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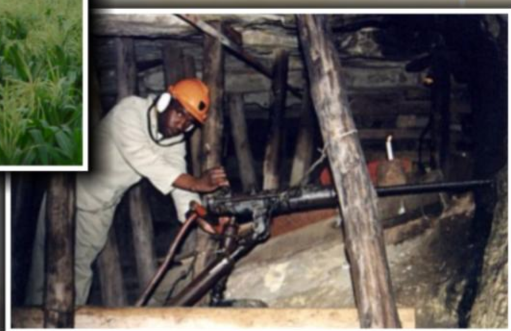
Vaal River System: Large Bulk Water Supply Reconciliation Strategy

IRRIGATION WATER USE AND RETURN FLOWS



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DEPARTMENT OF WATER AFFAIRS AND FORESTRY

DIRECTORATE: NATIONAL WATER RESOURCE PLANNING

VAAL RIVER SYSTEM: LARGE BULK WATER SUPPLY RECONCILIATION STRATEGY

Irrigation Water Use and Return Flows

February 2007

VAAL RIVER SYSTEM: LARGE BULK WATER SUPPLY RECONCILIATION STRATEGIES

LIST OF REPORTS

Report No:	Title
P RSA C000/00/4406/01	Urban water requirements and return flows
P RSA C000/00/4406/02	Potential savings through WC/WDM in the Upper and Middle Vaal water management areas
P RSA C000/00/4406/03	Re-use options
P RSA C000/00/4406/04	Irrigation water use and return flows
P RSA C000/00/4406/05	Water resource analysis
P RSA C000/00/4406/06	Groundwater Assessment: Dolomite Aquifers
P RSA C000/00/4406/07	First stage reconciliation strategy

Above list of reports effective as at December 2006

VAAL RIVER SYSTEM: LARGE BULK WATER SUPPLY RECONCILIATION STRATEGY

IRRIGATION WATER USE AND RETURN FLOWS

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Authors:	***HG Maré and Task Team***
Project Name:	***Vaal River System: Large Bulk Water Supply Reconciliation Strategy***
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VAAL RIVER SYSTEM: LARGE BULK WATER SUPPLY RECONCILIATION STRATEGY

IRRIGATION WATER USE AND RETURN FLOWS

EXECUTIVE SUMMARY

Introduction

The Large Bulk Water Supply Reconciliation Strategy for the Vaal River System Study has the objective to develop strategies for meeting the growing water requirements of the industrial and urban sectors that are served by the Integrated Vaal River System.

The key objectives of the study are to:

- *Update the current and future urban and agricultural water requirements.*
- *Assess the water resources and existing infrastructure.*
- *Take into account the Reserve requirements for alternative classifications.*
- *Formulate reconciliation interventions, both structural and administrative/regulatory.*
- *Conduct stakeholder consultation in the development of the strategies.*

The core of the study area consists of the Upper, Middle and Lower Vaal River Water Management areas (WMA's), however, due to the numerous inter-basin transfers that link this core area with other WMA's, reconciliation planning has to be undertaken in the context of the Integrated Vaal River System which also includes portions of the Komati, Usutu, Thukela and Senqu River (Located in Lesotho) catchments.

<u>This report describes</u> the Irrigation Sector developments, economic importance and related demands and return flows. To be able to achieve this, the following aspects were addressed:

- *Comparisons of data from different data sources*
- *The economic importance of the irrigation sector*
- *Possible Water Conservation and Water Demand Management (WC/WDM) measures*
- *Possible trading of water rights*
- *Alternative future irrigation demand scenarios*
- *Assurance of supply requirements and operating rules*
- *Application of a water requirement and return flow model for irrigation*

Comparisons of data from different data sources

Three separate Water Authorisation Registration Management System (WARMS) databases were received from the Department of Water Affairs & Forestry (DWAF), one from Gauteng, one from the Free State and one from the Northern Cape. The data was up to November 2005. This data was consolidated, manipulated and adjusted where appropriate.

For comparison purposes the following data sets were used:

- *The theoretical irrigation water use based on the typical crop combinations as obtained from the Loxton Venn study.*
- *The irrigation demands obtained from the Vaal River System Analysis Update (VRSAU) study which was used mainly in the Water Resource Yield Model (WRYM) and for the Lower Vaal also in the Water Resource Planning Model (WRPM) data sets.*
- *The irrigation volumes obtained from the WARMS data base and processed for the purposes of this study, for the scenario where all the allocations greater than 12 000 m^3/ha/a were capped at a maximum of 12 000 m^3/ha/a.*
- *Other sources, which typically includes studies on localised areas, which can provide more insight into irrigation development for some of the sub-catchments.*
- *For the Upper Vaal WMA, the data obtained from the "Validation and Verification of the existing lawful use in the Upper Vaal Water Management Area" study, which will most probably also be used as the suggested data set for the analyses to be carried out as part of this study.*

The validation of irrigation development in the Upper Vaal WMA showed that the registered data provided in most cases a total over estimation of the actual water use, and can therefore not be relied upon. It was therefore necessary to improve the irrigation data for the Middle and Lower Vaal WMAs as no validated data were available for these two WMAs. The data from the Validation Verification study provided the best data currently available for the Upper Vaal WMA. Meetings were held with the DWAF Regional offices in Bloemfontein and Kimberley as well as with the Irrigation Scheme manager at the Vaalharts Irrigation Scheme, to discuss the data from the different data sources. Based on their experience and knowledge of the irrigation schemes and catchments, the most appropriate irrigation volume was selected for use in this study and in some cases more accurate and recent data were provided by the Regional Offices.

*Summarised results are given in **Table i**. The irrigation data selected for the Upper Vaal WMA was obtained from the Verification Validation study and is the best data currently available. Although the Verification Validation study currently mainly focuses on the* *validation of the registered data, a preliminary estimation of the law-full use was also included. This is not the final verified law-full use, but can be used as a first order indication of the law-full irrigation in the sub-catchments. Due to the large increase in irrigation between 1998 and 2005 it can be expected that the increasing trend will continue for some time until sufficient measures had been put in place and actions had been taken to eradicate the unlawful water use in the catchments (see Figure A-2 in Appendix A). The largest increase in irrigation occurred in the Frankfort and Vaal Dam incremental catchments. This is a great concern as these two catchments receive large volumes of expensive transferred water from the Lesotho Highlands and Thukela schemes which is seemingly used for unlawful irrigation.*

Table i : Comparison of irrigation requirements in Vaal River System (million m³/a)

Description	VRSAU	Loxton Venn	WARMS	Suggested 2005	Validation / Verification		
					2005	1998	Lawful
Upper Vaal WMA		*					
Upstream of Vaal Dam	94	63	449	269	269	133	85
Vaal Dam to Mooi River	134	80	145	125	125	89	68
Sub-total	**228**	**143**	**594**	**394**	**394**	**223**	**153**
Middle Vaal WMA	**210**	**162**	**369**	**228**			
Lower Vaal WMA	*						
Vaalharts Scheme	350	354	364	328			
Remainder of irrigation	113	106	48	110			
Sub-total	**462**	**460**	**412**	**438**			
Total Vaal	**900**	**765**	**1375**	**1060**			

*Note: * - The data in the highlighted column was used in the WRPM data sets for the annual operating analysis of the Integrated Vaal River System, preceding this Reconciliation Study.*

The fact that not all the allocated irrigation areas within the Vaalharts and Taung irrigation schemes is currently developed or utilised, is the main reason for the recommended irrigation volume to be approximately 6% lower than what was previously used in the models.

The recommended irrigation volume for 2005 development level for the total Vaal River catchment is approximately 295 million m³/a higher than that used in recent studies. This is a substantial volume and will have a significant impact on the water supply situation in the Vaal River system. At the 2005 development level there is already approximately 235 million m³/a of unlawful irrigation (preliminary estimates) abstractions within the Upper Vaal.

Alternative future irrigation demand scenarios

Given that the current (year 2005) water use estimates are significantly higher than the preliminary estimates of what is considered lawful, a scenario was compiled where it was assumed that the current water use will be reduced over the medium term through legal interventions and water use compliance monitoring. This is referred to as Scenario 1, and for this scenario it was assumed that the growing trend continuous for two years until 2008 when eradication of unlawful irrigation water becomes effective and decrease the water use over a period of 4 years to the lawful volume plus 15% by the year 2011.

For Scenario 2 it is assumed that no curtailment of illegal use will take place and that irrigation demand will continue to grow until the registered volume from the WARMS database is reached.

The Irrigation Scenario 2 will create an unsustainable situation in the Vaal River System and is not considered to be viable. However, this scenarios was derived to illustrate the potential impact should the situation arises where the interventions are not successful to cut back the illegal water use.

Other possible irrigation demand growth scenarios will be addressed and evaluated in Stage 2 of the Vaal River System Reconciliation strategies based on results and recommendations from Stage 1.

Assurance of supply requirements and operating rules

Different types of user groups or categories will require a different assurance of supply. Irrigation will typically be supplied at a lower assurance than water for domestic and industrial purposes and water for strategic industries such as power generation at an even higher assurance. It is therefore important to sub-divide the demand of the different user categories into three or four priority classes, which represent different assurance or reliability levels. This is generally referred to as the priority classification. The priority classification currently used in the Vaal River System Analyses is shown in ***Table ii.***

From ***Table ii*** *it is evident that 50% of the irrigation demand is supplied at a low assurance of 95%, which is in general a fairly good assurance for irrigation purposes. The other 50% of the irrigation demand is supplied at very high assurances, in particular for irrigation purposes. There is therefore room for changes in the priority classification, in particular with regards to the irrigation users. Allowing a larger portion of the irrigation demand to be supplied at the low assurance of 95% or even at lower assurances, will make more water available for use in the Vaal River System.*

To determine the effect of different priority classifications and other operating rules on the water supply to irrigation in the Vaal System will be carried out as part of Stage 2 of the Vaal River System Reconciliation strategies. Different possible scenarios in this regard will largely follow from the findings and recommendations obtained from Stage 1 of the study.

Table ii: Priority classifications and assurances of supply for Vaal System

User	User priority classification (Assurance of Supply)		
	Low (95%) or 1 in 20 years	Medium (99) or 1 in 100 years	High (99.5%) or 1 in 200 years
	Proportion of Water demand supplied (%)		
Domestic	30	20	50
Industrial	10	30	60
Strategic Industries	0	0	100
Irrigation	50	30	20

Possible WC/WDM measures

Water conservation and water demand management in the irrigation sector is a very important aspect and was addressed in a separate report "Potential savings through WC/WDM in the Upper and Middle Vaal water management areas, P RSA C000/00/4405/02" which is part of the set of reports prepared for this study. The general perception with regards to savings in the irrigation sector is that the savings will be utilised for use by resource poor farmers or by the farmers themselves to increase their area of irrigation.

The economic importance of the irrigation sector at 2006 development level

An economic model was used with the objective to estimate the economic value of agricultural production in the Vaal catchment area. In order to do this, a mathematical programming model was compiled in order to simulate current agricultural production in financial terms in the project area. Once this has been achieved, various economic analyses and scenarios can be undertaken.

The *main assumptions for the financial analysis were the following:*

- *The financial analysis is undertaken over a 20 year period.*
- *The financial analysis is done in constant 2006 Rand values (therefore projected inflation is not included in the model and the estimated returns should be seen as real returns).*

- *No residual value or salvage value of the project is included at the end of the project.*
- *The cost of land and existing infrastructure is not included.*
- *No finance costs are included in the analysis*
- *Income and production costs are derived from the gross margin estimates.*
- *In regard to perennial orchard crops it is assumed that 5% of the total area is established every year, therefore the aging of the enterprise is estimated accordingly. For lucerne it is assumed that 20% of the total area will be established every year.*
- *Overhead costs have been estimated for each enterprise and is included in the analysis. These include management salaries, general repairs, bank charges, auditing fees etc.*

The model was run to estimate the net present value (NPV) of the different enterprise areas. This analysis excludes all existing infrastructure and land costs as this is assumed to be a sunk cost. A summary of the results is given in ***Table iii.***

Table iii: Results from the financial model

Item	***Rands (million)***
Gross Income	*2,253*
Direct production Costs	*1,329*
Gross Margin	*923*
Overhead Costs	*239*
Net Income (before finance costs and tax)	*684*
Net Present Value (Discount rate of 15% over 20 years)	*4,285*
Water Use efficiency (NPV/total m^3)	*R4.40*

As can be seen from ***Table 3.5*** *above, agriculture production contributes significantly to the economy of the region. The multiplier effect in the agricultural industry is relatively high compared to other industries and therefore any decrease in the amount of agricultural production will have a significant negative impact on the general economy of the region.*

In regards to labour, it is estimated that the amount paid to direct labour costs (unskilled and semi skilled) for the enterprises (R147 million) is equivalent to 15,300 full time jobs at the minimum wage rate. Therefore any decrease in agricultural production will result in a significant decrease of jobs in the region.

A number of economic scenarios have been undertaken with the financial simulation model. These include:

- *A scenario was undertaken assuming that the current enterprise mix would change over time. It was assumed that the area under citrus and table grape would increase to 10% of the total cropped area.*
- *A scenario is undertaken only on estimated lawful use of water. From the study results it is estimated that only 40% of irrigation is lawful in the Upper Vaal region. At this time no information is available on the other regions and it is therefore assumed that 80% of current irrigation is lawful in the Middle Vaal region and 90% in the lower Vaal region.*
- *It is assumed that there will be a 10% decrease in water allocation for irrigation purposes*
- *There will be a 10% increase in the water cost for irrigation water.*

***Table iv** below summarises the results of the above scenarios estimating the change in the NPV of the various scenarios compared to the base (simulation) model.*

Table iv: Summary of results estimating the change in the NPV

Description	***NPV (millions)***	***% change***	***R/M3 of water***	***% change***
Base model	*4,285*	-	*4,40*	-
Increase in higher value crops	*4,686*	*+9.3%*	*4.59*	*4.3%*
Only estimated lawful use	*2,704*	*-37%*	*4.24*	*-3.9%*
10% decrease in water allocation	*3,856*	*-10%*	*4.40*	*No change*
10% increase in irrigation water costs	*4,284*	*-0,007%*	*4.40*	*No change*

From the above it can be seen that agriculture will be contributing significantly more to the economy as farmers' move towards higher value crops; this will also increase water use efficiency. If only lawful use of irrigation water is enforced this will have a severe negative impact on the economy of the region. However, if the water cost is increased this leads to an insignificant decrease in the value of agricultural output as it is a relatively small amount in terms of costs of production.

Possible trading of water rights

Trading of water rights is still in its infancy but is expanding rapidly around the world, especially in regions of water scarcity. The concept of trading water rights, both within a specific water use sector (e.g. agriculture) and between sectors (e.g. agriculture to industry), *has been investigated for its economic advantages within the South African economy for a number of years.*

The scene has been set for the South African water sector to embark on the trading of water rights with the prospect of:

- *Giving value to a scarce commodity*
- *Using the country's limited water resources more efficiently and sustainably*
- *Promoting economic water use efficiency through:*
  - *New investment in high value-added agriculture*
  - *Switching the use of water, where appropriate, to economically more profitable or strategic or secure industries / water use sectors*
- *Allowing flexibility in terms of location, time and water use sector*
- *Managing risk and changing circumstances.*

And, at the same time, ensuring that:

- *There is an overall balance of water use with available water resource for the longer term*
- *There is an equitable distribution of water allocation, especially in respect to historically disadvantaged individuals and their social well-being, and*
- *The environment is protected.*

Similar to the more traditional methods of water allocation, water rights trading will be measured by its social and economic benefits, and environmental integrity. A range of economic parameters may be used to measure the efficiency of water use, including: returns per hectare, returns per annum, returns per 1000m^3 water used, employment per 1000m^3 water used and possibly the productivity indices.

It should be noted from the outset that the information gathered so far indicates that the overwhelming issue in terms of water use is unlawful use especially in the Upper Vaal region. It is obvious that any reference to water rights will only pertain to lawful use which in the Upper Vaal is only equal to 40% of the estimated irrigation water used for agriculture.

It is envisaged that any development of trading of water rights will more than likely be between other sectors of the economy and that a relatively small amount will be traded within agriculture.

The net effect of this will be a reduction in the cropping area. This will also encourage the use of more efficient use of irrigation water which will lead to more efficient irrigation systems and switch to higher value crops.

The medium to long-term effect will be an increase in water costs as a result of a new equilibrium being established for the demand and supply of water. However it was shown in the economic analysis that this would have a very small impact on agricultural production.

Application of a water requirement and return flow model for irrigation

Very little or no data is in most cases available regarding any measurements of return flow volumes from irrigation. In most hydrological studies and system analysis 10% of the gross irrigation demand is taken as the typical irrigation return flow volume. More accurate modelling of irrigation return flows is becoming more and more important. This is due to the effect of these return flows on water quality as well as possible reduction in return flows from existing irrigation areas as result of the increasing pressure on the use of more effective irrigation systems. An irrigation return flow model was as result of this need, recently developed as part of the Crocodile (West) River Return Flow Analysis Study and was tested on several irrigation schemes in the Crocodile River Catchment.

It was therefore decided to configure the irrigation return flow model for the major irrigation schemes in the Vaal River System, to obtain an improved understanding of irrigation return flows in the Vaal River basin. The aim of the model was to also asses the likely impact of WC/WDM measures on the water requirements and return flows as well as to and to update the Irrigation Block modules contained in the Water Resource Planning Model (WRPM). The irrigation schemes selected for this purpose includes:

- *Vaalharts and Taung Irrigation Scheme*
- *Allemanskraal & Erfenis irrigation Schemes which is also referred to as the Sand-Vet irrigation scheme.*
- *Klerksdorp Irrigation Scheme.*
- *Schoonspruit Irrigation Scheme.*
- *Mooi River Irrigation Scheme.*

Very little observed water return flow data were in general available for the selected irrigation areas which can be used in the return flow model for calibration purposes. The return flow model can however also be calibrated against the observed volume released into the main irrigation canals, which will contribute to improved modelling and to obtain the most appropriate water loss components for the irrigation scheme. This is important as some of these loss components directly contribute to the potential return flow volume from the scheme. The model can also be calibrated against observed return flow volumes and for this purpose the model distinguishes between return flows from canal tail water losses, return flows through seepage and return flows from surface runoff. Possibilities for calibration were in most cases limited to the observed water supply data and canal tail water losses, as no *information was available on observed seepage and surface runoff related return flows.*

*In the current WRPM configuration it is only Vaalharts, of the schemes listed above that is simulated as an irrigation block in which return flows are calculated during the simulation process. For all the other irrigation schemes it was assumed that 10% of the demand will return to the river as return flows from the irrigation fields. The return flows as used in the WRPM is included in **Table v** and compared with that obtained from the Return flow Model analyses.*

Table v : Summary and comparison of return flow simulation results

Irrigation Scheme	Gross inflow (million m³/a)	Return flows (million m³/a)		Percentage Return flow	
		Return flow model	WRPM	Return flow model	WRPM
Vaalharts *North Canal*	*341.74*	*43.2*	*56.3*	*13*	*16*
West Canal	*51.21*	*5.83*	*0.44*	*11*	*1*
Sub-total	***392.95***	***49.03***	***56.74***	***12***	***14***
Klerksdorp Scheme	*4.93*	*0.25*	*0.91*	*5*	*18 (10)+*
Schoonspruit Scheme	*24.10*	*5.31*	*1.69*	*22*	*7 (10)+*
Mooi River Scheme	*165.50* *(71.38)**	*97.08* *(2.96)**	*3.68*	*59* *(4)**	*2 (10)+* *(5)**
Erfenis Canal Scheme	*42.84*	*4.73*	*4.64*	*11*	*11(10)+*
Erfenis River Scheme	*9.76*	*0.38*	*0.98*	*4*	*10*
Allemanskraal Canal	*34.89*	*6.63*	*3.97*	*19*	*10*
Sub-total	***282.02*** ***(187.90)****	***114.38*** ***(20.26)****	***15.87***	***40*** ***(11)****	***5 (10)+*** ***(8)****
Total	***674.97*** ***(580.85)****	***163.41*** ***(69.29)****	***72.61***	***24*** ***(12)****	***11*** ***(12)****

Notes:- A very high percentage of the Mooi River Scheme return flows is as result of the large volume of tail water flow from the canal end. When the effect of the tail water flow is removed the result is given by the value in brackets.*

+- The value in brackets represent the percentage return flows (10%) generally used in the WRPM. The gross inflow as used in the return flow model is not always the same as that used in the WRPM and therefore results in a different percentage when compared with the return flow model gross inflow.

From the comparisons the following conclusions are made:

- *The total modelled return flow for the Vaalharts Scheme is slightly less than that currently used in the WRPM, but the main difference is in the distribution of return flows between North and West canals. The distribution used in the WRPM is clearly not realistic.*
- *The return flows for the Klerksdorp Irrigation Scheme as used in the WRPM is obviously too high and need to be reduced. The main reasons for the reduction in return flows are (firstly) that the actual water use is much lower than the allocated volume, secondly as result of the low permeability of the soils and thirdly the limited canal distribution systems within the scheme.*
- *The modelled return flows for the Schoonspruit Scheme is significantly higher than that used in the WRPM. This is to a large extent as result of the tail water flows and the fact that the irrigation is in general located close to the river.*
- *The tail water flows at the bottom end of the Mooi River Scheme is very high and is the main reason for the very high return flows of almost 60% in comparison with the 10% used in the WRPM. When the tail water flow is excluded from the return flow calculation, the results from the Return Flow Model and that currently used in the WRPM is almost the same.*
- *The return flows from the Erfenis canal scheme is somewhat higher than that obtained from the Allemanskraal canal scheme, which is both part of the Sand/Vet irrigation scheme. The main reason or the higher return flows from the Erfenis canal scheme is the higher hydraulic gradient that is in general evident in the Erfenis scheme. In the Allemanskraal scheme the height difference between the irrigation fields and the river is less and the distance from the river more than that for the Erfenis Scheme. This therefore results in a lower hydraulic gradient for the Allemanskaal scheme and less return flows as the permeability of the soils is in the same order of magnitude.*
- *The total return flows from all the irrigation schemes as obtained from the return flow model is more than double that currently used in the WRPM. When the effect of the large volume of tail water flow from the Mooi River Scheme is removed the total return flows from the Return Flow Model is almost equal to that used in the WRPM.*
- *The return flows used in the WRPM is generally based on a fixed 10% value except for the Vaalharts Scheme. The results from the return flow model however showed that it is not correct as return flow percentages vary significantly between schemes. Results showed return flow percentages from as low as 4% to as high as 22% and even 59% in the case of the Mooi River Scheme with its high tail water flow.*

Perspective on Irrigation for Poverty Alleviation

To provide water at an adequate assurance of supply and quality, water is already transferred into the Vaal River catchment at high cost. Poverty eradication by means of irrigation schemes are unlikely to be sustainable if the full cost of the water is to be applied. Opportunities will therefore have to be found where existing water allocations are made available or where water saved through WC&DM can be utilised for this purpose.

Several projects in this regard had already been established and others are in process. Existing projects include food gardens established through the provincial department of Agriculture, schemes using effluent for irrigation of woodlots and the trading of existing water allocations on the Sand-Vet Irrigation Scheme. Some of these projects also failed due to poor soil and management.

Projects currently in progress include the following:

- *Use of purified sewage water in Carlton area and obtaining some of the water previously allocated to the Oberholzer Irrigation Board for a large irrigation project by the North West Province.*
- *The building of weirs in the Lower Vet River to improve the system yield and storage. The increase in yield will be utilized to develop a further 50ha in Hoopstad area.*
- *Beatrix mine planning to develop an irrigation project using their existing allocation to produce essential oils.*
- *Matjabeng Municipality launched a project to utilize purified sewage to irrigate paprika.*
- *Revitalising of the Taung Scheme (2 660 ha with allocation from Vaal River to be developed in the next 3 to 5 years as well as 150 ha of the Ganspan development within the Vaalharts Irrigation Scheme)*
- *The Aganang Beef Trust applied for 11 million m³/a from Vaal River close to Christiana to be used for the irrigation of pastures and power fodder.*

Recommendations

Based on the results and findings from this task, the following recommendations are made:

- *The eradication of the unlawful water use, mainly in the irrigation sector, is an essential strategy that has to be implemented in order to rectify the current deficit (negative water balance) in the Vaal River System. The legal actions and procedures that will be implemented should be designed to achieve legal precedence's to protect the entitlements of lawful water users and assist in compliance monitoring and water use regulation in future.*
- *The effect on the economy of the region should also be taken into account in the*

whole process planned to reduce unlawful water use by irrigation as this will also lead to significant job losses in the region.

- *Validation and Verification studies for all three the WMAs in Vaal River catchments need to be completed as soon as possible. The water balance for the system then needs to be re-evaluated.*
- *Refinement on the assurance of supply requirements should be considered to increase the availability of water in the Vaal River System. Irrigation and garden watering in urban areas should receive specific attention in this regard.*
- *Irrigation demand scenarios should be refined and analysed in stage 2 of the study.*
- *The use of the irrigation return flow model should also be considered in future studies, specifically in areas with large irrigation schemes and significant return flows.*
- *Trading of water rights should be encouraged as it will improve the efficient use of water.*
- *Poverty eradication by means of irrigation schemes should continue as is. Opportunities should mostly be found where existing water allocations are made available or water is saved through WC&DM initiatives. Lessons need to be learnt from past failures in this regard to avoid similar situations in the future.*

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LIST OF ABBREVIATIONS

Acronym	Meaning
CMA	Catchment Management Agency
CMS	Catchment Management Strategy
Dir: HI	Directorate: Hydrological Information
Dir: NWRP	Directorate: National Water Resource Planning
CMS	Catchment Management Strategy
Dir: OA	Directorate: Option Analysis
Dir: PSC	Directorate: Policy and Strategic Co-ordination
Dir: WRPS	Directorate: Water Resource Planning Systems
Dir: RDM	Directorate: Resource Directed Measures
Dir: WCDM	Directorate: Water Conservation and Demand Management
Dir: WDD	Directorate: Water Discharge and Disposal
Dir: WUE	Directorate: Water Use Efficiency
DWAF	Department of Water Affairs and Forestry
GDP	Gross Domestic Product
GGP	Gross Geographical Product
IDP	Integrated Development Plan
ISP	Internal Strategic Perspective
LHWP	Lesotho Highlands Water Product
LORMS	Lower Orange River Management Study
MAP	Mean Annual Precipitation
MAR	Mean Annual Runoff
NWA	National Water Act
NWRS	National Water Resource Strategy
ORRS	Orange River Replanning Study
WARMS	Water Allocation Registration Management System
WDM	Water Demand Management
WC	Water Conservation
WMA	Water Management Area
WSDP	Water Services Development Plan
WRPM	Water Resource Planning Model
WRSAS	Water Resource Situation Assessment Study
WUA	Water User Association

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1. INTRODUCTION

1.1. Background

The Department of Water Affairs and Forestry (DWAF) has, as part of the development of the Internal Strategic Perspectives (ISPs) for the Vaal River Water Management Areas (WMAs) identified and prioritised several studies that are necessary to further support Integrated Water Resource Management in the Vaal River System. Although previous water balance assessments indicated that augmentation of the Vaal River System is only required by the year 2025 (**DWAF, 2004a to d**), several factors were identified that could influence this date and require further investigations.

Firstly, it was acknowledged that the water requirement projection scenarios used in the ISP study did not explicitly include the effect of water conservation and water demand management initiatives (**DWAF, 2004d**) and as a result the Directorate Water Use Efficiency commissioned the Water Conservation and Water Demand Management study with particular focus on the Upper and Middle Vaal River WMAs.

Secondly, it was recognised that the time it takes to implement a large water resource augmentation scheme could be as long as fifteen years and coupled with the fact that the future water requirement scenarios exhibit low growth rates makes the timing of any future intervention critical.

Thirdly a comprehensive Reserve Determination has not been undertaken for the Vaal River System and will have to be incorporated into the development of reconciliation strategies

In view of the above considerations as well as other uncertainties identified in the assumptions used in the ISP study (see **DWAF, 2004d** for details), the Directorate: National Water Resource Planning (D:NWRP) has commissioned the reconciliation study of the large bulk water supply system of the Vaal River.

The ISPs for the Vaal River WMAs further identified the need for integrated water quality management of the Vaal River and its major tributaries. Although there are several individual Catchment Management Strategies already completed, these strategies and their objectives need to be integrated and co-ordinated in a system context. To this end, the D:NWRP has commissioned a study to develop an Integrated Water Quality Management Plan for the Vaal River System which is running concurrently with the Reconciliation and Water Conservation and Water Demand Management studies.

During the inception phases of these studies it was identified by the respective management teams that the integration of strategies and co-ordination of study activities would be essential to development coherent water resource management measures for the Vaal River System. The management of the studies was therefore coordinated by combining the project management of the Water Conservation and Reconciliation studies and have cross representation of study managers on the Water Quality Study.

In each of the tree abovementioned studies the importance of stakeholder involvement in the development of the strategies was emphasised and an integrated stakeholder engagement process was designed. This resulted in combining the stakeholder meetings for all three the studies, combining the Steering Committee Meetings of the Water Conservation and Reconciliation studies and having shared representation on the Water Quality Study.

1.2. Objective of the Study

The Large Bulk Water Supply Reconciliation Strategies for the Vaal River System Study has the objective to develop strategies for meeting the growing water requirements of the industrial and urban sectors that are served by the Integrated Vaal River System. The development of these strategies requires reliable information of the water requirements and the water resources for the current situation as well as likely future scenarios for a planning horizon of twenty to thirty years.

The key objectives of the study are to:

- Update the current and future urban and agricultural water requirements.
- Assess the water resources and existing infrastructure.
- Take into account the Reserve requirements for alternative classifications.
- Formulate reconciliation interventions, both structural and administrative/regulatory.
- Conduct stakeholder consultation in the development of the strategies.

In order to achieve these objectives the study was undertaken through a series of tasks which culminated into a set of study reports that are listed on the back of the cover page of the report. The information from the task reports were combined to formulate the reconciliation strategy, the main deliverable from the study, which are presented in this report.

1.3. Study area

The core of the study area consists of the Upper, Middle and Lower Vaal River Water Management areas, however, due to the numerous inter-basin transfers that link this core area with other WMA's, reconciliation planning has to be undertaken in the context of the Integrated Vaal River System which also includes portions of the Komati, Usutu, Thukela and Senqu River (Located in Lesotho) catchments. In addition, significant water transfers occur to water users in the Olifants and Crocodile (West) River catchments of which most are totally dependant on the water resources of the Integrated Vaal River System. **Figure A-1** in **Appendix A** shows a geographical map of the Integrated Vaal River System which is the area of concern for the study.

The water resource components of the Integrated Vaal River System are highly inter-dependant due to the cascading orientation of the three Vaal River WMAs as well as the links that exist as a result of the transfer schemes (indicated by the arrows on **Figure A-1**). The water resource system provides water to one of the most populated and important areas in the country as reflected by the magnitude of the developments located in the Upper and Middle Vaal, the Olifants and the upper portion of the Crocodile West Marico Water Management areas. These developments include many of the country's power stations, gold mines, platinum mines, petro-chemical plants as well as various other strategic industries. The water requirements in the area are therefore very important to sustain the economy of the country and the well being of its people.

It should be noted that the study area of the Integrated Water Quality Management Study (IWQMS) covers a slightly larger area than the three Vaal River WMAs and also include the Riet and Modder River Catchments, which is part of the Upper Orange WMA. The inclusion of these catchments was necessary to cover all water quality aspects of the entire Vaal River's catchment down to it's confluence with the Orange River.

1.4. Purpose and Structure of this Report

This report describes the Irrigation Sector developments, economic importance and related demands and return flows. To be able to achieve this, the irrigation task was sub-divided into the following sub-tasks:

- Assemble data from other studies
- Undertake comparisons of data from different data sources
- Assess the economic importance of the irrigation sector
- Identify and assess possible WC/WDM measures
- Assess the possible trading of water rights
- Develop alternative future irrigation demand scenarios
- Review the assurance of supply requirements and operating rules
- Application of a water requirement and return flow model for irrigation

- Reporting

The findings, results, conclusions and recommendations of the sub-tasks are documented in this report in **Sections 2 to 9**. The only exception is that for the WC/WDM measures for which a separate stand alone report was prepared.

2. COMPARISON OF DATA FROM DIFFERENT SOURCES

2.1. General

This section summarises work that was done on the Water Allocation Registration Management System (WARMS) data relating to the Vaal River received from DWAF in November 2005. The data was consolidated, manipulated and compared to previous data used in the WRYM and WRPM data sets. This section presents these comparisons.

2.2. WARMS Data Base

2.2.1. Brief description of available data

Three separate databases were received from DWAF Gauteng region, one from Gauteng, one from the Free State and one from the Northern Cape. The data was up to November 2005. The three databases were combined into one with a total of 20 814 entries. Only the data for the Vaal (C region tertiary catchment) was required and the first step was to delete additional data provided from the B, D, F, V, W and X tertiary areas. At this point it was noted that a number of data entries had blank entries under the quaternary catchment heading. **Table 2.1** summarises the registered volumes for all water user sectors in the C region initially provided in the data base.

Table 2.1:Summary of registered volumes for all water use sectors in C Region

WATER USER SECTOR	REGISTERED VOLUME (million m^3/a)	
	C TERTIARY	QUATERNARY LEFT BLANK
AGRICULTURE: AQUACULTURE	0.507	
AGRICULTURE: IRRIGATION	4243.27	1165.42
AGRICULTURE: WATERING LIVESTOCK	10.443	1.003
EMPTY	0.002	0.325
INDUSTRY (NON-URBAN)	29.302	3.536
INDUSTRY (URBAN)	409.919	0.020
MINING	108.570	4.835
RECREATION	0.186	
SCHEDULE 1	0.005	
URBAN (EXCLUDING INDUSTRIAL &/OR DOMESTIC)	0.027	
WATER SUPPLY SERVICE	336.121	27.419
Grand Total	**5138.354**	**1202.559**

It was decided to only focus on the entries specifically related to the Agriculture: Irrigation water user sector (i.e. 4243.27 and 1165.42 from above table).

The first step involved assigning each quaternary to a specific sub-catchment as used for hydrology purposes in the VRSAU study. This was done using maps obtained from the VRSAU study reports as shown in **Appendix A Figure A-1**. It was fairly clear cut in which area most of the quaternaries fitted. There were, however, some entries (specifically schemes) that, while they were geographically located in a specific area, their water use was accounted for in another area. **Table 2.3** presents how the quaternaries were divided into VRSAU sub-catchments.

It was necessary to assign each of the entries without reference to a specific quaternary to a certain sub-catchment. This refers to the 1 165,42 million m^3/a volume presented in **Table 2.1**. The next best way to determine where these data fit, was to look at the name of the water sources where they obtained their water from. Upon closer inspection of the water source names, it was necessary to exclude some more data entries, as their source names showed that they are not positioned in the Vaal study area. **Table 2.2** presents how this was broken down.

Table 2.2 : Inclusion and exclusion of entries with no reference to quaternaries

WATER SOURCE NAME	REGISTERED VOLUME FOR AGRICULTURE: IRRIGATION WATER USER SECTOR (million m^3/a)	
	INCLUDED	EXCLUDED
BOREHOLE		1.835
GROUNDWATER		0.064
LEEU RIVER	26.427	
MODDER RIVER	29.837	
NO NAME		0.010
ORANGE RIVER		834.754
RENOSTER DAM	0.022	
RENOSTER RIVER	18.065	
RIET RIVER	69.131	
RIETSPRUIT	9.853	
SAND RIVER	36.986	
SCHOONSPRUIT	60.046	
TIERPOORT RIVER	24.300	
VET RIVER	48.863	
WITTESPRUIT		5.228
Sub-totals	**323.53**	**841.891**
Grand Total	**1 165.421**	

The total volume registered for the Vaal Study area, according to the database, that was used in the further analyses was therefore 4 566.80 million m^3/a (4 243.27 + 323.53).

Table 2.3 presents the various sub-catchment areas used in the VRSAU study and as also currently modelled in the WRPM and WRYM models as well as how the quaternaries and other water sources were distributed. “Sch” refers to entries where an irrigation scheme was specified as the water source for a specific quaternary. In this case the scheme is physically located in the quaternary as allocated to in the data base, but the water resource (storage dam) is located in another quaternary, which is in most cases physically part of a different WRPM sub-catchment. Look for example at quaternary C24F in Sand/Vet Allemanskraal sub-catchment which includes a sch indicator. This means that although C24F is located physically outside the Allemanskraal sub-catchment, the scheme in C24F receives its water from Allemanskraal Dam that is located in the Allemanskraal sub-catchment. Within the Sand/Vet Sand sub-catchment one will again find quaternary C24F but with an indicator excl sch, meaning that the irrigation scheme within C24F is excluded from the total irrigation added to the Sand/Vet Sand sub-catchment, as it was allocated to the Allemanskraal sub-catchment.

Table 2.3 : Summary of sub-catchments versus quaternary catchments

WRPM Area	Quaternary catchments included									
Grootdraai	C11A	C11B	C11C	C11D	C11E	C11F	C11G	C11H	C11J	
KLIP (Dela9)	C13A	C13B	C13C	C13D	C13E	C13F				
Frankfort	C81A	C81B	C81C	C81E	C81F	C81G	C81H	C81J	C81K	C81L
	C81M	C82A	C82B	C82C	C82D	C82E	C82F	C82G	C82H	C83A
	C83B	C83C	C83D	C83E	C83F	C83G	C83H	C83J		
Vaal	C11K	C11L	C11M	C12A	C12B	C12C	C12D	C12E	C12F	C12G
	C12H	C12J	C12L	C12K	C13G	C13H	C83K	C83L	C83M	
Suikerbosrand	C21A	C21B	C21C	C21D	C21E	C21F	C21G			
Klip	C22A	C22B	C22C	C22D	C22E					
Riet (BARR9)	C22F	C22G	C22H	C22J	C22K					
Mooi Boskop: Diffuse KLERK9	C23F									
Mooi Boskop: Diffuse BOSK9 & RR19	C23D	C23E	C23G excl sch							
Mooi GWS	C23H Sch	C23L Sch	C23G sch							
Mooi: Klipdrift	C23K Sch	C23J								
Skoonspruit	Schoon spruit	Rietspruit	C24C	C24D	C24E	C24F	C24G			
Renoster	Renoster Dam	Renoster River	C70A	C70B	C70C	C70D	C70E	C70F	C70G	C70H
	C70J									
Vals	C60A	C60B	C60C	C60D	C60E	C60F	C60G	C60H	C60J	
Sand/Vet ALLEM 9	Sand River	C42F sch	C42G sch	C42H sch	C42A	C42B	C42C	C42D	C42E	
Sand/Vet ERF 9	Vet River	C41G sch	C41H sch	C41J sch	C41A	C41B	C41C	C41D	C41E	
Sand/Vet SAND 9	C41G excl sch	C41H excl sch	C41J excl sch	C42F excl sch	C42G excl sch	C42H excl sch	C41F	C42J	C42K	C42L

WRPM Area	Quaternary catchments included									
	C43A	C43B	C43C	C43D						
Bloemhof Incr	C23H excl sch	C23K excl sch	C23L excl sch	C23A	C23B	C23C	C24A	C24B	C24H	C24J
	C25A	C25B	C25C	C25D	C25E	C25F	C70K			
Upper harts	C31A	C31B	C31C	C31D	C31E excl sch					
VH Scheme: Upper Harts	C31E Sch									
Middle Harts	C31F	C32A	C32B	C32C	C32D	C33A excl sch	C33B excl sch			
VH Scheme: Middle Harts	C33A Sch	C33B Sch								
VH Scheme: Vaalharts Wier	C91A	C91B								
VH Scheme: De Hoop Wier	Leeu River	C91C	C91D							
VH Scheme: other	C33C Sch	C91E Sch	C92A Sch	C92B Sch						
Rustfontein Dam	C52A									
Krugersdrift Dam	C52B	C52C	C52D	C52E	C52F	C52G				
Lower Modder	Modder River	C52H	C52J	C52K	C52L					
Tierpoort Dam	C51D									
Kalkfontein Dam	Tierpoort river	C51A	C51B	C51C	C51E	C51F	C51G	C51H	C51J	
Aucampshoop	Riet River	C51K	C51L							
Other (Lower Vaal)	C33C excl sch	C51M	C91E excl sch	C92B excl sch	C92B excl sch	C92C				

2.2.2. Analyses and processing of WARMS Data

As indicated in the previous section, a total volume of 4 566.80 million m^3/a was registered for the Vaal River study area. Due to the format of the WARMS data base, it could not be assumed that this total volume was necessarily correct. Detailed further break downs were required and are described hereafter.

Reduction due to double cropping

The WARMS database is structured in such a way that some registered volumes for the same property are entered twice but should not necessarily be added twice. After discussions with DWAF the following methodology was used to eliminate duplicate entries of volumes. The data was sorted by title deed name. Where a volume was exactly the same as the volume entered immediately above it for the same title deed name, the field number was checked. If the field number was also the same, the volume was not included. If the field number differed, the volume was included.

Having done this manipulation of the data, the total volume of 4 566.80 million m^3/a was reduced to 3 005.23 million m^3/a. In other words, a volume of 1 561.57 million m^3/a was registered in the database but was not included as it was considered as duplicate registrations.

Reduction due to over registration

The value of 3 005.23 million m^3/a was still considered very high for the whole Vaal system, and the data was analysed in more detail in order find the reason for this. The registered volumes were then compared to the registered areas for each data entry. When dividing the volumes by the areas, many data entries showed very large water usage per ha per annum (m^3/ha/a). It was decided that the reason for this was either an inaccurate entry of the volume or that the farmers were attempting to register more water than is actually required for their specific irrigated area and crop combination. A cap of 12 000 m^3/ha/a was then put on the irrigation allocation. Where the figure was larger than 12 000 m^3/ha/a a volume of 12 000 m^3/ha/a was multiplied with the area to obtain a new and more realistic registered volume.

After doing this, the total volume dropped from 3 005.23 million m^3/a to 2 067.64 million m^3/a. The breakdown of the 2 067.64 million m^3/a is that 1 581.69 million m^3/a is actual registered volumes and 485.95 million m^3/a is recalculated reduced volumes due to over registration.

Elimination of boreholes

As the information used in the WRYM / WRPM tables related to surface water only, all data entries where the water source was indicated as borehole, were eliminated. After doing this the total volume dropped from 2 067.64 million m^3/a to 1 631.9 million m^3/a. The breakdown of the 1 631.9 million m^3/a is that 1 328.12 million m^3/a is actual registered volumes and 303.78 million m^3/a is recalculated reduced volumes due to over registration.

2.2.3. Final processed WARMS data to be used for comparison purposes

The final step in the process was to compare the analysed data with that currently modelled in the WRYM and WRPM. Three scenarios of WARMS data sets were included in the comparison as shown in **Tables 2.4, 2.5** and **2.6**. The WARMS scenarios include the following:

- All volumes registered were taken as correct
- All allocations greater than 12 000 m^3/ha/a capped at 12 000 m^3/ha/a
- All allocations greater than 12 000 m^3/ha/a left out completely

Boreholes were left out for all the comparisons. From the summarised data in **Tables 2.4 to 2.6** it can be seen that there is significant differences in the total irrigation volume for the three WARMS data related scenarios. For comparison purposes it was assumed that the scenario for which all allocations greater than 12000 m^3/ha capped at 12 000 m^3/ha/a is the most realistic option to be used in further comparisons.

The Loxton Venn irrigation requirements are currently mainly used in the WRPM analyses and the difference between the Loxton Venn volumes and the recommended WARMS option was therefore determined and included in **Tables 2.4 to 2.6.** For the Upper Vaal alone the WARMS data indicates an increase in irrigation of 432 million m^3/a in comparison with the Loxton Venn volumes. This is a huge increase and is more than 4 times that currently used in the WRPM. The largest differences occur in the Frankfort and Vaal sub-catchments, which is quite concerning, as both receives transferred water from the Lesotho Highlands and Tugela Vaal projects. It is only for the Mooi River GWS that the WARMS data indicated a lower irrigation volume than that currently used in the WRPM.

Table 2.4 : Summary of irrigation water use for the Upper Vaal WMA

Catchment	Irrigation module no.		WRYM	Loxton Venn Study (1999) WRPM	WARMS			Difference
	WRPM	WQT	Net Water Use (10^6m^3/a)	Theoretical Crop water use (10^6m^3/a)	all registered data (10^6m^3/a)	data above cap capped (10^6m^3/a)	data above cap left out (10^6m^3/a)	Loxton Venn & WARMS
Grootdraai	RR12	RR4	12.85	25.05	**56.41**	**45.92**	**31.87**	**-20.87**
	Diffuse (Breyten dem : 0.34)							
KLIP (DELA9)	**Diffuse**		**5.33**		**13.80**	**10.66**	**7.70**	**-10.66**
Frankfort	Diffuse		27.32					
	RR9	RR9	19.89	7.04				
	RR10	RR12	1.12	2.12				
	RR11	RR7		11.45				
Sub-Total :			**48.33**	**20.61**	**252.99**	**191.86**	**126.77**	**-171.25**
Vaal	Diffuse		20.99					
	RR13	RR8	6.76	16.66				
	RR14	RR10						
Sub-Total :			**27.75**	**16.66**	**243.77**	**199.93**	**124.97**	**-183.27**
Suikerbosrand	RR1	RR20	15.41	8.28				
	RR335	RR21						
Sub-Total :			**15.41**	**8.28**	**35.42**	**29.21**	**19.63**	**-20.93**
Klip	RR336	RR22	27.72	11.90	**44.16**	**31.76**	**19.45**	**-19.86**
Riet (BARR9)	RR337	RR23	1.92	13.28	**37.54**	**28.26**	**16.11**	**-14.98**
Mooi : Boskop	Diffuse : KLERK9		1.04		**0.17**	**0.17**	**0.17**	**-0.17**
Mooi : Boskop	Diffuse : BOSK9		0.24					
	RR19	RR10	0.16					
Sub-Total:			**0.40**		**3.74**	**3.68**	**3.52**	**-3.68**
Mooi GWS	12 monthly values		77.61	36.81	**25.73**	**24.39**	**21.93**	**12.42**
Mooi :Klipdrift	Diffuse		3.36					
	12 monthly values		5.00					
	RR20	RR21	0.78					
	RR21	RR23		8.91				
Sub-Total :			**9.14**	**8.91**	**7.97**	**7.60**	**7.23**	**1.31**
Upper Vaal WMA Total			**228**	**142**	**722**	**573**	**379**	**-432**

The increases in irrigation volumes in the Middle Vaal of 207 million m^3/a is also significant and is more than double that currently simulated in the WRPM, although it is not as severe as in the case of the Upper Vaal. The biggest differences occurred in the Sand/Vet and Bloemhof Dam incremental sub-catchments. Increases in the Bloemhof sub-catchment can also utilise transferred water which is released from Vaal Dam in support of Bloemhof Dam.

Table 2.5 : Summary of irrigation water use for the Middle Vaal WMA

	Irrigation module no.		WRYM	Loxton Venn Study (1999) WRPM	WARMS			Difference
Catchment	WRPM	WQT	Net Water Use ($10^6m^3/a$)	Theoretical Crop water use ($10^6m^3/a$)	all registered data ($10^6m^3/a$)	data above cap capped ($10^6m^3/a$)	data above cap left out ($10^6m^3/a$)	Loxton Venn & WARMS
Skoonspruit	Diffuse : RIETS9		1.04					
	RR22	RR26	12.77	16.40				
	RR23	RR10	3.35	9.69				
	RR24	RR12	2.89					
	RR25	RR27	13.80					
Sub-Total :			**33.85**	**26.09**	**72.27**	**31.16**	**20.23**	**-5.07**
Renoster	Diffuse : KOP9		1.97					
	Diffuse : RIETF9		9.60					
	RR15	RR3	1.31	15.23				
	RR16	RR5		1.71				
	RR17	RR12A	2.33					
	RR18	RR12A						
Sub-Total :			**15.21**	**16.94**	**40.59**	**35.96**	**32.52**	**-19.02**
Vals	Diffuse		14.85					
	RR333	RR18		1.83				
	RR332	RR3	7.35					
	RR334	RR5						
Sub-Total :			**22.20**	**1.83**	**48.29**	**29.75**	**17.54**	**-27.92**
Sand/Vet	Diffuse : ALLEM9		1.17					
	RR30	RR12A	2.91					
	RR26	RR12	32.44	39.67				
Sub-Total :			**36.52**	**39.67**	**44.99**	**44.52**	**44.32**	**-4.85**
	Diffuse : ERF9		1.28					
	RR331	RR11A	3.25					
	RR27	RR11	39.28	46.40				
Sub-Total :			**43.81**	**46.40**	**70.06**	**69.71**	**69.14**	**-23.31**
	Diffuse : SAND9		6.83					
	RR28	RR5	4.25					
	RR29	RR10		15.74				
Sub-Total :			**11.08**	**15.74**	**60.89**	**58.70**	**57.03**	**-42.96**
Kromdraai	RR338	RR3	**1.38**	**0.78**	**25.12**	**20.04**		**-19.26**
Bloemhof Incr.	RR338	RR3						
	RR340	RR5	7.23	6.92				
	RR339	RR3	39.61	1.58				
	RR341	RR36		0.93				
	RR2	RR31		4.81				
Sub-Total :			**46.84**	**14.24**	**129.64**	**78.61**	**37.20**	**-64.37**
Middle Vaal WMA Total			**211**	**162**	**492**	**368**	**278**	**-207**

The irrigation data provided for the Lower Vaal include the Lower Vaal WMA supplied from the Harts and Vaal rivers as well as the Riet/Modder catchment, which is a tributary of the Vaal River but forms part of the Upper Orange WMA. The Riet/Modder catchment does not form part of the study area, but was initially analysed due to uncertainties around the study area, and the results were therefore included.

The comparison of data for the Lower Vaal WMA is the only WMA that in total shows a slightly lower registered irrigation volume (11%) than that currently used in the WRPM. For the Lower Vaal WMA the WRYM or VRSAU irrigation volumes is used in the WRPM and not those from the Loxton Venn study.

The differences in the Riet/Modder catchment is in the order of 30% and in most cases the WARMS volumes is lower than that currently used in the models. It is only for the Krugersdrift and Lower Modder River sub-catchments where the WARMS data is somewhat higher than the irrigation volumes in the models.

Table 2.6: Summary of irrigation water use for the Lower Vaal

CATCHMENT	WRPM NODE #	WQT NODE #	Loxton Venn Study (1999)	Gross irrig demand WRPM and WRYM (million m3/a)	WARMS all registered data $(10^6m^3/a)$	WARMS all data capped $(10^6m^3/a)$	WARMS all capped left out left out $(10^6m^3/a)$	Difference
Upper Harts	357	RR8		1.21				
	360	RR11		3.62				
	362	RR13	0.92	1.20				
Sub-Total :			0.92	6.03	1.02	0.14	0.05	5.89
Middle Harts	376	RR33		1.50				
	HartU7.abs			0.36				
	HartD7.abs			0.61				
	407		12.81	0.00				
Sub-Total :			12.81	2.47	1.37	1.17	1.15	1.30
VH scheme De Hoop Weir	405	RR3	59.78	43.05	38.48	32.25	31.87	
VH scheme Upper Harts	370	RR21		10.72	0.09	0.01	0.00	
VH scheme Middle Harts	379	RR11	354.13	287.11	0.30	0.27	0.26	
	383	RR12		52.64				
VH scheme Vaalharts weir	397	RR3	32.2	61.45	26.74	13.88	8.67	
VH scheme other					404.86	365.00	361.56	
Sub-Total :			446.11	454.97	470.47	411.41	402.36	43.56
Lower Vaal WMA Total			460	463	473	413	404	51
Rustfontein Dam	435	RR5		1.10				
	438	RR7		3.29				
Sub-Total :				4.39	3.08	2.61	1.97	1.78
Krugersdrift Dam	416	RR20		2.26				
	420	RR12		5.43				
	424	RR16		9.29				
	430	RR14		7.00				
Sub-Total :				23.98	66.80	31.83	15.12	-7.85
Lower Modder	445	RR31		20.27				
	453	RR21		9.49				
	454	RR23		9.49				
	455	RR27		9.49				
Sub-Total :				48.74	61.45	61.43	61.42	-12.69
Tierpoort Dam	458	RR4		1.66				
	461	RR6		0.71				
Sub-Total :				2.37	2.34	1.97	1.30	0.40
Kalkfontein Dam	469	RR53		6.66				
	468	RR73		41.79				
	472	RR75		7.92				
Sub-Total :				56.37	49.12	44.75	39.36	11.62
Aucampshoop	479	RR65		93.53				
	484	RR60		33.51				
	482	RR63		40.76				
Sub-Total :				167.80	72.76	72.76	72.76	95.04
Other					411.16	411.16	411.16	-411.16
Riet/Modder Total			0	304	256	215	192	88
Grand Total			898	1070	1942	1570	1253	-500

For the total Vaal River catchment the WARMS volume is 500 million m³/a higher than that currently used in the models, which will definitely have a serious impact on water availability in the system. More than 400 million m³/a of this increase occurs in the Upper Vaal WMA where large volumes of expensive transferred water is entering the Vaal River system.

2.3. Data Comparison

2.3.1. Data sources used and processing of data for comparison purposes

Due to the large differences of the irrigation volumes between the processed and adjusted WARMS data and that currently used in the models, it was clear that none of the two data sources can just be accepted as the most appropriate or realistic irrigation water use to be used for further modelling purposes as part of this study. The verification validation study with regards to the registered water use in the Upper Vaal WMA was nearing completion and it was decided to use data already available from the validation process, to obtain a better indication of the irrigation volumes in the Upper Vaal WMA where the largest discrepancies occurred.

The verification validation processes for the Middle and Lower Vaal WMAs has not yet started and similar data for these WMAs were unfortunately not available. To obtain a better indication of the most realistic irrigation volumes to be used for the Middle and Lower Vaal WMAs, it was decided to discuss the available data sets with the appropriate DWAF regional offices with personnel that know the area the best. The main purpose of these discussions was to obtain a recommendation on the best data to be used for the purpose of the study.

2.3.2. Comparison of data

For comparison purposes it was decided to use the following data sets:

- The theoretical irrigation water use based on the typical crop combinations as obtained from the Loxton Venn study.
- The irrigation demands obtained from the VRSAU study which was used mainly in the WRYM and for the Lower Vaal also in the WRPM data sets.
- The irrigation volumes obtained from the WARMS data base and processed for the purposes of this study as described in **Section 2.2** for the scenario where all the allocations greater than 12 000 m^3/ha/a were capped at a maximum of 12 000 m^3/ha/a.
- Other sources, which typically includes studies on localised areas, which can provide more insight into irrigation development for some of the sub-catchments.
- For the Upper Vaal WMA, the data obtained from the Verification Validation Study,

which will most probably also be used as the suggested data set for the analyses to be carried out as part of this study.

The data used for comparison purposes for the Upper Vaal, Middle Vaal and Lower Vaal WMAs is summarised in **Tables 2.7, 2.8** and **2.9** respectively. The total irrigation water use volumes for each of the data sources is summarised per WMA. The difference with regards to the Loxton Venn volumes is given below each of the tables, as the Loxton Venn values are currently mainly used in the WRPM (also see **Figure A-2** in **Appendix A**).

The verification Validation study has not yet been completed, but as much as possible data were obtained from the Verification Validation study. For the catchment upstream of Vaal Dam the validation process was completed for approximately 73% of all the properties and for the catchment between Vaal Dam and the confluence of the Mooi River, approximately 59% of all the properties were validated. Detail on the completion of the validation process for the different sub-areas is given **Tables 2.10 and 2.11** for the Vaal Dam sub-catchment and for remainder of the Upper Vaal WMA, respectively.

The validated data was scaled up to provide an indication of what the total irrigation water use will be for the whole area, as if 100% of all the properties were validated. This was done by assuming that the average irrigation water use per property, as based on the properties already validated, will be the same for those that still need to be validated. The only exception to this approach was for quaternary catchment C23G located at the downstream end of the Boskop Dam sub-catchment, as only 6% of all the properties in this quaternary were validated. Scaling up this value will most probably result in an inaccurate estimation, as it increased the validated irrigation volume of 0.86 million m^3/a to 14.1 million m^3/a, while the registered volume from the WARMS data base was only 3.68 million m^3/a. For the purpose of this study it was assumed that the 2005 development level surface water use is equal to the registered water use of 3.68 million m^3/a.

Although the Verification Validation study currently mainly focuses on the validation of the registered data, the known law-full use was also included. This however is not the final verified law-full use, but can be used as a first order indication of the law-full irrigation in the sub-catchments. Validation was carried out for irrigation that existed in 1998 as well as for the year 2005, which is referred to as the current development.

The largest increase in irrigation occurred in the Frankfort and Vaal Dam incremental catchments. This is a great concern as these two catchments receives large volumes of expensive transferred water from the Lesotho Highlands and Thukela schemes which is seemingly used for illegal irrigation.

Table 2.7 : Summary of irrigation water use for the Upper Vaal WMA

Sub-catchment	Irrigation module no. & File name (WRPM)	VRSAU Study WRYM Net Water Use (million m³/a)	Loxton Venn Study (1999) WRPM Theoretical Crop water use (million m³/a)	WARMS data (million m³/a)	Verification Validation Study Upper Vaal WMA		
					Water use 2005 (million m³/a)	Water use in 1998 (million m³/a)	Possible Existing Lawful Use (million m³/a)
Grootdraai	RR12	**12.85**	**25.05**	**45.92**	**29.54**	**17.91**	**12.26**
DELANGESDRIFT	Diffuse	**5.33**		**10.66**	**9.91**	**4.4**	**2.79**
Frankfort	Diffuse	27.32					
	RR9	19.89	7.04		44.70	18.32	17.49
	RR10	1.12	2.12		1.66	1.05	0.98
	RR11		11.45		67.13	27.40	26.26
Sub-Total :		**48.33**	**20.61**	**191.86**	**113.49**	**46.77**	**44.73**
Vaal	Diffuse	20.99					
	RR13	6.76	16.66		28.68	15.91	6.34
	RR14				86.05	47.74	19.01
Sub-Total :		**27.75**	**16.66**	**199.93**	**114.73**	**63.65**	**25.34**
Suikerbosrand	RR1	15.41	8.28		14.54	7.89	3.75
	RR335						
Sub-Total :		**15.41**	**8.28**	**29.21**	**14.54**	**7.89**	**3.75**
Klip	RR336	27.72	11.90	31.76	27.12	19.42	7.9
Riet (BARR9)	RR337	1.92	13.28	28.26	28.69	15.3	10.32

Sub-catchment	Irrigation module no. & File name (WRPM)	VRSAU Study WRYM Net Water Use (million m³/a)	Loxton Venn Study (1999) WRPM Theoretical Crop water use (million m³/a)	WARMS data (million m³/a)	Verification Validation Study Upper Vaal WMA		
					Water use 2005 (million m³/a)	Water use in 1998 (million m³/a)	Possible Existing Lawful Use (million m³/a)
Mooi : Klerkskraal Dam	Diffuse : KLERK9	1.04		0.17	0.02	0.02	0
Mooi : Boskop Dam	Diffuse : BOSK9	0.24					
	RR19	0.16					
Sub-Total:		**0.40**		**3.68**	**3.68**	**0.32**	**0**
Mooi GWS	12 monthly values (Chan 102 &105)	77.61	36.81	24.39	35.27	35.27	35.27
Mooi :Klipdrift Dam	Diffuse	3.36			1.21	0.88	0.44
	12 monthly values(Chan 107)	5.00	8.91		7.12	7.12	7.12
	RR20	0.78					
	RR21						
Sub-Total :		**9.14**	**8.91**	**7.60**	**8.33**	**8**	**7.56**
Upper Vaal sub-total		**227.50**	**141.50**	**573.44**	**385.32**	**218.95**	**149.92**
Difference (*)		**86.00**	**0.00**	**431.94**	**243.82**	**77.45**	**8.42**

Note : (*) – Difference with regard to Loxton Venn

Table 2.8 : Summary of irrigation water use for the Middle Vaal WMA

Sub-catchment	Irrigation module no. & File name (WRPM)	VRSAU Study WRYM Net Water Use (million m³/a)	Loxton Venn Study (1999) WRPM Theoretical Crop water use (million m³/a)	WARMS data (million m³/a)	Other Sources (million m³/a)	Verification Validation Study Upper Vaal WMA		
						Water use 2005 (million m³/a)	Water use in 1998 (million m³/a)	Possible Existing Lawful Use (million m³/a)
Schoonspruit	Diffuse : RIETS9	1.04	0.00		0.07			
	RR22	12.77	10.44		18.68			
	RR23	3.35	4.17		2.46			
	RR24	2.89	2.34		2.31	No data	No data	No data
	RR25	13.80	9.14		10.25			
Sub-Total :		**33.85**	**26.09**	**31.16**	**33.77**			
Renoster	Diffuse : KOP9	1.97						
	Diffuse : RIETF9	9.60			4.28			
	RR15	1.31			2.4			
	RR16				0.66	No data	No data	No data
	RR17	2.33	3.39		3.57			
	RR18		13.55		10.68			
Sub-Total :		**15.21**	**16.94**	**35.96**	**21.59**			
Vals	Diffuse	14.85						
	RR333							
	RR332	7.35	0.75		No data	No data	No data	No data
	RR334		1.08					
Sub-Total :		**22.20**	**1.83**	**29.75**				
Sand/Vet Allemanskraal	Diffuse : ALLEM9	1.17						
	RR30	2.91						
	RR26	32.44	39.67		No data	No data	No data	No data
Sub-Total :		**36.52**	**39.67**	**44.52**				

Sub-catchment	Irrigation module no. & File name (WRPM)	VRSAU Study WRYM Net Water Use (million m³/a)	Loxton Venn Study (1999) WRPM Theoretical Crop water use (million m³/a)	WARMS data (million m³/a)	Other Sources (million m³/a)	Verification Validation Study Upper Vaal WMA		
						Water use 2005 (million m³/a)	Water use in 1998 (million m³/a)	Possible Existing Lawful Use (million m³/a)
Erfenis Dam	Diffuse : ERF9	1.28			No data	No data	No data	No data
	RR331	3.25						
	RR27	39.28	46.40					
Sub-Total :		**43.81**	**46.40**	**69.71**				
Sand/Vet incremental catchment	Diffuse : SAND9	6.83			No data	No data	No data	No data
	RR28	4.25	5.98					
	RR29		9.76					
Sub-Total :		**11.08**	**15.74**	**58.70**				
Kromdraai incremental	**RR338**	**1.38**	**0.78**	**20.04**		**6.85**	**3.78**	**2.94**
Bloemhof Incr.	RR340	7.23	1.58		No data	No data	No data	No data
	RR339	39.61	6.92					
	RR341		0.93					
	RR2		4.81					
Sub-Total :		**46.84**	**14.24**	**98.64**				
Middle Vaal		**210.89**	**161.69**	**388.48**				
Difference (*)		**49.20**	**0.00**	**226.79**				

Note : (*) – Difference with regard to Loxton Venn

Table 2.9 : Summary of irrigation water use for the Lower Vaal WMA

Sub-catchment	Irrigation module no. or file name (WRPM)	VRSAU Study WRYM & WRPM Net Water Use (million m³/a)	Loxton Venn Study (1999)Theoretical Crop water use (million m³/a)	WARMS data (million m³/a)
Upper Harts	357	1.21		
	360	3.62		
	362	1.2	0.92	
Upper Harts Sub-total		**6.03**	**0.92**	**0.14**
Middle & Lower Harts	376	1.5		
	HartU7.abs	0.36		
	HartDSP.abs	0.61	12.81	
Middle Harts Sub-total		**2.47**	**12.81**	**1.17**
Vaal u/s Vaalharts Weir	397	61.45	32.2	13.88
Vaal d/s Vaalharts u/s Douglas	405	43.05	59.78	32.25
Vaalharts Scheme (canals)	370+379+383	350.47	354.13	365.28
Vaalharts & Lower Vaal Sub total		**454.97**	**446.11**	**411.41**
Lower Vaal		**463.47**	**459.84**	**412.72**
Difference		**3.63**	**0.00**	**-47.12**
Total Vaal River Catchment		**901.86**	**763.03**	**1,374.64**
Difference (*)		**138.83**	**0.00**	**611.61**

Note : (*) – Difference with regard to Loxten Venn

Table 2.10: Status of Validation Process in the Vaal Dam Catchment

QUAT	Number of Properties			% Outstanding
	Validation completed	Outstanding	Total	
C11	363	219	582	37.63
C12	366	157	523	30.02
C13	101	30	131	22.90
C81	179	25	204	12.25
C82	216	34	250	13.60
C83	533	176	709	24.82
Total	**1758**	**641**	**2399**	**26.72**

From the Upper Vaal WMA comparison, it is clear that the registered volumes from the WARMS data provided a total overestimation of the actual irrigation development as it is more than 2.6 times that of the validated 1998 volume. The WARMS volume is approximately 430 million m³/a more than that currently simulated in the WRPM. It is also important to note that a large growth in irrigation occurred between 1998 and 2005, representing an increase of almost 170 million m³ or a 76% of the 1998 volume. It is interesting to note that the 1998 validated volume is fairly close to the 1995 irrigation volume obtained from the VRSAU Study, and that the law-full volume is close to the volume determined by the Loxton Venn Study (See **Figure A-3** in **Appendix A**).

Table 2.11: Status of Validation Process in the catchment Vaal Dam to Mooi River

QUAT	Number of Properties			
	Validation completed	Outstanding	Total	% Outstanding
C21B	21	13	34	62
C21C	12	8	20	60
C21D	17	21	38	45
C21E	35	17	52	67
C21F	15	12	27	56
C21G	30	27	57	53
C22A	4	23	27	15
C22B	16	24	40	40
C22C	15	17	32	47
C22D	9	39	48	19
C22E	107	68	175	61
C22F	39	27	66	59
C22G	5	1	6	83
C22H	4	20	24	17
C22J	35	43	78	45
C22K	98	195	293	33
C23A	3	1	4	75
C23B	44	19	63	70
C23C	93	41	134	69
C23D	13	19	32	41
C23E	43	32	75	57
C23F	28	12	40	70
C23G	9	139	148	6
C23H	12	96	108	11
C23J	54	33	87	62
C23K	26	114	140	19
C23L	92	206	298	31
Total	**879**	**1267**	**2146**	**41**

Table 2.12: Summary of validated and extended validated irrigation data in Upper Vaal WMA

Sub-catchment	Total Estimated (Validated & Extended)			Validated data			Extended from Validated		
	Suggested 2005 (million m³/a)	Suggested 1998 (million m³/a)	Possible Existing Lawful Use (million m³/a)	Suggested 2005 (million m³/a)	Suggested 1998 million m³/a)	Possible Existing Lawful Use (million m³/a)	Suggested 2005 (million m³/a)	Suggested 1998 (million m³/a)	Possible Existing Lawful Use (million m³/a)
Grootdraai	29.54	17.91	12.26	18.46	11.19	7.66	11.08	6.72	4.6
DELANGESDRIFT	**9.91**	**4.4**	**2.79**	**7.62**	**3.38**	**2.15**	**2.29**	**1.02**	**0.64**
Frankfort									
	44.70	18.32	17.49	36.78	15.03	14.12	7.92	3.29	3.37
	1.66	1.05	0.98	1.37	0.86	0.79	0.29	0.19	0.19
	67.13	27.49	26.26	55.24	22.55	21.20	11.89	4.94	5.05
Sub-Total :	**113.49**	**46.86**	**44.73**	**93.39**	**38.44**	**36.12**	**20.10**	**8.42**	**8.61**
Vaal									
	28.68	15.91	6.335	20.51	11.2	5.05	8.17	4.71	1.285
	86.05	47.74	19.005	61.55	33.59	15.15	24.5	14.15	3.855
Sub-Total :	**114.73**	**63.65**	**25.34**	**82.06**	**44.79**	**20.2**	**32.67**	**18.86**	**5.14**
Suikerbosrand	14.54	7.89	3.75	8.63	4.67	2.18	5.91	3.22	1.57
Sub-Total :	**14.54**	**7.89**	**3.75**	**8.63**	**4.67**	**2.18**	**5.91**	**3.22**	**1.57**
Klip	**27.12**	**19.42**	**7.9**	**11.52**	**8.36**	**3.89**	**15.6**	**11.06**	**4.01**
Riet (BARR9)	**28.69**	**15.3**	**10.32**	**12.66**	**6.26**	**4.96**	**16.03**	**9.04**	**5.36**
Mooi : Klerkskraal Dam	**0.02**	**0.02**	**0**	**0.01**	**0.01**	**0**	**0.01**	**0.01**	**0**
Mooi : Boskop Dam									
Sub-Total:	**3.68**	**0.32**	**0**	**1.01**	**0.15**	**0**	**2.67**	**0.17**	**0**
Mooi GWS	**35.27**	**35.27**	**35.27**	**35.27**	**35.27**	**35.27**	**0**	**0**	**0**
Mooi :Klipdrift Dam	1.21	0.88	0.44	0.75	0.55	0.27	0.46	0.33	0.17
	7.12	7.12	7.12	7.12	7.12	7.12	0	0	0
Sub-Total :	**8.33**	**8**	**7.56**	**7.87**	**7.67**	**7.39**	**0.46**	**0.33**	**0.17**
Upper Vaal sub-total	**385.32**	**219.04**	**149.92**	**278.50**	**160.19**	**119.82**	**106.82**	**58.85**	**30.10**
% of total estimated	**100**	**100**	**100**	**72**	**73**	**80**	**28**	**27**	**20**

To provide some indication of the current validated irrigation volumes and the volumes added to extend the volumes to be representative of 100% of the properties located in the Upper Vaal WMA, an additional table was prepared (see **Table 2.12**) and included for comparison purposes.

Although the Kromdraai sub-catchment is physically located in the Upper Vaal WMA, it is considered as part of the Bloemhof Dam sub-catchment in the WRPM and WRYM models. This sub-catchment was therefore included in the Middle Vaal WMA summary table (See **Table 2.8**). For the Middle Vaal WMA the registered water use from the WARMS is 227 million m³ more than that currently used in the WRPM. This is not as excessive as in the Upper Vaal WMA but is still a large volume and is 2.4 times of that currently used in the water resource models. Two smaller studies, the recently completed Schoonspruit and Renoster studies provided more up to date information on the irrigation developments in the two sub-catchments and were included in **Table 2.8** for comparison purposes.

It is only in the Lower Vaal WMA where the registered volume from the WARMS data base was lower than that from the other data sources. The difference was however relatively small, approximately 10%, with regards to the Loxton Venn and VRSAU study volumes. For the total Vaal River catchment, excluding the Riet/Modder catchment, the WARMS provides an irrigation volume of 1 375 million m³/a, which is 612 million m³ more than that currently used in the models.

2.4. Selection of data to be used in this study

2.4.1. Selection process followed

The validation of irrigation development in the Upper Vaal WMA already showed that the registered data provides in most cases a total over estimation of the actual situation, and can therefore not be relied upon. It was therefore necessary to improve the irrigation data for the Middle and Lower Vaal WMAs. The data from the Validation Verification study provided the best data currently available for the Upper Vaal WMA and need not to be improved at this stage. Meetings were set up with the DWAF Regional offices in Bloemfontein and Kimberley as well as with the Irrigation Scheme manager at the Vaalharts Irrigation Scheme, to discuss the data from the different data sources as summarised in **Table 2.8 & 2.9**. Based on their experience and knowledge of the irrigation schemes and catchments, the most appropriate irrigation volume was selected for use in this study and in some cases more accurate and recent data were provided. The current scheduled areas and quotas for each of the irrigation schemes were also obtained from them. The total irrigation volume for most of the schemes included in the final recommended data is therefore based on the scheduled area times the quota.

2.4.2. *Final selected data*

The irrigation data selected for the Upper Vaal WMA is that obtained from the Verification Validation study, as this is the best data currently available. It will however be important to update this data again, as soon as the validation process has been fully completed as well as when the verification process, which will still take some time, has been completed. The law-full use can typically be used as a low scenario, with the 2005 development as a high scenario (see **Table 2.7**). Due to the large growth in irrigation between 1998 and 2005 one can expect that the growth will still continue for some time until sufficient measures had been put in place and actions had been taken to eradicate the illegal water use in the catchments.

The recommended irrigation volumes to be used in this study for the Middle Vaal WMA, are provided in **Table 2.13**. The mining developments in the Renoster catchment resulted in the buying out of irrigation water rights to satisfy the growing mining water requirement, therefore the decrease in the volume for the Renoster catchment. The recommended irrigation volume is 71.6 million m³/a higher than the volume currently used in the water resource models, and is significantly less than the 227 million m³/a difference shown for the WARMS data. The total recommended volume is however very close to that obtained from the VRSAU study.

Recommended irrigation volumes for the Lower Vaal WMA are summarised in **Table 2.14** with detail of the Vaalharts Irrigation Scheme given in **Table 5.1 in Section 5.2.1**. The irrigation volumes obtained from the different data sources for the Lower Vaal WMA is very similar and the recommended value is between the WARMS volume and that currently used in the water resource models. The fact that not all the allocated irrigation areas within the Vaalharts and Taung irrigation schemes is currently developed or utilised, is the main reason for the recommended irrigation volume to be approximately 6% lower than that currently used in the models. In the Taung Irrigation Scheme 2 660ha of the allocated 6 424ha is not yet developed and 150ha of the Ganspan Settlement in the Vaalharts scheme is not currently utilised.

The recommended irrigation volume for 2005 development level for the total Vaal River catchment is approximately 290 million m³/a higher than that currently used in the WRPM simulations. This is a substantial volume and will certainly have a significant impact on the water supply situation in the Vaal River system. At the 2005 development level there is already approximately 235 million m³/a of illegal irrigation abstractions within the Upper Vaal

Table 2.13: Recommended irrigation volumes for use in the Vaal River Reconciliation Study for Middle Vaal WMA

Sub-catchment	Irrigation module no.WRPM	VRSAU Study WRYM (million m³/a)	Loxton Venn Study (1999) WRPM (million m³/a)	WARMS data (million m³/a)	Description of Irrigation based on WRYM and WRPM configurations	Other Sources (million m³/a)	Recommended 2005 Water use (million m³/a)
Schoonspruit	Diffuse : RIETS9	1.04	0.00		Diffuse irrigation upstream of Rietspruit Dam	0.07	0.07
	RR22	12.77	10.44		Irrigation supplied from Rietspruit & Elandskuil Dams and Schoonspruit Canal	18.68	18.68
	RR23	3.35	4.17		Irrigation from small dams in the sub-catchment in tributaries	2.46	2.46
	RR24	2.89	2.34		Irrigation directly from the main streams in tributaries	2.31	2.31
	RR25	13.80	9.14		Irrigation supplied from Johan Neser Dam & directly from river in Klerksdorp IB area	10.25	10.25
Sub-Total :		**33.85**	**26.09**	**31.16**	**Total from Schoonspruit Study**	**33.77**	**33.77**
Renoster #	Diffuse : KOP9	1.97			Diffuse irrigation upstream of Koppies Dam		
	Diffuse : RIETF9	9.60			Diffuse irrigation within the posible Rietfontein Dam incremental catchment	4.28	4.28
	RR15	1.31			Irrigation from small dams upstream of Koppies Dam	2.4	2.4
	RR16				Irrigation from the main stream upstream of Koppies Dam	0.66	0.66
	RR17	2.33	3.39		Irrigation from small dams within the posible Rietfontein Dam incremental catchment	3.57	3.57
	RR18		13.55		Irrigation from the main stream within the posible Rietfontein Dam incremental catchment Koppies GWS	10.68	5.8
Sub-Total :		**15.21**	**16.94**	**35.96**	**Total from Koppies Study**	**21.59**	**16.71**
Vals	Diffuse	14.85			Diffuse irrigation within the possible Klipbank Dam catchment	No data	
	RR333				Irrigation supplied from Serfontein Dam		
	RR332	7.35	0.75		Irrigation from small dams within the possible Klipbank Dam incremental catchment		6.47
	RR334		1.08		Irrigation from the main stream within the possible Klipbank Dam incremental catchment		23.28
Sub-Total :		**22.20**	**1.83**	**29.75**			**29.75**

Sub-catchment	Irrigation module no.WRPM	VRSAU Study WRYM (million m³/a)	Loxton Venn Study (1999) WRPM (million m³/a)	WARMS data (million m³/a)	Description of Irrigation based on WRYM and WRPM configurations	Other Sources (million m³/a)	Recommended 2005 Water use (million m³/a)
Sand/Vet Allemanskraal	Diffuse : ALLEM9	1.17			Diffuse irrigation within the Allemanskraal Dam catchment		1.15
	RR30	2.91			Irrigation from small dams within the Allemanskraal Dam catchment		6.38
	RR26	32.44	39.67		Irrigation supplied from the Allemanskraal Dam	No data	36.99
Sub-Total :		**36.52**	**39.67**	**44.52**			**44.52**
Erfenis Dam#	Diffuse : ERF9	1.28			Diffuse irrigation within the Erfenis Dam catchment		1.28
	RR331	3.25			Irrigation from small dams within the Erfenis Dam catchment	No data	3.25
	RR27	39.28	46.40		Irrigation supplied from Erfenis Dam		39.28
Sub-Total :		**43.81**	**46.40**	**69.71**			**43.81**
Sand/Vet # incremental catchment	Diffuse : SAND9	6.83			Diffuse irrigation within the Sand/Vet incremental catchment		1.28
	RR28	4.25	5.98		Irrigation from small dams within the Sand/Vet incremental catchment	No data	0.46
	RR29		9.76		Irrigation from the main stream within the Sand/Vet incremental catchment		9.34
Sub-Total :		**11.08**	**15.74**	**58.70**			**11.08**
Kromdraai incremental	**RR338**	**1.38**	**0.78**	**20.04**	Irrigation from small dams within the possible Kromdraai Dam incremental catchment		**6.85**
Bloemhof Incr. #	RR340	7.23	1.58		Irrigation from small dams (a) within the Bloemhof Dam incremental catchment		7.23
	RR339	39.61	6.92		Irrigation from the Vaal main stream in the Bloemhof Dam incremental catchment u/s of Schoonspruit confluence	No data	39.61
	RR341		0.93		Irrigation from small dams (b) within the Bloemhof Dam incremental catchment		
	RR2		4.81		Irrigation from the Vaal main stream in the Bloemhof Dam incremental catchment d/s of Schoonspruit confluence		
Sub-Total :		**46.84**	**14.24**	**98.64**			**46.84**
Middle Vaal		**210.89**	**161.69**	**388.48**			**233.33**
Difference		**49.20**	**0.00**	**226.79**			**71.64**

Table 2.14: Recommended irrigation volumes for use in the Vaal River Reconciliation Study for Lower Vaal WMA

Sub-catchment	Irrigation module no.WRPM	VRSAU Study WRYM & WRPM (million m³/a)	Loxton Venn Study (1999) (million m³/a)	WARMS data (million m³/a)	Description of Irrigation based on WRYM and WRPM configurations	Recommended 2005 Water use (million m³/a)
Upper Harts	357	1.21			Wentzel Dummy Dam	1.21
	360	3.62			Mainstream Irr u/s Wentzel	3.62
	362	1.2	0.92		Wentzel Dam Irr terminated	0
Sub-total		**6.03**	**0.92**	**0.14**		**4.83**
Middle & Lower Harts	376	1.5			Spitskop Dummy Dam	1.5
	HartU7.abs	0.36			Mainstream Irr Taung to Spitskop	3.19
	HartDSP.abs	0.61	12.81		Irrigation supplied from Spitskop	12.81
Sub-total		**2.47**	**12.81**	**1.17**		**17.5**
Vaal u/s Vaalharts Weir	397	61.45	32.2	13.88	Mainstream Irr Bloemhof to Vaalharts Weir	27.27
Vaal d/s Vaalharts u/s Douglas	405	43.05	59.78	32.25	Mainstream Vaalharts Weir to Vaal Riet confluence	59.79
Vaalharts Scheme (canals)	370+379+383	350.47	354.13	365.28	Vaalharts Weir Canals	327.82
Sub total		**454.97**	**446.11**	**411.41**		**414.88**
Lower Vaal		**463.47**	**459.84**	**412.72**		**437.21**
Difference		**3.63**	**0.00**	**-47.12**		**-22.63**
Total Vaal		**901.86**	**763.03**	**1,374.64**		**1,055.86**
Difference		**138.83**	**0.00**	**611.61**		**292.83**

Notes: # - These irrigation demands represent the net requirement (gross – returns flows) the rest is gross demands. Whether gross or net demands is used in the WRYM & WRPM model depends on the way it is configured in the model

WMA. If these are removed, the higher volume of 290 million m³/a will be significantly reduced to only 55 million m³/a.

2.5. Irrigation from Groundwater

Only irrigation from surface water is currently included in the water resource models and it was not the intention of this study to include irrigation from ground water resources. Irrigation from ground water was however addressed as part of the Verification Validation study for the Upper Vaal WMA and information in this regard was available for the Upper Vaal WMA and therefore included in this report.

Table 2.15: Irrigation volumes from ground water in Vaal Dam catchment

Catchment	Verification Validation Study (million m³/a)			
	Validated data		Extended Validated data	
	1998	Current	1998	Current
Grootdraai	0.52	0.60	0.83	0.95
Delangesdrift	0.01	0.05	0.01	0.06
Frankfort	0.17	0.44	0.22	0.59
Vaal	0.05	0.18	0.07	0.24
Total	**0.75**	**1.27**	**1.13**	**1.84**

Irrigation from ground water sources in the Vaal Dam catchment is very limited as evident from **Table 2.15**. The growth from 1998 to current (2005) of almost 70% is however quite significant although the associated volumes are relatively small. As the validation process is not yet completed for all the properties in the Upper Vaal WMA, the current available validated data were extended to represent a 100% coverage of the area. The methodology followed to do this, is as described for the surface water irrigation use.

Irrigation from groundwater in the remainder of the Upper Vaal WMA (Vaal Dam to the Mooi River confluence, Mooi River catchment included) is far more substantial than that upstream of Vaal Dam. The growth from 1998 to 2005 of 50% is less than that observed for the area upstream of Vaal Dam, but represents a much larger volume. The irrigation from groundwater in the remainder of the Upper Vaal WMA below Vaal Dam, amounts to more than 50% of the 2005 development level surface water irrigation.

Table 2.16: Irrigation volumes from ground water downstream of Vaal Dam to the Mooi River confluence

Catchment	Verification Validation Study			
	Validated data		Extended Validated	
	1998	Current	1998	Current
Part of Bloemhof incr	1.09	2.54	4.35	15.81
Mooi: Klipdrift	0.57	0.77	0.92	1.24
Mooi: Klerkskraal	2.33	2.93	3.33	4.19
Kromdraai	0.21	0.90	0.29	1.29
Mooi: Boskop	5.14	7.10	9.99	14.83
Barrage	0.39	0.47	0.71	0.85
Klip	6.55	9.29	11.85	17.33
Suikerbosrand	1.54	2.52	2.43	3.82
Total	**17.82**	**26.54**	**33.87**	**59.36**

3. ECONOMIC MODEL TO SHOW THE VALUE OF AGRICULTURAL PRODUCTION

3.1. Introduction and Objective

The objective of the economic model is to estimate the economic value of agricultural production in the Vaal catchment area. In order to do this, a mathematical programming model was compiled in order to simulate current agricultural production (2005/2006 production season) in financial terms in the project area. Once this has been achieved, various economic analyses / scenarios can be undertaken.

This section firstly discusses the main elements of the economic model along with the main assumptions of the model. The results of the simulation model and the economic analyses are then discussed.

3.2. Economic model

The objective of the economic model is to simulate in financial terms the agricultural production of the catchment area and then to undertake different scenarios. In order to do this, the amount of land under irrigation needs to be estimated along with the main enterprises grown. The building blocks of the economic model will be the gross margins for the main enterprises. These components are discussed separately below.

3.2.1. Land under Irrigation

The total amount of cropped area from the various irrigation schemes is given in **Table 3.1** below.

Table 3.1: Total Irrigated Cropped Area (ha)

Irrigation Board	Cropped Area (ha)
Upper Vaal	66 763
Middle Vaal	33 868
Lower Vaal	49 395
Total	**150 025**

Note: * - Total cropped area includes lawful and unlawful use

From the above the total amount of cropped area (including a percentage of double cropping) is 150 025 hectares.

The average size of an irrigation unit has been taken into account when estimating the overhead costs for farms.

3.2.2. Main Enterprises

The estimated area for each enterprise in the catchment area is given in **Table 3.2** below. The enterprises are divided into orchard crops and field crops (summer and winter). Some of the lesser grown field crops (e.g. sunflower) have been combined into the other main field crops grown.

Table 3.2: Present cropping patterns (ha)

Region	Citrus	Table Grape	Maize	Cotton	Pasture /Lucerne	Wheat	Groundnut	Veg.
Upper Vaal	3%	-	70%	-	19%	4%	-	4%
Middle Vaal	2%	-	60%	-	31%	7%	-	7%
Lower Vaal	3%	3%	20%	10%	22%	40%	24%	-

Note: *-The percentages given for the lower Vaal region includes 122% double cropping.

For the purposes of this analysis cabbage and onion is used to simulate vegetable production.

3.2.3. Future production trends

It has been reported that from observations in the area and from discussions with farmers there is a trend to move toward high value crops (e.g. citrus and table grapes). Given the current economics of cotton, it is envisaged that there will be a switch from cotton production to high value orchard crops in the future.

3.2.4. Irrigation System

From past studies and information on the area it has been estimated that only in the Lower Vaal region (Vaalharts Scheme) one still finds a significant amount of flood irrigation (70%). The remaining area is under centre pivot, sprinkler, drip and micro irrigation in the case of orchards.

This has been taken into account when calculating the irrigation costs and pumping costs for the gross margins for the various enterprises. In the Upper and Middle Vaal region there is less than 10% of the area under flood irrigation.

3.2.5. Water requirements and water costs

The water allocation for the irrigation schemes are presented in **Section 2** of this report. The water requirement for each of the enterprises has been estimated using SAPWAT and is also presented **Section 2** of the report.

Table 3.3 below gives the cost of water for various irrigation schemes.

Table 3.3: Cost of Water for Various irrigation Schemes

Irrigation Scheme	Tariff (c/m³/a)
Vaalharts	10.3
Mooi River	9.0
Schoonspruit	10.1
Sand/Vet - Canals	16.3
- River	15.0
Lawful irrigation directly from river (not part of a scheme)**	0.8
Other Irrigation Schemes	
Loskop	10,0
Hereford	9,9
Olifants River	6,5
Selons River	8,0

For the purposes of this analyses, it is assumed that the average cost of water for irrigation purposes is R0,10/m^3.

It should be noted that the total cost for the unlawful use of irrigation water was taken as equal to the current Vaal tariff of R1.90/m^3 (i.e. includes the cost of the Lesotho Highlands water scheme).

3.2.6. Gross Margins

Gross margins represent income from the sale of the produce, less all direct costs that can be allocated to the production of the specific crop. Generalised production programmes have been compiled for each of the proposed enterprises and indicative gross margins from the main crops for the region were calculated. The gross margins for each enterprise have been estimated from production plans and include the following assumptions:

- The gross margins are based on an average farmer in the area and attempt to be representative of a typical farming operation in the region. However in reality, there is a wide range of expertise and experience in farming which results in a wide variation in actual income and costs of enterprises.
- Gross income is based on representative yields and current prices for the enterprise. Where the gross margin applies over a number of years (e.g. citrus) the values are given in constant 2006 rand terms.
- All deductions from gross income such as market agents' commission are included. The market agents' commission on fresh produce is estimated at 12.5% of gross income.
- The gross margin costs include:
  - **input costs** such as seed, chemicals and fertilizer,
  - **mechanical operations** such as ploughing and spraying,
  - **water charges and pumping costs** (an average pumping head of 15 metres is assumed in estimating the energy costs for irrigation),
  - all directly allocated **labour costs** (overhead labour costs such as the farm manager's salary are not included in the gross margin),
  - **packaging and transport** costs to the market,
- A **contingency amount of 5%** of total costs to allow for miscellaneous expenses.

A summary of the gross margins for the selected enterprises is given in **Table 3.4** with a more detailed analysis given in the **Appendix C**. The gross margins show the returns for the specific enterprise at full development, therefore the gross margin shown for citrus is for the seventh year of production.

Also included in the gross margin analysis is the total gross revenue produced at full development per cubic metre of irrigation water. In this way the level of irrigation water use efficiency can be compared for the selected enterprises.

Table 3.4: Summary of indicative gross margins and employment potential for selected field crops (per ha)

Item (Units)	Citrus	Table grape	Maize	Cotton	Wheat	Onion	Cabbage	Pasture Lucerne	Ground-nut
Gross income (R/ha)	46,215	29,658	14,000	8,100	8,370	27,913	38,500	17,100	7,200
Production costs (R/ha)	16,424	66,800	8,243	7,862	4,704	11,513	23,848	11,051	5,833
Gross margins (R/ha)	29,791	62,858	5,757	238	3,666	16,400	14,652	6,049	1,367
Establishment costs (R/ha)	18,806	84,785	0	0	0	0	0	11,052	-
Water Use efficiency (R/ m^3)	1,42	5,18	1,06	0,03	0,95	4,26	3,81	0,6	0,33

Table 3.4 above shows that the orchard enterprises have the highest gross margins, however, they are capital intensive enterprises and have high establishment costs.

3.2.7. Main Assumptions of Model

From the information given in the previous sections an overall model can be compiled that simulates, in financial terms, the agricultural production of the catchment. The main assumptions for the financial analysis are listed below:

- The financial analysis is undertaken over a 20 year period.
- The financial analysis is done in constant 2006 Rand values (therefore projected inflation is not included in the model and the estimated returns should be seen as real returns).
- No residual value or salvage value of the project is included at the end of the project.
- The cost of land and existing infrastructure is not included.
- No finance costs are included in the analysis
- Income and production costs are derived from the gross margin estimates.
- In regard to perennial orchard crops it is assumed that 5% of the total area is established every year, therefore the aging of the enterprise is estimated accordingly. For lucerne it is assumed that 20% of the total area will be established every year.
- Overhead costs have been estimated for each enterprise and is included in the analysis. These include management salaries, general repairs, bank charges, auditing fees etc.

3.2.8. Results of Model

The model was run to estimate the net present value (NPV) of the enterprise areas as given in the previous section. This analysis excludes all existing infrastructure and land costs as this is assumed to be a sunk cost. A summary of the results is given in **Table 3.5.**

Table 3.5: Summary of Results from financial model

Item	Rands (million)
Gross Income	2,253
Direct production Costs	1,329
Gross Margin	923
Overhead Costs	239
Net Income (before finance costs and tax)	684
Net Present Value (Discount rate of 15% over 20 years)	4,285
Water Use efficiency (NPV/total m^3)	R4.40

As can be seen from **Table 3.5** above, agriculture production contributes significantly to the economy of the region. In terms of linkages to other related industries the main production costs can be broken down as shown in **Table 3.6**.

Table 3.6: Breakdown of main production costs

Item	Rands (million)
Seed	90
Chemical	188
Fertilizer	371
Total	**649**

The multiplier effect in the agricultural industry is relatively high compared to other industries and therefore any decrease in the amount of agricultural production will have a significant negative impact on the general economy of the region.

In regards to labour, it is estimated that the amount paid to direct labour costs (unskilled and semi skilled) for the enterprises (R147 million) is equivalent to 15,300 full time jobs at the minimum wage rate. Therefore any decrease in agricultural production will result in a significant decrease of jobs in the region.

A number of economic scenarios have been undertaken with the financial simulation model. These include:

- A scenario was undertaken assuming that the current enterprise mix would change over time. It was assumed that the area under citrus and table grape would increase to 10% of the total cropped area.
- A scenario is undertaken only on estimated lawful use of water. From the study results it is estimated that only 40% of irrigation is lawful in the Upper Vaal region. At this time no information is available on the other regions and it is therefore assumed that 80% of current irrigation is lawful in the Middle Vaal region and 90% in the lower Vaal region.
- It is assumed that there will be a 10% decrease in water allocation for irrigation purposes
- There will be a 10% increase in the water cost for irrigation water.

Table 3.7 below summarises the results of the above scenarios estimating the change in the NPV of the various scenarios compared to the base (simulation) model.

Table 3.7: Summary of results estimating the change in the NPV

Description	NPV (millions)	% change	R/M3 of water	% change
Base model	4,285	-	4,40	-
Increase in higher value crops	4,686	+9.3%	4.59	4.3%
Only estimated lawful use	2,704	-37%	4.24	-3.9%
10% decrease in water allocation	3,856	-10%	4.40	No change
!0% increase in irrigation water costs	4,284	-0,007%	4.40	No change

The base model estimate of R4.40/m^3 can be compared with a similar study undertaken for the Olifants catchment where a figure of R5.59/m^3 was estimated. The reason why the Olifants study is higher is that there is a higher proportion of high value crops (grapes and citrus) grown in the area. However it should be noted that the value in these estimates is not so much in the absolute value but in the relative changes in values when various scenarios/sensitivities are applied. The reason for this is that each farmer will have his own set of specific circumstances especially regarding overhead costs, the above model attempts to simulate the region as a whole and not specific farms.

The reason there is a change in the NPV when comparing lawful use and unlawful use is that there is a difference in the proportion of crops in the different regions and the percentage lawful use is different in each region (i.e. if the percentage lawful use was the same for each region then the NPV would stay the same).

As has been stated earlier the true cost of the unlawful use of irrigation water from the Upper Vaal region is R1.90/m^3. When this water cost is included for the unlawful use portion of irrigation water, then the overall NPV drops to R2.02/m^3. If this cost was brought in and enforced, most of the unlawful irrigation being undertaken in the Upper Vaal region would be unviable.

It should also be noted that one of the main reasons why returns are higher in this analysis as compared to individual return shown by farmers is that this analysis does not include finance costs (e.g. interest) which in many cases is a high proportion of overhead costs for farmers.

From the above it can be seen that agriculture will be contributing significantly more to the economy as farmers' move towards higher value crops; this will also increase water use efficiency. If only lawful use of irrigation water is enforced this will have a catastrophic negative impact on the economy of the region. However if the water cost is increased this leads to an insignificant decrease in the value of agricultural output as it is a relatively small amount in terms of costs of production.

4. ASSESSMENT OF THE POSSIBLE TRADING OF WATER RIGHTS

4.1. Water rights trading worldwide

Trading of water rights has been successfully promoted in a number of countries worldwide in recent years. The purpose of these initiatives is captured by the conclusions reached by an Australian parliamentary committee of inquiry (Parliament of Australia, 2004), which states:

> *"….water trading is a key mechanism in ensuring that water is used more efficiently. Water markets allow industries to make better, and more flexible, use of limited water resources and provide the opportunity for new investment in high value-added agriculture. Trade helps individual irrigators to adjust to changing circumstances and to manage risk. A well-developed water market can stimulate the movement of water to higher value, more sustainable use."*

The Commission recommended that the expansion of water markets and water trading be expanded to the greatest extent possible, as part of Australia's National Water Initiative.

In contrasting economic and environmental circumstances, the UK Environment Agency also endorses water rights trading (Environment Agency, 2003):

> *"We consider that a more efficient allocation of water rights and a greater awareness of the value of water among abstractors have a vital role to play; placing a tradable value on water resources will encourage water rights to move to the person who places the highest value on them and will promote economic efficiency.*
>
> *Water rights trading is expected to:*
>
> - *Provide an incentive for abstractors to invest in water efficiency measures to make surplus water available to trade*
> - *Allow potential abstractors in areas where water would not otherwise be available due to environmental objectives to access water resources currently licensed to other abstractors*
> - *Enable licence holders to manage their water needs more flexibly in response to temporary changes, for example in relation to irrigation needs for different crops*
> - *Allow licence holders to adjust the level of water rights they hold in response to any change in the reliability of their abstraction*
> - *Enable licence holders seeking to retire, restructure or diversify to realise the value of their water rights whilst retaining their land or selling it separately."*

In a research report, the Department for Environment, Food and Rural Affairs (2000) summarised the water trading programmes of countries leading the way in water rights trading.

In Australia and South Africa, water rights trading has tended to focus on agricultural use in conditions where water demand has often equalled or even outstripped the available water resources. Still in its infancy, water trading In South Africa has been mostly geared to the longer term. Under the Orange River Scheme, however, water trading has been arranged on a temporary or permanent basis, following a clearly defined administrative procedure. The main criterion is that the land identified for irrigation is assessed to be suitable for that purpose.

The water market in Australia is well-developed and is characterised by more rapid short-term trading to counter the effects of adverse weather conditions and possible crop failure. Water trading schemes operate in Queensland, South Australia, Victoria and New South Wales. Most trading is water for irrigation and usually takes place through formal exchange and informal agreement using various types of auction and dealer markets.

In Chile and the USA, water rights have been traded between different types of water users, and this has not been restricted to agricultural use. In the USA, water rights and water allocation are the responsibility of State governments and each State has developed its own procedure for transferring water rights. Trading regulations and procedures vary widely, but most appear to be complex, time-consuming and costly. However, those states with active water rights marketing, tend to have rapid turn-around times on applications.

The Chilean process is complicated by the fact that many water rights are not legally enshrined, leading to high transaction costs and the favouring of a more active market for temporary water leases (based on a traditional system of proportional allocation).

It is important to note that, in most countries, the regulatory parameters have been, or are being, framed so that there is an overall balance of water use for the longer term and that the environment is protected.

In England and Wales, changes introduced in the Water Act 2003 have facilitated water rights trading, although some non-formal trading was already possible under the previous legislation (Environment Agency, 2006). In balancing argument, environmental organisations (The Wildlife Trusts, RSBP and WWF, -) comment that, given the background of over-allocation, environmental stress and loss of biodiversity, the prospect of trade increasing the uptake of under-utilised and sleeper licences is of great concern. However, they accept that trade could play a valuable role in re-allocating resources.

Common features of most water rights trading scenarios are the complex mechanisms for trade and transfer, the length of the trading process and the high transaction costs (Department for Environment, Food and Rural Affairs, 2000).

4.2. Water rights trading in South Africa

The concept of trading water rights, both within a specific water use sector (e.g. agriculture) and between sectors (e.g. agriculture to industry), has been investigated for its economic advantages within the South African economy for a number of years.

Promulgation of the National Water Act, Act No. 36 of 1998 (NWA), opened the way for water trading rights to be introduced in South Africa for the first time:

> *"Transfer of water use authorisations*
>
> *25. (1) A water management institution may, at the request of a person authorised to use water for irrigation under this Act, allow that person on a temporary basis and on such conditions as the water management institution may determine, to use some or all of that water for a different purpose, or to allow the use of some or all of that water on another property in the same vicinity for the same or a similar purpose.*
>
> *(2) A person holding an entitlement to use water from a water resource in respect of any land may surrender that entitlement or part of that entitlement -*
>
> *(a) in order to facilitate a particular licence application under section 41 for the use of water from the same resource in respect of other land; and*
>
> *(b) on condition that the surrender only becomes effective if and when such application is granted.*
>
> *(3) The annual report of a water management institution or a responsible authority, as the case may be, must, in addition to any other information required under this Act, contain details in respect of every permission granted under subsection (1) or every application granted under subsection (2)."*

It is interesting to note that water resource planning reports dated after promulgation of the NWA did not necessarily refer to water rights trading as an option. For example, the Vaal River Irrigation Study (1999) quantified agricultural water use in the Vaal River catchment and showed the financial implications of: a) increasing yields through improved crop management, and b) introducing high value crop enterprises. The study did not take the logical extra step to show the financial and economic effects of water rights trading and transfer, firstly within the irrigation sector and shifting crop production patterns, and secondly, between economic sectors, thereby changing the economic characteristics of the region. NB This was however clearly stated in the Internal Strategic Perspectives reports (ISP's) prepared for each WMA.

Based on the provisions of Chapter 4 of the NWA, and following comprehensive public participation throughout the country, DWAF launched the National Water Resource Strategy (NWRS), the first edition being in September 2004. The NWRS gave effect to water rights trading in Chapter 3, Part 2 (Department of Water Affairs and Forestry, 2004):

"3.2.3.12 Transfer of water use authorisations

In section 25 the Act provides for two distinctly different circumstances under which water use authorisations may be transferred.

The first refers to the temporary transfer of water authorised for irrigation, either on the same property for a different use or to another property for the same or a similar use. In the latter case, the two properties may, but need not necessarily be owned by the same person. Although every case will be considered on its merits and within its local context, in general temporary transfers will be granted for one year only, but the user will have the option of applying for an extension of a further year. Applications for permission to affect a transfer must be made to the water management institution that has jurisdiction in the area.

The second circumstance refers to permanent transfers, which may be effected by one user offering to surrender all or part of an allocation to facilitate a licence application by another prospective user. Transfers of this nature constitute trade in water use authorisations, and require new licence applications, which will be subject to all the relevant requirements of the Act relating to applications for licences, including the need for a Reserve determination if one has not already been carried out. Permanent transfers become effective only when the new licence is granted. They may be authorised only by a responsible authority, which may attach different conditions to the new licence than were attached to the surrendered licence. One such condition may be that the new user must pay compensation to the original licence holder.

Transfers, whether temporary or permanent, will only be permitted where both the original and the transferred water use are from the same water resource. Procedures have been developed to deal with such transfers and [NWA] Section 26 regulations may be written to provide a nationally consistent basis for transfers of this nature.

In addition, when land owned by a person to whom a licence has been issued, changes ownership, Section 51 of the Act permits the successor-in-title to continue with the water use under the conditions attached to the licence, provided the responsible authority is promptly informed of the new licensee's name."

The scene has therefore been set for the South African water sector to embark on the trading of water rights with the prospect of:

- Giving value to a scarce commodity
- Using the country's limited water resources more efficiently and sustainably
- Promoting economic water use efficiency through:
  - New investment in high value-added agriculture
  - Switching the use of water, where appropriate, to economically more profitable or strategic or secure industries / water use sectors
- Allowing flexibility in terms of location, time and water use sector
- Managing risk and changing circumstances.

And, at the same time, ensuring that:

- There is an overall balance of water use with available water resource for the longer term
- There is an equitable distribution of water allocation, especially in respect to historically disadvantaged individuals and their social well-being, and
- The environment is protected.

4.3. Water trading as part of water allocation reform

In his foreword to DWAF's Position Paper for Water Allocation reform in South Africa (2005), the Minister: Water Affairs and Forestry stressed the promotion of the beneficial use of water in the best interests of all South Africans. The water allocation process should promote equity, address poverty, generate economic growth and create jobs – as well as ensuring the sustainable use of water resources and promoting the efficient and non-wasteful use of water – all in the public interest.

The Minister emphasised that water allocations, while causing minimal impact on existing lawful water users who are already contributing to development, should promote shifts in water use patterns as long as they are equitable, gradual and carefully considered. DWAF is addressing these challenges by reviewing and developing alternative and creative solutions to water allocation.

The Position Paper stresses that the water allocation process must support Government's poverty eradication and economic development strategic objectives. The paper indicates that the role of water allocation in supporting economic development will increase as water becomes more limiting. It is therefore significant that water trading is listed among those water allocation processes identified for catchments prioritised for compulsory licensing.

4.4. Economic considerations

The management of the allocation of limited water supplies among competing water users and decisions to invest in projects to increase effective water supply [and use] are open to well-known and widely applied economic methods (Freebairn, 2003).

However, the efficiency of the pattern of allocation of water among the different water users will vary over time. Unpredictable rainfall patterns will give rise to variable water supplies. Market product prices will vary. Industries and small enterprises will thrive and fail. Technologies will improve. Social water demands will increase. Environmental needs (the Reserve) will change. In effect, changes in both water supply and water demand in a catchment will require modification in the water allocation pattern from time to time if a balance between social, economic and environmental strategic objectives is to be achieved.

Water rights trading, applied in appropriate circumstances, forms part of the suite of tools that will achieve the social, economic and environmental balance of effective water allocation. Similar to the more traditional methods of water allocation, water rights trading will be measured by its social and economic benefits, and environmental integrity. A range of economic parameters may be used to measure the efficiency of water use, including: returns per hectare, returns per annum, returns per 1000m^3 water used, employment per 1000m^3 water used and possibly the productivity indices.

In assessing the use of employment as a measure of water use efficiency (jobs per 1000m^3 water use), the New Zealand Ministry of Agriculture and Fisheries (2001) warns that the available data is often not sufficiently accurate to assist in water allocation decisions. The margins of error for water use within industries are in some cases sufficiently large that industries are not statistically different from each other. The Ministry suggests that water allocation decisions should be based on reliable information generated for specific industries in specific geographic areas, rather than making use of averages.

It is expected that this approach would apply to all methods of measuring water use efficiency and equally to traditional water allocation and water rights trading.

Developing markets for water rights and water supply systems are improving the way in which water is used (Landry and Anderson, -). Landry and Anderson conclude that water trading provides buyers and sellers with the incentive to conserve water and to bring about equitable and efficient water reallocation. Private sector investment has been spurred and the markets so created are expanding the poor's access to water. Water rights trading is still in its infancy but is expanding rapidly around the world, especially in regions of water scarcity.

4.5. In regard to the Vaal Catchment area

It should be noted from the outset that the information gathered so far indicates that the overwhelming issue in terms of water use is unlawful use especially in the Upper Vaal region. It is obvious that any reference to water rights will only pertain to lawful use which in the Upper Vaal is only equal to 40% of the estimated irrigation water used for agriculture.

It is envisaged that any development of trading of water rights will more than likely be between other sectors of the economy and that a relatively small amount will be traded within agriculture.

The net effect of this will be a reduction in the cropping area. This will also encourage the use of more efficient use of irrigation water which will lead to more efficient irrigation systems and switch to higher value crops.

The medium to long-term effect will be an increase in water costs as a result of a new equilibrium being established for the demand and supply of water. The reason for the increase is that the supply of water is fixed, however with the development of trading of water rights between sectors, this will increase the overall demand in water currently used for agriculture which will result in a shift outwards of the demand curve . However it was shown in the economic analysis that only large increases over the current water cost will have a significant impact on agricultural production.

Trading in water rights will also promote the more efficient use of water within agriculture where the trend should be to move to water efficient crops in the irrigation sector (e.g. maize has a NPV of R1.17 /m^3 compared to grape of R5.27/m^3).

5. MODELLING OF IRRIGATION RETURN FLOWS

5.1. General

Very little or no data is in most cases available regarding any measurements of return flow volumes from irrigation. In most hydrological studies and system analysis 10% of the gross irrigation demand is taken as the typical irrigation return flow volume. More accurate modelling of irrigation return flows is becoming more and more important. This is due to the effect of these return flows on water quality as well as possible reduction in return flows from existing irrigation areas as result of the increasing pressure on the use of more effective irrigation systems. An irrigation return flow model was as result of this need, recently developed as part of the Crocodile (West) River Return Flow Analysis Study and was tested on several irrigation schemes in the Crocodile River Catchment.

As detail information regarding all the components and factors which effect return flows from irrigation are seldom available, an attempt was made to achieve a balance in the model between simplicity and the data available. In the development of the Irrigation Return Flow Model it was therefore aimed to use as the basis for the return flow estimations, data that is frequently available for most irrigation areas. The design of the model is such that different components of the water balance on the irrigation land are modelled explicitly in order to obtain a better understanding of the drivers of water requirements and return flows. Although the model uses a fairly simplified approach and is currently operating through a normal excel spreadsheet, it did provide acceptable results as proven by several test cases analysed as part of the Crocodile (West) River Return Flow Analysis Study.

It was therefore decided to setup the irrigation return flow model for the major irrigation schemes in the Vaal River System, to obtain a better indication and understanding of irrigation return flows in the Vaal River basin. The aim of the model was to also asses the likely impact of WC/WDM measures on the water requirements and return flows and to be used to update the Irrigation Block modules contained in the WRPM. The irrigation schemes selected for this purpose includes:

- Vaalharts and Taung Irrigation Scheme
- Allemanskraal & Erfenis irrigation Schemes which is also referred to as the Sand-Vet irrigation scheme.
- Klerksdorp Irrigation Scheme.
- Schoonspruit Irrigation Scheme.
- Mooi River Irrigation Scheme.

5.2. Description of Irrigation Schemes included for analysis purposes

5.2.1. Vaalharts and Taung Irrigation Schemes

The Vaalharts and Taung irrigation schemes are currently supplied with water from the Vaalharts Weir with support from Bloemhof Dam. Water is diverted from the Vaal River at the Vaalharts Weir into the main canal which feeds into the Klipdam-Barkly, the Western and Northern canals. From the three main canals the water is distributed to the irrigation farmers through a network of secondary and tertiary canals (See **Figure A-4** of **Appendix A**). The total length of canals on the scheme is in the order of 1 140km and all the canals are lined. Water is delivered into lined storage reservoirs on the farms. The weir and the canal system were constructed in 1934/35 and the main canal was upgraded in 1991 to increase the flow rate from 24 to 48 cumec. The system is a demand driven system and the water distribution is controlled by officials of the Vaalharts Water User Association based in Jan Kempdorp.

The Vaalharts North canal delivers water directly to the Taung irrigation scheme. Although the Taung Dam was built to augment the water supply to the Taung Scheme, all the irrigation water is currently still supplied from the Vaalharts canal system.

The Klipdam-Barkley canal is supplying water to smallholdings which are mainly used for cattle and sheep farming. The canal water is supplied to enable the farmers to produce fodder in support of the cattle farming.

A summary of the irrigation areas on the Vaalharts Scheme is given in **Table 5.1**. Although the total area allocated to the resource is 38 537 ha, only 92% or 35 526 ha is currently developed. The total volume allocated to the developed area based on the given quotas, amounts to 327.8 million m^3/a of which 80% is utilised through the Northern & Taung canal, 13% through the West canal and only 7% through the Klipdam-Barkley canal.

Severe water logging problems occurred during the 1970's resulting in high losses in crop production. The above average rainfall during the 1974 to 1976 years contributed to this problem. A comprehensive network of 240 sub-surface drains to combat the water logging problem was installed between the years 1976 and 1979 at an approximate depth of 1.8 m below ground level.

This was followed by the installing of internal drainage systems (mainly pipe drains) and currently approximately 30% of the irrigation areas supplied from the North canal have internal drainage systems and approximately 15% of irrigation areas supplied from the West canal.

Table 5.1: Vaalharts Irrigation Scheme summary of irrigation areas

Canal and irrigation area area description	Total Allocated			Currently developed		
	Area (ha)	Quota (cub. m/ha)	Volume (mcm/a)	Area (ha)	Quota (cub. m/ha)	Volume (mcm/a)
Barkley-Wes Canal	1951.3	11855.0	23.1	1951.3	11855.0	23.1
West canal	4344.0	9140.0	39.7	4344.0	9140.0	39.7
Ganspan settlement	299.8	7700.0	2.3	150.0	7700.0	1.2
Small Farms	123.0	11855.0	1.5	123.0	11855.0	1.5
Sub-total West Canal	**4766.8**		**43.5**	**4617.0**		**42.3**
Main Canal	381.0	7700.0	2.9	180.5	7700.0	1.4
Vaalharts North Block Q & R	1858.6	9140.0	17.0	1858.6	9140.0	17.0
Block A to D	5526.8	9140.0	50.5	5526.8	9140.0	50.5
Block EFG	5528.2	9140.0	50.5	5528.2	9140.0	50.5
Block H	2110.8	9140.0	19.3	2110.8	9140.0	19.3
Block I	2308.5	9140.0	21.1	2308.5	9140.0	21.1
Block J to N	7504.5	9140.0	68.6	7504.5	9140.0	68.6
Vharts Small Farms	176.3	11855.0	2.1	176.3	11855.0	2.1
Sub-total Vaalharts North Canal	**25013.7**		**229.1**	**25013.7**		**229.1**
Sub-total Vaalharts North+Main Canal	**25394.7**		**232.0**	**25194.2**		**230.5**
Taung	6424.0	8470.0	54.4	3764.0	8470.0	31.9
Total	**38536.8**		**353.1**	**35526.5**		**327.8**

5.2.2. Allemanskraal and Erfenis Irrigation Schemes

The Sand-Vet Irrigation Scheme includes both the Erfenis Irrigation Scheme and the Allemanskraal Irrigation Scheme. These schemes are currently supplied with water from the Erfenis Dam and Allemanskraal Dam, respectively. Erfenis Dam supplies water for the irrigation of 5 489 ha; and any excess water at the canal tail end flows into the Vet River. Downstream of the confluence of the Sand and the Vet River, there is another 1 297 ha of irrigation which is mainly supplied directly from the Vet River. During droughts water is also released from Erfenis Dam in support of the river irrigation, on the condition that there is sufficient water available in Erfenis Dam. For the Allemanskraal Scheme, water is diverted from Allemanskraal Dam into the main canal. This canal then splits into two separate canals downstream of the dam supplying water for irrigation on the left and the right banks of the Sand River. Any excess water at the tail ends of these canals flows back to the Sand River. The total irrigation supplied from the Allemanskraal Dam is 5 137 ha.

A summary of the irrigation areas on the Sand-Vet Irrigation Scheme is given in **Table 5.2**. The total area allocated to the resource is 11 923 ha, the total volume allocated to the irrigation areas based on the given quotas amounts to 85.84 million m^3/a of which 46% is utilised through the Vet Canal and 43% through the Sand Canal and the remaining 11% directly from the river. According to the DWAF Bloemfontein Office, the percentage of the time that the canals are normally dry is 5.8%.

Table 5.2: Sand-Vet Irrigation Scheme Summary of Irrigation Areas

Resource	Description	Irrigated Area (ha)	Full Quota (m^3/ha/a)	Irrigation Demand ($10^6m^3/a$)
Erfenis Dam	Irrigation supported from Vet Canal downstream of Erfenis Dam	5 489	7 200	39.52
	Directly from River	1 297	7 200	9.34
Allemanskraal Dam	Irrigation supported from separate Sand Canals (Left and Right Bank) downstream of Allemanskraal Dam	5 137	7200	36.98
Total		**11923**	**7 200**	**85.84**

5.2.3. Klerksdorp Irrigation Scheme

Klerksdorp irrigation scheme was developed around the Johan Neser Dam, which was built in 1914. The major purpose of the dam is to provide water for the irrigation. With time, the water availability has reduced, mainly as result of upstream developments and increasing groundwater abstractions. Currently the average area irrigated is much smaller than the scheduled area, and the only time when the irrigation is not curtailed, is when the dam spills.

Table 5.3 : Klerksdorp Irrigation Scheme – curtailment levels

Johan Neser Dam level	Irrigation curtailment
≥ 100%	0%
50 – 100%	25%
10 – 50%	50%
≤ 10%	100%

There are five sub-areas in the scheme (see also **Figure A-5** in **Appendix A**):

- Irrigation from the Schoonspruit just upstream of Johan Neser Dam;
- Abstractions directly from the dam basin;
- Abstractions via the pipeline from the dam (below the dam);
- Irrigation directly from the canal supplied from the dam (also below the dam); and
- Abstractions from the Schoonspruit below the dam.

Table 5.4 : Klerksdorp Irrigation Scheme - summary of irrigation areas

Irrigation	Total allocated			Currently irrigated from surface resources		
	Scheduled area	Quota vol	Quota vol	Actual area	Quota vol	Actual vol
	[ha]	[m^3/ha/a]	[million m^3/a]	[ha]	[m^3/ha/a]	[million m^3/a]
From Schoonspruit, u/s of JN Dam	1,082.0	6,100	6.600	500.0	6,100	3.050
Directly from dam basin	325.4	6,100	1.985	151.0	6,100	0.921
From pipeline	90.0	6,100	0.549	42.0	6,100	0.256
From canal	136.8	6,100	0.834	65.0	6,100	0.397
From Schoonspruit below dam	47.7	6,100	0.291	22.0	6,100	0.134
TOTAL for scheme	**1,681.9**		**10.260**	**780.0**		**4.758**

The dam is operated by Klerksdorp Irrigation Board.

5.2.4. Schoonspruit Irrigation Scheme

The Schoonspruit Irrigation Scheme originates at the Ventersdorp Eye. A weir has been built to divert the Eye's water into a canal on the Right Bank of the Schoonspruit. Flow over this weir is measured at gauge C2H064. The water that is diverted into the canal is measured at gauge C2H109. The policy of the DWAF is to divert the maximum capacity into this canal (i.e. 3039m^3/h). This Right Bank canal conveys the water to the Ventersdorp Municipality off take as well as to irrigation located further downstream along the canal system. Further, along the canal at Kalkdam the Municipality also abstracts water for agricultural use in the town. The combined maximum legal abstraction rate for the Municipality is set at 400m^3/h.

At the Kalk Dam there is a structure that can reject excess water into the Schoonspruit as well as allowing water to flow underneath the Schoonspruit by means of a siphon (pipes) to a canal on the left bank of the Schoonspruit. This canal now supplies irrigation water up to the Rietspruit Dam (506,7 ha scheduling) as well as supplying water by means of the Elandskuil siphon to the Elandskuil Dam and canal on the Right Bank of the Schoonspruit. All the excess water flows into the Rietspruit Dam.

The Elandskuil Dam supplies water for irrigation of 647,6 ha. The canal system has tail ends that allow any excess water to flow into the Schoonspruit. Because of the small catchment of the Elandskuil Dam, this dam is considered mainly as a balancing dam with its water being supplemented through the Elandskuil siphon.

The Rietspruit Dam supplies water for irrigation by means of a canal system to irrigators on the right and left banks of the Schoonspruit. The canals on the Right Bank are supplied by means of two siphons through the Schoonspruit. The total irrigation for this section is 1279,6 ha. Tailends of the canals also flow back to the Schoonspruit. The quota applicable to the Schoonspruit Scheme is 7700m^3/ha.

Table 5.5: Schoonspruit Irrigation Scheme summary of irrigation areas

Resource	**Description**	**Irrigated Area (ha)**	**Full Quota (m^3/ha)**	**Irrigation Demand (10^6m^3/a)**
Schoonspruit Eye via the Schoonspruit Canal	Irrigation supported from Schoonspruit Canal downstream of Kalkdam and upstream of Rietspruit Dam	506.7	7700.02	3.90
Elandskuil Dam with support from Schoonspruit Eye via Schoonspruit Canal & Elandskuil Siphon	Irrigation supported from Elandskuil Dam	647.6	7704.76	4.99
Rietspruit Dam with support from Schoonspruit Eye via Schoonspruit Canal	Irrigation supported from Rietspruit Dam	1279.6	7689.75	9.84
Total		**2433.9**	**23094.52**	**18.73**

A summary of the irrigation areas on the Schoonspruit Scheme is given in **Table 5.5**. Although the total area allocated to the resource is 2 433.9 ha. The total volume allocated to the irrigation area based on the given quotas, amounts to 18.73 million m³/a, of which 21% is utilised through the Eye canal, 27% through the Elandskuil canal and 53% through the Rietspruit canal. According to the DWAF Ventersdorp Office, the percentage of the time that the canals are normally dry is in the order of 7.7%. The layout of the Schoonspruit Irrigation Scheme is given in **Figure A-6** of **Appendix 6**.

5.2.5. Mooi River Irrigation Scheme

The Mooi River Government Water Scheme consists of four major sources of water, namely:

- Klerkskraal Dam;
- Boskop Dam;
- Lakeside Dam, and
- Gerhard Minnebron Eye.

These components are linked by means of concrete lined canals, referred to as the main canals. There are very few secondary or branch canals.

Overall in the scheme, the average irrigated area from surface sources is much smaller than the scheduled area (the ratio of volume utilized over scheduled is only 49%). There is a significant ground water use in the upper part of the scheme, where dolomitic compartments are located. As a general rule, most of the flow in the scheme (from the Klerkskraal Dam to the confluence with the Vaal River) is diverted through canals to avoid bed losses. The scheme is operated by the DWAF regional office in Potchefstroom. At the time of compilation of this report, no detailed operating rules of the scheme were available.

The locality plan of the scheme is shown on **Figure A-7** of **Appendix A**, and a short description of the scheme is provided below.

The Klerkskraal Dam is located on the Mooi River, on the northern boundary of the scheme. Water from the dam is delivered to irrigation fields via the left and right bank canals. Very limited irrigation is taking place along the left canal, and irrigation fields are situated mainly in its upper reach, just downstream of the dam. The left canal discharges back into the Mooi River, about 9 km upstream of the Boskop Dam.

The right canal supplies water to numerous irrigation fields and at the end discharges into the Mooi River, just a few hundred metres upstream of the Boskop Dam.

The Gerhard Minnebron Eye lies on the left bank of the Mooi River, between the Klerkskraal and Boskop dams. This important source is linked to the scheme with the Gerhard Minnebron canal, which ends about 3 km downstream of Boskop Dam, discharging into the Boskop Dam left canal.

Water from the Boskop Dam is transferred through the right and left bank canals. Flow in the left bank canal is, as mentioned above, also supported by the flow from the Gerhard Minnebron canal. There is very little irrigation in the upper and middle reach of the left canal. It is linked to the Lakeside Dam with a diversion structure, which enables additional support from the canal when necessary. The canal ends to the east of Potchefstroom, where it supplies water to the Vyfhoek irrigation plots. Water in that area is distributed through the pipeline network.

The Boskop Dam right canal has very little irrigation in its upper part. It passes the Lakeside Dam and runs on the western side of Potchefstroom. Only after the urban section the irrigation fields start and are stretched out up to the confluence with the Vaal River.

The last major canal of the scheme starts at the Lakeside Dam and runs along the left bank of the Mooi River. It crosses the Potchefstroom urban area and ends just before the confluence of the Mooi and Vaal Rivers.

Table 5.6 : Mooi River GWS - Major canals

Canal	Length [km]
Klerkskraal Right	41.2
Klerkskraal Left	21.7
Gerhard Minnebron	19.8
Boskop Right	147.4
Boskop Left	47.5
Lakeside	50.4
TOTAL	**328.0**

Table 5.7 : Mooi River GWS - summary of irrigation areas

Component	Total allocated			Currently irrigated from surface resources			Irrigated	Total
	Quota area	Quota vol	Quota vol	Actual area	Quota vol	Actual vol	from GW	irrigated
	[ha]	[m³/ha/a]	[million m³/a]	[ha]	[m³/ha/a]	[million m³/a]	[ha]	[ha]
Klerkskraal Dam RB canal	592.7	7,700	4.564	272.0	7,700	2.094	549.0	821.0
Klerkskraal Dam LB canal	272.7	7,700	2.100	89.0	7,700	0.685	47.0	136.0
Gerhard Minnebron canal	278.3	7,700	2.143	205.0	7,700	1.579	34.0	239.0
Boskop Dam RB canal	1,587.5	7,700	12.224	851.0	7,700	6.553	401.0	1,252.0
Boskop Dam LB canal	907.7	7,700	6.989	492.0	7,700	3.788	85.0	577.0
Lakeside Dam canal	939.2	7,700	7.232	330.0	7,700	2.541	72.0	402.0
TOTAL for Mooi scheme	**4,578.1**		**35.251**	**2,239.0**		**17.240**	**1,188.0**	**3,427.0**

5.3. Brief Description of the Irrigation Return Flow Modelling Process

The conceptual model is structured to be able to accommodate large irrigation schemes with a canal network conveying water to the users as well as to accommodate individual irrigators abstracting water directly from the river. A schematic diagram of the conceptual Irrigation Return Flow Model is given in **Figure A-8** of **Appendix A.** The three main return flow-generating components included in the model are:

- The losses from the irrigation distribution system which is used to convey the water from the source to the users;
- The irrigation application losses associated within the irrigation fields; and
- Leaching practices and over irrigation associated with the irrigation fields.

The model distinguishes between two types of return flows generated from irrigation areas. The first type of return flow is the network throwbacks or tail water from the canal systems. These flows enter the river or natural drainage systems almost directly from a canal outlet, and the quality of the water from these return flows is in most cases the same as that of the irrigation water source. The first type of return flow is only generated from the larger irrigation schemes, where canal systems are used to distribute the irrigation water to the users.

The second type of return flow originates from the losses that occur in the irrigation distribution system and on the irrigation fields. These return flows mainly enter the natural drainage system as seepage through the soil, although provision is also made in the model for return flows directly from surface runoff during irrigation. Return flow from surface runoff typically occurs when soils with a relatively high clay content and resulting low permeability are irrigated. The quality of the seepage water or return flows is generally worse than that of the resource.

As very little or no data is in most cases available regarding irrigation return flows, the model uses data that is frequently available for most irrigation areas to form the base for the return flow estimations. Crop types and total area under irrigation are therefore used as the input data to determine the consumptive crop water use. The crop water requirements were determined by means of the SAPWAT model (WRC: 1999b) and represents the consumptive crop water use.

Both over irrigation and leaching add more water to the irrigation fields than that required by the crops, and have similar effects on the generation of return flows and are therefore also combined in the model.

For the purpose of return flow modelling, the irrigation application efficiency was broken down into two components, as each component has a different mechanism driving the effect on return flows. The *first component* is the irrigation system efficiency. This efficiency refers to losses in the irrigation system from the point where it enters at the side of the irrigation field, to the point just before it enters the soil and in most cases evaporation forms a large component of these losses. The *second component* relates to the distribution uniformity of irrigation applications. This means that in some areas below the sprinkled or irrigated area, the application is above the average and in other areas below the average. The areas where the application is above average can then also contribute to the total volume of return flows.

As part of process (d) in **Figure A-8** in **Appendix A** the total water requirement as obtained from process (b) in **Figure A-8** in **Appendix A**, which includes leaching and over irrigation, will again be increased to take into account the irrigation system efficiency, on farm storage and on farm distribution system losses.

The irrigation requirement is further increased by means of process (f) in **Figure A-8** in **Appendix A** to accommodate the network losses. A portion of the network losses flows back to the river as network throwbacks or tail water and another portion as return flows through seepage. In cases where observed data for the bulk water supply is available, the calculated gross irrigation demand from process (f) in **Figure A-8** in **Appendix A** should be adjusted or calibrated to the observed releases.

The last process before the total return flow (seepage component) can be determined is to adjust the return flows as result of the distance between the return flow generation point and the point where the return flows reach the river or natural drainage system. The Darcy flow equation is used to determine the effect of the soil type, distance from the river as well as the height difference between the irrigation field and the river, on the volume of the return flows that can eventually reach the river or closest natural drainage point.

Based on the knowledge gained, the data obtained and the system descriptions for each of the irrigation schemes to be modelled, the user can adjust the scaling factors accordingly to obtain a better indication of the generated return flows. The model can also be calibrated against observed releases / supply and return flows, if it is available.

5.4. Irrigation Return Flow Model Input Data

5.4.1. General

A brief description of the required data is given in **Table 5.8** in this report. Due to the lack of observed data on return flows it is important to obtain as much data as possible on land use characteristics, management practices, conditions of the systems and overall operations of the irrigation schemes for a better understanding of the schemes as a whole. To this end the data collection exercise mainly focused on this type of information, which is in most cases more readily available. A list of typical data required for this exercise is given in **Table 5.8.**

Most of the initial data and understanding of the irrigation schemes was obtained from the "Vaal River Irrigation Study" report done by Loxton, Venn and Associates in 1999 for the DWAF. This was followed up with visits to some of the schemes, personal discussions with personnel at DWAF Regional offices as well as managers of the irrigation schemes. Information on the physical location of the irrigation areas, distance from and height above the natural drainage points were obtained from 1 in 50 000 maps. The soil data for each of the schemes were obtained from the Agriculture Research Council, Institute for Soil Climate and Water, Pretoria office and is based on the "Land Type Surveyor Staff (1972 –2001) Land Type of South Africa on 1:250 000" scale maps.

Most of the irrigation schemes were able to supply a so-called "Disposal" report, containing monthly information on the canal releases, water use and losses in the main distribution system. Information from these reports was used to determine the typical average releases, water use and different loss components over the last 5 year (approximately) period.

Table 5.8: List of irrigation related data required for this study

No.	Description
1.)	Scheme layout and infrastructure (Canals unlined or lined, balancing dams, pipelines and condition of the water conveyance systems)
2.)	Management and operation of the scheme (including curtailment practices etc.)
3.)	Soil types and depths
4.)	Crop types, amount of double cropping
5.)	Irrigation areas (scheduled, registered, actual, area over/under allocation)
6.)	Location of irrigation areas and distance from natural drainage courses such as rivers, smaller tributaries, etc.
7.)	Installed drainage systems (area location, measured flow)
8.) 8.1) 8.2) 8.3)	<u>On farm systems and operation</u> Distribution system description and irrigation system type On farm storage (type & description, leakage) Irrigation practices such as scheduling, leaching requirements, application rates and frequency, etc.
9.)	Crop yield (yield versus irrigation application according to soils and crops)
10.)	Any flow measurements of gross abstractions, actual water use, return flows, network throwbacks, canal losses, and even experienced estimates, etc.

5.4.2. Vaalharts and Taung Irrigation Schemes

The Vaalharts Irrigation Scheme was for the purposes of the "Disposal Reports" divided into four main components:

- Main canal (381ha)
- Klipdam-Barkley canal (1 951ha)
- West canal (4 767ha)
- North canal (25 014ha)

The North canal was further sub-divided into seven sub-components referring to the main feeder canals used to supply the water from the main canal to the different irrigation blocks.

These sub-components are:

- Feeder canals 1 & 2 supplying irrigation blocks Q & R and is referred to as Zone 1 for the purpose of this study (1 859ha)
- Feeder canals 4 to 7 supplying irrigation blocks A, B, C & D and is referred to as Zone 2 for the purpose of this study (5 527ha)
- Feeder canals 8 to 10 supplying irrigation blocks E, F & G and is referred to as Zone 3 (5 528ha)
- Feeder canal 11 supplying irrigation block H and is referred to as Zone 4 (2 111ha)
- Feeder canal 12 supplying irrigation block I and is referred to as Zone 5 (2 309ha)
- Feeder canals 13 to 17 supplying irrigation blocks J, K, L, M & N and is referred to as Zone 6 (7 504ha)
- Taung sub-canal supplying the Taung Irrigation Scheme located at the downstream end of the North Canal and is referred to as Zone 7 for the purposes of this study (3 764ha)

The Klipdam-Barkley canal is supplying water to farms to the south of the main irrigation area between the Vaal and Harts rivers. These farms are mainly used for cattle and sheep farming and canal water is supplied to enable the farmers to produce fodder for the cattle and or sheep on an approximately 17.2 ha irrigation field per main farm. These irrigation plots are in general located far apart and in most cases not close to the main river. Return flows generated from these areas are regarded as negligible and was therefore not modelled.

The bulk of the irrigation area is supplied from the North canal and most of the return flows will also be generated from this area. Due to the size of this irrigation area it was decided to setup an irrigation return flow model for each of the seven zones as described before. Detail information regarding inflows, losses, water use etc. was available for each of these zones from the "Disposal Reports". A separate model was also setup for the Western Canal.

Summarised data on inflows, water use and the different loss components for the North Canal system is given in **Table 5.9** and for the Western Canal system in **Table 5.10.** This data is based on the average values for the years 2001/02 to 2004/05 as given in the monthly disposal reports. The total volume of water use represents approximately 85% of the volume obtained from the area times the quota, showing that the irrigators are not utilising the full allocation. This is caused by several factors which includes the fact that water tariff starts to increase as soon as the irrigator uses more than 80% of his quota and that a portion of the irrigation fields is left fallow to prevent certain crop related diseases, finally also as result of some irrigators not farming full time. From **Table 5.9** it is evident that the losses from the canal distribution system are on average 33.4%

resulting in 66% of the water being utilised by the irrigation farmers. Depending on the type of irrigation system utilised by the farmer as well as the irrigation practices followed by him, only some of the 66% received by the farmer will in fact be utilised by the crop, due to inefficiencies of the irrigation systems and irrigation practises. Not all the canal loss components will contribute to the seepage return flow component to the Harts River. The contributing loss components will include the efficiency & leakage as well as seepage losses from the canals. These are given in the table as the potential seepage to the river. Similar data is summarised in **Table 5.5** for the Western Canal, showing slightly lower losses of 28.8%.

The inflow to the different zones is based on measured flows and can be used for calibration purposes. This also applies to most of the canal tail end outflows. The monthly irrigation usage is based on the volumes requested by the irrigation farmers. The other loss components are based on estimations.

The canal system was constructed in 1934/35 and is a demand driven system. The total length of canals is approximately 1 140km and due to the age of the canals they are generally in a poor state.

Table 5.9: Summarised data for North Canal

Component	Irrigation area (ha)	Inflow (mcm/a)	Water Use (mcm/a)	Water Use %	Losses: Tail Water (mcm/a)	%	Evaporation (mcm/a)	%	Seepage (mcm/a)	%	Efficiency & Leakage (mcm/a)	%	Total losses (mcm/a)	%	Potensial seep to River (mcm/a)	%
Main Canal	381.2	341.73	4.19	1.2	2.44	0.7	10.39	3.0	10.39	3.0	10.43	3.1	33.65	9.8	20.8	6.1
Zone 1	1858.6	27.22	18.50	68.0	1.04	3.8	2.93	10.8	3.22	11.8	1.22	4.5	8.40	30.9	4.4	16.3
Zone 2	5526.8	49.01	37.07	75.6	1.48	3.0	4.08	8.3	4.08	8.3	2.31	4.7	11.95	24.4	6.4	13.0
Zone 3	5528.2	57.12	43.01	75.3	2.92	5.1	4.67	8.2	4.67	8.2	2.03	3.6	14.29	25.0	6.7	11.7
Zone 4	2110.8	25.46	16.58	65.1	0.80	3.1	3.05	12.0	3.05	12.0	1.99	7.8	8.88	34.9	5.0	19.8
Zone 5	2308.5	27.64	18.27	66.1	1.10	4.0	3.26	11.8	3.26	11.8	1.75	6.3	9.37	33.9	5.0	18.1
Zone 6	7504.5	70.22	54.80	78.0	2.89	4.1	5.08	7.2	5.08	7.2	2.38	3.4	15.43	22.0	7.5	10.6
Zone 7	3764.0	44.67	32.65	73.1	1.14	2.5	3.73	8.4	3.73	8.4	3.42	7.7	12.02	26.9	7.2	16.0
System Total	**28982.6**	341.73	225.06	65.9	13.81	4.0	37.17	10.9	37.17	10.9	25.97	7.6	114.13	33.4	63.1	18.5

Table 5.10: Summarised data for West Canal

Component	Irrigation area (ha)	Inflow (mcm/a)	Water Use (mcm/a)	Water Use %	Losses: Tail Water (mcm/a)	%	Evaporation (mcm/a)	%	Seepage (mcm/a)	%	Efficiency & Leakage (mcm/a)	%	Total losses (mcm/a)	%	Potensial seep to River (mcm/a)	%
Main Canal	4617.0	51.21	36.38	71.0	2.68	5.2	4.39	8.6	4.39	8.6	3.30	6.4	14.76	28.8	7.7	15.0

Table 5.11: Summarised data on crop combinations for the Vaalharts and Taung irrigation schemes

Description	Irrigation Area (ha)	Crop and related (ha)													
		Lucerne (ha)	Maize (ha)	Wheat/Barley (ha)	Potato (ha)	Cotton (ha)	Groundnut (ha)	Vegetables Summer (ha)	Vegetables Winter (ha)	Grapes (ha)	Citrus (ha)	Nuts (ha)	Berries (ha)	Total crop area	Land use %
Vharts	25194	5905	5118	9841	39	2756	5905	20	20	315	394	787	94	31193	124
% of physical area		23.4	20.3	39.1	0.2	10.9	23.4	0.1	0.1	1.3	1.6	3.1	0.4	124	
Taung	3764	263	113	2447	0	0	941	0	0	0	0	0	0	3764	100
% of physical area		7.0	3.0	65.0	0.0	0.0	25.0	0.0	0.0	0.0	0.0	0.0	0.0	100	

Table 5.12: Summarised data typical irrigation systems used on the Vaalharts and Taung irrigation schemes.

Description		Irrigation System Type (% of area)					Total %
		Mech.	Spr	Micro	Drip	Flood	
Loxten Venn (1998)	V Harts	0	15	2	0	83	100
Loxten Venn (1998)	Taung	69	31	0	0	0	100
Current (2006)	V Harts	10	15	3	2	70	100
Current (2006)	Taung	70	25	0	0	5	100

Table 5.13: Crop requirements from SAPWAT in million m/a for three main irrigation areas

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Vaalharts North Canal												
27.30	19.63	13.21	7.25	2.16	2.02	5.42	10.41	19.46	24.96	14.61	21.86	168.29
6,680 m3/ha												
West Canal												
5.00	3.60	2.42	1.33	0.40	0.37	0.99	1.91	3.57	4.57	2.68	4.01	30.84
6,680 m3/ha												
Taung												
2.15	1.35	0.45	0.70	1.13	2.05	1.25	2.35	4.09	4.25	0.34	0.47	20.58
5,468 m3/ha												

The main crops on the Vaalharts Scheme are lucerne, maize, wheat/barley, cotton and groundnuts as shown in **Table 5.11.** Double cropping amounts to approximately 124% of the physical area. For Taung the main crops are wheat/barley, groundnuts and lucerne with almost no double cropping.

The crop requirements were obtained from the SAPWAT model and is summarised in **Table 5.13**. The crop requirement for the North and West canals represents approximately 73% of the quota and that of the Taung Scheme approximately 65% of the quota.

Soil data was obtained from the Agriculture Research Council, Institute for Soil Climate and Water, Pretoria office as well as from previous studies on the Vaalharts Scheme, where detailed drilling investigations and pump tests were carried out to determine the soil characteristics. This includes the report by Gombar and Erasmus (1976) entitled "Vaalharts Ontwateringsprojek" as well as the recent WRC Study (2004) "Quantification of the Impact of Irrigation on the groundwater resource in the Vaalharts Irrigation Scheme" by RG Ellington, BH Usher and GJ van Tonder. Both studies showed significantly higher hydraulic conductivities than those given by the Agriculture Research Council, Institute for Soil Climate and Water. As the information from these studies are based on actual pumping tests and drilling investigations carried out on the Vaalharts Irrigation scheme, and not on generalised information, it was decided to rather use the data based on these two studies. The hydraulic conductivity on the North Canal irrigation area varies between 2m/d to 20m/d with an average of approximately 7.4m/d (See **Figure A-9** of **Appendix A**). The selected K values for the different zones are given in **Table 5.14.**

Table 5.14: Permeability and Hydraulic gradient for different Zones

Irrigation area and Zone	**K value Permeability (m/d)**	**Hydraulic gradient (i – value)**
North canal		
Zone 1	7	0.0083 to 0.0111
Zone 2	3 to 5	0.0047 to 0.0056
Zone 3	6 to 7.5	0.0056 to 0.0074
Zone 4	8.5	0.0061
Zone 5	15	0.0061
Zone 6	7 to 16	0.0050 to 0.0068
Taung		
Zone 7	4	0.0067 to 0.0167
West Canal	4	0.0080 to 0.0100

The conceptual geology as described by Temperley in 1967 is shown in **Figure A-10 of Appendix A**. The geology is predominantly Karoo sedimentary. Very permeable Aeolian Kalahari sands largely overlie the Vaalharts valley with calcretes and alluvial gravels below the sands. Below these sediments lie shales, tillites and mudstones which are almost impermeable. The pre-Cambrian igneous lithologies at the bottom are largely divided between basic lavas of the Ventersdorp Group and granites of the Kameeldoorns Formation and are permeable only where it is weathered and fractured.

5.4.3. Allemanskraal and Erfenis Irrigation Schemes

The Sand-Vet Irrigation Scheme was divided into two main components:

- Vet Canal (5 489 ha)
- Sand Canal (5 137 ha)

The summarised data on inflows, water use and different loss components for the Vet Canal and the Sand Canal are given in **Table 5.15**. The data sourced from the monthly disposal reports unfortunately had a lot of missing data. The data on the canal inflows was therefore sourced from the flow gauges located at the dams at the canal outlets. This data was considered to be more accurate than that given in the monthly disposal reports. Inflows to the Vet and Sand canals are therefore based on the flows recorded at gauges C4H009A01 and C4H007A01, respectively for the period January 1999 to December 2005; note that both gauges had data only up to July 2005.

For the Sand Canal, there are no gauging stations that measure the split in flows into the two separate canals, one on the left and one on the right bank of the Sand River. Therefore in order to get an indication of the split in the flows, the areas irrigated from each of the canals were used as the basis for the split. These irrigation areas, as applicable to the Allemanskraal Scheme, were obtained from the WARMS Database, (**Reference the date of the database**). The disposal reports were used to determine the percentage split between the different water use and loss components. These percentages were then used to determine the average water use and different loss components for both the Vet and Sand Canals.

From **Table 5.15** it is evident that losses from the canal distribution system are on average 32.2%, resulting in 67.8% of the water being utilised by the irrigators. Due to inefficiencies of the irrigation systems and irrigation practises only some of the 67.8% received by the irrigators will in fact be utilised by the crop. Not all the canal loss components will contribute to return flows to the Vet and the Sand rivers.

Table 5.15: Summarised data for Vet Canal and Sand Canal

Component	Irrigation Area	Inflow	Water Use						Losses										Potential Seepage to River	
			Irrigation		Urban		Total Water Use		Tailwater		Evaporation		Seepage		Efficiency & Leakage		Total Losses			
	ha	mcm/a	mcm/a	%	mcm/a	%	mcm/a	%	mcm/a	%	mcm/a	%	mcm/a	%	mcm/a	%	mcm/a	%	mcm/a	%
Vet Canal	4865.0	55.0	30.3	55.0	12.2	22.1	42.4	77.1	2.6	4.8	1.5	2.7	4.3	7.8	4.2	7.6	12.6	22.9	8.5	15.4
Sand Canal (Left Bank)	4195.4	41.6	21.7	52.1	6.7	16.1	28.4	68.2	1.8	4.4	1.5	3.6	4.9	11.8	5.0	12.1	13.2	31.8	9.9	23.8
Sand Canal (Right Bank)	684.6	6.8	3.5	52.1	1.1	16.1	4.6	68.2	0.3	4.4	0.2	3.6	0.8	11.8	0.8	12.1	2.2	31.8	1.6	23.8
Total	9745.0	103.4	55.5	53.7	20.0	19.3	75.4	73.0	4.7	4.6	3.2	3.1	10.0	9.7	10.0	9.7	27.9	27.0	20.0	19.3

Table 5.16: Summarised data on crop combinations for the Sand-Vet Irrigation Scheme

Irrigation Area (ha)	Vegatables (winter)	Vegatables (summer)	Wheat	Lusern	Maize	Sunflower	Potatoes	Ground Nuts	Total Area (ha)
11042	94.4	94.4	7762.5	587.4	8601.7	482.5	1468.6	1888.2	**20979.8**
% of total area	0.45	0.45	37	2.8	41	2.3	7	9	100.00

Table 5.17: Summarised data on typical irrigation systems used on the Sand-Vet Irrigation Scheme

Irrigation Area	Irrigation System Type (% of area)		Total (%)
	Pivot	Sprinkler	
Sand-Vet Scheme	80	20	100

Table 5.18: Crop requirements from SAPWAT in million m/a for the irrigation areas in the Sand-Vet Scheme

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Sand-Vet Scheme 5446 m^3/ha/a	6.178	7.729	8.479	5.913	3.587	1.948	3.497	4.976	7.273	7.825	0.554	2.181	60.140

Table 5.19: Detailed Land Type Information for the Sand-Vet Scheme

LAND TYPE	Permeability and Depth Classes													NO SOIL	DOM CLASS	DOM PERC	DOM CLAY	DOM DEPTH	Depth Limiting Classes							
	A1	B1	B2	B3	C1	C2	C3	D1	D2	D3	E1	E2	E3						DLM1	DLM2	DLM3	DLM5	DLM7	DLM8	DLM9	DL
Ai6	0	89.2	2.8	0	0	0	2.0	0	0	5.0	0.0	1.0	0.0	0.0	B1	89.21	B	1	88.0	0.0	0.0	0.0	5.0	5.0	2.0	0.0
Ae40	8.3	83.7	1.0	2.0	0	0	0.0	0	3.0	2.0	0.0	0.0	0.0	0.0	B1	83.72	B	1	2.0	0.0	1.0	0.0	2.0	0.0	3.0	92.0
Dc4	0	2.9	0.0	11.1	5.1	0	2.9	0	0	39.6	0.0	21.1	0.0	17.2	D3	39.60	D	3	40.2	0.0	0.0	0.0	39.6	0.0	10.1	0.0
Ai5	0	89.2	2.8	0.0	0	0	2.0	0	0	5.0	0.0	1.0	0.0	0.0	B1	89.21	B	1	88.0	0.0	0.0	0.0	5.0	5.0	2.0	0.0
Ae38	8.3	83.7	1.0	2.0	0	0	0.0	0	3.0	2.0	0.0	0.0	0.0	0.0	B1	83.72	B	1	90.4	0.0	0.0	2.8	3.8	0.0	3.0	0.0
Bd20	0	65.7	24.8	0.0	0	0	0.0	0	0.4	1.2	0.0	1.4	6.6	0.0	B1	65.70	B	1	9.7	0.4	0.0	24.8	6.5	0.0	1.3	57.4
Ah20	0	76.4	0.8	4.8	9.0	0	0.0	0	4.0	4.9	0.0	0.0	0.0	0.0	B1	76.40	B	1	75.4	0.0	5.9	0.8	4.9	8.9	4.0	0.0
Dc8	9.4	11.0	0	0.0	8.9	0	0.0	0	0	11.3	31.5	0.0	22.9	5.0	E1	31.48	E	1	23.8	25.8	0.0	0.0	34.2	0.0	7.7	3.5
Dc12	0	0	0.4	17.2	0.0	3.3	6.7	0	0	4.3	0.0	8.7	53.6	5.8	E3	53.59	E	3	44.5	0.0	0.0	4.3	48.0	0.0	2.2	0.0
Bc30	0	10.7	1.9	2.7	17.4	37.4	0.0	0	2.0	23.2	0.0	0.0	0.0	4.6	C2	37.44	C	2	9.5	0.0	1.9	66.3	2.9	0.0	2.0	17.4
Da1	0	0	0	19.2	0	22.5	2.0	0	0	7.0	0.0	11.5	24.3	13.6	E3	24.25	E	3	57.3	0.0	8.4	0.0	29.3	0.0	5.0	0.0
Bd20	0	65.7	24.8	0	0	0	0	0	0.4	1.2	0.0	1.4	6.6	0.0	B1	65.70	B	1	9.7	0.4	0.0	24.8	6.5	0.0	1.3	57.4
Bd20	0	65.7	24.8	0	0	0	0	0	0.4	1.2	0.0	1.4	6.6	0.0	B1	65.70	B	1	9.7	0.4	0.0	24.8	6.5	0.0	1.3	57.4

Bd20	0	65.7	24.8	0	0	0	0	0	0.4	1.2	0.0	1.4	6.6	0.0	B1	65.70	B	1	9.7	0.4	0.0	24.8	6.5	0.0	1.3	57.4
Bd20	0	65.7	24.8	0	0	0	0	0	0.4	1.2	0.0	1.4	6.6	0.0	B1	65.70	B	1	9.7	0.4	0.0	24.8	6.5	0.0	1.3	57.4
Bd20	0	65.7	24.8	0	0	0	0	0	0.4	1.2	0.0	1.4	6.6	0.0	B1	65.70	B	1	9.7	0.4	0.0	24.8	6.5	0.0	1.3	57.4
Bd20	0	65.7	24.8	0	0	0	0	0	0.4	1.2	0.0	1.4	6.6	0.0	B1	65.70	B	1	9.7	0.4	0.0	24.8	6.5	0.0	1.3	57.4
Dc12	0	0.0	0.4	17.2	0	3.3	6.7	0	0	4.3	0.0	8.7	53.6	5.8	E3	53.59	E	3	44.5	0.0	0.0	4.3	48.0	0.0	2.2	0.0
Bd20	0	65.7	24.8	0.0	0	0	0	0	0.4	1.2	0.0	1.4	6.6	0.0	B1	65.70	B	1	9.7	0.4	0.0	24.8	6.5	0.0	1.3	57.4
Ea40	0	0	0	28.6	1.5	0	0	0	0	24.8	0.0	29.2	7.2	8.7	E2	29.16	E	2	85.7	1.5	0.0	0.0	11.3	0.0	1.0	0.0
Ea40	0	0	0	28.6	1.5	0	0	0	0	24.8	0.0	29.2	7.2	8.7	E2	29.16	E	2	85.7	1.5	0.0	0.0	11.3	0.0	1.0	0.0
Ca22	0	0	2.8	4.0	0	13.9	0	0	0	14.3	0.0	7.1	56.2	1.7	E3	56.21	E	3	18.9	0.0	0.0	22.9	55.5	0.0	2.8	0.0
Ea41	0	0	0	12.4	0	0.0	0	0	0	15.6	2.3	0.0	31.7	38.1	No soil	38.10	No soil	No soil	63.5	2.3	0.0	0.0	33.4	0.0	0.0	0.0
Ca22	0	0	2.8	4.0	0	13.9	0	0	0	14.3	0.0	7.1	56.2	1.7	E3	56.21	E	3	18.9	0.0	0.0	22.9	55.5	0.0	2.8	0.0
Ca22	0	0	2.8	4.0	0	13.9	0	0	0	14.3	0.0	7.1	56.2	1.7	E3	56.21	E	3	18.9	0.0	0.0	22.9	55.5	0.0	2.8	0.0
Dc16	0	0	0	0	0	0	10.4	4.8	0	2.5	0.0	18.3	55.3	8.8	E3	55.27	E	3	39.9	4.8	0.0	2.5	50.8	0.0	0.0	0.0

The loss components contributing to return flows typically include the efficiency, leakage and seepage losses from the canals. These are listed in the **Table 5.15** as the potential seepage to the river.

The main crops on the Sand-Vet Scheme are Maize, Wheat, Ground Nuts and Potatoes (See **Table 5.16**). The quota from the Vet canal is 39.52 million m^3/a, and for the Sand Canal the quota is 36.98 million m^3/a, while the irrigation water use from the Vet canal and Sand canal is 30.3 million m^3/a, and 25.20 million m^3/a, respectively. The average irrigation water use from the Vet canal therefore is 77% and only 68% from the Sand canal scheme.

Data on typical irrigation systems used in the scheme is shown in **Table 5.17.** This data was obtained from the Agro-Economic Assessment Report for the Sand-Vet Water User Association, prepared by Greyling & CO INC. Crop Requirements were obtained from the SAPWAT model and are summarised in **Table 5.18**.

Soil data was obtained from the Agriculture Research Council, Institute for Soil Climate and Water, Pretoria office. Two soil textural classes are observed in the scheme i.e. Clay and Sandy Loam. The permeability and depth classes for the Sand-Vet Scheme are given in **Table 5.19**. A permeability class B can for example be combined with a depth class 1 and will then be represented by the symbol B1. Land type Dc8 is taken as an example to explain the meaning of the various elements given in **Table 5.19**. Soils permeability classes A, B, C, D and E are found in this land type, with the dominant permeability being class E1 as 31.48% of the soils in this land type has a permeability class E which represents a permeability of approximately 0.1 m/day and a clay percentage of above 40%. The dominant soil depth is class 1. The depth limiting classes that are found in land type DC8 include DLM1, DLM2, DLM7, DLM9, DLM11 and DLM12 and the dominant class is DLM7.

5.4.4. Klerksdorp Irrigation Scheme

No water balance was available for the scheme, as the Irrigation Board does not keep any reliable records on water use and all other related flows.

In the irrigation return flow model the scheme was split into these five major sub-areas:

- Irrigation from the Schoonspruit just upstream of Johan Neser Dam (500ha);
- Abstractions directly from the dam basin (151ha);
- Abstractions via the pipeline from the dam - below the dam (42ha);
- Irrigation directly from the canal from the dam - below the dam (65ha); and
- Abstractions from the Schoonspruit below the dam (22ha).

Table 5.20 : Klerksdorp Irrigation Scheme - Summarised data for crop combination

Crop	[ha]	%
Rey-grass	115.0	14.74%
Maize	300.0	38.46%
Wheat	231.0	29.62%
Lucerne	72.0	9.23%
Soybeans	57.0	7.31%
Vegetables winter	5.0	0.64%
TOTAL	**780.0**	**100.00%**

Table 5.21: Klerksdorp Irrigation Scheme - Summarised data for irrigation systems

Quat	System	%
C24G	Centre pivot	39.28%
	Drip	6.86%
	Flood	7.42%
	Micro spray	7.19%
	Sprinkler	39.25%
	TOTAL	100.00%
C24H	Centre pivot	8.74%
	Drip	10.05%
	Flood	9.61%
	Micro spray	0.00%
	Sprinkler	71.60%
	TOTAL	100.00%

Table 5.22: Klerksdorp Scheme - crop requirements from SAPWAT in million m^3/a

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	TOTAL
0.38	0.34	0.46	0.28	0.21	0.23	0.31	0.48	0.63	0.33	0.07	0.14	3.87
4,965 m^3/ha												

Soil information for the model was obtained from the Agriculture Research Council, Institute for Soil Climate and Water in Pretoria. All irrigation fields are lying within one soil type classified as sandy loam/loam, with average permeability of 0.43 m/d.

5.4.5. Schoonspruit Irrigation Scheme

The Schoonspruit Irrigation Scheme was for the purposes of the "Disposal Reports" divided into three main components:

- Eye Canal (506.7 ha)
- Elandskuil Canal (647.6 ha)
- Rietsruit Canal (1279.6 ha)

The summarised data on inflows, water use and different loss components for the Eye Canal, Elandskuil Canal and the Rietspruit Canal are given in **Table 5.23**. This data is based on the average values for the years 2001/02 to 2004/05 as given in the monthly disposal reports. From **Table 5.23** it is evident that the losses from the canal distribution system are on average 34.2% resulting in 65.8% of the water being utilised by the farmer. Only some of the 65.8% received by the farmer will in fact be utilised by the crop, due to inefficiencies of the irrigation systems and irrigation practises. Not all the canal loss components will contribute to the seepage return flows. Only the efficiency & leakage as well as seepage losses from the canals will contribute to the seepage and is given in **Table 5.23** as the potential seepage to the river.

Table 5.23: Summarised data for Eye Canal, Elandskuil Canal and Rietspruit Canal

Component	Irrigation Area	Inflow	Water Use						Losses										Potential Seepage to River	
			Irrigation		Urban		Total Water Use		Tailwater		Evaporation		Seepage		Efficiency & Leakage		Total Losses			
	ha	mcm/a	mcm/a	%	mcm/a	%	mcm/a	%	mcm/a	%	mcm/a	%	mcm/a	%	mcm/a	%	mcm/a	%	mcm/a	%
Eye Canal	506.70	30.71	2.37	7.7	1.53	5.0	3.90	12.7	0.00 * (18.02)	0.0	0.31	1.0	0.49	1.6	10.02	32.6	10.83 * (28.85)	35.3	10.51	34.2
Elandskuil Canal	647.60	4.32	2.20	51.0	0.14	3.3	2.35	54.3	1.67	38.8	0.01	0.2	0.03	0.7	0.21	4.9	1.92	44.5	0.24	5.6
Rietspruit Canal	1279.6	7.17	5.43	75. 7	0.00	0.0	5.43	75.7	1.02	14.2	0.03	0.4	0.06	0.8	0.59	8.2	1.69	23.6	0.65	9.1
Total	**2433.9**	**42.20**	**10.00**	**23.7**	**1.68**	**4.0**	**11.68**	**27.7**	**2.69**	**6.4**	**0.35**	**0.8**	**0.58**	**1.4**	**10.82**	**25.6**	**14.45**	**34.2**	**11.4**	**27.0**

Note: * - Value in brackets includes the tailwater outflow which in the case of the eye canal is not a loss as it flows into the Rietspruit and Elandskuil dams:

Table 5.24: Summarised data on crop combinations for the Schoonspruit Irrigation Scheme

Scheduled Area (ha)	Vegatables (winter)	Vegatables (summer)	Wheat	Lusern	Maize	Pecan nut	Peaches	Rey-Grass	Sunflower	Sorgum	Green Beans	Total Area (ha)
2432	100.00	65.00	10.00	505.00	1302.00	7.00	4.00	199.00	41.00	40.00	10.00	**2283.00**
% of total area	4.38	2.85	0.44	22.12	57.03	0.31	0.18	8.72	1.80	1.75	0.44	100.00

Table 5.25: Summarised data on typical irrigation systems used on the Schoonspruit Irrigation Scheme

Irrigation Area	Irrigation System Type (% or area)					Total (%)
	Pivot	Drip	Flood	Micro	Sprinkler	
Eye and Elandskuil Canal	74.52	1.89	7.64	1.18	14.77	100
Rietspruit Canal	66.43	3.03	7.59	2.56	20.39	100

Table 5.26: Crop requirements from SAPWAT in million m/a for the irrigation areas in the Schoonspruit Scheme

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Schoonspruit Scheme	2.540	0.840	0.503	0.526	0.490	0.444	0.522	0.699	0.838	1.350	1.987	2.648	13.390

Table 5.27: Detailed Land Type Information for the Schoonspruit Scheme

LAND TYPE	Permeability and Depth Classes									NO SOIL	DOM CLASS	DOM PERC	DOM CLAY	DOM DEPTH	Depth Limiting Classes						DOM	DOM
	B1	B2	B3	C2	C3	D2	D3	E2	E3						DLM1	DLM5	DLM7	DLM8	DLM9	DLM12	DLM	DLM_P
Fa15	0	0	49.6	40.2	0	0	0	0	0	10.2	B3	49.6	B	3	98.0	2.0	0	0	0	0	DLM1	98.0
Bc33	0	0	35.1	6.9	32.3	1.4	8.0	3.6	0	12.8	B3	35.1	B	3	81.2	3.5	6.2	6.6	2.6	0	DLM1	81.2
Ba42	0	11.2	18.7	40.2	0	0	7.9	7.2	0	14.8	C2	40.2	C	2	73.7	4.4	3.9	18.0	0	0	DLM1	73.7
Ba42	0	11.2	18.7	40.2	0	0	7.9	7.2	0	14.8	C2	40.2	C	2	73.7	4.4	3.9	18.0	0	0	DLM1	73.7
Ba41	51.0	17.4	3.2	0	0	2.9	2.9	6.5	14.1	1.9	B1	51.0	B	1	61.8	8.9	17.0	11.4	0.9	0	DLM1	61.8
Bc35	0	0	35.8	11.2	30.0	2.4	5.7	0	3.2	11.7	B3	35.8	B	3	84.5	2.6	3.2	9.7	0	0	DLM1	84.5
Fb12	0	1.7	38.2	36.0	0	0	0	4.5	0	19.6	B3	38.2	B	3	96.1	0	0	3.4	0	0.5	DLM1	96.1
Bc34	0	7.4	12.1	52.6	0	2.5	16.9	0	0	8.5	C2	52.6	C	2	71.1	3.0	7.4	18.5	0	0	DLM1	71.1
Bc34	0	7.4	12.1	52.6	0	2.5	16.9	0	0	8.5	C2	52.6	C	2	71.1	3.0	7.4	18.5	0	0	DLM1	71.1
Bc23	0	0	25.4	12.8	19.9	3.0	12.7	4.6	0	21.6	B3	25.4	B	3	85.0	0	7.9	4.9	2.3	0	DLM1	85.0
Ba41	51.0	17.4	3.2	0	0	2.9	2.9	6.5	14.1	1.9	B1	51.0	B	1	61.8	8.9	17.0	11.4	0.9	0	DLM1	61.8

The main crops on the Schoonspruit scheme are Maize, Lucern, Rey-grass, winter vegetables and summer vegetables (see **Table 5.24)**. The scheduled area is 2 432 ha while the total area planted is 2 281 ha therefore only 93.8% of the scheduled area is planted.

Data on typical irrigation systems used in the scheme are shown in **Table 5.25**, this data was obtained from the Water Authorisation and Registration Management System (WARMS) in July 2006. Crop requirements were obtained from the SAPWAT model and these are summarized in **Table 5.26**. The crop requirements for the scheme represent 76% of the quota for all three canals.

Soil data was obtained from the Agriculture Research Council, Institute for Soil Climate and Water, Pretoria office. Two soil textural classes are observed in the scheme i.e. Loam and Sandy Loam. The permeability and depth classes for the Schoonspruit Scheme are given in **Table 5.27**. A permeability class B can for example be combined with a depth class 1 and will then be represented by the symbol B1. Land type Ba41 is taken as an example to explain the meaning of the various elements given in **Table 5.27.** Soils permeability classes B, D and E are found in this land type, with the dominant permeability being class B as 51% of the soils in this land type have a permeability class B, which represents a permeability of approximately 0.6 m/day and a clay percentage of 11% to 20%. The soil depth classes are given as 1 or 3 with class 1 being the dominant class. The depth limiting classes that are found in this land type include DLM1, DLM5, DLM7, DLM8 and DLM9 and the dominant class is DLM1.

5.4.6. Mooi River Irrigation Scheme

Detail information regarding inflows, losses, water use etc. for each of the main canals was available from the monthly “Disposal Reports” covering years 2001 to 2005. For the modelling purposes the whole scheme was divided into six components corresponding with the six main canals:

- Klerkskraal Dam Right Bank Canal (272 ha of irrigation);
- Klerkskraal Dam Left Bank Canal (89 ha of irrigation);
- Gerhard Minnebron Canal (205 ha of irrigation);
- Boskop Dam Right Bank Canal (851 ha of irrigation);
- Boskop Dam Left Bank Canal (492 ha of irrigation); and
- Lakeside Dam Canal (330 ha of irrigation).

Summarised data on inflows, water use and the different loss components for the whole system is given in **Table 5.28** below. This data represents the area currently irrigated from the surface water resources (see **Table 5.7**).

Table 5.28: Mooi River Scheme - summarised data for main canals

Canal	Irrigation area	Inflow	Water use		Losses										Potential seep. to river	
					Tail water		Evaporation		Seepage		Effic. & leakage		Total losses			
	(ha)	(mln m^3/a)	(mln m^3/a)	%	(mln m^3/a)	%	(mln m^3/a)	%	(mln m^3/a)	%	(mln m^3/a)	%	(mln m^3/a)	%	(mln m^3/a)	%
Klerkskraal RB	**272.0**	**8.27**	**2.51**	**30.4%**	**3.40**	**41.1%**	**0.19**	**2.3%**	**0.47**	**5.6%**	**1.70**	**20.5%**	**5.76**	**69.6%**	**2.16**	**26.2%**
- irrigation			2.10	25.3%												
- other users			0.42	5.0%												
Klerkskraal LB	**89.0**	**6.19**	**1.03**	**16.7%**	**3.54**	**57.1%**	**0.30**	**4.9%**	**0.46**	**7.5%**	**0.86**	**13.9%**	**5.16**	**83.3%**	**1.32**	**21.3%**
- irrigation			0.69	11.1%												
- other users			0.35	5.6%												
Gerhard Minnebron	**205.0**	**19.66**	**1.75**	**8.9%**	**16.84**	**85.7%**	**0.19**	**1.0%**	**0.14**	**0.7%**	**0.73**	**3.7%**	**17.90**	**91.1%**	**0.87**	**4.4%**
- irrigation			1.58	8.0%												
- other users			0.18	0.9%												
Boskop RB	**851.0**	**138.38**	**18.28**	**13.2%**	**89.24**	**64.5%**	**0.82**	**0.6%**	**0.48**	**0.3%**	**29.56**	**21.4%**	**120.10**	**86.8%**	**30.04**	**21.7%**
- irrigation			6.55	4.7%												
- other users			11.73	8.5%												
Boskop LB	**492.0**	**33.33**	**3.79**	**11.4%**	**22.27**	**66.8%**	**0.24**	**0.7%**	**0.20**	**0.6%**	**6.83**	**20.5%**	**29.54**	**88.6%**	**7.03**	**21.1%**
- irrigation			3.78	11.4%												
- other users			0.01	0.0%												
Lakeside	**330.0**	**10.34**	**3.88**	**37.5%**	**4.73**	**45.8%**	**0.22**	**2.2%**	**0.13**	**1.3%**	**1.37**	**13.2%**	**6.46**	**62.5%**	**1.50**	**14.5%**
- irrigation			2.54	24.6%												
- other users			1.33	12.9%												
TOTAL	**2,239.0**	**216.18**	**31.25**	**14.5%**	**140.03**	**64.8%**	**1.97**	**0.9%**	**1.88**	**0.9%**	**41.05**	**19.0%**	**184.93**	**85.5%**	**42.93**	**19.9%**
- irrigation			17.23	8.0%												
- other users			14.01	6.5%												

The tail water losses seem very high. The percentage tail water losses is however, misleading as in reality these are the outflows at the end of each canal, which also support other downstream components of the system.

The inflow to the different canals is based on measured flows and can be used for calibration purposes. The monthly usage is based on the volumes requested by the irrigation farmers. The canal tail end outflows and other loss components are based on estimations only.

Table 5.29: Mooi River Scheme - Summarised data for crop combination

Crop	[ha]	%
Vegetables - winter	73.5	2.14%
Maize	1,534.1	44.77%
Sunflower	145.0	4.23%
Wheat	122.4	3.57%
Rey-grass	547.8	15.98%
Fruit	1.5	0.04%
Dry bean	31.4	0.91%
Soya	20.2	0.59%
Lucern	851.8	24.85%
Potato	91.6	2.67%
Groundnut	7.7	0.22%
TOTAL	3,427.0	100.00%

Table 5.30: Mooi River Scheme - Summarised data for irrigation systems

Quat	System	%
C23G	Centre pivot	39.01%
	Drip	0.09%
	Flood	0.00%
	Micro spray	0.00%
	Sprinkler	60.90%
	TOTAL	**100.00%**
C23H	Centre pivot	8.26%
	Drip	0.25%
	Flood	11.21%
	Micro spray	0.02%
	Sprinkler	80.25%
	TOTAL	**100.00%**
C23L	Centre pivot	19.34%
	Drip	10.65%
	Flood	1.77%
	Micro spray	0.35%
	Sprinkler	67.89%
	TOTAL	**100.00%**

Table 5.31: Mooi River Scheme - crop requirements from SAPWAT in million m^3/a

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	TOTAL
3.03	1.20	0.78	0.93	0.92	0.97	1.15	1.46	1.86	2.07	2.38	3.34	20.08
5,859 m^3/ha												

Soil data was obtained from the Agriculture Research Council, Institute for Soil Climate and Water in Pretoria. In general, soils in the Mooi River Scheme area are of low permeability. In the upper part (Klerkskraal Dam canals) the dominant soils are sandy loam and loam with average permeability of 0.43 – 0.60 m/d. The rest of the area has even lower permeability with average values of 0.23 – 0.40 m/d and soils varying from loam to clay-loam and clay.

5.5. Calibration of Return Flow Model

5.5.1. General

Very little observed water return flow data were in general available for the selected irrigation areas which can be used in the return flow model for calibration purposes. The return flow model can however also be calibrated against the observed volume released into the main irrigation canal, which will contribute to improved modelling and to obtain the most appropriate water loss components for the irrigation scheme. This is important as some of these loss components directly contribute to the potential return flow volume from the scheme. The model can also be calibrated against observed return flow volumes and for this purpose the model distinguishes between return flows from canal tail water losses, return flows through seepage and return flows from surface runoff. Possibilities for calibration were in most cases limited to the observed water supply data and canal tail water losses, as no information was available on observed seepage and surface runoff related return flows.

5.5.2. Vaalharts Irrigation Scheme

Due to the size of the Vaalharts Irrigation Scheme, the scheme was sub-divided into eight different zones for irrigation return flow calibration and modelling purposes. A separate return flow model was set up for each zone and within each zone the irrigation area was in most cases further sub-divided into 1 to 5 sub-areas. The zones and sub-areas were selected based on the physical layout of the scheme and drainage systems, the soil characteristics, available input data and topography. The main canal was sub-divided proportionally into the zones as defined for the North canal irrigation area. The existing drainage systems in the Vaalharts Scheme increase the volume of drainage water from the scheme and therefore need to be taken into account in the modelling process. To be able to accommodate this in the return flow model, it was decided to model the return flows from two different layers. The upper layer of approximately 1.8m in depth contributes to the flows in the installed drainage systems. The layers below 1.8m will not be affected by the drains and will drain towards the closest natural drainage point. This required the setting up of two irrigation return flow models for each zone, one for the upper layer and one for the lower layer. The sub-areas within each zone was not the same for the upper and lower layers as the sub-areas for the upper layer was dictated by the drainage system layout and the lower layer by that of the natural drainage routes. An open drainage canal is generally running parallel with every second tertiary canal, with the internal sub-surface pipe drains, draining directly into the open drainage canals. For the purpose of the return flow modelling, the area irrigated directly from the main canal was subdivided and included into the different zones. A brief description of the zones and sub-areas for the upper layer is given in **Table 5.26** and is also shown in **Figure A-11** of **Appendix A.**

Table 5.32: Upper layer description of Zones and sub-areas

Zone	**Zone description**	**Sub-area**	**Sub-area description**	**Irrigation area (ha)**
Zone 1	First irrigation areas to be supplied from the North Canal just downstream of the West Canal take-off (Irrigation blocks Q & R)	1 2 3 4	Irrigation Block R Upper part of Block Q Middle part of Block Q Lower part of Block Q <u>Total</u>	467ha 744ha 434ha 248ha <u>1 893ha</u>
Zone 2	This zone includes irrigation blocks A, B, C and D located just north of Jan Kempdorp town.	1 2 3 4 5	Sub-areas running parallel with tertiary and drainage canals across irrigation blocks A to D and between drainage canals. <u>Total</u>	1 148ha 1 148ha 1 149ha 996ha 1 148ha <u>5 589ha</u>
Zone 3	This zone includes irrigation blocks E, F and G located directly north of Zone 2.	1 2 3 4 5	Sub-areas running parallel with tertiary and drainage canals across irrigation blocks E, F & G and between drainage canals. <u>Total</u>	1 400ha 784ha 784ha 784ha 1 848ha <u>5 600ha</u>
Zone 4	This zone includes only irrigation block H located directly north of Zone 3.	1 2 3 4 5	Sub-areas running parallel with tertiary and drainage canals across irrigation block H and between drainage canals. <u>Total</u>	350ha 350ha 350ha 350ha 743ha <u>2 143ha</u>
Zone 5	This zone includes only irrigation block I located directly north of Zone 4.	1 2 3 4 5	Sub-areas running parallel with tertiary and drainage canals across irrigation block I and between drainage canals.	469ha 469ha 469ha 469ha 467ha

			Total	2 343ha
Zone 6	This zone includes irrigation blocks J, K, L, M & N located directly north of Zone 5.	1 2 3 4 5	Sub-areas running parallel with tertiary and drainage canals across irrigation blocks J to N and between drainage canals. Total	1 944ha 1 130ha 1 130ha 1 130ha 2 259ha 7 593ha
Zone 7	This zone includes the total Taung Irrigation Scheme located directly north of Zone 6.		This zone was only modelled as a single layer due to the lower prominence of drainage systems.	See **Table 5.27** for detail.
Zone 8	This zone includes the total area supplied from the West Canal located directly South of Zone 1.	1 2 3 4 5	Sub-areas running parallel with main canal although actual drainage system is more complex. Detail was however not available but the assumed layout should still provide reasonable results. Total	150ha 316ha 1 779ha 971ha 1 581ha 4 617ha

The zones used for the lower layer is as described for the upper layer (see **Table 5.26**) but with different sub-areas as given in **Table 5.27** and shown on **Figure A-12** in **Appendix A.**

Table 5.33: Upper layer description of Zones and sub-areas

Zone	Sub-area	Sub-area description	Irrigation area (ha)
Zone 1	1 2	Irrigation Block R Irrigation Block Q Total	467ha 1 426ha 1 893ha
Zone 2	1 2 3	Irrigation Block A Irrigation Block B Irrigation Block C	1 117ha 1 322ha 1 524ha

	4	Irrigation Block D	1 626ha
		Total	5 589ha
Zone 3	1	Irrigation Block E	1 637ha
	2	Irrigation Block F	1 809ha
	3	Irrigation Block G	2 154ha
		Total	5 600ha
Zone 4	1	Irrigation Block H	2 143ha
		Total	2 143ha
Zone 5	1	Irrigation Block I	2 343ha
		Total	2 343ha
Zone 6	1	Irrigation Block J	1 496ha
	2	Irrigation Block K	1 746ha
	3	Irrigation Block L	1 962ha
	4	Irrigation Block M	2 041ha
	5	Irrigation Block N	384ha
		Total	7 593ha
Zone 7	1	Irrigation Block O & P	2 045ha
	2	Irrigation Block Q	368ha
	3	Irrigation Block R	755ha
	4	Irrigation Block S	357ha
	5	Irrigation Block T	295ha
		Total	3 821ha
Zone 8	1	Ganspan Settlement	150ha
	2	Irrigation Block U	316ha
	3	Irrigation Block V	1 779ha
	4	Irrigation Block W	971ha
	5	Irrigation Block X .	1 581ha
		Total	4 617ha

The crop requirements were determined for the Vaalharts and Taung Schemes using SAPWAT. The crop combinations as obtained from the Loxton Venn report were used for this purpose (see **Table 5.11**) in **Section 5.4.2**. The crop requirement for the Vaalharts Irrigation Scheme was determined as 6 680 m^3/ha/a and for the Taung Scheme as 5 468 m^3/ha/a. These crop requirements as well as the applicable irrigation system and canal distribution losses (See **Table 5.12** in **Section 5.4.2**) were used as input to the irrigation return flow model. In most cases the use of these values provided a total gross irrigation requirement as determined by the model to be very close to the actual observed releases into the main distribution canal of each of the zones as defined in **Table 5.9.** Only small changes to the losses were sometimes required to calibrate the return flow model against the observed irrigation releases.

The only observed return flow data that was available was the flow at the canal tail ends of the irrigation canals. The model was successfully calibrated against the observed values as shown in **Table 5.34**.

Table 5.34: Modelled results from the calibration

Irrigation Area & Sone	Total Inflow		Difference %	Tail water losses		Difference %
	Observed	Modeled		Observed	Modeled	
North Canal System						
Sone 1	30.86	30.44	1.36	1.26	1.26	0.00
Sone 2	55.58	55.47	0.20	1.88	1.88	0.00
Sone 3	64.78	64.55	0.36	3.38	3.37	0.30
Sone 4	28.88	28.68	0.69	1.01	1.01	0.00
Sone 5	31.35	31.22	0.41	1.33	1.32	0.75
Sone 6	79.63	79.31	0.40	3.46	3.47	-0.29
Vaalharts North sub-total	**291.08**	**289.67**	**0.48**	**12.32**	**12.31**	**0.08**
Taung Scheme						
Sone 7	50.66	50.27	0.77	1.5	1.5	0.00
Sub-total North & Taung	**341.74**	**339.94**	**0.53**	**13.82**	**13.81**	**0.07**
West Canal System						
Sone 8	51.21	51.15	0.12	2.68	2.68	0.00
Total	**392.95**	**391.09**	0.47	**16.5**	**16.49**	0.06

The approach followed to determine the return flows by means of the upper and lower layer models was as follows:

- The return flows through the drainage system for the upper layer was first determined as if the total area was equipped with internal drainage systems. Only 35% of the modelled return flow was than taken as the final return flow number as approximately 30% of the scheme is already equipped with internal drainage systems. The additional 5% is to allow for the effect of the external open drains.
- The return flows through layer two, also referred to as natural drainage, was determined for the total area as the internal drainage systems are not capable of draining all the excess water due to losses from the irrigation and canal systems.
- The losses from the irrigation fields and those from the canals that will potentially seep back to the river need to flow through the same soil area for the natural drainage purposes. The maximum volume that can seep back to the river according

to the Darcy flow equation from either the canal or irrigation field losses was selected as the volume that will seep back to the river. Seepage to the river from either the canal or the irrigation fields through natural drainage were therefore set to zero, as the soil is not capable to allow more than that indicated by the Darcy flow equation, to drain towards the river.

Valuable work was recently carried out by RG Ellington, BH Usher and GJ van Tonder for the WRC on the Vaalharts Scheme. Their findings were documented in the WRC Report 1322/1/04 titled "Quantification of the Impact of Irrigation on the Groundwater Resource in the Vaalharts Irrigation Scheme". They used Modflow, a numerical model, to determine the volume of return flows to the Harts River from the Vaalharts Scheme as well as the Darcy flow equation. Results from their study were compared with those obtained from the irrigation return flow model and were found to be very similar (See **Table 5.35**). Their results however exclude the Taung Irrigation Scheme and it seems that they had a different subdivision between the North and Western canal irrigation areas.

Table 5.35: **Comparison of Modelled return flows using different methods and models**

Description	Irrigation Section	Drains Seepage	Natural Seepage	Total Seepage
Numerical Model (MODFLOW)	North Canal	16.78	7.11	23.89
	West Canal	5.13	4.95	10.08
	Total	**21.91**	**12.06**	**33.97**
Empirically determined	Total	23.63	11.76	35.39
Irrigation Return Flow Model *	North Canal	21.59	8.32	29.91
	West Canal	1.84	2.19	4.03
	Total	**23.43**	**10.51**	**33.94**
Irrigation Return Flow Model **	North Canal	21.59	8.32	29.91
	West Canal	1.84	2.19	4.03
	Taung	0.00	2.66	2.66
	Total	**23.43**	**13.17**	**36.60**

Notes: * - Return flows for the North and West canals of the Vaalharts Scheme only

** - Return flows for the North and West canals of the Vaalharts Scheme including the Taung Scheme

The return flows due to the irrigation canal tail water losses and surface water return flows need to be added to the return flows from seepage to obtain the total volume of return flows entering the Harts River. For this purpose one needs to add another 20.19 million m³/a (see **Table 5.35**) to the total seepage return flows of 36.60 million m³/a giving a total return flow volume of 56.79 million m³/a.

Table 5.36: Summary of Return flows and related losses

Description	North Canal & Taung	West Canal	Total
Total return flow	**48.9**	**7.89**	**56.79**
Irrigation from river	2.2	1.1	3.3
Evaporation from River 85km & 17km	**1.08**	**0.22**	**1.3**
Seepage surfacing in wetland area and lost due to evaporation	3.75	1.84	5.59
10% Evap losses from open drains	2	0.22	2.22
Remaining in river	**39.87**	**4.51**	**44.38**

Notes: River reach along irrigation area upstream of the Espagsdrift gauge is 85km and from Espagsdrift to Spitskop Dam is 17km.

The modelled return flows (Detail in **Table 5.37**) do however not take into account losses from the drainage canals and losses from the seepage and tail water flow in the river as well as evaporation and evapo-transpiration of seepage water between the irrigation field and the natural drainage point. It is thus possible that the total modelled return flow volume of 56.79 million m³/a will not reach Spitskop Dam as result of the above mentioned losses. A summary of these losses are given in **Table 5.36** and results in a net return flow volume of 44.38 million m³/a.

The total return flow volume for the Vaalharts and Taung schemes currently simulated by the irrigation blocks in the WRPM accumulates to 56.68 million m³/a, which is almost equal to the gross return flow volume obtained from the Irrigation Return flow Model. The effect of the losses from return flows must therefore still be included in the WRPM.

Another way to determine an indication of the return flows from the Vaalharts and Taung Irrigation Schemes is to determine the difference in flow between the Espagsdrift (C3H007) and Taung (C3H003) flow gauges. The Taung gauge is located in the Harts River downstream of Taung Dam and upstream of the Taung Irrigation Scheme while Espagsdrift gauge is located in the Harts River upstream of Spitskop Dam almost directly in line with the divide between the North and West canal irrigation areas (see **Figure A-12** of **Appendix A**). The difference in flow between these two gauges was determined for the dry years and also taking into account the incremental flow generated between the two flow gauges. A total of 25 dry years between 1956 and 2005 were selected for this purpose and the average difference was found to be 33 million m³/a, which is slightly lower than the 39 million m³/a obtained from the Irrigation Return Flow model, after losses were taken into account. Looking at the annual flow duration curve for difference in flow between Taung and

Espagsdrift, the flows which is exceeded between 80% to 90% of the time is in the order of 37 to 33 million m³/a. Flows lower than 33 million m³/a are in general influenced by unreliable monthly values. It is therefore clear that all the different approaches followed to determine the volume of return flows from the Vaalharts and Taung Irrigation schemes confirms that obtained from the irrigation return flow model.

Table 5.37: Summary of results from the Irrigation return flow model (flows in million m^3/a)

Irrigation Area & Sone	Total Inflow	Crop water use	Losses Irr. Application	Network	Return Flows Drains Seepage	Natural Seepage	Seepage	Surface Water	Tail Water	Total	% Return Flow
North Canal System											
Sone 1	30.86	13.79	5.36	11.29	1.56	2.13	3.69	0.39	1.26	5.34	17.3
Sone 2	55.58	27.41	10.14	17.92	2.31	0.61	2.92	1.02	1.88	5.82	10.5
Sone 3	64.78	31.81	11.76	20.98	4.75	1.00	5.75	0.2	3.38	9.33	14.4
Sone 4	28.88	12.18	4.74	11.76	2.36	0.62	2.98	0	1.01	3.99	13.8
Sone 5	31.35	13.56	5.02	12.64	3.38	1.19	4.57	0	1.33	5.9	18.8
Sone 6	79.63	40.53	14.99	23.79	7.23	2.77	10.00	0	3.46	13.46	16.9
Vaalharts North sub-total	**291.08**	**139.28**	**52.01**	**98.38**	**21.59**	**8.32**	**29.91**	**1.61**	**12.32**	**43.84**	**15.1**
Taung Scheme											
Sone 7	50.66	24.22	8.96	17.09	0.00	2.66	2.66	0.9	1.5	5.06	10.0
Sub-total North & Taung	**341.74**	**163.5**	**60.97**	**115.47**	**21.59**	**10.98**	**32.57**	**2.51**	**13.82**	**48.9**	**14.3**
West Canal System											
Sone 8	51.21	26.59	9.83	14.73	1.84	2.19	4.03	1.18	2.68	7.89	15.4
Total	**392.95**	**190.09**	**70.8**	**130.2**	**23.43**	**13.17**	**36.60**	**3.69**	**16.5**	**56.79**	**14.5**

5.5.3. Allemanskraal and Erfenis Irrigation Schemes

The Sand-Vet Irrigation Scheme was sub-divided into 8 different zones (See **Figures A-13 & A-14** in **Appendix A**). For each zone a separate return flow model was set up. The zones were further sub-divided into about 3 or 4 sub-areas. Division of the zones and sub-areas was based on the physical layout of the scheme, soil characteristics, available input data and topography. **Table 5.38** lists the different zones and sub-areas for each return flow model. The crop requirements were determined for the Sand-Vet Scheme using the SAPWAT model and the combined crop requirement cumulated to an average of 5 446 m^3/ha/a. The combined crop requirements as well as the applicable irrigation system and canal distribution losses were all used as input to the irrigation return flow model. In most cases the use of these values provided a total gross irrigation requirement as determined by the return flow model to be very close to the actual observed releases into the main distribution canal for each of the zones as defined in **Table 5.38** below**.** Only small changes to the losses were sometimes required to calibrate the return flow model against the observed irrigation releases.

The only observed return flow data that was available is the flow at the irrigation canal tail ends. The model was successfully calibrated against the available observed values as shown in **Table 5.39** and **Table 5.40.**

The total releases from Erfenis Dam into the canals were on average 55 million m^3/a. Water for urban use (12.17 million m^3/a) is also abstracted from the canal relatively close to the dam. For the purpose of the irrigation return flow modelling, the inflow to the canals was therefore taken as 42.83 million m^3/a for the Erfenis irrigation scheme. The situation at Allemanskraal Dam is similar, and 6.69 million m^3/a is abstracted for urban purposes, leaving 34.89 million m^3/a as inflow to the irrigation area of the gross release of 41.58 million m^3/a.

Table 5.38: Zones and irrigation sub-areas in the Sand-Vet Scheme

Section	Zones	Sub-areas	Total Irrigated Area (ha)
Vet Canal - D/s of Erfenis Dam to confluence	Zone 1	Sub-area 1	43.2
		Sub-area 2	216.2
		Sub-area 3	172.9
	Zone 2	Sub-area 1	987.2
		Sub-area 2	789.8
		Sub-area 3	197.4
Vet Canal D/s of confluence	Zone 3	Sub-area 1	983.3
		Sub-area 2	860.4
		Sub-area 3	368.7
		Sub-area 4	245.8
	Zone 4	Sub-area 1	389.1
		Sub-area 2	907.9
Sub-total (Erfenis Scheme)			**6162.0**
Sand Canal D/s of Allemanskraal Dam to confluence (Left Bank)	Zone 5	Sub-area 1	63.08
		Sub-area 2	157.71
		Sub-area 3	220.79
		Sub-area 4	189.25
	Zone 7	Sub-area 1	1425.82
		Sub-area 2	2138.72
Sand Canal D/s of Allemanskraal Dam to confluence (Right Bank)	Zone 6	Sub-area 1	34.68
		Sub-area 2	14.86
		Sub-area 3	49.54
	Zone 8	Sub-area 1	234.22
		Sub-area 2	117.11
		Sub-area 3	234.22
Sub-total (Allemanskraal Scheme)			**4880**
Total (Sand-Vet Scheme)			**11042.0**

Table 5.39: Modeled results from the calibration exercise for the Erfenis Scheme.

Section	Zone	Total Inflow ($10^6m^3/a$)		Difference	Tailwater Losses ($10^6m^3/a$)		Difference
		Observed	Modelled	%	Observed	Modelled	%
Vet Canal - D/s of Erfenis Dam to confluence	Zone 1	42,835,733	42,835,733	0.00	39,261,814	39,261,712	0.000
	Zone 2	39,261,814	39,261,814	0.00	22,940,510	22,940,392	0.001
Vet Canal D/s of confluence	Zone 3	22,940,510	22,940,510	0.00	2,621,136	2,621,161	0.001
	Zone 4	9,338,400	8,510,195	8.87	no data	no data	

Table 5.40: Modeled results from the calibration exercise for the Allemanskraal Scheme.

Section	Zone	Total Inflow ($10^6m^3/a$)		Difference	Tailwater Losses ($10^6m^3/a$)		Difference
		Observed	Modelled	%	Observed	Modelled	%
Sand Canal D/s of Allemanskraal Dam to confluence (Left Bank)	Zone 5	34,886,882	34,886,882	0.00	29,915,234	29,917,348	0.007
	Zone 6	29,915,234	29,915,234	0.00	1,822,293	1,822,657	0.020
Sand Canal D/s of Allemanskraal Dam to confluence (Right Bank)	Zone 7	5,679,260	5,679,260	0.00	4,900,289	4,900,439	0.003
	Zone 8	4,900,289	4,900,289	0.00	296,652	296,635	0.006

The return flows due to the irrigation canal tail water losses and surface water return flows need to be added to the return flows from seepage to obtain the total volume of return flows entering the Sand Rivers and the Vet River. For the Vet Canal System one needs to add together the surface and seepage return flow components from each Zone 1, Zone 2, Zone 3 and Zone 4 as well as the tail water from zone 3. The tail water from zones 1 & 2 is in fact the inflow to the downstream zone and is therefore not regarded as a loss. The total return flow volume from the Vet Canal System into the Vet River therefore accumulates to 4.73 million m³/a, or approximately 11% of the total inflow to the Vet River Canal (See **Table 5.41**). Note that irrigation in Zone 4 is supplied directly from the Vet River and not from the Vet Canal, therefore tail water losses are not applicable to this zone.

Table 5.41: Summary of Return Flows from the Erfenis Irrigation Scheme

Section	Zone	Seepage ($10^6m^3/a$)	Surface Return Flow ($10^6m^3/a$)	Tailwater ($10^6m^3/a$)	Total
Vet Canal - D/s of Erfenis Dam to confluence	Zone 1	0.08	0.04	(39.26)*	0.12
	Zone 2	0.87	0.04	(22.94)*	0.91
Vet Canal D/s of confluence	Zone 3	0.52	0.18	2.62	3.32
	Zone 4	0.38	0.00	0.00	0.38
Total		**1.85**	**0.26**	**2.62**	**4.73**

Notes: * - These tail water flows is the inflow to the next zone and is therefore not a loss

Table 5.42:Summary of Return Flows from the Allemanskraal Irrigation Scheme

Section	Zone	Seepage ($10^6m^3/a$)	Surface Return Flow ($10^6m^3/a$)	Tailwater ($10^6m^3/a$)	Total
Sand Canal D/s of Allemanskraal Dam to confluence (Left Bank)	Zone 5	1.64	0.00	(29.92)*	1.64
	Zone 7	1.62	0.04	1.82	3.48
Sand Canal D/s of Allemanskraal Dam to confluence (Right Bank)	Zone 6	0.14	0.00	(4.90)*	0.14
	Zone 8	1.07	0.00	0.30	1.37
Total		**4.47**	**0.04**	**2.12**	**6.63**

Notes:*- These tail water flows is the inflow to the next zone and is therefore not a loss

Table 5.43: Summary of results from the Irrigation Return Flows model for the Erfenis Irrigation Scheme

Section	Zone	Total Inflow ($10^6m^3/a$)	Crop water use ($10^6m^3/a$)	Losses Irr. Application	Network	Return Flows				
						Seepage ($10^6m^3/a$)	Surface Water ($10^6m^3/a$)	Tail Water ($10^6m^3/a$)	Total	% Return Flow
Vet Canal D/s of Erfenis Dam to confluence	Zone 1	42.84	2.23	0.46	40.15	0.08	0.04	(39.26)*	0.12	3.35
	Zone 2	39.26	10.19	2.09	26.98	0.87	0.04	(22.94)*	0.92	5.64
Vet Canal D/s of confluence	Zone 3	22.94	12.69	2.60	7.66	0.52	0.18	2.62	3.32	14.47
	Zone 4	9.34	7.06	1.45	0.00	0.38	0.00	0.00	0.38	4.12

Notes:*- These tail water flows is the inflow to the next zone and is therefore not a loss
+ - The return flow is expressed as a percentage of the volume of water abstracted from the zone for irrigation and all the losses

Table 5.44: Summary of results from the Irrigation Return Flows model for the Allemanskraal Irrigation Scheme

Section	Zone	Total Inflow ($10^6m^3/a$)	Crop water use ($10^6m^3/a$)	Losses Irr. Application (%)	Network	Return Flows				
						Seepage ($10^6m^3/a$)	Surface Water ($10^6m^3/a$)	Tail Water ($10^6m^3/a$)	Total	% Return Flow
Sand Canal D/s of Allemanskraal Dam to confluence (Left Bank)	Zone 5	34.89	2.70	0.55	31.63	1.64	0.00	(29.92)*	1.63	32.80
	Zone 7	29.92	15.29	3.13	11.50	1.62	0.04	1.82	3.48	11.63
Sand Canal D/s of Allemanskraal Dam to confluence (Right Bank)	Zone 6	5.68	0.42	0.09	5.17	0.14	0.00	(4.90)*	0.14	17.95
	Zone 8	4.90	2.51	0.51	1.88	1.07	0.00	0.30	1.37	27.95

Notes:*- These tail water flows is the inflow to the next zone and is therefore not a loss
+ - The return flow is expressed as a percentage of the volume of water abstracted from the zone for irrigation and all the losses

For the Sand Canal system one needs to add together the surface return flow and seepage from Zone 5, Zone 6, Zone 7 and Zone 8 as well as the tail water losses from zones 7 & 8. The tail water from zones 5 & 6 is the inflow to the downstream zones and are therefore not regarded as losses. The total return flow volume from the Sand Canal System into the Sand River is therefore 6.63 million m³/a, or approximately 19% of the total inflow to the Sand River Canal; (See **Table 5.42**). A summary of results obtained from the irrigation return flow model is given in **Table 5.43** and **Table 5.44.** The percentage return flows from zone 3 is higher than the other zones within the Vet Canal system, as all the tail water losses were added to the return flow volume for this zone.

5.5.4. Klerksdorp Irrigation Scheme

After identifying the irrigation zones they were divided into numerous sub-areas. The division was dictated by the physical layout of the scheme, the soil characteristics, available input data and topography. All zones and the corresponding sub-areas are described in **Table 5.45** below. Their layout is shown on **Figure A-5** in **Appendix A**.

Table 5.45: Klerksdorp Irrigation Scheme - description of zones and sub-areas

Zone	Zone description	Sub-area	Sub-area description	Irrigation area (ha)
Zone 1	Irrigation from Schoonspruit just upstream of Johan Neser Dam	1 2	Irrigation Block A Irrigation Block B TOTAL	394ha 106ha 500ha
Zone 2	Abstractions directly from dam basin	1 2	Irrigation Block C Irrigation Block D TOTAL	113ha 38ha 151ha
Zone 3	Abstractions via the pipeline from dam - below dam	1 2	Irrigation Block E Irrigation Block F TOTAL	14ha 28ha 42ha
Zone 4	Irrigation directly from canal from dam - below dam	1 2	Irrigation Block G Irrigation Block H TOTAL	36ha 29ha 65ha
Zone 5	Abstractions from Schoonspruit below	1	Irrigation Block I	22ha

In the case of the Klerksdorp Irrigation Scheme no observed flows were available for the calibration of the model. The results from the irrigation return flow model are summarised in .

Table 5.46: Klerksdorp Scheme - summary of results from irrigation return flow model

Zone	Area	Total inflow	Crop water use	Losses irr. application	Losses network	Return flows				
						Seepage	Surface	Tail water	TOTAL	RFs
	[ha]	mln m^3/a	mln m^3/a	mln m^3/a	mln m^3/a	mln m^3/a	mln m^3/a	mln m^3/a	mln m^3/a	[%]
From Schoonspruit, u/s of dam	500.0	3.10	2.48	0.61	0.00	0.14	0.03	0.00	0.17	5.48
Directly from dam basin	151.0	0.94	0.75	0.19	0.00	0.02	0.02	0.00	0.04	4.26
From pipeline	42.0	0.27	0.21	0.06	0.00	0.00	0.01	0.00	0.01	3.70
From canal	65.0	0.48	0.32	0.06	0.10	0.02	0.01	0.00	0.03	6.25
From Schoonspruit below dam	22.0	0.14	0.11	0.03	0.00	0.00	0.00	0.00	0.00	0.00
TOTAL for scheme	780.00	4.93	3.87	0.95	0.10	0.18	0.07	0.00	0.25	5.07

The relatively low percentage return flows may be attributed to the following reasons:

- Very low permeability of soil within the scheme;
- Small irrigation area; and
- Almost all water distributed with pipes.

5.5.5. Schoonspruit Irrigation Scheme

The Schoonspruit Irrigation Scheme was divided into 3 different zones. A separate return flow model was set up for each zone and within each zone the irrigation area was in most cases further subdivided into sub-areas. The zones and sub-areas were selected based on the physical layout of the scheme, soil characteristics, available input data and topography. **Table 5.47** shows the different zones and sub-areas for each return flow model. The crop requirements were determined for the Schoonspruit scheme using the SAPWAT model with a resulting crop requirements of 5 865 m^3/ha/a. These crop requirements as well as the applicable irrigation system and canal distribution losses (See **Table 5.17, 5.18 and Table 5.19** in **Section 5.4.5**) were used as input to the irrigation return flow model. In all cases the use of these values provided a total gross irrigation requirement as determined by the model, to be very close to the actual observed releases into the main distribution canal of each of the zones as defined in **Table 5.48.** Only small changes to the losses were sometimes required to calibrate the return flow model against the observed irrigation releases.

The only observed return flow data that was available was the flow at the canal tail ends. The model was successfully calibrated against the observed values as shown in **Table 5.48**.

Table 5.47: Zones and irrigation sub-areas in the Schoonspruit Scheme

Zone	Sub-areas	Total Irrigated Area (ha)
Eye Canal	Sub-area 1	0
	Sub-area 2	0
	Sub-area 3	507
Elandskuil Canal	Sub-area 1	314
	Sub-area 2	333
Rietspruit Canal	Sub-area 1	1118
	Sub-area 2	86
	Sub-area 3	55
	Sub-area 4	20
Total		**2433**

Table 5.48: Modelled results from the calibration exercise.

Irrigation Area	Total Inflow ($10^6 m^3/a$)		Difference %	Tailwater Losses ($10^6 m^3/a$)		Difference %
	Observed	Modelled		Observed	Modelled	
Eye Canal System	30.706	30.750	0.14	18.077 *	18.103 *	0.14
Elandskuil Canal System	4.319	4.318	0.03	1.674	1.673	0.03
Rietspruit Canal System	7.175	7.135	0.56	1.015	1.010	0.56

Note * : The tailwater flow from the eye canal is not a loss as it flows into Rietspruit and Elandskuil Dams

In general the return flows due to the canal tail water losses and surface water return flows need to be added to the return flows from seepage to obtain the total volume of return flows entering the Schoonspruit River. For the Eye Canal system, however, the tail water flows is used to support the Rietspruit and Elandskuil canal systems. In this case one need not to add the tail water flow to the total seepage return and surface water flows of 0.46 million m³/a and 0.11 million m³/a respectively. The total return flow volume from the Eye Canal system is therefore only 0.57 million m³/a. For the Elandskuil Canal system one needs to add 1.67 million m³/a to the total seepage return flows of 0.58 million m³/a giving a total return flow volume of 2.25 million m³/a from the Elandskuil Canal system. For the Rietspruit

Table 5.49: Summary of results from the irrigation return flow model

Irrigation Area	Total Inflow ($10^6m^3/a$)	Crop water use ($10^6m^3/a$)	Losses Irr.		Return Flows				
			Application ($10^6m^3/a$)	Network ($10^6m^3/a$)	Seepage ($10^6m^3/a$)	Surface Water ($10^6m^3/a$)	Tail Water ($10^6m^3/a$)	Total ($10^6m^3/a$)	% Return Flow
Eye Canal System	30.71	2.97	0.84	26.94#	0.46	0.11	18.10	0.57 * (18.67)	1.9 * (60.8)
Elandskuil Canal System	4.32	1.87	0.52	1.92	0.58	0.00	1.67	2.25	52.1
Rietspruit Canal System	7.17	4.14	1.30	1.69	1.48	0.00	1.01	2.49	34.7

Note * - Value in brackets include tailwater flow. For the eye canal the tailwater flow is not a loss but flows into the Elandskuil and Rietspruit dams

- This value includes the tail water flows which is in the case of the Eye canal not losses, but is utilised by the Elandskuil and Rietspruit canal systems

Canal system one needs to add 1.01 million m³/a to the total seepage return flows of 1.48 million m³/a giving a total return flow volume of 2.49 million m³/a from the Rietspruit Canal system. Therefore the total return flow volume from the Schoonspruit Irrigation Scheme is 5.31 million m³/a (See **Table 5.49**) and represents approximately 20% of the gross inflow to the canals. A summary of results obtained from the irrigation return flow model is given in **Table 5.50**.

Table 5.50: Return flows from Irrigation Scheme

	Seepage ($10^6m^3/a$)	Surface Return Flow ($10^6m^3/a$)	Tailwater ($10^6m^3/a$)	Total
Eye	0.46	0.11	0.00	0.57
Elandskuil	0.58	0.00	1.67	2.25
Rietspruit	1.48	0.00	1.01	2.49
Total	2.52	0.11	2.68	5.31

The relatively high tail water flow from the canals is in some cases a loss to the Schoonspruit Scheme but is used by the Klerksdorp Irrigation Scheme located just downstream of the Schoonspruit Scheme.

5.5.6. Mooi River Irrigation Scheme

As mentioned in **Section 5.4.6**, the scheme was divided into six separate zones corresponding with the main canals. Further, each zone was divided into various sub-areas. This split depended on the physical layout of the scheme, the soil characteristics, available input data and topography.

Short descriptions of all the zones and sub-areas are provided in **Table 5.51** below. Their layout is shown on **Figure A-7** in **Appendix A**.

Table 5.51: Mooi River Scheme - description of zones and sub-areas

Zone	Zone description	Sub-area	Sub-area description	Irrigation area (ha)
Zone 1	Klerkskraal Dam Right Bank Canal	1	Irrigation Block A	368ha
		2	Irrigation Block B	101ha
		3	Irrigation Block C	120ha
		4	Irrigation Block D	170ha
		5	Irrigation Block E	62ha
			TOTAL	821ha

Zone 2	Klerkskraal Dam Left Bank Canal	1	Irrigation Block F	31ha
		2	Irrigation Block G	56ha
		3	Irrigation Block H	49ha
			TOTAL	136ha
Zone 3	Gerhard Minnebron Canal	1	Irrigation Block I	12ha
		2	Irrigation Block J	81ha
		3	Irrigation Block K	45ha
		4	Irrigation Block L	25ha
		5	Irrigation Block M	76ha
			TOTAL	239ha
Zone 4	Boskop Dam Right Bank Canal	1	Irrigation Block N	42ha
		2	Irrigation Block O	646ha
		3	Irrigation Block P	365ha
		4	Irrigation Block Q	80ha
		5	Irrigation Block R	119ha
			TOTAL	1 252ha
Zone 5	Boskop Dam Left Bank Canal	1	Irrigation Block S	86ha
		2	Irrigation Block T	491ha
			TOTAL	577ha
Zone 6	Lakeside Dam Canal	1	Irrigation Block S	175ha
		2	Irrigation Block T	227ha
			TOTAL	402ha

In all of the zones the modelled values were very close to the observed values (both inflows and return flows) and only small adjustments were required. It is important to note that the observed total inflows given in **Table 5.52** are slightly lower than those given in **Table 5.28**. The flows given in **Table 5.52** only represent the inflows for irrigation purposes as the focus for this analysis is on irrigation return flows. The comparison of the calibrated and observed flows is presented in **Table 5.52** below.

Table 5.52: Mooi River Scheme – comparison of observed and modeled flows

Zone	Total inflow - surface			Tail water losses		
	Observed [mln m^3/a]	Modelled [mln m^3/a]	Difference [%]	Observed [mln m^3/a]	Modelled [mln m^3/a]	Difference [%]
Klerkskraal Dam RB canal	7.86	7.86	0.00%	3.40	3.41	-0.29%
Klerkskraal Dam LB canal	5.85	5.84	0.17%	3.54	3.54	0.00%
Gerhard Minnebron canal	19.48	19.53	-0.26%	16.84	16.88	-0.24%
Boskop Dam RB canal	126.65	126.85	-0.16%	89.24	89.38	-0.16%
Boskop Dam LB canal	33.33	33.36	-0.09%	22.27	22.29	-0.09%
Lakeside Dam canal	9.00	9.01	-0.11%	4.73	4.74	-0.21%
TOTAL for Mooi scheme	**202.17**	**202.45**	**-0.14%**	**140.02**	**140.24**	**-0.16%**

To obtain the total return flows from the scheme, the surface water return flows and the return flows from seepage were calculated/modelled and added to the irrigation canal tail water losses. This will apply to the irrigation supplied from surface and groundwater resources. For this reason the area and total inflow given in **Table 5.53** include the areas supplied from both surface and ground water. The results from the irrigation return flow model are summarised in **Table 5.53**.

Table 5.53: Mooi River Scheme - summary of results from irrigation return flow model

Zone	Area [ha]	Total inflow (million m^3/a)	Crop water use (million m^3/a)	Losses		Return flows				
				Irrigation application (million m^3/a)	Network (million m^3/a)	Seepage (million m^3/a)	Surface (million m^3/a)	Tail water (million m^3/a)	TOTAL (million m^3/a)	TOTAL as [%]
Klerkskraal Dam RB canal	821	12.10	4.81	1.52	5.77	0.86	0.00	3.41	4.27	35.29
Klerkskraal Dam LB canal	136	6.21	0.80	0.25	5.16	0.29	0.00	3.54	3.83	61.67
Gerhard Minnebron canal	239	19.79	1.40	0.44	17.95	0.10	0.02	16.88	17.00	85.90
Boskop Dam RB canal	1,252	129.94	7.33	2.32	120.29	0.58	0.23	89.38	90.19	69.41
Boskop Dam LB canal	577	34.01	3.38	1.07	29.57	0.59	0.13	22.29	23.01	67.66
Lakeside Dam canal	402	9.57	2.36	0.74	6.47	0.08	0.08	4.74	4.90	51.20
TOTAL for scheme	3,427.00	211.62	20.08	6.34	185.21	2.50	0.46	140.24	143.20	67.67

Very high percentage of return flows is caused by high tail water volumes. These however are not tail water losses in true sense, but flows at canal ends, which support the users in the downstream components of the system. The main reasons for low seepage return flows are very low permeability of soils in the area, low hydraulic gradient and in many cases long distances between irrigation fields and the river.

5.6. Return Flow Scenarios

Different possible irrigation return flow scenarios will only be addressed and evaluated in Stage 2 of the Vaal River System Reconciliation strategies. The return flow models for the major irrigation schemes in the Vaal River System were calibrated as part of Stage 1 of the study, and the modelling of different possible scenarios will now be relatively easy. The scenarios that need to be analysed will largely follow from the findings and recommendations obtained from Stage 1 of the study. These suggested scenarios as well as other possible scenarios will therefore be assessed and discussed for detailed analyses as part of Stage 2 of the Vaal River System Reconciliation strategies.

5.7. Updating of irrigation blocks in WRPM

The updating of the irrigation blocks in the WRPM will be carried out as part of the Water

Resources Task. The main purpose of the updating is to ensure that the return flow volumes as obtained from the return flow analysis are in agreement with that simulated by the irrigation blocks in the WRPM and to ensure compatible salinity in return flows too previous calibrations.

5.8. Results and comparison of results

In the current WRPM it is only the Vaalharts Irrigation of the schemes listed in **Table 5.41** that is simulated as an irrigation block in which return flows are calculated. For all the other irrigation schemes it was assumed that 10% of the demand will return to the river as return flows from the irrigation fields. The return flows as used in the WRPM is included in **Table 5.54** and compared with that obtained from the Return flow Model analyses.

Some adjustment were made to the return flow volumes from the Return Flow Model to be able to compare apples with apples when comparing the results with the WRPM return flow data. These adjustments will typically include the removal of river losses and abstractions in the case of Vaalharts and some of the tail water losses in other schemes.

From the comparisons the following conclusions are made:

- The total return flow modelled for the Vaalharts Scheme is slightly less than that currently used in the WRPM, but the main difference is the distribution of return flows between North and West canals. The distribution used in the WRPM is clearly not realistic.
- The return flows for the Klerksdorp Irrigation Scheme as used in the WRPM is too high and need to be reduced. The main reasons for the reduction are firstly that the actual water use is much lower than the allocated volume, secondly as result of the low permeability of the soils and thirdly the limited canal distribution systems.
- The modelled return flows for the Schoonspruit Scheme is significantly higher than that used in the WRPM. This is to a large extent as result of the tail water flows and the fact that the irrigation is in general located close to the river.
- The tail water flows at the bottom end of the Mooi River Sheme is very high and this is the main reason for the very high return flows of almost 60% in comparison of the 10% used in the WRPM. When the tail water flow is excluded from the return flow calculation, the results from the Return Flow Model and that used in the WRPM is almost the same.
- The return flows from the Erfenis canal scheme is somewhat higher than that obtained from the Allemanskraal canal scheme, which is both part of the Sand/Vet irrigation scheme. The main reason or the higher return flows from the Erfenis canal scheme is the higher hydraulic gradient that is in general evident in the Erfenis

scheme. In the Allemanskraal scheme the height difference between the irrigation fields and the river is less and the distance from the irrigation fields to the river is longer than those evident from the Erfenis Scheme. This therefore results in a lower hydraulic gradient for the Allemanskraal scheme, which in turn produces less return flows. The permeability of the soils is in the same order of magnitude for both schemes.

Table 5.54: Summary and comparison of results

Irrigation Scheme	Gross inflow (million m^3/a)	Return flows (million m^3/a)		Percentage Return flow	
		Return flow model	WRPM	Return flow model	WRPM
Vaalharts					
North Canal	341.74	43.2	56.3	13	16
West Canal	51.21	5.83	0.44	11	1
Sub-total	**392.95**	**49.03**	**56.74**	**12**	**14**
Klerksdorp Scheme	4.93	0.25	0.91	5	18 (10)+
Schoonspruit Scheme	24.10	5.31	1.69	22	7 (10)+
Mooi River Scheme	165.50 (71.38)*	97.08 (2.96)*	3.68	59 (4)*	2 (10)+ (5)*
Erfenis Canal Scheme	42.84	4.73	4.64	11	11(10)+
Erfenis river Scheme	9.76	0.38	0.98	4	10
Allemanskraal canal	34.89	6.63	3.97	19	11
Sub-total	**282.02** **(187.90)***	**114.38** **(20.26)***	**15.87**	**40** **(11)***	**6 (10)+** **(8)***
Total	**674.97** **(580.85)***	**163.41** **(69.29)***	**72.61**	**24** **(12)***	**11** **(12)***

Notes:*- A very high percentage of the Mooi River Scheme return flows is as result of the large volume of tail water flow from the canal end. When the effect of the tail water flow is removed the result is given by the value in brackets.

+- The value in brackets represent the percentage return flows (10%) generally used in the WRPM. The gross inflow as used in the return flow model is not always the same as that used in the WRPM and therefore results in a different percentage when compared with the return flow model gross inflow.

- The total return flows from all the irrigation schemes as obtained from the return flow model is more than double that currently used in the WRPM. When the effect of the large volume of tail water flow from the Mooi River Scheme is removed the total return flows from the Return Flow Model is almost equal to that used in the WRPM.
- The return flows used in the WRPM is generally based on a fixed 10% value except for the Vaalharts Scheme. The results from the return flow model however show that it is not the case, as return flow percentages vary significantly between schemes. Results showed return flow percentages as low as 4% to as high as 22% and even 59% in the case of the Mooi River Scheme with its high tail water flow.

6. ALTERNATIVE FUTURE IRRIGATION DEMAND SCENARIOS

6.1. General

The information presented in **Section 2** focused on the historical and current irrigation water use. For planning purposes it is required to compile scenarios of future water use for the period up to 2030.

6.2. Description and motivation of selected scenarios

Given that the current (year 2005) water use estimates are significantly higher than the preliminary estimates of what is considered lawful, a scenario was compiled where it was assumed that the current water use will be reduced over the medium term through legal interventions and water use compliance monitoring. The assumptions used in the scenario are given in the next two sections

6.2.1. Irrigation Scenario 1: Curtailment of illegal irrigation water use

For Scenario 1 it is accepted that the eradication of illegal irrigation use in the Vaal River system will be implemented. The assumptions of how it will be implemented are given below:

- **Upper Vaal WMA**
  - Assume the growing trend, which was observed over the period 1998 to 2005, continuous for two years until 2008. This implies the interventions will take two years to become effective.
  - Eradication of unlawful irrigation water use from 2008 onwards and assumes the water use will decrease over a period of 4 year.
  - The assumption is made that the interventions will reduce the irrigation to the lawful volume plus 15% and that this will be achieved in the year 2011. The additional 15% above the estimates of the lawful water use is a conservative assumption providing for possible under estimations from the current data.
- **Middle and Lower Vaal WMA**

- Due to the absence of information from validation studies in these areas, it is assumed that the current suggested irrigation water use will remain constant over the planning period.

6.2.2. Irrigation Scenario 2: Recent trend continues unattended

In the case of Scenario 2 it is assumed that no curtailment of illegal use will take place and that irrigation demand will continue to grow. The assumptions with regards to this growth are given below:

- **Upper Vaal WMA**
  - The assumption was made that the irrigation water use will continue to increase at the trend observed between 1998 and 2005 until the registered volume from the WARMS database is reached.
- **Middle and Lower Vaal WMA**
  - Assume the future water use remains constant at the suggested water use levels.

The **Irrigation Scenario 2** will create an unsustainable situation in the Vaal River System and is not considered to be viable. However, this scenarios was derived to illustrate the potential impact should the situation arises where the interventions are not successful to cut back the illegal water use.

6.2.3. Future irrigation water use scenario results

Figure 6.1 presents the future irrigation water requirements for the two scenarios described in the previous sections and shows that the **Irrigation scenario 2** is about 450 million m^3/annum higher than **Irrigation Scenario 1** over the long term. These two irrigation water requirement scenarios will be used as input to the system analysis planning scenarios.

Other possible irrigation demand growth scenarios will be addressed and evaluated in Stage 2 of the Vaal River System Reconciliation strategies based on results and recommendations from Stage 1.

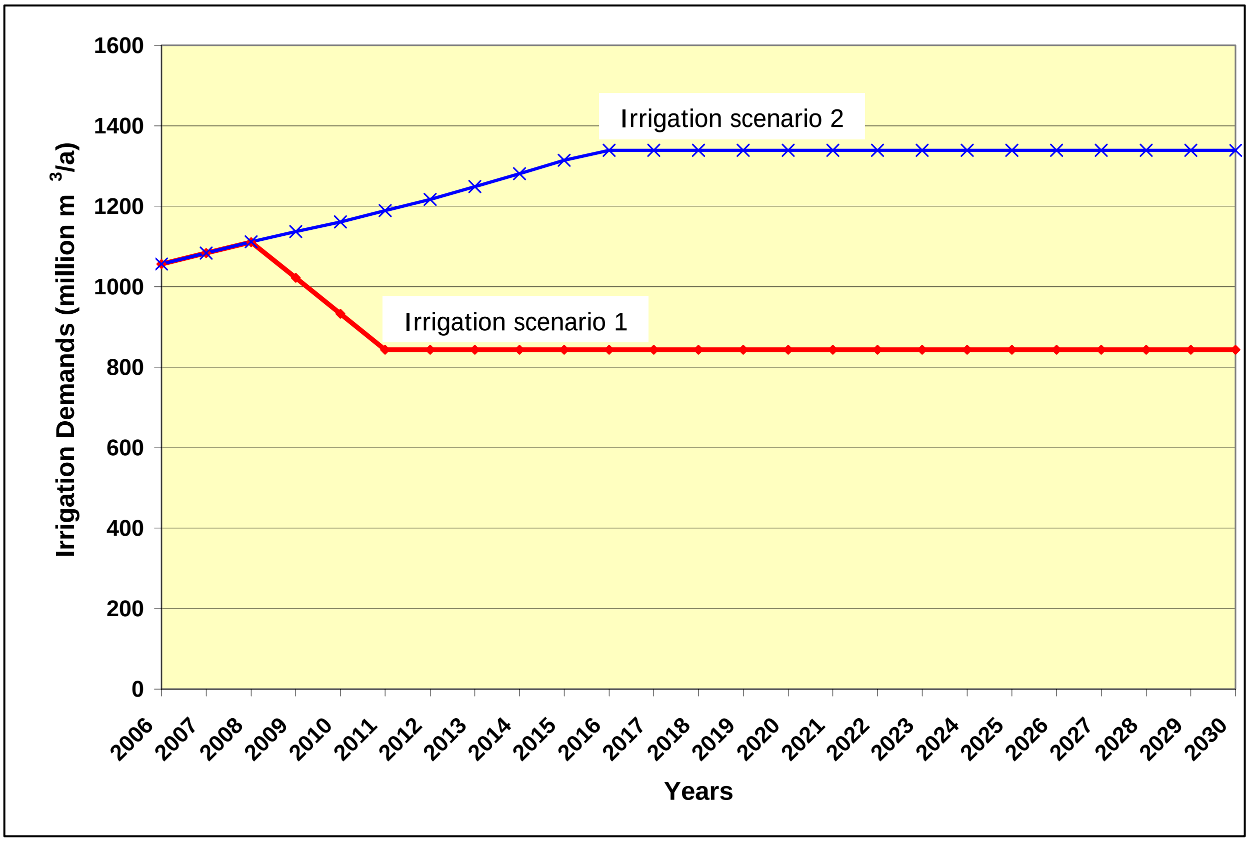

Figure 6.1: Irrigation water requirement scenarios for the Vaal River System

6.3. Effects of the different Scenarios on the water supply and water quality

The effect of the different irrigation demand scenarios will be described in the "Water resource analysis". It is however expected that the eradication of the illegal water use will greatly assist in the postponing of future intervention options, while scenario will result in an unsustainable situation in the Vaal River System. The eradication of the illegal water use will also result in a small reduction in irrigation return flows, mainly upstream of Vaal Dam.

The effects on the water quality will be addressed in the Water Quality Study "Integrated Water Quality Management Plan" which is running concurrently with the Reconciliation and Water Conservation and Water Demand Management studies.

7. ASSURANCE OF SUPPLY FOR IRRIGATION AND RELATED OPERATING RULES

7.1. General

Different types of user groups or categories will require a different assurance of supply. Irrigation will typically be supplied at a lower assurance than water for domestic and industrial purposes and water for strategic industries such as power generation at an even higher assurance. It is also logic to sub-divide the supply to irrigation into different assurance levels, as permanent crops such as export grapes would require a higher assurance than for example a cash crop. Using only the available historic flow record of say 70 years it is not possible to provide yield results representing the yield available at high assurances such as a 99% or 99.5% assurance, which means a possible failure of 1 in 100years and 1 in 200 years respectively.

By using stochastic yield analysis it is possible to determine the system yield at different reliabilities or assurance levels. At low reliability levels the system can typically provide a higher yield than would be available at a high reliability level. The stochastic yield characteristics therefore make it possible to supply the system demands at the required level of assurance in planning and operational analyses as well as in practise. For the purpose of these analyses it is therefore important to sub-divide the demand of the different user categories into three or four priority classes, which represent different assurance or reliability levels. This is generally referred to as the priority classification.

7.2. Current situation

Short-term stochastic yield characteristics are currently used as part of the operating rules for the major dams in the Vaal River System. These yield curves are in particular used to protect the resources in drought periods against total failure and to determine when support is required from one sub-system to another.

For the medium to smaller dams these yield characteristics are not available and these dams are generally operated according to certain fixed levels which dictate the supply and/or non supply to different users, as well as when curtailments need to be imposed. These dams typically included all the dams used mainly for the supply of irrigation water on most of the schemes in the Vaal River System. Currently as part of the Vaal River System Annual Operating Analysis, an additional task was included to determine drought operating rules for most of the irrigation schemes. This includes dams such as Allemanskraal, Erfenis, Koppies, Rietspruit, Johan Neser, Klerkskraal, Boskop, Lakeside and Klipdrift dams.

The priority classification currently applicable to the Vaal River System is summarised in **Table 7.1**.

Table 7.1 : Priority classifications and assurances of supply for Vaal System

User	User priority classification (Assurance of Supply)		
	Low (95%) or 1 in 20 years	**Medium (99) or 1 in 100 years**	**High (99.5%) or 1 in 200 years**
	Proportion of Water demand supplied (%)		
Domestic	30	20	50
Industrial	10	30	60
Strategic Industries	0	0	100
Irrigation	50	30	20

From **Table 7.1** it is evident that 50% of the irrigation demand is supplied at a the low assurance of 95%, which is in general still quite good for irrigation. The other 50% of the irrigation demand is supplied at very high assurances, in particular for irrigation purposes. There is therefore room for changes in the priority classification in particular with regards to the irrigation users. Allowing a larger portion of the irrigation demand to be supplied at the low assurance of 95% or even at lower assurances will make more water available for use in the Vaal River System.

To determine the effect of different priority classifications and other operating rules on the water supply to irrigation in the Vaal System will be carried out as part of Stage 2 of the Vaal River System Reconciliation strategies. Different possible scenarios in this regard will largely follow from the findings and recommendations obtained from Stage 1 of the study. These suggested scenarios as well as other possible scenarios will therefore be assessed and discussed for detailed analyses as part of Stage 2 of the Vaal River System Reconciliation strategies.

8. PERSPECTIVE ON IRRIGATION FOR POVERTY ALEVIATION

8.1. Current and Possible future initiatives

8.1.1. Upper Vaal WMA

The Upper Vaal WMA is economically of high importance to the country as it contributes to approximately 20% of South Africa's GDP. To provide water at an adequate assurance of supply and quality, water is already transferred into the catchment at high cost. Poverty eradication by means of irrigation schemes are unlikely to be sustainable if the full cost of the water is to be applied. Opportunities will therefore have to be found where existing water allocations are made available or water saved through WC&DM can be utilised for this purpose.

Current projects in this regard include some food gardens established through the provincial department of Agriculture, which has a relatively small impact. The North West province is currently in the planning process to request approval to undertake a large project in the Carltonville area. Not much of the details around the project are yet known. The intention is however to use purified sewage water, which is currently allocated but not used. In addition to this water resource, they plan to request that some of the water previously used by the Oberholzer Irrigation Board, be allocated to them.

8.1.2. Middle Vaal WMA

Local water resources in the Middle Vaal WMA are limited and water is already transferred into the WMA at high cost. Similar to the Upper Vaal WMA poverty eradication by means of irrigation schemes are unlikely to be sustainable if the full cost of the water is to be applied and opportunities will have to be found where existing water allocations are made available or where water saved through WC&DM can be utilised for this purpose. Several poverty eradication schemes using effluent for small irrigation schemes (woodlots) were started in the Middle Vaal WMA near Wesselsbron, Bloemhof, Kroonstad and Stillfontein, but they have all been unsuccessful mainly due to poor soil quality and poor management.

The trading of water allocations seems to be the best solution in the short-term. Land reform projects will also assist the allocation of water for agricultural purposes to resource poor farmers.

Irrigation projects for resource poor farmers currently in process includes 60 ha near

Hoopstad, involving the trading of water allocations on the existing Sand-Vet scheme. This project is supported by the Free State Coordinating Committee for Agricultural Water (CCAW) The DWAF provides financial assistance to the resource poor farmers to obtain water allocations.

The Sand-Vet Water User Association is investigating a project to build weirs in the Lower Vet River to improve the water supply in the area. The weirs will also contribute to the reduction of operational losses to irrigators along the Lower Vet River and will improve the system yield due to the additional storage created in the system. The increase in yield will be utilized to develop a further 50ha for irrigation purposes in the Hoopstad area. A couple of previously disadvantaged farmers bought irrigation plots in the sand-Vet Scheme and are currently actively farming.

Other projects in this regard include the irrigation of paprika from purified effluent, which was launched by the Matjabeng Municipality a few years ago, as well as Beatrix Mine which is in the process to start an irrigation project from their existing water allocation to produce essential oils.

8.1.3. Lower Vaal WMA

In the Lower Vaal WMA the DWAF is also attempting to eradicate poverty by making water easily available to poor communities and redressing imbalances in water allocations. There are certain schemes that had been initiated but need to be revitalised, in particular the Taung Scheme.

As part of the ACGISA (Accelerated growth initiatives of SA) initiatives the 2 660ha irrigation area within the Taung Scheme which has an existing allocation of 22.53 million m³/a (8 470 m³/ha/a) from the Vaal River will be developed in the next 3 to 5 year period for the establishing of resource poor farmers. This initiative will also include approximately 150ha of the Ganspan Settlement within the Vaalharts Irrigation Scheme which is currently not utilized.

The Aganang Beef Trust comprising of 96 Trustees and 270 to 300 beneficiaries has applied for an allocation of 11 million m³/a from the Vaal River close to Christiana. The allocation will mainly be used for the irrigation of pastures and power fodder for the fattening of weaner calves.

9. CONCLUSIONS AND RECOMMENDATIONS

9.1. Conclusions

The findings and results from the different tasks were given in the previous sections. In this section, the most important conclusions that can be drawn from these findings and results are given:

9.1.1. Comparison of Irrigation data from different sources

a) A significant growth in irrigation was experienced from 1998 to 2005 which is most probably, partly due to the registration of water use. It is expected that this growth will still continue for some time as the current 2005 development is still less than the total registered volume.

b) The registered water use in the Upper Vaal WMA is far more (approximately 200 million m³/a) than the actual 2005 development level water use.

c) Large volumes of unlawful abstractions are taking place in the Upper Vaal WMA and in particular upstream of Vaal Dam in the Frankfort and Vaal Dam incremental catchments. Large volumes of transferred water from the Lesotho Highlands and Thukela transfer schemes is flowing through these sub-catchments and is seemingly used illegally for irrigation purposes. In the order of 235 million m³/a, is currently used illegally only upstream of Vaal Dam.

d) Validation and Verification of registered water use in the Middle and Lower Vaal must still be carried out. From the available data from the different resources it however seems that the increase in irrigation in these two WMAs is far less severe than that experienced in the Upper Vaal WMA, where the validation process was largely completed.

e) The 2005 development level irrigation water use is approximately 290 million m³/a higher than that currently used in the WRPM analyses. This will have a significant impact on the water supply and assurance of supply in the Integrated Vaal River System.

9.1.2. Assurance of supply requirements

a) Currently 50% of the irrigation demand is supplied at a low assurance of 95%, which is in general a fairly good assurance for irrigation purposes. The other 50% of the irrigation demand is supplied at very high assurances (99% & 99.5%), in particular for irrigation purposes. There is therefore room for changes in the priority classification, in particular with regards to the irrigation users. Allowing a larger portion of the irrigation demand to be supplied at the low assurance of 95% or even at lower assurances, will make more water available for use in the Vaal River.

9.1.3. Economic importance of the irrigation sector

a) Agriculture production contributes significantly to the economy of the region. The multiplier effect in the agricultural industry is relatively high compared to other industries and therefore any decrease in the amount of agricultural production will have a significant negative impact on the general economy of the region.
b) In regards to labour, it is estimated that the amount paid to direct labour costs (unskilled and semi skilled) for the enterprises (R147 million) is equivalent to 15,300 full time jobs at the minimum wage rate. Therefore any decrease in agricultural production will result in a significant decrease of jobs in the region.
c) Agriculture will be contributing significantly more to the economy as farmers' move towards higher value crops; this will also increase water use efficiency.
d) If only lawful use of irrigation water is enforced this will have a severe negative impact on the economy of the region.
e) When the water cost is increased, it will lead to an insignificant decrease in the value of agricultural output as it is a relatively small amount in terms of costs of production.

9.1.4. Possible trading of water rights

a) The overwhelming issue in terms of water use is unlawful use especially in the Upper Vaal region. It is obvious that any reference to water rights will only pertain to lawful use which in the Upper Vaal is only equal to 40% of the estimated irrigation water used for agriculture.
b) It is envisaged that any development of trading of water rights will more than likely be between other sectors of the economy and that a relatively small amount will be traded within agriculture.
c) The net effect of water right trading will be a reduction in the cropping area. This will also encourage the use of more efficient use of irrigation water which will lead to more efficient irrigation systems and switch to higher value crops.
d) The medium to long-term effect will be an increase in water costs as a result of a

new equilibrium being established for the demand and supply of water. However it was shown in the economic analysis that this would have a very small impact on agricultural production.

9.1.5. Alternative future irrigation demand scenarios

a) For Scenario 1 it is accepted that the eradication of illegal irrigation use in the Vaal River system will be implemented. Due to the severe impact of this on the water supply in the Vaal River System, the eradication of illegal irrigation needs to be implemented. Scenario 1 can thus be seen as a fairly realistic future option.
b) For Scenario 2 it is assumed that no curtailment of illegal use will take place and that irrigation demand will continue to grow. This Scenario is considered as the maximum irrigation demand scenario and was purely used to illustrate the potential impact should the situation arises where the interventions are not successful to cut back the illegal water use.
c) The effect of the different irrigation demand scenarios will be described in the "Water resource analysis". It is however expected that the eradication of the illegal water use will greatly assist in the postponing of future intervention options, while scenario will result in an unsustainable situation in the Vaal River System. The eradication of the illegal water use will also result in a small reduction in irrigation return flows, mainly upstream of Vaal Dam.
d) The effects on the water quality will be addressed in the Water Quality Study "Integrated Water Quality Management Plan" which is running concurrently with the Reconciliation and Water Conservation and Water Demand Management studies

9.1.6. Application of a water requirement and return flow model for irrigation

a) The total modelled return flow from the Vaalharts Irrigation Scheme is slightly less than that currently used in the WRPM, but the main difference is the distribution of return flows between North and West canals. The distribution used in the WRPM is clearly not realistic.
b) The return flows for the Klerksdorp Irrigation Scheme as used in the WRPM is too high and need to be reduced. The main reasons for the reduction are firstly that the actual water use is much lower than the allocated volume, secondly as result of the low permeability of the soils and thirdly the limited canal distribution systems.
c) The modelled return flows for the Schoonspruit Scheme is significantly higher

than that used in the WRPM. This is to a large extent as result of the tail water flows and the fact that the irrigation is in general located close to the river.

d) The tail water flows at the bottom end of the Mooi River Scheme is very high. This is also the main reason for the very high return flows of almost 60% in comparison of the 10% used in the WRPM. When the tail water flow is excluded from the return flow calculation the results from the Return Flow Model and that used in the WRPM is almost the same.

e) Results obtained from the Return Flow model contributed to a much better understanding of the return flows generated at each of the irrigation schemes. The results also showed the large variance in irrigation return flows from as low as 5% at the Klerksdorp Scheme to as high as 59% at the Mooi River Scheme. Using the normal assumption that approximately 10% of the gross inflow to the irrigation scheme will in effect return back to the natural drainage system can be totally wrong.

f) The more data that is available with regards to water use, losses and return flow volumes, the better the calibration can be obtained with the model. This in the end will result in much better estimations of the return flows, as was illustrated with the modelling of the Vaalharts Irrigation Scheme where a lot of previous work was carried out in this regard.

9.1.7. Perspective on Irrigation for Poverty Alleviation

a) Poverty eradication by means of irrigation schemes are unlikely to be sustainable if the full cost of the water is to be applied. Opportunities will therefore have to be found where existing water allocations are made available or water is saved through WC&DM can be utilised for this purpose.

b) Several projects in this regard were already completed and others are in the planning process, covering all three the WMAs in the Vaal Catchment. Some of the projects failed mainly due to poor soil and management.

c) The trading of water allocations seems to be the best solution in the short-term. Land reform projects will also assist the allocation of water for agricultural purposes to resource poor farmers.

d) One of the largest initiatives in this regard is the 2 660ha irrigation area within the Taung Scheme which has not been developed yet and has an existing allocation of 22.53 million m³/a (8 470 m³/ha/a) from the Vaal River. This area is expected to be developed in the next 3 to 5 year period for the establishing of resource poor farmers. This initiative will also include approximately 150ha of the Ganspan

Settlement within the Vaalharts Irrigation Scheme which is currently not utilized

9.2. Recommendations

Based on the results and findings from this task, the following recommendations are made:

a) The eradication of the illegal water use, mainly in the irrigation sector, is an essential strategy that has to be implemented in order to rectify the current deficit (negative water balance) in the Vaal River System. The legal actions and procedures that will be implemented should be designed to achieve legal precedence's to protect the entitlements of lawful water users and assist in compliance monitoring and water use regulation in future.
b) The effect on the economy of the region should also be taken into account in the whole process planned to reduce illegal water use by irrigation as this will also lead to significant job losses in the region.
c) Validation and Verification studies for all three the WMAs in Vaal River catchments need to be completed as soon as possible. The water balance for the system then needs to be re-evaluated.
d) Refinement on the assurance of supply requirements should be considered to increase the availability of water in the Vaal River System. Irrigation and garden watering in urban areas should receive specific attention in this regard.
e) Irrigation demand scenarios should be refined and additional scenarios added in stage 2 of the study.
f) The use of the irrigation return flow model should also be considered in future studies, specifically in areas with large irrigation schemes and significant volumes of return flows.
g) Trading of water rights should be encouraged as it will encourage the efficient use of water.
h) Poverty eradication by means of irrigation schemes should continue as is. Lessons need to be learnt from past failures in this regard to avoid similar situations in the future.

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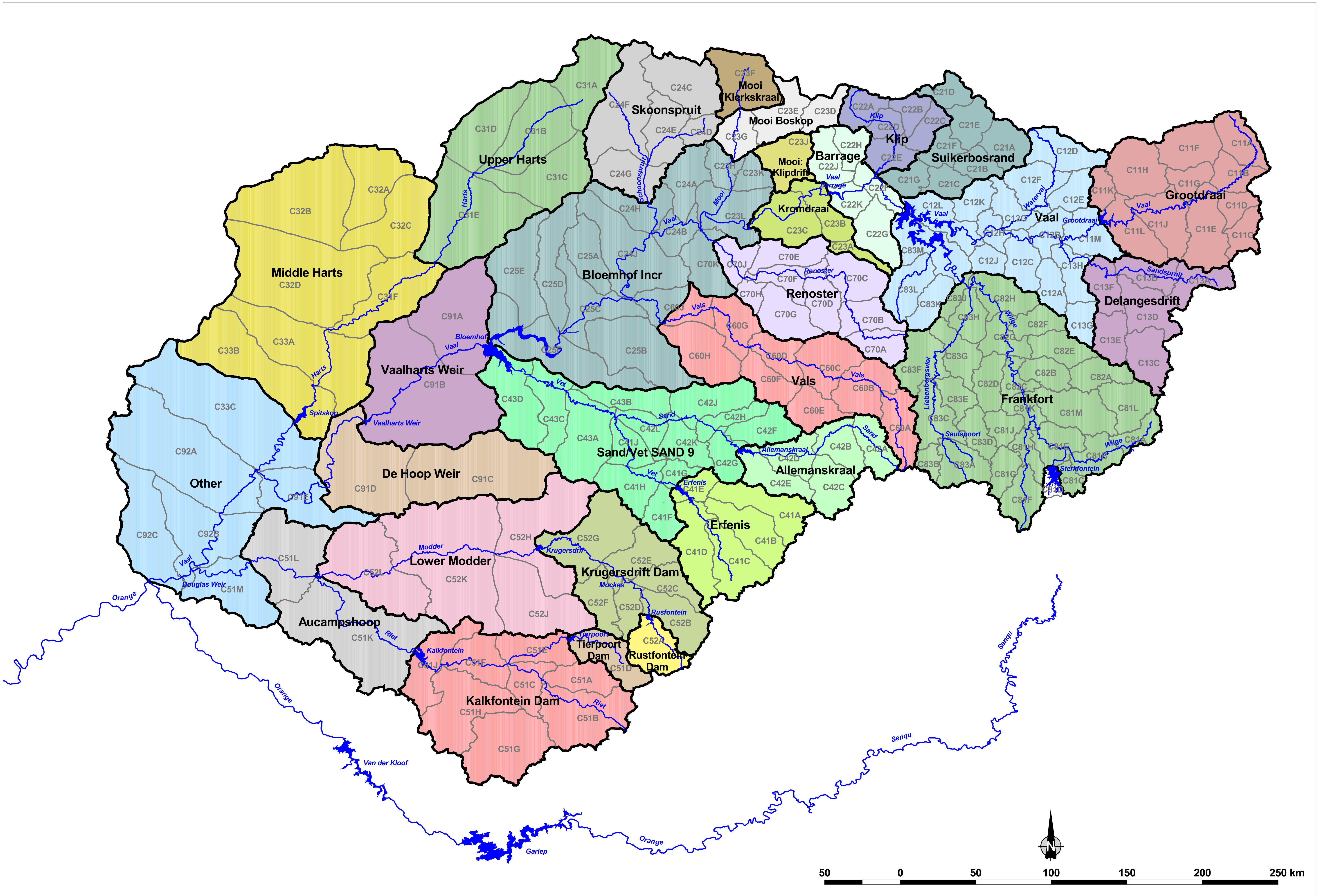
APPENDICES

1.) APPENDIX A: FIGURES.

2.) APPENDIX B: RETURN FLOW MODEL INPUT & OUTPUT

Appendix A

Figures



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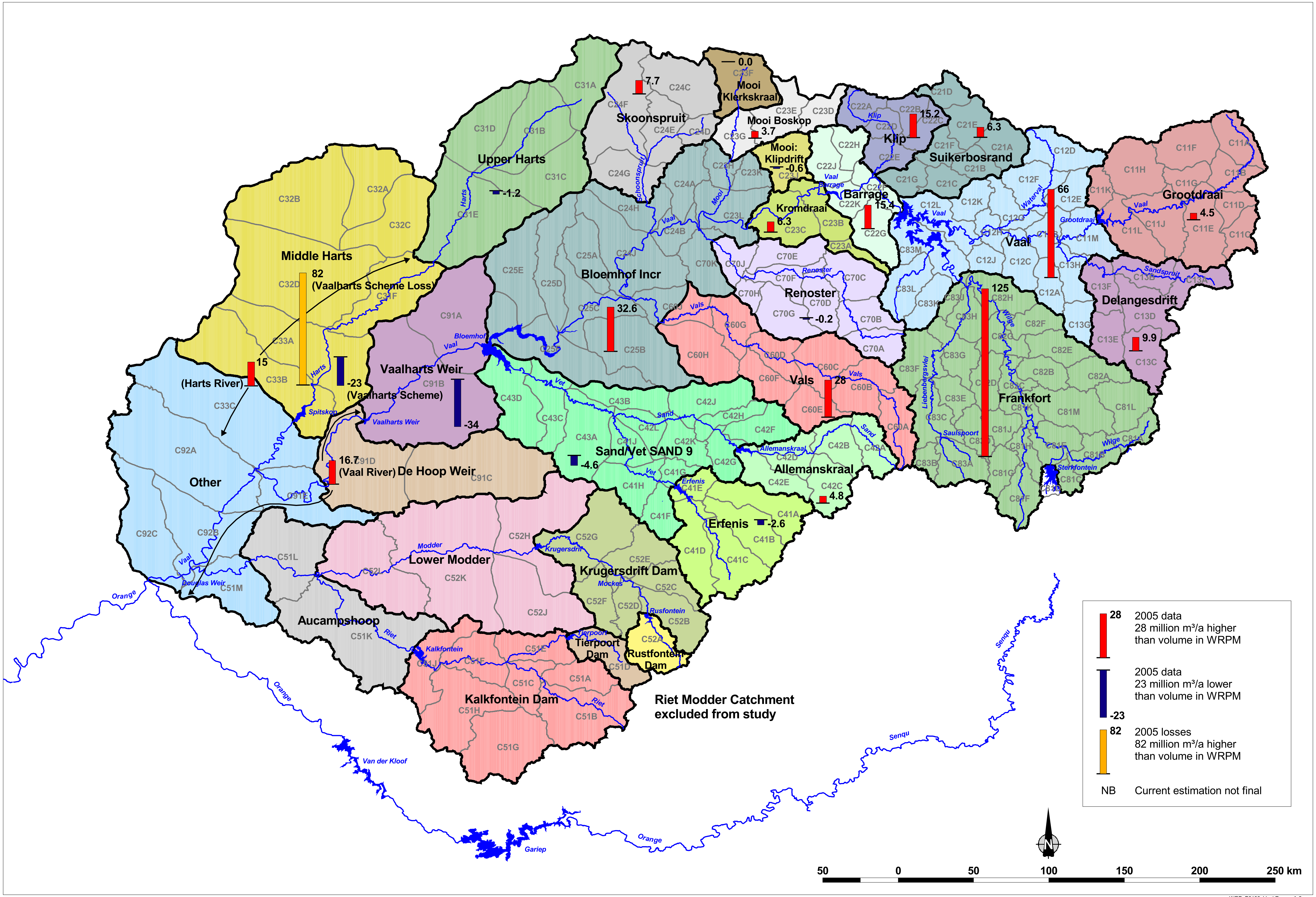
VAAL RIVER SYSTEM: LARGE BULK WATER SUPPLY RECONCILIATION STRATEGIES AND WATER CONSERVATION AND DEMAND MANAGEMENT STUDIES

Sub-catchments used in VRSAU study

A-1



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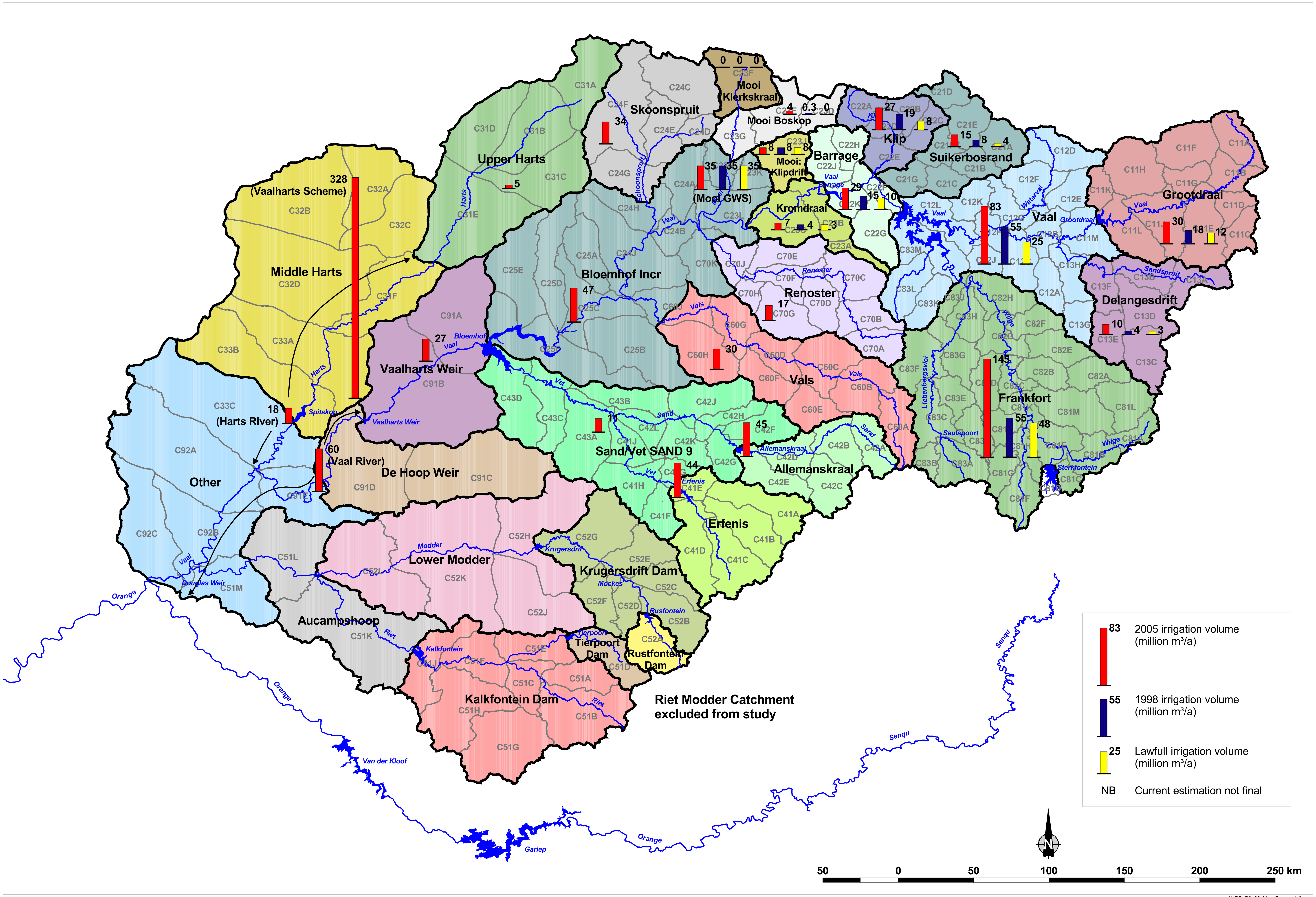
Current 2005 and WRPM irrigation data difference

A-2



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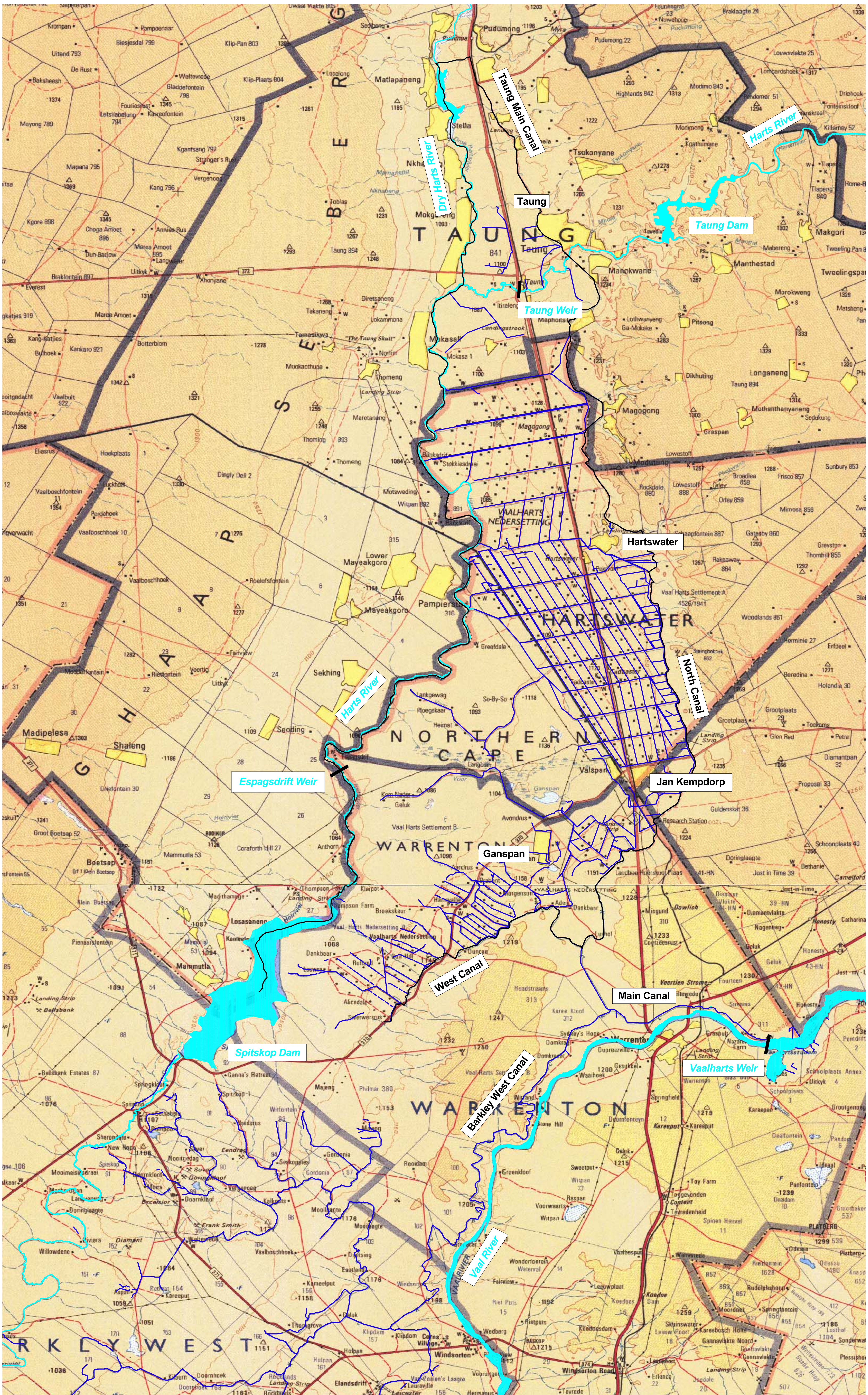
Irrigation development in the Vaal River basin

A-3



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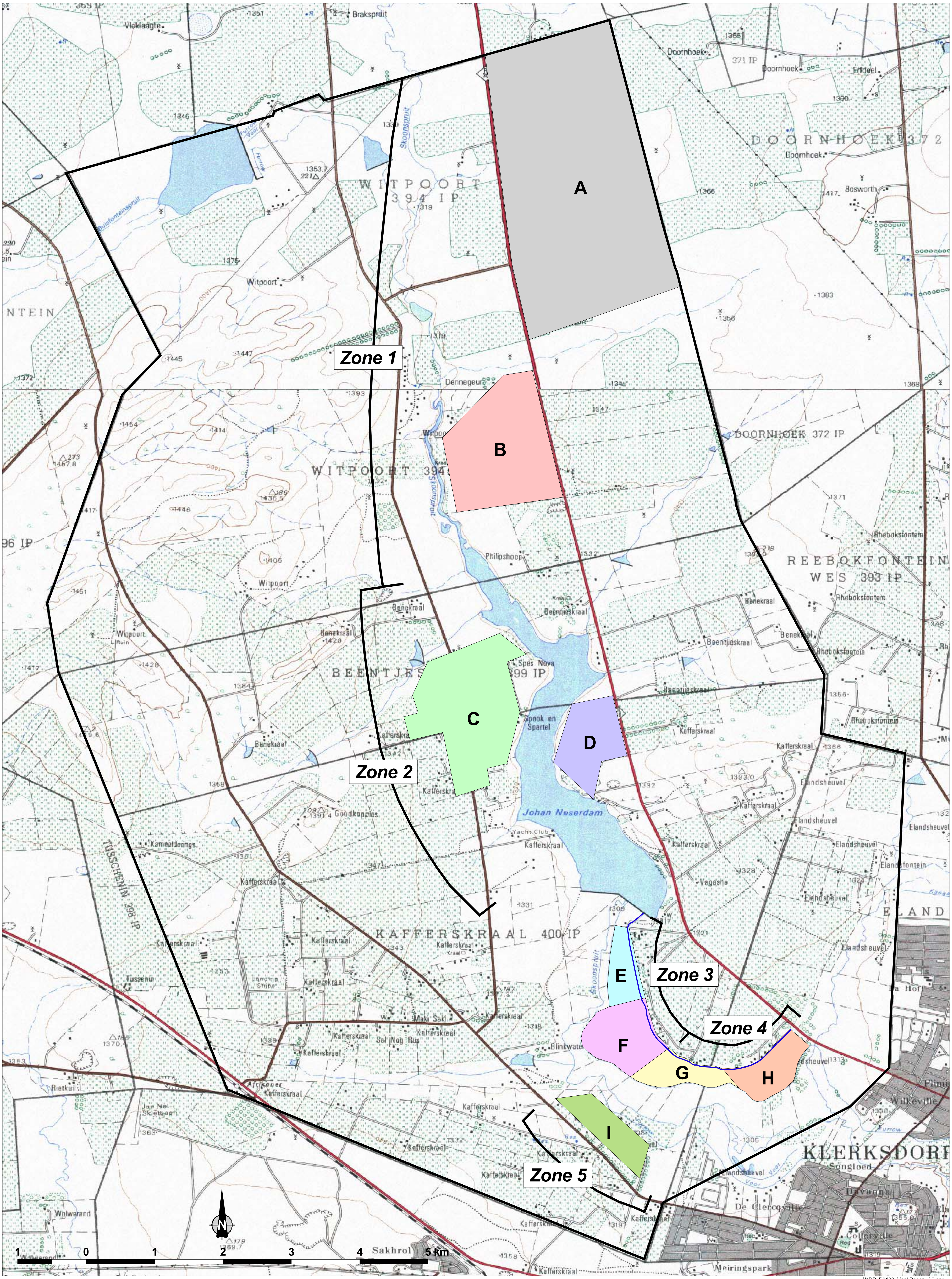
Vaalharts Irrigation Scheme

A-4



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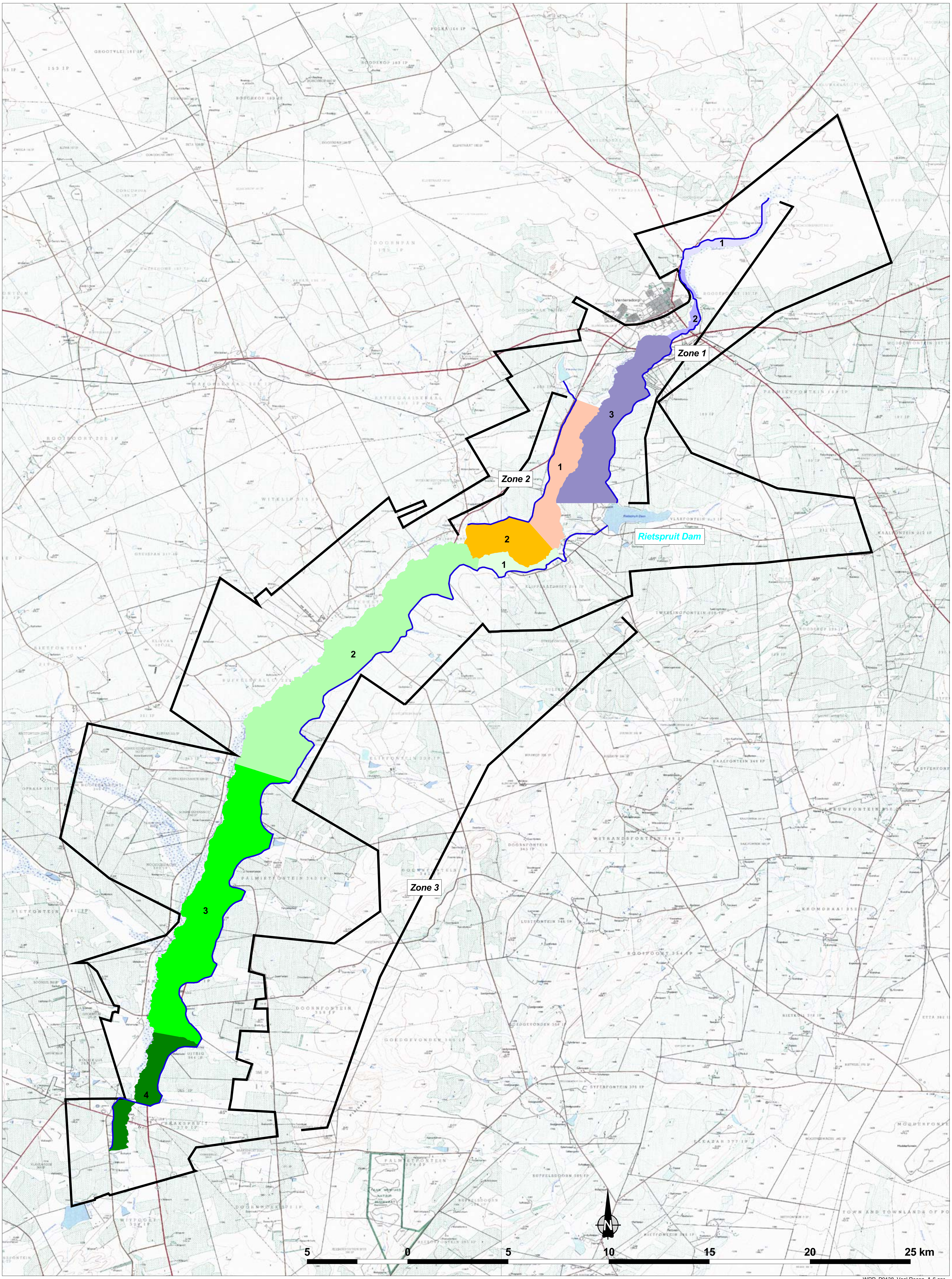
VAAL RIVER SYSTEM: LARGE BULK WATER SUPPLY RECONCILIATION
STRATEGIES AND WATER CONSERVATION AND DEMAND MANAGEMENT STUDIES

Klerksdorp Irrigation Scheme Sub-areas

A-5



WRP_P0138_Vaal Recon_A-6.apr

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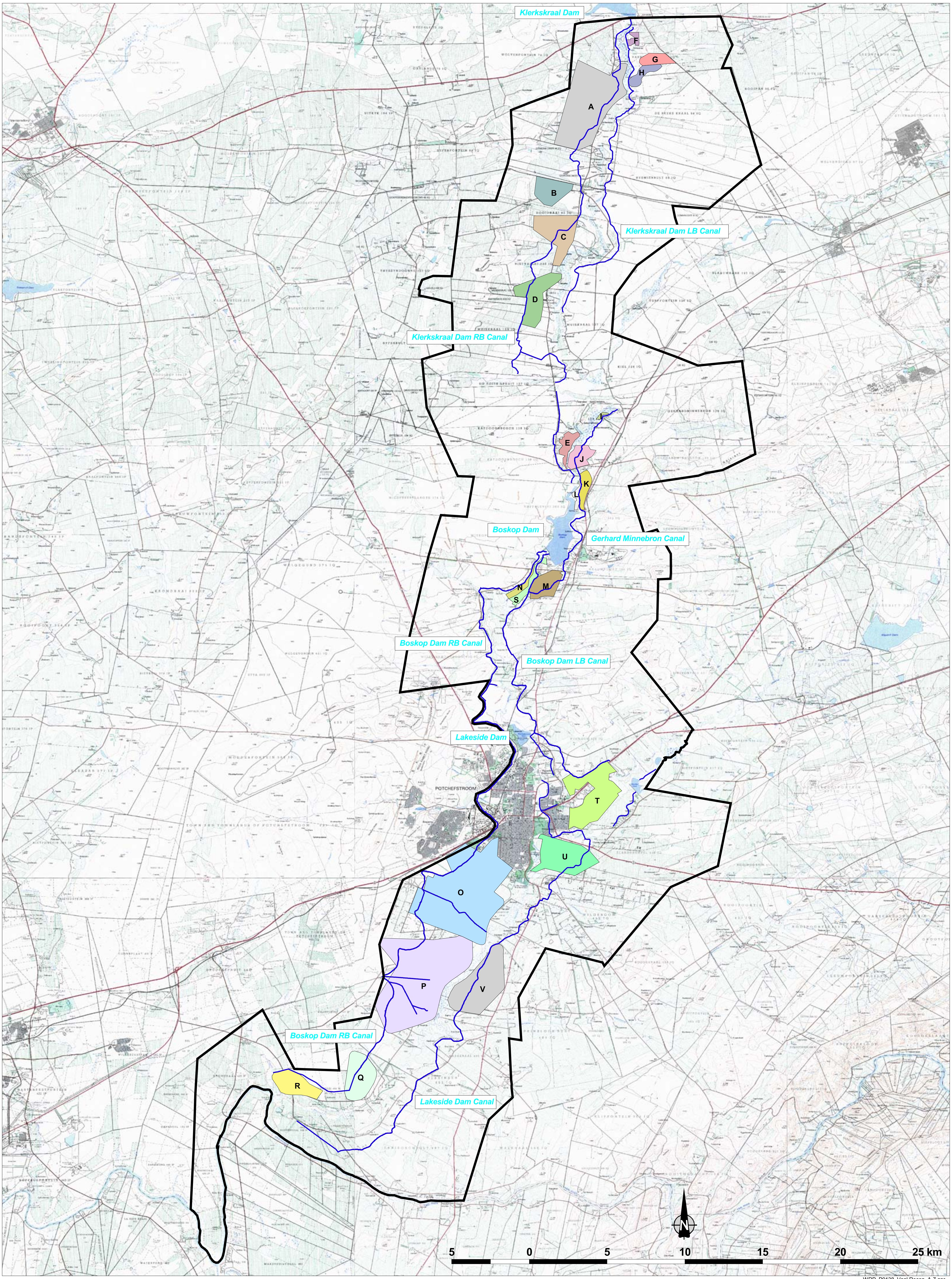
VAAL RIVER SYSTEM: LARGE BULK WATER SUPPLY RECONCILIATION STRATEGIES AND WATER CONSERVATION AND DEMAND MANEGEMENT STUDIES

Schoonspruit Irrigation Scheme Sub-areas

A-6



WRP_P0138_Vaal Recon_A-7.apr

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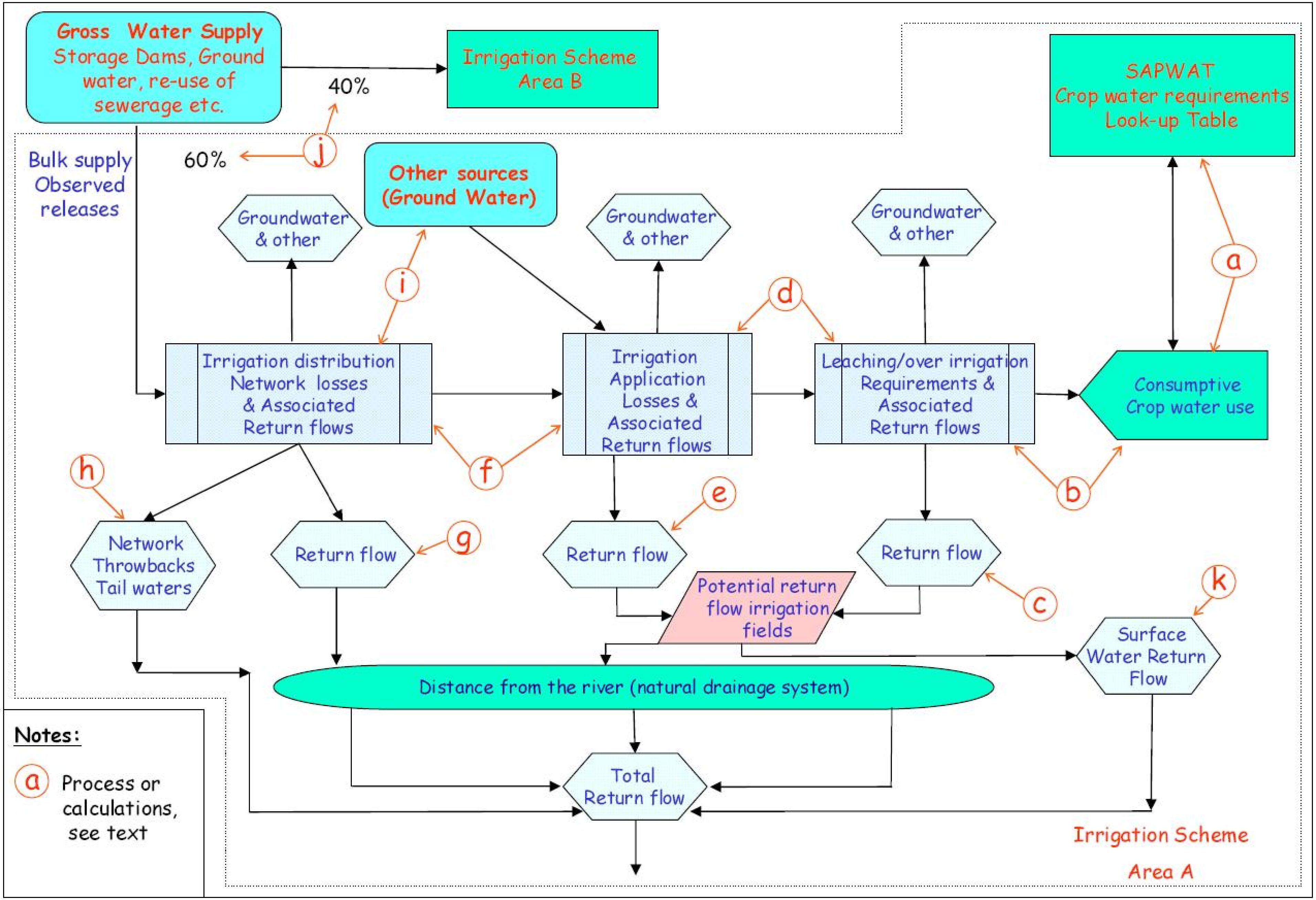
VAAL RIVER SYSTEM: LARGE BULK WATER SUPPLY RECONCILIATION STRATEGIES AND WATER CONSERVATION AND DEMAND MANEGEMENT STUDIES

Mooi River Irrigation Scheme Sub-areas

A-7



WRP_ P0138_Vaal Recon Study_Graphics_Fig8.cdr

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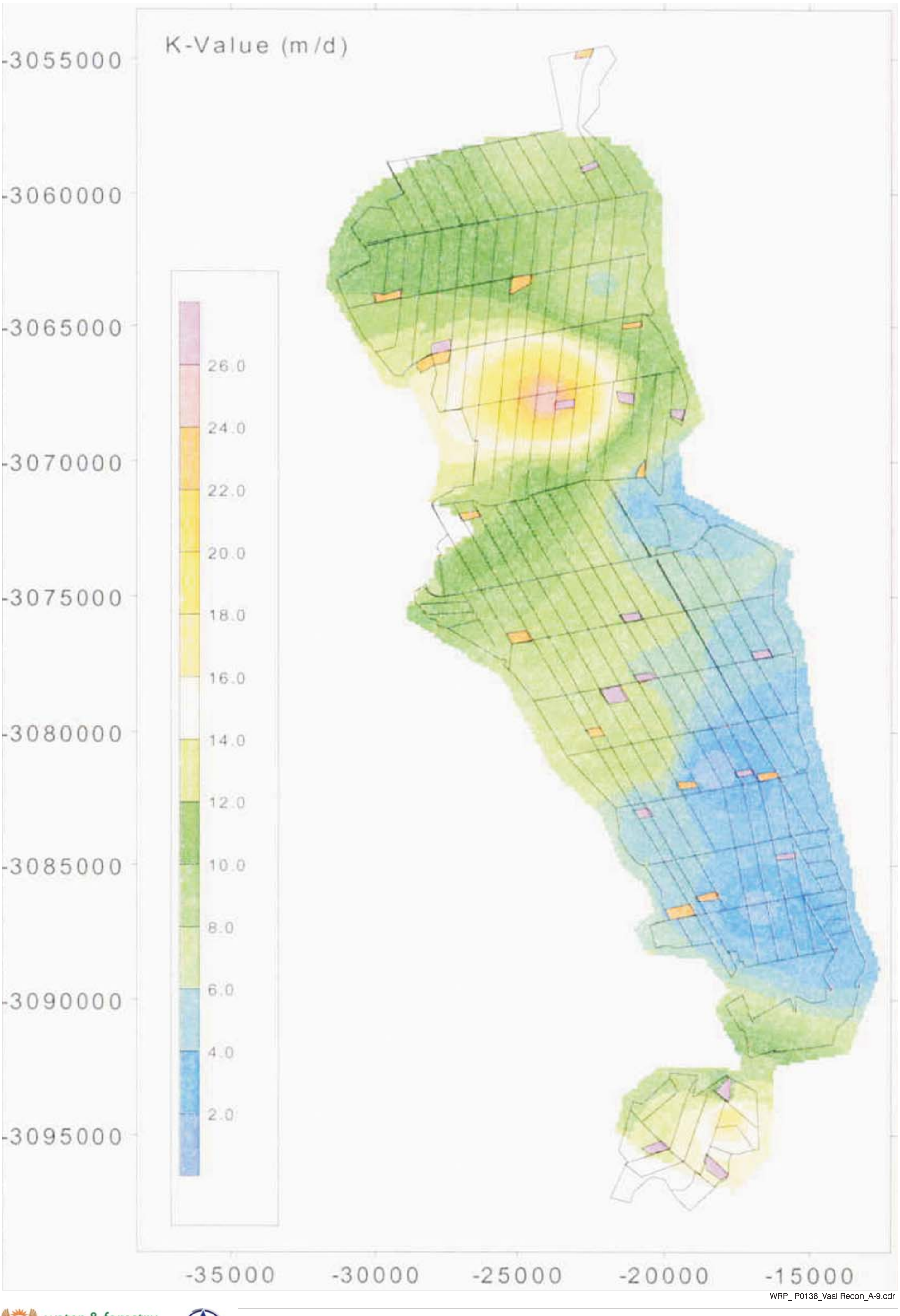
VAAL RIVER SYSTEM: LARGE BULK WATER SUPPLY RECONCILIATION STRATEGIES AND WATER CONSERVATION AND DEMAND MANAGEMENT

Schematic Diagram of Irrigation Return Flow Model

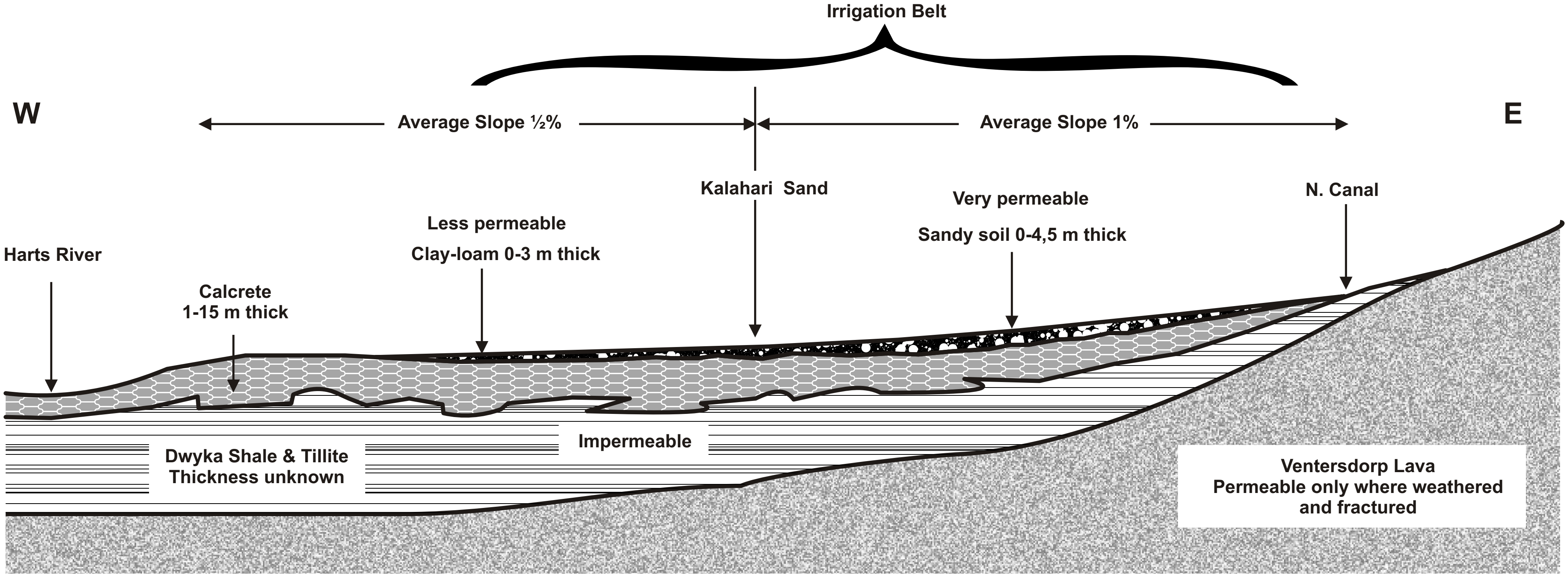
A-8



WRP_ P0138_Vaal Recon_A-9.cdr

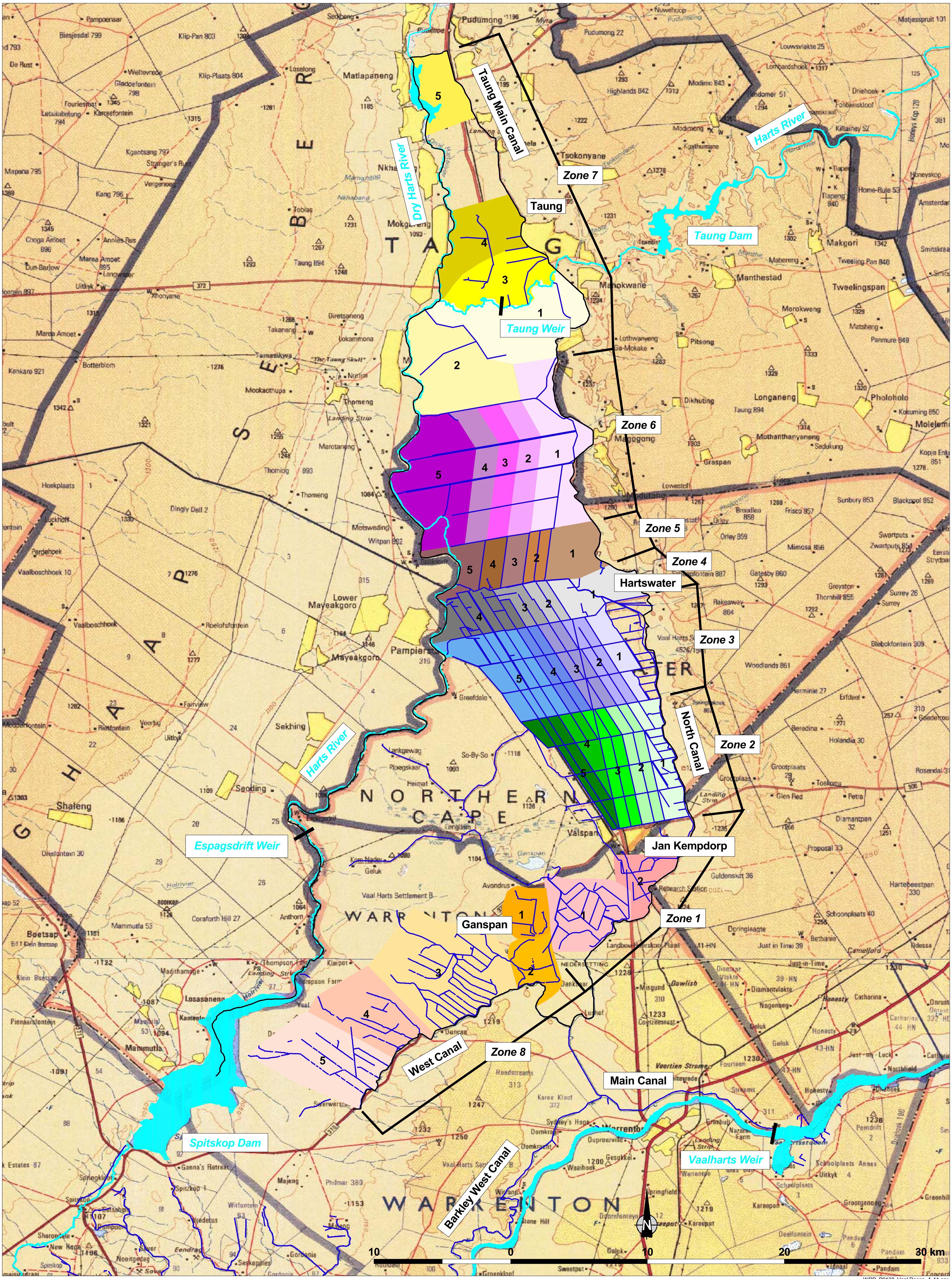
Hydraulic conductivities measured by Vaalharts Agricultural Station

A-9



Geological section across the North Canal area of the Vaal-Harts Irrigation Settlement. Generalized and largely inferred. Residual and alluvial deposits omitted.

WRP_ P0138_Vaal Recon Study_Graphics_Fig9.cdr



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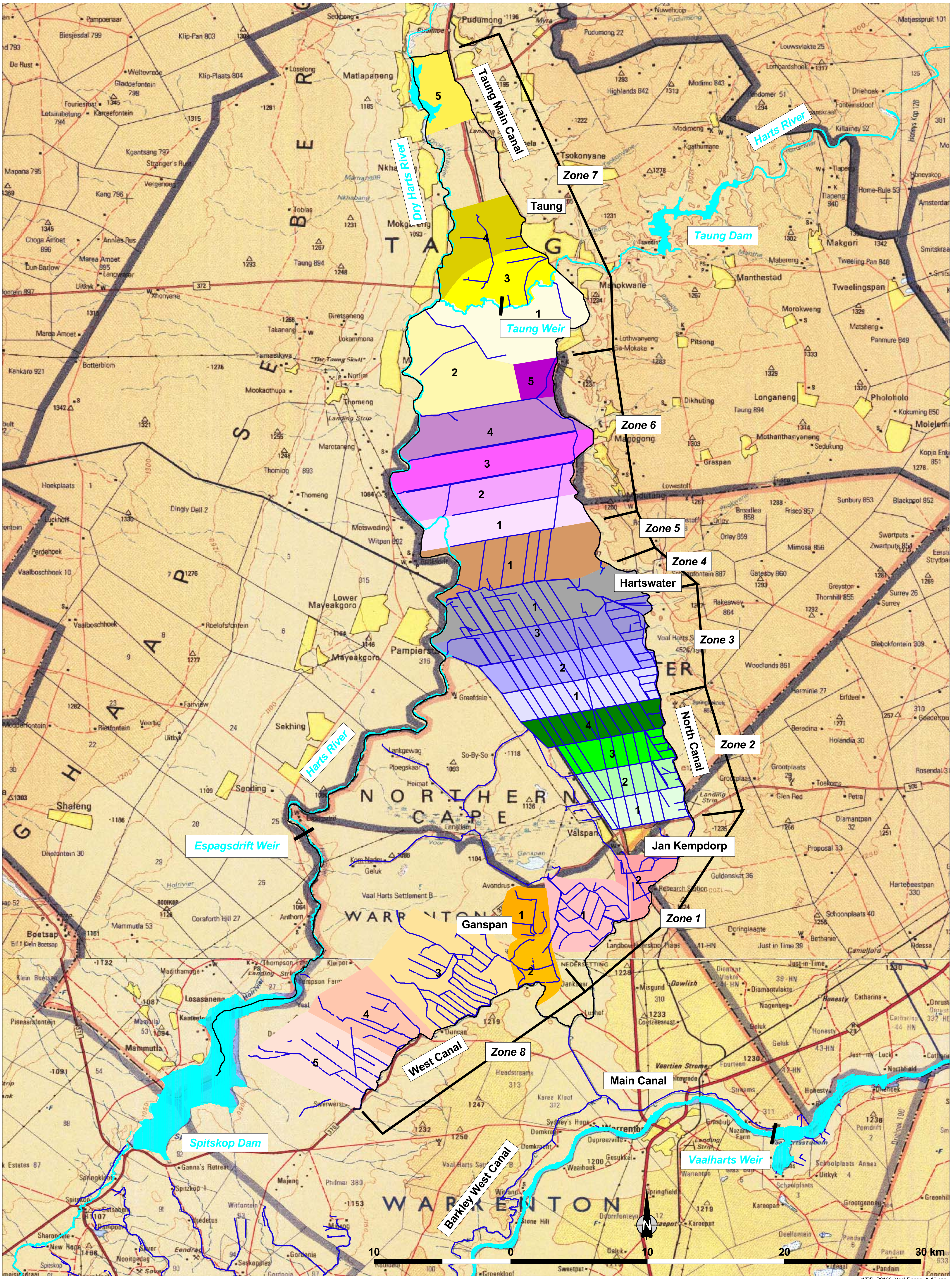
VAAL RIVER SYSTEM: LARGE BULK WATER SUPPLY RECONCILIATION STRATEGIES AND WATER CONSERVATION AND DEMAND MANAGEMENT STUDIES

Vaalharts Scheme Zones and sub-areas upper layer

A-11



WRP_P0138_Vaal Recon_A-12.apr

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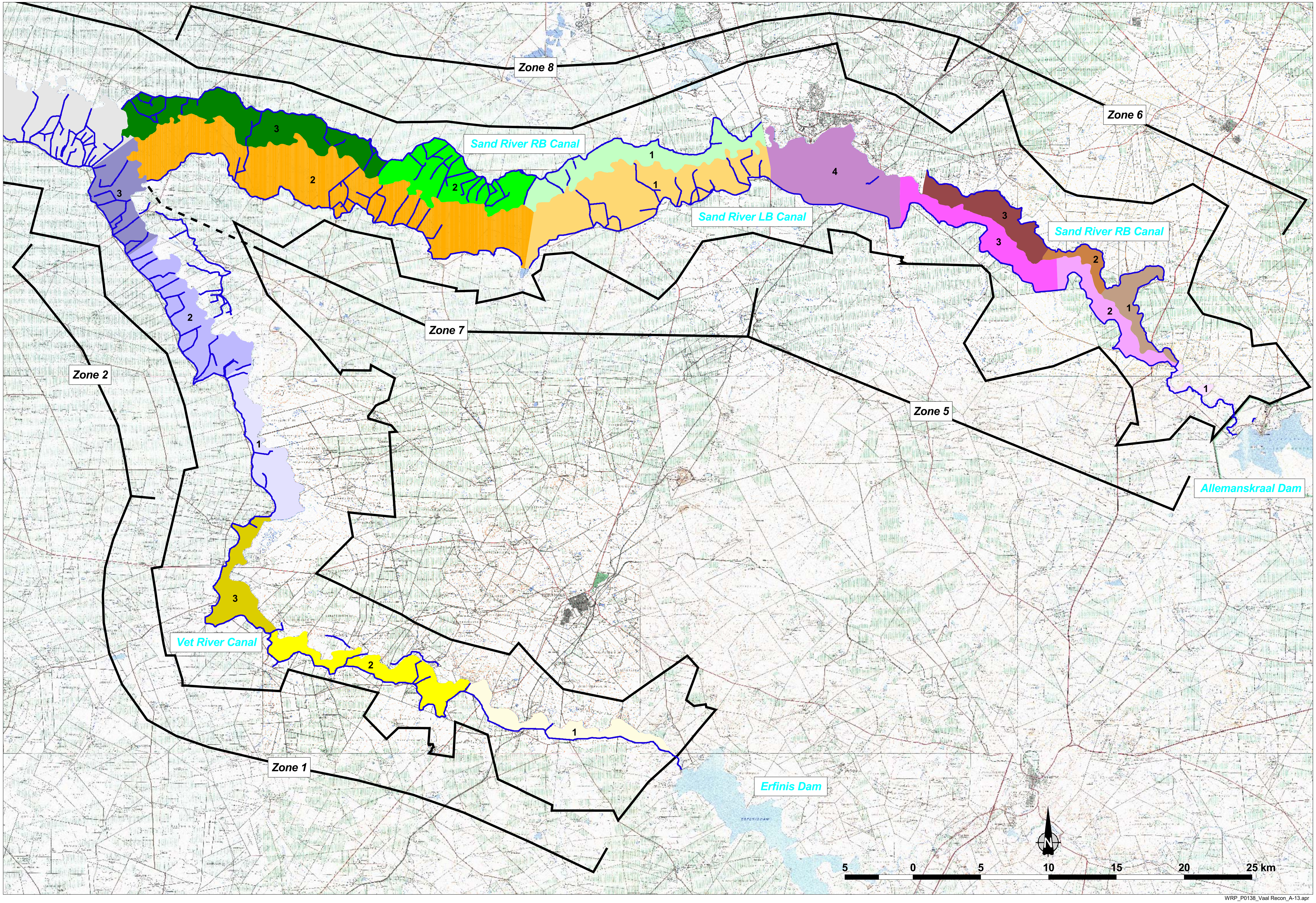
VAAL RIVER SYSTEM: LARGE BULK WATER SUPPLY RECONCILIATION
STRATEGIES AND WATER CONSERVATION AND DEMAND MANAGEMENT STUDIES

Vaalharts Scheme Zones and sub-areas lower layer

A-12



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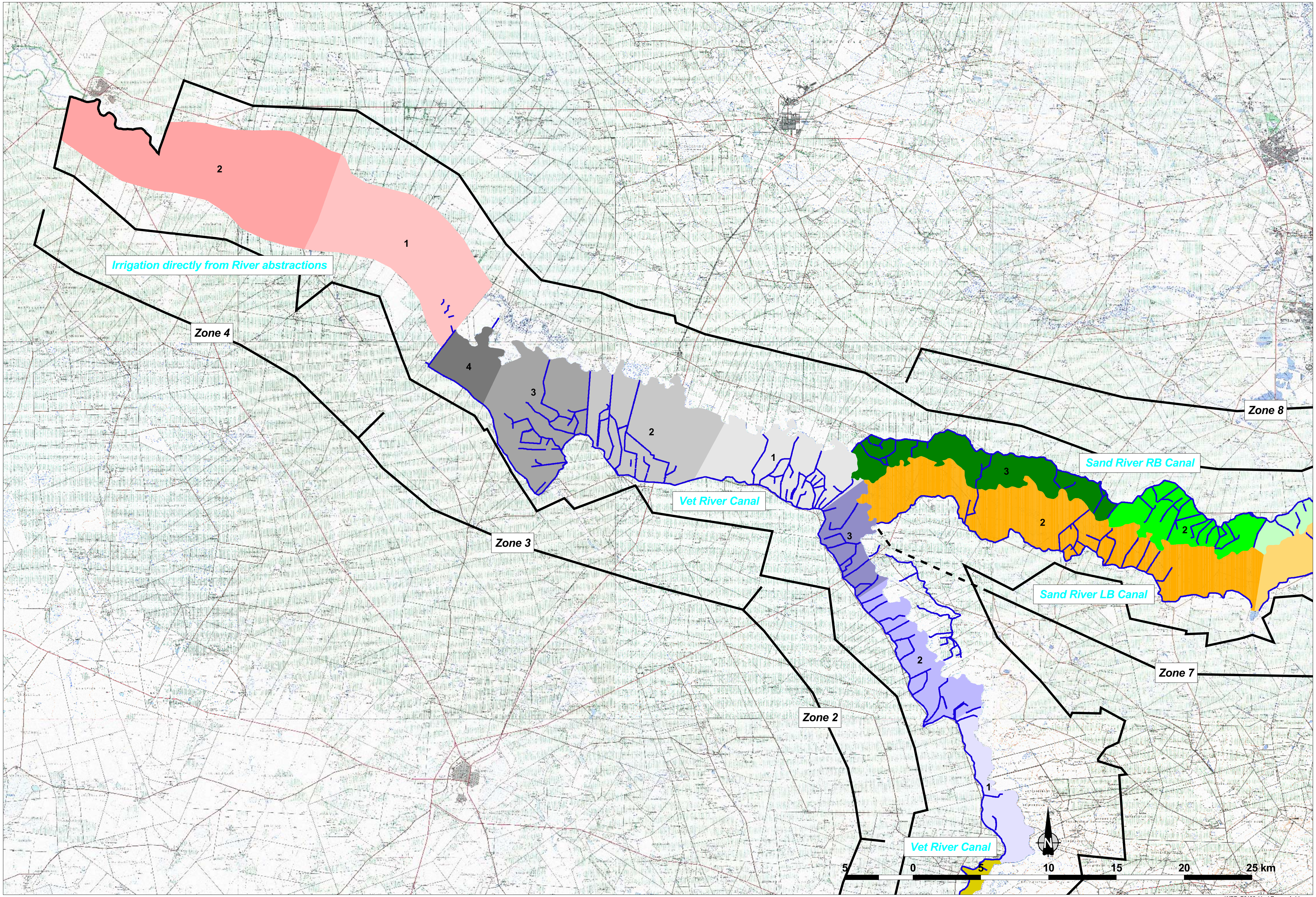
VAAL RIVER SYSTEM: LARGE BULK WATER SUPPLY RECONCILIATION
STRATEGIES AND WATER CONSERVATION AND DEMAND MANAGEMENT STUDIES

Upper Sand-Vet Irrigation Scheme - Sub-areas

A-13



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VAAL RIVER SYSTEM: LARGE BULK WATER SUPPLY RECONCILIATION
STRATEGIES AND WATER CONSERVATION AND DEMAND MANAGEMENT STUDIES

Lower Sand-Vet Irrigation Scheme - Sub-areas

A-14

Appendix B

Return Flow Model data & output

Appendix B *(Continue)*

Return Flow Model data & output

Appendix B (Continue)

Return Flow Model data & output

Sheet B-1: Vaalharts North Canal Zone 1: Upper layer input data

IRRIGATION RETURN FLOW MODEL INPUT DATA

Name of Irrigation Scheme: Vaalharts North Sone 1 Drainage
Calibration

Gross releases into canals

Include data	
Observed /Actual releases	
Source 1	Canal releases
cub. m/a	30,860,000
Area (ha)	1,893

Supply from other sources

Include data	
Observed /Actual releases	
Source 2	none
cub. m/a	no data avaiable
Area (ha)	0

Main distribution network input data

Include data	
% Network distribution losses	37.1
Network losses % tailwater	11.2
% Network losses return flow	55.26
% of Time canals dry	0

Sub Areas	Effective canal length (m)	Distance from River (m)	Height above River/drainage point (m)
sub area 1	4,000	570	8.0
sub area 2	6,000	570	8.0
sub area 3	3,500	570	8.0
sub area 4	2,000	570	8.0
sub area 5			
Total length	15,500		

Sub Areas	K Selected from table
sub area 1	7
sub area 2	7
sub area 3	7
sub area 4	7
sub area 5	

Typical value for soil between canal and drainage point

Soil class textural	Permiability(k) m/day
Silt Clay	0.06
Clay	0.12
Clay-loam	0.185
Loam	0.25
Sandy loam	0.61
Sandy	1.22

Irrigation application system input data

	Include data
	% Irrigation application losses
Accepted	28
Suggested	30.15

% of irrigated area irrigated with given system	Type of Irrigation system	Irrigation system efficiency (%) Accepted efficiency (%)	Suggested efficiency (%)	Application losses return flow factor	Distribution uniformity CU/EU (%) Accepted CU/EU	Suggested CU/EU
2	Drip	95	95	0.2	85	85
3	Micro	90	90	0.15	85	85
15	Sprinkler	75	75	0.1	73	73
10	Pivot	85	85	0.1	90	90
70	Flood	65	60	0.8	100	100
100	Weighted average	69.85	Suggested factor	0.59	94.2	Weighted average
			Accepted factor	0.59	Distibution uniformaty return flow factor	
					Suggested factor	0.015
					Accepted factor	0.015

Include data	
Total area irrigated (ha)	
1,893	
Irrigation days per year on average	
365	
Surface water return flow factor	
0.33	Default 0.33

Sub Areas	Wetted drainage Perimeter (m)	Distance from River (m)	Height above River/drainage point (m)	Total area irrigated (ha) Area
sub area 1	4,000	570	8.0	467
sub area 2	6,000	570	8.0	744
sun area 3	3,500	570	8.0	434
sun area 4	2,000	570	8.0	248
sun area 5				
	8.19	Average wetted perimeter per ha		

Sub Areas	K Selected from table
sub area 1	7.000
sub area 2	7.000
sun area 3	7.000
sun area 4	7.000
sun area 5	

Typical value for soil between irrigation field and drainage point

Soil class textural	Permiability(k) m/day
Silt Clay	0.060
Clay	0.120
Clay-loam	0.185
Loam	0.250
Sandy loam	0.610
Sandy	1.220

Leaching and over irrigation related data

Include data	
Leaching Factor	Over Irrigation factor
0	0
Combined factor	0

Include data
Leaching /over irr return flow factor
0

Observed Return Flow Data

Include data
Tail water flows cub. m/a
1.26

Include data
Surface return flows cub. m/a
no data

Include data
Seepage return flos cub. m/a
no data

Crop water use

TOTAL Consumptive Crop water use (cub.m/a) From SAPWAT
13,786,162

Sub Areas	Crop water use per sub area (cub.m/a)
sub area 1	3,403,899
sub area 2	5,413,609
sub area 3	3,159,174
sub area 4	1,809,480
sub area 5	

Sheet B-2: Vaalharts North Canal Zone 1: Upper layer results

IRRIGATION RETURN FLOW MODEL OUTPUT DATA

Name of Irrigation Scheme: Vaalharts North Sone 1 Drainage

Calibration

Gross releases into main canal

Source 1	Canal releases
Compare for calibration purposes	
Observed /Actual releases	30,860,000
Total requirement calculated	30,441,093

Source 2	none
Compare for calibration purposes	
Observed /Actual releases	no data avaiable
Total requirement calculated	0

Total requirement	30,441,093
Network distribution losses	11,293,645

Main distribution network return flow

Seepage Return Flow			
Total potensial return flow	cub. m/a	6,240,868	Based on estimated fraction
Max. possible return flow	cub. m/a	2,224,821	Based on Darcy flow equation

	cub. m/a	% of total network losses
Seepage Return flow from network losses (smallest of potensial and possible return flow)	778,687	7

	cub. m/a	% of total network losses
Tail water return flow	1,264,888	
Total return flow from network losses	2,043,575	18

Return flow from irrigation fields

Total potensial return flow	cub. m/a	3,369,951	Based on estimated fraction
Max. possible return flow	cub. m/a	2,223,298	Based on Darcy flow equation

	cub. m/a	% of Gross irr.
Return flow from irr. Area (smallest of potensial and possible return flow)	778,154	4 (network losses excluded)

Total return flow from irrigation scheme

Total return flow from scheme	cub. m/a	% of gross releases	Observed
Seepage	1,556,841	5.1	no data
Surface return flow	378,395	1.2	no data
Tail water	1,264,888	4.2	1.26
Total return flow from scheme	3,200,125	10.5	1

Sheet B-3: Vaalharts North Canal Zone 2: Upper layer input data

IRRIGATION RETURN FLOW MODEL INPUT DATA

Name of Irrigation Scheme: Vaalharts North Canal Sone 2 Drainage system

Calibration

Gross releases into canals

Include data	
Observed /Actual releases	
Source 1	Canal releases
cub. m/a	55,580,000
Area (ha)	5,589

Supply from other sources

Include data	
Observed /Actual releases	
Source 2	none
cub. m/a	no data
Area (ha)	0

Main distribution network input data

Include data
% Network distribution losses
32.3
Network losses % tailwater
10.5
% Network losses return flow
56.11
% of Time canals dry
0

Sub Areas	Effective canal length (m)	Distance from River (m)	Height above River/drainage point (m)
sub area 1	9,000	570	8.0
sub area 2	9,000	570	8.0
sub area 3	9,000	570	8.0
sub area 4	7,000	570	8.0
sub area 5	9,000	570	8.0
Total length	43,000		

Sub Areas	K Selected from table
sub area 1	3
sub area 2	3
sub area 3	3
sub area 4	5
sub area 5	5

Typical value for soil between canal and drainage point

Soil class textural	Permiability(k) m/day
Silt Clay	0.06
Clay	0.12
Clay-loam	0.185
Loam	0.25
Sandy loam	0.61
Sandy	1.22

Irrigation application system input data

	Include data
	% Irrigation application losses
Accepted	27
Suggested	30.15

% of irrigated area irrigated with given system	Type of Irrigation system	Irrigation system efficiency (%) Accepted efficiency (%)	Suggested efficiency (%)	Application losses return flow factor	Distribution uniformity CU/EU (%) Accepted CU/EU	Suggested CU/EU
2	Drip	95	95	0.2	85	85
3	Micro	90	90	0.15	85	85
15	Sprinkler	75	75	0.1	73	73
10	Pivot	85	85	0.1	90	90
70	Flood	65	60	0.8	100	100
100	Weighted average	69.85	Suggested factor	0.59	94.2	Weighted average
			Accepted factor	0.59	Distibution uniformaty return flow factor	
					Suggested factor	0.015
					Accepted factor	0.015

Include data	
Total area irrigated (ha)	
5,589	
Irrigation days per year on average	
365	
Surface water return flow factor	
0.33	Default 0.33

Sub Areas	Wetted drainage Perimeter (m)	Distance from River (m)	Height above River/drainage point (m)	Total area irrigated (ha) Area
sub area 1	9,000	570	8.0	1,148
sub area 2	9,000	570	8.0	1,148
sun area 3	9,000	570	8.0	1,149
sun area 4	7,000	570	8.0	996
sun area 5	9,000	570	8.0	1,148
	7.69	Average wetted perimeter per ha		

Sub Areas	K Selected from table
sub area 1	3.000
sub area 2	3.000
sun area 3	3.000
sun area 4	5.000
sun area 5	5.000

Typical value for soil between irrigation field and drainage point

Soil class textural	Permiability(k) m/day
Silt Clay	0.060
Clay	0.120
Clay-loam	0.185
Loam	0.250
Sandy loam	0.610
Sandy	1.220

Leaching and over irrigation related data

Include data	
Leaching Factor	Over Irrigation factor
0	0
Combined factor	0

Include data
Leaching /over irr return flow factor
0

Observed Return Flow Data

Include data
Tail water flows cub. m/a
1.88

Include data
Surface return flows cub. m/a
no data

Include data
Seepage return flos cub. m/a
no data

Crop water use

TOTAL Consumptive Crop water use (cub.m/a) From SAPWAT
27,413,459

Sub Areas	Crop water use per sub area (cub.m/a)
sub area 1	5,627,469
sub area 2	5,627,469
sub area 3	5,627,469
sub area 4	4,903,583
sub area 5	5,627,469

Sheet B-4: Vaalharts North Canal Zone 2: Upper layer results

IRRIGATION RETURN FLOW MODEL OUTPUT DATA

Name of Irrigation Scheme: Vaalharts North Canal Sone 2 Drainage system

Calibration

Gross releases into main canal

Source 1	Canal releases
Compare for calibration purposes	
Observed /Actual releases	55,580,000
Total requirement calculated	55,469,252

Source 2	none
Compare for calibration purposes	
Observed /Actual releases	no data
Total requirement calculated	0

Total requirement	
	55,469,252
Network distribution losses	17,916,568

Main distribution network return flow

Seepage Return Flow			
Total potensial return flow	cub. m/a	10,052,987	Based on estimated fraction
Max. possible return flow	cub. m/a	3,301,347	Based on Darcy flow equation

	cub. m/a	% of total network losses
Seepage Return flow from network losses (smallest of potensial and possible return flow)	1,155,471	6

	cub. m/a	% of total network losses
Tail water return flow	1,881,240	
Total return flow from network losses	3,036,711	17

Return flow from irrigation fields

Total potensial return flow	cub. m/a	6,393,344	Based on estimated fraction
Max. possible return flow	cub. m/a	3,299,088	Based on Darcy flow equation

	cub. m/a	% of Gross irr.
Return flow from irr. Area (smallest of potensial and possible return flow)	1,154,680	3 (network losses excluded)

Total return flow from irrigation scheme

Total return flow from scheme	cub. m/a	% of gross releases	Observed
Seepage	2,310,151	4.2	no data
Surface return flow	1,021,105	1.8	no data
Tail water	1,881,240	3.4	1.88
Total return flow from scheme	5,212,495	9.4	2

Sheet A-B: Vaalharts North Canal Zone 3: Upper layer input data

IRRIGATION RETURN FLOW MODEL INPUT DATA

Name of Irrigation Scheme: Vaalharts North Sone 3 Drainage system

Calibration

Gross releases into canals

Include data	
Observed /Actual releases	
Source 1	Canal releases
cub. m/a	64,780,000
Area (ha)	5,600

Supply from other sources

Include data	
Observed /Actual releases	
Source 2	none
cub. m/a	no data
Area (ha)	0

Main distribution network input data

Include data
% Network distribution losses
32.5
Network losses % tailwater
16.1
% Network losses return flow
51.52
% of Time canals dry
0

Sub Areas	Effective canal length (m)	Distance from River (m)	Height above River/drainage point (m)
sub area 1	12,500	570	8.0
sub area 2	7,000	570	8.0
sub area 3	7,000	570	8.0
sub area 4	7,000	570	8.0
sub area 5	16,500	570	8.0
Total length	50,000		

Sub Areas	K Selected from table
sub area 1	3
sub area 2	6
sub area 3	7
sub area 4	8
sub area 5	9

Typical value for soil between canal and drainage point

Soil class textural	Permiability(k) m/day
Silt Clay	0.06
Clay	0.12
Clay-loam	0.185
Loam	0.25
Sandy loam	0.61
Sandy	1.22

Irrigation application system input data

	Include data
	% Irrigation application losses
Accepted	27
Suggested	30.15

% of irrigated area irrigated with given system	Type of Irrigation system	Irrigation system efficiency (%) Accepted efficiency (%)	Suggested efficiency (%)	Application losses return flow factor	Distribution uniformity CU/EU (%) Accepted CU/EU	Suggested CU/EU
2	Drip	95	95	0.2	85	85
3	Micro	90	90	0.15	85	85
15	Sprinkler	75	75	0.1	73	73
10	Pivot	85	85	0.1	90	90
70	Flood	65	60	0.8	100	100
100	Weighted average	69.85	Suggested factor	0.59	94.2	Weighted average
			Accepted factor	0.59	Distibution uniformaty return flow factor	
					Suggested factor	0.015
					Accepted factor	0.015

Include data	
Total area irrigated (ha)	
5,600	
Irrigation days per year on average	
365	
Surface water return flow factor	
0.33	Default 0.33

Sub Areas	Wetted drainage Perimeter (m)	Distance from River (m)	Height above River/drainage point (m)	Total area irrigated (ha) Area
sub area 1	12,500	570	8.0	1,400
sub area 2	7,000	570	8.0	784
sun area 3	7,000	570	8.0	784
sun area 4	7,000	570	8.0	784
sun area 5	16,500	570	8.0	1,848
	8.93	Average wetted perimeter per ha		

Sub Areas	K Selected from table
sub area 1	3.000
sub area 2	6.000
sun area 3	7.000
sun area 4	8.000
sun area 5	9.000

Typical value for soil between irrigation field and drainage point

Soil class textural	Permiability(k) m/day
Silt Clay	0.060
Clay	0.120
Clay-loam	0.185
Loam	0.250
Sandy loam	0.610
Sandy	1.220

Leaching and over irrigation related data

Include data	
Leaching Factor	Over Irrigation factor
0	0
Combined factor	0

Include data
Leaching /over irr return flow factor
0

Observed Return Flow Data

Include data
Tail water flows cub. m/a
3.38

Include data
Surface return flows cub. m/a
no data

Include data
Seepage return flos cub. m/a
no data

Crop water use

TOTAL Consumptive Crop water use (cub.m/a) From SAPWAT
31,806,819

Sub Areas	Crop water use per sub area (cub.m/a)
sub area 1	7,959,204
sub area 2	4,447,155
sub area 3	4,447,155
sub area 4	4,447,155
sub area 5	10,506,150

Sheet A-B: Vaalharts North Canal Zone 3: Upper layer results

IRRIGATION RETURN FLOW MODEL OUTPUT DATA

Name of Irrigation Scheme: Vaalharts North Sone 3 Drainage system

Calibration

Gross releases into main canal

Source 1	Canal releases
Compare for calibration purposes	
Observed /Actual releases	64,780,000
Total requirement calculated	64,549,607

Source 2	none
Compare for calibration purposes	
Observed /Actual releases	no data
Total requirement calculated	0

Total requirement	
	64,549,607
Network distribution losses	20,978,622

Main distribution network return flow

Seepage Return Flow			
Total potensial return flow	cub. m/a	10,808,186	Based on estimated fraction
Max. possible return flow	cub. m/a	6,828,253	Based on Darcy flow equation

	cub. m/a	% of total network losses
Seepage Return flow from network losses (smallest of potensial and possible return flow)	2,360,541	11

	cub. m/a	% of total network losses
Tail water return flow	3,377,558	
Total return flow from network losses	5,738,099	27

Return flow from irrigation fields

Total potensial return flow	cub. m/a	7,417,960	Based on estimated fraction
Max. possible return flow	cub. m/a	6,823,579	Based on Darcy flow equation

	cub. m/a	% of Gross irr.
Return flow from irr. Area (smallest of potensial and possible return flow)	2,388,253	5 (network losses excluded)

Total return flow from irrigation scheme

Total return flow from scheme	cub. m/a	% of gross releases	Observed
Seepage	4,748,794	7.4	no data
Surface return flow	196,146	0.3	no data
Tail water	3,377,558	5.2	3.38
Total return flow from scheme	8,322,498	12.9	3

Sheet B-7: Vaalharts North Canal Zone 4: Upper layer input data

IRRIGATION RETURN FLOW MODEL INPUT DATA

Name of Irrigation Scheme: Vaalharts North Sone 4 Drainage System

Calibration

Gross releases into canals

Include data	
Observed /Actual releases	
Source 1	Canal releases
cub. m/a	28,880,000
Area (ha)	2,143

Supply from other sources

Include data	
Observed /Actual releases	
Source 2	none
cub. m/a	no data
Area (ha)	0

Main distribution network input data

Include data
% Network distribution losses
41
Network losses % tailwater
8.6
% Network losses return flow
58
% of Time canals dry
0

Sub Areas	Effective canal length (m)	Distance from River (m)	Height above River/drainage point (m)
sub area 1	3,300	525	8.0
sub area 2	3,300	525	8.0
sub area 3	3,300	525	8.0
sub area 4	3,300	525	8.0
sub area 5	7,000	525	8.0
Total length	20,200		

Sub Areas	K Selected from table
sub area 1	3
sub area 2	6
sub area 3	9
sub area 4	10
sub area 5	11

Typical value for soil between canal and drainage point

Soil class textural	Permiability(k) m/day
Silt Clay	0.06
Clay	0.12
Clay-loam	0.185
Loam	0.25
Sandy loam	0.61
Sandy	1.22

Irrigation application system input data

	Include data
	% Irrigation application losses
Accepted	28
Suggested	30.15

% of irrigated area irrigated with given system	Type of Irrigation system	Irrigation system efficiency (%) Accepted efficiency (%)	Suggested efficiency (%)	Application losses return flow factor	Distribution uniformity CU/EU (%) Accepted CU/EU	Suggested CU/EU
2	Drip	95	95	0.2	85	85
3	Micro	90	90	0.15	85	85
15	Sprinkler	75	75	0.1	73	73
10	Pivot	85	85	0.1	90	90
70	Flood	65	60	0.8	100	100
100	Weighted average	69.85	Suggested factor	0.59	94.2	Weighted average
			Accepted factor	0.59	Distibution uniformaty return flow factor	
					Suggested factor	0.015
					Accepted factor	0.015

Include data	
Total area irrigated (ha)	
2,143	
Irrigation days per year on average	
365	
Surface water return flow factor	
0.33	Default 0.33

Sub Areas	Wetted drainage Perimeter (m)	Distance from River (m)	Height above River/drainage point (m)	Total area irrigated (ha) Area
sub area 1	3,300	525	8.0	350
sub area 2	3,300	525	8.0	350
sun area 3	3,300	525	8.0	350
sun area 4	3,300	525	8.0	350
sun area 5	7,000	525	8.0	743
	9.43	Average wetted perimeter per ha		

Sub Areas	K Selected from table
sub area 1	3.000
sub area 2	6.000
sun area 3	9.000
sun area 4	10.000
sun area 5	11.000

Typical value for soil between irrigation field and drainage point

Soil class textural	Permiability(k) m/day
Silt Clay	0.060
Clay	0.120
Clay-loam	0.185
Loam	0.250
Sandy loam	0.610
Sandy	1.220

Leaching and over irrigation related data

Include data	
Leaching Factor	Over Irrigation factor
0	0
Combined factor	0

Include data
Leaching /over irr return flow factor
0

Observed Return Flow Data

Include data
Tail water flows cub. m/a
1.01

Include data
Surface return flows cub. m/a
no data

Include data
Seepage return flos cub. m/a
no data

Crop water use

TOTAL Consumptive Crop water use (cub.m/a) From SAPWAT
12,183,487

Sub Areas	Crop water use per sub area (cub.m/a)
sub area 1	1,990,372
sub area 2	1,990,372
sub area 3	1,990,372
sub area 4	1,990,372
sub area 5	4,221,999

Sheet B-8: Vaalharts North Canal Zone 4: Upper layer results

IRRIGATION RETURN FLOW MODEL OUTPUT DATA

Name of Irrigation Scheme: Vaalharts North Sone 4 Drainage System

Calibration

Gross releases into main canal

Source 1	Canal releases
Compare for calibration purposes	
Observed /Actual releases	28,880,000
Total requirement calculated	28,680,525

Source 2	none
Compare for calibration purposes	
Observed /Actual releases	no data
Total requirement calculated	0

Total requirement	
	28,680,525
Network distribution losses	
	11,759,015

Main distribution network return flow

Seepage Return Flow			
Total potensial return flow	cub. m/a	6,820,229	Based on estimated fraction
Max. possible return flow	cub. m/a	3,771,328	Based on Darcy flow equation

	cub. m/a	% of total network losses
Seepage Return flow from network losses (smallest of potensial and possible return flow)	1,319,965	11

	cub. m/a	% of total network losses
Tail water return flow	1,011,275	
Total return flow from network losses	2,331,240	20

Return flow from irrigation fields

Total potensial return flow	cub. m/a	2,978,186	Based on estimated fraction
Max. possible return flow	cub. m/a	3,768,747	Based on Darcy flow equation

	cub. m/a	% of Gross irr.
Return flow from irr. Area (smallest of potensial and possible return flow)	1,042,365	6 (network losses excluded)

Total return flow from irrigation scheme

Total return flow from scheme	cub. m/a	% of gross releases	Observed
Seepage	2,362,330	8.2	no data
Surface return flow	0	0.0	no data
Tail water	1,011,275	3.5	1.01
Total return flow from scheme	3,373,605	11.8	1

Sheet B-9: Vaalharts North Canal Zone 5: Upper layer input data

IRRIGATION RETURN FLOW MODEL INPUT DATA

Name of Irrigation Scheme: Vaalharts North Sone 5 Drainage System

Calibration

Gross releases into canals

Include data	
Observed /Actual releases	
Source 1	Canal releases
cub. m/a	31,350,000
Area (ha)	2,343

Supply from other sources

Include data	
Observed /Actual releases	
Source 2	none
cub. m/a	no data
Area (ha)	0

Main distribution network input data

Include data
% Network distribution losses
40.5
Network losses % tailwater
10.5
% Network losses return flow
55.5
% of Time canals dry
0

Sub Areas	Effective canal length (m)	Distance from River (m)	Height above River/drainage point (m)
sub area 1	5,600	490	8.0
sub area 2	3,600	490	8.0
sub area 3	3,600	490	8.0
sub area 4	3,600	490	8.0
sub area 5	3,600	490	8.0
Total length	20,000		

Sub Areas	K Selected from table
sub area 1	10
sub area 2	14
sub area 3	16
sub area 4	16
sub area 5	14

Typical value for soil between canal and drainage point

Soil class textural	Permiability(k) m/day
Silt Clay	0.06
Clay	0.12
Clay-loam	0.185
Loam	0.25
Sandy loam	0.61
Sandy	1.22

Irrigation application system input data

	Include data
	% Irrigation application losses
Accepted	27
Suggested	30.15

% of irrigated area irrigated with given system	Type of Irrigation system	Irrigation system efficiency (%) Accepted efficiency (%)	Suggested efficiency (%)	Application losses return flow factor	Distribution uniformity CU/EU (%) Accepted CU/EU	Suggested CU/EU
2	Drip	95	95	0.2	85	85
3	Micro	90	90	0.15	85	85
15	Sprinkler	75	75	0.1	73	73
10	Pivot	85	85	0.1	90	90
70	Flood	65	60	0.8	100	100
100	Weighted average	69.85	Suggested factor	0.59	94.2	Weighted average
			Accepted factor	0.59	Distibution uniformaty return flow factor	
					Suggested factor	0.015
					Accepted factor	0.015

Include data	
Total area irrigated (ha)	
2,343	
Irrigation days per year on average	
365	
Surface water return flow factor	
0.33	Default 0.33

Sub Areas	Wetted drainage Perimeter (m)	Distance from River (m)	Height above River/drainage point (m)	Total area irrigated (ha) Area
sub area 1	5,600	490	8.0	469
sub area 2	3,600	490	8.0	469
sun area 3	3,600	490	8.0	469
sun area 4	3,600	490	8.0	469
sun area 5	3,600	490	8.0	467
	8.54	Average wetted perimeter per ha		

Sub Areas	K Selected from table
sub area 1	10.000
sub area 2	14.000
sun area 3	16.000
sun area 4	16.000
sun area 5	14.000

Typical value for soil between irrigation field and drainage point

Soil class textural	Permiability(k) m/day
Silt Clay	0.060
Clay	0.120
Clay-loam	0.185
Loam	0.250
Sandy loam	0.610
Sandy	1.220

Leaching and over irrigation related data

Include data	
Leaching Factor	Over Irrigation factor
0	0
Combined factor	0

Include data
Leaching /over irr return flow factor
0

Observed Return Flow Data

Include data
Tail water flows cub. m/a
1.33

Include data
Surface return flows cub. m/a
no data

Include data
Seepage return flos cub. m/a
no data

Crop water use

TOTAL Consumptive Crop water use (cub.m/a) From SAPWAT
13,559,623

Sub Areas	Crop water use per sub area (cub.m/a)
sub area 1	2,713,099
sub area 2	2,713,099
sub area 3	2,713,099
sub area 4	2,713,099
sub area 5	2,707,227

Sheet B-10: Vaalharts North Canal Zone 5: Upper layer results

IRRIGATION RETURN FLOW MODEL OUTPUT DATA

Name of Irrigation Scheme: Vaalharts North Sone 5 Drainage System

Calibration

Gross releases into main canal

Source 1	**Canal releases**	
Compare for calibration purposes		
Observed /Actual releases		31,350,000
Total requirement calculated		31,218,195

Source 2	**none**	
Compare for calibration purposes		
Observed /Actual releases	no data	
Total requirement calculated		0

Total requirement	31,218,195
Network distribution losses	12,643,369

Main distribution network return flow

Seepage Return Flow			
Total potensial return flow	cub. m/a	7,017,070	Based on estimated fraction
Max. possible return flow	cub. m/a	6,488,033	Based on Darcy flow equation

	cub. m/a	% of total network losses
Seepage		
Return flow from network losses	2,270,811	18
(smallest of potensial and possible return flow)		

	cub. m/a	% of total network losses
Tail water return flow	1,327,554	
Total return flow from network losses	3,598,365	28

Return flow from irrigation fields

Total potensial return flow	cub. m/a	3,162,364	Based on estimated fraction
Max. possible return flow	cub. m/a	6,483,592	Based on Darcy flow equation

	cub. m/a	**% of Gross irr.**
Return flow from irr. Area	1,106,827	6
(smallest of potensial and possible return flow)		(network losses excluded)

Total return flow from irrigation scheme

Total return flow from scheme	**cub. m/a**	**% of gross releases**	Observed
Seepage	3,377,638	10.8	no data
Surface return flow	0	0.0	no data
Tail water	1,327,554	4.3	1.33
Total return flow from scheme	4,705,192	15.1	1

Sheet B-11: Vaalharts North Canal Zone 6: Upper layer input data

IRRIGATION RETURN FLOW MODEL INPUT DATA

Name of Irrigation Scheme: Vaalharts North Sone 6 Drainage System

Calibration

Gross releases into canals

Include data	
Observed /Actual releases	
Source 1	Canal releases
cub. m/a	79,630,000
Area (ha)	7,593

Supply from other sources

Include data	
Observed /Actual releases	
Source 2	none
cub. m/a	no data
Area (ha)	0

Main distribution network input data

Include data
% Network distribution losses
30
Network losses % tailwater
14.6
% Network losses return flow
52.92
% of Time canals dry
0

Sub Areas	Effective canal length (m)	Distance from River (m)	Height above River/drainage point (m)
sub area 1	17,200	640	8.0
sub area 2	10,000	640	8.0
sub area 3	10,000	640	8.0
sub area 4	10,000	640	8.0
sub area 5	20,000	640	8.0
Total length	67,200		

Sub Areas	K Selected from table
sub area 1	6
sub area 2	8
sub area 3	11
sub area 4	12
sub area 5	10

Typical value for soil between canal and drainage point

Soil class textural	Permiability(k) m/day
Silt Clay	0.06
Clay	0.12
Clay-loam	0.185
Loam	0.25
Sandy loam	0.61
Sandy	1.22

Irrigation application system input data

	Include data
	% Irrigation application losses
Accepted	27
Suggested	30.15

% of irrigated area irrigated with given system	Type of Irrigation system	Irrigation system efficiency (%) Accepted efficiency (%)	Suggested efficiency (%)	Application losses return flow factor	Distribution uniformity CU/EU (%) Accepted CU/EU	Suggested CU/EU
2	Drip	95	95	0.2	85	85
3	Micro	90	90	0.15	85	85
15	Sprinkler	75	75	0.1	73	73
10	Pivot	85	85	0.1	90	90
70	Flood	65	60	0.8	100	100
100	Weighted average	69.85	Suggested factor	0.59	94.2	Weighted average
			Accepted factor	0.59	Distibution uniformaty return flow factor	
					Suggested factor	0.015
					Accepted factor	0.015

Include data	
Total area irrigated (ha)	
7,593	
Irrigation days per year on average	
365	
Surface water return flow factor	
0.33	Default 0.33

Sub Areas	Wetted drainage Perimeter (m)	Distance from River (m)	Height above River/drainage point (m)	Total area irrigated (ha) Area
sub area 1	17,200	640	8.0	1,944
sub area 2	10,000	640	8.0	1,130
sun area 3	10,000	640	8.0	1,130
sun area 4	10,000	640	8.0	1,130
sun area 5	20,000	640	8.0	2,259
	8.85	Average wetted perimeter per ha		

Sub Areas	K Selected from table
sub area 1	6.000
sub area 2	8.000
sun area 3	11.000
sun area 4	12.000
sun area 5	10.000

Typical value for soil between irrigation field and drainage point

Soil class textural	Permiability(k) m/day
Silt Clay	0.060
Clay	0.120
Clay-loam	0.185
Loam	0.250
Sandy loam	0.610
Sandy	1.220

Leaching and over irrigation related data

Include data	
Leaching Factor	Over Irrigation factor
0	0
Combined factor	0

Include data
Leaching /over irr return flow factor
0

Observed Return Flow Data

Include data
Tail water flows cub. m/a
3.46

Include data
Surface return flows cub. m/a
no data

Include data
Seepage return flos cub. m/a
no data

Crop water use

TOTAL Consumptive Crop water use (cub.m/a) From SAPWAT
40,528,034

Sub Areas	Crop water use per sub area (cub.m/a)
sub area 1	10,373,247
sub area 2	6,030,957
sub area 3	6,030,957
sub area 4	6,030,957
sub area 5	12,061,916

Sheet B-12: Vaalharts North Canal Zone 6: Upper layer results

IRRIGATION RETURN FLOW MODEL OUTPUT DATA

Name of Irrigation Scheme: Vaalharts North Sone 6 Drainage System

Calibration

Gross releases into main canal

Source 1	Canal releases
Compare for calibration purposes	
Observed /Actual releases	79,630,000
Total requirement calculated	79,311,221

Source 2	none
Compare for calibration purposes	
Observed /Actual releases	no data
Total requirement calculated	0

Total requirement	79,311,221
Network distribution losses	23,793,366

Main distribution network return flow

Seepage Return Flow			
Total potensial return flow	cub. m/a	12,591,449	Based on estimated fraction
Max. possible return flow	cub. m/a	11,198,565	Based on Darcy flow equation

	cub. m/a	% of total network losses
Seepage Return flow from network losses (smallest of potensial and possible return flow)	3,919,498	16

	cub. m/a	% of total network losses
Tail water return flow	3,473,831	
Total return flow from network losses	7,393,329	31

Return flow from irrigation fields

Total potensial return flow	cub. m/a	9,451,915	Based on estimated fraction
Max. possible return flow	cub. m/a	11,190,900	Based on Darcy flow equation

	cub. m/a	% of Gross irr.
Return flow from irr. Area (smallest of potensial and possible return flow)	3,308,170	6 (network losses excluded)

Total return flow from irrigation scheme

Total return flow from scheme	cub. m/a	% of gross releases	Observed
Seepage	7,227,668	9.1	no data
Surface return flow	0	0.0	no data
Tail water	3,473,831	4.4	3.46
Total return flow from scheme	10,701,499	13.5	3

Sheet B-13: Vaalharts North Canal Zone 7: Upper layer input data

IRRIGATION RETURN FLOW MODEL INPUT DATA

Name of Irrigation Scheme: Taung Natural Drainage

Calibration

Gross releases into canals

Include data	
Observed /Actual releases	
Source 1	Canal releases
cub. m/a	50,660,000
Area (ha)	3,821

Supply from other sources

Include data	
Observed /Actual releases	
Source 2	none
cub. m/a	no data avaiable
Area (ha)	0

Main distribution network input data

Include data
% Network distribution losses
34
Network losses % tailwater
8.8
% Network losses return flow
60.2
% of Time canals dry
0

Sub Areas	Effective canal length (m)	Distance from River (m)	Height above River/drainage point (m)
sub area 1	5,000	1,275	20.0
sub area 2	6,000	3,000	13.0
sub area 3	6,000	2,000	18.0
sub area 4	3,000	2,390	20.0
sub area 5	2,000	2,000	16.0
Total length	22,000		

Sub Areas	K Selected from table
sub area 1	4
sub area 2	4
sub area 3	4
sub area 4	4
sub area 5	4

Typical value for soil between canal and drainage point

Soil class textural	Permiability(k) m/day
Silt Clay	0.06
Clay	0.12
Clay-loam	0.185
Loam	0.25
Sandy loam	0.61
Sandy	1.22

Irrigation application system input data

	Include data
	% Irrigation application losses
Accepted	27
Suggested	18.75

% of irrigated area irrigated with given system	Type of Irrigation system	Irrigation system efficiency (%) Accepted efficiency (%)	Suggested efficiency (%)	Application losses return flow factor	Distribution uniformity CU/EU (%) Accepted CU/EU	Suggested CU/EU
	Drip	95	95	0.2	85	85
	Micro	90	90	0.15	85	85
25	Sprinkler	75	75	0.1	73	73
70	Pivot	85	85	0.1	90	90
5	Flood	60	60	0.8	100	100
100	Weighted average	81.25	Suggested factor	0.14	86.25	Weighted average
			Accepted factor	0.59	Distibution uniformaty return flow factor	
					Suggested factor	0.034
					Accepted factor	0.015

Include data	
Total area irrigated (ha)	
3,820	
Irrigation days per year on average	
365	
Surface water return flow factor	
0.33	Default 0.33

Sub Areas	Wetted drainage Perimeter (m)	Distance from River (m)	Height above River/drainage point (m)	Total area irrigated (ha) Area
sub area 1	7,000	1,200	20.0	2,045
sub area 2	5,000	1,500	10.0	368
sun area 3	7,000	1,500	12.0	755
sun area 4	3,000	2,410	20.0	357
sun area 5	2,000	1,200	10.0	295
	6.28	Average wetted perimeter per ha		

Sub Areas	K Selected from table
sub area 1	4.000
sub area 2	4.000
sun area 3	4.000
sun area 4	4.000
sun area 5	4.000

Typical value for soil between irrigation field and drainage point

Soil class textural	Permiability(k) m/day
Silt Clay	0.060
Clay	0.120
Clay-loam	0.185
Loam	0.250
Sandy loam	0.610
Sandy	1.220

Leaching and over irrigation related data

Include data	
Leaching Factor	Over Irrigation factor
0	0
Combined factor	0

Include data
Leaching /over irr return flow factor
0

Observed Return Flow Data

Include data
Tail water flows cub. m/a
1.5

Include data
Surface return flows cub. m/a
no data

Include data
Seepage return flos cub. m/a
no data

Crop water use

TOTAL Consumptive Crop water use (cub.m/a) From SAPWAT
24,219,405

Sub Areas	Crop water use per sub area (cub.m/a)
sub area 1	12,964,999
sub area 2	2,336,878
sub area 3	4,785,927
sub area 4	2,262,098
sub area 5	1,869,503

Sheet B-14: Vaalharts North Canal Zone 7: Upper layer results

IRRIGATION RETURN FLOW MODEL OUTPUT DATA

Name of Irrigation Scheme: Taung Natural Drainage

Calibration

Gross releases into main canal

Source 1	Canal releases
Compare for calibration purposes	
Observed /Actual releases	50,660,000
Total requirement calculated	50,268,587

Source 2	none
Compare for calibration purposes	
Observed /Actual releases	no data avaiable
Total requirement calculated	0

Total requirement	
	50,268,587
Network distribution losses	
	17,091,319

Main distribution network return flow

Seepage Return Flow			
Total potensial return flow	cub. m/a	10,288,974	Based on estimated fraction
Max. possible return flow	cub. m/a	2,656,624	Based on Darcy flow equation

	cub. m/a	% of total network losses
Seepage		
Return flow from network losses	2,656,624	16
(smallest of potensial and possible return flow)		

	cub. m/a	% of total network losses
Tail water return flow	1,504,036	
Total return flow from network losses	4,160,660	24

Return flow from irrigation fields

Total potensial return flow	cub. m/a	5,648,430	Based on estimated fraction
Max. possible return flow	cub. m/a	2,922,379	Based on Darcy flow equation

	cub. m/a	% of Gross irr.
Return flow from irr. Area	0	0
(smallest of potensial and possible return flow)		(network losses excluded)

Total return flow from irrigation scheme

Total return flow from scheme	cub. m/a	% of gross releases	Observed
Seepage	2,656,624	5.3	no data
Surface return flow	899,597	1.8	no data
Tail water	1,504,036	3.0	1.5
Total return flow from scheme	5,060,257	10.1	2

Sheet B-15: Vaalharts West Canal Zone 8: Upper layer input data

IRRIGATION RETURN FLOW MODEL INPUT DATA

Name of Irrigation Scheme: Vaalharts West Canal Drainage System

Calibration

Gross releases into canals

Include data	
Observed /Actual releases	
Source 1	Canal releases
cub. m/a	51,210,000
Area (ha)	4,617

Supply from other sources

Include data	
Observed /Actual releases	
Source 2	none
cub. m/a	no data
Area (ha)	0

Main distribution network input data

Include data
% Network distribution losses
28.8
Network losses % tailwater
18.2
% Network losses return flow
52.2
% of Time canals dry
0

Sub Areas	Effective canal length (m)	Distance from River (m)	Height above River/drainage point (m)
sub area 1	2,500	570	8.0
sub area 2	2,500	570	8.0
sub area 3	10,000	570	8.0
sub area 4	6,000	570	8.0
sub area 5	11,000	570	8.0
Total length	32,000		

Sub Areas	K Selected from table
sub area 1	4
sub area 2	4
sub area 3	4
sub area 4	4
sub area 5	4

Typical value for soil between canal and drainage point

Soil class textural	Permiability(k) m/day
Silt Clay	0.06
Clay	0.12
Clay-loam	0.185
Loam	0.25
Sandy loam	0.61
Sandy	1.22

Irrigation application system input data

	Include data
	% Irrigation application losses
Accepted	27
Suggested	30.15

% of irrigated area irrigated with given system	Type of Irrigation system	Irrigation system efficiency (%) Accepted efficiency (%)	Suggested efficiency (%)	Application losses return flow factor	Distribution uniformity CU/EU (%) Accepted CU/EU	Suggested CU/EU
2	Drip	95	95	0.2	85	85
3	Micro	90	90	0.15	85	85
15	Sprinkler	75	75	0.1	73	73
10	Pivot	85	85	0.1	90	90
70	Flood	65	60	0.8	100	100
100	Weighted average	69.85	Suggested factor	0.59	94.2	Weighted average
			Accepted factor	0.59	Distibution uniformaty return flow factor	
					Suggested factor	0.015
					Accepted factor	0.015

Include data	
Total area irrigated (ha)	
4,617	
Irrigation days per year on average	
365	
Surface water return flow factor	
0.33	Default 0.33

Sub Areas	Wetted drainage Perimeter (m)	Distance from River (m)	Height above River/drainage point (m)	Total area irrigated (ha) Area
sub area 1	2,500	570	8.0	150
sub area 2	2,500	570	8.0	316
sun area 3	10,000	570	8.0	1,779
sun area 4	6,000	570	8.0	791
sun area 5	11,000	570	8.0	1,581
	6.93	Average wetted perimeter per ha		

Sub Areas	K Selected from table
sub area 1	4.000
sub area 2	4.000
sun area 3	4.000
sun area 4	4.000
sun area 5	4.000

Typical value for soil between irrigation field and drainage point

Soil class textural	Permiability(k) m/day
Silt Clay	0.060
Clay	0.120
Clay-loam	0.185
Loam	0.250
Sandy loam	0.610
Sandy	1.220

Leaching and over irrigation related data

Include data	
Leaching Factor	Over Irrigation factor
0	0
Combined factor	0

Include data
Leaching /over irr return flow factor
0

Observed Return Flow Data

Include data
Tail water flows cub. m/a
2.68

Include data
Surface return flows cub. m/a
no data

Include data
Seepage return flos cub. m/a
no data

Crop water use

TOTAL Consumptive Crop water use (cub.m/a) From SAPWAT
26,585,425

Sub Areas	Crop water use per sub area (cub.m/a)
sub area 1	864,937
sub area 2	1,820,920
sub area 3	10,242,672
sub area 4	4,552,299
sub area 5	9,104,598

Sheet B-16: Vaalharts West Canal Zone 8: Upper layer results

IRRIGATION RETURN FLOW MODEL OUTPUT DATA

Name of Irrigation Scheme: Vaalharts West Canal Drainage System

Calibration

Gross releases into main canal

Source 1	Canal releases	
Compare for calibration purposes		
Observed /Actual releases		51,210,000
Total requirement calculated		51,149,424

Source 2	none	
Compare for calibration purposes		
Observed /Actual releases	no data	
Total requirement calculated		0

Total requirement	51,149,424
Network distribution losses	14,731,034

Main distribution network return flow

Seepage Return Flow			
Total potensial return flow	cub. m/a	7,689,600	Based on estimated fraction
Max. possible return flow	cub. m/a	2,624,674	Based on Darcy flow equation

	cub. m/a	% of total network losses
Seepage Return flow from network losses	918,636	6
(smallest of potensial and possible return flow)		

Tail water return flow	2,681,048	
	cub. m/a	% of total network losses
Total return flow from network losses	3,599,684	24

Return flow from irrigation fields

Total potensial return flow	cub. m/a	6,200,231	Based on estimated fraction
Max. possible return flow	cub. m/a	2,622,877	Based on Darcy flow equation

	cub. m/a	% of Gross irr.
Return flow from irr. Area	918,007	3
(smallest of potensial and possible return flow)		(network losses excluded)

Total return flow from irrigation scheme

Total return flow from scheme	cub. m/a	% of gross releases	Observed
Seepage	1,836,643	3.6	no data
Surface return flow	1,180,527	2.3	no data
Tail water	2,681,048	5.2	2.68
Total return flow from scheme	5,698,218	11.1	3

Sheet B-17: Vaalharts North Canal Zone 1: Lower layer input data

IRRIGATION RETURN FLOW MODEL INPUT DATA

Name of Irrigation Scheme: Vaalharts North Sone 1 Natural Drainage
Calibration

Gross releases into canals

Include data	
Observed /Actual releases	
Source 1	Canal releases
cub. m/a	30,860,000
Area (ha)	1,893

Supply from other sources

Include data	
Observed /Actual releases	
Source 2	none
cub. m/a	no data avaiable
Area (ha)	0

Main distribution network input data

Include data
% Network distribution losses
37.1
Network losses % tailwater
0
% Network losses return flow
55.26
% of Time canals dry
0

Sub Areas	Effective canal length (m)	Distance from River (m)	Height above River/drainage point (m)
sub area 1	5,000	2,000	20.0
sub area 2	4,000	2,400	20.0
sub area 3			
sub area 4			
sub area 5			
Total length	9,000		

Sub Areas	K Selected from table
sub area 1	7
sub area 2	7
sub area 3	
sub area 4	
sub area 5	

Typical value for soil between canal and drainage point

Soil class textural	Permiability(k) m/day
Silt Clay	0.06
Clay	0.12
Clay-loam	0.185
Loam	0.25
Sandy loam	0.61
Sandy	1.22

Irrigation application system input data

	Include data
	% Irrigation application losses
Accepted	28
Suggested	30.15

% of irrigated area irrigated with given system	Type of Irrigation system	Irrigation system efficiency (%) Accepted efficiency (%)	Suggested efficiency (%)	Application losses return flow factor	Distribution uniformity CU/EU (%) Accepted CU/EU	Suggested CU/EU
2	Drip	95	95	0.2	85	85
3	Micro	90	90	0.15	85	85
15	Sprinkler	75	75	0.1	73	73
10	Pivot	85	85	0.1	90	90
70	Flood	65	60	0.8	100	100
100	Weighted average	69.85	Suggested factor	0.59	94.2	Weighted average
			Accepted factor	0.59		

Distibution uniformaty return flow factor	
Suggested factor	0.015
Accepted factor	0.015

Include data	
Total area irrigated (ha)	
1,893	
Irrigation days per year on average	
365	
Surface water return flow factor	
0.00	Default 0.33

Sub Areas	Wetted drainage Perimeter (m)	Distance from River (m)	Height above River/drainage point (m)	Total area irrigated (ha) Area
sub area 1	4,000	1,800	20.0	467
sub area 2	3,000	2,400	20.0	1,426
sun area 3				
sun area 4				
sun area 5				
	3.70	Average wetted perimeter per ha		

Sub Areas	K Selected from table
sub area 1	7.000
sub area 2	7.000
sun area 3	
sun area 4	
sun area 5	

Typical value for soil between irrigation field and drainage point

Soil class textural	Permiability(k) m/day
Silt Clay	0.060
Clay	0.120
Clay-loam	0.185
Loam	0.250
Sandy loam	0.610
Sandy	1.220

Leaching and over irrigation related data

Include data	
Leaching Factor	Over Irrigation factor
0	0
Combined factor	0

Include data
Leaching /over irr return flow factor
0

Observed Return Flow Data

Include data
Tail water flows cub. m/a
0

Include data
Surface return flows cub. m/a
no data

Include data
Seepage return flos cub. m/a
no data

Crop water use

TOTAL Consumptive Crop water use (cub.m/a) From SAPWAT
13,786,486

Sub Areas	Crop water use per sub area (cub.m/a)
sub area 1	3,403,979
sub area 2	10,382,507
sub area 3	
sub area 4	
sub area 5	

Sheet B-18: Vaalharts North Canal Zone 1: Lower layer results

IRRIGATION RETURN FLOW MODEL OUTPUT DATA

Name of Irrigation Scheme: Vaalharts North Sone 1 Natural Drainage Calibration

Gross releases into main canal

Source 1	Canal releases
Compare for calibration purposes	
Observed /Actual releases	30,860,000
Total requirement calculated	30,441,808

Source 2	none
Compare for calibration purposes	
Observed /Actual releases	no data avaiable
Total requirement calculated	0

Total requirement	30,441,808
Network distribution losses	11,293,911

Main distribution network return flow

Seepage Return Flow			
Total potensial return flow	cub. m/a	6,241,015	Based on estimated fraction
Max. possible return flow	cub. m/a	2,130,625	Based on Darcy flow equation

	cub. m/a	% of total network losses
Seepage Return flow from network losses (smallest of potensial and possible return flow)	2,130,625	19

	cub. m/a	% of total network losses
Tail water return flow	0	
Total return flow from network losses	2,130,625	19

Return flow from irrigation fields

Total potensial return flow	cub. m/a	3,370,030	Based on estimated fraction
Max. possible return flow	cub. m/a	1,774,306	Based on Darcy flow equation

	cub. m/a	% of Gross irr.
Return flow from irr. Area (smallest of potensial and possible return flow)	0	0 (network losses excluded)

Total return flow from irrigation scheme

Total return flow from scheme	cub. m/a	% of gross releases	Observed
Seepage	2,130,625	7.0	no data
Surface return flow	0	0.0	no data
Tail water	0	0.0	0
Total return flow from scheme	2,130,625	7.0	0

Sheet B-19: Vaalharts North Canal Zone 2: Lower layer input data

IRRIGATION RETURN FLOW MODEL INPUT DATA

Name of Irrigation Scheme: Vaalharts North Sone 2 Natural drainage
Calibration

Gross releases into canals

Include data	
Observed /Actual releases	
Source 1	Canal releases
cub. m/a	55,580,000
Area (ha)	5,589

Supply from other sources

Include data	
Observed /Actual releases	
Source 2	none
cub. m/a	no data avaiable
Area (ha)	0

Main distribution network input data

Include data
% Network distribution losses
32.3
Network losses % tailwater
0
% Network losses return flow
56.11
% of Time canals dry
0

Sub Areas	Effective canal length (m)	Distance from River (m)	Height above River/drainage point (m)
sub area 1	2,200	3,600	20.0
sub area 2	2,200	3,650	20.0
sub area 3	2,300	4,300	20.0
sub area 4	2,300	3,700	20.0
sub area 5			
Total length	9,000		

Sub Areas	K Selected from table
sub area 1	3
sub area 2	3
sub area 3	3
sub area 4	5
sub area 5	0

Typical value for soil between canal and drainage point

Soil class textural	Permiability(k) m/day
Silt Clay	0.06
Clay	0.12
Clay-loam	0.185
Loam	0.25
Sandy loam	0.61
Sandy	1.22

Irrigation application system input data

	Include data
	% Irrigation application losses
Accepted	27
Suggested	30.15

% of irrigated area irrigated with given system	Type of Irrigation system	Irrigation system efficiency (%) Accepted efficiency (%)	Suggested efficiency (%)	Application losses return flow factor	Distribution uniformity CU/EU (%) Accepted CU/EU	Suggested CU/EU
2	Drip	95	95	0.2	85	85
3	Micro	90	90	0.15	85	85
15	Sprinkler	75	75	0.1	73	73
10	Pivot	85	85	0.1	90	90
70	Flood	65	60	0.8	100	100
100	Weighted average	69.85	Suggested factor	0.59	94.2	Weighted average
			Accepted factor	0.59	Distibution uniformaty return flow factor	
					Suggested factor	0.015
					Accepted factor	0.015

Include data	
Total area irrigated (ha)	
5,589	
Irrigation days per year on average	
365	
Surface water return flow factor	
0.00	Default 0.33

Sub Areas	Wetted drainage Perimeter (m)	Distance from River (m)	Height above River/drainage point (m)	Total area irrigated (ha) Area
sub area 1	2,200	3,600	20.0	1,117
sub area 2	2,200	3,650	20.0	1,322
sun area 3	2,300	4,300	20.0	1,524
sun area 4	2,300	3,700	20.0	1,626
sun area 5				
	1.61	Average wetted perimeter per ha		

Sub Areas	K Selected from table
sub area 1	3.000
sub area 2	3.000
sun area 3	3.000
sun area 4	5.000
sun area 5	

Typical value for soil between irrigation field and drainage point

Soil class textural	Permiability(k) m/day
Silt Clay	0.060
Clay	0.120
Clay-loam	0.185
Loam	0.250
Sandy loam	0.610
Sandy	1.220

Leaching and over irrigation related data

Include data	
Leaching Factor	Over Irrigation factor
0	0
Combined factor	0

Include data
Leaching /over irr return flow factor
0

Observed Return Flow Data

Include data
Tail water flows cub. m/a
0

Include data
Surface return flows cub. m/a
no data

Include data
Seepage return flos cub. m/a
no data

Crop water use

TOTAL Consumptive Crop water use (cub.m/a) From SAPWAT
27,398,587

Sub Areas	Crop water use per sub area (cub.m/a)
sub area 1	5,478,726
sub area 2	6,475,308
sub area 3	7,471,891
sub area 4	7,972,662
sub area 5	

Sheet B-20: Vaalharts North Canal Zone 2: Lower layer results

IRRIGATION RETURN FLOW MODEL OUTPUT DATA

Name of Irrigation Scheme: Vaalharts North Sone 2 Natural drainage

Calibration

Gross releases into main canal

Source 1	Canal releases
Compare for calibration purposes	
Observed /Actual releases	55,580,000
Total requirement calculated	55,439,159

Source 2	none
Compare for calibration purposes	
Observed /Actual releases	no data avaiable
Total requirement calculated	0

Total requirement	55,439,159
Network distribution losses	17,906,849

Main distribution network return flow

Seepage Return Flow			
Total potensial return flow	cub. m/a	10,047,533	Based on estimated fraction
Max. possible return flow	cub. m/a	610,282	Based on Darcy flow equation

	cub. m/a	% of total network losses
Seepage Return flow from network losses (smallest of potensial and possible return flow)	0	0

	cub. m/a	% of total network losses
Tail water return flow	0	
Total return flow from network losses	0	0

Return flow from irrigation fields

Total potensial return flow	cub. m/a	6,389,876	Based on estimated fraction
Max. possible return flow	cub. m/a	609,865	Based on Darcy flow equation

	cub. m/a	% of Gross irr.
Return flow from irr. Area (smallest of potensial and possible return flow)	609,865	2 (network losses excluded)

Total return flow from irrigation scheme

Total return flow from scheme	cub. m/a	% of gross releases	Observed
Seepage	609,865	1.1	no data
Surface return flow	0	0.0	no data
Tail water	0	0.0	0
Total return flow from scheme	609,865	1.1	0

Sheet B-21: Vaalharts North Canal Zone 3: Lower layer input data

IRRIGATION RETURN FLOW MODEL INPUT DATA

Name of Irrigation Scheme: Vaalharts North Sone 3 Natural drainage
Calibration

Gross releases into canals

Include data	
Observed /Actual releases	
Source 1	Canal releases
cub. m/a	64,780,000
Area (ha)	5,600

Supply from other sources

Include data	
Observed /Actual releases	
Source 2	none
cub. m/a	no data avaiable
Area (ha)	0

Main distribution network input data

Include data
% Network distribution losses
32.5
Network losses % tailwater
0
% Network losses return flow
51.52
% of Time canals dry
0

Sub Areas	Effective canal length (m)	Distance from River (m)	Height above River/drainage point (m)
sub area 1	2,200	3,350	20.0
sub area 2	2,200	2,710	20.0
sub area 3	2,300	3,550	20.0
sub area 4			
sub area 5			
Total length	6,700		

Sub Areas	K Selected from table
sub area 1	6
sub area 2	6
sub area 3	7.5
sub area 4	
sub area 5	

Typical value for soil between canal and drainage point

Soil class textural	Permiability(k) m/day
Silt Clay	0.06
Clay	0.12
Clay-loam	0.185
Loam	0.25
Sandy loam	0.61
Sandy	1.22

Irrigation application system input data

	Include data
	% Irrigation application losses
Accepted	27
Suggested	30.15

% of irrigated area irrigated with given system	Type of Irrigation system	Irrigation system efficiency (%) Accepted efficiency (%)	Suggested efficiency (%)	Application losses return flow factor	Distribution uniformity CU/EU (%) Accepted CU/EU	Suggested CU/EU
2	Drip	95	95	0.2	85	85
3	Micro	90	90	0.15	85	85
15	Sprinkler	75	75	0.1	73	73
10	Pivot	85	85	0.1	90	90
70	Flood	65	60	0.8	100	100
100	Weighted average	69.85	Suggested factor	0.59	94.2	Weighted average
			Accepted factor	0.59	Distibution uniformaty return flow factor	
					Suggested factor	0.015
					Accepted factor	0.015

Include data	
Total area irrigated (ha)	
5,600	
Irrigation days per year on average	
365	
Surface water return flow factor	
0.00	Default 0.33

Sub Areas	Wetted drainage Perimeter (m)	Distance from River (m)	Height above River/drainage point (m)	Total area irrigated (ha) Area
sub area 1	2,200	3,350	20.0	1,637
sub area 2	2,200	2,710	20.0	1,809
sun area 3	2,300	3,550	20.0	2,154
sun area 4				
sun area 5				
	1.20	Average wetted perimeter per ha		

Sub Areas	K Selected from table
sub area 1	6.000
sub area 2	6.000
sun area 3	7.500
sun area 4	
sun area 5	

Typical value for soil between irrigation field and drainage point

Soil class textural	Permiability(k) m/day
Silt Clay	0.060
Clay	0.120
Clay-loam	0.185
Loam	0.250
Sandy loam	0.610
Sandy	1.220

Leaching and over irrigation related data

Include data	
Leaching Factor	Over Irrigation factor
0	0
Combined factor	0

Include data
Leaching /over irr return flow factor
0

Observed Return Flow Data

Include data
Tail water flows cub. m/a
0

Include data
Surface return flows cub. m/a
no data

Include data
Seepage return flos cub. m/a
no data

Crop water use

TOTAL Consumptive Crop water use (cub.m/a) From SAPWAT
31,836,818

Sub Areas	Crop water use per sub area (cub.m/a)
sub area 1	9,306,147
sub area 2	10,285,741
sub area 3	12,244,930
sub area 4	
sub area 5	

Sheet B-22: Vaalharts North Canal Zone 3: Lower layer results

IRRIGATION RETURN FLOW MODEL OUTPUT DATA

Name of Irrigation Scheme: Vaalharts North Sone 3 Natural drainage

Calibration

Gross releases into main canal

Source 1	Canal releases
Compare for calibration purposes	
Observed /Actual releases	64,780,000
Total requirement calculated	64,610,488

Source 2	none
Compare for calibration purposes	
Observed /Actual releases	no data avaiable
Total requirement calculated	0

Total requirement	64,610,488
Network distribution losses	20,998,409

Main distribution network return flow

Seepage Return Flow			
Total potensial return flow	cub. m/a	10,818,380	Based on estimated fraction
Max. possible return flow	cub. m/a	998,616	Based on Darcy flow equation

	cub. m/a	% of total network losses
Seepage Return flow from network losses (smallest of potensial and possible return flow)	998,616	5

	cub. m/a	% of total network losses
Tail water return flow	0	
Total return flow from network losses	998,616	5

Return flow from irrigation fields

Total potensial return flow	cub. m/a	7,424,957	Based on estimated fraction
Max. possible return flow	cub. m/a	997,932	Based on Darcy flow equation

	cub. m/a	% of Gross irr.
Return flow from irr. Area (smallest of potensial and possible return flow)	0	0 (network losses excluded)

Total return flow from irrigation scheme

Total return flow from scheme	cub. m/a	% of gross releases	Observed
Seepage	998,616	1.5	no data
Surface return flow	0	0.0	no data
Tail water	0	0.0	0
Total return flow from scheme	998,616	1.5	0

Sheet B-23: Vaalharts North Canal Zone 4: Lower layer input data

IRRIGATION RETURN FLOW MODEL INPUT DATA

Name of Irrigation Scheme: Vaalharts North Sone 4 Natural drainage
Calibration

Gross releases into canals

Include data	
Observed /Actual releases	
Source 1	Canal releases
cub. m/a	28,880,000
Area (ha)	2,143

Supply from other sources

Include data	
Observed /Actual releases	
Source 2	none
cub. m/a	no data avaiable
Area (ha)	0

Main distribution network input data

Include data
% Network distribution losses
41
Network losses % tailwater
0
% Network losses return flow
58
% of Time canals dry
0

Sub Areas	Effective canal length (m)	Distance from River (m)	Height above River/drainage point (m)
sub area 1	3,300	3,300	20.0
sub area 2			
sub area 3			
sub area 4			
sub area 5			
Total length	3,300		

Sub Areas	K Selected from table
sub area 1	8.5
sub area 2	
sub area 3	
sub area 4	
sub area 5	

Typical value for soil between canal and drainage point

Soil class textural	Permiability(k) m/day
Silt Clay	0.06
Clay	0.12
Clay-loam	0.185
Loam	0.25
Sandy loam	0.61
Sandy	1.22

Irrigation application system input data

	Include data
	% Irrigation application losses
Accepted	27
Suggested	30.15

% of irrigated area irrigated with given system	Type of Irrigation system	Irrigation system efficiency (%) Accepted efficiency (%)	Suggested efficiency (%)	Application losses return flow factor	Distribution uniformity CU/EU (%) Accepted CU/EU	Suggested CU/EU
2	Drip	95	95	0.2	85	85
3	Micro	90	90	0.15	85	85
15	Sprinkler	75	75	0.1	73	73
10	Pivot	85	85	0.1	90	90
70	Flood	65	60	0.8	100	100
100	Weighted average	69.85	Suggested factor	0.59	94.2	Weighted average
			Accepted factor	0.59	Distibution uniformaty return flow factor	
					Suggested factor	0.015
					Accepted factor	0.015

Include data	
Total area irrigated (ha)	
2,143	
Irrigation days per year on average	
365	
Surface water return flow factor	
0.00	Default 0.33

Sub Areas	Wetted drainage Perimeter (m)	Distance from River (m)	Height above River/drainage point (m)	Total area irrigated (ha) Area
sub area 1	3,300	3,300	20.0	2,143
sub area 2				
sun area 3				
sun area 4				
sun area 5				
	1.54	Average wetted perimeter per ha		

Sub Areas	K Selected from table
sub area 1	8.500
sub area 2	
sun area 3	
sun area 4	
sun area 5	

Typical value for soil between irrigation field and drainage point

Soil class textural	Permiability(k) m/day
Silt Clay	0.060
Clay	0.120
Clay-loam	0.185
Loam	0.250
Sandy loam	0.610
Sandy	1.220

Leaching and over irrigation related data

Include data	
Leaching Factor	Over Irrigation factor
0	0
Combined factor	0

Include data
Leaching /over irr return flow factor
0

Observed Return Flow Data

Include data
Tail water flows cub. m/a
0

Include data
Surface return flows cub. m/a
no data

Include data
Seepage return flos cub. m/a
no data

Crop water use

TOTAL Consumptive Crop water use (cub.m/a) From SAPWAT
12,298,018

Sub Areas	Crop water use per sub area (cub.m/a)
sub area 1	12,298,018
sub area 2	
sub area 3	
sub area 4	
sub area 5	

Sheet B-24: Vaalharts North Canal Zone 4: Lower layer results

IRRIGATION RETURN FLOW MODEL OUTPUT DATA

Name of Irrigation Scheme: Vaalharts North Sone 4 Natural drainage

Calibration

Gross releases into main canal

Source 1	Canal releases
Compare for calibration purposes	
Observed /Actual releases	28,880,000
Total requirement calculated	28,553,559

Total requirement	28,553,559
Network distribution losses	11,706,959

Source 2	none
Compare for calibration purposes	
Observed /Actual releases	no data avaiable
Total requirement calculated	0

Main distribution network return flow

Seepage Return Flow			
Total potensial return flow	cub. m/a	6,790,036	Based on estimated fraction
Max. possible return flow	cub. m/a	620,925	Based on Darcy flow equation

	cub. m/a	% of total network losses
Seepage Return flow from network losses (smallest of potensial and possible return flow)	0	0

	cub. m/a	% of total network losses
Tail water return flow	0	
Total return flow from network losses	0	0

Return flow from irrigation fields

Total potensial return flow	cub. m/a	2,868,134	Based on estimated fraction
Max. possible return flow	cub. m/a	620,500	Based on Darcy flow equation

	cub. m/a	% of Gross irr.
Return flow from irr. Area (smallest of potensial and possible return flow)	620,500	4 (network losses excluded)

Total return flow from irrigation scheme

Total return flow from scheme	cub. m/a	% of gross releases	Observed
Seepage	620,500	2.2	no data
Surface return flow	0	0.0	no data
Tail water	0	0.0	0
Total return flow from scheme	620,500	2.2	0

Sheet B-25: Vaalharts North Canal Zone 5: Lower layer input data

IRRIGATION RETURN FLOW MODEL INPUT DATA

Name of Irrigation Scheme: Vaalharts North Sone 5 Natural drainage

Calibration

Gross releases into canals

Include data	
Observed /Actual releases	
Source 1	Canal releases
cub. m/a	31,350,000
Area (ha)	2,343

Supply from other sources

Include data	
Observed /Actual releases	
Source 2	none
cub. m/a	no data avaiable
Area (ha)	0

Main distribution network input data

Include data
% Network distribution losses
40.5
Network losses % tailwater
0
% Network losses return flow
55.5
% of Time canals dry
0

Sub Areas	Effective canal length (m)	Distance from River (m)	Height above River/drainage point (m)
sub area 1	3,600	3,300	20.0
sub area 2			
sub area 3			
sub area 4			
sub area 5			
Total length	3,600		

Sub Areas	K Selected from table
sub area 1	15
sub area 2	
sub area 3	
sub area 4	
sub area 5	

Typical value for soil between canal and drainage point

Soil class textural	Permiability(k) m/day
Silt Clay	0.06
Clay	0.12
Clay-loam	0.185
Loam	0.25
Sandy loam	0.61
Sandy	1.22

Irrigation application system input data

	Include data
	% Irrigation application losses
Accepted	27
Suggested	30.15

% of irrigated area irrigated with given system	Type of Irrigation system	Irrigation system efficiency (%) Accepted efficiency (%)	Suggested efficiency (%)	Application losses return flow factor	Distribution uniformity CU/EU (%) Accepted CU/EU	Suggested CU/EU
2	Drip	95	95	0.2	85	85
3	Micro	90	90	0.15	85	85
15	Sprinkler	75	75	0.1	73	73
10	Pivot	85	85	0.1	90	90
70	Flood	65	60	0.8	100	100
100	Weighted average	69.85	Suggested factor	0.59	94.2	Weighted average
			Accepted factor	0.59	Distibution uniformaty return flow factor	
					Suggested factor	0.015
					Accepted factor	0.015

Include data	
Total area irrigated (ha)	
2,343	
Irrigation days per year on average	
365	
Surface water return flow factor	
0.00	Default 0.33

Sub Areas	Wetted drainage Perimeter (m)	Distance from River (m)	Height above River/drainage point (m)	Total area irrigated (ha) Area
sub area 1	3,600	3,300	20.0	2,343
sub area 2				
sun area 3				
sun area 4				
sun area 5				
	1.54	Average wetted perimeter per ha		

Sub Areas	K Selected from table
sub area 1	15.000
sub area 2	
sun area 3	
sun area 4	
sun area 5	

Typical value for soil between irrigation field and drainage point

Soil class textural	Permiability(k) m/day
Silt Clay	0.060
Clay	0.120
Clay-loam	0.185
Loam	0.250
Sandy loam	0.610
Sandy	1.220

Leaching and over irrigation related data

Include data	
Leaching Factor	Over Irrigation factor
0	0
Combined factor	0

Include data
Leaching /over irr return flow factor
0

Observed Return Flow Data

Include data
Tail water flows cub. m/a
0

Include data
Surface return flows cub. m/a
no data

Include data
Seepage return flos cub. m/a
no data

Crop water use

TOTAL Consumptive Crop water use (cub.m/a) From SAPWAT
13,559,624

Sub Areas	Crop water use per sub area (cub.m/a)
sub area 1	13,559,624
sub area 2	
sub area 3	
sub area 4	
sub area 5	

Sheet B-26: Vaalharts North Canal Zone 5: Lower layer results

IRRIGATION RETURN FLOW MODEL OUTPUT DATA

Name of Irrigation Scheme: Vaalharts North Sone 5 Natural drainage
Calibration

Gross releases into main canal

Source 1	Canal releases
Compare for calibration purposes	
Observed /Actual releases	31,350,000
Total requirement calculated	31,218,197

Source 2	none
Compare for calibration purposes	
Observed /Actual releases	no data avaiable
Total requirement calculated	0

Total requirement	
	31,218,197
Network distribution losses	
	12,643,370

Main distribution network return flow

Seepage Return Flow			
Total potensial return flow	cub. m/a	7,017,070	Based on estimated fraction
Max. possible return flow	cub. m/a	1,195,364	Based on Darcy flow equation

	cub. m/a	% of total network losses
Seepage Return flow from network losses (smallest of potensial and possible return flow)	1,195,364	9

	cub. m/a	% of total network losses
Tail water return flow	0	
Total return flow from network losses	1,195,364	9

Return flow from irrigation fields

Total potensial return flow	cub. m/a	3,162,364	Based on estimated fraction
Max. possible return flow	cub. m/a	1,194,545	Based on Darcy flow equation

	cub. m/a	% of Gross irr.
Return flow from irr. Area (smallest of potensial and possible return flow)	0	0 (network losses excluded)

Total return flow from irrigation scheme

Total return flow from scheme	cub. m/a	% of gross releases	Observed
Seepage	1,195,364	3.8	no data
Surface return flow	0	0.0	no data
Tail water	0	0.0	0
Total return flow from scheme	1,195,364	3.8	0

Sheet B-27: Vaalharts North Canal Zone 6: Lower layer input data

IRRIGATION RETURN FLOW MODEL INPUT DATA

Name of Irrigation Scheme: Vaalharts North Sone 6 Natural Drainage
Calibration

Gross releases into canals

Include data	
Observed /Actual releases	
Source 1	Canal releases
cub. m/a	79,630,000
Area (ha)	7,593

Supply from other sources

Include data	
Observed /Actual releases	
Source 2	none
cub. m/a	no data avaiable
Area (ha)	0

Main distribution network input data

Include data
% Network distribution losses
30
Network losses % tailwater
0
% Network losses return flow
52.92
% of Time canals dry
0

Sub Areas	Effective canal length (m)	Distance from River (m)	Height above River/drainage point (m)
sub area 1	2,200	2,950	20.0
sub area 2	2,200	4,000	20.0
sub area 3	2,200	4,000	20.0
sub area 4	3,000	3,300	20.0
sub area 5	2,700	3,650	20.0
Total length	12,300		

Sub Areas	K Selected from table
sub area 1	16
sub area 2	12
sub area 3	11
sub area 4	9
sub area 5	7

Typical value for soil between canal and drainage point

Soil class textural	Permiability(k) m/day
Silt Clay	0.06
Clay	0.12
Clay-loam	0.185
Loam	0.25
Sandy loam	0.61
Sandy	1.22

Irrigation application system input data

	Include data
	% Irrigation application losses
Accepted	27
Suggested	30.15

% of irrigated area irrigated with given system	Type of Irrigation system	Irrigation system efficiency (%) Accepted efficiency (%)	Suggested efficiency (%)	Application losses return flow factor	Distribution uniformity CU/EU (%) Accepted CU/EU	Suggested CU/EU
2	Drip	95	95	0.2	85	85
3	Micro	90	90	0.15	85	85
15	Sprinkler	75	75	0.1	73	73
10	Pivot	85	85	0.1	90	90
70	Flood	65	60	0.8	100	100
100	Weighted average	69.85	Suggested factor	0.59	94.2	Weighted average
			Accepted factor	0.59	Distibution uniformaty return flow factor	
					Suggested factor	0.015
					Accepted factor	0.015

Include data	
Total area irrigated (ha)	
7,593	
Irrigation days per year on average	
365	
Surface water return flow factor	
0.00	Default 0.33

Sub Areas	Wetted drainage Perimeter (m)	Distance from River (m)	Height above River/drainage point (m)	Total area irrigated (ha) Area
sub area 1	2,200	2,950	20.0	1,496
sub area 2	2,200	4,000	20.0	1,746
sun area 3	2,200	4,000	20.0	1,962
sun area 4	3,000	3,300	20.0	2,041
sun area 5	2,700	3,650	20.0	348
	1.62	Average wetted perimeter per ha		

Sub Areas	K Selected from table
sub area 1	16.000
sub area 2	12.000
sun area 3	11.000
sun area 4	9.000
sun area 5	7.000

Typical value for soil between irrigation field and drainage point

Soil class textural	Permiability(k) m/day
Silt Clay	0.060
Clay	0.120
Clay-loam	0.185
Loam	0.250
Sandy loam	0.610
Sandy	1.220

Leaching and over irrigation related data

Include data	
Leaching Factor	Over Irrigation factor
0	0
Combined factor	0

Include data
Leaching /over irr return flow factor
0

Observed Return Flow Data

Include data
Tail water flows cub. m/a
0

Include data
Surface return flows cub. m/a
no data

Include data
Seepage return flos cub. m/a
no data

Crop water use

TOTAL Consumptive Crop water use (cub.m/a) From SAPWAT
40,528,037

Sub Areas	Crop water use per sub area (cub.m/a)
sub area 1	7,988,603
sub area 2	9,320,037
sub area 3	10,473,946
sub area 4	10,893,548
sub area 5	1,851,903

Sheet B-28: Vaalharts North Canal Zone 6: Lower layer results

IRRIGATION RETURN FLOW MODEL OUTPUT DATA

Name of Irrigation Scheme: Vaalharts North Sone 6 Natural Drainage
Calibration

Gross releases into main canal

Source 1	Canal releases
Compare for calibration purposes	
Observed /Actual releases	79,630,000
Total requirement calculated	79,311,227

Source 2	none
Compare for calibration purposes	
Observed /Actual releases	no data avaiable
Total requirement calculated	0

Total requirement	
	79,311,227
Network distribution losses	
	23,793,368

Main distribution network return flow

Seepage Return Flow			
Total potensial return flow	cub. m/a	12,591,450	Based on estimated fraction
Max. possible return flow	cub. m/a	2,771,671	Based on Darcy flow equation

	cub. m/a	% of total network losses
Seepage		
Return flow from network losses	0	0
(smallest of potensial and possible return flow)		

	cub. m/a	% of total network losses
Tail water return flow	0	
Total return flow from network losses	0	0

Return flow from irrigation fields

Total potensial return flow	cub. m/a	9,451,915	Based on estimated fraction
Max. possible return flow	cub. m/a	2,769,774	Based on Darcy flow equation

	cub. m/a	% of Gross irr.
Return flow from irr. Area	2,769,774	5
(smallest of potensial and possible return flow)		(network losses excluded)

Total return flow from irrigation scheme

Total return flow from scheme	cub. m/a	% of gross releases	Observed
Seepage	2,769,774	3.5	no data
Surface return flow	0	0.0	no data
Tail water	0	0.0	0
Total return flow from scheme	2,769,774	3.5	0

Sheet B-29: Vaalharts West Canal Zone 8: Upper layer input data

IRRIGATION RETURN FLOW MODEL INPUT DATA

Name of Irrigation Scheme: Vaalharts West Canal Natural Drainage

Calibration

Gross releases into canals

Include data	
Observed /Actual releases	
Source 1	Canal releases
cub. m/a	51,210,000
Area (ha)	4,617

Supply from other sources

Include data	
Observed /Actual releases	
Source 2	none
cub. m/a	no data avaiable
Area (ha)	0

Main distribution network input data

Include data
% Network distribution losses
28.8
Network losses % tailwater
0
% Network losses return flow
52.2
% of Time canals dry
0

Sub Areas	Effective canal length (m)	Distance from River (m)	Height above River/drainage point (m)
sub area 1	2,500	2,000	16.0
sub area 2	2,500	2,000	17.0
sub area 3	5,000	2,000	17.0
sub area 4	3,500	2,000	20.0
sub area 5	4,500	2,000	20.0
Total length	18,000		

Sub Areas	K Selected from table
sub area 1	4
sub area 2	4
sub area 3	4
sub area 4	4
sub area 5	4

Typical value for soil between canal and drainage point

Soil class textural	Permiability(k) m/day
Silt Clay	0.06
Clay	0.12
Clay-loam	0.185
Loam	0.25
Sandy loam	0.61
Sandy	1.22

Irrigation application system input data

	Include data
	% Irrigation application losses
Accepted	28
Suggested	30.15

% of irrigated area irrigated with given system	Type of Irrigation system	Irrigation system efficiency (%) Accepted efficiency (%)	Suggested efficiency (%)	Application losses return flow factor	Distribution uniformity CU/EU (%) Accepted CU/EU	Suggested CU/EU
2	Drip	95	95	0.2	85	85
3	Micro	90	90	0.15	85	85
15	Sprinkler	75	75	0.1	73	73
10	Pivot	85	85	0.1	90	90
70	Flood	65	60	0.8	100	100
100	Weighted average	69.85	Suggested factor	0.59	94.2	Weighted average
			Accepted factor	0.59	Distibution uniformaty return flow factor	
					Suggested factor	0.015
					Accepted factor	0.015

Include data	
Total area irrigated (ha)	
4,617	
Irrigation days per year on average	
365	
Surface water return flow factor	
0.00	Default 0.33

Sub Areas	Wetted drainage Perimeter (m)	Distance from River (m)	Height above River/drainage point (m)	Total area irrigated (ha) Area
sub area 1	2,500	2,000	16.0	150
sub area 2	2,500	2,000	17.0	316
sun area 3	5,000	2,000	17.0	1,779
sun area 4	3,500	2,000	20.0	791
sun area 5	4,500	2,000	20.0	1,581
	3.90	Average wetted perimeter per ha		

Sub Areas	K Selected from table
sub area 1	4.000
sub area 2	4.000
sun area 3	4.000
sun area 4	4.000
sun area 5	4.000

Typical value for soil between irrigation field and drainage point

Soil class textural	Permiability(k) m/day
Silt Clay	0.060
Clay	0.120
Clay-loam	0.185
Loam	0.250
Sandy loam	0.610
Sandy	1.220

Leaching and over irrigation related data

Include data	
Leaching Factor	Over Irrigation factor
0	0
Combined factor	0

Include data
Leaching /over irr return flow factor
0

Observed Return Flow Data

Include data
Tail water flows cub. m/a
0

Include data
Surface return flows cub. m/a
no data

Include data
Seepage return flos cub. m/a
no data

Crop water use

TOTAL Consumptive Crop water use (cub.m/a) From SAPWAT
26,585,425

Sub Areas	Crop water use per sub area (cub.m/a)
sub area 1	864,937
sub area 2	1,820,920
sub area 3	10,242,672
sub area 4	4,552,299
sub area 5	9,104,598

Sheet B-30: Vaalharts West Canal Zone 8: Upper layer results

IRRIGATION RETURN FLOW MODEL OUTPUT DATA

Name of Irrigation Scheme: Vaalharts West Canal Natural Drainage

Calibration

Gross releases into main canal

Source 1	Canal releases
Compare for calibration purposes	
Observed /Actual releases	51,210,000
Total requirement calculated	51,859,833

Source 2	none
Compare for calibration purposes	
Observed /Actual releases	no data avaiable
Total requirement calculated	0

Total requirement	
	51,859,833
Network distribution losses	
	14,935,632

Main distribution network return flow

Seepage Return Flow			
Total potensial return flow	cub. m/a	7,796,400	Based on estimated fraction
Max. possible return flow	cub. m/a	2,194,239	Based on Darcy flow equation

	cub. m/a	% of total network losses
Seepage		
Return flow from network losses	2,194,239	15
(smallest of potensial and possible return flow)		

	cub. m/a	% of total network losses
Tail water return flow	0	
Total return flow from network losses	2,194,239	15

Return flow from irrigation fields

Total potensial return flow	cub. m/a	6,498,659	Based on estimated fraction
Max. possible return flow	cub. m/a	2,192,738	Based on Darcy flow equation

	cub. m/a	% of Gross irr.
Return flow from irr. Area	0	0
(smallest of potensial and possible return flow)		(network losses excluded)

Total return flow from irrigation scheme

Total return flow from scheme	cub. m/a	% of gross releases	Observed
Seepage	2,194,239	4.2	no data
Surface return flow	0	0.0	no data
Tail water	0	0.0	0
Total return flow from scheme	2,194,239	4.2	0

Sheet B-31: Klerksdorp IB: From Schoonspruit u/s of dam: Input data

IRRIGATION RETURN FLOW MODEL INPUT DATA

Name of Irrigation Scheme: Klerksdorp IB - irrigation from Schoonspruit u/s of dam

Scenario description Current System

Gross releases into canals

Include data	
Observed /Actual releases	
Source 1	
cub. m/a	
Area (ha)	

Supply from other sources

Include data	
Observed /Actual releases	
Source 2	JN dam basin
cub. m/a	3097318
Area (ha)	500

Main distribution network input data

Include data
% Network distribution losses
0
Network losses % tailwater
0
% Network losses return flow
0
% of Time canals dry
0

Sub Areas	Effective canal length (m)	Distance from River (m)	Height above River/drainage point (m)
sub area 1	0	0	0.0
sub area 2	0	0	0.0
sub area 3	0	0	0.0
sub area 4	0	0	0.0
sub area 5	0	0	0.0
Total length	0		

Sub Areas	K Selected from table
sub area 1	0.43
sub area 2	0.43
sub area 3	
sub area 4	
sub area 5	

Typical value for soil between canal and drainage point

Soil class textural	Permiability(k) m/day
Silt Clay	0.06
Clay	0.12
Clay-loam	0.185
Loam	0.25
Sandy loam	0.61
Sandy	1.22

Irrigation application system input data

	Include data
	% Irrigation application losses
Accepted	19.85
Suggested	19.85

% of irrigated area irrigated with given system	Type of Irrigation system	Irrigation system efficiency (%) Accepted efficiency (%)	Suggested efficiency (%)	Application losses return flow factor	Distribution uniformity CU/EU (%) Accepted CU/EU	Suggested CU/EU
7	Drip	95	95	0.2	85	85
7	Micro	90	90	0.15	85	85
39	Sprinkler	75	75	0.1	73	73
39	Pivot	85	85	0.1	90	90
8	Flood	60	60	0.8	100	100
100	Weighted average	80.15	Suggested factor	0.17	83.47	Weighted average
			Accepted factor	0.17	Distibution uniformaty return flow factor	
					Suggested factor	0.041
					Accepted factor	0.041

Include data	
Total area irrigated (ha)	
500	
Irrigation days per year on average	
365	
Surface water return flow factor	
0.40	Default 0.33

Sub Areas	Wetted drainage Perimeter (m)	Distance from River (m)	Height above River/drainage point (m)	Total area irrigated (ha) Area
sub area 1	4,100	2,150	28	394
sub area 2	1,950	950	11	106
sun area 3	0	0		
sun area 4	0	0		
sun area 5	0	0		
	12.10	Average wetted perimeter per ha		

Sub Areas	K Selected from table
sub area 1	0.430
sub area 2	0.430
sun area 3	
sun area 4	
sun area 5	

Typical value for soil between irrigation field and drainage point

Soil class textural	Permiability(k) m/day
Silt Clay	0.060
Clay	0.120
Clay-loam	0.185
Loam	0.250
Sandy loam	0.610
Sandy	1.220

Leaching and over irrigation related data

Include data	
Leaching Factor	Over Irrigation factor
0	0
Combined factor	0

Include data
Leaching /over irr return flow factor
0.3

Observed Return Flow Data

Include data
Tail water flows cub. m/a
no data

Include data
Surface return flows cub. m/a
no data

Include data
Seepage return flos cub. m/a
no data

Crop water use

TOTAL Consumptive Crop water use (cub.m/a) From SAPWAT
2,482,500

Sub Areas	Crop water use per sub area (cub.m/a)
sub area 1	1,956,210
sub area 2	526,290
sub area 3	
sub area 4	
sub area 5	

Sheet B-32: Klerksdorp IB: From Schoonspruit u/s of dam: Results

IRRIGATION RETURN FLOW MODEL OUTPUT DATA

Name of Irrigation Scheme:	Klerksdorp IB - irrigation from Schoonspruit u/s of dam
Scenario Description	Current System
Gross releases into main canal	

Source 1	**0**
Compare for calibration purposes	
Observed /Actual releases	0
Total requirement calculated	0

Source 2	**JN dam basin**
Compare for calibration purposes	
Observed /Actual releases	3,097,318
Total requirement calculated	3,097,318

Total requirement	0
Network distribution losses	0

Main distribution network return flow

Seepage Return Flow			
Total potensial return flow	cub. m/a	0	Based on estimated fraction
Max. possible return flow	cub. m/a	0	Based on Darcy flow equation

	cub. m/a	% of total network losses
Seepage		
Return flow from network losses	0	#DIV/0!
(smallest of potensial and possible return flow)		

	cub. m/a	% of total network losses
Tail water return flow	0	
Total return flow from network losses	0	#DIV/0!

Return flow from irrigation fields

Total potensial return flow	cub. m/a	206,301	Based on estimated fraction
Max. possible return flow	cub. m/a	136,816	Based on Darcy flow equation

	cub. m/a	**% of Gross irr.**
Return flow from irr. Area	136,816	4
(smallest of potensial and possible return flow)		(network losses excluded)

Total return flow from irrigation scheme

Total return flow from scheme	**cub. m/a**	**% of gross releases**	Observed
Seepage	136,816	4.4	no data
Surface return flow	27,794	0.9	no data
Tail water	0	0.0	no data
Total return flow from scheme	164,610	5.3	0

Sheet B-33: Klerksdorp IB: From Johan Neser dam: Input data

IRRIGATION RETURN FLOW MODEL INPUT DATA

Name of Irrigation Scheme:	Klerksdorp IB - abstractions directly from JN dam basin
Scenario description	Current System

Gross releases into canals

Include data	
Observed /Actual releases	
Source 1	canal releases
cub. m/a	
Area (ha)	

Supply from other sources

Include data	
Observed /Actual releases	
Source 2	
cub. m/a	935390
Area (ha)	151

Main distribution network input data

Include data
% Network distribution losses
Network losses % tailwater
% Network losses return flow
% of Time canals dry

Sub Areas	Effective canal length (m)	Distance from River (m)	Height above River/drainage point (m)
sub area 1			
sub area 2			
sub area 3			
sub area 4			
sub area 5			
Total length	0		

Sub Areas	K Selected from table
sub area 1	0.43
sub area 2	0.43
sub area 3	
sub area 4	
sub area 5	

Typical value for soil between canal and drainage point

Soil class textural	Permiability(k) m/day
Silt Clay	0.06
Clay	0.12
Clay-loam	0.185
Loam	0.25
Sandy loam	0.61
Sandy	1.22

Irrigation application system input data

	Include data
	% Irrigation application losses
Accepted	19.85
Suggested	19.85

% of irrigated area irrigated with given system	Type of Irrigation system	Irrigation system efficiency (%) Accepted efficiency (%)	Suggested efficiency (%)	Application losses return flow factor	Distribution uniformity CU/EU (%) Accepted CU/EU	Suggested CU/EU
7	Drip	95	95	0.2	85	85
7	Micro	90	90	0.15	85	85
39	Sprinkler	75	75	0.1	73	73
39	Pivot	85	85	0.1	90	90
8	Flood	60	60	0.8	100	100
100	Weighted average	80.15	Suggested factor	0.17	83.47	Weighted average
			Accepted factor	0.17	Distibution uniformaty return flow factor	
					Suggested factor	0.041
					Accepted factor	0.041

Include data	
Total area irrigated (ha)	
151	
Irrigation days per year on average	
365	
Surface water return flow factor	
0.40	Default 0.33

Sub Areas	Wetted drainage Perimeter (m)	Distance from River (m)	Height above River/drainage point (m)	Total area irrigated (ha) Area
sub area 1	2,200	750	6	113
sub area 2	1,400	500	7	38
sun area 3				
sun area 4				
sun area 5				
	23.84	Average wetted perimeter per ha		

Sub Areas	K Selected from table
sub area 1	0.430
sub area 2	0.430
sun area 3	
sun area 4	
sun area 5	

Typical value for soil between irrigation field and drainage point

Soil class textural	Permiability(k) m/day
Silt Clay	0.060
Clay	0.120
Clay-loam	0.185
Loam	0.250
Sandy loam	0.610
Sandy	1.220

Leaching and over irrigation related data

Include data	
Leaching Factor	Over Irrigation factor
0	0
Combined factor	0

Include data
Leaching /over irr return flow factor
0.3

Observed Return Flow Data

Include data
Tail water flows
cub. m/a
no data

Include data
Surface return flows
cub. m/a
no data

Include data
Seepage return flos
cub. m/a
no data

Crop water use

TOTAL Consumptive Crop water use (cub.m/a) From SAPWAT
749,715

Sub Areas	Crop water use per sub area (cub.m/a)
sub area 1	561,045
sub area 2	188,670
sub area 3	
sub area 4	
sub area 5	

Sheet B-34: Klerksdorp IB: From Johan Neser dam: Results

IRRIGATION RETURN FLOW MODEL OUTPUT DATA

Name of Irrigation Scheme:	Klerksdorp IB - abstractions directly from JN dam basin
Scenario Description	Current System
Gross releases into main canal	

Source 1	**canal releases**	
Compare for calibration purposes		
Observed /Actual releases		0
Total requirement calculated		0
Source 2		**0**
Compare for calibration purposes		
Observed /Actual releases		935,390
Total requirement calculated		935,390

Total requirement	0
Network distribution losses	0

Main distribution network return flow

Seepage Return Flow			
Total potensial return flow	cub. m/a	0	Based on estimated fraction
Max. possible return flow	cub. m/a	0	Based on Darcy flow equation

	cub. m/a	% of total network losses
Seepage		
Return flow from network losses	0	#DIV/0!
(smallest of potensial and possible return flow)		

	cub. m/a	% of total network losses
Tail water return flow	0	
Total return flow from network losses	0	#DIV/0!

Return flow from irrigation fields

Total potensial return flow	cub. m/a	62,303	Based on estimated fraction
Max. possible return flow	cub. m/a	19,054	Based on Darcy flow equation

	cub. m/a	% of Gross irr.
Return flow from irr. Area	19,054	2
(smallest of potensial and possible return flow)		(network losses excluded)

Total return flow from irrigation scheme

Total return flow from scheme	**cub. m/a**	**% of gross releases**	Observed
Seepage	19,054	2.0	no data
Surface return flow	17,300	1.8	no data
Tail water	0	0.0	no data
Total return flow from scheme	36,353	3.9	0

Sheet B-35: Klerksdorp IB: From Schoonspruit d/s of dam: Input data

IRRIGATION RETURN FLOW MODEL INPUT DATA

Name of Irrigation Scheme:	Klerksdorp IB - abstractions from Schoonspruit d/s of JN
Scenario description	Current System

Gross releases into canals

Include data	
Observed /Actual releases	
Source 1	canal releases
cub. m/a	
Area (ha)	

Supply from other sources

Include data	
Observed /Actual releases	
Source 2	
cub. m/a	142971
Area (ha)	22

Main distribution network input data

Include data
% Network distribution losses
Network losses % tailwater
% Network losses return flow
% of Time canals dry

Sub Areas	Effective canal length (m)	Distance from River (m)	Height above River/drainage point (m)
sub area 1			
sub area 2			
sub area 3			
sub area 4			
sub area 5			
Total length	0		

Sub Areas	K Selected from table
sub area 1	
sub area 2	
sub area 3	
sub area 4	
sub area 5	

Typical value for soil between canal and drainage point

Soil class textural	Permiability(k) m/day
Silt Clay	0.06
Clay	0.12
Clay-loam	0.185
Loam	0.25
Sandy loam	0.61
Sandy	1.22

Irrigation application system input data

	Include data
	% Irrigation application losses
Accepted	23.6
Suggested	23.6

% of irrigated area irrigated with given system	Type of Irrigation system	Irrigation system efficiency (%) Accepted efficiency (%)	Suggested efficiency (%)	Application losses return flow factor	Distribution uniformity CU/EU (%) Accepted CU/EU	Suggested CU/EU
10	Drip	95	95	0.2	85	85
0	Micro	90	90	0.15	85	85
71	Sprinkler	75	75	0.1	73	73
9	Pivot	85	85	0.1	90	90
10	Flood	60	60	0.8	100	100
100	Weighted average	76.4	Suggested factor	0.18	78.43	Weighted average
			Accepted factor	0.18	Distibution uniformaty return flow factor	
					Suggested factor	0.054
					Accepted factor	0.054

Include data	
Total area irrigated (ha)	
22	
Irrigation days per year on average	
365	
Surface water return flow factor	
0.40	Default 0.33

Sub Areas	Wetted drainage Perimeter (m)	Distance from River (m)	Height above River/drainage point (m)	Total area irrigated (ha) Area
sub area 1	1,550	425	4	22
sub area 2				
sun area 3				
sun area 4				
sun area 5				
	70.45	Average wetted perimeter per ha		

Sub Areas	K Selected from table
sub area 1	0.430
sub area 2	0.430
sun area 3	
sun area 4	
sun area 5	

Typical value for soil between irrigation field and drainage point

Soil class textural	Permiability(k) m/day
Silt Clay	0.060
Clay	0.120
Clay-loam	0.185
Loam	0.250
Sandy loam	0.610
Sandy	1.220

Leaching and over irrigation related data

Include data	
Leaching Factor	Over Irrigation factor
0	0
Combined factor	0

Include data
Leaching /over irr return flow factor
0.3

Observed Return Flow Data

Include data
Tail water flows
cub. m/a
no data

Include data
Surface return flows
cub. m/a
no data

Include data
Seepage return flos
cub. m/a
no data

Crop water use

TOTAL Consumptive Crop water use (cub.m/a) From SAPWAT
109,230

Sub Areas	Crop water use per sub area (cub.m/a)
sub area 1	109,230
sub area 2	
sub area 3	
sub area 4	
sub area 5	

Sheet B-36: Klerksdorp IB: From Schoonspruit d/s of dam: Results

IRRIGATION RETURN FLOW MODEL OUTPUT DATA

Name of Irrigation Scheme:	Klerksdorp IB - abstractions from Schoonspruit d/s of JN
Scenario Description	Current System
Gross releases into main canal	

Source 1	canal releases	
Compare for calibration purposes		
Observed /Actual releases		0
Total requirement calculated		0

Total requirement	0
Network distribution losses	0

Source 2		0
Compare for calibration purposes		
Observed /Actual releases		142,971
Total requirement calculated		142,971

Main distribution network return flow

Seepage Return Flow			
Total potensial return flow	cub. m/a	0	Based on estimated fraction
Max. possible return flow	cub. m/a	0	Based on Darcy flow equation

Seepage	cub. m/a	**% of total network losses**
Return flow from network losses	0	#DIV/0!
(smallest of potensial and possible return flow)		

Tail water return flow	0	
	cub. m/a	**% of total network losses**
Total return flow from network losses	0	#DIV/0!

Return flow from irrigation fields

Total potensial return flow	cub. m/a	11,972	Based on estimated fraction
Max. possible return flow	cub. m/a	4,579	Based on Darcy flow equation

	cub. m/a	**% of Gross irr.**
Return flow from irr. Area	4,579	3
(smallest of potensial and possible return flow)		(network losses excluded)

Total return flow from irrigation scheme

Total return flow from scheme	**cub. m/a**	**% of gross releases**	Observed
Seepage	4,579	3.2	no data
Surface return flow	2,957	2.1	no data
Tail water	0	0.0	no data
Total return flow from scheme	7,536	5.3	0

Sheet B-37: Klerksdorp IB: Abstractions from pipeline from dam: Input data

IRRIGATION RETURN FLOW MODEL INPUT DATA

Name of Irrigation Scheme:	Klerksdorp IB - abstractions via pipeline frm JN dam
Scenario description	Current System

Gross releases into canals

Include data	
Observed /Actual releases	
Source 1	canal releases
cub. m/a	
Area (ha)	

Supply from other sources

Include data	
Observed /Actual releases	
Source 2	
cub. m/a	272945
Area (ha)	42

Main distribution network input data

Include data
% Network distribution losses
Network losses % tailwater
% Network losses return flow
% of Time canals dry

Sub Areas	Effective canal length (m)	Distance from River (m)	Height above River/drainage point (m)
sub area 1			
sub area 2			
sub area 3			
sub area 4			
sub area 5			
Total length	0		

Sub Areas	K Selected from table
sub area 1	
sub area 2	
sub area 3	
sub area 4	
sub area 5	

Typical value for soil between canal and drainage point

Soil class textural	Permiability(k) m/day
Silt Clay	0.06
Clay	0.12
Clay-loam	0.185
Loam	0.25
Sandy loam	0.61
Sandy	1.22

Irrigation application system input data

	Include data
	% Irrigation application losses
Accepted	23.6
Suggested	23.6

% of irrigated area irrigated with given system	Type of Irrigation system	Irrigation system efficiency (%) Accepted efficiency (%)	Suggested efficiency (%)	Application losses return flow factor	Distribution uniformity CU/EU (%) Accepted CU/EU	Suggested CU/EU
10	Drip	95	95	0.2	85	85
0	Micro	90	90	0.15	85	85
71	Sprinkler	75	75	0.1	73	73
9	Pivot	85	85	0.1	90	90
10	Flood	60	60	0.8	100	100
100	Weighted average	76.4	Suggested factor	0.18	78.43	Weighted average
			Accepted factor	0.18		

Distibution uniformaty return flow factor	
Suggested factor	0.054
Accepted factor	0.054

Include data	
Total area irrigated (ha)	
42	
Irrigation days per year on average	
365	
Surface water return flow factor	
0.40	Default 0.33

Sub Areas	Wetted drainage Perimeter (m)	Distance from River (m)	Height above River/drainage point (m)	Total area irrigated (ha) Area
sub area 1	1,200	300	3	14
sub area 2	1,000	700	2	28
sun area 3				
sun area 4				
sun area 5				
	52.38	Average wetted perimeter per ha		

Sub Areas	K Selected from table
sub area 1	0.430
sub area 2	0.430
sun area 3	
sun area 4	
sun area 5	

Typical value for soil between irrigation field and drainage point

Soil class textural	Permiability(k) m/day
Silt Clay	0.060
Clay	0.120
Clay-loam	0.185
Loam	0.250
Sandy loam	0.610
Sandy	1.220

Leaching and over irrigation related data

Include data	
Leaching Factor	Over Irrigation factor
0	0
Combined factor	0

Include data
Leaching /over irr return flow factor
0.3

Observed Return Flow Data

Include data
Tail water flows cub. m/a
no data

Include data
Surface return flows cub. m/a
no data

Include data
Seepage return flos cub. m/a
no data

Crop water use

TOTAL Consumptive Crop water use (cub.m/a) From SAPWAT
208,530

Sub Areas	Crop water use per sub area (cub.m/a)
sub area 1	69,510
sub area 2	139,020
sub area 3	
sub area 4	
sub area 5	

Sheet B-38: Klerksdorp IB: Abstractions from pipeline from dam: Results

IRRIGATION RETURN FLOW MODEL OUTPUT DATA

Name of Irrigation Scheme:	Klerksdorp IB - abstractions via pipeline frm JN dam
Scenario Description	Current System

Gross releases into main canal

Source 1	canal releases
Compare for calibration purposes	
Observed /Actual releases	0
Total requirement calculated	0

Source 2	0
Compare for calibration purposes	
Observed /Actual releases	272,945
Total requirement calculated	272,945

Total requirement
0
Network distribution losses
0

Main distribution network return flow

Seepage Return Flow			
Total potensial return flow	cub. m/a	0	Based on estimated fraction
Max. possible return flow	cub. m/a	0	Based on Darcy flow equation

	cub. m/a	% of total network losses
Seepage Return flow from network losses (smallest of potensial and possible return flow)	0	#DIV/0!

	cub. m/a	% of total network losses
Tail water return flow	0	
Total return flow from network losses	0	#DIV/0!

Return flow from irrigation fields

Total potensial return flow	cub. m/a	22,855	Based on estimated fraction
Max. possible return flow	cub. m/a	3,274	Based on Darcy flow equation

	cub. m/a	% of Gross irr.
Return flow from irr. Area (smallest of potensial and possible return flow)	3,274	1 (network losses excluded)

Total return flow from irrigation scheme

Total return flow from scheme	cub. m/a	% of gross releases	Observed
Seepage	3,274	1.2	no data
Surface return flow	7,833	2.9	no data
Tail water	0	0.0	no data
Total return flow from scheme	11,106	4.1	0

Sheet B-39: Klerksdorp IB: Abstractions from canal from dam: Input data

IRRIGATION RETURN FLOW MODEL INPUT DATA

Name of Irrigation Scheme: Klerksdorp IB - abstractions via canal from JN dam

Scenario description Current System

Gross releases into canals

Include data	
Observed /Actual releases	
Source 1	canal releases
cub. m/a	422415
Area (ha)	65

Supply from other sources

Include data	
Observed /Actual releases	
Source 2	
cub. m/a	
Area (ha)	

Main distribution network input data

Include data
% Network distribution losses
20
Network losses % tailwater
2.5
% Network losses return flow
10
% of Time canals dry
2.5

Sub Areas	Effective canal length (m)	Distance from River (m)	Height above River/drainage point (m)
sub area 1	3,000	750	5.0
sub area 2	1,100	1,000	7.0
sub area 3			
sub area 4			
sub area 5			
Total length	4,100		

Sub Areas	K Selected from table
sub area 1	0.43
sub area 2	0.43
sub area 3	
sub area 4	
sub area 5	

Typical value for soil between canal and drainage point

Soil class textural	Permiability(k) m/day
Silt Clay	0.06
Clay	0.12
Clay-loam	0.185
Loam	0.25
Sandy loam	0.61
Sandy	1.22

Irrigation application system input data

	Include data
	% Irrigation application losses
Accepted	16
Suggested	23.6

% of irrigated area irrigated with given system	Type of Irrigation system	Irrigation system efficiency (%) Accepted efficiency (%)	Suggested efficiency (%)	Application losses return flow factor	Distribution uniformity CU/EU (%) Accepted CU/EU	Suggested CU/EU
10	Drip	95	95	0.2	85	85
0	Micro	90	90	0.15	85	85
71	Sprinkler	75	75	0.1	73	73
9	Pivot	85	85	0.1	90	90
10	Flood	60	60	0.8	100	100
100	Weighted average	76.4	Suggested factor	0.18	78.43	Weighted average
			Accepted factor	0.18	Distibution uniformaty return flow factor	
					Suggested factor	0.054
					Accepted factor	0.054

Include data	
Total area irrigated (ha)	
65	
Irrigation days per year on average	
365	
Surface water return flow factor	
0.33	Default 0.33

Sub Areas	Wetted drainage Perimeter (m)	Distance from River (m)	Height above River/drainage point (m)	Total area irrigated (ha) Area
sub area 1	1,500	725	4	36
sub area 2	1,050	800	6	29
sun area 3				
sun area 4				
sun area 5				
	39.23	Average wetted perimeter per ha		

Sub Areas	K Selected from table
sub area 1	0.430
sub area 2	0.430
sun area 3	
sun area 4	
sun area 5	

Typical value for soil between irrigation field and drainage point

Soil class textural	Permiability(k) m/day
Silt Clay	0.060
Clay	0.120
Clay-loam	0.185
Loam	0.250
Sandy loam	0.610
Sandy	1.220

Leaching and over irrigation related data

Include data	
Leaching Factor	Over Irrigation factor
0	0
Combined factor	0

Include data
Leaching /over irr return flow factor
0.3

Observed Return Flow Data

Include data
Tail water flows cub. m/a
no data

Include data
Surface return flows cub. m/a
no data

Include data
Seepage return flos cub. m/a
no data

Crop water use

TOTAL Consumptive Crop water use (cub.m/a) From SAPWAT
322,725

Sub Areas	Crop water use per sub area (cub.m/a)
sub area 1	178,740
sub area 2	143,985
sub area 3	
sub area 4	
sub area 5	

Sheet B-40: Klerksdorp IB: Abstractions from canal from dam: Results

IRRIGATION RETURN FLOW MODEL OUTPUT DATA

Name of Irrigation Scheme:	Klerksdorp IB - abstractions via canal from JN dam
Scenario Description	Current System
Gross releases into main canal	

Source 1	canal releases
Compare for calibration purposes	
Observed /Actual releases	422,415
Total requirement calculated	480,246

Source 2	0
Compare for calibration purposes	
Observed /Actual releases	0
Total requirement calculated	0

Total requirement
480,246
Network distribution losses
96,049

Main distribution network return flow

Seepage Return Flow			
Total potensial return flow	cub. m/a	9,605	Based on estimated fraction
Max. possible return flow	cub. m/a	11,783	Based on Darcy flow equation

	cub. m/a	% of total network losses
Seepage		
Return flow from network losses	9,605	10
(smallest of potensial and possible return flow)		

Tail water return flow	2,401	
	cub. m/a	% of total network losses
Total return flow from network losses	12,006	13

Return flow from irrigation fields

Total potensial return flow	cub. m/a	28,492	Based on estimated fraction
Max. possible return flow	cub. m/a	6,306	Based on Darcy flow equation

	cub. m/a	% of Gross irr.
Return flow from irr. Area	6,306	2
(smallest of potensial and possible return flow)		(network losses excluded)

Total return flow from irrigation scheme

Total return flow from scheme	cub. m/a	% of gross releases	Observed
Seepage	15,911	3.3	no data
Surface return flow	7,321	1.5	no data
Tail water	2,401	0.5	no data
Total return flow from scheme	25,633	5.3	0

Sheet B-41: Schoonspruit Scheme: Abstractions from eye canal : Input data

IRRIGATION RETURN FLOW MODEL INPUT DATA

Name of Irrigation Scheme: Schoonspruit Irrigation Scheme - Eye Canal Section

Calibration

Gross releases into canals

Include data	
Observed /Actual releases	
Source 1	Canal releases
cub. m/a	30,706,347
Area (ha)	507

Supply from other sources

Include data	
Observed /Actual releases	
Source 2	none
cub. m/a	no data avaiable
Area (ha)	0

Main distribution network input data

Include data
% Network distribution losses
87.6151
Network losses % tailwater
67.193
% Network losses return flow
39.095
% of Time canals dry
7.67

Sub Areas	Effective canal length (m)	Distance from River (m)	Height above River/drainage point (m)
sub area 1	5,200	200	5.0
sub area 2	2,800	700	16.0
sub area 3	8,500	1,700	20.0
sub area 4			
sub area 5			
Total length	16,500		

Sub Areas	K Selected from table
sub area 1	0.6
sub area 2	0.6
sub area 3	0.25
sub area 4	0
sub area 5	0

Typical value for soil between canal and drainage point

Soil class textural	Permiability(k) m/day
Silt Clay	0.06
Clay	0.12
Clay-loam	0.185
Loam	0.25
Sandy loam	0.61
Sandy	1.22

Irrigation application system input data

	Include data
	% Irrigation application losses
Accepted	22
Suggested	17.757

% of irrigated area irrigated with given system	Type of Irrigation system	Irrigation system efficiency (%) Accepted efficiency (%)	Suggested efficiency (%)	Application losses return flow factor	Distribution uniformity CU/EU (%) Accepted CU/EU	Suggested CU/EU
1.89	Drip	95	95	0.2	85	85
1.18	Micro	90	90	0.15	85	85
14.77	Sprinkler	75	75	0.1	73	73
74.52	Pivot	85	85	0.1	90	90
7.64	Flood	65	60	0.8	100	100
100	Weighted average	82.243	Suggested factor	0.16	88.0996	Weighted average
			Accepted factor	0.59	Distibution uniformaty return flow factor	
					Suggested factor	0.030
					Accepted factor	0.015

Include data	
Total area irrigated (ha)	
507	
Irrigation days per year on average	
365	
Surface water return flow factor	
0.33	Default 0.33

Sub Areas	Wetted drainage Perimeter (m)	Distance from River (m)	Height above River/drainage point (m)	Total area irrigated (ha) Area
sub area 1	0	0	0.0	0
sub area 2	0	0	0.0	0
sun area 3	9,100	800	20.0	507
sun area 4				
sun area 5				
	17.96	Average wetted perimeter per ha		

Sub Areas	K Selected from table
sub area 1	0.600
sub area 2	0.600
sun area 3	0.250
sun area 4	
sun area 5	

Typical value for soil between irrigation field and drainage point

Soil class textural	Permiability(k) m/day
Silt Clay	0.060
Clay	0.120
Clay-loam	0.185
Loam	0.250
Sandy loam	0.610
Sandy	1.220

Leaching and over irrigation related data

Include data	
Leaching Factor	Over Irrigation factor
0	0
Combined factor	0

Include data
Leaching /over irr return flow factor
0

Observed Return Flow Data

Include data
Tail water flows cub. m/a
18077202.81

Include data
Surface return flows cub. m/a
no data

Include data
Seepage return flos cub. m/a
no data

Crop water use

TOTAL Consumptive Crop water use (cub.m/a) From SAPWAT
2,970,485

Sub Areas	Crop water use per sub area (cub.m/a)
sub area 1	0
sub area 2	0
sub area 3	2,970,485
sub area 4	
sub area 5	

Sheet B-42: Schoonspruit Scheme: Abstractions from eye canal : Results

IRRIGATION RETURN FLOW MODEL OUTPUT DATA

Name of Irrigation Scheme: Schoonspruit Irrigation Scheme - Eye Canal Section

Calibration

Gross releases into main canal

Source 1	Canal releases
Compare for calibration purposes	
Observed /Actual releases	30,706,347
Total requirement calculated	30,749,655

Source 2	none
Compare for calibration purposes	
Observed /Actual releases	no data avaiable
Total requirement calculated	0

Total requirement	30,749,655
Network distribution losses	26,941,341

Main distribution network return flow

Seepage Return Flow			
Total potensial return flow	cub. m/a	10,532,717	Based on estimated fraction
Max. possible return flow	cub. m/a	253,668	Based on Darcy flow equation

	cub. m/a	% of total network losses
Seepage Return flow from network losses (smallest of potensial and possible return flow)	253,668	1

	cub. m/a	% of total network losses
Tail water return flow	18,102,695	
Total return flow from network losses	18,356,363	68

Return flow from irrigation fields

Total potensial return flow	cub. m/a	538,876	Based on estimated fraction
Max. possible return flow	cub. m/a	207,594	Based on Darcy flow equation

	cub. m/a	% of Gross irr.
Return flow from irr. Area (smallest of potensial and possible return flow)	207,594	5 (network losses excluded)

Total return flow from irrigation scheme

Total return flow from scheme	cub. m/a	% of gross releases	Observed
Seepage	461,262	1.5	no data
Surface return flow	109,323	0.4	no data
Tail water	18,102,695	58.9	18077202.8
Total return flow from scheme	18,673,281	60.7	18,077,203

Sheet B-43: Schoonspruit Irr: Abstractions from Elandskuil canal : Input data

IRRIGATION RETURN FLOW MODEL INPUT DATA

Name of Irrigation Scheme: Schoonspruit Irrigation Scheme - Elandskuil Canal Section

Calibration

Gross releases into canals

Include data	
Observed /Actual releases	
Source 1	Canal releases
cub. m/a	4,319,163
Area (ha)	648

Supply from other sources

Include data	
Observed /Actual releases	
Source 2	none
cub. m/a	no data avaiable
Area (ha)	0

Main distribution network input data

Include data
% Network distribution losses
44.5171
Network losses % tailwater
87.0533
% Network losses return flow
12.4201
% of Time canals dry
7.67

Sub Areas	Effective canal length (m)	Distance from River (m)	Height above River/drainage point (m)
sub area 1	6,500	1,200	25.0
sub area 2	5,200	2,200	21.0
sub area 3			
sub area 4			
sub area 5			
Total length	11,700		

Sub Areas	K Selected from table
sub area 1	0.25
sub area 2	0.6
sub area 3	0
sub area 4	0
sub area 5	0

Typical value for soil between canal and drainage point

Soil class textural	Permiability(k) m/day
Silt Clay	0.06
Clay	0.12
Clay-loam	0.185
Loam	0.25
Sandy loam	0.61
Sandy	1.22

Irrigation application system input data

	Include data % Irrigation application losses
Accepted	22
Suggested	17.757

% of irrigated area irrigated with given system	Type of Irrigation system	Irrigation system efficiency (%) Accepted efficiency (%)	Suggested efficiency (%)	Application losses return flow factor	Distribution uniformity CU/EU (%) Accepted CU/EU	Suggested CU/EU
1.89	Drip	95	95	0.2	85	85
1.18	Micro	90	90	0.15	85	85
14.77	Sprinkler	75	75	0.1	73	73
74.52	Pivot	85	85	0.1	90	90
7.64	Flood	65	60	0.8	100	100
100	Weighted average	82.243	Suggested factor	0.16	88.0996	Weighted average
			Accepted factor	0.59	Distibution uniformaty return flow factor	
					Suggested factor	0.030
					Accepted factor	0.015

Include data	
Total area irrigated (ha)	
648	
Irrigation days per year on average	
365	
Surface water return flow factor	
0.00	Default 0.33

Sub Areas	Wetted drainage Perimeter (m)	Distance from River (m)	Height above River/drainage point (m)	Total area irrigated (ha) Area
sub area 1	6,500	600	20.0	314
sub area 2	5,200	1,900	20.0	333
sun area 3				
sun area 4				
sun area 5				
	18.07	Average wetted perimeter per ha		

Sub Areas	K Selected from table
sub area 1	0.250
sub area 2	0.600
sun area 3	
sun area 4	
sun area 5	

Typical value for soil between irrigation field and drainage point

Soil class textural	Permiability(k) m/day
Silt Clay	0.060
Clay	0.120
Clay-loam	0.185
Loam	0.250
Sandy loam	0.610
Sandy	1.220

Leaching and over irrigation related data

Include data	
Leaching Factor	Over Irrigation factor
0	0
Combined factor	0

Include data
Leaching /over irr return flow factor
0

Observed Return Flow Data

Include data
Tail water flows cub. m/a
1673830.7

Include data
Surface return flows cub. m/a
no data

Include data
Seepage return flos cub. m/a
no data

Crop water use

TOTAL Consumptive Crop water use (cub.m/a) From SAPWAT
1,868,621

Sub Areas	Crop water use per sub area (cub.m/a)
sub area 1	906,873
sub area 2	961,748
sub area 3	
sub area 4	
sub area 5	

Sheet B-44: Schoonspruit Irr: Abstractions from Elandskuil canal : Results

IRRIGATION RETURN FLOW MODEL OUTPUT DATA

Name of Irrigation Scheme: Schoonspruit Irrigation Scheme - Elandskuil Canal Section

Calibration

Gross releases into main canal

Source 1	Canal releases
Compare for calibration purposes	
Observed /Actual releases	4,319,163
Total requirement calculated	4,317,849

Total requirement
4,317,849
Network distribution losses
1,922,181

Source 2	none
Compare for calibration purposes	
Observed /Actual releases	no data avaiable
Total requirement calculated	0

Main distribution network return flow

Seepage Return Flow			
Total potensial return flow	cub. m/a	238,737	Based on estimated fraction
Max. possible return flow	cub. m/a	248,167	Based on Darcy flow equation

	cub. m/a	% of total network losses
Seepage		
Return flow from network losses	238,737	12
(smallest of potensial and possible return flow)		

	cub. m/a	% of total network losses
Tail water return flow	1,673,322	
Total return flow from network losses	1,912,059	99

Return flow from irrigation fields

Total potensial return flow	cub. m/a	338,987	Based on estimated fraction
Max. possible return flow	cub. m/a	317,582	Based on Darcy flow equation

	cub. m/a	% of Gross irr.
Return flow from irr. Area	338,987	14
(smallest of potensial and possible return flow)		(network losses excluded)

Total return flow from irrigation scheme

Total return flow from scheme	cub. m/a	% of gross releases	Observed
Seepage	577,724	13.4	no data
Surface return flow	0	0.0	no data
Tail water	1,673,322	38.8	1673830.7
Total return flow from scheme	2,251,046	52.1	1,673,831

Sheet B-45: Schoonspruit Irr: Abstractions from Rietspruit canal : Input data

IRRIGATION RETURN FLOW MODEL INPUT DATA

Name of Irrigation Scheme: Schoonspruit Irrigation Scheme - Rietspruit Canal Section

Calibration

Gross releases into canals

Include data	
Observed /Actual releases	
Source 1	Canal releases
cub. m/a	7,174,970
Area (ha)	1,280

Supply from other sources

Include data	
Observed /Actual releases	
Source 2	none
cub. m/a	no data avaiable
Area (ha)	0

Main distribution network input data

Include data
% Network distribution losses
23.6197
Network losses % tailwater
59.9113
% Network losses return flow
38.3736
% of Time canals dry
7.67

Sub Areas	Effective canal length (m)	Distance from River (m)	Height above River/drainage point (m)
sub area 1	4,500	500	10.0
sub area 2	13,500	1,500	22.0
sub area 3	13,700	1,700	21.0
sub area 4	5,500	1,000	15.0
sub area 5			
Total length	37,200		

Sub Areas	K Selected from table
sub area 1	0.6
sub area 2	0.6
sub area 3	0.6
sub area 4	0.6
sub area 5	0

Typical value for soil between canal and drainage point

Soil class textural	Permiability(k) m/day
Silt Clay	0.06
Clay	0.12
Clay-loam	0.185
Loam	0.25
Sandy loam	0.61
Sandy	1.22

Irrigation application system input data

	Include data
	% Irrigation application losses
Accepted	24
Suggested	18.126

% of irrigated area irrigated with given system	Type of Irrigation system	Irrigation system efficiency (%) Accepted efficiency (%)	Suggested efficiency (%)	Application losses return flow factor	Distribution uniformity CU/EU (%) Accepted CU/EU	Suggested CU/EU
3.03	Drip	95	95	0.2	85	85
2.56	Micro	90	90	0.15	85	85
20.39	Sprinkler	75	75	0.1	73	73
66.43	Pivot	85	85	0.1	90	90
7.59	Flood	65	60	0.8	100	100
100	Weighted average	81.874	Suggested factor	0.16	87.0132	Weighted average
			Accepted factor	0.59	Distibution uniformaty return flow factor	
					Suggested factor	0.032
					Accepted factor	0.015

Include data	
Total area irrigated (ha)	
1,280	
Irrigation days per year on average	
365	
Surface water return flow factor	
0.00	Default 0.33

Sub Areas	Wetted drainage Perimeter (m)	Distance from River (m)	Height above River/drainage point (m)	Total area irrigated (ha) Area
sub area 1	4,000	350	7.0	1,118
sub area 2	13,000	1,400	20.0	86
sun area 3	13,000	1,400	17.0	55
sun area 4	5,500	700	10.0	20
sun area 5				
	27.74	Average wetted perimeter per ha		

Sub Areas	K Selected from table
sub area 1	0.600
sub area 2	0.600
sun area 3	0.600
sun area 4	0.600
sun area 5	

Typical value for soil between irrigation field and drainage point

Soil class textural	Permiability(k) m/day
Silt Clay	0.060
Clay	0.120
Clay-loam	0.185
Loam	0.250
Sandy loam	0.610
Sandy	1.220

Leaching and over irrigation related data

Include data	
Leaching Factor	Over Irrigation factor
0	0
Combined factor	0

Include data
Leaching /over irr return flow factor
0

Observed Return Flow Data

Include data
Tail water flows
cub. m/a
1015322.4

Include data
Surface return flows
cub. m/a
no data

Include data
Seepage return flos
cub. m/a
no data

Crop water use

TOTAL Consumptive Crop water use (cub.m/a) From SAPWAT
4,141,816

Sub Areas	Crop water use per sub area (cub.m/a)
sub area 1	3,620,446
sub area 2	278,496
sub area 3	178,108
sub area 4	64,766
sub area 5	

Sheet B-46: Schoonspruit Irr: Abstractions from Rietspruit canal : Results

IRRIGATION RETURN FLOW MODEL OUTPUT DATA

Name of Irrigation Scheme: Schoonspruit Irrigation Scheme - Rietspruit Canal Section

Calibration

Gross releases into main canal

Source 1	Canal releases
Compare for calibration purposes	
Observed /Actual releases	7,174,970
Total requirement calculated	7,135,030

Source 2	none
Compare for calibration purposes	
Observed /Actual releases	no data avaiable
Total requirement calculated	0

Total requirement	
	7,135,030
Network distribution losses	
	1,685,273

Main distribution network return flow

Seepage Return Flow			
Total potensial return flow	cub. m/a	646,700	Based on estimated fraction
Max. possible return flow	cub. m/a	1,016,506	Based on Darcy flow equation

	cub. m/a	% of total network losses
Seepage Return flow from network losses	646,700	38
(smallest of potensial and possible return flow)		

	cub. m/a	% of total network losses
Tail water return flow	1,009,669	
Total return flow from network losses	1,656,369	98

Return flow from irrigation fields

Total potensial return flow	cub. m/a	833,813	Based on estimated fraction
Max. possible return flow	cub. m/a	847,921	Based on Darcy flow equation

	cub. m/a	% of Gross irr.
Return flow from irr. Area	833,813	15
(smallest of potensial and possible return flow)		(network losses excluded)

Total return flow from irrigation scheme

Total return flow from scheme	cub. m/a	% of gross releases	Observed
Seepage	1,480,513	20.7	no data
Surface return flow	0	0.0	no data
Tail water	1,009,669	14.2	1015322.4
Total return flow from scheme	2,490,182	34.9	1,015,322

Sheet B-47: Mooi River GWS: Klerkskraal Right Bank canal abstractions : Input

IRRIGATION RETURN FLOW MODEL INPUT DATA

Name of Irrigation Scheme:	Mooi River GWS - Klerkskraal Right Bank canal abstractions
Scenario description	Current System

Gross releases into canals

Include data	
Observed /Actual releases	
Source 1	canal releases
cub. m/a	7,857,743
Area (ha)	272

Supply from other sources

Include data	
Observed /Actual releases	
Source 2	
cub. m/a	4076795
Area (ha)	549

Main distribution network input data

Include data
% Network distribution losses
73.33
Network losses % tailwater
59.08
% Network losses return flow
37.57
% of Time canals dry
7.67

Sub Areas	Effective canal length (m)	Distance from River (m)	Height above River/drainage point (m)
sub area 1	4,350	300	2.0
sub area 2	6,500	800	12.0
sub area 3	2,500	1,000	20.0
sub area 4	8,000	2,000	22.0
sub area 5	9,350	1,200	12.0
Total length	30,700		

Sub Areas	K Selected from table
sub area 1	0.43
sub area 2	0.6
sub area 3	0.4
sub area 4	0.6
sub area 5	0.4

Typical value for soil between canal and drainage point

Soil class textural	Permiability(k) m/day
Silt Clay	0.06
Clay	0.12
Clay-loam	0.185
Loam	0.25
Sandy loam	0.61
Sandy	1.22

Irrigation application system input data

	Include data
	% Irrigation application losses
Accepted	24
Suggested	21.1

% of irrigated area irrigated with given system	Type of Irrigation system	Irrigation system efficiency (%) Accepted efficiency (%)	Suggested efficiency (%)	Application losses return flow factor	Distribution uniformity CU/EU (%) Accepted CU/EU	Suggested CU/EU
0	Drip	95	95	0.2	85	85
0	Micro	90	90	0.15	85	85
61	Sprinkler	75	75	0.1	73	73
39	Pivot	85	85	0.1	90	90
0	Flood	60	60	0.8	100	100
100	Weighted average	78.9	Suggested factor	0.10	79.63	Weighted average
			Accepted factor	0.1	Distibution uniformaty return flow factor	
					Suggested factor	0.051
					Accepted factor	0.051

Include data	
Total area irrigated (ha)	
821	
Irrigation days per year on average	
365	
Surface water return flow factor	
0.40	Default 0.33

Sub Areas	Wetted drainage Perimeter (m)	Distance from River (m)	Height above River/drainage point (m)	Total area irrigated (ha) Area
sub area 1	6,000	1,300	30	368
sub area 2	1,570	2,850	31	101
sun area 3	3,200	1,900	35	120
sun area 4	3,700	1,200	15	170
sun area 5	2,400	275	1	62
	20.55	Average wetted perimeter per ha		

Sub Areas	K Selected from table
sub area 1	0.600
sub area 2	0.400
sun area 3	0.600
sun area 4	0.600
sun area 5	0.400

Typical value for soil between irrigation field and drainage point

Soil class textural	Permiability(k) m/day
Silt Clay	0.060
Clay	0.120
Clay-loam	0.185
Loam	0.250
Sandy loam	0.610
Sandy	1.220

Leaching and over irrigation related data

Include data	
Leaching Factor	Over Irrigation factor
0	0
Combined factor	0

Include data
Leaching /over irr return flow factor
0.3

Observed Return Flow Data

Include data
Tail water flows cub. m/a
3404359.462

Include data
Surface return flows cub. m/a
no data

Include data
Seepage return flos cub. m/a
no data

Crop water use

TOTAL Consumptive Crop water use (cub.m/a) From SAPWAT
4,810,239

Sub Areas	Crop water use per sub area (cub.m/a)
sub area 1	2,156,112
sub area 2	591,759
sub area 3	703,080
sub area 4	996,030
sub area 5	363,258

Sheet B-48:Mooi River GWS:Klerkskraal Right Bank canal abstractions:Results

IRRIGATION RETURN FLOW MODEL OUTPUT DATA

Name of Irrigation Scheme:	Mooi River GWS - Klerkskraal Right Bank canal abstractions
Scenario Description	Current System

Gross releases into main canal

Source 1	canal releases
Compare for calibration purposes	
Observed /Actual releases	7,857,743
Total requirement calculated	7,863,838

Total requirement	7,863,838
Network distribution losses	5,766,933

Source 2	0
Compare for calibration purposes	
Observed /Actual releases	4,076,795
Total requirement calculated	4,232,357

Main distribution network return flow

Seepage Return Flow			
Total potensial return flow	cub. m/a	2,166,637	Based on estimated fraction
Max. possible return flow	cub. m/a	461,564	Based on Darcy flow equation

	cub. m/a	% of total network losses
Seepage Return flow from network losses (smallest of potensial and possible return flow)	461,564	8

	cub. m/a	% of total network losses
Tail water return flow	3,407,104	
Total return flow from network losses	3,868,668	67

Return flow from irrigation fields

Total potensial return flow	cub. m/a	397,224	Based on estimated fraction
Max. possible return flow	cub. m/a	796,010	Based on Darcy flow equation

	cub. m/a	% of Gross irr.
Return flow from irr. Area (smallest of potensial and possible return flow)	397,224	6 (network losses excluded)

Total return flow from irrigation scheme

Total return flow from scheme	cub. m/a	% of gross releases	Observed
Seepage	858,788	7.1	no data
Surface return flow	0	0.0	no data
Tail water	3,407,104	28.2	3404359.46
Total return flow from scheme	4,265,892	35.3	3,404,359

Sheet B-49: Mooi River GWS: Klerkskraal Left Bank canal abstractions : Input

IRRIGATION RETURN FLOW MODEL **INPUT** DATA

Name of Irrigation Scheme:	Mooi River GWS - Klerkskraal Left Bank canal abstractions
Scenario description	Current System

Gross releases into canals

Include data	
Observed /Actual releases	
Source 1	canal releases
cub. m/a	5,846,850
Area (ha)	89

Supply from other sources

Include data	
Observed /Actual releases	
Source 2	
cub. m/a	349015
Area (ha)	47

Main distribution network input data

Include data
% Network distribution losses
88.26
Network losses % tailwater
68.55
% Network losses return flow
25.62
% of Time canals dry
7.67

Sub Areas	Effective canal length (m)	Distance from River (m)	Height above River/drainage point (m)
sub area 1	3,500	200	3.0
sub area 2	4,250	375	8.0
sub area 3	12,500	600	10.0
sub area 4			
sub area 5			
Total length	20,250		

Sub Areas	K Selected from table
sub area 1	0.43
sub area 2	0.6
sub area 3	0.4
sub area 4	
sub area 5	

Typical value for soil between canal and drainage point

Soil class textural	Permiability(k) m/day
Silt Clay	0.06
Clay	0.12
Clay-loam	0.185
Loam	0.25
Sandy loam	0.61
Sandy	1.22

Irrigation application system input data

	Include data
	% Irrigation application losses
Accepted	24
Suggested	21.1

% of irrigated area irrigated with given system	Type of Irrigation system	Irrigation system efficiency (%) Accepted efficiency (%)	Suggested efficiency (%)	Application losses return flow factor	Distribution uniformity CU/EU (%) Accepted CU/EU	Suggested CU/EU
0	Drip	95	95	0.2	85	85
0	Micro	90	90	0.15	85	85
61	Sprinkler	75	75	0.1	73	73
39	Pivot	85	85	0.1	90	90
0	Flood	60	60	0.8	100	100
100	Weighted average	78.9	Suggested factor	0.10	79.63	Weighted average
			Accepted factor	0.1	Distibution uniformaty return flow factor	
					Suggested factor	0.051
					Accepted factor	0.051

Include data	
Total area irrigated (ha)	
136	
Irrigation days per year on average	
365	
Surface water return flow factor	
0.40	Default 0.33

Sub Areas	Wetted drainage Perimeter (m)	Distance from River (m)	Height above River/drainage point (m)	Total area irrigated (ha) Area
sub area 1	850	750	13	31
sub area 2	750	1,650	41	56
sun area 3	1,350	750	17	49
sun area 4				
sun area 5				
	21.69	Average wetted perimeter per ha		

Sub Areas	K Selected from table
sub area 1	0.430
sub area 2	0.430
sun area 3	0.600
sun area 4	
sun area 5	

Typical value for soil between irrigation field and drainage point

Soil class textural	Permiability(k) m/day
Silt Clay	0.060
Clay	0.120
Clay-loam	0.185
Loam	0.250
Sandy loam	0.610
Sandy	1.220

Leaching and over irrigation related data

Include data	
Leaching Factor	Over Irrigation factor
0	0
Combined factor	0

Include data
Leaching /over irr return flow factor
0.3

Observed Return Flow Data

Include data
Tail water flows
cub. m/a
3537506.238

Include data
Surface return flows
cub. m/a
no data

Include data
Seepage return flos
cub. m/a
no data

Crop water use

TOTAL Consumptive Crop water use (cub.m/a) From SAPWAT
796,824

Sub Areas	Crop water use per sub area (cub.m/a)
sub area 1	181,629
sub area 2	328,104
sub area 3	287,091
sub area 4	
sub area 5	

Sheet B-50: Mooi River GWS: Klerkskraal Left Bank canal abstractions :Results

IRRIGATION RETURN FLOW MODEL OUTPUT DATA

Name of Irrigation Scheme:	Mooi River GWS - Klerkskraal Left Bank canal abstractions
Scenario Description	Current System
Gross releases into main canal	

Source 1	canal releases
Compare for calibration purposes	
Observed /Actual releases	5,846,850
Total requirement calculated	5,844,291

Source 2	0
Compare for calibration purposes	
Observed /Actual releases	349,015
Total requirement calculated	362,333

Total requirement	
	5,844,291
Network distribution losses	
	5,158,171

Main distribution network return flow

Seepage Return Flow			
Total potensial return flow	cub. m/a	1,321,523	Based on estimated fraction
Max. possible return flow	cub. m/a	225,317	Based on Darcy flow equation

	cub. m/a	% of total network losses
Seepage		
Return flow from network losses	225,317	4
(smallest of potensial and possible return flow)		

	cub. m/a	% of total network losses
Tail water return flow	3,535,926	
Total return flow from network losses	3,761,243	73

Return flow from irrigation fields

Total potensial return flow	cub. m/a	65,801	Based on estimated fraction
Max. possible return flow	cub. m/a	131,955	Based on Darcy flow equation

	cub. m/a	% of Gross irr.
Return flow from irr. Area	65,801	6
(smallest of potensial and possible return flow)		(network losses excluded)

Total return flow from irrigation scheme

Total return flow from scheme	cub. m/a	% of gross releases	Observed
Seepage	291,118	4.7	no data
Surface return flow	0	0.0	no data
Tail water	3,535,926	57.0	3537506.24
Total return flow from scheme	3,827,044	61.7	3,537,506

Sheet B-51: Mooi River GWS: Boskop Right Bank canal abstractions : Input

IRRIGATION RETURN FLOW MODEL INPUT DATA

Name of Irrigation Scheme: Mooi River GWS - Boskop Dam Right Bank canal abstractions

Scenario description: Current System

Gross releases into canals

Include data	
Observed /Actual releases	
Source 1	canal releases
cub. m/a	126,652,169
Area (ha)	851

Supply from other sources

Include data	
Observed /Actual releases	
Source 2	
cub. m/a	2981547
Area (ha)	401

Main distribution network input data

Include data
% Network distribution losses
94.83
Network losses % tailwater
74.31
% Network losses return flow
25.01
% of Time canals dry
7.67

Sub Areas	Effective canal length (m)	Distance from River (m)	Height above River/drainage point (m)
sub area 1	12,250	500	10.0
sub area 2	34,200	3,000	25.0
sub area 3			
sub area 4			
sub area 5			
Total length	46,450		

Sub Areas	K Selected from table
sub area 1	0.4
sub area 2	0.23
sub area 3	
sub area 4	
sub area 5	

Typical value for soil between canal and drainage point

Soil class textural	Permiability(k) m/day
Silt Clay	0.06
Clay	0.12
Clay-loam	0.185
Loam	0.25
Sandy loam	0.61
Sandy	1.22

Irrigation application system input data

	Include data
	% Irrigation application losses
Accepted	24
Suggested	21.2

% of irrigated area irrigated with given system	Type of Irrigation system	Irrigation system efficiency (%) Accepted efficiency (%)	Suggested efficiency (%)	Application losses return flow factor	Distribution uniformity CU/EU (%) Accepted CU/EU	Suggested CU/EU
11	Drip	95	95	0.2	85	85
0	Micro	90	90	0.15	85	85
68	Sprinkler	75	75	0.1	73	73
19	Pivot	85	85	0.1	90	90
2	Flood	60	60	0.8	100	100
100	Weighted average	78.8	Suggested factor	0.13	78.09	Weighted average
			Accepted factor	0.13	Distibution uniformaty return flow factor	
					Suggested factor	0.055
					Accepted factor	0.055

Include data	
Total area irrigated (ha)	
1,252	
Irrigation days per year on average	
365	
Surface water return flow factor	
0.40	Default 0.33

Sub Areas	Wetted drainage Perimeter (m)	Distance from River (m)	Height above River/drainage point (m)	Total area irrigated (ha) Area
sub area 1	2,750	200	2	42
sub area 2	7,000	3,700	30	646
sun area 3	7,400	1,500	13	365
sun area 4	1,250	2,200	25	80
sun area 5	2,850	950	11	119
	16.97	Average wetted perimeter per ha		

Sub Areas	K Selected from table
sub area 1	0.400
sub area 2	0.230
sun area 3	0.230
sun area 4	0.230
sun area 5	0.230

Typical value for soil between irrigation field and drainage point

Soil class textural	Permiability(k) m/day
Silt Clay	0.060
Clay	0.120
Clay-loam	0.185
Loam	0.250
Sandy loam	0.610
Sandy	1.220

Leaching and over irrigation related data

Include data	
Leaching Factor	Over Irrigation factor
0	0
Combined factor	0

Include data
Leaching /over irr return flow factor
0.3

Observed Return Flow Data

Include data
Tail water flows cub. m/a
89241949.55

Include data
Surface return flows cub. m/a
no data

Include data
Seepage return flos cub. m/a
no data

Crop water use

TOTAL Consumptive Crop water use (cub.m/a) From SAPWAT
7,335,468

Sub Areas	Crop water use per sub area (cub.m/a)
sub area 1	246,078
sub area 2	3,784,914
sub area 3	2,138,535
sub area 4	468,720
sub area 5	697,221

Sheet B-52: Mooi River GWS: Boskop Right Bank canal abstractions :Results

IRRIGATION RETURN FLOW MODEL OUTPUT DATA

Name of Irrigation Scheme:	Mooi River GWS - Boskop Dam Right Bank canal abstractions
Scenario Description	Current System

Gross releases into main canal

Source 1	canal releases
Compare for calibration purposes	
Observed /Actual releases	126,652,169
Total requirement calculated	126,847,008

Source 2	0
Compare for calibration purposes	
Observed /Actual releases	2,981,547
Total requirement calculated	3,091,393

Total requirement	126,847,008
Network distribution losses	120,286,470

Main distribution network return flow

Seepage Return Flow			
Total potensial return flow	cub. m/a	30,083,646	Based on estimated fraction
Max. possible return flow	cub. m/a	441,568	Based on Darcy flow equation

	cub. m/a	% of total network losses
Seepage Return flow from network losses (smallest of potensial and possible return flow)	441,568	0

	cub. m/a	% of total network losses
Tail water return flow	89,384,876	
Total return flow from network losses	89,826,443	75

Return flow from irrigation fields

Total potensial return flow	cub. m/a	704,591	Based on estimated fraction
Max. possible return flow	cub. m/a	140,625	Based on Darcy flow equation

	cub. m/a	% of Gross irr.
Return flow from irr. Area (smallest of potensial and possible return flow)	140,625	1 (network losses excluded)

Total return flow from irrigation scheme

Total return flow from scheme	cub. m/a	% of gross releases	Observed
Seepage	582,192	0.4	no data
Surface return flow	225,587	0.2	no data
Tail water	89,384,876	68.8	89241949.5
Total return flow from scheme	90,192,655	69.4	89,241,950

Sheet B-53: Mooi River GWS: Boskop Left Bank canal abstractions : Input

IRRIGATION RETURN FLOW MODEL INPUT DATA

Name of Irrigation Scheme: Mooi River GWS - Boskop Dam Left Bank canal abstractions

Scenario description Current System

Gross releases into canals

Include data	
Observed /Actual releases	
Source 1	canal releases
cub. m/a	33,334,115
Area (ha)	492

Supply from other sources

Include data	
Observed /Actual releases	
Source 2	
cub. m/a	669825
Area (ha)	85

Main distribution network input data

Include data
% Network distribution losses
88.63
Network losses % tailwater
75.38
% Network losses return flow
23.79
% of Time canals dry
7.67

Sub Areas	Effective canal length (m)	Distance from River (m)	Height above River/drainage point (m)
sub area 1	10,250	750	20.0
sub area 2	7,250	1,250	25.0
sub area 3	2,100	2,250	30.0
sub area 4			
sub area 5			
Total length	19,600		

Sub Areas	K Selected from table
sub area 1	0.4
sub area 2	0.23
sub area 3	0.23
sub area 4	
sub area 5	

Typical value for soil between canal and drainage point

Soil class textural	Permiability(k) m/day
Silt Clay	0.06
Clay	0.12
Clay-loam	0.185
Loam	0.25
Sandy loam	0.61
Sandy	1.22

Irrigation application system input data

	Include data
	% Irrigation application losses
Accepted	24
Suggested	25.65

% of irrigated area irrigated with given system	Type of Irrigation system	Irrigation system efficiency (%) Accepted efficiency (%)	Suggested efficiency (%)	Application losses return flow factor	Distribution uniformity CU/EU (%) Accepted CU/EU	Suggested CU/EU
1	Drip	95	95	0.2	85	85
0	Micro	90	90	0.15	85	85
80	Sprinkler	75	75	0.1	73	73
8	Pivot	85	85	0.1	90	90
11	Flood	60	60	0.8	100	100
100	Weighted average	74.35	Suggested factor	0.18	77.45	Weighted average
			Accepted factor	0.18	Distibution uniformaty return flow factor	
					Suggested factor	0.056
					Accepted factor	0.056

Include data	
Total area irrigated (ha)	
577	
Irrigation days per year on average	
365	
Surface water return flow factor	
0.40	Default 0.33

Sub Areas	Wetted drainage Perimeter (m)	Distance from River (m)	Height above River/drainage point (m)	Total area irrigated (ha) Area
sub area 1	3,500	50	3	86
sub area 2	4,500	850	3	491
sun area 3				
sun area 4				
sun area 5				
	13.86	Average wetted perimeter per ha		

Sub Areas	K Selected from table
sub area 1	0.400
sub area 2	0.230
sun area 3	
sun area 4	
sun area 5	

Typical value for soil between irrigation field and drainage point

Soil class textural	Permiability(k) m/day
Silt Clay	0.060
Clay	0.120
Clay-loam	0.185
Loam	0.250
Sandy loam	0.610
Sandy	1.220

Leaching and over irrigation related data

Include data	
Leaching Factor	Over Irrigation factor
0	0
Combined factor	0

Include data
Leaching /over irr return flow factor
0.3

Observed Return Flow Data

Include data
Tail water flows cub. m/a
22270689.42

Include data
Surface return flows cub. m/a
no data

Include data
Seepage return flos cub. m/a
no data

Crop water use

TOTAL Consumptive Crop water use (cub.m/a) From SAPWAT
3,380,643

Sub Areas	Crop water use per sub area (cub.m/a)
sub area 1	503,874
sub area 2	2,876,769
sub area 3	
sub area 4	
sub area 5	

Sheet B-54: Mooi River GWS: Boskop Left Bank canal abstractions : Results

IRRIGATION RETURN FLOW MODEL OUTPUT DATA

Name of Irrigation Scheme:	Mooi River GWS - Boskop Dam Left Bank canal abstractions
Scenario Description	Current System
Gross releases into main canal	

Source 1	**canal releases**
Compare for calibration purposes	
Observed /Actual releases	33,334,115
Total requirement calculated	33,359,117

Total requirement	33,359,117
Network distribution losses	29,566,185

Source 2	0
Compare for calibration purposes	
Observed /Actual releases	669,825
Total requirement calculated	655,283

Main distribution network return flow

Seepage Return Flow			
Total potensial return flow	cub. m/a	7,033,795	Based on estimated fraction
Max. possible return flow	cub. m/a	541,873	Based on Darcy flow equation

	cub. m/a	% of total network losses
Seepage **Return flow from network losses** (smallest of potensial and possible return flow)	541,873	2

	cub. m/a	% of total network losses
Tail water return flow	22,286,990	
Total return flow from network losses	22,828,863	77

Return flow from irrigation fields

Total potensial return flow	cub. m/a	381,479	Based on estimated fraction
Max. possible return flow	cub. m/a	47,990	Based on Darcy flow equation

	cub. m/a	% of Gross irr.
Return flow from irr. Area (smallest of potensial and possible return flow)	47,990	1 (network losses excluded)

Total return flow from irrigation scheme

Total return flow from scheme	**cub. m/a**	**% of gross releases**	Observed
Seepage	589,863	1.7	no data
Surface return flow	133,396	0.4	no data
Tail water	22,286,990	65.5	22270689.4
Total return flow from scheme	23,010,248	67.6	22,270,689

Sheet B-55: Mooi River GWS: Gerhardminnebron canal abstractions : Input

IRRIGATION RETURN FLOW MODEL INPUT DATA

Name of Irrigation Scheme:	Mooi River GWS - Gerhardminnebron canal abstractions
Scenario description	Current System

Gross releases into canals

Include data	
Observed /Actual releases	
Source 1	canal releases
cub. m/a	19,481,164
Area (ha)	205

Supply from other sources

Include data	
Observed /Actual releases	
Source 2	
cub. m/a	252479
Area (ha)	34

Main distribution network input data

Include data
% Network distribution losses
91.91
Network losses % tailwater
94.07
% Network losses return flow
4.85
% of Time canals dry
7.67

Sub Areas	Effective canal length (m)	Distance from River (m)	Height above River/drainage point (m)
sub area 1	2,550	375	3.0
sub area 2	6,200	350	3.0
sub area 3	4,600	1,000	12.0
sub area 4			
sub area 5			
Total length	13,350		

Sub Areas	K Selected from table
sub area 1	0.4
sub area 2	0.4
sub area 3	0.23
sub area 4	
sub area 5	

Typical value for soil between canal and drainage point

Soil class textural	Permiability(k) m/day
Silt Clay	0.06
Clay	0.12
Clay-loam	0.185
Loam	0.25
Sandy loam	0.61
Sandy	1.22

Irrigation application system input data

	Include data
	% Irrigation application losses
Accepted	24
Suggested	21.1

% of irrigated area irrigated with given system	Type of Irrigation system	Irrigation system efficiency (%) Accepted efficiency (%)	Suggested efficiency (%)	Application losses return flow factor	Distribution uniformity CU/EU (%) Accepted CU/EU	Suggested CU/EU
0	Drip	95	95	0.2	85	85
0	Micro	90	90	0.15	85	85
61	Sprinkler	75	75	0.1	73	73
39	Pivot	85	85	0.1	90	90
0	Flood	60	60	0.8	100	100
100	Weighted average	78.9	Suggested factor	0.10	79.63	Weighted average
			Accepted factor	0.1	Distibution uniformaty return flow factor	
					Suggested factor	0.051
					Accepted factor	0.051

Include data	
Total area irrigated (ha)	
239	
Irrigation days per year on average	
365	
Surface water return flow factor	
0.40	Default 0.33

Sub Areas	Wetted drainage Perimeter (m)	Distance from River (m)	Height above River/drainage point (m)	Total area irrigated (ha) Area
sub area 1	750	300	2	12
sub area 2	1,500	800	7	81
sun area 3	2,500	725	15	45
sun area 4	2,100	300	2	25
sun area 5	2,250	800	9	76
	38.08	Average wetted perimeter per ha		

Sub Areas	K Selected from table
sub area 1	0.400
sub area 2	0.400
sun area 3	0.230
sun area 4	0.400
sun area 5	0.400

Typical value for soil between irrigation field and drainage point

Soil class textural	Permiability(k) m/day
Silt Clay	0.060
Clay	0.120
Clay-loam	0.185
Loam	0.250
Sandy loam	0.610
Sandy	1.220

Leaching and over irrigation related data

Include data	
Leaching Factor	Over Irrigation factor
0	0
Combined factor	0

Include data
Leaching /over irr return flow factor
0.3

Observed Return Flow Data

Include data
Tail water flows
cub. m/a
16842988.85

Include data
Surface return flows
cub. m/a
no data

Include data
Seepage return flos
cub. m/a
no data

Crop water use

TOTAL Consumptive Crop water use (cub.m/a) From SAPWAT
1,400,301

Sub Areas	Crop water use per sub area (cub.m/a)
sub area 1	70,308
sub area 2	474,579
sub area 3	263,655
sub area 4	146,475
sub area 5	445,284

Sheet B-56: Mooi River GWS: Gerhardminnebron canal abstractions : Results

IRRIGATION RETURN FLOW MODEL OUTPUT DATA

Name of Irrigation Scheme:	Mooi River GWS - Gerhardminnebron canal abstractions
Scenario Description	Current System

Gross releases into main canal

Source 1	canal releases
Compare for calibration purposes	
Observed /Actual releases	19,481,164
Total requirement calculated	19,528,329

Source 2	0
Compare for calibration purposes	
Observed /Actual releases	252,479
Total requirement calculated	262,113

Total requirement	19,528,329
Network distribution losses	17,947,940

Main distribution network return flow

Seepage Return Flow			
Total potensial return flow	cub. m/a	870,475	Based on estimated fraction
Max. possible return flow	cub. m/a	40,570	Based on Darcy flow equation

	cub. m/a	% of total network losses
Seepage Return flow from network losses (smallest of potensial and possible return flow)	40,570	0

	cub. m/a	% of total network losses
Tail water return flow	16,883,628	
Total return flow from network losses	16,924,198	94

Return flow from irrigation fields

Total potensial return flow	cub. m/a	115,635	Based on estimated fraction
Max. possible return flow	cub. m/a	58,678	Based on Darcy flow equation

	cub. m/a	% of Gross irr.
Return flow from irr. Area (smallest of potensial and possible return flow)	58,678	3 (network losses excluded)

Total return flow from irrigation scheme

Total return flow from scheme	cub. m/a	% of gross releases	Observed
Seepage	99,248	0.5	no data
Surface return flow	22,783	0.1	no data
Tail water	16,883,628	85.3	16842988.9
Total return flow from scheme	17,005,658	85.9	16,842,989

Sheet B-57: Mooi River GWS: Lakeside canal abstractions : Input

IRRIGATION RETURN FLOW MODEL INPUT DATA

Name of Irrigation Scheme:	Mooi River GWS - Lakeside canal abstractions
Scenario description	Current System

Gross releases into canals

Include data	
Observed /Actual releases	
Source 1	canal releases
cub. m/a	9,001,437
Area (ha)	330

Supply from other sources

Include data	
Observed /Actual releases	
Source 2	
cub. m/a	535340
Area (ha)	72

Main distribution network input data

Include data
% Network distribution losses
71.78
Network losses % tailwater
73.28
% Network losses return flow
23.27
% of Time canals dry
7.67

Sub Areas	Effective canal length (m)	Distance from River (m)	Height above River/drainage point (m)
sub area 1	3,750	300	3.0
sub area 2	4,750	1,000	10.0
sub area 3	19,000	800	5.0
sub area 4	3,900	1,500	12.0
sub area 5			
Total length	31,400		

Sub Areas	K Selected from table
sub area 1	0.23
sub area 2	0.23
sub area 3	0.23
sub area 4	0.23
sub area 5	

Typical value for soil between canal and drainage point

Soil class textural	Permiability(k) m/day
Silt Clay	0.06
Clay	0.12
Clay-loam	0.185
Loam	0.25
Sandy loam	0.61
Sandy	1.22

Irrigation application system input data

	Include data % Irrigation application losses
Accepted	24
Suggested	21.2

% of irrigated area irrigated with given system	Type of Irrigation system	Irrigation system efficiency (%) Accepted efficiency (%)	Suggested efficiency (%)	Application losses return flow factor	Distribution uniformity CU/EU (%) Accepted CU/EU	Suggested CU/EU
11	Drip	95	95	0.2	85	85
0	Micro	90	90	0.15	85	85
68	Sprinkler	75	75	0.1	73	73
19	Pivot	85	85	0.1	90	90
2	Flood	60	60	0.8	100	100
100	Weighted average	78.8	Suggested factor	0.13	78.09	Weighted average
			Accepted factor	0.13	Distibution uniformaty return flow factor	
					Suggested factor	0.055
					Accepted factor	0.055

Include data	
Total area irrigated (ha)	
402	
Irrigation days per year on average	
365	
Surface water return flow factor	
0.40	Default 0.33

Sub Areas	Wetted drainage Perimeter (m)	Distance from River (m)	Height above River/drainage point (m)	Total area irrigated (ha) Area
sub area 1	2,350	800	5	175
sub area 2	4,700	1,000	10	227
sun area 3				
sun area 4				
sun area 5				
	17.54	Average wetted perimeter per ha		

Sub Areas	K Selected from table
sub area 1	0.230
sub area 2	0.230
sun area 3	
sun area 4	
sun area 5	

Typical value for soil between irrigation field and drainage point

Soil class textural	Permiability(k) m/day
Silt Clay	0.060
Clay	0.120
Clay-loam	0.185
Loam	0.250
Sandy loam	0.610
Sandy	1.220

Leaching and over irrigation related data

Include data	
Leaching Factor	Over Irrigation factor
0	0
Combined factor	0

Include data
Leaching /over irr return flow factor
0.3

Observed Return Flow Data

Include data
Tail water flows
cub. m/a
4734803.158

Include data
Surface return flows
cub. m/a
no data

Include data
Seepage return flos
cub. m/a
no data

Crop water use

TOTAL Consumptive Crop water use (cub.m/a) From SAPWAT
2,355,318

Sub Areas	Crop water use per sub area (cub.m/a)
sub area 1	1,025,325
sub area 2	1,329,993
sub area 3	
sub area 4	
sub area 5	

Sheet B-58: Mooi River GWS: Lakeside canal abstractions : Results

IRRIGATION RETURN FLOW MODEL OUTPUT DATA

Name of Irrigation Scheme:	Mooi River GWS - Lakeside canal abstractions
Scenario Description	Current System
Gross releases into main canal	

Source 1	canal releases
Compare for calibration purposes	
Observed /Actual releases	9,001,437
Total requirement calculated	9,013,916

Source 2	0
Compare for calibration purposes	
Observed /Actual releases	535,340
Total requirement calculated	555,063

Total requirement	9,013,916
Network distribution losses	6,469,877

Main distribution network return flow

Seepage Return Flow			
Total potensial return flow	cub. m/a	1,505,574	Based on estimated fraction
Max. possible return flow	cub. m/a	60,331	Based on Darcy flow equation

	cub. m/a	% of total network losses
Seepage		
Return flow from network losses	60,331	1
(smallest of potensial and possible return flow)		

	cub. m/a	% of total network losses
Tail water return flow	4,741,367	
Total return flow from network losses	4,801,699	74

Return flow from irrigation fields

Total potensial return flow	cub. m/a	226,234	Based on estimated fraction
Max. possible return flow	cub. m/a	22,811	Based on Darcy flow equation

	cub. m/a	% of Gross irr.
Return flow from irr. Area	22,811	1
(smallest of potensial and possible return flow)		(network losses excluded)

Total return flow from irrigation scheme

Total return flow from scheme	cub. m/a	% of gross releases	Observed
Seepage	83,142	0.9	no data
Surface return flow	81,369	0.9	no data
Tail water	4,741,367	49.5	4734803.16
Total return flow from scheme	4,905,879	51.3	4,734,803

Sheet B-59: Sand Vet Scheme: Allemanskraal canal zone 5: Input

IRRIGATION RETURN FLOW MODEL INPUT DATA

Name of Irrigation Scheme: Sand-Vet Irrigation Scheme_Sand Canal_Zone 5

Calibration

Gross releases into canals

Include data	
Observed /Actual releases	
Source 1	Canal releases
cub. m/a	34,886,882
Area (ha)	631

Supply from other sources

Include data	
Observed /Actual releases	
Source 2	none
cub. m/a	no data avaiable
Area (ha)	0

Main distribution network input data

Include data
% Network distribution losses
90.66
Network losses % tailwater
94.59
% Network losses return flow
4.71
% of Time canals dry
5.77

Sub Areas	Effective canal length (m)	Distance from River (m)	Height above River/drainage point (m)
sub area 1	5,300	300	10.0
sub area 2	8,500	1,500	25.0
sub area 3	11,500	1,700	35.0
sub area 4	9,000	3,000	30.0
sub area 5			
Total length	34,300		

Sub Areas	K Selected from table
sub area 1	0.1
sub area 2	0.6
sub area 3	0.6
sub area 4	0.6
sub area 5	

Typical value for soil between canal and drainage point

Soil class textural	Permiability(k) m/day
Silt Clay	0.06
Clay	0.12
Clay-loam	0.185
Loam	0.25
Sandy loam	0.61
Sandy	1.22

Irrigation application system input data

	Include data
	% Irrigation application losses
Accepted	17
Suggested	17

% of irrigated area irrigated with given system	Type of Irrigation system	Irrigation system efficiency (%) Accepted efficiency (%)	Suggested efficiency (%)	Application losses return flow factor	Distribution uniformity CU/EU (%) Accepted CU/EU	Suggested CU/EU
0	Drip	95	95	0.2	85	85
0	Micro	90	90	0.15	85	85
20	Sprinkler	75	75	0.1	73	73
80	Pivot	85	85	0.1	90	90
0	Flood	65	60	0.8	100	100
100	Weighted average	83	Suggested factor	0.10	86.6	Weighted average
			Accepted factor	0.1	Distibution uniformaty return flow factor	
					Suggested factor	0.034
					Accepted factor	0.034

Include data	
Total area irrigated (ha)	
631	
Irrigation days per year on average	
365	
Surface water return flow factor	
0.33	Default 0.33

Sub Areas	Wetted drainage Perimeter (m)	Distance from River (m)	Height above River/drainage point (m)	Total area irrigated (ha) Area
sub area 1	3,800	1,000	20.0	63
sub area 2	8,000	1,000	20.0	158
sun area 3	10,500	900	30.0	221
sun area 4	8,000	1,000	20.0	189
sun area 5				
	48.03	Average wetted perimeter per ha		

Sub Areas	K Selected from table
sub area 1	0.100
sub area 2	0.600
sun area 3	0.600
sun area 4	0.600
sun area 5	

Typical value for soil between irrigation field and drainage point

Soil class textural	Permiability(k) m/day
Silt Clay	0.060
Clay	0.120
Clay-loam	0.185
Loam	0.250
Sandy loam	0.610
Sandy	1.220

Leaching and over irrigation related data

Include data	
Leaching Factor	Over Irrigation factor
0	0
Combined factor	0

Include data
Leaching /over irr return flow factor
0

Observed Return Flow Data

Include data
Tail water flows cub. m/a
29915233.55

Include data
Surface return flows cub. m/a
no data

Include data
Seepage return flos cub. m/a
no data

Crop water use

TOTAL Consumptive Crop water use (cub.m/a) From SAPWAT
2,704,501

Sub Areas	Crop water use per sub area (cub.m/a)
sub area 1	270,450
sub area 2	676,125
sub area 3	946,575
sub area 4	811,350
sub area 5	

Sheet B-60: Sand Vet Scheme: Allemanskraal canal zone 5: Results

IRRIGATION RETURN FLOW MODEL OUTPUT DATA

Name of Irrigation Scheme:

Sand-Vet Irrigation Scheme_Sand Canal_Zone 5
Calibration

Gross releases into main canal

Source 1	Canal releases
Compare for calibration purposes	
Observed /Actual releases	34,886,882
Total requirement calculated	34,886,882

Total requirement	34,886,882
Network distribution losses	31,628,447

Source 2	none
Compare for calibration purposes	
Observed /Actual releases	no data avaiable
Total requirement calculated	0

Main distribution network return flow

Seepage Return Flow			
Total potensial return flow	cub. m/a	1,489,700	Based on estimated fraction
Max. possible return flow	cub. m/a	1,530,499	Based on Darcy flow equation

	cub. m/a	% of total network losses
Seepage		
Return flow from network losses	1,489,700	5
(smallest of potensial and possible return flow)		

Tail water return flow	29,917,348	
	cub. m/a	% of total network losses
Total return flow from network losses	31,407,048	99

Return flow from irrigation fields

Total potensial return flow	cub. m/a	147,346	Based on estimated fraction
Max. possible return flow	cub. m/a	1,878,290	Based on Darcy flow equation

	cub. m/a	% of Gross irr.
Return flow from irr. Area	147,346	5
(smallest of potensial and possible return flow)		(network losses excluded)

Total return flow from irrigation scheme

Total return flow from scheme	cub. m/a	% of gross releases	Observed
Seepage	1,637,046	4.7	no data
Surface return flow	0	0.0	no data
Tail water	29,917,348	85.8	29915233.5
Total return flow from scheme	31,554,394	90.4	29,915,234

Sheet B-61: Sand Vet Scheme: Allemanskraal canal zone 6: Input

IRRIGATION RETURN FLOW MODEL INPUT DATA

Name of Irrigation Scheme: Sand-Vet Irrigation Scheme_Sand Canal_Zone 6

Calibration

Gross releases into canals

Include data	
Observed /Actual releases	
Source 1	Canal releases
cub. m/a	5,679,260
Area (ha)	99

Supply from other sources

Include data	
Observed /Actual releases	
Source 2	none
cub. m/a	no data avaiable
Area (ha)	0

Main distribution network input data

Include data
% Network distribution losses
91.01
Network losses % tailwater
94.81
% Network losses return flow
4.52
% of Time canals dry
5.77

Sub Areas	Effective canal length (m)	Distance from River (m)	Height above River/drainage point (m)
sub area 1	7,200	1,400	20.0
sub area 2	4,800	1,100	20.0
sub area 3	9,500	1,900	25.0
sub area 4			
sub area 5			
Total length	21,500		

Sub Areas	K Selected from table
sub area 1	0.1
sub area 2	0.1
sub area 3	0.1
sub area 4	
sub area 5	

Typical value for soil between canal and drainage point

Soil class textural	Permiability(k) m/day
Silt Clay	0.06
Clay	0.12
Clay-loam	0.185
Loam	0.25
Sandy loam	0.61
Sandy	1.22

Irrigation application system input data

	Include data
	% Irrigation application losses
Accepted	17
Suggested	17

% of irrigated area irrigated with given system	Type of Irrigation system	Irrigation system efficiency (%) Accepted efficiency (%)	Suggested efficiency (%)	Application losses return flow factor	Distribution uniformity CU/EU (%) Accepted CU/EU	Suggested CU/EU
0	Drip	95	95	0.2	85	85
0	Micro	90	90	0.15	85	85
20	Sprinkler	75	75	0.1	73	73
80	Pivot	85	85	0.1	90	90
0	Flood	65	60	0.8	100	100
100	Weighted average	83	Suggested factor	0.10	86.6	Weighted average
			Accepted factor	0.1	Distibution uniformaty return flow factor	
					Suggested factor	0.034
					Accepted factor	0.034

Include data	
Total area irrigated (ha)	
99	
Irrigation days per year on average	
365	
Surface water return flow factor	
0.33	Default 0.33

Sub Areas	Wetted drainage Perimeter (m)	Distance from River (m)	Height above River/drainage point (m)	Total area irrigated (ha) Area	Suggested
sub area 1	7,000	500	10.0	35	
sub area 2	4,200	350	10.0	15	
sun area 3	6,200	1,300	20.0	50	
sun area 4					
sun area 5					
	175.61	Average wetted perimeter per ha			

Sub Areas	K Selected from table
sub area 1	0.100
sub area 2	0.100
sun area 3	0.100
sun area 4	
sun area 5	

Typical value for soil between irrigation field and drainage point

Soil class textural	Permiability(k) m/day
Silt Clay	0.060
Clay	0.120
Clay-loam	0.185
Loam	0.250
Sandy loam	0.610
Sandy	1.220

Leaching and over irrigation related data

Include data	
Leaching Factor	Over Irrigation factor
0	0
Combined factor	0

Include data
Leaching /over irr return flow factor
0

Observed Return Flow Data

Include data
Tail water flows cub. m/a
4900289.421

Include data
Surface return flows cub. m/a
no data

Include data
Seepage return flos cub. m/a
no data

Crop water use

TOTAL Consumptive Crop water use (cub.m/a) From SAPWAT
423,769

Sub Areas	Crop water use per sub area (cub.m/a)
sub area 1	148,319
sub area 2	63,565
sub area 3	211,885
sub area 4	
sub area 5	

Sheet B-62: Sand Vet Scheme: Allemanskraal canal zone 6: Results

IRRIGATION RETURN FLOW MODEL OUTPUT DATA

Name of Irrigation Scheme:

Sand-Vet Irrigation Scheme_Sand Canal_Zone 6	
Calibration	

Gross releases into main canal

Source 1	Canal releases
Compare for calibration purposes	
Observed /Actual releases	5,679,260
Total requirement calculated	5,679,260

Source 2	none
Compare for calibration purposes	
Observed /Actual releases	no data avaiable
Total requirement calculated	0

Total requirement
5,679,260
Network distribution losses
5,168,694

Main distribution network return flow

Seepage Return Flow			
Total potensial return flow	cub. m/a	233,625	Based on estimated fraction
Max. possible return flow	cub. m/a	119,215	Based on Darcy flow equation

	cub. m/a	% of total network losses
Seepage		
Return flow from network losses	119,215	2
(smallest of potensial and possible return flow)		

	cub. m/a	% of total network losses
Tail water return flow	4,900,439	
Total return flow from network losses	5,019,654	97

Return flow from irrigation fields

Total potensial return flow	cub. m/a	23,088	Based on estimated fraction
Max. possible return flow	cub. m/a	82,265	Based on Darcy flow equation

	cub. m/a	% of Gross irr.
Return flow from irr. Area	23,088	5
(smallest of potensial and possible return flow)		(network losses excluded)

Total return flow from irrigation scheme

Total return flow from scheme	cub. m/a	% of gross releases	Observed
Seepage	142,303	2.5	no data
Surface return flow	0	0.0	no data
Tail water	4,900,439	86.3	4900289.42
Total return flow from scheme	5,042,742	88.8	4,900,289

Sheet B-63: Sand Vet Scheme: Allemanskraal canal zone 7: Input

IRRIGATION RETURN FLOW MODEL INPUT DATA

Name of Irrigation Scheme: Sand-Vet Irrigation Scheme_Sand Canal_Zone 7

Calibration

Gross releases into canals

Include data	
Observed /Actual releases	
Source 1	Canal releases
cub. m/a	29,915,234
Area (ha)	3,565

Supply from other sources

Include data	
Observed /Actual releases	
Source 2	none
cub. m/a	no data avaiable
Area (ha)	0

Main distribution network input data

Include data
% Network distribution losses
38.44
Network losses % tailwater
15.85
% Network losses return flow
73.2
% of Time canals dry
5.77

Sub Areas	Effective canal length (m)	Distance from River (m)	Height above River/drainage point (m)
sub area 1	15,000	2,000	22.0
sub area 2	18,500	2,800	35.0
sub area 3			
sub area 4			
sub area 5			
Total length	33,500		

Sub Areas	K Selected from table
sub area 1	0.1
sub area 2	0.6
sub area 3	
sub area 4	
sub area 5	

Typical value for soil between canal and drainage point

Soil class textural	Permiability(k) m/day
Silt Clay	0.06
Clay	0.12
Clay-loam	0.185
Loam	0.25
Sandy loam	0.61
Sandy	1.22

Irrigation application system input data

	Include data
	% Irrigation application losses
Accepted	17
Suggested	17

% of irrigated area irrigated with given system	Type of Irrigation system	Irrigation system efficiency (%) Accepted efficiency (%)	Suggested efficiency (%)	Application losses return flow factor	Distribution uniformity CU/EU (%) Accepted CU/EU	Suggested CU/EU
0	Drip	95	95	0.2	85	85
0	Micro	90	90	0.15	85	85
20	Sprinkler	75	75	0.1	73	73
80	Pivot	85	85	0.1	90	90
0	Flood	65	60	0.8	100	100
100	Weighted average	83	Suggested factor	0.10	86.6	Weighted average
			Accepted factor	0.1	Distibution uniformaty return flow factor	
					Suggested factor	0.034
					Accepted factor	0.034

Include data	
Total area irrigated (ha)	
3,565	
Irrigation days per year on average	
365	
Surface water return flow factor	
0.33	Default 0.33

Sub Areas	Wetted drainage Perimeter (m)	Distance from River (m)	Height above River/drainage point (m)	Total area irrigated (ha) Area
sub area 1	13,500	1,500	15.0	1,426
sub area 2	16,000	2,300	30.0	2,139
sun area 3				
sun area 4				
sun area 5				
	8.28	Average wetted perimeter per ha		

Sub Areas	K Selected from table
sub area 1	0.100
sub area 2	0.600
sun area 3	
sun area 4	
sun area 5	

Typical value for soil between irrigation field and drainage point

Soil class textural	Permiability(k) m/day
Silt Clay	0.060
Clay	0.120
Clay-loam	0.185
Loam	0.250
Sandy loam	0.610
Sandy	1.220

Leaching and over irrigation related data

Include data	
Leaching Factor	Over Irrigation factor
0	0
Combined factor	0

Include data
Leaching /over irr return flow factor
0

Observed Return Flow Data

Include data
Tail water flows
cub. m/a
1822293.104

Include data
Surface return flows
cub. m/a
no data

Include data
Seepage return flos
cub. m/a
no data

Crop water use

TOTAL Consumptive Crop water use (cub.m/a) From SAPWAT
15,285,129

Sub Areas	Crop water use per sub area (cub.m/a)
sub area 1	6,114,052
sub area 2	9,171,077
sub area 3	
sub area 4	
sub area 5	

Sheet B-64: Sand Vet Scheme: Allemanskraal canal zone 7: Results

IRRIGATION RETURN FLOW MODEL OUTPUT DATA

Name of Irrigation Scheme: Sand-Vet Irrigation Scheme_Sand Canal_Zone 7

Calibration

Gross releases into main canal

Source 1	Canal releases
Compare for calibration purposes	
Observed /Actual releases	29,915,234
Total requirement calculated	29,915,234

Source 2	none
Compare for calibration purposes	
Observed /Actual releases	no data avaiable
Total requirement calculated	0

Total requirement	
	29,915,234
Network distribution losses	11,499,416

Main distribution network return flow

Seepage Return Flow			
Total potensial return flow	cub. m/a	8,417,572	Based on estimated fraction
Max. possible return flow	cub. m/a	898,168	Based on Darcy flow equation

Seepage	cub. m/a	% of total network losses
Return flow from network losses	898,168	8
(smallest of potensial and possible return flow)		

	cub. m/a	% of total network losses
Tail water return flow	1,822,657	
Total return flow from network losses	2,720,825	24

Return flow from irrigation fields

Total potensial return flow	cub. m/a	832,763	Based on estimated fraction
Max. possible return flow	cub. m/a	722,521	Based on Darcy flow equation

	cub. m/a	% of Gross irr.
Return flow from irr. Area	722,521	4
(smallest of potensial and possible return flow)		(network losses excluded)

Total return flow from irrigation scheme

Total return flow from scheme	cub. m/a	% of gross releases	Observed
Seepage	1,620,689	5.4	no data
Surface return flow	36,380	0.1	no data
Tail water	1,822,657	6.1	1822293.1
Total return flow from scheme	3,479,726	11.6	1,822,293

Sheet B-65: Sand Vet Scheme: Allemanskraal canal zone 8: Input

IRRIGATION RETURN FLOW MODEL INPUT DATA

Name of Irrigation Scheme: Sand-Vet Irrigation Scheme_Sand Canal_Zone 8

Calibration

Gross releases into canals

Include data	
Observed /Actual releases	
Source 1	Canal releases
cub. m/a	4,900,289
Area (ha)	586

Supply from other sources

Include data	
Observed /Actual releases	
Source 2	none
cub. m/a	no data avaiable
Area (ha)	0

Main distribution network input data

Include data
% Network distribution losses
38.41
Network losses % tailwater
15.76
% Network losses return flow
73.3
% of Time canals dry
5.77

Sub Areas	Effective canal length (m)	Distance from River (m)	Height above River/drainage point (m)
sub area 1	15,000	1,300	20.0
sub area 2	10,000	2,000	20.0
sub area 3	10,500	1,500	30.0
sub area 4			
sub area 5			
Total length	35,500		

Sub Areas	K Selected from table
sub area 1	0.1
sub area 2	0.6
sub area 3	0.6
sub area 4	
sub area 5	

Typical value for soil between canal and drainage point

Soil class textural	Permiability(k) m/day
Silt Clay	0.06
Clay	0.12
Clay-loam	0.185
Loam	0.25
Sandy loam	0.61
Sandy	1.22

Irrigation application system input data

	Include data
	% Irrigation application losses
Accepted	17
Suggested	17

% of irrigated area irrigated with given system	Type of Irrigation system	Irrigation system efficiency (%) Accepted efficiency (%)	Suggested efficiency (%)	Application losses return flow factor	Distribution uniformity CU/EU (%) Accepted CU/EU	Suggested CU/EU
0	Drip	95	95	0.2	85	85
0	Micro	90	90	0.15	85	85
20	Sprinkler	75	75	0.1	73	73
80	Pivot	85	85	0.1	90	90
0	Flood	65	60	0.8	100	100
100	Weighted average	83	Suggested factor	0.10	86.6	Weighted average
			Accepted factor	0.1	Distibution uniformaty return flow factor	
					Suggested factor	0.034
					Accepted factor	0.034

Include data	
Total area irrigated (ha)	
586	
Irrigation days per year on average	
365	
Surface water return flow factor	
0.33	Default 0.33

Sub Areas	Wetted drainage Perimeter (m)	Distance from River (m)	Height above River/drainage point (m)	Total area irrigated (ha) Area
sub area 1	15,000	1,000	15.0	234
sub area 2	10,000	1,500	15.0	117
sun area 3	10,500	1,000	25.0	234
sun area 4				
sun area 5				
	60.63	Average wetted perimeter per ha		

Sub Areas	K Selected from table
sub area 1	0.100
sub area 2	0.600
sun area 3	0.600
sun area 4	
sun area 5	

Typical value for soil between irrigation field and drainage point

Soil class textural	Permiability(k) m/day
Silt Clay	0.060
Clay	0.120
Clay-loam	0.185
Loam	0.250
Sandy loam	0.610
Sandy	1.220

Leaching and over irrigation related data

Include data	
Leaching Factor	Over Irrigation factor
0	0
Combined factor	0

Include data
Leaching /over irr return flow factor
0

Observed Return Flow Data

Include data
Tail water flows
cub. m/a
296652.3657

Include data
Surface return flows
cub. m/a
no data

Include data
Seepage return flos
cub. m/a
no data

Crop water use

TOTAL Consumptive Crop water use (cub.m/a) From SAPWAT
2,505,013

Sub Areas	Crop water use per sub area (cub.m/a)
sub area 1	1,002,005
sub area 2	501,003
sub area 3	1,002,005
sub area 4	
sub area 5	

Sheet B-66: Sand Vet Scheme: Allemanskraal canal zone 8: Results

IRRIGATION RETURN FLOW MODEL OUTPUT DATA

Name of Irrigation Scheme:

Sand-Vet Irrigation Scheme_Sand Canal_Zone 8
Calibration

Gross releases into main canal

Source 1	Canal releases
Compare for calibration purposes	
Observed /Actual releases	4,900,289
Total requirement calculated	4,900,289

Source 2	none
Compare for calibration purposes	
Observed /Actual releases	no data avaiable
Total requirement calculated	0

Total requirement
4,900,289
Network distribution losses
1,882,201

Main distribution network return flow

Seepage Return Flow			
Total potensial return flow	cub. m/a	1,379,653	Based on estimated fraction
Max. possible return flow	cub. m/a	936,421	Based on Darcy flow equation

	cub. m/a	% of total network losses
Seepage		
Return flow from network losses	936,421	50
(smallest of potensial and possible return flow)		

	cub. m/a	% of total network losses
Tail water return flow	296,635	
Total return flow from network losses	1,233,056	66

Return flow from irrigation fields

Total potensial return flow	cub. m/a	136,478	Based on estimated fraction
Max. possible return flow	cub. m/a	944,438	Based on Darcy flow equation

	cub. m/a	% of Gross irr.
Return flow from irr. Area	136,478	5
(smallest of potensial and possible return flow)		(network losses excluded)

Total return flow from irrigation scheme

Total return flow from scheme	cub. m/a	% of gross releases	Observed
Seepage	1,072,899	21.9	no data
Surface return flow	0	0.0	no data
Tail water	296,635	6.1	296652.366
Total return flow from scheme	1,369,534	27.9	296,652

Sheet B-67: Sand Vet Scheme: Erfenis canal zone 1: Input

IRRIGATION RETURN FLOW MODEL INPUT DATA

Name of Irrigation Scheme: Sand-Vet Irrigation Scheme_Vet Canal_Zone1

Calibration

Gross releases into canals

Include data	
Observed /Actual releases	
Source 1	Canal releases
cub. m/a	42,835,733
Area (ha)	432

Supply from other sources

Include data	
Observed /Actual releases	
Source 2	none
cub. m/a	no data avaiable
Area (ha)	0

Main distribution network input data

Include data
% Network distribution losses
93.724
Network losses % tailwater
97.794
% Network losses return flow
1.874
% of Time canals dry
5.77

Sub Areas	Effective canal length (m)	Distance from River (m)	Height above River/drainage point (m)
sub area 1	15,000	1,200	10.0
sub area 2	13,500	2,100	20.0
sub area 3	14,000	1,300	7.0
sub area 4			
sub area 5			
Total length	42,500		

Sub Areas	K Selected from table
sub area 1	0.1
sub area 2	0.1
sub area 3	0.1
sub area 4	0
sub area 5	0

Typical value for soil between canal and drainage point

Soil class textural	Permiability(k) m/day
Silt Clay	0.06
Clay	0.12
Clay-loam	0.185
Loam	0.25
Sandy loam	0.61
Sandy	1.22

Irrigation application system input data

	Include data
	% Irrigation application losses
Accepted	17
Suggested	17

% of irrigated area irrigated with given system	Type of Irrigation system	Irrigation system efficiency (%) Accepted efficiency (%)	Suggested efficiency (%)	Application losses return flow factor	Distribution uniformity CU/EU (%) Accepted CU/EU	Suggested CU/EU
0	Drip	95	95	0.2	85	85
0	Micro	90	90	0.15	85	85
20	Sprinkler	75	75	0.1	73	73
80	Pivot	85	85	0.1	90	90
0	Flood	65	60	0.8	100	100
100	Weighted average	83	Suggested factor	0.10	86.6	Weighted average
			Accepted factor	0.1	Distibution uniformaty return flow factor	
					Suggested factor	0.034
					Accepted factor	0.034

Include data	
Total area irrigated (ha)	
432	
Irrigation days per year on average	
365	
Surface water return flow factor	
0.33	Default 0.33

Sub Areas	Wetted drainage Perimeter (m)	Distance from River (m)	Height above River/drainage point (m)	Total area irrigated (ha) Area
sub area 1	0	500	5.0	43
sub area 2	0	700	10.0	216
sun area 3	6,400	1,100	5.0	173
sun area 4				
sun area 5				
	14.80	Average wetted perimeter per ha		

Sub Areas	K Selected from table
sub area 1	0.100
sub area 2	0.100
sun area 3	0.100
sun area 4	
sun area 5	

Typical value for soil between irrigation field and drainage point

Soil class textural	Permiability(k) m/day
Silt Clay	0.060
Clay	0.120
Clay-loam	0.185
Loam	0.250
Sandy loam	0.610
Sandy	1.220

Leaching and over irrigation related data

Include data	
Leaching Factor	Over Irrigation factor
0	0
Combined factor	0

Include data
Leaching /over irr return flow factor
0

Observed Return Flow Data

Include data
Tail water flows
cub. m/a
39261814.4

Include data
Surface return flows
cub. m/a
no data

Include data
Seepage return flos
cub. m/a
no data

Crop water use

TOTAL Consumptive Crop water use (cub.m/a) From SAPWAT
2,231,348

Sub Areas	Crop water use per sub area (cub.m/a)
sub area 1	223,135
sub area 2	1,115,674
sub area 3	892,539
sub area 4	
sub area 5	

Sheet B-68: Sand Vet Scheme: Erfenis canal zone 1: Results

IRRIGATION RETURN FLOW MODEL OUTPUT DATA

Name of Irrigation Scheme:

Sand-Vet Irrigation Scheme_Vet Canal_Zone1
Calibration

Gross releases into main canal

Source 1	Canal releases
Compare for calibration purposes	
Observed /Actual releases	42,835,733
Total requirement calculated	42,835,733

Total requirement
42,835,733
Network distribution losses
40,147,363

Source 2	none
Compare for calibration purposes	
Observed /Actual releases	no data avaiable
Total requirement calculated	0

Main distribution network return flow

Seepage Return Flow			
Total potensial return flow	cub. m/a	752,362	Based on estimated fraction
Max. possible return flow	cub. m/a	74,843	Based on Darcy flow equation

	cub. m/a	% of total network losses
Seepage		
Return flow from network losses	74,843	0
(smallest of potensial and possible return flow)		

	cub. m/a	% of total network losses
Tail water return flow	39,261,712	
Total return flow from network losses	39,336,555	98

Return flow from irrigation fields

Total potensial return flow	cub. m/a	121,568	Based on estimated fraction
Max. possible return flow	cub. m/a	2,655	Based on Darcy flow equation

	cub. m/a	% of Gross irr.
Return flow from irr. Area	2,655	0
(smallest of potensial and possible return flow)		(network losses excluded)

Total return flow from irrigation scheme

Total return flow from scheme	cub. m/a	% of gross releases	Observed
Seepage	77,498	0.2	no data
Surface return flow	39,241	0.1	no data
Tail water	39,261,712	91.7	39261814.4
Total return flow from scheme	39,378,451	91.9	39,261,814

Sheet B-69: Sand Vet Scheme: Erfenis canal zone 2: Input

IRRIGATION RETURN FLOW MODEL INPUT DATA

Name of Irrigation Scheme: Sand-Vet Irrigation Scheme_Vet Canal_Zone2

Calibration

Gross releases into canals

Include data	
Observed /Actual releases	
Source 1	Canal releases
cub. m/a	39,261,814
Area (ha)	1,974

Supply from other sources

Include data	
Observed /Actual releases	
Source 2	none
cub. m/a	no data avaiable
Area (ha)	0

Main distribution network input data

Include data
% Network distribution losses
68.729
Network losses % tailwater
85.014
% Network losses return flow
12.734
% of Time canals dry
5.77

Sub Areas	Effective canal length (m)	Distance from River (m)	Height above River/drainage point (m)
sub area 1	9,500	1,500	18.0
sub area 2	10,000	2,000	15.0
sub area 3	6,000	2,500	22.0
sub area 4			
sub area 5			
Total length	25,500		

Sub Areas	K Selected from table
sub area 1	0.6
sub area 2	0.6
sub area 3	0.6
sub area 4	0
sub area 5	0

Typical value for soil between canal and drainage point

Soil class textural	Permiability(k) m/day
Silt Clay	0.06
Clay	0.12
Clay-loam	0.185
Loam	0.25
Sandy loam	0.61
Sandy	1.22

Irrigation application system input data

	Include data
	% Irrigation application losses
Accepted	17
Suggested	17

% of irrigated area irrigated with given system	Type of Irrigation system	Irrigation system efficiency (%) Accepted efficiency (%)	Suggested efficiency (%)	Application losses return flow factor	Distribution uniformity CU/EU (%) Accepted CU/EU	Suggested CU/EU
0	Drip	95	95	0.2	85	85
0	Micro	90	90	0.15	85	85
20	Sprinkler	75	75	0.1	73	73
80	Pivot	85	85	0.1	90	90
0	Flood	65	60	0.8	100	100
100	Weighted average	83	Suggested factor	0.10	86.6	Weighted average
			Accepted factor	0.1	Distibution uniformaty return flow factor	
					Suggested factor	0.034
					Accepted factor	0.034

Include data	
Total area irrigated (ha)	
1,974	
Irrigation days per year on average	
365	
Surface water return flow factor	
0.33	Default 0.33

Sub Areas	Wetted drainage Perimeter (m)	Distance from River (m)	Height above River/drainage point (m)	Total area irrigated (ha) Area
sub area 1	9,500	1,000	15.0	987
sub area 2	10,000	1,500	8.0	790
sun area 3	6,000	1,800	20.0	197
sun area 4				
sun area 5				
	12.91	Average wetted perimeter per ha		

Sub Areas	K Selected from table
sub area 1	0.600
sub area 2	0.600
sun area 3	0.600
sun area 4	
sun area 5	

Typical value for soil between irrigation field and drainage point

Soil class textural	Permiability(k) m/day
Silt Clay	0.060
Clay	0.120
Clay-loam	0.185
Loam	0.250
Sandy loam	0.610
Sandy	1.220

Leaching and over irrigation related data

Include data	
Leaching Factor	Over Irrigation factor
0	0
Combined factor	0

Include data
Leaching /over irr return flow factor
0

Observed Return Flow Data

Include data
Tail water flows
cub. m/a
22940509.64

Include data
Surface return flows
cub. m/a
no data

Include data
Seepage return flos
cub. m/a
no data

Crop water use

TOTAL Consumptive Crop water use (cub.m/a) From SAPWAT
10,190,376

Sub Areas	Crop water use per sub area (cub.m/a)
sub area 1	5,095,188
sub area 2	4,076,151
sub area 3	1,019,038
sub area 4	
sub area 5	

Sheet B-70: Sand Vet Scheme: Erfenis canal zone 2: Results

IRRIGATION RETURN FLOW MODEL OUTPUT DATA

Name of Irrigation Scheme:

Sand-Vet Irrigation Scheme_Vet Canal_Zone2	
Calibration	

Gross releases into main canal

Source 1	Canal releases
Compare for calibration purposes	
Observed /Actual releases	39,261,814
Total requirement calculated	39,261,814

Source 2	none
Compare for calibration purposes	
Observed /Actual releases	no data avaiable
Total requirement calculated	0

Total requirement	39,261,814
Network distribution losses	26,984,252

Main distribution network return flow

Seepage Return Flow			
Total potensial return flow	cub. m/a	3,436,175	Based on estimated fraction
Max. possible return flow	cub. m/a	447,971	Based on Darcy flow equation

	cub. m/a	% of total network losses
Seepage Return flow from network losses (smallest of potensial and possible return flow)	447,971	2

	cub. m/a	% of total network losses
Tail water return flow	22,940,392	
Total return flow from network losses	23,388,363	87

Return flow from irrigation fields

Total potensial return flow	cub. m/a	555,191	Based on estimated fraction
Max. possible return flow	cub. m/a	426,776	Based on Darcy flow equation

	cub. m/a	% of Gross irr.
Return flow from irr. Area (smallest of potensial and possible return flow)	426,776	3 (network losses excluded)

Total return flow from irrigation scheme

Total return flow from scheme	cub. m/a	% of gross releases	Observed
Seepage	874,747	2.2	no data
Surface return flow	42,377	0.1	no data
Tail water	22,940,392	58.4	22940509.6
Total return flow from scheme	23,857,516	60.8	22,940,510

Sheet B-71: Sand Vet Scheme: Erfenis canal zone 3: Input

IRRIGATION RETURN FLOW MODEL INPUT DATA

Name of Irrigation Scheme: Sand-Vet Irrigation Scheme_Vet Canal_Zone3

Calibration

Gross releases into canals

Include data	
Observed /Actual releases	
Source 1	Canal releases
cub. m/a	22,940,510
Area (ha)	2,458

Supply from other sources

Include data	
Observed /Actual releases	
Source 2	none
cub. m/a	no data avaiable
Area (ha)	0

Main distribution network input data

Include data
% Network distribution losses
33.372
Network losses % tailwater
34.238
% Network losses return flow
55.879
% of Time canals dry
5.77

Sub Areas	Effective canal length (m)	Distance from River (m)	Height above River/drainage point (m)
sub area 1	7,500	2,800	22.0
sub area 2	7,500	5,000	20.0
sub area 3	7,000	2,900	25.0
sub area 4	5,000	3,500	8.0
sub area 5			
Total length	27,000		

Sub Areas	K Selected from table
sub area 1	0.6
sub area 2	0.6
sub area 3	0.6
sub area 4	0.6
sub area 5	0

Typical value for soil between canal and drainage point

Soil class textural	Permiability(k) m/day
Silt Clay	0.06
Clay	0.12
Clay-loam	0.185
Loam	0.25
Sandy loam	0.61
Sandy	1.22

Irrigation application system input data

	Include data
	% Irrigation application losses
Accepted	17
Suggested	17

% of irrigated area irrigated with given system	Type of Irrigation system	Irrigation system efficiency (%) Accepted efficiency (%)	Suggested efficiency (%)	Application losses return flow factor	Distribution uniformity CU/EU (%) Accepted CU/EU	Suggested CU/EU
0	Drip	95	95	0.2	85	85
0	Micro	90	90	0.15	85	85
20	Sprinkler	75	75	0.1	73	73
80	Pivot	85	85	0.1	90	90
0	Flood	65	60	0.8	100	100
100	Weighted average	83	Suggested factor	0.10	86.6	Weighted average
			Accepted factor	0.1	Distibution uniformaty return flow factor	
					Suggested factor	0.034
					Accepted factor	0.034

Include data	
Total area irrigated (ha)	
2,458	
Irrigation days per year on average	
365	
Surface water return flow factor	
0.33	Default 0.33

Sub Areas	Wetted drainage Perimeter (m)	Distance from River (m)	Height above River/drainage point (m)	Total area irrigated (ha) Area
sub area 1	7,500	3,000	15.0	983
sub area 2	7,500	5,000	15.0	860
sun area 3	7,000	6,000	20.0	369
sun area 4	5,000	2,000	5.0	246
sun area 5				
	10.98	Average wetted perimeter per ha		

Sub Areas	K Selected from table
sub area 1	0.600
sub area 2	0.600
sun area 3	0.600
sun area 4	0.600
sun area 5	

Typical value for soil between irrigation field and drainage point

Soil class textural	Permiability(k) m/day
Silt Clay	0.060
Clay	0.120
Clay-loam	0.185
Loam	0.250
Sandy loam	0.610
Sandy	1.220

Leaching and over irrigation related data

Include data	
Leaching Factor	Over Irrigation factor
0	0
Combined factor	0

Include data
Leaching /over irr return flow factor
0

Observed Return Flow Data

Include data
Tail water flows cub. m/a
2621135.841

Include data
Surface return flows cub. m/a
no data

Include data
Seepage return flos cub. m/a
no data

Crop water use

TOTAL Consumptive Crop water use (cub.m/a) From SAPWAT
12,686,386

Sub Areas	Crop water use per sub area (cub.m/a)
sub area 1	5,074,555
sub area 2	4,440,235
sub area 3	1,902,958
sub area 4	1,268,639
sub area 5	

Sheet B-72: Sand Vet Scheme: Erfenis canal zone 3: Results

IRRIGATION RETURN FLOW MODEL OUTPUT DATA

Name of Irrigation Scheme: Sand-Vet Irrigation Scheme_Vet Canal_Zone3

Calibration

Gross releases into main canal

Source 1	**Canal releases**
Compare for calibration purposes	
Observed /Actual releases	22,940,510
Total requirement calculated	22,940,510

Total requirement	22,940,510
Network distribution losses	7,655,707

Source 2	**none**
Compare for calibration purposes	
Observed /Actual releases	no data avaiable
Total requirement calculated	0

Main distribution network return flow

Seepage Return Flow			
Total potensial return flow	cub. m/a	4,277,932	Based on estimated fraction
Max. possible return flow	cub. m/a	361,020	Based on Darcy flow equation

Seepage	cub. m/a	**% of total network losses**
Return flow from network losses	361,020	5
(smallest of potensial and possible return flow)		

Tail water return flow	2,621,161	
	cub. m/a	**% of total network losses**
Total return flow from network losses	2,982,181	39

Return flow from irrigation fields

Total potensial return flow	cub. m/a	691,179	Based on estimated fraction
Max. possible return flow	cub. m/a	156,494	Based on Darcy flow equation

	cub. m/a	**% of Gross irr.**
Return flow from irr. Area	156,494	1
(smallest of potensial and possible return flow)		(network losses excluded)

Total return flow from irrigation scheme

Total return flow from scheme	**cub. m/a**	**% of gross releases**	Observed
Seepage	517,514	2.3	no data
Surface return flow	176,446	0.8	no data
Tail water	2,621,161	11.4	2621135.84
Total return flow from scheme	3,315,121	14.5	2,621,136

Sheet B-73: Sand Vet Scheme: Erfenis canal zone 4: Input

IRRIGATION RETURN FLOW MODEL INPUT DATA

Name of Irrigation Scheme: Sand-Vet Irrigation Scheme_Vet Canal_Zone 4

Calibration

Gross releases into canals

Include data	
Observed /Actual releases	
Source 1	Canal releases
cub. m/a	9,338,400
Area (ha)	1,297

Supply from other sources

Include data	
Observed /Actual releases	
Source 2	none
cub. m/a	no data avaiable
Area (ha)	0

Main distribution network input data

Include data
% Network distribution losses
0
Network losses % tailwater
0
% Network losses return flow
0
% of Time canals dry
0

Sub Areas	Effective canal length (m)	Distance from River (m)	Height above River/drainage point (m)
sub area 1	0	0	0.0
sub area 2	0	0	0.0
sub area 3			
sub area 4			
sub area 5			
Total length	0		

Sub Areas	K Selected from table
sub area 1	0
sub area 2	0
sub area 3	
sub area 4	
sub area 5	

Typical value for soil between canal and drainage point

Soil class textural	Permiability(k) m/day
Silt Clay	0.06
Clay	0.12
Clay-loam	0.185
Loam	0.25
Sandy loam	0.61
Sandy	1.22

Irrigation application system input data

	Include data
	% Irrigation application losses
Accepted	17
Suggested	17

% of irrigated area irrigated with given system	Type of Irrigation system	Irrigation system efficiency (%) Accepted efficiency (%)	Suggested efficiency (%)	Application losses return flow factor	Distribution uniformity CU/EU (%) Accepted CU/EU	Suggested CU/EU
0	Drip	95	95	0.2	85	85
0	Micro	90	90	0.15	85	85
20	Sprinkler	75	75	0.1	73	73
80	Pivot	85	85	0.1	90	90
0	Flood	65	60	0.8	100	100
100	Weighted average	83	Suggested factor	0.10	86.6	Weighted average
			Accepted factor	0.1	Distibution uniformaty return flow factor	
					Suggested factor	0.034
					Accepted factor	0.034

Include data	
Total area irrigated (ha)	
1,297	
Irrigation days per year on average	
365	
Surface water return flow factor	
0.33	Default 0.33

Sub Areas	Wetted drainage Perimeter (m)	Distance from River (m)	Height above River/drainage point (m)	Total area irrigated (ha) Area
sub area 1	14,000	3,000	10.0	389
sub area 2	16,000	2,500	22.0	908
sun area 3				
sun area 4				
sun area 5				
	23.13	Average wetted perimeter per ha		

Sub Areas	K Selected from table
sub area 1	0.600
sub area 2	0.600
sun area 3	
sun area 4	
sun area 5	

Typical value for soil between irrigation field and drainage point

Soil class textural	Permiability(k) m/day
Silt Clay	0.060
Clay	0.120
Clay-loam	0.185
Loam	0.250
Sandy loam	0.610
Sandy	1.220

Leaching and over irrigation related data

Include data	
Leaching Factor	Over Irrigation factor
0	0
Combined factor	0

Include data
Leaching /over irr return flow factor
0

Observed Return Flow Data

Include data
Tail water flows
cub. m/a
no data

Include data
Surface return flows
cub. m/a
no data

Include data
Seepage return flos
cub. m/a
no data

Crop water use

TOTAL Consumptive Crop water use (cub.m/a) From SAPWAT
7,063,462

Sub Areas	Crop water use per sub area (cub.m/a)
sub area 1	2,119,039
sub area 2	4,944,423
sub area 3	
sub area 4	
sub area 5	

Sheet B-74: Sand Vet Scheme: Erfenis canal zone 4: Results

IRRIGATION RETURN FLOW MODEL OUTPUT DATA

Name of Irrigation Scheme:

Sand-Vet Irrigation Scheme_Vet Canal_Zone 4	
Calibration	

Gross releases into main canal

Source 1	**Canal releases**
Compare for calibration purposes	
Observed /Actual releases	9,338,400
Total requirement calculated	8,510,195

Source 2	**none**
Compare for calibration purposes	
Observed /Actual releases	no data avaiable
Total requirement calculated	0

Total requirement	8,510,195
Network distribution losses	0

Main distribution network return flow

Seepage Return Flow			
Total potensial return flow	cub. m/a	0	Based on estimated fraction
Max. possible return flow	cub. m/a	0	Based on Darcy flow equation

Seepage	cub. m/a	**% of total network losses**
Return flow from network losses	0	#DIV/0!
(smallest of potensial and possible return flow)		

Tail water return flow	0	
	cub. m/a	**% of total network losses**
Total return flow from network losses	0	#DIV/0!

Return flow from irrigation fields

Total potensial return flow	cub. m/a	384,831	Based on estimated fraction
Max. possible return flow	cub. m/a	390,287	Based on Darcy flow equation

	cub. m/a	**% of Gross irr.**
Return flow from irr. Area	384,831	5
(smallest of potensial and possible return flow)		(network losses excluded)

Total return flow from irrigation scheme

Total return flow from scheme	**cub. m/a**	**% of gross releases**	Observed
Seepage	384,831	4.5	no data
Surface return flow	0	0.0	no data
Tail water	0	0.0	no data
Total return flow from scheme	384,831	4.5	0