A contribution to the Challenge Program Project 17
"Integrated Water Resource Management for Improved Rural Livelihoods: Managing risk, mitigating drought and improving water productivity in the water scarce Limpopo Basin"

Baseline Report Olifants River Basin in South Africa

International Water Management Institute (IWMI)
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1. Introduction

This document presents the salient features of the Olifants river basin, which makes up most of the South African portion of the Limpopo river basin. It is meant as a 'baseline' contribution to the CPWF PN17 project "Integrated water resource management for improved rural livelihoods: Managing risk, mitigating drought and improving water productivity in the water-scarce Limpopo basin". The report covers aspects related to climate, land-use and land-cover, and demographics. A bibliography of relevant reference material is also presented.

The information presented here is derived from a variety of sources. The Department of Water Affairs and Forestry (DWAF), the agency responsible for water management in South Africa, has established an extensive data collection network throughout the country; systems for data storage and retrieval as well as sophisticated software have also been developed. In addition, the International Water Management Institute (IWMI), as part of its own research in the basin as well as its global benchmark basin study (Molle, 2002), collected comprehensive data sets, comprising both biophysical and socio-economic information, from DWAF and a range of other sources.

The atlas of agro-hydrology and climatology that has been developed for South Africa and the kingdoms of Lesotho and Swaziland (Schulze *et al*., 1997) was another key source of information. This atlas comprises thematic agro-hydrological and agro-climatic maps developed from specialized methods of spatial analysis. The basis for the climatic parameter mapping is a 1 minute of a degree latitude by longitude grid (raster) covering the region. Made up of 437,000 grid points, this 1 minute x 1 minute digital database serves as a basis for mapping physiographic and climatic (e.g., rainfall and potential evaporation) attributes. For climate variables, statistical goodness of fit was determined between observed and estimated values at points of measurement in order to obtain the level of confidence to which equations could be use to interpolate and extrapolate at grid points where no observations had been made. Once acceptable equations had been developed these were used to extrapolate to grid points where no observations had been made (Schulze *et al.*, 1997). An electronic version of the atlas provides coverages for use in the ArcView GIS package (http://www.esri.com/). These coverages were interrogated to provide data specific to the Olifants catchment.

Data have also been obtained from two important water resource studies that have been conducted for the whole of South Africa. The first was the 5-year comprehensive national water resource assessment WR90 study undertaken "to provide a basis for preliminary planning of water resources development" and to make available "valuable data and information for water resources planning and development" (Midgley *et al*., 1994). The second is the project to develop a Water Situation Assessment Model (WSAM) for rapid evaluation of the status of water resources anywhere in South Africa (Schultz and Watson, 2002). The latter has built on the work undertaken in the WR90 study. Data specific to the Olifants catchment have been obtained from databases developed for both studies and provided to IWMI by DWAF.

In addition, partly as a consequence of its important role in the economy of South Africa, numerous water resources studies have been undertaken in the Olifants catchment. These reports have provided additional information. Of particular value is the Olifants River Basin Study, which collected and evaluated a lot of information necessary for addressing problems associated with human water utilization. The project comprised a comprehensive evaluation of the development potential and management of the water resources in the catchment and culminated in a main report, eight volumes of situation assessments and 28 supporting technical annexes (DWAF, 1991).

With the exception of the DWAF dam safety register, all the data used in this report are in the public domain.

2. Catchment Description

The Olifants River is one of the main tributaries of the Limpopo River. Its catchment area accommodates approximately 3,400,000 people, approximately 7% of South Africa's total population (DWAF, 2002). The population is predominantly rural with 67% of the population classified as living in rural areas (Chimpelo *et al.*, 2003). However, the distribution of wealth is highly skewed between the urban and rural areas and large differences prevail in the standard of living. Similar to the national demographic trends, and mainly attributable to HIV/AIDS and increasing urbanization, little if any increase is expected in the rural population after 2005 (Chimpelo *et al.*, 2003).

In addition to a considerable proportion of South Africa's mining (notably coal, copper, chrome, iron, vanadium and platinum), power production and agricultural activities (including intensive irrigation schemes), the Olifants river catchment also encompasses important tourist destinations (e.g., the Kruger National Park). Furthermore, the river is one of the principal rivers flowing through, and maintaining the ecology of, the Kruger National Park, which receives more than one million visitors a year. It is estimated that activities within the catchment generate about 6% of the GDP of South Africa. Consequently, the Olifants is one of South Africa's most significant waterways, in terms of its importance to the national economy.

In keeping with the National Water Act (1998) and the National Water Resources Strategy (NWRS), it is planned to establish a Catchment Management Agency (CMA) to manage the water resources of the Olifants river basin, which is a major sub-catchment of the Limpopo River Basin and lies within the Northern Region strategic planning area of DWAF (DWAF, 2002). The CMA will be responsible for managing water resources to the point where the Olifants River flows into Mozambique. At present, international cooperation with respect to the use and management of rivers in the Limpopo River basin is overseen by the Limpopo Basin Permanent Technical Committee (LBTC), which comprises members from South Africa, Botswana, Zimbabwe and Mozambique. However, for the Olifants River there is no accepted international agreement specifying trans-boundary flow requirements. It is anticipated that a Limpopo River Basin Commission will be established in the near future and it is probable that a formal agreement specifying flow requirements will be negotiated.

The Olifants river originates at Trichardt, to the east of Johannesburg, in the province of Gauteng, and flows north-east, through the provinces of Mpumalanga and Limpopo, into Mozambique. Major tributaries of the Olifants river are the Wilge, Moses, Elands and Ga-Selati on the left bank and the Klein Olifants, Steelport and Blyde on the right bank (Figure 1). The Letaba River is a major tributary (catchment area 3,264 km^2) that originates in South Africa and joins the Olifants River in the Kruger National Park, just before the river flows into Mozambique. However, at this time, the Letaba River catchment is not included in the Olifants River Water Management Area. For this reason, and because most previous studies have not included the Letaba River, the information presented in this technical note focuses only on the region (54,308 km^2) that will be incorporated in the Olifants Water Management Area, hereafter simply referred to as the "Olifants catchment" (Table 1).

Table 1: *Summary statistics for the major tributaries of the Olifants River*

Tributary	Catchment Area (km^2)	Mean annual flow (Mm^3)
Wilge	4,356	167
Moses	1,662	39
Elands	6,148	83
Ga-Selati	2,340	80
Klein Olifants	2,391	81
Steelport	7,136	396
Blyde	2,842	436
Other	27,433	758
Total	**54,308**	**2,040**

(source: derived from data in WSAM database - Schultz and Watson, 2002)

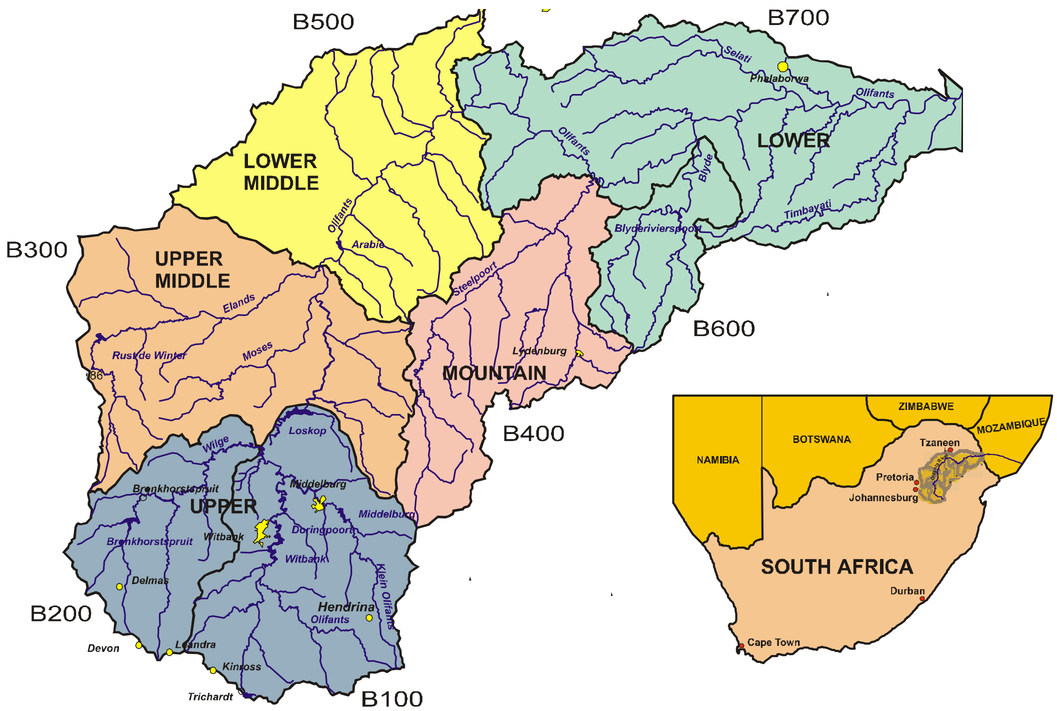


Figure 1: Location of the Olifants River Water Management Area and the boundaries of the five water management regions (source: DWAF, 2002)

For the purposes of managing water, the Olifants catchment has been divided into five regions (Figure 1 and Table 2). Each of these regions consists of a number of "quaternary catchments". Quaternary catchments are the principal water management unit in South Africa and were demarcated for the whole country as part of a comprehensive national water resource assessment, known as the Surface Water Resources of South Africa 1990 (WR90) study (Midgley *et al*., 1994). In the WR90 study, quaternary catchments were delineated to have similar runoff volumes (i.e., the greater the runoff the smaller the catchment area and vice-versa). Quaternary catchments are nested within tertiary, secondary and primary drainage areas. There are 22 Primary Drainage Regions in South Africa, of which the Olifants River Basin is one. Within the Olifants, there are 7 secondary, 13 tertiary and 114 quaternary catchments (Table 2).

Table 2: *Secondary, Tertiary and Quaternary Catchments in the Olifants River Basin (excluding the Letaba River)*

Water Management Region	Secondary Catchment identifier	Tertiary Catchment identifier	Quaternary Catchments identifier [1]	Description of Tertiary Catchment
Upper Olifants River	B1	1	A to L (11)	Olifants upstream of Loskop Dam
		2	A to E (5)	Klein Olifants
	B2	0	A to J (9)	Wilge River
Upper Middle Olifants River	B3	1	A to J (9)	Elands River
		2	A to J (9)	Olifants from Loskop Dam to confluence with Elands
Mountain Region	B4	1	A to K (10)	Steelport River
		2	A to H (8)	Spekboom River to confluence with Steelport
Lower Middle Olifants Region	B5	1	A to H (8)	Olifants from confluence with Elands to gauging station B5H002
		2	A to J (9)	Olifants & tributaries from confluence of Elands to gauging station B5H002
Lower OlifantsRegion	B6	0	A to J (9)	Blyde River
	B7	1	A to J (9)	Olifants and tributaries from gauging station B5H002 to confluence with Blyde River
		2	A to K (10)	Olifants to confluence with Selati River
		3	A to H (8)	Olifants from confluence with Selati River to Mozambique border

[1] the letter I, is not used as a quaternary catchment identifier. (Source: WSAM database)

3. Climate

3.1 Precipitation

In the Olifants catchment, precipitation data are available for 523 rainfall stations located within or very close to the catchment boundary. Of these, 47 have more than 50 years of data and 73 have more than 40 years of data. The South African Weather Bureau (SAWB) and other organizations (e.g., Department of Agriculture, South Africa Sugar Association and forestry companies) are responsible for these stations.

The climate of the Olifants catchment is largely controlled by the movement of air-masses associated with the Inter-Tropical Convergence Zone (ITCZ). During the summer, high land temperatures produce low pressures and moisture is brought to the catchment through the inflow of maritime air masses from the Indian Ocean. During the winter, the sun moves north and the land cools, causing the development of a continental high pressure system. The descending and outflowing air produces the regional dry season. For this reason, rainfall is seasonal and largely occurs during the summer months, October to April. Mean annual precipitation[1] for the whole catchment is 630 mm, but the rainfall pattern is irregular with coefficients of variation greater than 0.25 across most of the catchment (Table 3; Figure 2).

Table 3: *Mean annual precipitation and coefficient of variation for each of the secondary catchments*

Secondary catchment	Mean altitude (masl)	Mean annual precipitation (mm)	CV
B1	1,588	689	0.29
B2	1,501	670	0.29
B3	1,174	617	0.24
B4	1,430	681	0.26
B5	1,097	551	0.28
B6	1,207	823	0.27
B7	603	586	0.26
Total catchment	**1,149**	**630**	**0.27**

(Source: computed from data in Schulze *et al.,* 1997)

The catchment is divided into two by an escarpment, orientated approximately north-south. To the west of the escarpment the landscape is known as the highveld (i.e., altitude > 1,200 m) and to the east, it is known as the lowveld (i.e., altitude < 800 m). The highest precipitation is in the region of the escarpment. Orographic rainfall in the vicinity of the escarpment (caused when air is forced to rise over the escarpment) results in mean annual precipitation that exceeds 1,000 mm in some places. However, to both the east and the west of the escarpment, mean annual precipitation is generally 600 mm and less (Figure 2). Secondary catchment B6 lies on the escarpment and thus experiences considerably higher rainfall than the other secondary catchments in the Olifants River Basin. The lowest mean annual precipitation occurs in catchments B5 and B7 (Table 3).

[1] As a result of the seasonality of rainfall and hence flow across much of South Africa, DWAF uses a hydrological year that extends from 1 October to 30 September. For the purposes of consistency, throughout this report (unless stated otherwise) the hydrological year has been used when computing annual statistics. The standard convention of naming hydrological years after the year in which the month of October occurs has been adopted. Thus hydrological year 1956 (i.e., HY1956) extends from 1st October 1956 to 30th September 1957.

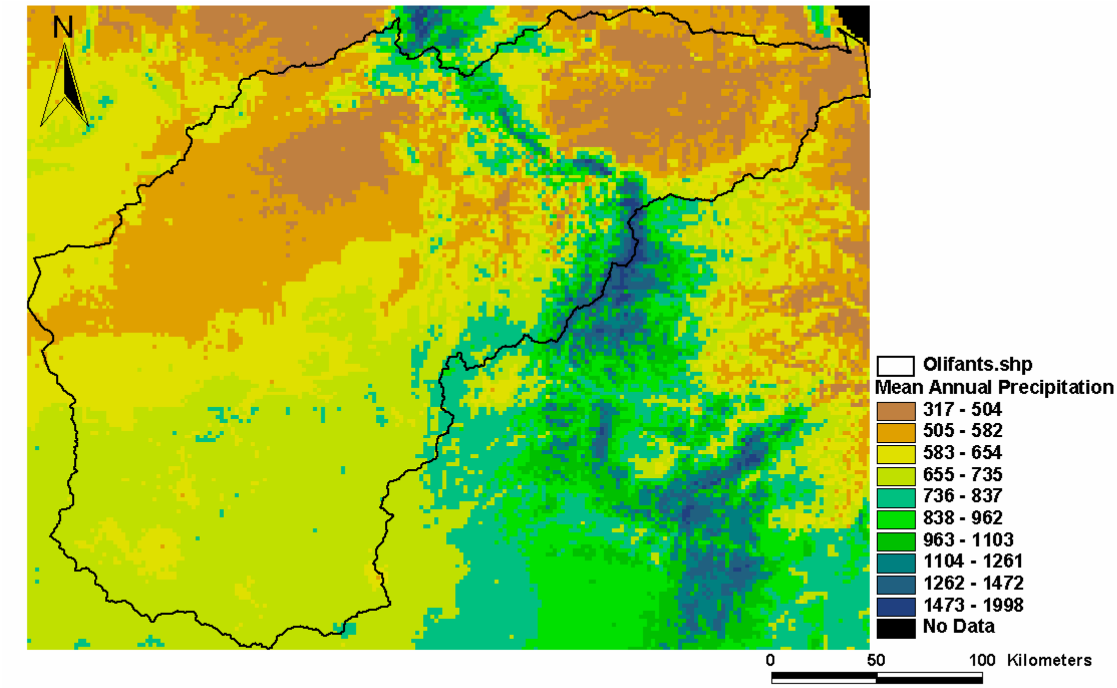
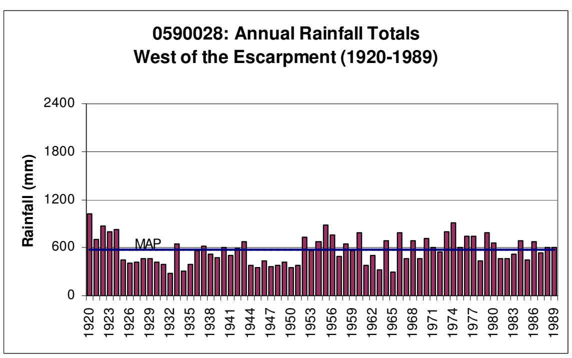
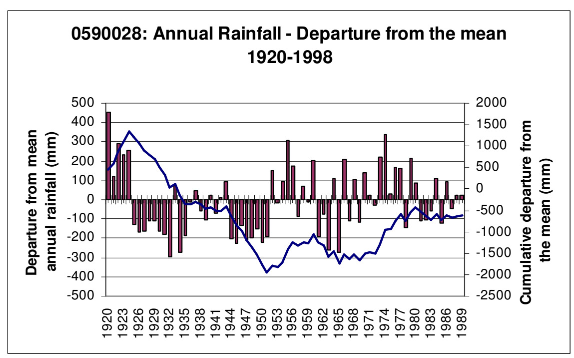


Figure 2: *Mean annual precipitation across the Olifants catchment* (Source: developed from data in Schulze *et al*., 1997)

Time series of annual precipitation and departure from the mean annual precipitation at three representative stations, located on the highveld, lowveld and the escarpment (Figure 3) illustrates:

i. higher rainfall on the escarpment than either to east or west.
ii. considerable inter-annual variability at all locations.
iii. often several consecutive years with below average rainfall.





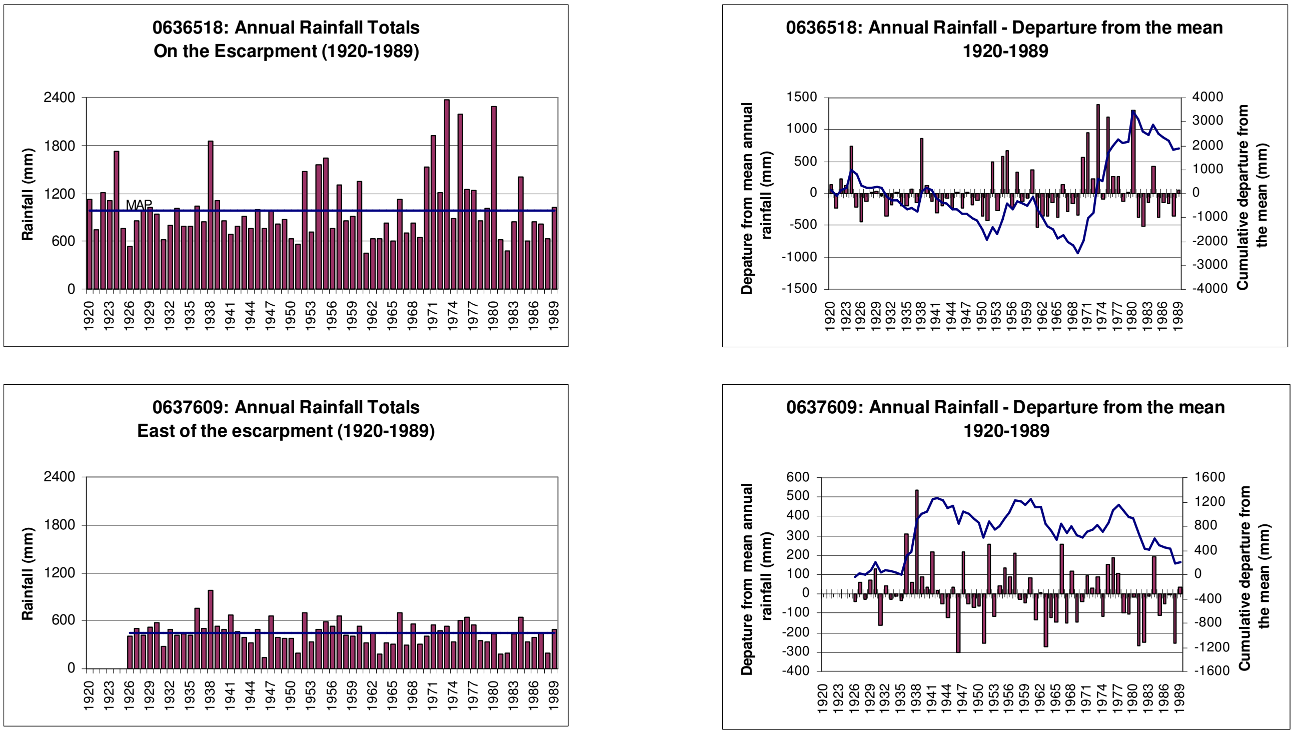


Figure 3: *Rainfall at three rain stations in the Olifants catchment for the period HY1920-HY1989. Located: i) on the highveld (i.e. to the west of the escarpment), ii) on the escarpment, iii) on the lowveld (i.e. to the east of the escarpment)*
(Source: derived from data provided by DWAF)

A plot of mean annual precipitation and altitude indicates that a different relationship exists between rainfall and altitude for sites in the vicinity of the escarpment than exists for locations elsewhere in the catchment, clearly illustrating the orographic influence of the escarpment (Figure 4).

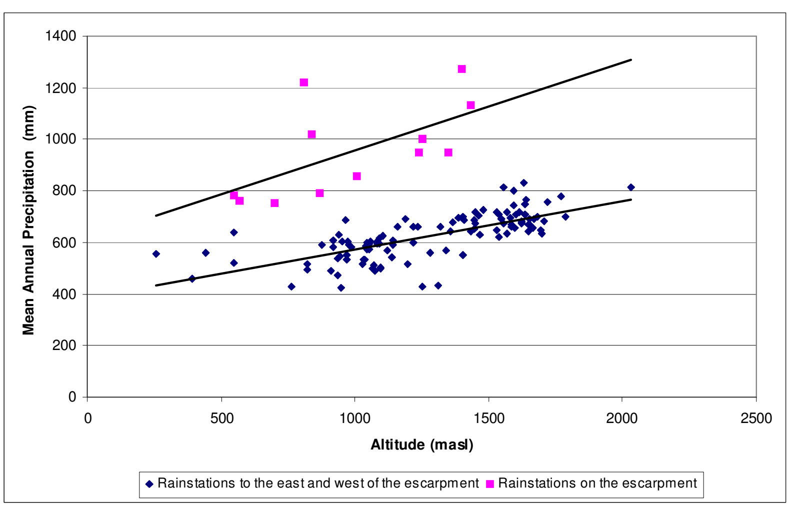


Figure 4: *Relationship between mean annual precipitation (for gauges with >30 years of data) in the vicinity of the escarpment and elsewhere in the Olifants catchment*
(source: derived from data provided by DWAF)

The intra-annual distribution of median monthly precipitation for each of the secondary catchments is presented in Table 4. A graph of mean monthly precipitation for the three representative stations used previously demonstrates the strong seasonal nature of the rainfall (Figure 5).

Table 4: *Median monthly precipitation (mm) for each of the secondary catchments in the Olifants catchment*

Secondary Catchment	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
B1	63.1	111.2	106.3	114.6	83.0	70.2	35.1	9.8	0.1	0.0	0.5	14.9
B2	57.2	102.9	103.6	112.9	83.0	72.4	32.7	9.2	0.1	0.0	0.1	12.7
B3	47.3	98.9	97.6	101.8	79.1	63.7	31.0	6.8	0.0	0.0	0.0	10.2
B4	52.8	107.1	110.6	110.9	85.9	70.1	37.3	8.6	0.3	0.1	0.3	13.4
B5	37.1	82.1	88.7	89.9	71.4	53.0	27.5	5.1	0.1	0.1	0.1	8.5
B6	50.4	105.7	122.0	127.3	114.8	89.1	44.5	12.4	1.8	2.4	2.5	14.8
B7	30.7	68.3	92.4	91.8	76.0	56.1	30.2	6.2	0.4	1.0	0.6	7.2
Total Catchment	45.5	92.4	99.4	102.4	80.5	63.8	32.4	7.5	0.2	0.4	0.4	10.7

(source: computed from data in Schulze *et al*., 1997)

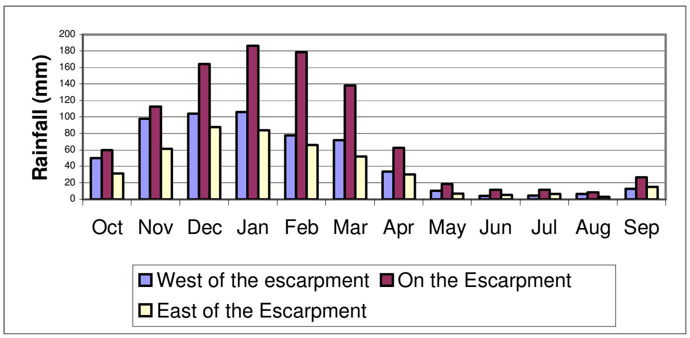


Figure 5: *Mean monthly precipitation for the same three rain stations as Figure 3.*

3.2 Temperature

The Limpopo basin is characterized by warm summers and mild winters, but temperatures vary in relation to altitude and proximity to the ocean. The South African portion of the basin has maximum temperatures of 30-34ºC in summer and 22-26ºC in winter, and minimum temperatures of 18-22ºC in summer and 5-10ºC in winter; the southern and western portions of the basin experience winter frost in contrast to the eastern and northern portions with their lower altitude and proximity to the ocean (ARC and IWMI 2003:3-4; FAO 2004:14-15).

3.3 Evaporation

Potential evaporation, i.e., evaporation that is not constrained by moisture deficit and so fully meets atmospheric demand, can be estimated in a number of different ways. One approach is direct measurement of evaporation from the surface of an evaporation pan. In southern Africa, there is a network of over 750 US Weather Bureau Class A pans. The A-pan provides an index of open water evaporation and many crop coefficients, which relate the consumptive water use of plants at different growth stages to a reference evaporation (Doorenbos and Pruitt, 1977), have been tried and tested against the A-pan (Schulze, 1995). Data are available for 56 evaporation pans located in or very close to the boundary of the Olifants catchment. Of these, 19 have 40 or more years of data.

There are a number of problems with extrapolating A-pan data from its measurement at a site to other locations (Smith, 1975). Consequently, for the South African Atlas of Agrohydrology and Climatology, simple climatic and physiographic variables, i.e., maximum daily temperature, extra-terrestrial radiation, altitude and median monthly rainfall, were used as surrogates to develop the grids of "A-pan equivalent" potential evaporation (Schulze *et al.*, 1997). The results for the Olifants catchment are shown in Figure 6 and summarized for each of the secondary catchments in Table 5.

Table 5: *Mean monthly and annual A-pan equivalent potential evaporation for each of the secondary catchments in the Olifants catchment (units: mm)*

Secondary Catchment	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Annual Mean
B1	210.8	205.6	215.1	204.8	170.5	173.0	141.0	125.0	102.8	115.0	156.1	188.5	2,013.7
B2	226.6	220.8	228.4	217.5	179.8	180.2	145.5	129.4	106.1	118.1	160.8	198.5	2,117.0
B3	230.8	226.1	233.3	228.6	189.7	187.3	149.0	133.2	110.2	122.0	163.6	200.1	2,179.4
B4	199.9	195.0	199.9	197.4	162.9	169.1	143.6	130.6	107.4	117.5	152.8	180.8	1,962.2
B5	221.2	220.7	221.6	222.5	181.4	181.9	148.7	133.0	110.8	121.2	159.2	193.4	2,121.0
B6	194.1	192.3	195.9	194.4	165.0	167.8	144.3	130.4	107.5	117.1	149.7	174.9	1,939.5
B7	201.3	209.4	214.6	217.3	183.1	178.6	143.2	125.7	105.8	117.5	150.0	179.2	2,031.2
Total Catchment	213.7	212.6	218.1	215.2	178.7	178.6	145.4	129.6	107.5	118.8	156.5	188.8	2,068.9

(source: computed from data in Schulze *et al*., 1997)

An alternative recommended reference for estimating irrigation water requirements of crops is the Penman-Montieth equation (FAO, 1992). This provides an estimate of potential evapotranspiration from a well-watered vegetation surface rather than an open water body (Penman 1948, Monteith, 1981). Water movement in plants is passive i.e., requires no input of biological energy, but even when the stomata of plants are fully open there is some resistance to the interchange of water between the plant and the atmosphere. Consequently, except in exceptional circumstances, evapotranspiration from a vegetated surface will always be less than that from open water. The FAO (1992) definition of potential evapotranspiration is:

> *The rate of evapotranspiration from a hypothetical crop with assumed crop height of 0.12 m, a fixed canopy resistance of 70 ms^{-1} and albedo of 0.23, which could closely resemble evapotranspiration from an extensive surface of green grass cover of uniform height, actively growing, completely shading the ground and not short of water.*

For the South African Atlas of Agrohydrology and Climatology, because the gridded A-pan equivalent potential evaporation estimates had been based on readily mappable and physiographically related variables and because extensive verification tests had been performed on the equations used to extrapolate the data, it was decided to relate month-by-month ratios of Penman-Montieth to A-pan values (Schulze *et al*., 1997). The resultant estimates of Penman-Monteith potential evapotranspiration for each of the sub-catchments of the Olifants are presented in Table 6.

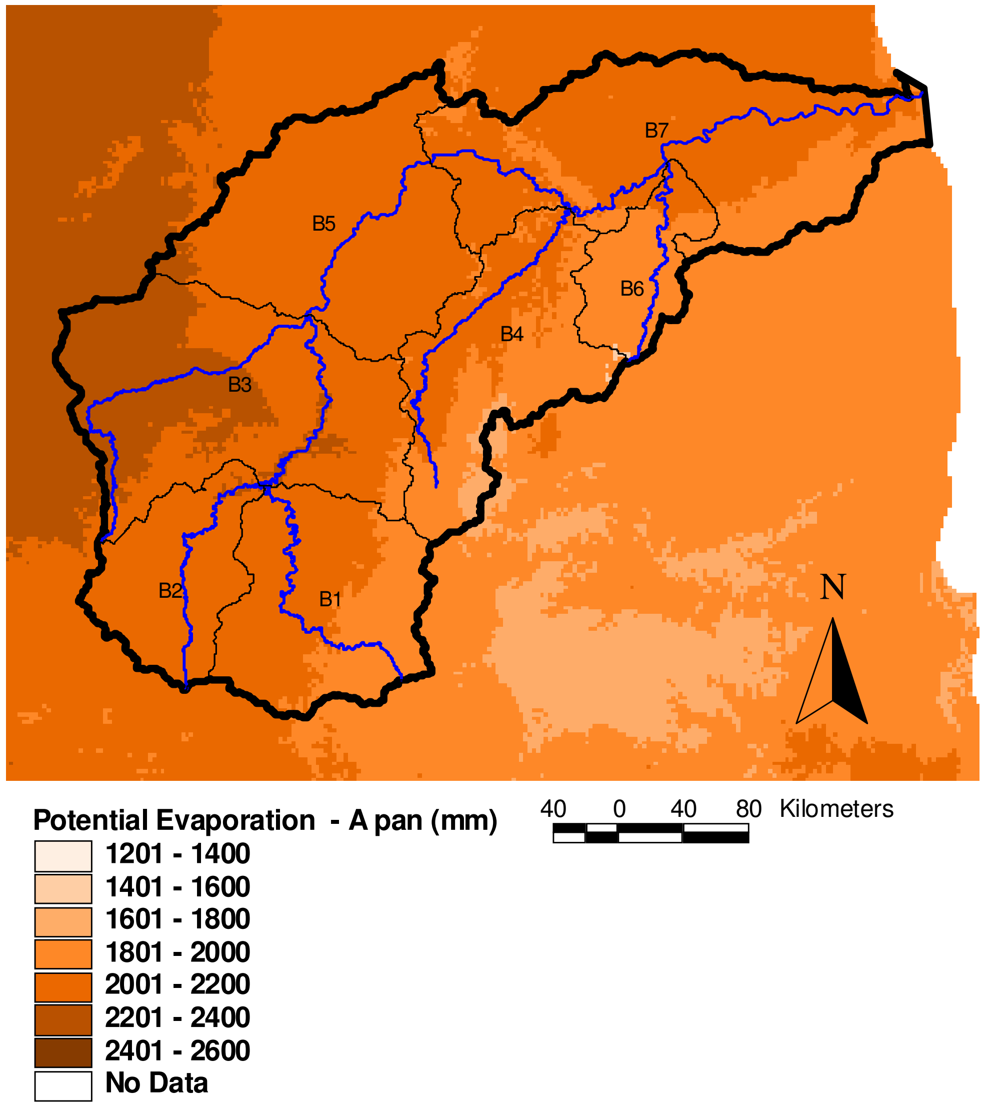


Figure 6: *Mean annual A-pan equivalent evaporation for the Olifants catchment* (source: derived from data in Schulze *et al.*, 1997)

Table 6: *Mean monthly and annual potential evapotranspiration (Penman-Montieth) for each of the secondary catchments in the Olifants catchment (units:mm)*

Secondary Catchment	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Annual
B1	149.5	150.0	156.9	149.4	124.4	122.8	95.8	77.4	60.5	67.7	96.6	126.2	1377.2
B2	160.8	161.5	167.6	160.1	132.3	129.4	99.8	81.2	63.4	70.5	100.5	133.3	1460.4
B3	163.8	165.9	172.1	169.6	140.7	135.8	102.9	84.6	66.6	73.8	103.2	134.7	1513.7
B4	141.8	142.5	146.2	144.5	119.3	120.6	97.9	81.3	63.6	69.6	95.0	121.2	1343.5
B5	156.9	163.0	165.8	168.5	137.3	135.7	105.1	87.2	69.3	75.9	103.0	118.9	1486.6
B6	139.4	141.7	144.7	143.7	122.3	121.2	99.7	82.9	65.3	71.2	95.0	131.2	1358.3
B7	149.4	158.8	164.9	167.5	142.4	137.0	105.1	87.4	71.0	78.9	102.9	127.5	1492.8
Total Catchment	153.2	157.1	162.3	160.9	133.9	131.1	101.8	83.9	66.5	73.5	100.5	128.7	1453.4

(source: computed from data in Schulze *et al*., 1997)

A comparison of the median monthly rainfall and the mean monthly Penman-Monteith potential evapotranspiration for the whole of the Olifants catchment shows that there are no months when rainfall exceeds potential evapotranspiration and typically it only exceeds 50% of potential evapotranspiration in the months November to February (Figure 7a). Consequently, rainfall conditions are not ideal for the growth of crops and irrigation is necessary to reduce the risk of water shortages. In relation to rainfall and potential evapotranspiration, the secondary catchment most suited for rain-fed agriculture is B6 (the Blyde River) in which rainfall typically exceeds the 50% potential evapotranspiration from November to March and is close to full potential evapotranspiration from December to February (Figure 7b).

a) b)

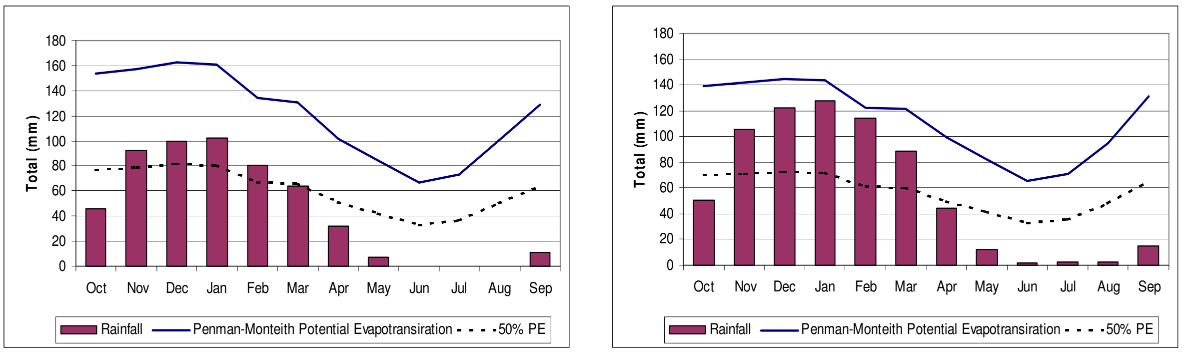


Figure 7: *Median monthly rainfall and mean monthly potential evapotranspiration for a) the whole of the Olifants catchment* b) *the Blyde River catchment*
(source: computed from data in Schulze *et al*., 1997)

4. Demography and economic activities in the Olifants Catchment

This section gives a brief overview of the situation in regard to demography, levels of poverty, access to services, and economic activities.

4.1 Population profile

The total population of the catchment is approximately 3.4 million. A striking characteristic of the catchment is the stark differentiation between the poor and the well-off, the blacks and whites, and the rural and urban people—they are even more extreme than is the case nationally in South Africa. Sixty percent of the population resides in the former homeland areas (former Lebowa, KwaNdbele, and parts of Bophuthatswana and Gazankulu), which constitute 26 percent of the area in the basin (Figures 8 and 9). Two thirds of the population resides in rural areas, mostly in scattered informal villages with limited commerce and services; the only major urban areas are the towns of Witbank and Middelburg, though there are important interactions with cities close to the basin. Black Africans constitute 94 percent of the basin population. The main languages spoken are Sesotho, Ndbele, Xitsonga, and Afrikaans (see Earle et al. 2006:8, Figure 4). Most future population growth in the catchment will be in the urban areas based on expanding mining and industrial development; the rural population is not expected to grow further, largely a function of the impact of HIV/AIDS (van Vuuren et al. 2003).

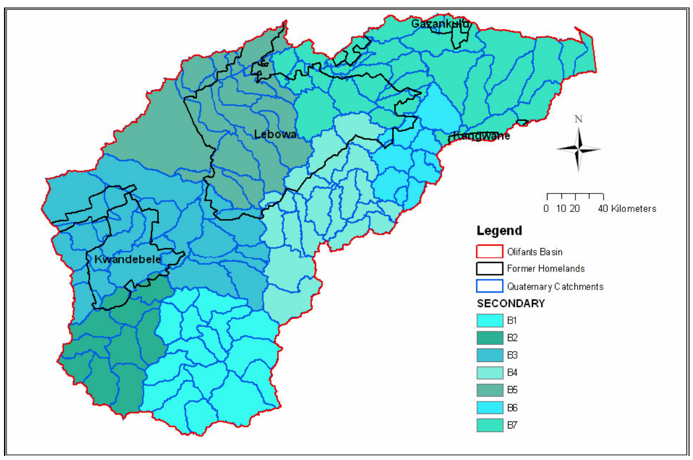


Figure 8: *Olifants Water Management Regions and Former Homelands*
(Source: Magagula et al. 2006:5, Figure 3)

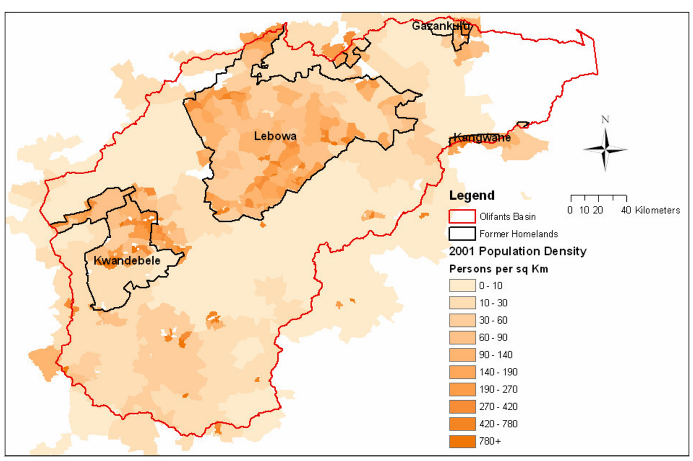


Figure 9: *Population Densities in Olifants Catchment (2001 Census)*
(Source: Magagula et al. 2006:14, Figure 6)

Measuring actual unemployment is difficult in South Africa, but according to the Census of 2001, 47 percent of the labor force in the Olifants catchment is not employed, and about two thirds of those who are employed work outside the former homeland areas (Magagula et al. 2006). The government accounts for nearly half of those employed, with an additional 21 percent in the mining sector and 19 percent in agriculture. Those categorized as "economically inactive" constitute a large proportion of the population.

Distribution of wealth is highly skewed between the urban and rural areas, and there are large differences in the standards of living (van Vuuren et al. 2003). A major part of the household economy in the rural areas is on a subsistence level, with some 70 percent of the population living in poverty. Table 7 gives a breakdown of household income for the former homeland and non-homeland areas. The high degree of dependency on a few income earners is indicated by the fact that 75 percent of the population has no monthly income, based on 2001 census data (Magagula et al. 2006).

Table 7: *Annual household income categories in Olifants River Basin (Census 2001); Source: IWMI*

	Former Homelands		**Non-Former Homelands**		
Income Category	**Number**	**%**	**Number**	**%**	**Basin %**
High Income Earners (R307 201 & above)	920	0.2	3,272	0.6	0.7
Upper Middle Income Earners (R38 401 - R307 200)	23,801	4.2	43,481	7.7	11.9
Lower Middle Income Earners (R4 801 - R38 400)	151,833	26.8	110,999	19.6	46.5
Low Income Earners (None - R4 800)	151,279	26.7	79,012	14.0	40.7
		57.9		41.9	99.8

4.2 Water access

An estimated 45 percent of the population in the Olifants catchment does not have access to water that meets government standards. Health services are also poor, and the literacy rate is only about 54 percent. There has been a movement of people to areas having better services; however, no statistics are available on this. Table 8 presents the annual urban-domestic water demand, estimated for the year 1995 and the total population for each of the water management regions in the catchment.

Table 8: *Population and urban/domestic water supply in each of the water management regions of the Olifants catchment*

Water Management Region	Population		**Annual Urban/Domestic Water Demand – 1995***	
	Nos.	**% total**	**Mm^3**	**% total**
Upper Olifants	592, 500	17.4	52.4	44.5
Upper Middle Olifants	923,120	27.1	18.7	15.9
Mountain	298,900	8.8	4.6	3.9
Lower Middle Olifants	979,594	28.8	14.1	12.0
Lower Olifants	608,328	17.9	28.0	23.8
Total	3,402,500		117.8	

* The demand includes smaller industrial demands, supplied by municipalities, but major industries are excluded (source: DWAF 2002)

Table 8 illustrates clear inequities in domestic water use. Although nearly 56% of the population lives in the Upper and Lower Middle Olifants regions, their domestic water demand comprises just 28% of the total. This equates to an annual per capita demand of 17,200 litres. At the present time, many thousands of people living in the Middle Olifants region do not have access to piped water. In contrast, the 35 % of the population in the Upper and Lower Olifants regions utilise 68% of the total demand, which equates to an annual per capita demand of 66,950 litres.

The domestic water demand is expected to almost double to approximately 222 Mm^3 by 2010, in part because of the South African government's commitment to supply potable water to the entire population of South Africa (National Water Act, 1998). However, the greatest increase is anticipated in the Upper Olifants River where demand is expected to increase to 125 Mm^3 by 2010 (DWAF, 2002).

Magagula et al. (2006) have attempted to assess the impact of water scarcity and lack of water access using the "water poverty index" (WPI). WPI is compromised of five component indices and additional sub-indices, resulting in a value ranging from 0 to 100 (bad to good). The Olifants catchment WPI is 27.1 for 2001, slightly more than half the national estimated WPI (52.2), again indicating that the Olifants is more extreme in terms of poverty and inequity than the country as a whole. Other studies (Prasad et al. 2006; Cullis and Van Koppen 2007) using different measures, also confirm the extreme inequity characterizing the Olifants basin. Not surprisingly, areas near the former homeland areas have significantly lower WPI scores than other areas, but a comparison of the WPI distribution in 2005 with that of 1994 (figure 10) also shows significant improvements (Magagula et al. 2006).

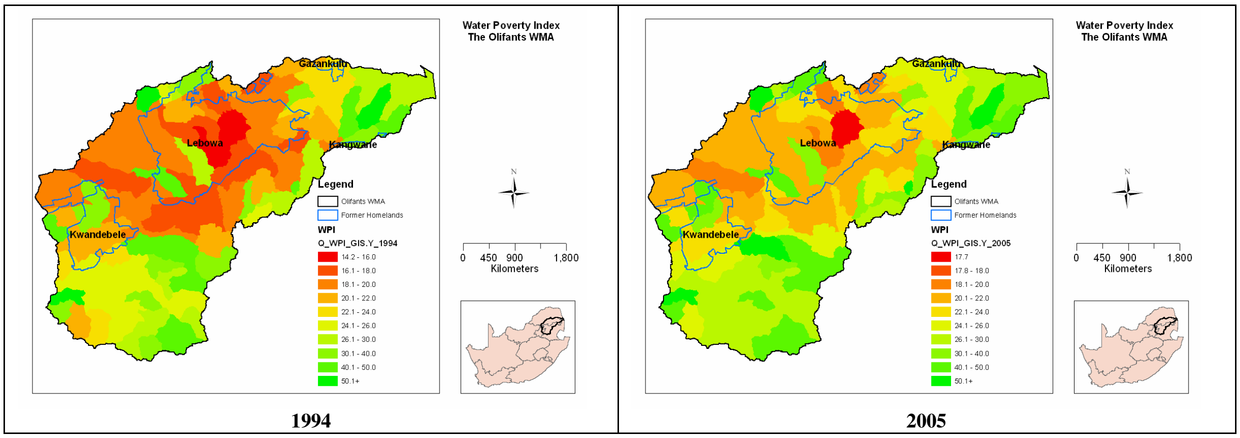


Figure 10: *Changes in Water Poverty Index, 1994-2005, in the Olifants Catchment*
(Source: Magagula et al. 2006:19, Figure 9)

4.3 Economic activity

DWAF has estimated the Gross Geographic Product (GGP)[2] of the Olifants catchment at R28.7 billion in 1997 (approximately US$ 4.1 billion), about five percent of GDP (DWAF 2004:7). Magagula and Sally (2005) report annual per capita GGP in the basin as US$1,200 in 2002, compared to US$2,200 per capita for South Africa as a whole.

Over two thirds of this was concentrated in the Upper Olifants Region where there is extensive mining, power generation and industry (see below). Overall, mining contributes 22.1 percent of GGP, manufacturing 18.2 percent, electricity 15.9 percent, government 15.6 percent, agriculture just seven percent, and 'other' 21.2 percent (van Vuuren et al. 2003).

4.4 Mining and manufacturing

Mining, a significant user (and polluter) of water[3], is the largest economic sector in the catchment (22.1 percent versus 7 percent nationally). With several very large new investments in mining being made or planned, it is considered an important source of future economic growth. However, employment in the sector is stagnant, with decline in gold mining balancing growth in platinum

[2] GGP is defined as the total income or payment received by the production factors (land, labor, capital and entrepreneurship) for their participation in the production within a specific area, i.e., the Olifants River catchment. In other words it is GDP for a specific region.

[3] In the early decades of the 20th century, mining used more water than did agriculture (Lévite et al. 2003)

mining. Manufacturing is to a large degree a function of the relatively cheap supply of coal and electricity and much of it is based on processing of minerals (18.2 percent versus 25 percent nationally). There are six active major coal-fired electricity power stations in the Olifants, and two moth-balled stations are expected to be re-activated by 2008 (van Vuuren et al. 2003).

4.5 Agriculture, livestock and forestry

At seven percent of GGP, agriculture makes a relatively small contribution to the Olifants basin economy compared to other sectors; but this is still nearly twice the level of agricultural contribution to national GGP[4]. However, when one takes into consideration agriculture's contribution to the livelihoods of the rural population, where it is often the only source of income, this sector plays a very important role in human survival and potentially poverty alleviation in this catchment. Child malnutrition leading to stunting of children's growth is widespread. The production of food, especially vegetables, for home use is critically important to many poor rural families and a potential entry point for poverty reduction[5].

Large parts of the Olifants catchment are used for livestock and game farming, though we were unable to find good data on numbers of livestock. Van Vuuren et al. (2003:3-33, Table 3.5.4.1) give a figure of 337,006 "ELU" (livestock units), but note there are no data on livestock (including domestic game) in the former homeland areas—a major gap.

Cattle are the most popular form of livestock and are mainly reared for meat. Sheep are also kept in considerable numbers, especially in the Upper Olifants and Steelpoort subareas. Goats are kept in relatively small numbers, with the largest number being kept in the Elands River catchment. Game is farmed for hunting and meat production, and has gained popularity in recent years. Nationally, the "hunting industry" has created some 70,000 jobs and generated nearly $ 100 million in income (http://www.phasa.co.za/index.php?pid=3); we have no figures for the Olifants but the numbers are significant. The main game types are impala, kudu, water buck, gemsbok and rhino. The eastern sub-catchments are more popular for game farming as they are drier and less suitable for cattle.

Livestock and game-farming are not officially considered to be significant users of water. Therefore, they do not carry much weight in these discussions of economic activities. However, this is undoubtedly a blind spot in the research done on water use and productivity; the cattle industry in particular is likely an important user of water (Peden et al. 2005; 2007). On the other hand, grazing game and livestock on rangeland as well as use of crop residues are likely to enhance net water productivity. We have no data on this dimension of water use.

Commercial forestry is also an important water consumer; it is estimated to cover 400 km^2 (Le Roy 2005a:10)[6]. Planting of large tracts of non-indigenous trees originated because mines needed large amounts of wood, but today commercial forestry is linked to paper production and other uses (Lévite et al. 2003a), and dominated by large national and international corporations. Although not irrigated, commercial forests growing non-indigenous tree species are seen as depleting far more water through evapotranspiration than indigenous forests. The assumption is that if the indigenous forests were in place there would be more stream flow[7]. Therefore, DWAF has proposed to charge commercial forestry companies for the additional 'stream flow reduction' caused by the higher rate of depletion.

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[4] We do not have exact figures on the value of agricultural processing, but it is undoubtedly very important in both financial and employment terms

[5] After more than a year of pilot testing, DWAF is nearly ready to scale up a program to provide household rainwater harvesting and storage to poor households precisely to enable them to grow more nutritious food; see DWAF 2007.

[6] van Vuuren et al. (2003:3-34, Table 3.5.5.1) give a figure of 139.0 km2, but this seems to be an underestimate

[7] No data on estimated consumption are given in the DWAF reports, but van Vuuren et al. (2003:3-35) suggest that it is on the order of 1,700 Mm^3

The largest commercial forestry plantations in the Olifants catchment can be found in the Blyde River sub-catchment, covering an area of about 220 km^2. Other sub-catchments with significant forested areas include the Steelpoort (74.5 km^2), Lower Olifants (40.9 km^2) and Upper Olifants Regions (39.2 km^2). These plantation areas account for 28 percent of commercial forestry in South Africa. The main types of trees in these commercial plantations are pine and eucalyptus, with eucalyptus being the dominant species in the Upper Olifants sub-area, and pine covering the rest of the catchment. In addition to these commercial plantations, there is a total area of about 1,399 km^2 of indigenous forests in the Blyde River sub-catchment and the rest of the Lower Olifants Region. No significant indigenous forest occurs in the rest of the Olifants catchment.

Assessment of actual evapotranspiration (ETa) in part of the Middle Olifants during one day in January 2002 using a remote sensing technique (SEBAL) found that even though more than half of *diverted* water is used in agriculture, agriculture accounts for only 24 percent of actual basin ETa, while 75 percent of ETa is largely through commercial forests (Ahmed et al. 2005). This suggests that DWAF is justified in charging for depletion of water by forests.

4.6 Tourism

Finally, there are many important tourist attractions in the Olifants catchment. The Lower Olifants sub-area contains a section of the Kruger National Park and the Klaserie, Umbabat, Timbavati (which is famous for its lion breeding program) and Thorny Bush privately owned game reserves that are located adjacent to the Kruger National Park. Other attractions in this sub-area are the Blyde River Canyon Nature Reserve, famous for its scenery and hiking trails, and several habitat and wildlife management areas. There are important fish hatcheries at Lydenburg in the Steelpoort sub-area. The area also has a number of trout farms that attract tourists. Some reservoirs are used for recreation in addition to other intended uses (for example Loskopdam). All of these are dependent on a good supply of water.

5. Geology and land use

5.1 Overview

Geologically, the catchment largely consists of igneous and metamorphosed rocks associated with the African and Post-African planation surfaces, which formed through uplift, approximately 100 million and 20 million years ago, respectively. These two surfaces comprise relatively low relief gently undulating plateau separated by a steep escarpment. Granite is the dominant rock type, but the area is geologically complex with the common occurrence of dolerite intrusions, in the form of dykes and sills, and silicified sedimentary formations (Figure 11). A detailed description is given in DWAF (1991).

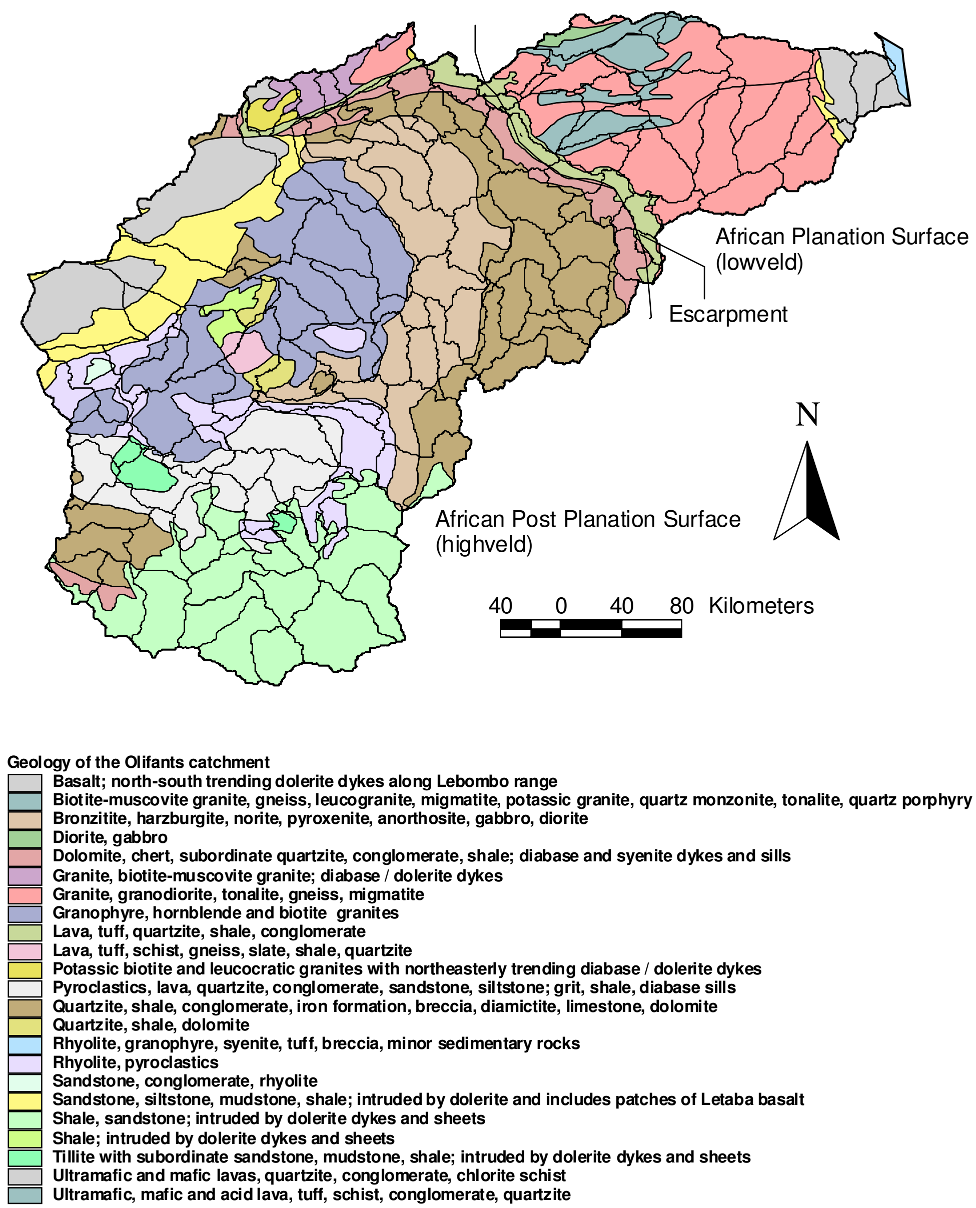

Figure 11: *Geology of the Olifants catchment* (source: data in Council of Geoscience, 2001)

Land use in the Olifants catchment consists primarily of irrigated and dryland cultivation, improved and unimproved grazing, mining, industry, forestry and urban and rural settlements. Figure 12 is a map of land-use within the catchment based on land cover estimates derived from high-resolution satellite imagery published by the South African National Land Cover Project (CSIR, 2003). From this map an estimate of the total cultivated area within the catchment is 1,172,389 ha (i.e. 11,724 km^2).

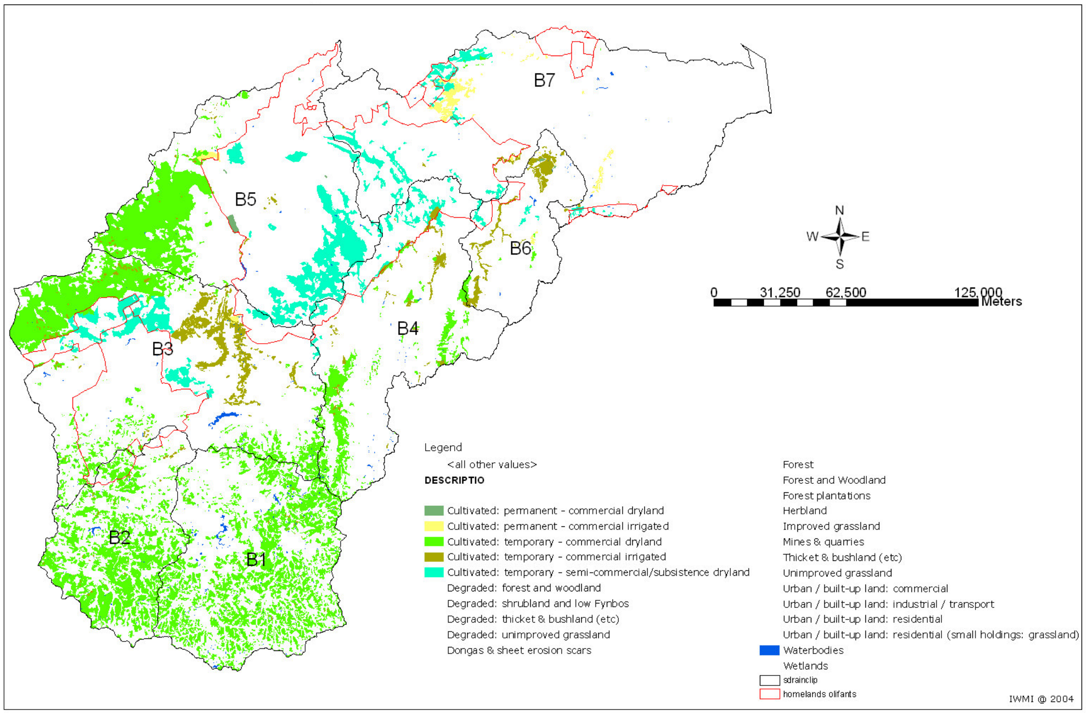

Figure 12: *Land use map of the Olifants catchment (all land classes) cultivated areas only* (source: data in the South African National Land-Cover database, CSIR, 2003)

Provisional analysis of the above databases by IWMI (Magagula, 2005) led to the quantitave estimation of land-use and land-cover shown in Table 9. The areas under different land cover are as accurate as satellite image analysis could be. The actual areas under cultivation can be determined for dry land (rain fed) areas and for irrigation areas and with a further distinction between permanent and temporary crops. Although table 9 does not explicitly include subsistence level irrigation, some data about this is provided in section 5.2.

A large-scale commercial agricultural sector, comprising mainly of large farms, coexists with a semi-commercial/subsistence sector made up of small farms in areas that, before the end of apartheid in 1994, were located within the so-called "homelands". Most of the homelands were located in marginal areas with lower rainfall and less fertile soils than is found in the commercial farming areas. Within the Olifants catchment, it is estimated that there are 945,948 ha of commercial and 226,441 ha of semi-commercial/subsistence cultivation. Of this, some 128,000 ha (i.e. 11% of the total cultivated area) is currently irrigated. Irrigation is almost exclusively within the commercial farming sector (Figure 13).

Table 9. *Land use and land cover in the Olifants water management area*

Land use / Land cover	Area (Km^2)	% Area
Cultivated: permanent - commercial dryland	33.46	0.1
Cultivated: permanent - commercial irrigated	245.24	0.4
Cultivated: temporary - commercial dryland	8,145.79	14.9
Cultivated: temporary - commercial irrigated	1,035.11	1.9
Cultivated: temporary - semi-commercial/subsistence dryland	2,264.47	4.1
Degraded: forest and woodland	3,917.05	7.2
Degraded: shrubland and low Fynbos	0.21	0.0
Degraded: thicket & bushland (etc)	729.82	1.3
Degraded: unimproved grassland	158.21	0.3
Dongas & sheet erosion scars	43.11	0.1
Forest	156.36	0.3
Forest and Woodland	14,202.09	26.0
Forest plantations	823.55	1.5
Herbland	0.07	0.0
Improved grassland	23.87	0.0
Mines & quarries	478.71	0.9
Thicket & bushland (etc)	9,016.95	16.5
Unimproved grassland	12,132.02	22.2
Urban / built-up land: commercial	4.02	0.0
Urban / built-up land: industrial / transport	43.93	0.1
Urban / built-up land: residential	989.53	1.8
Waterbodies	157.55	0.3
Wetlands	31.69	0.1
Urban / built-up land: residential (small holdings: grassland)	42.26	0.1
Unclassified	4.27	0.0
Total Area	**54,679.34**	

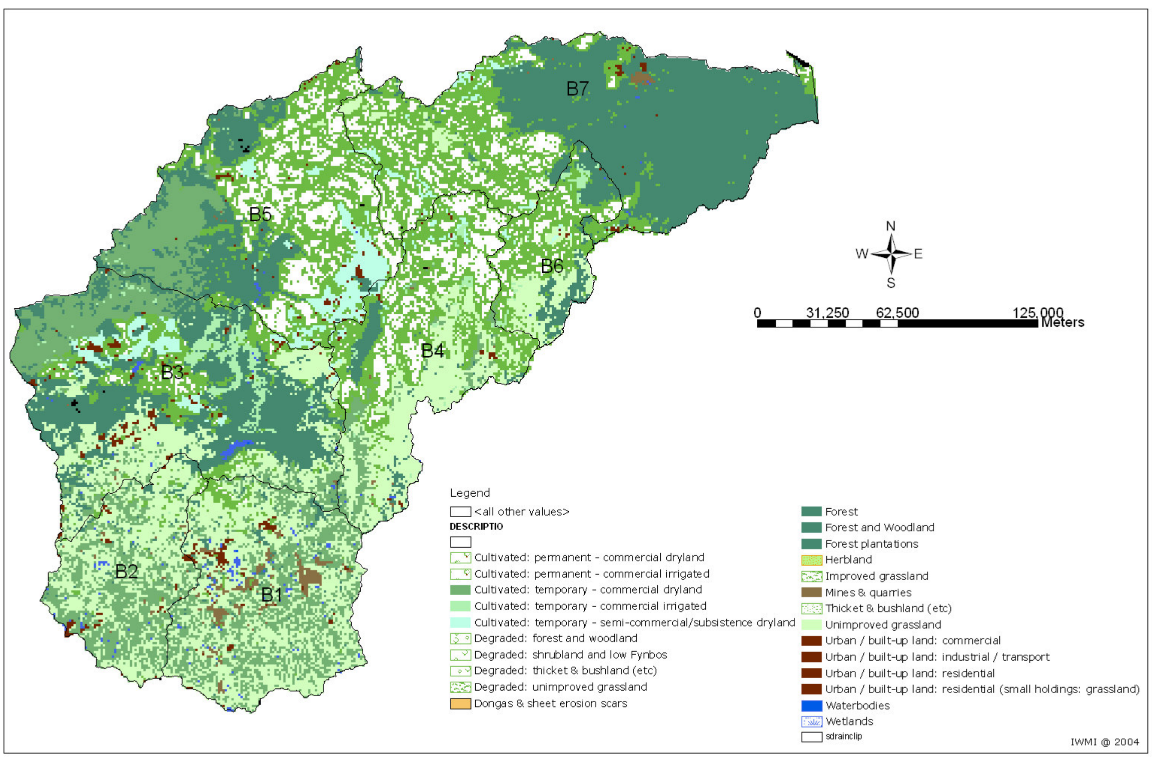

Figure 13: *Land use map of the Olifants catchment (cultivated areas only)* (source: data in the South African National Land-Cover database, CSIR, 2003)

5.2 Agriculture

South African agriculture can be broadly divided into three farming types: subsistence/semi-commercial farming (typically dry land), commercial dry land (typically large-scale and highly mechanized), and commercial irrigated farming (often export-oriented, highly mechanized) (Magagula and Sally 2005). All three occur in the Olifants catchment, with commercial dry land occupying over 70 percent of the cultivated area of 1.17 million ha; commercial irrigated land covers 11 percent of the area (128,000 ha, but see next paragraph) compared to 5 percent nationally (these figures seem to exclude small-scale irrigation, discussed below)[8]. Of the estimated R 5.3 billion (approximately US$ 828 million[9]) gross value of agricultural production, 60 percent is generated by commercial dry land farming and 37 percent by commercial irrigated farming

Figure 14 shows the distribution of different crops cultivated in the Olifants basin under dryland conditions; the total area under dryland cultivation is 945,948 ha. Maize is the dominant crop, grown in the summer.

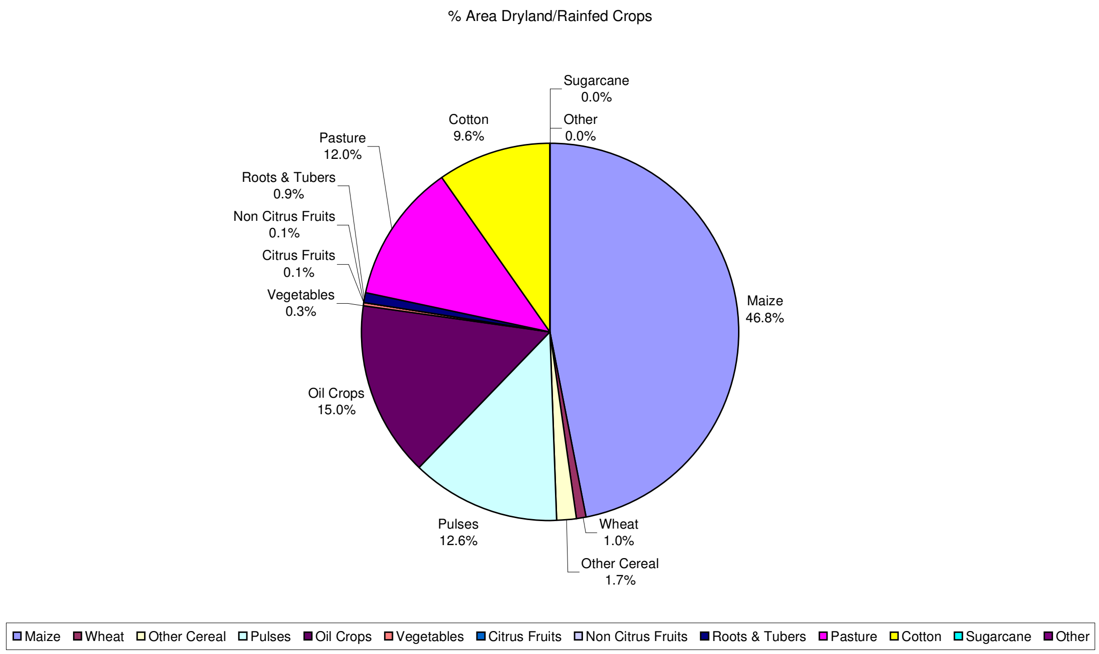

Figure 14. *Percentage of dryland area in the Olifants catchment in 2003 under different crops* (source: CSIR, 2003)

Commercial irrigated farming is highly diversified, as shown by Figure 15 (derived from the CSIR land-cover classification, 2003). Wheat, maize and cotton comprise approximately 50% of irrigated crops. But it must also be noted that a larger portion of high-value crops for export such as citrus are grown in this catchment than in most other South African irrigated areas.

8 McCartney and Arranz (2007:5, 13) claim there is an estimated 946,000 ha of rainfed agriculture

9 At a mid-2004 exchange rate of R 6.4 = US$ 1.00

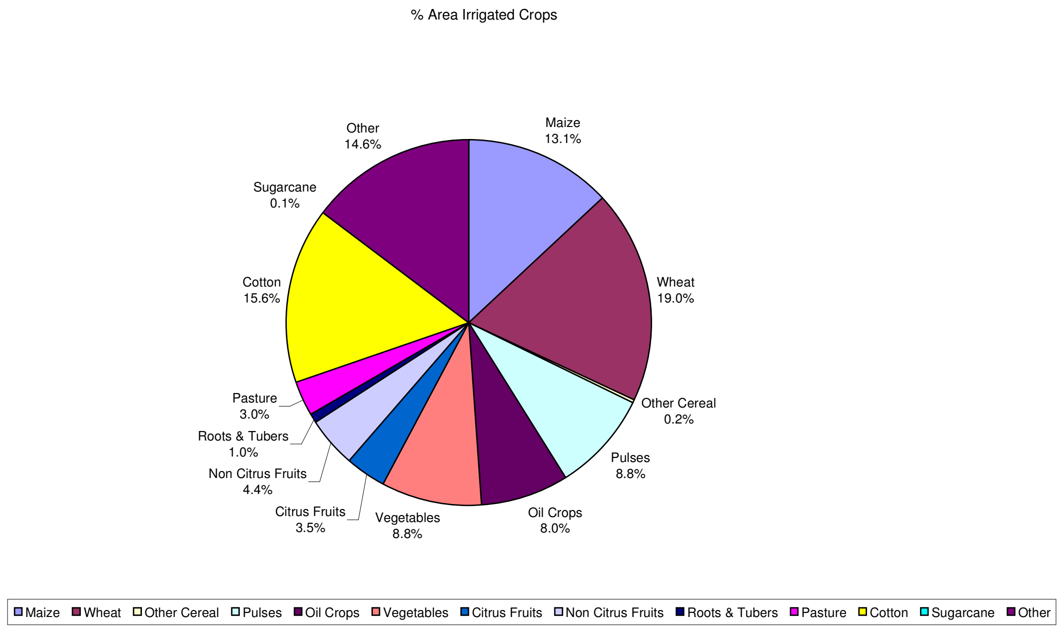

Figure 15: *Crop area distribution under irrigation in the Olifants River Basin* (Source: CSIR 2003)

While almost all irrigated agriculture is in the large-scale commercial farming sector, there is also a small-scale irrigation sector, mostly schemes constructed in the former homeland areas, which adds to the uncertainty about irrigated area (see below). A WRC report (Denison and Manona, 2006) estimates there are 317 such small schemes in the country, irrigating 49,504 ha and cultivated by 33,117 farmers on plots averaging 1.49 ha in size; but the average plot size figure fails to reflect the distribution from small food plots (0.05 ha) to 'subsistence' holdings (1 ha) to 'commercial' farms (Denison and Manona 2006:11, Table 2.1)[10]. Stimie et al. (2001:32) however cast doubt on official figures, suggesting there are "numerous" unidentified small-scale projects in the basin, especially in Mpumalanga Province. In the Olifants basin, there are an (officially) estimated 72 small-scale irrigation schemes with a command area of 9,534 ha, 5,564 farmers, and an average plot size of just 1.6 ha. However, many of these are either defunct or operating at a low level of productivity; around half or more of the farmers are women and often elderly (Mphahlele et al. 2000; Kamara et al. 2002). Figure 16 shows the location of these recognized schemes in the Olifants catchment—nearly all are in the former Lebowa homeland area.

[10] These figures seem to be based on official data; and the authors note data for Free State are incomplete

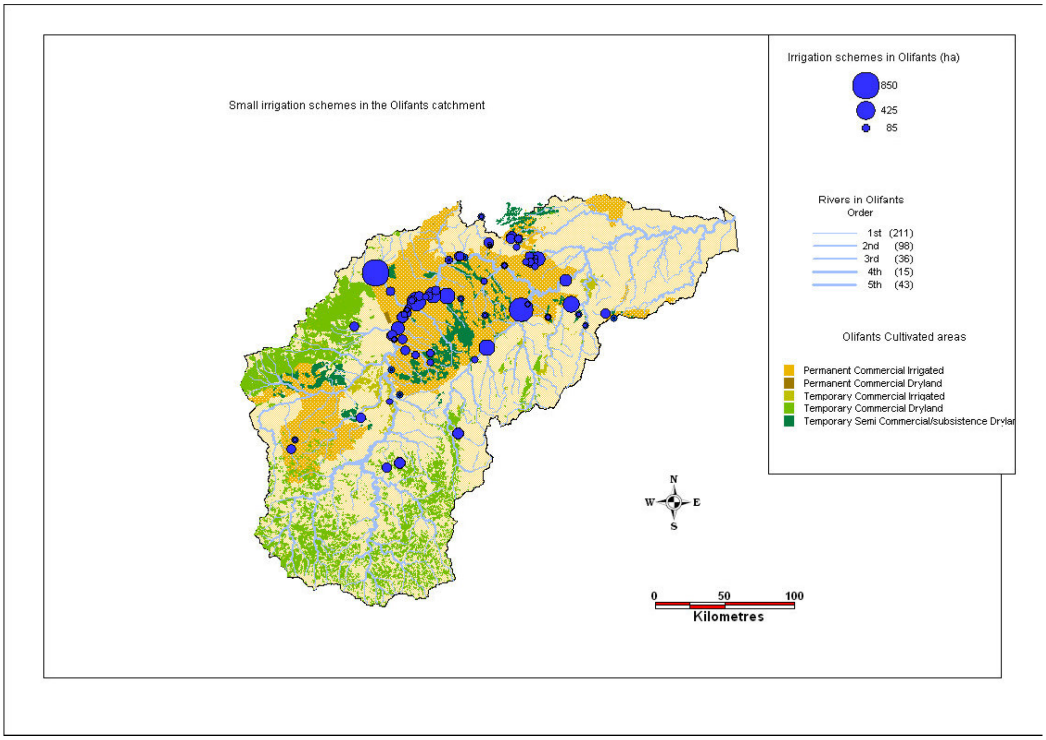

Figure 16. *Small-scale irrigation schemes in the Olifants Catchment (source: IWMI)*

As shown in Table 10 and Figure 17, the area of the catchment under irrigation increased steadily from approximately 34,000 ha in the 1950s to approximately 128,021 ha in 1995 (McCartney et al. 2004). Nearly half the irrigated area is in one secondary catchment, B3, below the Loskop Dam. However, in recent years there has been a significant increase in the area irrigated in the Lower Olifants, downstream of the Blyde Rivierspoort Dam.

Table 10: *Estimated area under irrigation in the subcatchments of the Olifants catchment*

Secondary Catchment	Area (km^2)	Area irrigated (ha)				
		1950-1960[1]	1965-1973[1]	1988[1]	1990-1995[2]	1995[3]
B1	7,105	625	920	4,760	6,560	2,110
B2	4,356	1,280	2,040	5,580	5,589	2,435
B3	11,242	13,170	38,975	49,295	51,621	57,618
B4	7,136	4,203	7,654	12,118	13,104	15,258
B5	9,728	7,700	9,338	6,455	15,850	6,043
B6	2,842	3,875	9,400	11,297	8,291	23,521
B7	11,899	2,933	5,311	9,410	9,230	21,035
Total catchment	54,308	33,786	73,638	98,915	110,245	128,021

(source: [1]DWAF, 1991, [2]WSAM, 1995 and [3]CSIR, 2003)

There is some uncertainty about the extent of irrigated area. The official DWAF estimate based on its WARMS database is 110,245 ha, also attributed to 1995 but may actually reflect an average over several years. In contrast, the estimate of 128,021 ha as of 1995 is based on a study combining remote georeferenced LANDSAT Thematic Mapper images captured in 1994 and 1995 and field observations by the South African Council for Scientific and Industrial Research (CSIR). The CSIR land-cover classification (CSIR, 2003) is assumed to be the best estimate currently available. However, despite the high resolution of the remote sensed images, it will almost certainly have underestimated the extent of small-scale irrigation in the catchment (CSIR, 1999). At present, there are no data available for the extent of irrigation in more recent years. But casual observation as one travels through the basin suggests that there is a great deal of expansion of irrigated citrus orchards in previously un-irrigated land, which is probably not captured in official figures either (personal observation)[11] .

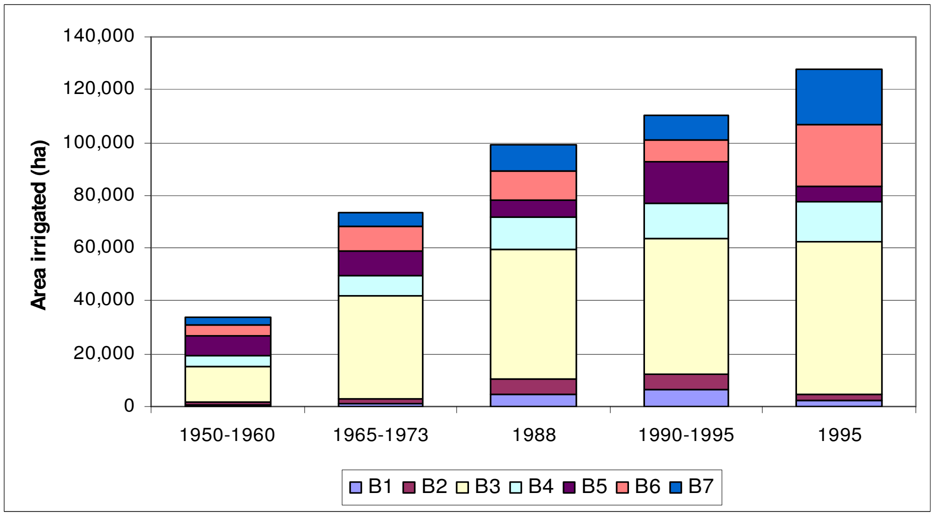

Figure 17: *Estimated area under irrigation in each of the sub-catchments of the Olifants River Basin* (source: DWAF, 1991, WSAM, 1995 and CSIR, 2003)

Irrigation is the main water-use sector in the Olifants catchment. An estimated seventy percent of all the water diverted and used by humans goes to irrigation; thirty percent of this is estimated to be from boreholes, the rest from surface sources (Magagula and Sally 2005)[12]. Table 11 provides estimated water use by economic sector in the basin based on data from the water use registration data base (WARMS) but these are considered preliminary estimates at best. Other estimates of water required by irrigation range from 436.8 Mm^3 (DWAF data) to 569.5 Mm^3 based on estimates using SAPWAT, a model developed in South Africa to estimate crop water requirements (Van Heerden 2004). The different figures probably reflect lack of clarity about exactly what is being measured, whether it is the water diverted or consumed.

Table 11: *Water use by sector in the Olifants river basin as derived (Source: WARMS database, 2004)*

Water Use by Sector in the Olifants River Basin (Mm^3)

	Aquaculture	Industry	Irrigation	Livestock	Mining	Schedule 1	Recreation	Water Supply	Total
Borehole	0.015	3.775	96.533	2.201	30.867	0.008	0.001	14.066	147.47
Dam		0.060	91.458	0.162	5.602			1.744	99.03
Estuary				0.015					0.01
Lake			0.719	0.001					0.72
River/Stream	29.542	3.195	118.327	0.377	3.678	0.025	0.011	0.679	155.83
Scheme		14.096	1.587	0.500	1.296			27.547	45.03
Spring/Eye		0.043	5.998	0.115	0.305			0.032	6.49
Wetland			3.557	0.012	0.269				3.84
Total (Mm^3)	**29.557**	**21.168**	**318.179**	**3.382**	**42.018**	**0.032**	**0.012**	**44.067**	**458.42**
%	**6.448**	**4.618**	**69.408**	**0.738**	**9.166**	**0.007**	**0.003**	**9.613**	**100**

Source: Magagula and Sally 2005:10, Table 8.

[11] This is mostly from groundwater and it is not clear whether it is fully captured in DWAF's records

[12] Aston (2000) says there is little commercial irrigation based on groundwater, so these figures are open to question.

6. Conclusion

This document has provided a broad overview of the salient features of the Olifants river basin with special focus on climate, land-use and land-cover and some key socio-economic features.

The Olifants basin is home to 3,400,000 people and is economically very important for the economy of South Africa, supporting significant mining, agricultural and industrial activities. All these sectors require large amounts of water. Rainfall in the basin is influenced significantly by the escarpment, which separates the highveld from the lowveld. Mean annual rainfall in the vicinity of the escarpment is relatively high, in excess of 800 mm, but to the east and west it is much less, dropping to below 600 mm in some places. In addition to the high spatial variability, rainfall also varies considerably between years. Averaged across the whole catchment, mean rainfall only exceeds 50% of mean potential evapotranspiration in 4 months of the year. Consequently, irrigation is required to reduce the risks of water shortage and support crop growth in many areas of the catchment.

Irrigation is the largest water-use sector in the basin. The irrigated area is estimated to be around 128,021 ha (i.e. 11% of the total cultivated area in the catchment) using approximately 540 million m^3/yr. Almost all the irrigation water is used in the commercial sector.

There has been extensive water resource development in the Olifants basin. There are nearly 40 major dams (with a storage capacity greater than 2 Mm^3) and several times more small and minor dams in the catchment. But this development has not yielded equitable benefits for all the people living in the basin: there is a significant discrepancy between development in what were the former homelands and the former Republic of South Africa. In fact, prior to the 1980s, there was considerable development in the Republic but very little development in the homelands. While it is not possible to give the reason for this discrepancy, it is possible that it reflects the different development priorities given to the "white" and "black" areas during the former apartheid regime. This is exemplified in the huge difference in the urban and domestic water consumed in different areas of the catchment. In the regions that incorporate the former homeland areas and where many people still lack basic water supply, per capita consumption equates to just 17.20 m^3/yr (i.e. 47 litres per capita per day). In contrast in the upper and lower catchment, where the majority of the white population lives, the average per capita consumption is 66.95 m^3/yr (i.e. 183 litres per capita per day).

One key factor that emerges is the high degree of complexity, and the contrasts among the rich and poor, in a context of increasing competition for scarce water resources. Redressing this imbalance, together with a major concern to safeguard the environment are some of the main considerations that underpin current and future land and water development plans in the basin. Some of the factors that merit further investigation and research are: (a) the implications of re-allocating water between sectors; (b) the implications of water conservation and demand management strategies; (c) the potential for increased utilisation of groundwater including inter-linkages between groundwater and surface water; (d) better understanding of irrigation abstraction, return flows and impacts on water quality; and (e) the potential for water reuse and recycling, including using mine water for irrigation.

References cited

Agricultural Research Council (ARC) and IWMI. 2003. Limpopo Basin Profile. ARC Institute for Soil Climate and Water, ARC-Institute for Agricultural Engineering, and IWMI, August 2003, for the Challenge Program on Water and Food. http://www.limpopo.arc.agric.za/profile.htm.

Aston, J.J. 2000. Conceptual overview of the Olifant River Basin's Groundwater, South Africa. *Occasional paper for International Water Mangement Institute and African Water Issues Research Unit* (AWIRU).

Chimpelo, J. *et al.*, 2003. Development of Internal Strategic Perspectives for the Northern Region: Olifants Water Management Area – Draft 2. Department of Water Affairs and Forestry, Pretoria.

Council of Geoscience, 2001. *Digital Metallogenic Map of the Republic of South Africa and the Kingdoms of Lesotho and Swaziland.*

CSIR, 2003. *National Landcover dataset attributes*. Satellite Applications Centre, ICOMTEX, Council for Scientific and Industrial Research, Pretoria.

CSIR, 1999. South African National Land-Cover Database Project. Data Users Manual Final Report (Phase 1,2 and 3). Council for Scientific and Industrial Research, Pretoria. 68 pp.

Cullis, James, and Barbara van Koppen. 2007. Applying the Gini Coefficient to Measure the Inequality of Water Use in the Olifants River Water Management Area, South Africa. IWMI Research Report 113.

Doorenbos, J. and Pruitt, W.O. 1977. *Guidelines for predicting crop water requirements*. FAO Irrigation and Drainage Paper 24, Rome 144 pp.

DWAF, 2002. *Proposal for the establishment of a Catchment Management Agency for the Olifants Water Management Area* – Appendix C. Department of Water Affairs and Forestry, Pretoria.

DWAF, 1991. *Water Resources Planning of the Olifants River Basin: Study of development potential and management of the water resources. Basin Study Report.* Department of Water Affairs and Forestry and Theron Prisloo Grimshel and Pullen, Pretoria.

DWAF. 2007. Programme Guidelines for Intensive Family Food Production and Rainwater Harvesting. Draft, March 2007. Pretoria: DWAF.

Earle, Anton, Jaqui Goldin, Rose Machiridza, Daniel Malzbender, Emmanuel Manzungu, and Tiego Mpho. 2006. Indigenous and Institutional Profile: Limpopo River Basin. IWMI Working Paper 112. Colombo: IWMI.

FAO, 1992. *Expert Consultations on revision of FAO Methodologies for Crop Water Requirements*. Land and Water Development Division, Food and Agriculture Organisation of the United Nations, Rome, Italy.

Foster, S.S.D. 1988. Quantification of groundwater recharge in arid regions: a practical view for resource development. In: Simmeers (Ed) *Estimation of Natural Groundwater Recharge*. Reidel, Dordecht. 323-338.

Houghton-Carr, H.A., Fry, M., McCartney, M.P. and Folwell, S.S. 2002. Drought and drought management in southern Africa. *Proceedings of the BHS Eighth National Hydrology Symposium* University of Birmingham 8-11 September 2002, 103-108.

Idowu, O. 2003. An assessment of the impact of irrigation with gypsiferous mine water on the water resources of the upper Olifants catchment. PhD proposal, University of Natal. 8 pp.

Lévite, H., Van Koppen, B. and McCartney, M.P. 2003. The basin development trajectory of the Olifants Basin, South Africa. *Paper presented at the 4nst WARSFA/ Waternet Symposium.* Gaborone, Botswana 15-17 October 2003.

Magagula, Thulani F., Barbara van Koppen and Hilmy Sally. 2006. Water Access and Poverty in the Olifants Basin: A Spatial Analysis of Population Distribution, Poverty Prevalence and Trends. Paper presented at 7th Waternet/WARFSA/GWPSA Symposium, 1-3 November 2006, Lilongwe, Malawi.

Meigh, J. 1995. The impacts of small farm reservoirs on urban water supplies in Botswana. *Natural Resources Forum* 19 (1), 71-83.

Midgley, D.C., Pitman, W.V. and Middleton, B.J. 1994a to f. *Surface Water Resources of South Africa*, Volumes I, II, III, IV, V and VI, Reports No's. 298/1.1/94, 298/2.1/94, 298/3.1/94, 298/4.1/94, 298/5.1/94 and 298/6.1/94, Water Research Commission, Pretoria, South Africa.

Molle, F. 2002. River Basin Development: a framework for case studies (http://www.iwmi.cgiar.org/ComAss/riverbasin_framework.htm).

Monteith, J.L. 1981. Evaporation and surface temperature. *Quarterly Journal of the Royal Meteorological Society*, 107, 1-27.

Penman, H.L. 1948. Natural evaporation from open water, bare soil and grass. *Proceedings of the Royal Society, London*, A193, 120-146.

Pitman, W.V. 1973. *A mathematical model for generating monthly river flows from meteorological data in South Africa*. Report No. 2/73, Hydrological Research Unit, University of Witwatersrand, Johannesburg.

Prasad, Krishna, Barbara van Koppen, and Ken Stryzepek. 2006. Equity and Productivity Assessment in the Olifants River Basin, South Africa. *Natural Resources Forum* 30: 63-75.

Raskin, P., Hansen, E. and Margolis, R. 1995. *Water and sustainability: a global outlook*. Polestar Series Report, No. 4. Stockholm Environment Institute. 66 pp.

Renn, S.E., Alexander, R.D., Sene, K.J, Houghton-Carr, H.A. and Black, K.B. 1999. *HYDATA hydrological database and analysis system version 4.1. Operation Manual.* Institute of Hydrology, Wallingford 186 pp.

Schulze, R.E. 1995. *Hydrology and Agrohydrology: a text to accompany the ACRU 3.00 Agrohydrological Modelling System*. University of Natal, Pietermaritzburg, Republic of South Africa.

Schulze, R.E., Maharaj, M., Lynch, S.D., Howe, B.J. and Melvil-Thomson, B. 1997. *South African Atlas for agrohydrology and Climatology*. University of Natal, Pietermaritzburg.

Schultz, C.B and Watson, M.D. 2002. *WSAM: Water Situation Assessment Model – Version 3: A Decision Support System for Reconnaissance Level Planning. Volume 1: Theoretical Guide*. ARCUS-GIBB and DWAF, Republic of South Africa.

Scott, D.F. and Le Maitre, D.C. 1994. *A synthesis of afforestation impacts on streamflow*. Report for the Department of Water Affairs and Forestry, Pretoria, South Africa.

Smith, L.P. 1975. Methods in agricultural meteorology. *Directions in Atmospheric Science*, 3, Elsevier, Amsterdam, Netherlands.

Turton, A.R. and Meissner, R. 2003. *A hydropolitical history of South Africa's International River Basins.* University of Pretoria. Report to the Water Research Commission, South Africa.

Tunha, W. 2003. Modelling surface water/groundwater interactions within the context of a river basin. Refinement of key hydrological processes in the ACRU model for water resources management purposes. PhD proposal, University of Natal. 15 pp.

van Vuuren, A Jansen, H. Jordaan, E. Van der Walt, and S. Van Jaarsveld. 2003. Olifants Water Management Area: Water Resources Situation Assessment – Main Report. DWAF Report No. P/04000/00/0101. Final Report, first issue (July 2003). Pretoria: DWAF Directorate of Water Resources Planning.

World Commission on Dams (WCD), 2000. *Dams and Development: a new framework for decision-making*. Earthscan Publications Ltd.: London. 404 pp.

Additional bibliography related to river basin management and the Olifants river basin

Abernethy, Charles, ed. 2001, Intersectoral Management of River Basins: Proceedings of an international workshop on "Integrated water management in water-stressed river basins in developing countries: Strategies for poverty alleviation and agricultural growth". Colombo, Sri Lanka: IWMI and DSE. (Available on CD.)

Ahmad, Mobin-ud-Din; Thulani F. Magagula; David Love; Victor Kongo; Marloes L. Mul; and Jeniffer Kinoti. 2005. Estimating Actual Evapotranspiration through Remote Sensing Techniques to Improve Agricultural Water Management: A Case Study in the Transboundary Olifants Catchment in the Limpopo Basin, South Africa. Paper presented at the 6th WaterNet/WARFSA/GWP Annual Symposium, 1-4 November 2005, Ezulwini, Swaziland.

Andersson, Lisa. 2005. Low-Cost Drip Irrigation: On-Farm Implementation in South Africa. Master of Science Programme in Environmental Engineering. Luleå University of Technology, Department of Civil and Environmental Engineering, Division of Water Resources Engineering.

Arranz, Robert. 2006. Future Water Demands and Resources in the Olifants Catchment, South Africa: a scenario analysis approach using the WEA model. M.Sc. thesis, Colorado State University, Fort Collins, USA.

Arranz, Robert, and Matthew McCartney. 2007. Application of the Water Evaluation and Planning (WEAP) Model to Assess Future Water Demands and Resources in the Olifants Catchment, South Africa. IWMI Working Paper 116. Colombo, Sri Lanka: IWMI.

Aston, John J. 2000. Conceptual Overview of Olifants Basin's Groundwater, South Africa. An Occasional Paper for IWMI and the Africa Water Issues Research Policy Unit (AWIRU), University of Pretoria. Unpublished.

Backeberg, Gerhard R. 2005. Water Institutional Reforms in South Africa. *Water Policy* 7 (1):107-123.

Barker, Randolph, Hammond Murray-Rust, and Arlene Inocencio. 2003. Economics of Water Productivity in Managing Water for Agriculture. In: Kijne, J.W., R. Barker, and D. Molden, eds. 2003. *Water Productivity in Agriculture: Limits and Opportunities for Improvement.* Comprehensive Assessment of Water Management in Agriculture Series 1. Cambridge, MA: CABI Publishing in association with IWMI.

Basson, M.S., van Niekerk, P.H. and van Rooyen, J.A. 1997. Overview of water resources availability and utilization in South Africa. Department of Water Affairs and Forestry and BKS (Pty) Limited. 72 pp.

Basson, M.S., and J.D. Rossouw 2003. Olifants Water Management Area: Overview of Water Resources Availability and Utilization. DWAF Report No. P WMA 04/000/00/0203. Final issue, September 2003. Pretoria: DWAF Directorate of Water Resources Planning and BKS (Pty) Ltd.

Bate, R. and Tren, R. 2002. *The cost of free water: the global problem of water misallocation and the case of South Africa.* Free Market Association, Johannesburg. Cambridge Resources International. 2003. Evaluation of the Olifants-Sand Water Transfer Scheme in the Northern Province of South Africa. Cambridge, MA, USA.

Biswas, A.K. 2004. Integrated Water Resources Management: A Reassessment. *Water International* 29(2): 248 - 256. Cambridge Resources International 2003. Evaluation of the Olifants-Sand water transfer scheme in the Northern Province of South Africa. Cambridge, MA, USA.

Cook, Simon, Francis Gichuki, and Hugh Turral. No date (a). Agricultural Water Productivity: Issues, Concepts and Approaches. CPWF Basin Focal Project Working Paper 1
http://www.waterandfood.org/fileadmin/CPWF_Documents/Documents/Basin_Focal_Projects/BFP_restricted/Paper_1_Final_14JY06.pdf.

Cook, Simon, Francis Gichuki, and Hugh Turral. No date (b). Water Productivity: Estimation at Plot, Farm and Basin Scale. CPWF BFP Working Paper 2.
http://www.waterandfood.org/fileadmin/CPWF_Documents/Documents/Basin_Focal_Projects/BFP_restricted/Paper_2_14JY06.pdf.

Carmo Vaz, Alvaro. 2000. Coping with Floods – The Experience of Mozambique. Paper presented at the first WARFSA/Waternet Symposium, Maputo, 1-2 November 2000.

De Conig, Christo, and Tamsyn Sherwill. 2004. An Assessment of the Water Policy Process in South Africa (1994 to 2003). Water Research Commission Report No. TT 232/04. Pretoria: WRC.

De Conig, Christo. 2006. Overview of the Water Policy Process in South Africa. *Water Policy* 8: 505-528.

de Lange, M. 2004. "Water Policy and Law Review Process in South Africa with a Focus on the Agricultural Sector." In P. P. Mollinga and A. Bolding, eds., *The Politics of Irrigation Reform: Contested Policy Formulation and Implementation in Asia, Africa, and Latin America*. Hans, UK: Ashgate.

de Lange, Marna. 2006. A Literature Study to Support the Implementation of Micro-AWM Technologies in the SADC Region. Paper produced for IWMI with support from USAID & FAO. Pretoria: IWMI (available on CD, "Resources on Agricultural Water Management in Southern Africa," May 2006).

de Lange, Marna; Merrey, Douglas J.; Levite, Herve; Svendsen, Mark. 2005. Water resources planning and management in the Olifants Basin of South Africa: Past, present and future. In Svendsen, Mark (Ed.), *Irrigation and River Basin Management: Options for Governance and Institutions*. Wallingford, UK; Colombo, Sri Lanka: CABI; IWMI. p.145-168.

Denison, Jonathan, and Siyabu Manona. 2007. Principles, Approaches and Guidelines for the Participatory Revitalization of Smallholder Irrigation Schemes. Volume 2 of 2: Concepts and Cases. WRC Report No. TT 309/07. Pretoria: WRC and Arcus Gibb.

Department of Water Affairs (DWA), RSA. 1991 Water Resources Planning of the Olifants River Basin - Study of Development Potential and Management of the Water Resources. Cited in Aston 2000; cited as DWAF 1991 in McCartney et al. 2004.

Department of Water Affairs and Forestry (DWAF), South Africa. 1999. Comprehensive ecological reserve methodology. Available online at:
http://www.dwaf.gov.za/docs/Water%20Resource%20Protection%20Policy/river%20eco systems/riv_sectionF_version10.doc

DWAF. 2004. Olifants Water Management Area: Internal Strategic Perspective. Prepared by GMKS, Tlou and Matji on behalf of the Directorate, Water Resources Planning. DWAF Report No. P WMA 04/000/00/0304 Pretoria: DWAF.

DWAF. 2005. A Draft Position Paper for Water Allocation Reform in South Africa: Towards a Framework for Water Allocation Planning. Discussion document, January 2005, Directorate: Water Application. Pretoria: DWAF.

Faysse, Nicolas. 2004. An Assessment of Small-scale Users' Inclusion in Large-scale Water Users Associations of South Africa. IWMI Research Report 84. Colombo: IWMI.

Faysse, Nicolas, and Jabulani Gumbo. 2004. The Transformation of Irrigation Boards into Water User Associations in South Africa: Case Studies of the Umlaas, Komati, Lomati, and Hereford Irrigation Boards. IWMI Working Paper 73, volume 2. Colombo: IWMI.

Food Insecurity and Vulnerability Information Management System (FIVIMS). 2006. Livelihood Survey Conducted in the Greater Sekhukhune District Municipality of Limpopo, 2006. Draft Report. Pretoria: Department of Agriculture.

Food and Agriculture Organization of the United Nations (FAO). 2004. Drought Impact Mitigation and Prevention in the Limpopo River Basin: A Situation Analysis. Land and Water Discussion Paper. 4, prepared by the FAO Subregional Office for Southern and East Africa, Harare. Rome: FAO.

Garduño, Héctor, and Manda Hinsch. 2005. IWRM Implementation in South Africa: Redressing Past Inequities and Sustaining Development with a View to the Future. Washington, D.C.: World Bank Institute.

Giordano, Meredith A., Frank R. Rijsberman, and R. Maria Saleth, eds. 2006. 'More Crop per Drop': Revisiting a Research Paradigm. Results and Synthesis of IWMI's Research, 1996-2005. London: IWA Publishing and IWMI.

Global Water Partnership (GWP). 2000. Integrated Water Resources Management. *GWP Technical Committee Background Paper 4*. Stockholm: GWP.

Görgens, A.H.M., and B.W. van Wilgen. 2004. Invasive Alien Plants and Water Resources in South Africa: Current Understanding, Predictive Ability and Research challenges. *South African Journal of Science* 100: 27-33.

Groenwald, Yolandi. 2007. Why the Kruger Rivers Ran Dry. *Mail and Guardian*, April 13-19, 2007, page 6.

Hassan, R.M., and S. Farolfi. 2005. Water value, resource rent recovery and economic welfare cost of environmental protection: A water-sector model for the Steelpoort sub-basin in South Africa. Water SA 31(1):9-16 (also available at www.wrc.org.za).

Hughes, D.A. 2001. Providing Hydrological Information and Data Analysis Tools for the Determination of the Ecological In-stream Flow Requirements for South African Rivers. *Journal of Hydrology* 241 (1-2), 140-151.

Hughes, DA and Hannart, P. 2003. A desktop model used to provide an initial estimate of the ecological in-stream flow requirements of rivers in South Africa. *Journal of Hydrology* 270(3-4), 167-181.

International Water Management Institute (IWMI). 2002. Achieving Sustainable Local Management of Irrigation Water in Water-Short Basins: South Africa Case Study. Final Technical Report to DFID, Reference NRE 9800 605/966/001A. Unpublished project report. Pretoria: IWMI.

Jonker, L. 2006. Integrated Water Resources Management: The Theory-praxis-nexus. Paper presented at the 7th WaterNet / WARFSA / GWP-SA Symposium, Lilongwe, Malawi, 1-3 November 2006.

Joubert, C. 2001. Olifants River Ecological Water Requirements Assessment. Social Utilisation of the Olifants River.) Department of Water Affairs and Forestry. Report PB 000-00-6099.

Kamara, A. B.; Van Koppen, B.; Magingxa, L. 2002. Economic viability of small-scale irrigation systems in the context of state withdrawal: The Arabie Scheme in the Northern Province of South Africa. *Physics and Chemistry of the Earth* 27:815-823.

Keller, Andrew, Jack Keller, and David Seckler. 1996. Integrated Water Resource Systems: Theory and Policy Implications. IIMI Research Report No. 3. Colombo: IIMI.

Kijne, J.W., R. Barker, and D. Molden, eds. 2003. Water Productivity in Agriculture: Limits and Opportunities for Improvement. Comprehensive Assessment of Water Management in Agriculture Series 1. Cambridge, MA: CABI Published in association with IWMI.

King, J., Tharme, R.E. and de Villiers, M.S. 2000. Environmental Flow Assessments for Rivers: Manual for the Building Block Methodology. Water Research Commission Technology Transfer Report No. TT 131/00, Pretoria, South Africa.

King, J. and Louw, M.D. 1998. Instream Flow Assessments for Regulated Rivers in South Africa Using the Building Block Methodology. *Aquatic Ecosystem Health and Management* 1, 1029-124.
Klarenberg, G. no date. Mining in the Olifants Basin. Unpublished report prepared for IWMI. Pretoria: IWMI.

Ladki, Marwan, Jetrick Seshoka, Nicolas Faysse, Heré Lévite, and Barbara van Koppen. 2004. Possible Impacts of the Transformation of Water Infrastructure on Productive Water Uses. IWMI Working Paper No. 74. Colombo: IWMI, CEMAGREF and Comprehensive Assessment of Water Management in Agriculture.

Lahiff, Edward P. 1999. Land Tenure on the Arabie-Olifants Irrigation Scheme. South Africa Working Paper No. 2. Colombo: IWMI and Nkuzi Development Association.

Lahiff, Edward. 2007. Land Redistribution in South Africa: Progress to Date. Paper prepared for workshop on "Land Redistribution in Africa: Towards a Common Vision." http://www.sarpn.org/documents/d0002695/Land_Redistribution_South_Africa.pdf.

Lankford, Bruce, Douglas J. Merrey, Julien Cour, and Nick Hepworth. 2007. From Integrated to Expedient: An Adaptive Framework for River Basin Management in Developing Countries. IWMI Research Report No. 110. Colombo: IWMI.

Le Maitre, D.C. 1999. *Adjustments of WR90 Naturalised flows to allow for streamflow reductions based on the CSIRs streamflow reduction model*. Report for the Department of Water Affairs and Forestry, Pretoria, South Africa.

Le Roy, Edouard. 2005a. A Study of the Development of Water Resources in the Olifants Catchment, South Africa: Application of the WEAP Model. Thesis submitted for M.Sc. and Diploma, Imperial College London.

Le Roy, Edouard. 2005b. Addendum [to thesis, Le Roy 2005a]. Impact of the New De Hoop Dam on the Steelpoort River Resources: Application of WEAP.

Lévite, Hervé, and Hilmy Sally. 2001. Linkages between Productivity and Equitable Allocation of Water. Paper presented at 2nd WARFSA/Waternet Symposium: Integrated Water Resources Management: Theory, Practice, Cases. Capetown, South Africa, 30-31 October 2001

Lévite, Hervé. 2003. Quantification of the Inequities in Water Use in Ex-homelands and ex-RSA in Olifants. Draft discussion note, 26 November 2003, IWMI. Unpublished.

Lévite, Hervé, Barbara Van Koppen, and Matthew McCartney. 2003a. The Basin Development Trajectory of the Olifants Basin, South Africa. Paper presented at the WARFSA/WaterNet Symposium, Gabarone, Botswana.

Lévite, Hervé, Hilmy Sally, and Julien Cour. 2003b. Testing Water Demand Scenarios in a Water-stressed Basin in South Africa: Application of the WEAP Model. *Physics and Chemistry of the Earth* 28: 779-786.

Lévite, Hervé, Nicolas Faysse, and Florence Adorino. 2003c. Resolving Water Use Conflicts through Stakeholder Participation: Issues and Examples from the Steelpoort Basin in South Africa. *African Water Journal*, December 2003, Pp. 30-42.

Ligthelm, Magda. 2001. Olifants Water Management Area: Catchment Management Agency Establishment. In: Abernethy, Charles, ed. 2001, *Intersectoral management of river basins: Proceedings of an international workshop on "Integrated water management in water-stressed river basins in developing countries: Strategies for poverty alleviation and agricultural growth"*. Colombo, Sri Lanka: IWMI and DSE. (Available on CD.)

Louw, M. D. and Palmer, C. 2001. Olifants River Ecological Water Requirements Assessment. Ecological Management Class: Technical Input. Final Report. Department of Water Affairs and Forestry. Report PB 000-00-5499.

Machethe, C.L., N. M. Mollel, K. Ayisi, M. B. Mashotala, D. D. K. Anin, and F. Vanasche. 2004. Smallholder Irrigation and Agricultural Development in the Olifants River Basin of Limpopo Province: Management Transfer, Productivity, Profitability and Food Security Issues. WRC Report No. 1050/1/04. Pretoria, South Africa: Water Research Commission.

Macleod, Fiona. 2007. Damned from the Start. *Mail & Guardian*, 12 February 2007 (http://www.mg.co.za/articlePage.aspx?articleid=263265&area=/insight/insight__national/).

Magombeyi, M.S., D. Rollin, and B. Lankford. 2006a. The Use of the River Basin Game as a Tool for the Implementation of the Waternet CP Project in South Africa. Paper presented at 7th Waternet/ WARFSA/ GWPSA Symposium, 1-3 November 2006, Lilongwe, Malawi.

Magombeyi, M.S., A.E. Taigbenu, and D. Rollin. 2006b. Integrating Hydrological and Socio-economic Aspects for Sustainable Catchment Management: Needs and Opportunities. Paper presented at 7th Waternet/ WARFSA/ GWPSA Symposium, 1-3 November 2006, Lilongwe, Malawi.

Marshall, Leon. 2007. Antidote Sought for Poisoned Water. *Pretoria News*, Friday 20 July 2007, p.13.

McCartney, M.P., Saranga, S.D. and Mugabe, J. 1998. Lower Limpopo river basin assessment: Hydrology and hydrogeology sectoral report. 47pp + appendices. Report to UNEP.

McCartney, Matthew Peter; Yawson, Daniel. K.; Magagula, Thulani F.; Seshoka, Jetrick. 2004. Hydrology and water resources development in the Olifants River Catchment. Colombo, Sri Lanka: IWMI. IWMI Working Paper No. 76). Colombo: IWMI.

McCartney, M.P., D. Yawson, and A. Huber-Lee. 2005. Simulating Water Resource Development in the Olifants Catchment, South Africa. IWMI Theme 1 Draft Report. Unpublished.

McCartney, Matthew, and Roberto Arranz. 2007. Evaluation of Historic, Current and Future Water Demand in the Olifants River Catchment, South Africa. Draft IWMI Research Report, 23 April 2007. Unpublished.

Merrey, D. J., Drechsel, P., Penning de Vries, P., and H. Sally. 2005. Integrating 'Livelihoods' into Integrated Water Resources Management: Taking the Integration Paradigm to its Logical Next Step for Developing Countries. *Regional and Environmental Change* 5:197-204.

Merrey, Douglas J., Regassa Namara, and Marna de Lange. 2006. Agricultural Water Management Technologies for Small Scale Farmers in Southern Africa: An Inventory and Assessment of Experiences, Good Practices and Costs. Final Report Produced by the International Water Management Institute (IWMI) Southern Africa Regional Office, Pretoria, South Africa for the Office of Foreign Disaster Assistance, Southern Africa Regional Office, United States Agency for International Development and the Investment Centre of the Food and Agriculture Organization of the United Nations. Pretoria: IWMI (available on CD, "Resources on Micro-Agricultural Water Management in Southern Africa," May 2006).

Merrey, D. J., Meinzen-Dick, R., Molinga, P., and Karar, E. 2007. Policy and Institutional Reform: The Art of the Possible. Chapter 5 in: D. Molden, ed., *Water for Food, Water for Life: The Comprehensive Assessment of Water Management in Agriculture*. Earthscan, UK. Pp.193-232.

Midgley, D.C., W.V. Pitman, and B.J. Middleton. 1994. Surface Water Resources of South Africa 1990. 6 volumes. WRC Reports No. 298/1.1/94 to 298/6.1/94. Pretoria: Water Resources Commission.

Mokuoane, Edward. 2001. Revised Protocol on Shared Watercourses in the Southern African Development Community. In: Abernethy, Charles, ed. 2001, *Intersectoral Management of River Basins: Proceedings of an international workshop on "Integrated water management in water-stressed river basins in developing countries: Strategies for poverty alleviation and agricultural growth"*. Colombo, Sri Lanka: IWMI and DSE.

Molden, D., 1997. Accounting for Water Use and Productivity. SWIM Paper 1. Colombo: IWMI.

Molden, D.J., R.C. Sakthivadivel, C. Perry, C. de Fraiture, and W.H. Kloezen. 1998. Indicators for Comparing Performance of Irrigated Agricultural Systems. IIMI Research Report 20. Colombo: IIMI.

Molden, D.J., R. Sakthivadivel, and Z. Habib. 2001. Basin Use and Productivity of Water: Examples from South Asia. IWMI Research Report No. 49. Colombo: IWMI.

Molden, D.J., Sakthivadivel, R. and Keller, J. 2001. Hydronomic zones for developing basin water conservation strategies. Research Report 56. Colombo, Sri Lanka. International Water Management Institute.

Molden, David, and Douglas Merrey. 2002. Managing Water from Farmers' Fields to River Basin: Implications of Scale. In: A.R. Turton and R. Henwood, eds.,*Hydropolitics in the Developing World: A Southern African Perspective*. Pretoria: Africa Water Issues Research Unit, Centre for International Political Studies, University of Pretoria. (CD-ROM produced by IWMI).

Molden, David, R. Sakthivadivel, M. Samad, and Martin Burton. 2005. Phases of River Basin Development: The Need for Adaptive Institutions. In: Mark Svendsen, ed.,*Irrigation and River Basin Management: Options for Governance and Institutions*. Wallingford, UK; Colombo, Sri Lanka: CABI; IWMI.

Molden, D., Sakthivadivel, R., and Keller, J. (2001). Hydronomic Zones for Developing Basin Water Conservation Strategies. *IWMI Research Report 56*. Colombo: IWMI.

Molden, David, Theib Y. Oweis, and others. 2007. Pathways to Increasing Agricultural Water Productivity. Chapter 7 in: David Molden, ed., *Water for Food, Water for Life: The Comprehensive Assessment of Water Management in Agriculture*. Earthscan, UK.

Molden, David, ed. 2007. Water for Food, Water for Life: The Comprehensive Assessment of Water Management in Agriculture. Earthscan, UK.

Molle, François. no date. River Basin Development: A Framework for Case Studies. http://www.iwmi.cgiar.org/assessment/files/word/ProjectDocuments/METHODO%20basin%20studies%20CA.pdf. Unpublished.

Molle, François. 2003. Development Trajectories of River Basins: A Conceptual Framework. IWMI Research Report 72. Colombo: IWMI.

Molle, François. 2006. Planning and Managing Water Resources at the River-Basin Level: Emergence and Evolution of a Concept. Comprehensive Assessment of Water Management in Agriculture Research Report 16. Colombo: IWMI.

Molle, François, and Peter Mollinga. 2003. Water Poverty Indicators: Conceptual Problems and Policy Issues. *Water Policy* 5:529-544.

Molle, François. Philippus Wester, and Phil Hirsch. 2007. River Basin Development and Management. Chapter 16 in: Molden, David, ed. 2007. *Water for Food, Water for Life: The Comprehensive Assessment of Water Management in Agriculture*. Earthscan, UK. Pp. 585-625.

Monson, J., K. Hall, C. Smith, and M. Shung-King, eds. 2006. South African Child Gauge 2006. Cape Town: Children's Institute, University of Cape Town.

Morgan, Lewis H. 1877. Ancient Society, or Researches in the Lines of Human Progress from Savagery to Barbarism to Civilization. London: MacMillan & Company. http://www.marxists.org/reference/archive/morgan-lewis/ancient-society/index.htm.

Mpahlele, R.E., T.M. Malakalaka, and B. Hedden-Dunkhorst. 2000. Characteristics of Smallholder Irrigation Farming in South Africa: A Case Study of the Arabie-Olifants River Irrigation Scheme. IWMI South Africa Working Paper No. 3. Colombo: IWMI and University of the North.

Muller, Mike. 2001. How National Water Policy is Helping to Achieve South Africa's Development Vision. In: Abernethy, Charles, ed. 2001, *Intersectoral Management of River Basins: Proceedings of an international workshop on "Integrated water management in water-stressed river basins in developing countries: Strategies for poverty alleviation and agricultural growth"*. Colombo, Sri Lanka: IWMI and DSE.

Newby, T., E.K. Mbatha, T. Germishuyse, and R. Tswai. 2005. Extended Household Survey Report for FIVIMS-ZA. January, 2005. Pretoria: Agricultural Research Council-Institute for Soil, Climate and Water.

Palmer, R. 2001a. Olifants River Ecological Water Requirements Assessment: Middle Olifants Comprehensive Ecological reserve (Water Quantity). Department of Water Affairs and Forestry. Report PB 000-00-5699.

Palmer, R. 2001b. Olifants River Ecological Water Requirements Assessment: Middle Olifants Comprehensive Ecological reserve (Water Quantity). Department of Water Affairs and Forestry. Report PB 000-00-5799.

Palmer, R. 2001c. Olifants River Ecological Water Requirements Assessment: Lower Olifants Comprehensive Ecological reserve (Water Quantity). Department of Water Affairs and Forestry. Report PB 000-00-5899.

Peden, D., A. Freeman, A. Astake, A. Notenbaert. 2005. Investment options for integrated water-livestock-crop production in sub-Saharan Africa. Final Report submitted to IWMI by the International Livestock Research Institute. Submitted by IWMI to the African Development Bank as part of the Collaborative Program on

"Investments in Agricultural Water Management in Sub Saharan Africa: Diagnosis of Trends and Opportunities." Pretoria: IWMI.

Peden, Don, Girma Tadesse, and A.K. Misra. 2007. Water and Livestock for Human Development. Chapter 13 in: D. Molden, ed., *Water for Food, Water for Life: The Comprehensive Assessment of Water Management in Agriculture*. Earthscan, UK. pp.485-514.

Prasad, Krishna Chandra. 2004. Socioeconomic Module for Decision Support for Water Resources Management in South Africa. Ph.D. Thesis submitted to the Department of Civil, Environmental and Architectural Engineering, University of Colorado.

Prasad, Krishna, Kenneth M. Stryzepek, and Barbara van Koppen. 2007. An Approach to Assessing Socioeconomic Implications of Water Management Alternatives. *Water Policy* 9: 131-147.

Ramoeli, Phera. 2002. The SADC Shared Protocol on Water Resources: Its Origins and Current Status. In: Anthony Turton and Roland Henwood, eds., *Hydropolitics in the Developing World: A Southern African Perspective*. Pretoria: AWIRU, Centre for International Political Studies, University of Pretoria (CD-ROM version produced by IWMI).

Reader, John. 1998. *Africa: A Biography of a Continent*. London: Penguin Books. Republic of South Africa. 2005. Invitation to submit written comments in terms of Section 110 the National Water Act, 1998 (Act 36 of 1998) on the proposed construction of phase 2 of the proposed Olifants River Water Resource Development Project and environmental impact assessment elating [*sic*] thereto. Government Gazette Volume 484. Pretoria, 28 October 2005. Number 28167 (DWAF No. 1057).

Sadoff, Claudia W., Dale Whittington, and David Grey. 2002. Africa's International Rivers: An International Perspective. Washington, D.C.: World Bank.

Schreiner, Barbara, and Barbara van Koppen. 2001. Catchment Management Agencies for Poverty Eradication in South Africa. Paper presented at 2nd WARFSA/WaterNet Symposium on Integrated Water Resources Management Theory, Practice, Cases, Capetown, 30-31 October 2001.

Schreiner, Barbara, Barbara van Koppen, and Tshepo Khumbane. 2002. From Bucket to Basin: A New Water Management Paradigm for Poverty Eradication and Gender Equity. In: A.R. Turton and R. Henwood, eds., *Hydropolitics in the Developing World: A Southern African Perspective.* Pretoria: Africa Water Issues Research Unit, Centre for International Political Studies, University of Pretoria. (CD-ROM produced by IWMI).

Schreiner, Barbara, Ndileka Mohapi, and Barbara van Koppen. 2004. Washing Away Poverty: Water, Democracy and Gendered Poverty Eradication in South Africa. *Natural Resources Forum* 28:171-178.

Seckler, David. 1996. The New Era of Water Resources Management: From 'Dry' to 'Wet' Water Savings. IWMI Research Report No. 1. Colombo: IWMI.

Seetal, Ashwin R., and Gavin Quibell. 2005. Water Rights Reform in South Africa. In: Bryan Randolph Bruns, Claudia Ringer, and Ruth Meinzen-Dick, eds. *Water Rights Reform: Lessons for Institutional Design*. Washington, D.C.: International Food Policy Research Institute.

Seshoka, J., W. de Lange, and N. Faysse. 2004. The Transformation of Irrigation Boards into Water Users Associations in South Africa: Case Studies of the Lower Olifants, Great Letaba and Vaalharts Water Users Associations. Volume 1. IWMI Working Paper 72. Colombo: IWMI.

Shah, T., Barbara van Koppen, Douglas Merrey, Marna de Lange, and Madar Samad. 2002. Institutional Alternatives in African Smallholder Irrigation: Lessons from International Experience with Irrigation Management Transfer. IWMI Research Report No 60. Colombo: IWMI.

Shah, Tushaar, Ian Makin, and R. Sakthivadivel. 2005. Limits to Leapfrogging: Issues in Transposing Successful River Basin Management Institutions in the Developing World. In: Mark Svendsen, ed., *Irrigation and River Basin Management: Options for Governance and Institutions*. Wallingford, UK; and Colombo, Sri Lanka: CABI; IWMI.

Simpungwe, Eliab. 2006. Water, Stakeholders and Common Ground: Challenges for Multi-Stakeholder Platforms in Water Resource Management in South Africa. Ph.D. Dissertation. Wageningen, The Netherlands: Wageningen University.

Small, H.S. and Chris M. Stimie. 2000. An Investigation into Water Use at the Arabie- Olifants Irrigation Scheme. IWMI South Africa Working Paper 4. Colombo: IWMI.

Soppe, Richard, Petra Hellegers, Chris. Perry, Dirk Boon, Wim Bastiaanssen, Martin de Wit, and Henk Pelgrum. 2006. Combining Remote Sensing and Economic Analysis to Assess Water Productivity: A Demonstration Project in the Inkomati Basin. Final Report. Wageningen and The Hague: Water Watch and LEI (accessed 17 January 2007, ftp://remote.waterwatch.nl.

Stimie, Chris, Eric Richters, Hubert Thompson, Sylvain Perret, Mampiti Matete, Khabbab Abdallah, Joseph Kau, and Elvis Mulibana. 2001. Hydro-Institutional Mapping in the Steelpoort River Basin, South Africa. IWMI Working Paper No. 17. Colombo: IWMI and ARC-ILI.

Stockholm Environment Institute (SEI) 2001. WEAP: Water Evaluation and Planning System – User Guide. Boston, USA: SEI.

Svendsen, Mark, ed. 2005. Irrigation and River Basin Management: Options for Governance and Institutions. Wallingford, UK; and Colombo, Sri Lanka: CABI; IWMI.

Svendsen, Mark, Philippus Wester, and François Molle. 2005. Managing River Basins: An Institutional Perspective. In: Svendsen, Mark, ed. 2005. *Irrigation and River Basin Management: Options for Governance and Institutions.* Wallingford, UK; and Colombo, Sri Lanka: CABI; IWMI.

Tapela, Barbara Nompumelelo. 2005. Joint Ventures and Livelihoods in Emerging Small-Scale Irrigation Schemes in Greater Sekhukhune District: Perspectives from Hereford. Programme for Land and Agrarian Studies Research Report No. 21, School of Government, Western Cape.

Tharme, R.E. and King, J.M. 1998. Development of the Building Block Methodology for Instream Flow Assessments and supporting research on the effects of different magnitude flows on riverine ecosystems. Water Research Commission Report No. 576/1/98. Pretoria: Water Research Commission.

Thompson, H., C.M. Stimie, E. Richters, and S. Perret. 2001. Policies, Legislation and Organizations Related to Water in South Africa, with Special Reference to the Olifants Basin. IWMI Working Paper 18. Colombo: IWMI and ARC-ILI.

Tren, R. and Schur, M. 2000. Olifants River Irrigation Schemes. Reports 1 & 2. South Africa Working Paper No. 5 (IWMI Working Paper No. 3). Colombo: IWMI.

Turton, A.R., and L. Ohlsson. 1999. Water Scarcity and Social Stability: Towards a Deeper Understanding of the Key Concepts Needed to Managing Water Scarcity in Developing Countries. Occasional Paper 17, Water Issues Study Group, SOAS, University of London.

Turton, Anthony, and Richard Meissner. 2002. The Hydrosocial Contract and its Manifestion in Society: A South African Case Study. Chapter 3 in: Anthony Turton and Roland Henwood, eds., *Hydropolitics in the Developing World: A Southern African Perspective*. Pretoria: African Water Issues Research Unit, University of Pretoria (cd version available through IWMI).

Turton, Anthony Richard. 2003. The Political Aspects of Institutional Developments in the Water Sector: South Africa and Its International River Basins. Unpublished PhD Thesis. Pretoria: University of Pretoria, 31 May 2003.

Turton, A.R., R, Meissner, P.M. Mampane, and O. Seremo. 2004. A Hydropolitical History of South Africa's International River Basins. WRC Report No. 1220/1/04.
Pretoria: Water Research Commission.

Turton, Anthony R., and Anton Earle. 2005. Institutions in South Africa International River Basins. In: Chennat Gopala Krishnan, Cecila Tortajada, and Asit K. Biswas, eds., *Water Institutions: Policies, Performance and Prospects*. Berlin: Springer.

Uiterweer, Nynke C. Post, Margreet Z. Zwarteveen, Gert Jan Veldwisch, and Barbara van Koppen. 2006. Redressing Inequities through Domestic Water Supply: A 'Poor' Example from Sekhukhune, South Africa. In: Sylvain Perret, Stefano Farolfi, and Rashid Hassan, eds., *Water Governance for Sustainable Development: Approaches and Lessons from Developing and Transitional Economies*. London: Earthscan. Pp. 54-74.

UN-HABITAT/UNEP. 2007. Limpopo Basin Strategic Plan for Reducing Vulnerability to Floods and Droughts. Draft for discussion with Riparian Governments. Maputo: UN-HABITAT.

van Heerden, Pieter. 2004. Estimating Water Requirements and Water Storage Requirements for Farms, Community and Backyard Gardens, and for Large Irrigation Systems: A User Manual for PLANWAT Version 1.2.3b and a CD-ROM to install this Program. IWMI Working Paper 82. Colombo: IWMI.

van Koppen, Barbara, Patrick Moriarty, and Eline Boelee. 2006a. Multiple-Use Water Services to Advance the Millennium Development Goals. IWMI Research Report No. 98. Colombo: IWMI.

van Koppen, Barbara, Tshepo Khumbane, Marna de Lange, and Ndileka Mohapi. 2006b. Gender and Agricultural Productivity: Implications for the Revitalization of Smallholder Irrigation Schemes Program in Sekhukhune District, South Africa. Accepted in: Kuntala Lahiri-Dutt, ed. *Fluid Bonds: Views on Gender and Water*. Calcutta: Stree.

van Koppen, Barbara. 2007. The Basin Development Trajectory of the Olifants Basin in South Africa before 1994. Draft, January 2007. Unpublished.

Van Veelen, M., T. Coleman, H. Thompson, T. Baker, K. Bowler, M. de Lange, and I. Sibuyi. 2002. Proposal for the Establishment of a Catchment Management Agency for the Olifants Water Management Area. BKS Report 8184h. Draft submitted to DWAF by BKS (Pty) Ltd.

Veldwisch, Gert. Jan. 2006. Local Governance Issues after Irrigation Management Transfer: A Case Study from Limpopo Province, South Africa. In: Sylvian Perret, Stefano Farolfi, and Rashid Hassan, eds., *Water Governance for Sustainable Development: Approaches and Lessons from Developing and Transitional Economies*. London: Earthscan.

Wallgren, Oskar. 2000. Water Allocation in the Olifants River Basin, South Africa: An Evaluation of Options. Master of Environmental Studies thesis, University of Waterloo, Ontario, Canada.

Wester, Philippus, and J.Warner. 2002. River Basin Management Reconsidered. In: A.R. Turton and R. Henwood, eds., *Hydropolitics in the Developing World: A Southern African Perspective*. Pretoria: Africa Water Issues Research Unit, University of Pretoria.

Wester, Philippus, Douglas J. Merrey, and Marna de Lange. 2003. Boundaries of Consent: Stakeholder Representation in River Basin Management in Mexico and South Africa. *World Development* 31 (5):797-812.

Wolf, Aaron T., Shira B. Yoffe, and Mark Giordano. 2003. International Waters: Identifying Basins at Risk. *Water Policy* 5: 29-60.

Yawson, D.K., H. Sally, and T. F. Magagula. no date. The Olifants River Basin: Water Accounting and Water Use. Draft Paper (never published). IWMI.

Ziervogel, Gina, Anna Taylor, Frank Thomalla, Takeshi Takama, and Claire Quinn. 2006. Adapting to Climate, Water and Health Stresses: Insights from Sekhukhune, South Africa. Stockholm: Stockholm Environment Institute.