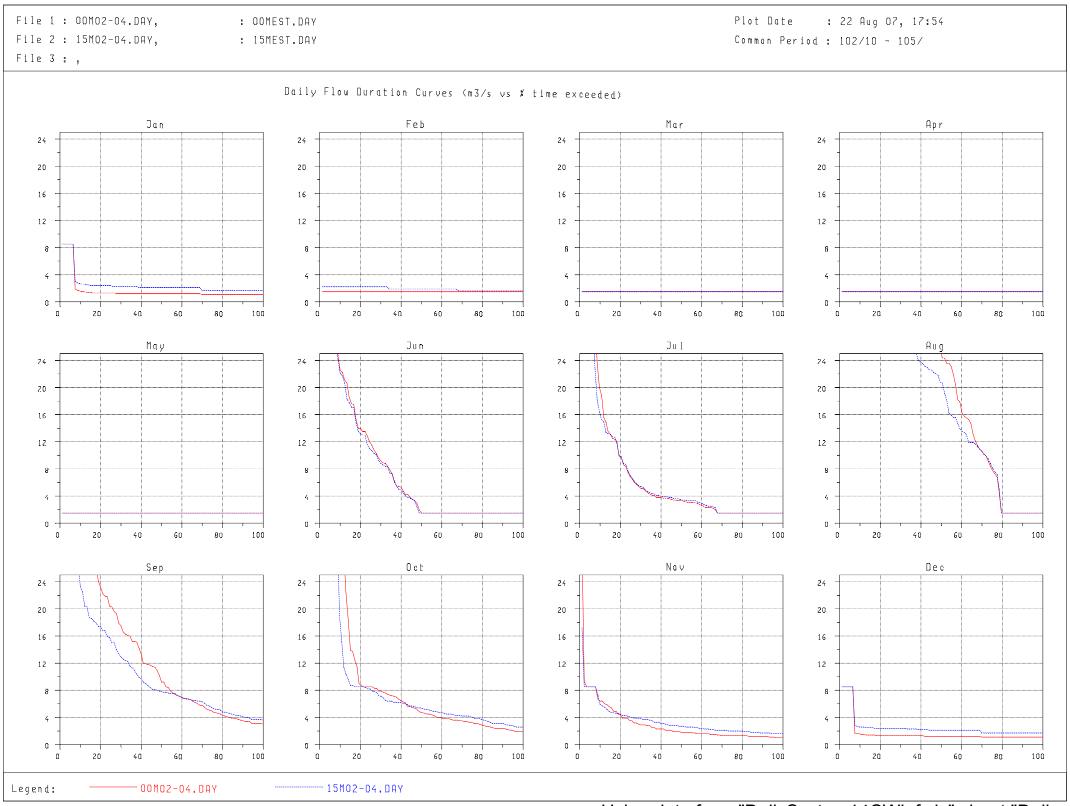
Figure 8.3 Simulated storage of the Clanwilliam Dam (Mm^3) for the scenario assuming that the dam is raised by 10 metres

The impact of increasing the storage of Clanwilliam Dam by 15 meters on the streamflow at the estuary is illustrated for the period from 1965 to 2006 and for a dry period from 2002 to 2005 in **Figure 8.4** and **Figure 8.5**. These flow duration curves indicate the frequency with which the flow exceeds a particular value. These curves are very useful to evaluate the efficiency with which pump stations can abstract from the river. If, for instance, a 4 m^3/s pump station were located downstream of the confluence of the Doring and the Olifants River and it only started pumping once the streamflows reached 6 m^3/s, leaving 2 m^3/s for the environment, then the curves indicate how often the pump station will be operational. For instance in **Figure 8.4** the graph for June shows that the flows exceeded 6 m^3/s about 55% of the time. The durations for other months during winter have been tabulated in **Table 8.1**. The table indicates that in normal years the pumps will be operational about 5% ess in the wintertime. During severe droughts, when the spills from Clanwilliam Dam would have been less, the reduction will be negligible. In the past the pump station would have relied more heavily on the contribution from the Doring River during droughts.



Using data from "DailySystem14CWInf.xls" sheet "Daily"

Figure 8.4 Flow exceedence curves for streamflows at estuary for the current capacity of Clanwilliam Dam (red) and a 15 m raising (blue) for the period from October 1965 to September 2006



Using data from "DailySystem14CWInf.xls" sheet "Daily

Figure 8.5 Flow exceedence curves for streamflows at estuary for the current capacity of Clanwilliam Dam (red) and a 15 m raising (blue) for the period from October 1965 to September 2006

Table 8.1 Approximate duration with which a 4 m^3/s pump station located downstream of the Doring River confluence will be operational

Month	Average conditions 1965 – 2006			Drought conditions 2002 -2005		
	Unraised	15 m raising	Decrease	Unraised	15 m raising	Decrease
A	b	c	D	e	f	g
May	25%	25%	-		-	
Jun	55%	55%	-	35%	35%	-
Jul	80%	75%	5%	25%	25%	-
Aug	90%	85%	5%	75%	75%	-
Sep	85%	80%	5%	70%	70%	-
Oct	50%	45%	5%	40%	40%	-

The flow duration curves can be used to evaluate the impact of raising the dam on other pump station capacities in a similar manner.

Figure 8.6 was included to illustrate the impact of raising Clanwilliam Dam on the high flows at the estuary.

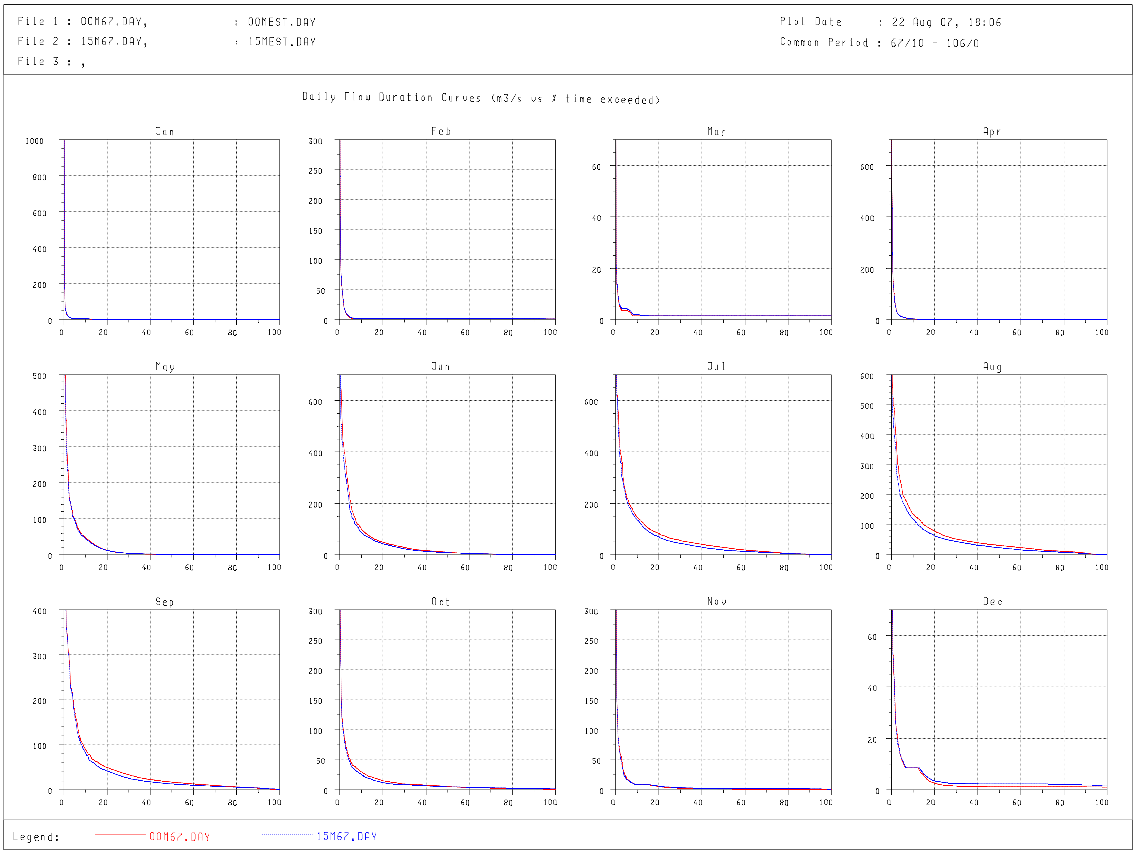


Figure 8.6 Flow exceedence curves for streamflows at estuary for the current capacity of Clanwilliam Dam (red) and a 15 m raising (blue) for the period from October 1967 to September 2006

9. CONCLUSIONS AND RECOMMENDATIONS

In its natural state the Olifants River estuary would receive half of its winter flows from each of the Doring and the Olifants Rivers and its summer baseflows from the naturally perennial Olifants River. Though the current Clanwilliam Dam is only about 30% of the MAR at its site, it does trap the early winter flows and the developments along the Olifants River below the dam modify the summer baseflow.

At present about 30% of the natural MAR is consumed in the catchment, about one third in the upper reaches of the Doring River and about two thirds in the Olifants River, primarily from the Clanwilliam Dam. A more detailed breakdown of the hydrology of the catchment is presented in **Table 9.1.**

The capacity of the Clanwilliam Dam is currently about 30 % of the MAR at its site and the most favoured development in the Olifants River is to increase the capacity of the Clanwilliam Dam, possibly up to 100% of the MAR. This will maximise the usage of the water in the Olifants River. Through careful management, it is intended to maintain the low flows to the estuary while the Doring River can continue to provide high flows to the estuary. If the Doring River provides these high flows it obviates the need to provide expensive (in terms of cost and impact on the yield) high flow outlet structures in the Clanwilliam Dam. The raising of Clanwilliam Dam becomes uneconomical if the recommended ecological status of the 18 km stretch of river between Bulshoek and the confluence with the Doring River is raised above its current ecological state, namely an E. Some of the damage in the reach, such as the cultivation of the river terraces, is non-flow related and the ecologists felt that there was a high risk that the streamflows associated with a Class D category would not in fact achieve this, because of non-flow related impacts. Acknowledging this, the Ecological Water Requirements Study recommended residual flows to maintain the water quality and vegetation in the reach at the current state.

The dam may be raised by up to 15 metres and under this scenario the runoff at the estuary may reduce by up to 10% of the natural MAR. The dam will have a lesser impact on pump stations located downstream of the confluence with the Doring River.

Various interventions can help to minimise the impact of the dam on the downstream environment:

- Avoid constructing large dams on the Doring River that will reduce the high flows.
- Provide a new multi-level outlet structure from the Clanwilliam Dam that will allow the mixing of water from various levels in the dam to regulate the temperature of the released water. Clanwilliam Yellowfish in the river reach upstream of the Bulshoek Barrage spawn if freshettes warmer than 19°C and having a peak flow of between 9 and 17 m^3/s are made during October and January. These freshettes can either be retained by the Bulshoek Barrage or released as pulses to the estuary where they will form part of the summer baseflows into the estuary.

Table 9.1 The revised catchment developments incorporated into this study

Reach			Mass Balance					Additional details			
				Usage							
From	To	Portion	Natural inflows (Mm³/a)	Supply (Mm³/a)	Evaporation (Mm³/a)	Return flows (Mm³/a)	Nett inflow (Mm³/a)	Cumulative inflow (Mm³/a)	Reference node or channel (ch-) with corresponding cumulative flow in 400418/ym/v8/ps149	Apportioned revised demand (Mm³/a)	Revised net dam capacities (Mm³)
A	B	C	D	E	F	G	H	I	J	K	L
Agter Witzenberg upstream of prop Rosendal Dam		Upstream farm dams	10.6	-4.1	-0.5		6.0	6.0	d/s 1	8.7	3.8
		Remainder	20.9	0			20.9	26.9	d/s 2	0.0	
Rosendal	Visgat		32.4	0			32.4	59.3	d/s 7	0.0	
Bo Boschkloof			10.1	-7.9	-0.7		1.5	60.8	d/s 5	16.0	14.7
Visgat	Grootfontein		79.4	0			79.4	140.2	d/s 6		
Grootfontein	Keerom (Ratel River)		13.4	-1.4	-0.3		11.7	151.8	d/s 7	1.4	0.8
Keerom	Downstream of Heks River confluence (EWR site 1)	Upstream farm dams	12.3	-9.5	-2.5		0.3	152.1		9.5	9.5
		Remainder	141.2	-23.3			117.9	270.1	d/s 10	33.2	
Rondegat R (u/s EWR 3)			7.3	0			7.3	7.3	d/s 64		
d/s Heks R	Upstream of Clanwilliam Dam	Upstream farm dams	2.1	-1.2	-0.2		0.7	278.1		2.1	0.8
		Remainder	80.6	-2.9			77.7	355.7		2.9	
Elandskloof			21.2	-8.4			12.8	368.5	d/s 19	17.6	4.7
Clanwilliam Dam pumps			0.0	-4.0			-4.0	364.5		4.0	
Clanwilliam Dam and canal			0.0	-9.7	-14.4		-24.1	340.4	d/s 11	9.9	122.0
Clanwilliam Dam	Upstream of Bulshoek Barrage		77.4	-21.5	-2.5		53.5	393.9		21.6	
Bulshoek Barrage			0.0	-138			-138.0	255.9	d/s 13	139.1	4.8
Doring River			515.4	-98.0	-12.2	0.0	405.2	405.2	d/s 57	128.0	134.2
Bulshoek Barrage	Estuary (excluding Doring River)		30.9	-3.5		29.3	56.7	717.8	ch 164	3.5	
Total			**1 055.2**	**-333.4**	**-33.3**	**29.3**	**717.8**			**397.7**	**295.4**

- Consider cancelling concessions granted to riparian irrigators downstream of Bulshoek Barrage. These concessions were granted to irrigators when the leakage from the Bulshoek Barrage to the estuary was seen as undesirable. Ecologists have now recommended that a baseflow be maintained to the estuary and there is a risk that these baseflow releases may be intercepted and not reach the estuary. The concessions were deliberately only granted to irrigators who already had access to water from the Bulshoek Canal (and were hence not dependent on the leaks as a means of livelihood) with the understanding that they could be terminated when the leak from Bulshoek Barrage is fixed.
- Measure all abstractions, including those by pump stations, from Clanwilliam Dam down to the estuary. Any over-abstraction results in less water remaining for the other users. The Clanwilliam WUA should monitor the abstractions from pump stations as the existing measurement system is not functioning. The flow measurement system installed at Eskom's cost in the Komati to ensure that pumping did not take place during peak electricity supply periods could be adopted at Clanwilliam. The system would be especially feasible in reaches where water is always available and pumping requirements are not dictated by the need to intercept natural river flow, such as the reach around Clanwilliam Dam and between Clanwilliam Dam and the Bulshoek Barrage. Water consumption records should be released to other parties such as LORWUA at least monthly so that they can determine the losses for the month.
- Halt all illegal activity in the river channel, such as bulldozing, which increases the volume of water that needs to be released to rectify the destruction of habitat and increases the rate at which silt accumulates in the dams
- Maintain baseflow releases from Bulshoek Barrage to supplement the return flows from irrigators along the Bulshoek Canal to maintain a flow of about 1.5 m^3/s entering the estuary. Under present day conditions, return flows were assumed to provide 0.6 m^3/s of the baseflow in winter and 1.0 m^3/s in summer. The summer releases at Bulshoek Barrage therefore averaged about 0.5 m^3/s, which gave 1.5 m^3/s at the estuary when combined with the 1.0 m^3/s return flow. To reduce the risk of these releases being intercepted by riparian irrigators further downstream they could be made as pulses, coinciding with the freshettes releases made from Clanwilliam Dam to trigger spawning. During droughts these baseflows reduced naturally to below 1.5 m^3/s. As a rough guide the baseflows could be limited to 12 times the flow in the Jan Dissels as measured at gauge E1H006. The flow at this gauge appears to be being impacted by upstream developments and this relationship may need to be rechecked in the future.
- Ongoing monitoring of the effectiveness of the proposed ecological releases in maintaining the ecological conditions at representative sites downstream of the Clanwilliam Dam (e.g. at Alwynskop [Site 2 downstream of Bulshoek (DWAF, 2005) and the estuary]). Ongoing refinement of the releases to optimise the balance between the ecological and the water supply requirements.

From the above it is clear that the yield ultimately obtained from the Clanwilliam Dam depends on the management of the system to prevent over-abstraction and to ensure that irrigation practices do not damage the river channel as this necessitates additional environmental flows to remedy the situation. Climate change could also impact on the yield of the system.

For the purposes of evaluating the yield from the Clanwilliam Dam a baseflow of 1.5 m^3/s was maintained into the estuary, unless this exceeded the natural streamflow into the estuary. Scenarios supplying various Ecological Water Requirements (EWR) below Bulshoek were evaluated, from supplying no EWR, to drought EWRs, baseflow and the full EWR. Under the current operation, no high flow releases are made from Bulshoek for the downstream reach and accordingly, the option making only baseflow releases for the downstream reach was adopted for the economic analyses. The yields for raising Clanwilliam Dam by 0, 5, 10 and 15 metres at different annual risks of failure (from the historical firm yield up to the 1 in 5 year yield) for the scenario releasing the baseflow component of the EWR from the Bulshoek Barrage are presented in **Figure 9.1**. For this scenario increasing the dam capacity from 122 (0m raising) to 362 million m^3 (15 m raising) increased the 1 in 10 year yield from 161 to 254 million m^3/a, i.e. by 93 million m^3/a. Yields for the other scenarios are also included in **Table 9.2**.

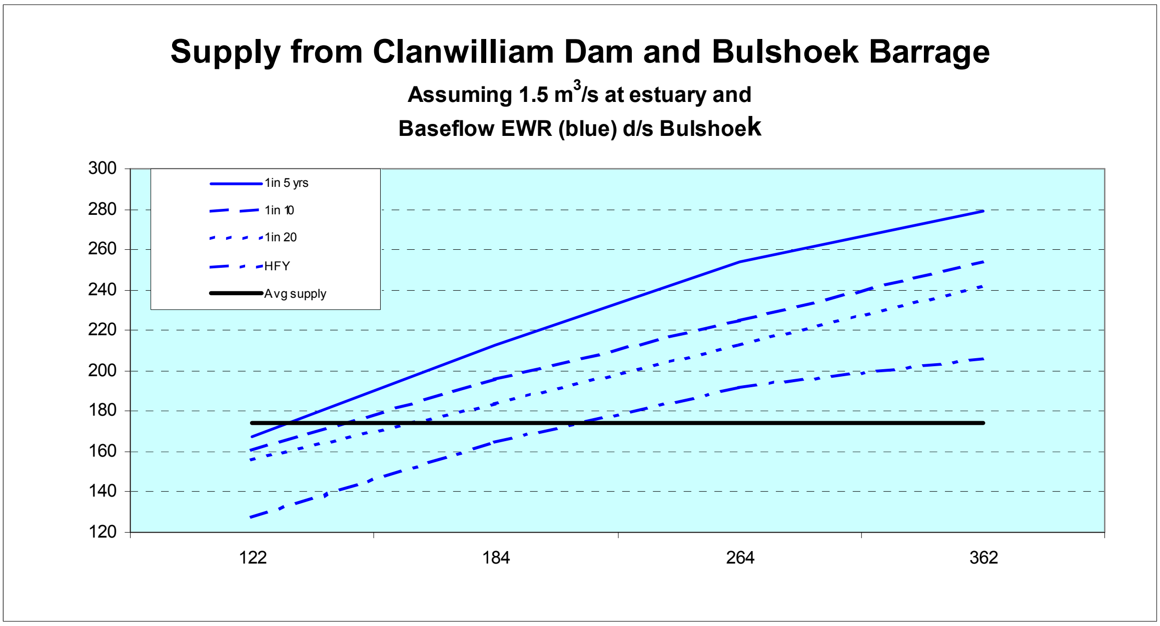


Figure 9.1 Reliability of supply from Clanwilliam Dam

Table 9.2 Yield analysis results derived from historical streamflow sequences

Scenario	Details		Absolute yield				Increase in yield with regard to current 122 Mm^3 capacity			
			Dam capacity				Dam capacity			
			122	184	264	362	122	184	264	362
			0 m raising	5 m	10 m	15 m	0 m	5 m	10 m	15 m
No EWR	Recurrence interval	1 in 5 yrs	185	235	274	305	-	50	89	120
		1 : 10	175	219	248	275	-	44	73	100
		1 : 20	169	197	234	263	-	28	65	94
		HFY	149	184	213	227	-	35	64	78
	Dataset in \hydro\400415\ym\v6		PD	5__	A__	F__				
Drought EWR	Recurrence interval	HFY	133	169	199	214	-	36	66	81
	Dataset in \hydro\400415\ym\v6		0DE	5DE	ADE	FDE				
Baseflow EWR	Recurrence interval	1 in 5 yrs	168	213	254	279	-	45	86	111
		1 : 10	161	196	225	254	-	35	64	93
		1 : 20	156	184	213	242	-	28	57	86
		HFY	128	165	192	206	-	37	64	78
	Dataset in \hydro\400415\ym\v6		0BE	5BE	ABE	FBE				
Full EWR	Recurrence interval	1 in 5 yrs	161	203	238	266	-	42	77	105
		1 : 10	154	183	207	239	-	29	53	85
		1 : 20	142	160	195	218	-	18	53	76
		HFY	124	157	172	187	-	33	48	63
	Dataset in \hydro\400415\ym\v6		OEE	5EE	AEE	FEE				

Development upstream of the Clanwilliam Dam could affect the yield of the dam. During the 2003-2005 drought, the Olifants River stopped flowing and irrigators in the lower reaches dug into the river channel to extract water for their crops, with severe ecological consequences. This situation was exacerbated by the extraction of water from shallow boreholes next to the river. The water extracted from these boreholes should be included with the riverine allocation of the farmers, and if this proves impractical, the boreholes should be closed.

An option to relieve the water stress upstream of the Clanwilliam Dam is to permit the construction of additional off-channel farm dams to store water for use in the summer. This option is quite costly, as in addition to the cost of building the off-channel farm dam and pump station, the upstream storage will reduce the yield of the Clanwilliam Dam. For instance, if a dam storing 4 million m^3 is constructed then this could decrease the yield of the raised Clanwilliam Dam by about 3 million m^3/a.

For the purposes of modelling pump stations along the Olifants River and the streamflows at the estuary a daily streamflow sequence into Clanwilliam Dam was determined. The task was complicated by the poor quality of some of the required records, particularly from 1997 to 2001, when there was no gauge operating downstream of the dam because E1H011 had been closed, and E1H016 had not yet been opened. At the time there were no records of the abstractions between the Clanwilliam Dam and the Bulshoek Barrage, and only scattered estimates of the spills through the Bulshoek Barrage. The new gauge E1H016 should improve future estimates significantly but for the operation of the system the following additional records would be required:

- Complete monthly record of abstractions from riparian pumps (and boreholes located along the river if these are not shut down)
- Flow downstream of Bulshoek Barrage (gauge E1H017 is not operated because of leaks underneath the weir)
- Summer flow at Lutzville (currently measured by E3H004 which needs to be cleaned of debris at the end of winter and after any unseasonal summer freshettes)
- Ongoing measurements at the Jan Dissels (E1H006) to check whether the baseflows at Bulshoek exceed the natural baseflow, which is about 12 x the flow at the Jan Dissels.
- Ongoing use of the rated section E1H013 for early flood warning and to check to what extent the summer baseflows are being impacted by pumping from the river and boreholes

Ultimately, the yield estimates are based on the historical inflows to Clanwilliam Dam since 1935, which are adjusted to take into account the increased developments upstream. From about 1962, when the raising of Clanwilliam Dam first appears to interfere with the spill estimates, to 2001 the spills from Clanwilliam Dam were not measured that accurately. However, before that period the spills were accurately determined and since 2001 gauge E1H016 has measured the spills. Additional rainfall gauges located in the mountains are required to improve the hydrological modelling of the catchment and to improve the natural streamflow estimates for catchments such as the Bo-Boschkloof and Elandskloof. The earlier *Olifants River Basin Study* (DWAF, 1990) used public appeal data at sites such as Die Berg, Soetfontein and Zoovoorbij, which are not collected at present, and would be valuable when extending the hydrology of the Olifants River catchment. The valuable raingauge at the Brakfontein Landgoed extends from 1935 and should also be collected. The inaccuracies at Bo-Boschkloof and Elandskloof should not have a significant impact on the yield estimates as both catchments are highly developed and contribute very little to the runoff entering the Clanwilliam Dam.

The additional water from the Clanwilliam Dam could be used at three sites, *inter alia*:

- Around Clanwilliam Dam and down to the Bulshoek Barrage (less than 4 100 ha)
- Downstream of the Bulshoek Barrage, on the farm Zypherfontein located in the wedge between the Olifants River and the Doring River (1 188 ha)
- Along the Bulshoek Canal (8 700 ha).

The area available around Clanwilliam Dam and down to the Bulshoek Barrage was estimated by deducting the existing land-use from the area of soils recommended for irrigation. The land available will decrease further when existing urban settlements (Clanwilliam Town) and riverbeds are deducted (see **Annexure O**).

The viability of additional irrigation at Zypherfontein was discussed in the *Irrigation Development and Water Distribution Options Report* (see DWAF, 2007).

The capacity of the Bulshoek Canal is constrained by the capacity of the main canal but there is additional spare capacity lower down. To access the spare capacity lower down the canal water needed to be released down the Olifants River from the Bulshoek Barrage and pumped back into the canal lower down when spare capacity of the canal increased and before the water became too saline. Up to 87 additional km^2 could be supplied if additional water is pumped into the Naauwkoes and Karoovlakte reaches (see **Annexure J**). These releases would blend with the saline return flows but the resultant water in the canal could still be acceptable if pumping took place above the Karoovlakte reach of the canal, providing the water for the Vredendal section is pumped in further upstream at Naauwkoes (see **Annexure N**. The canal capacity and salinities need to be checked to confirm the feasibility of the distribution options.

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ANNEXURE A

Typical allocation decision from Clanwilliam Dam

A TYPICAL ALLOCATION DECISION FROM CLANWILLIAM DAM

Table A.1 : Allocation of water from Clanwilliam Dam – assuming dam starts drawing down from October

LORWGV / CLANWILLIAM - Waterkwota - 12 Desember 2006

Berekening vir vanaf 02 Oktober 2006 tot 15 Mei 2007

Stand van die water met 100% water in Clanwilliamdam

		deur LORWUA			met syfers van Clanwilliam WVV
1. Daminhoud					
Soos op 02 Oktober 2006		**123.66**		100% = 123.66mil m3	**123.66**
Invloei in dam		-			
	1. Subtotaal	**123.66**	Mm^3		**123.66**
2. Reserwe in Clanwilliamdam					
Reserwe vir huishoudelike gebruik		**6.10**		Reserwe 5%	**6.10**
Beraamde verdampingsverlies		**11.07**		Verdamping tot 15 Mei 2007	**11.07**
	2. Subtotaal	**17.17**			**17.17**
3. Beskikbaar vir gebruik uit Clanwilliamdam		**106.49**	Mm^3	**1 minus 2**	**106.49**
4. Gebruik tussen damme en verlies					
Clanwilliam Pomponttrekkers		**5.63**		938ha x **6000**m^3	**9.32**
Clanwilliam kanaal		**3.81**		635ha x**6000**m^3	**4.36**
Verlies op Clanwilliamkanaal		**1.14**		30% x 635ha x **6000**m^3	**1.31**
Transitoverlies tussen damme		10.15		**10%** **van No 3 minus Clanwilliamkanaal**	6.00
	Subtotaal	**20.73**			**20.99**
5. Beskikbaar vir gebruik uit Bulshoekdam		**85.76**	Mm^3	**3 minus 4**	**85.50**
6. Gebruik op Skema (Besproeiers uitgesluit					
Munisipaliteite, Nywerhede & Huishoudelik(.8mx mnde)		**6.00**		tot 15 Mei 2007	**6.00**
Ditribusie veliese		23.15		**27%** van 5	23.08
	Subtotaal	**29.15**			**29.08**
7. Beskikbaar vir besproeiing tot middel Mei 2007		**56.60**	Mm^3	**5 minus 6**	**56.41**
8. Kwota beskikbaar tot einde van waterjaar (of tot dit weer reën)		**5,964**	m3/ha	7 X 1000000 /9491 = m3 / ha	**5,944**
9. Gemiddelde water reeds uitgegee		**0**	m3/ha		**0**
10. Totale water beskikbaar tot dit weer reên		**5,964**	m3/ha	**8 plus 9**	**5,944**
Nuwe Kwota		**0**			**0**

(1) Table 9 Review of demands for the Olifants River Catchment upstream of Bulshoek Weir

Beperking - Clanwilliamv2.xls sheet "Beperking 06-07 (2)"

Table A.2 indicates that the scheduled areas included in the allocation by LORWUA do not include the relatively small areas at Rondegat and Kransvleikloof, which may possibly take water from the dam, and the area that is included with the Jan Dissels, which probably is supplied from the Jan Dissels River.

Table A.2 : Scheduled areas included in the allocation decision

Section	Quaternary Catchment	Irrigated Area (ha) obtained from the Clanwilliam WUA		LORWUA Allocation decision
Rondegat	E10G	110	253	0
Kransvleikloof	E10G	143		
From Canal	E10J	734	1549	635
Seekoeivlei River	E10J	40		938
Rietvlei River	E10J	188		
Nardouskloof	E10J	0		
Langkloof	E10J	587		
Jan Dissels	E10H	500	500	0
Total for Clanwiliam WUA		**2302**	2302	1573

ANNEXURE B

Minister's letter regarding demands downstream of Bulshoek Barrage

B MINISTER'S LETTER RE DEMANDS DOWNSTREAM OF BULSHOEK BARRAGE

Telefoon/Telephone: No. 2/2/1

REPUBLIEK VAN SUID-AFRIKA—REPUBLIC OF SOUTH AFRICA

DEPARTEMENT VAN WATERWESE, DEPARTMENT OF WATER AFFAIRS,
PRIVAATSAK X313, PRIVATE BAG X313,
PRETORIA.

DEPT. VAN WATERWESE EN BOSBOU
STREEKDIREKTEUR: REGISTRASIE
PRIVAATSAK/PRIVATE BAG X16
1 - DEC 2003
REGIONAL DIRECTOR: REGISTRY
SANLAMHOF 7632
DEPT. OF WATER AFFAIRS AND FORESTRY

SY EDELE DIE MINISTER

5 -9- 1972

OLIFANTSRIVIER(VAN RHYNSDORP)-STAATSWATERBEHEERGEBIED : ALGEMENE BELEID : PERMITTE INGEVOLGE ARTIKEL 62(2) VAN DIE WATERWET, 1956.

1. Die omstandighede binne die bogenoemde staatswaterskema onderkant die Bulshoekdam waar die eienaars van grond kragtens artikel 63 van die Waterwet, 1956, ingelys is, verskil van ander staatswaterskemas in die Republiek deurdat water wat in die rivier vloei benede die dam baie gou verlore gaan vir besproeiers weens vermenging met soutwater laer-af in die rivier wat vanaf die see opstoot.

2. Die posisie het tot gevolg gehad dat een van u voorgangers, mnr. P.K. le Roux, op 12 Junie 1963 die uitreiking van permitte aan oewereienaars stroomaf van Bulshoekdam op die volgende voorwaardes goedgekeur het:

(i) Die vergunning, ingevolge 'n permit kragtens artikel 62(2) van die Waterwet, aan elke eienaar wat in die geleentheid is om uit die rivier te pomp, sal beperk word tot genoeg water, in ooreenstemming met die heersende waterkwota op die skema, vir die besproeiing van 'n bykomstige 10 morg grond, mits die water beskikbaar is en mits daar voldoende besproeibare grond is.

(ii) Die Staat handhaaf ten alle tye sy reg om die lekkasie in die Bulshoekdam te beëindig en om nuwe opgaring op die Olifantsrivier en die Doornrivier te skep, sonder dat die permithouers enige eis teen die Staat het indien die water wat vir hulle pompe beskikbaar is afneem.

c/s (?) 12/9

(iii) Die onus word op die permithouer en sy opvolgers-in-titel geplaas om voornemende kopers van grond wat voordeel trek uit die permitte op hoogte te stel omtrent die beperkings wat aan die bedoelde permitte heg.

(iv) Die permitte is gebaseer op die besondere omstandighede wat heers by die Olifantsrivier (Van Rhynsdorp), waar ongebruikte water in die rivierbedding na die see verlore gaan, en doen nie af van die beleid ten opsigte van pompe op ander Staatswaterskemas nie.

3. Daar word egter met die toepassing van hierdie vergunning in die praktyk probleme ondervind aangesien daar in die oorspronklike voorwaardes nie spesifiek bepaal is dat hierdie toegewing beperk is tot die aantal geregistreerde oewereienaars soos op datum van die goedkeuring van die bepaling nie. Die gevolg is dus dat eienaars van onderverdelings wat na genoemde datum ontstaan het ook kan aandring op 10 morg pomppermitte. Probleme word ook ondervind met die verdeling van die addisionele 10 morg pomppermitte in gevalle waar 'n eiendom wat op datum van die vergunning aan slegs een eienaar behoort het daarna onderverdeel is.

4. Ten einde hierdie probleme op te los word dit as algemene beleid, aanbeveel dat artikel 62(2) permitte vir 'n maksimum van 8.6 hektaar (10 morg) per eienaar teen die heersende waterkwota vir die skema toegestaan word aan elkeen wat daarvoor aansoek doen en wat oor die nodige besproeibare grond, bo en behalwe sy ingelyste grond beskik, onderhewig aan die volgende voorwaardes:

(i) dat die getal eienaars per eiendom dié getal is onder wie se name die eiendom geregistreer was op 12 Junie 1963;

(ii) dat in gevalle waar eiendomme na 12 Junie 1963 onderverdeel is, die nuwe eienaars skriftelik ooreen moet kom oor hoe die pomppermit onder hulle verdeel moet word en dat dié ooreenkoms hulle aansoek om pomppermitte moet vergesel;

(iii) dat permitte toegeken sal word slegs op eiendomme wat op 12 Junie 1963 oewer was aan die rivier;

(iv) dat eienaars self sal reël vir serwitute waar nodig;

(v) dat die Staat nie die toevoer van water vir permitdoeleindes waarborg nie, nie die gehalte van dié water waarborg nie en dat die Staat die reg voorbehou om te enige tyd die lekkasie in die Bulshoekdam te beëindig en om nuwe opgaring op die Olifantsrivier en die Doornrivier te skep sonder dat die permithouers enige eis teen die Staat het indien die water wat vir hulle pompe beskikbaar is, afneem en dat die Staat ook nie water uit die Staatsdamme sal los om permithouers in staat te stel om te kan pomp nie;

(vi) dat die permitte gebaseer is op die besondere omstandighede wat heers by die Olifantsrivier (v.R.), waar ongebruikte water in die rivierbedding na die see verlore gaan en doen nie af van die beleid ten opsigte van pompe op ander Staatswaterskemas en Beheergebiede nie.

5. Indien u akkoord gaan sal dit waardeer word as u sal goe dat aansoeke om permitte op die bostaande basis behandel

SEKRETARIS VAN WATERWE

ALGEMENE BELEID VIR DIE UITREIKING VAN 10 MORG POMPPERMITTE WAT ADDISIONEEL TOT INLYSTING OP DIE OLIFANTSRIVIER(VAN RHYNSDORP)-STAATSWATERSKEMA IS GOEDGEKEUR SOOS UITEENGESIT IN PARAGRAAF 4.

MINISTER VAN WATERWESE.

7-9-1972

ANNEXURE C

Demands along the Olifants River

Review of Demands for the Olifants River Catchment upstream of Bulshoek Weir

Report prepared as part of the Yield Analysis task for the Clanwilliam Dam Raising Study

Prepared by James Cullis

NINHAM SHAND
CONSULTING SERVICES

January 2007

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1. AIM AND OBJECTIVES

The objective of this study is to review existing information of land use, particularly irrigated areas, and to compare this to more recently available information. The updated landuse information will be used to calculate an estimated demand, which can be compared to the demands currently in the Yield Model for the Olifants River Catchment. Where necessary these demands will be updated and used to determine the potential yield from Clanwilliam Dam under a number of possible scenarios.

The Olifants/Doring River basin is considered to have an arid climate as it receives less than 300 mm/a of precipitation and evaporation is over 1600 mm/a. In these conditions there is a great demand for irrigation. There are other demands in the catchment, but these demands, such as urban and industrial demands account, for less than 5% of the total demand, making irrigation a high priority for water allocation. The main focus area for determining the current demands is therefore on the irrigated area.

2. SUMMARY OF INFORMATION FROM EARLIER STUDIES

The Olifants-Doring system has been the subject of numerous studies. Some of the previous reports that have information regarding the irrigated areas and associated demands of the Olifants-Doring system are listed below.

- Government Gazette (1987)
- Olifants River Systems Analysis (BKS, 1990)
- Olifants/Doring River Basin Study (DWAF, 1998)
- Western Cape Olifants/Doring River Irrigation Study, WODRIS (PGWC, 2001)
- Olifants/Doring Water Management Area: Water Resources Situation Assessment (DWAF, 2002)
- Olifants/Doring River Basin Study: Phase II (DWAF, 2003)

The information on irrigated areas and demands from these reports are discussed in thie following section. In addition further information on scheduled areas was obtained from some of the Water User Associations (WUA) in the area. Current estimates on the irrigated areas were also obtained by the DWAF. A further source of information that was considered in this review of the available information on irrigated areas was to make use of recent aerial photographs to determine the current crop areas using Geographical Information System (GIS). The results from this investigation are also discussed in the following section.

An attempt has been made to compare the information provided by the various data sources. This is complicated by the fact that each report uses slightly different areas and different assumptions. Based on this comparison a final irrigated area and crop mix has been selected to represent the current day situation. These final areas were used to make an estimate of the total irrigation demand in each quaternary catchment. To this was added the estimated urban and industrial demands for the towns of Clanwilliam and Citrusdal. The estimated demand supplied from ground water has been calculated in a separate report (DWAF, 2006) and this was used to determine the final demands for each catchment. These demands were compared to those currently used in the yield model to determine if the demands used to determine the yield from the raising of the Clanwilliam Dam needed to be increased, and by how much.

2.1 Government Gazette (1987)

Due to the growth of irrigation upstream of the Clanwilliam Dam, this area was declared a Government Water Control Area (GWCA) in the mid 1980s. The current and permissible irrigated areas as given in the Government Gazette (1987) are shown in **Table 1**. The area was divided into three zones. Zone A consists of the area above the farm Keerom 511 and has an allocated irrigation quota of 940 mm/yr. Zone B and Zone C make up the area between Kerrom 511 and the Clanwiliam Dam. They both have an allocated irrigation quota of 1220 mm/yr. The estimated demand based on these allocations is also given in Table 1.

Table 1 Irrigation Areas upstream of Claniwilliam Dam as published in the Government Gazette (1987)

Incremental Catchment	Irrigation area (ha)			Quota (mm/a)	Irrigation Demand (Mm^3/a)		
	Current	Permitted	Irrigable		Current	Permitted	Irrigable
Rosendal (Zone A)	770	870	1933	940	7.24	8.18	18.17
Grootfontein (Zone A)	89	89	120	940	0.84	0.84	1.13
Clanwilliam (Zone B and C)	4398	5909	14820	1220	53.66	72.09	180.80
Total	**5257**	**6868**	**16873**		**61.73**	**81.10**	**200.10**

2.2 Olifants River Systems Analysis (BKS, 1990)

The Olifants River System Analysis (ORSA) (BKS, 1990) consisted of an assessment of the existing hydrology of the area upstream of Clanwilliam Dam and the extension of the hydrology to include the area down to Bulshoek Weir. The study area and the sub-catchments used for determining the hydrology, including the irrigation demands, are given in **Figure 1**.

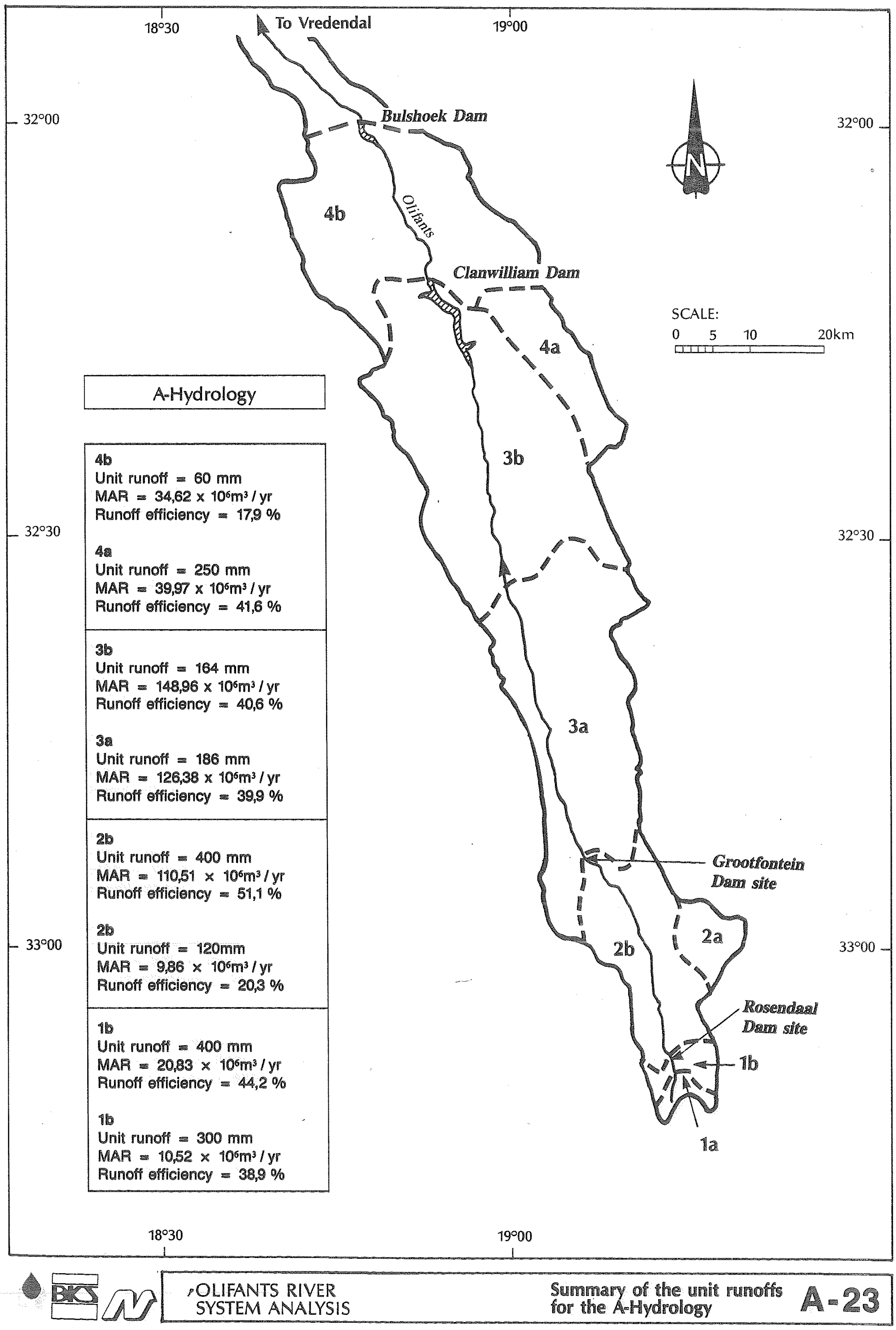

Figure 1 Map of Shown Catchment Areas for the ORSA (BKS, 1990)

To determine the current irrigated area, a survey of farmers in the Olifants catchment was conducted. The results of that survey are shown in Table 2.

Table 2 Summary of Irrigate Crop Areas of the Olifant River Systems Analysis

Sub-catchment	Deciduous Fruit	Potatoes	Onions	Other Vegetables	Pastures	Citrus	Vineyards	Total
1a and 1b	615	125	47	57	324	-	-	1168
2a and 2b	761	471	168	45	-	-	-	1445
3a and 3b	114	-	-	273	235	3030	254	3906

As part of the review of the hydrology, it was noted that a further 750 ha was present in catchments 3a and 3b, which was outside of the area controlled by the Citrusdal Irrigation Board. The irrigated area below Clanwiliam Dam up to Bulshoek Weir was also added. This was estimated to be a further 611 ha. The final areas used to determine the irrigation demands for the updated hydrology, the percentage of irrigated area by crop type, and the total estimated demands are given in Table 3.

Table 3 Irrigated Crop Areas from the Olifant River Systems Analysis

Sub catchment	Irrigated Area (ha)	Percentage of Irrigated Area							Average Demand (Mm^3/a)
		Deciduous Fruit	Potatoes	Onions	Other Vegetables	Pastures	Citrus	Vineyards	
1a	1011	53%	12%		8%	30%			9.60
2a	1220	54%	50%	16%	3%				9.87
3a	2870	3%			&%	6%	78%	6%	29.22
3b	1790	3%			&%	6%	78%	6%	18.43
4b	611	7%	80%		7%	7%			6.75
Total	**7502**								**73.87**

Subcatchments 1b and 2b were too mountainous to have any significant irrigation potential and the demands from subcatchment 4a, the Jan Dissels River, were considered to be too small to impact on the hydrology.

2.3 Olifants/Doring River Basin Study (DWAF, 1998)

The Olifants/Doring River Basin Study (ORBS) (DWAF, 1998) study consisted of an investigation into the yields and cost of potential dam sites in the Olifants and Doring River basins. Part of this study included a review of irrigated areas and associated demands. The sub catchments defined for this study are shown in Figure 2. These catchments are referred to as hydro-catchments so as to distinguish them from the standard WR90 quaternary catchments used during later assessments. These hydrological sub-catchments have been further subdivided in recent studies to accommodate the inclusion of instream flow requirement (IFR) sites for inclusion in the yield model. The major sub-division is in the Citrusdal catchment, which has been divided into two to accommodate an IFR site on the Olifants River. This subdivision occurs just downstream of Citrusdal and roughly coincides with the division between quaternary catchments E10E and E10F.

Figure 2 Catchment Boundaries used in the ORBS (DWAF, 1998)

The estimated current day (1997) irrigation areas and demands from the ORBS report on the physical characteristics and land use (DWAF, 1998) are given in Table 4.

Table 4 Irrigation Areas and Demands from ORBS (DWAF, 1998)

Region	Sub-catchment	Irrigation Area (ha)	Water Demand (Mm^3/a)
Witzenberg	O1	800	6
Bo-boskloof	O3	1900	14.25
Citrusdal	O5	5400	51.3
TOTAL U/S OF CLANWILLIAM DAM		**8100**	**98.55**
Clanwilliam	O6	1650	18.15
Total u/s of Bulshoek Weir		**9750**	**116.7**
Olifants GWS	O7	11500	126.5
Total for Olifants Catchment		**21250**	**243.2**

Note that, as with the ORSA, the demands in subcatchments O2 and O4 were considered to be negligible.

2.4 Western Cape Olifants/Doring River Irrigation Study (PGWC, 2001)

The Western Cape Olifants/Doring River Irrigation Study (WORDRIS) (PGWAC, 2001) used the same sub catchments as the Olifants/Doring Basin Study to estimate the total irrigation demand. The irrigated area given in this report is the same as that of the Olifants/Doring Basin Study, but the demands have been recalculated and show a slight increase, as shown in Table 5.

Table 5 Irrigated Areas and Demands from WODRIS (PGWC, 2001)

Region	River	Dominant Crop Type	Irrigation Area (ha)	Irrigation Demand (Mm^3/a)
Witzenberg	Olifants	Deciduous Fruit and vegetables	800	7.3
Bo-Boschkloof	Olifants	Deciduous Fruit and vegetables	1900	18.3
Citrusdal	Olifants	Deciduous Fruit and citrus	5400	58
Sub-total u/s of Clanwilliam Dam			**8100**	**83.6**
Clanwilliam	Olifants	Citrus and vegetables	1650	25.4
Sub-total u/s of Bulshoek Weir			**9750**	**109.0**
Olifants River GWSS	Olifants	Grapes and vegetables	11500	155.6
Urionskraal	Troe-Troe	Lucerne, vegetables and grapes	200	
Total for Olifants River			**21450**	**264.6**

2.5 Water Resources Situation Assessment Report (DWAF, 2002)

The Water Resources Situation Assessment Study (WRSAS) for the Olifants/Doorn WMA (DWAF, 2002) gives only an estimate of the total irrigated area for the upper Olifants River (i.e. above Bulshoek weir) of 107 Km^2 and associated demand of 80 Mm^3/a. More detailed information on the estimated irrigated areas for high, medium and low category crops, and the associated demands for each of the quaternary catchments, E10A to E10K, is given in the Appendix to the WRSAS. This information is given in Table 6.

Table 6 Irrigated Areas and Associated Demands from the WRSAS (DWAF, 2002)

Description	Area Under high category crops (km^2)	Area under medium category crops (km^2)	Area under low category crops (km^2)	Field Area Irrigated (km^2)	Total water use by irrigators (Mm^3/a)
E10A	12.56	0	0	12.56	10.76
E10B	3.01	7.74	0	10.75	8.97
E10C	4.03	0.05	0	4.08	4.93
E10D	8.14	0	0	8.14	9.84
E10E	19.98	0	0	19.98	24.23
E10F	19.56	0	0	19.56	23.72
E10G	0	6.32	0	6.32	7.39
Sub-total upstream of Clanwilliam Dam				**81.39**	**80.00**
E10H	1.47	0	0	1.47	1.86
E10J	4.73	10.3	0	15.03	18.84
E10K	8.8	0	0	8.8	12.27
Sub-total upstream of Bulshoek Weir				**106.69**	**112.97**
E33G	71.01	0	0	71.01	93.65
E33H	33.47	0	0	33.47	44.12
Total for Olifants River Catchment				**211.165**	**260.582**

2.6 Olifants/Doring River Basin Study: Phase II (DWAF, 2003)

This objective of this report was to investigate the potential raising of the Clanwiliam Dam. While the hydrology records were extended by ten years from 1989 to 1999, no changes were made to the irrigation demands upstream of Bulshoek Weir. Hence the irrigation areas and demands used were the same as for Phase I of the ORBS (DWAF, 1998). The demands downstream of Bulshoek were revised based on a survey conducted in 1998. The results of this survey are given in Table 7.

Table 7 Irrigation Areas downstream of Bulshoek from ORBS: Phase II (DWAF, 2003)

Description	Area			Total Area (Ha)	%
	Lutzville	Vredendal	Klawer		
Wine Grapes Production	920	1937	682	3539	30.4%
Wine Grapes Young	919	2008	1059	3986	34.2%
Table Grapes	13	99	146	258	2.2%
Currants	98	253	204	555	4.8%
Lucerne	256	735	563	1554	13.3%
Vegetables	822	463	465	1750	15.0%
Total	3028	5495	3119	11642	100.0%

2.7 Scheduled Areas provided by Water User Associations

Information on the current allocations in terms of the scheduled or taxable areas was provided by three of the main Water User Associations (WUA) in the area. The information consisted of current allocations to individual farms as of 2005 for the LORWUA, Citrusdal and Clanwilliam WUAs in terms of scheduled areas for irrigation in hectares. No similar information, however, could be obtained from the farmers in the Witzenberg or the Bo-boschkloof areas.

2.7.1 Citrusdal WUA

The Citrusdal WUA is located upstream of the Clanwilliam Dam. The area is dominated by citrus orchards, which use water either directly from the river or from numerous small farm dams in the area. The scheduled areas for the various sections of the WUA are summarized in Table 8. The scheduled allocation in the Citrusdal WUA is 12 200 m^3/ha/a. This has been used to calculate the total scheduled allocation for the WUA.

Table 8 Scheduled Areas for Citrusdal WUA

Description of Sub-section	Scheduled Area (Ha)	Scheduled Allocation (Mm^3/a)
Sub-section 1: Original irrigation areas	5145	62.77
Sub-section 2: Area west of Olifants River, that was not part of original irrigation board	813	9.92
Sub-section 3: Allendale Sub-section	503	6.14
Sub-section 4: Northern riparian section of Olifants River from La Rhyn to the start of Clanwilliam Dam	432	5.27
Total for Citrusdal WUA	**6893**	**84.09**

2.7.2 Clanwilliam WUA

The Clanwilliam WUA covers the area upstream of the Clanwilliam Dam and below the dam as far as the Bulshoek Weir. Water is conveyed to the farmers downstream of the dam either via a canal or via the main river channel. The WUA also includes the irrigation demand directly out of the Jan Dissels River. The WUA, however, does not appear to include the farms along the Elandskloof River. The extent of the Clanwilliam WUA is shown in Figure 3.

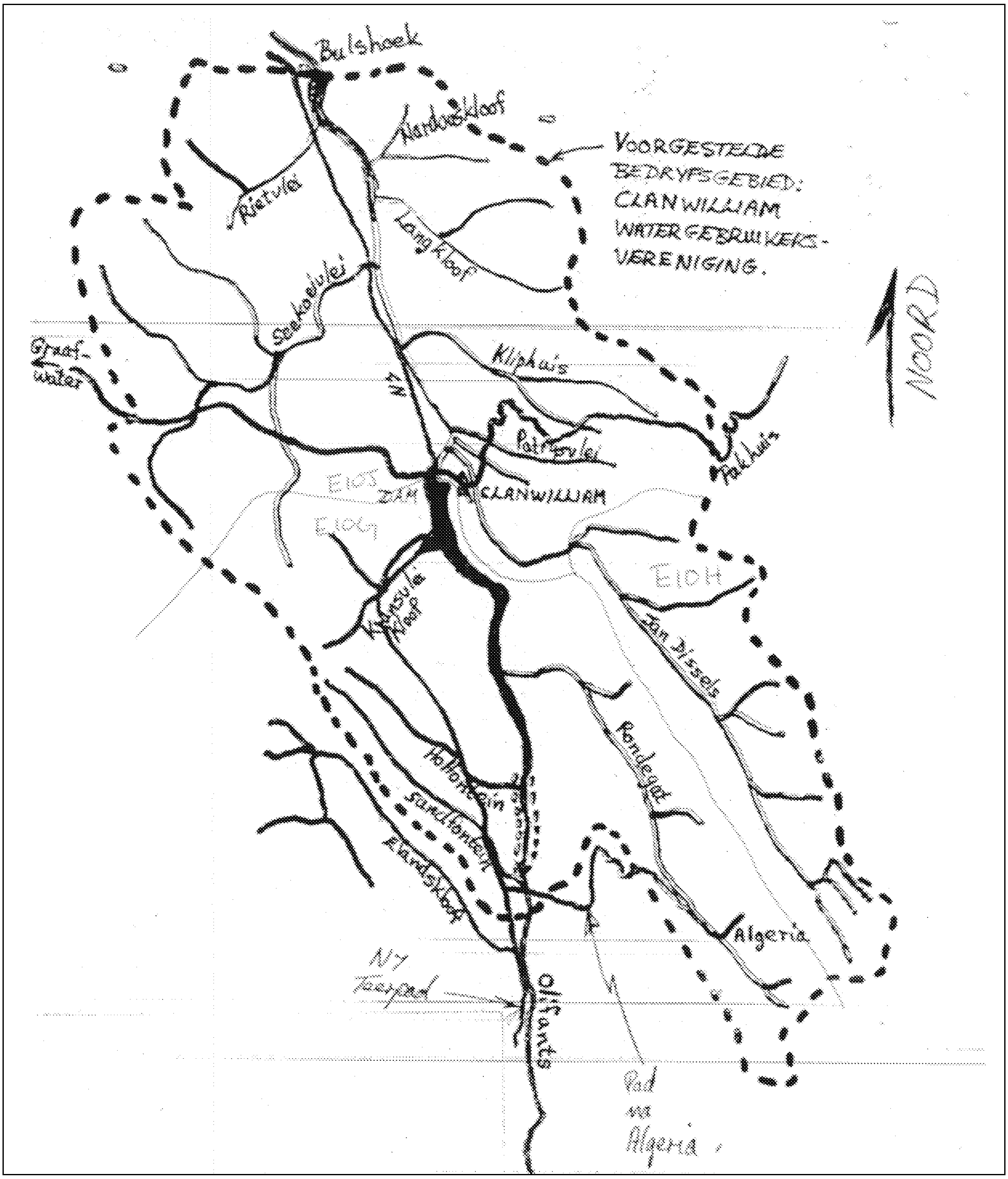

Figure 3 Area covered by the Clanwilliam Water User Association

The scheduled areas for the different sections of the Clanwilliam WUA are summarised in Table 9. The sub-totals for the sections occurring in each quaternary catchment are also given. This enables a comparison to be made between the allocations upstream of the dam (E10G), downstream of the dam (E10J) and from the Jan Dissels River (E10H). The current quota for the Clanwilliam WUA is 12 200 m^3/ha/a. This is used to calculate a scheduled volume for each section as shown in Table 9.

Table 9 Current Irrigation Areas as Provided by Clanwilliam WUA

Section	Quaternary Catchment	Irrigated Area (ha)	Estimated Demand (Mm^3/a)
From Canal	E10J	734	8.95
Rondegat	E10G	110	1.34
Jan Dissels	E10H	500	6.10
Kransvleikloof	E10G	143	1.74
Seekoeivlei River	E10J	40	0.49
Rietvlei River	E10J	188	2.29
Nardouskloof	E10J	0	0
Langkloof	E10J	587	7.16
SUB TOTAL FOR E10G		**253**	**3.09**
SUB TOTAL FOR E10H		**500**	**6.10**
Sub Total for E10J		**1548**	**18.89**
Total for Clanwiliam WUA		**2301**	**28.07**

2.7.3 Lower Olifants River Water User Association (LORWUA)

Information on allocations to individual sluices along the canals below Clanwilliam Dam and Bulshoek weir was provided by LORWUA. This is summarised in Table 10 in terms of the total scheduled areas for specific crop types from the canal below Clanwilliam Dam (Clanwilliam), and the canal below the Bulshoek Weir (Vredendal).

Table 10 Irrigation Areas using Detailed Sluice information provided by LORWUA

	Permanent Crops (ha)						Cash Crops (ha)					Total Irrigated Area[1]
	Export Grapes	Wine Grapes	Raisins	Lucern	Other	Citrus	Tomatoes	Maize	Tea	Seed	Vegetables	
Vredendal	558	8453	859	354	392		821			128	998	**12 563**
Clanwilliam	110	146		37	75	391	21	221	20		327	**780**
TOTAL	**668**	**8599**	**859**	**391**	**467**	**391**	**842**	**221**	**20**	**128**	**1325**	**13 343**

[1] Total for crops with significant irrigation demand, i.e. excluding Maize and Tea.

The current allocation for LORWUA is 12 200 $m^3/ha/a$ applied to an allocation area of 9491Ha. Hence the scheduled allocation for this area is equal to 115.8 plus losses of about 27% on the Bulshoek Canal or 147 Mm^3/a on the Vredendal canal section and 9.5 Mm^3/a along the Clanwilliam canal section.

No information was provided on the demand met directly from the river below Bulshoek Weir.

2.8 Information Provided by Farmers in the Citrusdal Area

Information on the current irrigated areas in the Citrusdal WUA was also obtained by Mr. G van Zyl directly from the farmers themselves. This information is summarized by crop type in Table 11. The information provided by the farmers was also used to check the crop types identified from aerial photos for subsequent analysis of the current irrigated areas using GIS. This is discussed in Section 2.10. In addition information on the capacities of farm dams was also provided and is summarised in Table 11.

Table 11 Irrigated Areas and Farm Dam Capacities as provided by Citrusdal Farmers

	Permanent Crops			Cash Crops			Total Crop Area	Total Storage Capacity (Mm^3)
	Fruit	Citrus	Pasture	Vegetable	Vineyard	Rooibos Tea		
Crop Area (ha)	18	1303	1221	62	23	758	3324	2.69
Percentage of Irrigated Crop Area (%)	1%	50%	47%	2%	1%	-	-	

A significant area is used to grow Rooibos tea. Rooibos tea, however, requires very little irrigation. If Rooibos is excluded from the calculation of irrigated area, then the total irrigated area is only 2 566 ha or 77% of the total crop area. The percentage of this irrigated area for the crops requiring irrigation (fruit, citrus, pastures, vegetables and vineyards) is also given in Table 11. This was not a comprehensive survey of farmers as it was intended to supplement the GIS analysis (see Section 2.10). The survey was used to check that the correct crop types and approximate areas had been identified in the GIS analysis.

2.9 Information from the Department of Water Affairs and Forestry

Mr Francois van Heerden, the regional manager for the DWAF, also provided information on the DWAF's estimates of the current area under irrigation in the catchment. He also provided information on the scheduled quota, but noted that this was not often met. Hence he also provided an estimate of the average quota as well as the average actual use for the area below Bulshoek Weir. This information along with the scheduled allocation and the estimated average and likely actual demand is provided in Table 12 for each quaternary catchment.

Table 12 Information on Current Irrigation Demands provided by DWAF

Quaternary Catchment	Quota (m^3/ha/a)			Irrigation area (ha)	Estimated Demand (Mm^3/a)		
	Scheduled	Average	Actual		Scheduled	Average	Actual
E10A	12200	12000	-	1000	12.2	12	-
E10B	12200	12000	-	1900	23.18	22.8	-
E10C	12200	12000	-	1600	19.52	19.2	-
E10D	12200	12000	-	1000	12.2	12	-
E10E	12200	12000	-	1600	19.52	19.2	-
E10F	12200	12000	-	1900	23.18	22.8	-
E10G	12200	12000	-	2100	25.62	25.2	-
SUB-TOTAL U/S CLANWILLIAM DAM				**11100**	**135.42**	**133.2**	**-**
E10H	12200	11000	8500	190	2.318	2.09	1.615
E10J and part of E10K (up till Bulshoek)	12200	11000	8500	1770	21.594	19.47	15.045
SUB-TOTAL U/S BULSHOEK WEIR				**13060**	**159.33**	**154.76**	**-**
E10K and part of E33E – only out of Olifants River bed	12200	11000	8500	750	9.15	8.25	6.375
E33K, E33G, part of E33E, E33H only out of GWS canal	12200	11000	8500	11000	134.2	121	93.5
TOTAL FOR OLIFANTS RIVER				**24810**	**302.68**	**284.01**	**-**

2.10 GIS Analysis

As part of the current study into the potential raising of Clanwiliam Dam, current areas under irrigation were identified from aerial photographs and captured in a geographic information system (GIS). Where possible, color aerial photographs, taken by Working for Water during 2001/02 were used. In some areas these were not available and so older photos or images from Google Earth were used. The identified crop areas were coded according to the dominant crop type and plotted on large-scale maps. These maps were shown to farmers in the Citrusdal and Clanwilliam areas to confirm that the correct areas had been identified. The additional information provided by the farmers in the Citrusdal area, discussed in Section 2.10, was also used to check the crop types for the irrigated areas identified from the aerial photographs.

The crop areas identified from aerial photographs and captured in the GIS for the Witzenberg/Bo-boschkloof area, Citrusdal area, and Clanwilliam area down to Bulshoek Weir, are shown in Figure 4, Figure 5 and Figure 6 respectively.

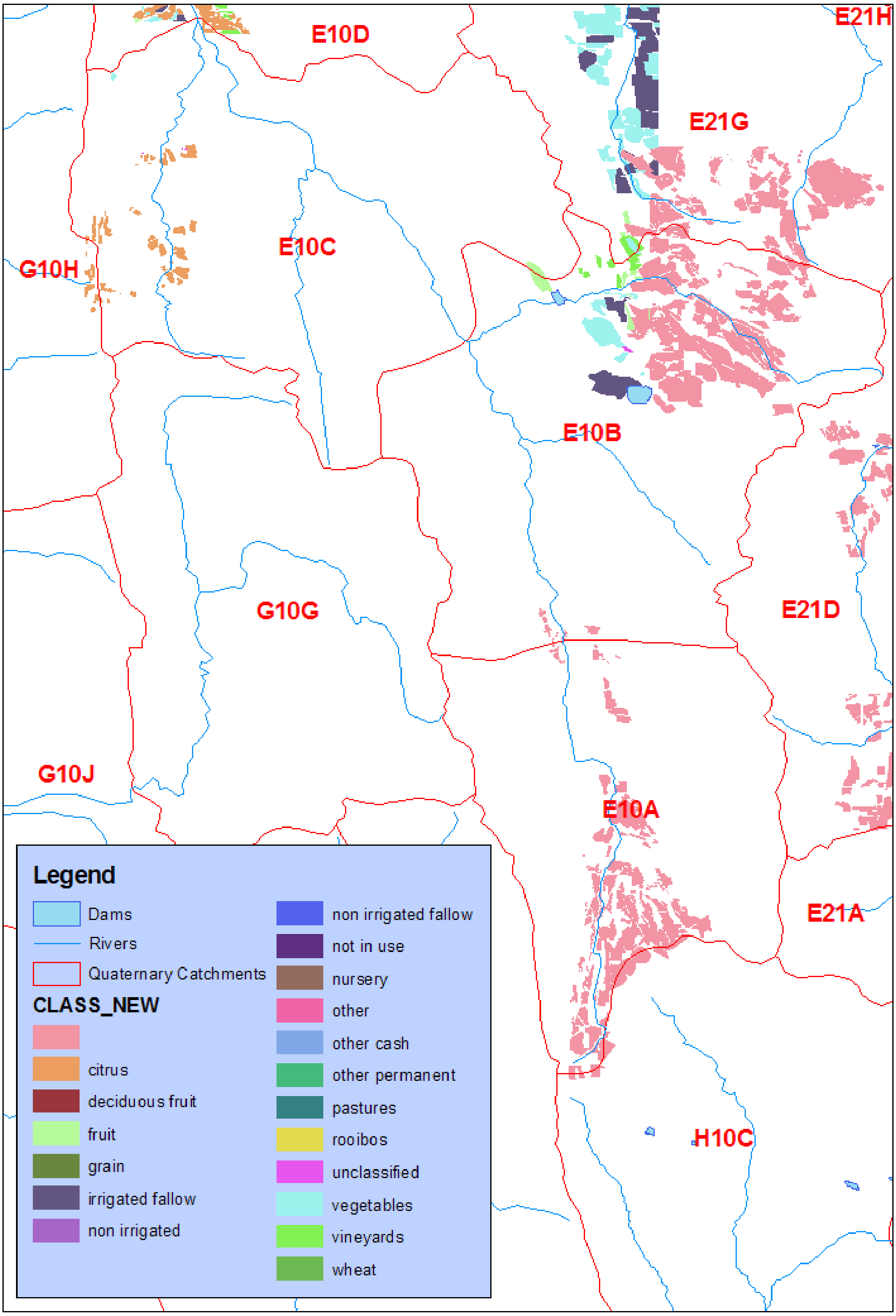

Figure 4 Crop areas identified from aerial photographs: Witzenberg/Bo-Boschkloof area

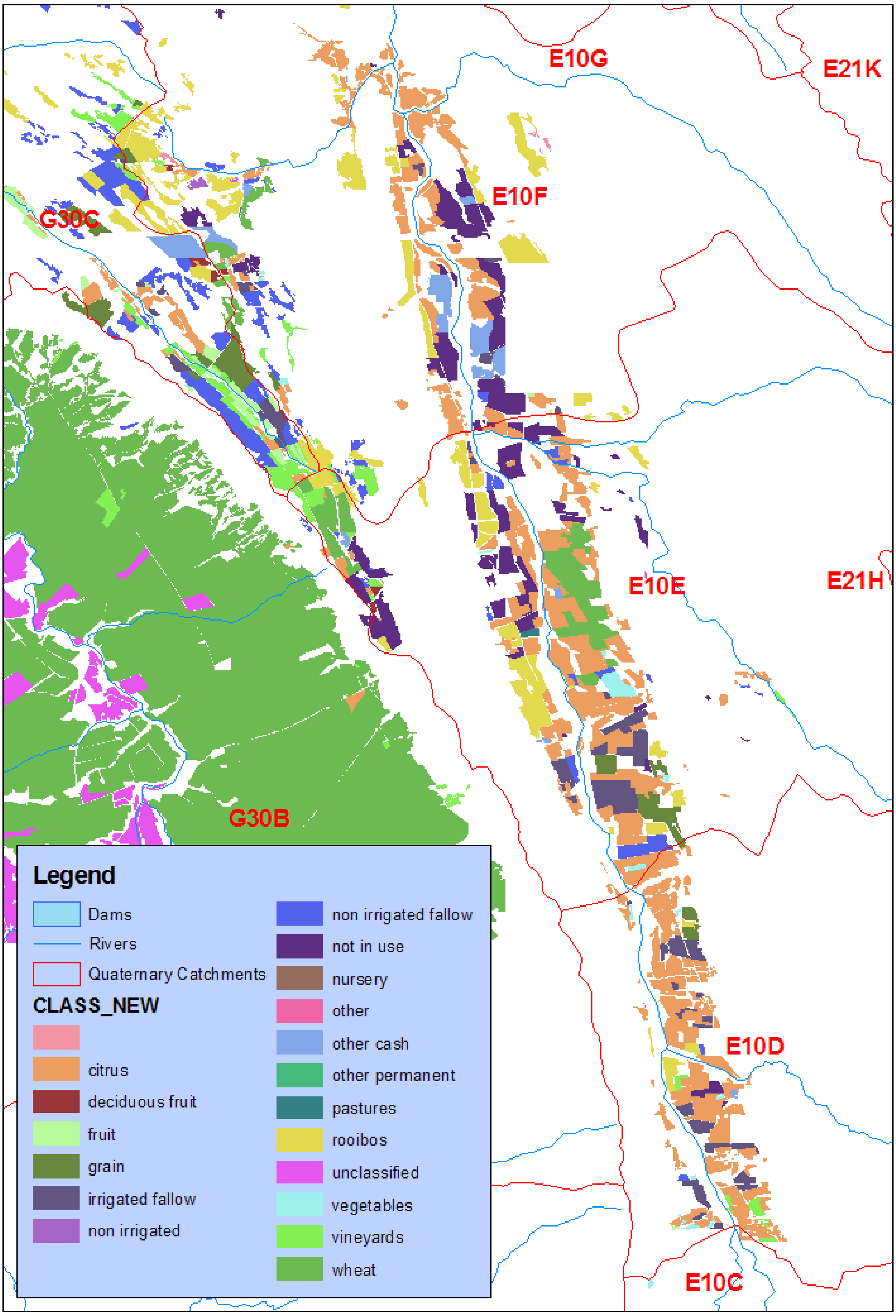

Figure 5 Crop areas identified from aerial photographs: Citrusdal Area

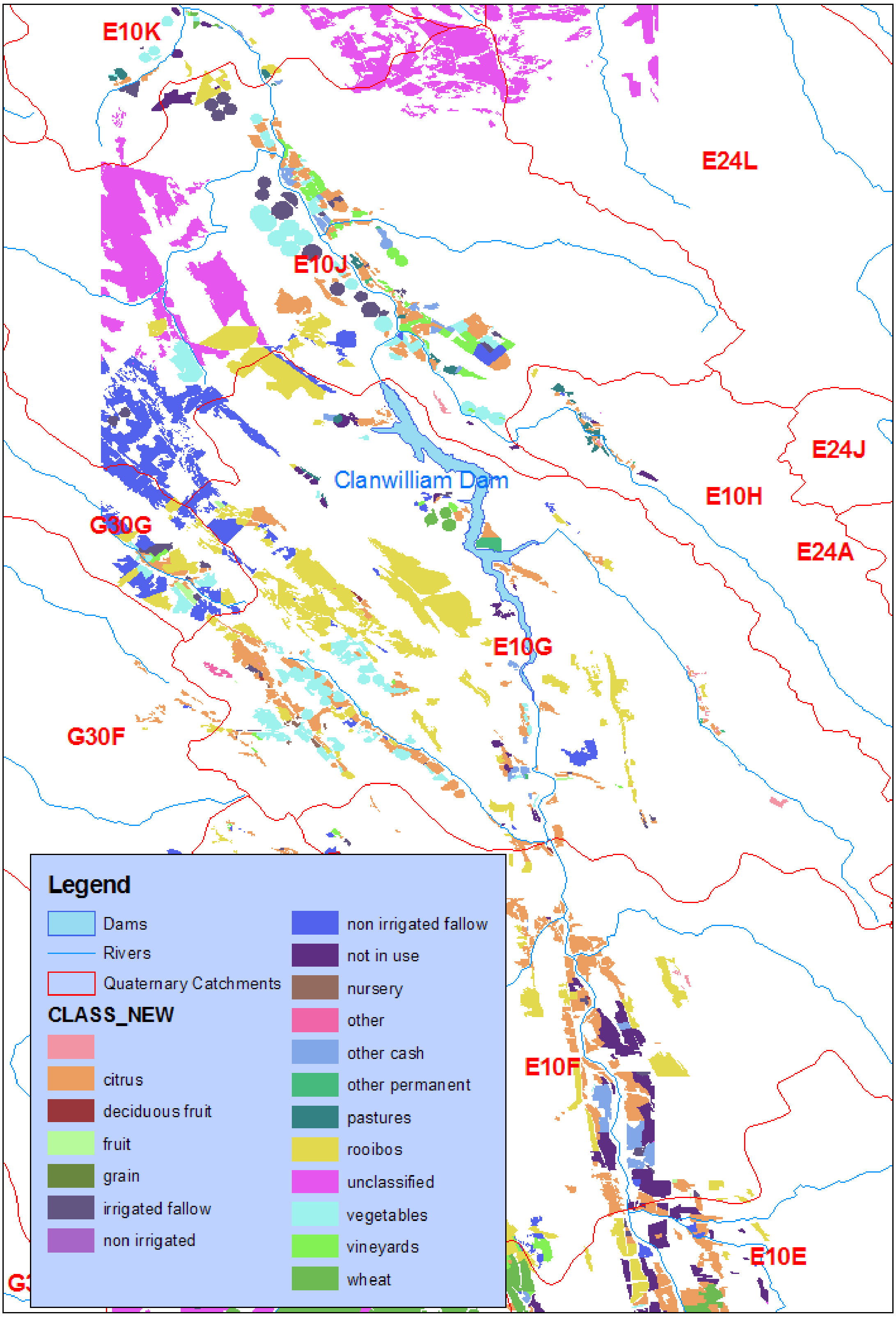

Figure 6 Crop areas identified from aerial photographs: Clanwilliam Area

The area downstream of Bulshoek Weir was not mapped, and no additional information was provided by the farmers in the Witzenberg Area (E10A). Only limited information was provided by the farmers in the Bo-Boschkloof area (E20B). This explains why large parts of these areas have been labeled as “unclassified”.

Shape files of the individual crop types were created using GIS and these were intersected with the quaternary catchment boundaries to calculate the total irrigated area in each quaternary catchment. The crop areas were also intersected with the hydrological catchment boundaries used in the calibration of the original hydrological model (DWAF, 1998), The results are shown in Table 13 in terms of the total areas identified for each crop type, by quaternary catchment.

Table 13 Crop Areas Identified from GIS Analysis summarised by Quaternary Catchment

	E10A	E10B	E10C	E10D	E10E	E10F	E10G	Total u/s Clanwilliam	E10H	E10J	E10K	Total u/s Bullshoek
Permanent Crops												
Fruit	0	173	20	3	15	24	35	**269**	0	3	1	**273**
Citrus	0	0	224	1624	2382	1439	1336	**7004**	56	708	34	**7802**
Grapes	0	57	0	69	109	138	36	**408**	0	294	58	**761**
Other Permanent	0	0	0	0	0	0	67	**67**	1	9	0	**78**
Sub-total for Permanent Crops	0	229	244	1696	2506	1600	1473	**7749**	57	1014	93	**8913**
Cash Crops												
Vegetables	0	156	4	37	109	20	886	**1213**	0	715	92	**2020**
Wheat/Grain	0	0	0	61	1030	219	86	**1396**	0	0	18	**1414**
Rooibos Tea	0	0	0	92	654	1217	3071	**5034**	0	792	63	**5888**
Nursery	0	0	0	0	0	0	32	**32**	0	0	0	**32**
Pastures	0	0	0	0	18	0	29	**47**	79	29	46	**200**
Other Cash	0	0	0	8	30	357	74	**470**	10	169	9	**657**
Sub-total for Cash Crops	0	156	4	198	1841	1813	4179	**8192**	89	1705	227	**10213**
Other Land-use												
Irrigated Fallow	0	156	0	348	426	81	46	**1057**	0	546	38	**1642**
Non-irrigated Fallow	0	0	0	16	206	225	673	**1121**	2	1490	32	**2644**
Unclassified/Other[1]	1267	1829	7	43	799	922	242	**5109**	31	3607	1241	**9987**
Sub-total for Other Land-use	1267	1984	7	407	1431	1229	961	**7286**	33	5643	1311	**14273**
Total Mapped Area (i.e. Permanent and Cash Crops and Other Land-use)												
Total by Quaternary	1267	2370	255	2301	5779	4642	6613	**23228**	179	8361	1631	**33399**
Total for Current Irrigated Area (i.e. Permanent and Cash Crops excluding Wheat and Grain, and Rooibos Tea)												
Total by Quaternary	0	385	249	1742	2664	1978	2495	**9512**	146	1927	239	**11824**
Total for Potential Current Irrigated Area (i.e. Permanent and Cash Crops excluding Wheat and Grain, and Rooibos Tea, plus irrigated fallow)												
Total by Quaternary	0	541	249	2089	3090	2059	2540	**10569**	146	2473	277	**13465**

[1] Unclassified/Other includes areas classed as "unclassified", "not in use", "non-irrigated fallow", and "other".

In the above table it is assumed that wheat, grain and rooibos tea have negligible irrigation demand. They have therefore been excluded from the calculation of the total currently irrigated area. In addition the total potential current irrigated area has been calculated. This includes the areas identified as "irrigated fallow". These areas tend to be areas that have previously been irrigated using centre pivots, but are currently not in use. These areas may either have been left fallow due to the low level of assurance of water or as part of the normal crop rotation. They may, however, also be areas that will be used for cash crops, such as onions and potatoes that will be planted later in the season and were therefore not evident at the time of taking the photographs.

3. COMPARISON OF INFORMATION ON IRRIGATION AREAS

A large amount of information on the current irrigation areas in the Olifants Catchment has been presented in the previous section. This information comes from a variety of sources and it is difficult to compare directly as the information is based on different time periods, covers different areas and is based on different assumptions.

In terms of the spatial relationship there are two main spatial units. These are the quaternary catchments and the hydrological catchments used in the ORBS (DWAF, 1998) and subsequent reports. These two spatial units do not always coincide. However in terms of determining the irrigated areas it is clear from the GIS developed from aerial photographs that the crop areas only occur in specific parts of the catchments which enables a comparison to be made between the areas given in terms of quaternary catchments and in terms of hydrological catchments. For example in the Witzenberg Area, the irrigated area reported in quaternary catchment E10A almost all occurs in hydrological catchment O1. The same can be said for the Bo-boschkloof area where all the irrigation for E10B occurs in hydrocatchment O3.

The extent of the various WUAs can also be roughly determined in terms of quaternary catchments with the Citrusdal WUA consisting of catchments E10C to E10F and the Clanwilliam WUA consisting of E10G upstream of the Dam and E10H, E10J and about half of E10K downstream of the dam. Although the location of Bulshoek Weir does not coincide exactly with a quaternary catchment boundary, there is limited space for irrigated agriculture in the remainder of E10K and hence it is assumed for this comparison that all irrigated areas identified in E10K occur upstream of Bulshoek, unless specified otherwise.

The comparision of irrigation demands is further complicated by the fact that a different system for grouping demands is used in the yield model. This is not based exactly on either quaternary catchment boundaries or specified hydrological catchments. This is discussed in Section 5.1.

In order to be able to make some comparison between the information provided in the various reports, the information on irrigated areas has been summarised by quaternary catchment in Table 14 based on the assumptions described above. The final areas selected as representative of the current level of development is also given in this Table. This selection of the final representative areas is described in the following section.

Table 14 Summary of Irrigated Areas (ha) from various sources for the Olifants River Catchment

Source of Information	Year	Section in Report	E10A	E10B	E10C	E10D	E10E	E10F	E10G	Sub-total upstream of Clanwilliam	E10H	E10J	E10K	Sub-total upstream of Bulshoek	Sub-total downstream of Bulshoek	Total for Olifants River
Government – Current	1987	2.1	770	89	4398					**5257**	-	-	-	**-**	-	**-**
Government Gazette - Permitted	1987	2.1	870	89	5909					**6868**	-	-	-	**-**	-	**-**
ORSA	1990	2.2	1 168	1 445	3 906					**6 519**	611			**7 130**	11 500	**18 630**
ORBS – Phase I	1998	2.3	800	1 900	5 400					**8 100**	1 650			**9 750**	11 500	**21 250**
WODRIS	2001	2.4	800	1 900	5 400					**8 100**	1 650			**9 750**	11 500	**21 250**
WRSAR	2002	2.5	1256	1075	408	814	1998	1956	632	**8 139**	147	1 503	880	**10 669**	10 448	**21 1117**
					5 176							2 383				
ORBS – Phase II	1998	2.6	800	1 900	5 400					**8 100**	1 650			**9 750**	11 642	**21 392**
Citrusdal WUA	2006	2.7	-	-	6 893				-	**-**				**-**	-	**-**
Clanwilliam WUA	2006	2.7	-	-	-	-	-	-	253	**-**	500	1548		**-**	-	**-**
LORWUA	2006	2.7	-	-	-	-	-	-	-	**-**	-	780[1]	-	**-**	12 563	**-**
Citrusdal Farmers	2006	2.8	-	-	2 566				-	**-**	-	-	-	**-**	-	**-**
DWAF Estimates	2006	2.9	1 000	1 900	1 600	1 000	1 600	1 900	2 100	**11 100**	190	1 770		**13 060**	11750	**24 810**
GIS – Current	2002	2.10	0 [2]	385 [2]	249	1742	2664	1978	2495	**9 512**	146	1 927	239	**11 824**	-	**-**
					6633							2 166				
GIS -Potential	2002	2.10	0 [2]	541 [2]	249	2089	3090	2059	2576	**10 569**	146	2 473	277	**13 465**	-	**-**
					7 487							2 750				
Final Selected Irrigated Areas	2006	4.6	1256	1075	259	1810	2768	2056	2459	**11683**	146	2473	277	**14579**	12 563	**27 142**

[1] Allocation from canal only

[2] GIS analysis incomplete

4. SELECTION OF FINAL IRRIGATED AREAS

The final selection of the best representation of the current irrigated area in the Olifants catchment is discussed in the following sections based on the results of the review of the various sources of information presented in **Error! Reference source not found.**.

4.1 Witzenberg (E10A)

No additional information could be obtained for this area either in terms of the current scheduled areas or from the aerial photographs and the GIS. For this reason it was necessary to base the estimated crop area on the results of previous studies. It was decided to use the total irrigated area presented in the WRSAS (DWAF, 2002) as this represented the most recent assessment of crop areas in this region. The total irrigated area of 1256 ha indicates a growth of approximately 8% from the area reported in the ORBS. This area is also 50% greater than the original scheduled area in the Government Gazette (1987).

The dominant crop types in this area are fruit, vegetables and pastures. The percentage split between the various crop types was based on that given in the ORBS (DWAF, 1990) as the WRSAR only made a distinction between high value and medium value crops.

4.2 Bo-Boschkloof (E10B)

The only part of E10B that is suitable for irrigation is the Bo-Boschkloof area. While limited information on specific crop types was obtained from the aerial photographs, this does not appear to cover the whole area. Instead it was decided to also base the estimate of current irrigated crop area on that given in the WRSAS. The total irrigated area of 1075 ha appears to indicate a decrease in the irrigated area since the ORBS, which gave an area of 1445 ha. It is also significantly less than the ORBS, DWAF, and WODRIS estimates, which are all 1900 ha.

The dominant crops in this area are fruit and vegetables. The limited information on areas of specific crop types, including irrigated fallow, that was available from the aerial photographs was used. This accounted for 541 ha and the additional 534 ha was assumed to be split equally between fruit and vegetables.

4.3 Citrusdal (E10C, E10D, E10E, E10F)

A significant amount of effort went into capturing the correct information for this area in the GIS. This included ground-truthing and comparing identified crop types with those reported by the farmers themselves. For this reason it was decided to use the information captured in the GIS as representative of the current irrigated area. The total irrigated area (i.e. excluding wheat and grain, Rooibos Tea and irrigated fallow) identified for this area was 6 633 ha. This is very close to the current scheduled area for the Citrusdal WUA (6893 ha). The fact that the identified area is slightly lower than the scheduled area may be due to the current low level of assurance. Hence in the final analysis it was decided to use the current scheduled area and use the GIS to determine the approximate area per quaternary catchment and for each crop type.

The final selected irrigate area for this section is therefore 6893 ha. This shows an increase of approximately 28% from the figure used in the ORBS and WODRIS. The area used in the original system analysis (ORSA), is only 3 906 ha. This is significantly less than the area identified in the GIS and is of concern in terms of the demands used in the Yield Model. This can partly be explained by the growth in the citrus industry in recent years, but could also indicate that the original hydrology did not consider the demands away from the main river where there are substantial numbers of farm dams capturing local runoff.

The split between the various crop types was obtained from the GIS. The dominant crop type in this area is citrus. There is also a significant amount of Rooibos Tea, but as had been mentioned previously this is assumed to have a negligible irrigation demand. Much of this Rooibos tea has been planted in recent years in response to the relatively low levels of assurance of supply. In same cases the Rooibos tea has replaced citrus orchards.

4.4 Clanwilliam (E10G, E10H, E10J, E10K)

The irrigation areas from the GIS were also considered to be representative of the current situation in this area. The total irrigated area downstream of the dam and including the Jan Dissels River is 2 312 ha. This appears to show a marginal increase on the currently scheduled area of 2 048 ha, but is slightly less than the estimate in the WRSAS (2530 ha). The estimated area downstream of the dam in the ORSA is only 611 ha. The area upstream of the dam (E10G) shows quite a substantial area under irrigation (2459 ha). This is much larger than any of the previous estimates, but is consistent with DWAF’s estimate of the current irrigated area in this catchment. The primary reason for this appears to be the large amount of activity along the Elandskloof River, which does not appear to be part of the Clanwilliam WUA.

The scheduled area supplied from the canal is equal to 780 ha (excluding maize and rooibos tea) according to the information provided by LORWUA. This is slightly more than the scheduled area provided by the Clanwilliam WUA (734ha). The percentage of the irrigation demand between Clanwilliam Dam and Bulshoek Weir that is met from the canal rather than the river is therefore equal to 780/2312 = 34%.

The dominant crop types identified in this area from the GIS are citrus, vegetables and Rooibos tea.

4.5 Below Bulshoek Weir (E10K, E22E, E33G, E33H)

The area below Bulshoek Weir, which includes a small part of E10K, but mainly comprises E33E, E33G and E33H, was not the focus of this investigation, and so was not mapped in the GIS. Instead the actual historical demand could be used to determine the demands in the yield model based on the observed flow records from the LORWUA canal. The assumed irrigated areas for this section is based on the actual scheduled areas provide by LORWUA. This is equal to 12 563 ha allocated from the canal. No indication of the scheduled allocation, if any out of the river is given, although it is known that many farmers do pump directly from the river, often illegally, particularly during restrictions. The dominant crop types for this area are grapes and tomatoes. The percentage split between these crops is also given in the scheduled information provided by LORWUA.

4.6 Summary of Final Areas

The final assumed crop areas for the main crop types in each quaternary catchment are shown in Table 15. The total irrigated area assumes that rooibos tea, wheat and grain have negligible irrigation demand.

Table 15 Final Assumed Crop Areas for the Olifants River upstream of Bulshoek Weir

	E10A	E10B	E10C	E10D	E10E	E10F	E10G	Total u/s Clanwilliam	E10H	E10J	E10K	Total u/s Bulshoek
Citrus	0	0	224	1 624	2 382	1 439	1 403	**7 072**	57	717	34	**7 880**
Fruit	666	439	20	3	15	24	35	**1 201**	0	3	1	**1 205**
Grapes	0	57	0	69	109	138	36	**409**	0	294	58	**761**
Vegetables	239	421	4	114	243	456	996	**2473**	10	884	101	**3 217**
Pastures / Nursery	352	0	0	0	18	0	61	**431**	79	29	46	**584**
Rooibos Tea	0	0	0	92	654	1 217	3 071	**5 034**	0	792	63	**5 888**
Wheat / Grain	0	0	0	61	1 030	219	86	**1 396**	0	0	18	**1 414**
Irrigated Fallow	0	156	0	280	322	3	46	**807**	0	546	38	**1 642**
Total - Cultivated	**1 256**	**1 073**	**249**	**2 242**	**4 774**	**3 495**	**5 734**	**18 823**	**146**	**3 265**	**358**	**22 591**
Total – Irrigated[1]	**1256**	**917**	**249**	**1810**	**2768**	**2056**	**2530**	**11586**	**146**	**1927**	**239**	**13898**

[1] Excludes Rooibos tea, wheat and grain, and irrigated fallow.

5. COMPARISON OF DEMANDS

5.1 Irrigation Demands

The current irrigation demand was estimated based on the final assumed irrigated crop areas given in Table 15. The average demand was calculated using monthly precipitation and evaporation data from WR90 for the period 1920 to 1989. The average monthly demand was calculated according to the following equation:

$$\text{Demand} = Area..\left(\frac{\text{MAE}\cdot\text{MF}_\text{E}\cdot\text{CF}-\text{MAP}\cdot\text{MF}_\text{P}\cdot\text{EP}}{\text{EF}}\right)$$

Where
- Area = Crop area
- MAE = Mean annual evaporation
- MF_e = Monthly factor for evaporation
- CF = Crop factor
- MAP = Mean annual precipitation
- MF_p = Monthly factor for precipitation
- EP = Effective precipitation factor
- EF = Efficiency factor based on irrigation method

The crop factors used were taken from the ORSA Report (DWAF, 1990) and are given in Table 16.

Table 16 Crop Factors used to Estimate Irrigation Demand

Crop Type	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
Citrus	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	-	-	-	0.40
Fruit	0.27	0.31	0.41	0.50	0.42	0.20	-	-	-	-	-	0.23
Grapes	0.20	0.30	0.35	0.39	0.37	0.27	0.20	-	-	-	-	0.23
Vegetables	0.50	0.60	0.60	0.60	0.60	0.60	0.60	0.50	0.30	-	-	0.30
Pastures / Nursery	0.70	0.80	0.80	0.80	0.80	0.80	0.70	0.70	-	-	-	-

For comparison a number of crop factors where compared as part the soils and crop water requirements assessment, which was done as a separate report for this Study (DWAF, 2006). The crop factors given for deciduous fruit and citrus in this report are given in Table 17.

Table 17 Crop Factors given in Soils Assessment Report (DWAF,2006)

Crop Type	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
Citrus (Infruitec)	0.40	0.40	0.40	0.40	0.40	0.50	0.50	0.50	0.50	0.50	0.40	0.40
Citrus (ISCW)	0.45	0.45	0.50	0.55	0.60	0.65	0.70	0.65	0.60	0.45	0.45	0.45
Fruit early	0.40	0.45	0.50	0.50	0.50	0.40	0.20	0.20	0.20	0.20	0.25	0.30
Fruit middle	0.35	0.40	0.45	0.50	0.50	0.45	0.20	0.20	0.20	0.20	0.20	0.27

A comparison of these crop factors shows that the factors used for both citrus and fruit are slightly on the low side. In addition it is assumed that there is no irrigation demand during the winter months. The result of this is that the calculated demands are likely to be slightly on the low side.

There was limited information available on the specific irrigation method used. It was assumed that the permanent crops would have drip irrigation, while the cash crops such as vegetables and pastures would use overhead irrigation from center pivots. The assumed irrigation method and corresponding efficiency factor used is given in Table 18. The effective precipitation factor was assumed to be 60%.

Table 18 Irrigation Method and Efficiency Factor

Crop Type	Irrigation Method	Irrigation Efficiency Factor
Citrus	Drip	0.95
Fruit	Drip	0.95
Grapes	Drip	0.95
Vegetables	Centre Pivot	0.85
Pastures	Centre Pivot	0.85

The demands in the yield model represent the total demand. This demand is not always met and so during certain dry periods less land is planted. To determine the total average demand it is necessary to consider the possibility that land currently classified as “irrigated fallow” could be cultivated. The total demand has therefore been calculated by assuming that this area has been planted with vegetables. The total average monthly irrigation demand for all crops including the areas classified as irrigated fallow is given in Table 19 by quaternary catchment.

Table 19 Estimated Irrigation Demands upstream of Bulshoek weir

Quaternary Catchment	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total Annual
E10A	0.70	1.47	2.21	2.54	2.17	1.63	0.40	0.00	0.00	0.00	0.00	0.00	11.12
E10B	0.45	0.96	1.44	1.65	1.42	1.06	0.27	0.00	0.00	0.00	0.00	0.00	7.24
E10C	0.13	0.22	0.30	0.32	0.26	0.22	0.08	0.00	0.00	0.00	0.00	0.04	1.57
E10D	1.04	1.71	2.24	2.37	1.89	1.66	0.67	0.00	0.00	0.00	0.00	0.35	11.94
E10E	1.72	2.78	3.60	3.76	3.03	2.69	1.17	0.02	0.00	0.00	0.00	0.68	19.44
E10F	1.33	2.12	2.76	2.89	2.33	2.05	0.91	0.05	0.00	0.00	0.01	0.57	15.01
E10G	1.83	3.10	3.97	4.13	3.35	3.00	1.40	0.09	0.00	0.00	0.00	0.57	21.44
Sub-total u/s Clanwilliam	**7.20**	**12.37**	**16.53**	**17.66**	**14.43**	**12.32**	**4.90**	**0.15**	**0.00**	**0.00**	**0.01**	**2.21**	**87.76**
E10H	0.15	0.25	0.32	0.33	0.26	0.24	0.10	0.00	0.00	0.00	0.00	0.02	1.66
E10J	1.45	2.45	3.15	3.30	2.67	2.33	1.14	0.20	0.00	0.00	0.02	0.53	17.24
E10K	0.21	0.36	0.46	0.48	0.39	0.34	0.17	0.03	0.00	0.00	0.00	0.05	2.49
Total u/s Bulshoek	**9.00**	**15.42**	**20.46**	**21.77**	**17.75**	**15.23**	**6.30**	**0.38**	**0.00**	**0.00**	**0.03**	**2.80**	**109.15**

The above table represents that actual estimated crop demand. The total irrigation demand, however, must make allowances for losses and leaching requirements. These are assumed to be equal to 5% each. This is consistent with the recommendations of the Soils and Crop Water Requirement Assessment (DWAF, 2006, which concluded that the losses could be in the range of 5% and leaching component could be as high as 10% to 20%, north of Bulshoek weir, but is generally less upstream of Bulshoek.

The total calculated irrigation demand, including leaching and losses, for the assumed current level of developed upstream of Bulshoek Weir is given in Table 20.

Table 20 Estimated Average Irrigation Demand (Mm^3/a) upstream of Bulshoek Weir

Quaternary Catchment	Crop Area (ha)	Total Demand (Mm^3/a)	Losses (Mm^3/a) (5%)	Leaching (Mm^3/a) (5%)	Irrigation Demand (Mm^3/a)	Average Annual Demand (mm/a)
E10A	1256	11.12	0.56	0.56	12.23	974
E10B	917	7.24	0.36	0.36	7.96	869
E10C	249	1.57	0.08	0.08	1.72	693
E10D	1810	11.94	0.60	0.60	13.13	725
E10E	2768	19.44	0.97	0.97	21.39	773
E10F	2056	15.01	0.75	0.75	16.52	803
E10G	2530	21.44	1.07	1.07	23.58	932
Subtotal u/s Clanwilliam	**11585**	**87.76**	**4.39**	**4.39**	**96.53**	**833**
E10H	146	1.66	0.08	0.08	1.83	1255
E10J	1927	17.24	0.86	0.86	18.97	984
E10K	239	2.49	0.12	0.12	2.74	1145
Subtotal u/s Bulshoek	**2312**	**21**	**1.07**	**1.07**	**23.53**	**1018**
Total for E10	**13897**	**109.15**	**5.46**	**5.46**	**120.07**	**864**

The average annual irrigation demand of 833 mm upstream of Clanwiliam Dam and 1018 mm between Clanwilliam Dam and Bulshoek weir is consistent with the estimated irrigation demand made using SAPWAT as part of a separate report for this Study (DWAF, 2006). The average annual demand for the Citrusdal area was calculated in this Study to range from 1328 mm/a for citrus under micro jets to 599 mm/a for potatoes under center pivot irrigation. In addition, it was reported at a workshop of leading farmers in the area that the gross water application at Citrusdal for citrus was 8 000 and 10 000 m^3/ha/a for drip and micro irrigation respectively. As this is the dominant crop type in the area upstream of Clanwilliam Dam, it confirms that the estimated average irrigation demand of 8 960 m^3/ha/a is a reasonable assessment.

5.2 Other Demands

While irrigation demands are dominant in the catchment, there is a small urban demand from the towns of Citrusdal and Clanwilliam. The total direct and indirect use for these towns is estimated in the WRSAR (DWAF, 2002) as 1.07 Mm^3/a for Citrusdal and 1.16 Mm^3/a for Clanwilliam. These are located in quaternary catchments E10E and E10J respectively.

There is no significant bulk industrial or mining demand from the Olifants catchment upstream of Bulshoek weir.

There is some limited rural demand upstream of Bulshoek, but this is assume to be negligible in determining the potential yields from the raising of Clanwilliam Dam

5.3 Demands met from Groundwater

Part of the irrigation demand in the Olifants catchment is supplied from groundwater. An assessment of the data on the use of groundwater done as part of this study produced Table 21, which shows the estimated demands from two previous studies. The first was done by Parsons and Wentzel (2005) and the other are the results for DWAF's Groundwater Resources Assessment Phase II (DWAF, 2005).

Table 21 Groundwater Use Estimates for Olifants Catchment

Quaternary Catchment	Parsons and Wentzel (2005)						DWAF (2005)
	Urban Domestic	Rural Domestic	Irrigation	Stock watering	Other	Total	Total
E10A	0.2	0.0	5.5	0.0	0.0	5.7	3.5
E10B	0.0	0.0	0.3	0.0	0.0	0.3	3.7
E10C	0.2	0.0	0.4	0.0	0.0	0.6	0.3
E10D	0.0	0.1	0.9	0.0	0.1	1.1	0.6
E10E	1.2	0.1	3.4	0.0	0.0	4.7	0.3
E10F	0.1	0.0	2.7	0.0	0.0	2.8	4.9
E10G	0.0	0.0	1.5	0.0	0.0	1.5	0.1
E10H	0.0	0.0	0.1	0.0	0.0	0.1	1.0
E10J	0.0	0.0	0.6	0.0	0.0	0.6	2.0
E10K	0.0	0.0	0.4	0.0	0.0	0.4	0.1
Total	**1.7**	**0.2**	**15.8**	**0.0**	**0.0**	**17.8**	**19.5**

5.4 Comparison with Current Demands in the Yield Model

A number of specified demand files in the yield model are used to simulate the irrigation demand upstream of Clanwilliam Dam. A summary of the average monthly demands for each of these demand files is given in Table 22. These demand files were used in the original configuration of the system model for the ORBS (DWAF, 1998).

Table 22 Demands in the Yield Model for upstream of Clanwilliam Dam

File Name	Average Annual Demand (Mm³/a)	Irrigation Area	Quaternary Catchments
Dem1.C97	7.01	Witzenberg	E10A
Dum2.dem	16.00	Upper Boschkloof	E10B
Kerom1.dem	0.59	Keerom	E10C
Dem3us.C97	9.27	Citrusdal-u/s IFR from farm dams	E10D, E10E, E10F
Citus1.dem	27.60	Citrusdal-u/s IFR from river	E10D, E10E, E10F
Dem3ds.C97	6.72	Clanwilliam-d/s IFR from farm dams	E10G
Citds1.dem	19.99	Clanwilliam-d/s IFR from river	E10G
Total	**87.18**	**Total demand upstream of Clanwilliam Dam**	**E10A – E10G**

The demands between Clanwilliam Dam and Bulshoek Weir are captured either in terms of the yield to the canal (Channel 19) or included with the losses (Channel 165). The average annual demand through these channels is shown in Table 23.

Table 23 Demands in the Yield Model downstream of Clanwilliam Dam

File Name	Average Annual Demand (Mm³/a)	Irrigation Area	Quaternary Catchments
Channel 165	27.48	Transmission losses and abstraction from catchment and river	E10H, E10J
Channel 19	11.58	Demand from Canal	E10J
Total	**39.06**	**Total demand between Clanwilliam Dam and Bulshoek Weir**	**E10H, E10J**

The calculated demands, taking into account the irrigation and urban demand as well as the demand met from groundwater, using the GRAII estimate, are compared with the demands currently captured in the yield model in Table 24.

Table 24 Comparison of Current Demands with Yield Model Demands

Quaternary Catchment	Calculated Irrigation Demand	Estimated Urban Demand	Demand met from Groundwater	Net Surface water demand		Current Demand in Yield Model	Difference	
E10A	12.23	0.00	3.50	8.73	8.73	7.01	1.72	25%
E10B	7.96	0.00	3.70	4.26	4.26	16.06	-11.80	-73%
E10C	1.72	0.00	0.30	1.42	1.42	0.59	0.83	141%
E10D	13.13	0.00	3.60	9.53	43.30	37.46	5.84	16%
E10E	21.39	1.07	0.30	22.16				
E10F	16.52	0.00	4.90	11.62				
E10G	23.58	0.00	0.10	23.48	23.48	26.70	-3.22	-12%
Sub-total u/s of Clanwilliam Dam	**96.53**	**1.07**	**16.40**	**81.20**	**81.20**	**87.77**	**-6.57**	**-7%**
E10H	1.83	0.00	1.00	0.83	21.59	39.06	-17.47	-45%
E10J	18.97	1.16	2.00	18.13				
E10K	2.74	0.00	0.10	2.64				
Total u/s of Bulshoek Weir	**120.07**	**2.23**	**19.50**	**102.80**	**102.80**	**126.83**	**-24.03**	**-19%**

From the above table it appears that the average demand upstream of Clanwilliam Dam is currently about 7 Mm³/a, or 7%, less than is currently recorded in the yield model. The estimated current demand for the Bo-boschkloof area (E10B) however, appears to be significantly lower than is currently given in the yield model. This may be an error in the demands in the yield model as the MAR for this catchment is only 10.1 Mm^3/a. However the total farm dam capacity for this area is approximately 14 Mm^3/a, so alternatively the concern could be with the hydrology. In either event, almost all runoff is used in this catchment with neglegable contribution to the yield from Clanwilliam dam. It is therefore recommended that this specific demand kept constant in the yield model until a more detailed analysis of this catchment is required. In addition it is noted that there appears to be an decrease in the demand in E10G. This however, may be due to the uncertainty over the demands from the Elandskloof River, which does not appear to have been calculated in any of the previous studies, but is included in the demand for this area. It is therefore recommended that a separate node be included in the yield model to accommodate this and that the total demand be kept constant with that currently in the yield model until further analysis of the demands in E10G is required.

The remaining demands upstream of Clanwilliam dam show a general increase in demand and it is therefore recommended that these files should be increased to reflect the current estimated irrigated demand.

It is difficult to compare the estimated demand downstream of Clanwilliam Dam with the current demands in the yield model is this includes river losses. It is recommended that a specified demand file be included below Clanwilliam Dam to account for the demand directly from the Olifants River as well as the Jan Dissels and other tributaries that join the main stem along this reach. The irrigated area estimated from this study should be used to determine the demands, and the losses, if considered to be significant, should be accounted for with a separate loss channel. The currently modeled flow in the Channel 19 of the Yield Model (11.58 Mm^3/a) is based on the observed flow in the canal. The remaining demand that is met directly from the river can therefore be assumed to be equal to 21.59 Mm^3/a, less 11.58 Mm^3 supplied from the canal, which equals 10.01 Mm^3/a.

The final assumed increase in the demand, appears to be consistent with and representative of the anticipated growth in agricultural demands in the area as well as the demands given in other studies as shown in Table 25. The total average growth in demand upstream of Clanwilliam Dam is approximately 9.5%, which is reasonable given the anticipated growth in demand between 1998, when the original demand files were developed, and today.

Table 25 Summary of Average Annual Demands (Mm3/a) from various sources for the Olifants River Catchment

<table>
<tr><th>Source of Information</th><th>Year</th><th>Section in Report</th><th>E10A</th><th>E10B</th><th>E10C</th><th>E10D</th><th>E10E</th><th>E10F</th><th>E10G</th><th>Sub-total upstream of Clanwilliam</th><th>E10H</th><th>E10J</th><th>E10K</th><th>Sub-total upstream of Bulshoek</th></tr>
<tr><td>Government Gazette – Current</td><td>1987</td><td>2.1</td><td>7.24</td><td>0.84</td><td colspan="6">53.66</td><td>61.74</td><td>-</td><td>-</td><td>-</td><td>-</td></tr>
<tr><td>Government Gazette - Permitted</td><td>1987</td><td>2.1</td><td>8.18</td><td>0.84</td><td colspan="6">72.09</td><td>81.11</td><td>-</td><td>-</td><td>-</td><td>-</td></tr>
<tr><td>ORSA</td><td>1990</td><td>2.2</td><td>10.1</td><td>12.2</td><td colspan="6">46.6</td><td>68.9</td><td colspan="3">6.8</td><td>75.7</td></tr>
<tr><td>ORBS – Phase I</td><td>1998</td><td>2.3</td><td>9.6</td><td>9.9</td><td colspan="6">47.6</td><td>67.1</td><td colspan="3">13.3</td><td>80.4</td></tr>
<tr><td>WODRIS</td><td>2001</td><td>2.4</td><td>7.3</td><td>18.3</td><td colspan="6">58.0</td><td>83.6</td><td colspan="3">25.4</td><td>109</td></tr>
<tr><td rowspan="2">WRSAR</td><td rowspan="2">2002</td><td rowspan="2">2.5</td><td rowspan="2">10.8</td><td rowspan="2">9.0</td><td>4.9</td><td>9.8</td><td>24.2</td><td>23.7</td><td rowspan="2">7.4</td><td rowspan="2">89.8</td><td rowspan="2">1.9</td><td>18.8</td><td>12.3</td><td rowspan="2">122.8</td></tr>
<tr><td colspan="4">62.6</td><td colspan="2">31.1</td></tr>
<tr><td>ORBS – Phase II</td><td>1998</td><td>2.6</td><td>9.6</td><td>9.9</td><td colspan="6">47.6</td><td>67.1</td><td colspan="3">13.3</td><td>-</td></tr>
<tr><td>Citrusdal WUA[1]</td><td>2006</td><td>2.7</td><td>-</td><td>-</td><td colspan="4">84.09</td><td>-</td><td>-</td><td>-</td><td>-</td><td>-</td><td>-</td></tr>
<tr><td>Clanwilliam WUA[1]</td><td>2006</td><td>2.7</td><td>-</td><td>-</td><td>-</td><td>-</td><td></td><td>-</td><td>3.09</td><td>-</td><td>6.10</td><td colspan="2">18.89</td><td>-</td></tr>
<tr><td>DWAF Estimates</td><td>2006</td><td>2.9</td><td>12.0</td><td>22.8</td><td>19.2</td><td>12.0</td><td>19.2</td><td>22.5</td><td>25.2</td><td>133.2</td><td>2.09</td><td colspan="2">19.47</td><td>154.76</td></tr>
<tr><td>Yield Model Estimates[2]</td><td></td><td>5.4</td><td>7.01</td><td>16.00</td><td>0.59</td><td colspan="3">37.46</td><td>26.70</td><td>87.77</td><td colspan="3">39.06[3]</td><td>126.83</td></tr>
<tr><td rowspan="2">Surface Water Demand using Final Selected Crop Areas</td><td rowspan="2"></td><td rowspan="2">5.4</td><td rowspan="2">8.73</td><td rowspan="2">16.00[4]</td><td>1.42</td><td>9.53</td><td>22.16</td><td>11.62</td><td rowspan="2">26.70[4]</td><td rowspan="2">96.15</td><td rowspan="2">0.83</td><td>18.13</td><td>2.64</td><td rowspan="2">117.75</td></tr>
<tr><td colspan="4">44.73</td><td colspan="2">20.76</td></tr>
<tr><td colspan="15">[1] Based on scheduled allocation of 12200 m^3/ha/a</td></tr>
<tr><td colspan="15">[2] Demand files used in configuration of yield model for ORBS (DWAF, 1998)</td></tr>
<tr><td colspan="15">[3] Includes transmission losses and 11.58 Mm^3/a supplied via canal</td></tr>
<tr><td colspan="15">[4] Based on current demand files rather than estimated crop area</td></tr>
</table>

6. RECOMMENDATIONS

Based on this investigation into the current demands in the Olifants catchment, it can be concluded that the demands currently used in the yield model need to be adjusted to reflect the changes in development, particularly with regards to an increase in the irrigated crop area. Based on estimates of the average irrigation demand it is recommended that the demand files currently used in the yield model upstream of Clanwilliam Dam be increased according to the percentages given in Table 26.

Table 26 Recommended Percentage Increase in Yield Model Demand Files

File Name	Irrigation Area	Current Average Annual Demand (Mm^3/a)	Recommended Increase (%)	Updated Average Annual Demand (Mm^3/a)
Dem1.C97	Witzenberg	7.01	+25 %	8.76
Dum2.dem	Upper Boschkloof	16.00	0 %	16.00
Kerom1.dem	Kerom	0.59	141 %	1.42
Dem3us.C97	Citrusdal-u/s IFR from farm dams	9.27	16 %	10.75
Citus1.dem	Citrusdal-u/s IFR from river	27.60	16 %	32.02
Dem3ds.C97	Clanwilliam-d/s IFR from farm dams	6.72	0 %	6.72
Citds1.dem	Clanwilliam-d/s IFR from river	19.99	0 %	19.99
Total	**Total demand upstream of Clanwilliam Dam**	**87.18**	**10 %**	**95.66**

The demands below Clanwilliam Dam are currently included in the yield model as a specified flow in the canal, while the demands directly from the river are included as a loss file along with the other transmission losses. It is recommended that a specified demand file be included in this reach to include the demands not met from the canal. The recommended average annual demand is equal to 21.59 Mm^3/a., which is based on the estimated irrigated area using the GIS and includes the observed flow in the canal of 11.58 Mm^3/a.

In terms of changes to the yield model configuration it is proposed that a separate node be included to account for the demand from the Elandskloof River, which would be separated from the demand from the Clanwilliam WUA in E10G. It is also proposed that a separate demand node be considered for the demands below Clanwilliam dam to distinguish the demand met from the river from the demands met through the canal and the associated losses.

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ANNEXURE D

Alien vegetation upstream of Bulshoek Barrage

Review of Impact on Streamflow Reduction and Yield of Invasive Alien Plants in the Olifants River Catchment

Report prepared as part of the Yield Analysis task for the Clanwilliam Dam Raising Study

Prepared by James Cullis

NINHAM SHAND
CONSULTING SERVICES
FOUNDED IN 1932

December 2006

"I:\HYDRO\400415 Clanwilliam Dam\R40 Yield analyses\Alien Veg\Report\Review of SFR due to IAPv1_JCDec06.doc"

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1. AIMS AND OBJECTIVES

The general aim of this investigation was to study the potential impact that the removal of invasive alien plants (IAPs) would have on the yield from a raised Clanwilliam Dam. The specific objectives were:

1. Review the available information on invasive alien vegetation in the catchment,
2. Calculate the estimated streamflow reduction (SFR) due to both upland and riparian IAPs using the available information, and
3. Prepare demand files for inclusion in the yield model.

The demand files would then be incorporated in the analysis of various scenarios for the raising of Clanwilliam Dam and the impact on the available yield.

2. REVIEW OF INFORMATION ON INVASIVE ALIEN VEGETATION

This investigation focused on the section of the Olifants River catchment upstream of the Clanwilliam Dam. Three sources of data were considered for obtaining information on the current state of IAPs:

- Original CSIR estimates from the early 1990s (Versfeld *et al*. 1998)
- Research report for the Agricultural Research Council (ARC) on threats to Biodiversity in the Western Cape (Lloyd et al. 1999)
- Latest information obtained from Working for Water (Wannenberg, 2006)

2.1 ORIGINAL CSIR ASSESSMENT

In the early 1990s the *CSIR carried out a study to map the current status of IAPs for the whole country (*Versfeld *et al*. 1998). This data was captured from a variety of sources on 1:250 000 scale maps in terms of polygons of invaded areas, the species type, and the density of invasion in terms of canopy cover. The extent of the invaded areas identified in the Olifants catchment is shown in Figure 1.

The individual invaded polygons for the Olifants catchment were classified in terms of density class, as shown in Table 1, and dominant species. This information was used to determine the equivalent condensed area in each polygon and the biomass type of the dominant species.

Table 1 Density classes for IAPs

Density Class	Canopy Cover (%)	Invasion Density (%)
Rare	<< 0.1	0.1
Occasional	< 5	2.5
Scattered	5 – 25	15
Moderate	25 – 75	50
Dense	> 75	87.5

The invaded polygons were intersected with the shapefile of South African quaternary catchments (QCs) to determine the total condensed area for each biomass type in each quaternary catchment. A second intersection was also done with a riparian strip buffer around all perennial and non-perennial rivers in the 500k database of South African rivers. The width of the riparian strip was assumed to be equal to 20m on either side of a non-perennial river and 50m on either side of a perennial river. For each intersected area the equivalent condensed area of each species class was determined from the density and the total intersected area.

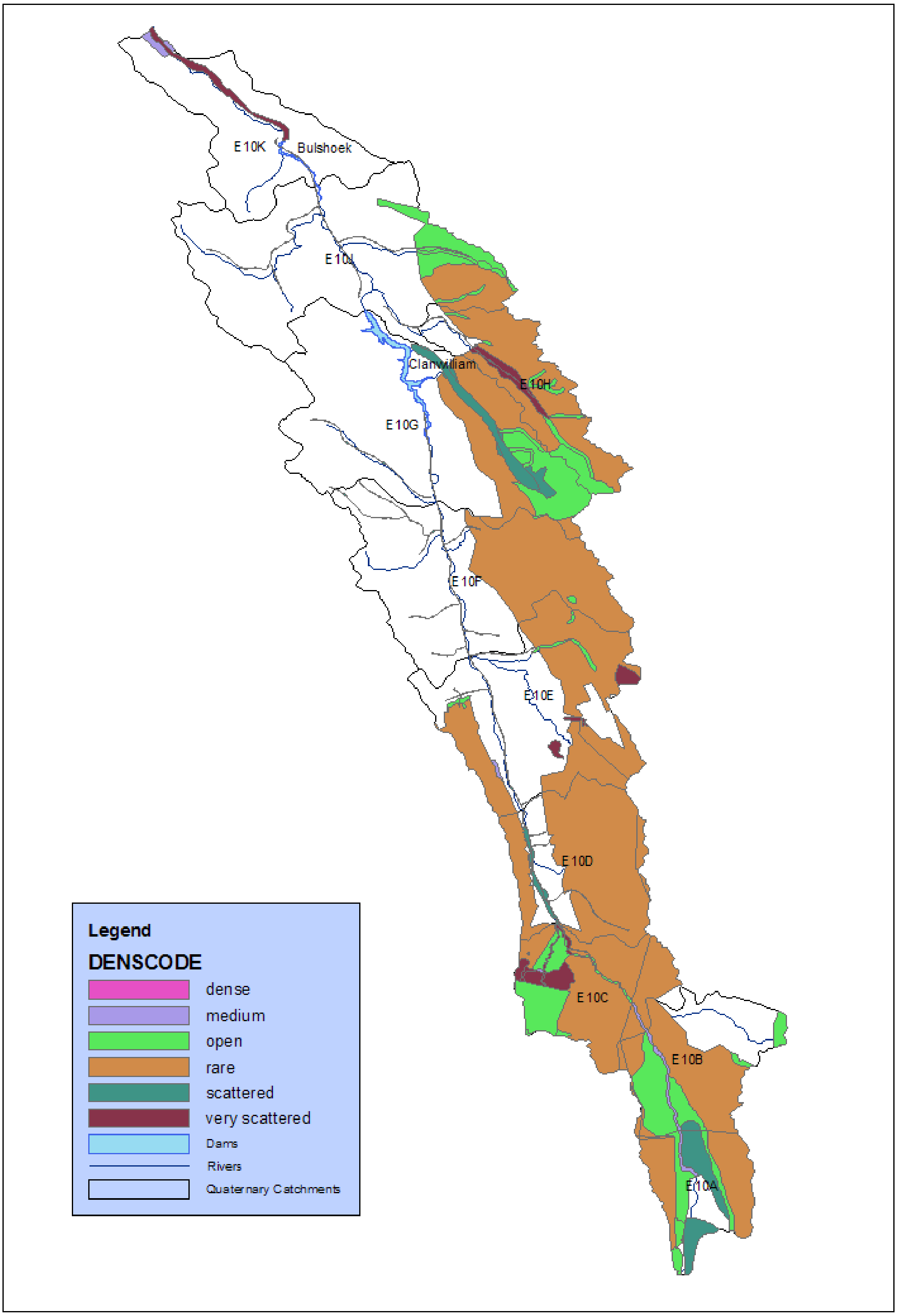

Figure 1 Invaded areas identified in original CSIR study

The estimated equivalent condensed areas by location (upland or riparian) and biomass type for the Olifants catchment upstream of Clanwilliam Dam are given in Table 2.

Table 2 Summary of equivalent condensed areas of IAPs from CSIR data

Quaternary Catchment	Equivalent Condensed Area (ha)						
	Upland			Riparian			Total for all IAPs
Biomass Type	Tall Tree	Medium Tree	Tall Shrub	Tall Tree	Medium Tree	Tall Shrub	
E10A	559	159	1	2	0	0	721
E10B	192	0	0	0	0	0	192
E10C	804	29	2	6	0	0	841
E10D	260	149	67	0	0	0	477
E10E	50	143	12	0	0	0	206
E10F	47	41	4	0	0	0	92
E10G	529	336	2	0	0	0	868
E10H	95	10	30	0	0	0	135
E10J	160	73	0	0	0	0	234
E10K	586	468	12	0	0	0	1066
Total	3283	1407	133	7	0	0	4832

What is noticeable about the above table is the very low level of invasion in the riparian areas. This is, however, not considered to be a true reflection of the reality of the situation. It was noted in the CSIR report, that the mapping of riparian IAPs was particularly difficult given the scale at which information was available (1:500 000). This would also apply to the buffering used to distinguish between upland and riparian areas. The riparian areas that had been identified in the CSIR database for the Olifants River catchment were assigned a scattered (5 – 25%) level of invasion, despite the fact that it is noted in the report that expert knowledge in the Western Cape simply claimed, "all rivers are invaded".

The CSIR data was used to estimate the impact of riparian IAPs in the Water Resources Assessment Study (DWAF, 2002). It was assumed that 10% of the equivalent condensed area was in the riparian zone and the Water Situation Assessment Model was used to determine the impact on streamflow reduction. The average estimated streamflow reduction due to IAPs in the upper Olifants was estimated to be 0.8 Mm^3/a. The impact of the afforested areas was calculated separately with a total estimated reduction in runoff of 1.3 Mm^3/a for the upper Olifants catchment.

2.2 ARC MAPPING OF THREATS TO BIODIVERSITY

The Geoinformatics Division of the Agricultural Research Council– Institute for Soil, Climate and Water (ARC - ISCW) was sub-contracted by the Institute for Plant Conservation (IPC) at the University of Cape Town (UCT) to delineate the spatial extent of threats to biodiversity in the Cape Floral Region at a scale of 1:250 000 using remote sensing and geographic information systems (GIS) (Lloyd *et al*., 1999)

One of the identified threats was that of invasive alien vegetation, which was classified as either low density (< 20% cover), medium density (20% - 75 % cover) and high density cover (>75%). The broad scale (1:250 000) map was produced by the use of unsupervised classification routines on seven LANDSAT Thematic Mapper satellite images that were selected for optimizing the contrast between alien vegetation and indigenous vegetation. The identified areas in the Olifants catchment are shown in Figure 2.

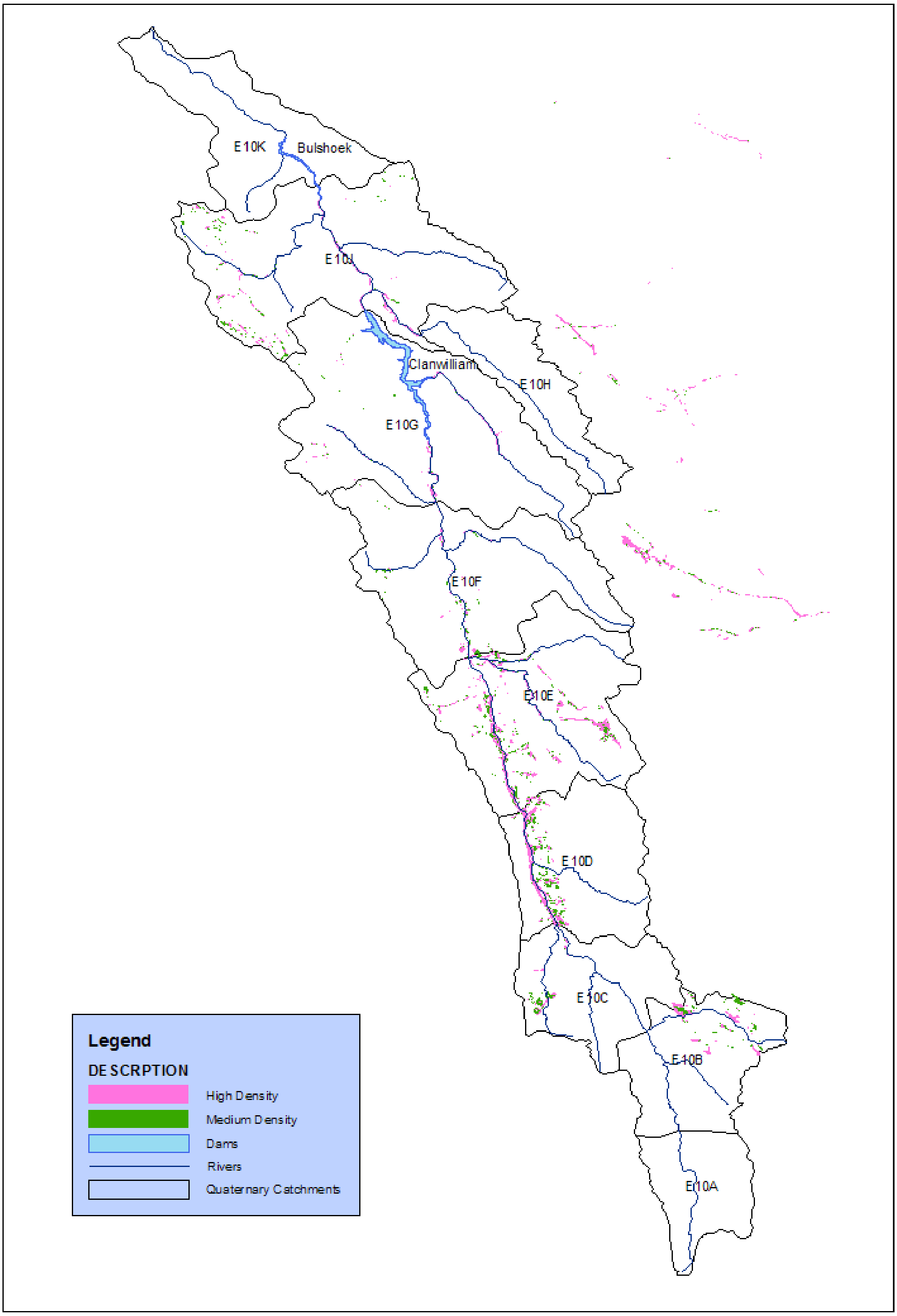

Figure 2 Invaded areas identified by ARC Study

The ARC study made no distinction between upland and riparian vegetation or between species types. It is, however, apparent from the above map that the majority of the identified areas are located close to rivers. The above map was therefore used to roughly classify the identified areas into upland and riparian based on the proximity to the primary rivers in the 500k national river database. A summary of the total invaded areas for each quaternary catchment in terms of upland and riparian areas is given in Table 3.

Table 3 Total invaded areas identified in ARC Study

Total Invaded Areas (ha)					
	Upland		Riparian		
Quaternary Catchment	**Alien Vegetation (High)**	**Alien Vegetation (Medium)**	**Alien Vegetation (High)**	**Alien Vegetation (Medium)**	**Total**
E10A	0	0	0	0	0
E10B	181	122	0	0	303
E10C	41	98	76	77	292
E10D	199	433	22	52	706
E10E	802	497	278	146	1723
E10F	81	63	134	100	378
E10G	48	53	298	31	429
E10H	0	0	0	0	0
E10J	249	283	361	89	982
E10K	0	0	0	0	0
Total	1600	1548	1170	495	4813

The equivalent condensed areas were determined using an average density of 75% for the high-density areas and an average density of 50% for the medium-density areas. There were no areas identified as low-density in this area. The estimated equivalent condensed areas based on these assumptions are given in Table 4.

Table 4 Equivalent condensed areas for ARC Study

Equivalent Condensed Areas (ha)					
	Upland		**Riparian**		
Quaternary Catchment	**Alien Vegetation (High)**	**Alien Vegetation (Medium)**	**Alien Vegetation (High)**	**Alien Vegetation (Medium)**	**Total**
E10A	0	0	0	0	0
E10B	136	61	0	0	197
E10C	31	49	57	39	175
E10D	149	217	17	26	408
E10E	601	249	209	73	1132
E10F	61	31	101	50	243
E10G	36	26	223	15	301
E10H	0	0	0	0	0
E10J	187	141	271	45	644
E10K	0	0	0	0	0
Total	**1200**	**774**	**878**	**248**	**3099**
Average Density	**75%**	**50%**	**75%**	**50%**	**64%**

2.3 AREAS IDENTIFIED BY WORKING FOR WATER

The Working for Water (WfW) programme currently have three active areas in the Olifants catchment:

- Agter Witzenberg
- Citrusdal
- Clanwilliam

While the initial clearing of identified areas has been completed in the Clanwilliam and the Agter Witzenberg areas, WfW is still active in these areas in support of local land owners as part of the maintenance phases regulated via the CARA Act (1983). There is still much work to be done in the Citrusdal area and WfW anticipate that they will be involved for at least the next three years. In addition they are assisting Cape Nature with the clearing of IAPs in the Cederberg area.

The latest information on the areas identified as being invaded was obtained from WfW (Wannenberg, 2006). This information is provided in the form of digitised polygons that were identified using aerial photographs. These polygons do not contain any addition information except for the areas that have subsequently been cleared. This additional information includes the average density, the dominant plant type, and the costs of both the initial clearing as well as any follow up clearing. This information was used to determine the equivalent condensed area for each biomass type (i.e. tall tree, medium tree or tall shrub). The dominant species identified in the area are *Pinus spp*. (Tall Tree), *Eucalyptus spp*. (Tall Tree), *Acacia Mearnsii*. (Tall Tree), *Populus spp*. (Tall Tree), *Accacia Saligna* (Medium Tree), and *Rubus spp*. (Tall Shrub). The first date for the completion of the initial clearing of an area is February 2001 and the latest date is July 2005. The invaded identified areas identified by WfW are shown in Figure 3. A distinction is made in this figure between the cleared and non-cleared areas.

As can be seen from Figure 3, the vast majority of the identified areas appear to be in the riparian zone. This was confirmed by WfW and is consistent with the findings of the ARC study. There are, however, a few identified areas of IAPs that are in the upland area, particularly in the Agter Witzenberg and the Cederberg Areas. These areas were identified in terms of their proximity to the primary rivers in the 500k national river database.

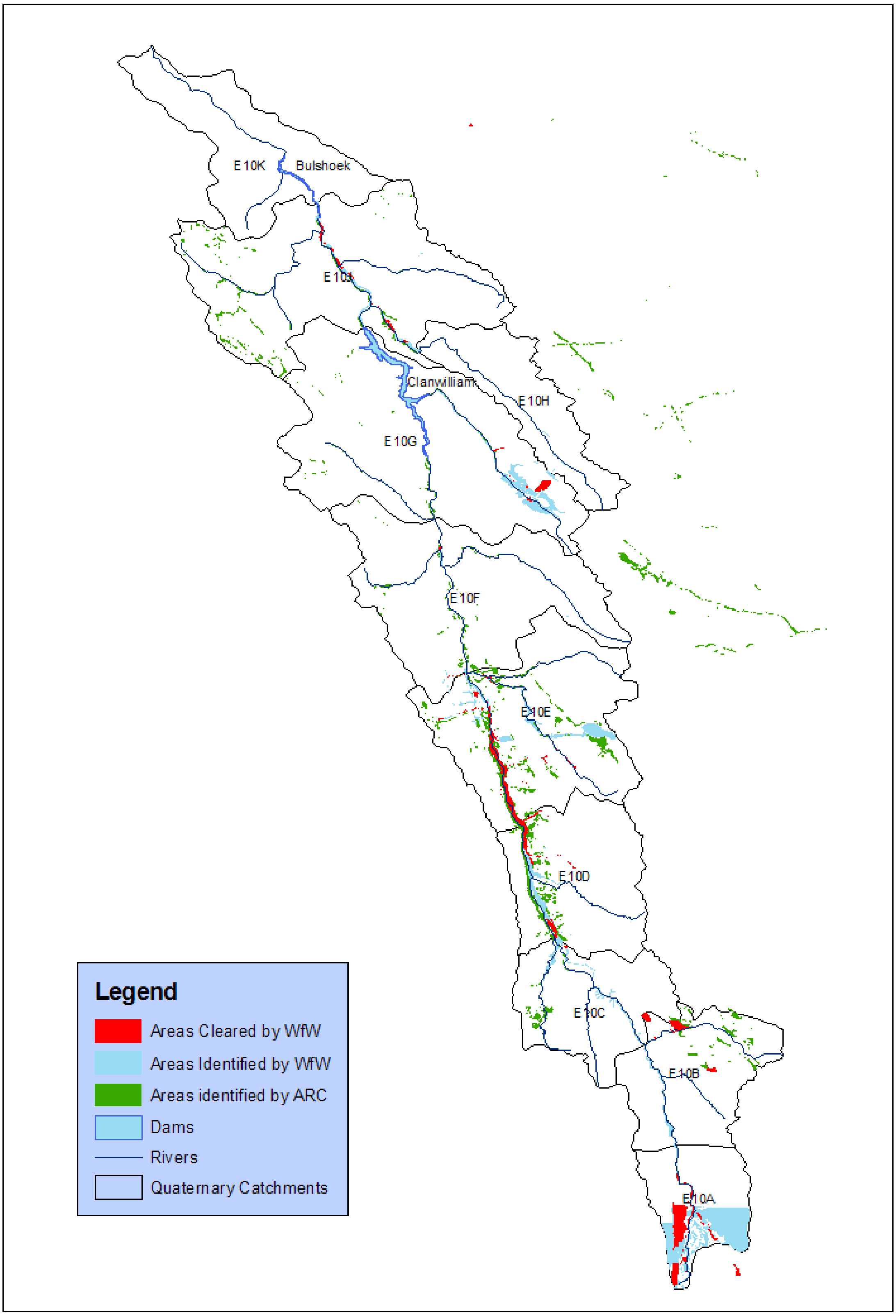

Figure 3 Invaded areas identified and cleared by Working for Water

A summary of the total invaded areas cleared by WfW between Feb 2001 and June 2005 is given in Table 5. Note that not all biomass types were identified in each quaternary catchment.

Table 5 Invaded areas cleared by Working for Water between Feb 2001 and June 2005

Quaternary Catchment	Biomass Type	Invaded Area (ha)			Condensed Area (ha)			Average Density	
		Riparian	Upland	Total	Riparian	Upland	Total	Riparian	Upland
E10A	Tall Trees	162	805	967	104	93	198	64%	12%
	Medium Tree	-	-	0	-	-	0	-	-
	Tall Shrubs	10	0	10	5	0	5	52%	75%
E10B	Tall Trees	50	200	250	31	61	92	63%	31%
	Medium Tree	-	-	0	-	-	0	-	-
	Tall Shrubs	-	-	0	-		0	-	-
E10C	Tall Trees	12	37	49	5	5	10	39%	15%
	Medium Tree	-	-	0	-	-	0	-	-
	Tall Shrubs	-	-	0	-	-	0	-	-
E10D	Tall Trees	176	-	176	110	-	110	62%	-
	Medium Tree	121	-	121	90	-	90	74%	-
	Tall Shrubs	38	-	38	9	-	9	23%	-
E10E	Tall Trees	201	-	201	127	-	127	64%	-
	Medium Tree	641	-	641	400	-	400	62%	-
	Tall Shrubs	0	-	0	0	-	0	-	-
E10F	Tall Trees	-	-	0	-	-	0	-	-
	Medium Tree	14	-	14	5	-	5	39%	-
	Tall Shrubs	6	-	6	3	-	3	40%	-
E10G	Tall Trees	15	169	184	12	42	53	77%	25%
	Medium Tree	-	-	0	-	-	0	-	-
	Tall Shrubs	-	-	0	-	-	0	-	-
E10H	Tall Trees	-	-	0	-	-	0	-	-
	Medium Tree	-	-	0	-	-	0	-	-
	Tall Shrubs	-	-	0	-	-	0	-	-
E10J	Tall Trees	115	-	115	49	-	49	42%	-
	Medium Tree	83	-	83	54	-	54	65%	-
	Tall Shrubs	-	-	0	-	-	0	-	-
Total		1644	1211	2855	1004	202	1206	61%	17%

The information on the cleared areas was used to make an initial estimate of the dominant biomass types and the average density in the uncleared areas. Where information was available the same split between biomass types as seen in the cleared areas of the quaternary catchment was used as well as the average density.

In areas where no information from cleared areas was available the split from a neighbouring quaternary catchment was used. For example the split between riparian tall trees, medium trees and tall shrubs in E10H and E10K was assumed to be the same as for E10J. For the invaded upland areas where there was no information provided from cleared areas it was assumed that the invaded area consisted of tall alien trees only, but at a low density of only 25%. The assumed invaded and condensed areas for the uncleared areas are given in Table 6.

Table 6 Invaded areas identified by WfW, but not yet cleared

Quaternary Catchment	Biomass Type	Invaded Area (ha)			Condensed Area (ha)			Average Density	
		Riparian	Upland	Total	Riparian	Upland	Total	Riparian	Upland
E10A	Tall Trees	144	3066	3210	93	355	448	64%	12%
	Medium Tree	-	-	0	-	-	0	-	-
	Tall Shrubs	9	1	10	4	1	5	52%	75%
E10B	Tall Trees	206		206	130	-	130	63%	-
	Medium Tree	-	-	0	-	-	0	-	-
	Tall Shrubs	-	-	0	-	-	0	-	-
E10C	Tall Trees	470	-	470	181		181	39%	
	Medium Tree	-	-	0	-	-	0	-	-
	Tall Shrubs	-	-	0	-	-	0	-	-
E10D	Tall Trees	257	4	261	160	1	161	62%	25%
	Medium Tree	177	-	177	131	-	131	74%	-
	Tall Shrubs	56	-	56	13	-	13	23%	-
E10E	Tall Trees	232	81	313	148	20	168	64%	25%
	Medium Tree	742	-	742	464	-	464	62%	-
	Tall Shrubs	0	-	0	0	-	0	-	-
E10F	Tall Trees	-	-	0	-	-	0	-	-
	Medium Tree	58	-	58	23	-	23	39%	-
	Tall Shrubs	27	-	27	20	-	20	74%	-
E10G	Tall Trees	152	1058	1210	117	261	378	77%	25%
	Medium Tree	-	-	0	-	-	0	-	-
	Tall Shrubs	-	-	0	-	-	0	-	-
E10H	Tall Trees	4	30	34	2	8	9	42%	25%
	Medium Tree	3	-	3	2	-	2	65%	-
	Tall Shrubs	-	-	0	-	-	0	-	-
E10J	Tall Trees	217	-	217	91	-	91	42%	-
	Medium Tree	157	-	157	102	-	102	65%	-
	Tall Shrubs	-	-	0	-	-	0	-	-
E10K	Tall Trees	2	-	2	1	-	1	42%	-
	Medium Tree	1	-	1	1	-	1	65%	-
	Tall Shrubs	2914	4241	7155	1683	646	2329	58%	15%
Total		2914	4241	7155	1979	661	2640	67%	16%

3. ASSESSING THE IMPACT ON STREAMFLOW AND YIELD

It is almost impossible to compare the data from the above three sources as they represent different time period, different areas and use different methods for identification and classification of IAPs. In order to assess the impact on streamflow reduction of the IAPs in the Olifants catchment, it was decided to make use of the information provided by WfW. The motivation for this is as follows:

- The information supplied for the cleared area is the most accurate as it is obtained directly during the clearing process.
- These areas have already been prioritised by WfW and if they have not already been cleared then they are the most likely areas to be cleared as part of the WfW programme in the immediate future.

- The information supplied for the cleared areas can be used to estimate the cost of clearing and the relative cost in terms of volumes of water made available through reduced streamflow reduction.

It appears that the areas identified by WfW, and shown in Figure 3, cover the majority of the primary riparian areas along the Olifants River and some of the main tributaries upstream of Clanwilliam Dam. The only area that does not appear to have been identified is between Citrusdal and the Clanwilliam Dam. This area, however, does not appear to be heavily invaded as only a few areas of invasion where identified in the ARC study (Lloyd, 1999). It can therefore be assumed that although the areas identified by WfW do not cover all invaded areas, they would appear to account for the majority of areas that would have a significant impact on the streamflow to Clanwilliam Dam

To investigate the potential impact of IAPs on streamflow reduction two separate models for upland and riparian IAPs were used to develop monthly time series of streamflow reduction. The impact of upland IAPs was assessed using the CSIR age-biomass-stream flow reduction model (Scott et al, 1999). The impact of the riparian IAPs was assessed using a new method which has been developed by Ninham Shand, assisted by the University of Stellenbosch and the CSIR, as part of a Water Research Commission (WRC) project entitled "*The development of guidelines for the treatment of scale and resolution in assessing the stream flow reduction impacts of alien plant infestations and commercial afforestation in integrated water resource management*" (Dzvukamanja *et al*. 2006)

The main distinction between the models used for the upland IAPs and the riparian IAPs is the fact that the upland IAPs can only utilise streamflow arising in the catchment in which they are located. The impact is therefore given in terms of a percentage reduction in the natural runoff of the catchment. Riparian IAPs, however, have access to additional streamflow from the river or stream and are therefore not dependent only on streamflow from the catchment in which they are located, unless the river or stream along which they are located runs dry. The streamflow reduction is then considered to be equal to the evapotranspiration (ET) demand that cannot be met directly from rainfall.

3.1 STREAMFLOW REDUCTION DUE TO UPLAND IAPS

The CSIR biomass model for streamflow reduction due to IAPs was originally developed by Scott and Smith (1997). It is based on an observed relationship between above ground biomass and percentage streamflow reduction. The above ground biomass is based on the type of plant and the average age. Biomass equations have been developed for three biomass types; tall trees, such as pine and eucalyptus; medium trees, such as port jackson wattle; and tall shrubs such as *Hakea*. The following biomass equations, obtained from Le Maitre and Görgens (2001), were used in this study:

Tall Tree Biomass (t/ha) $= 300/(1 + e^{3.67947} \times a^{-1.4109})$

Medium Tree Biomass (t/ha) $= 96.0732 \times \log_{10} a - 4.8081$

Tall Shrub Biomass (t/ha) $= 76/(1+e3.18628 \times a^{-1.25973})$

where: a = age in years

Streamflow reduction is based on one of two forms of flow reduction curves, long lag or short lag, with a distinction made between the impact on average flows and on the low flows. For this study only the long lag curve was used as it was used only for determining the impact of upland IAPs and the area is not considered to be an optimal growing area for IAPs. The long lag equations for the impact on annual stream flow reduction and low flow reduction are given below (after Le Maitre and Görgens, 2001):

Annual flow reduction (%) $= 75/(1 + e^{14.2216} \times b^{-2.9194})$

Low flow reduction (%) $= 100/(1+e^{10.0252} \times b^{-2.0927})$

where: b = biomass (t/ha)

The above equations were used to determine the average streamflow reduction due to upland IAPs by applying the annual flow reduction equation to the estimated natural monthly winter streamflow sequence for each quaternary catchment obtained from WR90 and the low flow reduction curve to the summer flows. The total biomass was determined using the equivalent condensed areas for each bio-mass type for both the cleared and the non-cleared areas given in Table 5 and Table 6 respectively. An assumed average age of 7 years was used to represent an average fire cycle of 14 years.

An example of the average biomass, unit streamflow reduction and total streamflow reduction for the cleared non-riparian areas in E10A is given in Table 7.

Table 7 Average biomass and streamflow reduction for cleared areas in E10A

	Tall Tree	Medium Tree	Tall Shrub
Average Age (years)	7	7	7
Biomass (t/ha)	85	76	25
Annual Flow Reduction (%)	17%	13%	1%
Low Flow Reduction (%)	32%	28%	3%
Average Annual SFR (mm)	85	69	4
Condensed Areas (ha)	96	0	0
Total Annual SFR (Mm^3/a)	0.082	0.000	0.000

The monthly distribution of unit streamflow compared to the natural run-off is given in Figure 4.

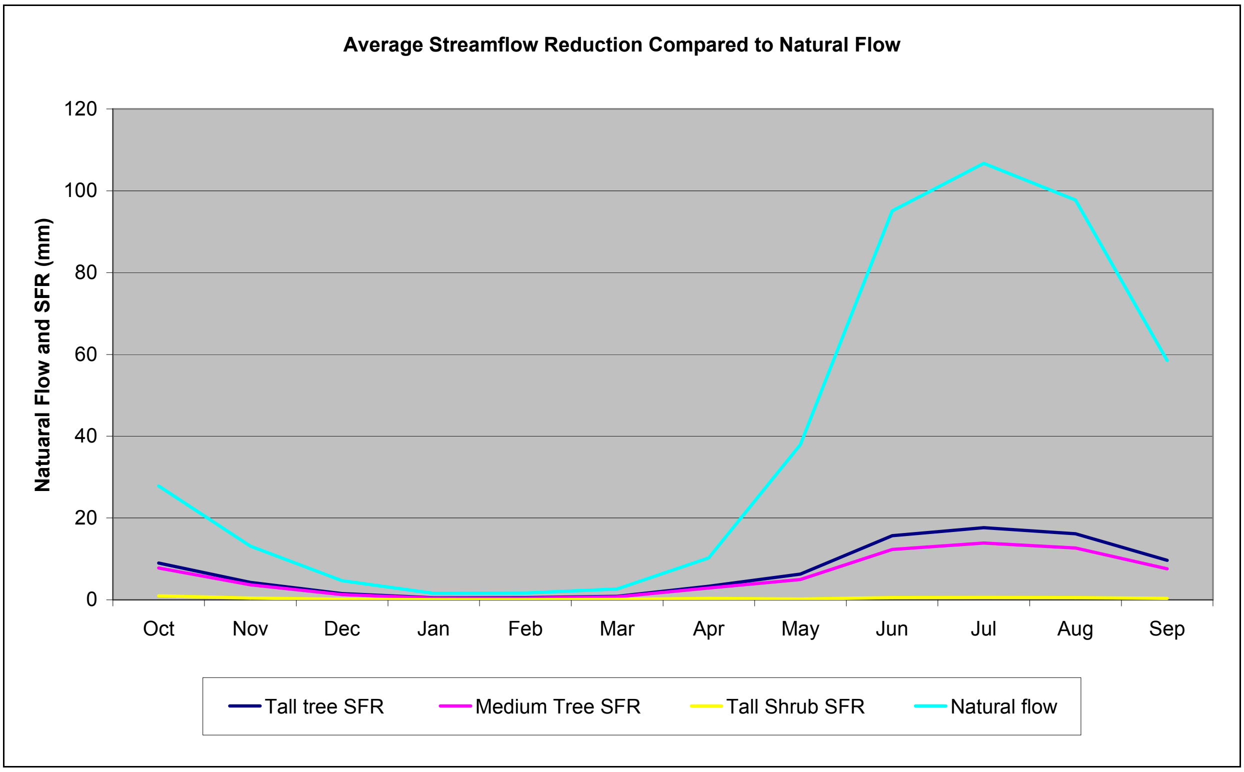

Figure 4 Monthly streamflow reduction and natural runoff for E10A

The average streamflow reduction for all the cleared and not-cleared areas based on the natural streamflow record for each catchment obtained from WR90 for the period 1920 to 1990 is given in Table 8.

Table 8 Streamflow reduction due to upland IAPs (Mm^3)

Quaternary Catchment	Cleared Areas			Non-cleared Areas		
	Summer	Winter	Annual	Summer	Winter	Annual
E10A	0.02	0.06	0.08	0.07	0.24	0.31
E10B	0.01	0.03	0.04	0.00	0.00	0.00
E10C	0.00	0.00	0.00	0.00	0.00	0.00
E10D	0.00	0.00	0.00	0.00	0.00	0.00
E10E	0.00	0.00	0.00	0.00	0.00	0.01
E10F	0.00	0.00	0.00	0.00	0.00	0.00
E10G	0.00	0.01	0.01	0.02	0.05	0.07
Total above Clanwilliam	**0.03**	**0.10**	**0.14**	**0.09**	**0.30**	**0.39**
E10H	0.00	0.00	0.00	0.00	0.00	0.00
E10J	0.00	0.00	0.00	0.00	0.00	0.00
E10K	0.00	0.00	0.00	0.00	0.00	0.00
Total bellow Clanwilliam	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**
Total for E10	**0.03**	**0.10**	**0.14**	**0.09**	**0.30**	**0.39**

From the above table it is clear that the impact of the non-riparian IAPs is very small. This is partly due to the relatively small areas identified, but is also due to the relatively low run-off from these areas. For this reason the impact of the clearing of upland IAPs can be considered to be negligible in terms of the impact on the yield from Clanwiliam Dam, and attention should be focused on the impact of the riparian IAPs.

3.2 STREAMFLOW REDUCTION DUE TO RIPARIAN IAPS

The impact on streamflow reduction by riparian IAPs was assessed using a new model developed by Ninham Shand for the WRC (Dzvukamanja *et al*., 2006). The model is based on the assumption that riparian IAPs have permanent access to water to supplement fully that portion of their evapo-transpiration (ET) demand not met through daily rainfall (i.e. net ET). The basic steps in the model are as follows:

- Determine the equivalent condensed area of IAPs in terms of the biomass types: tall tree, medium tree and tall shrub.
- Obtain information on daily rainfall.
- Determine the daily net ET (in mm) for each of the three biomass types as well as for the natural vegetation using appropriate crop factors and an effective rainfall factor.
- Correct for negative net ET, by making net ET equal to zero on days when effective rainfall is greater than the ET demand.
- Calculate the total monthly net ET and find the minimum monthly net ET for each biomass type.
- Determine the monthly net ET values using monthly rainfall values and the selected crop factors.
- Adjust the monthly net ET values based on the minimum monthly net ET calculated from the daily rainfall data.
- Produce a monthly time series of adjusted net ET, which is equivalent to the monthly streamflow reduction due to the riparian IAPs.

The resultant monthly time series of adjust net ET for riparian IAPs were calculated for each quaternary catchment in the Olifants catchment based on the estimated condensed areas of riparian IAP in the cleared and non-cleared areas given in Table 5 and Table 6 respectively. The daily rainfall data was obtained from a database developed by Lynch (2004) using the Daily Rainfall Extraction Utility developed by Kunz (2004) for rain gauges located in or near to the respective quaternary catchment. The rain gauges used for each quaternary catchment are given in Table 9 along with the average annual observed rainfall, the factored catchment MAP from WR90 and the catchment MAE

Table 9 Raingauges used to determine daily net ET

Quaternary Catchment	Raingauges used to get daily rainfall distribution		Average MAP of Raingauges (mm)	WR90 Catchment MAP (mm)	WR90 Catchment MAE (mm)
E10A	0042281 W		801	899	1806
E10B	0042281 W		801	736	1806
E10C	0041871 W		405	587	1795
E10D	0062768 W		291	518	1795
E10E	0063005 W		465	419	1795
E10F	0063005 W		465	407	1801
E10G	0084558 W		510	407	1806
E10H	0084701 W	0085162 W	425	495	1838
E10J	0084878 W	0084701 W	341	344	1833
E10K	0107510 W		242	284	1849

The daily rainfall was factored up by the ratio of the average MAP for the raingauges to the average catchment MAP from WR90. WR90 was also used to provide the catchment MAE, the average monthly A-pan evaporation, and the sequence of monthly catchment rainfall for the period 1920 to 1990. The crop factors used for the various biomass types as well as the natural vegetation, which is Fynbos or Machea, are given in Table 10. An effective rainfall factor of 60% was used.

Table 10 Crop factors used to calculate net ET for riparian IAPs

Plant Type	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
Tall Tree	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85
Medium Tree	0.76	0.75	0.75	0.75	0.75	0.75	0.74	0.72	0.73	0.74	0.75	0.76
Tall Shrub	0.64	0.58	0.52	0.52	0.52	0.58	0.70	0.70	0.70	0.70	0.70	0.70
Natural Vegetation	0.55	0.50	0.45	0.45	0.45	0.50	0.60	0.60	0.60	0.60	0.60	0.60

An example of the average monthly ET demand from one of the areas of riparian IAPs (E10D) is given in Figure 5. This shows the seasonal fluctuation in the total ET demand, the ET met from rainfall, the net ET, and the net ET demand subject to a minimum ET demand which is met from streamflow. The total annual ET demand in this example for a tall tree is 1526mm and the ET demand met from streamflow, i.e. the annual SFR is 1344 mm or 13 440 m^3/ha. This compares favorably with the results of experiments for clearfelling of riparian pines in Jonkershoek (Scott and Lesch, 1995), which measured an average increase in the first year run-off of 11 505 m^3/ha. The reason for the higher unit streamflow reduction in the Olifants catchment as opposed to the Jonkershoek catchment, is the much higher level of evaporation which leads to an increase in the ET demand, and the lower rainfall which means that a greater proportion of this demand has to be met from streamflow.

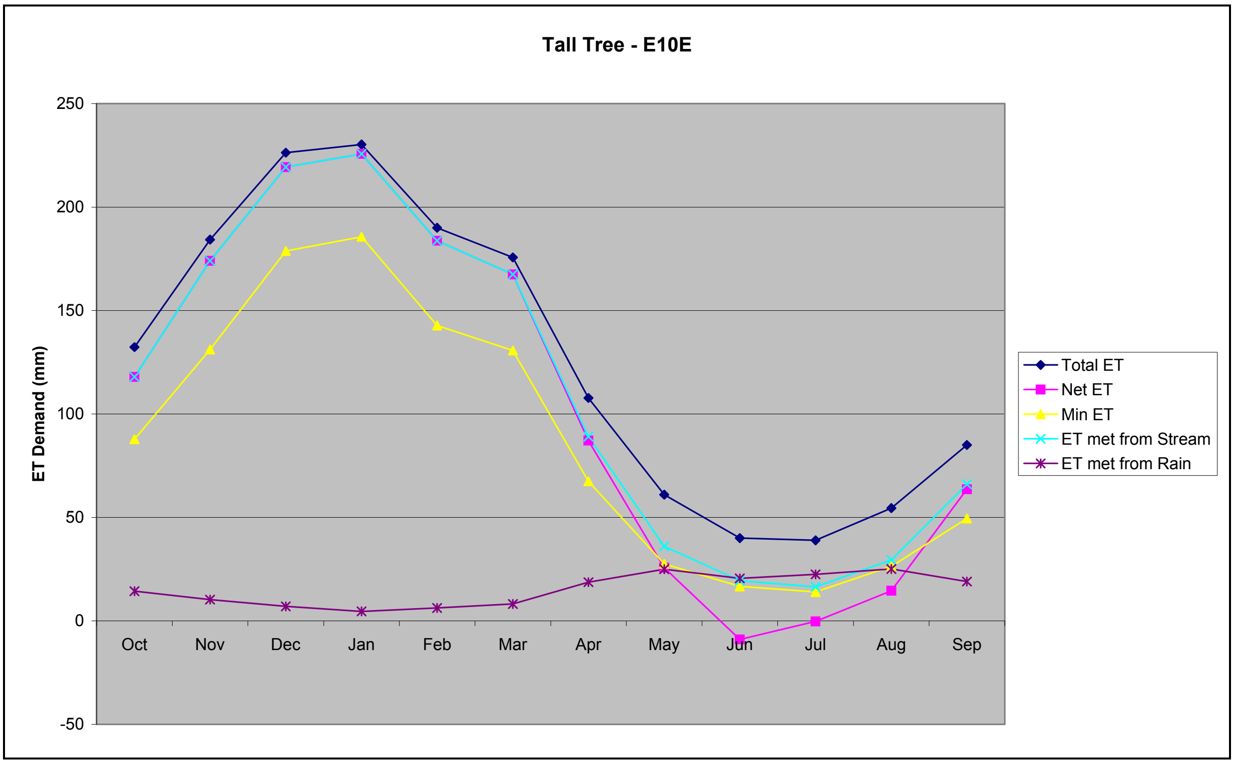

Figure 5 Average monthly ET demand from riparian tall tree IAPs for E10E

The annual incremental streamflow reduction, i.e. in addition to that of natural vegetation, in this catchment (E10E) is equal to 587 mm for tall alien trees, 416 mm for medium alien trees and 140 mm for tall alien shrubs. The average monthly incremental SFR due to IAPs (i.e. in addition to the SFR of the natural vegetation) for E10E is given in Figure 6.

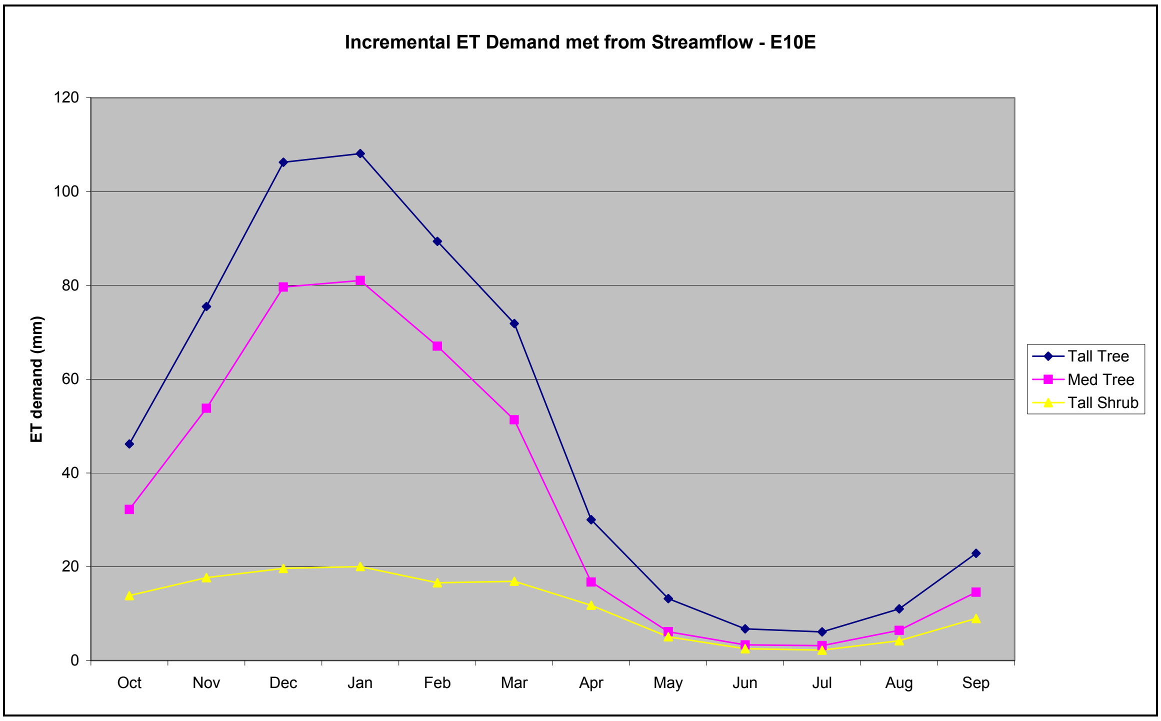

Figure 6 Incremental SFR due to IAPs for E10E

The total average annual streamflow reduction due to cleared and non-cleared riparian IAPs for each quaternary catchment is given in Table 11.

Table 11 Average incremental streamflow reduction due to riparian IAPs (Mm³/a)

Quaternary Catchment	Cleared Areas			Non-cleared Areas		
	Summer	Winter	Annual	Summer	Winter	Annual
E10A	0.50	0.09	0.59	0.45	0.08	0.53
E10B	0.15	0.03	0.18	0.62	0.12	0.74
E10C	0.03	0.01	0.04	1.12	0.24	1.37
E10D	0.85	0.17	1.02	1.24	0.25	1.49
E10E	2.01	0.40	2.41	2.36	0.56	2.92
E10F	0.02	0.01	0.03	0.10	0.03	0.13
E10G	0.06	0.01	0.07	0.57	0.14	0.72
Total above Clanwilliam	**3.62**	**0.72**	**4.33**	**6.46**	**1.42**	**7.88**
E10H	0.00	0.00	0.00	0.02	0.00	0.02
E10J	0.44	0.09	0.53	0.81	0.17	0.99
E10K	0.00	0.00	0.00	0.01	0.00	0.01
Total bellow Clanwilliam	**0.44**	**0.09**	**0.53**	**0.84**	**0.18**	**1.02**
Total for E10	**4.05**	**0.81**	**4.86**	**7.30**	**1.60**	**8.90**

The average annual unit streamflow reduction is given in Table 12.

Table 12 Average annual incremental streamflow reduction due to riparian IAPs

Quaternary Catchment	Cleared Areas			Non- Cleared Areas		
	Condensed Area (ha)	Annual SFR (Mm³/a)	Unit SFR (mm)	Condensed Area (ha)	Annual SFR (Mm³/a)	Unit SFR (mm)
E10A	109	0.59	541	97	0.53	543
E10B	31	0.18	570	130	0.74	570
E10C	5	0.04	755	181	1.37	755
E10D	209	1.02	489	304	1.49	489
E10E	527	2.41	457	612	2.92	477
E10F	8	0.03	326	43	0.13	301
E10G	12	0.07	611	117	0.72	611
Total above Clanwilliam	**901**	**4.33**	**481**	**1484**	**7.88**	**531**
E10H	0	0.00	0	4	0.02	514
E10J	103	0.53	513	193	0.99	512
E10K	0	0.00	0	2	0.01	526
Total below Clanwilliam	**103**	**0.53**	**513**	**199**	**1.02**	**512**
Total for E10	**1004**	**4.86**	**484**	**1683**	**8.90**	**529**

The above estimates of streamflow reduction are significant and are much greater than those predicted in the WRSAS. The main reason for this is the use of the revised model for estimating the streamflow reduction due to riparian IAPs which recognizes that riparian IAPs have constant access to water, which is used to satisfy their full ET demand rather than only having access to certain percentage of the incremental runoff which is the case for upland IAPs.

3.3 ASSESSING THE IMPACT ON YIELD

The impact of IAPs was not considered when calibrating the original hydrology for the yield model for the Olifants catchment (DWAF, 1990). The only mention was of a small amount of forestry in the Witzenberg catchment, but this was deemed to be insignificant. It can therefore be concluded that any impact of IAPs was accounted for in the calibration of the pitman parameters for the model.

The first record of IAPs was the original CSIR data (Versfeld *et al*. 1997). This did not show a high degree of invasion, particularly in the riparian zone although it was qualified by the claim that all rivers in the Western Cape should be considered to be invaded. If it is assumed that the riparian zones were in fact fairly heavily invaded at the time of calibrating the model then the subsequent clearing of these invaded areas represents an additional streamflow equivalent to the estimated streamflow reduction due to the IAPs. Based on this assumption it is possible to assess the potential impact that the clearing of IAPs will have on the potential yield from the raising of Clanwilliam Dam.

4. COST OF CLEARING OF INVASIVE ALIEN PLANTS

The information provided by Working for Water on the cleared areas was used to estimate the initial clearing costs for the removal of both upland and riparian IAPs. These costs are summarised in Table 13 in terms of current (2006) prices per hectare for the equivalent condensed area.

Table 13 Average initial clearing costs for IAPs in the Olifants Catchment

Project Area	Upland/ Riparian	Condensed Area (ha)	Cost (2006) (R)	Average Cost (R/ha)
Agter Witzenberg	Riparian	182.03	R 831,934	R 4,570.32
	Upland	163.23	R 176,864	R 1,083.55
Citrusdal	Riparian	832.69	R 2,820,033	R 3,386.66
	Upland	0	-	-
Clanwilliam	Riparian	174.53	R 678,105	R 3,885.21
	Upland	0	-	-
Cederberg	Riparian	11.73	R 53,223	R 4,537.55
	Upland	44.60	R 228,994	R 5,134.81
Total	Riparian	1200.98	R 4,383,294	R 3,649.75
	Upland	207.82	R 405,858	R 1,952.91
	Total	**1408.81**	**R 4,789,152**	**R 3,399.44**

While there is some variation in the above costs the total average cost of R3 400/ha is close to that given in other studies in the Western Cape. For example, the average cost of clearing in the Breede River Basin (DWAF, 2003) was calculated to be R3 300/ha, escalated to 2006 prices.

In addition to the initial clearing costs there are substantial costs involved with follow up clearing. The data supplied by WfW included costs for up to the fourth follow up. These costs indicated that the cost of follow up remained fairly high at between R1000/ha and R1500/ha in terms of the original condensed area. This is due to the rapid regrowth of the riparian IAPs, particularly the *Acacia spp*. and *Eucalyptus spp*. Over time this should reduce as the level of invasion is reduced to a lower density class.

5. ADDITIONAL BENEFITS OF CLEARING INVASIVE ALIEN PLANTS

In addition to the water resource benefits of clearing of IAPs, there a number of other social, economic and environmental benefits. Some of these additional benefits are briefly summarized in this section.

5.1 CONSERVATION OF PLANT BIODIVERSITY AND ASSOCIATED TOURISM SPIN-OFFS

The Olifants catchment is in the Fynbos biome, which is world renowned for its endemic biodiversity as one of the major floral kingdoms of the world. The invasion by alien plants poses a significant threat to the biodiversity of this region. Although it is difficult to quantify the economic value of fynbos biodiversity, it is considered to be of major significance. Many fynbos plants have been developed as food and drug products. In addition, the cut flower trade contributes significantly to the local and national economy. The Cape flora is considered to be one of the world's most significant areas of endemic plant biodiversity. This along with the rugged scenic beauty of the area is one of the major tourist attractions for the area. Tourism contributes significantly to the local economy in terms of direct and indirect employment and income generation.

5.2 REDUCTION OF FIRE HAZARD

The decrease in above ground biomass reduces fuel loads and fire hazard as a result of clearing. This also has beneficial impacts on catchment stability, erosion and siltation. The economic value of a reduction of fire hazard could be substantial, but is difficult to quantify, as it is related to the additional damage that is caused by a fire in an invaded area, over and above the damage that would have occurred, had the area not been invaded.

5.3 EMPLOYMENT OPPORTUNITIES AND SECONDARY INDUSTRIES

A widely publicized benefit of the clearing of IAPs has been the employment of many previously disadvantaged South Africans through the WfW Programme. Secondary benefits are also derived by industries that utilise the timber that is removed.

5.4 RESTORATION OF LOW FLOWS FOR THE MAINTENANCE OF RIVERINE ECOLOGY

The water that is regained through the clearing of IAPs during low flow periods is particularly valuable as an improvement in low flows is considered one of the most important aspects of the provision of ecological water requirements.

5.5 CLOGGING OF RIVERS

The invasion of riparian areas by alien plants not only leads to a reduction in the flow volume, but also leads to a reduction in the flow rate due to the clogging up of rivers. This results in the trapping of sediment and other debris, which further blocks up the river. Removal of the alien vegetation would restore the natural flow of the river, which has benefits for the riparian ecology as well as the downstream water quality.

In conclusion, it is considered that when compared to the cost of construction of new water supply schemes, the elimination or reduction of water use by IAPs presents by far the most beneficial means of unlocking water resources for the benefit of the environment and future consumptive water needs in the catchment.

6. CONCLUSIONS

Although a number of studies have been conducted into the level of invasive alien plants in the upper Olifants catchment it is difficult to compare the results of these studies to get a comprehensive picture of the true level of invasion and the impact that this would have on the yield from Clanwilliam Dam. For this investigation it was decided to make use of the most recent data supplied by WfW on the areas that have been identified for clearing as well as those areas cleared in the past six years.

This information tended to focus on the riparian areas, which has a much greater impact on streamflow reduction than upland IAPs. Based on this information it was estimated that a total invaded riparian area of 1 644 ha has been cleared. The average density of this area was found to be 61% resulting in an equivalent condensed area of 1 004 ha. The additional streamflow resulting from the clearing of this area was estimated to be approximately 4.86 Mm^3/a. This is significantly higher than previous estimates and is likely to have a significant impact on the available yield from Clanwilliam Dam. The average cost of clearing this invaded area was R3 400/ha in terms of the equivalent condensed area, with the average follow up cost being between R1 000/ha and R1 500/ha.

WfW has identified a further 2 914 ha of invaded riparian area in the upper Olifants catchment. Based on the information obtained from the cleared area this represents an equivalent condensed area of 1 979 ha with an average streamflow reduction of 8.90 Mm^3/a.

If it is assumed that the riparian areas in the upper Olifants were already fairly heavily invaded when the yield model for this catchment was configured then the impact on the potential yield from the raising of the Clanwilliam Dam can be investigated by considering the additional streamflow made available through the clearing of the riparian IAPs. Based on the significant impact on streamflow reduction discussed in this Report, it is likely that the impact of clearing of IAPs from the riparian area will have a significant impact on the available yield.

In addition to the water resources benefits of clearing IAPs, there are a number of other socio-economic benefits that must be considered. These include the protection of plant biodiversity, employment and income generation, reduced clogging of rivers and the restoration low flows for the maintenance of riparian ecology.

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ANNEXURE E

Estimation of volumes of farm dams upstream of the Clanwilliam Dam

DEPARTMENT OF WATER AFFAIRS AND FORESTRY

POLICY ON

FINANCIAL ASSISTANCE TO RESOURCE POOR IRRIGATION FARMERS

IN TERMS OF SECTIONS 61 AND 62 OF THE

NATIONAL WATER ACT, 1998

CONTENTS

1. STRUCTURED SUPPORT

1.1 INTRODUCTION

The National Water Act, 1998 has equity and sustainability as central guiding principles to protect, use, develop, conserve, manage and control water resources. It is thus necessary to address the need to promote social and economic development through the use of water in an equitable way, and to provide different forms of assistance, which will promote these objectives through self-sufficiency and sustainability of the different water management institutions (WMIs).

1.2 BROADER CONTEXT

Looking at the broader context of water management as one of the Department's main tasks, and within that task, focusing on the institutional aspects, we should identify the key intervention areas.

The key interventions needed in order to achieve the objective of sustainable WMIs, are:

- Decentralisation of Water Resources Management;
- Developmental institutions contributing to social and economic development;
- Redressing past imbalances;
- Stakeholder empowerment with regard to historically disadvantaged individuals, and others.
- ensuring necessary powers and functions are devolved to appropriate levels that will enable the WMI to perform effectively
- implementing support structures to assist WMIs in executing their functions
- implementing monitoring and reporting strategy to monitor progress and identify interventions as needed

1.3 PURPOSE

In order to ensure effective, efficient and sustainable WMIs, the following aspects need to be facilitated, while remembering that this process is of prime importance:

- ensuring community participation as a departure point rather than an afterthought
- facilitating stakeholder empowerment through stakeholder involvement in every step of the process
- developing socio-economically viable, practical, manageable and sustainable institutions, schemes and/or projects
- promoting through co-ordinating with the other role-players, the availability of support services, such as
  - capacity building and training in management and institutional skills
  - accessible credit facilities
  - real-time market and product information
  - technical and agricultural support
  - administrative and legal support

- effective monitoring systems in place

As experience has proven, supplying financial assistance in the form of grants on the strict condition that the above-mentioned process is carefully followed, always serves as a very strong motivation to stakeholders and all other role-players to take this process seriously. Especially at this stage when the focus is on the development of new schemes and/or projects, one of the keys to success is the use of funding as a lever to ensure that the process that support sustainable development best, is followed. Therefore this policy should serve both objectives, namely to provide the necessary financial assistance to those who need it most for development and empowerment, as well as to ensure that a process of real stakeholder consultation, capacity building and training is followed, in order to ensure sustainable development towards prosperity.

1.4 DEVELOPMENT MECHANISMS:

Rural development should be promoted through the following mechanisms:

Empowerment, family food security and poverty alleviation

Empowerment through capacity building and training

- to restore the dignity of the poor
- decision taking on solving long term problems
- development and management of institutional structures

Water utilised for family food production

- dietary requirements for family food supply
- optimal utilisation of water for production of vegetables, grain and fruit
- access to rain water harvesting infrastructure and management

Infrastructure revitalisation

- planning of infrastructure
- considering manageability, maintainability and affordability
- construction, operation and maintenance of schemes

National government irrigation scheme infrastructure transfer

- HR management
- infrastructure operation and maintenance
- business Plan development and scheme viability
- agricultural and agribusiness development
- public participation and support services

Institutional, social and economic sustainability

Cooperative governance

- activating structures within provincial and local government to support/ enable successful development projects
- ensuring involvement of traditional leadership
- addressing land tenure/ownership

CMA

- establishment process of CMA
- develop institutional legitimacy
- develop Catchment Management Strategy
- seed-funding
- support and aftercare

WUA

- agri-economic and socio-economic viability analyses
- development of business plans
- establishment process of WUA
- seed-funding
- development of Water Management Plan
- support and aftercare

CMF

- operational support

Civil society partnerships

Partnerships within civil society (with investors, successful commercial farmers, experts, etc.) within WMI context

- Promotion of access to successful commercial enterprises
- Capacity building i.t.o. financing, marketing and management
- Conclusion of empowerment objective.

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2. FINANCIAL ASSISTANCE FOR IRRIGATED AGRICULTURAL DEVELOPMENT BY RESOURCE POOR FARMERS

The majority of poor people in South Africa live in rural areas. A way to help them is through the development of sustainable irrigation schemes, or the revitalisation of existing ones, if the resources are available. That will enable them to take charge of their own situations by firstly allowing them to provide in the basic food requirements of their families, and then moving on to become economically independent and eventually full-scale commercial farmers.

Financial assistance will therefore be supplied in terms of Sections 61 and 62 of the NWA, 1998, which states the following:

" Financial assistance by Minister
61. *(1) The Minister may, subject to a regulation made under section 62, give financial assistance to any person for the purposes of this Act, including assistance for making licence applications, in the form of grants, loans or subsidies, which may be made subject to such conditions as the Minister may determine.*
(2) The financial assistance must be from funds -
(a) appropriated by Parliament; or
(b) which may under this Act or otherwise lawfully be used for the purposes in question.
(3) Before giving any financial assistance, the Minister must take into account all relevant considerations, including -
(a) the need for equity;
(b) the need for transparency;
(c) the need for redressing the results of past racial and gender discrimination;
(d) the purpose of the financial assistance;
(e) the financial position of the recipient; and
(f) the need for water resource protection.
(4) A person who wilfully fails to comply with any obligations imposed by this Act is not eligible for financial assistance under this Act.

Regulations on financial assistance
62. *The Minister may make regulations concerning -*
(a) the eligibility for financial assistance;
(b) the manner in which financial assistance must be applied for; and
(c) terms and conditions applicable to any financial assistance granted. "

2.1 SUMMARY OF PROPOSED PRODUCTS:

1. Grant on the **capital cost** for the construction and/or upgrading of irrigation schemes, to resource poor farmers who are members of WUAs or other approved legal entities, for:
    - consultant services for facilitation, needs assessments, technical planning and design, including the socio-economic feasibility studies;
    - the assessment of long term water availability, existing infrastructure, different options available and development prospects for irrigation schemes,
    - the cost of materials, equipment and construction of new bulk-supply water works or the rehabilitation or upgrading of existing schemes;
    - water conservation and water management measures on irrigation schemes;
    - dealing with the legal and administrative requirements for the development or rehabilitation of irrigation schemes.

2. Grant or subsidy on **operation and maintenance** of waterworks and **WRM and depreciation charges**, phased out over a six year period, to resource poor farmers who access:
   - GWS that are managed by DWAF;
   - GWS that are operated and maintained by WUAs or other approved legal entities;
   - Other WUAs or approved legal entities
3. Grant for the **acquisition of water entitlements** for irrigation;
4. Grant for preliminary or remedial **socio-economic viability studies** and investigations on irrigation schemes;
5. Grant on **training of Management Committees** of WUAs or other approved legal entities on:
   - Efficient water distribution management on irrigation schemes;
   - Water use and conservation programmes, techniques and practices;
   - Financial management, business plan development, budgeting and legal aspects; and
   - Measures on how to ensure scheme sustainability.
6. Grant for **rain-water tanks** for family food production and other productive uses.

2.2 THE FRAMEWORK

This new policy framework endeavours to promote initial access to irrigated agriculture and to enhance sustainable irrigation development for resource poor farmers by making available to them various types of grants or subsidies, in terms of Sections 61 and 62 of the National Water Act, 1998, like:

- Government Water Schemes (GWS); or
- ex-homeland GWS; or
- water user association (WUA) schemes; or
- schemes of other approved legal entities.

Applications for these grants or subsidies should be channeled through the provincial Coordinating Committees on Agricultural Water (CCAWs) and when recommended by that body, the relevant Regional Offices will provide all the necessary information and documentation to Head Office, needed to prepare the grant or subsidy application for submission to the Minister. This role played by the Regional Offices, will eventually be taken over by the relevant CMAs, once they have been established. The Directorate: WR Finance and Pricing will provide Regional Offices with a list of requirements that are needed in order to deal with applications. Comprehensive guidelines in a clear step-by-step format will be supplied to all CCAWs, in order to ensure that every proposed applicant can be advised correctly on the procedures and best practices, and to ensure standardisation of the process that will be followed.

Beneficiaries will qualify for each of these six products once only per specific use. That means that neither would the same user qualify for a second grant or subsidy for the same use, nor would another user qualify for a grant or subsidy for the same use, if somebody else has already been subsidised for the specific use.

Since it is very difficult to prioritise resource poor farmer irrigation schemes that are spread over the country, and because serious efforts are being made to speed up development, the applications will, unless special circumstances require otherwise, be dealt with on a *'first come, first serve'* basis.

If the legal entity, in its present or in a modified/reconstituted form, has in the past been:

i. found guilty of financial misconduct or fraud;
ii. declared bankrupt; or
iii. failed to pay any amounts previously required from it by DWAF,

except for the subsidisation of WRM charge or depreciation charge, DWAF may decide not to consider the approval of a grant or subsidy if there is a good reason according to DWAF's judgement.

Funding for all six products, except the grant or subsidy for O&M, which should be budgeted for by the Regional Offices, will be supplied by the Directorate: WR Finance and Pricing from Program 2 of the Exchequer Account. See **Table 1** on page 12 for more detail. The grant or subsidy on the WRM charge and depreciation tariff will be calculated and reported monthly, but will only be paid over from Program 2 of the Exchequer Account every six months.

The total annual financial implication for DWAF for the six different grants or subsidies proposed here, is expected to be about **R27 million** during the first year or two, which could be serviced from the above-mentioned budget. The possible growth in the need for this financial assistance will be closely monitored, in order to budget adequately in future.

2.3 KEY DEFINITIONS

Resource poor farmers:

Farmers who are citizens of South Africa and who are members of the historically disadvantaged population groups. In a case where the individual resource poor farmers, who are members or shareholders of an approved legal entity (like an approved trust or an approved company), and where this legal entity is a member of a WUA or other approved legal entity that applies for a grant or subsidy, the individual resource poor farmers will be counted separately when the grant or subsidy is calculated.

Gender equity: A condition for qualifying for the full extent of the three grant products, namely the i) capital cost for water distribution infrastructure, ii) socio-economic viability studies and iii) training of management committees, is that the proportion of historically disadvantaged female decision makers/farmers within the legal entity, must be officially represented on the Management Committee (MC) of the relevant WUA or other approved legal entity, otherwise the grant will be reduced.

The full extent of the relevant grants are therefore only applicable when at least the proportion of the scheduled area on a scheme which is under control of historically disadvantaged female decision makers/farmers, is represented on the MC of the WUA or other approved legal entity, as reflected in the legal entity's official list of scheduled areas.

If less than this proportion is represented by historically disadvantaged female decision makers or farmers, the total amount of the grant will be percentage-wise reduced according to the following rule:

$$R = \tfrac{1}{2}(F - C)$$

where: **R (%)** is the percentage reduction in the total grant to the legal entity, with **R** always bigger than or equal to zero (**R** ≥ 0);

F (%) is the percentage of the irrigated area on a scheme which is under the control of historically disadvantaged female decision makers/farmers, as reflected in the legal entity's official list of scheduled areas;

C (%) is the proportion of historically disadvantaged women on the MC of the relevant WUA or other approved legal entity.

This has the implication that no reduction in the total grant is applied when the proportion of historically disadvantaged women on the MC is equal to or more than the percentage of the scheduled area on a scheme which is under the control of historically disadvantaged female decision makers/farmers.

Example:

If on a certain irrigation scheme, 40% of the irrigated area on the scheme is controlled/farmed by historically disadvantaged women, but the MC consisting of six members, only contains one historically disadvantaged women, the total grant will be reduced by ½ (40% - 16,7%) = 11,7%. If there is not even one historically disadvantaged women on the MC, the grant will be reduced by ½ (40% - 0%) = 20,0%.

This should provide the clear message that women's rights and privileges within their communities are promoted and protected by DWAF.

Approved legal entity: A registered legal entity that complies with the following criteria:

- Acceptable financial management, as specified by the Public Finance Management Act (Act 1, 1999 as amended by Act 29 of 1999).
- Provide full information of its individual members and the share every individual person has in terms of liabilities and benefits in the legal entity,
- The constitution of the entity should adequately (to DWAF) specify and/or prescribe
  - the sustainable management, operation and maintenance of its irrigation related systems and assets, and
  - its objectives with regard to efficient water use, water conservation and demand management within its area of operation.
- The actions of the legal entity should adequately (to DWAF) comply with its constitution.

Before any legal entity other than a WUA applies for a grant, that legal entity should apply for approval with DWAF, which application for approval will be considered against the criteria given above. If a legal entity does not comply with these criteria, it will be informed accordingly and an application for a grant will not be considered. DWAF will supply some advice to the legal entity, in order for the legal entity to amend its constitution and actions (if it wishes to) before it applies for approval once more. The approval of a legal entity can be withdrawn if it, to DWAF's discretion, stops complying with any of the above criteria, in which case the legal entity will be notified as such in writing by DWAF.

Scheduled area, or irrigated area: In cases where water entitlements in a specific WUA or approved legal entity is made only on the basis of a volume of water per annum, DWAF can with the assistance of the SAPWAT model, determine the area on which that amount of water could be applied for the specific crop composition, irrigation system and other relevant factors that typically prevail in the area. That area, expressed in hectares, will then be regarded the scheduled area.

2.4 DESCRIPTION OF GRANT OR SUBSIDY PRODUCTS

2.4.1. CAPITAL COST OF WATER DISTRIBUTION INFRASTRUCTURE

The establishment of the infrastructure for an irrigation scheme normally constitutes the biggest single investment needed for the development of such a scheme. Expensive lessons have been learnt from irrigation schemes previously developed in South Africa, which were for several reasons not sustainable.

We have to ensure that the social, institutional and technical aspects are dealt with in a way that we today believe is the more judicious approach. It is thus expected from the developers of an irrigation scheme that a fully participatory and consultative approach is followed.

This grant is available to WUAs and other approved legal entities, for the capital costs related to

- the direct costs in terms of
  - community consultations, the assessment of social, technical and training needs of communities, and/or the facilitation of these services,
  - the assessment of long term water availability, existing infrastructure, different options available and development prospects for irrigation schemes,
  - socio-economic, agri-economic and benefit-cost studies and to determine the financial, social and environmental sustainability (including the environmental impact assessment, if necessary) of the development of irrigation schemes,
  - the technical planning, design and supervision for the construction and/or upgrading and rehabilitation of water distribution infrastructure and other waterworks for irrigation,
  - dealing with the legal and administrative requirements for the development or rehabilitation of irrigation schemes.
- the acquisition of materials and equipment, the construction, installation and commissioning of new water distribution infrastructure for irrigation, as well as the physical upgrading and rehabilitation of such waterworks, and
- efficient water management, water conservation and demand management measures planned and implemented by the WUA or approved legal entity.

2.4.1.1 EXTENT OF GRANT

The maximum extent of the grant payable will be based on the lowest value of:

i. The proportional share (percentage of total annual water allocations) of the beneficiaries in the total grantable capital cost investment in the scheme, or

ii. R15 000 per scheduled hectare belonging to a resource poor farmer, or

iii. R75 000 per scheduled member belonging to a resource poor farmer.

The Minister may under extraordinary circumstances waive this limitation in meritorious cases.

2.4.1.2 FINANCIAL IMPACT

The short term financial impact that the introduction of this grant may have, in order to give access to irrigated farming to an expected 200 farmers at R75 000 per farmer, is **R15,0 million per annum**.

2.4.1.3 CONDITIONS

The payment of a grant is subject to the prior approval of the Minister or her/his delegated nominee. It is further subject to the availability of funds on the DWAF budget, as well as the following conditions:

(a) The grant only applies to WUAs or approved legal entities;

(b) The grant will only be considered for bulk water distribution infrastructure on irrigation schemes that directly supply water to resource poor farmers, or of which the water supply to resource poor farmers form an integral part of any bigger scheme. Bulk water distribution infrastructure means communal infrastructure that distributes irrigation water to the different members of the relevant WUA or approved legal entity. On-farm and in-field infrastructure and equipment, serving only the owner or occupier of the land, does therefore not qualify for this grant. However, water management measures like sluice gates, water meters, etc. installed at off-take points to individual farmers may be regarded as communal infrastructure;

(c) A water allocation or license must be obtained from DWAF before any payments of grants will be considered. The application for a water allocation will be considered taking into account the factors contained in section 27 of the NWA, 1998, with the emphasis on the efficient and beneficial use of water in respect of water-scarce areas;

(d) The application should also include a description of an applicable needs assessment that has been done or will be done as well as the steps that will be taken at the inception of the project to achieve full stakeholder participation and community involvement, and how capacity building and empowerment of the broader community will be promoted through the implementation of the project.

(e) Any socio-economic, agri-economic investigation or benefit-cost study should be performed in accordance with guidelines laid down by the relevant provincial Co-ordinating Committee on Agricultural Water (CCAW) in order to investigate the financial, social and environmental sustainability of the irrigation scheme;

(f) A recommendation by the relevant CCAW, confirming the consent of the involved departments, is needed before a grant in this regard will be considered by DWAF. It should be noted further that a grant would not be considered for costs that are granted by any other government department;

(g) Every application for a grant should be accompanied by a comprehensive training plan for the RPFs who will use the infrastructure. This training plan should be developed in consultation with the role-players on the scheme and the relevant CCAW, and should eventually be recommended by the CCAW before DWAF will consider it for approval. DWAF may require among others the utilisation of applicable SETA accredited training courses, if available. The training should be directed towards the efficient use of the infrastructure by the RPFs. Between a half and one percent (0,5 – 1,0%) per annum every year for the first five years after completion of the project, should be budgeted for this training. The full approved training cost (as represented by certified claims of the actual costs) will be paid by DWAF as a grant to the WUA or approved legal entity, every year after the training has been done satisfactorily. If the upper limit according to 2.4.1.1

(previous page) has been reached, this amount will be paid over and above that upper limit;

(h) The grant must be approved before construction may commence. Any increase in the cost above the approved amount, could be considered a separate grant application;

(i) Payment of the grant to the WUA or approved legal entity will only be made after the new irrigators have been established and constituted as members of the WUA or approved legal entity, or when the process of establishment has reach an irreversible stage;

(j) Signed contracts between the WUA or approved legal entity and resource poor farmers must be in place to protect the rights of the new farmers;

(k) The beneficiaries of the grant should either have the land registered in their names or in the case of communal land, they should have permission to occupy that land;

(l) The grant must be used to directly provide in the proportional capital cost share of the beneficiaries, resulting in differential tariffs to be imposed on them;

(m) The work is done according to approved plans and specifications and to the satisfaction of DWAF;

(n) Reporting procedures including inspection schedules are established to the satisfaction of DWAF

(o) Payment of the grant will be subject to the submission of certified claims of actual expenditure;

(p) To prevent speculation and the sale of granted farming units to established farmers, a grant repayment condition may be imposed in collaboration with other state departments;

(q) The grant should only be paid after confirmation has been received from other role-players responsible for the financing of the scheme, e.g. the Land Bank or Departments of Land Affairs or Agriculture, that the conditions set by them for the financing of the project, have been met;

(r) Before any funds are transferred, a written assurance must be issued by the WUA or approved legal entity, on an official letterhead, to the accounting officer of DWAF or the relevant official in DWAF, to the effect that that WUA or approved legal entity implements effective, efficient and transparent financial management and internal control systems in terms of section 38(1)(j) of the Public Finance Management Act, 1999 (Act No 1 of 1999 as amended by Act 29 of 1999) (PFMA) or if such written assurance is not or cannot be given, the transfer of funds must be subject to conditions and remedial measures requiring the WUA to establish and implement the said measures.

2.4.1.4 EXAMPLES

1. *A new WUA in a former homeland, supplies water to 42 resource poor farmers irrigating 36 ha in 0,86 ha blocks of maize and vegetables each, through a 3,7 km long earth canal. The WUA applies for a grant for a concrete lining for the canal and sluice gates at all the off-take points. The total cost of the work will be R475 200. The following applies:*

Maximum grant payable to the WUA amounts to the lowest value of:

i. 36 ha x R475 200 / 36 ha = R475 200

ii 36 ha x R15 000/ha = R540 000

iii 42 farmers x R75 000/farmer = R3 150 000

which is R475 200.

The amount added to the project cost by the WUA for training of the resource poor farmers for the effective participation to and efficient utilisation of the canals, should be between R2 400 (0,5% of R475 200) and R4 800 (1,0% of R475 200) per annum for five years.

2. *A WUA plans the construction of a weir and canal system that will serve 142 commercial and 100 resource poor farmers with irrigation water. The resource poor farmers will grow sugar cane under irrigation on 6,0 ha blocks each. The following information applies:*

Contract cost of scheme = R92,0 million
Proposed scheduling of emerging farmers = 600 ha
Scheduling of commercial farmers = 5 678 ha

Maximum grant payable to the WUA amounts to the lowest value of:

i. $\frac{600\ ha}{6\ 278\ ha}$ *x R92,0 million = R8,8 million,*

ii. *600 ha x R15 000/ha = R9,0 million, and*

iii. *100 farmers x R75 000/farmer = R7,5 million*

which is R7,5 million.

The amount added to the project cost by the WUA for training of the resource poor farmers for the effective participation to and the efficient utilisation of the scheme, should be between R44 000 (0,5% of R8,8 m) and R88 000 (1,0% of R8,8 m) per annum for five years.

2.4.2 OPERATION & MAINTENANCE (O&M), WRM AND DEPRECIATION CHARGES

The management bodies of WUAs or other approved legal entities with irrigation schemes are expected to mobilise their own resources to meet the O&M cost of their schemes. The expected O&M costs of a scheme should be within the potential long term affordability of a WMI, in order to be viable. However, during the transitional period DWAF will provide assistance to resource poor farmers, to assist them in becoming able to farm independently and cover the O&M costs within six years, in which period the O&M grant or subsidy will be phased out linearly.

As in the past, Regional Offices should budget for the O&M grants or subsidies in their respective regions, deal with the applications, get approval and pay the grants or subsidies directly to the WUAs or other legal entities.

The grant or subsidy also covers the WRM charges for the resource poor farmers in the form of a charge grant or subsidy, phased out similarly over six years. It is important to note that the depreciation charges (where applicable), are waived for the first six years, and are invoiced in full in the seventh year, that is the year after the resource poor farmers started to pay the full WRM and O&M charges.

Table 1: How the grants or subsidies on the different charges should be applied:

Different situations where this policy will be applied to	**WRM charge**	**Depreci-ation charge**	**O&M charge**
Resource Poor Farmers (RPFs) on irrigation schemes where the resource and the distribution system belongs to DWAF, and the distribution system is still managed by DWAF	At time of invoicing, relevant RPF subsidy amount brought into consideration within SAP, which amount is then debited to an appropriate SAP ledger account, and is credited twice a year from Program 2, Exchequer Account (EA).		
RPFs on irrigation schemes where the resource and the distribution system belongs to DWAF, but the management of the distribution system has been transferred to a WUA.	At time of invoicing, relevant RPF grant brought into consideration within SAP, which amount is then debited to an appropriate SAP ledger account, and is credited twice a year from EA.		Region should budget, and pay grant directly to WUA. SAP is not involved.
RPFs on irrigation schemes where the resource belongs to DWAF, but the distribution system is owned by a WUA	Until individual water users have been registered onto WARMS, SAP invoices full charge to relevant WUA. In such cases, the WUA should apply for grant for RPFs, Minister approves it and the relevant grant is paid back to the WUA from EA.		Region should budget, and pay grant directly to WUA. SAP is not involved.
RPFs on irrigation schemes where neither the infrastructure of the resource (if any), nor the distribution system belong to DWAF	Until individual water users have been registered onto WARMS, SAP invoices full charge to relevant WUA. In such cases, the WUA should apply for grant for RPFs, Minister approves and relevant grant is paid back to the WUA from EA.	No depreciation charge imposed by DWAF.	Region should budget, and pay grant directly to WUA or approved legal entity. SAP is not involved.

The grant which will be paid to a WUA or approved legal entity (on the condition that only the resource poor farmers' accounts should be credited), is applicable to the real and proven operation and maintenance (O&M) charges, phased out linearly over a six year period, for resource poor farmers who access:

- GWS that are managed by DWAF
- GWS that are operated and maintained by WUAs or legal entities
- WUAs other than previous GWSs
- Other approved legal entities.

2.4.2.1 EXTENT OF GRANT OR SUBSIDY

The real and proven O&M and WRM charges to the resource poor farmers, will be subsidised as follows:

Table 2: Phased out grants or subsidies on O&M, WRM and depreciation charges:

	Grant or subsidy on O&M and WRM charges	**Grant or subsidy on depreciation charge (if applicable)**
1st year (or part of year)	100%	100%
2nd year	80%	100%
3rd year	60%	100%
4th year	40%	100%
5th year	20%	100%
6th year	0%	100%
7th year onwards	0%	0%

Note: The depreciation charges (where applicable) are in the majority of cases a relatively small amount, and can be phased in in one go, namely in the seventh year, without being overly problematic to the resource poor farmers.

Please note further that the financial year within which the specific water use commences, is taken as the 1st year. This first year may therefore be a full year, it may be part of a year or it may even be only one month. From the second year onwards, the years should coincide with the DWAF financial years.

The Minister may under extraordinary circumstances waive this limitation in meritorious cases.

2.4.2.2 FINANCIAL IMPACT

The expected short term financial impact that the introduction of this grant or subsidy will have, is expected to be about **R1,5 million per annum.**

2.4.2.3 CONDITIONS

The payment of a grant or subsidy is subject to the prior approval of the Minister or her/his delegated nominee. It is further subject to the availability of funds on the DWAF budget, as well as the following conditions:

(a) Proof is supplied of the real operation and maintenance (O&M) costs of the WUA or approved legal entity;
(b) The grant or subsidy is to be used to cover the O&M cost attributable to the resource poor farmers only;
(c) O&M grants or subsidies are paid from the Regional Offices' budgets, and only when funds are available on such budgets;
(d) Before any funds are transferred, a written assurance must be issued by the WUA or approved legal entity, on an official letterhead, to the accounting officer of DWAF or the relevant official in DWAF, to the effect that that WUA or approved legal entity implements effective, efficient and transparent financial management and internal control systems in terms of section 38(1)(j) of the Public Finance Management Act, 1999 (Act No 1 of 1999 as amended by Act 29 of 1999) (PFMA) or if such written assurance is not or cannot be given, the transfer of funds must be subject to conditions and remedial measures requiring the WUA or approved legal entity to establish and implement the said measures.

2.4.3. ACQUISITION OF WATER ENTITLEMENTS FOR IRRIGATION

Section 25(2) of the National Water Act, 1998 makes provision for the transfer of a water entitlement or part thereof to use water from a water resource on any land to someone who is making an application for a license to use water from the same resource in respect of other land. The transfer only becomes effective if the new water use license is granted.

This grant should financially assist resource poor farmers to either buy a water entitlement in the case of new irrigation development, or to provide a grant the monitory value of the water entitlement, together with any bulk water supply infrastructure, which has not previously been subsidised by DWAF, when purchasing land with a water entitlement. This endeavours to allow resource poor farmers access to irrigated farming, not only through new development, but also in existing commercial farming enterprises.

The targeted beneficiaries are resource poor farmers or prospective resource poor farmers, who will access existing or new GWS or will be registered or licensed under ex-homeland GWS, or become members of WUAs or other approved legal entities and who either collectively or privately buy water entitlements or land with water entitlements in terms of the stipulations of the National Water Act, 1998.

A condition attached to this grant, is that if the relevant water entitlement or land with a water entitlement on which a grant has been paid by DWAF, is sold within a period of 10 years, the full amount (or a portion in specific cases) of the grant plus interest, should be repaid.

2.4.3.1 EXTENT OF GRANT

a) For a water entitlement alone:

The maximum extent of the grant for the acquisition of water entitlements alone, together with any accrued debt on this same water entitlements as a result of unpaid charges for water, will be based on the lowest value of:

i. 75% of the purchase price of a water entitlement and the accrued debt on this same water entitlement as a result of unpaid charges for water,
ii. R7 500 per scheduled hectare water entitlement purchased, and
iii. R37 500 per individual member on the water entitlement purchased.

b) For the value of the water entitlement, together with the value of any bulk water supply infrastructure, when developed land is being purchased.

The maximum extent of the grant for the acquisition of land with a water entitlement, together with any accrued debt on this same water entitlement as a result of unpaid charges for water, will be based on the lowest value of:

i. 75% of the monitory value of the water entitlement, as well as the value of any bulk water supply infrastructure (as stipulated under 2.4.3.3 (e)(ii)), when purchasing land with a water entitlement, as well as the accrued debt on this same water entitlement as a result of unpaid charges for water,

ii. R7 500 per scheduled hectare water entitlement, which is attached to the land, and

iii. R37 500 per individual member on the water entitlement purchased.

The Minister may under extraordinary circumstances waive this limitation in meritorious cases.

2.4.3.2 FINANCIAL IMPACT

The expected short term financial impact that the introduction of this grant will have, to provide a grant for the purchase of about 500 ha per annum, is about **R3,75 million per annum**.

2.4.3.3 CONDITIONS

The payment of a grant is subject to the prior approval of the Minister or her/his delegated nominee. It is further subject to the availability of funds on the DWAF budget, as well as the following conditions:

(a) Section 34 of the NWA is applicable and the lawfulness and extent of the existing water use must be verified in terms of section 35 of the NWA;

(b) The socio-economic impact resulting from the surrender of the existing entitlement in respect of workers and tenants must be addressed in terms of section 27 of the NWA;

(c) The conditions stipulated in the Policy for Surrendering of Water Use Entitlements must be adhered to;

(d) Every individual that applies for a grant of this type will be requested, before the grant is considered, to sign an agreement with DWAF to repay the Applicable Portion of the grant plus interest, calculated according to the interest rate as announced from time to time by National Treasury, if the relevant water entitlement or land with a water entitlement is sold within a period of 10 years from the date of approval of the grant. The Applicable Portion of the grant will be determined in the following way:

- If the relevant water entitlement is sold to anybody other than a resource poor farmer, the full grant should be repaid together with the interest, or
- if the relevant water entitlement is sold to another resource poor farmer, the percentage of the grant which is equal to the remaining portion of the original 10 years, should be repaid together with the pro rata portion of the interest. In this case the resource poor farmer that acquires the relevant water entitlement, may only qualify for the same percentage of the grant that is determined to be repaid by the previous owner.

(e) The monitory value of the water entitlement, together with the value of any bulk water supply infrastructure on developed land could be determined in consultation between DWAF, the Department of Land Affairs (DLA), the Department of Agriculture (DoA) and any other relevant department. The service of an independent valuator could be used to break down the value of already developed land into

(i). the value that the land would have had, if it was undeveloped, unimproved and without any water entitlement (for which an application for financial assistance should be directed to DLA),

(ii). value that the water entitlement, together with any bulk water supply infrastructure (the sum of which could be considered for grant under 2.4.3.1 (b) above by DWAF) add to the value of the land,

(iii). the value of all improvements to the land itself, like the addition of infrastructure and other production measures on the farm, as well as soil and water conservation measures (for which an application for financial assistance should be directed to DoA or the relevant provincial Department of Agriculture).

A recommendation by the relevant CCAW regarding this subdivision of the value of developed land, is required before a grant for 2.4.3.3 (e)(ii) will be considered by DWAF;

Discussions between the Departments of Water Affairs and Forestry, Land Affairs, Agriculture, the provincial Departments of Agriculture and other relevant departments is envisaged that may lead to a set of guidelines based on the principles set out in 2.4.3.3 (e).

(f) A definite commitment for adequate extension support for the prospective farmers, should be given by the relevant provincial Department of Agriculture;

(g) An application for a grant should be submitted by the relevant resource poor farmer or prospective resource poor farmer (as set out in the definition above) who's intention it is to become a member of a WUA or approved legal entity. If the applicant will not become the sole proprietor of the water entitlement involved in this application, he/she can apply for his/her specific share in the water entitlement, which share will be taken into account by DWAF in considering the application;

(h) A letter from the relevant WUA or approved legal entity confirming that the applicant will qualify for membership after the acquisition of the water entitlement or land with the water entitlement, should be submitted with the application;

(i) The grant must be used as direct payment towards the acquisition of a water entitlement or farm with an existing water entitlement, depending on the case at hand, or the redemption of debt accrued upon the water entitlement by a previous entitlement holder as a result of unpaid charges for water;

(j) Payment of the grant will be subject to the submission of certified claims of actual expenditure, and

(k) Before any funds are transferred, a written assurance must be issued by the WUA or approved legal entity, on an official letterhead, to the accounting officer of DWAF or the relevant official in DWAF, to the effect that that WUA or approved legal entity implements effective, efficient and transparent financial management and internal control systems in terms of section 38(1)(j) of the Public Finance Management Act, 1999 (Act No 1 of 1999 as amended by Act 29 of 1999) (PFMA) or if such written assurance is not or cannot be given, the transfer of funds must be subject to conditions and remedial measures requiring the WUA or approved legal entity to establish and implement the said measures.

2.4.3.4 EXAMPLE

A resource poor farmer wants to buy an existing fruit farm of 15 ha with a 7,5 ha water entitlement. The price of the farm, which has 7,5 ha sub-tropical fruit under micro irrigation as *well as the necessary on-farm infrastructure, is R471 000. The water is supplied through a canal system from a weir belonging to a WUA.*

An independent valuator was approach and he/she determined the following values in accordance with the principles laid down above:

i. *The value the land would have had, if it was undeveloped:*
R4 700/ha for the 15 ha farm.

ii. *The value of the water entitlement and the bulk water supply infrastructure:*
R7 800/ha for the 7,5 ha water entitlement.

iii. *The value of all agriculture-related improvements on the farm:*
R22 800/ha for the 15 ha farm.

The grant from DWAF for which the proposed farmer may qualify, is the lowest value of

- *75% of R7 800/ha x 7,5 ha = R43 875,*
- *R7 500/ha x 7,5 ha = R56 250, and*
- *R37 500,*

which is R37 500.

Together with an application for a grant from DWAF on the value of the water entitlement and the bulk water supply infrastructure (of which the value of the water entitlement is R7 800/ha in this case), the farmer could also approach DLA for a grant to the value of the land (which is R4 700/ha in this case), as well as DoA for a grant to the value of the agriculture-related improvements on the farm (which is R22 800/ha in this case).

2.4.4. SOCIO-ECONOMIC VIABILITY STUDIES AND INVESTIGATIONS

In the proposed development of irrigation schemes, it is sometimes needed and often advantageous to execute a preliminary socio-economic viability investigation, before serious consideration is given to either the development of a new irrigation scheme, or the upgrading or revitalisation of an existing scheme. There is thus the need for such preliminary investigations, which could assist in the normal scheme development process if the scheme is found viable. It is also important to determine the possible viability of an irrigation scheme, before the establishment of a WUA or approved legal entity. In cases where existing resource poor farmer schemes do not perform satisfactorily, and such investigations were never done or are out-dated, this could be done as part of a remedial exercise to enhance the economic prospects of such schemes.

For this purpose it is normally necessary to either undertake a water availability analysis and/or a socio-economic viability investigation, or else an appropriate diagnostic analysis to pinpoint major constraints and problems. Such analyses should form the basis for the planning of a new irrigation scheme or of the refurbishment of an existing one, including the changes in the layout and design of the distribution infrastructure, and also in the management and participation of farmers in the scheme. The overall objective of these investigations is to give direction to, to support and to accompany decisions and actions undertaken by DWAF and/or other departments, NGOs, development operators or existing scheme management, whichever is applicable, some or all of which can be stipulated by DWAF as conditions for the approval of a grant for any further work.

Investigations to determine the socio-economic viability of existing or new irrigation schemes will require the services of consultants with applicable and relevant capacity, knowledge and experience of the potential and constraints for resource poor farmer irrigation schemes.

The direct cost of these investigations may be partly granted by DWAF. In cases where a WUA or approved legal entity does not yet exist, DWAF will consider the likelihood of a positive outcome of such investigations, in which case the appointment of consultants will be considered by DWAF, according to the normal procedure for this purpose.

2.4.4.1 EXTENT OF GRANT

The maximum extent of the grant payable to the WUAs and other approved legal entities, will be based on the lowest value of:

- The proportional share (percentage of total annual water allocations) of the beneficiaries in the total cost of the study, or
- R500 per scheduled hectare of the beneficiaries, or
- R2 500 per scheduled member of the beneficiaries. In the case of a new scheme where beneficiaries have not been identified yet, this condition can be ignored.

The Minister may under extraordinary circumstances waive this limitation in meritorious cases.

2.4.4.2 FINANCIAL IMPACT

The expected short term financial impact that the introduction of this grant will have, to provide a grant for the assessment of about 2 000 ha per annum, is about **R1,0 million per annum**.

2.4.4.3 CONDITIONS

The payment of a grant is subject to the prior approval of the Minister or her/his delegated nominee. It is further subject to the availability of funds on the DWAF budget, as well as the following conditions:

(a) The grant only applies to WUAs or approved legal entities;

(b) The socio-economic and/or agri-economic investigation should be performed in accordance with guidelines laid down by the relevant provincial Co-ordinating Committee on Agricultural Water (CCAW) in order to investigate the financial, social and environmental sustainability of an irrigation scheme;

(c) A recommendation by the relevant CCAW for the appointment of the consultant or consultants is needed before a grant in this regard will be considered by DWAF. It should be noted further that a grant would not be considered for costs that are granted by any other government department.

(d) The application should also include a description of an applicable needs assessment that has been done or will be done as well as the steps that will be taken at the inception of the project to achieve full stakeholder participation and community involvement, and how capacity building and empowerment of the broader community will be promoted through the implementation of the project.

(e) The grant must directly pay the applicable proportional cost share of the beneficiaries, resulting in differential tariffs to be imposed on them;

(f) Payment of the grant will be subject to the submission of certified claims of actual expenditure; and

(g) Before any funds are transferred, a written assurance must be issued by the WUAs or legal entities, on an official letterhead, to the accounting officer of DWAF or the relevant official in DWAF, to the effect that that WUA or approved legal entity, implements effective, efficient and transparent financial management and internal control systems in terms of section 38(1)(j) of the Public Finance Management Act, 1999 (Act No 1 of 1999 as amended by Act 29 of 1999) (PFMA) or if such written assurance is not or cannot be given, the transfer of funds must be subject to conditions and remedial measures requiring the WUA or approved legal entity, to establish and implement the said measures.

2.4.4.4 EXAMPLE

A WUA has constructed a new dam 8 years ago and due to a number of factors, the WUA developed some difficulties in repaying its loan. The WUA plans to appoint consultants to analyse the situation and to recommend the most viable options available to them to ensure financial sustainability. The 128 resource poor farmers on the scheme occupy 576 ha water entitlements against the 354 ha of the commercial farmers.

The study by the consultants will cost the WUA R294 200 and they apply for a grant from DWAF.

If a grant is approved, it should be the lowest value of:

- $\frac{576\ ha}{930\ ha}$ *x R294 200 = R182 215*
- *R500/ha x 576 ha = R288 000*
- *R2 500/farmer x 128 farmers = R320 000*

which is R182 215.

In this particular case, this amount is the exact amount that the resource poor farmers needs to pay towards the viability study.

2.4.5. TRAINING OF MANAGEMENT COMMITTEES

This grant is provided for the training to resource poor farmers who are members of Management Committees (or key personnel appointed by them), of WUAs or approved legal entities, on:

- The obligations, responsibilities and value of water management;
- Effective scheme water distribution management;
- On-farm water use and conservation principles, techniques and practices;
- Financial management, business plan development and budgeting; and
- Sustainability of irrigation schemes.

Some of these training topics may overlap with the training done by other directorates, and in such cases proper alignment with those directorates should be ensured.

2.4.5.1 EXTENT OF GRANT

The maximum extent of the grant payable to the WUA or approved legal entity will be the lowest value of

- R1 800/Management Committee or Board Member per annum, or
- 90% of the course fees per annum

for a total of five years. The five years need not be consecutive and can be extended over a longer period.

The Minister may under extraordinary circumstances waive this limitation in meritorious cases.

2.4.5.2 FINANCIAL IMPACT

The expected short term financial impact that the introduction of this grant will have, to provide a grant for the training of an expected 200 members of Management Committees, is about **R0,4 million per annum**.

2.4.5.3 CONDITIONS

The payment of a grant is subject to the prior approval of the Minister or her/his delegated nominee. It is further subject to the availability of funds on the DWAF budget, as well as the following conditions:

(a) The contents of the course(s) that will be given, are subject to the recommendation of the CCAW and the approval of DWAF, and should be based on a proper training needs assessment in the WUA or approved legal entity.

(b) The application should also include a description of an applicable needs assessment that has been done or will be done as well as the steps that will be taken at the inception of the project to achieve full stakeholder participation and community involvement, and how capacity building and empowerment of the broader community will be promoted through the implementation of the project.

(c) The payment of the grant is subject to the availability of funds on the DWAF budget;

(d) Payment of the grant will be subject to the submission of certified claims of actual expenditure, and

Before any funds are transferred, a written assurance must be issued by the WUA or approved legal entity, on an official letterhead, to the accounting officer of DWAF or the relevant official in DWAF, to the effect that that WUA or approved legal entity, implements effective, efficient and transparent financial management and internal control systems in terms of section 38(1)(j) of the Public Finance Management Act, 1999 (Act No 1 of 1999 as amended by Act 29 of 1999) (PFMA) or if such written assurance is not or cannot be given, the transfer of funds must be subject to conditions and remedial measures requiring the WUA or approved legal entity, to establish and implement the said measures.

2.4.6. RAIN-WATER TANKS FOR HOUSEHOLD PRODUCTIVE USESBY THE POOR

This grant will be paid to WUAs or other approved legal entities for the capital cost towards the construction of storage tanks for rain-water and related rain-water harvesting works for poor households in rural areas and villages, for family food production and other household economic activities. The purpose of the grant is to contribute to South Africa's achievement of the UN Millenium Development Goals (MDGs), and specifically to reduce by half the number of food insecure households. This consideration should guide the selection of beneficiary families. It has been found in work done so far in this regard, that where the underground rain-water tanks are dug by the family, ownership, dignity and pride are promoted within the family. Even in cases of HIV households, the holes could be dug by healthy friends and relatives, which contributes to restoring dignity and mutual care within the community. The water should be used primarily for productive uses by the family, such as food gardens and other household economic activities.

The tanks, which could be underground or above ground level, should be water-proof and well constructed of acceptably durable materials. If underground, the tanks should have sturdy roofs. The tanks should be built according to plans approved by DWAF. Standardised plans, specifications and construction methods would be supplied by DWAF, when available.

Since the rain-water tanks will normally be within the yard, a strict condition is that the accidental or deliberate entrance of children and unauthorised persons into the tank should not be possible at all. The entrance needed for purposes of cleaning and maintenance of the tank, should therefore be lockable and tamper-proof and kept locked at all relevant times. The seriousness of any form of neglect in this regard should be explained to the families, but DWAF can not take responsibility for the consequences of incidents, including damage to property, injury or loss of live.

2.4.6.1 EXTENT OF GRANT

A maximum of R5 000 to establish a tank and related rain-water harvesting works, as well as an appropriate manual pump. Only one tank and pump per household will be supported.

The Minister may under extraordinary circumstances waive this limitation in meritorious cases.

2.4.6.2 FINANCIAL IMPACT

An expected 1 000 rain-water tanks would be built per annum when this grant is implemented, with a short term financial impact of approximately **R5,0 million per annum**.

2.4.6.3 CONDITIONS

The payment of a grant is subject to the prior approval of the Minister or her/his delegated nominee. It is further subject to the availability of funds on the DWAF budget, as well as the following conditions:

(a) The requirements of the 'National Guidelines on Integrated Management of Agricultural Water Use' are applicable;

(b) The entity that will be responsible for the management of the project or a portion of the project should be an approved legal entity, and must further be specifically approved by DWAF for this purpose, for which some additional requirements may be set. Apart from these additional requirements, the approval of such a legal entity can be withdrawn by DWAF at any stage, if the legal entity does not comply with the conditions set out in this policy.

(c) This grant is not available for any costs that are, or were granted by any other government department, institution or person.

(d) There should be evidence of a process of targeting to ensure that this grant would contribute to the achievement of the MDGs.

(e) The application should also include a description of an applicable needs assessment that has been done or will be done as well as the steps that will be taken at the inception of the project to achieve full stakeholder participation and community involvement, and how capacity building and empowerment of the broader community will be promoted through the implementation of the project.

(f) There should be sufficient evidence that beneficiary households have developed clear plans on how to utilise the water for productive use. In most instances this would require a process of facilitation. The tank size should be adequate to achieve the intended activity.

(g) Generally, the grant is not available for the digging of the holes of underground tanks, or for the preparation of the terrain for tanks above ground level, except where physical soil conditions require expert intervention.

(h) The tanks should be built according to plans (with at least basic details and specifications), approved by DWAF. Standardised plans, specifications and construction methods would be supplied by DWAF, when available;

(i) Responsibility for the safety of people and especially children should rest on the owner or occupier of the home at which the tank is erected. DWAF does therefore not take any responsibility whatsoever for loss, injury or death as a result of the design, construction and usage of the structures erected through this grant;

(j) A recommendation by the relevant CCAW, confirming the consent of the involved departments, is needed before a grant in this regard will be considered by DWAF.

(k) The legal entity approved by DWAF for managing the project, must oversee the construction and erection of the tanks and related rain-water harvesting works;

(l) In order to claim payment, the legal entity responsible for the management of the project must supply reports to DWAF of every structure, containing the following, and which are verifiable during an inspection:

   i. Name and ID number of the head of the household, and the address of the house;

   ii. A basic 'As built' plan;

   iii. Certified claims of actual expenditure on materials, labour, transport and other relevant expenses.

(m) The work is done to the satisfaction of DWAF;

(n) A written assurance must be issued by the legal entity, on an official letterhead, to the accounting officer of DWAF or the relevant official in DWAF, to the effect that that legal entity implements effective, efficient and transparent financial management and internal control systems in terms of section 38(1)(j) of the Public Finance Management Act, 1999 (Act No 1 of 1999 as amended by Act 29 of 1999) (PFMA) or if such written assurance is not or cannot be given, the transfer of funds must be subject to conditions and remedial measures requiring the legal entity to establish and implement the said measures.

(o) Payment is only made by DWAF to the legal entity approved by DWAF, if:

   i. DWAF is satisfied that all conditions are met;

   ii. funds are available on DWAF's budget;

ANNEXURE F

Operational meeting

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ANNEXURE G

System diagrams

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ANNEXURE H

Environmental flow requirements downstream between Bulshoek Barrage and the confluence with the Doring River

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ANNEXURE I

Ecological consequences of different runoff scenarios on the Olifants Estuary

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ANNEXURE J

Current usage and capacity constraints along the Bulshoek Canal

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ANNEXURE K

Sedimentation in the Clanwilliam Dam

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ANNEXURE L

Estimating the impacts on salinity of releasing water down the Olifants River for abstraction further downstream

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ANNEXURE M

White Papers

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ANNEXURE N

Evaluating the proposed releases from Clanwilliam Dam for compliance with the recommended reserve scenario

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ANNEXURE O

Evaluating the proposed releases from Clanwilliam Dam for compliance with the recommended Reserve scenario

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