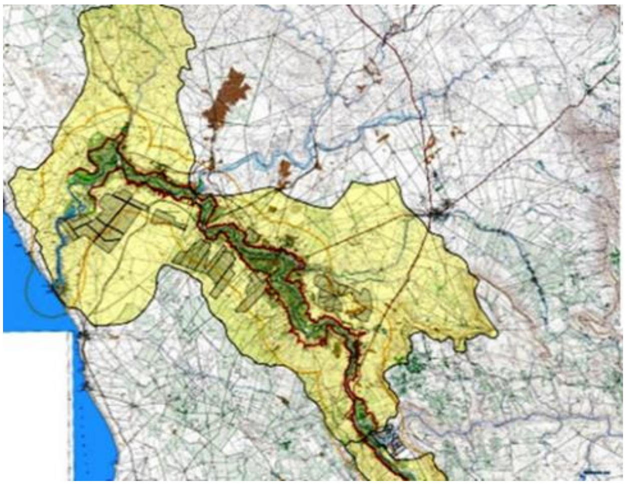
DWS Report Number: P WMA 09/E10/00/0417/6

water & sanitation

Department:
Water and Sanitation
REPUBLIC OF SOUTH AFRICA

Post Feasibility Bridging Study for the Proposed Bulk Conveyance Infrastructure from the Raised Clanwilliam Dam (WP0485)

Existing Conveyance Infrastructure and Irrigated Land Report



January 2019

Department of Water and Sanitation
Directorate: Options Analysis

POST FEASIBILITY BRIDGING STUDY FOR THE PROPOSED BULK CONVEYANCE INFRASTRUCTURE FROM THE RAISED CLANWILLIAM DAM

APPROVAL

Title	:	Existing Conveyance Infrastructure and Irrigated Land Report
DWS Report Number	:	P WMA 09/E10/00/0417/6
Consultants	:	Aurecon South Africa (Pty) Ltd
Report status	:	Final
Date	:	January 2019

STUDY TEAM

Approved for Aurecon South Africa (Pty) Ltd:

....

E VAN DER BERG
Technical Director

DEPARTMENT OF WATER AND SANITATION
Directorate Options Analysis

Approved for Department of Water and Sanitation:

....

M MUGUMO

CHIEF ENGINEER: OA (South)

....

C FOURIE

DIRECTOR: OPTIONS ANALYSIS

Document control record

Document prepared by:

Aurecon South Africa (Pty) Ltd

1977/003711/07

Aurecon Centre
1 Century City Drive
Waterford Precinct
Century City
Cape Town
7441

PO Box 494
Cape Town
8000
South Africa

T +27 21 526 9400
F +27 21 526 9500
E capetown@aurecongroup.com
W aurecongroup.com

Document control						aurecon
Report title		Existing Conveyance Infrastructure and Irrigated Land Report				
Document ID			**Project number**		113834	
File path		P:\Projects\113834 Bridging Study Clanwilliam Dam\03 Prj Del\04 Task 5 Existing Infr & Land\TASK 5 Existing Conveyance Infrastructure and Irrigated Land_Final.docx				
Client		Department of Water and Sanitation	**Client contact**		Mr M Mugumo	
Rev	**Date**	**Revision details/status**	**Prepared by**	**Author**	**Verifier**	**Approver**
0	28 September 2018	Draft 1	Aurecon	A Chang	E v/d Berg	E v/d Berg
1	7 December 2018	Draft 2	Aurecon	A Chang	E v/d Berg	E v/d Berg
2	15 January 2019	Final	Aurecon	A Chang	E v/d Berg	E v/d Berg
Current Revision		**2**				

Approval			
Author signature		Approver signature	
Name	Alice Chang	Name	Erik van der Berg
Title	Project Support Engineer	Title	Technical Director

water & sanitation

Department:
Water and Sanitation
REPUBLIC OF SOUTH AFRICA

DEPARTMENT OF WATER AND SANITATION

Directorate: Options Analysis

Post Feasibility Bridging Study for the Proposed Bulk Conveyance Infrastructure from the Raised Clanwilliam Dam

EXISTING CONVEYANCE INFRASTRUCTURE AND IRRIGATED LAND REPORT

January 2019

Prepared by: Aurecon South Africa (Pty) Ltd
P O Box 494
Cape Town, 8000
South Africa

Tel: 021 526 5790
Fax: 086 526 9500
e-mail: erik.vanderberg@aurecongroup.com

Prepared for: Director: Options Analysis
Department of Water and Sanitation
Private Bag X313
Pretoria 0001
South Africa

Mr Menard Mugumo (CE: OA, South)
Tel: 012 336 6838
E-mail: mugumom@dws.gov.za

This report is to be referred to in bibliographies as:

Department of Water and Sanitation, South Africa. 2019. *Existing Conveyance Infrastructure and Irrigated Land Report*. Prepared by Aurecon South Africa (Pty) Ltd as part of the Post Feasibility Bridging Study for the Proposed Bulk Conveyance Infrastructure from the Raised Clanwilliam Dam.

Post Feasibility Bridging Study for the Proposed Bulk Conveyance Infrastructure from the Raised Clanwilliam Dam

Reports produced as part of this project are indicated below.

Bold type indicates this report.

Report Index	Report Number	Report Title
1		Inception Report
2	P WMA 09/E10/00/0417/2	Capacity Building & Training Year 1
3	P WMA 09/E10/00/0417/3	Capacity Building & Training Year 2
4	P WMA 09/E10/00/0417/4	Water Requirements Assessment
5	P WMA 09/E10/00/0417/5	Distribution of Additional Available Water
6		Existing Infrastructure and Current Agricultural Development Sub-Report
7	**P WMA 09/E10/00/0417/6**	**Existing Conveyance Infrastructure and Irrigated Land**
8		Suitable Agricultural Areas and Land Ownership Report
9		Evaluation of Development Options Sub-Report
10	P WMA 09/E10/00/0417/10	Suitable Areas for Agricultural Development
11		Right Bank Canal Design Sub-Report
12		Conceptual Design Sub-Report
13		Environmental Screening Sub-Report
14		Jan Dissels and Ebenhaeser Schemes Design Sub-Report
15	P WMA 09/E10/00/0417/13	Feasibility Design
16	P WMA 09/E10/00/0417/7	Topographical Surveys
17	P WMA 09/E10/00/0417/8	Geotechnical Investigations
18	P WMA 09/E10/00/0417/9	Soil Survey
19		Financial Viability of Irrigation Farming Sub-Report
20	P WMA 09/E10/00/0417/11	Agricultural Production and Farm Development
21		Right Bank Canal Cost Analysis Sub-Report
22		Socio-Economic Impact Analysis Sub-Report
23	P WMA 09/E10/00/0417/12	Socio-Economic Impact Analysis
24	P WMA 09/E10/00/0417/14	Record of Implementation Decisions Report
25	P WMA 09/E10/00/0417/1	Main Report
26	P WMA 09/E10/00/0417/15	Historically Disadvantaged Farmers Report

Concise Description of the Content of Study Reports

Report Index	Report Number	Report Title and Description of Content
1		Inception The report forms part of the contract and stipulates the scope of work for the study, the contract amount and the contract period. It contains a detailed description of tasks and methodology, a study programme, human resource schedule, budget and deliverables. The Capacity Building and Training Plan has been included.
2	P WMA 09/E10/00/0417/2	Capacity Building & Training Year 1 Describes the range of capacity building and training activities planned for the study, and the activities undertaken during the first year of the study, including field-based training, training workshop 1 and mentorship of DWS interns through secondment.
3	P WMA 09/E10/00/0417/3	Capacity Building & Training Year 2 Describes the range of capacity building and training activities planned for the study, and the activities undertaken during the second year of the study, including field-based training, training workshop 2 and mentorship of DWS interns through secondment.
4	P WMA 09/E10/00/0417/4	Water Requirements Assessment Provides an analysis of the existing water use and current water allocations in the study area, and addresses ecological water requirements, water use for irrigated agriculture and projections for future use, current domestic and industrial water use and projections for future use, water use for hydropower and water losses in the water supply system.
5	P WMA 09/E10/00/0417/5	Distribution of Additional Available Water Confirms the volume of additional water available for development, after water has been reserved for the current water uses, as well as making recommendations on how the additional yield should be distributed among water use sectors and water users.
6		Existing Infrastructure and Current Agricultural Development Sub-Report Provides an overview of the extent and general condition of the current bulk water storage and conveyance infrastructure. This report also provides an overview of the locality and extent of the existing agricultural areas determined by reviewing Geographic Information System (GIS) data obtained from various sources.
7	P WMA 09/E10/00/0417/6	Existing Conveyance Infrastructure and Irrigated Land An update of the Sub-Report, providing a refinement of the current agricultural water requirements following evaluation of the current crop types, an assessment of the desirability of diverting releases for downstream irrigators via the Clanwilliam Canal and Jan Dissels River, to meet the summer ecological flows in the lower Jan Dissels River, and presents an Implementation Action Plan with costs.

Report Index	Report Number	Report Title and Description of Content
8		Suitable Agricultural Areas and Land Ownership Sub-Report Description of the collection of information and the preparation undertaken for the analysis of options, which includes a summary of existing irrigated areas and water use, cadastral information, land ownership, environmental sensitivity, soils suitability, water quality considerations and constraints, and the initiation of the process to identify additional areas suitable for irrigation.
9		Evaluation of Development Options Sub-Report Describes the salient features, costs and impacts of identified potential irrigation development options for new irrigation development in the lower Olifants River. This provides the background and an introduction to the discussions at the Options Screening Workshop held in December 2018.
10	P WMA 09/E10/00/0417/10	Suitable Areas for Agricultural Development Describes the supporting information, process followed and the salient features, costs and impacts of identified potential irrigation development options for new irrigation development in the lower Olifants River. Recommends the preferred options to be evaluated at feasibility level.
11		Right Bank Canal Feasibility Design Sub-Report Describes the Design Criteria Memorandum, based on best practice in engineering and complying with recognised codes and standards. Description of route alignments and salient features of the new Right Bank canal. Feasibility-level design of bulk infrastructure, including evaluation of capacities, hydraulic conditions, canal design, surface flow considerations, canal structures, power supply and access roads. Operational considerations and recommendations.
12		Conceptual Design Sub-Report Describes the scheme layouts at a conceptual level and infrastructure components to be designed, alternatives to consider or sub-options, and affected land and infrastructure, as well as the updated recommended schemes for new irrigation development.
13		Environmental Screening Sub-Report Describes and illustrates the opportunities and constraints, and potential ecological risks/impacts and recommendations for the short-listed bulk infrastructure development options at reconnaissance level. Describes relevant legislation that applies to the proposed irrigation developments.

Report Index	Report Number	Report Title and Description of Content
14		Jan Dissels and Ebenhaeser Schemes Feasibility Design Sub-Report Describes the Design Criteria Memorandum, based on best practice in engineering and complying with recognised codes and standards. Description of route alignments and salient features of the Jan Dissels and Ebenhaeser schemes. Feasibility-level design of bulk infrastructure, including evaluation of capacities, hydraulic conditions, intake structures, balancing dams and reservoirs, rising mains and gravity pipelines and trunk mains where relevant, power supply and access roads. Operational considerations and recommendations.
15	P WMA 09/E10/00/0417/13	Feasibility Design Description of the approach to and design of selected bulk infrastructure at feasibility level, with supporting plans and implementation recommendations.
16	P WMA 09/E10/00/0417/7	Topographical Surveys Describes the contour surveys for the proposed identified bulk infrastructure conveyance routes and development areas, the surveying approach, inputs and accuracy, as well as providing the survey information.
17	P WMA 09/E10/00/0417/8	Geotechnical Investigations Presents the findings of geotechnical investigations of the various identified sites, as well as the approach followed, field investigations and testing, laboratory testing, interpretation of findings and geotechnical recommendations.
18	P WMA 09/E10/00/0417/9	Soil Survey Describes the soil types, soil suitability and amelioration measures of the additional area covering about 10 300 ha of land lying between 60 to 100 m above river level, between the upper inundation of the raised Clanwilliam Dam and Klawer.
19		Financial Viability of Irrigation Farming Sub-Report Describes the findings of an evaluation of the financial viability of pre-identified crop-mixes, within study sub-regions, and advises on the desirability of specific crops to be grown in these sub-regions. It includes an evaluation of the financial viability of existing irrigation farming or expanding irrigation farming, as well as the identification of factors that may be obstructive for new entrants from historically disadvantaged communities.
20	P WMA 09/E10/00/0417/11	Agricultural Production and Farm Development This report will focus on policy, institutional arrangements, available legal and administrative mechanisms as well as the proposed classes of water users and the needs of each. This would include identifying opportunities for emerging farmers, including grant and other types of Government and private support, and a recommendation on the various options and opportunities that exist to ensure that land reform and water allocation reform will take place through the project implementation.

Report Index	Report Number	Report Title and Description of Content
21		Right Bank Canal Cost Analysis Sub-Report Provides an economic modelling approach to quantify the risk of the failure of the existing main canal and the determination of the economic viability of the construction of the new right bank canal to reduce the risk of water supply failure.
22		Socio-Economic Impact Analysis Sub-Report Describes the socio-economic impact analysis undertaken for the implementation of the new irrigation development schemes, for both the construction and operational phases. This includes a description of the social and economic contributions, the return on capital investment, as well as the findings of a fiscal impact analysis.
23	P WMA 09/E10/00/0417/12	Socio-Economic Impact Analysis Synthesis of agricultural economic and socio-economic analyses undertaken, providing an integrated description of agricultural production and farm development and socio-economic impact analysis, as well as the analysis of the right bank canal costs and benefits.
24	P WMA 09/E10/00/0417/14	Record of Implementation Decisions Describes the scope of the project, the specific configuration of the schemes to be implemented, the required implementation timelines, required institutional arrangements and the required environmental and other approval requirements and mitigation measures, to ensure that the project is ready for implementation.
25	P WMA 09/E10/00/0417/1	Main Report Provides a synthesis of approaches, results and findings from the supporting study tasks and interpretation thereof, culminating in the study recommendations. Provides information in support of the project funding motivation to be provided to National Treasury.
26	P WMA 09/E10/00/0417/15	Historically Disadvantaged Farmers Report Describes the activities undertaken by an independent consultant to evaluate existing HDI Farmers policies and legislative context, identify, map and analyse prospective HDI farmers and potential land for new irrigation, as well as propose a mechanism for the identification and screening of HDI farmers.

Executive Summary

An overview of the extent and general condition of the current water infrastructure is required as input for the development of infrastructure options, for the distribution of additional water from a raised Clanwilliam Dam. This report provides the overview, which includes the current conveyance infrastructure (the Clanwilliam Canal and the Lower Olifants Canal), the Clanwilliam Dam, the Bulshoek Weir and the Ebenhaeser Scheme. Information required was obtained by conducting a literature review of previous studies done in the study area, verification by a field trip and public meetings, and confirmation of additional information with stakeholders such as the water user associations.

It was found that the general condition of the canals ranged from fair to very poor. Those sections of the existing canals that need urgent rehabilitation have been identified and included in the development of an Implementation Action Plan.

This report also provides an overview of the existing agricultural development, obtained by reviewing GIS data obtained from various sources, such as the '*Feasibility Study for the Raising of Clanwilliam Dam'* (DWAF, 2008), and the Western Cape Provincial Department of Agriculture's *Cape Farm Mapper*, etc.

The locality and extent of the existing agricultural areas is provided. The *'Existing Conveyance Infrastructure and Irrigated Land*' Report provides a refinement of the current agricultural water requirements, following an evaluation of the current crop types.

Contents

Figures

Tables

Acronyms

CBA	Critical biodiversity area
DWAF	Department of Water Affairs and Forestry
DWS	Department of Water and Sanitation
FOS	Factor of safety
GIS	Geographical information system
GWS	Government water scheme
HDPE	High density polyethylene
LORGWS	Lower Olifants River Government Water Scheme
LORWUA	Lower Olifants River Water User Association
MAR	Mean annual runoff
NPV	Net present value
P&G	Preliminary and General
uPVC	Unplasticised polyvinyl chloride
VAT	Value added tax
WCDoA	Western Cape Department of Agriculture (Provincial)
WUA	Water User Association

1 Introduction

1.1 Study Background and Objective

The Clanwilliam Dam is situated near the town of Clanwilliam, on the Olifants River in the Western Cape Province. The planned raising of the Clanwilliam Dam by the Department of Water and Sanitation (DWS) will result in an increase in the capacity of the dam from 122 million m^3 to 344 million m^3, with an additional yield of 82.1 million m^3/a. This increased capacity will provide additional water for irrigation and for other uses.

The objective of this study is to provide recommendations on the bulk conveyance infrastructure required for the equitable distribution of water from the existing dam, as well as the additional water which will be available from the raised Clanwilliam Dam.

1.2 Report Objectives

This report is focused on the review and confirmation of the extent of the existing bulk conveyance infrastructure and current agricultural development in the supply area. This report aims to:

1. Provide an overview of the extent and general condition of the current bulk water infrastructure, which includes obtaining the following information:
    a. Identification of the sections of the existing Clanwilliam and Lower Olifants canals that need urgent rehabilitation to avoid serious disruptions of the water supply; and
    b. Maintenance or upgrade projects planned for the canal systems.
2. Present an Implementation Action Plan.
3. Assess the desirability of diverting releases for downstream irrigators via the Clanwilliam Canal and Jan Dissels River, to meet the summer ecological flows in the lower Jan Dissels River.

4. Obtain and present information regarding the current agricultural development, which includes:
   a. The locality and extent of the agricultural areas;
   b. The potential for further agricultural development adjacent to the existing development and the suitability of these areas in terms of topography, soil type, crops, ownership, etc.; and
   c. The water requirements and allocations for the various areas and reconciliation with the information obtained in the Water Requirements Assessment Report.

1.3 Study Area

The study area mainly comprises the supply area of the Clanwilliam Dam, located within the Cederberg and Matzikama Local Municipalities, and includes the towns of Clanwilliam, Klawer, Lutzville, and Vredendal. The study area may potentially include portions of the Olifants River valley upstream of Clanwilliam Dam. Some activities may even extend beyond the study area, such as the Jakkals River and small coastal towns.

For the purposes of this study, the Olifants River catchment's study area, shown in **Figure 1.1** has been separated into three relatively homogeneous regions, namely:

- Region 1: Catchment area upstream of Clanwilliam Dam;
- Region 2: Catchment area downstream of Clanwilliam Dam and upstream of Bulshoek Weir;
- Region 3: Catchment area downstream of Bulshoek Weir to the estuary.

1.4 Report Structure

This report comprises an executive summary and **Section 1** to **Section 6**. The different sections have been structured as follows:

Section 1 provides the background to this study and the purpose of this report.

Section 2 describes the approach and methodology followed to carry out this task.

Section 3 describes the extent of the current water infrastructure and provides the assessment of their existing condition.

Section 4 discusses the meeting of the Reserve in the lower Jan Dissels River.

Section 5 describes the evaluation of the current agricultural development.

Section 6 summarises the findings of this report.

Project: CLANWILLIAM BRIDGING STUDY	Scale: 0 5 10 20 30 40 km, 1 : 1 300 000, N
Drawing Title: *Study Area Zones and Municipalities of the Oilfants/Doorn WMA*	Path: Document Path: S:\Projects\2017\G113834\mxd\maps\A4_studyAreaZones.mxd

water & sanitation, Department: Water and Sanitation, REPUBLIC OF SOUTH AFRICA — aurecon

Figure 1.1 | The study area zones and municipalities

2 Approach and Methodology

In order to provide an overview and determine the condition of the current water infrastructure, a literature review on previous studies and initiatives was undertaken, which included the '*Feasibility Study for the Raising of Clanwilliam Dam'* (DWAF, 2008), the '*Provide Support to Compulsory Licensing in the Jan Dissels River Catchment: Western Cape'* (DWAF, 2008) and the '*Western Cape Olifants / Doring River Irrigation Study'* (WCDoA, 2005). In addition to the literature review on previous studies, various newspaper and magazine articles that describe the impacts of canal breaks on the irrigation community were consulted.

In November 2017, the project team conducted a field trip to the study area. During this field trip, the project team met with the Lower Olifants River Water User Association (LORWUA), the Clanwilliam Water User Association (WUA), officials from the local DWS and the Provincial Government Western Cape, Department of Agriculture (WCDoA) who provided insight to various operational issues experienced in the schemes. Public meetings were also held in Ebenhaeser, Clanwilliam and Vredendal in February 2018, where concerns of the communities in the study area were raised. The project team also obtained additional information from these stakeholders following both the field trip and the public meetings.

A GIS mapping exercise was undertaken to obtain information on the current agricultural development in the study area. Shapefiles showing the existing extent of the cultivated and irrigated areas were obtained from the '*Validation and Verification of existing lawful water uses within the Berg Olifants WMA'* study, also referred to as the V&V Study. The Crop Census data of 2013 provided shapefiles on the crop types, and soil mapping was extracted from the '*Feasibility Study for the Raising of Clanwilliam Dam'* (DWAF, 2008). Considering that Clanwilliam and LORWUA have significant developments above the canals, it was decided to extend the soil surveys to cover the lateral extent of 100 m above the level of the river or existing canals. The findings of the soil surveys will be provided in the Soil Testing Report.

3 Existing Infrastructure

Figure 3.1 provides an overview of the existing conveyance infrastructure discussed in this report.

3.1 Clanwilliam Dam

The Clanwilliam Dam was originally constructed in 1935 with a capacity of 69.86 million m^3. The Dam was raised in 1962 by 6.10 m to increase the capacity to 128 million m^3. The Dam basin currently has a live storage capacity of 122 million m^3. The current mean annual runoff (MAR) at the dam is 360 million m^3. The dam currently supplies approximately 11 000 ha of scheduled water downstream of the dam. There are 318 ha scheduled allocations from the dam basin.

Due to proposed betterments to improve the safety of the dam wall, the opportunity to raise the dam was investigated. The Feasibility Study, concluded in 2008, found that a 13 m dam raising would be economically viable as a substantial increase in yield from the dam of 70 million m^3 (based on the increase in firm yield) could be achieved, thereby increasing the current storage volume to 344 million m^3, i.e. nearly a 1 MAR capacity dam.

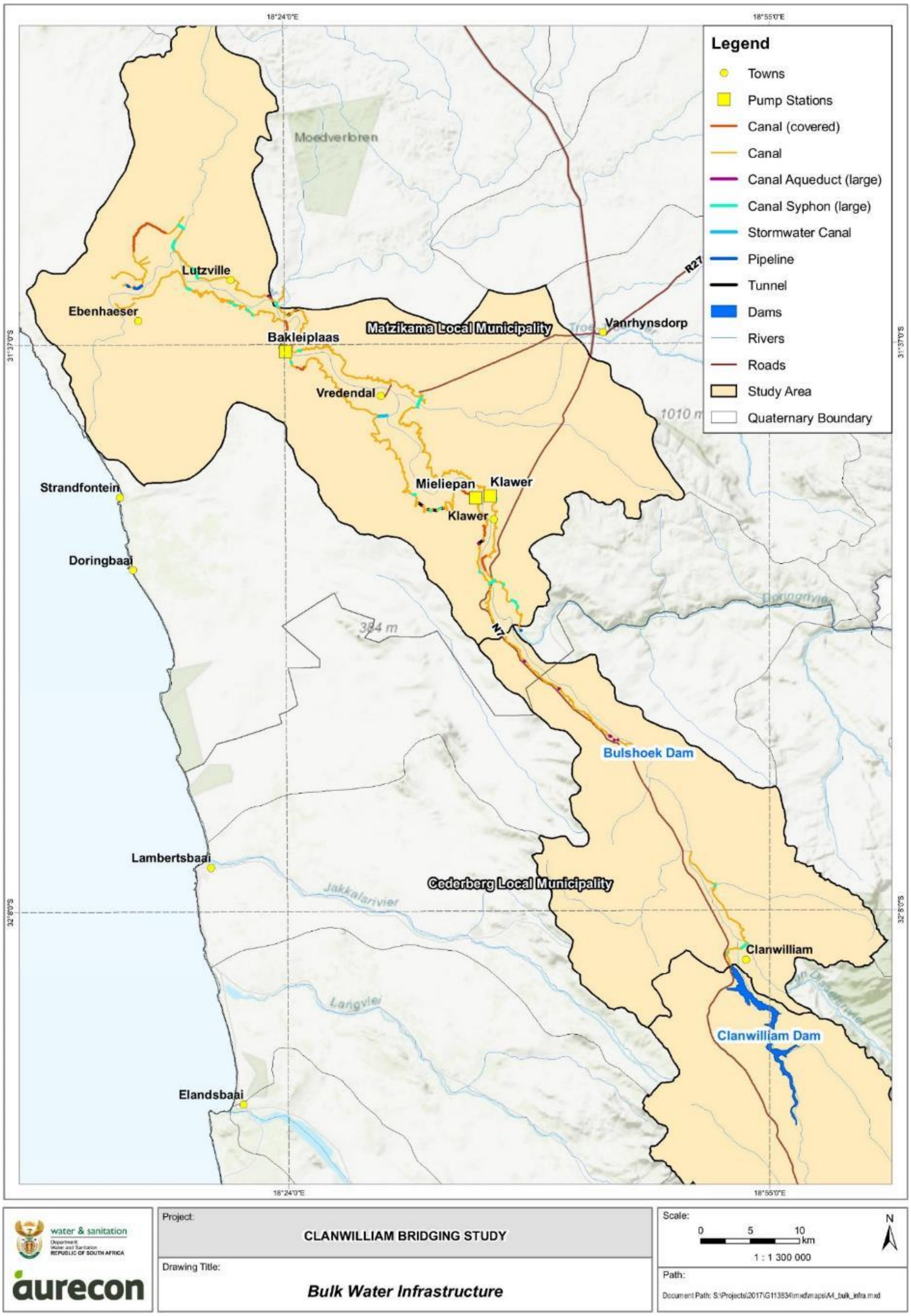


Figure 3.1 | Existing bulk water infrastructure

During a recent visit to the study area in November 2017, the Clanwilliam Dam was 39% full (**Figure 3.2**). The dam's water level may be allowed to drop to 6% before the next rain season.

Figure 3.2 | Low water levels in the Clanwilliam Dam in November 2017

The only power station in the area is a small privately-owned hydro-electric installation (non-consumptive water user) on the right bank at Clanwilliam Dam which supplies electricity to the town of Clanwilliam (**Figure 3.3**). In 1998, Clackson Power (Pty) Ltd bought the hydropower station from the Cederberg Municipality. On 17 April 2001, the DWS and Clackson Power entered into an operations agreement that the power station will not consume any water, but that it will make use of water released from the Clanwilliam Dam, as and when water is released, for power generation. On 28 March 2008, Clackson Power registered with NERSA to generate 1.5 MW hydropower.

The plant provides base load and helps to stabilise the current voltage variations in Clanwilliam. Turbines of 1.7 MW capacity have been installed, but only 1.1 MW is currently generated. There is therefore capacity for expansion, as well as significant demand for additional power generation (as the cost of power generation is lower than Eskom's).

Provision has been made in the proposed new outlet works on the left bank to supply the hydropower plant. The plant has to move to the left bank. Although the construction of the civil structure to accommodate the hydropower plant is not occurring at the same time as the raising of the Clanwilliam Dam, the latest civil design drawings indicate spatial provision for the structure in the future. The flow to the hydro power plant will increase due to larger volumes of water allocated to downstream uses. All normal flows released to the river pass through the plant.

Figure 3.3 | Existing turbine on the right bank of Clanwilliam Dam

3.1.1 Operating Rules – Clanwilliam Dam Releases

The Clanwilliam Dam is operated at a draft that exceeds its historical firm yield. In most years, it is drawn down to between 5% and 20% of its full supply capacity. As its capacity is only 33% of the present-day mean annual runoff, it usually fills during the wet winter months. Releases from the Clanwilliam Dam are dependent on the water demand from the Clanwilliam WUA and the LORWUA.

The government notice (no. 1152) issued in Government Gazette No. 41216 on 31 October 2017 currently limits the use of water in the catchment area above and below the Clanwilliam Dam. This is in light of the recent water shortage due to below normal rains experienced over the past three seasons up to 2017. These limitations placed by the government notice are for this extreme drought event and should not be regarded as normal.

The notice also enforces that all water user sector groups and individuals abstracting water from the Olifants River catchment area, dams and/or rivers that form part of the system, must install electronic recording, monitoring or water measuring devices to enable monitoring of abstraction, storage and use of existing lawful water. In addition, links need to be established with any monitoring or management system, and records of the water use need to be kept.

The restricted releases from the Clanwilliam Dam are also to be further limited to operating and applied rules agreed to by the National Water Resources Infrastructure Branch: Southern Operations of the Department (and/or delegated officials) and the LORWUA. These agreed rules are to be reviewed on a weekly basis.

3.2 Clanwilliam Canal

The Clanwilliam Canal, approximately 18 km in length, originates at the Clanwilliam Dam wall (**Figure 3.4**), passes through Clanwilliam town and crosses the Jan Dissels River. The canal, which was built during 1940, supplies water for irrigation.

The Clanwilliam Canal is owned by the DWS; however, the Clanwilliam WUA is responsible for the canal's operation and maintenance. Water off-takes from the canal are set twice in one season and farmers currently pay total charges of R811.16 per hectare per annum (**Table 3.1**). Farmers making use of the canal pay for their scheduled allocations and receive a rebate only on government charges in cases of severe restrictions.

In the Clanwilliam scheme, there are 564 ha of scheduled allocations from the Clanwilliam Canal and 665 ha allocated from the Olifants River. Water from the canal to water users is supplied at a rate of 0.83 ℓ/s/ha, thus the maximum capacity required is 1685 m^3/h. However, the maximum carrying capacity of the canal is accepted as 1700 m^3/h (0.47 m^3/s), which means that during peak periods the canal is close to full capacity. According to discussions with the Clanwilliam WUA in November 2017 however, the canal currently has some spare capacity. Canal losses are estimated as 20%.

Figure 3.4 | Start of the Clanwilliam Canal

Table 3.1 | Clanwilliam WUA annual water tariffs

Clanwilliam WUA Canal	2017 / 2018 charges (per hectare)
Catchment Management Agency	R244.00
Infrastructure	R291.58
Water Research	R5.95
WUA Management	R77.76
WUA Audit	R13.18
WUA Canal Maintenance	R178.69
Total (excluding VAT)	**R811.16**

The canal has a uniform profile. A recent site visit to the canal revealed that the Clanwilliam Canal has patch repairs along most of its length (**Figure 3.5**). In many canal sections, the stone aggregate in the concrete canal lining was exposed due to the aggressive water. The canal lining was on average less than 100 mm thick.

Figure 3.5 | Typical condition of concrete lining along the Clanwilliam Canal

3.2.1 Condition Assessment

The DWS appointed LTE Consulting and Pula Strategic Resource Management to conduct a condition assessment of the Clanwilliam Canal (DWS, 2016a).

The key study outputs included: (1) the verification of existing assets according to location, type and size, and (2) an evaluation of the condition of the infrastructure and the associated requirements to rehabilitate, repair or replace assets for effective water supply to irrigation farmers and other users.

The comprehensive study assessed the condition of the canal lining, shoulders, berms and stormwater management, supers and culverts, fences and safety, bridges, service roads, siphons, measuring infrastructure, long-weirs, outlets, emergency spills and rejects, and balancing dams. It found that the condition of the infrastructure generally ranged from fair to poor.

The study proposed short-term, medium-term and longer-term interventions. The short-term actions (1 to 3 years) include *inter-alia* resolving the maintenance backlog, replacement of broken canal lining panels and relining of very poor canal sections. The medium-term actions

(4 to 6 years) include repairing berms and stormwater management structures, repairing service roads, reinstatement of safety measures, repairing siphons and water meter structures. The longer-term actions (7 to 9 years) include upgrades to the balancing dams, service points, emergency spills and new canal sections, as well as renewal of the aged infrastructure, and replacement of the entire canal. Estimated costs of these intervention actions are indicated in **Table 3.2** below. The amount indicated in **Table 3.2** for the long-term interventions will not be sufficient. These costs estimated in the DWS (2016a) study were investigated and updated for the Implementation Action Plan included in **Section 0**.

Table 3.2 | Estimated cost to repair, upgrade and maintain the Clanwilliam WUA infrastructure (DWS, 2016a)

Term	Period	2016 Amount (incl. fees, P&G's, contingencies, VAT)
Short-term	1 – 3 years	R 30 425 202
Medium-term	4 – 6 years	R 6 864 542
Longer-term	7 – 9 years	R 1 405 038

3.2.2 Implementation Action Plan

In this section, an Implementation Action Plan is proposed based on information obtained from the DWS (2016a) report.

Maintenance actions recommended in the DWS (2016a) report (i.e. the removal of sediment in the canal, removal of sediment on the structures, removal of vegetation along the canal and structures, repair of fencing, etc.) are not included as these are considered on-going activities undertaken by the WUA. Repairs on the structures such as canal outlets, canal spills and supers, etc. are also not assessed because the DWS (2016a) describes these as sum values and the criticality of each could not be determined from the information provided in this report. The WUA may refer to the DWS (2016a) cost estimates should they wish to determine the amount required for repairs to these structures.

The focus of this Implementation Action Plan is thus on the short- and medium-term actions required for the lining of the Clanwilliam Canal:

- Short-term actions for the canal lining comprise canal repairs such as earthwork repairs (including berm, shoulder level and gaps) and concrete repairs (including crack repairs, surface finishes, expansion joint and sealing repairs, and broken panel repairs).
- Medium-term actions for the canal lining comprise replacement/renewal of the lining.

Long-term actions could involve infrastructure upgrades such as canal balancing dams or new pipelines. These long-term actions will be investigated in the Task 7 '*Options for Bulk Conveyance Infrastructure'* of this study.

The DWS (2016a) '*Condition Assessment Audit of Irrigation Scheme Infrastructure: Scheme Report'* assessed the condition of various components of the canal, along different sections, rating them from '*Very Good'* to '*Very Poor'* or '*Not Working'*. The canal components that were assessed were: lining (repairs required), lining (replacement/renewal required), joints, embankment, berm, fence, service road, superduct, bridge, longweir, flow meter, syphon and aqueduct. The canal components that were assessed to be of '*Poor'* or worse condition, for a particular section, were considered as part of the work that will be required under either the short- or medium-term actions.

A map of the points inspected along the Clanwilliam Canal for the DWS (2016a) report is provided in **Figure 3.6**. Since these inspection points covered only a 100 m section of canal, the length of the stretches of canal of different conditions was extrapolated to the midpoint between each inspection point. A summary of the various components of the canal at each of these inspection points is provided in **Table A.1** in **Appendix A**.

Short-term Actions

The short-term actions considered were related to repairing components of the canal system that were identified as being in a '*Poor'* or worse condition in the DWS (2016a) condition assessment.

The estimated cost for the short-term actions are R33 million (incl. VAT).

As it is not practical within the scope of this report to determine the extent of earthworks activity to repair the canal berms, shoulder gaps and level, and erosion, the costs indicated in the DWS (2016b) study were escalated to allow for inflation, and adopted for this report.

The extent of crack repairs was determined based on canal sections with '*Poor'* or worse condition for '*Canal lining condition repair action required'* in **Table A.1** and an average estimation of 2.5 m total length of cracks per 100 m length of canal, of small cracks (< 3 mm); and 5.5 m total length of cracks per 100 m of canal, of large cracks (> 3 mm) (DWS 2016a). These estimations of the total length of cracks appear to be very low. In the update of the cost estimation for the crack repairs, it was assumed that each panel is 4 m long and the crack lengths per panel add up to the length of the canal perimeter. Note, this is a very high-level estimate.

Figure 3.6 | Inspection points along the Clanwilliam Canal (DWS,2016a)

The canal area requiring resurfacing/rescreeding was determined based on the assessment of the canal lining sections in '*Poor'* or worse condition. An average of 77% of the canal sections inspected required resurfacing/rescreeding (DWS 2016a).

Resealing of expansion joints was determined based on the observation of 3 m of joint seal requiring replacing per 100 m length of canal affected. This again appears to be too low. In the cost estimate for the implementation action plan, panels were assumed to be 4 m long and the joint length was assumed to be the perimeter length. It was assumed that joint repairs would be required on the full joint on the 'Very Poor' sections, and only half of the joint would require repairs on the 'Poor' sections.

No allowance was made for the construction of diversion works.

Table 3.3 | Estimated cost for short-term actions

Activity	Cost (R)*
Earthworks	
- Repair berm	R 5 120 000
- Repair shoulder gaps	R 6 080 000
- Repair shoulder level	R 3 360 000
- Repair erosion	R 640 000
Concrete Works	
- Crack repairs to concrete lining	R 140 000
- Resurfacing / rescreeding	R 1 240 000
- Expansion joints and resealing	R 534 000
Sub-total (excl. P&Gs, fees, contingencies & VAT)	**R 17 120 000**
Total (incl. 25% P&Gs, 15% engineering fees, 15% contingencies, 15% VAT)	**R 32 550 000**

* 2016 costs escalated to September 2018

Medium-term Actions

The canal sections requiring lining replacement are those that are in '*Poor*' condition as indicated in **Table A.1** in **Appendix A** for a total length of approximately 3 km. If the existing canal was to remain operational during the canal lining replacement, then temporary diversion works consisting of a 600 m temporary pipeline bypass would be required to avoid interruption of water supply to farmers. Three times the 600 m of piping could be used to allow replacement of more than one section at a time, and leapfrog one section to the next conveniently.

The estimated cost required to replace the concrete lining, including diversion works for the 3 km long section is R47 million (incl. VAT). Refer to **Table 3.4** for a summary of the canal lining replacement costs. Note that some of the cost items in this estimate may be an order of magnitude out as much of the data was extracted from the DWS (2016a) report and a more definitive evaluation of actions required would need to be done.

Table 3.4 | Estimated cost for canal lining replacement (medium-term action)

Activity	Cost (R) (incl. 25% P&Gs, 15% engineering fees, 15% contingencies, 15% VAT)
Replace concrete lining	R 10 800 000
Diversion works	R 36 300 000
Total	**R 47 100 000**

3.3 Olifants River (Vanrhynsdorp) Government Water Scheme (ORGWS)

The Olifants River (Vanrhynsdorp) Government Water Scheme (ORGWS), which forms the backbone of the local economy, consists of the canal system fed from Bulshoek Weir with water released from the Clanwilliam Dam. The canal system (the Lower Olifants Canal) supplies irrigation, industrial, and domestic water to the Matzikama Municipality for the following towns and communities: Vredendal, Klawer, Lutzville, Koekenaap, Ebenhaeser, Papendorp, Strandfontein, Doring Bay and Vanrhynsdorp. The Tronox Mine at Brand-se-Baai and its smelter near Koekenaap are also supplied with water from the canal system.

The LORWUA is responsible for the general operation and maintenance of the canal, whereas the DWS is responsible for upgrading and refurbishment, including repairs of major breaks. The transfer of the operation and maintenance of the Olifants River (Vanrhynsdorp) State Irrigation Scheme from the Department of Water Affairs and Forestry (DWAF) (now DWS) to the LORWUA was approved in 2001. The LORWUA was established with the purpose of taking over the operation and maintenance of the Bulshoek Weir and the canal distribution system of the scheme. Upon approval of the transfer, certain powers and duties in terms of the National Water Act of 1998 were delegated to the LORWUA.

3.4 Bulshoek Weir

The Bulshoek Weir was constructed across the Olifants River about 26 km downstream of Clanwilliam town. The weir, with a capacity of 5.754 million m^3 (reduced to a current capacity of 4.2 million m^3 due to siltation) together with a system of unlined canals, comprised the irrigation scheme for 9 510 ha of land along the Olifants River, Van Rhynsdorp District, which was completed in 1923. The weir's catchment area is 2 679 km^2 in extent.

The Bulshoek Weir, completed in 1920, is a stone-masonry gravity structure (**Figure 3.7**). A series of connected arches and buttresses supporting a bridge deck and a gantry for the spillway gate hoists make up the dam wall. Sixteen gates are positioned between the buttresses on top of the ogee-shaped crests.

The dam is operated at close to its full supply capacity to divert water into the irrigation canal. Seepage through and under the Bulshoek Weir is pumped back into the canal, supplying water to the LORWUA, during dry periods.

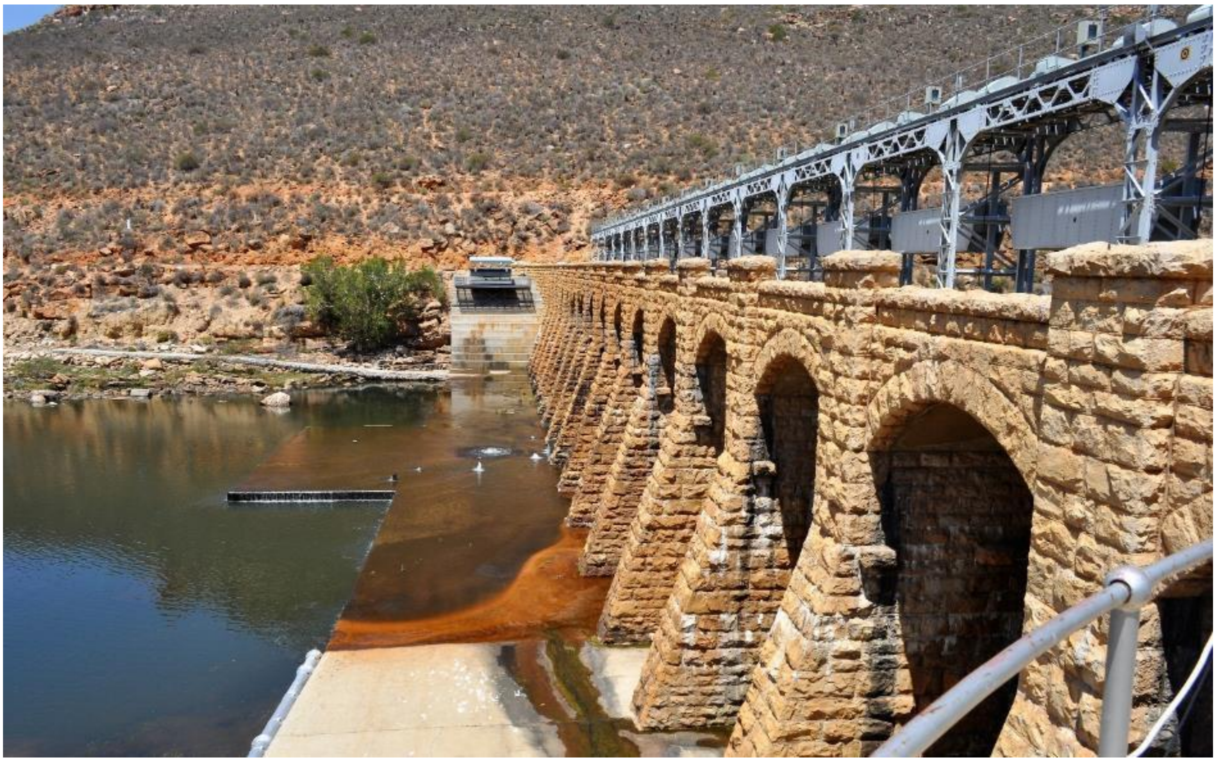


Figure 3.7 | Bulshoek Weir

Leakage through the foundation of the dam has been a problem since its completion, as indicated by grouting records from as early as the 1930s (Schall, cited by Oosthuizen and Brink 2015). A 1998 investigation documented large, deep cavities in the foundation where substantial flows were visible on the surface of the tail water. From 1999 to 2001, local operational and maintenance staff attempted to reduce the leak by using a geofabric upstream, sealing the downstream cavities with sand, and channelling the major leaks through pipes. The leak was estimated at 800 ℓ/s, as noted by Oosthuizen and Brink (2015); however, Mr R Nieuwoudt's (DWS) assessment is that the leak was more in the order of 400-500 ℓ/s. Although the flow was substantially decreased after each attempt, the leakage would gradually increase afterwards (Oosthuizen and Brink, 2015). The first two formal Dam Safety Inspections by the (then) Sub-Directorate: Dam Safety of DWAF, noted cracks in the masonry balustrade on the top of the dam, as well as at one of the spillway gates, which indicated problems with the foundations.

The Bulshoek Weir is founded on the quarzitic sandstone and sandstone of the Table Mountain Group of the Cape Supergroup. Seepage water moving along the sandstone's sub-horizontal bedding planes is intercepted by a fault in the foundation that runs parallel to the dam wall. The leaking water also washed fine material from the bedding planes and created cavities in the foundation. Since the bedding planes are continuous over large areas, the shear strength loss could eventually spread along the entire base of the dam.

From November 2003 until February 2005, the DWS undertook remedial work on the Bulshoek Weir, with the main objective to protect the dam from structural failure. A concrete apron was provided downstream of the existing structure and doweled into the rock foundation to increase the sliding resistance of the structure. As part of the remedial work undertaken, mass concrete retaining walls were provided on each flank to reduce potential further erosion of the foundation rock downstream. Instrumentation comprising survey beacons, targets and bench marks was provided, as well as 3D Crack Tilt Gauges. The mechanical and electrical equipment for operating the spillway gates was refurbished at the same time.

The work performed was originally not intended to prevent or limit leakage from the structure; but rather to address leakage as part of the planned work to be done during the raising of the Clanwilliam Dam, while (it was foreseen that) its construction team would be available in the area. It was envisaged that a grouting programme would be designed to reduce the leakage. However, no provision was made either in the priced Bill of Quantities or the grouting tender, which was prepared for the Clanwilliam Dam (Swart 2018, personal communication, 14 May).

The leakage amount differs, depending on the water level in the dam. At full supply level in the dam (5.5 m), an estimated 2 400 m^3/h is lost. It was also noted that there is a large leak (250 m^3/h) on the southern flank of the dam.

During the 2004 drought period, a pumping system (two pumps, pipework and electrical works) was installed for R600 000, in order to recover some of the leaked water (**Figure 3.8**). Water is pumped straight into the canal while it is operational; otherwise water is pumped into the reservoir of the Bulshoek Weir. Operational costs for the pumping system are approximately R60 000 per month.

Figure 3.8 | Pumping system installed at Bulshoek Weir to recover leakage

Following a review of various documents provided by the DWS Dam Safety Office (DWAF (2002a); DWAF (2002b); DWAF (2008); and DWS (2016b)), several recommendations are made with respect to the Bulshoek Weir:

1) It is proposed that the weir's foundations be grouted when a DWS construction activity is undertaken nearby, e.g. to coincide with the raising of the Clanwilliam Dam. The grouting would consolidate the foundations and also reduce their permeability. Consolidation of the foundations is important. The slabs which were installed downstream of the weir during 2005 have reduced the risk of sliding failure, but progressive erosion of fine material from the foundation joints over the long term should be halted.

2) Leakage could still take place below a consolidation grouted block. Reduction of the leakage could be achieved by providing a grout curtain to a greater depth than that required for consolidation. New drainage relief holes should then be provided downstream of the curtain to reduce uplift pressures on the structure.
3) The slabs and blocks constructed downstream provide good platforms/caps for grouting. Some of the slabs are tied down with grouted anchors; however, the anchors may not be installed everywhere due to high leakage. The anchors that were installed will strengthen the slabs to act as grout caps. The remaining slabs could still be anchored if planned properly during the grouting programme. It is possible that the anchors will eventually corrode over the long term and no longer provide any shear strength to resist sliding. However, the slabs themselves have rendered the dam safe and the consolidation grouting would improve the situation further, thus the anchors are not critical in the long term.
4) There are also plans to grout the foundations of the weir to reduce leakage. Although this is not essential, further grouting of the main dam would hopefully reduce the leakage through the foundation. Accurate monitoring of the remaining leakage is not that important, as it would merely contribute to the environmental release requirement.
5) It is not possible to check the stability or sliding Factors of Safety (FOSs) of the weir based on the information provided in the reports obtained from the DWS Dam Safety Office; however, it is assumed that this work was done properly.
6) Minor issues include unsatisfactory general 'housekeeping' maintenance.
7) If the wood of the existing walkways/platforms is in poor condition, it is recommended that they be replaced with metal grids.
8) The spillway gates and other sluices have undergone fairly extensive refurbishment and upgrading. These require on-going maintenance.
9) In general, gates on spillways should be avoided, unless they can be maintained properly to ensure that they are always in a state of readiness to be operated. In addition, if they not automatically operated, it is critical for access to be available to the controls at all times. It is also essential for someone to be available and to know when and how to operate the gates. It would be preferable to remove the gates and construct a fixed raising to maintain the storage capacity. Analyses would be required to assess the feasibility and practicalities of doing so.
10) Although there is no current provision for releases to the river, there are five sluices discharging into the canal. A controlled outlet from the canal to the river could be

provided if necessary. An alternative could be to replace one of the gates with an outlet through the dam wall, but this could be more expensive.

11) Extensive movement monitoring instrumentation was provided in 2005. Based on the readings taken up to 2008 when the Dam Safety Evaluation Report was produced it was stated that no abnormal behaviour of the structure was detected from the results.
12) As the dimensions and levels quoted in the documents are not consistent, they should be clarified. The same applies to the design flood sizes.

3.5 Lower Olifants Canal

At of the Bulshoek Weir, water is diverted into the Lower Olifants Canal (**Figure 3.9**) which is the main conveyance system in the Olifants River (Van Rhynsdorp) Government Water Scheme (GWS). The canals and tunnels were mainly constructed during the 1930s.

Figure 3.9 | The Lower Olifants Canal near Bulshoek Weir (left) and downstream

The canal runs on the left bank (western side) of the Olifants River for approximately 32.6 km, before it crosses the river with a siphon, and then runs on both sides of the river (**Figure 3.10**), with a small section of the canal running upstream along the right bank. The canals continue towards Lutzville, becoming gradually smaller downstream. Water is abstracted at numerous points along the canal (approximately 529 off-takes). Secondary canals distribute water from near Lutzville towards the coast. The lead time for water to travel in the canal from the Bulshoek Weir to the last point at Ebenhaeser is about three days. The total length of the canal system is approximately 237 km. A summary of the lengths and capacities of the different canal sections is provided in **Table 3.5** (LORWUA, 2004).

The system is currently over-allocated. The maximum release into the canal is 26 000 m^3/h (7.2 m^3/s). The canal was designed for a maximum abstraction rate of 280 m^3/ha/week. However, this was increased to 325 m^3/ha/week in some sections where bricks were used to raise the canal walls, which equates to a water allocation of 8 200 m^3/ha/a released in the canal from 1 October to 30 April, equivalent to two-thirds of the scheduled allocations of 12 200 m^3/ha/a. The remainder of the allocation is released during the remaining months of the year, if water is available.

Table 3.5 | Lower Olifants Canal section lengths and capacity

Section	Length (m)	Capacity (m^3/s)
Trawal	32 632	8.57
Naauwkoes	33 011	5.52
Naauwkoes/Vredendal	11 888	3.26
Vredendal/Sandkraal	21 400	1.40
Sandkraal	26 570	1.24
Klawer/Karoovlakte	29 826	2.90
Karoovlakte/Retshof	12 398	5.59
Retshof	30 592	1.92
Koekenaap	14 907	1.42
Koekenaap	15 229	1.82
Doringrivier	8 657	0.47

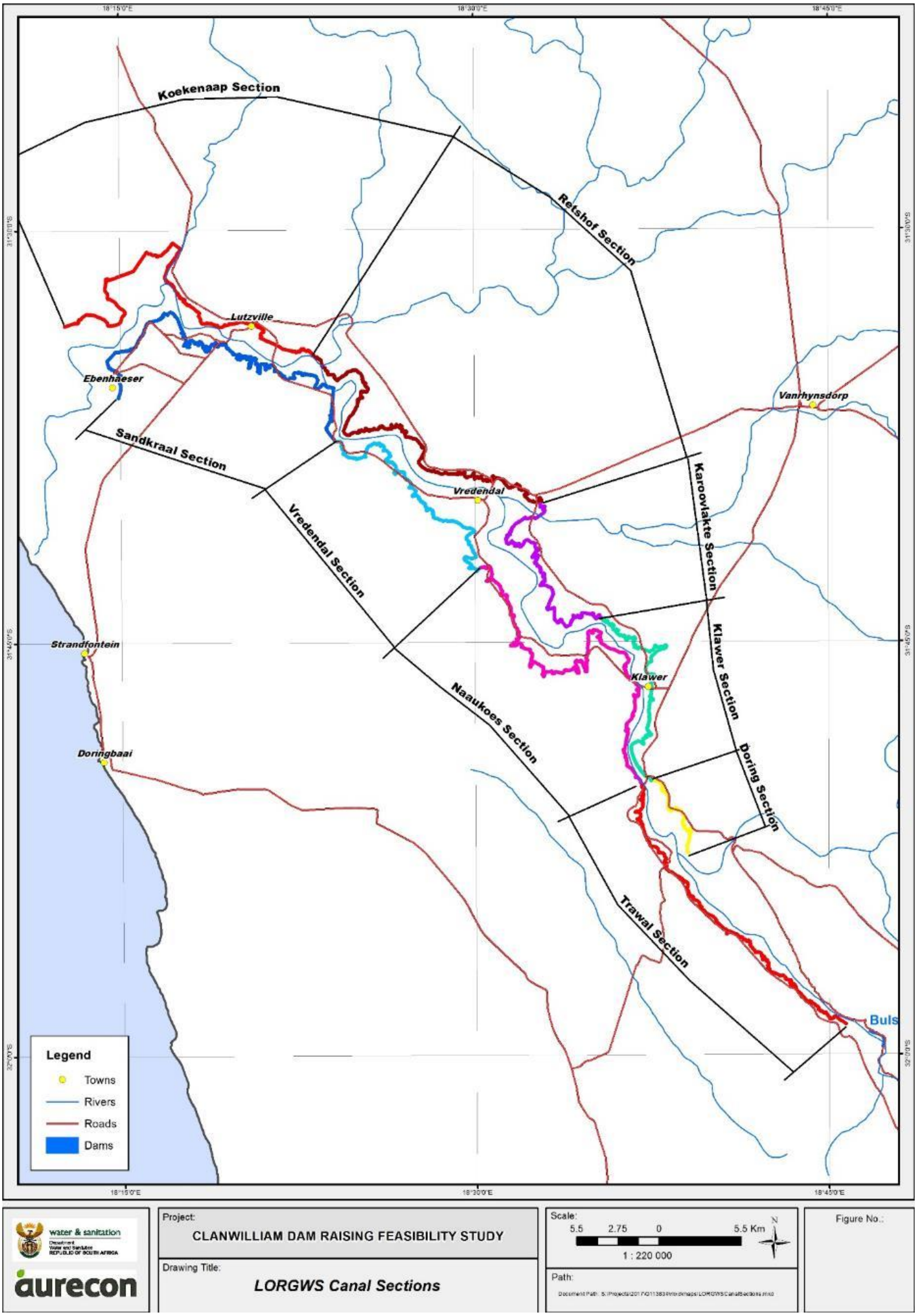


Figure 3.10 | The Lower Olifants Canal sections

Besides supplying irrigation water, the Lower Olifants Canal also supplies water for domestic use (to the Matzikama Municipality) and various industries. The annual allocation to the various water use categories is summarised in **Table 3.6**. In addition, there are approximately 349 unmetered 25 mm house connections from the canal system. These unmetered connections abstract an estimated 383 900 m^3 per week (i.e. on average 1 100 m^3 per week per connection) (LORWUA, 2004).

Table 3.6 | Water use allocation

(R Nieuwoudt 2018, personal communication, 15 June)

Water Use Category	Area (ha)	Scheduled Allocation (m^3/ha)	Annual Allocation (m^3)
Scheduled irrigation	9 013	12 200	109 958 600
Ebenhaeser small farmers	257	12 200	3 135 400
Emerging farmers	240	12 200	2 928 000
Matzikama Municipality	-	-	5 151 000
Industries	-	-	3 200 000
Total	**9 510**		**124 373 000**

3.5.1 Operating Rules

The LORWUA is responsible for the operation and maintenance of the water conveyance system from Bulshoek Weir to Ebenhaeser and Koekenaap. Their responsibility includes the existing waterworks infrastructure at Bulshoek Weir but excludes management of the internal distribution system of the Ebenhaeser small-scale farmers. The Lower Olifants Canal operates for between 38 and 42 weeks during the year, and the rest of the year is reserved for maintenance on the canal.

The existing system allows abstractions from the canal as requested by irrigators, i.e. a demand system. The 529 or so off-takes are set on a weekly basis. **Figure 3.11** shows a typical offtake. Irrigators must apply for a specific volume of water for the next week as well as the period in which the water must be supplied to his/her property. Flows are controlled by sluices and are measured with V-notches on all outlets where the stream is less than 150 m^3/h. A telemetry system is used where automatic control gates are installed on the main canals. There are five automatic sluices: one at Bulshoek Weir, and two at each of the left and right bank bi-furcation works. There are additional telemetric controlled outlets at the municipality, Namakwa

Sands and at Ebenhaeser Dam. The LORWUA is investigating further automation of the secondary distribution canals.

Figure 3.11 | Typical canal off-take

The water level in the canal varies continuously, and surplus and deficit flow conditions can occur frequently. The variation increases with further progression down the canal, which can lead to considerable operational water losses if not managed properly. Irrigators compensate for this variation by building their own small balancing dams.

The LORWUA irrigators currently pay water tariffs of approximately R3 600 per hectare per year (incl. VAT). A breakdown of the composition of the tariffs as well as a comparison between the 2016/2017 and 2017/2018 years is provided in **Table 3.7**.

Two quotas are in effect, *viz*. an annual allocation of 12 200 m^3/ha/a and a weekly quota (or maximum extraction rate) of 325 m^3/ha/week. During years of drought, both quotas are reduced, and restrictions are imposed on water users. If the quota for the next year is uncertain, farmers become more conservative in irrigation development. If there is insufficient water to meet full irrigation requirements, the existing use is reduced by a percentage, according to the water available. The quota is based on an assessment of the state of the Clanwilliam Dam after the rainy season each year during the latter half of September, which considers factors such as the rainfall in the catchment, inflow and extent of snow during winter in the catchment.

Table 3.7 | LORWUA annual water tariffs

(J Matthee 2018, personal communication, 12 February)

LORWUA Irrigators	2016/2017 (per hectare)	2017/2018 (per hectare)	Percentage Difference
O&M (LORWUA)	R 2 194.00	R 2 316.86	5.60%
Water Research Fund (DWS)	R 6.00	R 5.89	-1.83%
Contribution to Reserve Fund for Major Canal Failures (LORWUA)	R 200.00	R 200.00	0.00%
Infrastructure Charge (DWS)	R 295.14	R 361.12	22.36%
WMA (DWS)	R 242.78	R 244.0	0.50%
Subtotal	**R 2 937.92**	**R 3 127.87**	**6.47%**
VAT (14%)	R 411.31	R 437.90	6.47%
Total	**R 3 349.23**	**R 3 565.78**	**6.47%**

3.5.2 Maintenance

Several major breaks have been experienced along the Lower Olifants Canal due to ageing infrastructure (see **Table 3.8**). The largest break happened in January 2015 with a repair cost of R11.5 million, and the most recent one in January 2017 with a repair cost of R2.4 million. The LORWUA reported (J Matthee 2018, personal communication, 12 February) that it spends approximately R4.2 million per annum on normal maintenance with its own teams, and contracts out approximately R5.8 million per annum on more serious repairs.

Table 3.8 | Major canal breaks and associated repair costs

(J Matthee 2018, personal communication, 12 February)

Date of Major Canal Break	Repair Cost
2006	R1.9 million
March 2010	R1.9 million
December 2010	R2.4 million
January 2015	R11.5 million
January 2017	R2.4 million

The 2015 break was as a result of a 180 m long failure in the soil supporting the dry concrete packed lining near Klawer (**Figure 3.12**). The canal collapse cost the agriculture sector an estimated R100 million (Creamer Media, 2017). Following this break, the WCDoA committed to a R4 million proactive maintenance programme for the canal, in which funds are released on an emergency basis, given the importance of infrastructure to the agriculture sector in the area. The plan involved the LORWUA assisting WCDoA in identifying the most critical areas for maintenance. In 2016, R1.2 million was spent to fix a 1200 m section near Verdeling, and in 2017, repair work on a 1400 m section near Vredendal was earmarked as a priority area.

The 2017 break was caused by an electronic malfunction of the telemetry system which controls the water level in the canal. This resulted in an overflow at certain canal sections and washed away the soil supporting the canal lining. An 18 m section of canal was replaced and about 250 000 m^3 of water was lost (Kriel, 2017).

After more than 80 years of usage, the concrete lining has become frail and prone to damage, which results in canal breaks occurring frequently.

Figure 3.12 | Lower Olifants Canal break in 2015 (IOL, 2015)

3.5.3 Condition Assessment

Two condition assessments of the Lower Olifants Canal were carried out independently by Element Consulting (LORWUA, 2004), and by LTE Consulting and Pula Strategic Resource Management (DWS, 2016c).

a) An Investigation into the Rehabilitation of the Canal Downstream of Bulshoek Dam (LORWUA, 2004)

The report by Element Consulting Engineers undertaken in 2004 surveyed the canal system and focussed on three aspects, *viz*. the hydraulic components of the canals; a visual inspection and structural investigation of the canal to determine the short- to long-term rehabilitation requirements; and an economic investigation on the different rehabilitation scenarios in terms of their net present value (NPV).

A hydraulic investigation of the canal revealed that the existing measurement tables for the various flow gauging structures were adequate, except for the Right Bank weir, Retshof weir, Holrivier measurement plate and the Koekenaap weir. The use of a flow formula was recommended instead of using the existing tables. More accurate measurement for the water balance could be attained using additional measurement structures. Discontinuous flow recording in the canal system results in inadequate control and no data for a proper water balance. Existing measurement structures should be made part of a telemetry system. The existing operational system only allows abstractions from the canal as requested by users. It was recommended that feedback on actual water quantities (vs the monitoring of flow rate) should be incorporated in the operations of the canal system. In 2004, the average existing water balance showed that only 52% (80% of the maximum allowed abstractions) of the total flow in the canal went to abstractions through sluices. It was advised that a proper telemetry system be installed to review and increase the confidence in the water balance, and by minimising unaccounted for losses with structural repair work and by monitoring data. As previously mentioned, the LORWUA has since installed a telemetry system whereby automatic control gates are installed on the main canals.

A structural investigation of the canal was also conducted. It was found that structural defects, ranging from exposed aggregate on concrete surfaces to large structural cracks, exist along 63% of the canal length.

Certain sections of the canal were identified as critical sections (**Table 3.9**). These sections are situated on embankments and in the event of a failure in the canal, the embankment and adjacent orchards would be subjected to flooding and erosion. As these are high risk sections, maintenance of the critical sections should take priority.

The visual inspection identified short-term rehabilitation of structural defects, which would cost in the order of R2.8 million (incl. VAT) (2004 cost). The proposed medium-term rehabilitation measures consisted of critical sections as identified by the LORWUA (R40.5 million, incl. VAT) (2004 cost)). A possible long-term measure would involve rehabilitating the canal with in-situ cast concrete lining at an estimated cost of R721.5 million (incl. VAT) (LORWUA, 2004).

Table 3.9 | Critical sections of the canal as identified in Element Consulting report

Section	Approx. Chainage of Critical Section	Length of Critical Section (m)
Trawal	0 – 3 000	3000
	27 500 – 32 500	5000
Klawer	0 – 3000	3000
	15 400 – 18 000	2600
Naauwkoes	4 000 – 4 300	300
	7 500 – 8 800	1300
	11 000 – 15 000	4000
Karoovlakte	8 750 – 12 250	3500
	16 500 – 17 750	1250
Retshof	1 000 – 3 000	2000
	6 000 – 9 500	3500
	18 000 – 31 000	13000
Vredendal	15 500 – 16 600	1100
	21 000 – 22 400	1400
Sandkraal	800 – 1 100	300
	1 500 – 3 000	1500
	4 500 – 5 500	1000
	12 000 – 19 500	7500
	22 500 – 26 500	4000
	27 600 – 28 500	900
Koekenaap	9 000 – 11 200	2200
	12 500 – 16 000	3500

b) Condition Assessment Audit of Irrigation Scheme Infrastructure: Olifants River Van Rhynsdorp GWS (Bulshoek Dam) (DWS, 2016c)

Similar to what was done for the Clanwilliam Canal, LTE Consulting and Pula Strategic Resource Management (DWS, 2016c) carried out a condition assessment of the irrigation infrastructure owned by DWS in the LORGWS. It found that the condition of the infrastructure generally ranged from good to very poor. However, a large proportion of the infrastructure is in poor to very poor condition, thus requiring urgent rehabilitation or repair.

The study proposed similar intervention actions for the repair, upgrade and maintenance of the conveyance infrastructure. The estimated costs for these intervention actions are provided in **Table 3.10**.

Table 3.10 | Estimated cost to repair, upgrade and maintain the irrigation infrastructure (DWS, 2016c)

Term	Period	2016 Amount (incl. fees, P&G's, contingencies, VAT)
Short-term	1 – 3 years	R 1 085 928 785
Medium-term	4 – 6 years	R 1 050 102 607
Longer-term	7 – 9 years	R 1 500 120 986

c) Comparison of the Condition Assessments

The DWS (2016c) condition assessment accounts for any maintenance, rehabilitation and repairs undertaken by the LORWUA since the LORWUA (2004) study was first conducted. **Table 3.11** provides a comparison of the costs estimated in the two studies.

Table 3.11 | Comparison of estimated costs between LORWUA (2004) and DWS (2016c)

Term	LORWUA (2004)	DWS (2016c)
Short-term	R 2 810 132	R 1 085 928 785
Medium-term	R 40 530 260	R 1 050 102 607
Longer-term	R 721 448 761	R 1 500 120 986

It is evident from **Table 3.11** that the estimated costs given in DWS (2016c) are significantly higher than those indicated in LORWUA (2004). An explanation for this is that the LORWUA (2004) costs have not yet been escalated; as well as likely further deterioration of the conveyance infrastructure during the 12-year period between the two condition assessments, and possibly a more comprehensive assessment.

3.5.4 Implementation Action Plan

In this section, an Implementation Action Plan is proposed, based on information obtained from the DWS (2016c) report.

Maintenance actions recommended in the DWS (2016c) report (i.e. the removal of sediment in the canal, removal of sediment on the structures, removal of vegetation along the canal and structures, and repair of fencing) are not included as these are considered on-going activities undertaken by the WUA. Repairs on the structures such as canal outlets, canal spills and supers, etc. are also not assessed because the DWS (2016c) describes these as sum values and the criticality of each is unable to be determined from the information provided in this report. Should the WUA wish to determine the amount required for repairs to these structures, they may refer to the DWS (2016c) cost estimates.

The focus of this Implementation Action Plan is thus on the short- and medium-term actions required for the Lower Olifants River Canal lining itself:

- Short-term actions for the canal lining comprise canal repairs such as earthwork repairs (including shoulder level and gaps), crack repairs, surface finishes, expansion joint and sealing repairs, and broken panel repairs.
- Medium-term actions for the canal lining comprise replacement/renewal of the lining.

Long-term actions involve infrastructure upgrades such as new canal balancing dams, or a new main canal on the right bank of the Olifants River. These long-term actions will be investigated in Task 7 'Options for Bulk Conveyance Infrastructure' as part of this study.

The DWS (2016c) '*Condition Assessment Audit of Irrigation Scheme Infrastructure: Scheme Report'* assessed the condition of various components of the canal along different sections, rating them from '*Very Good'* to '*Very Poor'* or '*Not Working'*. The canal components assessed were: lining (repairs required), lining (replacement/renewal required), joints, embankment, berm, fence, service road, superduct, bridge, longweir, flow meter, syphon and aqueduct. The canal components that were assessed to be of '*Poor'* or worse condition for a particular section were considered as part of the amount of work required for the short- or medium-term actions.

A map of the points inspected along the Lower Olifants Canal during the DWS (2016c) report is provided in **Figure 3.13**. Since these inspection points covered only a 100 m section of canal, the length of the stretches of canal of different conditions was extrapolated to the midpoint between each inspection point. A summary of the various components of the canal system at each of these inspection points is provided in **Table A.2** in **Appendix A**.

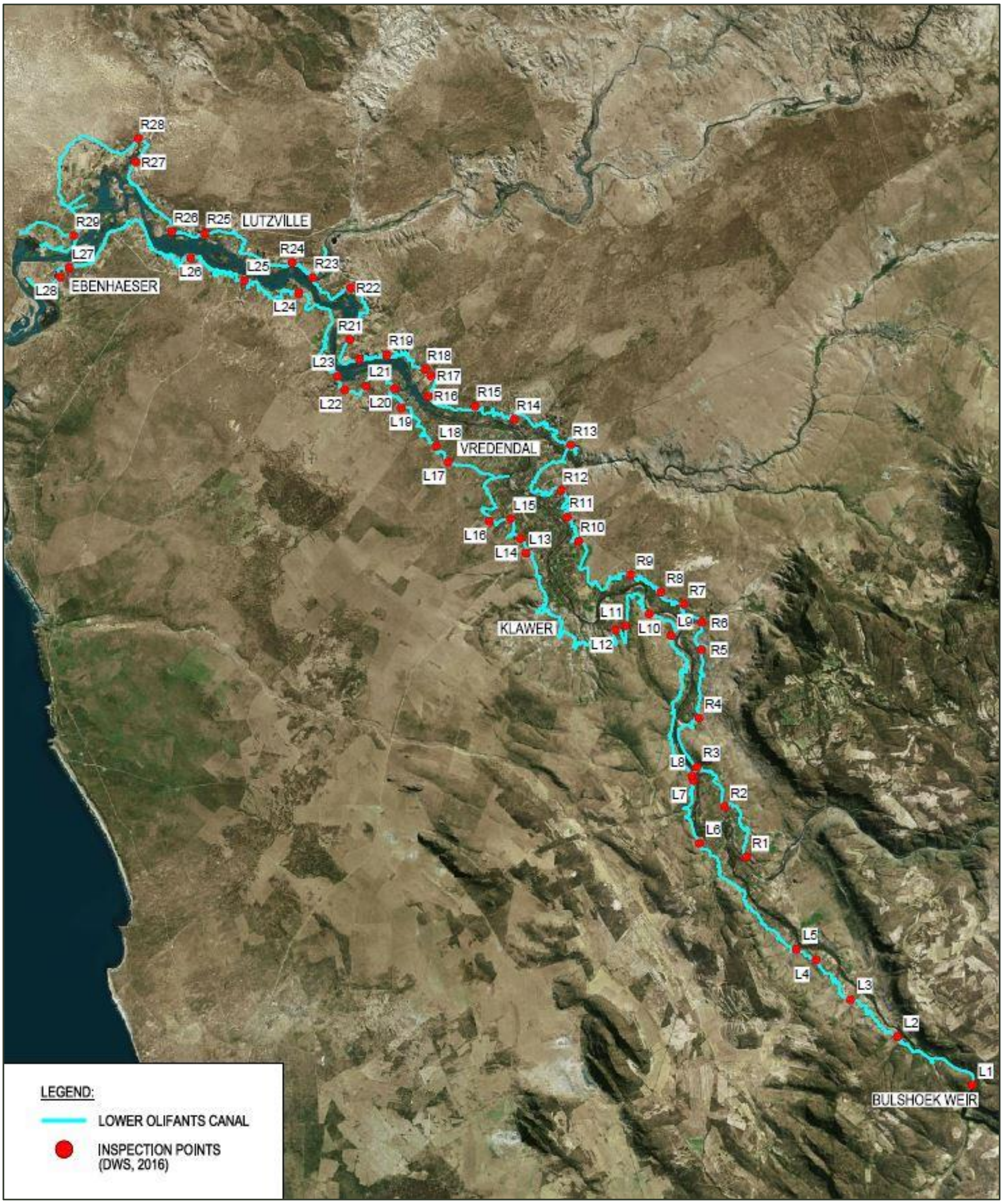


Figure 3.13 | Inspection points along the Lower Olifants Canal (DWS, 2016c)

Short-term Actions

The short-term actions considered were related to repairing components of the canal system that were identified as being in a '*Poor'* or worse condition in the DWS (2016c) condition assessment.

The estimated cost for the short-term actions are R260 million (incl. VAT) (refer to **Table 3.12**). As it is not practical within the scope of this report to determine the extent of earthworks activity to repair the canal berms, shoulder gaps and level, the costs indicated in the DWS (2016c) study were escalated to allow for inflation and adopted for this report. The same was done for the cost of repairing broken panels.

The extent of crack repairs was determined based on canal sections with '*Poor*' or worse condition for '*Canal lining condition repair action required'* in **Table A.2** and an average estimation of 8.8 m total length of cracks per 100 m of canal, of small cracks (< 3 mm); and 4.3 m total length of cracks per 100 m of canal, of large cracks (> 3 mm) (DWS 2016c). In the update of the cost estimation for the crack repairs, it was assumed that each panel is 4 m long and the crack lengths per panel add up to the length of the canal perimeter. Note, this is a very high-level estimate.

The canal area requiring resurfacing/rescreeding was determined based on the assessment of the canal sections in 'Poor' or worse condition which would not be addressed in the medium-term (**Figure 3.14**). An average of 67.5% of the canal sections inspected required resurfacing/rescreeding (DWS 2016c).

Resealing of expansion joints was determined based on the observation of 6.9 m of joint seal requiring replacement per 100 m of canal affected. This figure again appears to be too low. In the cost estimate for the implementation action plan, panels were assumed to be 4 m long and the joint length was assumed to be the perimeter length. It was assumed that joint repairs would be required on the full joint on the 'Very Poor' sections, and only half of the joint would require repairs on the 'Poor' sections.

It is proposed that the short-term actions be carried out during LORWUA's maintenance periods during the winter period from March to September, during which there are cycles of a two week standing period followed by a week of flowing water for irrigation. The accumulated total number of weeks downtime is therefore approximately 17 weeks. The estimated costs for the short-term actions indicated in the **Table 3.12** thus exclude any allowance for construction of diversion works for working outside of the maintenance periods.

Figure 3.14 | Canal lining rescreeding sections

Table 3.12 | Estimated cost for short-term actions

Activity	Cost (R)
Earthworks	
- Repair berm	R 52 200 000
- Repair shoulder gaps	R 4 300 000
- Repair shoulder level	R 14 100 000
Concrete Works	
- Crack repairs to concrete lining	R 8 800 000
- Resurfacing / rescreeding	R 41 900 000
- Expansion joints and resealing	R 6 400 000
- Repair broken panels	R 8 900 000
Sub-total (excl. P&Gs, fees, contingencies & VAT)	**R 136 600 000**
Total (incl. 25% P&Gs, 15% engineering fees, 15% contingencies, 15% VAT)	**R 260 000 000**

Medium-term Actions

In addition to the information obtained from the DWS (2016c) condition assessment, LORWUA indicated which canal sections they considered to be in critical condition. These sections were compared to the '*Poor*' or worse sections of the canal lining identified in the DWS (2016c) report. The overlapping sections were considered as 'Priority 1', i.e. highest priority, and the non-overlapping sections were considered as 'Priority 2'. The Priority 1 and Priority 2 sections total approximately 40 km and 114 km respectively. The canal sections requiring lining replacement are shown in **Figure 3.17**.

It is important that water flows through the canal during the summer period from September to March. As mentioned above, LORWUA schedules its maintenance periods during the winter period from March to September, during which there are cycles of a two-week standing period followed by a week of flowing water for irrigation. The accumulated total number of weeks standing period is approximately 17 weeks. It is necessary to evaluate the practicality of implementing actions in relation to the downtime/maintenance schedule of the canal system. The actions should, as far as possible, be implemented during the downtime of the canal system. However, it may be necessary to construct diversion works, such as a temporary pipeline bypass (pumped if necessary), for construction done outside of the "dry" weeks.

A preliminary assessment of the construction programme for the canal lining replacement as a medium-term action was carried out. The canal lining replacement could be done using in-situ cast concrete or precast concrete construction methods. It is estimated that an approximate canal length of 50 m could reasonably be replaced using in-situ cast concrete for the larger cross-sectional canal sections (e.g. for the Trawal and Naauwkoes sections) over a two-week period, i.e. during LORWUA's scheduled downtime (refer to **Figure 3.15)**. Similarly, it is estimated that an approximate canal length of 180 m could reasonably be replaced using precast concrete for the smaller cross-sectional canal sections further downstream (e.g. for the Sandkraal and Koekenaap sections) over a two-week period (refer to **Figure 3.16**). These canal replacement rates are low, and it is evident that undertaking the canal lining replacement during LORWUA's scheduled downtime is not feasible. It is thus recommended that temporary diversion works, consisting of a 600 m temporary pipeline bypass, be constructed to allow for replacement of the canal lining without interrupting the water supply to farmers. Other measures could include construction work done on different sections at the same time using different teams; or placement of precast interlocking elements while the water is flowing, followed by final adjusting if necessary and joint sealing of significant lengths during a "dry" period.

In-situ Canal Lining Replacement (approx. 50 m)															
Task	Duration (days)	Day													
		1	2	3	4	5	6	7	8	9	10	11	12	13	14
1. Remove existing canal lining (assuming no reinforcement) to spoil	2	■	■												
2. Prepare bedding	1			■											
3. Formwork for base (assuming steel fixing already done)	2				■	■									
4. Cast base (approx. 90 m^3)	1						■								
5. Strip formwork	1							■							
6. Formwork and bracing for walls	3								■	■	■				
7. Cast walls (approx. 50 m3)	1											■			
8. Strip internal formwork and prepare for water	2												■	■	

Figure 3.15 | Estimated construction programme for in-situ canal lining replacement

Precast Canal Lining Replacement (approx. 180 m)															
Task	Duration (days)	Day													
		1	2	3	4	5	6	7	8	9	10	11	12	13	14
1. Remove existing canal lining	10	■	■	■	■	■	■	■	■	■	■				
2. Prepare bedding	10			■	■	■	■	■	■	■	■	■	■		
3. Lay precast canal	9				■	■	■	■	■	■	■	■	■		
4. Sealing	9					■	■	■	■	■	■	■	■	■	
5. Connections and preparation for water	2													■	■

Figure 3.16 | Estimated construction programme for precast canal lining replacement

Figure 3.17 | Canal lining replacement sections

The estimated cost required to replace the concrete lining, including diversion works, for the Priority 1 sections for an approximate total length of 40 km is R740 million (incl. VAT). The estimated cost for the Priority 2 sections for an approximate total length of 114 km is R1 700 million (incl. VAT). Refer to **Table 3.13** for a summary of the canal lining replacement costs. Note that some of the cost items in this estimate may be an order of magnitude out as much of the data was extracted from the DWS (2016c) report and a more definitive evaluation of actions required would need to be done.

Table 3.13 | Estimated cost for canal lining replacement (medium-term action)

Activity	Cost (R) (incl. 25% P&Gs, 15% engineering fees, 15% contingencies, 15% VAT)
Priority 1 sections (± 40 km)	
- Replace concrete lining	R 422 900 000
- Diversion works	R 317 400 000
Priority 1 sections: Subtotal	**R 740 300 000**
Priority 2 sections (± 114 km)	
- Replace concrete lining	R 883 000 000
- Diversion works	R 815 900 000
Priority 2 sections: Subtotal	**R 1 698 900 000**
Total	**R 2 439 200 000**

3.6 Ebenhaeser

The ORGWS also provides water to the Ebenhaeser community irrigation project. In 1926, the Ebenhaeser families were moved from Lutzville to their current location, further down the Olifants River near the estuary, at the end of the canal system. An area of 257 hectares of irrigable land was split among the then-150 families. These plots of land are too small for commercial agriculture and over time farming activities have reduced to mainly small subsistence farming activities.

In 2005, the Ebenhaeser community, comprising a total population of approximately 3 500 people, predominantly Afrikaans speaking descendants of the original Ebenhaeser farmers won a breakthrough land settlement claim to the value of R100 million. However, this settlement was not implemented, and it was renegotiated to R350 million in 2014. This amount includes money to buy about 50 privately owned vineyard farms. The area includes 1 566 ha of privately owned commercial land along the Olifants River and 1 919 ha of state-owned land (IOL, 2014). It is hoped that this land claim will enable the community to return to some of the more fertile land along the Olifants River from which they were previously removed.

The LORWUA operates and maintains the canal system up to the Ebenhaeser balancing dam. From there on, there is a canal to the Ebenhaeser community, which is operated and maintained by the community itself. Roux and Keuck (2009) provide a comprehensive description of the Ebenhaeser scheme.

The Ebenhaeser balancing dam was constructed in 2003 as an earth fill dam with a storage capacity of 140 000 m^3 and a full supply depth of 6 m. It is lined with a 1.5 mm HDPE waterproofing geomembrane, of which the top portion is covered with a rock lining. The dam functions as a balancing dam, as the top 2 m water depth is utilised for approximately 80% of the time. The liner is thus covered with a rock lining to protect the exposed section against sunlight, wave action, wear-and-tear, and vandalism, etc.

A long-weir and adjustable sluice gates (**Figure 3.18**) are used to control the water level in the canal according to allocated water demand, and the surplus water is diverted to the balancing dam. When the water level in the canal is less than required, the canal water flow is stabilised by pumping water from the balancing dam to the canal.

Figure 3.18 | Sluice gates installed near the Ebenhaeser balancing dam

A pump station, which has four variable speed pumps in parallel, is automatically controlled by an ultrasonic water level recorder in the Parshall measuring flume in the canal. The maximum pumping capacity of the pumps is 600 m^3/h. Raw water is also pumped from the balancing dam for domestic use to a water purification plant, via a 200 mm diameter, 1.3 km long uPVC rising main. The pump capacity is 170 m^3/h. The domestic and irrigation water pumps use the same suction pipe from the balancing dam and are pre-primed by the vacuum pump system.

Additional infrastructure in the form of a high-pressure irrigation scheme is expected to be provided to the Ebenhaeser farmers. This scheme was advertised in a tender by the Department of Rural Development and Land Reform (DRDLR) in 2014. In this proposed scheme, water will be pumped from the canal to a balancing dam on the hill, from where water will gravitate to clusters of farmers as per a pre-determined schedule of releases. The balancing dam will also provide drinking water to Papendorp and upstream commercial farmers could also benefit from the scheme. The tender was awarded, but an appeal process followed, and the latest information is that the matter has been referred back to the DRDLR.

The LORWUA supplies water to Ebenhaeser at the Parshall measuring gauge at the start of the Ebenhaeser channel. The water supplied is subject to the water allocation Ebenhaeser is entitled to, as well as to any restrictions applicable to the entire LORWUA distribution system. Flow measurements are continuously and automatically monitored by the measuring gauge.

At a public meeting on 12 February 2018, the Ebenhaeser farmers claimed that they are not receiving their scheduled water allocations due to operational mismanagement by the LORWUA, i.e. no policing and monitoring of water abstraction along the canal is implemented. Several of the farmers criticised the LORWUA for its perceived lack of control over the water allocations. However, these views are in contrast to those of some DWS and WCDoA staff who have commented that there are management concerns relating to the internal management by the Ebenhaeser farmers themselves.

A breakdown of the Ebenhaeser annual water tariffs is provided in **Table 3.14**.

Table 3.14 | Ebenhaeser annual water tariffs

Ebenhaeser	2017/2018 (per hectare)
Water Research Fund (DWS)	R 5.89
WMA (DWS)	R 244.00
Subtotal	**R 249.89**
VAT (14%)	R 34.98
Total	**R 284.87**

Information on the high-pressure irrigation system could not be obtained from DRDLR, despite many attempts to source this information.

4 Meeting of the Reserve in the lower Jan Dissels River

4.1 Jan Dissels River Compulsory Licensing study

In this section, the recommendation made in the Jan Dissels River Compulsory Licensing study to supply water to the lower Jan Dissels River, via the Clanwilliam Canal, is assessed in more detail. The aim of this water supply is to improve the ecological condition of this stretch of the river. The objective of this assessment is to determine whether the recommendation with regards to the meeting of the ecological Reserve in the lower Jan Dissels River is still valid.

Figure 4.1 shows irrigated areas in the Jan Dissels River (2008).

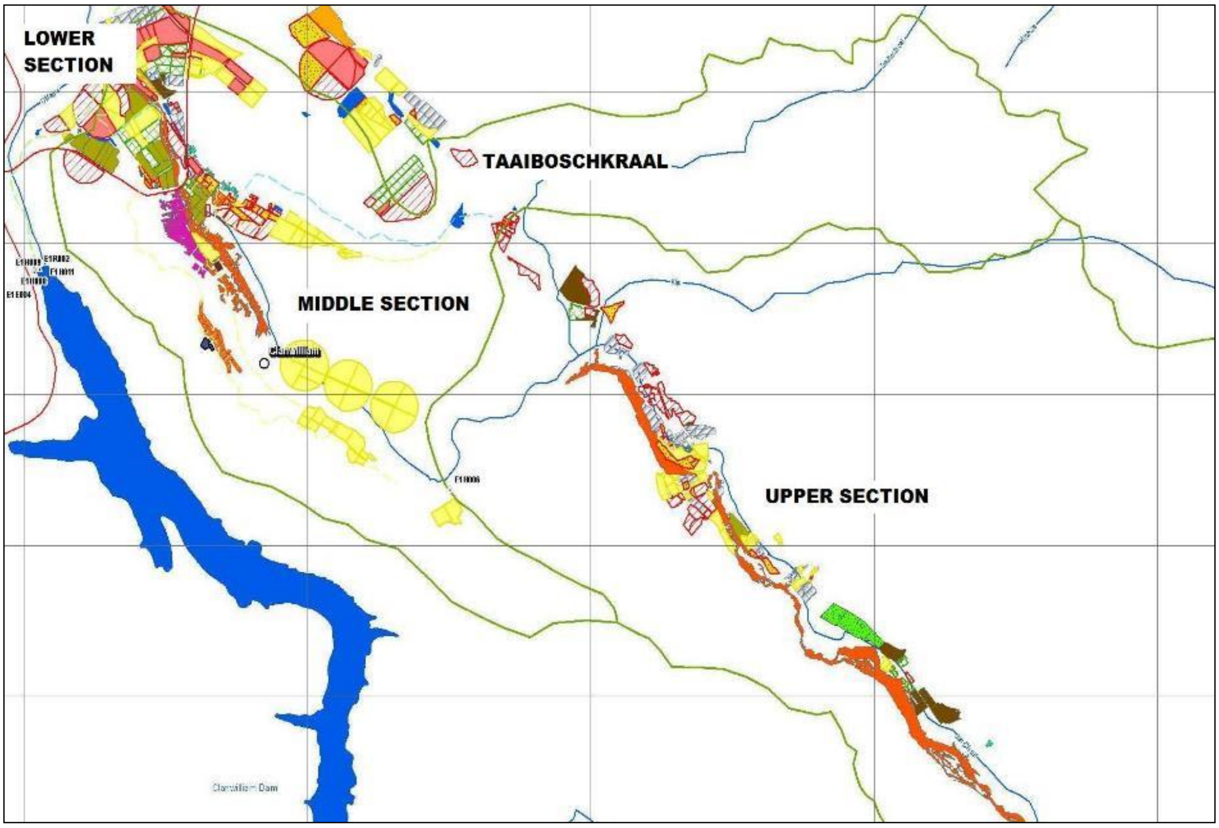


Figure 4.1 | Irrigated areas in the Jan Dissels River

The Jan Dissels River can be sub-divided into four (4) segments, as indicated in **Figure 4.1** (Jan Dissels River Compulsory Licensing study, 2008), as follows:

- The upper section, above the Gauge (E1H006);
- The 'Taaiboschkraal' Tributary;
- The middle section, below the Gauge; and
- The lower section, below the Clanwilliam Canal, adjacent to the Olifants River.

The average water use profile of the lower section of the Jan Dissels River, according to the Compulsory Licensing Study, is provided in **Table 4.1**. This constitutes some of the most extensive and intensive agricultural water use (approximately 32%) on the river, as illustrated in **Table 4.2**. It is surpassed only by the section above the gauge (36%).

Table 4.1 | Average water use profile along the lower Jan Dissels River below the Clanwilliam Canal (DWAF, 2008)

Below Clanwilliam Canal	Area (ha)	Crop water Requirement (m^3/ha)	Water Use (million m^3)				
			Dec	Jan	Feb	Mar	Dry Season
Pastures	4.8	14 900	0.011	0.012	0.012	0.011	0.046
Citrus	35.3	12 600	0.059	0.075	0.078	0.080	0.292
Grapes	11.1	13 100	0.026	0.030	0.029	0.021	0.106
Summer Vegetables	15.2	11 700	0.029	0.051	0.050	0.033	0.163
Total	**66.4**		**0.125**	**0.168**	**0.169**	**0.145**	**0.607**

Table 4.2 | Summary of existing agricultural water use in different sections of the Jan Dissels River (DWAF, 2008)

Section	Water Use (million m^3)					Percentage
	Dec	Jan	Feb	Mar	Dry Season	
Above the gauge	0.145	0.186	0.186	0.173	0.690	36%
Taaiboschkraal	0.068	0.057	0.045	0.052	0.222	12%
Below the gauge	0.068	0.119	0.119	0.077	0.383	20%
Below the canal	0.125	0.168	0.169	0.145	0.607	32%
Total	**0.406**	**0.530**	**0.519**	**0.447**	**1.902**	**100%**

The lower section (of the Jan Dissels River) is located below the Clanwilliam Canal syphon and much of it has access to, or is adjacent to the Olifants River itself, which raises the possibility of using this as an alternative water supply.

The Jan Dissels River Compulsory Licensing Study recommended the following two potential interventions to improve the ecological condition of the lower section of the Jan Dissels River:

- Move some or all of the existing irrigators in the lower Jan Dissels River to either the Olifants River or to the Clanwilliam Canal.
- Release flows to the full capacity of the Clanwilliam Canal, during the dry season, (December to March) and divert flows over-and-above the irrigation requirements to the lower Jan Dissels River.

4.2 Move irrigation to the Olifants River or the Clanwilliam Canal

Indications are that the Clanwilliam Canal has adequate capacity to accommodate additional irrigators, although the capacity of the canal would need to be confirmed, and balancing dams might be needed for pumping. It has been mentioned by local DWS personnel that there is a significant backwater effect from the Olifants River into a long pool in the Jan Dissels River. Three big water users already pump directly from the Olifants River, below the Canal siphon crossing the Jan Dissels River. With higher future releases from a raised Clanwilliam Dam, this will become an even more common occurrence.

Table 4.3 shows all the current licences to irrigators in the lower part of the Jan Dissels River.

It is evident that there are only a few licensed irrigators that take water downstream of the point where the canal syphon crosses the Jan Dissels.

Moving these current off-takes in the lower Jan Dissels River to the canal or to the Olifants River may only provide limited ecological flow benefits, because of the short stretch of the Jan Dissels River that will be affected. Moving the off-takes will however help to improve summer flows, and in some cases also correct the situation where irrigators already generally pump directly from the Olifants River. This recommendation is therefore supported and should be evaluated further as a potential option for the distribution of water from a raised Clanwilliam Dam.

Table 4.3 | Compulsory Licences in the lower Jan Dissels River

Licence No	Licensee	Volume (m^3/a)	Total Volume (m^3/a)	Location
17_E10H_A_2259	G.J. Nieuwoudt	65 712	65 712	At the siphon
17_E10H_A_2261	Mouton Trust	45 000	45 000	Approximately 240 m upstream of the siphon
17_E10H_A_2266	G.J. Nieuwoudt Ptn 18	300 000	300 000	Abstraction point on the Olifants River (excluding summer months)
17_E10H_A_2269	Patrysvlei Plaas (Pty) Ltd	226 366	226 366	At confluence of Jan Dissels River and Olifants River
17_E10J_A_2265	FWG Pieters Trust	279 800	279 800	Just upstream of siphon
17_E10J_A_2271	Twee Riviere Trust Erf 1417	19 000	99 385	At confluence of Jan Dissels River and Olifants River
	Twee Riviere Trust Erf 1417	80 385		
		Total:	**1 016 263**	

4.3 Release flows down the lower Jan Dissels River

The Jan Dissels River, which drains the western slopes of the Cederberg Mountains, is the only perennial river that joins the Olifants River between the Clanwilliam Dam wall and the upper inundation area of the Bulshoek Weir. The mountainous upper reaches of the Jan Dissels River are undisturbed, with well-developed riparian vegetation. The upper reaches are typical of a mountain stream, with pool-rapid sequences. The lower reaches are heavily impacted by agriculture (mainly citrus farming) and abstraction is high.

A Rapid II Reserve determination was done for the Jan Dissels River, as part of the Jan Dissels Compulsory Licensing study, in which the current state of the river was determined for three different reaches:

- Source to causeway at Boschkloof – Category B;
- Causeway to confluence with Taaiboschkraal River – Category C; and
- Downstream of Taaiboschkraal River to confluence with Olifants River – Category D.

A Rapid II level evaluation is similar to a Rapid III level evaluation, but without hydraulic information. A flow measurement was done during the site visit so that at least one point can be compared with the values generated by the rule-based hydrological Desktop model. The Ecological Importance and Sensitivity of the lower Jan Dissels River, even for the present-day, is rated as Moderate-High.

Specific concerns are the Geomorphology/Floodplain component (category D/E), riparian vegetation (category E) and Fish (category D), resulting in an overall D ecological category.

The ecological Reserve, which is representative of the lower portion of the Jan Dissels River, requires a minimum Reserve flow requirement of 0.05 m^3/s to remain in a category D, which is the lowest (worst) allowable ecological state. The minimum ecological Reserve requirements for the dry season in this stretch of river were calculated and are as indicated in **Table 4.4**.

Table 4.4 | Ecological Reserve flow requirements (million m^3) (DWAF, 2008)

Month	Dec	Jan	Feb	Mar	Dry Season	Annual
Flow	0.21	0.19	0.20	0.16	0.76	7.45

This ecological requirement is not met for at least three months of the year, as illustrated in **Figure 4.2**, which suggests that more than 400 000 m^3 needs to be freed up during these months to meet the requirements of the ecological Reserve.

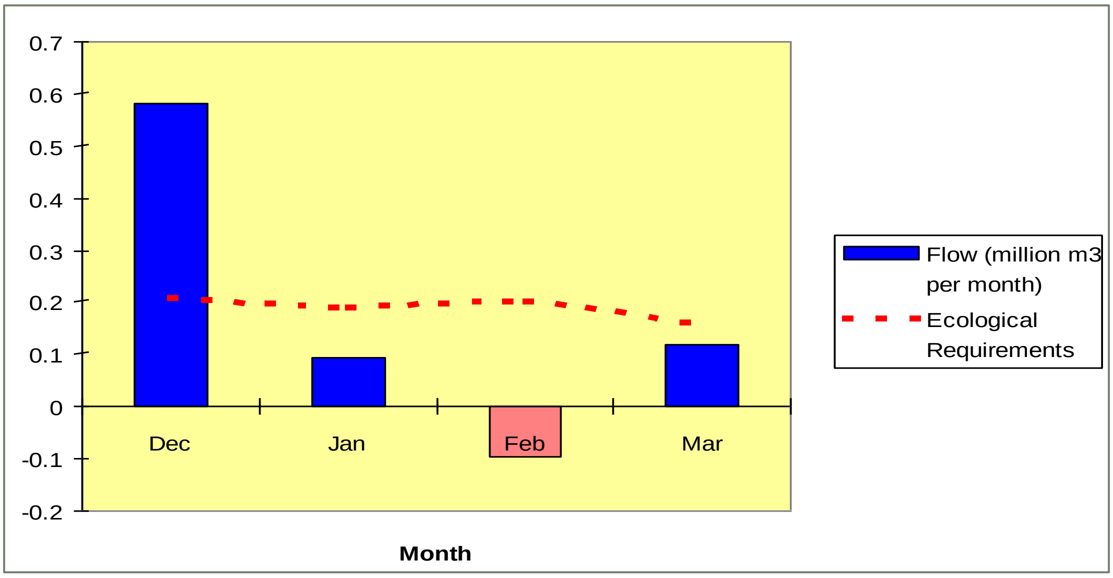


Figure 4.2 | Current average dry season flow profile in lower Jan Dissels section

The option considered to meet the ecological Reserve in the lower Jan Dissels River is to release flows to the full capacity of the Clanwilliam Canal, during the dry season (December to March), and to divert such flows, that are over-and-above the irrigation requirements, to the lower Jan Dissels River. The assumption made during the Compulsory Licensing Study was that water could be released at the bridge. In practice though, the canal syphon crosses the river only about 1 km from the river junction, as indicated in **Figure 4.3**. Releasing water at the syphon is therefore regarded of very limited value, because of the short stretch of river that will benefit from additional summer flows.

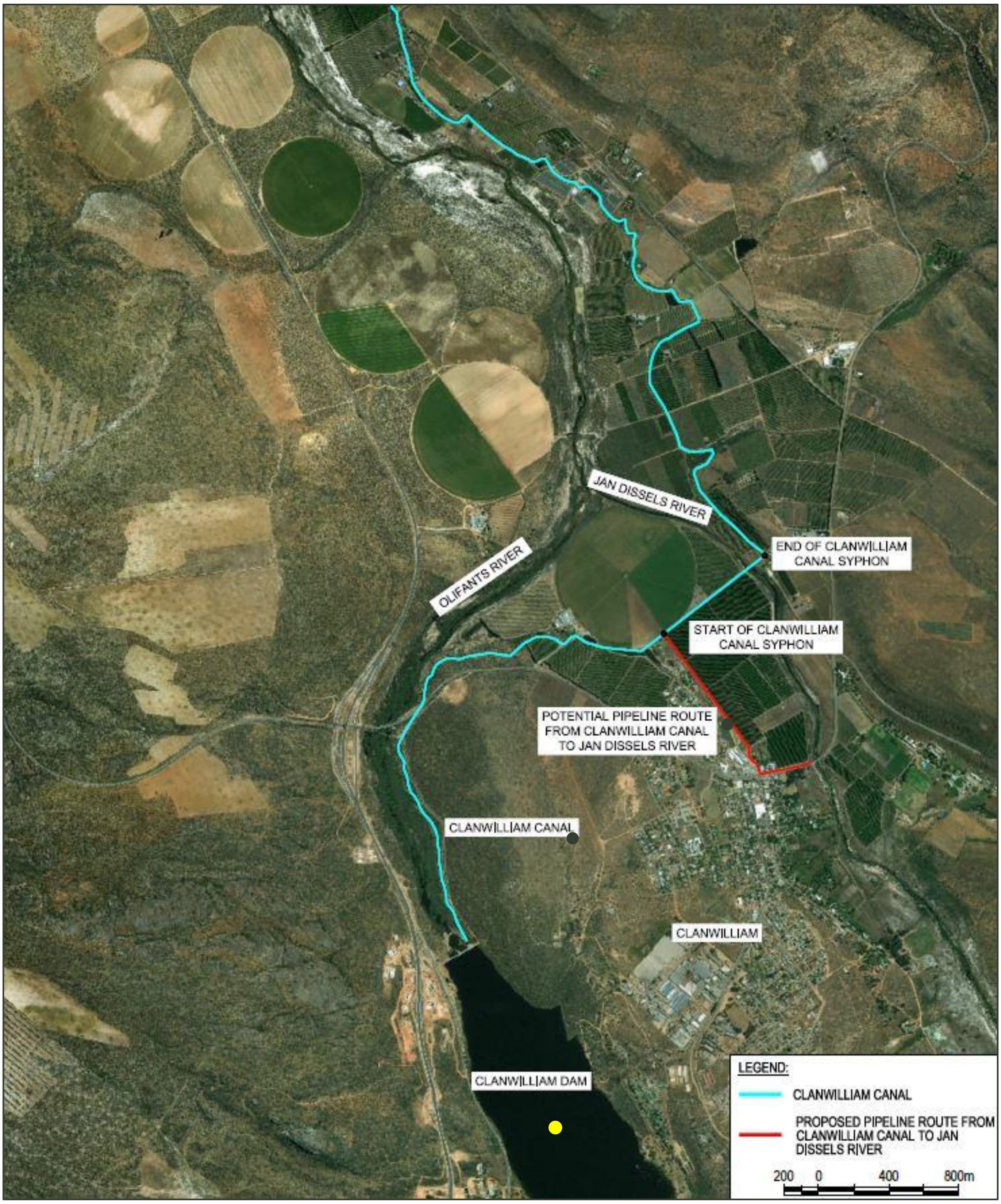


Figure 4.3 | Proposed pipeline route to Jan Dissels River

A possible solution considered to increase summer flows in the lower Jan Dissels River, to meet the ecological Reserve, is to abstract water from the Clanwilliam Canal, just before the syphon, and to divert it into the Jan Dissels River further upstream (**Figure 4.3**) at the road bridge, via a pipeline of approximately 1.5 km in length. An additional 1.3 km of the river reach would then receive the required summer flows.

This option requires capital investment and more complex operational requirements than were not foreseen during the Compulsory Licensing study. Given the additional information, it is debatable whether this intervention will be worthwhile, as it was originally recommended as a 'low-hanging fruit' that could render ecological benefits with very limited investment or effort. This would also only remain a possibility while there is adequate spare capacity in the Clanwilliam Canal, which currently does not seem to be the case. It is not regarded as worthwhile to proceed with this recommendation.

5 Existing Agricultural Areas

5.1 Locality and Extent of the Agricultural Areas

The existing agricultural areas located within the study area, as shown in **Figure 5.1**, were split into the three regions mentioned in **Section 1.3** of this report. Currently, the agricultural areas are divided into three categories, namely:

1. Cultivated irrigated areas;
2. Cultivated dry-land areas;
3. Uncultivated or dry/arid area.

The existing agricultural land use areas, obtained from the National Department of Environmental Affairs (2013-2014) and updated with Bing Imagery (2016-2017) are summarised in **Table 5.1** below. Refer to **Figure 5.1** below for the location of the existing agricultural areas.

Table 5.1 | Existing agricultural areas per region

Study Area Region	Cultivated Irrigated (ha)	Cultivated Dryland (ha)	Uncultivated, Dry/Arid (ha)	Total (ha)
Region 1: Upstream of Clanwilliam Dam	12 000	16 000	225 000	253 000
Region 2: Clanwilliam Dam to Bulshoek Dam	2 900	22 000	45 200	70 100
Region 3: Bulshoek Dam to Olifants Estuary	15 800	31 200	218 700	265 700
Total	**30 700**	**69 200**	**488 900**	**588 800**

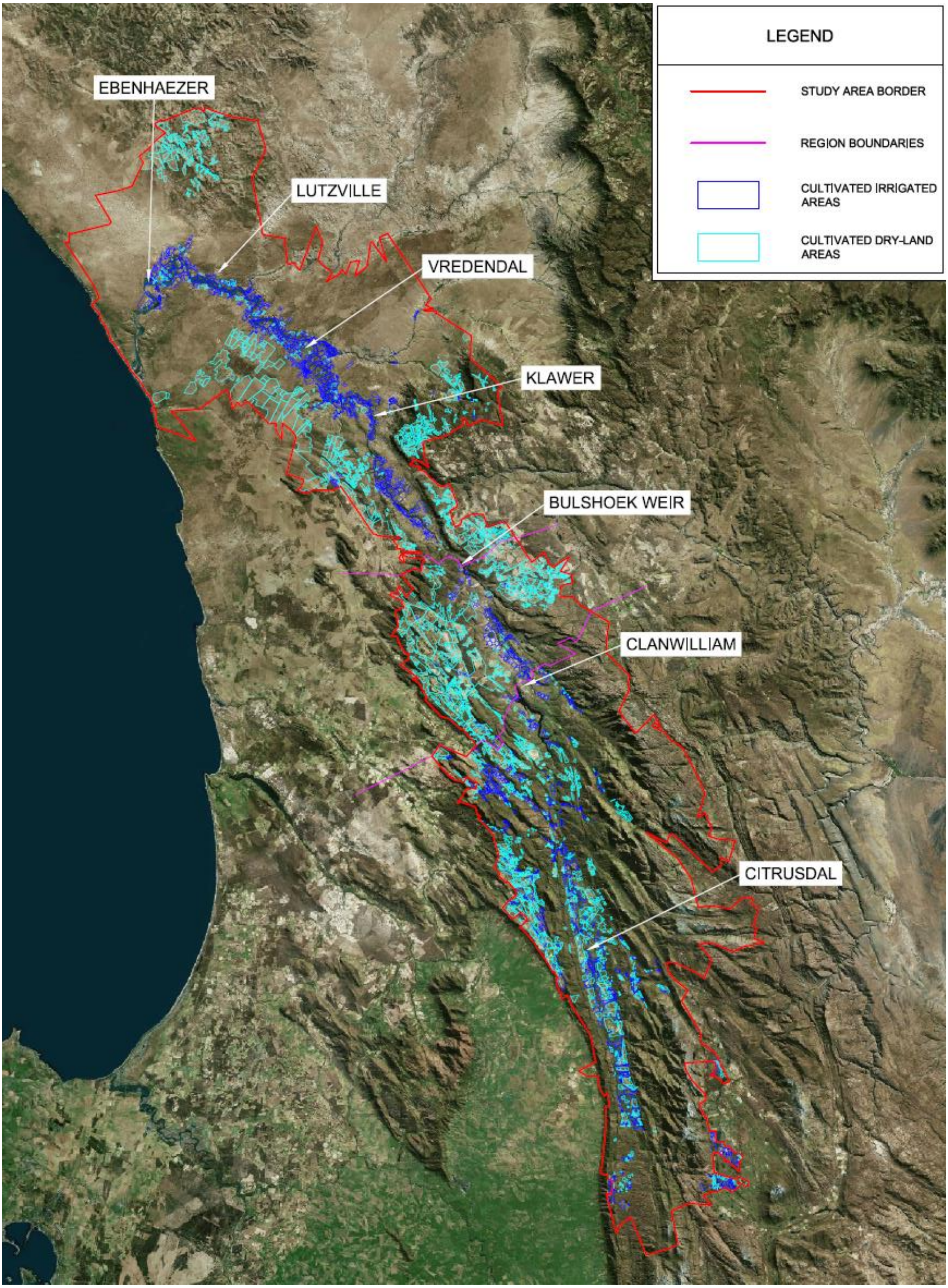


Figure 5.1 | Existing agricultural land use

5.2 Existing Agricultural Areas and Water Requirements

The tables and figures in this section indicate the crop types in the existing agricultural areas, the crop irrigation quotas and the total agricultural water requirements.

Distribution and Areas of Crop Types

Figure 5.2 shows the distribution of crop types according to the Cape Farm Mapper Crop Census (2013) data.

Table 5.2 summarises the areas per crop type in each region downstream of the Clanwilliam Dam.

Water Requirements per Crop Type

Table 5.3 shows the crop irrigation quotas relevant to each crop type in each of the respective regions as indicated in the '*Financial Viability of Irrigation Farming*' sub-report. By applying the crop water requirements indicated in **Table 5.3** to the crop areas shown in **Table 5.2**, the total agricultural water requirements for each crop type per region could be determined, as summarised in **Table 5.4**.

The total agricultural water use for the area downstream of the Clanwilliam Dam (i.e. Region 2 and Region 3) is approximately 142 million m^3 for 14 500 ha, which is similar to the irrigation water usage of 140 million m^3 determined in the '*Water Requirements Assessment*' Report.

Table 5.2 | Existing crop type areas per region downstream of Clanwilliam Dam

Crop Type	Area (ha)		
	Region 2 (Clanwilliam Dam to Bulshoek Weir)	Region 3 (Bulshoek Weir to Olifants Estuary)	Total (Downstream of Clanwilliam Dam)
Irrigated			
Citrus	650	0	650
Table grapes	190	835	1 025
Wine grapes	230	10 970	11 200
Vegetables	500	970	1 470
Other fruit	50	150	200
Total	**1 620**	**12 925**	**14 545**
Non-Irrigated			
Rooibos	10 580	3 420	14 000

Crop Type	Area (ha)		
	Region 2 (Clanwilliam Dam to Bulshoek Weir)	Region 3 (Bulshoek Weir to Olifants Estuary)	Total (Downstream of Clanwilliam Dam)
Grains	2 740	6 980	9 720
Flowers	3	2	5
Total	**13 323**	**10 402**	**23 725**

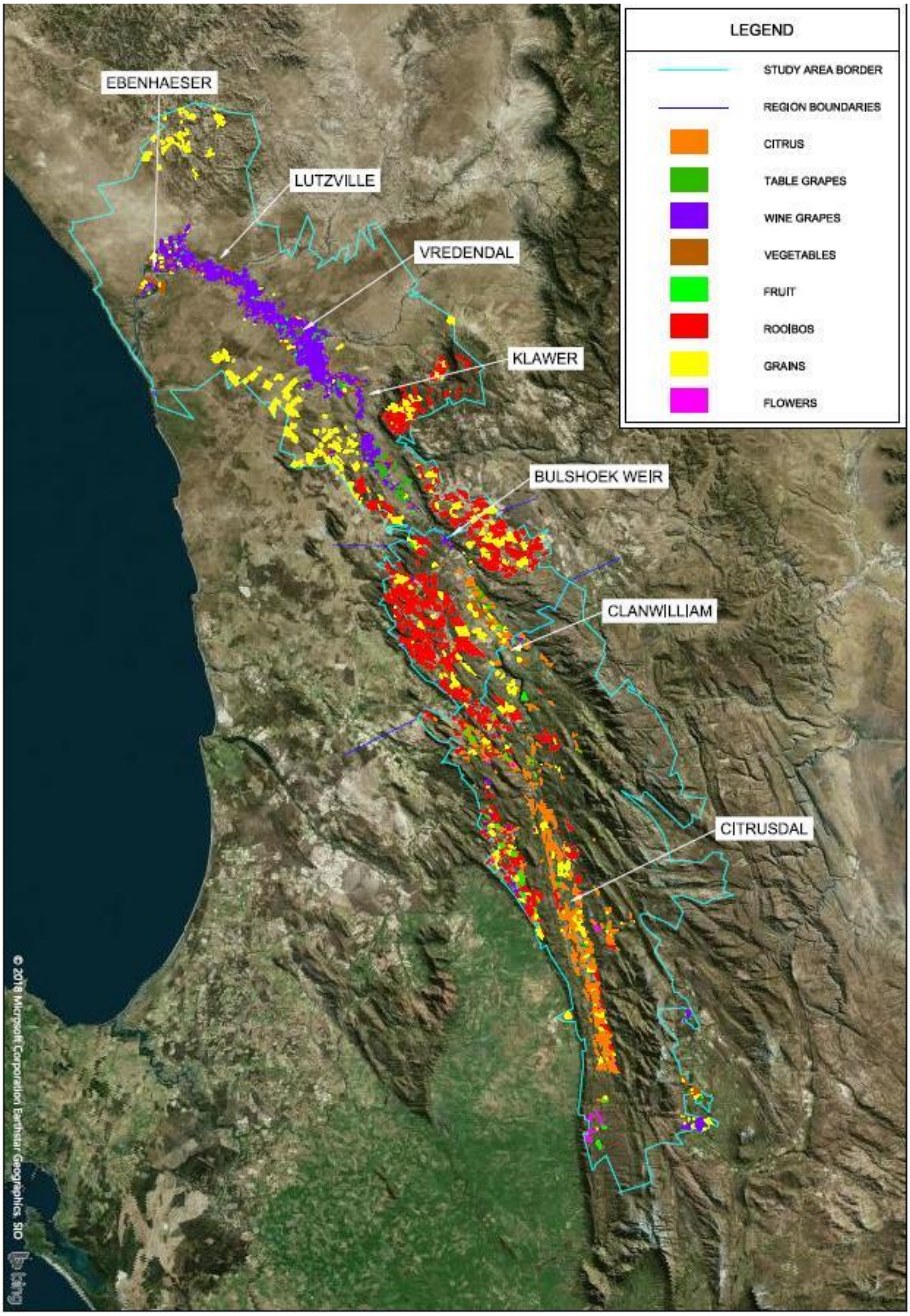


Figure 5.2 | Cape Farm Mapper Crop Census Data

Table 5.3 | Crop type irrigation quotas per region

Crop Type	Irrigation Quotas (m^3/ha)		
	Region 1 (Upstream of Clanwilliam Dam)	Region 2 (Clanwilliam Dam to Bulshoek Weir)	Region 3 (Bulshoek Weir to Olifants Estuary)
Citrus	11 380	12 250	11 000
Table grapes	11 340	9 000	13 580
Wine grapes	9 500	9 500	9 500
Vegetables	8 250	8 250	8 250
Other fruit	9 900	9 900	9 900
Pastures/grazing	12 000	11 700	13 200

Table 5.4 | Crop type irrigation requirement areas per region

Crop Type	Irrigation Requirements (million m^3)		
	Region 2 (Clanwilliam Dam to Bulshoek Weir)	Region 3 (Bulshoek Weir to Olifants Estuary)	Total (Downstream of Clanwilliam Dam)
Citrus	7.96	0	7.96
Table grapes	1.70	11.34	13.04
Wine grapes	2.16	104.24	106.4
Vegetables	4.13	8.00	12.13
Other fruit	0.50	1.49	1.99
Total	**16.45**	**125.07**	**141.52**

5.3 Potential for Further Agricultural Development

5.3.1 Locality and Extent of the Agricultural Areas

Land (properties) owned by government and privately-owned land were identified (**Figure 5.3**) and are described in this section. The land ownership details (name, address, contact details, etc.) have also been recorded for each property in the study area. **Table 5.5** summarises the property ownership for each region in the study area. The study area boundary and regions are as previously defined in the '*Feasibility Study for the Raising of Clanwilliam Dam'* (DWAF, 2008). The government-owned properties do not include the urban/town areas such as Citrusdal, Vredendal, Klawer and Ebenhaeser, but only properties with possible development potential up to the above-mentioned town borders.

Table 5.5 | Property ownership per region

Study Area Region	Government (ha)	Private (ha)
Region 1: Upstream of Clanwilliam Dam (inclusive of the properties around the dam)	82 600	170 500
Region 2: Clanwilliam Dam to Bulshoek Weir (inclusive of the properties around the weir)	900	69 100
Region 3: Bulshoek Weir to Olifants Estuary	43 000	222 700
Total	**126 500**	**462 300**

From the table above, it is evident that only a small fraction of the study area is government-owned. Depending on the suitability of the government-owned land, the approach should be to first consider the development of new farms on these properties. For the expansion of existing farms, privately-owned land will likely be considered.

The locality of the government-owned properties in Region 1, in relation to existing irrigated agriculture and surface water sources, is another factor that must be considered. The majority of the 82 600 ha of government-owned properties are located in the upper regions of the Cederberg Mountains consisting of steep slopes and possible Critical Biodiversity Areas. Thus, only a small area could be considered for the development of any new agricultural areas.

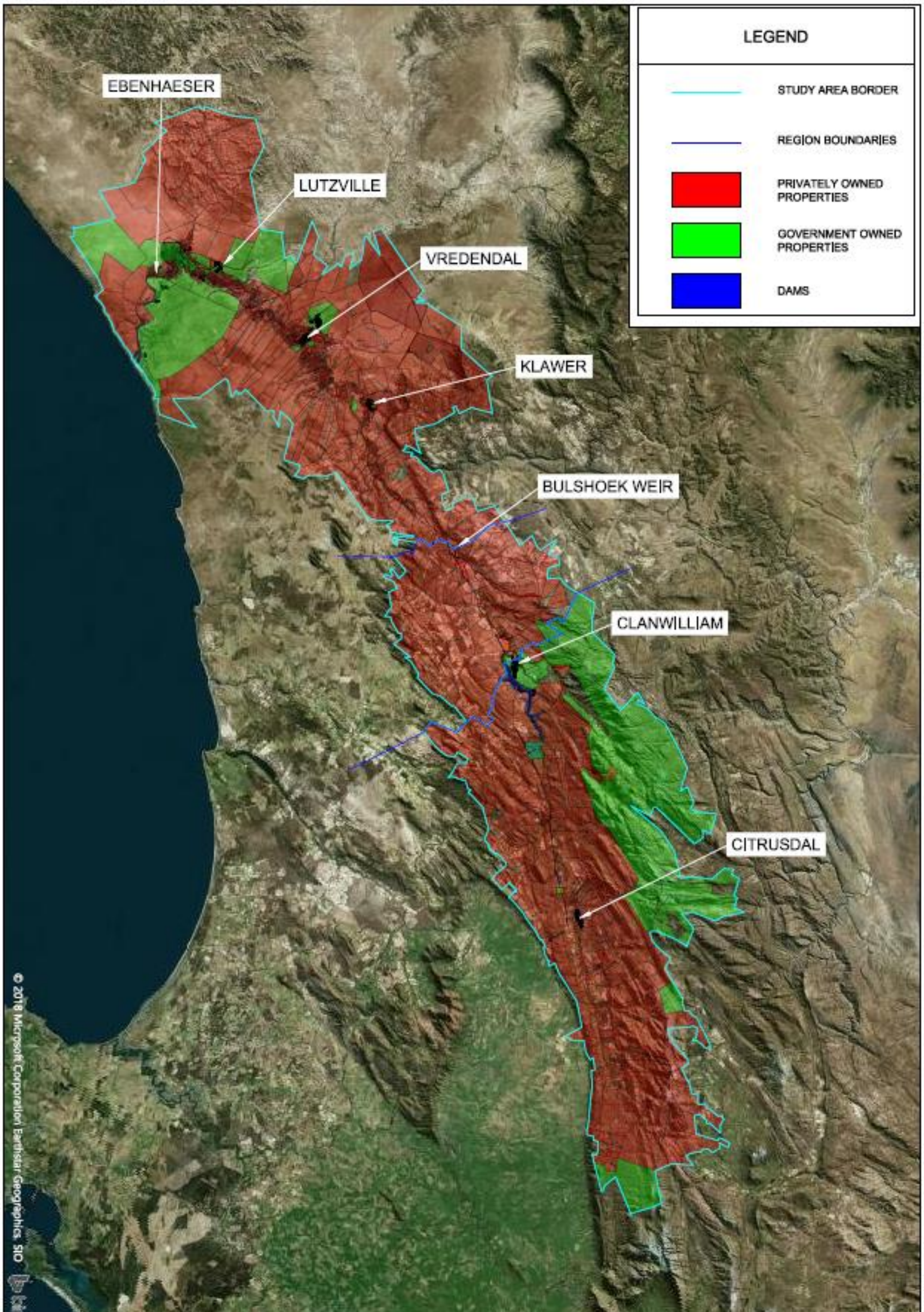

LEGEND
STUDY AREA BORDER
REGION BOUNDARIES
PRIVATELY OWNED PROPERTIES
GOVERNMENT OWNED PROPERTIES
DAMS
EBENHAESER
LUTZVILLE
VREDENDAL
KLAWER
BULSHOEK WEIR
CLANWILLIAM
CITRUSDAL
© 2018 Microsoft Corporation Earthstar Geographics SIO

Figure 5.3 | Land ownership of study area

5.3.2 Soil Suitability

The '*Soils, Water Requirements and Crops'* Report (DWAF, 2004), prepared as part of the Feasibility Study for the Raising of Clanwilliam Dam, included mapping of soils upstream of Bulshoek Weir to a lateral extent of about 60 m above the level of the river or existing canals. The figures in **Appendix B** show the potential rating of soils for the production of annual tuberous, annual non-tuberous, and perennial crops.

The potential irrigable areas previously identified will be reviewed, taking influencing factors into account. The findings from a soil survey and expert interpretation should be available before the future irrigation water requirements and associated infrastructure requirements are addressed. Due to advanced farming technology and management skills that exist in the developed sections of the study area, the inherent soil limitations do not pose any serious constraints on the irrigation development. It is rather factors such as relative position to water sources and environmental impacts that dictate further development.

Region 1 and 2 Soil Suitability

Based on these evaluations, about 2 000 ha are recommended for perennial crops (e.g. citrus and wine grapes) in the southern section of the basin from Keerom to Bulshoek Weir. Another 19 000 ha are marginally and conditionally recommended provided that subsoil limitations are properly ameliorated. About 8 600 ha of this class has a potential rating that is near the upper limit of the conditionally recommended class. The main limitations in this class are wetness and shallow underlying weathering rock combined with low clay content. These limitations are relatively easy to ameliorate and with judicious irrigation practices approximately 10 000 ha can be used for economically viable production of citrus and wine grapes. Within the lateral extent of the survey approximately 10 000 ha is available in the Keerom to Bulshoek section for any combination of irrigated annual (tuberous and non-tuberous) and perennial (citrus, wine grapes, mangos) production.

Region 3 Soil Suitability

The soils in the surveyed area from Bulshoek Weir to the coast differ greatly from those in the southern section in terms of the dominant limitation(s). Deep, well-drained red sandy soils can be highly recommended for irrigated tuberous and non-tuberous crops without any subsoil amelioration measures. However, these soils are only conditionally recommended for perennial crops due to the very sandy nature and risk of sandblasting of crops. Non-tuberous crops are conditionally recommended, while perennial crops are recommended on these soils after amelioration of subsoil limitation. In this section there is approximately 105 000 ha that can be recommended to produce perennial crops after amelioration of subsoil limitations, in particular hardpans, and if provision is made for leaching and drainage to remove soluble salts from saline environments. Most of the areas recommended for perennial crops can also be used for irrigated non-tuberous annual crop production.

Increasing the extent of the soil survey

Considering that Clanwilliam and LORWUA have significant developments above the river and existing canals, it was decided to extend the soil surveys to cover the lateral extent of 100 m above the level of the river or existing canals. The findings of the soil surveys will be provided in the Soil Testing Report.

5.3.3 Environmental Considerations

Figure 5.4 shows the extent of the environmentally protected areas in the study area. There are also environmentally sensitive areas, critical biodiversity areas, wetlands, etc. which will influence which land is available for agriculture. The various environmental layers will be used to screen out the agriculture development and distribution options.

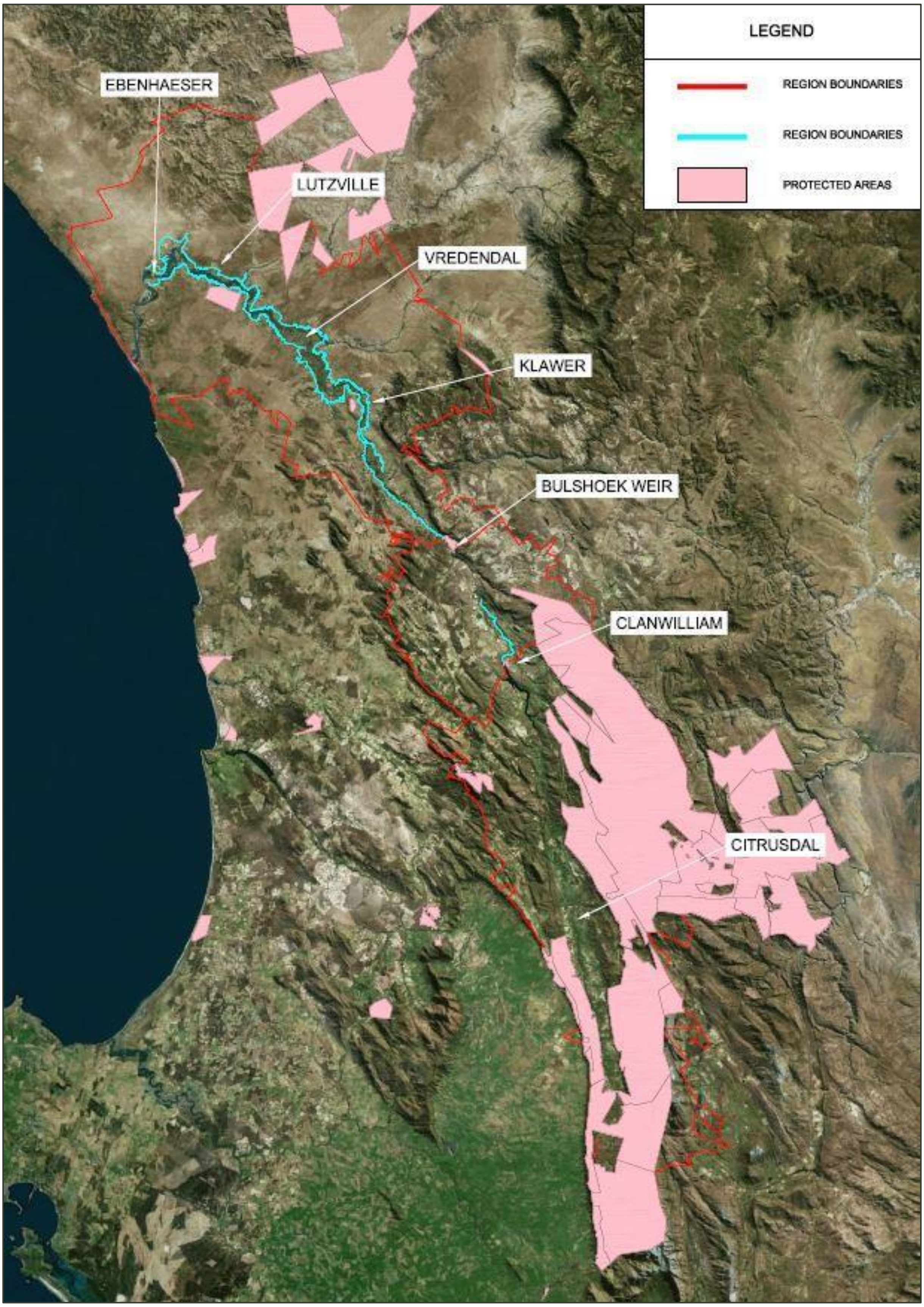


Figure 5.4 | Environmentally protected areas

6 Conclusions

In this report, the extent and condition of the existing infrastructure in the study area was discussed, following a literature review of available information from previous studies, a field trip and public meetings held in the study area, and communication with various stakeholders. It was found that most of the conveyance infrastructure is over 80 years old and requires urgent rehabilitation, maintenance and repair. An Implementation Action Plan was prepared as part of this Report.

The suggestions of the Jan Dissels River Compulsory Licensing Study to improve the ecological condition of the lower section of the Jan Dissels River was evaluated in more detail and recommendations made.

The report also investigated the current agricultural development in the study area. It was found that the existing irrigated areas total 29 090 ha, i.e. 1 620 ha in Region 1, 12 925 ha in Region 2 and 14 545 ha in Region 3.

This report confirmed the current agricultural water requirements following an evaluation of the current crop types. Total agricultural water use for the area downstream of the Clanwilliam Dam (i.e. Region 2 and 3) is approximately 142 million m^3, which confirms the irrigation water usage of 140 million m^3 determined in the '*Water Requirements Assessment'* Report.

References

Creamer Media. 2017. *Western Cape: Multi-million rand maintenance plan underway to stem agriculture losses in Clanwilliam.* http://www.polity.org.za/article/western-cape-multi-million-rand-maintenance-plan-underway-to-stem-agriculture-losses-in-clanwilliam-2017-01-20. Accessed: 29 January 2018.

Department of Agriculture: Western Cape, South Africa. 2018. *CapeFarmMapper ver 2.0.6.7*. https://gis.elsenburg.com/apps/cfm/. Accessed: 26 March 2018.

Department of Water Affairs and Forestry, South Africa. 2002a. *Bulshoek Dam: Remedial Works Construction Complete Report*. Report No. 20/2/E100-04/C/1/4/2.

Department of Water Affairs and Forestry, South Africa. 2002b. *Bulshoek Dam: Operation and Maintenance Manual.*

Department of Water Affairs and Forestry, South Africa. 2004. *Soils, Water Requirements and Crops*. Prepared by J J N Lambrechts, B H A Schloms and F Ellis of the University of Stellenbosch, as part of the Feasibility Study for the Raising of the Clanwilliam Dam. DWAF Report No. P WMA 17/E10/00/1106.

Department of Water Affairs and Forestry, South Africa. 2008. *Bulshoek Dam: Report on Third Dam Safety Inspection Carried Out in terms of Government Notice R 1560 of 25 July 1986*. Report No. 20/2/E100-04/C/1/22.

Department of Water Affairs and Forestry, South Africa and Department for International Development, United Kingdom. 2007. *Inception Report*. Prepared by E van der Berg of Ninham Shand (Pty) Ltd, in association with Pegasys (Pty) Ltd and Informage, as part of the Support to Compulsory Licensing in the Jan Dissels river Catchment, Western Cape.

Department of Water Affairs and Forestry, South Africa and Department for International Development, United Kingdom. 2007. *Rapid II Reserve Determination Report.* Prepared by C Brown and R Magoba of Southern Waters Ecological Research and Consulting cc, as part of the Support to Compulsory Licensing in the Jan Dissels River Catchment, Western Cape.

Department of Water Affairs and Forestry, South Africa and Department for International Development, United Kingdom. 2007. *Groundwater Report.* Prepared by R Parsons of Parsons & Associates cc, as part of the Support to Compulsory Licensing in the Jan Dissels River Catchment, Western Cape.

Department of Water Affairs and Forestry, South Africa and Department for International Development, United Kingdom. 2007. *Opportunities for productive water use by emerging farmers Report*. Prepared by K von der Heyden and A Selby of Pegasys (Pty) Ltd, in association with Ninham Shand (Pty) Ltd and Informage, as part of the Support to Compulsory Licensing in the Jan Dissels River Catchment, Western Cape.

Department of Water Affairs and Forestry, South Africa and Department for International Development, United Kingdom. 2008. *A Framework for Water Allocation in the Jan Dissels River Catchment*. Prepared by A Selby of Pegasys, in association with Ninham Shand (Pty) Ltd and Informage, as part of the Support to Compulsory Licensing in the Jan Dissels River Catchment, Western Cape.

Department of Water and Sanitation, South Africa. 2016a. *Condition assessment audit of irrigation scheme infrastructure*. Prepared by LTE Consulting and PULA Strategic Resource Management. Document ID: WP0485WTE-Southern- Clanwilliam GWS.

Department of Water and Sanitation, South Africa. 2016b. *Bulshoek Dam: Operation and Maintenance Manual.*

Department of Water and Sanitation, South Africa. 2016c. *Condition assessment audit of irrigation scheme infrastructure*. Prepared by LTE Consulting and PULA Strategic Resource Management. Document ID: WP0485WTE-Southern- Olifants River van Rhynsdorp GWS.

IOL. 2015. *Relief for Clanwilliam farmers.* https://www.iol.co.za/news/south-africa/western-cape/relief-for-clanwilliam-farmers-1810878. Accessed: 16 May 2018.

Kriel, G. 2017. *Olifants River Valley farmers' irrigation woes*. https://www.farmersweekly.co.za/crops/field-crops/olifants-river-valley-farmers-irrigation-woes/. Accessed: 26 January 2018.

LORWUA. 2004. *Investigation into the rehabilitation of the canal downstream of Bulshoek Dam*. Prepared by Element Consulting Engineers. Project No. 03046.

Ndlendle, S. 2017. *Canal emergency repair saves water levels*. https://www.iol.co.za/news/south-africa/western-cape/canal-emergency-repair-saves-water-levels-7509419. Accessed: 26 January 2018.

Oosthuizen, C. and Brink, J. A. 2015. *Bulshoek Dam: Failure in slow motion or time bomb?* SANCOLD Conference, 1-3 September 2015, Cape Town, South Africa.

Roux, A. S. and Keuck, P. G. 2009. *Applying modern technology to solve water supply problems at Ebenhaeser in the Western Cape Province of South Africa*. 60th International Executive Council Meeting & 5th Asian Regional Conference, 6-11 December 2009, New Delhi, India.

Western Cape Government. 2017. *R4 million maintenance plan at Clanwilliam Dam canals stem water losses*. https://www.westerncape.gov.za/news/r-4-million-maintenance-plan-clanwilliam-dam-canals-stem-water-losses-1. Accessed: 26 January 2018.

Appendix A: Information from DWS 2016 study

INFORMATION FROM THE DWS (2016a, 2016c) STUDY

Table A.1 | Condition of Clanwilliam Canal components at DWS (2016a) inspection points

Inspection Point No.	Canal lining condition (repair action required m/100m)	Canal lining condition (visit points)	Canal joints condition	Canal shoulder condition	Canal embankment condition	Canal berm condition	Canal fence condition (% replace left fence)	Canal fence condition (% replace right fence)
1	Fair	Poor	Fair	Fair	Fair	n/a	Not Working	Not Working
2	Fair	Poor	Fair	Fair	Fair	n/a	Not Working	Not Working
3	Fair	Fair	Very Poor	Poor	Very Poor	Poor	Very Poor	Very Poor
4	Fair	Good	Fair	Poor	Very Poor	Fair	Very Poor	Not Working
5	Good	Good	Very Poor	Poor	Very Poor	Very Poor	Not Working	Not Working
6	Good	Good	Very Poor	Poor	Poor	Poor	Not Working	Not Working
7	Good	Good	Very Poor	Poor	Fair	Poor	Very Poor	Very Poor
8	Good	Good	Fair	Poor	Very Poor	Very Poor	Not Working	Very Poor
9	Fair	Good	Poor	Poor	Fair	Fair	Not Working	Not Working
10	Poor	Poor	Poor	Fair	Poor	Poor	Not Working	Very Poor

Table A.2 | Condition of Lower Olifants River Canal components at DWS (2016c) inspection points

Inspection Point No.	Canal lining condition (repair action required m/100m)	Canal lining condition (visit points)	Canal joints condition	Canal shoulder condition	Canal embankment condition	Canal berm condition	Canal fence condition (% replace left fence)	Canal fence condition (% replace right fence)
L1	Fair	Poor	Fair	Fair	Fair	n/a	Not working	Not working
L2	Fair	Poor	Poor	Fair	Fair	n/a	Good	Good
L3	Poor	Poor	Fair	Poor	Fair	Fair	Not working	Good
L4	Fair	Fair	Fair	Poor	Poor	Poor	Not working	Good
L5	Fair	Fair	Fair	Poor	Fair	Poor	Good	Very Poor
L6	Good	Fair	Good	Poor	Poor	Very Poor	Very poor	Fair
L7	Good	Good	Good	Poor	Fair	Not working	Fair	Very Poor
L8	Good	Good	Good	Poor	Poor	Very Poor	Good	Not working
L9	Good	Very good	Very good	Fair	Fair	Fair	Not working	Not working
L10	Good	Very good	Very good	Fair	Poor	Poor	Good	Not working
L11	Fair	Fair	Poor	Poor	Fair	Poor	Good	Not working
L12	Good	Fair	Good	Fair	Fair	Poor	Good	Good
L13	Poor	Poor	Poor	Good	Fair	n/a	Poor	Good
L14	Fair	Poor	Poor	Good	Good	Fair	Not working	Not working
L15	Fair	Poor	Fair	Poor	Fair	Fair	Very poor	Fair
L16	Good	Good	Good	Good	Fair	Poor	Good	Good
L17	Poor	Poor	Fair	Fair	Fair	Fair	Poor	Good
L18	Fair	Fair	Poor	Good	Fair	n/a	Not working	Good
L19	Fair	Fair	Poor	Fair	Fair	Very Poor	Good	Not working
L20	Fair	Fair	Poor	Fair	Fair	Fair	Good	Good
L21	Fair	Fair	Poor	Good	Good	Fair	Good	Good
L22	Good	Good	Fair	Fair	Fair	Good	Not working	Good
L23	Fair	Fair	Poor	Fair	n/a	n/a	Good	Fair
L24	Good	Fair	Good	Poor	Fair	n/a	Good	Not working
L25	Good	Good	Fair	Fair	Fair	n/a	Good	Not working
L26	Good	Good	Good	Poor	Fair	n/a	Good	Not working
L27	Good	Fair	Good	Fair	Fair	n/a	Not working	Good
L28	Good	Good	Fair	Fair	Fair	Very Poor	Not working	Not working
L29	Poor	Good	Poor	Poor	Poor	Poor	Not working	Not working
R1	Fair	Fair	Fair	Poor	Fair	n/a	Good	Good
R2	Fair	Poor	Fair	Poor	Poor	Poor	Good	Good
R3	Fair	Poor	Fair	Poor	Fair	Fair	Good	Good
R4	Good	Good	Good	Poor	Fair	n/a	Good	Good
R5	Fair	Fair	Poor	Fair	Fair	n/a	Good	Good
R6	Fair	Fair	Poor	Poor	Fair	n/a	Poor	Good
R7	Poor	Poor	Poor	Fair	Fair	n/a	Good	Good
R8	Fair	Fair	Poor	Poor	Poor	n/a	Not working	Good
R9	Fair	Fair	Poor	Fair	Fair	n/a	Not working	Good
R10	Fair	Poor	Fair	Fair	Fair	n/a	Not working	Poor
R11	Good	Good	Good	Poor	Fair	n/a	Good	Good
R12	Fair	Fair	Fair	Fair	Fair	Fair	Not working	Not working
R13	Poor	Poor	Poor	Fair	Fair	Poor	Good	Not working
R14	Fair	Fair	Poor	Poor	Poor	Fair	Not working	Good
R15	Fair	Fair	Fair	Good	Fair	Poor	Not working	Very poor
R16	Good	Fair	Fair	Good	Fair	n/a	Not working	Good
R17	Fair	Fair	Fair	Good	Good	n/a	Good	Fair
R18	Fair	Poor	Poor	Good	Fair	n/a	Good	Fair
R19	Good	Good	Good	Fair	Fair	n/a	Not working	Good
R20	Good	Good	Good	Fair	Fair	n/a	Not working	Good
R21	Fair	Fair	Fair	Poor	Poor	n/a	Not working	Not working
R22	Fair	Fair	Poor	n/a	Poor	n/a	Poor	Very poor
R23	Good	Good	Good	Fair	Fair	n/a	Not working	Good
R24	Good	Good	Good	Fair	Fair	n/a	Not working	Good
R25	Fair	Fair	Poor	Fair	Fair	Good	Good	Good
R26	Fair	Poor	Poor	Fair	Fair	n/a	Not working	Good
R27	Fair	Fair	Poor	Fair	Fair	n/a	Good	Good
R28	Fair	Fair	Good	Fair	Fair	Fair	Not working	Good
R29	Good	Good	Good	Fair	Good	Good	Not working	Not working

Appendix B: Soil Survey

SOIL SURVEY FROM THE FEASIBILITY STUDY FOR THE RAISING OF THE CLANWILLIAM DAM (DWAF, 2004)

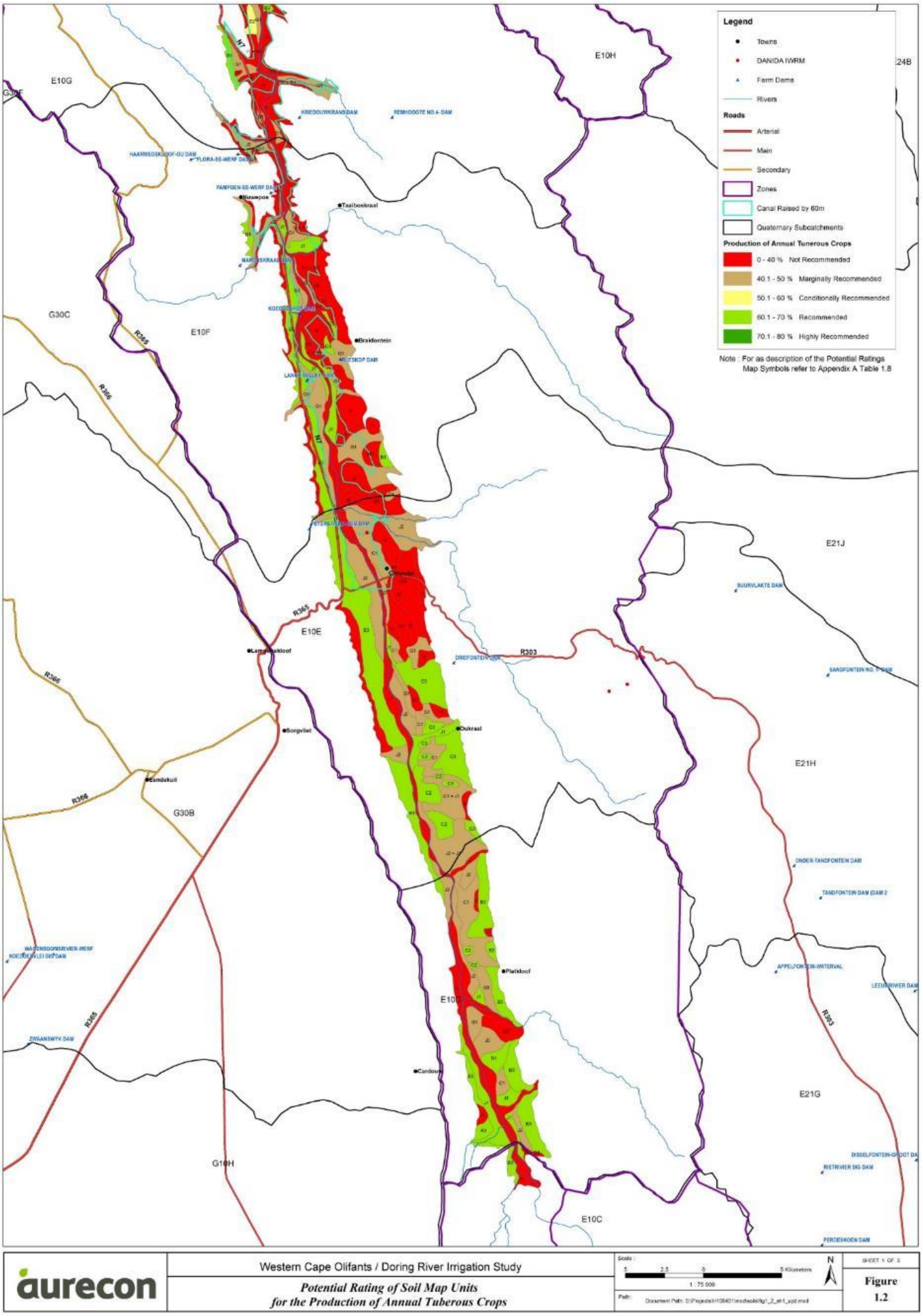


Figure B.1 | Potential rating of soils for the production of annual tuberous crops (sheet 1 of 3)

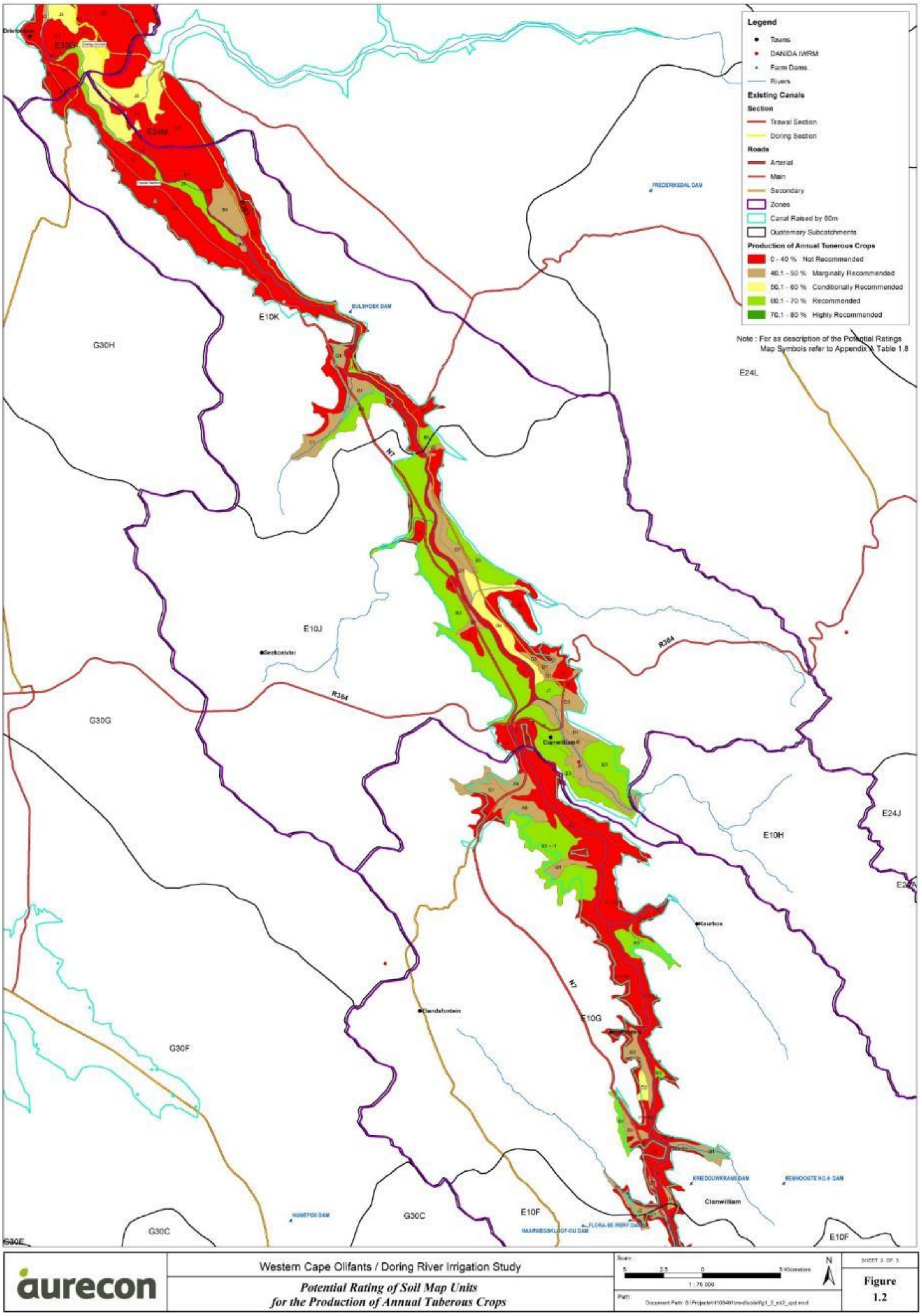


Figure B.2 | Potential rating of soils for the production of annual tuberous crops (sheet 2 of 3)

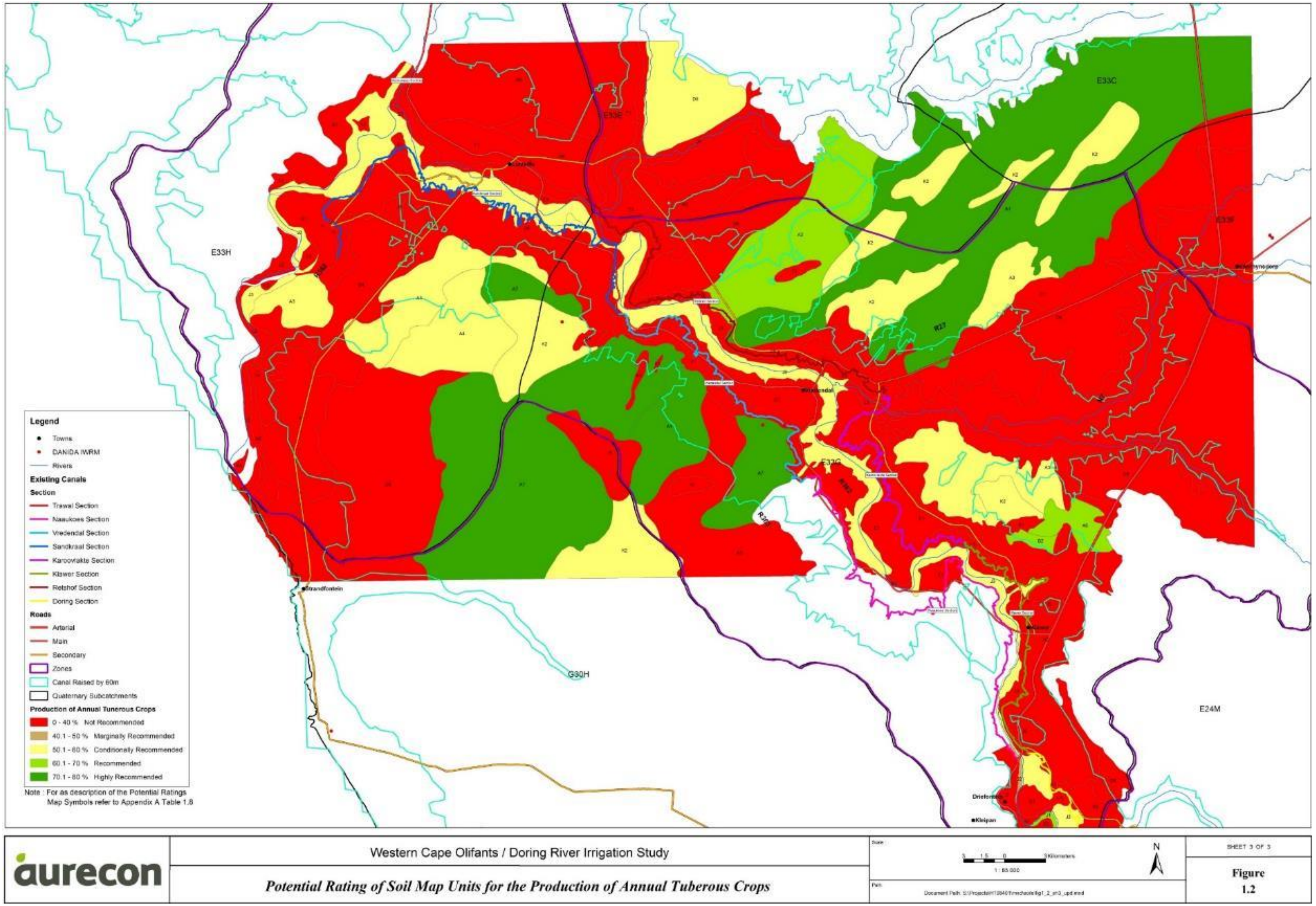


Figure B.3 | Potential rating of soils for the production of annual tuberous crops (sheet 3 of 3)

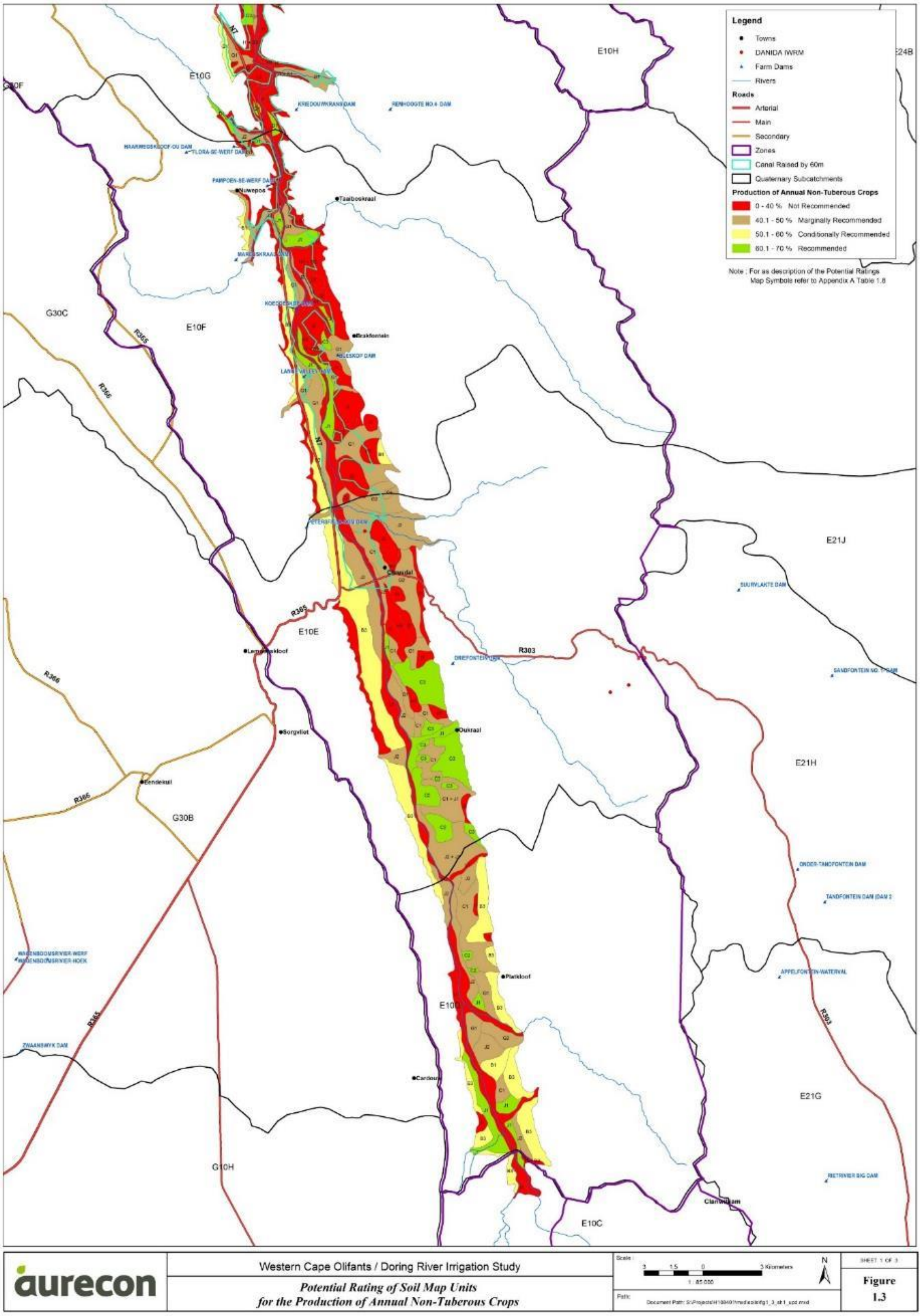


Figure B.4 | Potential rating of soils for the production of annual non-tuberous crops (sheet 1 of 3)

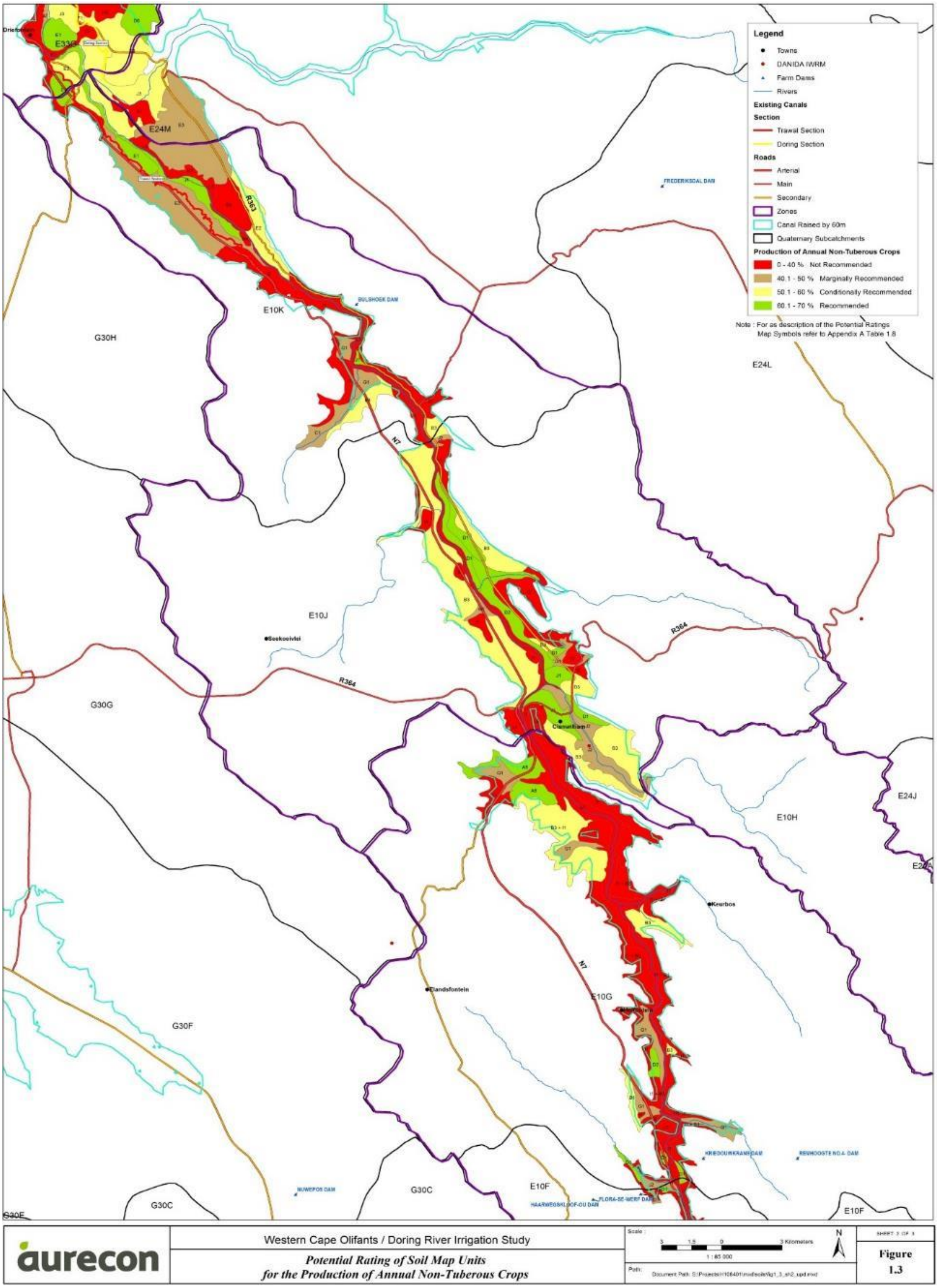


Figure B.5 | Potential rating of soils for the production of annual non-tuberous crops (sheet 2 of 3)

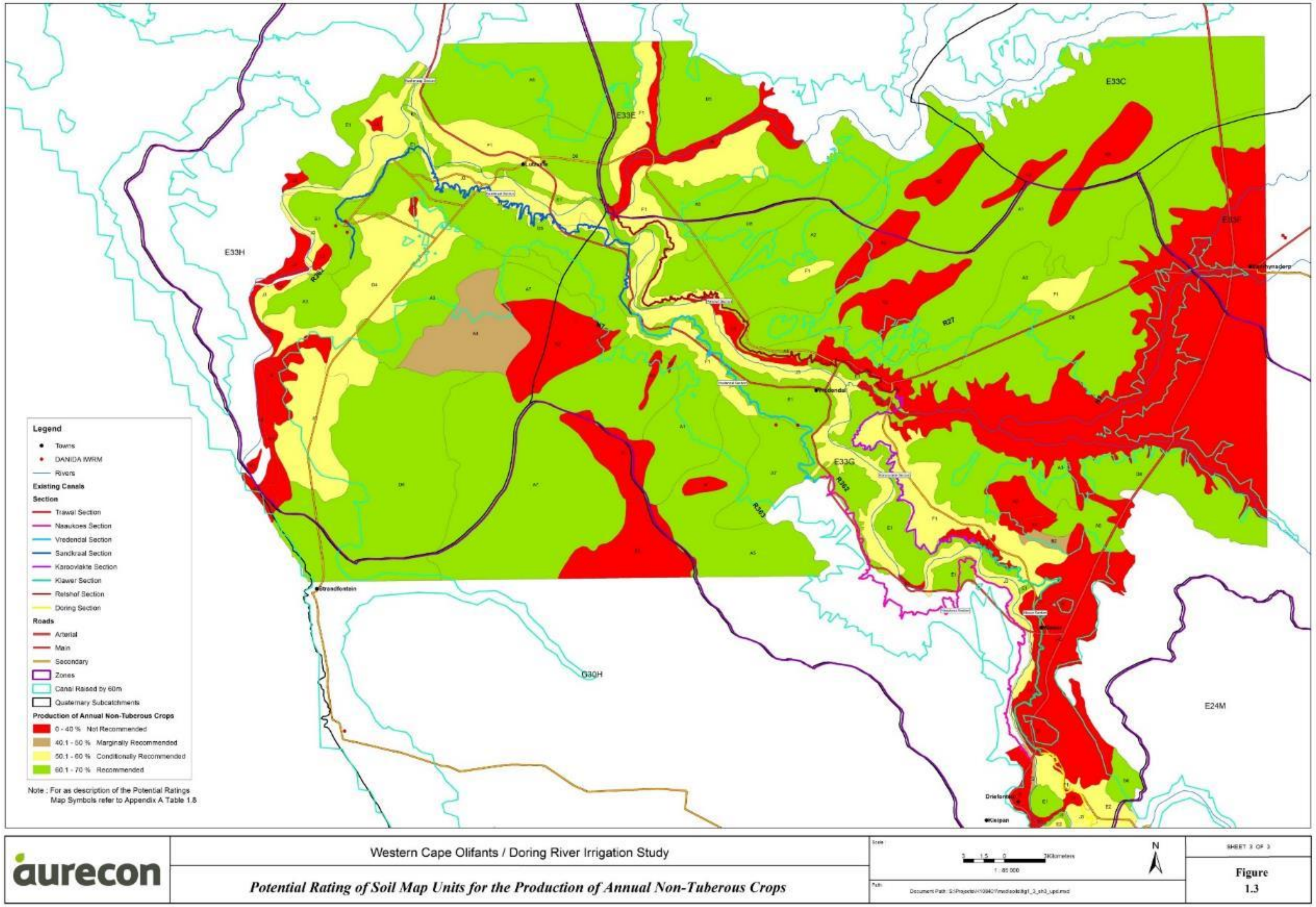


Figure B.6 | Potential rating of soils for the production of annual non-tuberous crops (sheet 3 of 3)

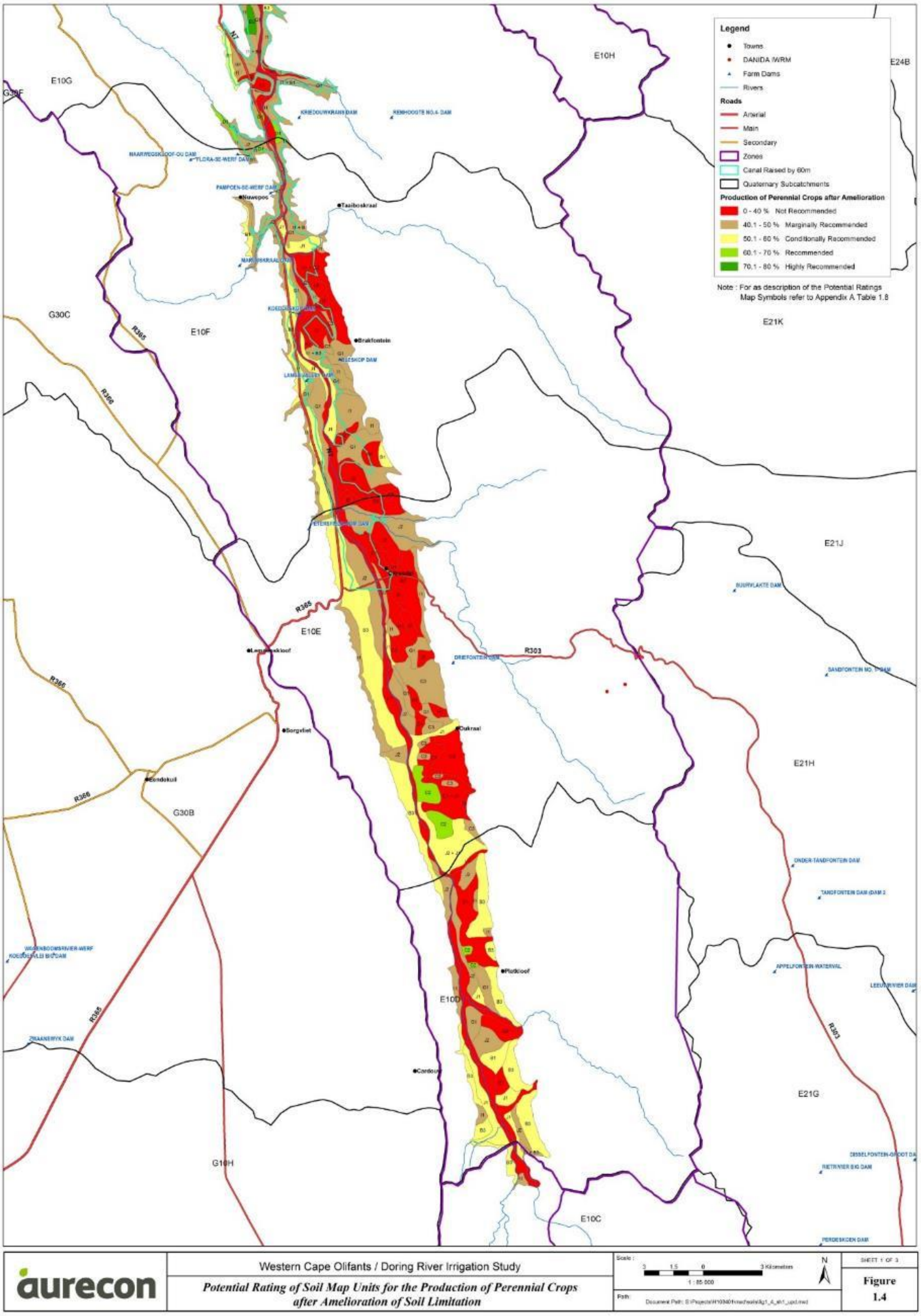


Figure B.7 | Potential rating of soils for the production of perennial crops (sheet 1 of 3)

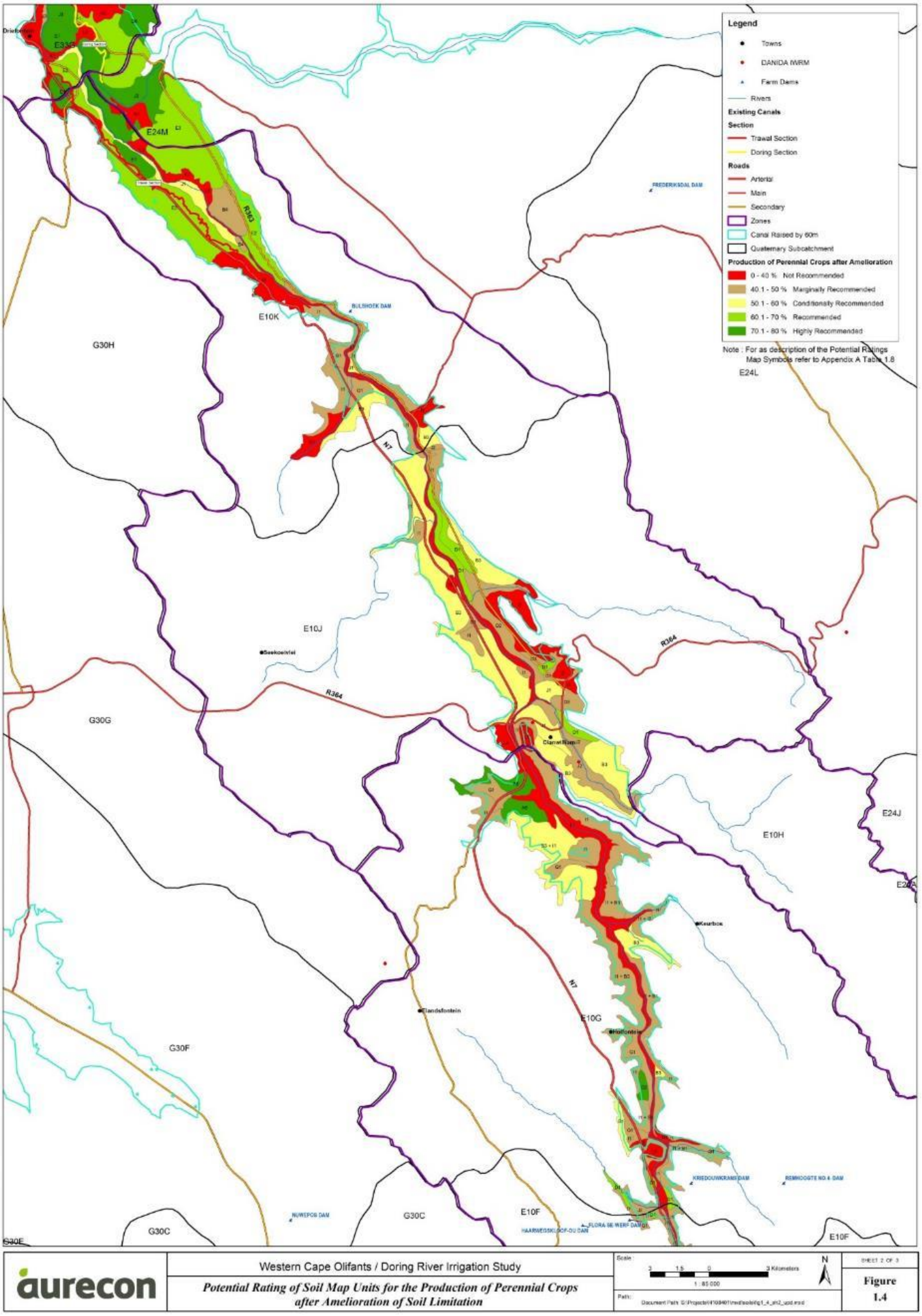


Figure B.8 | Potential rating of soils for the production of perennial crops (sheet 2 of 3)

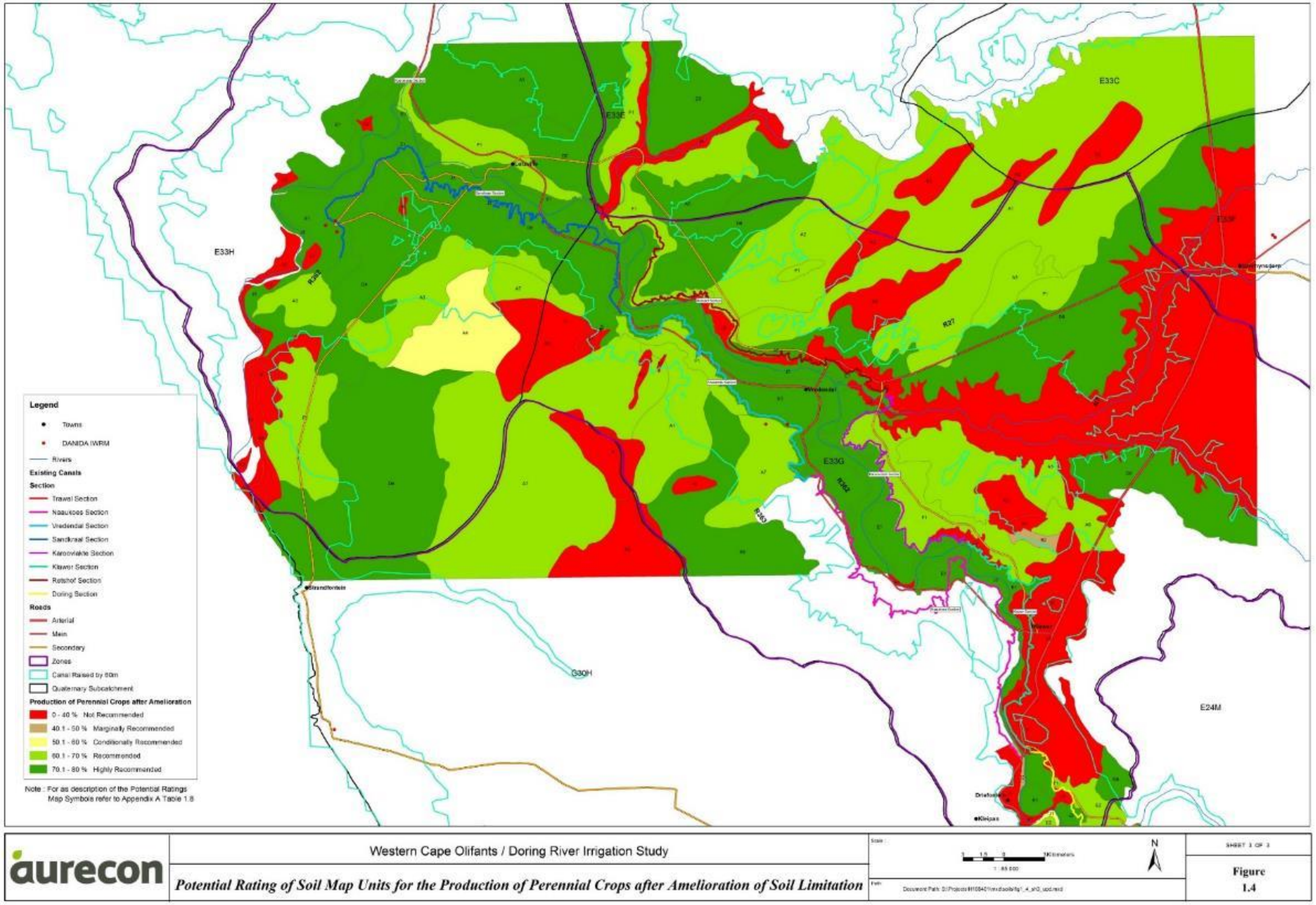


Figure B.9 | Potential rating of soils for the production of perennial crops (sheet 3 of 3)

Aurecon South Africa (Pty) Ltd
1977/003711/07
Aurecon Centre
1 Century City Drive
Waterford Precinct
Century City
Cape Town
7441
PO Box 494
Cape Town
8000
South Africa
T +27 21 526 9400
F +27 21 526 9500
E capetown@aurecongroup.com
W aurecongroup.com