water affairs

Department:
Water Affairs
REPUBLIC OF SOUTH AFRICA

DIRECTORATE: WATER USE EFFICIENCY

CONTRACT NO. WP 10276

Development and Implementation of Irrigation Water Management Plans to Improve Water Use Efficiency in the Agricultural Sector

NZHELELE IRRIGATION SCHEME WATER MANAGEMENT PLAN

FINAL REPORT

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EXECUTIVE SUMMARY

Background

The Department of Water Affairs (DWA) through the Directorate: Water Use Efficiency commissioned a study to develop pilot Water Management Plans (WMPs) for fourteen (14) selected irrigation schemes as part of its assistance to the agriculture sector as well as to initiate a process whereby all irrigation schemes develop their own WMPs for implementation as required by the National Water Act (36 of 1998).

The study was informed by the fact that no progress had been made by the agricultural sector with respect to the development and implementation of WMPs for that sector. Furthermore the study was initiated to address the increasing water scarcity[1] in a number of Water Management Areas (WMAs).

One of the approaches in addressing the increasing water scarcity and competition for water is to ensure that existing water users utilise their existing water entitlement efficiently.

Project Objectives and approach taken

The primary objective of the study is the development and implementation of irrigation WMPs for 14 irrigation schemes to improve water use efficiency in the agricultural sector. However the focus of the study was at the irrigation scheme level with minimal work conducted to determine on-farm irrigation water use efficiency levels.

In order to achieve this objective, the following tasks have to be undertaken:

- Compilation of a situation assessment of the current water use and irrigation water use practices in the fourteen irrigation schemes
- Determination of the irrigation water budget and establishing water use baseline for each irrigation scheme
- Determination of the irrigation water management issues based on the situation assessment and water budgets prepared for each irrigation scheme
- Identification of opportunities to improve water use efficiency in the agricultural sector

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[1] Water scarcity – this is an imbalance of supply and requirement under prevailing institutional arrangements indicating an excess of water requirements over available water at the required assurance of supply, especially if the remaining supply options are difficult or costly to tap. The current utilisation as a percentage of total available resources at the required assurance of supply can illustrate the scale of the problem and the latitude for policymakers

- Benchmarking of irrigation water use efficiency and setting irrigation water use efficiency targets for each scheme
- Preparation of an irrigation water management plan for each irrigation scheme
- Capacity building of the Government Water Schemes (GWSs), Irrigation Boards (IBs) and Water User Associations (WUAs) to implement the identified opportunities to improve irrigation water use efficiency

Overview of the Nzhelele Irrigation Scheme

The Nzhelele Irrigation Scheme was established in the late 1940's with the construction of the Nzhelele Dam (which has a storage capacity of 51.2 million m^3). **Figure 1** below provides a schematic layout of the Nzhelele Irrigation Scheme.

Schedule of rateable area

The Nzhelele Irrigation Scheme has a total schedule of rateable area of 2 914 hectares, which is supplied from the Nzhelele Dam canal system. There are also river irrigators just below the dam, who are supplied directly from the Nzhelele Dam and not through the canal system. The Nzhelele Irrigation Scheme has a total scheduled quota of 24.49 million m^3/a, at 8 400 m^3 per ha per annum scheduled allocation.

The main types of crops irrigated in the Nzhelele Irrigation Scheme are oranges and grape fruit which comprise approximately 86% of the irrigated area in the irrigation scheme area. The other crops include citrus fruits, namely lemons and naartjies.

Conveyance and delivery infrastructure

Water to the water users in the Nzhelele Irrigation Scheme is delivered through a system of canal infrastructure comprising the main canal known as the N canal.

There are five (5) branch canals from the main canal which include (i) A canal system which is concrete lined, (ii) B canal which is a pipeline supplying two irrigators; (iii) C canal which supplies irrigators in the furthest area of the scheme; (iv) the D canal which is the first branch canal below the balancing dam; (v) the E canal which is the last branch canal in the scheme; and (vi) the F canal which supplies an irrigator just before the balancing Dam. All these branch canals deliver water to the sluice gates at the irrigators' farms.

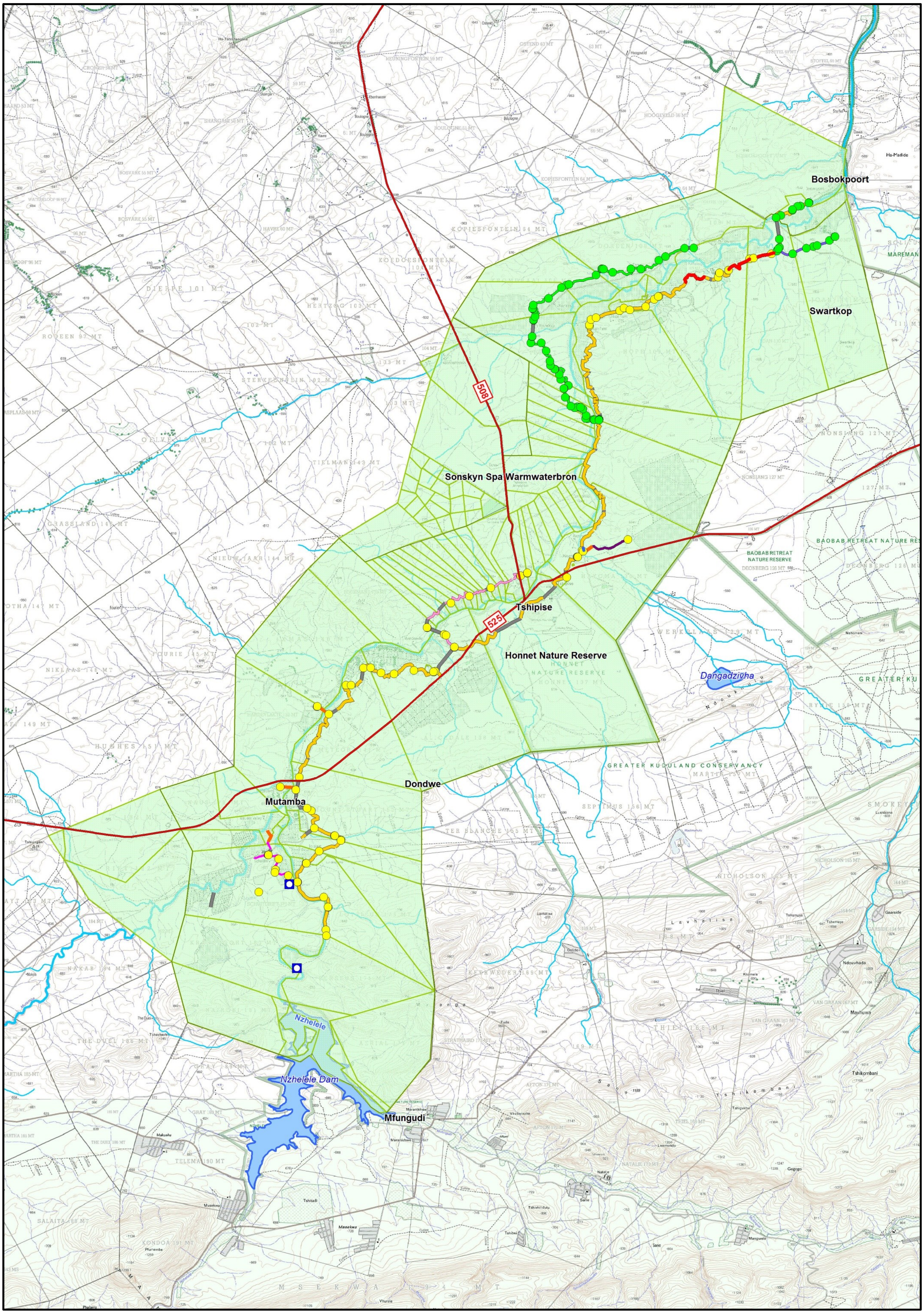

Figure 1: Layout of the Nzhelele Government Water Scheme

The total length of the canal infrastructure excluding drainage canals is approximately 63.25 km with all the canals concrete lined. There is approximately 10.9 km of canal siphons in the Nzhelele irrigation scheme including the 0.7 km pipeline which is known as the B canal.

The condition of the canals was found to be generally fair to very poor in some sections, particularly in the Nzhelele canal were some panels had shifted mainly due to run-off and drainage problems.

Besides the canal infrastructure there are sluice gates and Parshall Flumes to measure the volume of water taken by each water user in the canal. There are 75 sluice gates at the farm turnouts through which irrigation water is delivered to the farmers.

Irrigation storage and regulation

There is a balancing dam in the Nzhelele Irrigation Scheme. The Nzhelele Balancing Dam provides the balancing and regulation of flow to downstream water users of the Nzhelele GWS. This balancing dam has the effect of reducing the time it takes to deliver water to downstream water users while balancing any irrigation spills from upstream water users.

The storage capacity of the Nzhelele balancing dam is not known. However there are flow measurements upstream and downstream of the balancing dam. This provides sufficient data and information to determine the changes in storage and therefore enable the determination of the water balance assessment of the scheme.

Findings of the situation assessments

A situation assessment of the Nzhelele Government Scheme was conducted to determine the water management issues affecting the effective and efficient use of the available water to the scheme. The assessment was not conducted at sub-scheme level, because there was no information available on the weekly inflows and irrigation applications to each of the branch canals in the scheme area.

Best Management Practice - Expected water losses

An evaluation of the expected water losses based on the existing canal infrastructure and assuming the infrastructure is maintained was conducted for the Nzhelele canal system. The analysis indicated that the unavoidable water losses due to evaporation and seepage based on the expected hydraulic conductivity of lined canals were 0.45 million m^3/a and 1.50 million m^3/a respectively, making a total of 1.95 million m^3/a of the unavoidable water losses. This translates into 8% of the total volume of water diverted into the Nzhelele canal system.

There are expected to be operational inefficiencies due to the canal filling required after the dry periods, the metering errors even after calibration as well as problems in matching supplies and demands when applicants make changes to their requirements during the week. This was determined to be 10% of the total releases into the Nzhelele canals respectively.

Based on the evaluation of the unavoidable water losses and the expected operational inefficiencies for the Nzhelele Irrigation Scheme, the water delivery Best Management Practice (BMP) should be based on the allowable water losses of approximately 18 % of the total inflow into the Nzhelele irrigation canals.

Water balance assessment

A water balance assessment that was conducted for the Nzhelele GWS irrigation scheme indicated that the water losses in scheme exceeded the minimum expected seepage and evaporation losses as well as the operational losses to achieve an economic level of water losses.

The average water losses based on the historic water use records was determined to be 32% (see **Table 1** below) of the total water diverted into the Nzhelele GWS. The estimated avoidable water losses was determined to be 6.2 million m^3/a or 24% of the total water diverted into the Nzhelele irrigation canal system.

Table 1: Summary of Water Losses in the Nzhelele Government Water Scheme

Description	Unavoidable losses ($m^3 * 10^6$)	BMP for operation & distribution	Avoidable losses ($m^3 * 10^6$)	Total losses ($m^3 * 10^6$)	% of total losses
Seepages	1.504		-		18%
Evaporation	0.448				5%
Filling losses		2.59	3.65	6.240	0%
Leakages					76%

Description	Unavoidable losses (m^3*10^6)	BMP for operation & distribution	Avoidable losses (m^3*10^6)	Total losses (m^3*10^6)	% of total losses
Spills					0%
Operational Losses					0%
Over delivery to users					0%
Canal end returns					0%
Other					0%
Total	1.952	2.59	3.65	8.193	
% of total losses	24%	32%	45%	100%	
% of total volume released into system	8%	10%	14%	32%	

Equivalent depth of water diverted per actual unit area irrigated

In order to determine the extent of conveyance water use efficiency in the Nzhelele Government Water Scheme, a performance indicator (PI) was developed based on the actual irrigation water and the water diverted into the scheme. The PI known as the equivalent depth of water diverted per actual unit area irrigated was determined.

In the Nzhelele Government Scheme, the trend line indicates the equivalent depth has been declining from 1 260 mm per m^2 of irrigated area in 2009 to 1 220 mm per m^2 of irrigated area in the 2011 water year (see **Figure 2** below). This decline could be an indication that the conveyance efficiency of the Nzhelele Government Water Scheme has been improving over the period after 2009. However, there were insufficient annual records to determine whether the decline in the equivalent depth would continue or not.

Because the equivalent depth indicator was determined at scheme level, it is likely that in some branch canals, the equivalent depth is increasing, which would be an indication that the water losses are much higher as is likely to be the case in the A canal because of the submerged conditions and the problems of algae and water grass.

Any improvements, for example, in on-farm water use efficiency may likely be offset with the increase in water losses. This conclusion has however only been reached with very limited data as no other historical data was available and will need to be verified in time.

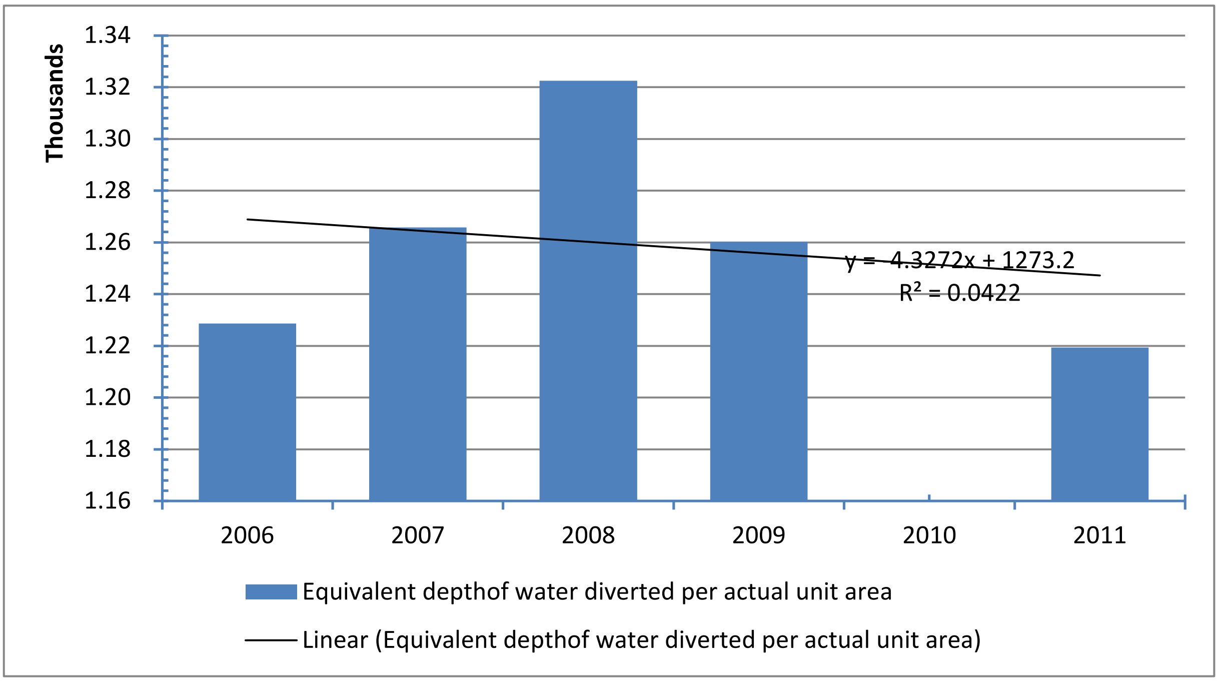

Figure 2: Irrigation water diversion expressed as an equivalent depth of water diverted per actual unit area irrigated for the Nzhelele GWS canals

Water Management Issues

A number of water management issues affecting the effective and efficient use of water in the Nzhelele Irrigation Scheme were identified based on the water balance assessment, discussions with scheme managers and some field work that was conducted. The main water management issues identified include the following:

(i) There is lack of measurement at some of the critical points in the scheme for a comprehensive water balance assessment to be conducted. These include the canal tail ends as well as flows into the balancing dam and the branch canals. The spills at the last canal tail-end are considered losses and can be avoided if regular flow measurements were taken. Therefore the current water balances are not accurate as they are based on estimates.

(ii) The accuracy of some of the measuring systems such as Parshall Flumes which were found to be operating in submerged conditions was found to be very low.

(iii) There is lack of continuous flow monitoring to enable quick responses to operational problems and this has resulted in the low water use efficiency levels in the Nzhelele Irrigation Scheme.

(iv) The water administration system to manage water use is not being fully utilised for sub-scheme water budgets.

(v) The conditions of the canal infrastructure, particularly in the Nzhelele right bank canal system were found to be poor. There are sections of the canal which will require complete renewal as some of the concrete panel sections have moved. This is attributed to soils conditions of the area. The DWA has already commenced with the refurbishment of these canal sections.

(vi) The capacity of the Nzhelele GWS to conduct full maintenance of the canal infrastructure including refurbishment is limited while the current water charge by the DWA for the Return on Assets (ROA) does not appear to cover for the full cost of depreciation of the assets.

(vii) The current water rate structure does not have elements of incentive based pricing aspects. The fact that water users are charged a flat rate based on their scheduled quota does not provide an incentive to improve water use efficiency through managing demand.

Water Management Plan for the Nzhelele Irrigation Scheme

Establishment of water saving targets at sub-scheme level

The implementation of a Water Management Plan for the Nzhelele Irrigation Scheme to reduce water losses will imply reducing the water diverted per unit of the land area irrigated in the scheme. As is expected, this will not affect the yields of the maize, wheat and vegetable crops being irrigated in the scheme area.

Therefore reducing the water diverted per unit of land area would mean an increase in productivity per unit of water which would be a clear indication of progress towards greater efficiency for the Nzhelele Irrigation Scheme assuming the scheduled quota of 8 400 m^3/ha/a remains constant.

A number of water management intervention measures were identified and a management plan developed to improve irrigation conveyance water use efficiency by reducing the avoidable water losses. The long term water savings targets for improving water use conveyance efficiency in the Nzhelele Government Water Scheme is to save approximately 5.24 million m^3/a over a 10 year period (see **Table 1** below).

Table 2: Estimated water saving targets for the Nzhelele Government Water Scheme (million m^3/a)

Description	System Inflow	Present Situation - Losses					Acceptable Water Losses		Target Water Savings		
		Unavoidable losses	BMP for distribution losses	Avoidable losses	Total losses	% of Total Volume Released	Annual Volume	% of Total Volume Released	Annual Volume	% of Total Volume Released	Intervention measure
Seepages		1.50			1.50	5.8%			0	0%	None
Evaporation		0.45			0.45	1.7%			0	0%	None
Filling losses										0%	
Over delivery to users										0%	
Leakages									1.55	6%	Refurbishment & resealing
Infrastructure condition			2.59	3.65	6.24	24.1%					
Operational Losses									0.91	4%	Removal of aquatic weeds & water grass
									0.73	3%	Flow measurement

Description	System Inflow	Present Situation - Losses					Acceptable Water Losses		Target Water Savings		
		Unavoidable losses	BMP for distribution losses	Avoidable losses	Total losses	% of Total Volume Released	Annual Volume	% of Total Volume Released	Annual Volume	% of Total Volume Released	Intervention measure
											& monitoring
										0%	Recalibration of Parshall flumes
Canal end returns									0.46	2%	Canal tail ends
										0%	Operational spills
Other					0.00	0.0%				0%	
Total Loss		1.95	2.59	3.65	8.19	31.6%	4.54	18%	3.65	14%	
Loss as a % of total losses		24%	32%	45%	100%						
Loss as a % of total volume released into system		8%	10%	14%	32%						
Total releases into Scheme	25.95										

Identified water management measures to improve water use efficiency in the Nzhelele Irrigation Scheme

The priority water management measures to improve irrigation water use efficiency on the Nzhelele Government Water Scheme include the following:

(1) Water measurements of the flow rates, duration and volume of flows at all the critical points, which include the inflow and outflow at the balancing dam, the branch canals, as well as the canal tail ends, etc.

(2) Preparation of more detailed water balance assessments for the Nzhelele Government Water scheme, as well as the sub-schemes to enable prioritisation of intervention on the sub-schemes where the conveyance efficiency levels are found to be very low.

(3) Implementation of a more complete water accounting system such as the WAS programme to enable irrigation monitoring and control of water use to reduce operational losses such as canal tail ends spills to be carried out as well as undertake water balance assessment at scheme as well as sub-scheme level,

(4) Reducing the algae and water grass problems which are affecting the hydraulic capacity of the canal infrastructure resulting in flow measurement inaccuracy.

(5) Installation of telemetry infrastructure to enable real time monitoring of irrigation water in the long term.

(6) Maintenance and refurbishment of the existing delivery canals as well as the siphons, in order to reduce leakage losses, improve flow rates and increase head at diversion points.

(7) Developing an incentive based water pricing structure to improve irrigation water use efficiency and reduce significant fluctuations in demand.

Conclusions and Recommendations

A water management plan for the Nzhelele Irrigation Scheme was developed to address the water losses taking place in the scheme and to improve irrigation water management of the scheme. The identified measures for implementation to reduce the water losses from the current 32% to 18% of the total inflow into the irrigation scheme include the following:

(i) *Reduce operational losses at canal tail ends* - This measure has a high benefit with estimated water savings of 0.46 million m^3/a. These can be achieved at the least cost as no capital investment requirements is necessary to change the current operating procedures which ensures minimal or no flows take place at the canal tail ends.

(ii) *Improving water measurement system and flow monitoring* - This measure is the main driver for the above intervention. The direct estimated water savings of 0.73 million m^3/a, can be achieved by calibration of the Parshall Flumes and taking flow measurements consistently at the identified critical points. It is also easier to implement and should be considered a priority as all other measures are dependent on availability of sufficient water measurements in the Nzhelele Irrigation Scheme.

(iii) *Chemical management of aquatic weeds and algae growth in canals* - This measure benefits the scheme with estimated water savings of 0.91 million m^3/a. It should be carried out at the same time as the first two intervention measures because of its impact on the hydraulic capacity of the canals.

(iv) *Water Accounting System* - This measure is aligned to the first measure listed above and will provide the system necessary to identify areas where irrigation water management can be improved. The changes in operation of the canals and canal tail ends can result in significant water savings if no water is allowed to flow out the canal tail ends at the end of the scheme.

(v) *Refurbishment of the canals and siphons* - The capital investment requirements for this measure is very high and requires a long lead time to implement. However it has the highest water saving target with approximately 1.55 million m^3/a being able to be achieved over a 10 year period.

(vi) *Incentive based water pricing structure*- This measure has a high benefit with estimated water savings of 1.5 million m^3/a. However there are legislative and administrative matters that need to be in place to enable incentive based pricing to be implemented effectively. Therefore a long lead time is required to implement this intervention measure.

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ABBREVIATIONS

AIC	Average Incremental Cost
BMP	Best Management Practice
DWA	Department: Water Affairs
ET	Evapo-Transpiration
EWR	Environmental Water Requirements
GWS	Government Water Scheme
GIS	Geographic Information System
GWS	Government Water Scheme
IB	Irrigation Board
MAE	Mean Annual Evaporation
MAP	Mean Annual Precipitation
MISD	Matching Irrigation Supply and Demand
O&M	Operation and Maintenance
RAT	Remote Assessment Tool
ROA	Return on Assets
RTU	Remote Telemetry Unit
SLA	Service Level Agreement
WARMS	Water Allocation Registration Management System
WAS	Water Administration System
WCA	Water Control Aid

WCD	Water Control Department
WC/WDM	Water Conservation and Water Demand Management
WCO	Water Control Officer
WMA	Water Management Area
WMP	Water Management Plans
WUA	Water User Association
WUEAR	Water Use Efficiency Accounting Report

GLOSSARY OF TERMS

Application efficiency The ratio of the average depth of irrigation water infiltrated and stored in the root zone to the average depth of irrigation water applied, expressed as a percentage.

Applied water: Water delivered to a user. Also called delivered water. Applied water may be used for either inside uses or outside watering. It does not include precipitation or distribution losses. It may apply to metered or unmetered deliveries

Conduit: Any open or closed channel intended for the conveyance of water.

Conservation: Increasing the efficiency of energy use, water use, production, or distribution.

Consumptive use (evapo-transpiration) Combined amounts of water needed for transpiration by vegetation and for evaporation from adjacent soil, snow, or intercepted precipitation. Also called: Crop requirement, crop irrigation requirement, and consumptive use requirement.

Conveyance loss: Loss of water from a channel or pipe during conveyance, including losses due to seepage, leakage, evaporation and transpiration by plants growing in or near the channel.

Conveyance system efficiency: The ratio of the volume of water delivered to irrigators in proportion to the volume of water introduced into the conveyance system.

Cropping pattern: The acreage distribution of different crops in any one year in a given farm area such as a county, water agency, or farm. Thus, a change in a cropping pattern from one year to the next can occur by changing the relative acreage of existing crops, and/or by introducing new crops, and/or by cropping existing crops.

Crop water requirement: Crop consumptive use plus the water required to provide the leaching requirements.

Crop irrigation Quantity of water, exclusive of effective precipitation, that is needed

requirement: for crop production.

Crop root zone: The soil depth from which a mature crop extracts most of the water needed for evapo-transpiration. The crop root zone is equal to effective rooting depth and is expressed as a depth in mm or m. This soil depth may be considered as the rooting depth of a subsequent crop, when accounting for soil moisture storage in efficiency calculations.

Deep percolation: The movement of water by gravity downward through the soil profile beyond the root zone; this water is not used by plants.

Demand scheduling: Method of irrigation scheduling whereby water is delivered to users as needed and which may vary in flow rate, frequency, and duration. Considered a flexible form of scheduling.

Distribution efficiency: Measure of the uniformity of irrigation water distribution over a field.

Distribution loss: See conveyance loss.

Distribution system: System of ditches, or conduits and their appurtenances, which conveys irrigation water from the main canal to the farm units.

Diversion (water): Removal of water from its natural channels for human use.

Diversion (structure): Channel constructed across the slope for the purpose of intercepting surface runoff; changing the accustomed course of all or part of a stream.

Drainage: Process of removing surface or subsurface water from a soil or area.

Drainage system: Collection of surface and/or subsurface drains, together with structures and pumps, used to remove surface or groundwater.

Drip (trickle) irrigation: An irrigation method in which water is delivered to, or near, each plant in small-diameter plastic tubing. The water is then discharged at a rate less than the soil infiltration capacity through pores, perforations, or small emitters on the tubing. The tubing may be laid on the soil

	surface, be shallowly buried, or be supported above the surface (as on grape trellises).
Drought:	Climatic condition in which there is insufficient soil moisture available for normal vegetative growth.
Dry Period :-	A period during which there will be no water flowing in the canal system.
Evaporation	Water vapour losses from water surfaces, sprinkler irrigation, and other related factors.
Evapo-transpiration:	The quantity of water transpired by plants or evaporated from adjacent soil surfaces in a specific time period. Usually expressed in depth of water per unit area.
Farm consumptive use:	Water consumptively used by an entire farm, excluding domestic use. See irrigation requirement, consumptive use, evapo-transpiration.
Farm distribution system:	Ditches, pipelines and appurtenant structures which constitute the means of conveying irrigation water from a farm turnout to the fields to be irrigated.
Farm loss (water)	Water delivered to a farm which is not made available to the crop to be irrigated.
Geographic Information System (GIS)	Spatial Information systems involving extensive satellite-guided mapping associated with computer database overlays
Incentive pricing	This involves setting water rates that provide motivation to use water efficiently
Irrigation schedule	This is the list prepared by the Board showing the sequence the Irrigators will lead and dependent on the scheduled area the time period that the Irrigator is entitled to receive water
Maintenance	This is the process of keeping the irrigation and drainage infrastructure assets in good repair and working order to fulfil the

functions for which they were created.

Modernisation This is the process of upgrading (replacing) an existing asset in order to meet enhanced technical capacity and level of service objectives.

On-farm: Activities (especially growing crops and applying irrigation water) that occur within the legal boundaries of private property.

On-farm irrigation efficiency: The ratio of the volume of water used for consumptive use and leaching requirements in cropped areas to the volume of water delivered to a farm (applied water).

Operational losses: Losses at the tail ends, sluices not opened or closed on time or opened to big and spills

Operational waste: Water that is lost or otherwise discarded from an irrigation system after having been diverted into it as part of normal operations.

Pan evaporation: Evaporative water losses from a standardized pan. Pan evaporation is sometimes used to estimate crop evapo-transpiration and assist in irrigation scheduling.

Parshall flume: A calibrated channel-like device, based on the principle of critical flow, used to measure the flow of water in open conduits. Formerly termed the Improved Venturi Flume.

Percolation: Downward movement of water through the soil profile or other porous media.

Rehabilitation This is the process of renovating an existing asset whose performance is failing to meet its original objective to its original design specifications. This may also be referred to as asset reproduction.

Reservoir: Body of water, such as a natural or constructed lake, in which water is collected and stored for use.

Return flow: That portion of the water diverted from a stream which finds its way back to the stream channel, either as surface or underground flow.

Return-flow system:	A system of pipelines or ditches to collect and convey surface or subsurface runoff from an irrigated field for reuse. Sometimes called a "reuse system" or "recovery system".
Risk cost	This is usually expressed as the product of the cost of damage caused by the actual hazard occurrence and the probability of occurrence.
Run-off	This is the water produced when irrigation water is applied to fields at rates and in amounts greater than can be infiltrated into the soil profile
Request Form :	A form on which an Irrigator requests the quantity of water he requires.
Tail end water	This is water at the endpoint of a canal
Telemetry	Involving a wireless means of data transfer
Water Note	A form issued by the Control Officer informing the Irrigator of the quantity of water he will be receiving.

1 INTRODUCTION

1.1 Background

Irrigation agriculture is the biggest water user in the South Africa, accounting for approximately 62% of the current water use nationally. With the increasing competition between existing water use sectors, the available water cannot meet the demand under current water use practices and operating conditions in all water use sectors. It is therefore imperative to ensure that available water supplies are used efficiently and effectively to avoid supply shortages and intermittent water supplies, which would have a major impact on the socio-economic growth and development of the country.

The savings that can potentially be made from implementing WC/WDM measures will delay in the need for the development of additional new water supplies, while ensuring that the natural environment is maintained or is not degraded further. The Department of Water Affairs (DWA) identified that, based on preliminary assessment of water losses in the agricultural sector, there was potential to implement measures to improve water use efficiency in the sector. The overall aim in reducing water losses and improving irrigation water use efficiency levels in the Water User Associations (WUAs)/Irrigation Boards (IBs) and Government Water Schemes (GWS) is that the limited available water can be optimally utilised to ensure a high economic return for the irrigators in the scheme.

The study was commissioned because of the increasing water scarcity[2] and competition for water in a number of Water Management Areas (WMAs). One of the approaches in addressing the increasing water scarcity and competition for water is to ensure that existing water users utilise their existing water entitlement efficiently. The Department of Water Affairs (DWA) Directorate: Water Use Efficiency, which has the mandate to ensure the efficient use of the water resources in the country by all water use sectors, identified that since the development of the pilot Water Management Plans (WMPs) for improving water use efficiency in irrigation agriculture, no progress had been made by the irrigation sector with respect to the development and implementation of WMPs for that sector.

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[2] Water scarcity – this is an imbalance of supply and requirement under prevailing institutional arrangements indicating an excess of water requirements over available water at the required assurance of supply, especially if the remaining supply options are difficult or costly to tap. The current utilisation as a percentage of total available resources at the required assurance of supply can illustrate the scale of the problem and the latitude for policymakers

In order to ensure the irrigation sector review their current water use efficiency levels and develop strategies to improve their water use efficiency, the DWA has identified a need to assist a number of irrigation schemes in developing their irrigation water management plans in order to primarily reduce their water losses. A secondary outcome can be seen as the enablement of irrigators to increase their on-farm irrigation efficiency.

Following the meetings with DWA Directorate: Water Use Efficiency, the Scheme Managers and the DWA Regional Office, this report provides the following:

- Overview of the water allocation and irrigation water use situation in the irrigation scheme and related institutional arrangement for irrigation water management.
- Identification and assessment of the water management issues and management goals expected to address the irrigation water management issues identified.

1.2 Study Objectives

The primary objective of the study is the development and implementation of irrigation WMPs for 14 irrigation schemes to improve water use efficiency and reduce water losses in the agricultural sector (See **Figure 1.1** below). In order to achieve this objective, the following tasks have to be undertaken:

- Compilation of a situation assessment of the current water use and irrigation water use practices in the fourteen irrigation schemes based on the irrigation scheme characteristics;
- Determination of the irrigation water balances and establishing water use baseline for each irrigation scheme;
- Determination of the irrigation water management issues based on the situation assessment and water budgets prepared for each irrigation scheme;
- Identification of opportunities to improve water use efficiency in the agricultural sector;
- Benchmarking of irrigation water use efficiency and setting irrigation water use efficiency targets for each scheme;
- Preparation of an irrigation water management plan for each irrigation scheme;
- Capacity building of the irrigation schemes to implement the identified opportunities to improve irrigation water use efficiency.

Figure 1.1 Location of the 14 irrigation schemes where WMPs have been developed

The development of WMPs for the selected irrigation schemes will not only provide a plan for reducing water losses and improve system efficiencies, but if the management plan is implemented and water losses and water demand is reduced, the benefits to the agricultural sector, irrigators and the users in the catchment in general will include:

- Improved system efficiencies;
- Reduction in irrigation water return flows;
- Reduction in system operation and maintenance expenses;
- Potential cost savings due to deferral or downsizing of capital works;
- Benefits which are important but difficult to quantify such as reduced environmental impact resulting from delays in or deferment of construction of water sources and the maintenance of higher water levels in rivers and reservoirs.

1.3 Structure of the report

This report has been structured to first provide a perspective of the Nzhelele Irrigation Scheme as well as the potential for irrigated agriculture in the Nzhelele River catchment.

Chapter 1 provides the overall objective of assessing water conservation and demand management measures in the context of increasing competition between existing water users and the need for water for the environment.

Chapter 2 describes the catchment characteristics of the Nzhelele River catchment in which the Nzhelele Irrigation Scheme is situated.

Chapter 3 describes the history of the Nzhelele Irrigation Scheme and the scheduled quota. It also describes the catchment and the current land-use practices in the catchment. The chapter also describes the background to the scheme and the institutional arrangements.

Chapter 4 gives an overview of the inventory of the existing irrigation water management infrastructure which includes the size and capacity of the canals, the dams supplying the scheme; any balancing dams in the Nzhelele Irrigation Scheme as well as the flow measurements available in the scheme.

Chapter 5 describes the condition of the conveyance infrastructure. A framework for determining the condition assessment of the infrastructure is described while the condition of the various sections of the main canals and the branch canals are discussed based on discussions with scheme operators; surveys conducted during the various site visits, and any available information.

Chapter 6 of this report describes how the scheme is currently being operated to provide water to the irrigators and any other users. The scheme operating procedures including how the irrigators are supplied during drought periods is presented in this chapter.

Chapter 7 uses the information from the previous chapters to determine the irrigation water Best Management Practices for the irrigation schemes. This determines how much water losses would be expected if the scheme infrastructure is well maintained. Therefore the approach used to determine the expected seepage losses as well as the evaporation losses are described in this chapter of the management plan. It then describes the standards that can be adopted as appropriate for benchmarking of irrigation water use and management practices.

Chapter 8 describes the water balance assessment, as conducted, based on the water use and compared with expected irrigation efficiency levels for the different irrigation systems. This chapter also provides the performance benchmarking of the irrigation sector when compared with the expected standards.

Chapter 9 of this report describes the existing irrigation water management measures that the irrigation scheme is currently undertaking to improve irrigation water management efficiency and reduce the water losses taking place in the irrigation scheme. These include flow measurement, availability of balancing dams, flow monitoring to reduce operational losses if any, canal maintenance during the dry periods; etc.

Chapter 10 then discusses the water management issues identified from the previous chapters. It then sets the management goals required to ensure any identified water management issues can be addressed.

Chapter 11 of the report provides an assessment of the identified water management measures that can be implemented to achieved the goals and objectives set in chapter 10. This is the strategic WC/WDM business plan for irrigation agriculture. The chapter also provides an estimate of the capital investment required to implement the strategy. It also provides the performance indicators for monitoring and controlling the implementation of the measures.

Chapter 12 presents the water management plan. This summarises all the water management issues, the irrigation water saving targets recommended to be achieved and the water management tasks to achieve the targets set to reduce water losses and improve irrigation water management efficiency of the scheme.

Chapter 13 provides conclusions and recommendations for the Irrigation Scheme.

2 CATCHMENT CHARACTERISTICS OF NZHELELE AND NZHELELE RIVER CATCHMENT

2.1 Overview

The Nzhelele Government Water Scheme (GWS) is situated in the Limpopo Water Management Area, which is in the Limpopo Province. It is in the Vhembe District Municipality with the nearest main town in the Nzhelele GWS being Mfungudi, located upstream of the government water supply scheme area. **Figure 2.1** presents the locality map of the Nzhelele Irrigation Scheme area.

The Nzhelele River has its headwaters in the Soutpansberg Mountains, upstream of Nzhelele Dam, the only major storage dam in the Nzhelele catchment. The dam has a storage capacity of 51.20 million m^3 and was constructed in 1948 to meet the irrigation water requirements of the lands downstream in the Nzhelele River catchment.

2.1.1 Climate and rainfall distribution

2.1.1.1 Precipitation

The climate and temperature variations of the Nzhelele River catchment are closely related to elevation. The study area experiences extreme conditions between the summer and winters months (DWAF: 1999) with rainfall categorised into one climatic zone.

The catchment in which the Nzhelele Government Water Scheme (GWS) is located is characterised by a mean annual precipitation (MAP) ranging from 400 mm to 499 mm in the whole scheme area (see **Figure 2.2** below). The low MAP indicates the need for irrigating the lands in the Nzhelele Irrigation Scheme area.

2.1.1.2 Evaporation

The Nzhelele Irrigation Scheme is located in one evaporation zone. The evaporation ranges between 1800 mm to 2000 mm in the whole of the irrigation scheme. The high evaporation rate has a direct correlation with the irrigation water use requirements.

Figure 2.1: Locality Map of Nzhelele Government Water Scheme

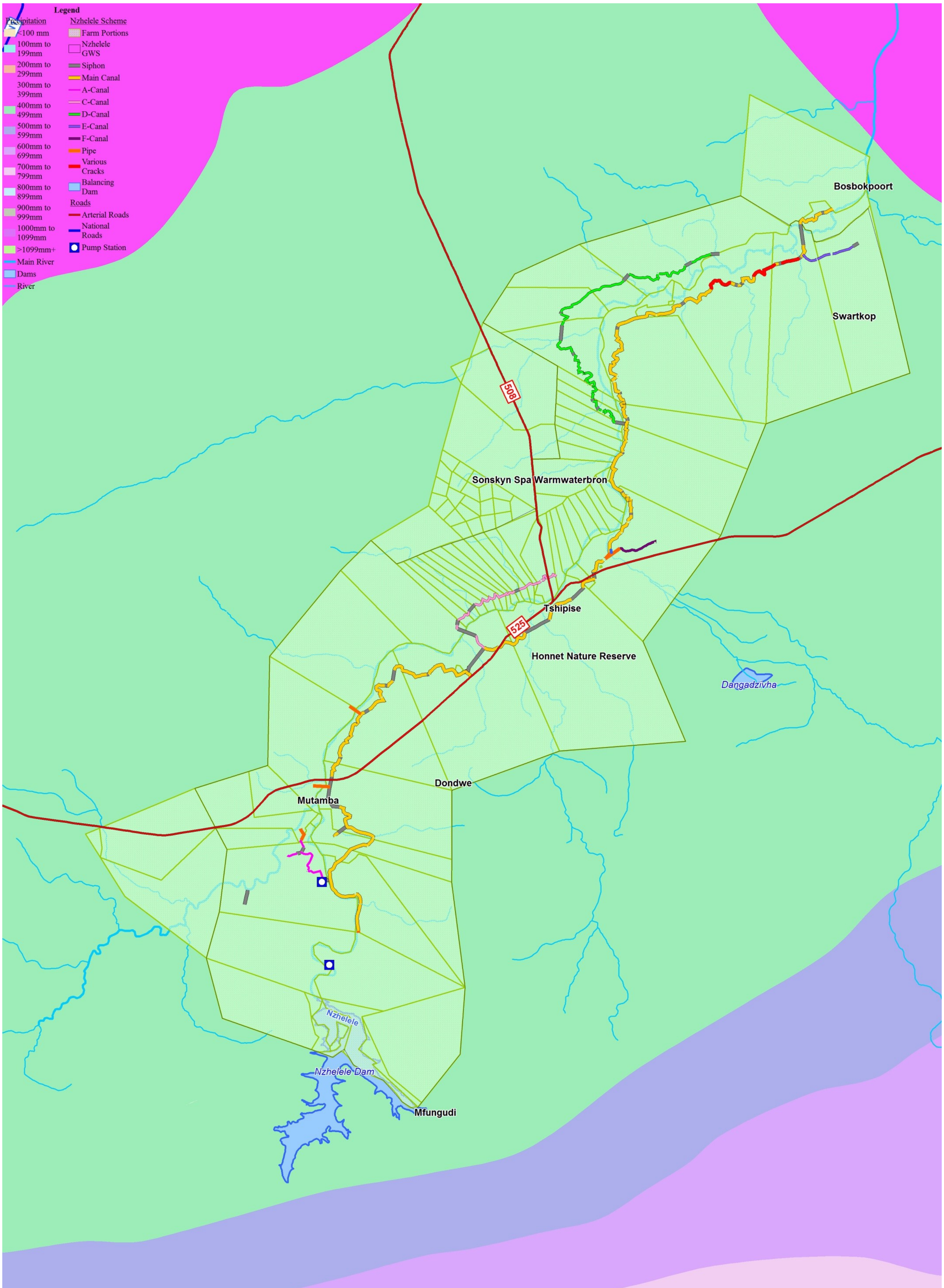

Figure 2.2: Precipitation Map of the Nzhelele Irrigation Scheme

2.1.2 Geology and soils of the catchment

The geology of the area supplied by Nzhelele Government Water Scheme (GWS) has predominantly an assemblage of sedimentary rocks.

As a result of the predominant geological strata as well as the climate, the soils of the Nzhelele Irrigation Scheme can be categorised as moderate to deep soils on flat terrain (see **Figure 2.3** below). The average soil depth in the scheme area is 1048.75 mm. These soils are coarse textured soils where the water and plant nutrient losses may be greater, so the timing and quantity of chemical and water applications is particularly critical.

There are four important levels of soil moisture content that reflect the availability of water in the soil. These levels are commonly referred to as: 1) saturation, 2) field capacity, 3) wilting point and 4) oven dry. The water held between field capacity and the wilting point is available for plant use and is known as water holding capacity. The water holding capacity of the Nzhelele soils ranges between 141.67 mm per m to 183.3 mm per m depth of available water for the crop (J.L. Schoeman and M. van der Walt. Therefore in order to meet this water holding capacity and because the Nzhelele soils possess a good characteristic and ability for draining water, supplemental irrigation water is required to meet the soil moisture requirements in the Nzhelele River catchment.

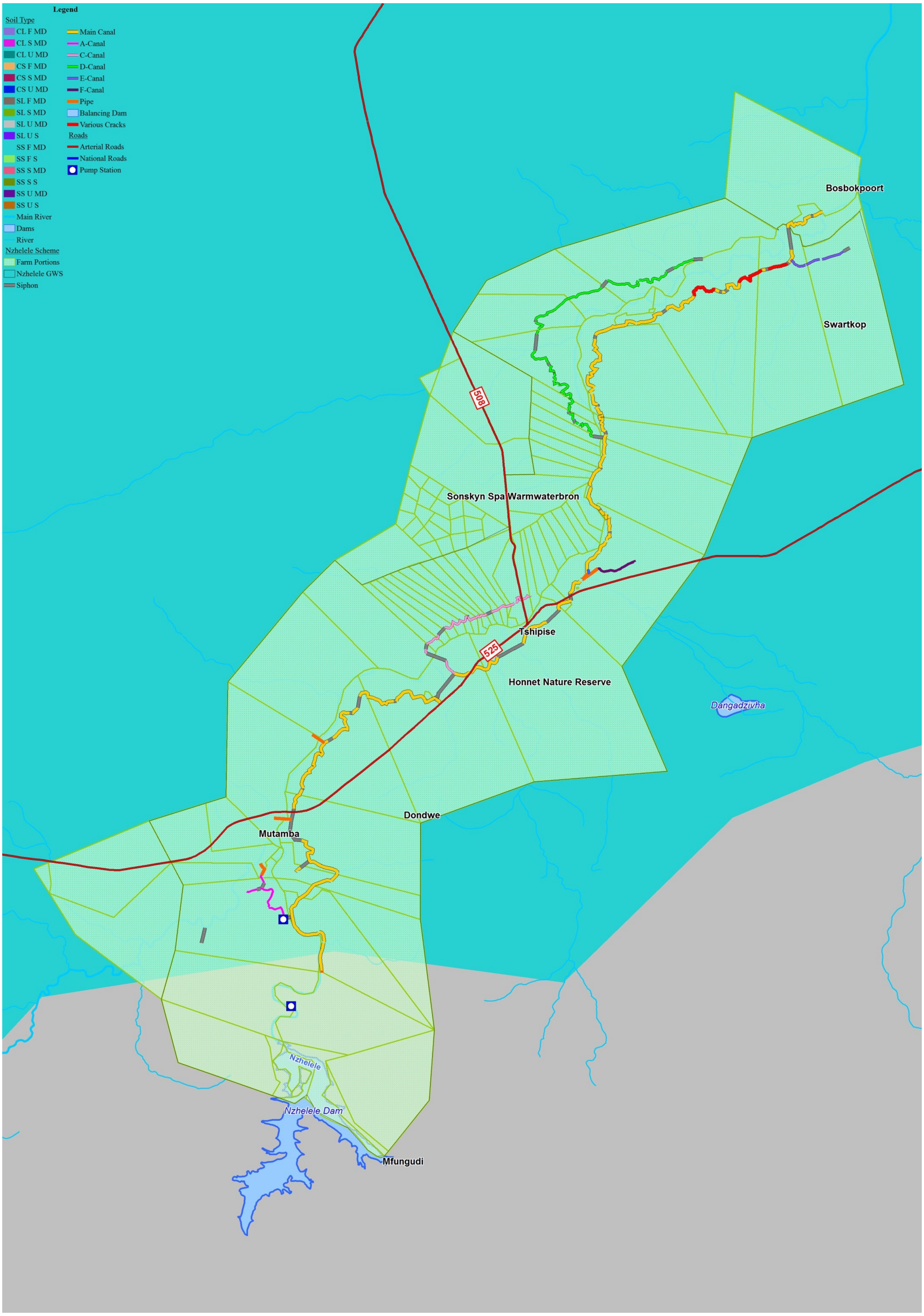

Figure 2.3: Nzhelele Irrigation Scheme Soil Map

3 OVERVIEW OF THE NZHELELE GOVERNMENT WATER SCHEME

3.1 History of the Nzhelele Irrigation Scheme

The scheme is located in the Musina area, near the border with Zimbabwe and receives its water from the Nzhelele Dam which is located in the Nzhelele River.

The Nzhelele Government Water Scheme was developed in the early 1950's after the construction of the Nzhelele Dam. The main irrigation canals were constructed downstream of the Nzhelele Dam on right bank of the Nzhelele River as discussed in the latter sections. However the branch canals cross the Nzhelele River to supply the irrigators who are mainly situated in the left bank of the river.

These canals convey the water to the irrigation areas located downstream of the dam and the weir along the Nzhelele River as indicated **in Figure 3.1** below.

3.2 Schedule rateable area

The Nzhelele Government Water Scheme (GWS) comprises a total of 2 914 hectares. The major irrigation area is below the Nzhelele Dam and stretches for approximately 35 km until Bosbokpoort.

The irrigation area is situated on both the right bank where the main canal traverses as well as the left bank where the branch canals cross the Nzhelele River through siphons to supply the farmers.

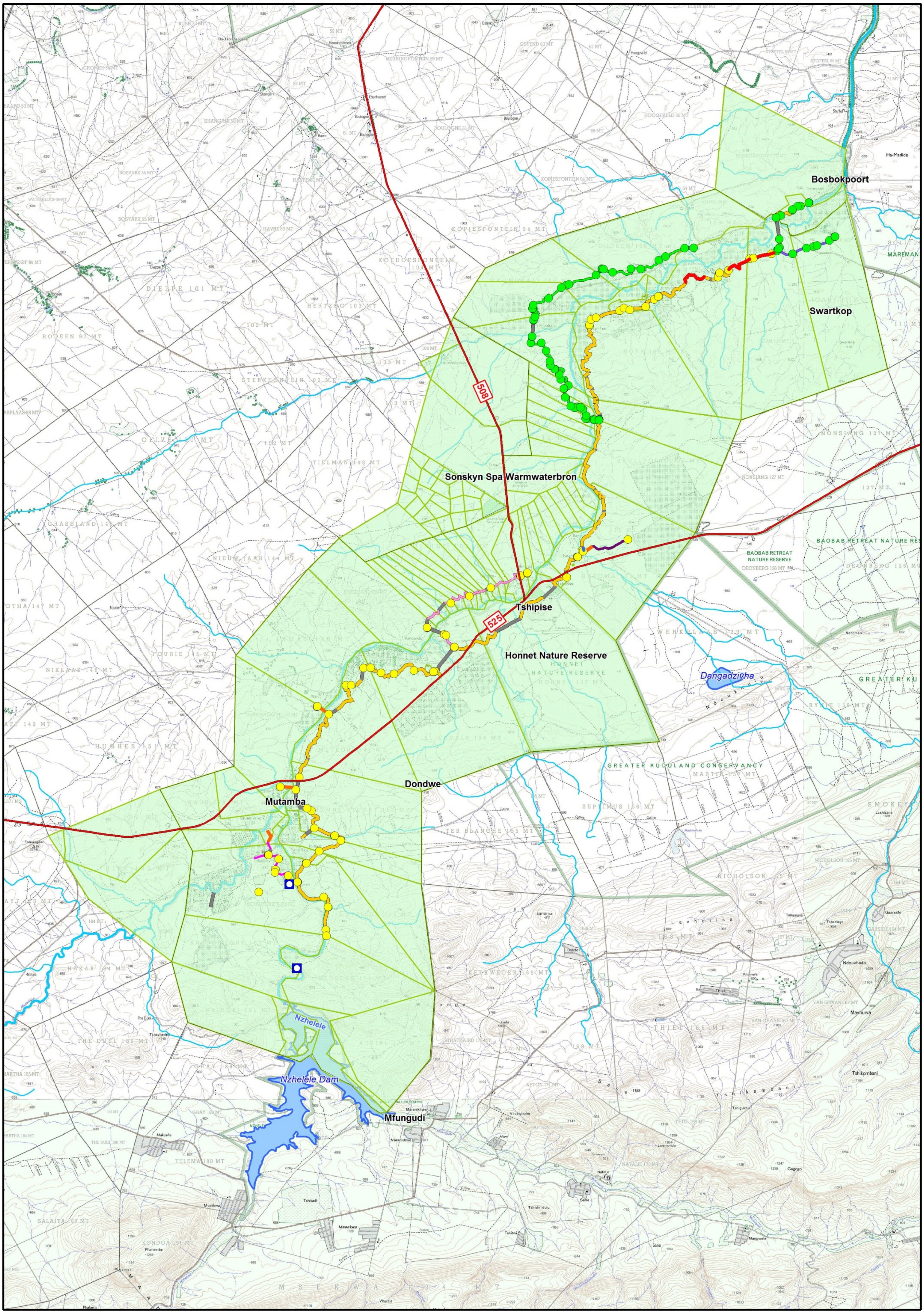

Figure 3.1: Nzhelele Government Water Scheme layout

3.3 Organisational arrangements

The Nzhelele Irrigation Scheme has been a government water scheme (GWS) since it was established. The DWA, through its Infrastructure Branch, is responsible for the operation and maintenance of the scheme. As part of the operation of the irrigation scheme, the Infrastructure Branch supplies water not only to the irrigators in the Nzhelele Government Water Scheme but also provides the water requirements for Tshipise, a holiday resort in the scheme area which withdraws raw water for treatment from the Nzhelele canal infrastructure.

Because ownership of the irrigation infrastructure (i.e. irrigation canals, balancing dam and associated appurtenance works such as sluices and weirs to deliver the water to irrigators) is owned and managed by the DWA Infrastructure Branch, any major refurbishment of the infrastructure is still being undertaken by the Department of Water Affairs.

Besides ownership of the irrigation infrastructure, the DWA Infrastructure Branch is responsible for the operation and maintenance of the irrigation scheme.

3.3.1 Water distribution Section

One of the key functions of the Nzhelele GWS is the distribution of irrigation water as required and on time as well as civil and/or mechanical maintenance of the Nzhelele Irrigation Scheme (see **Figure 3.2** below).

As part of the water distribution and/or operation of the irrigation scheme, the Nzhelele GWS supplies not only the irrigators but also the water requirements of domestic users and industries through the canal infrastructure of the scheme.

There are three levels in the water distribution section which include, the Chief: Water Control Officer (CWCO), the Water Control Officers (WCOs); as well as the Water Control Aids. Their responsibilities are discussed in the following sections.

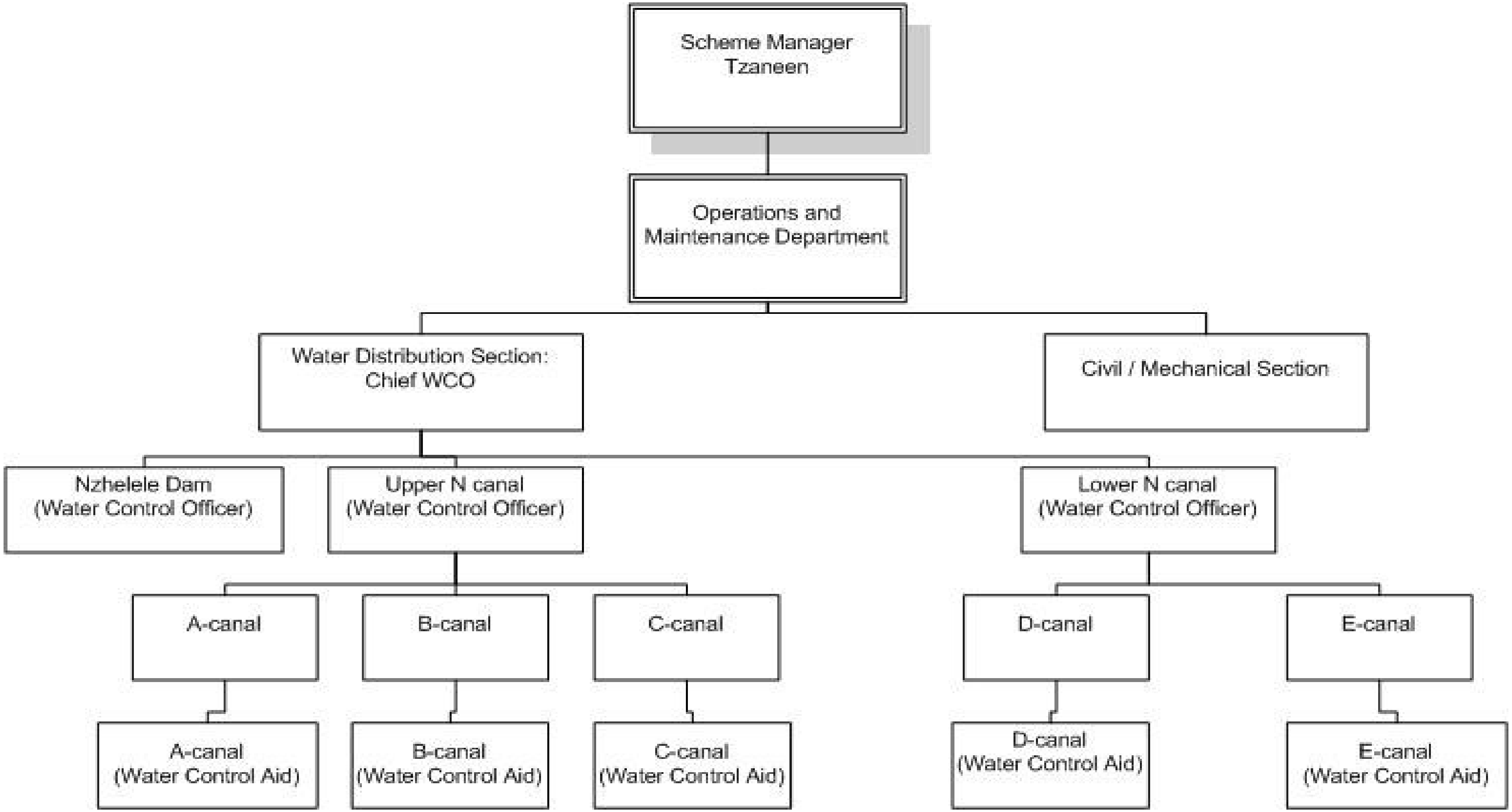

Figure 3.2: Organisational structure for water distribution in the Nzhelele Government

3.3.1.1 Chief Water Control Officer

The Nzhelele GWS has Chief Water Control Officer (CWCO) for Water Distribution who is responsible for the operation of the whole irrigation scheme. His main function is to collect the information provided by the Water Control Officers, process it and issue the operational orders to be executed. These include the amount and timing of releases from the Nzhelele Dam, the setting of the sluice gates and structures to deliver the amount and timing of irrigation water requested by the irrigator on a weekly basis

The job description of the CWCO ideally is mainly to carry out the following tasks:

(i) Receive the weekly water requests from the Water Control Officers (WCOs) (see their job description below);
(ii) Planning the operation of the scheme in order to match the supply as closely as possible with the irrigation water applications (i.e. demand);
(iii) Transmit the operational orders to the WCOs and WCAs according to the instruction to set the sluice gates to prescribed levels to supply the water ordered;
(iv) Supervise that the orders provided to the WCOs are executed accurately;
(v) Coordinate with the WCOs the operation of the main canal gates and the releases required including the timing of the releases;
(vi) Monitoring of the operation (i.e. collection of data related to water use and preparing accounting reports) and preparation of the annual irrigation plans and reports.

3.3.1.2 Water Control Officers

The Nzhelele Government Water Scheme is sub-divided into three (3) sections, each with a Water Control Officer (WCO) who is responsible for managing the section. The job description of the WCO is mainly to carry out the following tasks:

(i) Read the water levels in the canal off takes, river and balancing dams in those sections they are available;
(ii) Transmit the data to the Water Control Aids (WCAs) responsible for the different sections;
(iii) Manipulate or set the sluice gates and structures as indicated by the Nzhelele GWS main office;
(iv) Report to the CWCO any malfunctioning of sluice gates and structures and any water thefts;
(v) Control and report on the state of maintenance of the stretch of canal for which they are responsible.

Manpower requirements

Data from several projects indicate that one WCO can cover 10 - 15km depending on the number of hydraulic structures in the canal. The main intake works which is the Nzhelele Dam requires one or two people depending on the complexity of operation. The operation of the dam gates requires one person.

In the Nzhelele GWS, there are three WCOs with one of the WCOs responsible for operation of the Nzhelele Dam outlet gates. Given the fact that the Nzhelele canal system has approximately 75 km of canal, each WCO is responsible for 25 km of canal.

3.3.1.3 Water Control Aids (previously Canal Guards)

The Water Control Aids (WCAs) are the main communication channel between the CWCO and the farmer. Therefore the success of a smooth relationship between the two parties depends on their capabilities and honesty.

Although the job descriptions of the WCAs may vary slightly, the following are considered to be the usual expected tasks to be carried out:

(i) Distribute and control the flows that each sluice must deliver;
(ii) Open and close sluice gates and valves;
(iii) Collection of water requests;
(iv) Preparation of the forms for the water delivery;
(v) Communication to the WCO of the requests for water;
(vi) Control of the canals and watercourses to avoid unauthorised use of water;
(vii) Compilation of the agricultural and water data as needed;
(viii) Delivery of water bills.

In the Nzhelele Government Water scheme, the water control aids not only perform functions related to the operation of the system, but also do minor maintenance work during the off-season. The added duties during this period include the following:

- Cleaning of the irrigation canals;
- Small repairs in the hydraulic works (sluices, siphons, joints, etc.);
- Supervision of major repair works;
- Repairing and maintaining the sluice gates in their section.

Manpower requirements

The Nzhelele GWS has to distribute irrigation water to 2 914 ha. Given the local circumstances such as transport facilities, ease of access, the configuration of the irrigation canal scheme layout, the medium size of the farm, it can be regarded that there are sufficient WCA resources on the Scheme.

As illustrated in the **Figure 3.1** above, the Nzhelele GWS has sufficient resources to carry out the water distribution to its constituents, the irrigators in all the sections.

3.3.2 Civil / Mechanical Maintenance Section

The maintenance section is entrusted with the overall responsibility for keeping the irrigation and drainage infrastructure working in a satisfactory manner, within the limitations imposed by design. The manpower requirements for this function is situated in Tzaneen.

The main functions of the Civil/Mechanical Maintenance Section to be undertaken include the following:

(i) Planning the maintenance activities;

(ii) Implementing the maintenance activities planned and those unforeseen. Maintenance activities can be easily undertaken during the dry periods in the off-season;

(iii) Monitoring the abovementioned activities - a maintenance service requires data for good planning which can be obtained by regular monitoring. Without reliable data on costs for the different units of work and on productivity no realistic planning can be done.

The existing organisation structure for the Civil/Mechanical Maintenance section is provided in **Figure 3.3** below.

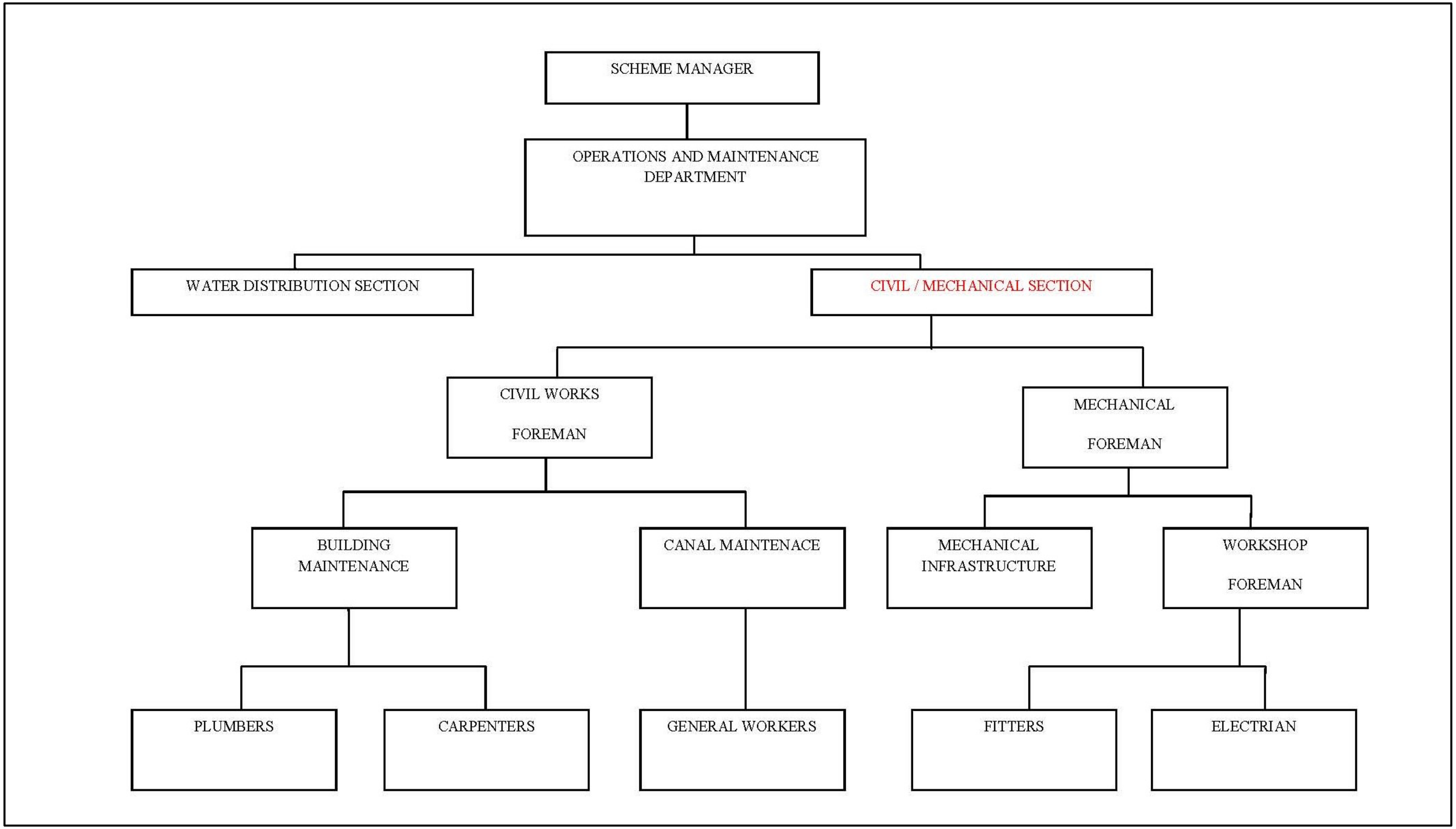

Figure 3.3: Organisational structure for the maintenance of the Nzhelele Government Water Scheme

3.4 Irrigation water use charge

3.4.1 Water User Charge

The irrigators in the Nzhelele Government Water Scheme were charged a water use charge of 11.06 c/m^3, which is equivalent to R 929.04 per ha/a, while the river irrigators are charged at 4.012 c/m^3 which is equivalent to R 346.08 per ha/a for the 2009/10 financial year. Compared to other irrigation schemes, these costs can be considered to be reasonable to ensure irrigation agriculture is a viable option. These are administered prices which are heavily subsidised.

The WRI charge paid by the domestic and industries that are supplied from the canal system for 2009/10 financial year was 30.89 c per m^3, which when compared to agriculture would be R 2 378.53 per ha/a. This clearly indicates that the WRI charge for irrigation agriculture is currently heavily subsidised when compared to the water use charge for domestic and industries from the same scheme.

Each irrigator is responsible for the payment of the WRI charge to the Department of Water Affairs (DWA). The collection of the water use charge is also carried out by the DWA.

3.4.2 Water Resource Management Charge

Besides paying for the use of the water released from the Nzhelele Dam, the irrigators in the Nzhelele Irrigation Scheme also pay for the water resource management charge of the catchments. The current WRM charge for the Limpopo WMA in which the Nzhelele GWS is located, is 1.33 c/m^3 or R 11.72 per ha/a.

The WRM charge is the same for all water users in the Limpopo Water Management Area (WMA). The purpose of the WRM charge is to cover all management activities that are undertaken by the Catchment Management Agency (CMA) or a proto-CMA where one has not been established and to ensure sustainable water resource management so that all users in the WMA have fair and equitable share of the available water. The activities that are covered by the WRM include the following:

(i) water abstraction control to ensure that all get their fair share of water,
(ii) monitoring and pollution control to keep the rivers healthy,
(iii) planning for development of new schemes and to extend existing schemes,
(iv) clearing of invading alien plants which consume water that should be available for use.

For the canal irrigators in the Nzhelele Government Water Scheme, the total cost of irrigation water including the management charge amounts to R 1 040.76 per ha/a. This is lower than a number of other irrigation schemes.

3.5 Water use permits / licenses and contracts

The authorisation for the water use within the Nzhelele Government Water Scheme (GWS) area of jurisdiction, lies in the Schedule for 2 914 ha, drawn up in terms of section 88 of the 1956 Water Act, and approved by the Department in 1999. This scheduled use is deemed to be an Existing Lawful Water Use under section 32 of the National Water Act, 1998 and as such, does not require a Licence but does need to be registered. The irrigators have permission to continue irrigating this scheduled area until licensing takes place, provided they pay all charges due to the Nzhelele GWS.

The permit for domestic water use for Tshipise Holiday Resort and surrounding communities supplied by the scheme is held by the holiday resort. There is a service level agreement (SLA) between the domestic users and the Nzhelele GWS for the delivery of water for domestic purposes through the irrigation canal infrastructure.

The total allocations for the scheme is 24.5 million m^3/a, at 8 400 m^3/ha/a. This does not include irrigators supplied directly from the dam through the Nzhelele River. A review of the Water Allocation Registration Management System (WARMS) database indicates that the total registered water use in the scheme area is 25.5 million m^3/a, which is supplied from the canal infrastructure.

3.6 Irrigated areas and types of crops

The current irrigated area is 2 914 hectares, which is supplied by the Nzhelele Dam. Each of the irrigators in the Nzhelele Irrigation Scheme area is registered individually and the Registration certificates reflect the enlisted area as well as the non-scheduled areas.

The irrigators in the scheme are growing diverse crops which include citrus and mangoes, as well as cash crops which include maize and vegetables. **Table 3.1** below provides an estimate of the distribution of the citrus farming taking place in the Nzhelele Government Water Scheme.

3.6.1 Citrus

Approximately 70% (2 000 ha) of the irrigated area in the Nzhelele Government Water Scheme is under citrus. The average production of citrus under irrigation in the scheme area is estimated to range from 15 tons per hectare to 25 tons per hectare. Harvesting normally takes place throughout the winter, that is May to October, depending on the type of fruit.

3.6.2 Grape Fruit

South African grapefruit is harvested from mid-April to late June. This area is characterized by warm subtropical climatic temperatures which are best suited for grapefruit production. The most popular grapefruit varieties in South Africa are Star Ruby and Marsh.

Table 3.1: Typical irrigated area in Nzhelele Irrigation Scheme

Crop	Total crop area	Percentage of total area	Production (tonnes per ha)
			Average farmer
Oranges	2 039.80	70%	20.00
Grape Fruit	466.24	16%	36.59
Lemons	203.98	7%	
Naartjies	203.98	7%	
Total	2 914.00	100%	

3.6.3 Other crops

Besides the above main crops, there are other crops which are mainly annual crops such as vegetables and tomatoes which are grown to supplement the main perennial crops from a revenue perspective.

3.7 Historic water use

In order to evaluate the water use of the Nzhelele Government Water Scheme, the scheme was treated as being one scheme without sub-schemes, although there are three main branch canals as well as three smaller branch canals. This was because there was no data available of flow measurements taken at branch canals to carry out the water balance assessment at the sub-scheme level.

The reporting system is currently set up to only conduct scheme level water balance assessments as the irrigators are not divided by the sub-schemes or the branch canal system. This issue is discussed in more detail later in this report.

3.7.1 Historic water use - Nzhelele Government Water Scheme

The historic water use of the Nzhelele GWS is provided in **Table 3.2** below. This was based on five years of historic records although there were no records available for the 2010/11 water year for the Nzhelele GWS.

Because of the quality of the previous year's data which was considered questionable, only last year's records have been used in the water balance assessment conducted. There were 12 months of irrigation water application and household use was available as well as the monthly diverted volume from the hydrological branch gauging station at the weir. This is provided in **Table 3.2 below**. Water for irrigation that was used was measured as 20.03 million m^3/a for the current 2011/12 water year. When compared to the scheduled quota for the scheme, this is approximately 80% of the water allocation for the Nzhelele GWS of 24.5 million m^3/a. This does not include the river irrigators who are located between the Nzhelele Dam and the weir.

The scheme also provides household domestic consumption for the farming communities. The household consumption has been constant over the year with the household water use on the farms given as 0.79 million m^3/a. This may include the water requirements for Tshipise holiday resort.

The inflow into the Nzhelele GWS for the same period as the irrigation water use information was 29.07 million m^3/a. This however did not take into account the changes in storage of the balancing dam in the scheme area. When the total water diverted is compared with the water requirements for the same period, an additional 8.25 million m^3/a, was required to compensate for the gross water losses comprising canal seepage losses, leakage, evaporation and operational spills at canal tail ends. Therefore the water losses required by the Nzhelele GWS to deliver the irrigation water to the irrigators were 28% more than the total water diverted.

No flows at the canal tail ends are currently being measured and are not reflected in the historical water use figures.

Table 3.2: Historic water use levels (million m^3/a) for the whole of the Nzhelele GWS

User	2006/07	2007/08	2008/09	2009/10	2010/11	2011/12	5 year average
Irrigation	15.58	15.89	16.69	16.46	-	20.03	18.25
Household	-	-	-	-	-	0.79	0.79
Industrial use	-	-	-	-	-	-	-
Total	15.58	15.89	16.69	16.46	-	20.82	18.64
Inflow into the Scheme	22.79	23.94	26.28	26.87		29.07	27.97
Water Losses	7.21	8.05	9.59	10.41	-	8.25	9.33
% losses	32%	34%	32%	38%	-	28%	33%

4 INVENTORY OF THE EXISTING WATER INFRASTRUCTURE

4.1 Overview

The Nzhelele Irrigation Scheme comprises a dam, a weir from which irrigation water is diverted into the scheme, primary and branch canals to convey the irrigation water to the farms, drainage canals to drain water from the irrigation fields back to the Nzhelele River. The primary and branch canal system delivers the water ordered to the irrigators at their farm turnouts through a number of sluice gates where flow measurement is done using Parshall flumes.

4.2 Source of Supply - Nzhelele Dam

The source of water supply for irrigation is from the Nzhelele Dam which is located in the headwaters of the Nzhelele River. The dam was built and commissioned in 1948 and has a storage capacity of 51.2 million m^3. Water is diverted into the primary irrigation canal on the right bank of the Nzhelele River. The canal is known as the N canal and is the only primary canal in the Nzhelele Irrigation Scheme.

The volume of water that is released from the Nzhelele Dam is first released into the Nzhelele River and is then diverted into the primary N canal at the weir approximately 4.8 km downstream of the Nzhelele Dam based on the requests from irrigators.

4.3 Irrigation conveyance infrastructure

4.3.1 Overview

Figure 4.1 below illustrates the conveyance and distribution infrastructure of the Nzhelele Irrigation Scheme. Water is diverted at a weir below the Nzhelele Dam as discussed above. From the N canal (primary canal) there are several branch canals which supply mainly the irrigators on the left bank of Nzhelele River as the N canal traverses the right bank. The total length of the main canal including the branch canals and pipelines was measured to be 63.3 km, all of which is concrete lined.

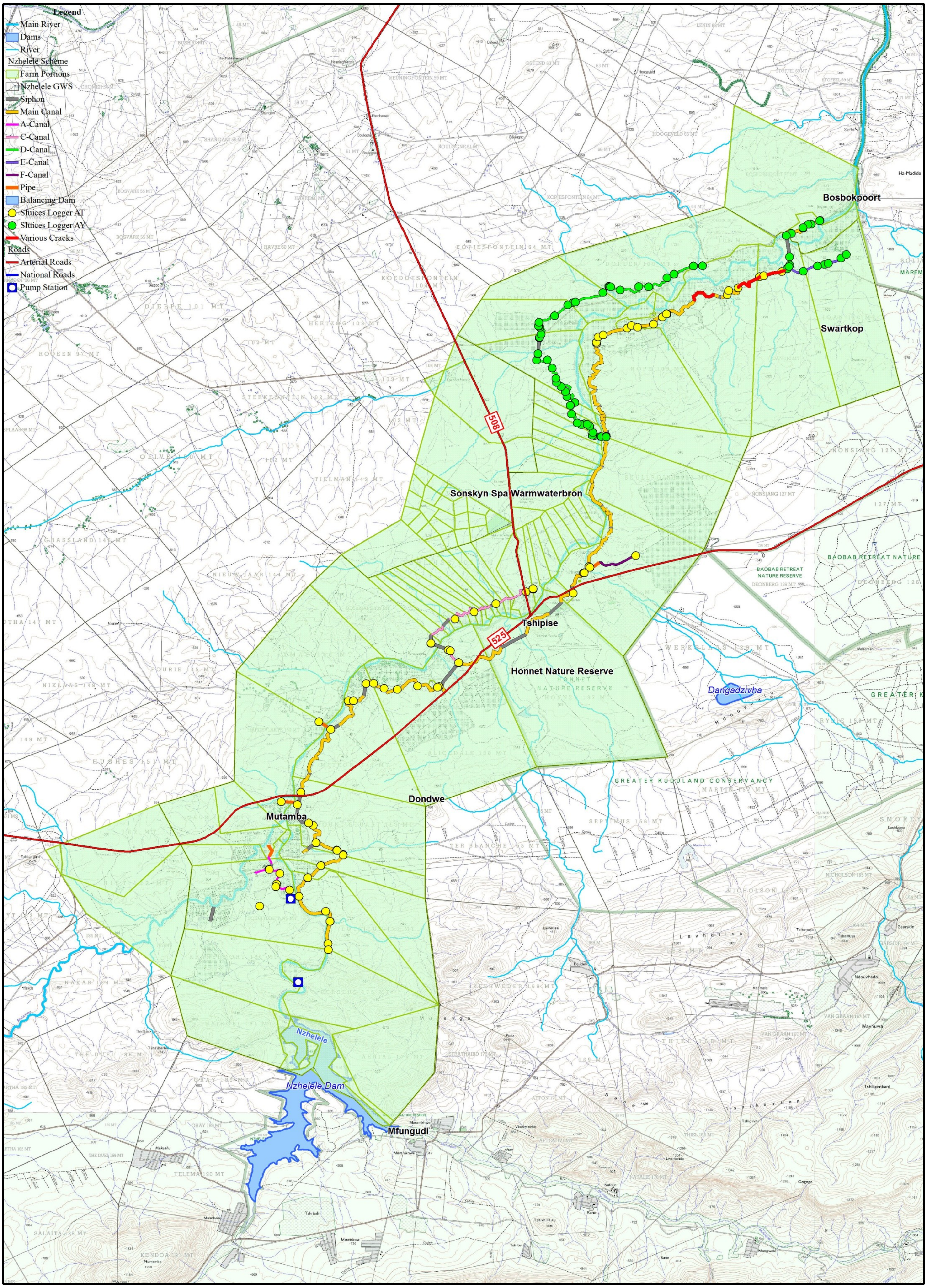

Figure 4.1: Nzhelele Irrigation Scheme Infrastructure

4.3.2 Nzhelele irrigation canal system

Table 4.1 below lists the canal infrastructure downstream of Nzhelele Dam. Downstream of the Nzhelele Dam at the weir there is a primary canal where water is diverted before the branch canals bifurcate to the left bank to supply irrigators. The total length of the canal system is 74.2 km of canals including the siphon infrastructure: The characteristics of the canal system are as follows:

(i) *Nzhelele main N canal:* This is the primary canal from the weir which traverses the government water scheme supplying irrigators on the right bank of the Nzhelele River. It comprises approximately 38.6 km of concrete lined canal as well as 6.5 km of siphons. The last section of the canal crosses the Nzhelele River and supplies irrigators on the left bank. The N canal is the largest canal based on geometry, with a maximum design capacity of 7 140 m^3/h or 2.0 m^3/s. Any excess water not taken up by irrigators will flow back to the Nzhelele River at the canal tailend.

4.3.3 Branch canals

The Nzhelele GWS comprises six (6) branch canals which supply the irrigators located on the left bank of the Nzhelele River. The characteristics of the branch canal system are as follows:

(ii) *Nzhelele A branch canal*: This is the first branch canal which conveys the irrigation water for the farmers on the left bank of the Nzhelele River downstream of the weir. It is estimated that there is 2.7 km of concrete lined canal and 0.4 km of siphons. The maximum hydraulic capacity of the branch canal is 600 m^3/h or 0.2 m^3/s. The A canal ends at the irrigators farm dams. Therefore any operational spills are measured at the irrigators Parshall Flumes.

(iii) *Nzhelele B branch canal*: The B branch canal is a pipeline supplying two irrigators on the left bank of the Nzhelele River. It is estimated that there is 0.68 km of the steel pipeline include the siphons. The maximum hydraulic capacity of the branch canal is 150 m^3/h or 0.04 m^3/s. The B canal ends at the irrigators' farm dams. Therefore any operational spills are measured at the irrigators Parshall Flumes.

(iv) *Nzhelele C branch canal*: The C branch canal also conveys the irrigation water for the farmers on the left bank of the Nzhelele River. It comprises approximately 5.2 km of concrete lined canal and 1.3 km of siphons. The maximum hydraulic capacity of the branch canal is 600 m^3/h or 0.2 m^3/s. The C canal ends at an irrigator's farm dam. Therefore any operational spills are measured at the irrigators Parshall Flumes.

(v) *Nzhelele D branch canal*: The D branch canal also conveys the irrigation water for the farmers on the left bank of the Nzhelele River downstream of the balancing dam. It comprises approximately 11.7 km of concrete lined canal and 1.97 km of siphons. The maximum hydraulic capacity of the branch canal is 600 m^3/h or 0.2 m^3/s. Any excess water not taken up by irrigators will flow back to the Nzhelele River at the canal tailend.

(vi) *Nzhelele E branch canal*: The E branch canal conveys the irrigation water for the farmers on the right bank of the Nzhelele River downstream of the balancing dam. It comprises of approximately 2.7 km of concrete lined canal and 0.2 km of siphons. The maximum hydraulic capacity of the branch canal is 600 m^3/h or 0.2 m^3/s. Any excess water not taken up by irrigators will flow back to the Nzhelele River at the canal tailend.

Table 4.1: Canal Infrastructure on the Nzhelele Irrigation Scheme

Item No	Canal Name	Type of canal	Total Length of canal (km)	Total length of siphons (km)	Canal capacity (m^3/h)	Canal capacity (m^3/s)
1	N Primary canal	Concrete lined	38.55	6.54	7140	1.98
2	A Branch canal	Concrete lined	2.735	0.405	600	0.17
	B pipeline	Steel pipeline	0.682		150	0.04
	C Branch canal	Concrete lined	5.2	1.323	600	0.17
	D Branch canal	Concrete lined	11.71	1.973	600	0.17
	E Branch canal	Concrete lined	2.696	0.201		-
3	F Branch	Concrete	1.68	0.504		-

Item No	Canal Name	Type of canal	Total Length of canal (km)	Total length of siphons (km)	Canal capacity (m^3/h)	Canal capacity (m^3/s)
	canal	lined				
Total length of canal system (km)			63.253	10.946		

(vii) *Branch canals:* There are other smaller branch canals supplying the water users with their allocations. The branch canals are either pipelines or concrete lined canal system with various maximum hydraulic capacities. This includes the F branch canal.

4.4 Irrigation storage and regulation system

4.4.1 General

Besides the main dam and the canal system for conveyance of the irrigation water to the irrigators' farms, the Nzhelele Irrigation Scheme also has a balancing dam, to reduce the time of delivery to downstream irrigators. The balancing dam is indicated in **Figure 4.1** above and is discussed in the following sections.

4.4.2 Nzhelele Balancing Dam

The Nzhelele Balancing Dam provides the water requirements of the downstream irrigators supplied from the D and E canal as well as supplements the N canal by reducing the time of delivery to the downstream irrigators.

The Nzhelele Balancing dam is intended to provide significant operational flexibilities to the Nzhelele GWS depending on the distribution of users requesting water for the week, downstream of the balancing dam. It is also likely to reduce the delivery time for the downstream irrigators supplied from the balancing dam.

However the storage capacity of Nzhelele Balancing Dam is not known which makes it difficult to determine the extent of its benefit to irrigation water management. Furthermore, during the dry periods when the irrigation canals are emptied to carry out maintenance, it can provide water to the downstream irrigators thereby providing sufficient downtime for the canals to be properly maintained.

4.4.3 Irrigators' sluice gates

As illustrated in **Figure 4.1** and **Table 4.1** above, there are several kilometres of canals in the Nzhelele irrigation scheme which distribute the irrigation water to approximately 75 sluices which are measured using V-notches and Parshall flumes.

The entire distribution canal infrastructure is concrete lined. No information with respect to the hydraulic capacity of the different distribution canal infrastructure was available; to compare with the maximum and average demands expected in the different irrigation sections.

4.4.4 Irrigation Farm Dams

A number of irrigators have farm dams which they use to provide balancing storage. Any water ordered by the irrigators and not utilised directly for crop water irrigation is stored in the farm dams and used when the soil moisture levels are low. Farmers utilise the water from the farm dams before putting in new water applications.

4.5 Flow Measurement and telemetry system

4.5.1 Measurement of flow into the scheme area

Figure 4.2 below provides the existing location of the flow measurement system to manage the irrigation water requirements in the Nzhelele Government Water Scheme.

As illustrated, the first measurement of the water diverted at the weir from the Nzhelele Dam into the Nzhelele canal system is located immediately downstream of the weir. This comprises a flow recorder as well as the 8 ft Parshall flume. There is a telemetry system linked to the flow measurement at the Nzhelele main canal inlet.

4.5.2 Measurement into the various canal systems

The Nzhelele Irrigation Scheme has one main canal and branch canals supplying the water users in the Nzhelele River catchment. There are flow measuring weirs constructed at the inlets of these canals.

In the Nzhelele River canal system there are some flow measurement structures which include Parshall Flumes as well as a V notch weir besides the Parshall flume at the inlet into the main canal. The following flow measurement structures exist on the Nzhelele GWS canal system:

(i) There is a 2 ft Parshall flume which measures flows at the inlet of the A canal (see **Photo 4.1** below).

(ii) The B canal off take comprises a 1 ft Parshall Flume to measure the diversion into the B canal which supplies two sluice gates.

(iii) Below the B canal, there is a 6 ft Parshall Flume on the main canal including a flow recorder which is currently not operational. Therefore a water balance can be done for the upstream canal system if required.

(iv) At the C canal off take there is a 1 ft Parshall Flume to measure the diversion into the C canal. This can be used to conduct a water balance assessment with the fifteen (15) sluices which draw water from the canal.

(v) At the F canal off take there is a 2 ft Parshall Flume and a telemetry-linked flow recorder to measure the diversion into the F canal. There is also a 4 ft Parshall Flume to measure the flows into the Balancing Dam.

(vi) Downstream of the balancing dam there is a 2 ft Parshall flume linked to a telemetry system that is currently being used by hydrology branch.

(vii) At the D canal off take there is a 2 ft Parshall Flume to measure the diversion into the canal. This can be used to conduct a water balance assessment with the twelve (12) sluices which draw water from the canal.

Photo 4.1: Flow measurement at the inlet to the A canal siphon on the Nzhelele River canal system

(viii) At the E canal off take there is a 1 ft Parshall Flume to measure the diversion into the E canal.

(ix) At the canal tail end of the main canal there is a 4 ft Parshall Flume and a flow recorder which is currently not operational.

4.5.3 Measurement at user outlets

The Nzhelele Government Water Scheme (GWS) measures the weekly volume of water delivered to the water users at the farm gate using either Parshall flumes or V notch weirs located downstream of the sluice gates. The sluice gates are adjusted depending on the water application by the irrigators.

4.5.4 Telemetry system

The Nzhelele Irrigation Scheme has telemetry infrastructure that is used by the hydrological branch to measure real time flows at three points in the irrigation scheme. These are currently not accessible for use by the scheme operators. There are also some flow recorders in the scheme which are currently not operational.

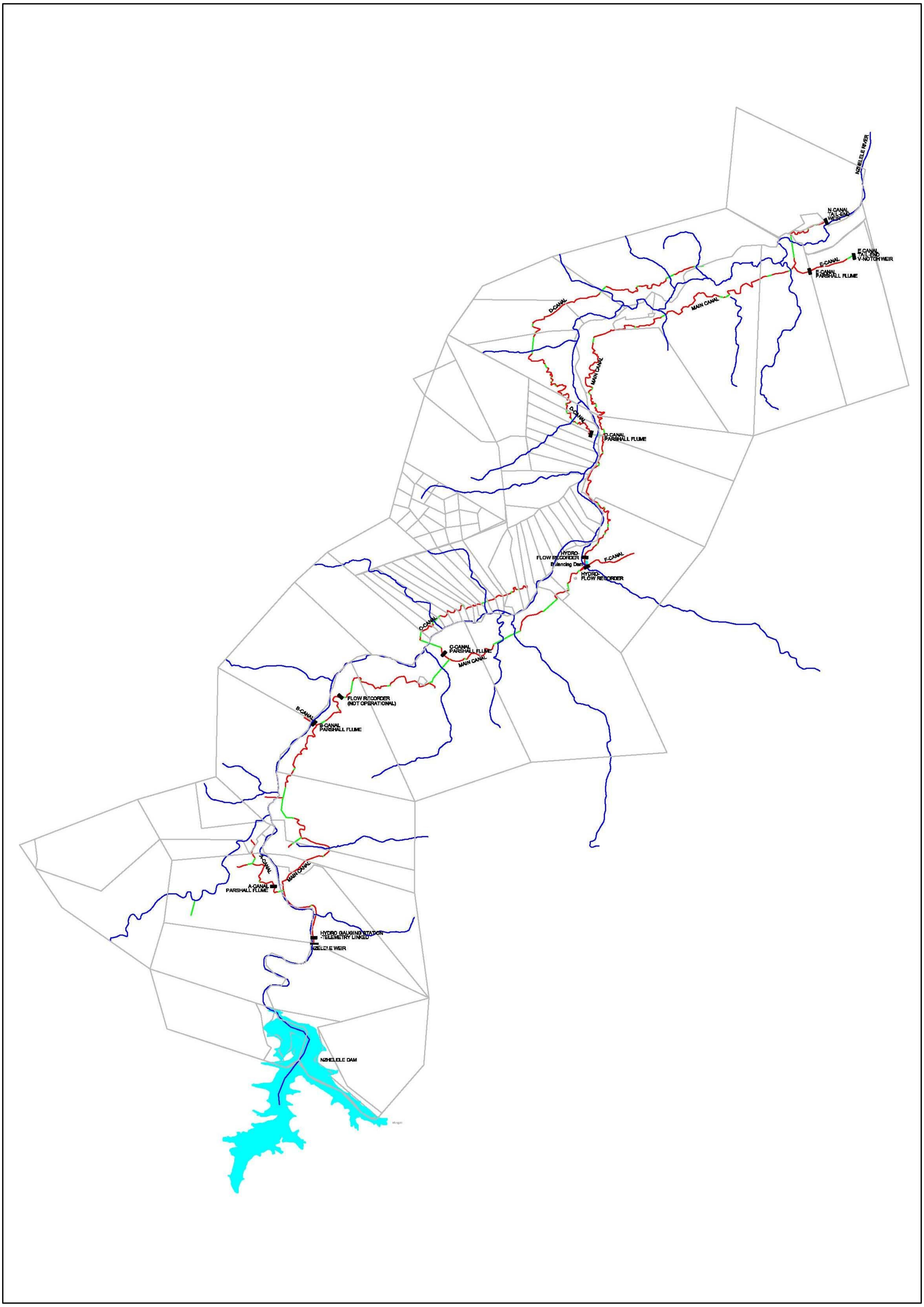

Figure 4.2: Schematic layout of the Nzhelele State Water Scheme with the existing water measurement system

5 INFRASTRUCTURE CONDITION ASSESSMENT

5.1 Overview

In order to determine the condition of the canal infrastructure, a methodology has been developed known as the Rapid Assessment Tool (RAT). This is a combination of methodologies designed to provide a quick and cost-effective analysis of condition within an irrigation scheme.

The main objective of undertaking a condition assessment is to define the extent and seriousness of problems contributing to poor conveyance efficiency and to develop a maintenance and refurbishment programme to ensure the infrastructure is maintained timeously to enable it to meet the service level it was designed for.

RAT methodologies include surveys, rating of infrastructure, flow measurement, seepage loss tests, and GIS-based mapping and analysis, among other activities. These methodologies are still evolving. Two visual rating procedures have been developed:

- water supply conditions (“head conditions”);
- canal conditions.

The overall goal of this effort is to provide information which will allow decision makers involved in irrigation resource management to assess and compare the rehabilitation needs of irrigation networks.

The condition of the canal infrastructure in the Nzhelele Irrigation Scheme was determined based on the preliminary assessments carried out during the site visits.

5.2 Canal Condition Evaluation

Although it was not possible to undertake the condition assessment of the irrigation canals of the Nzhelele Irrigation Scheme, because at the time of developing the WMP, there were no dry periods to inspect the canals, the results of the preliminary investigations carried out by our project team as part of the data capture have been used to provide a situation assessment of the condition of the infrastructure.

Before discussing the condition of the Nzhelele irrigation canal system, criteria for undertaking canal condition assessment was developed for use during the implementation phase. The Canal Condition Evaluation component of RAT includes visual rating methodologies on:

- the general condition of the canal
- conditions which indicate seepage or structural problems

There are service factors that are used in this procedure which may be grouped as follows:

- general condition of the canals
- presence of cracks (hairline, pencil-size, and large)
- amount of patchwork
- vegetation in canal and along embankment

Tables 5.1 - 5.5 provide details on the rating factors and definition of numerical values that are recommended to be used during the dry periods.

Table 5.1: General Condition rating

Rating	Definition
1	Excellent – no visible cracks or vegetation
2	Good – having cracks greater than 3.0 m and some weeds
3	Fair – cracks 1.5-3.0 m apart, with moderate vegetation in canal and drainage ditch
4	Poor – cracks 1.0-1.5 m apart, with dense vegetation in canal and drainage ditch
5	Serious Problems – visible large cracks less than 1.0m apart with lush vegetation

Table 5.2: Criteria for hairline, pencil size and large cracks

Rating	Definition
1	None to Sparse
2	Greater than 3.0 m apart
3	1.5 – 3.0 m apart
4	1.0 – 1.5 apart
5	Less than 1.0 m apart

Table 5.3: Noticeable amounts of maintenance and repair (patchwork)

Rating	Definition
1	None to Sparse
2	A few areas
3	Sparse
4	Moderate
5	Severe

Table 5.4: Vegetation growing in canal lining

Rating	Definition
0	None
1	Sparse
2	Moderate
3	Dense

Table 5.5: Vegetation in drainage canals and along the outer embankment of the levee

Rating	Definition
1	Normal; rain-fed weeds only
2	Canal fed grass or small weeds only
3	Moderate; bushes & some small to no trees with no water near levee or drain

4	Dense; more bushes & larger trees, little or no standing water, little or no aquatic vegetation
5	Dense and lush; bushes, trees, lots of aquatic vegetation with standing water

5.3 Results and analysis of canal infrastructure condition assessment

5.3.1 Overview

The condition assessment of the canal infrastructure of the Nzhelele Irrigation Scheme was conducted for the entire main canal as well as the branch canals from the weir up to the canal tail ends. The findings of the condition of the infrastructure are discussed in the following sections.

5.3.2 Condition assessment of the Nzhelele main canal

5.3.2.1 Condition of the concrete lined canal

An assessment of the condition of the Nzhelele main canal was conducted by driving along the main canal and using the RAT to determine the structural defects and any visual leaks that could be observed, bearing in mind that at the time the canal was operational.

There are cracks and vegetation growth that was identified in the Nzhelele main canal from the site survey. As illustrated in **Photo 5.1 and Photo 5.2** below, the soils behind the concrete panels have eroded which has resulted in the concrete joints shifting.

Photo 5.1: Open joints between the concrete panels as well as growth in the canal

The condition of the main N canal section between the N3 sluice and the major siphon is considered to be poor and was given a condition rating of 4. This will require urgent attention because the scheme is losing significant volumes of water through leakage.

Photo 5.2: Major Cracks on the N canal in the joints of the concrete panels

Besides the structural condition of the concrete panels, another problem identified was the presence of algae in the main Nzhelele canal (see **Photo 5.3** below). This has had the effect of reducing the hydraulic performance of the canal. This has meant that more water is diverted to address the increased flow resistance in the canals.

Photo 5.3: Algae in the main Nzhelele canal

5.3.2.2 Condition of the siphons

Although the assessment was conducted when the Nzhelele main canal system was operational, the condition of the siphons could be determined by visual inspection of any blockage of the siphons and the wet areas which indicated leakage from the siphons.

The major leaks were on the siphon immediately downstream of the Nzhelele weir, where the N canal starts as well as the main siphon before the B branch canal off-take. Both siphons appear to be in very poor condition as determined by the leakages which were visible in the area where the siphons traversed. The leakages from the siphons could be attributed to either cracks in the pipes and possible problems at the pipe joints. This is illustrated in **Photo 5.4** and **Photo 5.5** respectively.

Photo 5.4: Leakage due to cracks on the siphon pipes downstream of the Nzhelele weir

Because the conditions of the pipes on the above canal siphons are in a poor state, it may be necessary to replace some of the pipes besides flashing and cleaning of the siphons.

Photo 5.5: Leakage on the N canal siphon as a result of the cracks

5.3.3 Condition assessment of the A branch canal

An assessment of the condition of the A branch canal was conducted by driving along the main canal and using the RAT to determine the structural defects and any visual leaks that can be observed.

The major problem that was identified on the A branch canal was the presence of algae (see **Photo 5.6** below). Because of the reduced hydraulic capacity of the canal infrastructure, this has resulted in overtopping which is now eroding the canal banks. The vegetation growth alongside the canal is a clear indication that as a result of the algae the canal can no longer deliver the irrigation water without overtopping. This is illustrated in **Photo 5.7** below.

The condition of the branch canal is considered to be poor and was given a condition rating of 4. This will require urgent attention because the scheme is losing significant volumes of water through overtopping while at the same time damaging the canal.

Photo 5.6: Presence of algae in the A branch canal

Photo 5.7: A branch canal overtopping as a result of the algae growth in the canal

5.3.4 Condition assessment of the C branch canal

An assessment of the condition of the C branch canal was conducted by driving along the main canal and using the RAT to determine the structural defects and any leaks that can be observed visually.

The major problem that was identified on the C branch canal was also the presence of algae (see **Photo 5.8** below). Because of the reduced hydraulic capacity due to high frictional losses on canal infrastructure; this has resulted in the blockage of the canal siphon. This is illustrated in **Photo 5.9** below.

The condition of the branch canal is considered to be poor and was given a condition rating of 4. This will require urgent attention because the scheme is losing significant volumes of water through overtopping while at the same time damaging the canal.

Photo 5.8: Presence of algae in the C branch canal

Photo 5.9: Leakage on the canal siphon as a result of the algae infested canal

Figure 5.1 below indicates the general condition rating of the different segments of the Nzhelele Irrigation Scheme canal system. This will form the basis for prioritisation of the canal segments for maintenance, including any canal section renewals that will be required.

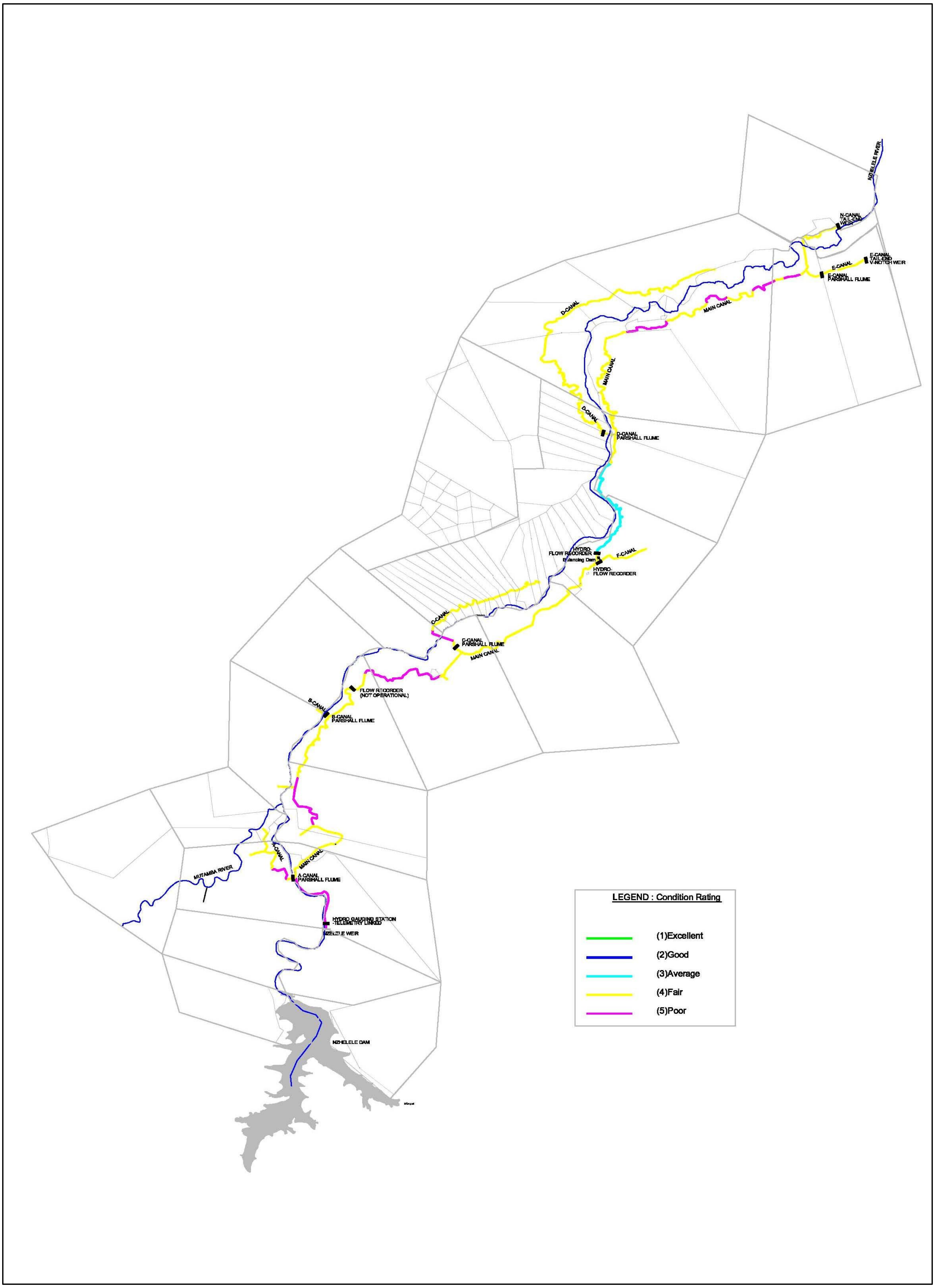

Figure 5.1: General Condition Rating of the surveyed canal segments

6 SCHEME OPERATIONS AND OPERATING PROCEDURES

6.1 General scheme options

An Operation Service has as its chief objective being the timely delivery of the irrigation water necessary to satisfy crop water requirements. The accomplishment of this objective implies the following main activities:

(i) Planning the Operation (preparation of the so-called Irrigation Plans based on irrigation applications)

(ii) Implementation of the Plan (actual water distribution by releasing irrigation water to the different canals)

(iii) Monitoring of the Operation (collection of data related to water use and preparation of the water use accounting reports).

The Nzhelele State Water Scheme is dependent on the storage dam in the Nzhelele River as its source of supply for downstream irrigators. Water is diverted into the main canal on the right bank of the Nzhelele River to supply irrigators either from the main canal or through the several branch canals that divert water from the main canal to irrigators situated on the left bank of the Nzhelele River. The irrigation water is abstracted at the sluices by irrigators according to their water applications provided to the scheme operators during the week.

Since the Nzhelele Government Water Scheme became operational, the irrigation scheme has experienced some water restrictions, where the scheduled quotas have not been delivered to the farmers.

The Nzhelele GWS is owned and operated by the Department of Water Affairs (DWA). Water is only released from the dam for two reasons;

(i) releases for Nzhelele Irrigation Scheme to meet the irrigation water requirements based on the weekly irrigation water applications from users in the scheme area, as well as domestic water use and

(ii) to meet the compensation requirements for downstream water users. Currently no managed flow releases to supply the ecological water requirements (EWR) of the downstream Nzhelele River are being made.

6.2 Water ordering and delivery procedures

6.2.1 Overview

In order to ensure that the irrigators receive their scheduled quota as and when required, the Nzhelele GWS operates the irrigation scheme based on "delivery on request" where each water user (irrigator) must submit a written request on a weekly basis. Based on the weekly applications the water is released to the various canals and delivered to the irrigator's sluice(s). No written scheme regulations were available at the time of writing the report. However the scheme operators and irrigators understand the water ordering and delivery procedures as discussed below.

6.2.2 Operation of matching irrigation supply and demand

The procedures followed by the irrigators in ordering their water requirements are as follows:

(i) Each irrigator determines how much water they require to order for the following week from the scheme, based on their irrigation scheduling as well as their scheduled quota.

(ii) The irrigators submit their requests to the Nzhelele GWS, by the close of business on Thursday, for their total water requirements, to be delivered the following week. Irrigators must specify their needs clearly on the request form and the GWS will endeavour to supply the water as requested.

(iii) The management at the Nzhelele GWS then reconciles the total requested volume from the beginning of the water year with each irrigator's scheduled quota. The total volume of water required in each branch canal, is then calculated to determine how much water should be supplied in each of the different sections of canal based on the request. This is compared with the hydraulic capacity of the canal section to ensure that either the volume of water ordered is above the threshold for delivery into the canal section or the volume of water ordered does not exceed the hydraulic capacity of the canal system including the expected canal losses.

(iv) The above process is repeated from the branch canals up to the main canal to determine how much water needs to be diverted at the weir downstream of Nzhelele Dam. This includes the total transmission and evaporation losses required to deliver the requested water.

(v) The requested water, including the transmission losses are then reconciled with the available water in the dam and the volume of water required to be released from the dam. Water is then released from Nzhelele Dam in time to meet the requested water for the following week.

(vi) In the event that the requested volume exceeds the maximum hydraulic capacity of the canal systems, the requested volumes are reduced proportionally to the determined hydraulic capacity of the canal infrastructure, taking into account the estimated water losses.

(vii) In order to reduce the water losses, the Nzhelele GWS also determines the minimum volume of water that can be delivered in each canal system without significant water losses. If the requests amount to less than the minimum threshold for release, then the irrigators in that particular section will not receive their requests.

(viii) The Water Control Department (WCD) of Nzhelele GWS sets up a flow chart of the streams to be used at each sluice gate to meet the requested water by the irrigator. This also includes the time the stream will flow during the week.

(ix) Based on the availability and priorities, decisions are then made to release from Nzhelele Dam into the main canal based on the calculated volumes for the week to be delivered continuously during the week. The cycle commences on Monday morning and ends on Sunday evenings.

(x) The information regarding the volume of water allocated to each user is then communicated back by the WCOs to the consumers.

The above water ordering and delivery procedures have not been formally documented. This is required as a service level agreement (SLA) between the irrigators and the scheme operators. This will enable all irrigators as well as the water control officers to be aware of the responsibilities of each stakeholder in ensuring effective and efficient delivery of water to the consumers. This will be useful particularly for new irrigators and WCOs to understand the process.

The water is supplied by setting the sluice gates according to a certain height through the V notch to the irrigators with measurements taken as part of the monitoring to ensure that each irrigator does not exceed his/her schedule quota. Approximately 74 of the individual offtakes are installed with sluice gates and either Parshall flumes or V-Notch weirs to measure the flows.

The stop and start nature of the operation of the canals and laterals in sections of the Nzhelele GWS areas increases the extent of evaporation as well as leakage and seepage losses due to changes in the capillary forces and gravity as well as changes in the water table.

Due to the pressure variance in the canal system there is a margin of error in the volume of water delivered to the water user and water users are requested to accept a margin of error of 10%.

6.3 Procedures during water supply shortages

There has been some water shortages experienced since the construction of the Nzhelele dam because the historic yield of the dam is 24.5 million m³/a. However, there are procedures that are followed to address any water supply shortages and these include the following:

(i) At the start of the water year, the available water from the Nzhelele Dam that can be supplied to irrigators is reconciled with the scheduled quota. Where it is envisaged that less water is available, the allocations to irrigators are reduced equitably regardless of the types of crops irrigated. A percentage of the scheduled allocation is then published to enable the irrigators to plan the type of crops or to manage the existing trees.

(ii) Priority is given to supply domestic water users in the event of water shortages. In the case of Nzhelele Irrigation Scheme the domestic demand is low and is limited to Tshipise Holiday Resort and the surrounding communities.

(iii) The available water allocation to each irrigator is then supplied based on the delivery on request basis

(iv) The available water is reviewed during the course of year depending on the rainfall and any necessary changes are then made to the annual water allocation.

6.4 Water trading - Temporary water transfers

There may be periods when existing irrigators exhaust their scheduled quota before the end of the water year and may require additional irrigation water. The current practice is as follows:

(i) Irrigators cannot make a temporary transfer to lands that do not have any water rights. This is because the canals were designed to supply the existing water entitlements and are not likely to meet the additional demand.

(ii) Irrigators can however transfer water temporarily to another land which has a water use entitlement if there are shortages. However the transfer is subject to the canal having sufficient capacity for the additional stream.

(iii) Furthermore the temporary transfer can only be supplied during those periods that the canal feeding existing irrigators is not being required by other irrigators. This should however be arranged with the WCO prior to delivery.

The irrigators then approach the Nzhelele GWS to facilitate the temporary transfer with the Department of Water Affairs (DWA) based on whether there is sufficient hydraulic capacity of the irrigation canal system for the transfer to be delivered to the temporary user.

Currently the GWS is not involved in any of the negotiations as the water use entitlements are held by the individual water user.

6.5 Water pricing structure

6.5.1 Setting of the irrigation pricing

6.5.1.1 Water Use Charge

On the Government Water Schemes, the Department of Water Affairs (DWA) sets the water use charge for irrigation water, based on the pricing strategy. This is the case with Nzhelele Government Water Scheme. The irrigators pay two sets of charges. The first charge is known as the water use charge, which is the cost to recover the capital investment which was used by DWA to develop the irrigation canals as well as Nzhelele Dam.

The Water User Charge for the Nzhelele Irrigation Scheme for the 2009/10 financial year was 11.06 cents per m^3. Based on the scheduled quota of 8 400 m^3/ha/a, irrigators are therefore paying R 929.04 per hectare per annum. For the domestic and industrial water users, the water user charge from the same scheme is 30.89 c per m^3. The high cost of the domestic water use charge is because of the higher assurance of supply given to domestic and industrial consumers who are curtailed last in the scheme.

6.5.1.2 Operation and Maintenance Charge

The second charge is the cost for the operation and maintenance based on the annual budgeted operation and maintenance costs of the scheme. This charge is not applicable to the Nzhelele Irrigation Scheme as the O&M charge is included in the water use charge discussed in the previous section.

6.5.1.3 Water Resource Management Charge

Besides the water use charge, the pricing strategy requires that all users pay for the management of the catchments including the cost of managing the Reserve, dam safety control, etc. This is the water resource management (WRM) charge. The WRM charge for irrigation agriculture in the Limpopo Water Management Area in which the Nzhelele Irrigation Scheme is located for the 2009/10 financial year, was 1.33 c per m^3 or R 111.72 per ha/a, while the WRM charge for domestic and industrial users is the same as for agriculture.

6.5.2 Collection of the irrigation water use charges

The Nzhelele GWS scheme operators, which is the DWA Infrastructure Branch is responsible for collection of the water use charges on behalf of the Department of Water Affairs (DWA), which includes the money which it uses to pay for the operation and maintenance of the irrigation scheme. Irrigators, domestic and industrial users are also billed directly by DWA for the WRM charges.

7 BEST MANAGEMENT PRACTICES FOR WATER MANAGEMENT IN NZHELELE IRRIGATION SCHEME

7.1 OVERVIEW

Before determining the irrigation water use efficiency of the Nzhelele Government Water Scheme, it was important to assess the expected seepage and evaporation losses if the irrigation scheme infrastructure was well maintained while taking into account the useful life of the canal system infrastructure. This establishes the Best Management Practice (BMP) for irrigation water management in the government water scheme.

This is discussed in the following sections of this chapter.

7.2 Water Use Efficient Best Management Practice for irrigation water management

7.2.1 Overview

According to Howell (2001), there are four basic losses that can result when water is diverted for irrigation. These losses are as follows:

(i) Part of the water is consumed in evaporation (e.g. from channels) and transpiration (e.g. vegetation growing next to the channel).

(ii) Some water percolates to surface or subsurface areas (e.g. canal seepage or deep percolation) and cannot be recaptured (e.g. in the vadose zone, the ocean, or a salt sink) or can be recaptured (e.g. interceptor drains into a drainage canal or a drainage well) and used as an additional supply.

(iii) The drainage water becomes polluted with salts or chemicals (e.g. nutrients or pesticides) that are so concentrated that the water can no longer be used and must be discharged to a sink for disposal.

(iv) Untimely deliveries of water that cannot be used.(In the case of this section of the scheme, either operational spills at the canal tail ends representing a loss to the scheme or excess water which is delivered to downstream storages or canals within the scheme).

Quantifying these losses is the first step in determining the efficiencies of conveyance and distribution systems and to compare with the Best Management Practices (BMP) for each component of the conveyance water losses.

In order to establish the generally accepted BMP that results in more efficient use, conservation or management of water, the estimate of the level of acceptable water losses due to seepage, evaporation and leakage was determined as part of setting the Best Management Practices (BMP) for acceptable water losses for the Nzhelele Government Water Scheme.

7.2.2 Best Management Practice for seepage losses:

Canals continue to be the major conveyance systems for delivering water for irrigation agriculture. The seepage losses from irrigation canals constitute a substantial percentage of usable irrigation water. Therefore computation of the canal seepage losses is an important aspect of determining the best management practices for sustainable irrigation water management practices for the scheme.

Canals are often lined to reduce the seepage losses, as is the case in the Nzhelele Government Water Scheme. A perfect canal lining which is well maintained reduces significantly the amount of seepage through the lining although the canal lining deteriorates with time and becomes ineffective in controlling the seepage.

Seepage losses from concrete lined, and unlined canals are normally expressed in l/s per 1 000 m^2 of wetted area and appear to fluctuate between approximately 0.35 l/s per 1 000 m^2 wetted area and 1.9 l/s per 1 000 m^2 (Reid, Davidson and Kotze (1986). For design purposes Butler (1980) suggested a value of 1.9 l/s per 1 000 m^2 wetted area. Therefore depending on the wetted area, this could result in an unavoidable loss rate of up to 15% of the inflow into an irrigation canal.

The seepage losses from concrete lined canal system depend on a number of driving factors among which the following can be said to have a marked influence:

(i) The hydraulic conductivity of the canal lining which is the concrete;
(ii) Subsurface condition in so far as they affect drainage and the groundwater table;
(iii) The age of the canal and the amount and fineness of the material carried in suspension;
(iv) The flow of water in the canal and its depth and velocity;
(v) The relation between the wetted perimeter and other hydraulic elements of the canal, particularly the discharge;
(vi) The temperature of the water.

In order to determine the seepage losses of the Nzhelele canals, the geometry of main canal as well as for the branch canals were collected and used to determine the wetted perimeter and flow area of each segment of the canal. The formula used to calculate the seepage losses for curvilinear canal systems (i.e. parabolic canal geometry) is expressed as follows:

$q_s = k*y*F$ (1)

where q_s = seepage discharge per unit length of canal (m_2/s); k = hydraulic conductivity of the lining (m/s); y = depth of water in the canal (m); F = function of channel geometry (dimensionless); and yF = width of seepage flow at the infinity. The seepage function, F for parabolic canals was taken as

$F = (T/y) + Pi^{\wedge 2}/4G$ (2)

Where

T = top width of the channel at the water surface, (m);

Y = flow depth of water (m); and

G = 0.915965594, known as Catalan's Constant.

The seepage loss per unit length was then calculated using the hydraulic conductivity of the concrete lining; the canal geometry and the seepage rate based on the wetted perimeter. However because there was insufficient information on the canal geometry, the seepage losses were estimated based on some of the measurements taken during the site visit. The expected seepage losses for the different canal sections in the Nzhelele canal system are indicated in **Table 7.1** below.

As illustrated in **Table 7.1** below, the minimum seepage losses expected in the Nzhelele GWS canal system is 1.5 million m^3/a in order to supply the scheduled allocation of 24.49 million m^3/a. As a percentage of the input volume, the minimum seepage losses that should be provided as additional to the scheduled allocation are 5.8%.

When the above percentage seepage losses are compared with the best management practices, canal seepage would be approximately 5% of the input volume (Streutker, 1981 and Muller, 1984). Other factors that have an effect on seepage losses are, *inter alia*, soil characteristics, water depth in the canal, flow speed, soil capillary tension, amount of sediment, etc.

The minimum seepage losses as calculated above have been compared with the water losses of each canal system in the Nzhelele Irrigation Scheme based on the water balance assessment which is discussed in the following chapter. The difference in the water losses and the minimum seepage losses were taken as unavoidable water losses.

Table 7.1: Expected seepage losses in the Nzhelele River canal system

Canal Name	Max Hydraulic Capacity	Seepage Loss	Canal Length (km)	Expected Seepage losses
	(m^3/hr)	Qs (m^3/d per unit length)		(million m^3/a)
N Canal	7 140.00	0.08489	38.55	1.10
A Canal	600.00	0.03302	2.74	0.03
C Canal	600.00	0.04646	5.20	0.08
D Canal	600.00	0.04533	11.71	0.18
E Canal	450.00	0.03302	2.70	0.03
Total Seepage Losses Nzhelele Canal			60.89	1.5

7.2.3 Best Management Practices for evaporation losses

Evaporation loss depends on (1) the supply of energy to provide the latent heat of vaporization and (2) the ability to transport the vapour away from the evaporating surface, which in turn depends on the wind velocity over the surface and the specific humidity gradient in the air above the water surface.

The evaporation loss, expressed as a percentage of total inflow was determined based on the total surface area of the irrigation canals, the mean annual evaporation (MAE) based on the S-pan evaporation figure for the 1970 - 1979 hydrological record from the station at the Nzhelele Dam (see **Table 7.2** below). The MAE in the Nzhelele GWS taken as the measurement at the evaporation station at Tshipise was 2 433 mm per year. **Table 7.2** below provides the estimated evaporation losses for the different canals based on the average width of the canal and the total length of the canals.

The total annual evaporation from the irrigation canal surface area was determined to be 0.45 million m^3/a. This was taken as the average over the seven years records. Based on the calculated evaporation losses, the evaporation losses as a percentage of the total inflows were determined to be 1.7%. This is much higher than the estimated evaporation losses at approximately 0.3% of total inflow volume (Reid, Davidson and Kotze; 1986).

Therefore the BMP evaporation loss in the Nzhelele Irrigation Scheme area that was used was 1.7% of the total inflows which was taken as the unavoidable evaporation losses for the scheme area. This amount has been taken out of the gross water losses.

Table 7.2: Expected evaporation losses in the Nzhelele Government Water Scheme

Canal Name	Max Hydraulic Capacity	Average Surface width	Canal Length (m)	Pan evaporation	Expected evaporation losses
	(m3/hr)	m		mm	(million m^3/a)
N Canal	7 140.00	3.75000	38 550.00	2.43	0.35
A Canal	600.00	1.35000	2 735.00	2.43	0.01
C Canal	600.00	1.25000	5 200.00	2.43	0.02
D Canal	600.00	1.50000	11 710.00	2.43	0.04
E Canal	450.00	0.50000	2 696.00	2.43	0.00
Total Evaporation Losses Nzhelele Canal			60 891.00		0.45

8 NZHELELE GOVERNMENT WATER SCHEME - WATER BALANCE ASSESSMENT

8.1 Overview

The previous chapter 7 described the Best Management Practice (BMP) for irrigation water management in the Nzhelele Government Water Scheme (GWS). This chapter describes the findings of the water balance assessment and the level of water losses for the whole of the Nzhelele Government Water Scheme. The key aspects in developing and implementing water management plans (WMP) in the agricultural sector, is to understand:

- how much water is diverted into the irrigation scheme area;
- how much water is delivered to the various sub-schemes or sections of the irrigation scheme;
- how much water is delivered to the irrigators in the various sub-schemes, and
- how much water is returned to the river/water resource.

This approach provides the irrigation water budget to account for any inefficiency in irrigation water management in the scheme. The Nzhelele GWS uses the Water Administration System (WAS) to account for the water used by the scheme and the water use efficiency accounting report (WUEAR) for reporting on matching irrigation supply and demand (MISD).

The purpose of calculating the water balance and water budget is to help Nzhelele Irrigation Scheme to answer three questions:

1) Is the water being distributed equitably among the irrigators, domestic and industrial consumers in the scheme?
2) How efficiently is water being distributed within the scheme area?
3) Is the scheme receiving its target allocation of water from the sources of supply?

The irrigation water budget for the Nzhelele Irrigation Scheme was intended to be undertaken at two levels. The first level was to determine the overall water budget, with a view to determining the extent of water losses at an irrigation scheme level.

The second level, which could not be conducted because of lack of information at sub-scheme level, was intended to determine the water balance for two sub-schemes of the Nzhelele GWS, namely the Nzhelele right bank and left bank canals. This is one of the recommendations that in future water use efficiency accounting reporting should be conducted at sub-scheme level.

8.2 Quality and integrity of the available information

8.2.1 Sources of information

It is important to note that the available records from the WUEARs that were used to conduct the water budget for the Nzhelele irrigation scheme are for the 2009/2010 water year and for the 2011/12 water year. The monthly records for the 2010/11 were not available to enable three years of record to be available for the water balance analysis.

Another source of information for the volume of water diverted from the dam was from the DWA hydrological branch. This was used to compare with the inflows into the Nzhelele irrigation scheme.

There was a need for a long period of records in order to take into account the drought periods when water restrictions were imposed as well as wet periods in order to review whether there have been any significant changes in the irrigation scheme water use efficiency. This would also have assisted in determining a longer term average BMP based on dry years and wet years.

8.2.2 Integrity of the available data and information

The data and information used to date to carry out the water budgets for the Nzhelele irrigation scheme was from the available WUEARs prepared by the scheme operators and submitted to the DWA Directorate of Water Use Efficiency. The data used to prepare the WUEARs were based on measured data of the inflows into the canal irrigation; measured data on the outlet of weir downstream of Nzhelele Dam at the beginning of the irrigation cycle; data from the water applications and supplied at the sluices of each irrigator. All other information was estimated in the WUEAR and therefore not necessarily used.

Flow recorders are not functional at some of the branch canals and flows are not being recorded at canal tail ends. There may also have been canal tail ends which end at the irrigator's dam which would have been measured at the Parshall for the water delivered to the irrigator through the sluice.

The water balance assessment has not included any precipitation figures during the period of delivery of water to irrigators. The assumption made is that the amount of precipitation during delivery of irrigation water is negligible and/or has been taken into account by irrigators as part of their irrigation scheduling. This may not be the case during the rainy season and consideration of incorporating information regarding precipitation should be made in future irrigation water use accounting if the irrigators are not taking this into account in their water applications.

There were gaps in yearly records from the WUEARs. In order to evaluate the full year's records a process of patching using average monthly records for the year was conducted This has resulted in patching some of the records to determine the total annual inflow and outflow records in some of the years.

8.3 Evaluation of the operational losses

8.3.1 Overview

The determination of operational losses (and mechanisms to minimise it) is one of the most important tools for improving irrigation water use efficiency levels. Higher accuracy in determining these losses, can underpin the efforts to decrease losses over the extent of the whole canal distribution system. Decreasing “avoidable losses” from irrigation canals is often the only “relatively” inexpensive method available when contemplating water management measures.

Avoidable losses occur as a result of inefficient management in the operation of the canal system and can mainly be attributed to poor canal maintenance (leaks), incorrect headwork and inefficient runtime release determination, inaccurate water measuring structures and other restricting factors such as algae growth, etc.

Unavoidable losses from canal systems can be attributed to seepage and evaporation and is related to the surface area of water in the canal, wetted perimeter area of the canal and to the structural condition of the canal network. These were used to estimate the seepage and deep percolation of irrigation water.

8.3.2 Determination of the water losses

An irrigation water balance was prepared for the Nzhelele Irrigation Scheme. The water balance assessment was based on information from the WUEARs, where records of inflows and water applications were provided as well as the inflow records from the hydro section. The records of inflows, which consist of all the sources of water supply to the Nzhelele Irrigation Scheme were provided on a weekly basis. These flows were converted to monthly records.

The water demand consists of all the water that was order and delivered by the scheme operators at the farm turnouts as well as for other uses who are provided from the canals.

This includes delivery to the irrigators and other users as well as deliveries to downstream canals. The rest of the water not accounted for such the canal seepage, operational spills, evaporation from the canals and percolation was taken as gross water losses of the scheme or section of the irrigation scheme.

The water balance is an important tool for analysing the water management issues provided adequate and reliable data is available. At a scheme level, there was sufficient data to determine a water budget, based on the WUEARs.

8.4 Overall scheme level Water Balance Assessment - Nzhelele Irrigation Scheme

8.4.1 Overview

The Nzhelele irrigation scheme was analysed on the basis that although it comprises sub-schemes namely the main canal and the branch canals, the scheme level water balance analysis was the only one which could be carried out. Therefore the findings of the scheme level water balance assessment are discussed in the following section.

8.4.2 Diversion into the Nzhelele Irrigation Scheme

8.4.2.1 Diversion from the Nzhelele weir

The source of supply where the water is diverted into the Nzhelele Irrigation Scheme canal is the weir downstream of the dam where there is a hydro station. Flow measurements taken immediately downstream of the weir were used to determine the inflow into the Nzhelele main canal. No other inflows take place in the scheme area. Individual groundwater abstraction data was not taken into account.

The monthly flow records of the inflows into the main canal were taken and used to determine the total annual water diverted into the Nzhelele Government Scheme canal system. The records were aggregated into monthly records. Monthly records from 2009/10 water year and the 2011/12 water year were generated as illustrated in **Table 8.1** below.

The total average annual diversion into the Nzhelele Scheme for the two years of records, was determined to be 24.89 million m^3/a. The maximum diversion took place in the current water year when the total diversion for the year was approximately 26.25 million m^3/a. The water allocation for 2 914 ha enlisted area for irrigation is 24.5 million m^3/a (excluding water losses). With the water allocation over the last couple of years restricted to 85% of the scheduled quota at 20.8 million m^3/a, the high diversion was required on matching the demand for irrigation water use and domestic use taking into account the water losses required to deliver the water demand.

The lowest volume of irrigation water diversion occurred in the 2009/10 water year when 25.24 million m^3/a, was diverted from the dam into the main irrigation canal.

8.4.2.2 Precipitation

No data was available on the monthly rainfall in the Nzhelele Irrigation Scheme area for the same period. Therefore the precipitation was not included as an input into the water budget.

Table 8.1: Nzhelele Irrigation Scheme - Water Balance

		INFLOWS					DEMANDS								GROSS WATER LOSSES			NON BENEFICIAL WATER LOSSES			BENEFICIAL WATER LOSSES			UTILISATION
WATER YEAR	MONTH	Nzhelele Dam	Other Supplements	Balancing Dam	Precipitation	Total inflows	Irrigation water application	Households/Stock Consumption	Industrial	Municipality	Government	Free Water	Other Canals	Total Outflows	Total water losses	% of inflow	Water Use Index	Evaporation	Seepage	Unavoidable water losses	Canal End Point	Seepage & Leakage	% avoidable water losses	% of scheduled volume
2001/02																								
	April					-								-	-	#DIV/0!	#DIV/0!	-	-	-		-	#DIV/0!	
	May					-								-	-	#DIV/0!	#DIV/0!	-	-	-		-	#DIV/0!	
	June					-								-	-	#DIV/0!	#DIV/0!	-	-	-		-	#DIV/0!	
	July					-								-	-	#DIV/0!	#DIV/0!	-	-	-		-	#DIV/0!	
	August					-								-	-	#DIV/0!	#DIV/0!	-	-	-		-	#DIV/0!	
	September					-								-	-	#DIV/0!	#DIV/0!	-	-	-		-	#DIV/0!	
	October					-								-	-	#DIV/0!	#DIV/0!	-	-	-		-	#DIV/0!	
	November					-								-	-	#DIV/0!	#DIV/0!	-	-	-		-	#DIV/0!	
	December					-								-	-	#DIV/0!	#DIV/0!	-	-	-		-	#DIV/0!	
	January					-								-	-	#DIV/0!	#DIV/0!	-	-	-		-	#DIV/0!	
	February					-								-	-	#DIV/0!	#DIV/0!	-	-	-		-	#DIV/0!	
	March					-								-	-	#DIV/0!	#DIV/0!	-	-	-		-	#DIV/0!	
Sub-total		-	-	-	-	-	-	-	-	-	-	-	-	-	-	#DIV/0!	#DIV/0!	-	-	-	-	-	#DIV/0!	0%
2009/10																								
	April	2 265 519.16				2 265 519.16	1 314 000.00							1 314 000.00	951 519.16	42.0%	1.72	39 107.51	131 365.61	170 473.12		781 046.04	34.5%	
	May	1 703 092.17				1 703 092.17	1 370 000.00							1 370 000.00	333 092.17	19.6%	1.24	29 398.87	98 753.41	128 152.28		204 939.89	12.0%	
	June	2 206 791.84				2 206 791.84	1 037 000.00							1 037 000.00	1 169 791.84	53.0%	2.13	38 093.76	127 960.32	166 054.08		1 003 737.76	45.5%	
	July	2 209 050.59				2 209 050.59	968 000.00							968 000.00	1 241 050.59	56.2%	2.28	38 132.75	128 091.29	166 224.04		1 074 826.54	48.7%	
	August	2 170 651.96				2 170 651.96	1 631 000.00							1 631 000.00	539 651.96	24.9%	1.33	37 469.91	125 864.76	163 334.67		376 317.29	17.3%	
	September	2 331 022.70				2 331 022.70	1 552 000.00							1 552 000.00	779 022.70	33.4%	1.50	40 238.24	135 163.82	175 402.06		603 620.65	25.9%	
	October	2 953 000.00				2 953 000.00	2 261 000.00							2 261 000.00	692 000.00	23.4%	1.31	50 974.84	171 229.03	222 203.87		469 796.13	15.9%	
	November	928 000.00				928 000.00	716 000.00							716 000.00	212 000.00	22.8%	1.30	16 019.19	53 809.87	69 829.05		142 170.95	15.3%	
	December	1 864 000.00				1 864 000.00	1 311 000.00							1 311 000.00	553 000.00	29.7%	1.42	32 176.47	108 083.61	140 260.08		412 739.92	22.1%	
	January	2 467 000.00				2 467 000.00	1 920 000.00							1 920 000.00	547 000.00	22.2%	1.28	42 585.49	143 048.43	185 633.92		361 366.08	14.6%	
	February	2 037 000.00				2 037 000.00	1 012 000.00							1 012 000.00	1 025 000.00	50.3%	2.01	35 162.80	118 114.98	153 277.78		871 722.22	42.8%	
	March					-								-	-	#DIV/0!	#DIV/0!	-	-	-		-	#DIV/0!	
Sub-total		23 135 128.42	-	-	-	23 135 128.42	15 092 000.00	-	-	-	-	-	-	15 092 000.00	8 043 128.42	34.8%	1.53	399 359.82	1 341 485.13	1 740 844.95	-	6 302 283.47	27.2%	62%
2010/11																								
	April					-								-	-	#DIV/0!	#DIV/0!	-	-	-		-	#DIV/0!	
	May					-								-	-	#DIV/0!	#DIV/0!	-	-	-		-	#DIV/0!	
	June					-								-	-	#DIV/0!	#DIV/0!	-	-	-		-	#DIV/0!	
	July					-								-	-	#DIV/0!	#DIV/0!	-	-	-		-	#DIV/0!	
	August					-								-	-	#DIV/0!	#DIV/0!	-	-	-		-	#DIV/0!	
	September					-								-	-	#DIV/0!	#DIV/0!	-	-	-		-	#DIV/0!	
	October					-								-	-	#DIV/0!	#DIV/0!	-	-	-		-	#DIV/0!	
	November					-								-	-	#DIV/0!	#DIV/0!	-	-	-		-	#DIV/0!	
	December					-								-	-	#DIV/0!	#DIV/0!	-	-	-		-	#DIV/0!	
	January					-								-	-	#DIV/0!	#DIV/0!	-	-	-		-	#DIV/0!	
	February					-								-	-	#DIV/0!	#DIV/0!	-	-	-		-	#DIV/0!	
	March					-								-	-	#DIV/0!	#DIV/0!	-	-	-		-	#DIV/0!	
Sub-total		-	-	-	-	-	-	-	-	-	-	-	-	-	-	#DIV/0!	#DIV/0!	-	-	-	-	-	#DIV/0!	0%
2011/12																								
	April	1 889 025.00				1 889 025.00	1 374 648.00	64 079.00						1 438 727.00	450 298.00	23.8%	1.31	32 608.45	109 534.68	142 143.13	101 376.00	206 778.87	16.3%	
	May	1 737 047.00				1 737 047.00	1 404 624.00	94 383.00						1 499 007.00	238 040.00	13.7%	1.16	29 985.00	100 722.27	130 707.27	101 376.00	5 956.73	6.2%	
	June	1 889 026.00				1 889 026.00	1 171 560.00	129 872.00						1 301 432.00	587 594.00	31.1%	1.45	32 608.47	109 534.74	142 143.21	101 376.00	344 074.79	23.6%	
	July	1 790 290.00				1 790 290.00	1 353 196.00	161 780.00						1 514 976.00	275 314.00	15.4%	1.18	30 904.08	103 809.56	134 713.64	101 376.00	39 224.36	7.9%	
	August	2 140 713.00				2 140 713.00	1 337 060.00	4 244.00						1 341 304.00	799 409.00	37.3%	1.60	36 953.10	124 128.75	161 081.86	101 376.00	536 951.14	29.8%	
	September	2 977 156.00				2 977 156.00	1 914 312.00	41 051.00						1 955 363.00	1 021 793.00	34.3%	1.52	51 391.83	172 629.71	224 021.54	101 376.00	696 395.46	26.8%	
	October	2 140 715.00				2 140 715.00	1 337 060.00	43 296.00						1 380 356.00	760 359.00	35.5%	1.55	36 953.14	124 128.87	161 082.01	101 376.00	497 900.99	28.0%	
	November	2 140 713.00				2 140 713.00	1 577 208.00	47 483.00						1 624 691.00	516 022.00	24.1%	1.32	36 953.10	124 128.75	161 081.86	101 376.00	253 564.14	16.6%	
	December	2 140 717.00				2 140 717.00	1 337 060.00	19 843.00						1 356 903.00	783 814.00	36.6%	1.58	36 953.17	124 128.99	161 082.16	101 376.00	521 355.84	29.1%	
	January	2 513 544.00				2 513 544.00	1 780 128.00	41 540.00						1 821 668.00	691 876.00	27.5%	1.38	43 388.93	145 747.27	189 136.20	101 376.00	401 363.80	20.0%	
	February	2 702 703.00				2 702 703.00	1 897 296.00	40 423.00						1 937 719.00	764 984.00	28.3%	1.39	46 654.20	156 715.62	203 369.82	101 376.00	460 238.18	20.8%	
	March	2 590 403.00				2 590 403.00	1 875 776.00	38 022.00						1 913 798.00	676 605.00	26.1%	1.35	44 715.67	150 203.93	194 919.60	101 376.00	380 309.40	18.6%	
Sub-total		26 652 052.00	-	-	-	26 652 052.00	18 359 928.00	726 016.00	-	-	-	-	-	19 085 944.00	7 566 108.00	28.4%	1.40	460 069.14	1 545 413.14	2 005 482.28	1 216 512.00	4 344 113.72	20.9%	75%

8.4.2.3 Changes of volume in storage of Nzhelele Balancing Dam

The impact of a regulatory storage such as Nzhelele Balancing Dam by providing storage opportunities for downstream irrigators reduces the time to supply the irrigators. The potential benefit in management flexibility and improved water use efficiency associated with a balancing dam in irrigation schemes is illustrated in **Figure 8.1** below. The storage capacity of Nzhelele Balancing Dam is currently not known.

The Nzhelele balancing dam is currently not being included in the water inflow into the canal system. This is because the scheme operators are not taking the flow measurements at the inlet and outlet of the balancing dam to determine the changes in the storage capacity in the balancing dam with any reduction being added to the diversion from the Nzhelele weir while the positive storage being subtracted from the diversion from the Nzhelele weir over the year. Therefore the current inflow data is not adequate and does not reflect the complete picture of the inflows into the Nzhelele canal system.

As illustrated in **Figure 8.1** below, the available storage capacity in Nzhelele Balancing Dam is supposed to reduce the diversion rate from the Nzhelele Dam depending on how much storage is available in the next irrigation schedule.

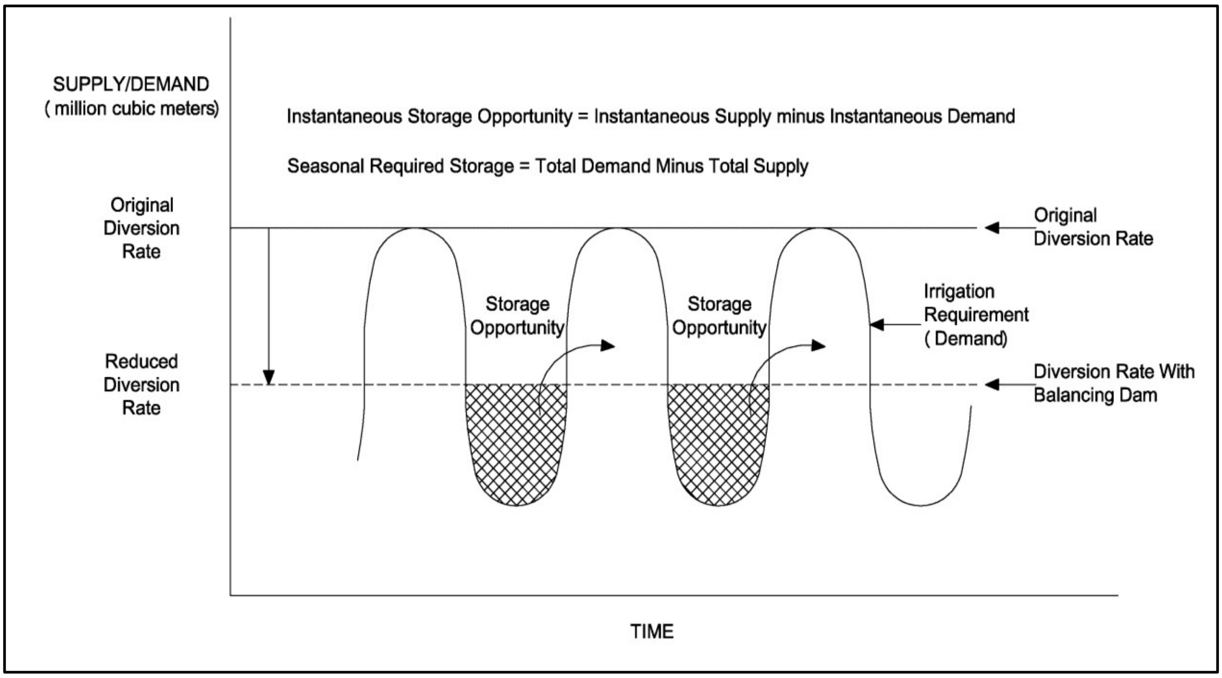

Figure 8.1: Possible demand and supply relationship and potential benefit in flexibility from a balancing dam

8.4.3 Water Demands from Nzhelele scheme

The supply to individual water users is measured (or rather administered) through the head and hence the variable water pressure at different adjustable sluice gates at each of the farm turnouts that has an allocation from this section of the scheme. The Water Control Aids measure the water through the V-notches or Parshall sluices. The sluices are adjusted by hand in increments based on the irrigation application for the week.

Due to the water level and hence pressure variance in the canal system, there is a margin of error in the volume of water delivered to the water user and water users are requested to accept a margin of error of 10%. The monthly data on releases at the individual sluices through the Parshall Flumes and V-Notch weirs were aggregated in the WUEARs to provide monthly records of water supplied to the irrigators.

This was taken as the crop evapo-transpiration (ET). The monthly records of water deliveries to other water users, namely for household consumption, was included in the water demand from the canal system.

8.4.3.1 Irrigation water demands

The volume of water applied for by the irrigators in the Nzhelele Irrigation Scheme area varies from year to year, as does the cropping pattern for each year. With only 2 years of records available the irrigation water applications has ranged from 16.42 million m^3/a in 2009/10 water year to 18.36 million m^3/a in 2011/12.

The average irrigation water demands was 17.44 million m^3/a. When compared with the scheduled quota for canal irrigators this represents on average approximately 70% of the scheduled area that was irrigated over the period. This indicates that not all the irrigators took up their full scheduled allocation.

8.4.3.2 Other demands

Besides irrigation water demands, the Nzhelele Irrigation Scheme also supplies household water to the surrounding communities.

It is not clear whether; the domestic water demand from the irrigation canal infrastructure has been growing significantly over the past 2 years. No figures for household consumption were provided for the 2009/10 water year. The household consumption for 2011/12 was provided as 0.73 million m^3/a.

8.4.3.3 Delivery to downstream canals

There are no downstream canals which are supplied from the Nzhelele Dam.

8.4.4 Comparison of monthly diversions with monthly demands

There is some correlation between the monthly diversions in the Nzhelele irrigation canals with the monthly demands as illustrated in **Figure 8.2** below. The irrigation water supplied is more than the water requested by irrigators and other water users in the scheme.

The difference in matching the supply to the demand is to take into account the losses needed to deliver the water required by the irrigators. There may also be excess water being delivered into the canals of the Nzhelele government water scheme, which is considered operational spills at the canal tail ends. Without actual measurements of the amount of water flowing back at the canal tail ends, only estimates can be used until the scheme operators begin to take flow measurement at the Parshall Flumes and V-Notch weirs at the canal tail ends.

As illustrated in **Figure 8.2** below, there is a significant difference in trying to match the irrigation supply to the irrigation water demands, as more water needs to be diverted to meet the irrigated water ordered.

The two year average percentage of water losses in order to meet the irrigation demands and downstream canals was determined to be 32% of the total water released from the dam. The additional water can be attributed to irrigation water losses owing to seepage, leakage losses in the irrigation canals, and evaporative losses from the open irrigation canal infrastructure and spills due to aquatic weeds and algae.

The above average percentage has been benchmarked against best management practice (BMP) in order to determine the avoidable water losses that will need to be reduced in order to only supply the additional water based on the BMP for seepage losses in lined canals and the expected evaporation losses of the Nzhelele Irrigation Scheme.

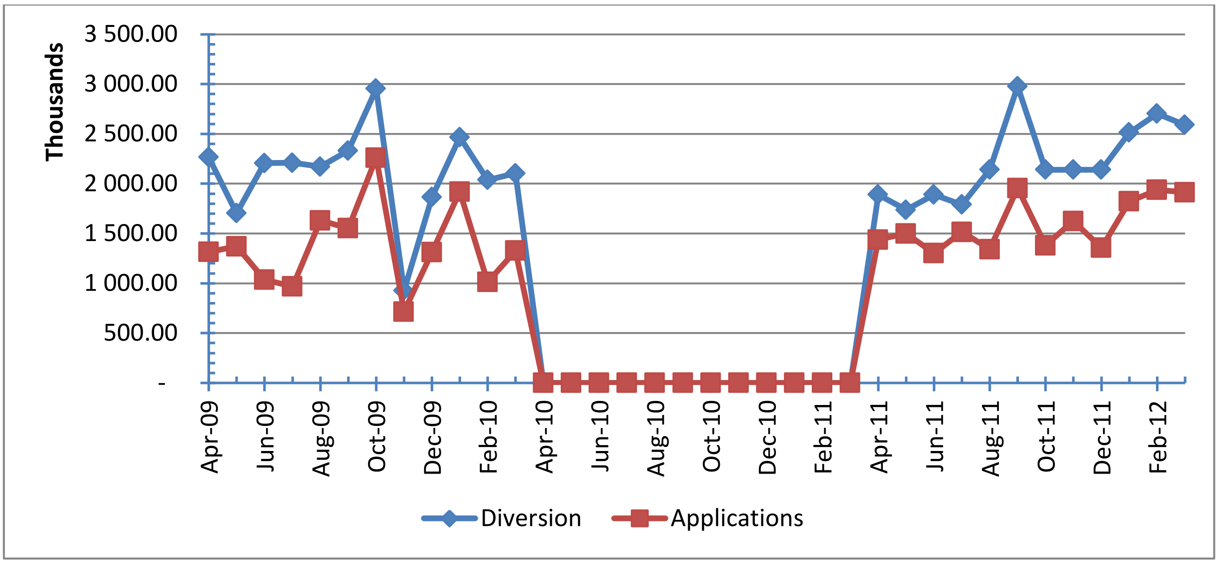

Figure 8.2: Comparison of deliveries and the irrigation demands

8.5 Gross Water losses

8.5.1 Overview

Figure 8.3 below indicates that the monthly average gross water losses including the return flow, over the period.

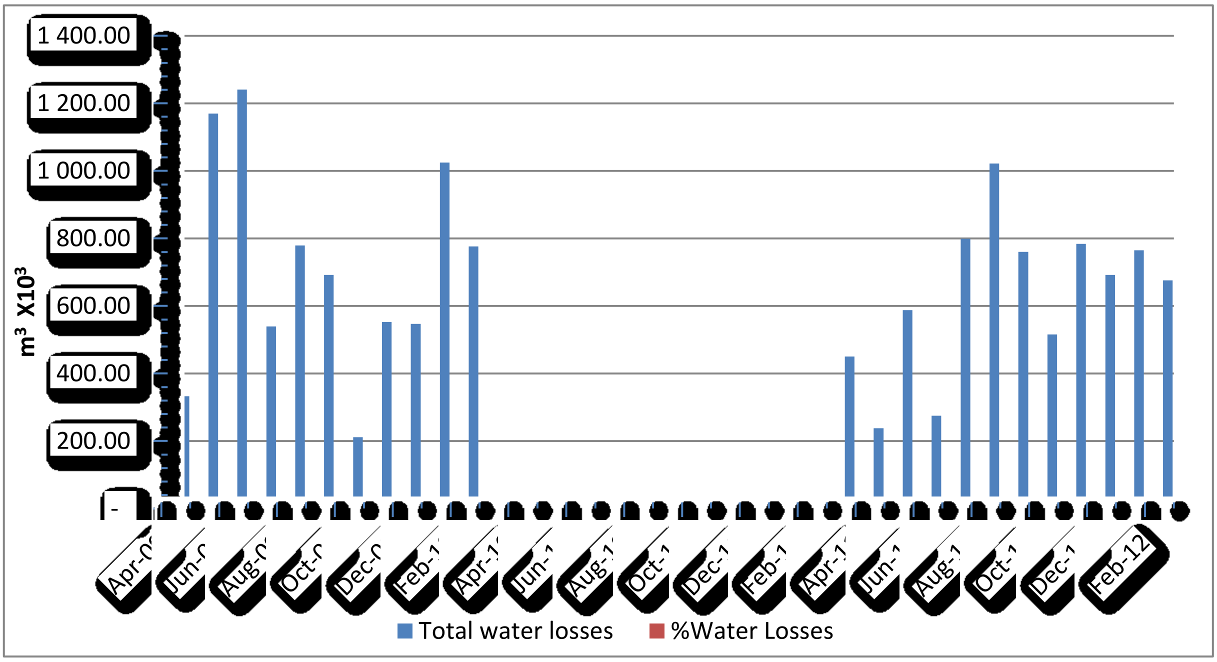

Figure 8.3: Percentage water losses in Nzhelele Irrigation Scheme area

A review of the monthly figures indicate that the difference between supply and demand is significantly more during the months of June/July as well as during September / October when the percentage water losses is much higher. This may be attributed to the fact that this is the harvest period for the citrus and grape fruit which is irrigated before harvesting.

The other reason may be due to the fact that the evaporation losses during the summer periods of September / October are generally higher than the average used in the BMP for the Nzhelele Government Water Scheme.

Because of the high water demands during this period, the water depth in the canal infrastructure is high and there is potential for overflows because of the aquatic weeds found in the canals. Because of the high water depth the top section of irrigation canals are more exposed to the elements and general wear and tear (small breakages, chips, etc.) than the lower section resulting in higher leakages when the canal is running close to or at full capacity as discussed in the condition assessment chapter.

8.5.2 Water losses - Nzhelele Government Water Scheme

The average estimated water losses for the whole Nzhelele GWS were calculated to be 32% of the net inflow over the two years of records. The water losses are equivalent of 8.2 million m^3/a including the operational spills at the canal tailend, estimated during the site visit to be 1.2 million m^3/a. This was based on the measurement taken during the site visit. Although this is an estimate for the full water year, it indicates that the operational spills appear to be high in the Nzhelele Government Water Scheme. This is illustrated in **Table 8.2** below.

When compared with the Best Management Practice (BMP) for evaporation losses and expected seepage losses from lined canal infrastructure, which was determined to be 8% (see **Table 8.2** below) of the net inflow into the Nzhelele GWS, the avoidable water losses is significant at 6.24 million m^3/a. There is therefore significant potential to reduce the water losses in order for the scheme to manage irrigation water at the BMP.

8.5.3 Unavoidable water losses

As illustrated in **Table 8.2** above, the minimum seepage losses as calculated in the previous chapter for the Nzhelele canal system is 1.5 million m^3/a while the evaporation losses was calculated based on the canal surface area and the MAE as 0.45 million m^3/a. The total minimum unavoidable losses that has to be added to the irrigation water requirements or the schedule allocation is 1.95 million m^3/a, or 8% of the total diverted into the Nzhelele canal system.

Based on the above Best Management Practice (BMP) for evaporation losses, and expected seepage losses from lined canal infrastructure, the estimated seepage losses for the Nzhelele irrigation canal is 8% of the net inflow.

Table 8.2: Summary of water losses in the Nzhelele Government Water Scheme

Description	Unavoidable losses (m^3*10^6)	BMP for operation & distribution (m^3*10^6)	Avoidable losses (m^3*10^6)	Total losses (m^3*10^6)	% of total losses
Seepages	1.504		-		18%
Evaporation	0.447				5%
Filling losses		2.59	3.65		0%
Leakages					76%
Spills					0%
Operational Losses					0%
Over delivery to users					0%
Canal end returns					0%
Other					0%
Total	**1.952**	**2.59**	**3.65**	**8.192**	
% of total losses	**24%**	**32**	**45%**	**100%**	
% of total volume inflow to scheme	**8%**	**10**	**14%**	**32%**	

8.5.4 Avoidable water losses

8.5.4.1 Total avoidable water losses

The unavoidable losses calculated in the previous section were based on the assumption that the condition of the Nzhelele canals are being well maintained and are refurbished in time to maintain the level of service from the canals. This was considered to be the economic level of seepage (ELS) for the Nzhelele canal system.

Having determined the unavoidable water losses which are required to deliver the irrigation water requirements, the remainder of the gross water losses are considered avoidable water losses to the scheme, although they are beneficial to downstream water users. This is because these losses can be prevented by implementing appropriate water management intervention measures.

The total avoidable water losses for the Nzhelele canal system was determined to be 6.2 million m^3/a, or 76% of the gross water losses. The avoidable water losses include leakage and operational spills, particularly at canal tail ends.

8.5.4.2 Operational losses and canal end returns:

There are water losses on the canal system which can be classified as operational losses due to the way the scheme is operated. Such losses include start-up and shut-down losses, operational wastage due to the lack of quick response to changes in demand, water not used (outflows) due to unexpected drops in demand and losses due to incorrect metering. These losses are estimated to fluctuate between 9% and 17% of the irrigation water losses (Reid, Davidson and Kotze, 1986).

Because of lack of sufficient flow measurement data particularly at canal tail ends, it was not possible to disaggregate the avoidable losses into operational losses and leakage losses. However the preliminary estimates that were taken during the site visit of the operational losses at the canal tailend was estimated to be 1.2 million m^3/a. This is approximately 21% of the avoidable water losses. This is much higher than the norm and a clear indication that there are operational problems in the Nzhelele irrigation scheme.

The operational losses at canal tail ends represent that more water is being diverted into the canal system than is required, which could have been left in the Nzhelele Dam to meet demands during low flow periods. In the Nzhelele irrigation canal system where the scheme is manually operated these losses are likely to be high as the time to react to any changes in demand is likely to be longer.

8.5.4.3 Leakage losses:

The determination of the volume of water that is wasted as a result of leakages is very difficult and can only be done through accurate measuring or undertaking tests such as ponding tests on the irrigation canals. Leaks normally occur in broken sections of the canals and at the top sections of canal bodies and can be attributed to maintenance problems and the general deterioration of the canal network due to its age (see **Photo 8.1** below).

An important factor that has a marked effect on leakages is the water depth in a canal system. The leakage losses which can be avoided are due to the constant movement of water through the bottom and sides of the canal system due to small cracks including abnormally large cracks in the canal infrastructure which can be reduced through canal maintenance. The top section of irrigation canals are more exposed to the elements and general wear and tear (small breakages, chips, etc.) than the lower section resulting in higher leakages when the canal is running close to or at full capacity.

As expected because of the age of the canal infrastructure and the condition of some sections of the canals as discussed in the previous chapter 5, the leaks due to the poor condition of the canal infrastructure are high. This is estimated to be 5.0 million m^3/a based on the difference between the total avoidable losses and the estimated operational losses.

The leakage losses were estimated to be more than the operational losses which is an indication that the condition of the concrete lined canal in the Nzhelele Government Water Scheme is very poor. There are abnormally large cracks in the canal system due to a lack of renewal and refurbishment of the irrigation canals. A review of the condition of the infrastructure (see **Photo 8.1** below) does seem to confirm that there are significant leakage losses due to the major cracks and vegetation growth in the Nzhelele canal system. Furthermore there are hairline cracks resulting in leakage losses, particularly with the changes in the capillary rise and fall due to the start and stop procedure of operating the scheme.

Photo 8.1: Broken section of concrete panels of canal system

8.5.4.4 Aquatic weeds and algae:

Aquatic weed and algae growth in irrigation canal systems is fast becoming one of the major operational problems in scheme management, especially on those schemes where water is becoming progressively eutrophic. Du Plessis and Davidson (1996) listed the following impacts of excessive aquatic weed growth on irrigation canal systems:

(i) A negative influence on hydraulic capacity and flow speeds in the canals. This decrease in canal capacity occurs particularly when the water demand is at its highest.

(ii) Overestimation of the amount of water supplied, because of the artificially increased water levels that are measured at calibrated weirs.

(iii) Water loss because of the flooding of canals.

(iv) Impediment of floodgate and sluices at dividing structures.

(v) Water logging of long-weirs.

(vi) Structure (slab) failure of concrete-lined irrigation canals due to flooding.

(vii) Aquatic weed fragments block irrigation systems and filters at water purification plants.

(viii) The mechanical removal of the biomass is extremely labour intensive, expensive and mostly ineffective.

The aquatic weeds and algae is a major issue in the Nzhelele Irrigation Scheme (see **Photo 8.2** below).

Photo 8.2: Aquatic weeds and algae in the Nzhelele Irrigation Canals

9 EXISTING WATER MANAGEMENT MEASURES AND PROGRAMMES

9.1 Overview

Chapter 8 indicated that the water losses in the Nzhelele Government Water Scheme (GWS) are generally high. The water balance assessment has indicated that there is a need to determine and implement water management measures to reduce irrigation water losses and improve the water use efficiency of the scheme.

Before determining the necessary water management measures to improve irrigation water management, an assessment of the existing water management measures and initiatives, if any, was carried out. These have been identified based on discussions with the scheme operators on the programme in place as part of efficient and effective irrigation water management of the Nzhelele GWS.

The Nzhelele GWS has been implementing measures to improve the management of delivery to the irrigators. These have included the following:

(i) Water order and request measures which ensures that only the water applied for is supplied;

(ii) Flow measurement and preparation of WUEARs which provides an indication of the extent of water losses and irrigation water use efficiency levels in the scheme;

(iii) Carrying out maintenance of the canal system during dry periods to reduce avoidable canal losses.

These existing water management measures are discussed in more detail below.

9.2 Existing Water Management Measures

9.2.1 Flow measurements

9.2.1.1 Flow measurements at all branch canals and at the canal tail ends

There are flow measurement structures, namely Parshall Flumes and V-Notch weirs at nearly all of the critical diversion points to measure how much water is diverted at different points of the irrigation scheme. These include flow measurement at the branch canal off takes as well as the canal tail end of the Nzhelele irrigation scheme, although these may not be recorded on a regular basis. Therefore water balances can be conducted for each branch canal if the flow measurements are taken and included in the WUEARs.

There are flow measurements at the Nzhelele weir which provides the flow rate and volume of water diverted into the canal; the flow measurements at the canals at Nzhelele weir and Nzhelele Dam which provides information on the volume of water diverted into the Nzhelele main canal.

9.2.1.2 Flow measurement at the irrigators sluice gates

The Nzhelele GWS has installed flow measurement structures at all the farm turnouts in order to measure the water delivered to each irrigator in the scheme. These are mainly Parshall Flumes as well as V-Notch weirs. All the flow measurement structures were calibrated.

The availability of sluices at each farm turnout ensures that each irrigator can only get the scheduled allocation they are entitled to.

9.2.2 Water ordering policy

The Nzhelele Irrigation Scheme has a water ordering policy which enables only the amount of water applied for plus the estimated water losses to be diverted into the main irrigation canals. The irrigators and other users put their water application for the following week by the Thursday to allow the scheme operators to plan how much water to be released to meet these demands only.

9.2.3 Water Shortage Contingency Plan

The Nzhelele Irrigation Scheme has a water contingency plan. The basic objectives of the plan:

(i) Hydrologic forecasting to predict water supply
(ii) Definition of water allocation procedures to be used during drought periods
(iii) Identification of alternative or supplemental water supplies

At the beginning of each water year, information on hydrologic forecasting to predict water availability is provided to water users that will help them decide which crops to irrigate and how many hectares to farm. For example, given a forecast, farmers can choose to irrigate less land or grow crops that require less water.

Defining the water allocation and curtailments to farmers before the drought conditions begin provides irrigators with fairly certain information as to what they can expect in terms of water deliveries and will allow them to plan accordingly.

9.2.4 Operation and maintenance of the canal infrastructure

9.2.4.1 Maintenance of the canal system

The ownership of the canal infrastructure at the Nzhelele Irrigation Scheme is with the DWA Infrastructure Branch which is also responsible for the operation and maintenance of the canal infrastructure.

During dry periods, significant maintenance is carried out on the primary canal and secondary canals. The availability of the Nzhelele balancing dam provides the flexibility during the dry period to provide some of the irrigators from the dam. It also reduces the amount of water required for filling the dam before supplying to irrigators below the Balancing dam.

9.2.4.2 Penalties for not taking up the requested water

According to the scheme operating rules, when an irrigator orders a certain volume of water and does not take it up, nor cancels the order in time, the scheme operators book this against their quota.

The irrigators must provide changes to their irrigation water application or cancel their applications by a certain timeframe to enable the scheme operators to adjust the supplies to the scheme. Any losses due to changes in demand during this timeframe are to the account of the irrigator.

This procedure provides incentives for irrigators to schedule their irrigation water requirements and minimise the scheme water losses.

9.3 Impact of existing water management measures

The existing water management measures described have helped reduce water losses in the Nzhelele Irrigation Scheme. However, the findings of the water balance assessment indicate that the water losses in the GWS are still very high. There is still significant potential to improve irrigation water use efficiency in the Nzhelele Irrigation Scheme if specific water loss control and operational measures are put in place.

The water management issues contributing to the high water losses and the management options to improve irrigation water management in the Nzhelele Government Water Scheme are discussed in detailed in the following chapter.

10 WATER MANAGEMENT ISSUES AND GOALS

10.1 Overview the management issues

The water use performance benchmarking and water balance analysis of the Nzhelele Irrigation Scheme which were presented in chapter 7 and chapter 8 together with site visits and discussions held with scheme operators of the Nzhelele GWS, has helped to identify several key water management issues. Firstly, the comparison of the best management practice (BMP) for irrigation water conveyance with the water balance analysis has identified that the water losses taking place in the Nzhelele Irrigation Scheme are high. This is due to a number of reasons which are discussed in the following sections.

The water balance analysis also revealed that on an annual basis, there is sufficient water to meet the Nzhelele Irrigation Scheme's irrigation demands as the irrigation applications have not exceeded the available supply. It also highlighted that irrigators are currently not utilising their full water allocation.

10.2 Flow measurement data and assessments

10.2.1 Adequacy of flow measurement data

Good information is fundamental to making decisions on managing irrigation water at any irrigation scheme. **Figure 10.1** below provides the extent of flow measurement that is ideal for conducting an irrigation scheme water budget. The availability of flow measurements helps inform both the water user and the WUA about the quantity, timing, and location of water use and therefore enables the WUA to conduct a water balance analysis not only at scheme level but also for sub-schemes within the irrigation scheme.

As illustrated **in Figure 10.1** below, it would be ideal to have flow measurements at the inlet to the primary canals, at the main branch canals, at balancing dams as well as at the canal tail water ends. This would assist in determining the water losses in each section of the canal system, as well as the operational spills, if any.

As indicated in **Figure 4.2**, the Nzhelele Irrigation Scheme appears to have adequate flow measurement structures in place at the ideal places to measure the flows. The scheme operators are currently taking flow measurements at the canal headworks, the branch canals as well as adjusting sluice gates according to the irrigator's weekly water application. The flow measurement structures include weirs and Parshall flumes on the canals, and V-notches and rated sluice gates on the laterals to the individual farmers.

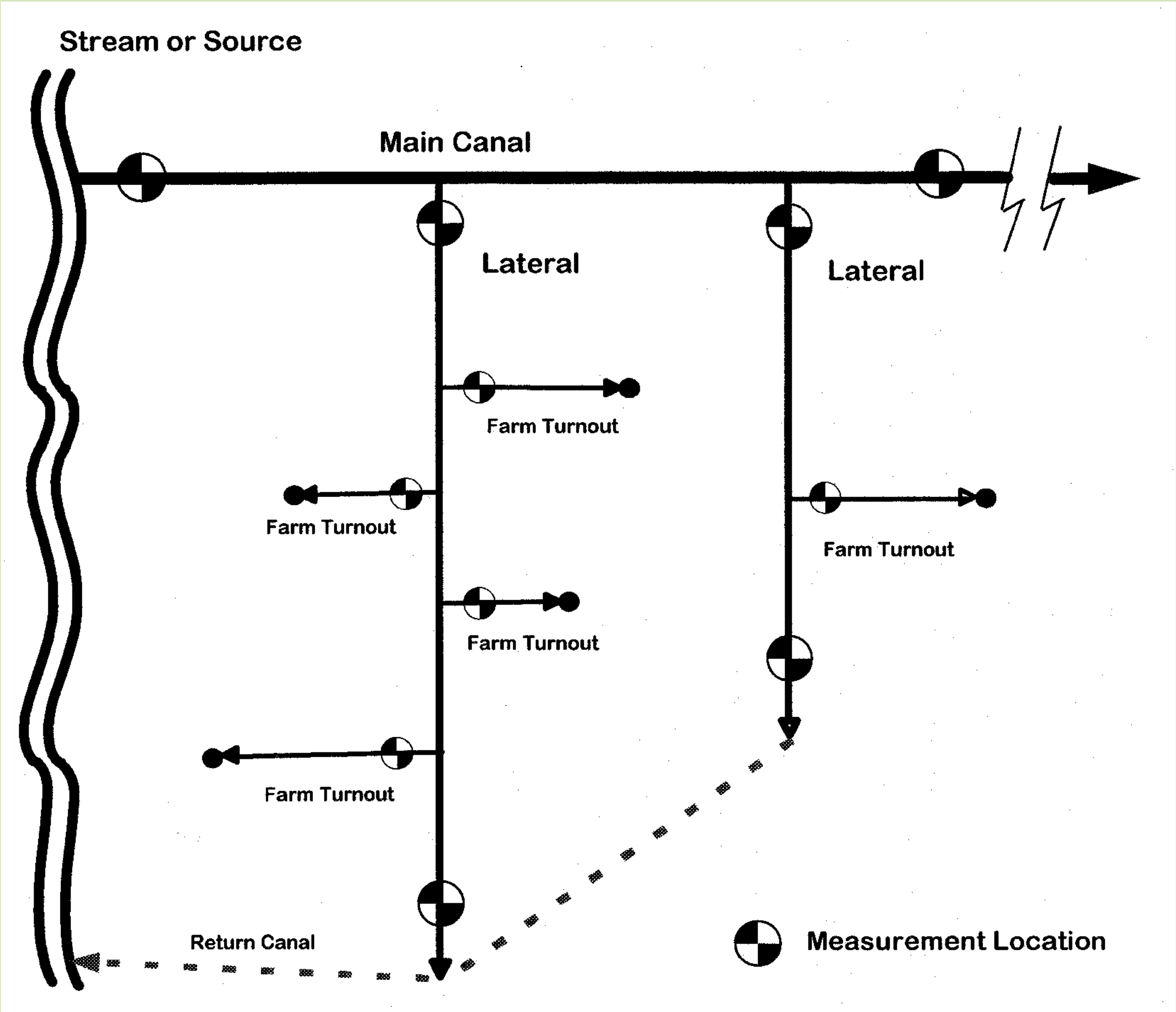

Figure 10.1: Irrigation Scheme with ideal water measurement system

Source: Bureau of Reclamation

Although currently the existing Parshall flumes and V-Notch weirs at the farm turnouts are being measured, the measurement at the canal tail ends is not being done. Furthermore, the actual flow rate at the branch canals appears not to be read as the percentage of water losses added is consistently the same for different irrigation applications. At the D-branch canal and the canal tail end where there were flow recorders which would provide continuous flow monitoring, these are currently not functional.

As an example, during the site visit the reading taken at the measurement point after the D canal indicated a gauge plate reading of 0.25 m on a 2 ft Parshall. This translated to a flow rate of 600 m^3/h. The flow rate indicated in the feeder chart which was based on 20% losses reflected a grand total of 554 m^3/h. There is no figure of 554 in the calibration table for a 2 ft Parshall. Therefore the losses added to main canal section 4 was much more than the sum of the sluices in the section plus 20%.

Therefore the Nzhelele GWS cannot conduct detailed water balances at scheme and sub-scheme level to determine the extent of water losses, including operational losses at canal tail ends if accurate flow measurements are not taken.

The above example, together with measurement at the canal tail end, would have determined that there was more irrigation water in the main section 4 than is required. This could have been adjusted in time to potentially save water in this section of the canal. The extent of water losses in the branch canal could be used to address any operational issues or prioritise the branch canals for maintenance.

10.2.2 Lack of continuous monitoring

The Nzhelele Irrigation Scheme is a manually operated system with no continuous flow recording taking place as the existing flow recorders are not operational. There is no telemetry infrastructure linked to any of the existing flow measurements within the scheme area to carry out real time or near real time flow monitoring and control of deliveries. The only real-time flow monitoring is being done at the canal headworks, upstream and downstream of the Nzhelele balancing dam where the Department of Water Affairs (DWA) Hydrological Branch has remote control flow measurements. These are currently not accessible to the scheme operators. The flow information is obtained by the Area Manager's office on a daily basis and should be made available to the scheme operators.

The ideal system for improving irrigation water use efficiency would be to provide data on a real-time or near real-time basis through the use of automatic and data transmission devices such as a telemetry system used by some irrigation schemes in the country.

The lack of real time reduces the scheme operators' capacity and flexibility to respond to changes in demand by water users or operational spills at canal tail ends thereby improving the efficiency of irrigation water management.

However, with the installation of the Water Administration System (WAS) to undertake water accounting reports, it would be ideal to install a telemetry system that is compatible with the WAS programme to enable real time or near real time measurement and changes to be made. This will significantly improve the water use efficiency of the Nzhelele Irrigation Scheme.

10.2.3 Management Goal 1

The objective to address the above irrigation water management issue is to ensure that the following is achieved by the Nzhelele GWS:

(i) Regular measurement of flows into all primary and branch canals, as well as measurement at the tail ends of the canal system to enable detailed water balance assessments to be carried out.

(ii) Ensuring that all measuring devices in the scheme are in good operating condition and regularly calibrated.

(iii) Planning for the installation of telemetry system infrastructure, so that the flow measurement data is sent via the telemetry to the Nzhelele GWS office for direct input into the WAS programme. This should be with a view to have real time flow monitoring in order to reduce the time required to adjust flow rates, identify where losses are occurring and allow the Nzhelele GWS to operate the scheme more efficiently.

In the meantime it is proposed that the scheme operators have access to the telemetry system operated by hydrological branch for continuous flow monitoring at the canal headworks and the balancing dam.

10.3 Irrigation water balance assessment

10.3.1 Irrigation water balance is not conducted in detail

Although a lot of measurement structures are available including the Parshall flumes at branch canals, at the balancing dams as well as at canal tail ends in the Nzhelele Irrigation Scheme, there are some components of the water balance that are not being measured, estimated or included in the water balance assessment. These include the following:

(i) Measurement of evaporation using pan evaporation, to determine local evaporation losses. Therefore the losses calculated at present from the water budget are unreliable or inaccurate.

(ii) Measurement at the canal branches to enable sub-scheme water balance assessments to be conducted.

(iii) Measurement of changes in the Nzhelele balancing dam to include in the water balance assessment.

(iv) Measurement of operational losses at the tail ends, as well as at the rejects.

(v) Measurement of precipitation records is currently not being included in the water budget, which may indirectly result in higher operational spills if irrigators do not take up their full water demands.

10.3.2 Irrigation outfalls and operation spills are not included in the irrigation water budget

The irrigation water balance at scheme level for the Nzhelele Irrigation Scheme, indicated that the scheme "water losses", comprising seepage losses, evaporative losses, operational spills, as well as the flows at the canal tail ends, were averaging approximately 8.2 million m^3/a. Not all of this volume can be considered avoidable water losses, as some is unavoidable losses, such as evaporation losses due to the exposed canal surface area and the seepage losses due to the hydraulic conductivity of the concrete lining as well as the water table in which the canal system was built.

It is currently difficult to disaggregate the avoidable losses into the different components of water losses. This is because no measurements are being taken at the canal tail ends although there are measuring structures. This would provide the operational losses at canal tail ends assuming there are no other demands downstream that are supplied by the scheme. At this stage, it is difficult to determine how much water is returned back to the Nzhelele River and the tributaries. Therefore the available flow measurements can provide a more accurate water balance if the measurements are included in the WAS programme and as part of the water balance assessment.

As a result of the lack of sufficient flow measurement instrumentation, the actual water losses are estimated, which would complicate the setting of water saving targets to implement different management intervention measures to reduce the avoidable water losses.

Although there are Parshall Flumes to measure the inflows into most of the branch canals as well as the canal end points in the Nzhelele Irrigation Scheme, the measurements from these points are currently not being included in the determination of a comprehensive irrigation water balance at both scheme and sub-scheme level. This would assist the Nzhelele GWS in determining which of the sub-schemes has the highest seepage losses and what measures are needed to reduce the losses.

10.3.3 Management Goal 2

The goal to address the above issue is as follows:

(i) Ensure that actual flow rates at the canal tail ends, into and out of the Nzhelele balancing dam and branch canals are measured in the Nzhelele Irrigation Scheme on a weekly basis;

(ii) Ensure that all measured data is included in determining the water balance and calculating water losses within 1 year at scheme as well as sub-scheme level.

10.4 Full utilisation of the Water Administration System

10.4.1 The installed WAS is currently not being fully utilised

The Water Administration System (WAS) was developed as a tool to be used by Irrigation Boards, WUAs and Government Water Schemes to optimise their irrigation water management and minimise management-related distribution losses in irrigation canal systems. The WAS consists of seven modules, integrated into a single programme and these modules can be implemented partially or as a whole. The system includes the following seven modules:

10.4.1.1 Administration module

This module provides the details of all water users on an irrigation scheme. Information managed by this module includes addresses, notes, cut-off list, list of rateable areas, scheduled areas, household and livestock pipes installed on canals, industrial water quotas, crops and areas planted and crop yields. This module was installed and is currently operational.

10.4.1.2 Water order module

This module captures all the weekly and monthly water requested by each farmer in the scheme. It also includes any additional water requests or any cancellations of water orders.

This module is very useful to determine the extent of additional requests, as well as the cancellations, as this will provide a clear indication of the extent of operational spills on rejects and tail ends in the case of cancellations. It will also highlight the flexibility that the Nzhelele Irrigation Scheme has in responding to cancellations.

10.4.1.3 Water release module

This module takes information from the water request module and calculates the volume of water to be diverted from the Nzhelele Dam at the Nzhelele weir into the main canal and all its branches allowing for lag times and any water losses and accruals to supply the irrigation applications for the week.

A schematic layout of the total canal network or river system, is captured with detail such as the cross sectional properties, positioning of sluices or pumps, canal or river slope, structures and canal or river capacities. Discharges are converted to the corresponding measuring gauge plate readings where needed, so that the sluice gates can be set to deliver the flow rates required to meet the water required for the week which is 120 hours.

The Nzhelele GWS is currently not utilising the water release module. Instead all the calculations are currently being done in a spreadsheet and the gauge plate settings provided to the scheme operators to set at the beginning of the week.

10.4.1.4 Measured data module

This module provides the field data that is measured from the flow rates and volume of water delivered to each user and the flow rate and volume of water released at the Nzhelele Dam, as well as the flow rate and total volumes measured at different points in the canal system. This data is very useful in conducting water balance assessment not only at scheme level but also at sub-scheme level.

Currently the data that is measured manually is not being captured into the data module.

10.4.1.5 Other modules

The above three modules are the key modules in accounting for water use in an irrigation scheme. However there are other modules which include the following:

(i) *Water accounts module*- this module administers all water accounts for an irrigation scheme or water management office. The water accounts module is a full debit system, from which monthly reports can be printed, including invoices on pre-printed stationery, reconciliation reports, age analysis and audit trail reports.

(ii) *Crop water use module* is used to calculate the water usage per crop between two specified dates for all the planted crops on a scheme, based on the plant date, the area planted and the crop water use curve.

(iii) *Reporting Module* – includes an extensive range of water and financial reports. Water balance sheets, distributions sheets, WUEAR and various other operator defined reports can be generated. This module is currently in use at the scheme.

However, at present the WAS is not being fully utilised by the scheme as the release module is not being utilised. There will be substantial benefit in utilising the WAS system to undertake Water Use Efficiency Accounting Reporting (WUEAR), with a view to determining which of the irrigation sub-schemes are experiencing significant water losses. This can provide priority areas, where issues need to be addressed in irrigation water management in the Nzhelele Irrigation Scheme.

It has been estimated that field measurements indicated water savings of between 10% and 20% on fully implementing the water release module of the WAS program alone. In the case of Nzhelele Irrigation Scheme, the WAS programme has been installed for some time but the records indicate that these savings have not been achieved because the WAS programme has not been fully utilised.

10.4.2 Management Goal 3

The management objective to address the above issue, is to ensure that all the modules of the WAS programme, particularly the water order and water release modules, are implemented fully and that weekly and monthly reports from the modules are generated for both the scheme and sub-schemes of the Nzhelele Government Water Scheme.

Furthermore, the measured data module should be linked to a telemetry system, to enable direct reading of the measured data in the WAS programme. This can be used to undertake automatic reporting on water losses, not only at scheme level, but also at sub-scheme levels.

10.5 Capacity of Balancing Dams and availability of farm dams

10.5.1 Overview

There is balancing dam in the Nzhelele Government Water Scheme, which regulates flows to downstream irrigators from the N19 sluice gate up to the canal tail end including the D and E branch canal irrigators.

One of the benefits of having regulating structures such as balancing dams, is that the balancing dam reduces the time it takes to deliver water to the irrigators, thereby reducing the seepage and evaporative losses as well as leakages in the canal conveyance system. However in order to determine the benefits of having balancing dams, it is important to know the capacity of the Nzhelele Balancing Dam as well as measure the weekly changes in the storage. This is a problem in the Nzhelele irrigation scheme as discussed below.

10.5.2 Capacity of Nzhelele Balancing is not known

The capacity of the Nzhelele Balancing Dam is not known. As a result it is not known whether the capacity of the balancing dam is sufficient to supply the downstream irrigators including the municipality or not.

Besides the fact that the capacity of Nzhelele balancing dam is not known, the scheme operators are not utilising the existing measurements upstream and downstream of the dam to determine the changes in the storage volume of the balancing dam. These changes will contribute to the water diverted into the scheme.

10.5.3 Capacity and availability of farm dams

One of the problems that was highlighted by the scheme operators was that there are periods when the capacity of the irrigators existing farm dams are not sufficient to take up the irrigation water applied for during the week. As a result some of the irrigators put temporary sandbanks in order to stop the scheme operators supplying the requested volume of water.

This has, in some cases, resulted in canal overtopping as the downstream hydraulic capacity of the canal is exceeded. This has been an occurrence in the C branch canal and it is causing damage to the canal.

10.5.4 Management Goal 4

The management goal to address this operational problem is carry out the following:

(i) Determine the capacity of the Nzhelele balancing dam and to start measuring the inflow and outflow of the balancing dams in order to determine the changes in the weekly storage of the balancing dam. The changes in the storage of the balancing dam are currently not being factored in the water balance assessments.

(ii) Encourage the irrigators to have sufficient capacity in their farm dams to take up the irrigation water they apply for. In the event that the irrigation application is more than the irrigator requires, the scheme operators must encourage the farmers to cancel their orders.

10.6 Aquatic weeds and algae growth in the canals

10.6.1 Hydraulic capacity of the canals affected by the aquatic weeds

One of the major issues that were identified in the Nzhelele Irrigation Scheme is the growth of aquatic weeds and algae in the canals. This has had a serious impact on the condition of the canals and the hydraulic capacity of the canal systems. The algae proliferation during the summer in particular, is as a result of several factors including high levels of nitrogen (N) and phosphorous (P) from untreated domestic wastewater and agricultural runoff, long daylight duration, high temperature, low flow velocity, and long watercourse retention time.

The current canal slope is fixed and cannot be changed. Current operation of the canal is demand-based, meaning that the flow in the canal is directly related to the water delivery requirements downstream. Water is only delivered based upon demand, and the rate of delivery is based on the rate of downstream water use. Hence, canal flow must be matched to water use and canal flow cannot be increased without an increase in downstream use. Based on the irrigation demands for the 6 years of records, the demand is not anticipated to increase significantly in the near future; therefore canal flow will not be able to be increased.

The algae growth and aquatic weeds in the canal systems is likely to exacerbate. This will affect the water use efficiency of the scheme unless the aquatic weeds and algae are completely removed. Currently the algae are removed using hand rakes and this is not addressing the problem.

Therefore, effective management of aquatic weeds in the canal will result in the ability of the canal to convey water at design flows. Further, improvements in water quality (i.e., less algae present to clog farmer's drip emitters and filters) are anticipated to increase the demand for water delivery. An increase in demand will require an increase in flow. An increase in flow may result in less algae establishment and proliferation.

10.6.2 Management Goal 5

The management objective to address the above issue is to develop and implement an effective management of the aquatic weeds and algae proliferation as well as refurbishment programme to reduce irrigation canal losses within 5 years.

10.7 Losses in the A branch canal

10.7.1 Water loss management issue in the A branch canal

A review and evaluation of the official feeder chart indicated that there are periods when the percentage water losses in the A branch canal is zero. Further discussions with the scheme operators indicated that this may be due to the irrigator who may not be pumping the full application. Therefore the difference in the irrigation water application and the actual volume of water pumped to the private canal is making up for the water losses in the A canal.

Therefore the actual conveyance water losses in the A branch canal are currently being taken as part of the irrigation application, giving a skewed picture of the actual conveyance losses in the branch canal.

There may be another problem the current set up is causing. Because the irrigator is not pumping the full application from the A2 sluice, the excess water is conveyed by the A canal to the other sluices downstream. As a result of more water in the branch canal, this may be the reason besides the presence of aquatic weeds and algae, that the canal is overtopping as illustrated in **Photo 10.1** below. This is likely to be causing the damage to the concrete panels and the joints. With the irrigators not pumping the same flow rate as per their order, this may be causing submergence (see **Photo 10.2** below). This is when the downstream level is high enough so that flow is backed up into the throat, the hydraulic jump isn't visible, and the flow is said to be submerged flow. This is resulting in inaccurate measurements at the Parshall Flumes. Therefore the water losses in the A branch canal are expected to be high than is currently recorded.

10.7.2 Management Goal 6

The management objective to address the above issue is to undertake the following:

(i) Determine the actual water used by the irrigator from the A2 sluice gate and compare this with the actual irrigation application at the sluice gate.

(ii) Determine actual flow measurement based on the submergence correction for the 1 ft Parshall Flumes supplying the irrigators.

Photo 10.1: Overtopping in the A branch canal due to aquatic weeds and excessive irrigation water as upstream irrigator does not pump the full order

Photo 10.2: Submerged Parshall Flume on the A branch canal with no visible hydraulic jump at the throat

10.8 Irrigators receiving irrigation water without submitting water orders

10.8.1 Problems with canal tail ends ending at farm dams

The canal tail ends of the branch canals in the Nzhelele Government Water Scheme all end up at irrigator's farm dams except for the E branch canal. Although this is not a problem, discussions with the scheme operators highlighted that in some of the cases the last irrigator in most cases does not put an application for their irrigation water. This was the case particularly for the C branch canal.

A visit to some of the canal tail ends clearly indicated that there was more water coming into the last sluice as the farm dam appeared to be constantly full. This would appear to indicate that the scheme operators are diverting more water into the C branch canal than is required. However the excess water appears to benefit the last irrigator even without him putting in a water order in some cases.

Because the payment of irrigation water is area based from a revenue perspective, the Nzhelele GWS will not lose. However from the perspective of irrigation water management, in such a case it would indicate that more water is being diverted into the branch canals than is necessary.

10.8.2 Management Goal 7

The management objective to address the above issue is to undertake the following:

(i) Encourage and ensure that all irrigators apply for their irrigation water to enable a proper water balance to be conducted on the C branch canal. This can be done by ensuring the minimal flow occurs at the tailend of the C branch canal when there are no irrigation applications for sluice C15.

10.9 Condition of the conveyance and measurement facilities

10.9.1 General

In order to properly develop the Nzhelele Irrigation scheme water management plan, it was essential that an assessment of the overall condition of the facilities to identify potential issues is carried out. As indicated in Chapter 5, a high level condition assessment together with discussions with the Nzhelele GWS was undertaken. No assessment of the on-farm delivery systems was conducted. The main issues that were identified are discussed in the following sections.

10.9.2 Condition of canal infrastructure

Although there are no measurements to determine the actual avoidable water losses in the Nzhelele Irrigation Scheme, the assessment carried out in the previous chapter together with the preliminary condition assessment in Chapter 5, has highlighted that there are likely to be very high water losses due to the condition of the canal infrastructure.

The condition of the Nzhelele canal infrastructure was found to range between fair and poor condition. There were sections of the canals where the concrete joints had shifted creating holes for water to escape. There were breaks in some sections of the concrete lining indicating that relining of the canal sections was required.

Based on the preliminary assessment the sections of the canals, it is therefore important to undertake a detailed condition assessment of the canal conveyance infrastructure during the dry periods to determine the sections that require refurbishment.

10.9.3 Condition of the siphons

On the Nzhelele canal system, it was found that the major problems related to the leakage of the canal siphons, particularly on the main canal as well as the C and D canals. Significant water losses are taking place at the canal siphons that are leaking. This will likely further deteriorate over the life of the siphons if these are not refurbished in the near future.

10.9.4 Limited resources available to undertake maintenance

Due to the limited resources both financial and management, the Nzhelele Irrigation Scheme cannot undertake all the maintenance requirements needed during the dry periods. As a result, there is a significant backlog in the maintenance of the canal infrastructure as well as the canal siphons.

Furthermore there are sections of the canals where complete renewal of these sections is required. This requires significant financial resources which, given the fact that ownership of the canal infrastructure belongs to the Department of Water Affairs (DWA), the responsibility for conducting renewal of canal infrastructure would appear to lie with the DWA.

The lack of maintenance of the canals may be resulting in a rapid deterioration of the canal infrastructure.

10.9.5 Management Goal 8

The management objective to address the above issues is to undertake the following:

(i) Develop a maintenance schedule based on the priority sections of the canal system in order to improve the canal infrastructure within 2 years with a view to reducing the irrigation water leakage in the system.

(ii) Develop and implement a refurbishment programme to reduce irrigation canal losses within 5 years, in order to reduce the amount of water losses with the water saved stored in the Nzhelele Dam to provide security of water supply during drought periods.

10.10 Ownership of irrigation infrastructure

10.10.1 Roles and responsibilities in infrastructure maintenance

In the Nzhelele Irrigation Scheme, the Department of Water Affairs (DWA) still owns the irrigation infrastructure; including the Nzhelele Dam, the main, primary and branch canals. The GWS, is an arm of the DWA which operates the irrigation infrastructure and undertakes the normal maintenance of the irrigation infrastructure.

The problems in the Nzhelele irrigation scheme arise, when the major infrastructure needs replacement/total refurbishment, as is the case with the sections of the Nzhelele canals.

Although the GWS is a part of DWA, they do not have the financial capacity to undertake the refurbishment of the assets and need the support of the DWA Infrastructure Branch.

10.10.2 Management Goal 9

The broad objective to address this issue is to ensure that the levels of responsibility between the various DWA entities are refined, in order to enable the responsible party to refurbish the canals particularly the identified Nzhelele canal as a matter of urgency.

10.11 Institutional Water Management Issues

10.11.1 Lack of incentive in current irrigation water pricing structure

One of the ways to encourage efficient water use is to base the scheme's pricing and billing procedures at least in part, on the quantity of water delivered. This is not the case in the agricultural sector where the water pricing for the sector is based on the area irrigated or fixed charge per area of irrigated land, regardless of the quantity of water used which is a major disincentive to efficient water use.

Because irrigators are charged for their scheduled quota regardless of the volume of water they use, this can lead to excessive water use as irrigators are likely to order up to their allocation even if they do not necessarily require the water.

The Nzhelele GWS could benefit from implementing an incentive based water pricing structure to encourage efficient water use by increasing the unit price of water as deliveries increase. With incentive based pricing, a base price per unit of water is charged for all water deliveries up to a certain amount to cover the operating costs. Water use in excess of the amount is then charged at a higher unit price.

10.11.2 Management Goal 10

The objective to address the issue of a lack of incentive based water pricing structure is to review the current pricing structure of the Nzhelele Irrigation Scheme and take into account the scheme operating costs in developing an incentive based pricing structure for the scheme.

10.12 Summary of the water management issues

Table 10.1 below presents a summary of the water management issues as discussed above. In order to improve water use efficiency in the Nzhelele GWS these management issues need to be addressed as discussed in the following chapter.

Table 10.1: Nzhelele Irrigation Scheme: Identified water management issues

Item No.	Water Management Issue category	Issue description	Comments
1	Water Measurement,	There is a lack of electronic equipment for the measurement of flows at balancing dams, branch canals and canal tail ends (i) Although there are adequate flow measurement structures which can be used to measure flows at the canal tail ends, readings are not taken at the measurement structures. (ii) Measurements at the branch canals are not being measured to conduct detailed water balances	Encourage the scheme managers to ensure consistent reading of flow measurements at branch canals and canal tail ends
2	Water balance assessments	Current water balances being conducted at Nzhelele are not accurate & comprehensive. (i) There are no sub-scheme water balances being conducted to assist in determining where the focus should be in repairs and maintenance of the irrigation canals during the dry periods (ii) Water balances contain estimates of water losses - there are no measurements (iii) Water budget does not include precipitation	Implement detailed water balance including electronic measurement of canal tail ends and balancing dam in order to disaggregate the water losses by sub-scheme as well as differentiate between operational and leakage losses.

Item No.	Water Management Issue category	Issue description	Comments
3	Flow monitoring	There is a lack of continuous flow monitoring in the scheme: (i) The flow recorders at the canal tail ends are currently not operational (ii) No manual flow monitoring is taking place as measurements are not being taken at the critical points (iii) The manual reading of flow records, is cumbersome and has a high risk of errors (iv) There are no automated controls	Encourage flow monitoring either through installation of telemetry system in order to make improvement in irrigation water management
5	Water Accounting & Reporting	The water administration system to manage water use is not being fully utilised for sub-scheme water budgets (i) The water release module is currently not being fully utilised to improve water management (ii) It is not known how much and where water losses are occurring in the scheme area	Implement use of WAS to conduct detailed sub-scheme irrigation water budget within 1 year
6	Operational issues	The current operation procedures for the A and C branch canal indicates that no water losses are included in the A canal while the last irrigator in the C branch canal is dependent on excess water from the canal. This may be because irrigators are taking up their full applications. This is resulting in the	Review the current operation of the A and C branch canals to determine actual water losses while encouraging

Item No.	Water Management Issue category	Issue description	Comments
		following: (i) The canal is overtopping (ii) The Parshall Flumes of the irrigators are operating in submergence conditions resulting in inaccurate measurements	irrigators to use their irrigation applications or cancel their applications timeously.
7	Infrastructure related issues	Gross water losses are substantially higher than the expected BMP for lined canal irrigation scheme (i) Condition of sections of the canal infrastructure is very poor (ii) Some of the major siphons are blocked resulting in the overtopping of the canal	Implement refurbishment of canals.
		Aquatic weeds and algae growth in canal systems - The scheme has a serious problem of aquatic weeds and algae growth in the canals. This is reducing the hydraulic capacity of the canals meaning more water than is necessary is being diverted. This is contributing to the high water losses of the scheme	Develop and implement a programme to eradicate aquatic weeds and algae
8	Water pricing & revenue	Irrigators are paying the DWA based on their full water allocation (i) Current pricing is area based (per ha)	Financial incentives are necessary to encourage

Item No.	Water Management Issue category	Issue description	Comments
	management issues	(ii) Irrigators are losing on the benefits of their full water use entitlements (iii) Area based assessment encourage water waste and produce inequitable water costs between efficient and inefficient users.	efficient water use
9	Institutional management	The Nzhelele GWS is both owned and managed by DWA. However, there is still a disjuncture in ensuring the assets are maintained, resulting in deterioration of the infrastructure and increase in water losses. The priorities between the two Directorates may differ in terms of when to undertake rehabilitation of the infrastructure.	There needs to be some form of Service Level Agreement between the DWA Infrastructure and Nzhelele GWS to ensure timeous rehabilitation of the infrastructure.

11 NZHELELE GWS WATER MANAGEMENT PLAN

11.1 Identification and evaluation of water management measures

There are numerous water management measures that accomplish a wide range of the goals identified in the previous chapter. However, only a few of the measures have the capacity to accomplish the goals to improve irrigation water use efficiency in the Nzhelele Government Water Scheme.

The priority water management measures to improve irrigation water use efficiency on the Nzhelele Government Water Scheme include the following:

(1) Water measurements of the flow rates, duration and volume of flows at all the critical points which include the inflow and outflow at the balancing dams, the branch canals, as well as the canal tail ends, etc.;

(2) Preparation of more detailed water balance assessments for Nzhelele irrigation scheme, including at the sub-scheme level which include the branch canals;

(3) Implementation of all modules of the WAS programme to enable irrigation monitoring and control of water use to reduce operational losses such as canal tail ends spills to be carried out as well as undertake water balance assessment at scheme and sub-scheme level;

(4) Removal of aquatic weeds and algae from the irrigation canals to reduce water losses;

(5) Address the submergence of the Parshall Flumes which is occurring on some of the branch canals;

(6) Ensure that all irrigators are putting in their water orders on time and cancelling their water orders in time when they do not require them;

(7) Installation of telemetry infrastructure to enable real time monitoring of irrigation water in the long term;

(8) Developing an incentive based water pricing structure to improve irrigation water use efficiency and reduce significant fluctuations in demand;

(9) Maintenance and refurbishment of the existing delivery canals as well as the siphons, in order to reduce leakage losses, improve flow rates and increase head at diversion points.

11.2 Best Management Practices for irrigation water management in Nzhelele Government Water Scheme

11.2.1 Overview

In order to evaluate the candidate water management measures it was important to first of all determine the water loss target by incorporating not only the unavoidable water losses but also determining the attainable level of water losses based on the Best Management Practices (BMP) that can be achieved in the Nzhelele Irrigation Scheme that takes account of the technical and managerial capacity of the Government Water Scheme. This is discussed in the following sections.

11.2.2 Gross water losses

The water losses in the Nzhelele Irrigation Scheme are considered to be very high at 32% of the total system input volume of water diverted at Nzhelele Dam. The total water losses were determined to be 8.2 million m^3/a based on the two years of available records.

In order to determine the potential water that can be saved from the two sub-schemes, the unavoidable water losses as well as the BMP for operational and distribution efficiency were determined

11.2.3 Unavoidable water losses

It has been estimated that the unavoidable water losses due to evaporation losses and seepage due to the age and condition of the infrastructure is 1.95 million m^3/a, which translates to 8% of the total volume of water diverted into the Nzhelele canal system.

The unavoidable water losses for the Nzhelele Irrigation Scheme contribute to the determination of the Best Management Practice (BMP) for the allowable water Nzhelele irrigation scheme.

11.2.4 Water losses due to operational and distribution inefficiencies

Besides the seepage and evaporation losses which are unavoidable because of the type of conveyance infrastructure which are open channels and are liable to leak because of the hydraulic conductivity of the concrete lining, there are operational losses which are unlikely to be recovered at a scheme level due to a number of factors. These factors include the following:

(i) Canal filling – The Nzhelele GWS allows for a minimum of 2 weeks scheduled dry period to allow for the maintenance of the canal infrastructure and repairs necessary at measuring structuring, etc. During this period the canal is emptied to allow for the maintenance to be carried out. A significant volume of water is then required to fill the canals before they can deliver the irrigation applications to the users in the scheme. This canal filling is included as part of the operational losses which cannot be recovered through any major intervention measures.

(ii) Operational performance losses – The existing sluices and Parshall flumes have in inherent error that needs to be included in the operational performance of the scheme even after improving the calibration of the flow measurements. These metering errors have to be taken into account when determining the Best Management Practice (BMP) for in the Nzhelele Irrigation Scheme distribution efficiency

(iii) Untimely deliveries of water that cannot be used as a result of cancellations which will take a minimum of 12 hours to make adjustments to the releases. These losses can result in either operational spills at the canal tail ends representing a loss to the scheme or excess water which is delivered to downstream storages or canals within the scheme.

A Water Research Commission (WRC, TT466/10) which was conducted in 2010, has provided guidelines of the desired range of operational losses due to metering errors, canal filling losses after each dry period that have to be included in order to determine the BMP for operational and distribution efficiency (WRC 2010). This is additional to the unavoidable losses determined in the previous sections. This desired range is expressed as a percentage of inflow into the irrigation scheme. The desired range for operational losses (i.e. metering errors, canal fillings, etc.) is 10% of the inflow into the irrigation scheme.

Therefore on the basis of the WRC study a BMP for operational and distribution efficiency has been taken as 10% of the inflow into the Nzhelele irrigation canal systems. This amounts to 2.59 million m^3/a based on the average inflow into the canals. This together with the unavoidable losses has been used in setting the water savings and the acceptable water losses of each of the two canal systems.

11.2.5 Acceptable water losses in the Nzhelele Irrigation Scheme

The unavoidable water losses in the Nzhelele irrigation scheme were determined to be 8% of the total releases into the Nzhelele canal system. This water is additional to the irrigation water use required at the farm edge.

Furthermore there are operational performance inefficiencies in operating the Nzhelele scheme including trying to match the delivery to the irrigation applications as mentioned in the previous section. Based on the WRC study the attainable range of operational losses which are not likely to the recovered through water management intervention measures is 10% of the total releases into the Nzhelele canal systems. **Table 11.1** below provides the water loss target for the Nzhelele canal system.

As illustrated in **Table 11.1** below, the expected average water losses taking into account the unavoidable water losses and the expected inefficiencies in the distribution of irrigation water due to problems of matching supply and delivery as well as metering errors and canal filling losses will be 18% of the total releases into the Nzhelele canal system.

Therefore based on the 2 year average and taking into account the unavoidable water losses and expected operational inefficiencies, the expected water losses were determined to be 4.55 million m^3/a. When compared with the total losses of 8.2 million m^3/a for the same period, there is still potential to implement water saving measures to reduce the current water losses from 32% to 18% of the total releases into the Nzhelele canal system.

Table 11:1: Acceptable water losses in the Nzhelele canal system (million m^3/a)

Description	Unavoidable losses	BMP Distribution Efficiency	Avoidable water losses	Total losses	Acceptable water losses	Potential water savings
Seepages	1.50			1.50	1.50	
Evaporation	0.45			0.45	0.45	
Filling losses		2.59	3.65	6.24	2.59	3.65
Over delivery to users						
Leakages						
Spills						
Operational Losses						
Canal end returns						
Other				-		
Total	1.95	2.59	3.65	8.19	4.54	3.65
% of total volume released into system	8%	10%	14	32%	18%	14%

Description	Unavoidable losses	BMP Distribution Efficiency	Avoidable water losses	Total losses	Acceptable water losses	Potential water savings
% of total losses	24%	32%	45%	100%	55%	45%
Total releases	25.95					

11.3 Task 1: Regular measurements of flows at the critical points of the irrigation scheme, calibration of the flow measurements and detailed water balance assessment

11.3.1 Regular measurement of flows at the branch canals and canal tail ends

As indicated in the previous chapter, the Nzhelele irrigation scheme has all the necessary flow measurement structures at the critical points in the scheme. There are Parshall Flumes which can be used to measure the flow rates, and determine the volume of water diverted into each of the branch canals or returning to the river system at canal tail ends.

Therefore with the existing measurement infrastructure, the Nzhelele irrigation scheme should be taking weekly flow measurements at all the branch canals as well as the canal tail ends. As a matter of priority, the Nzhelele GWS should commence with measurements at the canal tail ends. This will improve the information provided in the water use accounting reports submitted to the Department of Water Affairs (DWA).

This can be followed by taking flow measurements at the branch canals so that water balance assessments at sub-scheme level can be carried out.

11.3.2 Initial capital and operation and maintenance costs

There will be capital cost required for the Nzhelele GWS to install electronic flow measurement system in order to start taking electronic flow measurements at the canal tail ends or at the branch canals. However the functions and responsibilities of the existing scheme operators will need to be updated to include taking of flow measurements on a regular basis.

11.3.3 Impact of the identified water management

Although it is difficult to determine exactly how much water will be saved by taking flow measurements, this will provide the Nzhelele GWS with appropriate and relevant information on where there are water losses and what measures to put in place to reduce water losses. For example by taking flow measurements at the canal tail ends, the Nzhelele GWS will be able to determine by how much they can reduce the flow rate at the canal headworks.

However, there will be some cost related to the calibration of the Flumes to improve the accuracy of the measurement structures.

Based on the preliminary work that was done during the site visit when flow measurements were taken at the Nzhelele main canal tailend, the water that can potentially be saved by changing the current operational procedures would be 0.46 million m^3/a.

11.4 Task 2: Installation of flow monitoring system

11.4.1 Installation of a telemetry system

The existing flow recorder, at the endpoint, is not operational. There is limited monitoring through manual operation of the irrigation scheme. The need for continuous monitoring of water supply delivery to the irrigators and irrigation water management is considered to be critical in reducing losses such as operational spills at rejects and at the canal tail ends.

The gross water losses in the Nzhelele Irrigation Scheme over the past two water years has averaged 8.19 million m^3/a, which is considered to be very high when the BMP for the scheme are taken into account. The likelihood of a significant portion of the gross water loss being due to operational losses is high. Therefore by improving the monitoring of the scheme through telemetry significant water savings can be made for the scheme.

The Hydrological branch of the DWA already has a telemetry system on three measurement structures in the scheme. Therefore the Nzhelele Irrigation Scheme should consider installing a telemetry system to monitor the flows in the canal conveyance system. The first urgent action to be undertaken by the Nzhelele GWS is to ensure that the proposed telemetry system is compatible with the WAS programme so that the flow measurements can be monitored on a real time basis and the reading can be entered directly into the Water Administration System (WAS) for use by the release module.

In order to get the telemetry system operational, the Nzhelele GWS needs to appoint a specialist telemetry expert to assess and carry out the design and installation of the telemetry system. This will include ensuring that the software is compatible with the WAS programme. The telemetry system should be able to display current, last 24 hours flow rates and monthly water and flow level data on the Remote Telemetry Unit (RTU). It will also store all engineering and conversion data necessary for converting flow levels into flow rates. This will be done to ensure compatibility with the WAS so that all flow records can be read directly into the WAS programme. This will provide data on a real time basis and provide the tracking and accounting of water use in the irrigation scheme.

The installation of the telemetry system and ensuring compatibility is envisaged to take 2 years with an ensuing expected useful life of 15 years.

11.4.2 Initial and O&M Costs

Table 11.1 below indicates that initial capital costs and related operation and maintenance costs.

The estimated initial capital investment is the cost of the telemetry expert and software requirements related to the compatibility issues. This has been estimated to be R 915 000, comprising the supply and installation of the telemetry infrastructure, estimated at R 610 000, and the time for the telemetry expert and the software link with the WAS estimated to cost about R 305 000.

As indicated further in **Table 11.1** below, the expected water savings due to the flow monitoring as a result of installation of the telemetry that is aligned to the WAS programme including training of the WCOs, is estimated to be approximately 20% of the avoidable water losses as determined in the irrigation water budget. This has been estimated to be 0.73 million m^3/a, allowing for an 80% success rate.

The water saved will be available in the Nzhelele Dam for distribution as required. This will improve the yield of the Nzhelele River system with the scheme benefiting during the low flow periods or drought periods as there will be more water available to mitigate any drought.

The average incremental cost (AIC) of installing the telemetry system for real time monitoring will be 19 c/m^3 which when compared with the current heavily subsidised water use charge of 11.08 c/m^3 would appear to be high. However, as the subsidies on irrigation agriculture are removed to reflect the scarcity value of irrigation water in future, the implementation of the real time monitoring will be beneficial in the long term.

Table 11.2: Summary of the costs and potential savings - Telemetry system update and alignment with WAS

Item	Description	Water Savings Million m^3/a	Cost Savings R per year	Sub-Total	Total
Telemetry	Install telemetry system which is compatible with WAS programme				
Installation period					12 months
Productive period					20 years
Initial Capital Investment Costs	Software			305 000.00	
	Telemetry infrastructure			610 000.00	915 000.00
Annual O&M Expenses	Software licence, replacement of parts, and batteries, etc			40 000.00	
Water Losses					
Reduction in water losses due to flow monitoring	Flow monitoring	0.73	87 501.68		
Average Incremental Cost (AIC)					0.19

11.5 Task 3: Full implementation of WAS and alignment with the telemetry systems

11.5.1 Implementation of WAS release module

The importance of relevant and opportune information in decision making cannot be overemphasized. Managing irrigation systems is no exception to the rule. On the contrary, information is vital since daily decisions with regard to water deliveries and other aspects may affect the well-being of many farmers. Traditionally, managers of irrigation systems have tried to cope with this problem through the compilation of field information that was manually processed.

Unfortunately, the number of users in the Nzhelele irrigation system runs in the order of hundreds and manual processing of information becomes a lengthy and costly exercise. As a consequence, relevant information is often not available on time or is incomplete and many *ad hoc* decisions have to be made.

11.5.1.1 Review the current use of WAS

As mentioned earlier, the Nzhelele Government Water Scheme does not have a comprehensive water accounting system to track water deliveries and determine the areas of improving irrigation water management. The scheme is not using all modules of the WAS programme to manage and reduce water losses.

The system includes the following seven modules:

Administration module

This module provides the details of all water users on an irrigation scheme. Information managed by this module includes addresses, notes, cut-off list, list of rateable areas, scheduled areas, household and livestock pipes installed on canals, industrial water quotas, crops and areas planted and crop yields.

Water order module

This module captures all the weekly and monthly water requested by each farmer in the scheme. It also includes any additional water requests or any cancellations of water orders.

This module is very useful to determine the extent of additional requests, as well as the cancellations, as this will provide a clear indication of the extent of operational spills on rejects and tail ends in the case of cancellations. It will also highlight the flexibility that the Nzhelele Irrigation Scheme has in responding to cancellations.

Currently there is no reporting from this water order module, which could assist the Nzhelele WUA in responding to changes in water ordering system.

Water release module

This module takes information from the water order module and calculates the volume of water to be released from the water supply sources into the main canal and all its branches allowing for lag times and any water losses and accruals to supply the request for the week.

A schematic layout of the total canal network or river system, is captured with detail such as the cross sectional properties, positioning of sluices or pumps, canal or river slope, structures and canal or river capacities. Discharges are converted to the corresponding measuring plate readings where needed, so that the sluice gates can be set to deliver the volume of water requested.

The Nzhelele GWS is currently not utilising the water release module.

Measured data module

This module provides the field data that is measured from the rates and volume of water delivered to each user and the rate and volume of water diverted into the scheme, as well as the rate and flow at different points in the canal system. This data is very useful in conducting water balance assessment not only at scheme level but also at sub-scheme level.

Other modules

The above four modules are the key modules in accounting for water use in an irrigation scheme. However there are other modules which include the following:

(i) *Water accounts module*- this module administers all water accounts for an irrigation scheme or water management office. The water accounts module is a full debit system, from which monthly reports can be printed, including invoices on pre-printed stationery, reconciliation reports, age analysis and audit trail reports.

(ii) *Crop water use module* is used to calculate the water usage per crop between two specified dates for all the planted crops on a scheme, based on the plant date, the area planted and the crop water use curve.

(iii) *Reporting Module* – includes an extensive range of water and financial reports. Water balance sheets, distributions sheets, WUEAR and various other operator defined reports can be generated. This module is currently in use at the scheme.

Therefore, the Nzhelele Government Water Scheme needs to ensure that they utilise the existing WAS programme, particularly the release module effectively.

11.5.2 Initial Capital Expenditure and O&M Costs

The Nzhelele GWS already has the WAS programme installed at their offices. However, in order to ensure that all WAS modules are operational, they will require the training of the water control personnel in its use. The programme should also be set up to enable that water balance assessments at sub-scheme levels can be carried out (i.e. for each of the six canals in the irrigation scheme).

The estimated operation and maintenance costs for operating the WAS programme includes an annual fee of R 24 000 to obtain the latest updates of the programme and maintenance of the programme.

The estimated water savings has been included together with the installation of water measurements discussed above. As mentioned above, it is estimated that 0.73 million m^3/a, could be saved, by undertaking the installation of telemetry system and full implementation of a water efficiency accounting system such as the WAS programme, per branch canal.

The capital investment required to carry out these two tasks is minimal, compared to the significant benefit in reducing water losses in the Nzhelele Irrigation Scheme. This should be considered priority by the Nzhelele Government Water Scheme.

11.6 Task 4: Management of aquatic weeds and algae

11.6.1 Chemical aquatic weed management

Considering the losses caused by aquatic weeds, their management is of utmost importance to improve the availability of water from the source to its end users. This does not only improve availability but also the conveyance efficiency. Irrigation and drainage systems provide favourable conditions for the growth of aquatic weeds which interfere with the delivery systems of irrigation water, maintenance of canals, drains, etc. This is the case in the Nzhelele Government Water Scheme.

Mechanical removal has been used in the Nzhelele Irrigation Scheme with very little effect. It has also been found that in peak summer months the biomass cannot be removed efficiently.

Therefore the recently recommended chemical process of removing aquatic weeds is proposed based on the successful pilot projects conducted at Hartbeespoort and Roodeplaat canals. This water-soluble aldehyde, which comes in liquid form and has Acrolein as its active ingredient, can be used in operational systems without interrupting irrigation water deliveries, and is characterised by superior effectiveness and quick dissipation without any residue.

Acrolein has been found to be effective in controlling submerged aquatic weeds and algae. It is used on a large scale in many countries in flowing canals and drainage ditches for quick control of aquatic vegetation. Being volatile, it evaporates from treated water within a short time of its application. It is effective at concentration varying from 4 -15 ppmv.

However Acrolein has pungent and foul smell and is a non-selective, contact herbicide for control of submerged weeds. Canals require regular treatment as the Acrolein is not translocated to the root systems of the plants but merely chemically mows the plants off at bed level. It also kills snails and mosquitoes.

The herbicides may be introduced over a time period of 30 min to 4 hours at 3 m^3/s. Dosages are to be adjusted with water temperature, weed intensity and speed of water flow in system.

Acrolein is injected in water directly from the cylinder container through an injecting system. It is toxic to fish which may hinder its use in the branch canals as irrigators do not want its presence in their farm dams where there is fish. It is irritating to eyes and generally toxic to humans but can be applied without any problem when proper application equipment is used.

Research and extensive field use during a period of 10 years with Acrolein showed that this chemical is not toxic to irrigated crops at concentrations required to control submerged aquatic weeds (Timmons et.al., 1969, USDA 1963).

11.6.2 Initial Capital Costs and O&M Costs

The initial capital expenditure for the treating the aquatic weeds and algae with Acrolein is estimated to be R 400 000. This is illustrated in **Table 11.2** below.

The removal or management of the aquatic weeds and algae growth in the irrigation canals has the potential to save approximately 0.91 million m^3/a, while the average incremental cost of implementing the measure is only R 0.12 per m^3 or R 1 041.51 per ha per annum. This would be very prohibitive if the cost is to be borne by the irrigators. Hence the need for the DWA to cover the initial costs of managing the aquatic weeds as this problem is external to the irrigation water management of Nzhelele GWS.

Table 11.3: Summary of the costs and potential savings - Chemical management of aquatic weeds and algae

Item	Description	Water Savings Million m^3/a	Cost Savings R per year	Sub-Total	Total
Chemical treatment of aquatic weeds	Inject acrolein to manage aquatic weeds and algae				
Installation period					Annually
Productive period					20 years
Initial Capital Investment Costs	Procurement of contractors			400 000.00	
	Chemical injection of Acrolein				
				-	400 000.00
Annual O&M Expenses	Annual maintenance of aquatic weeds			80 000.00	
Water Losses					
Estimated reduction in water losses due to removal of aquatic weeds	Water loss reduction	0.91	110 634.94		
Average Incremental Cost (AIC)					0.12

Based on the above capital cost estimates and the estimated water savings, this measure is considered to be justifiable for implementation by the DWA on the Nzhelele GWS. The capital investment required to carry this out is minimal compared to the significant benefit in not only reducing water losses in the Nzhelele Irrigation Scheme but also ensuring the condition of the canals is not compromised due to canal overtopping which is taking place on the A branch canal. This should be considered a priority by the irrigation scheme.

11.7 Task 5: Improve the measurement at Parshall Flumes by accounting for submergence condition

11.7.1 Introduction

The calibration of the Parshall Flumes in the Nzhelele Government Water Scheme (and possibly most irrigation schemes in the country) has been done on the basis that free flow conditions exist with the critical depth occurring at all times in the throat of these Parshall Flumes. This was tested with the calibration tables provided by the scheme operators. Furthermore the only head measurement on these Flumes is the upstream depth in the converging section (see **Photo 11.1** below). Therefore provided critical depth occurs in the throat of a Parshall flume, the discharge is dependent upon only, the upstream depth which is located approximately 2/3 of the converging section from the throat.

However in the Nzhelele Government Water Scheme it was recognised that at a number of the Parshall Flumes, the critical depth was not being achieved at all times. This was due to a number of factors which include the following:

(i) A number of irrigators have their pumps located immediately downstream of the Parshall Flume and pump from the canal after the Parshall Flume to their balancing storages. However during the site visit it was identified that a number of these pumps were not running while the irrigators' orders were being supplied from the branch or main canal. This was creating submerged flow conditions resulting in inaccurate flow measurements at these points. Some of the irrigators had queried the accuracy of the flow measurement with the scheme operators.

(ii) The presence of the aquatic weeds and algae in the canals particularly the A and C branch canals was affecting the hydraulic performance of these canals. This was causing the downstream channel conditions to back up into the throat resulting in submerged flow conditions in some cases.

Photo 11.1: Sluice A8 suspected of submerged flow conditions

Because of the above problems, the flow measurements based on the current setting of the sluice gates is likely to be less than the actual flow measurement taking place under submerged flow conditions. In this scenario, irrigators are being supplied with less water than they are ordering while the actual water losses are much higher than is currently being reflected in the WUEARs. This might be the reason why scheme operators feel the water losses are much higher than what they are currently calculating and why some of the irrigators are concerned that they are not getting their actual water orders.

11.7.2 Incorporate submerged flow conditions in the flow measurements

As a way to address the above inaccuracy in the measurement on the Parshall Flumes, there is an urgent need to introduce measurement which takes into account the submerged flow conditions that may occur on the Parshall Flumes, particularly in the A and C branch canals.

In order to introduce submerged flow conditions in the measurement the following will be required:

(i) Upgrade the Parshall flumes to include the gauge plate reading of the throat depth, H_b on those Parshall Flumes where submerged conditions are occurring from time to time.

(ii) Recalibrate these Parshall Flumes to include the correction factor for the submerged flow conditions when the ratio of the upstream head (H_a) and the throat depth (H_b) which is H_b/H_a is more than 0.7 as most of these Parshall Flumes are between 1ft and 8ft Parshall Flumes (see **Figure 11.1** below).

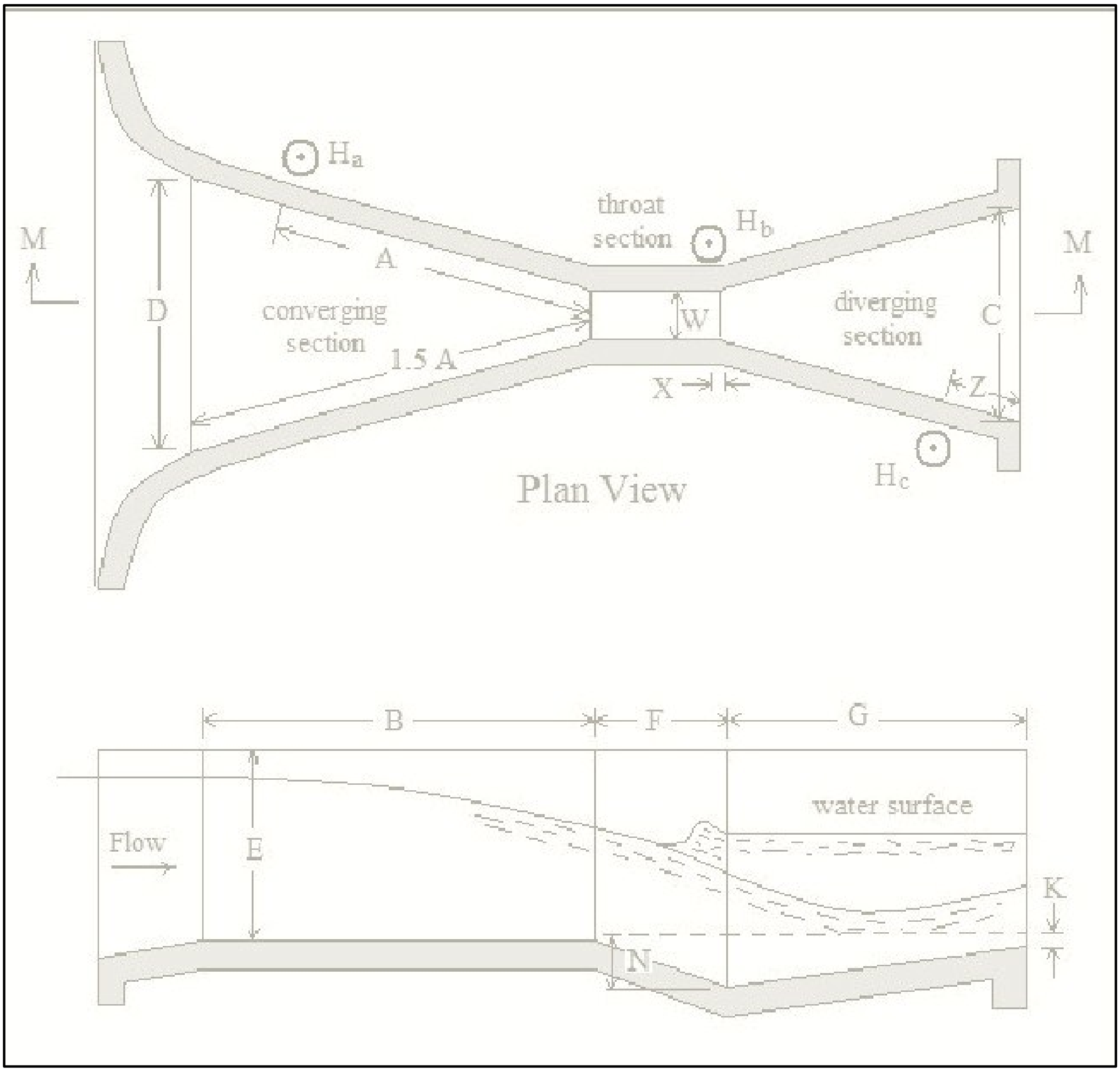

Figure 11.1: Plan and Elevation View of a Parshall Flume

(iii) Consider installation of crump weirs at the identified Parshall Flumes where submerged conditions are occurring frequently. This should be based on the cost implications of installing crump weirs compared to installing throat gauge plates and recalibration of the existing Parshall Flumes.

11.7.3 Impact of improving the accuracy of flow measurements

Although this water management plan will not directly result in the reduction in irrigation water losses it will ensure that the extent of water losses in the Nzhelele Government Water Scheme will be well understood. As a result the impact of the other intervention measures can be refined.

11.8 Task 6: Conveyance infrastructure water management measures

11.8.1 General

The conveyance infrastructure rehabilitation programme is to carry out the refurbishment of the infrastructure in the conveyance system that was found to be causing significant leaks and seepage. The discussion with Nzhelele Government Water Scheme indicated that the major problems currently, are the sections after the Nzhelele Balancing Dam where sections of the concrete panels have been damaged and shifted. This is discussed in the following section.

11.8.2 Conveyance infrastructure refurbishment and canal relining

The preliminary assessment conducted as well as the information supplied by the scheme operators of the Nzhelele GWS on the infrastructure survey they conducted indicates that the condition of sections of the Nzhelele canal system is very poor (see **Figure 5.1** in chapter 5).

Given the high water losses, due to structural failure of concrete lined irrigation canals caused by overtopping in the case of the A branch canal, erosion on the canal banks, the age of the canal and to some extent drainage problems, there is significant scope for refurbishment of the existing canal infrastructure, in order to reduce the current water losses. This will provide the Nzhelele GWS with the baseline to ensure efficient utilisation of the assets. These sections will require complete refurbishment at significant capital costs while other sections will require sealing of the wetted perimeter of the canal with polyfelt and bitumen emulsion that is sprayed.

It was estimated that approximately 6.5 km of the canal in the Nzhelele GWS will require total construction and/or relining of the canal with concrete. Approximately 40 km of the canal will require sealing of the wetted perimeter with polyfelt and bitumen emulsion. This was based on the preliminary assessment of the canal.

The total cost estimate for relining of the canal sections with concrete and sealing of the wetted perimeter was determined to be R 16.8 million, while the operation and maintenance costs to maintain the infrastructure in good condition from thereon was calculated as R 0.04 million per year (see **Table 11.3** below).

The refurbishment of the irrigation canals has the potential to save approximately 1.55 million m^3/a, while the average incremental cost of implementing the measure is only R 2.53 per m^3 or R 21 264.60 per ha per annum. This would be very prohibitive if the cost is to be borne by the irrigators. Hence the need for the DWA to cover the initial costs of managing the aquatic weeds as this problem is external to the irrigation water management of Nzhelele GWS

11.8.3 Repair the canal siphons that are leaking

Besides the leakages on the canals in the Nzhelele Government Water Scheme, there are also leakage problems with the pipes on the siphons of the main canal as well as the C branch canal. Although the extent of the water losses on these canal siphons could not be determined, the surrounding areas indicated that a significant volume of water was being lost.

The refurbishment of the above siphons should be included with the refurbishment of the concrete lined canals in the Nzhelele Government Water Scheme.

11.8.4 Recommendations

A more detailed condition assessment of the canal system is required in order to verify the sections requiring total construction of the canal; the sections requiring the relining of the concrete canal as well as the sections which require resealing of the canal. The above figures can then be refined and updated when the water management plan is revised in future. The findings of the condition assessment can then be used to develop a more detailed canal refurbishment and renewal programme for the Nzhelele Irrigation Scheme.

Where the condition assessment has already been conducted the findings of these studies should be taken into account in the refinement and updating of this water management plan for the Nzhelele Government Water Scheme.

Table 11.4: Summary of capital investment requirement & benefits - Rehabilitation of the canal infrastructure

Item	Description	Water Savings Million m^3/a	Cost Savings R per year	Sub-Total	Total
Refurbishment of canal sections	*Construction of canal sections with concrete, relining & sealing of the canal with bitumen emulsion*				
Installation period					Five years
Productive period					20 years
Initial Capital Investment Costs	Construction & relining of canal sections			15 740 881.85	
	Sealing of canal with bitumen emulsion			1 044 549.35	16 785 431.20
Annual O&M Expenses	Repair & sealing of joints			40 005.05	
Water Losses					
Reduction in water losses due to canal refurbishment	Leakage reduction	1.55	1 368 821.50		
Average Incremental Cost					2.53

The capital cost requirements to enable the Nzhelele irrigation scheme to carry out the refurbishment of the infrastructure is beyond the normal maintenance costs of the scheme. The total construction and relining of canals requires significant capital investment which the DWA will need to provide, since they own the assets. Priority in refurbishment of the Nzhelele canal system should be on the very poor canal sections once a detailed condition assessment has been conducted.

Currently the refurbishment budget is with the DWA, who still own the infrastructure. Therefore the DWA should carry out the rehabilitation of the deteriorating conveyance infrastructure.

11.9 Task 7: Incentive based water pricing

11.9.1 General

To achieve an incentive for efficient water use, the price of irrigation water must be directly related to the volume delivered unlike the current situation where it is based on the scheduled quota.

In order to encourage irrigators to use water efficiently, it is recommended that an incentive based water pricing structure for Nzhelele Irrigation Scheme be considered, based on the optimal crop water requirements of the main crop, which is citrus and grape fruit. The implementation of incentive water pricing in irrigation agriculture, requires that comprehensive regulatory and operational criteria be met before considering the economic criteria for incentive based pricing of irrigation water.

11.9.2 Regulatory aspects for incentive pricing

An orderly system of distributing water is already in place in the Nzhelele Irrigation Scheme, based on the regulatory framework for distributing water among the farmers. The rules and procedures defining the water ordering and water releases are in place. These include responsibilities of the GWS and those of the irrigators, priorities in case of shortage or excess supplies; penalties for breach of rules, and so on. Based on this, there is immediate scope for improving water distribution through pricing. Furthermore, there are already flow measurement devices (i.e. sluice gates and Parshall flumes), for measurement of the quantity delivered.

From a regulatory perspective, the water pricing strategy can be used in determining incentive pricing structure with two or three levels of pricing, to encourage efficient use of irrigation.

11.9.3 Operational aspects for incentive pricing

Measurement and charging at the farm level will require substantial investment in equipment, and an associated administrative bureaucracy, to collect and collate data on farm-level deliveries, and undertake the billing process.

The Nzhelele Irrigation Scheme already has the operational systems in place such as weekly ordering, as well as the sluice gates (however not very accurate) to measure each irrigator's use. Furthermore, the scheme has the administrative system to carry out billing based on actual use, rather than on a scheduled basis.

With the above operational aspects in place, the direct link between service and payment are achieved, and the efficiency incentive that pricing is designed to produce, can be met.

11.9.4 Economic aspects for incentive pricing

The current pricing, based on the scheduled quota does not provide the economic incentives for improving water use efficiency at farm level, as irrigators feel that they are entitled to the full use of their scheduled quota, even when they can achieve higher levels of production with less water.

If the charging system is to have an impact on consumption, then the system of payment must be such as to induce the desired economic response. In the case of the Nzhelele Government Water Scheme, the benefit of incentive pricing means irrigators can expect to pay less for their irrigation compared to the current scheduled quota which provides an economic incentive to the irrigators.

Because the Nzhelele GWS needs to undertake fixed operation and maintenance activities, the incentive based pricing should consider the potential effects on revenue generated through water sales. However any savings made from reduction in water use at field edge, can be sold to other users such as the domestic sector whose demand is growing. This will provide supplemental revenue that could be used to develop more improvements to the scheme.

11.9.5 Potential water savings

The potential water that can be saved from implementing incentive based pricing can vary depending on a number of on-farm irrigation and water management decisions that the irrigators take. The water saved from incentive based pricing is likely to range between 5% and 10% of the annual irrigation applications. A water saving target of 7.5% of the annual average irrigation water applications has been envisaged for the Nzhelele Government Water Scheme. This translates to approximately 1.5 million m^3/a.

In order to achieve this target the measures above need to be put in place which will have financial implications as illustrated in **Table 11.4** below. The average incremental cost of implementing incentive based pricing (excluding metering if required) was calculated to be R 0.05 per m^3 or R 461.73 per ha per year. The cost of implementing incentive based pricing will likely be borne by the Department of Water as part of overall sustainable management of the country's water resources.

Table 11.5: Incentive based pricing

Item	Description	Water Savings Million m3/a	Cost Savings R per year	Sub-Total	Total
Incentive based pricing					
Installation period					One year
Productive period					20 years
Initial Capital Investment Costs	Update regulation and administration system				
	Billing & measurement system			250 000.00	
	Communication			500 000.00	750 000.00
Annual O&M Expenses	Billing & measurement			150 000.00	
Water Use efficiency					
Estimated reduction irrigation water use	Irrigation water use reduction	1.50	270 391.67		
Average Incremental Cost (AIC)					0.05

The water saved can be used by the irrigators to expand their irrigation areas where possible. With the additional 1.5 million m^3/a, of water saved, an additional 178 hectares of citrus can be developed in the Nzhelele Government Water Scheme. With the production of approximately 20 tonnes per hectares of citrus and, although the market prices are almost impossible to predict since so much depends on variations in annual crops in key producing countries, it can be expected that a gross margin of R 38 889 per hectare can be generated. Approximately 2% of the gross margin can be attributed to the irrigation water application. Therefore the benefit from the additional water saved can be as much as R 775 per hectare per annum. When compared with the AIC of implementing incentive based pricing, there is a business case for such a water management intervention measure to be undertaken if there is excess land available for irrigators to expand.

12 NZHELELE GOVERNMENT WATER SCHEME - IMPLEMENTATION PLAN

12.1 Legal provision for developing and implementing a WMP

The development and implementation of a Business Plan is a legal requirement to be undertaken by a GWS in terms of section 21 of Schedule 4 of the National Water Act (Act 36 of 1998). The constitution of a GWS - referred to schedule 5 for model constitution - outlines the principle functions to be performed by the GWS and will include the following:

(i) Prevent water from any water resource being wasted;

(ii) Exercise general supervision over water resources;

(iii) Regulate the flow of water course;

(iv) Investigate and record quantities of water;

(v) Supervise and regulate the distribution and use of water from a water resource.

The Business Plan for a GWS will thus incorporate a Management Plan setting out standards and Best Management Practices. Another key clause in the National Water Act is Section 29(1), which reads as follows:

"*A responsible authority may attach conditions to every general authorisation or licence -*

b) relating to water management by:

(i) specifying management practices and general requirements for any water use, including water conservation measures;

(ii) requiring the monitoring and analysis of and reporting on every water use and imposing a duty to measure and record aspects of water use, specifying measuring and recording devices to be used;

(iii) requiring the preparation and approval of and adherence to, a water management plan."

In light of the above legal requirements, the Nzhelele GWS has developed a WMP in terms of the provisions of the act to enable it to manage the irrigation water in the scheme effectively and efficiently.

12.2 Establishment of water saving targets for Nzhelele Government Water Scheme

12.2.1 Introduction

The implementation of a Water Management Plan for the Nzhelele Government Water Scheme to reduce water losses will imply reducing the water diverted per unit of the land area irrigated in the scheme. As is expected this will not affect the yields of the citrus or grape fruit being irrigated in the scheme area. Therefore reducing the water diverted per unit of land area would mean an increase in productivity per unit of water which would be a clear indication of progress towards greater efficiency for the Nzhelele Government Water Scheme.

In the Nzhelele Government Water Scheme, the trendline indicates a slight lower diversion per unit of irrigated areas since the 2006 water year (see **Figure 12.1** below). Hardly much has changed in irrigation water use efficiency over the 5 years of records (excluding 2010). The slightly decreasing diversions per unit of irrigated land are a clear indication that there is no major improvement in water use efficiency.

As the irrigation area increased over the period from 2006 to 2011, the allocated water per unit has remained nearly the same over the same period. Any improvements for example in on-farm water use efficiency maybe likely to be offset with the increase in water losses. This conclusion has however only been reached with very limited data as no other historical data was available and will need to be verified in time.

Therefore in setting water saving targets for the Nzhelele Government Water Scheme, the use of the equivalent depth per unit area irrigated as a performance indicator is proposed. Any decrease per unit of actual irrigated area will indicate progress being made by the scheme towards greater irrigation water use efficiency. This performance indicator can be used at scheme as well as at sub-scheme level in the Nzhelele Government Water Scheme. Currently this measure is not being used when the irrigation schemes submit their WUEARs.

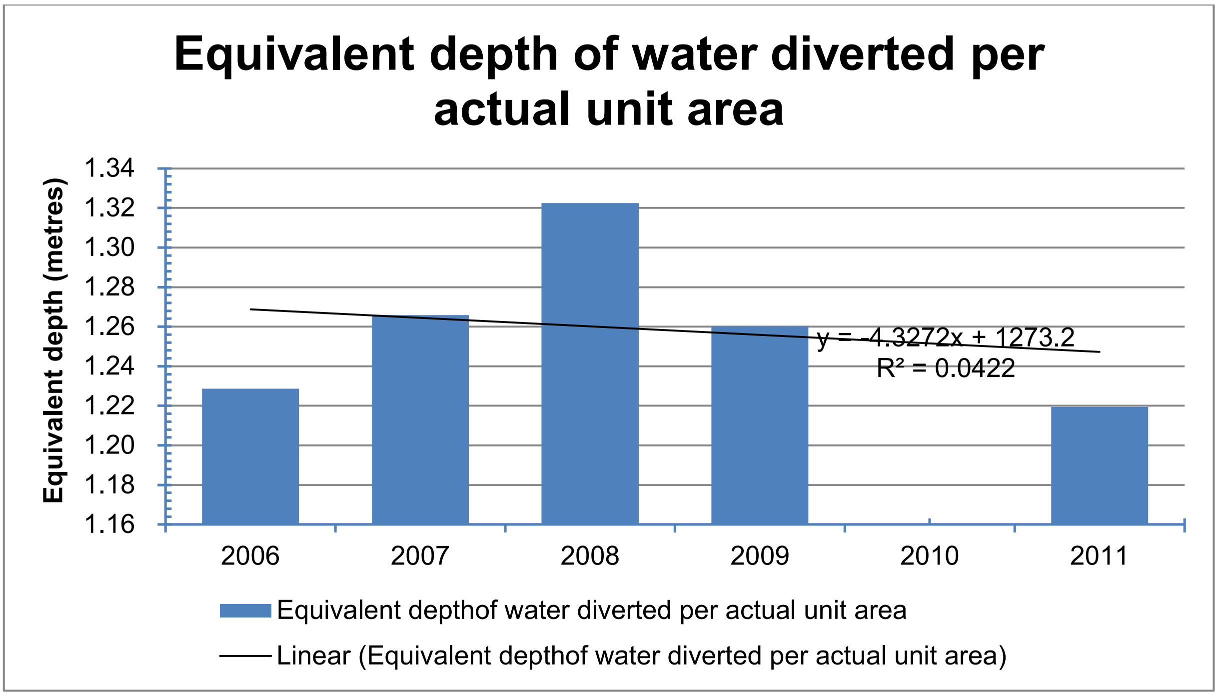

Figure 12.1: Trend line of slightly decreasing irrigation water diversion expressed as an equivalent depth of water diverted per actual unit area irrigated

12.2.2 Recommended water saving targets

Because there has not been a steep decline in the trendline of the diversions per unit area irrigated over the observed period, it would appear there is significant scope in implementing the irrigation management intervention measures discussed in the previous chapter. The water saving targets recommended for the Nzhelele Government Water Scheme are provided in **Table 12.1** below. Based on the projected water saving targets, the Nzhelele Government Water Scheme can achieve a 14% reduction in irrigation water losses relative to 2012 levels, by the end 2022 based on the components provided in **Table 12.1**.

12.2.2.1 Short term water saving targets

For the short term which has been taken as 3 years, the water savings from implementing the flow measurements; recalibration of Parshall Flumes will be 0.73 million m^3/a while monitoring of operational spills at the canal tail ends can reduce 0.46 million m^3/a. Furthermore the management of the aquatic weeds and water grass which is causing overtopping will potentially save an additional 0.91 million m^3/a, can be achieved. This is the water savings that has been targeted to be saved over a period of 3 years for the Nzhelele Irrigation scheme until 2015.

Therefore a total of 2.1 million m^3/a can potentially be saved within the next 3 years, i.e. by 2015, if the above identified intervention measures are implemented.

Table 12.1: Projected water saving targets for the Nzhelele Government Water Scheme

Irrigation Component	Intervention	Estimated water savings	Percentage of irrigation diversion	Time frame for implementation
Conveyance Infrastructure	Refurbishment	1.55	6%	3-5 years
	Aquatic weeds removal	0.91	4%	3 years
Distribution infrastructure	Flow measurement	0.73	3%	2 years
	Recalibration of Parshall Flumes		0%	
Operational	Canal tail ends /	0.46	2%	1 year
	Operational spills		0%	
Sub-Total Scheme target		3.65	14%	
On Farm irrigation	Incentive pricing	1.50	6%	5 years
	Irrigation systems		0%	

12.2.2.2 Long term water saving targets

For the long term a further 1.55 million m^3/a, is envisaged to be saved by refurbishment of the canal infrastructure while another 1.5 million m^3/a could potentially be saved through implementing incentive based pricing. This will require amendments to the current water pricing strategy which is currently being reviewed. It is unlikely that these water savings can be realised in the next three years. They are considered for the medium to long term in this water management plan. Therefore because of the complexities in implementing incentive based pricing and the timeline, it is recommended that this measure be implemented last.

The long term target is however to reduce the water losses from the current 32% of the total inflows to the Scheme to approximately 18%. The annual water savings targets are discussed together with the action plans for implementation of the identified measures.

12.3 Implementation plan to achieve the water saving targets

12.3.1 General

The evaluation of the potential measures for implementation in the Nzhelele Irrigation Scheme area, to improve water use efficiency and reduce water losses, indicates that there are some financial and socio-economic imperatives to implement the identified water management based on the envisaged water savings. There is potential in the Nzhelele Government Water Scheme to expand irrigation areas based on the gross margins from growing citrus and grape fruit.

12.3.2 Target 1: Conduct flow measurement at all critical measurement points in the scheme

Table 12.2 below provides the plan of activities which are required to ensure all flow measurements are taken by the Nzhelele GWS and detailed water balance assessments are conducted on a monthly basis and a management report presented to DWA on the status of water losses, water saving targets as well as the actions taken to reduce water losses.

As discussed in the previous chapters, the Nzhelele irrigation scheme has all the measurement structures to enable the GWS to take flow measurements at all critical points albeit by manually reading the flow levels and converting these levels to volumes using the available calibration tables. This is because the existing flow recorders at the measurement points are not operational.

Table 12.2: Nzhelele Irrigation Scheme: Water Management Measures and action plan

Priority	Goal	Action Plan	Timeline	Responsible Authority
1	To measure all critical points in the Nzhelele irrigation scheme	(i) Measure the main canal tail ends on a continuous basis by installing electronic equipment.	March 2013	DWA / Nzhelele GWS
		(ii) Measure the inflow and outflow at the balancing dam to determine weekly changes in storage	March 2013	
		(iii) Identify and incorporate measurement structures at the throats of the Parshall Flumes exhibiting submerged flow conditions at times	June 2013	
		(iv) Calibrate the measurement structures as required	August 2013	
2	Undertake detailed water balance assessments of the scheme	(i) Split the Nzhelele scheme into the different sub-schemes as per the branch canals and prepare water balance assessments and WUEAR to DWA Regional Office	March 2013	Nzhelele GWS
		(ii) Prepare detailed water balance assessment for the sub-schemes and split the losses to reflect operational losses from canal tail ends	April 2013	
		(iii) Revise the water losses at scheme and sub-scheme and identify the nature of	April 2013	

Priority	Goal	Action Plan	Timeline	Responsible Authority
		the water losses		
		(iv) Set water saving targets based on new water balance assessment information	April 2013	
3	To enable real or near real time flow monitoring	(i) Detailed design of the flow measurement and remote telemetry units (RTU) required for flow measurement	June 2013	Nzhelele GWS
		(ii) Install new telemetry system infrastructure including software to ensure compatibility with WAS	Aug 2013	
		(iii) Calibrate the flow measurements such as flumes and sluices to improve the accuracy in flow measurement	Aug 2013	
		(iv) Prioritise areas of significant water losses	Sept 2013	
4	To fully implement the WAS programme	(i) Review current use of WAS programme modules	April. 2013	Nzhelele GWS
		(ii) Implement the full use of the WAS ordering and release modules	June. 2013	
		(iii) Set up WAS programme to carry out water balances at scheme and sub-scheme level	July 2013	

Priority	Goal	Action Plan	Timeline	Responsible Authority
		(iv) Implement full use of the WAS programme including the reporting module.	July 2013	
5	To conduct the refurbishment of the canals	(i) Classify the condition of all canal segments based on the condition of the canals. In cooperation with scheme personnel, conduct field reconnaissance to obtain attribute data and rate the condition of segments	June 2013	Nzhelele GWS
		(ii) Prepare a motivation to DWA for refurbishment of the poor sections of the canals requiring total reconstruction as well as relining	Aug 2013	
		(iii) Engage with the DWA Infrastructure branch to motivate for refurbishment of the identified canal sections	Sept 2013	DWA/ Nzhelele GWS
		(iv) Prepare tender documents & specifications; Procure SP & undertake total reconstruction of canal sections and relining of the canals with bitumen emulsion	Oct 2013	DWA
		(v) Assess water savings made from total reconstruction of sections of the Nzhelele canal and relining of canal sections	May 2015	DWA
		(vi) Hand over the refurbished canals to Nzhelele GWS for on-going maintenance		

Priority	Goal	Action Plan	Timeline	Responsible Authority
6	To implement incentive pricing structure for the WMA	(i) Review current irrigation water pricing strategy and update administration systems (ii) Provide inputs in updating the DWA water pricing strategy (iii) Engage with irrigators on incentive pricing structure (iv) Install accurate flow measurement & implement water billing based on incentive pricing rate (v) Update the operating rules of Nzhelele Dam to supply irrigators based on incentive pricing rate	Feb 2013 April 2013 June 2013 Jan 2014 Feb 2014	DWA / Nzhelele GWS
7	Reduce algae growth in canals	(i) Identify the types and species composition of aquatic weeds and algae (ii) Prepare a tender for supply of Acrolein or similar approved (iii) Apply Acrolein to manage aquatic weeds and algae (iv) Assess the effect of chemical removal of algae	March 2012 June 2013 Oct 2013 June 2014	Nzhelele GWS

It is therefore considered a priority that the Nzhelele GWS initiates the daily manual reading of flow measurements (in the absence of an electronic measuring system) at the following critical points:

(i) All three main canal tail ends of the main N canal, the D canal and the E canal. This will require the Water Control Officers to measure these points on a daily basis.

(ii) Incorporate the Nzhelele balancing dam information by taking flow measurements at the inflow and outflow of the dam so that changes in storage capacity are included in the water balance assessment.

(iii) At the main branch canals particularly the A, B, C, D and E canals in the Nzhelele Government Water Scheme

12.3.3 Target 2: Conduct detailed water balance assessment at sub-scheme level

In order for the Nzhelele GWS to benefit from taking the flow measurements, detailed water balances should be prepared to incorporate actual flow measurements than is currently the case where the GWS has relied on estimates, particularly of the water losses. As a first step, water balance assessments should be conducted to include the measurements at the balancing dams as well as the canal tail ends.

12.3.4 Target 3: Implementation of WAS programme

The benefits of installing sufficient water measurement cannot be fully realised without the implementation of the WAS programme or a similar such system that can provide detailed analysis of the water balance assessment. The system will need to be linked with the data and records from the flow measurement system. The following actions are required to implement a water accounting system for the Nzhelele Irrigation Scheme:

(i) Review and evaluate the existing water accounting system being used by the scheme operators and identify where the gaps are;

(ii) Determine how the water release and water use modules should be linked to the flow measurement system;

(iii) Implement the WAS programme or similar system that can provide relevant information on water savings, progress to date and impact on performance indicators.

The WAS programme can then use the information and flow records to match the water releases and the water requested, to minimise operational spills, as well as to reduce any current flows at the tail ends. The flow at the tail ends is considered as a loss, although it may have a beneficial use downstream. The downstream demands can however be supplied by direct flows in the Nzhelele River and/or releases from Nzhelele Dam.

12.3.5 Target 4: Management of aquatic weeds and algae

One of the most critical water management measures that need to be implemented is the removal and control of the aquatic weeds and algae growth in the Nzhelele irrigation canals. The following actions are needed to implement a programme to control aquatic weeds and algae growth in the canals:

(i) Identify the types and species composition of aquatic weeds and algae growing in the canals as well as the source of the problem. This should include determining the physical and chemical characteristics of water and sediment in the canal system;

(ii) Conduct a critical evaluation of the benefits and problems encountered with on-going management activities to provide a useful baseline for development of a management plan that enhances cost effectiveness and efficacy of aquatic vegetation management in canals;

(iii) Prepare a management plan to implement aquatic weed and algae removal and control based on chemical process using herbicides such as Acrolein. Prepare a tender document for outsourcing the aquatic weed & algal removal;

(iv) Invite tenders and implement an aquatic weed and algae removal and control programme for Nzhelele Irrigation Scheme;

(v) Conduct a post project evaluation of the impact of the programme on reducing water losses and improving irrigation water management.

12.3.6 Target 5: Installation of the telemetry system for real time flow and level monitoring

Telemetry basically refers to accessing the data and controlling the system by remote means. With a telemetry setup, the Nzhelele GWS can program the system to run automatically and let the GWS know the status of a canal system at any time. If something goes wrong with the system, it can be set up to alarm the GWS.

Figure 12.2 below provides a layout plan of where the installation of the telemetry base station and the location of the remote terminal units are required in order to access the flow and level data which can be sent to the base station at the Nzhelele GWS offices. A number of activities and tasks for implementation of installation of telemetry infrastructure is presented in **Table 12.1** above. As illustrated in the Table, the first priority action plans focuses on designing the telemetry infrastructure and network in the scheme. It is important that the telemetry system first focuses on installing the infrastructure at the N primary canal where the diversion takes place, the main branch canals, the balancing dam as well as the canal tail ends.

With the installation of the telemetry system the Nzhelele GWS will be in a position to conduct the real time flow measurements at all critical points of the Nzhelele irrigation scheme, including the spills at the canal tail ends as well as the flow into the different branch canals. This will assist the scheme in determining where any critical changes to the expected flows such as at canal tail ends can be done thereby allowing the scheme operators to react to any operational losses or even theft of irrigation water.

Besides the monitoring of flows, the Nzhelele GWS will now be in a position to conduct detailed irrigation water balances for the scheme as well as at sub-scheme level. This will enable the scheme operators to determine which of the sub-schemes has the highest water losses and therefore develop specific intervention measure to reduce water losses. Furthermore, the scheme operators will be able to determine the different types of water losses.

The updating and calibration of the existing flumes should also be conducted to enable accurate flow measurements to be taken.

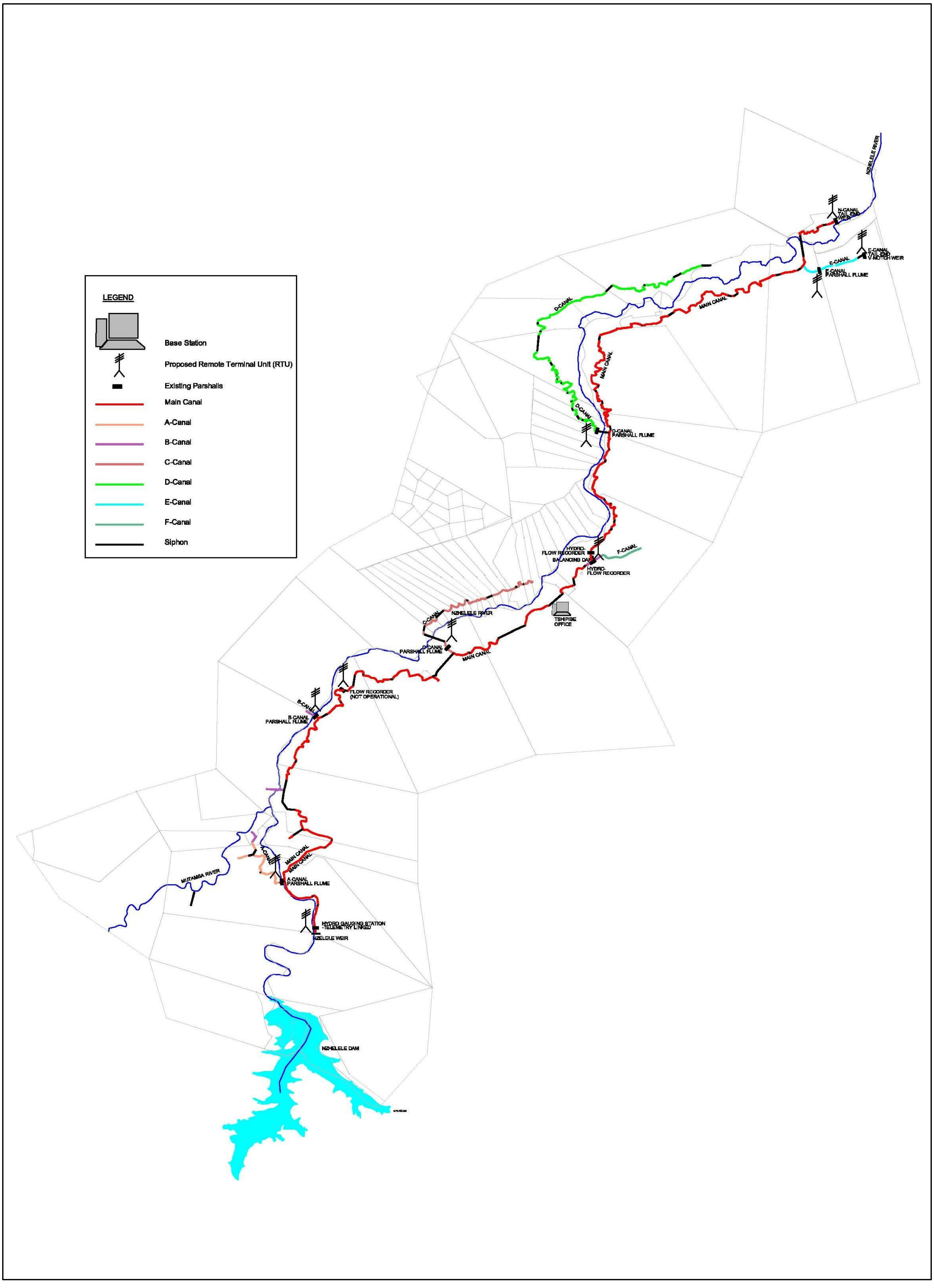

Figure 12.2: Proposed additional flow measurement and refurbishment of the existing telemetry system infrastructure

The updating and calibration of the existing Parshall flumes should also be conducted to enable submerged flow conditions to be done and therefore improve the accuracy of flow measurements in the irrigation scheme.

12.3.7 Target 6: Implement incentive based pricing

This requires a review and updating of any regulatory and operational criteria required to enable the Nzhelele GWS to implement incentive based pricing. The action plans and time frame including the following:

(i) Review and update the regulatory aspects of incentive based water pricing structure by providing inputs into the updating of the water pricing strategy;
(ii) Evaluate the average actual water use by irrigators as a percentage of their scheduled allocation. This can be done through a questionnaire and reviewing the historical records of irrigation demands;
(iii) Determine the fixed operation and maintenance costs of the Nzhelele Irrigation Scheme and assess the revenue requirements for sustainable operation of the scheme;
(iv) Establish the base price of irrigation water per unit of water, based on the revenue requirements of the scheme to meet the O&M costs;
(v) Determine the marginal costs per unit of water in excess of the base price and design one or more pricing levels above the base price;
(vi) Establish that the operational and accounting aspects of water pricing are in place;
(vii) Implement the incentive based water pricing structure for Nzhelele Government Water Scheme.

Besides the reduction in water use and potential additional revenue that Nzhelele Irrigation Scheme may benefit from implementing incentive based pricing, the reduction in on-farm irrigation will help the scheme to:

(i) Reduce erosion;
(ii) Improve the crop yield and quality of the crops;
(iii) Reduce fertiliser leaching; and
(iv) Reduce drainage problems and downstream water quality problems.

As the DWA's water pricing strategy is currently under review and update, where amendments may be required to encourage incentive based pricing in the strategy, this should be considered.

12.3.8 Updating and implementation of the Water Management Plan

The Scheme Manager will be responsible for amongst others the implementation and updating of the Water Management Plan (WMP) for the scheme.

The roles and responsibilities of the applicable Scheme Manager for the updating and implementation of the WMP will be the following:

(i) Take flow measurements and conduct a detailed water balance assessment on a monthly basis at scheme and sub-scheme level

(ii) Compile Water Use Efficiency Accounting Reports and submit it on a monthly basis to the DWA Regional Office and SAAWUA

(iii) Do recommendations on observations regarding water conservation issues and report to the Chief Executive: SAAFWUA and DWA on ways to address the identified issues

(iv) Develop activities that build on and complement other WC/WDM initiatives taking place at other water schemes

(v) Present water conservation information and training to irrigators and inform other scheme managers about success stories undertaken by the scheme

(vi) Maintenance and modernisation of the irrigation infrastructure

(vii) Liaise with DWA and other scheme managers to ensure consistent, efficient and effective deployment of water conservation messages, resources and services throughout the scheme

(viii) Monitor the plan and schedule for implementing water conservation program components

(ix) Report quarterly to DWA on the implementation status of the WMP, i.e. actions taken to reduce water losses and achievements towards achieving water saving targets, goals and objectives

(x) Annually review and update the WMP with a water conservation program for the scheme with goals, objectives, improved water saving targets, action steps, measures, and timelines taking into consideration the latest measured data and the measures that have already been implemented.

12.4 Summary of the implementation plan to achieve proposed water saving targets

The priority for implementation based on the amount of water savings and the average incremental cost of water saved is as follows:

(i) *Reduce operational losses at canal tail ends* - This measure has a high benefit with estimated water savings of 0.46 million m^3/a. These can be achieve at the least cost as no capital investment requirements is necessary to change the current operating procedures which ensures minimal or nor flows take place at the canal tail ends.

(ii) *Improving water measurement system and flow monitoring* - This measure is the main driver for the above intervention. The direct estimated water savings of 0.73 million m^3/a, can be achieved by calibration of the Parshall Flumes and taking flow measurements consistently at the identified critical points. It is also easier to implement and should be considered a priority as all other measures are dependent on availability of sufficient water measurements in the Nzhelele Irrigation Scheme.

(iii) *Chemical management of aquatic weeds and algae growth in canals* - This measure benefits the scheme with estimated water savings of 0.91 million m^3/a. It should be carried out at the same time as the first two intervention measures because of its impact on the hydraulic capacity of the canals.

(iv) *Water Accounting System* - This measure is aligned to the first measure listed above and will provide the system necessary to identify areas where irrigation water management can be improved. The changes in operation of the canals and canal tail ends can result in significant water savings if no water is allowed to flow out the canal tail ends at the end of the scheme.

(v) *Refurbishment of the canals and siphons* - The capital investment requirements for this measure is very high and requires a long lead time to implement. However it has the highest water saving target with approximately 1.55 million m^3/a being able to be achieved over a 10 year period.

(vi) *Incentive based water pricing structure*- This measure has a high benefit with estimated water savings of 1.5 million m^3/a. However there are legislative and administrative matters that need to be in place to enable incentive based pricing to be implemented effectively. Therefore a long lead time is required to implement this intervention measure.

The above first three measures indicate that the avoidable water losses that will be saved with relative ease amount to 2.10 million m^3/a out of a total of 3.65 million m^3/a of the estimated avoidable water losses. This does not include the savings that can be achieved by refurbishment of the canal infrastructure.

12.5 Funding of the Nzhelele Irrigation Scheme WMP

12.5.1 General

All of the Water Conservation and Demand Management measures involve an initial capital investment requirement, including the replacement costs over the useful life of the infrastructure. This is followed by on-going operations and maintenance, which is required to ensure the installed infrastructure assets can provide the required performance for its intended use.

It has been proven in the analysis of the identified water use efficiency measures that implementation of these measures provides the most viable option at present to improving irrigation water use efficiency and reduce water losses in the Nzhelele Irrigation Scheme. However, this will come at a cost to the water users. The additional cost for implementing these measures was done using the least cost planning approach where the average incremental costs (AIC) of each intervention measure were determined.

The financing of the candidate measures should, however, take into account the benefits from water savings made during the implementation of the above identified measures. This is discussed in the following section.

12.5.2 Financing by water users of the Nzhelele GWS

The benefits in implementing the flow monitoring of irrigation water supplied to irrigators will directly benefit the Nzhelele irrigators and ensure that irrigation water is managed effectively to enable the scheme operators to provide the water to irrigators when required and on time. Therefore based on the fact that the beneficiaries are the irrigators in the Nzhelele Irrigation Scheme, the financing of the following aspects should be borne by Nzhelele GWS water users;

(i) Upgrade the flow measurement, including calibration and installation of a flow monitoring system

(ii) Providing the full operation of the WAS programme or similar system to enable water accounting to be conducted as well as to fulfil the legal requirements in terms of the Act to provide annual reporting to the DWA on the irrigation water management for the scheme.

12.5.3 Financing by the DWA

The canal infrastructure in the Nzhelele Irrigation Scheme is owned by the Department of Water Affairs (DWA) as the Nzhelele Scheme is a GWS. The responsibilities of the irrigation scheme include the operation and normal annual maintenance of the infrastructure while the refurbishment of the infrastructure would be carried out by the DWA – Infrastructure Branch.

The impact of the aquatic weeds and algae on the condition of some of the infrastructure may have resulted in deterioration to the extent that it requires refurbishment, the cost of which is prohibitive to be carried out by the irrigators through increase in water tariffs. Furthermore this problem is external to the operation of the scheme as the reasons for aquatic weeds may be due to upstream management. This problem is considered a water management area problem and requires DWA financing to reduce the water losses and deterioration of canals.

It is therefore recommended that the DWA provide the funding necessary to reduce water losses for the following intervention measures:

(i) Implementation of a programme to remove and control the aquatic weeds and algae growth in canal systems.

(ii) Refurbishment of the sections of irrigation canals which are in a bad condition which are identified through a ponding test.

(iii) Implementation of the incentive based pricing by Nzhelele GWS

13 CONCLUSIONS AND RECOMMENDATIONS

13.1 Conclusions

The following can be concluded from the assessment of the water supply/requirements conducted for the Nzhelele Irrigation Scheme area and can be summarised as follows:

- The Nzhelele Irrigation Scheme is situated in the Limpopo Water Management Area in the Vhembe District Municipality. The scheme has an enlisted area of 2 794 ha at an allocation of 8 400 ha/a, which excludes the river irrigators. The total water allocation from the Nzhelele is 24.5 million m^3/a for canal irrigators.
- The main crops that are under irrigation include citrus and grape fruit, as well as annual cash crops such as vegetables and maize.
- The Nzhelele Government Water Scheme receives its raw water supplies from the storage dam in the Nzhelele River, namely Nzhelele Dam, with a weir downstream where irrigation water is diverted into the main canal delivering water to the scheme.
- The Nzhelele Dam has a total storage capacity of 51.2 million m^3 while the historical yield of the dam is 24.5 million m^3/a. Water is released from the dam to supply Nzhelele Irrigation Scheme, based on the weekly orders by the irrigators.
- The Nzhelele Irrigation Scheme has a total length of approximately 74.2 km of irrigation canal including siphons, which supplies the irrigators as well as household consumption. There is one main flow measurement structure measuring diversion into the main canal. The canals distribute irrigation and domestic water to approximately 74 sluice gates with the flow measured at either the Parshall flumes or V-Notch weirs.
- Although no detailed condition assessment could be undertaken on the Nzhelele Irrigation Scheme, a preliminary assessment and discussion with scheme operators indicated that the Nzhelele canals are in a very poor condition because of the age and lack of sufficient maintenance of the canals.
- It was determined that there were significant problems of aquatic weeds and algae growth in the canals which affected the hydraulic performance and condition of the canal system.
- In order to ensure that the irrigators receive their scheduled quota as and when required, the Nzhelele GWS operates the irrigation scheme based on “delivery on request” where each water user (irrigator) must submit a written request on a weekly

basis and the water is delivered to some 74 abstraction points along the canal systems. These procedures are not all formerly documented.

- Irrigation water use in Nzhelele has averaged 18.97 million m^3/a for the available two years of records for 2009/10 and 2011/12 water years. The household consumption is very small at 0.75 million m^3/a in the 2011/12 water year.
- The average total water diverted within the Nzhelele Irrigation Scheme during the same two year period, was 27.97 million m^3/a, for the same two years of records available.
- An irrigation water balance assessment conducted for Nzhelele Irrigation Scheme indicated that the water losses averaged 32% of the total inflow into the Scheme. This amounted to a total gross water losses of 8.2 million m^3/a, for the whole scheme. This was considered to be very high.
- The total water losses were disaggregated to determine the unavoidable and avoidable water losses with a view to establishing the irrigation water delivery BMP for Nzhelele Irrigation Scheme. The total unavoidable water losses comprising evaporation losses and unavoidable seepage due the material of the infrastructure was determined to be 1.95 million m^3/a or 8% of the total water released into the scheme.
- However an assessment of the operational inefficiencies due to over delivery, metering errors, etc. means that approximately 10% of the total releases will unlikely be able to be saved. This translates to 2.59 million m^3/a, which will be uneconomical to save because of the practical inefficiencies inherent in matching supply and demand.
- The water losses that can be saved was determined to be 3.65 million m^3/a out of an average total water loss of 8.19 million m^3/a for the Nzhelele GWS. This was considered to be operational wastage, leakage and spills which could potentially be saved.
- Based on the unavoidable water losses, there was significant potential to reduce irrigation water losses and improve irrigation efficiency in the Nzhelele Irrigation Scheme. The avoidable water losses of 3.65 million m^3/a, could potentially be saved. This also includes the spills at the canal tail ends.
- The irrigation water balance assessment together with discussions with Nzhelele GWS operators highlighted that there were number of management issues which included the following:
  - (i) Although there are flow measurements structures, there are a number of measurements which are currently not being read. The most critical points to

measure and monitor flows which are not being done include the canal tail ends as well as measurement of changes in the storage capacity of the balancing dam. Because these critical points are currently not being measured, the integrity and validity of the WUEARs currently being submitted are questionable.

(ii) Because of insufficient flow measurements, the Nzhelele GWS is not conducting a detailed water balance assessment. The current water balance assessments include estimation of flows at some of the points where measurements exist. These include the canal tail ends. There is a need to address this in order to clearly determine where and how much water can be considered as water losses.

(iii) There are problems with the accuracy of some of the Parshall Flumes because of submerged flow conditions being experienced. Therefore the actual volume of water delivered to some of the irrigators may be overstated.

(iv) There is no flow monitoring system in place besides the manual monitoring taking place. This is because the flow recorders which were used to monitor the flows and levels at different critical points such as canal tail ends are not operational.

(v) Not all the modules of the WAS programme which was installed are being utilised. The main ones are the release and measured data modules which are currently not being used. Together with the compatibility issues of the telemetry system only the administration module is being utilised.

(vi) The condition of the canal infrastructure was in a very poor state resulting in significant water leakages.

- Based on the above water management issues, a number of measures were identified to address the issues with the main management goal being to reduce the high water losses and improve irrigation water use efficiency in Nzhelele. These measures were evaluated and prioritised based on the water savings and the average incremental cost (AIC) of implementing the measures.

13.2 Recommendations

13.2.1 Nzhelele Water Management Plan

A water management plan for the Nzhelele Irrigation Scheme was developed to address the water losses taking place in the scheme and to improve irrigation water management of the scheme. The identified measures for implementation to reduce the water losses from the current 32% to 18% of the total inflow into the irrigation scheme include the following:

(vii) *Reduce operational losses at canal tail ends* - This measure has a high benefit with estimated water savings of 0.46 million m^3/a. These can be achieved at the least cost as no capital investment requirements is necessary to change the current operating procedures which ensures minimal or nor flows take place at the canal tail ends.

(viii) *Improving water measurement system and flow monitoring* - This measure is the main driver for the above intervention. The direct estimated water savings of 0.73 million m^3/a, can be achieved by calibration of the Parshall Flumes and taking flow measurements consistently at the identified critical points. It is also easier to implement and should be considered a priority as all other measures are dependent on availability of sufficient water measurements in the Nzhelele Irrigation Scheme.

(ix) *Chemical management of aquatic weeds and algae growth in canals* - This measure benefits the scheme with estimated water savings of 0.91 million m^3/a. It should be carried out at the same time as the first two intervention measures because of its impact on the hydraulic capacity of the canals.

(x) *Water Accounting System* - This measure is aligned to the first measure listed above and will provide the system necessary to identify areas where irrigation water management can be improved. The changes in operation of the canals and canal tail ends can result in significant water savings if no water is allowed to flow out the canal tail ends at the end of the scheme.

(xi) *Refurbishment of the canals and siphons* - The capital investment requirements for this measure is very high and requires a long lead time to implement. However it has the highest water saving target with approximately 1.55 million m^3/a being able to be achieved over a 10 year period.

(xii) *Incentive based water pricing structure*- This measure has a high benefit with estimated water savings of 1.5 million m^3/a. However there are legislative and administrative matters that need to be in place to enable incentive based pricing to be implemented effectively. Therefore a long lead time is required to implement this intervention measure.

13.2.2 Financing options for the WMP

All of the Water Conservation and Demand Management measures involve an initial capital investment requirement including the replacement costs over the useful life of the infrastructure. However the financing of the candidate measures should take into account the benefits from water savings made during the implementation of the above identified measures.

Two sources of funding were identified and are recommended based on the benefits of the intervention measures. The recommendation is that

(i) Nzhelele GWS should look at financing the measures which will benefit and improve the operation and monitoring of irrigation water in the scheme. These measures will also allow Nzhelele to fulfil its legal requirements in terms of the National Water Act on reporting and efficient management of irrigation water. These include updating the flow measurements, refurbishing the telemetry system and to fully implement the WAS programme.

(ii) The DWA owns the infrastructure in Nzhelele Irrigation Scheme. The refurbishment of the canal infrastructure including management of the aquatic weeds and algae requires significant funding which cannot be met from the maintenance budget of Nzhelele GWS. As the water savings from the refurbishment of canals will benefit downstream consumers, the financing of the refurbishment of the infrastructure should be undertaken by the DWA. This also includes the implementation of incentive based pricing which will improve the on-farm irrigation efficiency while the savings will benefit downstream users unless Nzhelele GWS can use the water to expand their irrigation area.

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