SALINITY PROBLEMS IN THE DOUGLAS WEIR AND LOWER RIET RIVER

INSTITUTE FOR WATER QUALITY STUDIES
DEPARTMENT OF WATER AFFAIRS AND FORESTRY

IWQS

"The rise and fall of a number of past civilizations have been linked to their ability to sustain irrigated agriculture. The inability to control salinisation and degradation of irrigated lands are mostly viewed as main causes for their decline."`

(South African Water Quality Guidelines, Department of Water Affairs and Forestry, 1993, Volume 4 - Agricultural Use)

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- Staff of the Vaalharts Irrigation Scheme (DWAF) who took water quality samples in the Douglas Weir and Vaal River
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1 INTRODUCTION

1.1 BACKGROUND

The Douglas Weir on the lower Vaal River, and the Orange-Riet Government Water Scheme on the Riet River were built by the Department of Water Affairs and Forestry (DWAF) specifically to provide irrigation water to farmers along the lower Vaal River and the Riet River downstream of Jacobsdal (Map 1). However, farmers in the area have been complaining that the high salt content of the irrigation water is leading to yield losses and a gradual salinisation of the soils.

At present both irrigation schemes are operated to be conservative with water, and only sufficient water is supplied to meet irrigation demands. This means that they are operated as closed systems and salts tend to accumulate in some parts of these schemes. As a result high salinities are recorded in these areas. However, previous studies have suggested that excess water transferred via the Orange-Riet Canal could be used to manage the salinity of the lower Riet River, and that excess better quality water in the lower Riet River may also improve the quality of water in the Douglas Weir.

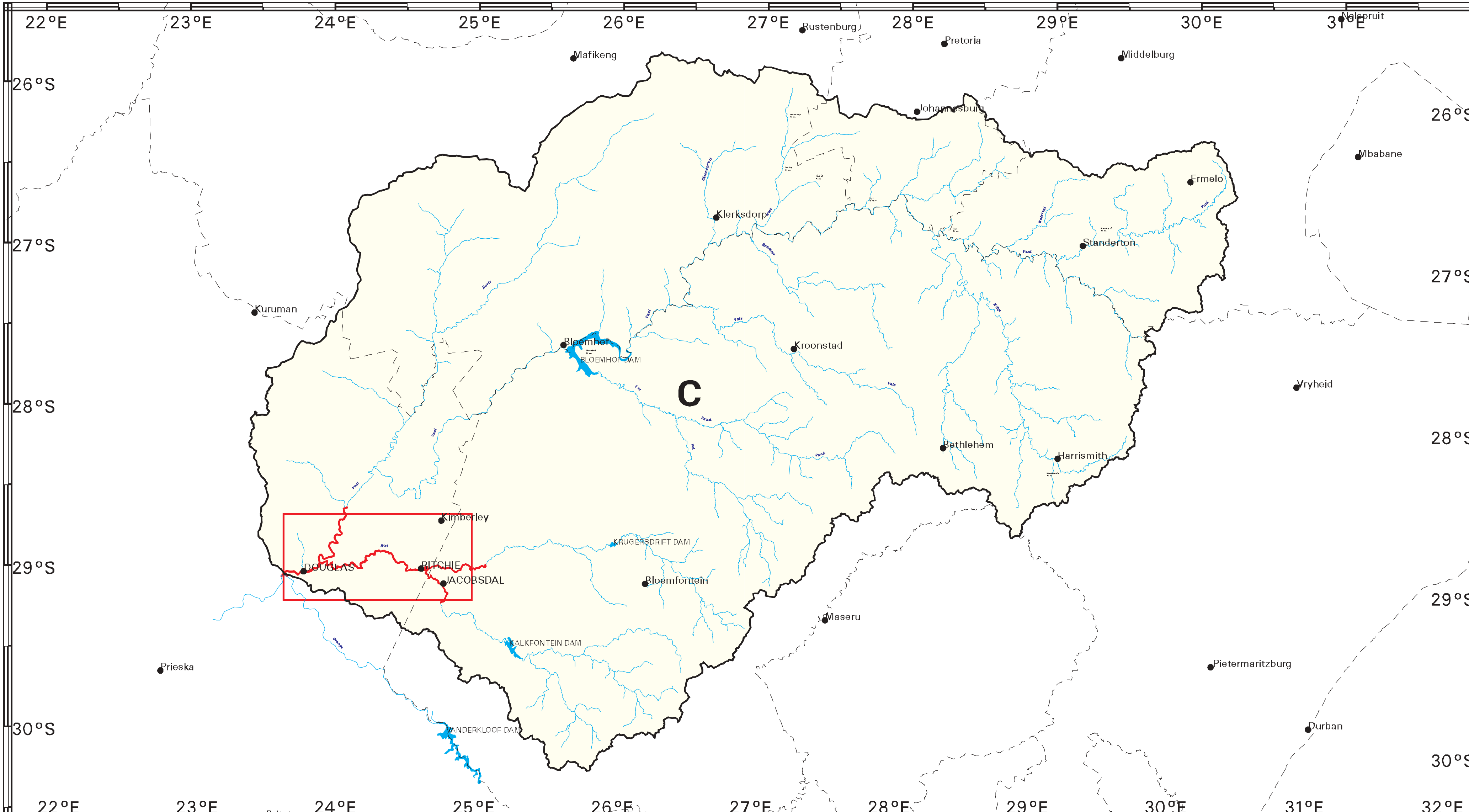
Since high salinity and salinisation of the soils in this area would, to a large extent, negate the value of these irrigation schemes, the Institute for Water Quality Studies (IWQS) has undertaken a study to examine the nature and extent of salinity related problems in the Lower Riet River and Douglas Weir, as well as to address possible solutions to these problems. The study was, therefore, initiated with the objectives as described in the following section.

1.2 OBJECTIVES

In order to examine the nature and extent of salinity related problems in the area, the quality of the water supplied for irrigation must be characterised. This requires the formulation of site specific water quality guidelines. These guidelines are based on the soil characteristics and the crops grown in the area. Furthermore, the assessment of the potential of various management options to address these problems requires water quality modelling. The following objectives, therefore, have been formulated for this study:

- Identify the water users in the area, including an assessment of the major crops cultivated. (Chapters Two and Three)
- Establish site specific water quality guidelines for irrigation users, based on the different soil types and crop types in the area. (Chapter Four)
- Characterise the quality of the water supplied in terms of these guidelines. (Chapter Four)
- Simulate the processes transporting salts in the Lower Riet River and Douglas Weir, and use these models to suggest potential management strategies. (Chapter Five)

> Note:
> Only irrigation related water quality problems will be considered in depth as this forms the major use of water in the area. However it must be borne in mind that other water quality related problems may also exist.

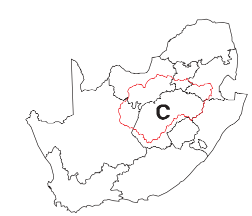


KEY

- Rivers
- Rivers of the study area
- Vaal River catchment
- RSA Provincial borders
- Towns
- Dams

0 25 50 75 100 km

MAP 1
LOCATION OF THE DOUGLAS WEIR AND RIET RIVER STUDY AREA (indicated in red) WITHIN THE VAAL RIVER CATCHMENT



Location within South Africa

2 DESCRIPTION OF THE STUDY AREA

2.1 INTRODUCTION

Like many irrigation systems in South Africa, the Douglas Weir and Riet River schemes are operated to conserve both water and pumping costs. Inflows to these schemes via the Vaal, Riet and Modder Rivers (Map 2) are, therefore, kept to a minimum and these systems are entirely dependent on water imported from the Orange River. These imports define the study area as extending from the inflow of the Orange-Riet Canal (at Jacobsdal) down the Riet River as far as the weir at Soutpansdrift, and along the Douglas Weir from the weir structure upstream as far as the farm De Bad, including the section of the Riet River between Soutpansdrift and the Riet-Vaal confluence (Map 2). It is the way in which these two systems are operated which has the dominant impact on the quality of the irrigation water supplied.

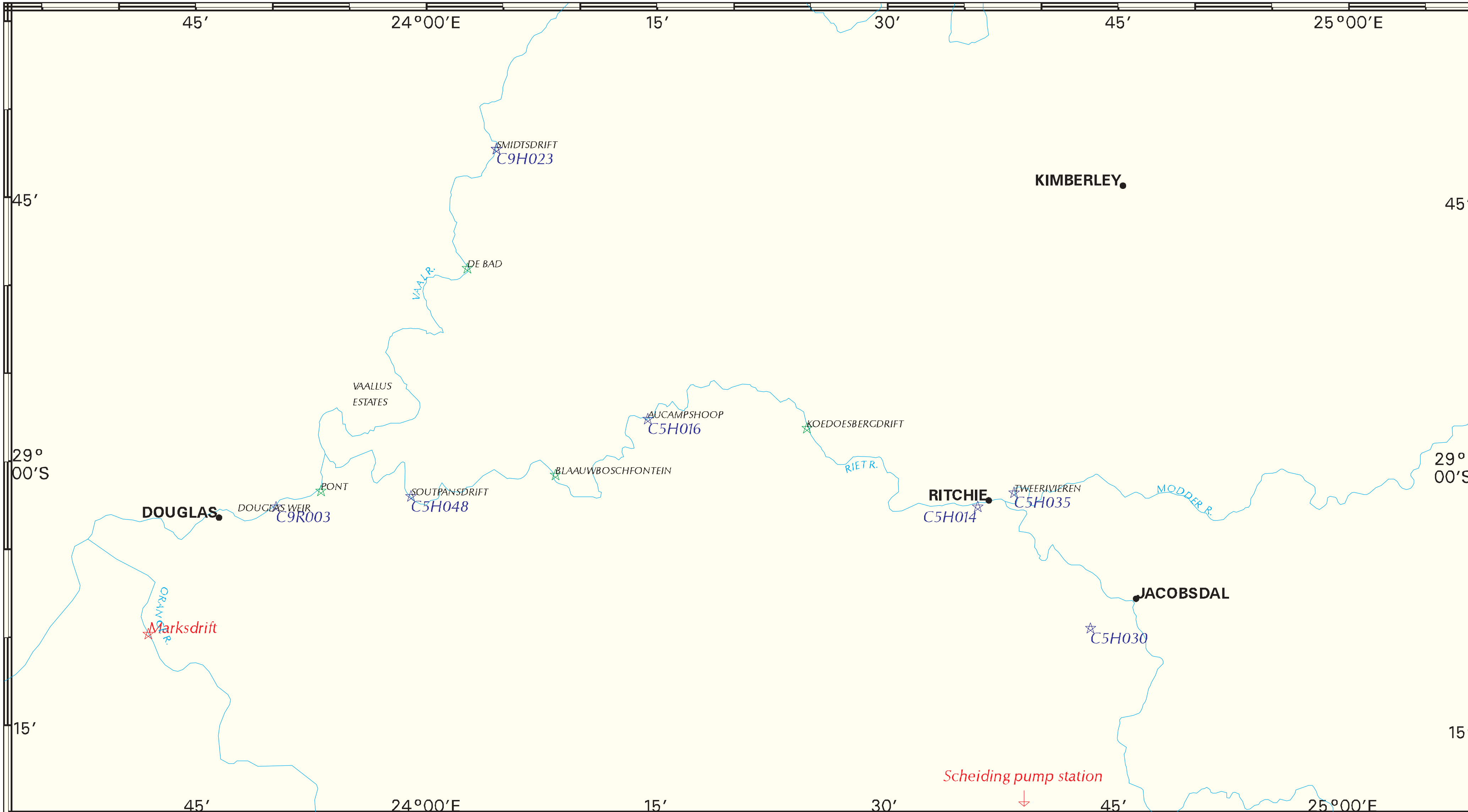
2.2 SYSTEM OPERATION

The Douglas Weir together with the Louis Bosman Canal, and the Orange-Riet Government Water Scheme (GWS) together with the Orange-Riet Canal are the two main water transfer and storage schemes in operation in the study area (Map 3). Both these schemes involve the pumping of Orange River water into canals and the transfer of this water to irrigators along the Vaal and Riet Rivers, respectively.

2.2.1 DOUGLAS WEIR

A weir structure to provide irrigation water was first built in the Vaal River upstream of Douglas in 1896. To increase storage capacity this wall was replaced by a higher structure in 1976. The Douglas Weir currently has a full supply capacity of 16.7 million m^3 and extends upstream from the weir structure along the Vaal River as far as the farm De Bad. Prior to 1984 the Weir was supplied by water released from the Bloemhof Dam. However, as a result of the decreasing quality of water in the Vaal River and the introduction of severe water restrictions during the drought of the early 1980's an emergency canal was built to transfer water from Marksdrift on the Orange River, to the Douglas Weir. This canal, later called the Louis Bosman Canal, was completed in 1984 and has a peak capacity of $7m^3/s$ (Map 3). Although originally unlined, the concrete lining of the canal was started in 1994. From Marksdrift the water is pumped with a vertical head of 39m into the 22km long canal which discharges into the Douglas Weir just upstream of the weir structure. The Bloemhof Dam is currently operated in such a manner that as little water as possible enters the Douglas Weir via the Vaal River, and all water demands are met from the Orange River.

The Louis Bosman Canal is managed by the Douglas Irrigation Board. This board regulates the amount of water transferred to farmers along the Douglas Weir and the Riet River downstream of Soutpansdrift, as well as the areas along the Vaal River downstream of the Douglas Weir served by the Bucklands and Atherton Canals (Map 3). The Bucklands canal transports water for 24km to irrigators on the southern bank of the Vaal River, while the Atherton canal transports water to irrigators on the northern bank of the Vaal River. To prevent supply problems along these sections of the Vaal River the Douglas Weir must be operated at not less than 1.1m below full supply level.



KEY

- Rivers
- Towns
- C5H014 - DWAF gauging points
- Pump stations

MAP 2

THE DOUGLAS WEIR AND RIET RIVER STUDY AREA EXTENDING ALONG THE VAAL RIVER FROM THE ORANGE-VAAL CONFLUENCE TO THE FARM DE BAD AND ALONG THE RIET RIVER DOWNSTREAM OF JACOBSDAL. THE MARKSDRIFT AND SCHEIDING PUMP STATIONS ON THE ORANGE RIVER ARE ALSO INDICATED

0 5 10 15 20 km

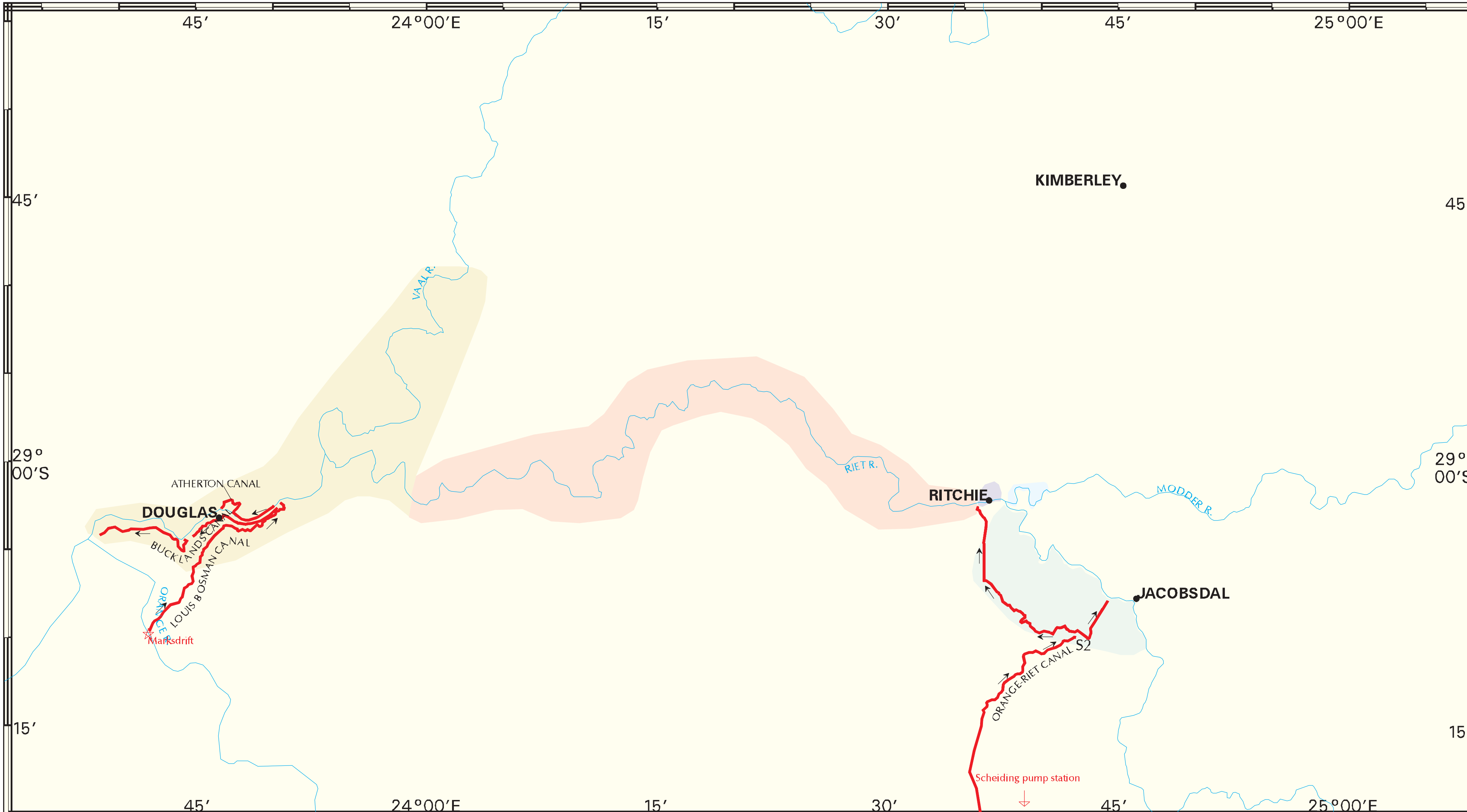
2.2.2 ORANGE-RIET GOVERNMENT WATER SCHEME

The Kalkfontein Dam, on the Riet River, was completed in 1938 for the purpose of supplying water via canal to the farmers downstream of the dam, including the Riet River Settlement, the Ritchie Irrigation District, the Scholtzburg Irrigation District, as well as potable water for the towns of Jacobsdal and Koffiefontein.

However, the dam proved unable to supply the full irrigation requirements of the existing scheduled areas, and thus the building of the Orange-Riet Canal was started in 1983, to transfer water from the Vanderkloof Dam on the Orange River. This water is pumped with a head of 49m at the Scheiding pump station into the Orange-Riet Canal from where it is transferred 112km to a balancing dam located near Jacobsdal (Map 3). This canal has a capacity of $16m^3/s$ for the first 73 km and 13 m^3/s for the remainder of the distance. From the balancing dam the water is distributed to the farmers of the Riet River Settlement and the Scholtzburg and Ritchie Irrigation Districts (Map 3) via a network of smaller canals. Water is also supplied to the Lower Riet Irrigation Board, which includes all the farmers along the Riet River downstream of Ritchie as far as the weir at Soutpansdrift, by direct releases of Orange River water from the canal and the balancing dam into a drainage canal which discharges into the Riet River. Only sufficient water is pumped to meet the demands of these farmers so that spills over Soutpansdrift are minimised.

2.3 CONCLUSIONS

Both the Orange-Riet and Douglas Weir irrigation schemes are operated to minimise pumping costs and water wastage. Inflows and spillages are kept to a minimum and under normal operating conditions these areas are dependent on imported water from the Orange River. Both schemes are, therefore, operated as closed systems. While water is consumed within the system, the salts carried in this water are returned to the rivers in irrigation return flows. This leads to a build up of salts in some parts of these systems and salinities of up to 1400mg/l have been recorded. When these schemes were first planned it was envisaged that occasional floods would wash these salts from the system (WP C-86).



KEY	
	Rivers
	Main canals
☆	Pump stations
→	Direction of flow of Orange River water

0 5 10 15 20 km

MAP 3

IRRIGATION BOARDS AND MAIN CANALS OF THE DOUGLAS WEIR AND RIET RIVER STUDY AREA

IRRIGATION DISTRICTS

- RIET RIVER SETTLEMENT
- SCHOLTZBURG IRRIGATION DISTRICT
- RITCHIE IRRIGATION DISTRICT
- LOWER RIET RIVER IRRIG. DISTRICT
- DOUGLAS IRRIGATION DISTRICT

3 WATER USERS

3.1 INTRODUCTION

Water quality must be evaluated in terms of the intended use of the water. The Department of Water Affairs and Forestry recognises four categories of water use (in addition to the aquatic ecosystem, which forms part of the resource):

- Domestic - drinking water and household use
- Industrial - industrial process use
- Agriculture - irrigation and livestock watering
- Recreation - non-consumptive use of water bodies for contact and non-contact recreation

The original brief given to the Institute for Water Quality Studies was to investigate water quality problems associated with irrigation use. However, all the user categories listed above are represented within the study area (Map 4) and are briefly discussed in the following sections.

3.2 DOMESTIC

Urban areas falling within the study area are the towns of Douglas, Ritchie, Modderrivier and Jacobsdal (Map 4). Prior to 1994 Douglas abstracted water for domestic use from the Bucklands canal. However, since then water has been obtained from the Louis Bosman Canal. Water use in Douglas in 1988 was estimated at 900 000m^3/a.

Jacobsdal obtains most of its water for domestic use from boreholes, although some water is obtained from the Kalkfontein canal for small-scale irrigation. The annual consumption from groundwater sources for 1985 was estimated at 56 250m^3 with an estimated increase of 2.5% p.a. It is expected that the groundwater sources will be sufficient to support this increase. Effluent return flows from Jacobsdal are discharged into the veld and not directly into the river system.

Domestic water for Ritchie is supplied from boreholes and releases into the Riet River from the Orange-Riet Canal. In 1985 the average annual water use for the town was estimated at approximately 240 000m^3/year. Effluent is treated in an oxidation dam and there is no return flow from the town to the Riet River.

Domestic users, therefore, neither discharge into the river system, nor abstract from it. As such, they do not impact on irrigation users, nor are affected by irrigation return flows, and do not need to be considered further in this study.

3.3 RECREATION

The Louis de Jager holiday resort (Map 4) is situated on the left bank of the Douglas Weir about 1km upstream of the Weir structure. The resort hosts angling competitions as well as being used for casual fishing and boating. This is the only formal recreational area along this stretch of the Vaal River, although many of the farmers living further upstream along the banks of the Vaal River have built boathouses and/or weekend homes from which they can enjoy fishing and other water sports. However, the impact of salinity on recreational uses such as angling will not be included in this study.

3.4 INDUSTRIAL

Industrial activity in the study area is minimal and in no way affects the quality of the water in the main rivers. Some wine is produced at Jacobsdal and Douglas, but the water used is neither abstracted from, nor returned to, the Riet River or the Douglas Weir. There is also a small diamond mine located at Koedoesbergdrift on the Riet River (Map 4) which uses river water for gravel washing. This use, also, is not affected by salinity and is excluded from this study.

3.5 LIVESTOCK WATERING

Limited livestock farming takes place within the study area. Where it does occur, groundwater sources are mostly used to provide water, and this water use can, therefore, also be excluded from this study.

3.6 IRRIGATION

As a result of the low mean annual precipitation of the area (< 400mm/a) there is no dryland cultivation of crops and irrigation is by far the largest user of water in the area (Map 4).

3.6.1 WATER VOLUMES

Farmers of the Riet River Settlement, abstracting water from the canal network supplied by the Orange-Riet Canal, use some 31% of the total irrigation water supplied, or approximately 40.3 million m^3/a. Irrigators abstracting directly from the Riet River between Jacobsdal and Soutpansdrift use approximately 28%, or some 37 million m^3/a. The remaining 41% (53.5 million m^3/a) is supplied from the Louis Bosman Canal, administered by the Douglas Irrigation Board. This includes farmers living along the Vaal River as far upstream as the farm De Bad, farmers abstracting from the Riet River downstream of the Soutpansdrift weir (the Riet River Arm of the Douglas Weir), and abstractions from the Bucklands and Atherton canals. Farmers along the Riet River Arm use approximately $11x10^6$ m^3/year.

3.6.2 IRRIGATION TYPE

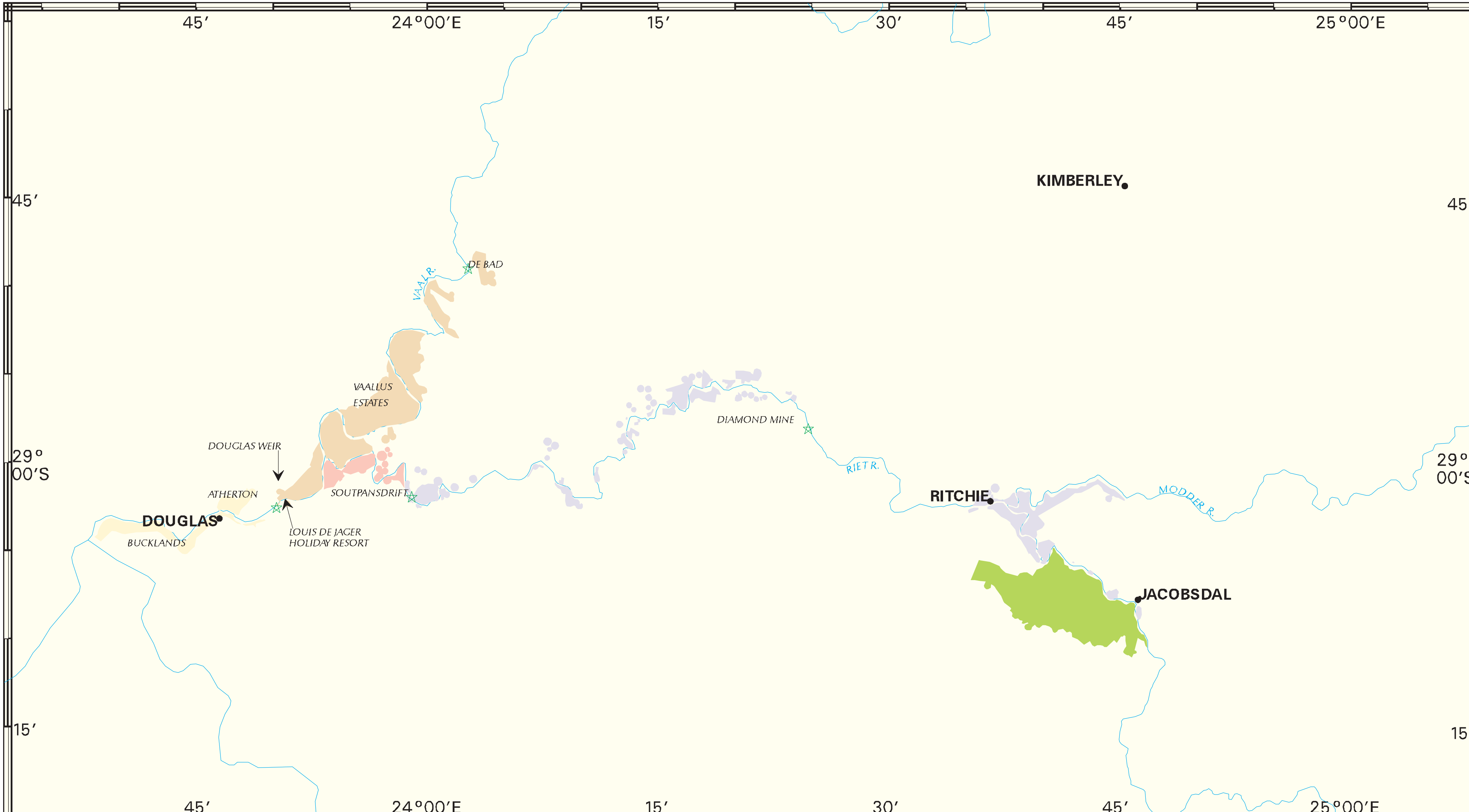
Some 65% of the Douglas Weir area is irrigated by overhead irrigation and the remaining 35% by flood irrigation. Along the Riet River, however, flood irrigation is more common than overhead irrigation.

3.6.3 AREAS UNDER IRRIGATION

The total area under irrigation in the study area covers about 24500ha, and can be roughly divided into a number of sections based on the source of irrigation water (Table1 and Map 4).

Table 1: River sections as identified according to water source and quality (see Map 4)

NAME	DESCRIPTION	WATER SOURCE	% OF TOTAL AREA UNDER IRRIGATION
RIET RIVER SETTLEMENT	Includes the farmers of the Riet River Settlement, Ritchie Irrigation District and the Scholtzburg Irrigation District	Canals of the Orange-Riet Government Water Scheme (GWS) provided from a balancing dam at the end of the Orange-Riet Canal.	31%
RIET RIVER	The Riet River extending from Jacobsdal to Soutpansdrift	Orange-Riet Canal water released into the Riet River	22%
RIET RIVER ARM	The Riet River extending from Soutpansdrift to the confluence of the Riet and Vaal rivers	Riet River downstream of Soutpansdrift, extending into Douglas Weir and supplied by the Louis Bosman Canal	5%
BUCKLANDS + ATHERTON	The area along the Vaal River downstream of Douglas Weir	Louis Bosman Canal water via the Bucklands and Atherton canals	7%
DOUGLAS WEIR BASIN	The section extending upstream along the Vaal River from the wall of the Douglas Weir to the farm De Bad.	Abstractions from the Douglas Weir basin supplied from the Louis Bosman Canal	35%
		TOTAL AREA UNDER IRRIGATION	24453ha



KEY	IRRIGATION SECTIONS
Rivers	BUCKLANDS AND ATHERTON
Towns	DOUGLAS WEIR BASIN
	RIET RIVER SETTLEMENT
	RIET RIVER
	RIET RIVER ARM

MAP 4

WATER USERS AND IRRIGATION SECTIONS IN THE DOUGLAS WEIR AND RIET RIVER STUDY AREA

N

0 5 10 15 20 km

The farmers in the Riet River Settlement and along the Riet River between Jacobsdal and Soutpansdrift receive irrigation water via the Orange-Riet Canal, while requirements for the Douglas Weir Basin, Bucklands and Atherton, and the Lower Riet River Arm sections are provided from the Louis Bosman Canal. The largest single irrigated area lies within the Riet River Settlement (31%) which receives Orange-River water from the "S2" balancing dam. Water is also released into the Riet River to provide the 5400ha (22%) of irrigation along the Riet River.

Irrigators receiving water from the Louis Bosman Canal make up some 11500ha, or 47%, of the total irrigated area (Table 1). Of these areas almost 6000ha are located in the Vaallus and De Bad areas (Map 4).

3.6.4 CROP TYPES

Wheat is the most common crop (Table 2) grown in the study area covering more than 50% of the irrigated area in all the sections, with the exception of the Riet River Settlement. Maize and lucerne are the next most common crops, followed by peanuts and potatoes (Table 2). The Bucklands and Atherton section is made up of mostly smaller plots than the other sections, but crops such as wheat, lucerne and maize remain most common.

> NOTE:
> The percentages in Table 2 are based on crop surveys undertaken in 1993 and 1994 and may vary slightly between different years. They do not add up to 100% for each section because not the whole section is planted at one time, while some fields may be planted twice - to different crops at different times of the year. This table thus represents only the relative occurance of each crop in each section.

Table 2: Percent of river section cultivated - according to crop type

	(%) AREA							
CROP TYPE	**RIET RIV. SET.**	**RITCHIE TO SOUTPANS-DRIFT**	**LOWER RIET ARM**	**DOUGLAS TO VAALLUS**	**VAALLUS**	**VAALLUS - DE BAD**	**BUCKLANDS + ATHERTON**	**% of TOTAL (24453ha)**
Carrot						9%		0.5%
Bean	3.5%	1%		0.8%	1.1%		2%	2%
Onion	0.5%			3.6%	1.6%	4.9%		0.7%
Vegetables	2%	5%						2%
Sweet						0.5%		0.02%
Grape	1.5 %		1.4%	0.4%	2.8%	0.2%	13%	1.7%
Sunflower	0.09%			2.1%	15%	1.8%		1.5%
Fruit	0.07%							0.02%
Potato	4%	4%	4.7%	8.3%	5.5%	13%		4.2%
Maize	14.5%	20%	18.5%	25.1%	13.1%	21.9%	13%	15.5%
Pumpkin + Watermelon					0.5%	2.3%		0.16%
Pasture				0.3%	2.1%	0.2%		0.2%
Rye Grass						1.8%		0.09%
Lucerne	23%	9%	26.2%	13%	6.7%	8.3%	25%	14.8%
Peanut	12%	2%	6.7%	6.1%		9.6%		6.1%
Soyabean				1.6%	3.7%	0.1%		0.4%
Oats	1%			0.9%		0.4%		0.5%
Wheat	36.5%	55%	50.1%	63.2%	64%	55.5%	65.6%	44.4%
Cotton	1%	3%	0.1%		5.7%			1.7%

3.7 CONCLUSIONS

Whilst all the recognised water users are represented in the study area, only the irrigation users abstract from the Riet River and the Douglas Weir and are, therefore, the only users to be affected by the salinity of this water. The Riet River Settlement is the largest section under irrigation making up 31% of the study area. A further 22% of the area is irrigated along the Riet River as far as Soutpansdrift, and the remainder of the study area is irrigated out of the Douglas Weir basin. Wheat is the most common crop in all sections, although to a lesser extent in the Riet River Settlement.

4. WATER QUALITY IN THE ORANGE-RIET AND DOUGLAS WEIR IRRIGATION SYSTEMS

4.1 INTRODUCTION

Water quality is assessed by comparing guidelines to measured concentrations in the water supplied. These guidelines link some impact to the user, for example crop yield reduction, to a given concentration range. Although generalised South African water quality guidelines for irrigation are available, the quality of water required for irrigation depends on the crop being irrigated, the type of irrigation used and the suitability of the soil for irrigation. Farm management practices such as drainage and gypsum applications will also impact on guidelines for irrigation. The South African Water Quality Guidelines therefore recommend that site specific guidelines be formulated. This chapter describes the formulation of site-specific water quality guidelines for the Orange-Riet and Douglas Weir irrigation areas. These guidelines are based on the soils, the required leaching fractions and the crop types present. The existing farm management practices were also taken into account. The existing water quality of the study area is then characterised in terms of these guidelines.

4.2 ESTABLISHING SITE SPECIFIC WATER QUALITY GUIDELINES

The most important water quality constituents in terms of irrigation are: salinity (indicated by electrical conductivity - EC), sodium adsorption ratio (SAR), chloride, sodium and boron. Since no industrial or domestic effluent enters the rivers within the study area water quality problems related to factors other than irrigation return flows are not expected. Site specific guidelines were, therefore, only established for the constituents affecting irrigation. These guidelines were based on the soil characteristics, such as clay content and leaching fraction, and the crop types being irrigated in the area. This part of the study, conducted by the Institute for Soil, Climate and Water (ISCW), is reported on in full in Appendix A.

4.2.1 SOIL CLASSES

The soils in the area were classified according to suitability for irrigation using soil surveys done in the late 1980's and soil samples collected in 1994. The higher the clay content of the soil, the poorer the drainage and thus the higher the soil water salt content. Three main classes were identified:

- **Class 1** - Soils highly suited to irrigation, consisting of soil types that are well drained and have a 10-25% clay content. There is very little, if any, accumulation of salts in these soils and soil water salinity is low (Table 3). As a result of the good drainage, crops grown on these soils can tolerate higher salt concentrations in the irrigation water;
- **Class 2** - Soils moderately suited to irrigation, consisting of soil types made up of 15-35% clay with moderate internal drainage and soil water salt concentrations are higher than those of class 1 (Table 3);
- **Class 3** - Soils poorly suited to irrigation, having poor internal drainage and consisting of 35-55% clay. Salts, therefore, tend to accumulate in these soils and soil water EC is high (Table 3). The poor drainage will cause crops grown on these soils to display the highest yield losses as result of salt in the irrigation water.

The sampled soils in class 1, which have a median clay content of 5% - 8%, have a median soil water EC of 68mS/m (in 1994), while soils in class 3 have a median clay content of 32% - 45%, and a median soil water EC of 120mS/m (Table 3).

Table 3: Median clay content (%) and Electrical Conductivity (mS/m) of soil samples taken in the late 1980's and 1994

		DEPTH (mm)	CLASS 1	CLASS 2	CLASS 3
MEDIAN CLAY CONTENT 1994		0-300	5	22	32
		300-800	8	27	45
MEDIAN EC	1986 - 1989	0-300	110	234	370
		300-800	115	198	302
	1994	0-300	68	69	120
		300-800	70	56	179

Comparison of the soil survey data from the late 1980's to that obtained in 1994 has shown that, contrary to the expectations of local residents and previous studies, no long term accumulation of salts is evident (Table 3). Soils in class 1 had a median soil water EC of 110mS/m in the upper 30cm in the late 1980's, and a median of only 68mS/m in 1994. Similarly, class 2 soils had a soil water EC of 234mS/m in the 1980's and 69mS/m in 1994; and class 3 soils 370mS/m and 120mS/m, respectively. This reduction is due to either over-irrigation and the subsequent leaching of salts out of the soils, or occasional heavy rains washing any accumulated salts out of the soils.

Fifty-four percent of the entire area under irrigation is situated on good (class 1) soils, whilst 12% is on medium (class 2) soils and 34% on poor (class 3) soils (Table 4). However, these soils are not evenly distributed throughout the system (Map 5). The Riet River Settlement is dominated by good soils (81%) while the soils along the Riet River are of mostly poorly (47%) and moderately (30%) suited for irrigation. Irrigation along the Riet River Arm is situated on predominantly medium (53%) and some poor soils (4%), while as much as 72% of the Bucklands and Atherton section is on poor soils. Although only 43% of the farms along the Douglas Weir Basin are irrigating poor and medium soils, two-thirds of the Vaallus Estates are situated on poor soils (Map 5) and 55% of the good soils in the Basin are situated across or upstream of the Vaallus Estates (Map 5).

Table 4: Percentage of the irrigated area on each soil class, according to river sections

SOIL CLASS	RIET RIV. SET.	RIET RIVER	RIET RIVER ARM	BUCKLANDS + ATHERTON	DOUGLAS WEIR BASIN	TOTAL %(ha)
GOOD	64%	36%	43%	23%	57%	54% (13192)
MEDIUM	10%	28%	53%	5%	3%	12% (2937)
POOR	26%	36%	4%	72%	40%	34% (8324)
TOTAL (ha)	7619	5297	1317	1745	8457	24453

4.2.2 IRRIGATION TYPE AND LEACHING FRACTION

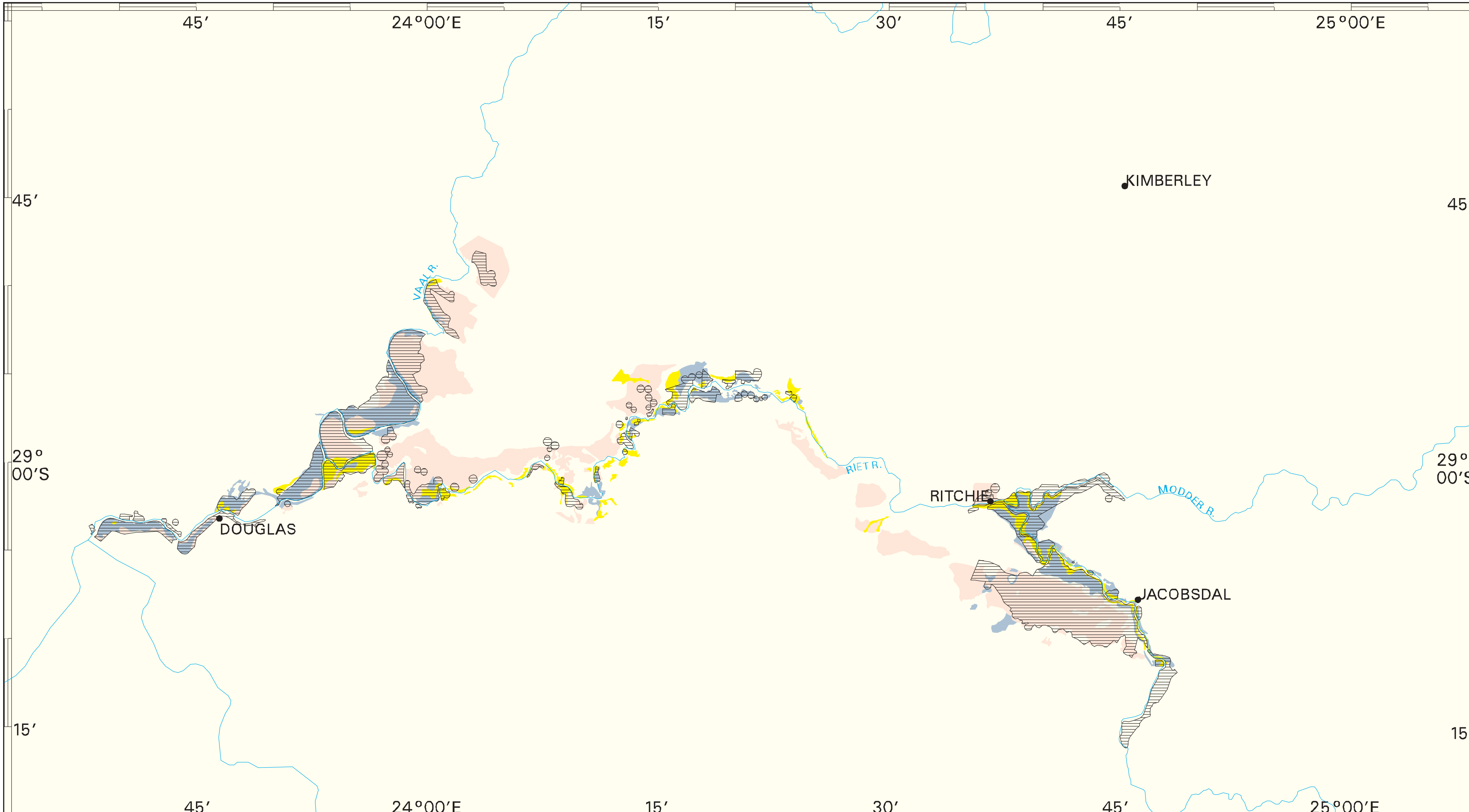
Some 65% of the Douglas Weir area is irrigated by overhead irrigation and the remaining 35% by flood irrigation. In the Riet River area, however, flood irrigation is more common than overhead irrigation.

The leaching fractions feasible for the different soils will vary according to clay content. Leaching fractions of 20% for the good soils, 15% for medium soils and 10% for the poor soils, were considered realistic and were assumed when establishing the site specific water quality guidelines.

No drainage management practices were noted on any of the farms visited. However, this is possibly due to the fact that the good soils are so well drained that artificial drainage is unnecessary, while the poor soils have such a high clay content that drainage pipes would have to be too close together to be economically viable. The area is also very flat, and this may limit water drainage towards drainage canals. Furthermore, even on good soils isolated patches have been observed where the water table has been raised due to the drainage being blocked by subsoil structures.

4.2.3 CROP TYPES AND SALINITY TOLERANCE

Plants absorb water from the soil leaving behind most of the salts that were present. This concentrates the salt in the soil water and the plants must then take up water against an increasing osmotic gradient. High salt concentrations in the irrigation water will increase this effect, influencing crop yield in a way similar to drought. Excess salts can be leached out of the soil by irrigating with more water than the crop requirements and these salts return to the river with the irrigation return flows. However, soils with high clay content and, hence, poor leaching characteristics, will inhibit this process of salt removal.



KEY	SOIL CLASS
Rivers	Good
Towns	Medium
Irrigated areas	Poor

MAP 5

IRRIGATION POTENTIAL OF SOILS IN THE IRRIGATED AREAS OF THE DOUGLAS WEIR AND RIET RIVER STUDY AREA

0 5 10 15 20 km

Crops differ in the amount of salt they can tolerate in irrigation water and this tolerance is also affected by the characteristics of the soil in which the crop is grown. The EC of the irrigation water at which each of the crops identified in the study area can be expected to have no yield loss can, therefore, be calculated for each of the three soil classes identified, assuming the leaching fractions indicated in section 4.2.2. Crops can, furthermore, be classified according to their salinity tolerance (Table 5) and the characterisation of the quality of the irrigation water in each section of the study area is based on these salinity tolerance classifications.

Table 5: Common crops grown in the Douglas Weir, Lower Riet River study area, classified according to salt tolerance

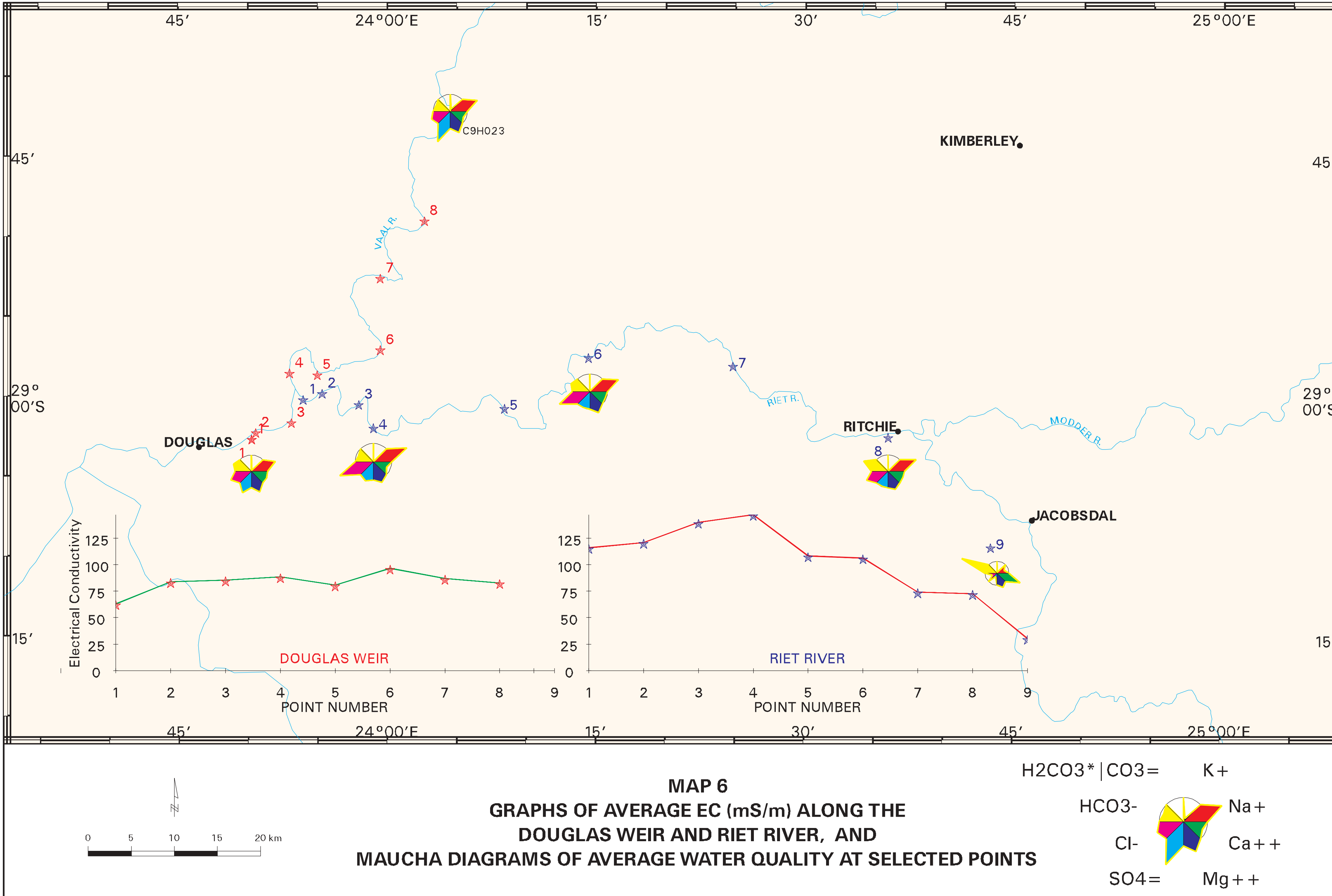
CROP	SALT TOLERANCE
carrot bean onion	**SENSITIVE**
sunflower peach grape sweet potato potato maize cabbage pumpkin watermelon lucerne spinach cucumber tomato broccoli peanut	**MODERATELY SENSITIVE**
beetroot squash soyabean	**MODERATELY TOLERANT**
wheat cotton	**TOLERANT**

4.3 WATER QUALITY OVERVIEW

The existing water quality of the irrigation water was assessed using data from registered DWAF sampling points, as well as data collected by the Douglas Irrigation Board and the Orange-Riet Government Water Scheme, and from a monitoring program initiated specifically for this study.

The salinity of the Orange River water entering the Riet River system is low, with an average EC of 22 (point no. 9 on Map 6), but irrigation return flows lead to increasing salinity and EC increases downstream of Jacobsdal reaching the highest values in the Riet River Arm of the Douglas Weir (see points no. 1,2,3 and 4 on Map 6). Average EC values in the Douglas Weir are fairly constant, but increase slightly in the Vaallus region (point no. 6 on Map 6).

Water from the Orange River entering the Riet River and the Douglas Weir via the Orange-Riet (point no. 9 on Map 6) and Louis Bosman Canals is dominated by calcium (Ca) and carbonate (CO_3) ions, while the industrial and mining effluents from higher upstream in the Vaal River produce water dominated by the sulphate (SO_4) ion (C9H023 on Map 6). When the water is used for irrigation the calcium and carbonate ions tend to be held back in the soils. However, the sodium and chloride ions are more mobile and are, thus, typically, the most common ions in irrigation return flows. As a result of this the water in the Riet River is increasingly sodium chloride (NaCl) dominated downstream, as the volume of return flows becomes larger. Boron concentrations in the irrigation return flows are high, and boron concentrations are also highest in the lower reaches of the Riet River and in the region of Vaallus (section 4.4.4).



MAP 6
GRAPHS OF AVERAGE EC (mS/m) ALONG THE DOUGLAS WEIR AND RIET RIVER, AND MAUCHA DIAGRAMS OF AVERAGE WATER QUALITY AT SELECTED POINTS

4.4 CHARACTERISING THE WATER QUALITY

As indicated earlier, site specific water quality guidelines were established by combining the soil suitability classes, leaching fraction, type of irrigation and crop tolerance. These guidelines were established for the constituents affecting irrigation: salinity, sodium adsorption ratio (SAR), chloride, sodium and boron.

4.4.1 SALINITY

Salinity can be determined by measuring the EC of a solution which gives an indirect indication of the total dissolved salt (TDS) concentration in the solution. Tables 6 and 7 show the water quality guidelines for salinity for each soil class assuming no crop yield loss and 10% crop yield loss, respectively.

> Note:
> This only includes possible yield losses due to the quality of the irrigation water. Additional yield losses may occur due to other factors, eg. pests.

The measured EC of the irrigation water was compared to these guidelines and is presented diagramatically in Maps 7, 8 and 9 for salt sensitive, moderately sensitive and salt tolerant crops, depending on the class of the soil being irrigated. It was assumed that concentrations exceeding:

- the guideline for NO YIELD LOSS for **<u><= 5%</u>** of the time would produce **NO YIELD LOSS**;
- the guideline for NO YIELD LOSS for **<u>> 5%</u>** of the time, BUT, the guideline for 10% YIELD LOSS for **<u><= 5%</u>** of the time, would produce **SOME YIELD LOSS**;
- the guideline for 10% YIELD LOSS for **<u>> 5%</u>** of the time would produce **SUBSTANTIAL YIELD LOSS**.

Table 6: Salinity water quality guidelines of selected crops according to irrigation class (mS/m), which would result in **NO** crop yield loss

SALT TOLERANCE	CROP	SOIL CLASS		
		GOOD	MEDIUM	POOR
SENSITIVE	carrot	83	65	45
	bean	83	65	45
	onion	100	78	55
MODERATELY SENSITIVE	sunflower	142	110	77
	peach	142	111	77
	grape	125	98	68
	sweet potato	125	98	68
	potato	142	111	77
	maize	150	118	81
	cabbage	150	118	81
	pumpkin	158	124	86
	watermelon	163	127	88
	lucerne	167	130	91
	spinach	167	130	91
	cucumber	250	163	114
	tomato	208	163	114
	broccoli	223	183	127
	peanut	267	208	145
MODERATELY TOLERANT	beetroot	333	261	182
	squash	392	306	214
	soyabean	417	326	227
TOLERANT	wheat	500	391	273
	cotton	641	502	350

Table 7: Salinity water quality guidelines of selected crops according to irrigation class (mS/m), which would result in **10%** crop yield loss

SALT TOLERANCE	CROP	SOIL CLASS		
		GOOD	MEDIUM	POOR
SENSITIVE	carrot	142	111	77
	bean	125	98	68
	onion	150	117	81
MODERATELY SENSITIVE	sunflower	183	143	100
	peach	183	143	100
	grape	208	163	114
	sweet potato	200	157	109
	potato	208	163	114
	maize	208	163	114
	cabbage	233	183	127
	pumpkin	238	186	130
	watermelon	242	189	132
	lucerne	283	222	155
	spinach	275	215	150
	cucumber	275	215	150
	tomato	292	228	159
	broccoli	325	254	177
	peanut	333	261	182
MODERATELY TOLERANT	beetroot	425	333	193
	squash	483	378	220
	soyabean	458	359	208
TOLERANT	wheat	617	483	280
	cotton	800	626	363

4.4.1.1 Salt Sensitive Crops

Irrigators in the Riet River Settlement area who receive low salinity water directly from canals supplied from the Orange-Riet Canal will experience no problems with the cultivation of salt sensitive crops (using onions as an example), irrespective of the soil class (Map 7). Farmers along the Vaal River upstream of Vaallus will have no problems cultivating salt sensitive crops on good soils, but will experience some problems on medium soils and can expect substantial yield losses on poor soils (Map 7). Farmers of the Vaallus Estates, as well as those abstracting from the Riet River between Jacobsdal and Ritchie, can expect some losses cultivating salt sensitive crops on good soils and substantial losses on medium and poor soils (Map 7). The rest of the study area will experience substantial yield losses when cultivating salt sensitive crops, irrespective of the soil class.

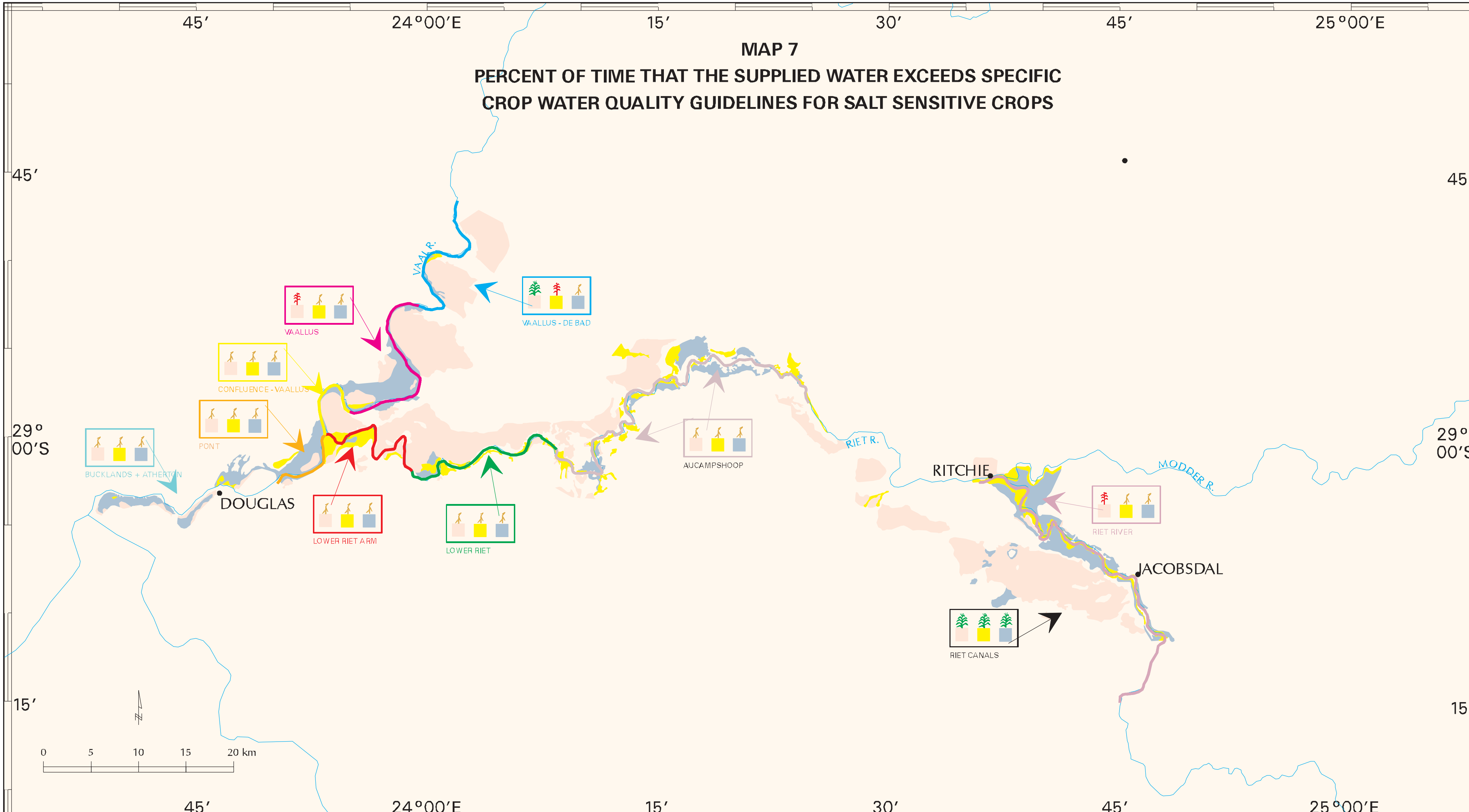
Forty-two percent of the study area will experience no problems with the cultivation of salt sensitive crops (Table 8). However, this is dominated by the Orange-Riet GWS which makes up a third of the entire area and the section of the Douglas Weir Basin upstream of Vaallus which is situated predominantly on good soils. Only 5% of the study area will have some yield loss, and the rest of the area will experience substantial yield loss if cultivating salt sensitive crops (Table 8). This includes 94% of the irrigated area along the Riet River between Jacobsdal and Soutpansdrift, 77% of the Bucklands and Atherton area, 59% of the area irrigated directly out of the Douglas Weir Basin and the entire Lower Riet Arm of the Douglas Weir (Table 8).

Table 8: Percent of area in each river section affected when water quality exceeds the guidelines for salt ***sensitive*** crops

EXCEEDANCE	RIET RIVER SETTLEMENT	RIET RIVER	RIET RIVER ARM	BUCKLANDS + ATHERTON	DOUGLAS WEIR BASIN	TOTAL % (ha)
No yield loss	100%	0%	0%	0%	31%	51% (12429)
Some yield loss	0%	0%	0%	0%	10%	4% (896)
Substantial yield loss	0%	100%	100%	100%	59%	45% (11128)

MAP 7

PERCENT OF TIME THAT THE SUPPLIED WATER EXCEEDS SPECIFIC CROP WATER QUALITY GUIDELINES FOR SALT SENSITIVE CROPS



SOIL IRRIGATION POTENTIAL

- Good
- Medium
- Poor

FREQUENCY OF GUIDELINE EXCEEDANCE

- No yield loss
- < 10% yield loss
- > 10% yield loss

RIVER SECTIONS

- Canals of the Orange-Riet Government Water Scheme
- Soutpansdrift to the Riet-Vaal confluence
- Lower Riet River up to Soutpansdrift
- Vaal River from Riet-Vaal confluence to the wall of Douglas Weir
- Orange-Riet Government Water Scheme - extracting from the Riet River
- Riet River from Koedoesberg Drift to Blaauwboschfontein
- Vaal River upstream of De Bad
- Vaallus area
- Vaal River from Riet-Vaal confluence to Vaallus
- Bucklands and Atherton canal areas

4.4.1.2 Moderately Salt Sensitive Crops

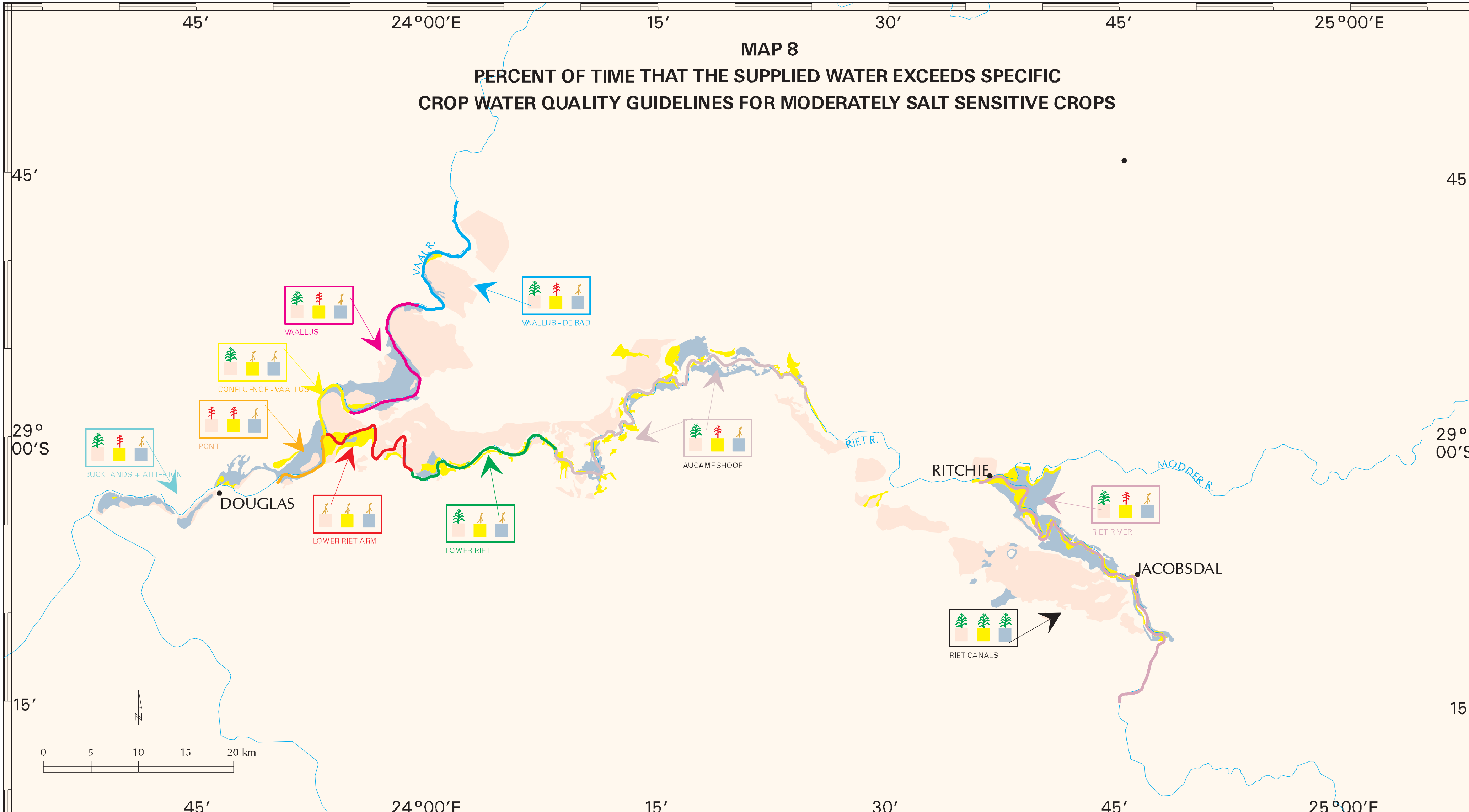
Moderately salt sensitive crops (using maize as an example), can be grown on good soils in almost all sections except the Riet River Arm, where substantial yield losses can be expected on all soil classes, and the section of the Vaal River downstream of the confluence with the Riet River where some yield loss can be expected on good soils. Farmers cultivating moderately sensitive crops on poor soils, however, will experience substantial yield losses in all areas, except those abstracting from the canals supplying the Riet River Settlement.

Only 36% of the study area can expect substantial yield losses when cultivating moderately sensitive crops, but this includes 72% of the Bucklands and Atherton area (which is on predominantly poor soils), and the entire Riet River Arm of the Douglas Weir (Table 9). It also includes the two-thirds of the Vaallus Estates which are on poor soils (Map 8).

Table 9: Percent of area in each river section affected when water quality exceeds the guidelines for ***moderately salt sensitive*** crops

EXCEEDANCE	RIET RIVER SETTLEMENT	RIET RIVER	RIET RIVER ARM	BUCKLANDS + ATHERTON	DOUGLAS WEIR BASIN	TOTAL % (ha)
No yield loss	100%	36%	0%	23%	54%	65% (15950)
Some yield loss	0%	20%	0%	5%	4%	4% (1040)
Substantial yield loss	0%	44%	100%	72%	42%	31% (7463)

MAP 8
PERCENT OF TIME THAT THE SUPPLIED WATER EXCEEDS SPECIFIC CROP WATER QUALITY GUIDELINES FOR MODERATELY SALT SENSITIVE CROPS



SOIL IRRIGATION POTENTIAL	FREQUENCY OF GUIDELINE EXCEEDANCE	RIVER SECTIONS		
Good	No yield loss	Canals of the Orange-Riet Government Water Scheme	Vaal River from Riet-Vaal confluence to the wall of Douglas Weir	Vaal River upstream of De Bad
Medium	< 10% yield loss	Soutpansdrift to the Riet-Vaal confluence	Orange-Riet Government Water Scheme - extracting from the Riet River	Vaallus area
Poor	> 10% yield loss	Lower Riet River up to Soutpansdrift	Riet River from Koedoesberg Drift to Blaauwboschfontein	Vaal River from Riet-Vaal confluence to Vaallus
				Bucklands and Atherton canal areas

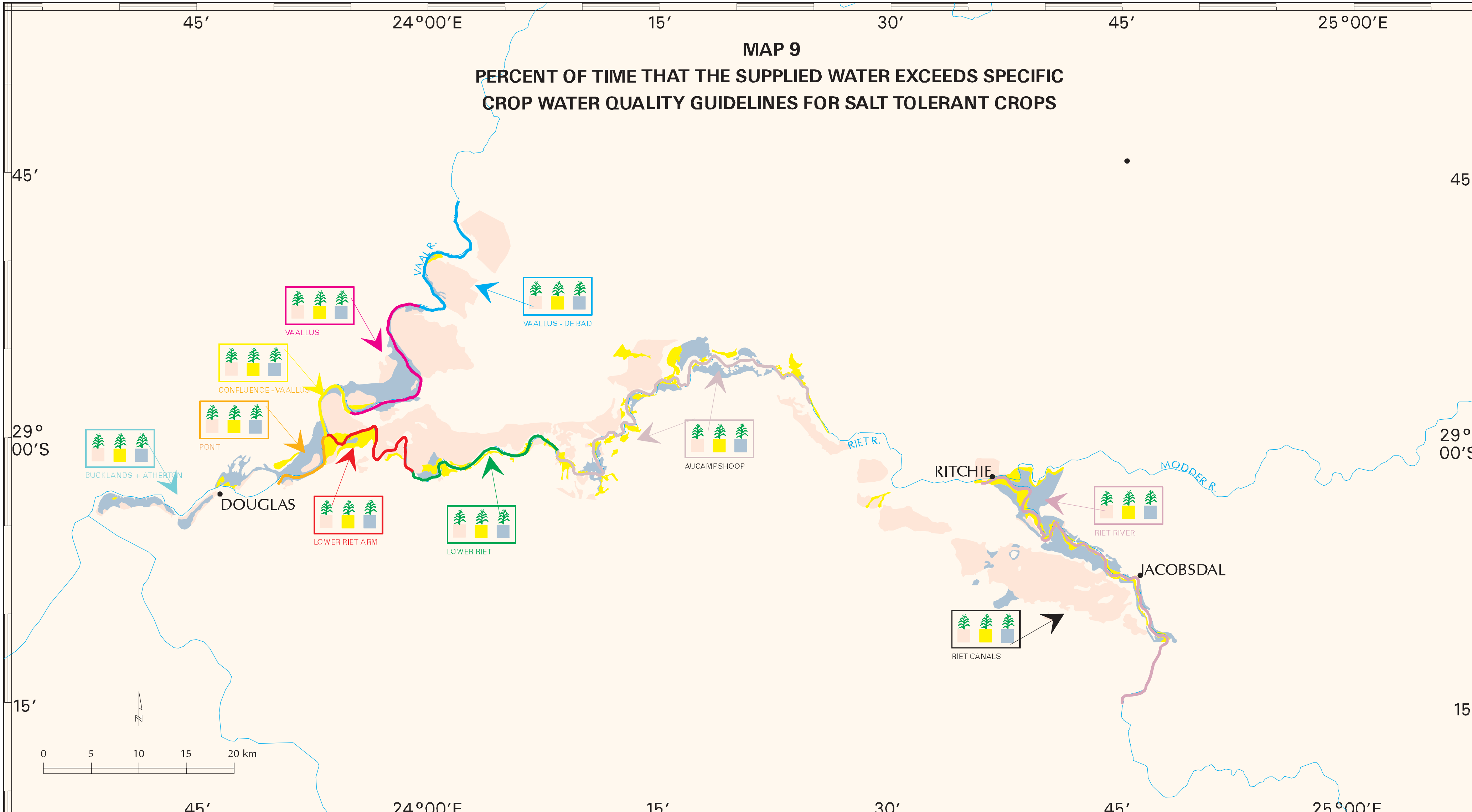
4.4.1.3 Salt Tolerant Crops

No salinity associated yield losses are expected for salt tolerant crops (using wheat as an example), on any of the soil classes, in any part of the study area (Map 9 and Table 10). The entire study area, therefore, is suitable for the cultivation of salt tolerant crops (Table 10).

Table 10: Percent of area in each river section affected when water quality exceeds the guidelines for salt ***tolerant*** crops

EXCEEDANCE	RIET RIVER SETTLEMENT	RIET RIVER	RIET RIVER ARM	BUCKLANDS + ATHERTON	DOUGLAS WEIR BASIN	TOTAL % (ha)
No yield loss	100%	100%	100%	100%	100%	100% (24453)
Some yield loss	0%	0%	0%	0%	0%	
Substantial yield loss	0%	0%	0%	0%	0%	

MAP 9
PERCENT OF TIME THAT THE SUPPLIED WATER EXCEEDS SPECIFIC CROP WATER QUALITY GUIDELINES FOR SALT TOLERANT CROPS



SOIL IRRIGATION POTENTIAL	FREQUENCY OF GUIDELINE EXCEEDANCE
Good	No yield loss
Medium	< 10% yield loss
Poor	> 10% yield loss

RIVER SECTIONS

- Canals of the Orange-Riet Government Water Scheme
- Soutpansdrift to the Riet-Vaal confluence
- Lower Riet River up to Soutpansdrift
- Vaal River from Riet-Vaal confluence to the wall of Douglas Weir
- Orange-Riet Government Water Scheme - extracting from the Riet River
- Riet River from Koedoesberg Drift to Blaauwboschfontein
- Vaal River upstream of De Bad
- Vaallus area
- Vaal River from Riet-Vaal confluence to Vaallus
- Bucklands and Atherton canal areas

4.4.2 SODIUM

The application of sodic (sodium-rich) water to soil reduces the permeability of the soil and affects its structural stability. The sodium adsorption ratio (SAR) is calculated from the concentration of sodium, calcium and magnesium in the water and is an index of the potential of the water to induce sodic soil conditions. There is very little in the available literature concerning crop specific effects of SAR. Crops having problems with salinity, in general, can be expected to also experience problems at high sodium levels; however, the effects of sodium can be detected more in terms of soil problems. General guidelines are presented in Table 11.

Table 11: Guideline for SAR in irrigation water according to the SA Water Quality Guidelines (DWAF, 1993)

SAR range (mmol/ℓ)$^{0.5}$	**EFFECT**
SAR 0 - 1.5	Should ensure an adequate infiltration rate for soils sensitive to the formation of infiltration rate reducing surface seals under conditions of rainfall during the irrigation season. It could be assumed with a high degree of certainty that the limits imposed by infiltration rate measurements would also satisfy the requirements of hydraulic conductivity (HC)
SAR 1.5 - 3.0	Should ensure an adequate infiltration rate for soils moderately sensitive to the formation of infiltration rate reducing surface seals under conditions of rainfall during the irrigation season
SAR 3.0 - 5.0	Soil amelioration by surface applications of easily dissolvable gypsum (at rates of about 5 ton per hectare) should decrease the formation of infiltration rate reducing surface seals and ensure adequate infiltration rate for sensitive soils when subjected to rain
SAR 5.0 - 10.0	Increasing difficulty is experienced in maintaining infiltration rate through soil amelioration. At ESP's exceeding 10 on sensitive soils, infiltration rate cannot be maintained with chemical amelioration measures alone

SAR has been calculated at selected points in the study area (Table 12). SAR in the lower part of the Riet River, at Soutpansdrift, and in the Riet River Arm are high enough to cause soil problems (Table 12), but gypsum application should ensure adequate infiltration rates. Minor problems may occur along the Riet River between Ritchie and Soutpansdrift, and in the Vaallus area (Table 12).

Table 12: Average SAR calculated for selected points in the study area

	SAR
ORANGE-RIET CANAL 2/3/94-29/11/94	1.27
TWEERIVIERE (C5H035) 18/1/93-1/11/93	1.2
RITCHIE WEIR (C5H014) 8/2/93-1/11/93	2.4
SOUTPANSDRIFT (C5H048) 10/8/90-21/10/93	**3.7**
DOUGLAS WEIR (C9R003) 7/2/83-21/10/93	1.7
VAALLUS AREA 24/2/94-17/8/94	2.41

4.4.3 CHLORIDE

Chlorides can be taken up by plant roots together with the soil water from where they are transported to finally accumulate in the leaves. If this concentration exceeds the tolerance of the crop it can result in leaf burn. Absorption of chlorides can also take place through the leaves and overhead irrigation using water high in chloride concentration can cause further damage to the leaves. Chloride guidelines for the crops grown in the study area are presented in Table 13, acccording to the irrigation class of the soil. Average chloride concentrations measured at selected points in the study area are shown in Table 14. Soutpansdrift (representing the lower part of the Riet River and the Riet River Arm) has the highest levels, exceeding the guidelines for sensitive crops on medium and poor soils, and some moderately sensitive crops on poor soils. However, no chloride associated problems can be expected in other parts of the study area.

Table 13: Chloride water quality guidelines of selected crops, by irrigation class (mg/l)

CROP TYPE	SOIL CLASS		
	GOOD	MEDIUM	POOR
Carrot	296	232	161
Bean	296	232	161
Onion	296	232	161
Sweet potato	444	347	242
Peach	444	347	242
Potato	444	347	242
Maize	444	347	242
Cabbage	444	347	242
Grape	592	463	323
Sunflower	592	463	323
Watermelon	592	463	323
Lucerne	592	463	323
Spinach	592	463	323
Cucumber	740	578	403
Tomato	740	578	403
Broccoli	740	578	403
Peanut	740	578	403
Pumpkin	887	695	485
Beetroot	1183	926	645
Soyabean	1183	926	645
Squash	1331	1042	726
Wheat	1775	1389	968
Cotton	2219	1736	1210

Table 14: Average chloride concentrations measured at selected points in the study area

	CHLORIDE (mg/l)
ORANGE-RIET CANAL 2/3/94-29/11/94	5
TWEERIVIERE (C5H035) 18/1/93-1/11/93	51
RITCHIE WEIR (C5H014) 8/2/93-1/11/93	98
SOUTPANSDRIFT (C5H048) 10/8/90-21/10/93	**269**
DOUGLAS WEIR (C9R003) 7/2/83-21/10/93	87
VAALLUS AREA 24/2/94-17/8/94	103

4.4.4 BORON

Boron, although an essential plant nutrient, becomes toxic at high concentrations. Guidelines for crop sensitivity to boron are shown in Table 15, according to soil irrigation class. It is important to note that wheat and peanuts, although salt tolerant crops, are boron sensitive. Cotton, however, is tolerant to both salts and boron.

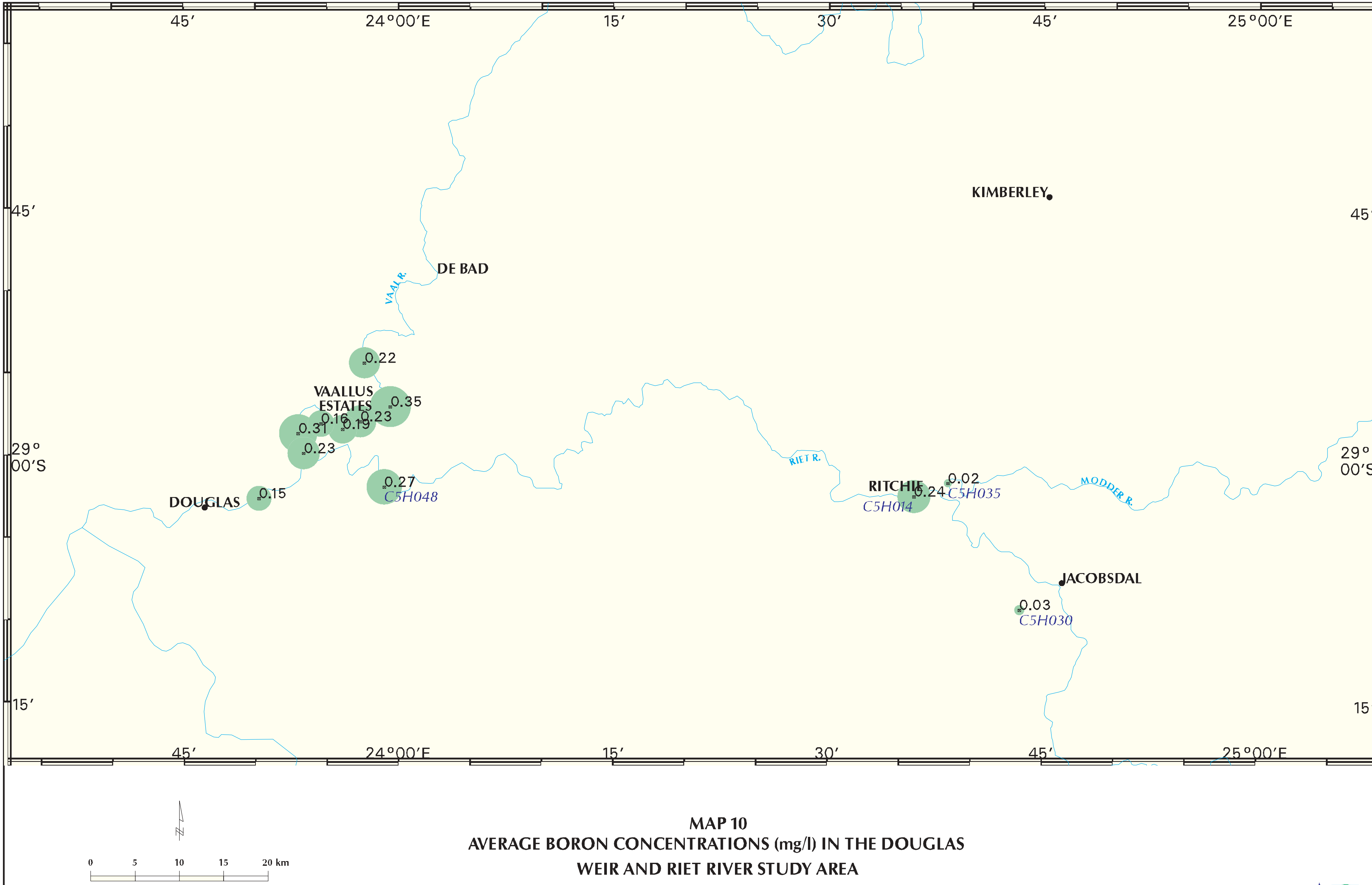
Boron levels measured at selected points in the study area are shown in Table 16. Although boron levels in the study area are generally low they increase downstream along the Riet River reaching levels which exceed the guidelines for boron sensitive crops on medium and poor soils (Map 10). Boron concentrations measured in the Vaallus section exceed the guidelines for boron sensitive crops cultivated on poor soils. Boron concentrations are, therefore, highest in areas dominated by poor and medium soils (Map 10).

Table 15: Water quality guidelines of selected crops for boron (mg/l)

CROP TYPE	**SOIL CLASS**		
	GOOD	**MEDIUM**	**POOR**
Wheat	0.4	0.3	0.2
Grape	0.4	0.3	0.2
Broccoli	0.4	0.3	0.2
Peanut	0.4	0.3	0.2
Sweet potato	0.4	0.3	0.2
Sunflower	0.4	0.3	0.2
Peach	0.4	0.3	0.2
Bean	0.4	0.3	0.2
Onion	0.4	0.3	0.2
Carrot	0.7	0.6	0.5
Potato	0.7	0.6	0.5
Cucumber	0.7	0.6	0.5
Maize	1.5	1.3	1.0
Cabbage	1.5	1.3	1.0
Squash	1.5	1.3	1.0
Pumpkin	1.5	1.3	1.0
Tomato	2.1	1.8	1.4
Lucerne	2.2	1.9	1.5
Beetroot	2.2	1.9	1.5
Cotton	3.1	2.5	2.0

Table 16: Average boron levels measured between February 1994 and August 1994, at selected points in the study area

	BORON (mg/l)
ORANGE-RIET CANAL	0.04
TWEERIVIERE (C5H035)	0.03
RITCHIE WEIR (C5H014)	**0.24**
SOUTPANSDRIFT (C5H048)	**0.36**
DOUGLAS WEIR (C9R003)	0.15
VAALLUS AREA	**0.22**



MAP 10
AVERAGE BORON CONCENTRATIONS (mg/l) IN THE DOUGLAS WEIR AND RIET RIVER STUDY AREA

4.5 CONCLUSIONS

Characterising water quality in the Douglas weir and Lower Riet River study area required the formulation of site specific water quality guidelines for the constituents affecting irrigation. These guidelines are based mainly on crop type and the suitability of the soil for irrigation.

Sections of the study area with high water salinity and predominantly medium and/or poor soils will experience the most problems. The Riet River Settlement, which receives the best quality water, consists of 81% good soils; while the Riet River Arm section, which receives the poorest quality water, consists of more than 50% medium and poor class soils.

Most sections can expect salinity related yield losses when cultivating salt sensitive and moderately sensitive crops (particularly on poor and medium class soils), but salt tolerant crops can be cultivated throughout the study area, irrespective of soil class.

Although 42% of the entire irrigated area experiences no problems with the cultivation of salt sensitive crops, this is dominated by only two sections - the Riet River Settlement (using Orange River water) and the section of the Douglas Weir Basin upstream of Vaallus. The rest of the study area can expect problems with the cultivation of salt sensitive crops.

Furthermore, although less than 50% of the entire area can expect substantial yield losses in the cultivation of moderately sensitive crops, this includes the entire Riet River Arm and 72% of the areas irrigated in the Bucklands and Atherton section. This latter section is dominated by small plots not suited to the viable cultivation of salt tolerant crops such as wheat and cotton. Only salt tolerant crops can be grown with no yield loss in the Lower Riet Arm.

No significant problems are expected with the sodium adsorption ratio and chloride concentrations in the study area. However, the amount of boron in the irrigation water can become a limiting factor in areas which are best suited to the cultivation of salt tolerant and moderately tolerant crops since some of these crops, such as peanuts and wheat, are boron sensitive. Wheat is the most common crop cultivated in the study area, especially in areas with poor soils and high salinity in the irrigation water, such as the Riet River Arm and Vaallus. However, these areas are also prone to elevated boron concentrations, which may lead to some boron associated yield losses. Cotton, though, is both boron and salt tolerant and is perhaps a more suitable crop.

5 MANAGING WATER QUALITY

5.1 INTRODUCTION

The previous chapters have shown that salinity levels exceed the guidelines for salt sensitive and moderately sensitive crops, particularly on poor and medium class soils, at a number of points in the study area. However, salt tolerant crops should not experience salinity associated yield losses, on any of the soil types, at any point in the study area. This appears to have influenced the choice of crops and wheat, which is salt tolerant, is the most commonly cultivated crop, particularly in the lower reaches of the Riet River and the Douglas Irrigation area. However, wheat is sensitive to high boron concentrations in the irrigation water, and the guidelines for boron are exceeded in particularly the Riet River Arm of the Douglas Weir Basin (see Map 10). In addition, the small farms typical of the Bucklands and Atherton areas are not suited to the cultivation of salt tolerant crops.

These issues suggest that the management of water quality could ameliorate problems in the study area. This chapter investigates the factors influencing water quality in the study area by simulating the movement of water and salts through the system. These simulations were also used to assess the potential of increased transfers via the Orange-Riet Canal to address water quality problems in the lower Riet River.

5.2 SALINITY SIMULATIONS

The two main irrigation areas - namely, the area served by the Douglas Irrigation Board, and the Orange-Riet GWS together with the Lower Riet River Irrigation Board - were simulated separately. These areas are described below:

a) The Douglas Weir area extending upstream along the Vaal River as far as the farm De Bad, including the Bucklands and Atherton areas and the Riet River Arm section of the Douglas Weir Basin. These areas receive water via the Louis Bosman Canal and, again, transfers are only sufficient to meet irrigation demands. This area was modelled by dividing the Weir into a number of cells and then simulating the movement of water and salts between these cells using an advection-dispersion type model.

b) The Riet River from Jacobsdal to the weir at Soutpansdrift. Irrigators along this reach receive water via the Orange-Riet Canal and this system is operated so that overflows at the weir at Soutpansdrift are kept to a minimum. The simulations in this area were based on a conservation of mass approach, in a spreadsheet format.

5.2.1 SIMULATING THE DOUGLAS WEIR SYSTEM

The movement of water and salts in the Douglas Weir area was simulated using an advection-dispersion model in which the weir is conceptualised as a series of uniformly mixed cells and water moves into and out of each cell depending on the difference in water level between adjacent cells.

> NOTE:
> This modelling approach requires information concerning the physical configuration of each cell. However, the only available survey of the Weir was done before the construction of the new weir structure. The water and salt movement in the system could therefore only be modelled conceptually and the model only simulates the behaviour of the water behind the weir.

The Douglas Weir Irrigation area is operated to minimise the amount of water which needs to be pumped from the Orange River. The Douglas Weir is, therefore, operated below full supply level, spills are minimised and the system acts as a salt trap.

In the White Paper outlining the operation of the system (WP C-86), it was envisaged that occasional floods would serve to flush accumulated salts from the system. However, the simulation undertaken for this study has shown that increases in salt concentration can occur very rapidly and within one irrigation season. In any one cell these increases occur when flow in the system is reversed: this happens when water is transferred via the Louis Bosman Canal, causing water to be pushed upstream from the weir structure to Vaallus and also into the Riet River Arm of the Weir. This movement of water carries salts into these areas, where they accumulate resulting in highest concentrations in these parts (See Maps 7 and 11).

This is most evident in the Riet River Arm of the Douglas Weir. This section receives occasional spills of high salinity water from Soutpansdrift, as well as advection inflows from the Vaal River. Water is used by the irrigation in the area, but the salts (and the boron) in this water are returned to the Weir as part of the irrigation return flows. However, as long as net river flows occur in the downstream direction (i.e. water moves from the Riet River towards the Vaal River), these salts and boron will be exported from the system and concentrations remain low (Figure 2). These low concentrations can be maintained by flows as low as $0.5m^3/s$ ($15.6x10^6$ m^3/year) from the Riet River to the Vaal River. But when flows are reversed (i.e. water moves from the Vaal River to the Riet River, as occurs when the Louis Bosman Canal is flowing) the salts begin to accumulate and concentrations rise rapidly (Figure 2). This effect has been confirmed by observations made on the Douglas Weir. In February 1994 good rains flushed the system and salt concentrations in the Riet River Arm were low (EC of 40mS/m -50mS/m), but by April 1994 these had risen to between 90mS/m and 100mS/m and by June 1994 EC's over 200mS/m were being measured.

The upstream movement of water into the Vaallus area also causes salts to accumulate in this region. However, the only way to maintain a net downstream movement of water (thereby exporting salts and boron) in this area would be to increase the flow entering the area from further upstream in the Vaal River (eg. from Bloemhof Dam).

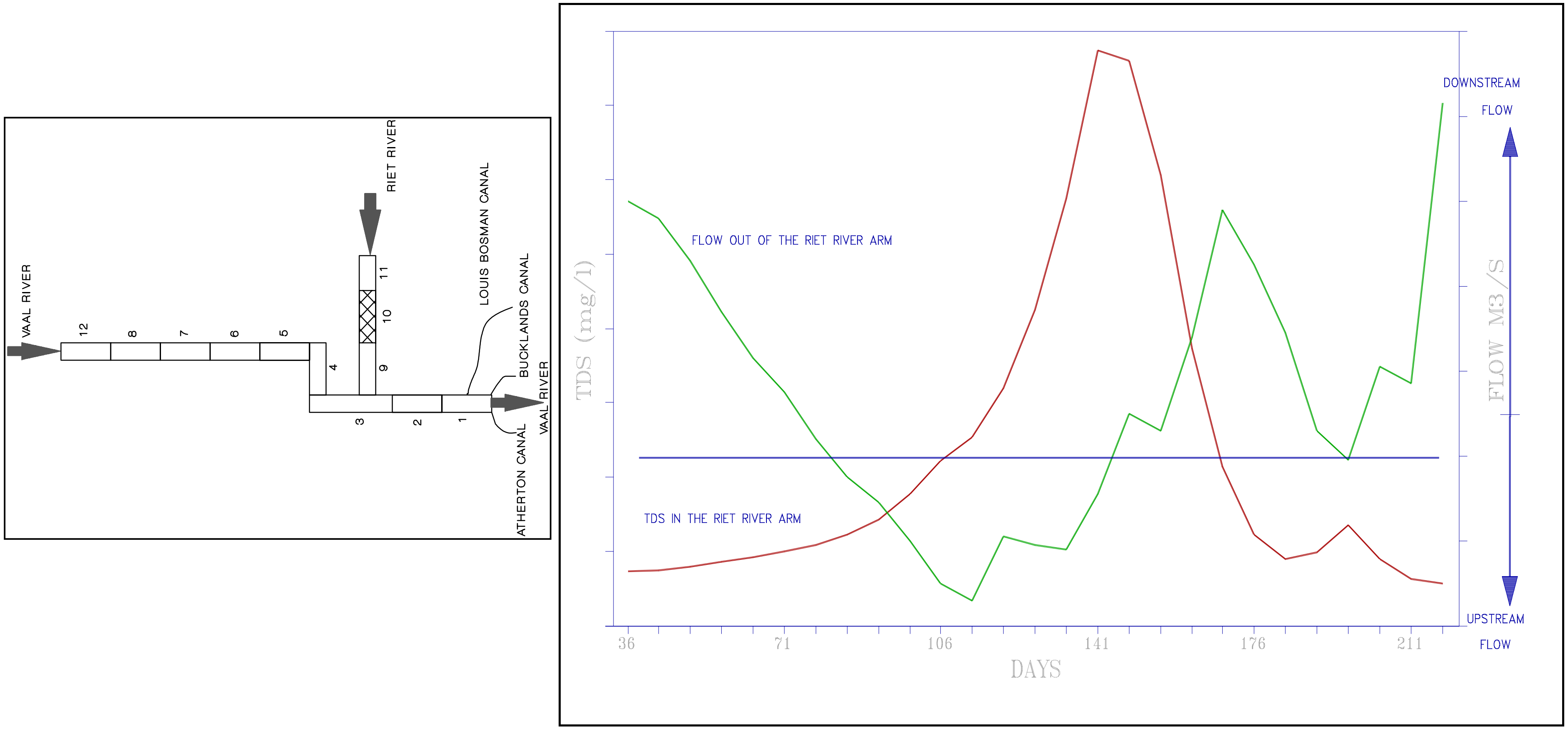


Figure 1 A graph showing TDS in the Riet River Arm of the Douglas Weir, and the flow from the Riet River to the Vaal River.

5.2.2 SIMULATING THE RIET RIVER SYSTEM

Simulations in this area were based on the assumption that the mass of salts entering the system in any month would remain constant through the system, but that irrigation demands would reduce the amount of water in which to carry these salts. Salt concentrations would, therefore, increase downstream. A leaching fraction (irrigation return flow) of 10% of the irrigated water was assumed. This may be more if drainage is installed. The simulated concentrations remain mostly between the maximum and minimum concentrations measured at various points on the river system (Map 11).

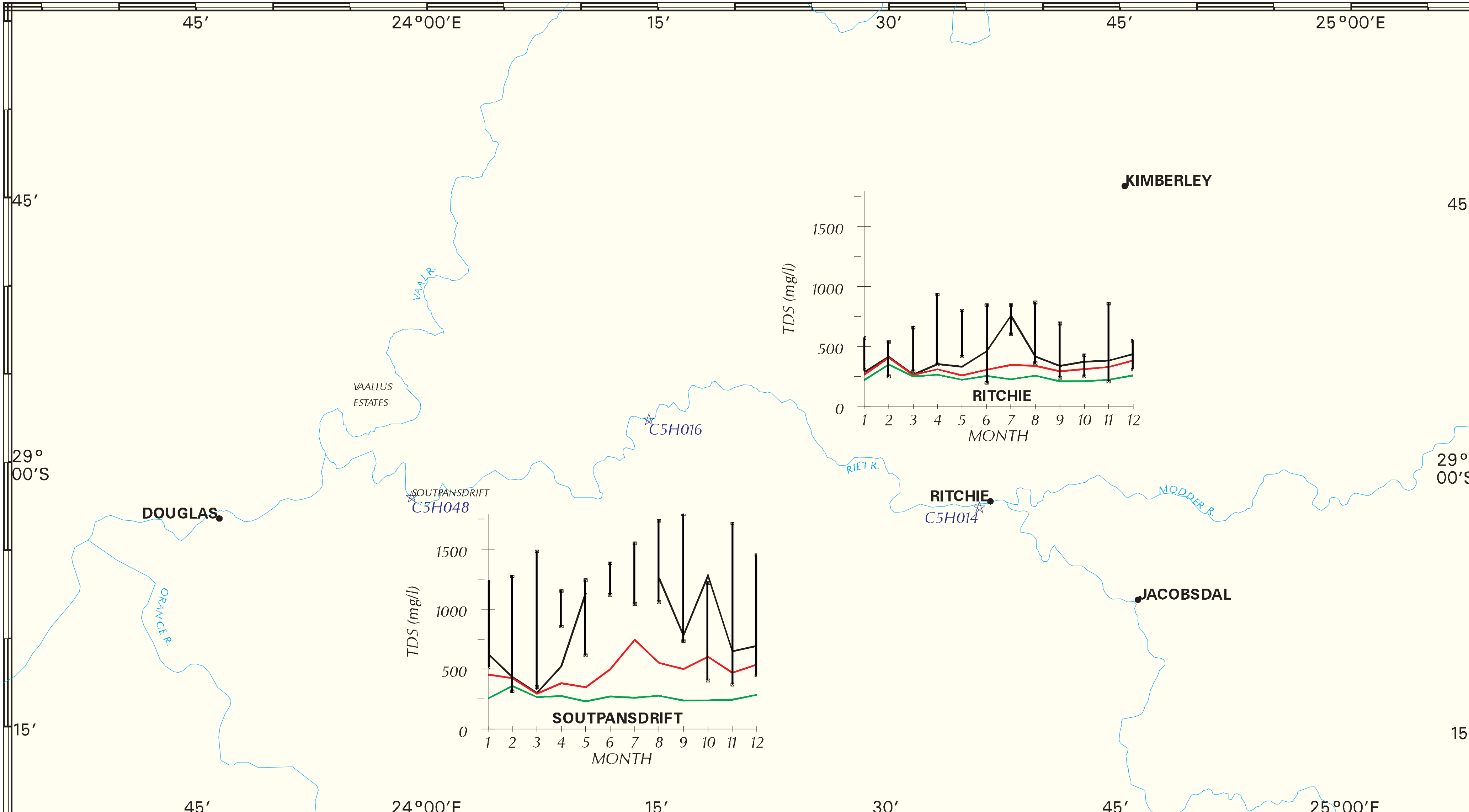
The effect of operating the system so that no flow occurs over Soutpansdrift is that there is no mechanism to export salts from the system. Salts, therefore, accumulate behind the Soutpansdrift weir and salt concentrations are highest at this point (Map 11).

The amount of water in the Orange-Riet Canal currently depends on the irrigation demands of farmers in the Riet River Settlement and the Lower Riet River Irrigation area. However, these demands do not always utilise the full capacity (13.2 m^3/s) of the canal. The effect of utilising different amounts of this spare capacity, on salt concentrations downstream in the Riet River was, therefore, also simulated. It was shown that salt concentrations can be lowered in this way (Map 11). The improvement is greatest in the winter months when irrigation demands are lower resulting in a greater available spare capacity, and least in the summer months when high irrigation demands take up more of the capacity of the canal (Table 17). Simulated concentrations at Ritchie decreased in July from 757mg/l to 345mg/l using 10% of the spare capacity and 225mg/l using 100% of the spare capacity (Table 17). Salt concentrations during June and July were not simulated at Soutpansdrift because modelled flows did not reach this point in these months. The total extra amount of water pumped per annum is some $300x10^6$ m^3 using 100% of the spare capacity, and some $30x10^6$ m^3 using 10% of the spare capacity.

Table 17: Change in simulated salt concentrations (mg/l) at Ritchie Weir and Soutpansdrift Weir using 10% and 100% of the spare capacity of the Orange-Riet Canal

	RITCHIE				SOUTPANSDRIFT		
	SIMULATED	!0% SPARE	100% SPARE		SIMULATED	!0% SPARE	100% SPARE
JAN	285	265	220	JAN	625	454	254
FEB	414	405	348	FEB	434	423	359
MAR	265	262	250	MAR	300	294	266
APR	351	309	263	APR	522	381	274
MAY	331	258	222	MAY	1134	348	231
JUNE	459	306	253	JUNE	-	-	-
JULY	757	345	225	JULY	-	-	-
AUG	415	338	255	AUG	1257	550	277
SEP	336	293	209	SEP	780	501	238
OCT	372	310	210	OCT	1281	603	240
NOV	382	327	222	NOV	649	469	244
DEC	435	382	258	DEC	693	537	285

These simulations, therefore, have shown that even small amounts of extra water transferred via the Orange-Riet Canal can make noticeable improvements in water quality in the lower Riet River. There is also sufficient spare capacity in the Orange-Riet Canal to accommodate these extra volumes. The extra water provided to dilute the salts would also serve to lower the concentrations of other constituents such as boron.



KEY

Rivers

Towns

C5H014 - DWAF gauging points

0 5 10 15 20 km

MAP 11

GRAPHS OF MODELLED SALT CONCENTRATIONS AT RITCHIE AND SOUTPANSDRIFT SHOWING THE EFFECTS OF USING 10% (red) AND 100% (green) ORANGE-RIET CANAL SPARE CAPACITY

GRAPH KEY

UNMODIFIED SIMULATED TDS

TDS USING 10% SPARE CAPACITY

TDS USING 100% SPARE CAPACITY

MAXIMUM AND MINIMUM OBSERVED TDS

5.3 POTENTIAL MANAGEMENT OPTIONS

The Orange-Riet and Douglas Weir systems are currently operated to be conservative with the water used and to keep spills of water out of the system to a minimum. As a result salts accumulate in the system and no extra water is available to flush out these salts.

The simulations, as discussed in sections 5.2.1 and 5.2.2, have shown that using as little as 10% of the spare capacity of the Orange-Riet Canal (about $30x10^6$ m^3/year) will reduce salt concentrations at Soutpansdrift and that at least $15.6x10^6$ m^3/year is required to move salts out of the Riet River Arm of the Douglas Weir. This allows the following potential management options to be described, in order of benefit in terms of reductions in salt concentration:

Option 1 Providing sufficient flow into the system via from both the Vaal River (from Bloemhof Dam) and the Riet River (via the Orange-Riet Canal) to maintain spills over the Douglas Weir. This would improve water quality in the Riet River Arm as well as in the Vaallus area. However, it would be the most expensive option in terms of water, and may place excessive demands on the already limited resources in the Vaal River. This method would also require the pumping of at least $30x10^6$ m^3/year extra water via the Orange-Riet Canal.

Option 2 Transferring extra water via the Orange-Riet Canal <u>but not</u> reducing the Louis Bosman Canal by the corresponding amount, and not increasing flows in the Vaal River. This will improve conditions in the lower Riet River and Riet River Arm. Under this scenario there will still be flow over the Douglas Weir. However, since this water returns to the Orange River there should be little impact on the total water resources. Nonetheless, this option does require that at least an extra $30x10^6$ m^3/year be pumped. Slight increases in salt concentration at Vaallus may also occur.

Option 3 Pumping at least an extra $30x10^6$ m^3/year via the Orange-Riet Canal <u>and reducing</u> the Louis Bosman Canal by the corresponding amount. This extra Orange-Riet water will then flush the lower Riet River and the Riet River Arm and will be available for the dilution of the Douglas Weir. The balance of the flow from the Louis Bosman Canal will still ensure better quality irrigation water for the Bucklands and Atherton areas. This scenario does not require the pumping of any extra water, but as the pumping head at Scheiding pump station is 10m higher than that at Marksdrift (49m vs 39m) pumping at this point is slightly more expensive. Again, slight increases in salt concentrations at Vaallus may occur.

Option 4 Supplying the irrigation needs of the Riet River Arm of the Douglas Weir via the Orange-Riet Canal and reducing flow in the Louis Bosman Canal correspondingly. This would increase flow in the Orange-Riet Canal by $11x10^6$ m^3/year. This option would remove some salts from the Lower Riet River and slightly lower salt concentrations in this area. However, since only sufficient is being transferred to meet the irrigation needs, all the extra water will be used in the Riet River Arm and none will be available for the dilution and removal of salts from return flows in this area. This scenario requires the pumping of an extra $11x10^6$ m^3/year of water via the Orange-Riet Canal, but an equivalent reduction via the Louis Bosman Canal, and minimal extra costs.

Note:
Considering only differences in pumping costs between the two pump stations in use, minimum costs for the various options can be summarised as follows:

	Marksdrift	Scheiding	Net costs
Option 1		+ R60 000	+ R60 000
Option 2		+ R60 000	+ R60 000
Option 3	- R52 000	+ R60 000	+ R8 000
Option 4	- R20 000	+ R22 000	+ R2 000

All costs quoted are approximate, and are based on 1995 rates

5.4 SUMMARY

Both the Orange-Riet and Douglas Weir systems are operated as closed systems. Whilst water is used by irrigation, salts tend to accumulate. This accumulation is most evident in the Lower Riet River, Vaallus and Riet River Arm sections which, therefore, have the highest salt and boron concentrations.

When these systems were first planned (WP C-86) it was envisaged that occasional floods would flush excess salts out of the system. However, these modelling studies have shown that the accumulation of salts occurs very rapidly (within four months), and this has been confirmed by data collected after high flow events.

In the Riet River Arm of the Douglas Weir the reversal of flow from the Vaal River to the Riet River when the Louis Bosman Canal is flowing leads to the rapid accumulation of salts in the area. The simulations undertaken, however, showed that this problem can be avoided by allowing overflows over the Soutpansdrift weir to ensure flows of at least 0.5 m^3/s, or $15.6x10^6$ m^3/month, into the Vaal River.

Simualtions on the lower Riet River have shown that salts can be exported from the system using as little as 10% of the spare capacity in the Orange-Riet Canal - $30x10^6$ m^3/year or an average of $2.4x10^6$ m^3/month. This is already twice the minimum amount recommended to enter the Riet River Arm of the Douglas Weir.

A similar effect is observed in the Vaallus Estates area, but the problem here can only be alleviated by releasing water from further upstream in the Vaal River (eg. from Bloemhof Dam).

Despite the reversal of flow in the Vaal River as a result of flow from the Louis Bosman Canal, this water does ensure a pool of better quality water at the weir structure for the irrigators in the Bucklands and Atherton areas, as well as those downstream of the Riet-Vaal confluence. Some inflow via the Louis Bosman Canal should therefore continue.

Based on the modelling studies undertaken in the Riet River and Douglas Weir a range of ameliorative options have been identified, and are listed in order of success in terms of lowering salt concentrations:

1. Provide sufficient flow into the system via the Vaal River (from Bloemhof Dam) and the Riet River to maintain spills over the Douglas Weir and thereby export the salts. However, this increases the demand on the water resources of the Vaal River.
2. Pumping at least an extra $30x10^6$ m^3/year via the Orange-Riet Canal <u>but not</u> reducing the Louis Bosman Canal by the corresponding amount.
3. Pumping at least an extra $30x10^6$ m^3/year via the Orange-Riet Canal to supply the irrigation needs of the Riet River Arm <u>and reducing</u> the Louis Bosman Canal by the corresponding amount. This would increase costs slightly.
4. Supplying only the irrigation needs of the Riet River Arm of the Douglas Weir via the Orange-Riet Canal and reducing flow in the Louis Bosman Canal correspondingly. Extra costs would be minimal.

6 CONCLUSIONS AND RECOMMENDATIONS

6.1 CONCLUSIONS

The following points can be highlighted:

- Irrigation is the largest user of water in the study area.
- More than 50% of the study area is planted to wheat, which is salt tolerant. However, wheat is less common in the Riet River Settlement which uses low salinity Orange River water pumped directly from the Orange-Riet Canal and is situated on predominantly good soils. This suggests that farmers have adapted their choice of crops to cope with the high salt concentrations in the irrigation water.
- Fifty-four percent of the entire area is situated on good soils, 12% on medium class soils and 34% on soils poorly suited to irrigation.
- Apart from in the Riet River Settlement, salt sensitive and moderately sensitive crops can be expected to show a loss in yield, particularly on poor and medium class soils. However, no salt-related yield losses are expected for salt tolerant crops, irrespective of soil class. But in sections of the study area such as the lower reaches of the Riet River and the Riet River Arm, wheat could be affected because of its boron sensitivity.
- The high salt and boron concentrations in the study area are the result of the closed nature of the system operation. These concentrations are highest along the lower sections of the Riet River, the Riet River Arm of the Douglas Weir and, to a lesser extent, in the region of the Vaallus Estates. The simulations, as well as actual observations, have suggested that although occasional floods will remove salts from the system, concentrations rise back to their original levels within a short space of time.
- The simulations have also shown that salts (and boron) can be exported from an area using only small volumes of water and that it is important to maintain river flows in a positive (downstream) direction, thus having a noticeable impact on water quality.

6.2 RECOMMENDATIONS

Option 3 indicated in the previous section appears to hold the greatest benefits for the least costs in terms of both water resources and pumping costs. This option will involve pumping at least an extra 30×10^6 m^3 of water per annum via the Orange-Riet Canal, but reducing the amount pumped via the Louis Bosman Canal by an equivalent amount. This results in an increase in pumping costs of R8 000/year.

It is recommended that this option, and some of the others indicated, be investigated in greater depth before experimental releases are made.