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DEPARTMENT OF WATER AFFAIRS
AND FORESTRY
DIRECTORATE OF WATER RESOURCES PLANNING

BREEDER RIVER BASIN STUDY

MAIN REPORT

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NINHAM SHAND
CONSULTING SERVICES



**JAKOET &
ASSOCIATES**



**DEPARTMENT OF
WATER AFFAIRS AND FORESTRY**

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OCTOBER 2003

REFERENCE

This report is to be referred to in bibliographies as :

Department of Water Affairs and Forestry, South Africa. 2003. *Breede River Basin Study : Main Report*. Prepared by H Beuster, M J Shand and C A Carter of Ninham Shand (Pty) Ltd in association with MBB Consulting Engineers and Jakoet & Associates as part of the Breede River Basin Study. DWAF Report No. P H 00/00/3102.

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DEPARTMENT OF WATER AFFAIRS AND FORESTRY

DIRECTORATE : NATIONAL WATER RESOURCE PLANNING

BREEDER RIVER BASIN STUDY

TITLE : **Main Report**

DWAF REPORT NO. : **P H 00/00/3102**

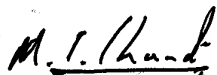
PROJECT NAME : **Breede River Basin Study**

CONSULTANTS : **Ninham Shand (Pty) Ltd
MBB Consulting Engineers
Jakoet & Associates**

REPORT STATUS : **Final**

DATE : **October 2003**

Approved for Study Team :



.....
M J SHAND
Ninham Shand

DIRECTORATE : NATIONAL WATER RESOURCE PLANNING

Approved for Department of Water Affairs and Forestry



.....
F A STOFFBERG
Chief Engineer



.....
J VAN ROOYEN
Director

BREEDERIVER BASIN STUDY

MAIN REPORT

EXECUTIVE SUMMARY

E1. INTRODUCTION

In 1999, the Department of Water Affairs and Forestry (DWAF) commissioned the Breede River Basin Study (BRBS) to provide the information that is required for the effective management and beneficial use of the water resources of the Breede River and its main tributary the Riviersonderend River.

The decision to undertake the study was determined by the water situation in the south western region of the Western Cape. The demands for water from the Western Cape Water Supply System (WCWSS) and the water needs in the Breede Water Management Area (WMA) were placing severe pressure on the water resources of the region. The provision of information that would allow planning for optimum utilisation of the water resources on a regional basis was therefore essential.

The National Water Act of 1998 set in motion a process of fundamental change in the way in which water resources are managed in South Africa. One of the most significant aspects of this process is the establishment of new water management institutions that will allow water users and interest groups to participate in the management of their water resources. The process of establishing a Catchment Management Agency (CMA) for the Breede WMA (which also includes the Palmiet, Sout and Bot River catchments), commenced shortly after the inception of the BRBS. While the actual establishment of the CMA remained a separate process, it was intended from the start to support the development of the CMA through the BRBS. CMA stakeholders were involved in the technical working groups and feedback meetings of the BRBS. Together with the stakeholders, information forthcoming from the study was used to prepare a series of discussion papers that formed the basis of a proposal for the establishment of the CMA.

In addition to the important link that was established between the study and the development of the CMA, the study was designed to provide the technical information that would be required for good water resource management. The findings of the BRBS have since provided invaluable baseline information for the Department's Internal Strategic Perspectives (ISP) process, which is intended to develop interim water resource management strategies to be applied by DWAF until such time as the CMA can take over. The CMA will presumably also use BRBS information to eventually develop a Catchment Management Strategy (CMS) for the Breede River.

The basic objectives of the study were therefore to:

- assist with the institutional development of the CMA
- provide the information that will be required for good water resource management, especially to support decisions on license applications
- provide a sound foundation for the development of an ISP and a CMS
- enable and facilitate follow-up broad regional planning for the Berg and Breede WMAs, as well as more detailed feasibility studies

To address the objectives of the study, all aspects relating to the water resources of the Breede River catchment had to be investigated and evaluated. This included assessments of present water use and possible future use scenarios, assessments of current water availability and possible future availability (including allowance for the Reserve), water quality, yield balance scenarios, balance interventions such as the implementation of water conservation and demand management (WCDM) measures, re-use of water, promotion of a water market, water transfers, and new schemes. The findings of the specialist investigations are documented in more than twenty separate technical reports. This, the Main Report of the study, presents an overview of the prominent features of the specialist investigations, and draws on the findings of these investigations to present a framework for the beneficial use of the water resources of the Breede River catchment.

The Main Report commences with a discussion of significant features of the catchment, including natural features, land use, water supply infrastructure, and prevailing socio-economic conditions. The methods that were used to quantify present levels of consumptive water use and to estimate future growth in water requirements are explained, and the results are discussed.

Environmental sustainability forms one of the cornerstones of the National Water Act. In recognition of this, a considerable portion of study resources was directed towards increasing the available knowledge regarding the ecological water requirements of the aquatic ecosystems in the Breede River catchment. The findings of a series of groundwater, riverine, estuarine, and wetland Reserve determinations as well as the quality requirements of the Reserve are presented and discussed in terms of the effect that these requirements may have on future water availability.

Efforts to identify and evaluate options for water conservation and demand management were focussed on two areas where substantial savings can be achieved, namely through the control and eradication of invasive alien plants, and the implementation of WCDM measures in especially the agricultural sector. The findings of this work are discussed, and comment on the potential for WCDM in urban areas is also provided.

The quantity and quality of the surface and groundwater resources in the catchment are discussed.

When considering present and possible future water balances, the first emphasis is on interventions that will not require large capital investment and will not have significant impact on

the environment, but the development of further resources appears inevitable in the long run. With this in mind, a range of potential water supply options that were previously identified, and a number of new possibilities were assessed at reconnaissance level. These development options are discussed, and the more favourable options for local use and for possible water transfers to the Berg WMA are identified.

The information produced by the BRBS will be used to inform strategic decisions on future resource use in the larger region, which includes neighbouring WMAs. The Breede River catchment can therefore not be viewed in isolation, and resource development must be considered in the context of the Western Cape Region as a whole. Considerations that would have to be taken into account are discussed, and finally, a framework for the beneficial use and future development of the water resources of the Breede River catchment is presented.

E2. INSTITUTIONAL DEVELOPMENT AND PUBLIC INVOLVEMENT

Public participation was regarded as an important component of the BRBS. Not only did active public participation alert study teams to important issues that required their specialist attention, but it also played an important role in preparing water users and interest groups to assume future responsibility for the management of their water resources.

The Public Participation Programme (PPP) for the BRBS was integrated with the PPP for the establishment of the Breede CMA. This not only led to significant cost savings, but valuable synergy was achieved. Public participation was facilitated through a series of public meetings and supporting documentation. Focussed inputs by a Stakeholder Committee and Technical Working Groups for the Agricultural Water Demand, Environmental, and Water Quality components of the BRBS were received at key points in the study. The Stakeholder Committee also participated in the establishment of the Breede CMA Reference Group, which guided the development of a proposal for the establishment of a CMA for the Breede WMA.

The PPP also facilitated the very important buy-in by stakeholders of the future CMA into the BRBS and its findings.

E3. CURRENT WATER USE AND POSSIBLE FUTURE REQUIREMENTS

Year 2000 water use from the Breede River catchment amounted to about 870 million m³/a. This volume includes groundwater abstractions for irrigation of about 100 million m³/a. Figure E3.1 shows a broad split of current water use in the catchment.

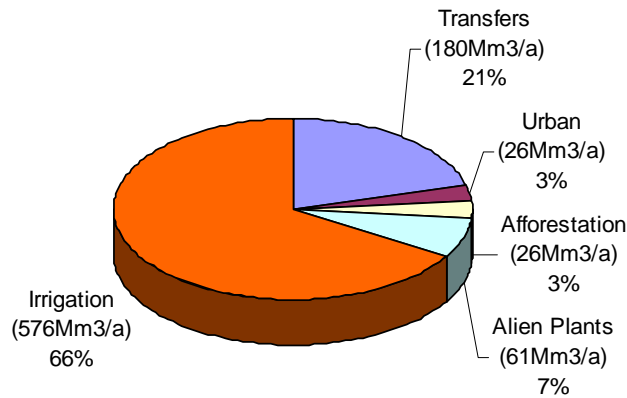


Figure E3.1 : Present Day (2000) Consumptive Water Use

Urban Water Use in the Breede River Catchment

Urban water use is small compared to agricultural usage in the Breede Basin, accounting for about 3% of current water use. During the past decade, growth in urban water usage has averaged about 3,3% per year, with the towns of Wolseley (8,6% per year) and Robertson (9,3% per year) experiencing the highest growths.

There is considerable scope for urban WCDM with potential reductions in demands of the order of 20% to 30%. After accounting for the effect of water demand management, urban usage may initially decrease from the present level of about 26 million m³/a, but is then expected to continue growing to around 43 million m³/year by 2030.

The provision of water to meet the basic human needs of people living in the catchment, has the highest priority. These requirements, together with the remainder of urban domestic and industrial water requirements are not large enough to impact strongly on the potential availability of water for other uses.

Commercial Irrigated Agriculture

The agricultural sector directly produces about 36% of the region's Gross Geographical Product (GGP). It also makes a considerable contribution to the other components of the GGP. Studies undertaken by the Western Cape Department of Agriculture have indicated that irrigated agricultural development is a good vehicle for job creation. In addition to jobs created directly, increased wealth and expansion of the economy will foster the growth of employment in service

industries ranging from shop-keeping to finance. Importantly, profitable expansion of irrigation farming will facilitate the growth of emergent farmers if conducive conditions are created.

This outlook must be balanced against the fact that irrigation is a major user of water, in a water scarce environment. Many of the job opportunities that are created by irrigated agriculture are seasonal labour, which in the past provided income at or near the poverty line. The affordability of water from new schemes to supply irrigators is a potential constraint on further development.

After accounting for re-use of return flows, reduction of crop water requirements in irrigated areas located in the seepage path between canals and the river, and low assurance supplies from run-of-river schemes, consumptive use by irrigated agriculture is estimated at 580 million m³/a. About 100 million m³/a, or 17% of this consumption is supplied from groundwater, with the remainder supplied from surface water sources.

Possible further growth in the demand for irrigation water will be closely linked to factors such as the availability of undeveloped land with irrigable soils, market conditions and the financial viability of irrigation farming which in most cases is linked to the Rand exchange rate.

The study identified some 172 000 ha of undeveloped land (or land that is presently afforested or under dryland cultivation) that is suitable for irrigated agriculture. Due to the widespread occurrence of suitable soils, there is virtually no sub-region within the catchment where the availability of land, rather than the (economic) provision of water or market potential, limits the further development of irrigated agriculture.

As the remaining areas with irrigation potential and low cost infrastructure are progressively developed, the opportunities for the development of affordable water supplies (from an agricultural point of view) will become less and less, up to the point where the cost of water will be too high for it to be used economically for additional irrigation. Under these circumstances, further water resource developments may still be affordable for urban use, both locally and in the form of transfers to the Berg WMA.

To assess the possible future growth of irrigated agriculture, a number of growth scenarios were developed, ranging from a "No Growth" to a "Maximum Growth" scenario. These scenarios were based on variations of the conditions discussed above, and included the effect of successful implementation of WCDM. The assessments indicate that it is very unlikely that irrigation demand will have increased by more than 120 million m³/a in 2020 and by more than 150 million m³/a in 2030 ("Balanced" scenario). Under rather unfavourable but more likely conditions ("Limited" scenario), growth could be limited to 65 million m³/a in 2020 and 75 million m³/a in 2030. In all future use scenarios the proviso or assumption is that the CMS will make provision for the allocation of water to such use.

The continuing incremental development of irrigated agriculture through the expansion of existing farms and the establishment of new schemes supplied from small, local water resources

developments will benefit the economy of the region. Provided that these developments are shown to be economically viable, and to embrace the concepts of environmental protection and WCDM, licensing of water use should not be unnecessarily constrained.

Resource Poor Farmers

In the Breede River catchment, opportunities abound to address poverty through agricultural water use and related activities. Already, many previously disadvantaged people derive their livelihood through employment on commercial farms and there is some measure of own production in and around villages and townships. However, there have not been many examples of historically disadvantaged people emerging from their current situation into dramatically or even incrementally improved livelihoods based on agricultural water use or related business opportunities.

A narrow focus on the 'water requirements for emerging irrigation farmers' will not result in the development of strong and independent black and coloured farming enterprises. Any serious effort to mainstream the marginalized through the use of agricultural water in the Breede River, will, in addition to facilitating access to water, have to address a wide range of socio-economic issues. Institutions that can arrange to make available land, water, and a variety of services related to the agricultural sector need to work together to plan and support new farmer development.

In the Western Cape, the planning and development of irrigation developments is coordinated through the Irrigation Action Committee, which is chaired by the provincial Department of Agriculture. DWAF is an original member of this committee, and the Department of Land Affairs plays an increasingly active role. Local government is not as yet part of this planning forum. It is suggested that there is a need for a programme to inspire, educate and train new entrants into the irrigation sector. An implementing agent (perhaps a NGO) would be required to drive such a programme, to assist new farmers, and to facilitate access to available support.

A large number of resource poor farmer developments in the Breede River catchment have been registered with the Department of Land Affairs. Of these developments, 15 projects had been completed by March 2002, benefiting in excess of 1000 participants on some 2 200 hectares, and a further 29 projects benefiting 1 700 participants on 1 900 hectares are in the process of implementation. The extent of further opportunities for the establishment of resource poor farmers will be largely dependent on the degree of support, including access to land and water, which can be mobilised for the new ventures. In the short to medium term future, the availability of water is not likely to impose a constraint on the establishment of these farmers.

The study has indicated that future irrigation development in the Breede River catchment would in most cases be through the expansion of existing farming concerns, which is more likely to be economically viable than the establishment of new farms. In spite of the prevailing poor economic conditions in the sector, there is still a demand for expansion, as evidenced by the number of water use licence applications received by the DWAF Regional Office. This situation could be used to create opportunities for the establishment of resource poor farmers by

encouraging the formation of joint partnerships between such emerging farmers and existing commercial farmers where new irrigation developments are undertaken. This could be achieved through the implementation of a licensing strategy that would limit (or at least favour) the issuing of new licenses for irrigation water use to such joint partnerships. Such an approach would provide established commercial farmers with a vested interest in the successful establishment of new entrants, and provide incentives for knowledge and skills transfer. Depending on the targets that could be set for such a strategy, and assuming that the "Limited" irrigation growth scenario materialises, it is conservatively estimated that this could result in an increase in resource poor farmer developments from about 4 100 ha (with a water requirement of about 30 million m³/a) at present, to about 7 000 ha (requiring about 60 million m³/a) by 2020.

An alternative to the above approach would be to reserve most, if not all, of existing water surpluses for the establishment of resource poor farmers. In this scenario, which could be time-limited, the bulk of the financial, technical and training support will have to be provided by the government, rather than the commercial irrigation sector. Depending on the extent of the support that could be made available, this approach could benefit a larger number of resource poor farmers within a shorter time frame than the previous scenario, but can be expected to be more expensive per developed ha, as it would require the establishment of new farms from scratch.

Water Conservation and Demand Management (WCDM)

With the notable exception of the efforts to clear invasive alien vegetation in the study area, to date there have been very few attempts made by water management institutions or water service providers to implement WCDM in the Breede catchment. Measures to balance supply and demand have been focussed on supply-side solutions, and in particular on development of new water resources.

The largest component of water use is irrigation. Within this component, there is varied scope for moderating water demands. The majority of on farm irrigation infrastructure comprise of water efficient drip and microjet systems. On the other hand, most of the existing water distribution infrastructure supplying the major water user association (WUA) schemes in the study area is ageing rapidly, and significant savings could be achieved through upgrading and programmed maintenance. Improved management of saline return flows would reduce the need for freshening releases and thus increase water availability.

While the potential volumetric savings of urban water use are small in relation to total water use in the catchment, the importance of establishing a WCDM culture in the catchment cannot be over-emphasised. According to national estimates provided in the draft WCDM Strategy for the Water Services Sector, potential savings of about 40% of existing consumption can be realised in urban areas through the implementation of water demand management measures. At present there is an almost entire lack of water loss data for towns in the Breede River catchment, and it is therefore difficult to gauge the performance of the towns against this yardstick. This very fact indicates that effective water demand management measures are not in place, and that significant water savings can still be achieved. In considering future yield balances for the Breede

catchment, it has been assumed that effective WCDM will indeed be realised through facilitation by the DWAF Regional Office and the CMA.

E4. WATER AVAILABILITY

Surface and Groundwater Resources

The naturalised mean annual runoff (MAR) in the Breede River catchment is estimated to be about 1 800 million m³/a. Approximately 46% of the runoff is generated in the catchments upstream of Greater Brandvlei Dam, which cover only about 16% of the total land area of the Breede catchment. About 43% of the total MAR is currently used (excluding groundwater use of about 100 million m³/a), leaving about 1 030 million m³/a flowing into the estuary.

Total groundwater use in the catchment is about 100 million m³/a, far less than the annual groundwater recharge for the catchment of 640 million m³/a. The majority of this recharge (75%) takes place along the western and northern fringes of the catchment. A significant component of recharge that occurs in the mountains rapidly becomes baseflow that feeds streams and recharges the alluvial aquifers in the valley bottoms.

The Reserve

At the commencement of this study, it was widely perceived that the Breede River catchment was the area offering the greatest scope in the Western Cape for exploitation of water resources, and that after a liberal allowance had been made for future development within the catchment, significant quantities of water could be made available for transfer to the Berg WMA. One of the key findings of the study has been the effect that the Reserve could have on the exploitable portion of the water resource. It has become clear that if the classification assumptions and Reserve determinations done by the team of ecological scientists for the BRBS should eventually be accepted, that instead of a situation of abundant water, Reserve requirements would greatly reduce the potentially exploitable water from the Breede River.

In terms of total system yield, it was found that the Reserves for the lower reaches of the Breede River would limit the catchment-wide amount of surplus water that would be available for further abstraction and use during the dry summer months, while the Reserve for the estuary would limit the quantities of water that are available for storage during some of the high runoff winter months. At first glance, it would appear that the recommended Reserve for the estuary of about 950 million m³/a is much larger than the estimated Reserve requirement for the lower Breede River of about 580 million m³/a. Floods with return periods greater than about 1:5 years are not usually specified as part of riverine Reserve requirements, as the major portion of these floods would spill over most storage dams. If the volumes of these floods were to be included in the riverine Reserve, the two requirements would be of the same order of magnitude. Selection of a lower ecological Reserve category for one of these two components would therefore not significantly increase the yield potential of the system. The integrated Reserve requirement for the Lower Breede River and the estuary, as recommended by the ecological scientists, is about 975 million m³/a, corresponding to more than 50% of the MAR and representing one of the higher requirements among the larger rivers in the country.

The future use of the water resources of the Breede River will require trade-offs between development and conservation with, as a point of departure, conservation receiving preference. Water use in the Breede catchment has already severely lowered the classification of most of the main river channel and many of the tributaries. Any further abstractions will need to be carefully managed to minimise further lowering of its environmental status. Before the Reserve is finally decided upon by the Minister, it should be carefully reviewed in the light of the latest information and taking all interests into consideration.

The impact that the selection of Reserve categories may have on exploitable water is discussed at the end of this section.

Invasive Alien Plants

An estimated 46 000 ha (equivalent area at 100% density) of the Breede River catchment land area has been invaded by alien plant species. The riparian zones of the Riviersonderend and Upper Breede catchments are the most affected by invader species. Investigations have shown that water use by these plants amounts to as much as 61 million m³/a, or 3% of the total surface water runoff in the catchment. The equivalent impact on the yield of the system is estimated at about 53 million m³/a. Should the spread of alien plants be allowed to go unchecked, the invaded areas could triple in size by 2020, cover about 250 000 ha by 2040, and have a disastrous impact on available water resources.

Clearing of alien plants in the Riviersonderend catchment has been undertaken for several decades. Clearing projects have also been initiated in other parts of the Breede River catchment where extensive invasions have taken place, mainly in the catchments of the Upper Breede River. DWAF water resource managers (and the future CMA) should liaise with Working for Water managers to identify other areas where clearing would be beneficial for the restoration of river flows, and establish a programme for clearing these areas. Besides the water related benefits that will be derived from continuing and intensifying the clearing efforts, other social and ecological benefits have considerable economic value. Significant opportunities to move clearing operations onto a self-sustaining basis exist through the utilisation of cleared vegetation for paper or charcoal production.

Elimination or reduction of water use by invasive alien plants represents by far the most beneficial means of unlocking water resources for the benefit of the environment and future consumptive water needs in the catchment. The strategy to be followed by DWAF in this regard will be developed in the Internal Strategic Perspective (ISP) for the Breede WMA.

Possible Further Development Opportunities

A wide range of water supply options that were investigated in the past, as well as some new possibilities, were assessed at a reconnaissance level to identify the more favourable developments. The larger regional schemes (with yields in excess of 10 to 15 million m³/a) were evaluated from financial, technical, socio-economic and environmental perspectives. Yields and corresponding unit reference values (URVs) were determined. There are also numerous smaller

local development possibilities with individual yields of generally less than 10 million m³/a. Comparative assessments of these local schemes were limited to cost estimates and comment on the potential accumulative environmental impacts.

The Greater Brandvlei Dam is one of the two largest water resource developments in the Breede catchment. At present water can be stored in the dam through diversions from the Holsloot and Smalblaar Rivers only up to a level of 207 m above mean sea level, corresponding to a capacity of 342 million m³ and a yield of 115 million m³/a, which is virtually fully subscribed. A further 133 million m³ of storage is available up to the full supply level of 210,5 m. Water can be pumped into this storage zone by means of the Papenkuils pump station. By increasing the quantity of water that can be fed into the dam, better use can be made of the existing dam storage capacity, providing the most economical means of increasing the yield of the system by a substantial margin.

The Theewaterskloof Dam has a capacity of 434 million m³ and is the source reservoir for the Riviersonderend-Berg-Eerste River Government Water Scheme, an inter-catchment water transfer project that supplies water for urban use to the Greater Cape Town Area, including Stellenbosch, and water for urban and agricultural use in the Berg River Catchment and demand centres along the West Coast. The system has a one in fifty year yield of 234 million m³/a (inclusive of the Banhoek and Wolwekloof diversions and the local yield of Kleinplaas Dam in the Eerste River). Some 60 % of the yield has been allocated for irrigation in the Berg River catchment and the Lower Riviersonderend catchment, and the balance to the Cape Town Metropolitan Area. Water use in the catchment of the dam, releases for downstream irrigators, and supplies to the Berg WMA via the tunnel system have taken up the maximum yield of the Upper Riviersonderend catchment, and the only way in which the tunnel supply to the Berg WMA could be increased would be to supplement inflows to the dam from Greater Brandvlei Dam.

The possible schemes for transferring water to the Berg Water Management Area considered in the study are shown in Table E1.

TABLE E.1 : TRANSFER SCHEMES (in order of preference)

SCHEME NAME	MAXIMUM YIELD (Mm ³ /a)	URV (c/m ³)**	MCDA SCORE***
Michell's Pass diversion	53	11	84
Upper Molenaars diversion	27	82	74
Brandvlei-Theewaterskloof scheme	41	114*	52
Lower Wit River diversion	30	87	42

* Including the cost of increasing the yield of Greater Brandvlei Dam.

** URVs exclude the cost of additional bulk conveyance infrastructure to deliver transferred water to the Cape Town Metropolitan Area.

*** Development options were evaluated by means of a multi-criteria decision analysis (MCDA). The MCDA included financial, technical and socio-economic considerations, as well as environmental concerns.

The Michell's Pass Scheme is by a large margin the most economical transfer scheme. Moreover, it would have limited environmental impact. The URV is substantially lower than that of any alternative option for supply to the Berg WMA. The substantial yield, taken together with other means of increasing the yield of Voëlvlei Dam, will probably require that a second pipeline to Cape Town be constructed. This would increase the effective URV substantially, but it would still be a favourable option to augment supplies to the WCWSS and the Lower Berg River.

The other schemes listed above, in addition to being much more expensive than the Michell's Pass diversion, would all have more serious impacts on the environment and on in-basin supplies.

Due to the generally poor transmissivity of aquifers in the Breede catchment, conventional groundwater schemes are not able to deliver the volumes of water typical of regional surface water schemes. However, future in-basin water resource developments are likely to take place incrementally, in the form of schemes supplying individual municipalities or groups of farms. At this scale, groundwater developments are viable, and in some areas, preferable alternatives to surface water developments. Future groundwater exploitation could be located on the alluvial, Bokkeveld or TMG aquifers of the western part of the catchment. Abstraction schemes in the eastern half of the catchment would have to exploit the TMG aquifers, since the water of other aquifers is generally too saline for irrigation.

The City of Cape Town (CCT) is currently investigating the possibility of extracting water from deep boreholes in aquifers of the TMG. One such area is to the south-west of Theewaterskloof Dam. The CCT estimates indicate that 15 million m³/a could be abstracted from 10 deep boreholes in this area and pumped into Theewaterskloof Dam when storage capacity is available in the dam. It is not yet known what the effects of these wellfields (if developed) would be on surface water yields.

Remaining Yield Potential

In an effort to quantify the remaining water resources potential in the Breede catchment, the study has found that it might be practical to provide between 300 and 400 million m³ of additional storage capacity in the catchment, depending on environmental concerns regarding dam construction. Assuming that the Minister eventually accepts the Reserve categories as recommended by the ecological scientists, this storage volume would increase the system yield by 75 million m³/a. If lower Reserve categories are adopted, the system yield could be increased by a further 20 million m³/a. Removal of most of the invasive alien plants in the catchment could recover about 45 million m³/a of "lost" yield. An optimistic maximum value of potential water supply remaining is therefore about 140 million m³/a. It is possible that a significant portion of this potential yield could be developed from groundwater sources in the Upper Breede and Hex River catchments.

E5. COMPARISON OF WATER REQUIREMENTS AND AVAILABILITY

E5.1 Current Yield Balance

The BRBS has improved on previous estimates of water availability and water requirements in the Breede catchment. This information will form the basis of the detailed water reconciliation strategies that will be developed as part of the DWAF ISP process. The current yield balance (Year 2000) in the Breede catchment is the departure point of these strategies, and is discussed in the remainder of this section. The yield balance is calculated by comparison of water availability at 98% assurance, with equivalent water requirements at 98% assurance.

Water Availability

The estimated available yield is shown in Table E.2. The yield consists of surface and groundwater yields, estimated re-usable return flows, impacts on the yield due to water use by alien plants, provisional Reserve requirements, and estimates of river channel losses.

As mentioned in Section E4, acceptance of the classification assumptions and Reserve determinations done by the team of ecological scientists would greatly reduce the potentially exploitable water from the Breede River catchment. In terms of the present availability of water, investigations have shown that, with the exception of the Riviersonderend River, the recommended requirements could be met without impacting significantly on the availability of supplies. Should the provisional Reserve be implemented in the Riviersonderend River, it would result in an impact on the yield of the system of about 85 million m³/a (at 98% assurance). The provisional Reserve is based on the requirement that Category E systems (such as the Riviersonderend River) have to be restored to at least a Category D system, but to achieve this the shortfall would have to be replaced from other sources, and the cost would be very high. For the purposes of estimating the remaining water resources exploitation potential of the Breede River catchment, it was assumed that present day flows would not be further reduced in months when deficits occur, but that the present condition of the Riviersonderend River would not be upgraded. It is, however, essential that this aspect of RDM policy be reviewed, and that the implications associated with meeting this requirement be explored in the ISP and CMS strategy development process.

TABLE E2 : WATER AVAILABILITY IN THE BREEDE CATCHMENT (million m³/a, Year 2000)

SUB-AREA	SURFACE WATER	GROUND-WATER	USABLE RETURN FLOWS		IMPACT ON YIELD		LOCAL YIELD	TRANS-FERS IN	AVAILABLE YIELD (1:50 YEAR)
			IRRI-GATION	URBAN	RESERVE	ALIEN PLANTS			
UPPER BREEDE	432	94	74	12	(16)	(30)	566	0	566
RIVIER-SONDEREND	264	5	9	1	0*	(15)	264	24	288
LOWER BREEDE	61	4	7	0	0	(9)	63	13	76
TOTAL	757	103	90	13	(16)	(53)	894	37	930

* Assuming the Riviersonderend River will not be restored to a Category D River.

Water Requirements

Table E3 shows the sectoral water requirements within the Breede catchment at the Year 2000 level of development.

TABLE E3 : REQUIREMENTS IN THE BREEDE CATCHMENT (million m³/a, Year 2000)

SUB-AREA	IRRIGATION	URBAN	BULK INDUSTRIAL	RURAL	AFFORESTATION	RIVER LOSSES	LOCAL REQUIREMENTS	TRANSFERS OUT	TOTAL REQUIREMENT
UPPER BREEDE	495	23	0	4	0	5	527	22	549
RSE	91	2	0	2	1	0	96	192	288
LOWER BREEDE	72	1	0	1	0	0	74	0	74
TOTAL	658	26	0	7	1	5	697	214	911

Reconciliation of Requirements and Availability

Table E4. shows the yield balance for the Breede catchment at the Year 2000 level of development.

TABLE E4: COMPARISON OF REQUIREMENTS AND AVAILABILITY (million m³/a, Year 2000)

SUB-AREA	AVAILABLE WATER (1:50 YEAR)			WATER REQUIREMENTS (1:50 YEAR)			BALANCE
	LOCAL YIELD	TRANSFERS IN	TOTAL	LOCAL REQUIREMENTS	TRANSFERS OUT	TOTAL	
UPPER BREEDE	566	0	566	527	22	549	17
RIVIER-SONDEREND	264	24	288	96	192	288	0
LOWER BREEDE	63	13	76	74	0	74	2
TOTAL	894	37	930	697	214	911	19

The surplus that is shown in the Upper Breede relates mainly to portions of the yields of the Koekedouw Dam near Ceres, and the Stettynskloof Dam in the Holsloot River. The small surplus in the Lower Breede is due to inflows from upstream, and also from some spare yield that is available from the Buffeljagts Dam near Swellendam. If the provisional Reserve for the Rivier-sonderend River were to be implemented, the overall surplus of 19 million m³/a would be reduced to a large deficit of about 66 million m³/a.

E5.2 Reconciliation of Future Water Requirements and Availability

The future utilisation of the water resources of the Breede River catchment cannot be viewed in isolation and must be considered in the context of the Western Cape region as a whole. It is one of the recommendations of the BRBS that reconciliation of water requirements and water availability in the Breede and Berg WMAs be done as part of an integrated follow-up study. The BRBS has put in place much of the information that will be needed to, in the mean time, develop strategies for the local management and future use of the water resources of the Breede River catchment itself. In doing so, it was necessary to at least develop some understanding of the

wider regional issues that will affect future decisions on the sharing of water resources in the Western Cape. These issues were explored through the involvement of the DWAF Strategic Environmental Assessment (SEA) Team, and through the work undertaken for the Regional Economics component of the study. The following broad water use scenarios were identified, which could form a departure point for the reconciliation of future regional water requirements and water availability:-

- Urban demand growth is given priority (i.e. meeting future demands for water from the WCWSS and urban demands within the Breede River catchment).
- Development for resource poor farmers gets priority.
- Tourism and conservation are given strong emphasis.
- The existing irrigation sector continues to develop to a greater or lesser extent.
- Balanced development.

The agricultural development scenarios (prioritisation of developments for resource poor farmers, and commercial irrigated agriculture continues to develop) can conceivably be combined as one scenario – this being the most plausible way forward for the agricultural sector.

Reconciliation of future water requirements and availability in the Breede and Berg WMAs will have to be based on the relative benefits of water use by different sectors in the region, including the natural environment. Some considerations with regard to the reconciliation of future water requirements and water availability are outlined in the following sections.

Water Availability

Future water availability will largely depend on the degree to which water use by invasive alien plants can be controlled on the one hand, and the levels at which the Reserve is eventually set. As previously mentioned, a possible maximum value of potential water supply remaining is about 140 million m³/a.

Future Water Requirements (2030)

It appears unlikely that the total Breede River irrigation demand will have increased by more than 75 million m³/a by 2030. Allowing for an increase in urban water requirements of about 17 million m³/a, the total additional in-basin water requirement by the year 2030 could therefore be of the order of 90 million m³/a.

Reconciliation of Future Requirements and Availability

From the above, it appears that there may be an opportunity to enable a significant quantity of water (about 50 million m³/a) to be transferred from the Breede River catchment without impacting on in-basin water requirements prior to 2030. In reality, the water supply that would be required during final stages of agricultural growth is likely to come at a higher price than agriculture can afford. If no, or very little expansion of commercial irrigation should be authorised in the Breede River catchment, but about 35 million m³/a is taken up by resource poor

farmers, the total additional in-basin water requirement could drop to about 50 million m³/a. In this scenario, the upper limit for transfers could be of the order of 90 million m³/a.

Possible Reconciliation Interventions

The effective implementation of WCDM measures is of prime importance, and should be the first intervention. BRBS estimates of future water requirements have already been reduced to account for the effect of WCDM.

The development of water supplies for irrigation is likely to facilitate provision of the relatively small quantities needed to augment the water supplies of the various towns in the Breede catchment.

Supplementary water supplies to meet future WCWSS demands (after the Berg Water Project) could be derived from several sources in and around the Berg WMA. Options within the Berg WMA would have advantages and should be considered first, but these local options would become more expensive as the more economical ones are developed and exploited. In the medium term future, transfers to the Berg WMA through the relatively inexpensive Michell's Pass diversion scheme (53 million m³/a) or even the Molenaars diversion scheme (27 million m³/a) could be developed ahead of more expensive schemes in the Berg WMA. In the longer term, the benefits of transfers from any area where surplus water may exist would be weighed against the cost of desalination.

The implementation of the Greater Brandvlei – Theewaterskloof – Berg WMA transfer scheme would virtually preclude sizeable irrigation developments that could be supplied from the augmented yield of Greater Brandvlei Dam. A limited time should be allowed for clarification of whether the Greater Brandvlei transfer scheme should be retained as an option.

Further investigations should be carried out to determine the best use of water from the raised Buffeljags Dam (irrigation development or supply of ecological water requirements in the Lower Breede River).

E6. MANAGEMENT APPROACHES AND STRATEGIES

The devolution of catchment management functions from DWAF to the future Breede River CMA will be phased over a period of about ten years to match the establishment of capacity within the CMA. In the mean time, DWAF will have to take responsibility for and later assist with water resource management in the WMA. The Department's ISP process is intended to develop interim water resource management strategies to be followed by DWAF until such time as the CMA can take over with its own CMS. The baseline information provided by the BRBS should feed into this process, and presumably also into the eventual CMS. The following is an abbreviated list of the issues and broad management approaches that were identified in the BRBS:

The Reserve

The setting of ecological classes and the implementation of the Reserve could have a significant effect on the availability of water for other users. The BRBS assessments of water availability were based on the classifications and ecological water requirements (nearly 1000 million m³/a or, 53% of MAR) suggested by the ecological scientists on the study team. It is difficult, if not impossible to do meaningful planning without clear DWAF policy regarding the setting of the Reserve and its implementation. At present there are no precedents to go by. It is therefore important that ongoing progress be made in this regard, possibly by including policy statements on this issue in the second edition of the NWRs. Other issues that relate to the implementation of the Reserve in the Breede catchment include:

- The protocol for estuarine Reserve determination should be reviewed, and if possible, amended to introduce a flexible, iterative means of refining the estimates of ecological water requirements.
- Further studies should be undertaken to fully assess the potential impacts of future developments in the feeder rivers of the Papenkuils Wetland, and to facilitate management of this wetland system. The possibility of mechanical intervention to rehabilitate the system by, for example, diverting flows from the main channel of the Breede River into the wetland, should be investigated. Further work should also be done to determine the volumetric quantities, seasonal distribution, and assurances of the ecological flow requirements that are associated with the frequencies and levels of inundation that were determined during the course of this study. The relative contributions of groundwater and surface water to these requirements should be quantified.
- The financial and socio-economic implications of restoring the Riviersonderend River to a Category D river should be explored. In a wider context, consideration should be given to the concept of identifying and balancing the distribution of localised "sacrificial" and "conservation-worthy" systems within a wider regional biosphere.
- Environmental monitoring should be implemented to evaluate the validity of the Reserve provision.
- With the exception of IFR Site 4 (in the Lower Breede River), all IFR Sites are located near a DWAF flow gauging station. These stations should form the basis of a compliance monitoring network that could be expanded to include other stations as the Reserves are extrapolated into the remainder of the catchment.
- The parallel application of the BBM and DRIFT methodologies in the Breede catchment has shown that DRIFT produces time series of riverine ecological water requirements that are more closely aligned with present day flows in the system than those produced with the BBM. The disparity between the two sets of estimates was most pronounced at the downstream end of the system (IFR Site 4), where the DRIFT sequence indicated that present flows in the system are sufficient to meet provisional Reserve Requirements, whereas the BBM sequence indicated a substantial shortfall of about 76 million m³/a.

Yield Balances

According to study estimates, groundwater use in the Ceres catchment exceeds the available allocation in this area. Licensing of further surface and groundwater abstractions during the summer months should therefore be avoided. There may be further potential for groundwater use by means of artificial recharge of aquifers during the winter months, or abstractions from confined or deep aquifers, but this will have to be verified by means of further studies.

Water use in the catchment of the Theewaterskloof Dam, releases for downstream irrigators, and supplies to the Berg WMA via the tunnel system have taken up the maximum yield of the upper Riviersonderend catchment, and licensing of new water use in this catchment should also be restricted. Future water availability in the Riviersonderend catchment downstream of Theewaterskloof Dam will largely depend on the degree to which invasive alien plants can be eradicated in this area, as well as on the level of the Reserve that will be set for the river.

In the Hex River catchment, water resource developments have taken up the major portion of the potentially exploitable yield. Limited amounts of water could still be made available through groundwater developments, provided that these do not further reduce summer flows, or by means of storing surplus winter runoff.

Prior to commencement of the study, a number of transfer options from the Breede to the Berg WMA were investigated. The sizes of the transfers ranged up to 100 million m³/a. The investigations carried out for the BRBS have shown that some transfer of water to the Berg WMA would be acceptable from the Breede development perspective. Assessment of transfer options should be refined in an integrated regional water resource study. In the mean time, an element of conservatism should be built into decisions on water allocations for transfers.

The wide spread in the growth scenarios for Breede River irrigation is indicative of the uncertainties around the future of the sector. The risk associated with over-investment in irrigation water supplies is therefore high. At the other extreme, the reservation of all the remaining water in the Breede catchment for future demands for water from the WCWSS would preclude its use for irrigation in the interim, and would entail substantial loss of opportunity. This issue should be further addressed in the Breede ISP, but it will only be possible to make final decisions on the allocation of water after more detailed further regional studies and comparisons.

Resource Poor Farmers

The development and support of resource poor farmers must receive highest priority. The large number of resource poor farmer developments in the Breede River catchment that have already been registered with the Department of Land Affairs indicate a substantial demand for the redressing of past inequities. It is essential that a strategy with clearly defined targets be put into place to guide this process. A development model that encourages support and skills transfer from existing commercial farmers could have many advantages in the long run. Incentives could be provided through a licensing policy that would limit (or at least favour) the issuing of new licenses for irrigation water use to joint partnerships between existing and emerging farmers.

Water Conservation and Demand Management

Elimination or reduction of water use by invasive alien plants represents by far the most viable means of unlocking water resources for the benefit of the environment and future consumptive water needs in the catchment. Clearing efforts should be sustained, and if possible, intensified. There is also considerable scope for water savings in the irrigated agriculture and urban sectors, and the importance of establishing a WCDM culture in the catchment cannot be over-emphasised. Measures that should be implemented in the Breede catchment include:

- In towns where water shortages are being experienced or where shortages are imminent such as De Doorns, Bonnievale, and to a somewhat lesser extent Robertson, Ashton, Villiersdorp and Riviersonderend, the implementation of WCDM measures should receive priority attention.
- The yields of virtually all the existing irrigation water supply schemes in the catchment are fully committed. Farmers should be encouraged to use water more efficiently, thereby making water available for resource poor farmers or even for some limited expansion of existing operations, by implementing WCDM measures.
- Real-time monitoring systems should be installed at selected points on the Breede River, the Riviersonderend River, and on the major canal systems and pumping schemes to improve the efficiency of releases from dams.
- Water user databases maintained by Water User Associations (WUAs) must be modified to include information necessary for the successful implementation of WCDM measures.
- DWAF should promote the concept of managing irrigation water supply schemes on the basis of compulsory weekly demand projections, based on reliable soil moisture and crop water demand data.
- A workshop should be arranged to decide on, and adopt a set of benchmarks and benchmark values for efficient water use on irrigated crops. Such a workshop should include all role players in irrigated agriculture in the Breede WMA.
- The pilot study that was planned by DWAF for the testing of its Agricultural WCDM Implementation Guidelines in the Breede WMA should now be in order to gain a quantitative picture of the scope for WCDM in the area.
- Bulk water meters must, as a matter of urgency, be installed on all urban water supply schemes from which supplies are not currently measured. Meters should also be installed to record water consumption at zone level, and volumes recorded meticulously.
- Procedures for the comparison of bulk-metered consumption with the totals of individual water meters should be instituted to quantify "unaccounted for water" and system losses in urban water supply systems.
- Municipalities should be encouraged to implement structured water tariff systems that will promote the efficient use of water. This should be supplemented by informative billing to empower water users to improve their own water use efficiencies.
- A programme to educate local government water services officials and councillors on the need for, and importance of the implementation of WCDM measures should be initiated as a matter of urgency.

- Municipalities should be required to record and report on the per capita and per household water consumption in the water use zones in their respective service areas. This will provide a measure of progress made with the implementation of WCDM, and will also assist in the identification of areas that should receive priority attention.

Water Quality

In the past, the general water quality in the Breede River catchment was not considered to be a major concern, except for the rising salinity in the Middle Breede River and its tributaries. The occurrence of algal blooms under low flow conditions at certain locations within the Middle Breede River, clogging of canals by filamentous algae and aquatic weed, and point pollution from, in particular, distilleries, cheese factories, and textile factories have been identified as additional problems. Several measures to improve water quality were investigated, leading to the following recommendations:

- Management strategies for the application of fertilisers should be developed and implemented to reduce nitrogen and phosphorus loads in rivers.
- Very little information on the occurrence of algal blooms in the catchment exists, and a reporting system for water bailiffs should be initiated to quantify the extent of these occurrences.
- For the purposes of improving crop quality and yields in the Middle Breede River, the possibility of lowering the target salinity limits at the Zanddrift canal offtake in certain months should be considered.
- Meaningful short-term salinity alleviation could be achieved through the construction of return flow interceptor drains, combined with the freshening release strategy. Further detailed investigations should be carried out to optimise and cost this option, taking into account the current salinity profile in the Breede River between Robertson and Bonnievale, and making use of detailed soil surveys that are available for this area.
- Further development of irrigation in areas producing highly saline return flows should be actively discouraged. It is recommended that, based on the soils investigations carried out for this study, these areas be demarcated on a map, and that the future CMA make use of regulatory and financial instruments at its disposal to influence further irrigation development in the demarcated areas. These measures could include the conditional approval of new water use licenses, penalties for offences in terms of water use regulations or licensing conditions, and a pricing strategy that would allow for an increased price of water in demarcated areas.

E7. THE WAY FORWARD

The study has highlighted the need for the development of a strategy for the integrated management of the water resources of the Breede River catchment, together with those of the Berg River catchment. The strategy development process will be initiated through the Department's Internal Strategic Perspectives (ISP) process, which is intended to develop interim

water resource management strategies to be applied by DWAF until such time as the CMA can take over.

The study provides much of the information that would be needed to inform the strategy about the local development of the water resources of the Breede River and about possible transfers. However, the following additional information would among others be needed to develop compatible catchment management strategies for the Berg and Breede WMAs:

- Assessment of the economic and social benefits of water usage for irrigation in the Breede WMA, and comparison of these with the benefits associated with transferring water to the Berg WMA. This information is required to inform decisions on possible eventual transfers.
- Evaluation, comparison and prioritisation of options for the further development of water supplies to meet the needs of the Berg WMA, in order to give the transfer options (especially the Michell's Pass and Molenaars diversion schemes) their correct positions in an implementation schedule.
- Setting the Reserve for the Breede River and its tributaries in order to clarify the potential for the further development of the water resources. It is suggested that this should include a review of the RDM policy to take into consideration the concept of localised "sacrificial" and "conservation-worthy" sub-systems. Thereafter, a public participation process taking account of both the impacts of further abstractions on the environment as well as the benefits of further developments, will be needed.

BREDE RIVER BASIN STUDY

MAIN REPORT

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- A Reports of Previous Studies in the Breede River Catchment
- B Yields and Unit Reference Values of Schemes

ABBREVIATIONS

BRBS	Breede River Basin Study
CMA	Catchment Management Agency
DWAF	Department of Water Affairs and Forestry
ERC	Ecological Reserve Category
EWR	Ecological water requirements
GCTMA	Greater Cape Town Metropolitan Area
GGP	Gross Geographical Product
ha	hectare
IRR	Internal rate of return
MAR	Mean annual runoff
mm	millimetre
m ³	cubic metres
m ³ /a	cubic metres per annum
SEA	Strategic Environmental Assessment
WCDM	Water Conservation and Demand Management
WMA	Water management area
WUA	Water User Association

BREEDER RIVER BASIN STUDY

MAIN REPORT

1. INTRODUCTION

1.1 THE PURPOSE OF THE STUDY

In 1999, the Department of Water Affairs and Forestry (DWAF) commissioned the Breede River Basin Study (BRBS) to provide the information that is required for the effective management and beneficial use of the water resources of the Breede River and its main tributary the Riviersonderend River.

The decision to undertake the study was determined by the water situation in the south western region of the Western Cape. The demands for water from the Western Cape Water Supply System (WCWSS) and the water needs in the Breede Water Management Area (WMA) were placing severe pressure on the water resources of the region. The provision of information that would allow planning for optimum utilisation of the water resources on a regional basis was therefore essential.

The National Water Act of 1998 set in motion a process of fundamental change in the way in which water resources are managed in South Africa. One of the most significant aspects of this process is the establishment of new water management institutions that will allow water users and interest groups to participate in the management of their water resources. The process of establishing a Catchment Management Agency (CMA) for the Breede WMA (which also includes the Palmiet, Sout and Bot River catchments), commenced shortly after the inception of the BRBS. While the actual establishment of the CMA remained a separate process, it was intended from the start to support the development of the CMA through the BRBS. CMA stakeholders were involved in the technical working groups and feedback meetings of the BRBS. Together with the stakeholders, information forthcoming from the study was used to prepare a series of discussion papers that formed the basis of a proposal for the establishment of the CMA.

In addition to the important link that was established between the study and the development of the CMA, the study was designed to provide the technical information that would be required for good water resource management. The findings of the BRBS have since provided invaluable baseline information for the Department's Internal Strategic Perspectives (ISP) process, which is intended to develop interim water resource management strategies to be applied by DWAF until such time as the CMA can take over. The CMA will presumably also use BRBS information to eventually develop a Catchment Management Strategy (CMS) for the Breede River.

The basic objectives of the study were therefore to:

- assist with the institutional development of the CMA
- provide the information that will be required for good water resource management, especially to support decisions on license applications
- provide a sound foundation for the development of an ISP and a CMS
- enable and facilitate follow-up broad regional planning for the Berg and Breede WMAs, as well as more detailed feasibility studies

Principles adhered to for the execution of the work included:

- Conforming to the principles, spirit and content of the National Water Act (36 of 1998) and Water Services Act (108 of 1997).
- Emphasising environmental sustainability.
- Emphasising water conservation.
- Optimising resource allocation to extract maximum economic return and job creation opportunity from each cubic metre of water utilised.
- Identification of opportunities for redistribution of resources to ensure their equitable allocation and use in future, especially for historically disadvantaged communities.
- Identifying and taking into account the public's views in an open and transparent manner.

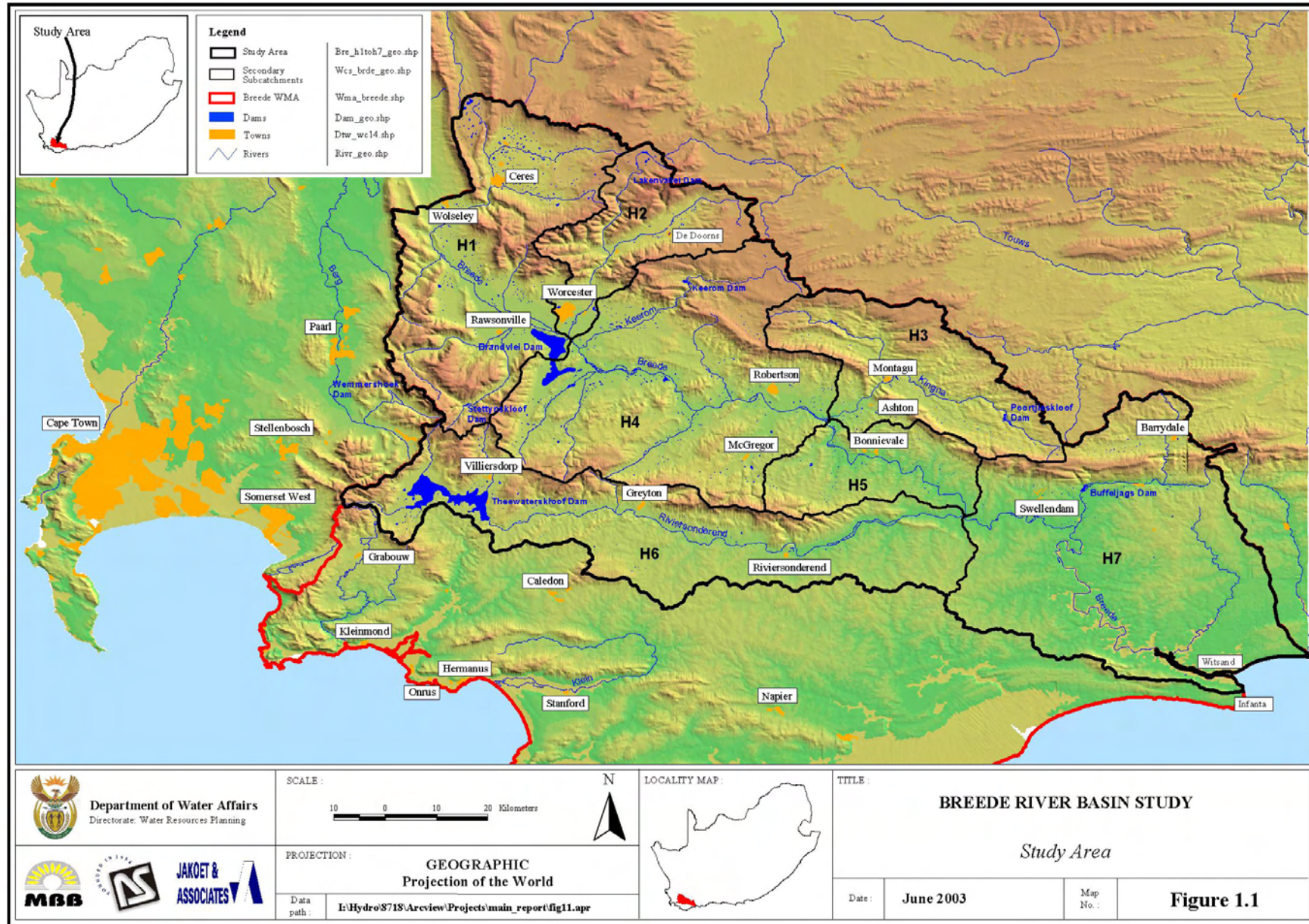
1.2 THE STUDY AREA

The limits of the study area are defined by the water catchment area of the Breede River, as shown on Figure 1.1. The Breede River catchment and the Palmiet and Overberg areas together form the Breede Water Management Area (WMA).

1.3 STUDY APPROACH

1.3.1 General Methodology

An index of previous reports on studies carried out in the Breede River is contained in Appendix A. The most relevant of these are the reports that document the work undertaken for the Breede River Hydrological Study and the Breede River System Analysis, which work was completed under this study. There are also various reports on water quality issues, and on development proposals and their likely environmental impacts. Some of these proposals have been evaluated and are described in the Breede River Basin Study reports.



The Study was carried out in three phases :

- The **Inception Phase** was used to refine the Terms of Reference, budget and work programme.
- The objective of the **Preliminary Phase** was to prepare a preliminary framework for the study, and in so doing, to provide substantive but preliminary results at an early stage of the study. This approach served to focus the activities of the Final Phase of the Study, and provided the opportunity to present some substantive information to the public and interested and affected parties at an early stage of the study. This facilitated meaningful public involvement through the course of the remainder of the Study.
- Activities in the **Final Phase** comprised surface and groundwater assessments, Reserve determinations, agricultural studies, assessment of the potential for water conservation and demand management (WCDM), and investigation of possible further water resource developments.

1.3.2 Addressing the Objectives of the Study

The objectives of the Study were addressed in a series of specialist investigations that are documented in more than twenty separate technical reports. The contributions of the various specialist investigations toward addressing the overall objectives of the Study, and the reports that document the findings, are described below.

(i) Assist with the institutional development of the CMA

The Public Participation Programme (PPP) was integrated with the PPP for the establishment of the Breede CMA. This not only led to significant cost savings, but valuable synergy was achieved. Public participation was facilitated through a series of public meetings and supporting documentation. Focussed input by a Stakeholder Committee and Technical Working Groups for the Agricultural Water Demand, Environmental, and Water Quality components of the BRBS were received at key points in the study. The Stakeholder Committee also participated in the establishment of the Breede CMA Reference Group, which guided the development of a proposal for the establishment of a CMA for the Breede WMA.

The PPP also facilitated the very important buy-in by stakeholders of the future CMA into the BRBS and its findings.

(ii) Provide the information that will be required for good water resource management, especially to support decisions on license applications

A mapping exercise was carried out to determine historical and current day (Year 2000) land-use, which provides the basis for quantifying historical growth in agricultural water use, current levels of agricultural water requirements, and water consumption in areas covered by commercial

forests and invasive alien plants. The findings of this task are documented in DWAF Report No. PH 00/00/1602 *Land Use*.

The hydrological analyses that were undertaken for the Upper and Middle Breede regions (secondary catchments H1 to H5) as part of the Breede River Hydrological Study, were updated and extended to cover the Riviersonderend (H6) catchment, and the Lower Breede region (H7). This work quantifies the surface water resources of the catchment, and is reported on in Report PH 00/00/2402 *Hydrology*.

The availability and current use of groundwater in the Breede River catchment, and the potential for further use from this source was investigated, and is reported on in Report PH 00/00/2502 *Groundwater Assessment*.

During the Preliminary Phase of the Study, a catchment-wide review of surface water quality was prepared, with an emphasis on the increasing salinisation of the Middle Breede River. The findings of this assessment is documented in Report PH 00/00/2502 *Water Quality Situation Assessment*.

Historical growth of water consumption in urban areas, together with estimates of current use and future requirements, water sources, and comment on the adequacy of these are documented in Report PH 00/00/3502 *Urban Water Demands*.

The study area is characterised by an advanced state of development from an agricultural point of view. A large number of irrigation board schemes have been developed over time, and virtually the entire study area is criss-crossed by canals and pipelines supplying water for irrigation of commercial crops. Numerous dams of various sizes are used to store winter run-off for use in summer. Water for urban use is generally also impounded in dams and conveyed to towns by means of canals and pipelines. The major water infrastructure components, and the operations of irrigation boards and water supply schemes serving local authorities are described in Report PH 00/00/1702 *Infrastructure and Irrigation Schemes*.

A socio-economic situation analysis was carried out during the Preliminary Phase to provide information on demography, institutional arrangements, development guidelines and development scenarios for other study tasks. This information is not documented in a stand-alone report, but is synthesised in Section 2 of this, the Main Report.

The suitability of the soils and climate in the Breede River catchment for sustained commercial irrigated crop production was evaluated from available soil classification information and maps, and supplemented with delineation of uniform terrain units in areas not covered by previous surveys. This work is documented in Report PH 00/00/1902 *Evaluation of Soil and Climate Suitability for Irrigated Agriculture*.

The financial viability of existing irrigated farms, possible future expansions, and new farming areas that might be established, were investigated to gauge the growth potential of this sector.

The findings of these investigations are documented in Report PH 00/00/2802 *Financial Viability of Irrigation Farming*.

Agricultural water usage and requirements were assessed according to locality, source, crop type and area, and irrigation system. These are documented in Report PH 00/00/1802 *Agricultural Water Demands*. This report also provides an assessment of prevailing market conditions for produce of the Breede River catchment, and estimates of the cost of developing water resources for agricultural use in the form of localised surface and groundwater schemes. The report draws on this work and the preceding two reports to provide projections of future requirements associated with a number of development scenarios.

- (iii) Provide a sound foundation for the development of an ISP and a CMS
and**
- (iv) Enable and facilitate follow-up broad regional planning for the Berg and Breede WMAs, as well as more detailed feasibility studies**

Environmental sustainability forms one of the cornerstones of the National Water Act. In recognition of this, and to provide the information that would be required to ascertain the availability of water at particular locations in the catchment and to set a Preliminary Reserve in the Breede Water Management Area, a considerable portion of Study resources was directed toward determining the ecological water requirements of the aquatic ecosystems in the Breede River catchment.

Reserve determinations were carried out for the following components of the Reserve :

- Reserve determinations for riverine water quantity and quality were undertaken at an intermediate level, utilising comprehensive technical methods at six sites, and rapid estimates elsewhere in the catchment. This work is documented in Reports PH 00/00/1302 *Ecological Reserve Determination for Six Representative Sites using the Building Block Methodology*, PH 00/00/3402 *Ecological Reserve Determination (Water Quality)*, and PH 00/00/3602 *Ecological Reserve Determination (Water Quality) – Recalculation of the Water Quality Reserve*.
- An intermediate level Reserve determination was carried out for the Breede River Estuary, and is documented in Report PH 00/00/3602 *Intermediate Determination of Resource Directed Measures for the Breede River Estuary*.
- A low-confidence, intermediate level Reserve determination was carried out for the Papekuils (Bokkieskraal) Wetland near Worcester, the only major wetland in the Breede River catchment. This is documented in Report PH 00/00/1402 *Papekuils Wetland Intermediate (Ecological) Reserve Determination (Low Confidence)*.
- Groundwater Reserve determinations were performed at an intermediate level for two areas of high groundwater potential, and at a rapid level elsewhere in the catchment. This work is documented in Report PH 00/00/1202 *Groundwater Reserve Determination*.

The growing imbalances between the availability of scarce water resources and the demand for water in South Africa have put a premium on the efficient use of available water resources. Considerable effort was therefore expended on the identification and evaluation of water conservation and demand management options. The work was focussed on two areas where substantial savings can be achieved, namely through the control and eradication of invasive alien plants, and the implementation of water demand management measures in the agricultural sector. Comment on the potential for water demand management in urban areas is provided in the form of a case study of water use in the town of Robertson. Findings are documented in Reports PH 00/00/2002 *Invasive Alien Plants* and PH 00/00/2102 *Water Conservation and Demand Management*.

A wide range of potential water supply options that were previously identified, and a number of new possibilities, were assessed at a reconnaissance level to identify the more favourable developments. The larger regional schemes (in-basin and transfer schemes with yields in excess of 10 – 15 million m³/a) were evaluated from financial, technical, socio - economic and environmental perspectives. The findings of this work are presented in Report PH 00/00/2702 *Scheme Development and Environmental Impacts*. There are numerous smaller "local" water supply development possibilities with individual yields of generally less than 10 million m³/a. Comparative assessments of these local schemes were limited to cost estimates and comment on the potential accumulative environmental impacts, and are reported on in Report PH 00/00/1802 *Agricultural Water Demands*.

A systems model (Water Resources Yield Model – WRYM) was compiled for the Breede River system, and used to determine the yield potential of possible future water resources developments, subject to environmental water requirements, and current use from the system. The water quality component of the Water Resources Planning Model (WRPM) was used to assess the yield implications of salinity alleviation measures in the Middle Breede region. The compilation of these models, and the findings of the analyses are documented in Report PH 00/00/2602 *Regional Yield Assessment*.

The information forthcoming from the Breede River Basin Study will be used to inform strategic decisions on future resource use in the region. Therefore the Breede River catchment cannot be viewed in isolation, and resource development must be considered in the context of the Western Cape Region and the needs of the country as a whole. To put this vision into practice, a high level group of decision makers and planners from a range of disciplines were invited to provide the study team and stakeholders with their insights, understanding, visions, plans and ideas of how the Breede River and its water resources should be developed within the context of the Western Cape and its wider needs. The proceedings of this workshop are summarised in Section 9 of this, the Main Report.

An important element of these decisions is the economic implications of different resource use choices. In this regard, a regional economic model was developed that would in future help explore the economic implications of water resource allocations between the affected catchments. The functionality and use of this tool is also described in Section 9 of the Main Report.

The specialist investigations carried out by the BRBS Team, relied on active input of local people. Public participation was facilitated through a series of public meetings and documentation. Focussed input by a Stakeholder Committee and Technical Working Groups for the Agricultural Water Demand, Environmental, and Water Quality components of the BRBS were received at key points in the study. The Stakeholder Committee also participated in the establishment of the Breede CMA Reference Group, which guided the development of a proposal for the establishment of a Catchment Management Agency (CMA) for the Breede Water Management Area. The activities and outcomes of the Public Participation component of the Study are recorded in Report PH 00/00/3002 *Public Participation Programme*.

Finally, this *Main Report* (Report PH 00/00/3102) presents an overview of the prominent features of the specialist investigations, and draws on the findings of these investigations to present a foundation for the strategy development process that will be initiated in the ISP, and taken further in the development of a CMS by the Breede CMA.

1.4 STRUCTURE OF THIS REPORT

This report presents the findings of the Study. Factors that are likely to influence the development of water resources are discussed in terms of:

- ❑ significant features of the catchment, including natural features, land use, infrastructure, institutional arrangements, and prevailing socio-economic conditions;
- ❑ environmental and consumptive water requirements;
- ❑ the scope for water savings through conservation and demand management;
- ❑ water availability, and
- ❑ water resources development options.

The document concludes with a discussion of the issues and broad management approaches that will inform the development of interim water resource management strategies, and the eventual CMS for the Breede River WMA.

2. CATCHMENT DESCRIPTION

2.1 LOCATION

The Breede River is the largest river in the Western Cape and originates in the Ceres Valley approximately 100 km north-west of Cape Town. The river flows in a south-easterly direction until, after approximately 320 km, it reaches St Sebastian Bay near Witsand/Infanta on the Southern Cape Coast. The Rivieronderend is the main tributary of the Breede River and together these catchment areas are referred to as the Breede River Basin (or catchment).

In this report, and in many of the supporting technical reports, references are made to sub-regions within the Breede River catchment. The boundaries of these sub-regions (shown on Figure 1.1) follow watersheds within the catchment, and define areas with relatively uniform climatic, hydrological and development characteristics. In some instances, the downstream ends of sub-regions coincide with the location of major existing water resources developments.

The sub-regions are the **Ceres catchment** (from the source to Michell's Pass – comprising part of the H1 secondary catchment); the **Upper Breede River** (from Michell's Pass to Greater Brandvlei Dam – rest of H1); the **Hex River** (H2); the **Kogmanskloof** catchments (H3), the **Middle Breede River** (from Greater Brandvlei Dam to the confluence of the Breede and Rivieronderend Rivers – H4 and H5); the **Theewaterskloof** catchment (Rivieronderend upstream of Theewaterskloof Dam – part of H6); the **Lower Rivieronderend** (Rivieronderend downstream of Theewaterskloof Dam – rest of H6); and the **Lower Breede River** (H7).

In some instances, these sub-regions have been further divided to suit particular tasks.

2.2 DEVELOPMENT OF THE LAND

The Hessequa clan of the Khoikoi ('men-of-men') people were of the earliest inhabitants of the Breede River catchment, and lived as herders in the coastal region stretching from L'Agulhas to the mouth of the Gouritz River. At the same time, San people lived further inland, in the mountainous areas of the Breede River Valley, and other parts of the Western Cape.

The first written records of the Breede River were those of the Portuguese explorer, Bartholomew Dias who landed near the mouth in 1488. He named the river "Rio Nazaré", and the bay into which it empties, "Shelter Bay", which was later renamed St Sebastian Bay. Early Dutch explorers subsequently changed the name of the river to Breede River, reflecting its size and great width.

The commercial possibilities of coastal trade resulted in the establishment in 1817 of Port Beaufort on the northern shore of the Breede Estuary as a trading port. This coincided with the first commercial and agricultural development in the Overberg. With the rise of Mossel Bay as a sea port, the use of the estuary has largely reverted to recreational use.

The first significant irrigation development in the Breede River catchment took place between 1898 and 1918. Since then, the region has developed into the largest single food and wine producing region in South Africa, and is an important agricultural area for the production of high value crops under intensive cultivation.

2.3 THE PEOPLE OF THE BREEDE RIVER CATCHMENT

2.3.1 Population

In 1996, the total population of the Western Cape Province was estimated to be 3 957 000 people, and by mid-year 1999 this population was estimated to have increased to a new total of 4 171 000 people (Statistics South Africa, 1999). The demographic characteristics of the Breede River catchment are similar to those of the Western Cape Province. In 1996, the total population in the Breede River catchment was in the region of 282 300 people. Assuming the same population growth in the Breede River catchment as that for the Province as a whole, the total Breede River catchment population was estimated to be about 297 600 people by mid-year 1999.

2.3.2 Employment

In 1996, the rate of unemployment in the Breede River catchment was estimated as 13,4% (16 200 unemployed people of a potentially economic active population of 121 200 people in 1996), moderately lower than the unemployment rate of 17,9% for the Province as a whole (Statistics South Africa, 1996). Due to the significant downturn in the agricultural sector during the past decade, it is expected that the unemployment rate in the study area has since increased significantly. Of the formally employed people, 45,5% are directly employed by the agricultural sector (see Figure 2.1), compared to the Provincial total of 12,3%. A large proportion of the rest of the population receive their livelihoods from agro-industries that are associated with the fruit and wine industries. Many of the employed are seasonal workers, with jobs for only a few months of the year.

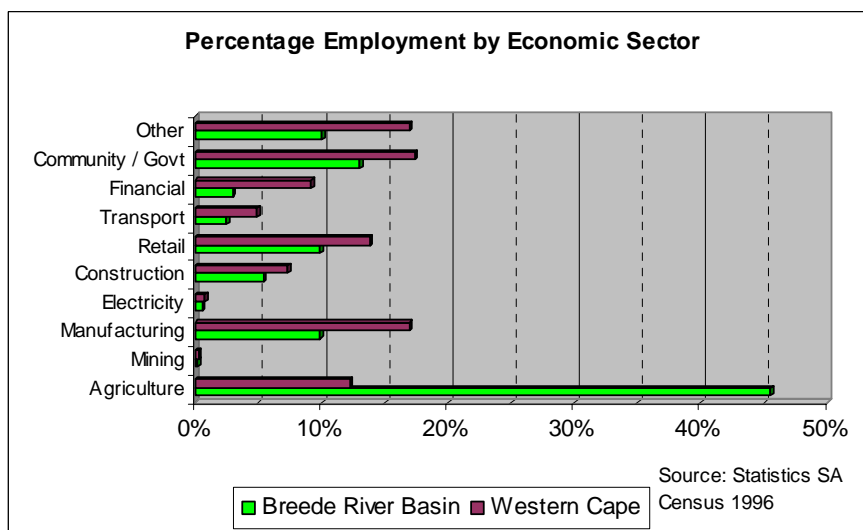


Figure 2.1 : Employment by economic sector

Figure 2.2 shows the distribution of unemployment in the Breede River catchment in accordance with the 1996 Census enumerator areas. In the rural areas, high rates of unemployment occur in areas around Genadendal, Greyton, Suurbraak, Barrydale, Rawsonville and De Doorns. Unemployment in the informal settlements that are located in most of the towns is also high.

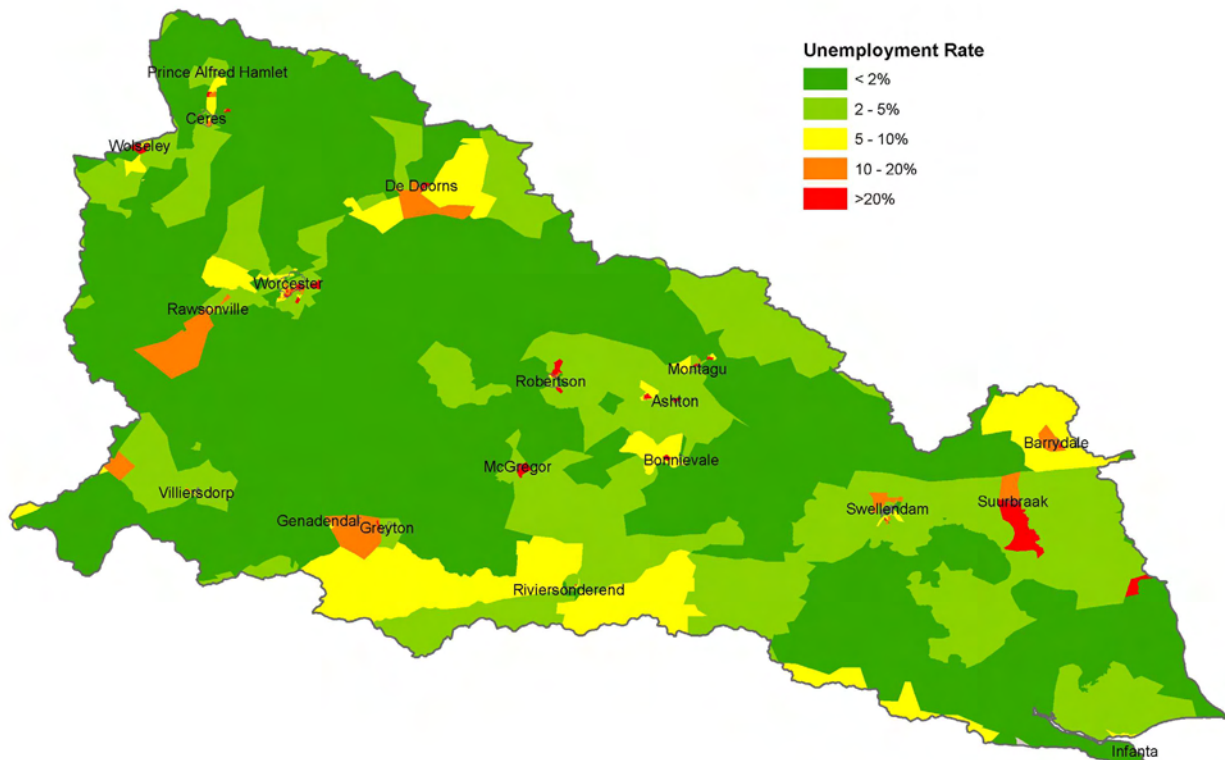


Figure 2.2 : Distribution of unemployment in the Breede River catchment

2.4 ECONOMIC ACTIVITIES

A brief socio-economic overview of the Breede River catchment was given in the Breede River Basin Study *Inception Report* (Report No. PH 00/00/0999). That overview, based in large measure on the Western Cape Economic Overview (Urban-Econ, 1998), is reproduced here by way of background.

The Breede River region is the third largest producer in the Western Cape Province in terms of contribution to Gross Geographical Product (GDP). It provides 4,5% of the provincial GDP. The economy of the Breede River region is dominated by the agricultural sector, which produced 35,5% of the region's GDP in 1997. The manufacturing, trade, finance and government services sectors are the other significant economic sectors in the Breede River region.

Agricultural Sector

Agriculture is mainly irrigation-based and occurs along the river valley. The agricultural sector is focused on the production of fruit and wine, and has been dominant in the region for a long time. The agricultural sector is the largest employment provider as it is relatively labour intensive. The Ceres Valley is the most important fruit producing area in the region. The major agricultural activities in the Breede River region are the fruit industry, wine and table grapes and vegetable cultivation.

Industrial Sector

The industrial development is generally associated with the processing of agricultural products, or providing services and goods to the agricultural community. Although the manufacturing sector of the Breede River catchment produces only 3% of the provincial manufacturing GGP, it is the fourth largest proportional contributor in the Province. Manufacturing activities are concentrated on food and beverage processing and are relatively labour intensive. Some of the well-known manufacturing operations in the region are the canning industries at Montagu and Ashton, fruit juice production at Ceres, and the cheese factory at Bonnievale. There are also a few manufacturing concerns operating in metal products and motor parts, timber and furniture as well as the other non-metal industries.

Trade Sector

The trade sector, which includes the tourism industry, produced 14% of the region's GGP. Trading activities are concentrated on wine, fruit, wheat and other agricultural products. The tourism industry is not as strong in this region as it is in some of the other parts of the Western Cape, but is growing.

Finance and Government Sectors

The finance and government service sectors are the fourth and fifth strongest economic sectors in the region, contributing 12,9% and 10% respectively of the regional GGP. The finance sector is supported by a relatively strong property market for agricultural land. Financial services are located in the main towns of Ceres, Worcester, Montagu and Robertson. The government service sector is supported by a wide variety of national, provincial, regional and local public bodies.

Since most of the industrial and trade sector, and large parts of the finance and government sectors are dependent on agriculture, it can be surmised that about 80% of the GGP is derived from agriculture.

2.5 PREVAILING ECONOMIC CONDITIONS

In the period from approximately 1998 to 2001, the wine industry in the Breede River Valley, and in the remainder of the Western Cape experienced a sharp decline, following a very good period from 1995 to 1998. Simultaneously, the fruit industry, including stone fruit, pome fruit and citrus, also experienced three mediocre seasons with low prices realized on the export markets. This has resulted in a number of farming concerns being forced out of business, with associated job losses and the intensification of poverty levels experienced in the rural townships. This

situation and the subsequent volatility of the Rand has inevitably influenced the views taken in this study on the future of agriculture in the study area, and is discussed in more detail in Report PH 00/00/1802 *Agricultural Water Demands*. The situation is discussed further in Section 5.2 of this report. The question remains whether this is a "once off" situation or whether this is indicative of what can be expected for the future of irrigated agriculture in the Western Cape.

2.6 CLIMATE

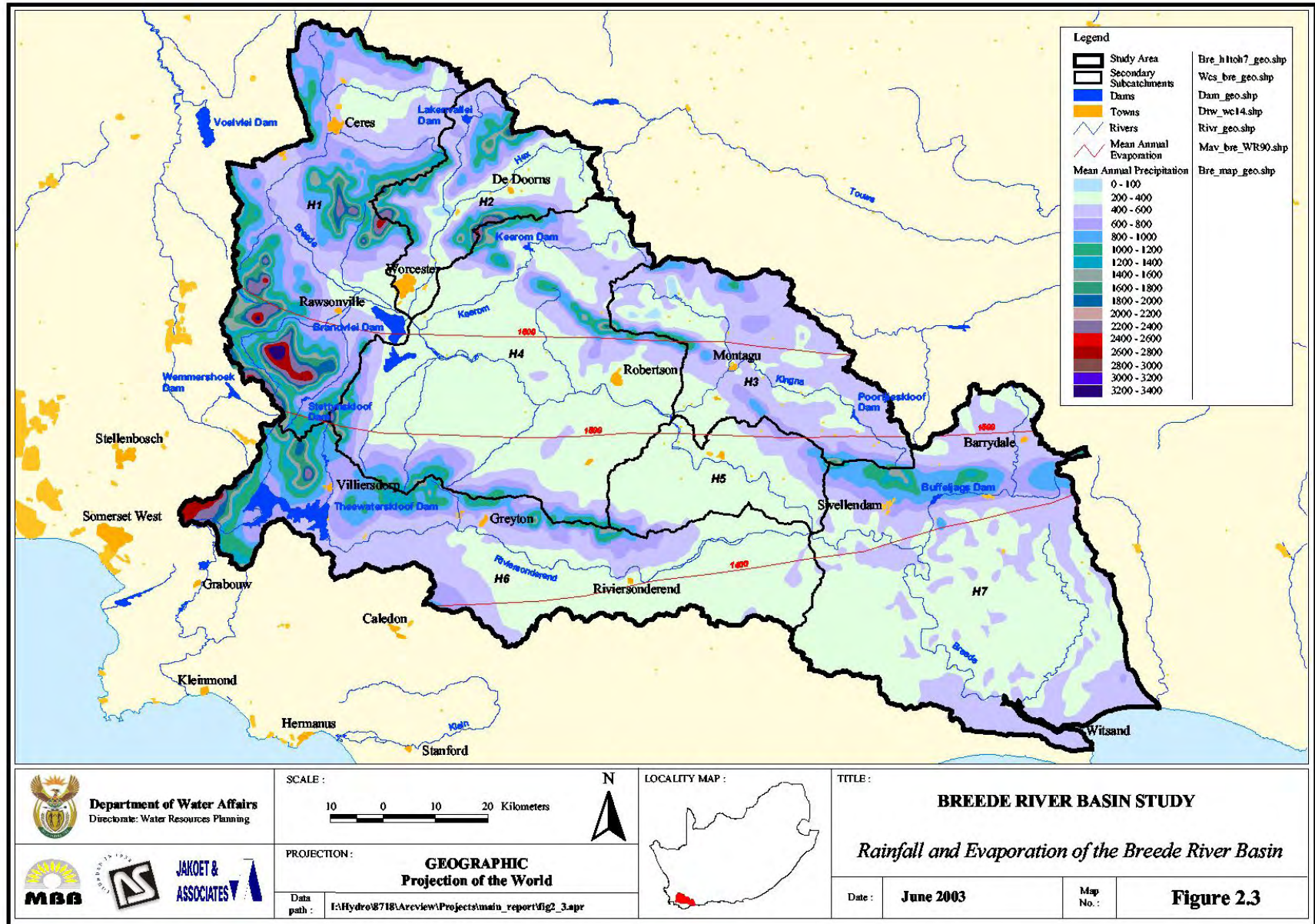
The western, northern and central parts of the study area fall within the winter rainfall region of South Africa. The southern and eastern areas fall between a winter and summer rainfall region and hence an all year tendency prevails. As such, the mountains experience high winter rainfalls with roughly 80% of the annual total occurring between the months of April and September. Average annual rainfall over the study area varies considerably, mainly in accordance with change in altitude (see Figure 2.3). The mean annual precipitation (MAP) ranges from approximately 400 mm in the south-eastern area to about 2 500 mm in the mountains to the north west of Greater Brandvlei Dam. The summers are dry with generally high evaporation. The winter climate ranges from very cold in the higher lying sections of the Ceres catchment to moderate, virtually frost free throughout the rest of the study area. The gross mean annual Symons Pan evaporation is estimated to be 1 520 mm.

2.7. GEOLOGY

Geological formations in the Breede River catchment range from the Late Proterozoic Malmesbury basement through Palaeozoic Cape and Karoo cover rocks, to isolated outliers of the Mesozoic Uitenhage Group, the Cenozoic Bredasdorp Group and various Quaternary surficial deposits (Figure 2.4). The mountains are mostly formed of sandstone of the Cape Supergroup while shale and siltstone of the Malmesbury and Bokkeveld Groups usually underlying the valleys and areas of subdued relief. A wide variety of terrace gravels, scree, ferricrete, soils and alluvium cover the valley floors and mountain slopes throughout the area.

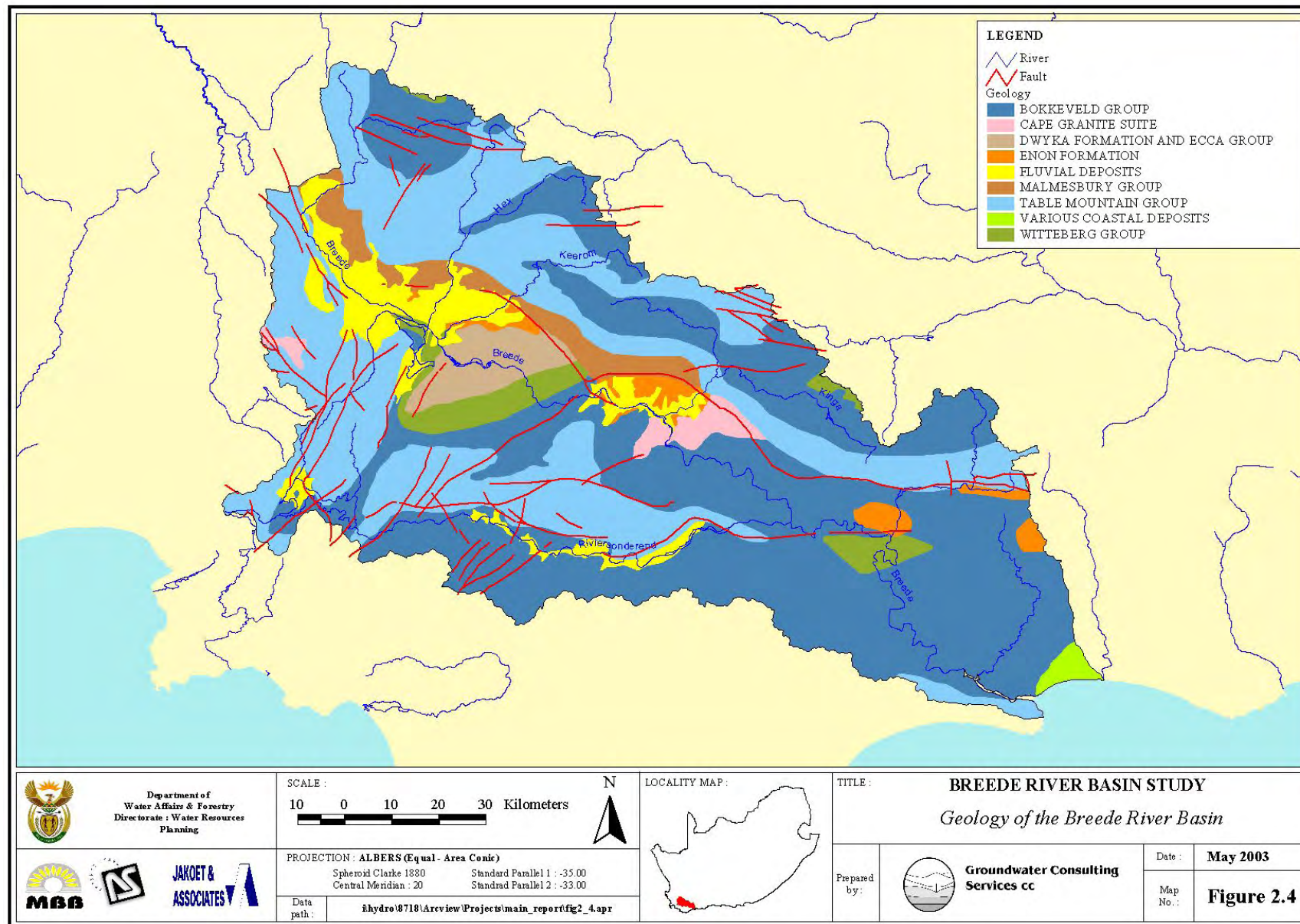
The Upper and Middle Breede catchment comprises most of the area known as the Cape syntaxis - a zone in which the western and southern branches of the Cape Fold Belt meet. The syntaxis, with its very high mountains (2 249m in the Matroosberg), forms a prominent watershed between rivers flowing west (Berg River), north (Olifants and Doring Rivers), East (Breede and Riveriersonderend Rivers) and south (Bot, Klein and Nuwejaars Rivers).

The Cape Supergroup, which comprises in excess of 90% of the outcrop in the Breede River catchment, is differentiated into the Table Mountain Group, the Bokkeveld Group, and the alternating shales and sandstones of the Witteberg Group. The remainder of the surface area of the Breede River catchment is comprised of outcrops of the Malmesbury Group, the Bredasdorp Group, the Karoo Supergroup (Dwyka, Uitenhage and Ecca Groups), the Cape Granite Suite, Alluvium and other unconsolidated sedimentary deposits.



<p>Department of Water Affairs Direkte: Water Resources Planning</p>	<p>SCALE :</p>	<p>N</p>	<p>LOCALITY MAP :</p>	<p>TITLE :</p> <p>BREDE RIVER BASIN STUDY</p> <p><i>Rainfall and Evaporation of the Breede River Basin</i></p>			
	<p>PROJECTION :</p> <p>GEOGRAPHIC Projection of the World</p>			<p>Date : June 2003</p>	<p>Map No. :</p>	<p>Figure 2.3</p>	

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The geohydrology of the Breede River catchment is controlled by the occurrence of the rocks of the Table Mountain Group (which form the mountainous areas), the occurrence of high levels of faulting and folding in the syntaxis area of the upper catchment and the variable rainfall, being highest in the mountainous areas in the west. These factors result in a catchment with highest groundwater potential in the west, where recharge, yields and abstraction potential are greatest and the quality is the best. As a result of these factors, the western half of the catchment is also the area with the greatest groundwater use.

The geology has a profound effect on water quality in that much of the runoff is generated in the quartzitic and sandstone highland areas. This water is generally of high quality (viz. low TDS), but deteriorates by leaching salts and mixing with water draining from the valley areas, especially where the naturally salt-bearing shales and mudstones of the Karoo Supergroup and the Bokkeveld Group predominate. These areas are generally fairly flat and the soils are generally more fertile and are often developed for irrigation purposes. Irrigation return flows are often salt laden.

The geohydrology of the catchment is discussed in Section 7.2 of this report. Further detail on the geology and geohydrology of the Breede River catchment is presented in Report PH 00/00/2502 *Groundwater Assessment*.

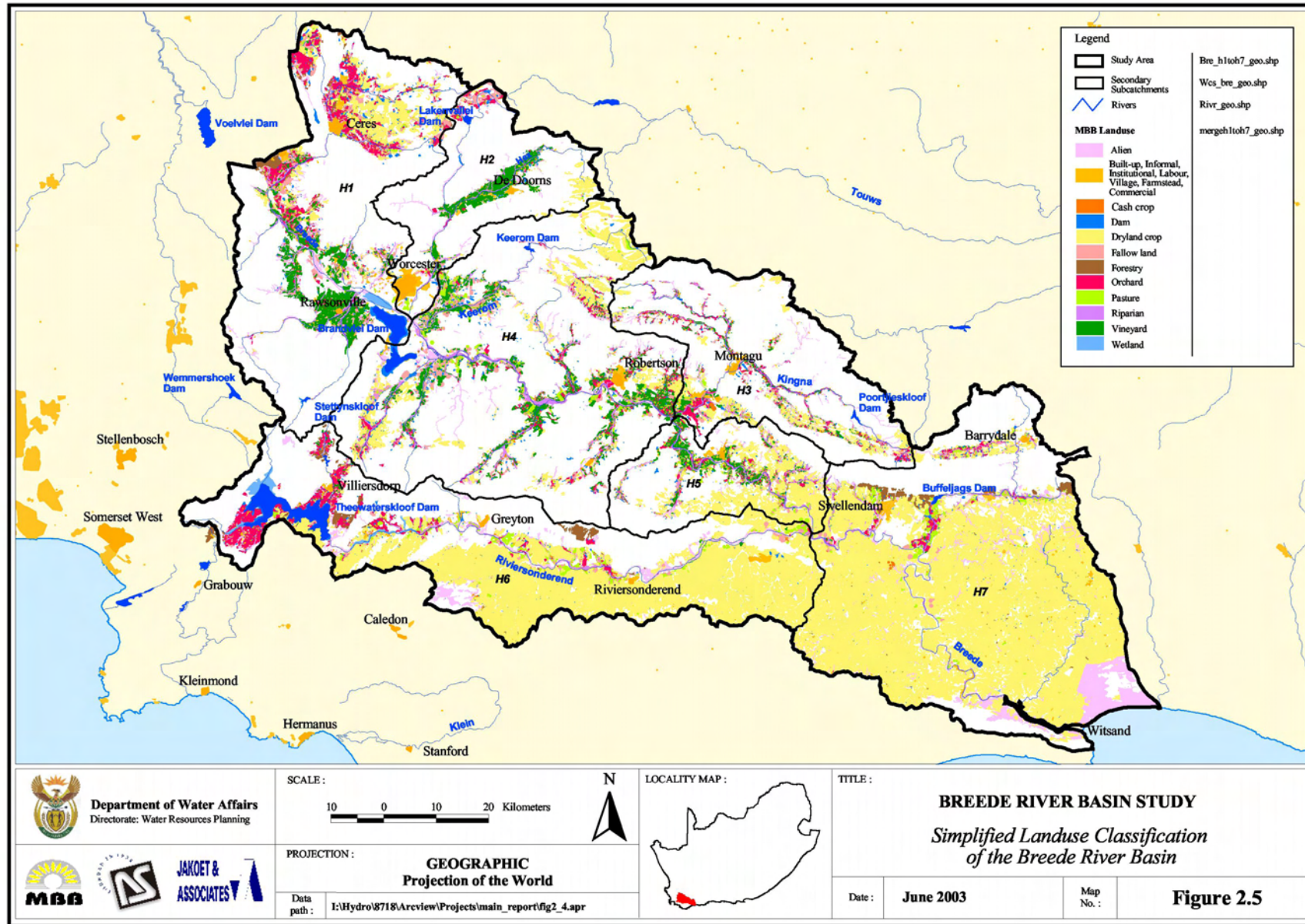
2.8 LAND USE

To provide information on current land use in the catchment, colour aerial photography at a scale of 1:30 000 was undertaken during the period from February to May 2000. The photography was extended to include the "back slopes" of mountain ranges along the boundaries of the study area for the purpose of future mapping of conservation areas, state forests, mountain catchment areas and invasive alien vegetation.

Figure 2.5 shows a simplified version of the land use mapping prepared for the Study. Land use in the sub-catchments of the catchment is predominantly cultivated lands as indicated in Table 2.1. The flatter areas between mountain ranges, particularly along river courses in valleys, are planted with vineyards and orchards. Figure 2.5 shows quite clearly how cultivated lands track the major river courses in the Breede River catchment. The southern portion of the catchment is dominated by rain-fed cereals with only small areas of natural vegetation on higher lying koppies that are not suitable for cultivation.

TABLE 2.1 : BREEDE RIVER CATCHMENT YEAR 2000 LAND USE

SUB-CATCHMENT	H1	H2	H3	H4	H5	H6	H7	TOTAL
Total area (ha)	204 647	83 200	120 725	260 820	69 510	224 165	292 270	1 255 337
Irrigated Agriculture (ha)	27 358	7 336	7 600	27 538	13 741	13 780	6 757	99 116
Dryland crops (ha)	10 732	1 557	5 574	14 838	12 571	84 617	157 453	287 343
Forestry (ha)	1 338	51	64	167	28	2 221	2 284	5 807
Built-up Areas (ha)	2 937	2 885	1 259	2 016	754	1 966	2 738	14 556
Dams (ha)	4 439	565	606	3 494	465	5 924	655	16 148
Invasive Alien Plants (condensed ha)	17 477	1 413	769	4 966	1 383	13 578	6 494	46 080
Total Developed (ha)	64 281	13 807	15 872	53 019	28 942	122 086	176 381	474 388
Water Intensive Development %	26,2	14,7	8,5	14,6	23,6	12,8	6,5	14,9
Total Development %	31,4	16,6	13,1	20,3	41,6	54,4	60,3	37,8



In terms of water intensive land use, the Upper Breede (catchment H1), which includes the Ceres catchment, and the Bonnievale area (secondary catchment H5) are most developed, with 26% and 24% respectively of the land areas covered by irrigated agriculture, afforestation, urban areas, invasive alien plants, and dams. While the Lower Breede (catchment H7, downstream of the confluence of the Breede and Riviersonderend Rivers) is extensively developed with predominantly dryland agriculture, only 7% of the land area is covered by water intensive developments.

2.9 EXISTING WATER SUPPLY SCHEMES

2.9.1 Introduction

Over time, numerous water supply schemes have been developed in the Breede River catchment, and with the exception of the Lower Breede region, the valley floors in the Study area are criss-crossed by canals and pipelines supplying water for irrigation of commercial crops. Water for urban use is generally also impounded in dams and conveyed to towns by means of canals and pipelines.

Numerous dams of various sizes are used to store winter run-off for use in summer. The two largest impoundments in the Breede River catchment are Greater Brandvlei Dam and the Theewaterskloof Dam. Details of the major storage dams in the catchment are shown in Table 2.2.

TABLE 2.2 : MAJOR IMPOUNDMENTS IN THE BREEDE RIVER CATCHMENT

DAM NAME	RIVER	TYPE OF EMBANKMENT	HEIGHT (m)	PURPOSE	FULL SUPPLY CAPACITY (million m ³)
Ceres	Koekedouw	Rockfill with bitumen core	56	Urban / Irrigation	17
Theewaterskloof	Riviersonderend	Earth	38	Urban / Irrigation	434
Greater Brandvlei	N/A	Earth	18	Irrigation	342 (Gravity inflows) 475 (Total)
Lakenvallei	Sandriftkloof	Gravity	56	Irrigation	10
Roode Elsberg	Sandriftkloof	Arch	72	Irrigation	8
Elandskloof	Elands	Gravity	67	Irrigation	11
Poortjieskloof	Groot	Arch	33	Irrigation	10
Buffeljags	Buffeljags	Gravity / earth	24	Irrigation	6
Pietersfontein	Keisie	Arch	29	Irrigation	2
Keerom	Nuy	Arch	37	Irrigation	10
Stettynskloof	Holsloot	Gravity / rockfill	48	Urban	15

Some 58 irrigation boards that are in various degrees of transformation to water user associations, administer numerous water abstraction and supply schemes of varying ages and degrees of sophistication comprising canals, pipelines and pump stations. Details of these water schemes are provided in Report PH 00/00/1702 *Infrastructure and Irrigation Schemes*. The larger water infrastructure developments are briefly discussed below.

2.9.2 Greater Brandvlei Dam Government Water Scheme

Brandvlei Dam was constructed in 1949 to a full supply level (FSL) of 207,12 m. In 1972, it was raised to FSL 210,5 m and extended by the construction of Kwaggaskloof Dam to form the Greater Brandvlei Dam. It is surrounded by low hills and is situated in two valleys to the south of the Breede River and the town of Worcester.

Greater Brandvlei Dam is filled mainly during the winter months with water from the Smalblaar River (i.e. the lower reaches of the Molenaars River) and the Holsloot River. Diversion structures on these streams are situated downstream of Rawsonville. The diversion canal enters the dam at elevation 207,12 m which corresponds to a capacity of 342 million m³. A further 133 million m³ of storage is available up to the full supply level of 210,5 m. Water can be pumped into this storage zone from the Breede River at the Papenkuils Pump Station. This pump station is in working condition, but is not frequently used due to the cost of pumping energy. The pump station has a capacity of 5 m³/s, and provision has been made to increase the pumping capacity to 20 m³/s. Water can only be pumped when flows in the Breede River exceed about 5 m³/s.

The historical firm yield of Greater Brandvlei Dam is estimated as 127 million m³/a. Stochastic analyses have shown that this yield is associated with a risk of failure of less than one in two hundred years.

During the summer irrigation period, water is released from the dam into the Breede River to supplement river flows for use by a number of irrigation boards with canals and pump schemes abstracting water from the river. Some of this water is diverted into the Le Chasseur Irrigation Canal at measuring weir H4H006, immediately downstream of the dam outlet. Water can also be fed directly into the Le Chasseur Canal from the Kwaggaskloof Dam outlet. The Bossieveld Pump Scheme withdraws water directly from Kwaggaskloof Dam.

Since 1981, water for downstream users has been released from Greater Brandvlei Dam through the tunnel outlet of the Papenkuils Pump Station. There are four canal systems and five pump schemes, as well as a number of private pumps that abstract water from the river between Greater Brandvlei Dam and the confluence of the Breede and Riviersonderend Rivers. The canal schemes are operated by the Le Chasseur and Goree, Breede River (Robertson), Angora, and Zanddrift Irrigation Boards. Pumping schemes are operated by the Agterkliphoogte, Uitnood, Klaasvoogds, Cogmanskloof and Worcester East Irrigation Boards.

2.9.3 Riviersonderend-Berg-Eerste River Government Water Scheme

The Theewaterskloof Dam has a capacity of 434 million m³ and is the source reservoir for the Riviersonderend-Berg-Eerste River Government Water Scheme, an inter-catchment water transfer project that supplies water for urban use to the Greater Cape Town Area, including Stellenbosch, and water for urban and agricultural use in the Berg River Catchment and demand centres along the West Coast.

The Riviersonderend River originates some 40 km upstream of the embankment on the eastern slopes of the Franschoek Mountains. Downstream of the dam the river flows eastwards to its confluence with the Breede River.

Construction of the earthfill embankment was completed in 1980. The river bed level at the wall is 276 m above mean sea level and the main road between Villiersdorp and Caledon runs along the embankment crest. A tower within the dam basin some 13 km from the embankment, houses the inlet to and outlet from the tunnel system that links the dam with the Berg River and Eerste River catchment areas.

The dam forms part of an extensive water supply scheme of which a salient feature is the tunnel system to transfer water to and from the dam as well as to and from different catchment areas separated from one another by mountain ranges. The purpose of the dam is to provide storage for the larger quantities of runoff that become available during the winter rainy season in the upper reaches of the Riviersonderend and Berg River catchments. During the dry summer season water from the Theewaterskloof Dam can be transferred back to the Berg River and Eerste River valleys by means of the tunnel system. Both irrigation water, as well as potable water for the Cape Town Metropolitan Area, is supplied. The construction of the tunnel system is such that it allows flow in both directions between the dam and the Berg River catchment.

Theewaterskloof Dam is one of the larger dams in South Africa and the system has a one in fifty year yield of 234 million m³/a (inclusive of the Banhoek and Wolwekloof diversions and the local yield of Kleinplaas Dam in the Eerste River). Some 60 % of the yield has been allocated for irrigation in the Berg River catchment and the Lower Riviersonderend catchment, and the balance to the Cape Town Metropolitan Area.

2.9.4 Other Major Water Supply Schemes

The Ceres catchment

The Koekedouw River originates on a plateau between the Skurweberg and Witzenberg Mountains, to the northwest of Ceres. Due north of Ceres it joins the Dwars River before flowing through the town. On the southern side of town the Titus River joins the stream before flowing through Michell's Pass and becoming the Breede River.

In 1998, the new Ceres Dam was constructed in the Koekedouw River, replacing an older dam, which was demolished. The new embankment is situated immediately upstream of the original wall placement.

Water from the dam is supplied to the town of Ceres as well as to the Koekedouw Irrigation Board for direct summer irrigation. The dam has a capacity of 17 million m³ and was designed to supply 17 million m³/a at an 85% assurance of supply. Instream flow requirements (IFR) of some 7 million m³/a (in good years) and 4 million m³/a (in dry years), are catered for prior to the supply of water to the two parties.

Upper Breede Region

The Stettynskloof and Fairy Glen Dams are the two major dams in the Upper Breede area. The dams are operated in conjunction to supply water to the town of Worcester. Water for irrigation along the Holsloot River is also supplied from Stettynskloof Dam. The original Stettynskloof Dam (located on the Holsloot River) had a capacity of 5 million m³. In 1981, the first of two stages of the enlargement of the dam was completed. The raised dam has a full supply capacity of 15,4 million m³. Fairy Glen Dam is located on the Hartebees River, and has a much smaller full supply capacity of 0,52 million m³. The combined one in fifty year yield of the two dams is estimated as 25 million m³/a. The Worcester Municipality presently draws about 10,5 million m³/a from the system, and even after the supplementation of irrigation water along the Holsloot River, the system has considerable spare yield.

Hex River Valley

The Hex River Valley is a pronounced valley between the Hex River mountains to the north-west and the Kwadous Mountains to the south east. The valley is approximately 20 km long and 5 km wide. The town of De Doorns with a population of 6 000 is located roughly in the middle of the valley.

The Sanddrift River Government Water Supply Scheme is the major supplier of water in the Hex River Valley. The scheme comprises the Lakenvallei and Roode Elsberg Dams, situated in the Sanddrift River, a tributary of the Hex River, together with a sophisticated distribution system distributing water to De Doorns and irrigators in the Hex River Valley. The total capacity of the two dams is 18,0 million m³.

In 1991 the firm yield of the Sanddrift Scheme was accepted to be 9 million m³/a. At that date the Worcester East Main Irrigation Board (now a Water User Association) started pumping water from the Breede River, and relinquished its share of 54% of this quantity, i.e. 4,86 million m³/a, but was compensated by an allocation from Greater Brandvlei Dam. The Sandhills area is presently supplied with up to 2,2 million m³/a of compensation water from the Sanddrift Scheme.

It has become clear that previous estimates of the yield of the Sanddrift Scheme were too optimistic, and that the combined firm yield of the two dams is about 7,9 million m³/a. This yield is over-subscribed, and the current demand of about 11.5 million m³/a is supplied at a relatively

high risk of failure. Conditions governing the release of compensation water from Roode Elsberg Dam have long been the source of disputes between water users in the Upper and Lower Hex River Valleys. The Hexvallei Irrigation Board and the Hex River sub-area of the Worcester-East Main Water User Association have recently entered into negotiations in an attempt to resolve these disputes.

Middle Breede River Region

Water from the Keerom Dam in the Nuy River is used exclusively in the Nuy district to the south-east of Worcester. The dam is owned by the Nuy Irrigation Board, and was built to store winter surplus water for use during the summer irrigation period. Due to silting, the dam's capacity had decreased from the original 8,4 million m³ to 7,4 million m³ in 1989. It was then decided to raise the wall to provide the current full supply capacity of 10,4 million m³. The work was completed in 1990.

Riviersonderend

The Elands River originates in the Klein Tafelberg and flows in a southerly direction through the town of Villiersdorp to join the Riviersonderend River about 4 km upstream of the Theewaterskloof Dam embankment. Elandskloof Dam has been built on the Farm Twist Niet, about 4 km to the north of Villiersdorp. The dam has a full supply capacity of 11,4 million m³ and supplies a scheduled irrigated area of 1 880 ha with 12,9 million m³/a. In addition, the Villiersdorp Municipality and the Villiersdorp Co-operative receive about 0,7 million m³/a from the Elandskloof Dam.

Lower Breede Region

The Buffeljags Dam is located on the Buffeljags River to the north-east of Swellendam. The dam commands a large catchment area with a fairly high annual precipitation of 660 mm. Mean annual runoff at the dam site is about 118 million m³/a. The dam was constructed in 1967 to a full supply capacity of 5,7 million m³, and has a firm yield of about 11,0 million m³/a. The dam supplies about 8,8 million m³/a of irrigation water to a scheduled area of 1 450 ha. The water is transported to the farms by means of two concrete lined canals on the left and right banks of the Buffeljags River.

2.9.5 Smaller Schemes

A large number of farm dams command substantial portions of the Ceres and Upper Breede catchments. In the steeper valleys found in the Hex River Valley and Riviersonderend catchments, farm dams are used to store run-of-river winter diversions from mountain streams. In the broad, flat Middle Breede region, farm dams are used for balancing storage, and are fed from canals and pumping schemes conveying water from Greater Brandvlei Dam.

3. ENVIRONMENTAL WATER REQUIREMENTS

3.1 COMPONENTS OF THE RESERVE

Reserve determinations were carried out to ascertain the water requirements of the aquatic environment at particular locations in the catchment, and to provide the information required to establish a preliminary Reserve that will be used to inform water abstraction and wastewater discharge licence applications in the Breede River catchment. In the catchment, the component of the Reserve that is required to satisfy basic human needs (set at 25 litres/person/day), comprises a very small percentage of available water resources and of current consumption, and could be met from existing allocations and available resources and was therefore not assessed in further detail.

Determinations were undertaken for the following components of the Reserve :

- Riverine water quantity and quality.
- The Breede River Estuary.
- The Papenkuils Wetland.
- Groundwater.

Reserve determinations are linked to Ecological Reserve Categories (ERCs), which describe the present, or desired status of the aquatic system. These Categories range from an "A" classification, indicating that the system is virtually unmodified (natural), while an "F" classification indicates a system where an almost complete loss of natural habitat and biota has occurred. In terms of the *"Resource Directed Measures for the Protection of Water Resources"* (DWAF, 1999), an ecological category of "E" (extensive loss of natural habitat and biota) or "F" is unacceptable, and these systems will have to be restored to at least a "D" (largely modified) classification.

The *Resource Directed Measures for the Protection of Water Resources* (sometimes referred to as "RDM protocols") prescribe a range of methods and procedures for determination of the Reserve. These are classified in terms of **levels** of assessment. In order of increasing complexity, and generalising somewhat, the levels are :

- "Desktop" (or "Rapid") assessments - carried out with readily available information, and in some instances, with pre-configured software models.
- "Intermediate" assessments require field investigations and more sophisticated technical analyses.
- "Comprehensive" assessments require extensive fieldwork, and employ state-of-the-art technical methods for the estimation of ecological flow requirements. (For some components, the same technical methods are employed for "Intermediate" and "Comprehensive" assessments, but with differing levels of data collection).

The selection of appropriate levels of Reserve determination depend largely on the degree of stress to which water resources of affected catchments are subjected, as well as the desired level of protection (based on ecological importance and sensitivity). These levels could therefore vary between sub-catchments, and could also be different for individual components of the Reserve.

Finally, the specialists that are tasked with Reserve determinations assign a **confidence level** to the results of the determinations. Selection of a confidence level depends on the completeness of the data that was available for the Reserve determination, and also on the technical methods that were employed. Confidence levels range from "low" to "medium" to "high".

3.2 RIVERINE FLOW REQUIREMENTS

3.2.1 Methodology

The biophysical component of the Reserve Determination for River Quantity was conducted according to the RDM requirements for a Comprehensive Reserve Determination, using the Building Block Methodology (BBM). The DRIFT method (Downstream Response to Imposed Flow Transformations) is an alternative to the BBM. This method was developed under the supervision of an international Panel of Experts, for use on the Lesotho Highlands Water Project and was also used on a recent project to determine the instream flow requirements of the Palmiet River in the Western Cape. In order for the DRIFT method to be recognized as an approved tool for Reserve determination in South African river systems, the method had to be applied in a test catchment, and subjected to a peer review.

The BRBS provided an ideal opportunity for the testing of the DRIFT method, and the additional work that was required for a dual application of the BBM and DRIFT methodologies was funded through the Water Research Commission (WRC) and the RDM Office of DWAF. A comparative assessment of the two methods will form the subject of a WRC report.

3.2.2 Present Ecological Status

During the Preliminary Phase of the Study, the present ecological condition of the rivers in the study area was assessed. The assessment provided an indication of the degree that ecosystem functioning has been modified from the original pristine state. Based on ratings of the ecological importance and sensitivity (EIS) of the rivers, and an assessment of the potential for restoration of the rivers, preliminary ecological Reserve categories (ERCs), which set long-term targets for the protection and maintenance of water resources, were selected.

Figure 3.1 shows the present ecological status of the rivers in the catchment.

In general, there is a gradual increase in the number and severity of perturbations and therefore a decline in the condition of rivers, starting from mountain streams, through foothill cobble bed rivers and foothill gravel bed rivers, down to the lowland rivers. In summary :

mountain streams:	80 % of the sites were assigned a Category A or B status;
foothill cobble bed rivers:	63 % of the sites were assigned a Category B or C status;
foothill gravel bed rivers:	50% of the sites were assigned a Category D status;
lowland rivers:	68% of the sites were assigned a Category D status.

In the Breede River catchment, as the gradient of the land flattens out and mountain streams become cobble bed foothill rivers, the surrounding areas become extensively developed with vineyards and orchards. Not only are these areas more accessible, but the soils are fertile and good quality water flowing from higher lying areas is used for irrigation. Therefore rivers flowing through these areas are impacted by :

- abstraction;
- the extensive development of farm dams, both in- and off-channel;
- the removal of indigenous riparian vegetation;
- invasion of alien vegetation, and
- manipulation of the channel through bulldozing and infilling to extend cultivated lands.

3.2.3 Selection of Instream Flow Requirement (IFR) Sites

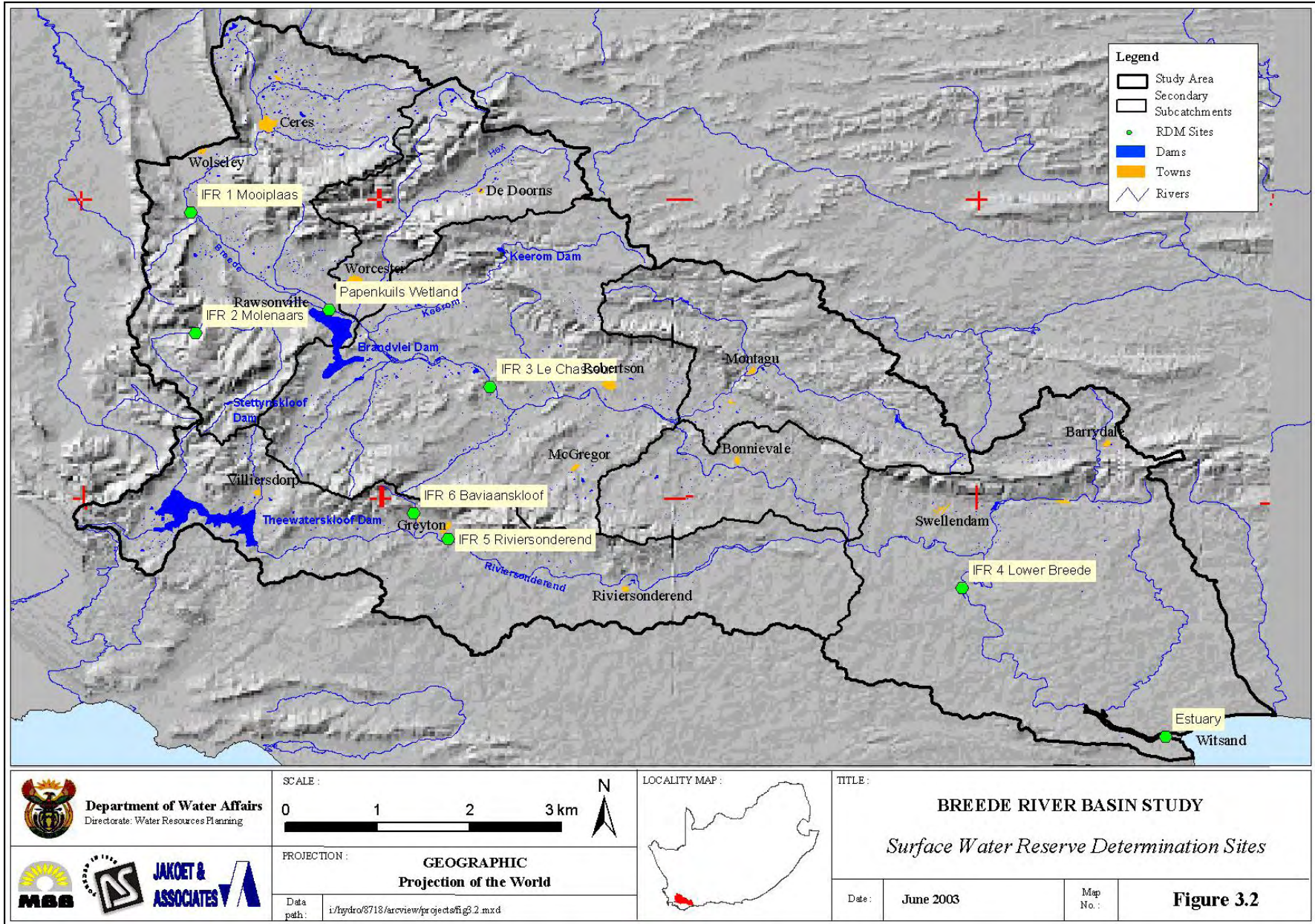
Reserve determinations were conducted for six sites intended to represent specific reaches of the river system. The number of sites was limited by time and financial constraints. The IFR sites were expected to fulfil several criteria, namely that they should be :

- representative of as many rivers within the catchment as possible;
- downstream of possible major water resource developments;
- associated with "key management points" within the Breede River catchment;
- near DWAF gauging weirs.

The limitation on the number of sites did not allow for satisfying all of the above criteria. Thus, the sites eventually chosen represent those sections of the river perceived to be most important at a catchment planning level. The six sites that were selected are shown on Figure 3.2, and are located at :

IFR SITE 1:	Breede River downstream of Wit Brug on the farm Mooiplaas.
IFR SITE 2:	Molenaars River downstream of DWAF gauging weir H2H018.
IFR SITE 3:	Breede River upstream of Le Chasseur.
IFR SITE 4:	Breede River downstream of Felix Unite camp on the Farm Ou Werf.
IFR SITE 5:	Riviersonderend River at the Greyton Campsite.
IFR SITE 6:	Baviaans River upstream of DWAF gauging weir H6H005.

The Hex River was not included in the BRBS Reserve Determination, as this was undertaken in a separate study commissioned by the Western Cape Regional Office of DWAF.



3.2.4 Instream Flow Requirements

The Reserve determinations that were carried out for the Study provide site-specific recommendations of Ecological Reserve Categories (ERCs) and water requirements associated with these. These recommendations will form the departure point for the setting of a preliminary Reserve. Before the Reserve can be set, a separate stakeholder consultation process must first take place. With a view to this process, ecological water requirements for alternative Reserve Categories ("scenarios") were determined at a number of sites.

The results of the assessments are documented in Report PH 00/00/1302 *Ecological Reserve Determination for Six Representative Sites using the Building Block Methodology*. The ecological flow requirements are specified in the form of monthly distributions of maintenance low flows, high flows, and drought low flows. To facilitate management of the IFRs, "rule tables" are provided for each IFR site. These tables specify the percentage of time that certain flows are required, and can be related to suitable indicator sites (measured runoffs from representative, largely natural catchments) to determine ecological flows that are required in the prevailing runoff conditions. For the purposes of this report, the results are simplified and summarised in Table 3.1 below.

TABLE 3.1 : RECOMMENDED ECOLOGICAL FLOW REQUIREMENTS

SITE	PRESENT CATEGORY	RECOM-MENDED CATEGORY	PERIOD	NATURAL MAR	PRESENT MAR	INSTREAM FLOW REQUIREMENT	
				(million m ³ /a)	(million m ³ /a)	(million m ³ /a)	% Natural MAR
1. Upper Breede River d/s of Witbrug (Mooiplaas)	D/E	D	1961-1990	333	287	103	31
2. Molenaars River d/s of gauging weir	B	B	1969-1990	158	131	79	50
3. Middle Breede River u/s of Le Chasseur	C/D	C/D	1980-1990	1210	763	539	45
4. Lower Breede River on the Farm Ou Werf	C	B/C	1967-1990	1720	1059	582	34
5. Riviersonderend at Greyton Camp Site	E	D	1964-1993	347	94	134	39
6. Baviaans River, i.e. tributary of the Riviersonderend	B	B	Low confidence determination			8.5	

KEY:

A = Natural

B = Largely natural with few modifications

C = Moderately modified

D = Largely modified

E = Seriously modified

F = Critically modified

The present conditions of the representative river reaches, the recommended ERCs and associated water requirements, the attainability of the recommended ERCs and the alternative scenarios are summarised in Table 3.2 overleaf.

Detailed information on the determination of the recommended Reserves, and descriptions of the water quantity requirements (in the form of monthly rule curves) can be found in Report PH 00/00/1302 *Ecological Reserve Determination for Six Representative Sites using the Building Block Methodology*.

TABLE 3.2 : SUMMARY OF RECOMMENDED ECOLOGICAL FLOW REQUIREMENTS

SITE	ENVIRONMENTAL IMPORTANCE AND SIGNIFICANCE		CURRENT CONDITION		ECOLOGICAL WATER REQUIREMENTS			
	Rating	Attributed to	Category	Causes and origins of degradation	ERC	million m ³ /a	% MAR	Attainability of Recommended ERC
IFR SITE 1 Breede River downstream of Wit Brug on the farm Mooiplaas	Moderate	presence of rare and endangered species; presence of diverse habitat types and refugia; importance for migration of fish and eels.	E	non-flow related: presence of alien fish and vegetation species; mechanical changes to the floodplain and river channel resulting in a modified river; irrigation return flows and sewage impacting on water quality; flow related: abstraction resulting in flow cessation in summer	D (Recommended)	103	31	Reinstating summer low flows at IFR Site 1 will achieve a D Category for aquatic invertebrates and riparian vegetation. If a D Category is to be achieved, non-flow related impacts, such as mechanical disturbance to the channel and presence of alien fish species, will also need to be addressed.
					No scenarios were produced for IFR Site 1. The recommended Category (D) will be difficult to achieve as it is dependent on the correction of non-flow related impacts			
IFR SITE 2 Molenaars River	Very High	presence of rare and endangered species; presence of intolerant biota (water quality); species/taxon richness; presence of diverse habitat types, refugia and habitats sensitive to quality changes; conservation and natural areas	B	non-flow related, namely: presence of alien fish and vegetation species; presence of the NI; trout farming (effluent and alien fish); increased fire frequency	B (Recommended)	79	50	The river is presently in an excellent state. It would be difficult to improve the current condition. By meeting the IFR the existing B ecological category could be maintained with minimal to no risk of moving to a lower class
					C	54	34	
IFR SITE 3 Breede River at Le Chasseur	Moderate	presence of rare and endangered species; presence of diverse habitat types and refugia; importance for migration of fish.	C/D	non-flow related: Presence of alien fish and vegetation species; agricultural use of the floodplain; salinity due to return flows from agriculture; and flow-related: turbid releases from Greater Brandvlei Dam; unseasonal releases from the dam	C/D (Recommended)	539	45	The major issue in this river reach is the increased summer base flows, lack of flow variability and turbidity of water released from Greater Brandvlei Dam. It will be difficult to address these problems, and the category may degrade to a D
					C	628	52	
					D	539	45	

TABLE 3.2 : SUMMARY OF RECOMMENDED ECOLOGICAL FLOW REQUIREMENTS (CONTINUED)

SITE	ENVIRONMENTAL IMPORTANCE AND SIGNIFICANCE		CURRENT CONDITION		ECOLOGICAL WATER REQUIREMENTS			
	Rating	Attributed to	Category	Causes and origins	ERC	million m ³ /a	% MAR	Attainability of Recommended ERC
IFR SITE 4 Lower Breede	High	Importance as a migration route for fish; conservation and natural areas	C	non-flow related , namely the presence of alien fish and vegetation species, and salinity due to return flows from agriculture (sediments and nutrients)	B/C (Recommended)	582	34	If mitigation measures such as the creation of buffer riparian zones and overall improved catchment management, were implemented then the negative trajectory for vegetation and geomorphology could be halted
					B	723	42	
					C	470	27	
IFR SITE 5 Riviersonderend at Greyton Camp Site	High	presence of rare and endangered species, species and taxon richness, diversity of habitat types and refugia, sensitivity to flow related water quality changes, migration routes	E	flow related : lack of floods and environmental releases from Theewaterskloof compounded by abstraction for irrigation. non-flow related : impacts (most post-Theewaterskloof construction) include the presence of alien fish and vegetation species and considerable mechanical disturbance to the channel	D (Recommended)	134	39	The recommended Reserve will not be sufficient on its own to accomplish a D Class status, and will need to be accompanied by extensive mechanical restoration of the channel, and removal of alien trees.
Scenarios lower than a Category D should not be considered (DWAF 1999). Given the difficulties associated with providing IFR releases from Theewaterskloof Dam, it was deemed unrealistic to provide scenarios for conditions better than a D Category								
IFR SITE 6 Baviaans River	Very High	Presence of rare, endangered and unique species as well as intolerant biota. Important refugia and habitats that are sensitive to flow and flow related water quality changes	B	flow related : Abstraction in summer for purposes of Genadendal and environment. non-flow related : grazing	B (Recommended)	8,5	Uncertain	As there is no negative trajectory of change, no action is required to maintain the river in its present state.
No scenarios were produced, due to problems related to the observed flow record at the nearby flow gauging station								

3.2.5 Discussion

One of the key findings of the Study has been the impact that the environmental flow requirements will have on the exploitable portion of the water resource, as will be explained in Section 7.3 of this report. It has become clear that earlier, coarser estimates of ecological flow requirements (of the order of 10% to 30% of natural mean annual runoff) have significantly under-estimated these requirements.

Of the sites investigated, the Riviersonderend River downstream of Theewaterskloof Dam is the most degraded (primarily due to the construction of the Dam), and is the only site where annual ecological flow volume requirements are in excess of present day mean annual flows. The recommended ecological flows will not be sufficient on their own to restore the river to a D Category. This will need to be accompanied by extensive mechanical reshaping of the river channel, and removal of alien trees. The Category D recommendation is based on the requirement that Category E systems have to be restored to at least a Category D system. The practicality of the requirement in the Riviersonderend is discussed further in Section 3.8, dealing with the implementation and management of the Reserve.

As implied above, the recommended annual ecological flow requirements are, other than the Riviersonderend site, substantially less than mean annual present day flows. However, at most of the sites, the monthly distributions of present day flows (particularly during summer months), do not conform to the recommended distributions of ecological flows. In rivers that serve as conduits for irrigation releases, present day flows may greatly exceed ecological flow requirements during the summer months. On the other hand, when irrigation requirements are drawn from unregulated river flows, ecological flow requirements may not be met during periods of low flow. In fact, there are numerous cases where rivers are at times drained dry. In some instances, it may be sufficient to limit the issuing of new licences to periods of surplus (usually winter months, which would require seasonal storage), but this would have to be evaluated on a case-by-case basis.

3.3 THE WATER QUALITY COMPONENT OF THE RESERVE

The study area was divided into ten water quality resource units (Figure 3.3, Table 3.3) for determination of the water quality Reserve. Most of these correspond to the reaches represented by the six IFR sites described in Section 3.2 above. Additional water quality resource units were selected to cover the entire length of the Breede and Riviersonderend Rivers.

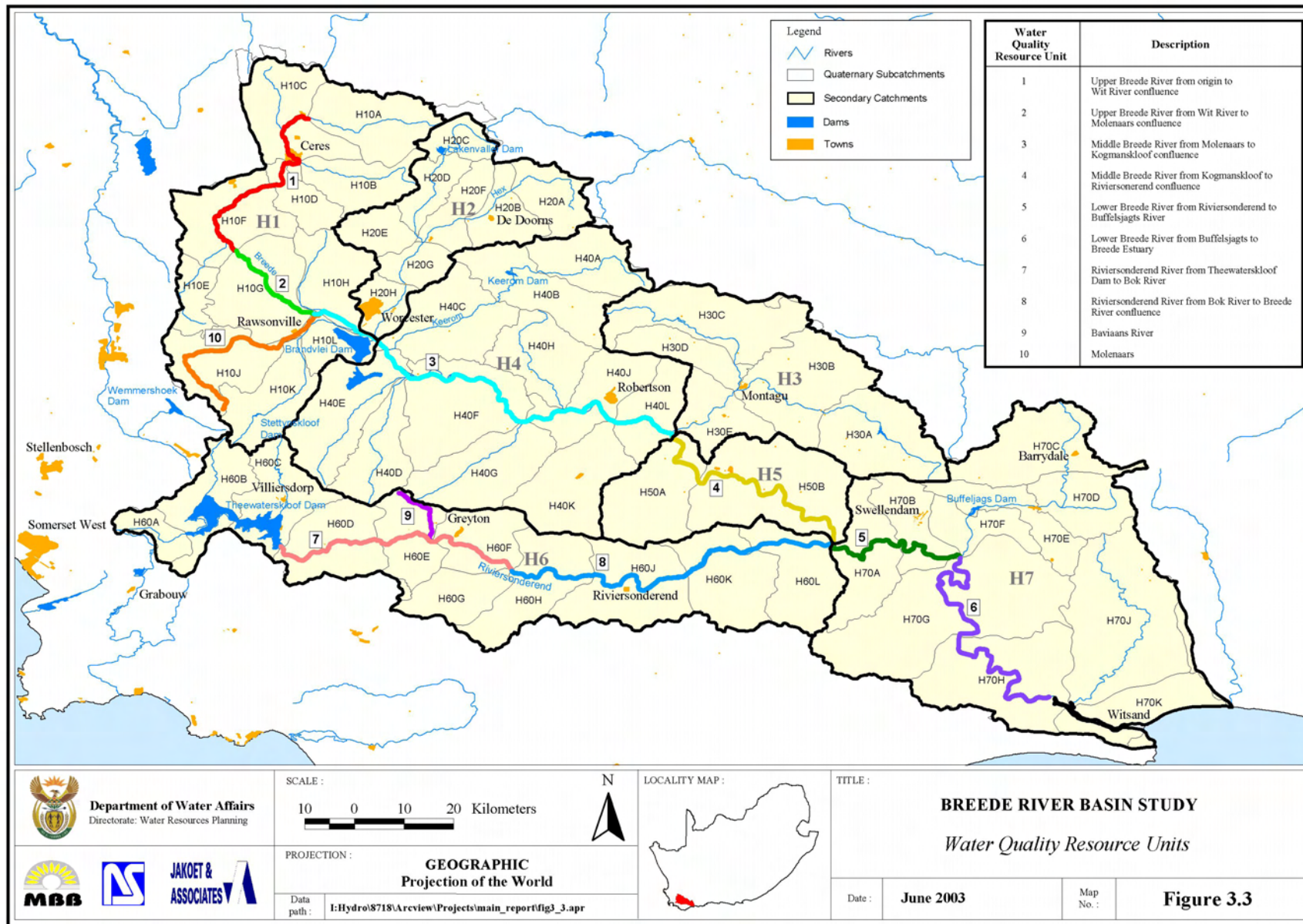


TABLE 3.3 : WATER QUALITY RESOURCE UNITS

WATER QUALITY RESOURCE UNIT	DESCRIPTION	IFR SITE WITHIN RESOURCE UNIT
1	Upper Breede River from origin to Wit River confluence	IFR 1
2	Upper Breede River from Wit River to Molenaars confluence	
3	Middle Breede River from Smalblaar to Kogmanskloof confluence	IFR 3
4	Middle Breede River from Kogmanskloof to Riviersonderend confluence	
5	Lower Breede River from Riviersonderend to Buffelsjagts River	
6	Lower Breede River from Buffelsjags to Breede Estuary	IFR 4
7	Riviersonderend River from Theewaterskloof Dam to Bok River	IFR 5
8	Riviersonderend River from Bok River to Breede River confluence	
9	Baviaans River	IFR 6
10	Molenaars River	IFR 2

The Reserve is aimed at the provision of water of a quality suitable for human consumption and for aquatic ecosystems, and does not address water quality for other uses such as irrigation. The analyses of water samples drawn from the various water quality sampling points indicate that these quality requirements are likely to be met throughout the system if Reserve quantity requirements are also met.

Throughout the Breede River catchment there are reaches and tributaries with particularly good water quality, which play an important role in the improvement of downstream water quality conditions, and act as safe havens for biota from adjacent, more impacted, reaches. In the integrated management of water quality of the Breede River, these areas should be identified and protected in order to maintain the downstream river health.

The two key water quality problems in the Breede River catchment that have received most attention have been salinisation of the river and high nutrient concentrations in some reaches of the river and its tributaries. Further concerns have been expressed about:

- suspended sediment loads result from inappropriate farming practices such as not adhering to guidelines for establishing buffer strips next to watercourses or changing watercourses;
- the bacteriological quality of the water in the Breede River and its tributaries;
- the presence of agrochemicals in surface and ground waters in the Breede River catchment.

A Water Research Commission project which was completed recently, investigated the quality of surface and ground water supplies in the rural Western Cape with regard to agrochemicals (London *et al*, 2000). Initial findings indicate that even though endosulfan and chlorpyrifos levels were low, elevated levels of these pesticides have been recorded in the Hex River study

area. It is assumed that the pesticide situation would probably be similar in other areas in the Breede River catchment where pesticides are used for intensive agriculture.

Detailed information on the determination of the recommended Reserves, and descriptions of the water quality requirements can be found in Reports PH 00/00/3402 *Ecological Reserve Determination (Water Quality)*, and PH 00/00/3602 *Ecological Reserve Determination (Water Quality) – Recalculation of the Water Quality Reserve*.

3.4 THE PAPENKUILS WETLAND

Within the Breede River catchment, the Papenkuils Wetland is a rare and important example of a wetland that contains a variety of wetland and terrestrial flora that are worthy of conservation. Particulars are presented in Report PH 00/00/1402 *Papenkuils Wetland Intermediate (Ecological) Reserve Determination (Low Confidence)*. The wetland is located next to Brandvlei Dam, downstream of the confluence of the Smalblaar (Molenaars) and Breede Rivers. The Smalblaar River bypasses the wetland, but may overflow into the wetland during high flow conditions. The Holsloot River drains into the wetland. Greater Brandvlei Dam forms an integral part of a number of likely future water resource developments. Most of these developments could impact on the wetland in some way or another. The functioning of the wetland is complex, and relies on groundwater gains and losses, and flood influxes from the Breede, Smalblaar and Holsloot Rivers.

The health of the wetland is declining as a result of diversion of flows in the Smalblaar and Holsloot Rivers, which feed into the wetland, artificial drainage of portions of the wetland, and abstraction of groundwater from the recharge area. The present ecological status category of the wetland is a "declining C", contrasting with its ecological importance rating of "B/C". The latter implies that steps must be taken to rehabilitate the functioning of the wetland. An Intermediate level, low confidence assessment was carried out to determine ecological flow requirements of the wetland. These were defined in terms of the levels and frequency of inundation that are considered to be required to sustain the wetland in its present form.

Further studies should be undertaken to fully assess the potential impacts of future developments in the wetland feeder rivers, and to facilitate management of the system. The possibility of mechanical intervention to rehabilitate the system by, for example, diverting flows from the main channel of the Breede River into the wetland, should also be investigated.

3.5 ESTUARINE FLOW REQUIREMENTS

3.5.1 Location

The Breede River Estuary stretches roughly from 10 km north-west of Malgas to the town of Witsand at the mouth of the Breede River. Tidal influence extends beyond the pont at Malgas to approximately 52 km upstream of the mouth (Figure 3.4). The estuary enters the sea through a permanently open mouth located at the southern end of an extensive sand spit. The channel of the estuary is incised in the coastal plain and depths of 3 to 6 m and even more are common over the first 28 km. The mouth of the Breede River Estuary is permanently open because of the volumes of tidal exchanges and the still relatively high run-off of the system. It is considered

highly unlikely that the mouth will close under present day conditions. This relates to a present day mean annual runoff (MAR) of about 1034 million m³/a (57% of natural MAR).

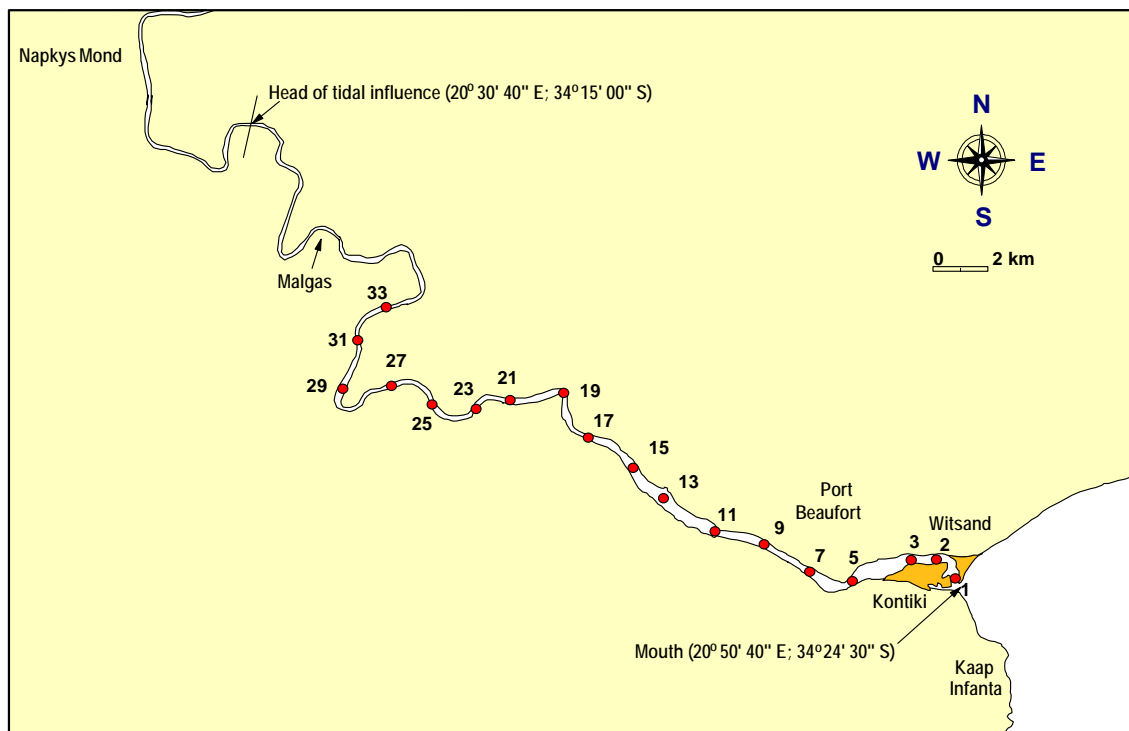


Figure 3.4 : The Breede River Estuary

3.5.2 Present Condition

The Breede River Estuary is the largest of the few permanently open estuaries on the South African coast. The large freshwater input creates a salinity gradient in the estuary along which different plants and animals are distributed, leading to a high biodiversity. Although the fresh water entering the estuary is only of "average" water quality, the ecological condition of the estuary is presently classified as "good".

The Estuarine Health index score for the Breede River Estuary, based on its present condition, is 78 translating into a Present Status Category of B. The estuarine Importance score came to 86, indicating a 'highly important' estuary. (These scoring systems are described in Appendices E3 and E4 of the *Resource Directed Measures for Protection of Water Resources: Estuarine Ecosystem Component*, DWAF 1999)

3.5.3 Recommended Ecological Reserve Category and Ecological Flow Requirements

According to the protocol for estuarine Reserve determination, the Ecological Reserve Category should be :

- Because the Breede River Estuary is highly important (reflected by Estuarine Importance Score of 86), the recommended Ecological Reserve Category should be elevated to one category above the Present Status Category, which implies a Category A or, if not possible,
- Best attainable state, with Category B the minimum requirement.

The largest factor that has contributed to the change from an un-impacted system to its present condition is the large reduction in inflows due to upstream development. A large re-allocation of water, already abstracted in the catchment, would therefore be required to improve the present condition of the Estuary to match its ecological importance. As it was assumed unlikely that large volumes of water could be re-allocated to the estuary and being within the rules of the protocol (i.e. minimum score to be allocated to a 'highly important' estuary is Category B), the specialist team recommended a Category B ERC for the Breede River Estuary.

The methodology for estuarine Reserve determination is based on assessments of the effects that a range of modified runoff sequences could have on the biotic and abiotic components of the estuarine ecosystem. The Reserve is a runoff sequence that allows the maximum benefit for upstream users while not reducing the Status Category below that specified.

Future development scenarios that were used in determination of the Reserve for water quantity are described in Table 3.4.

TABLE 3.4 : DEVELOPMENT SCENARIOS FOR ESTUARINE RESERVE DETERMINATION

DEVELOPMENT SCENARIO		MEAN ANNUAL RUNOFF	SHORT DESCRIPTION ⁽¹⁾	RESULTANT CATEGORY
Limited Future		954 million m ³	The two schemes associated with the limited development scenario (Michell's Pass and Upper Molenaars diversions) are essentially run-of-river diversions of winter flows. Due to the fact that the Michell's Pass scheme relies on only limited storage, high flows and very high flows are largely unaffected. As can be expected, winter low flows are reduced to some extent.	B
Moderate Future		863 million m ³	In addition to the schemes mentioned above, the further implementation of the Ouplaas scheme in the Molenaars River, and the raising of Buffeljags Dam impact on inflows to the estuary in different ways: Winter low flows are reduced due to the regulation of winter floods in the Molenaars River and the additional storage created at Buffeljags Dam. Winter high flows remain largely unaffected due to the limited storage of the two schemes. Summer high flows are reduced significantly as a result of the operation of the enlarged Buffeljags Dam.	C
High Future	Bromberg Dam	772 million m ³	These two scenarios comprise of the schemes mentioned above, with the further implementation of either the Bromberg scheme, or the Le Chasseur scheme. Even after the provision of environmental releases to meet instream flow requirements, the implementation of Le Chasseur Dam on the main stem of the Breede River would severely reduce summer high and low inflows to the estuary. Substantial reductions of early to mid winter low and high flows are caused by the filling of available storage in Le Chasseur Dam. Flows during August and September when dams are likely to be full are the least affected. During a prolonged drought, a reduction of flows during this period can also be expected. The Bromberg Future Development scenario has a similar impact although slightly less severe, due to the smaller size of the proposed dam.	C
	Le Chasseur Dam	649 million m ³		C

Note (1) : More information on these schemes are provided in Section 8.

In investigating the impact on the estuary, the schemes were assumed to be operated to release IFR flows and thereafter to maximise the benefits to users, without additional releases to minimise the impacts on the estuary. The Limited Future scenario, which provided a mean annual inflow to the estuary of 954 million m³/a, was considered as meeting the conditions for the recommended ERC of B. The Moderate scenario, which reduced inflow to the estuary to

863 million m³/a, and the High Future scenarios (Bromberg inflow 772 million m³/a, Le Chasseur inflow 649 million m³/a) were found to impact on the estuary in a way that would reduce the classification to C. On this basis, the Reserve for Water Quantity for an ERC of B is determined at 954 million m³/a (53.4% of natural MAR).

It is considered that the prevailing water quality of inflows to the head of the estuary (as measured over the period 1994 to 1999) is unlikely to deteriorate the ERC of the estuary beyond a Category B. Using the precautionary approach, the Reserve for Water Quality at the head of the estuary, is therefore estimated as the median water quality concentrations measured at the Swellendam Monitoring Station (H7H006Q01) over the period 1994 to 1999.

Detailed descriptions of the water quantity scenarios (in the form of monthly flow duration curves), and the water quality requirements (in the form of limits to system variables, inorganic nutrients, and toxic substances) are provided in Report PH 00/00/3602 *Intermediate Determination of Resource Directed Measures for the Breede River Estuary*.

3.6 GROUNDWATER RESERVE

3.6.1 General

The groundwater Reserve as defined in National Water Act of 1998 is the quality and quantity of groundwater to satisfy basic human needs and to protect aquatic ecosystems, in order to secure ecologically sustainable development. In the Breede catchment groundwater for basic human needs (presently set at 25 ℓ/p/p/d) comprises a very small percentage of resource potential and consumption. Therefore, if one ignores the small volume for basic human needs, the groundwater Reserve can be thought of as the volume that must reach rivers to ensure the integrity of riparian ecology and is most important during low flow periods.

In the winter rainfall region of South Africa, groundwater is the main source of stream flow in summer and therefore groundwater abstraction over this period (and close to riparian zones) has the potential to affect low flows essential for meeting the in-stream flow requirements (IFR) of surface watercourses.

The protocol for groundwater Reserve determination (DWAF, 1999) defines the sum of basic human needs and the groundwater component of baseflow as the groundwater Reserve. This volume is subtracted from the groundwater harvest potential to arrive at a volume that is available for abstraction (groundwater allocation). Harvest potential is defined as the sustainable volume of groundwater that can be abstracted if environmental and socio-economic issues are not considered, and is determined from the estimated recharge and storage capacity of aquifers. Due to concerns about the application of the harvest potential approach in the wetter parts of the country, the RDM Office of DWAF has recommended the use of recharge estimates in place of harvest potential. The latter approach was adopted for Reserve determinations in the Breede River catchment.

The groundwater Reserve (sum of the groundwater contribution to baseflow and basic human needs) is a conservative volume and, by implication, makes allowance for all of the groundwater

contributions to streams and rivers. The low maintenance baseflow component of the instream flow requirements is frequently less than the groundwater contribution to baseflow, and the monthly differences between these volumes should therefore, theoretically, be available for abstraction. In consultation with the RDM Office, it was agreed that this volume be referred to as the 'usable groundwater contribution to river flow', and that it be added to the difference between the recharge potential and the groundwater Reserve to determine groundwater allocation volumes. Figure 3.5 illustrates this concept.

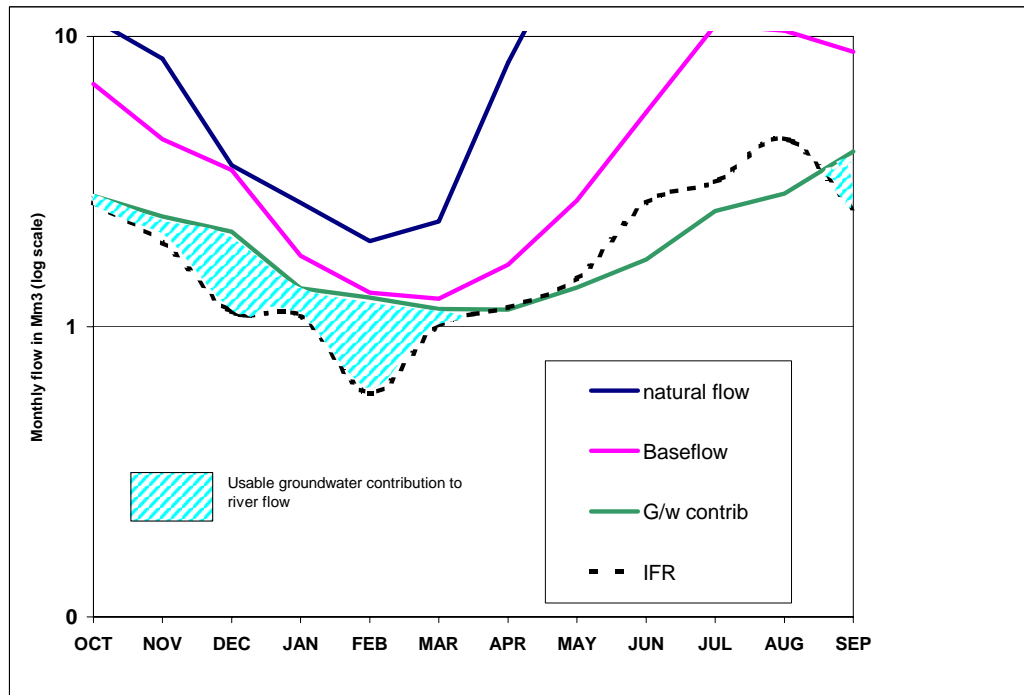


Figure 3.5 : Representation of the 'usable groundwater contribution to river flow'

The time delay that would have occurred between the groundwater passing the abstraction point and discharging into the watercourse was not considered. Consequently, if the abstraction area is distant from the point of discharge, abstractions up to the limit of the Reserve could lead to reduced discharge during the critical period, and hence to a shortfall in the IFR.

Determinations of the groundwater component of the Reserve were carried out at an intermediate level (presently the most detailed level of investigation) for two areas in the Upper Breede catchment, and at a rapid level for twelve areas covering the remainder of the catchment. These areas are shown on Figure 3.6. The intermediate determinations were done for the areas stretching from Wolseley to the Greater Brandvlei Dam (Area 1), and from Worcester to the Nuy valley (Area 2). (The Hex River Valley was excluded – Reserve determinations for this area are the subject of a separate study).

The results of the rapid Reserve determinations are shown in Table 3.5. Results of the intermediate determinations carried out for water resource areas 1 (Wolseley to Greater Brandvlei Dam) and 2 (Worcester to the Nuy Valley) are shown in Tables 3.6 and 3.7, respectively. More detailed descriptions are provided in Report PH 00/00/1202 *Groundwater Reserve Determination*.

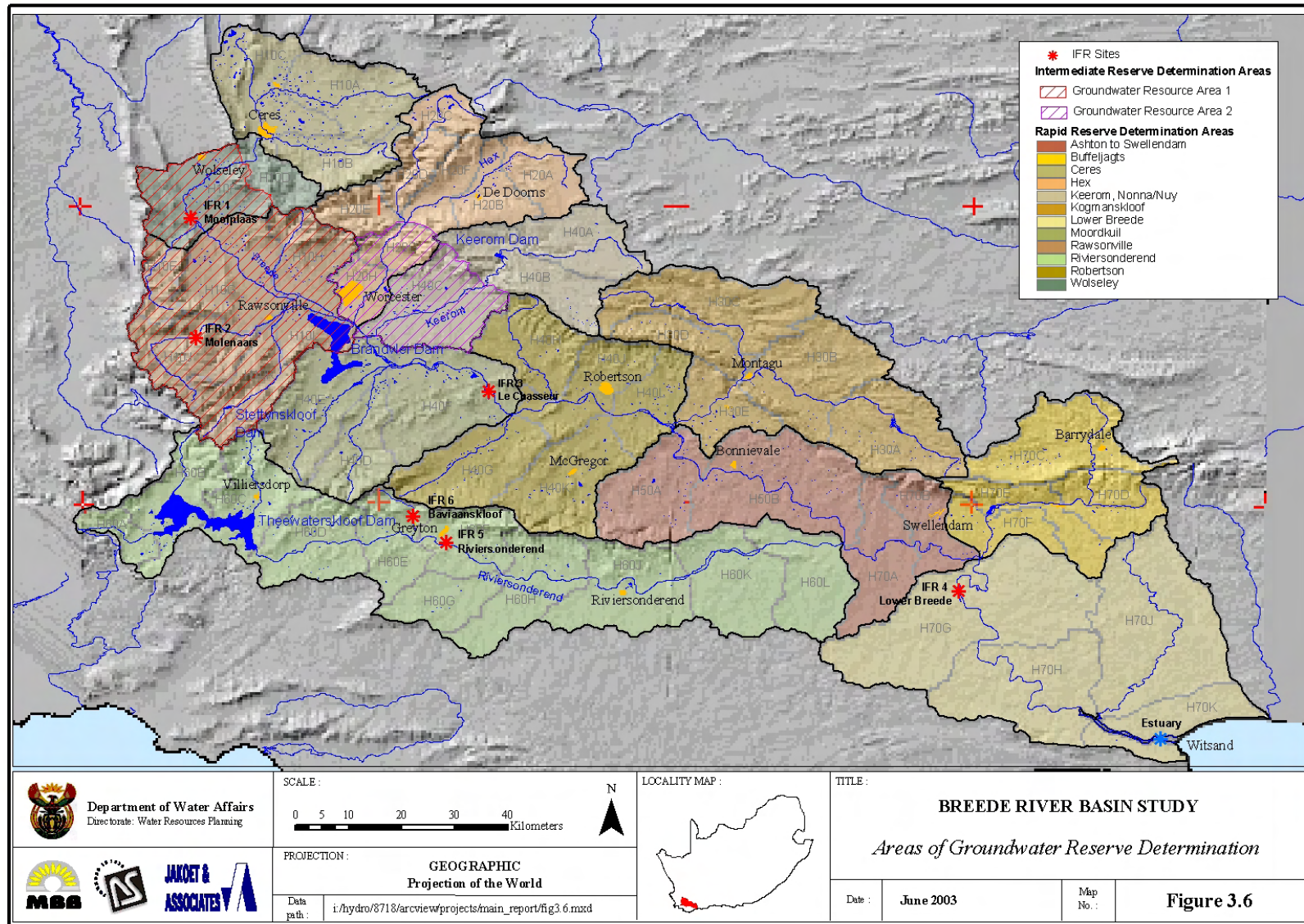


TABLE 3.5 : SUMMARY OF RAPID RESERVE DETERMINATIONS, GROUNDWATER ALLOCATIONS AND USE

QUATERNARY CATCHMENT	RESOURCE UNIT	AREA (km ²)	RECHARGE POTENTIAL	RESERVE (GROUNDWATER CONTRIBUTION TO BASEFLOW)		USABLE CONTRIBUTION TO RIVER FLOW (million m ³ /a)	GROUNDWATER ALLOCATION (million m ³ /a)	REGISTERED GROUNDWATER USE (million m ³ /a)	REMAINING ALLOCATION (million m ³ /a)
			(million m ³ /a)	(million m ³ /a)	%				
			a	b	b/a * 100				
H10A, B, C	Ceres	659	31.6	17.3	55	0	14.3	18.5	0
H10D, F	Wolseley	348	32.7	24.7	75	4.2	12.2	7.5	4.7
H10E, G, H, J, K, L	Rawsonville	1052	177.4	115	65	23.6	86	24.8	61.2
H200A to H	Hex	837	54.3	16.5	30	7.6	45.4	20.5	24.9
H40A, B, C	Keerom, Nuy/Nonna	700	27.2	4.7	17	4.1	26.6	3.2	23.4
H40D, E, F	Moordkuil	812	27.3	17.5	64	0	9.8	6.7	3.1
H40G, H, J, K, L	Robertson	1111	32.9	15.9	48	15.9	32.9	4.1	28.8
H30A to E	Kogmanskloof	1212	33.4	3.7	11	2.8	32.5	14.3	18.2
H50A, B, H70A, B	Bonnievale to Swellendam	1077	26.5	36.7 (Unreliable)	>100	3.3 (Unreliable)	3.3 (Unreliable)	0.9	2.4 (Unreliable)
H70C, D, E, F	Buffeljags	737	30.0	25.3	84	2.6	7.3	2.5	4.8
H60A to L	Riviersonderend	2251	139.2	18.9	14	2.2	122.5	1.9	120.6
H70G, H, J	Lower Breede	1606	25.3	9.9	33	9.9	25.3	0	25.3

TABLE 3.6 : WATER RESOURCE AREA 1 INTERMEDIATE GROUNDWATER RESERVE DETERMINATION

BOUNDARIES AND TYPING		MANAGEMENT CATEGORY		AREA (km ²)	RECHARGE (million m ³ /a)	RESERVE (GROUNDWATER CONTRIBUTION TO BASEFLOW) (million m ³ /a)	USABLE GROUNDWATER CONTRIBUTION TO RIVER FLOW (million m ³ /a)	GROUNDWATER ALLOCATION (million m ³ /a)
					a	b	c	a-b+c
Homogenous Response Units	Geohydrological Region Typing	Current Status	Desired Management Category					
Unit A	Stream flow	A	A	640.2	179.3	116.5	17.5	80.3
Unit B	B(i) Stream flow and high volume abstraction	E	C	194.8	7.1	4.6	0.7	3.2
	B(ii) Papenkuils Wetland			6.9	0.14	0.1	Exclusion	Exclusion
Unit C	C(i) High volume abstraction	D	B	329.4	22.9	14.9	2.4	10.4
	C(ii) Saline area			18.1	0.7	0.45	Exclusion	Exclusion
TOTAL				1274	210.1	136.6	20.6	94.1

Unit A: Mountain Recharge areas (TMG);

Unit B: Alluvial deposits;

Unit C: Hill slope and valley bottom fractured rock aquifers (Bok & Karoo).

TABLE 3.7: WATER RESOURCE AREA 2 INTERMEDIATE GROUNDWATER RESERVE DETERMINATION

BOUNDARIES AND TYPING			MANAGEMENT CATEGORY		AREA (km ²)	RECHARGE (million m ³ /a)	RESERVE (GROUNDWATER CONTRIBUTION TO BASEFLOW) (million m ³ /a)	USABLE GROUNDWATER CONTRIBUTION TO RIVER FLOW (million m ³ /a)	GROUND WATER ALLOCATION (million m ³ /a)
Homogenous Response Units	Geohydrological Region Typing	Current Status	Desired Management Category	a		b	c	a-b+c	
QUATERNARY CATCHMENTS H20G AND H (HEX RIVER)	Unit A	Stream flow	A	A	60.2	6.40	1.06	0.9	6.24
	Unit B	Stream flow and high volume abstraction	E	C	4.9	0.10	0.02	0.01	0.09
	Unit C	High volume abstraction	B	B	83.2	2.08	0.34	0.29	2.03
		Saline Water	A	A	25.9	0.54	0	0.07	Exclusion
	TOTALS					174.1	9.12	1.42	1.27
QUATERNARY CATCHMENT H40C (NUY AND NONNA RIVERS)	Unit A	Stream flow	B	B	47.6	4.56	0.11	0.67	5.12
	Unit C	High volume abstraction	D	C	62.7	1.46	0.04	0.22	1.64
		Saline Water	A	A	161.5	3.06	0.07	Exclusion	Exclusion
	TOTALS					271.8	9.08	0.22	0.89

Unit A: Mountain Recharge areas (TMG);

Unit B: Alluvial deposits;

Unit C: hill slope and valley bottom fractured rock aquifers (Malmesbury and Karoo).

3.6.2 Discussion

The Reserve determinations have indicated further potential for groundwater development except in the Ceres Valley where the registration of groundwater use exceeds the allocation. In the remainder of the Upper Breede catchment, approximately two-thirds of the groundwater allocation is registered, whereas in all the remaining areas, less than 50% is registered. In many parts of the Middle and Lower Breede catchment, although there are substantial volumes of groundwater that could be allocated, poor water quality limits the use of groundwater for irrigation.

Three homogenous response units are recognised in the Upper Breede catchment. These are the Table Mountain Group (Unit A), alluvial deposits (Unit B) and hillslope-and-valley fractured aquifers (Unit C). The alluvial aquifers are the most utilised aquifers in the Upper Breede catchment whereas the TMG aquifers, where most of the groundwater allocation is available, are hardly used. This is because of the practical constraints of establishing boreholes in mountainous terrain and the distance from irrigable land.

There is a need to establish dedicated monitoring boreholes in proximity to rivers and streams in areas where significant abstraction is taking place. A variety of hydrogeological settings should be studied to evaluate the effects of abstraction on stream flow. Site specific data will be required to improve understanding of the effects of abstraction on stream flows, the surface-groundwater interaction between homogenous response units and recharge mechanisms of geohydrological region types.

3.7 INTEGRATION OF THE RESERVE COMPONENTS

3.7.1 General

A significant portion of the Study resources was invested in the various Reserve determinations. The geographical spread and confidence levels of the determinations were planned to deliver, as far as present knowledge and available resources permitted, Reserve determinations commensurate with the management needs of the Breede River catchment which encompasses sub-catchments where resource use is approaching maximum sustainable use, conservation worthy areas, and catchments with significant water resource development potential.

Numerous interrelations exist between the different components of the Reserve in the Breede River catchment. These had to be taken into account to provide a holistic reflection of current and future water availability. The information will be useful when setting a Preliminary Reserve, and to manage the system accordingly.

An overarching protocol for the integration of Reserve components has not yet been developed. Relatively simple procedures were therefore developed during the course of the Study to address the more significant inter-relationships between Reserve components. These procedures can

potentially be applied in other catchments. A brief overview of the methods that were used is provided here. The effect that these integrated requirements have on the developable yield of the system, is discussed in Section 7.3 of this report.

3.7.2 Instream Flow Requirements and Estuarine Flow Requirements

Instream flow requirements are described in the form of monthly IFR "rule curves" which specify the percentage of time that certain flows are required, and can be related to the natural flow regime. In estuaries, the volume of water may be so large that inflows over a period of several years, and not only seasonal flows, may be significant. Consequently, estuarine flow requirements (EFRs) are usually specified in the form of a long-term monthly flow sequence associated with a future development scenario. To compare the IFR at the head of the estuary with flows required to maintain the health of the estuary, it is necessary to translate the EFR time series into monthly rule curves. Integrated rule curves were developed by selecting the higher of the two requirements at each point on the monthly rule curve. However, it must be remembered that the EFR is derived from a particular development scenario (including operating rules), whereas the IFR is independent of any particular development.

3.7.3 Water Quantity and Water Quality Components of Instream Flow Requirements

Water quality and water quantity Reserve determinations were carried out for the same representative reaches in the catchment. Additional water quality resource units were selected to cover the entire length of the Breede and Riviersonderend Rivers. The Reserve determinations were done at the same workshop, and no further integration was required.

3.7.4 Instream Flow Requirements and the Groundwater Reserve

Time series of instream flow requirements that were determined for six key sites in the catchment, and extrapolated estimates for the remainder of the catchment were used as a departure point for the integration of IFRs and the Groundwater Reserve. The downstream boundaries of groundwater resource units were selected to coincide with points for which IFRs were determined. The time series of IFRs were compared with groundwater baseflow estimates to establish proportions of baseflow that contribute to the IFRs. Once the groundwater contributions to the IFRs were established, remaining groundwater exploitation potential was determined according to the procedure described in Section 3.6 above.

3.7.5 Integration of Wetland, Riverine and Groundwater Components

The functioning of the Papenkuils Wetland is complex, and relies on groundwater gains and losses, flood influxes from the Breede River, and tributary inflows. The integration of the wetland, groundwater and riverine Reserve components was not undertaken as part of the BRBS, as the scope of this work would have resulted in a substantial delay to other components of the study. This means that the ecological flow requirements of the wetland were not taken into consideration in the determination of the yields of schemes that may impact on the wetland. A

limited amount of fieldwork was done to provide a conceptual understanding of the role that groundwater plays in maintaining water levels in the Papenkuils Wetland.

3.7.6 Lessons Learnt

The development of procedures for the integration of Reserve components in the Breede River catchment required a certain amount of trial-and-error experimentation. The procedures that were devised are suited to conditions in the Breede River catchment, but with some adjustments, could be applied in other catchments. With a view to this possibility, the lessons that were learnt in the BRBS are summarised here:

- (a) Ideally, Reserve determinations should be programmed to commence with the determination of IFRs (water quantity and quality), followed by groundwater and estuarine Reserve determinations (the latter two components in no particular order). This sequence will allow for:
 - (i) selection of groundwater resource units to correspond with the location of IFR sites;
 - (ii) the use of IFR time series in the determination of available groundwater allocations as described in Section 3.7.4 above; and
 - (iii) the use of the downstream-most IFR time series (for the recommended, as well as the alternative Reserve Categories) as inflow sequences ("scenarios") to be used in the estuarine Reserve determination.
- (b) Estuarine and groundwater specialists should attend the IFR scoping meeting, and provide input to the IFR site selection process.
- (c) Estuarine Reserve determination is essentially a re-active process. The process commences with the development of long-term estuary inflow sequences that correspond to a range of development scenarios (including a reference, or undeveloped scenario). The effects that these inflow sequences have on the ecological functioning and health of the estuary are then assessed, and an acceptable scenario (which permit the desired Ecological Reserve Category to be achieved) is selected. The estuarine Reserve for water quantity is then defined in terms of the hydrological characteristics of the selected inflow sequence. A number of potential pitfalls in this approach have come to the fore during the course of the Study:
 - Cost and time constraints limit the number of scenarios that can be assessed. This could of necessity lead to large volumetric increments between successive development scenarios.
 - Relatively simple changes to the operating rules of the schemes that make up the postulated development scenarios could substantially alleviate (or intensify) the potential impacts on the estuary. Assessment of these effects would require a number of trial-and-error iterations, and would have significant cost implications.

Provided that the ecological flow requirements of the lower reaches of the river, and of the estuary that it flows into are of the same order (as seems to be the case with the Breede River and its estuary), recommendation (a) (iii) above could go some way to avoiding these problems. However, it is a recommendation of this study that the protocol for estuarine Reserve determination be reviewed, and if possible, amended to introduce a flexible, iterative means of refining the estimates of ecological flow requirements.

3.8 IMPLEMENTATION AND MANAGEMENT OF THE RESERVE

3.8.1 Introduction

A considerable amount of research has been directed at the development of methods and procedures for Reserve determination. However, very little experience has thus far been gained in the implementation and management of Reserves, and little is known about the effectiveness of the ecological water requirements (EWRs) as recommended by team specialists in achieving the recommended ecological management categories. In recognition of the limited experience available, some further study work was approved to explore the implications that the system-wide implementation of recommended EWRs may have on water availability in the catchment. It was expected that, by developing a thorough understanding of these implications, knowledge would be gained to inform water use licensing, and also to provide some guidance in the ways that existing or proposed water resources developments could be utilised for provision of the recommended EWRs. The additional work that was carried out, comprised of :

- (a) comparison of present day flows with recommended EWRs, to identify deficits and surpluses;
- (b) apportionment of the cascade of sub-system flow contributions to EWRs at various points in the system; and
- (c) yield assessments to investigate the possibility of "unlocking" significant yield potential by reducing ecological Reserve categories at one or two system-critical sites, or conversely, of upgrading recommended categories in certain conservation-worthy subsystems without adversely affecting system yield.

This work is described in detail in Report PH 00/00/2602, *Regional Yield Assessment*, and is summarised in the following paragraphs.

3.8.2 Present Day Compliance with Recommended EWRs

A comparison of recommended EWRs and simulated present day average flows was made at IFR Sites 1,2 and 3. A comparison of the integrated requirements of IFR Site 4 and the Estuary (Section 3.7.2), and present day flows at IFR Site 4 was also made. The results of the comparisons are summarised in Table 3.8 and discussed below. Where actual present day flows exceeded EWRs, they were set in the table at zero.

Site 1, Upper Breede River at Mooiplaas, lies between major irrigation abstractions at Witbrug and the major inflow of the Wit River. At this site, the present ecological state (PES) is given a Category D/E due mainly to deficient summer flows, and is degrading further. The Environmental Importance and Sensitivity (EIS) is given as "moderate" and the social importance (SI) as "low". The recommended ecological Reserve Category (ERC) for Site 1 is a Category D.

Recommended EWRs for Site 1 are largely met during the winter, spring, and early summer months. "Surplus" flows (not shown in Table 3.8) occur during these months. Shortfalls occur during the months of February and March. Because the quantity of water needed to make up the shortfall is small (about 3 million m³/a, Table 3.8), it should be practical to upgrade this reach to the recommended Category D. However, if a Category D is to be achieved, non-flow related impacts such as mechanical disturbance to the channel, and the presence of alien fish species, will also have to be addressed. Upstream of the Witbrug abstraction point, as far as the confluence with the Wit Els River, the PES must be substantially better than at Site 1, but further upstream in the environmentally and socially important gorge, the heavy summer abstractions in the Ceres valley are unrelieved by inflow from the Wit Els River.

TABLE 3.8 : COMPARISON OF EWRs AND SIMULATED PRESENT DAY FLOWS

SITE		PERIOD	MEAN MONTHLY FLOW (million m ³ /m)											TOTAL	
			OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG		SEP
1	Recom ⁽¹⁾	1961-1990	8,08	4,08	3,16	1,67	1,10	1,53	2,37	7,80	7,31	8,74	38,36	18,49	102,7
	Supplied ⁽²⁾		8,08	4,07	3,04	1,62	0,55	1,04	2,19	7,74	7,31	8,74	36,53	17,97	98,9
	% Recom ⁽³⁾		100	100	96	97	50	68	92	99	100	100	95	97	96
2	Recom ⁽¹⁾	1969-1990	4,87	2,80	2,39	1,87	1,77	1,61	2,20	5,30	7,25	19,32	12,78	16,39	78,5
	Supplied ⁽²⁾		4,87	2,71	2,18	1,35	1,02	1,31	2,00	5,30	7,25	19,31	12,78	15,74	75,8
	% Recom ⁽³⁾		100	97	91	72	58	81	91	100	100	100	100	96	97
3	Recom ⁽¹⁾	1980-1990	30,55	19,08	13,19	10,16	6,45	10,76	20,05	40,70	79,02	153,46	93,81	62,23	539,5
	Supplied ⁽²⁾		30,55	19,08	13,19	10,08	5,95	9,33	19,01	40,68	73,32	147,67	92,64	62,23	523,7
	% Recom ⁽³⁾		100	100	100	99	92	87	95	100	93	96	99	100	97
5	Recom ⁽¹⁾	1964-1993	9,45	8,84	2,70	2,32	1,89	1,51	5,74	10,02	14,44	21,50	34,61	21,25	134,3
	Supplied ⁽²⁾		5,16	4,41	2,70	2,27	1,60	1,37	3,33	2,41	2,64	8,09	15,92	12,00	61,9
	% Recom ⁽³⁾		55	50	100	98	85	91	58	24	18	38	46	57	46
4	Recom ⁽¹⁾	1927-1990	53,37	39,05	16,72	14,71	16,16	11,55	21,67	21,20	90,02	79,56	129,98	87,81	581,8
	Supplied ⁽²⁾		49,65	27,67	14,92	10,85	9,04	8,64	15,13	17,87	68,11	76,78	122,59	84,56	505,8
	% Recom ⁽³⁾		93	71	89	74	56	75	70	84	76	97	94	96	87
4 + Estuary (4)	Recom ⁽¹⁾	1927-1990	80,19	61,47	22,32	20,77	22,88	19,29	51,56	100,53	120,32	157,03	209,83	109,22	975,4
	Supplied ⁽²⁾		59,03	42,78	18,95	15,50	16,03	17,61	38,68	66,93	100,45	131,33	190,24	98,39	795,9
	% Recom ⁽³⁾		74	69	85	75	70	91	75	67	84	84	91	90	82

Notes:

1. Average monthly recommended EWR
2. Average monthly present day volume "supplied", i.e. excluding surplus flows
3. Average monthly compliance (%)
4. Integrated EWR for IFR Site 4 and the Estuary

Shaded months indicate shortfalls in excess of 25%

Site 2 is located on a reach of the Molenaars River that is almost pristine, and is given a PES of B. The only low component rating, fish, is due to the presence of alien trout and bass, which have virtually displaced indigenous species. The EIS is "very high" and the SI "high". The recommended ERC for Site 2 is a Category B. With the exception of the summer months of January and February, EWRs at Site 2 (Molenaars) are largely met. Clearing of the remaining alien vegetation in the Molenaars catchment would more than compensate for the shortfalls that occur sporadically. Significant surplus flows occur during winter.

Downstream of the Smalblaar confluence, flow in the main channel is severely disturbed by the abstraction in winter of a large quantity of water to fill Brandvlei Dam, and its subsequent release in summer. This situation is demonstrated at Site 3 (Le Chasseur), where the PES is given as Category C/D, and is degrading further, due to the unnaturally high and uniform summer base flows coupled with reduced winter flows, and turbidity. The recommended ERC for Site 3 is a Category C/D. The present condition of the river could be maintained by conveying irrigation requirements by canal instead of by river channel, but it is unlikely that such a scheme will be implemented any time soon, and the implication is that the PES is expected to fall. The EIS and SI are given as "moderate".

For all practical purposes, the EWRs at Site 3 are currently met. Approximately 60% of the summer requirements are satisfied through irrigation water and freshening releases from Greater Brandvlei Dam, with the remaining 40% provided in almost equal proportions from the Wit River, Holsloot, and the combined runoff from other, smaller tributaries between Site 1 and Site 3. The situation changes in the winter months, with most of the flow contribution originating from catchments that are located upstream of Site 1.

Summer flows downstream of Site 3 are reduced by abstractions at the intake of the Robertson canal (37 million m³/a), and the Angora canal (23,5 million m³/a) and the Zanddrift canal (52 million m³/a) intakes, both immediately upstream of the Kogmanskloof confluence. Consequently, summer flows are greatly reduced, probably well below Category D requirements.

Of the sites investigated, Site 5 on the Riviersonderend River downstream of the Baviaans River confluence is the most degraded, and is the only site where mean annual ecological flow volumes are very significantly in excess of mean annual present day runoff. At this site, where conditions are considered better than elsewhere in the vicinity, the PES is E for all components other than water quality. The EIS is given as "high" and the SI "low". The main cause of the low present status arises from the reduction in MAR downstream of Theewaterskloof Dam from 237 million m³/a to 45 million m³/a. Of the latter figure, 36 million m³/a represents releases for irrigation and the balance the average annual spillage. Additional losses between the dam and Site 5 are caused by alien vegetation, and irrigation and urban abstractions. The situation may improve in the downstream direction on account of the accrual of run-off, offset to some extent by losses due to alien plants. At the confluence with the Breede River, the present day MAR is 35% of the naturalised MAR, compared with about 25% at Site 5.

From Table 3.8 it can be seen that, over the long term, the average annual shortfall at Site 5 is of the order of 72 million m³/a. The recommended EWR is based on the requirement that Category E systems have to be restored to at least a Category D system, but to achieve this the 72 million m³/a would have to be replaced from other sources, and the cost would be very high. For the purposes of estimating the remaining water resources exploitation potential of the Breede River catchment, it was assumed that present day flows would not be further reduced in months when deficits occur, but that EWRs would be limited to existing flows, and that in particular, the present condition of the Riviersonderend River would not be upgraded.

Downstream of the confluence of the Breede and Riviersonderend Rivers, the condition of the Breede River improves due to the substantial inflow from the Riviersonderend River. Additional improvement is derived from the inflow of the Buffeljags River. Site 4, downstream of the latter confluence, is given a PES of C, the EIS is rated "high" and the SI "moderate". The PES is lower than it might otherwise be mainly on account of the presence of alien fish and vegetation, and pesticides, nutrients and general salinity in the water. The recommended ERC for Site 4 is a Category B/C, which could possibly be achieved by means of non-flow related measures.

Finally, consideration needs to be given to the Breede River estuary. The estuary is rated as "highly important", because of its functional importance, its size, and, to only a slightly less degree, its habitat diversity and bio-diversity importance. One could add that the estuary is also socially important, on account of the settlements along the estuary banks and adjacent coastline, and the use made of the estuary for recreation and the supply of fish, as well as the access to the adjacent sea facilitated by the estuary.

Based on an evaluation of the impacts on the estuary of three alternative scenarios for the development of the Breede River water resources, it was concluded that flows derived from the "limited development" scenario represented the EWR of the estuary. The EWR determined in this way amounted to 975 million m³/a.

The three scenarios considered by no means cover the range of practical scenarios. Moreover, the operation of the schemes was based purely on meeting consumptive water needs, without adjustments to benefit the estuary. It is thought that other scenarios, together with suitable operating rules, could meet the needs of the estuary and possibly even improve on its present ecological status. In making such adjustments to flows into the estuary, account should be taken of human requirements, in particular the supply of fresh water to communities that draw their water from the upstream section of the estuary, who could be threatened by the risk of occasional high salinity values.

On average, the integrated ecological flow requirements of Site 4 (Lower Breede), and the Estuary are only partly met during winter (although large surpluses could occur in some wet years). Significant shortfalls occur during summer. During winter, between 60% and 80% of the flows that contribute to these requirements originate from catchments upstream of Site 3, with smaller contributions from the Riviersonderend River (+- 10%), and the Buffeljags catchment (+- 5%). During the summer months, the bulk of the EWRs are still provided from the catchments

upstream of Site 3, but could vary widely (between 35% and 90% of the total contribution), depending on prevailing runoff conditions. The Buffeljags catchment plays a significant role in summer, and provides between 10% and 20% of the present inflows to the Estuary during these months.

The parallel application of the BBM and DRIFT methodologies in the Breede catchment has shown that DRIFT produces time series of riverine ecological water requirements that are more closely aligned with present day flows in the system than those produced with the BBM. The disparity between the two sets of estimates was most pronounced at the downstream end of the system (IFR Site 4), where the DRIFT sequence indicated that present flows in the system are sufficient to meet provisional Reserve Requirements, whereas the BBM sequence indicated a substantial shortfall of about 76 million m³/a (Table 3.8).

3.8.3 Selection of Recommended Ecological Management Categories

Yield assessments were carried out to investigate the effects of reducing ecological Reserve categories (ERCs) at system-critical sites, and conversely, of upgrading recommended categories in certain sub-systems. This aspect is discussed further in Section 7.3, but in order to illustrate the consequences with regard to the setting and implementation of the Reserve, a few observations are made here.

- The recommended ERCs for the Upper Breede (Site 1), and the Riviersonderend River (Site 5), are "D" Categories. In terms of current RDM policy it is not possible to reduce the recommended Categories for these rivers.
- On account of the near pristine condition of the Upper Molenaars River, the selection of a higher or lower ERC would presently have no effect on exploitable yields further downstream. Should the development of the Upper Molenaars diversion scheme (Section 8.3) be pursued, a lower ERC would substantially enhance the yield of such a scheme, but the ecological importance and sensitivity of this subsystem could preclude this possibility.
- Selection of a higher ERC for the Middle Breede River (Site 3) than the recommended Category C/D would slightly reduce exploitable yields in this reach of the river, and would provide further contributions to the ecological flow requirements of the Lower Breede River and the Estuary. Lowering the ERC to a Category D would provide a significant increase in exploitable yields (of the order of 45 million m³/a). However, if this yield is developed at Site 3, ecological flows in the Lower Breede River will be reduced, and will have to be sourced from elsewhere.
- At first glance, it would appear that the recommended Reserve for the estuary of about 950 million m³/a is much larger than the estimated Reserve requirement for the lower Breede River of about 580 million m³/a. Floods with return periods greater than about 1:5 years are

not usually specified as part of riverine Reserve requirements, as the major portion of these floods would spill over most storage dams. If the volumes of these floods were to be included in the riverine Reserve, the two requirements would be of the same order of magnitude. Selection of a lower ERC for one of these two components would therefore not significantly increase the yield potential of the system. Should the ERCs of both the Lower Breede River (Site 4) and the Estuary be lowered, a limited amount of water (of the order of 15 to 30 million m³/a, depending on the availability of storage) could be made available for further use in the upstream catchments.

3.8.4 Recommendations for the Implementation and Management of the Reserve

- (a) Besides the new Ceres Dam, there are no major storage units in the Ceres catchment that could be utilised to regulate the provision of EWRs in the Upper Breede catchments. The relatively small present day runoff contribution from the Koekedouw catchment to flows in the Upper Breede River probably also precludes the use of the Ceres Dam for management of EWRs on a regional scale. The shortfall in EWRs in late summer are therefore likely to remain, and the possibility of limiting the issuing of new licences in the Ceres catchment and in the catchments of the Upper Breede River to periods of surplus should be considered.
- (b) According to study estimates, groundwater use in the Ceres catchment already exceeds the available allocation in this area. However, in some localised areas it may still be possible to develop groundwater schemes without affecting river flows. The potential impacts of proposed groundwater schemes on river flows should therefore be investigated in detail prior to the approval of licenses for such schemes.
- (c) Before considering applications for new licenses or planning new schemes upstream of the Papenkuils Wetland, further studies should be undertaken to fully assess the potential impacts on the feeder-rivers of the Papenkuils Wetland, and to facilitate management of the system. The possibility of mechanical intervention to rehabilitate the system by, for example, diverting flows from the main channel of the Breede River into the wetland, should also be investigated. Work is needed to determine the volumetric quantities, seasonal distribution, and assurances of the ecological flow requirements that are associated with the frequencies and levels of inundation that were determined during the course of this Study. The relative contributions of groundwater and surface water to these requirements should also be quantified.
- (d) During the summer months, most of the ecological flow requirements at IFR Site 3 on the Middle Breede River are generally met through the release of irrigation water and freshening volumes from Greater Brandvlei Dam. Further downstream, particularly below the offtakes of the Angora and Zanddrift Canals, summer flows may be substantially less than would be recommended. This aspect requires further investigation. In winter it would be possible to regulate the provision of ecological flows

to the Middle Breede River to some extent through the control of diversions from the Holsloot and Molenaars (Smalblaar) Rivers.

- (e) The financial and socio-economic implications of providing an additional 72 million m³/a to provide for ecological flow requirements to improve the condition of the Riviersonderend to a Category D are not known, and should be explored. The removal of alien plants will go some way toward reducing the deficit. Other possibilities include the revoking of existing water rights, and releasing additional water from Theewaterskloof Dam. The latter would necessitate replacing a portion of the supply from Theewaterskloof Dam to the Berg WMA by new water resource developments in the Berg WMA.

The situation in the Riviersonderend is reflected elsewhere in South Africa where the reconciliation of ecological flow requirements and existing consumptive use will prove to be very difficult. It is therefore suggested that serious consideration should be given to the concept of balancing the distribution of localised "sacrificial" sub-catchments, where Categories lower than D is accepted, against "conservation-worthy" systems within a wider regional biosphere. By implication, this would require a review of aspects of RDM policy.

- (f) The existing Buffeljags Dam is located in a position that is suited for the management of ecological flows in the Lower Breede River and the Estuary. If the dam were raised for this purpose, this would release Breede River water for use upstream.
- (g) In most catchments, clearing of alien invasive vegetation would contribute to the restoration of low flows required for the maintenance of the aquatic ecosystems.
- (h) As will be explained in Section 7.3 of this report, a Preliminary Reserve that is based on the newly determined environmental flow requirements will limit further exploitation of the water resources in the catchment to much lower levels than previously thought. For this reason, and also to compensate for uncertainties that still exist in the methods of Reserve determination, it is imperative that environmental monitoring be implemented to evaluate the effects of Reserve provision. If indicated by such a programme, the Reserve should be modified accordingly.
- (i) With the exception of the IFR Site 4 (in the Lower Breede River), all IFR Sites are located near DWAF flow gauging stations. These stations should form the basis of a compliance monitoring network that could be expanded to include other stations as the Reserves are extrapolated into the remainder of the catchment. The respective stations are:

IFR Site 1:	H1H006
IFR Site 2:	H1H018
IFR Site 3:	H4H017

IFR Site 5: H6H009

IFR Site 6: H1H005

- (j) The closest flow gauging station to IFR Site 4 (Lower Breede River) and the Estuary is station H7H006, close to Swellendam (about 15 km and 102 km upstream of Site 4 and the mouth of the Estuary, respectively). The Buffeljags tributary is measured at station H7H013, and correlations will have to be established in order to be able extrapolate observed data from these stations to Site 4 and the head of the Estuary.

4. URBAN WATER REQUIREMENTS

Urban water use is small compared to agricultural usage in the Breede catchment, accounting for about 3% of current water use in the catchment. During the past decade, growth in urban water usage has averaged about 2,4% per year.

There is considerable scope for urban water demand management with potential reduction in demands of the order of 20% to 30% (Section 6.3). Future growth in urban water use is expected to slow down as a result of the implementation of water demand management measures (Figure 4.1), in which case urban usage may increase from 26 million m³/a at present to around 43 million m³/a by 2030. A high growth scenario is also shown on Figure 4.1, corresponding to a less likely situation where urban demands continue growing according to historical rates of between 2,5% and 3% per year, to about 60 million m³/a by 2030.

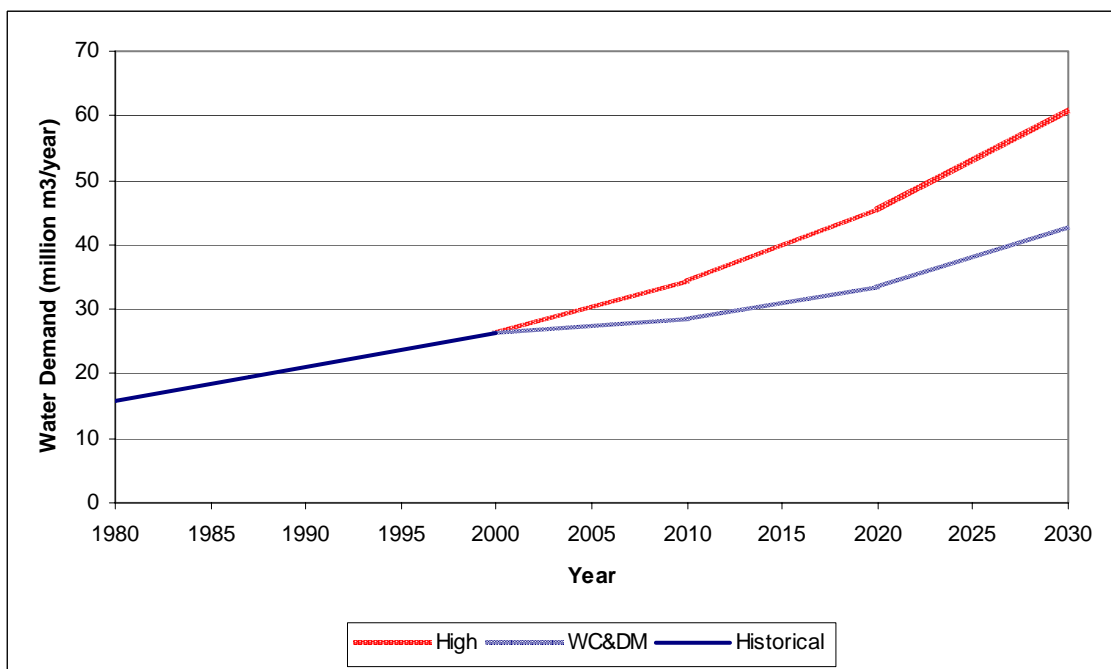


Figure 4.1 : Historical and projected urban water demand

The water supply situation of each town was compared with the yields of the existing water sources of each. From this comparison it was concluded that De Doorns already has problems, and that Bonnievale will very soon start experiencing shortages. The towns of Robertson, Ashton, Villiersdorp and Riviersonderend will have to start planning for increased water supplies in the near future. In towns where water shortages are being experienced or where shortages are imminent such as De Doorns and Bonnievale, the implementation of WCDM measures should receive priority attention.

5. AGRICULTURAL WATER REQUIREMENTS

5.1 INTRODUCTION

The agricultural sector is by far the most important source of primary production in the Breede River catchment, and directly produces of the order of 36% of the region's Gross Geographical Product (GGP) (Urban-Econ, 1997). Agriculture also makes a considerable economic contribution to the other sectors of the region's GGP. As a water use sector, irrigated agriculture is also the biggest consumer of water, accounting for some 66% of total current water use (including transfers) in the catchment. It is clear that, after provision for the Reserve has been made, optimum resource allocation will be achieved by striking the correct balance between future allocation of water for irrigated agriculture in the catchment and for transfers to the Berg Water Management Area. This balance will shift along with changing development needs in the competing sectors, and an ongoing re-appraisal of the relative benefits of water use for local irrigation and for transfers would be required to optimally utilise the water resources of the region.

5.2 EXISTING WATER USE BY IRRIGATED AGRICULTURE

Agriculture in the Breede River catchment went through a number of phases over time. Initially, farmers exploring the interior and settling in the area made a living from stock farming. Apparently they then started producing dryland wheat and rye. In areas close to water sources such as the low-lying parts of the valley, simple diversions and canals were subsequently constructed. From flood irrigation of grain crops, farming turned to flood irrigated wine grapes and deciduous fruit. A problem with the marketing of wine products and diseases in the vineyards prompted farmers to turn to the much more lucrative ostrich farming. The disastrous crash of the ostrich feather industry forced farmers to turn back to wine and deciduous fruit production in the early 1900s.

Over the last century, agriculture in the catchment evolved to the present situation with marked differences in the cropping patterns from one part of the catchment to the other. This evolution was driven by a number of factors including:

- Climate – some types of fruit such as apples and pears generally need colder winters than for instance peaches and plums. Equally, certain varieties of wine grapes produce best in warmer climates, etc. Thus local "regional" climates dictated which crops were best suited to a specific part of the catchment.
- Infrastructure – development of facilities such as wineries or packing houses in certain areas obviously encouraged the planting of specific crops around such facilities.
- Availability of water – infrastructure for the provision of irrigation water developed earlier in some parts of the catchment than in others. Thus some areas developed into the irrigation farming areas that they have been for generations, while others did not. This is certainly the reason why the Riviersonderend region is still generally a stock farming and dry land grain

farming area, and the full potential for irrigated crops along the Riviersonderend River has not yet been realised.

The extent of existing irrigated agriculture in the study area was determined from the mapping of present day land-use. This was based on aerial photography that was undertaken in the first quarter of 2000. The areas under various irrigated crops are shown in Table 5.1.

TABLE 5.1 : EXTENT OF EXISTING IRRIGATION

DESCRIPTION	AREA BY SUB-CATCHMENT (ha)							
	H100	H200	H300	H400	H500	H600	H700	TOTAL
Total catchment area	204 647	83 200	120 725	260 820	69 510	224 165	292 270	1 255 337
Total developed area	47 030	12 400	15 103	48 055	22 358	108 509	170 091	423 546
Irrigated cash crops	100	1	183	275	109	148	205	1 020
Irrigated orchards	9 146	827	3 194	4 757	1 540	7 708	1 877	29 049
Irrigated pastures	1 210	299	477	3 312	1 772	3 561	3 248	13 880
Irrigated vineyards	10 986	4 987	2 269	12 734	3 507	365	151	35 000
Fallow land *	5 916	1 222	1 477	6 461	1 611	1 998	1 481	20 166
Total irrigated crops	27 358	7 336	7 600	27 539	8 539	13 780	6 962	99 115
Total dry land crops	10 732	1 557	5 574	14 838	12 571	84 617	157 453	287 342

Note: * Fallow land refers to areas which clearly have been cultivated and irrigated in the recent past, but were not planted at the time of the photography.

By differentiating between cash crops, pastures, orchards and vineyards, and using the applicable gross irrigation demand figures for the seven sub-catchments, the theoretical on-farm irrigation demand of the existing irrigated area is calculated as **826 million m³/a**, equating to a weighted average application requirement of 833 mm/year. The total net consumptive use (excluding evaporative losses from dams) by irrigated agriculture in the catchment is considerably less than this figure. Most of the irrigated areas in the Breede River catchment are located around the main stem of the Breede River, and along the major tributaries of the system. This has the effect that a progressively larger portion of irrigation return flows is re-used as one moves in a downstream direction. Crop water requirements are also reduced in irrigated areas located in the seepage path between canals and the river. Lastly, winter storage in the system is limited, and many of the irrigation schemes are reliant on run-of-river abstractions. This has the effect of increasing the risk of supply failure (relative to schemes that make use of seasonal storage), which for many schemes is of the order of 1 in 3 years to 1 in 5 years. After accounting for these factors, the present day hydrology indicates that the consumptive use of irrigated agriculture (including losses before field edge) in the catchment is **576 million m³/a**. About 100 million m³/a, or 17% of this consumption is supplied from groundwater, with the remainder supplied from surface water sources.

Detailed information is available in Report PH 00/00/1802 *Agricultural Water Demands*.

5.3 POTENTIAL FOR THE EXPANSION OF IRRIGATED AGRICULTURE

The potential for further irrigation development is closely linked to :

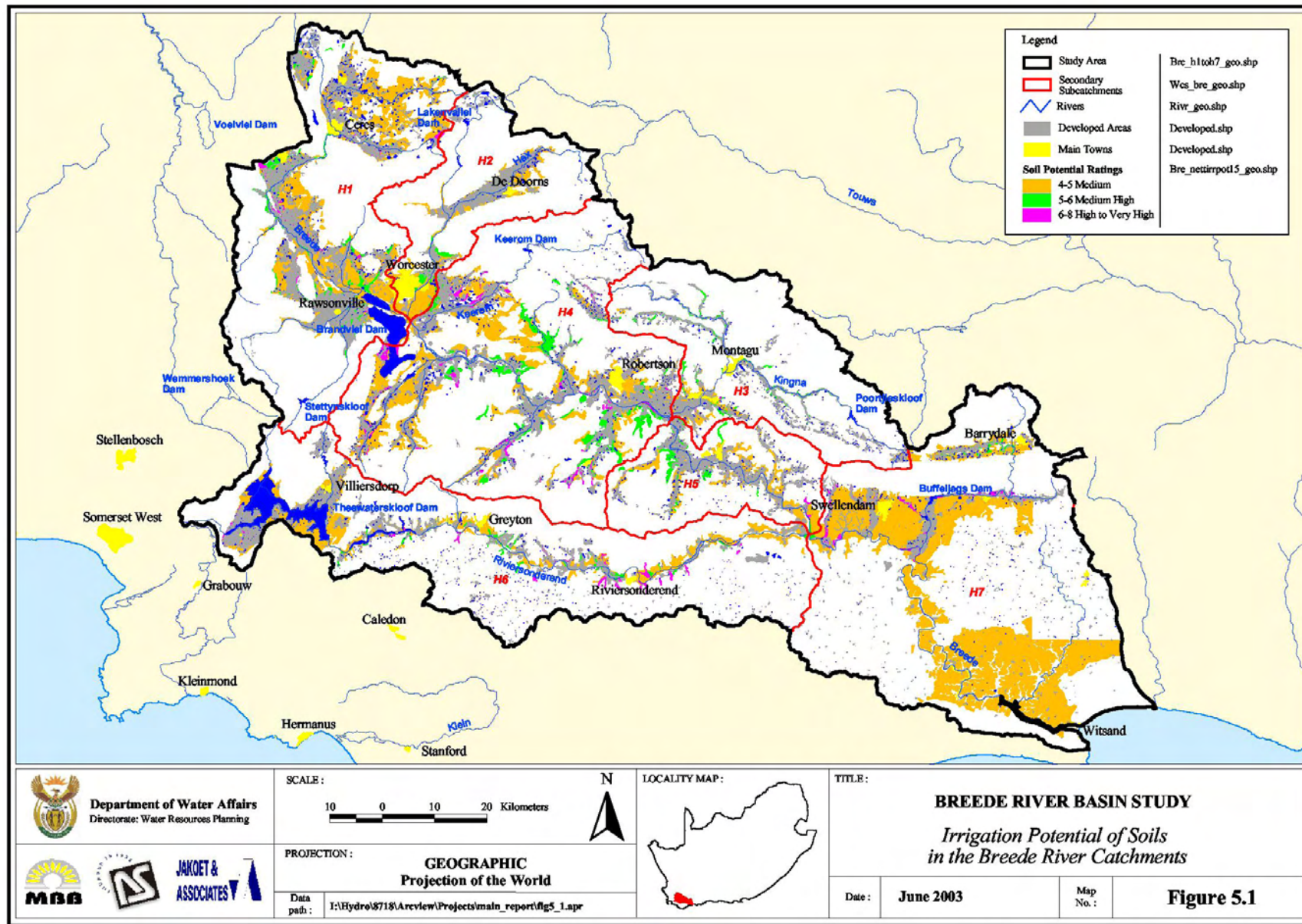
- the availability of undeveloped land with soils that are suitable for sustained irrigated agriculture;
- market conditions and the financial viability of irrigation farming;
- the availability of undeveloped water resources, and the cost of water supply schemes to harness these resources.

5.3.1 Availability of Land for Development

The study has identified some 172 000 hectares of undeveloped land (or land that is presently afforested or under dryland cultivation), that is suitable for irrigated agriculture. As can be seen from Figure 5.1, these areas are scattered throughout the catchment, with the largest extent in the Lower Breede region. At a catchment-wide average irrigation demand of about 833 mm/year, this represents a potential irrigation water requirement of about 1 430 million m³/a, which is much larger than the total remaining water resource potential. Due to the widespread occurrence of suitable soils, there is virtually no sub-region within the catchment where the availability of land, rather than the (economic) provision of water or market potential, limits the further development of irrigated agriculture.

5.3.2 Market Conditions and Financial Viability of Irrigation Farming

The decline in the financial situation of farming operations in the Western Cape from the 1996/1997 season to the 2000/2001 season has been reported widely in the national press. The reasons for the decline are varied, and include the decrease in international competitiveness due to the deregulation of the agricultural marketing system and the consequent proliferation of competing export agencies, slow adjustments to changing market preferences and optimum crop selection, and negative impacts on crop production and quality due to a series of dry, warm winters preceding 2000/01. This situation is reflected in the results of viability assessments of existing farming operations under the conditions of 2000/2001, with a number of existing (typical) farming operations appearing not to be financially viable, and the remainder providing only small to modest returns. These assessments included the replacement costs of land and infrastructure, and were based on average currency exchange rates applicable at that time. The situation in that year can be summarised as follows :



Irrigation farming in the **Riviersonderend, Robertson, Moordkuil, Ashton, Bonnievale** and **Buffeljags** areas was, in general, moderately viable, and escaped the worst effects of the downturn in the fortunes of the sector. Compared to the other sub-regions in the catchment, this is ascribed to diversification and lower reliance on exports, coupled with relatively inexpensive water supplies and lower overheads. Typical farming operations in the **Ceres catchment, Koo Valley, Worcester/Nuy, Montagu, the Hex River Valley, and Villiersdorp** areas appeared not to be financially viable, due to high levels of overhead costs relative to farm income, irrigation water shortages (Koo Valley), the high price of irrigation water (Ceres/Koekedouw), and the production of crop varieties that had fallen from favour.

The viability assessments commenced at the beginning of 2001, and export produce price levels were based on an average exchange rate of about R7,60 / US \$. In the subsequent export season, 2001/2002, the average rate was about R10,30 / US \$, an increase of about 35%. It is estimated that the reduction in the value of the Rand led to increases in gross profit (about 10 - 15%, depending on product), despite associated increases in the price levels of imported inputs. Consequently, the export oriented concerns in the **Hex River Valley** and **Villiersdorp** regions were probably also profitable operations in that year. However, the subsequent strengthening of the Rand will have again reduced the profitability of export-oriented concerns.

Even with small to modest returns such as were experienced in 2000/2001, farms on most of the existing schemes can be expected to continue to function, because in most cases much of the capital investment has been paid off. In some instances, insolvent concerns have been sold at well below replacement cost, resulting in reduced capital investment for the new owner, thereby allowing for a viable concern.

Future opportunities for growth may arise out of favourable trade agreements with the European Union and the Southern African Development Community, and, to a lesser extent, by diversification into citrus, plums, olives, nuts, vegetables and other crops.

5.3.3 Availability and Cost of Water

As the remaining areas with irrigation potential and low cost infrastructure are progressively developed, the opportunities for the development of affordable water supplies (from an agricultural point of view) will become less and less, up to the point where the cost of water will be too high for it to be used economically for additional irrigation. Under these circumstances, further water resource developments may still be affordable for urban use, both locally and in the form of transfers to the Berg Water Management Area.

Financial viability assessments were carried out for the establishment of a number of new irrigation schemes, and also through extensions of existing schemes, the more likely route of agricultural development.

In the Upper Breede River Valley/Goudini/Rawsonville and Robertson/Ashton/Bonnievale producer areas, future irrigation development is likely to take the form of expansion of existing farming operations. Under these circumstances, it was found that the cost of water could be as high as R2,00/m³ without adversely affecting profitability.

In the Swellendam and Buffeljags region there is, as is shown on Figure 5.1, a vast area of potentially irrigable soil, while existing irrigation areas are relatively small. If a major scheme were to be established here, it would entail the development of new farms. Under current economic conditions, profitability becomes marginal at a tariff substantially lower than can be borne by established farms. The situation is even more problematic in the Witsand region where there are no irrigated areas of substantial size.

The Study has furthermore shown that the financial viability of irrigation development throughout the various producer areas in the catchment is extremely sensitive to changes in export produce price levels. Irrigation developments aimed at local markets, such as the dairy farms in the Buffeljags region, are sheltered from these fluctuations and have remained profitable.

5.3.4 The Scope for Affordable Agricultural Water Resource Developments

A first indication of the scope for financially viable agricultural water resource developments can be provided by the combined yield of potential water resource developments that are apparently affordable for the development of new irrigation or for the expansion of existing irrigation schemes. (Some of these water resource development possibilities are described in more detail in Section 8.)

Table 5.2 lists the most viable developments, two or more in number in each of the most favourable regions. Costs are at year 2000 price levels, and produce prices are as in alternative years 2000 and 2002. Capital costs are discounted at 17,5% per year. The cost of water delivered to the farms averages R1,10/m³. The maximum cost of water, which occurs in the economically favourable Rawsonville region, is R2,05/m³. At year 2000 produce prices, only six of the thirteen developments have real Internal Rates of Return (IRR) exceeding 7,5% per year. This number increases to nine at year 2002 prices, and IRRs increase by a factor of about 1,5. The total quantity of water required by the six highly favourable schemes (in 2002), is 99 million m³/a.

It is important to understand that this development potential assumes that markets will be available for the produce from these developments. To put this statement into perspective, it is worth noting that Study estimates have placed the immediate additional market potential for deciduous fruit and citrus produce in the catchment at around 2 400 hectares, equating to a water need of only about 19 million m³/a. To this should be added a substantial, but unquantified potential for irrigated dairy farming and wine grapes. The uncertainties attached to the former hinge around health regulations (there is a large potential market for unpasteurised milk), while the prospects of the wine industry will depend almost entirely on its ability to adapt to the changing needs of the global market.

While the schemes listed in Table 5.2 account for the major part of remaining exploitable water resources in some areas, the list is by no means exhaustive. For the purposes of the study it is provisionally assumed that new irrigation demand could be as high as 140 million m³/a. This figure could increase somewhat in the event of an upswing in market conditions.

TABLE 5.2 : POTENTIAL FOR THE DEVELOPMENT OF AGRICULTURAL WATER RESOURCES

PRODUCER AREA	WATER SOURCE	DEVELOPMENT TYPE	COST OF WATER (R/m ³)	IRR (%)		WATER DEMAND (million m ³ /a)
				2000	2002	
Riviersonderend	Reenen Weir	Expansion	0,27	12,3%	19,9%	1,5
Riviersonderend	Kwartel River	Expansion	0,32	12,1%	19,7%	12,0
Breede, Goudini, Rawsonville	Raising of Stettynskloof Dam	Expansion	1,03	9,5%	12,8%	15,0
Breede, Goudini, Rawsonville	Worcester Irrigation Scheme ¹	Expansion	1,40	Not assessed	12,6%	44,2
Breede, Goudini, Rawsonville	Lower Wit River Dam	Expansion	1,55	Not assessed	12,4%	23,4
Breede, Goudini, Rawsonville	Tierstel Dam	Expansion	2,05	8,0%	11,2%	3,3
Hex River Valley	Osplaas	Expansion	1,53	4,5%	8,7%	2,3
Hex River Valley	Amandel River	Expansion	1,33	4,6%	8,7%	3,1
Swellendam	Raising of Buffeljags Dam	Expansion	1,42	Not assessed	8,5%	10,8
Suurbraak	Off-channel storage	New	0,84	4,2%	7,4%	2,5
Moordkuil, Robertson	Rooiberg Dam/Pump	New	1,16	3,8%	6,3%	5,6
Ceres catchment	Titus River	New	0,59	4,0%	6,0%	7,6
Ceres catchment	Groundwater wellfield	New	0,83	2,6%	4,5%	0,8

NOTES :

1. To avoid double counting, only one scheme that utilises supply potential of about 44 million m³/a that could be made available from Greater Brandvlei Dam (after supply to the dam has been augmented) is shown here.

5.4 FUTURE GROWTH OF IRRIGATED AGRICULTURE

The assessments of the financial viability of existing and future irrigated agriculture developments have highlighted the dramatic effects that changes in economic climate could have on agricultural prospects. Under these conditions, it could be argued that predictions of growth in the sector could at best be informed guesstimates. However, provided that the underlying assumptions are clearly understood, an informed long term view can allow decisions to be taken that will prevent the foreclosure of development routes, be these further development of irrigated agriculture (for resource poor farmers and/or commercial irrigation), the increase of transfers out of the catchment, or the conservation of water resources to benefit the natural environment and tourism.

To explore future possibilities for irrigated agriculture, a number of growth scenarios were developed. These scenarios may be compared with historical growth, which has averaged about 1,4% per year; peaking at 2% per year prior to 1980, and slowing to about 0.7% per year over the past decade. Water demand in all scenarios assumes that water conservation and demand management measures will lead to savings of about 1% per year of the demand levels associated with the expanding areas, sustained over the next seven years. Four scenarios were evaluated :

- **Maximum growth.** This foreseeable scenario is likely to depend on further improvement in export produce prices, restrained growth in import prices, improved marketing, and possibly governmental assistance to promote rural development and job creation. Water savings provide an inexpensive means of making water available for expansion. In the short to medium term, growth averages 1,8% per year, reducing to about 1,1% over the remainder of the planning period.

- **No growth.** This scenario unfolds under unfavourable conditions (from an agricultural perspective), which include deteriorating market conditions and restrictive financial circumstances, and lead to a situation where it is impossible for the agricultural sector to expand. The response of the industry includes a shift from perennial crops to cash crops and irrigated pastures. The result, including the effect of water demand management, is for water demand to fall over a period of seven years from 594 million m³/a in 2003 to 567 million m³/a.
- **Limited growth.** This scenario assumes that a number of current uncertainties will negatively impact the rate of expansion of irrigated agriculture, and that as a result annual growth in irrigated area is limited to a meagre 0,5% per year in all areas. In this case the additional water needed for irrigation would reach only 70 million m³/a.
- **Balanced growth.** This scenario represents perhaps a realistically optimistic estimate of future growth, given the current state of the agricultural sector. While the development of this scenario is subject to a fair amount of subjectivity, it is nevertheless grounded in the identification of growth opportunities in areas with a combination of good soil potential, relatively plentiful water, and affordable resource development options. In the growth areas, irrigation expansion occurs at a moderate rate of 1,0% per year. In this scenario, the 140 million m³/a growth in water requirements as suggested above, would be reached in 2025.

The results of the scenario development are shown in Figure 5.2 below.

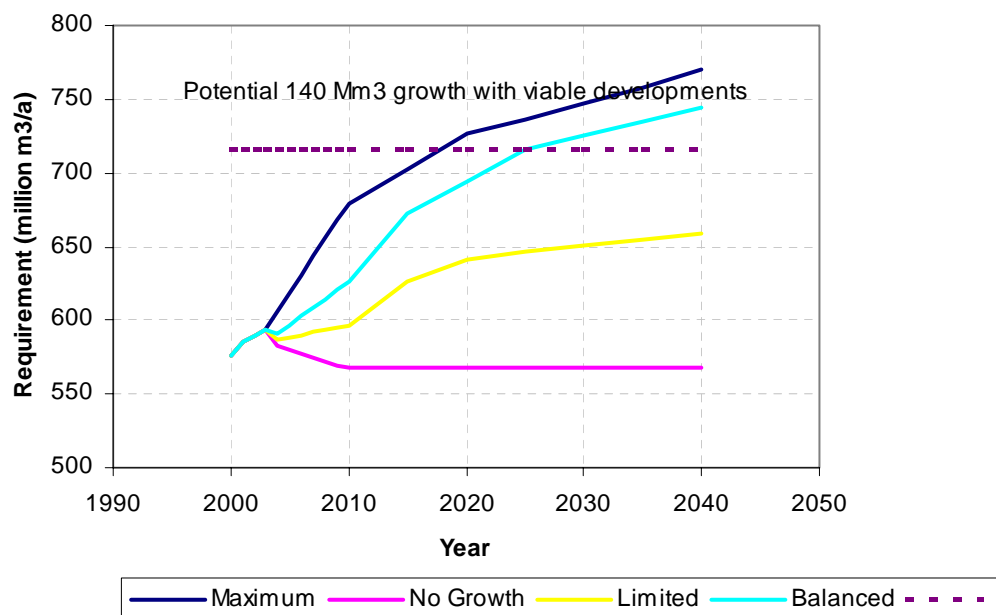


Figure 5.2 : Agricultural water demand growth scenarios

5.5 POTENTIAL FOR EMERGING FARMER DEVELOPMENT

5.5.1 The Present Situation

In the Breede River catchment, opportunities abound to address poverty through agricultural water use and related activities. Already, many disadvantaged people derive their livelihood through employment on the commercial farms and there is some measure of own production in and around the villages and townships in the Breede River catchment. However, there are presently few examples of historically disadvantaged people emerging from their current situation into dramatically or even incrementally improved livelihoods based on agricultural water use or related business opportunities. (It is recognised that there is a need to investigate the socio-economic situation in the study area in more detail, but field investigations in this regard fall outside the ambit of the Study.)

A large number of emerging farmer (recently termed "resource poor farmer") developments in the Breede River catchment have been registered with the Department of Land Affairs. Of these developments, 15 projects have been completed by March 2002, benefiting in excess of 1000 participants on some 2 200 hectares, and a further 29 projects benefiting 1 700 participants on 1 900 hectares are in the process of implementation. The information on the projects is not complete, and the total area and number of beneficiaries could be somewhat more than stated here.

5.5.2 Mainstreaming the Marginalised through Agricultural Water Use in the Breede Catchment

The October 2001 draft of the joint agricultural water use policy commissioned by the Co-ordinating Committee on Small-scale Irrigation Support (CCSIS) promotes a dual objective to combat poverty and set historically marginalised people on a growth path through agricultural water use initiatives.

This dual objective is :

- improved food security through own production ('food first'), and
- mainstreaming historically disadvantaged farmers in the local, national and international economy through active support for business and market development.

A narrow focus on the 'water requirements for emerging irrigation farmers' will not result in the development of strong and independent black and coloured farming enterprises. Any serious effort to mainstream the marginalised through the use of agricultural water in the Breede River, will have to start with the envisioning of a shared desired future by the people of the Breede River who are serious about actively building a new future in the valley. This vision will need to consider and recognise the following realities and the challenges facing the realisation of such a new future:

- *Inherent profitability and sustainability of agriculture in South Africa today:* The 'Strategy for Agriculture in South Africa', jointly developed by the Department of Agriculture, Agri-SA and the National African Farmers' Union, was released in November 2001. This strategy highlights several factors that currently affect the ability of farmers to be productive and profitable on a sustainable basis. In the context of the Breede River catchment, the capital intensive nature of irrigation farming presents difficulties related to:
 - The cost of suitable land
 - The high preparation and establishment costs of perennial crops
 - The high cost of new water source developments.

These constraints need to feature realistically in a vision of the future.

- *Strata of needs and opportunities:* Household food security, farming and agri-business aspirations of the people of the Breede River all need to be reflected in a shared vision. The development of full-blown commercial farming systems is important, but on its own it is unlikely to address the spectrum of aspirations and possibilities. All these views should be respected and incorporated in planning for the future.
- *Start big, fall hard:* Development principles derived from empirical evidence stress the need to start development at a level that people are comfortable with and to grow from there. Today's commercial farmers had the good fortune to grow into the enterprises they manage today, often building up the skills over several successive generations. Similarly, the mainstreaming of the marginalised would need to be a deliberate, step-by-step process that maximises opportunities for entry, yet constantly guards against over-exposing new entrants, particularly in their first few years.
- *Lack of knowledge of and experience with the development of successful small-scale farming systems:* Knowledge on commercial farming systems abounds in the Breede River Valley, with many examples from which to derive current, albeit dynamic, determinants of success and failure. The same depth of knowledge is not available on small-scale farming systems, since these had not emerged in the former South African policy context, which was explicitly geared towards medium and large-scale commercial farming development. The use of family labour and manual techniques typical of low-input sustainable agriculture found elsewhere in the world is often socially unacceptable to South Africans who compare such activities to the more common, but risky high capital intensive practices. Thus, South Africa is facing a serious challenge to develop homegrown farming systems suited to the deliberate development of a spectrum of new farmers and agri-businesses.
- *Support needs:* South Africa's commercial farming sector has enjoyed substantial support from government over many decades and its productive capacity demonstrates the success of this policy. It would be unreasonable to expect new entrants to achieve similar success without substantial support.

Planning and implementation of new initiatives need to take place in the institutional context of the day. Institutions governing land, water and a variety of services relevant to the agricultural sector need to work together to enable integrated and sustainable development.

National policy targets the newly demarcated Municipal Districts as the point of delivery for government services. In most parts of the country, provincial departments have been required to restructure their district offices according to the new demarcations and to collaborate closely with local government in these Districts. National departments' budgets are now justified insofar as they support service delivery in the Districts. The Integrated Rural Development Programme (IRDP) in the Deputy-President's office is aimed at coordinating envelopes of expenditure to integrate rural development efforts, starting in priority poverty-stricken Districts. While the Breede River Valley does not fall within one of the first thirteen priority nodes targeted by the IRDP, the direction of the institutional framework is clear.

Several sources of financial support are available to new farmers, including the following government-funded schemes :

- Department of Water Affairs and Forestry: Subsidies of up to R10 000 per hectare to Water User Associations (WUAs) on schemes for previously disadvantaged farmers.
- National and Provincial Departments of Agriculture: Grants of up to R10 000 per individual for on-farm and off-farm infrastructure, and an Irrigation Improvement Scheme with subsidies of up to R7 500 per individual.
- Department of Land Affairs: Grants of between R20 000 and R100 000 per individual.
- Department of Public Works: Funding of infrastructure delivery projects and start-up grants of up to 10% of total project cost.
- Department of Health: Grants for community gardening to increase household food security.
- Land Bank: Incremental low interest rate loan schemes for emerging farmers.

There is a clear need for coordination between departments and institutions to plan and support new farmer development. In the Western Cape, the planning and development of irrigation developments is coordinated through the Irrigation Action Committee, which is chaired by the provincial Department of Agriculture. The Department of Water Affairs and Forestry is an original member of this committee, with increasing participation by the Department of Land Affairs. Local government is not as yet part of this planning forum.

It is further suggested that there is a need for a programme to inspire, educate and train new entrants. An implementing agent (perhaps a NGO) would be required to drive such a programme, to assist new farmers, and to facilitate access to available support.

The study has indicated that future irrigation development in the Breede River catchment would in most cases be through the expansion of existing farming concerns, which is more likely to be economically viable than the establishment of new farms. In spite of the prevailing poor

economic conditions in the sector, there is still a demand for expansion, as evidenced by the number of water use licence applications received by the DWAF Regional Office. This situation could be used to create opportunities for the establishment of resource poor farmers by encouraging the formation of joint partnerships between such emerging farmers and existing commercial farmers where new irrigation developments are undertaken. This could be achieved through the implementation of a licensing strategy that would limit (or at least favour) the issuing of new licenses for irrigation water use to such joint partnerships. Such an approach would provide established commercial farmers with a vested interest in the successful establishment of new entrants, and provide incentives for knowledge and skills transfer. Depending on the targets that could be set for such a strategy, and assuming that the "Limited" irrigation growth scenario materialises, it is conservatively estimated that this could result in an increase in resource poor farmer developments from about 4 100 ha (with a water requirement of about 30 million m³/a) at present, to about 7 000 ha (requiring about 60 million m³/a) by 2020.

An alternative to the above approach would be to reserve most, if not all, of existing water surpluses for the establishment of resource poor farmers. In this scenario, which could be time-limited, the bulk of the financial, technical and training support will have to be provided by the government, rather than the commercial irrigation sector. Depending on the extent of the support that could be made available, this approach could benefit a larger number of resource poor farmers within a shorter time frame than the previous scenario, but can be expected to be more expensive per developed ha, as it would require the establishment of new farms from scratch.

6. WATER CONSERVATION AND DEMAND MANAGEMENT (WCDM)

6.1 GENERAL

It is probably safe to say that in the study area there have been to date very few attempts made by water management institutions or water service providers to implement demand management or demand-side management. Measures to balance supply and demand have been focussed on supply-side solutions, and in particular on development of new water resources. Water conservation measures in times of drought or scarcity are however not a rarity. The Central Breede River Water User Association for instance, manages water supply from Greater Brandvlei Dam, and whenever it seems as if supply is going to fall short of annual allocations, stringent water conservation measures are implemented.

Against this background the potential for WCDM in the study area was considered, together with more conventional supply-side solutions, to balance future demand and supply in the Breede River catchment.

Year 2000 water use from the Breede River catchment amounted to 869 million m³/a. This can be broken down as shown in Figure 6.1 below:

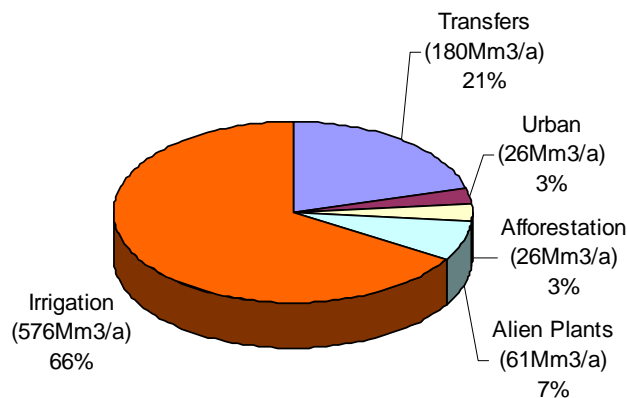


Figure 6.1 : Consumptive water use

6.2 AGRICULTURAL WCDM

The largest component of water use is agricultural, consisting almost entirely of irrigation. Within this component, there is varied scope for moderating water demands. Most of the existing water distribution infrastructure supplying the major water user association (WUA) schemes in the study area is ageing rapidly, and significant savings could be achieved through upgrading and programmed maintenance. Improved management of saline return flows could also reduce the need for freshening releases and thus increase water availability.

In a study of a typical irrigation district in the Robertson area, undertaken between 1986 and 1988 for the Water Research Commission (MBB, 1988), the losses from the various components of a water supply scheme were quantified. Data from this study has been used as a "case study" to evaluate the scope for WCDM in typical irrigation schemes in the study area.

From the study of the Robertson Canal mentioned above, typical losses have been quantified as percentages of inflows to Greater Brandvlei Dam:

- Evaporation and seepage losses from Greater Brandvlei Dam = 15 %
- Transportation losses from the Breede River = 25 %
- Canal transportation losses = 24 %

Therefore it is estimated that of the water diverted into the dam only 36 % actually reaches the farm boundary. Taking into account that the research was done some 15 years ago, and with the near exponential increase in riparian invasive alien infestation, the present day river transportation losses can be expected to be even higher than 25 %. The losses indicated above, do not include any allowance for losses relating to poor management of the system (matching irrigation water releases with abstraction requirements). In reality, the potential for water savings in the distribution system is significantly less than these figures suggest. This is due to the fact that a substantial portion of these "losses" is (inadvertently) reused in the form of downstream abstractions of return flows, and reduction of crop water requirements in irrigated areas located in the seepage path between canals and the river.

On farm water demand management measures such as the implementation of soil moisture monitoring used in conjunction with drip and microjetTM irrigation systems are already extensively utilised throughout the area. Extension of their use and the application of more advanced computer based scheduling, risk management and administrative models, recently developed by the Water Research Commission, could lead to further savings.

It should be noted that in most typical situations investigated as part of the agricultural financial viability assessments, the current cost of agricultural water amounts to something between 0,5 % and 10,0 % of the total turnover of a farm. Therefore with the current cost structures there is little incentive for a farmer to save water from a cost point of view. The expansion of existing farms as a means of driving much needed economic growth and increased on-farm turnover will however serve as a significant incentive for the more efficient use of water in the agricultural sector.

The following practical measures are recommended for the effective implementation of agricultural WCDM in the study area:

- (a) The suitability to local conditions of flow measuring devices developed for Water Research Commission projects should be tested at pilot sites in the Breede River catchment.
- (b) Real-time monitoring systems should be installed at selected points on the Breede River, the Riviersonderend River, and on the major canal systems and pumping schemes to improve the efficiency of water releases from dams.
- (c) Water user databases maintained by Water User Associations (WUAs) must be modified to include information necessary for the successful implementation of WCDM measures.
- (d) The Department of Water Affairs and Forestry should promote the concept of managing irrigation water supply schemes on the basis of compulsory weekly demand projections, based on reliable soil moisture and crop water demand data.
- (e) The yields of virtually all the existing irrigation water supply schemes in the catchment are fully committed, and water users should be encouraged to "create" water for new developments and for expansion of existing operations by implementing WCDM measures on existing farms.
- (f) A workshop should be arranged to decide on, and to adopt, a set of benchmarks and benchmark values for efficient water use on irrigated crops. Such a workshop should include all role players in irrigated agriculture in the Breede WMA. Thereafter, DWAF should review the basis of allocations on the assumption that irrigation would be using efficient technology. It may be possible to take into account situations where farms lie on percolation paths between canals and rivers.
- (g) The planned pilot study for the testing of the Department of Water Affairs and Forestry's WCDM Implementation Guidelines in the Breede WMA should be undertaken as a matter of urgency in order to gain a quantitative picture of the scope for WCDM in the area.

6.3 URBAN WCDM

Significant opportunities exist for WCDM in the urban areas. While the potential volumetric savings of urban water use are small in relation to total water use in the catchment, the importance of establishing a WCDM culture in the catchment cannot be over-emphasised. According to national estimates provided in the draft WCDM Strategy for the Water Services Sector, potential savings of about 40% of existing consumption can be realised in urban areas through the implementation of water demand management measures. It has proved to be near impossible to gauge the performance of towns in the Breede River catchment against this yardstick, primarily due to an almost entire lack of loss measurement data. This very fact indicates that effective water demand management measures are not in place, and that significant water savings can still be achieved.

Measures such as steeply rising stepped tariffs and informative billing, have been shown to be highly successful in Hermanus, achieving a reduction in demand of between 16% and 25%. In the Breede River catchment itself, the towns of Ceres, Worcester, Greyton and Riviersonderend have implemented stepped tariff structures. Wolseley and Genadendal have flat fixed charges for water use, while the remaining towns charge a flat rate per kilolitre consumed. Figure 6.2 shows current per capita consumption rates for the towns in the catchment. The towns of Worcester, Robertson, McGregor, Villiersdorp and Swellendam still maintain the quaint but wasteful "leiwater" system, the water supply of which is included in the total usage of the town.

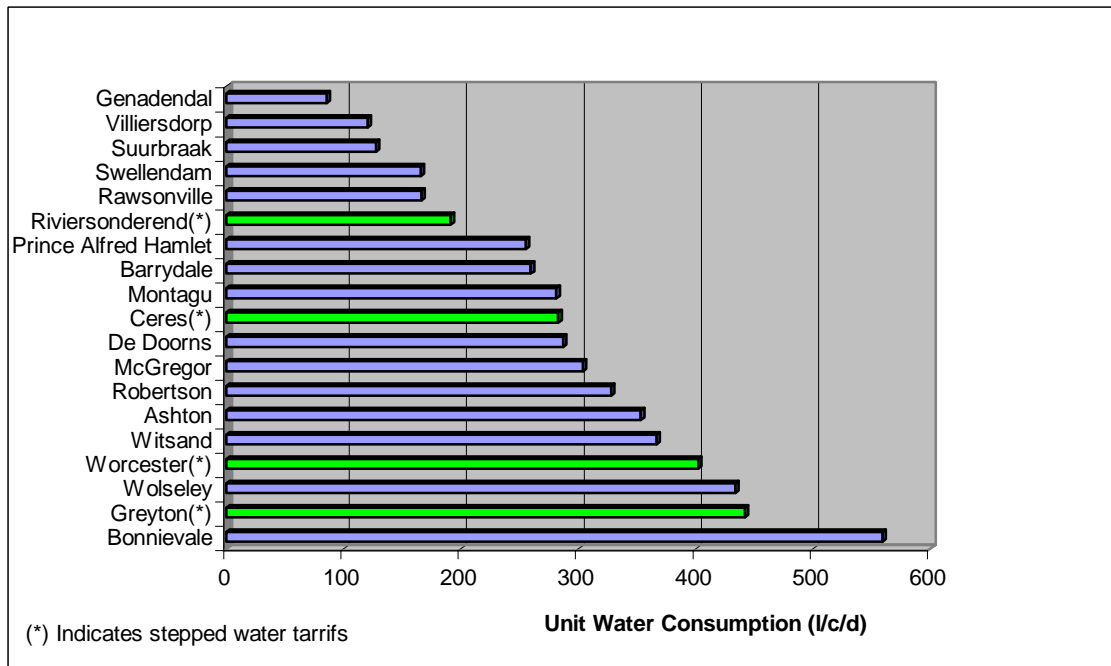


Figure 6.2 : Unit water consumption

A case study of the degree to which the town of Robertson complies with the objectives and goals of the draft strategy seems to indicate that the most important issues regarding the successful implementation of WCDM in towns in the Study Area are the successful education of water services officials and councillors on the need for, and importance of the implementation of WCDM measures, and of the funding of such measures.

The following measures, to be initiated and monitored by Provincial Government, are recommended for the promotion of WCDM in urban areas:

- (a) Bulk water meters should, as a matter of urgency, be installed on all urban water supply schemes from which supplies are not currently measured. Meters should also be installed to record water consumption at zone level, and volumes recorded meticulously.
- (b) Procedures for the comparison of bulk metered consumption and the totals of individual water meters, should be instituted to quantify "unaccounted for water" and system losses.

- (c) Municipalities should be encouraged to implement structured water tariff systems that will promote the efficient use of water. This should be supplemented by informative billing to empower water users to improve their own water use efficiencies.
- (d) A training program should be instituted to improve the level of awareness amongst water services officials and managers of the need for, and benefits of WCDM. This should be undertaken as a matter of urgency.
- (e) Municipalities should be required to record and report on the per capita and per household water consumption in the water use zones in their respective service areas. This will provide a measure of progress made with the implementation of WCDM, and will also assist in the identification of areas that should receive priority attention.

6.4 INVASIVE ALIEN PLANTS

An estimated 45 000 hectares (equivalent area at 100% density) of the Breede River catchment land area has been invaded by alien plant species. The riparian zones of the Riviersonderend and Upper Breede catchments are the most affected by invader species. Hydrological investigations have shown that water use by these plants (over and above the quantity that would have been consumed by natural veld), amount to as much as 61 million m³/a, or 3% of the total surface water runoff in the catchment. The severity of the problem is illustrated by Study estimates indicating that, should the spread of alien plants be allowed to go unchecked, the invaded areas could triple in size by 2020, and cover about 220 000 hectares by 2040 (Figures 6.3 and 6.4). The rate of reduction in river flow would initially accelerate, followed by a discernable tapering off as low flows become progressively more depleted.

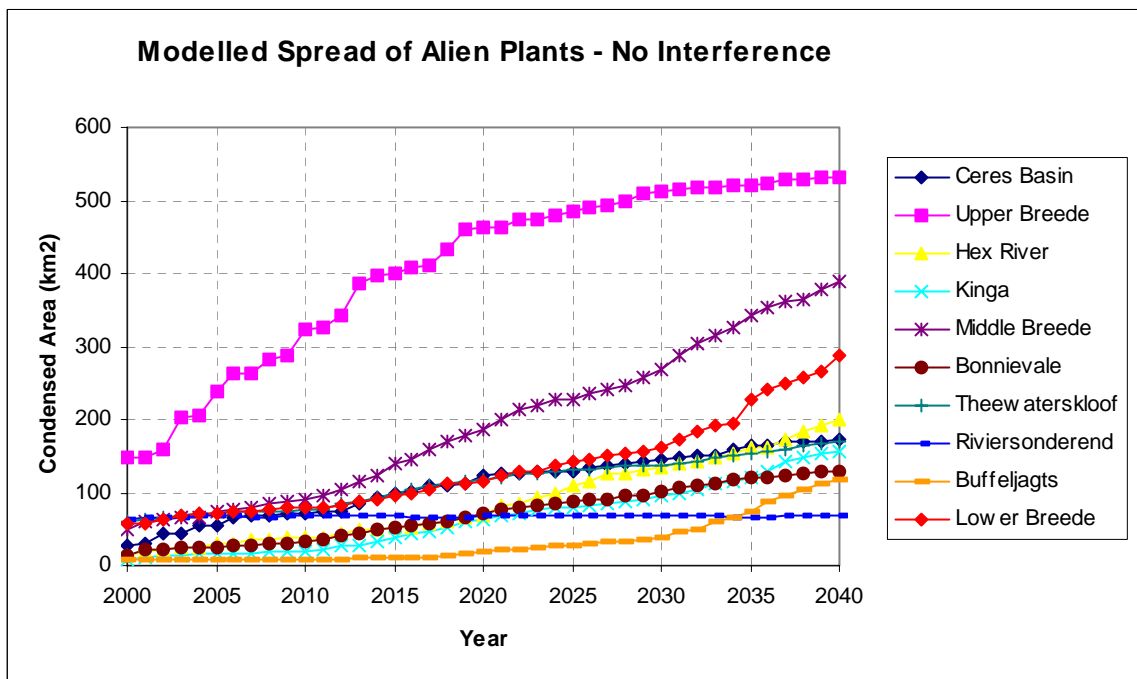


Figure 6.3 : Projected spread of alien plants in sub-regions – "no interference"

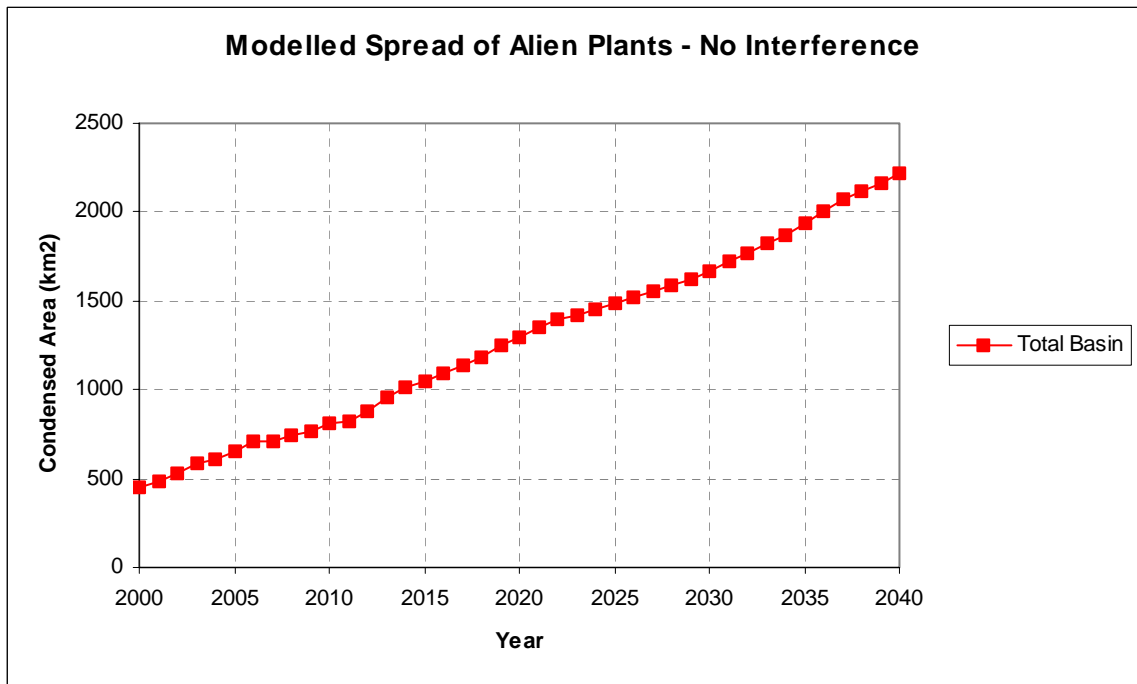


Figure 6.4 : Projected spread of alien plants in the catchment – "no interference"

A review of studies carried out in the Riviersonderend catchment shows that the removal of alien plants would provide additional water at a considerably lower cost than the same quantity provided by constructing dams. Cost estimates of clearing operations are of the order of 10% to 20% of the costs of new infrastructure that would be required to make the same quantities of water available. Other significant benefits, which are difficult to quantify in economic terms include:

- Conservation of endemic plant biodiversity and associated tourism spinoffs.
- Reduction in fire hazard which impacts on catchment stability, erosion and siltation.
- Socio-economic benefits deriving from employment opportunities created by the clearing operations, and by secondary industries that utilise the timber that is removed.
- Restoration of low flows required for the maintenance of riverine ecology.

Significant opportunities to move clearing operations onto a self-sustaining basis exist through the utilisation of cleared vegetation. Recent estimates by paper and charcoal manufacturers (Cape Argus, 30 July 2003) indicate that cleared vegetation could fetch between R5 and R10 per ton.

Elimination or reduction of this water use represents by far the most beneficial means of unlocking water resources for the benefit of the environment and future consumptive water needs in the catchment. DWAF water resource managers (and the future CMA) should liaise with Working for Water managers to identify areas that would be most beneficial (in water and timber) and establish a programme for clearing. This should increase the flows in rivers where the need is greatest and at least stabilise the extent of infestation elsewhere.

7. WATER AVAILABILITY

7.1 SURFACE WATER RESOURCES

7.1.1 Hydrology

The records of most river flow measurement stations in the Breede River catchment are too short to be used for reliable estimates of runoff and scheme yields. The hydrological component of the Study was designed to extend these records by means of monthly Pitman rainfall/runoff modelling. Flow records were naturalised to provide basic flow sequences applicable to undeveloped conditions, which could then be adjusted to represent present day (Year 2000) or anticipated future conditions. Representative rainfall records were generated to produce long-term naturalised and present day flow sequences of about 67 years in length.

The river systems in the Breede River catchment were the subject of a number of hydrological investigations prior to commencement of the Breede River Basin Study. The most comprehensive of these was the Breede River Hydrological Study (BRHS) that was carried out by the Department of Water Affairs and Forestry, and completed in 1995 (DWAF, 1995). The BRHS investigation spanned the upper and middle parts of the Breede River catchment comprised of hydrological catchments H1 to H5. Long term naturalised and present day flow sequences were generated at points where river flow measurements were available, and also at a number of points of interest. These flow sequences spanned hydrological years 1925 to 1990.

During the Inception Phase of the Breede River Basin Study, the BRHS hydrology was reviewed to determine whether, (a) the hydrological data which has become available in the intervening years to September 1999 should be used to extend the previous hydrology, and (b) whether it was necessary to revisit the previous hydrological calibrations.

For this purpose, the BRHS hydrology in two pilot catchments (the Ceres catchment and the catchment of the Molenaars River) was extended to hydrological year 1998. A comparison of the extended and original sequences indicated that the critical drought was also contained in the original shorter sequence, and that the wide range of historical firm yields derived from the two sequences was of the same order. Based on these findings, it was decided not to extend the original hydrology.

An inspection of the original calibration results indicated significant discrepancies between measured and simulated low flows at the calibration points. The differences were ascribed to limitations in the software that was used for the BRHS calibrations. As the discrepancies could have significant implications for the water quality assessments that were to be carried out for the Middle Breede River reaches, and also for the yield and viability assessments of development options, it was recommended that the hydrological calibrations for the H1 secondary catchment be revisited. Low flows in the H4 secondary catchment are dominated by irrigation return flows and flows entering the upstream end of the catchment, and re-calibration of the original hydrology in H4, and by implication, H5 was therefore not considered necessary.

The compilation of a complete hydrology for the Breede River catchment can be summarised as follows:

- The BRHS hydrology for secondary catchment H1, to the nearest downstream flow gauging station at H4H017 (Le Chasseur), was recalibrated, but not extended;
- DWAF hydrology (DWAF, 1997), previously updated by Ninham Shand (Ninham Shand, 1999) for the Hex River catchments (secondary catchment H2), was adopted as is;
- BRHS hydrology for secondary catchments H3 and H4 was adopted as is;
- New hydrological models were developed for the Riviersonderend catchment (H6), and the Lower Breede (H7).

A detailed description of the compilation of the hydrological models is provided in Report PH 00/00/2402 *Hydrology*.

On average, about 27% of the rainfall in the Breede River catchment appears as runoff in the rivers. The naturalised mean annual runoff (MAR) in the catchment is estimated to be about 1 803 million m³/a. Approximately 46% of the runoff is generated in the catchments upstream of Greater Brandvlei Dam, which cover only about 16% of the total land area of the catchment. About 43% of the total MAR is currently consumed (excluding groundwater use of about 100 million m³/a), leaving about 1 033 million m³/a flowing into the estuary. By comparing the monthly flow distributions of the naturalised and present day inflow sequences to the Breede River Estuary (Figure 7.1), it can be seen that developments in the upstream catchments have reduced winter low flows substantially, and high flows to a lesser extent. The large reductions in winter are linked to the storage in large units such as Theewaterskloof and Greater Brandvlei Dams, as well as to the filling of numerous farm dams that have been drawn down in summer.

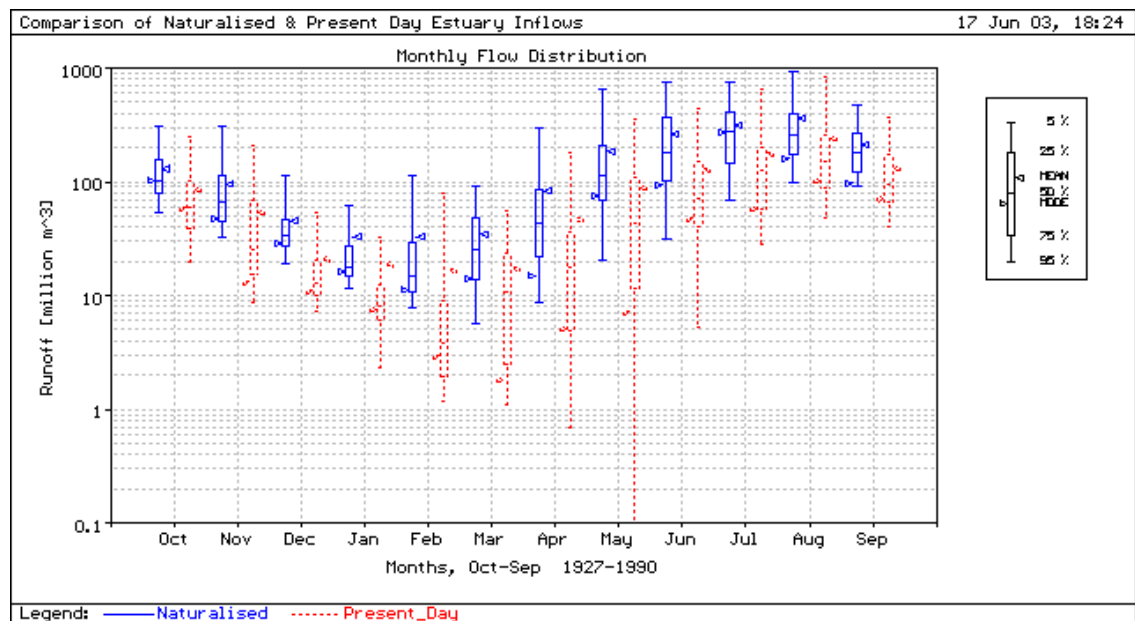


Figure 7.1 : Comparison of naturalised and present day estuary inflows

Summer low and high flows have also been reduced substantially, to the extent that some of the tributaries in the catchment have changed from perennial to non-perennial rivers. These reductions are mainly due to run-of-river abstractions for direct irrigation, and to some extent, re-filling of smaller farm dams during summer when freshettes permit.

The flow gauging stations that were used for hydrological model calibration, and the calibration sub-catchments, are shown on Figure 7.2 overleaf. Mean annual runoff contributions of the various sub-systems to river flow in the Breede River main stream are shown for naturalised and present day (Year 2000) conditions on Figures 7.3 and 7.4, respectively.

The existing network of flow gauging stations in the study area was generally found to provide data of good quality. Where minor problems were encountered, these were documented in Report PH 00/00/2402 *Hydrology*. The spatial distribution of the stations provided adequate coverage for the level of assessments that were undertaken for the Study.

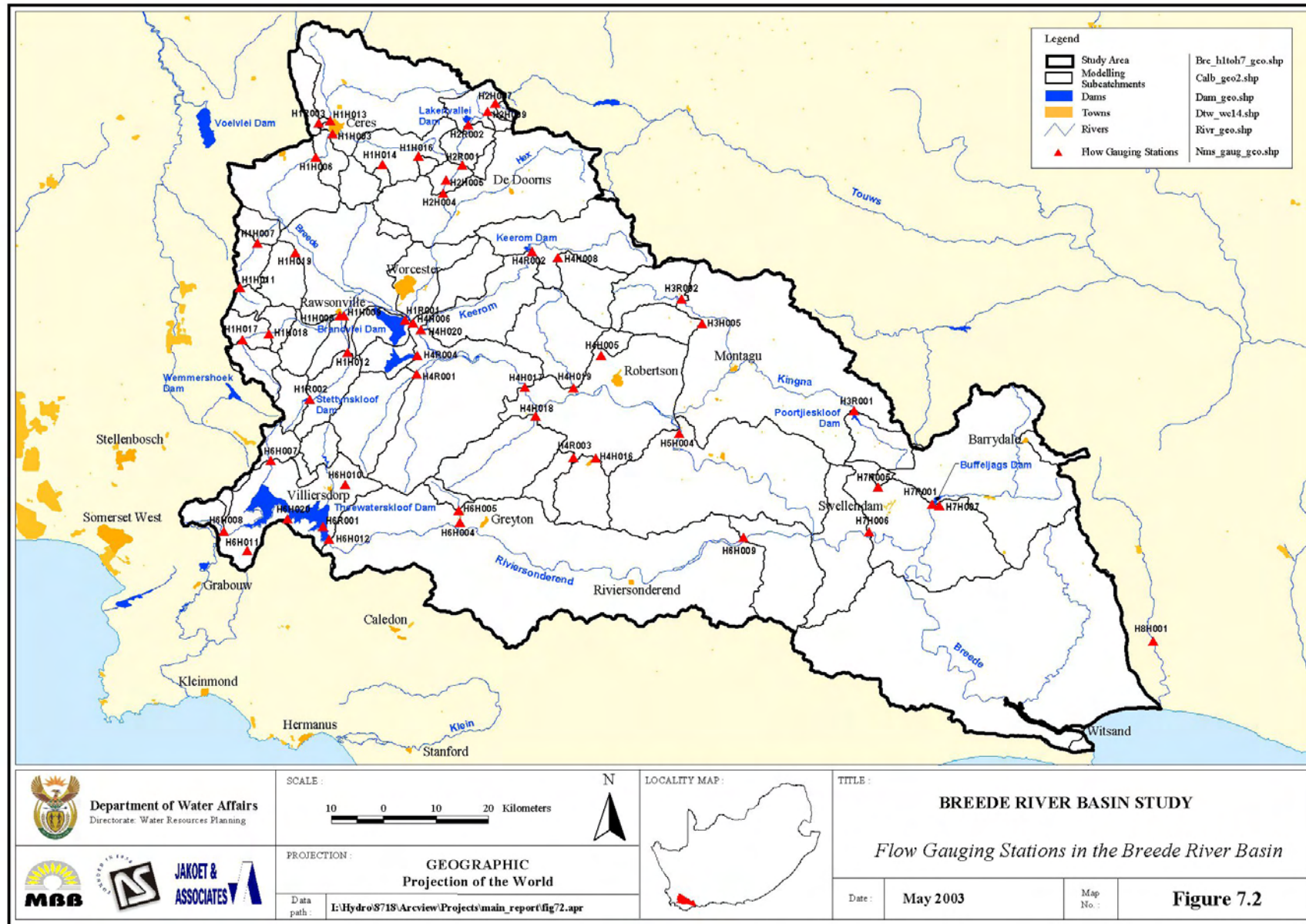
7.1.2 Water Quality

In the past, the general water quality in the Breede River catchment was not considered to be a major concern, except for the rising salinity in the Middle Breede River and its tributaries. The occurrence of algal blooms under low flow conditions at certain locations within the Middle Breede River, clogging of canals by filamentous algae and aquatic weed, and point pollution from, in particular, distilleries, cheese factories, and textile factories have however been identified as additional problems.

The concerns mentioned above result from nutrient enrichment of the river through the addition of nitrogen and phosphorus present in domestic and industrial effluent and in diffuse sources such as urban runoff and drainage from land on which fertilizer has been applied.

A basin-wide trend analysis of inorganic nitrogen and phosphorus has shown that the main stem of the Breede River is moderately enriched during the summer low flow period, i.e. nitrogen and phosphorus loads are high enough to sustain nuisance growth of aquatic plants and blooms of free-floating algae.

In the lower reaches of the Hex River nitrogen levels are sufficiently high to lead to eutrophic conditions where algal blooms may interfere with domestic water supply and with livestock and wildlife watering. Phosphorus levels are also sufficiently high to lead to highly enriched conditions (eutrophic conditions) in the lower reaches of the Nuy, Poesjenels, Kogmanskloof, Riviersonderend and the Huis/Buffeljags Rivers.



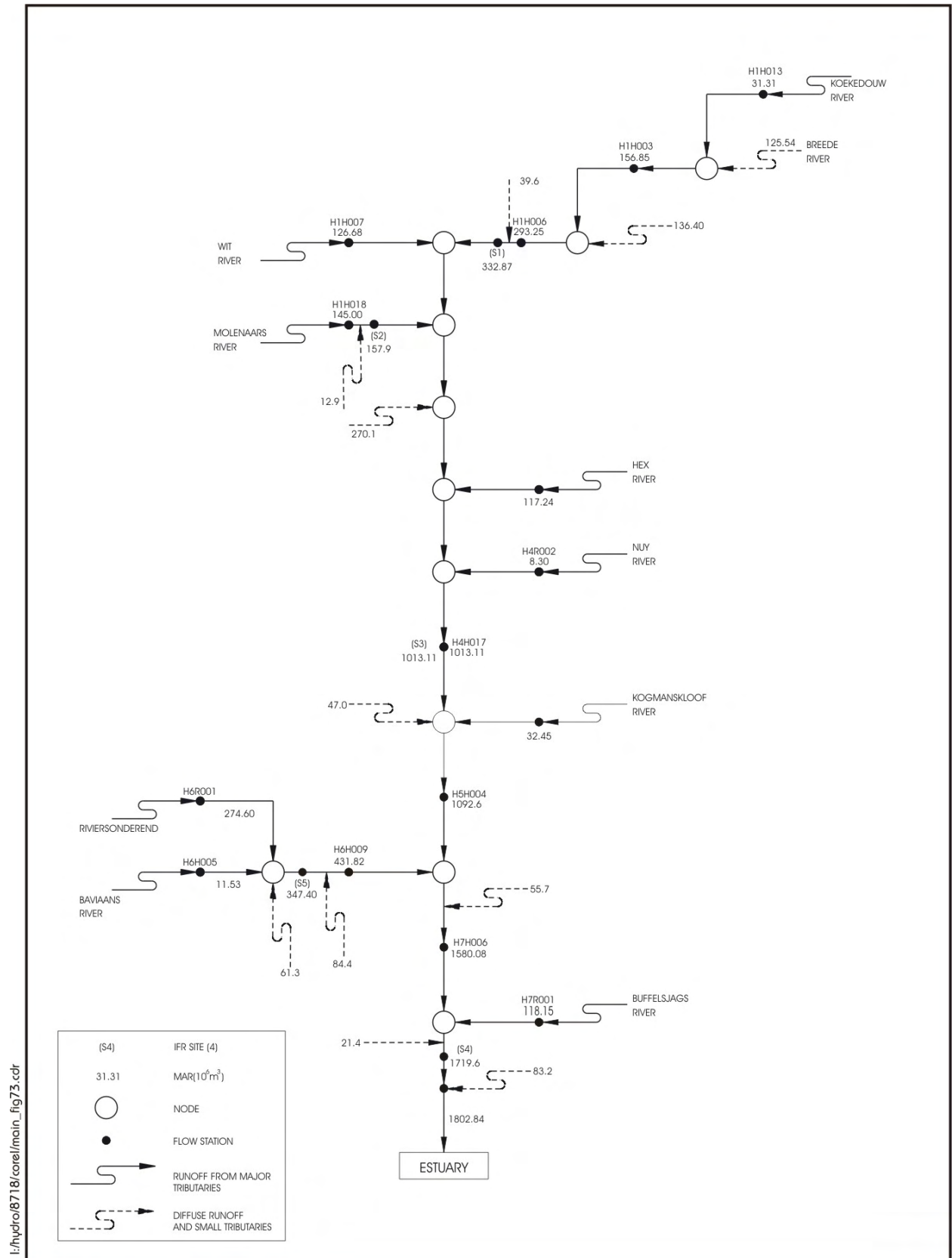
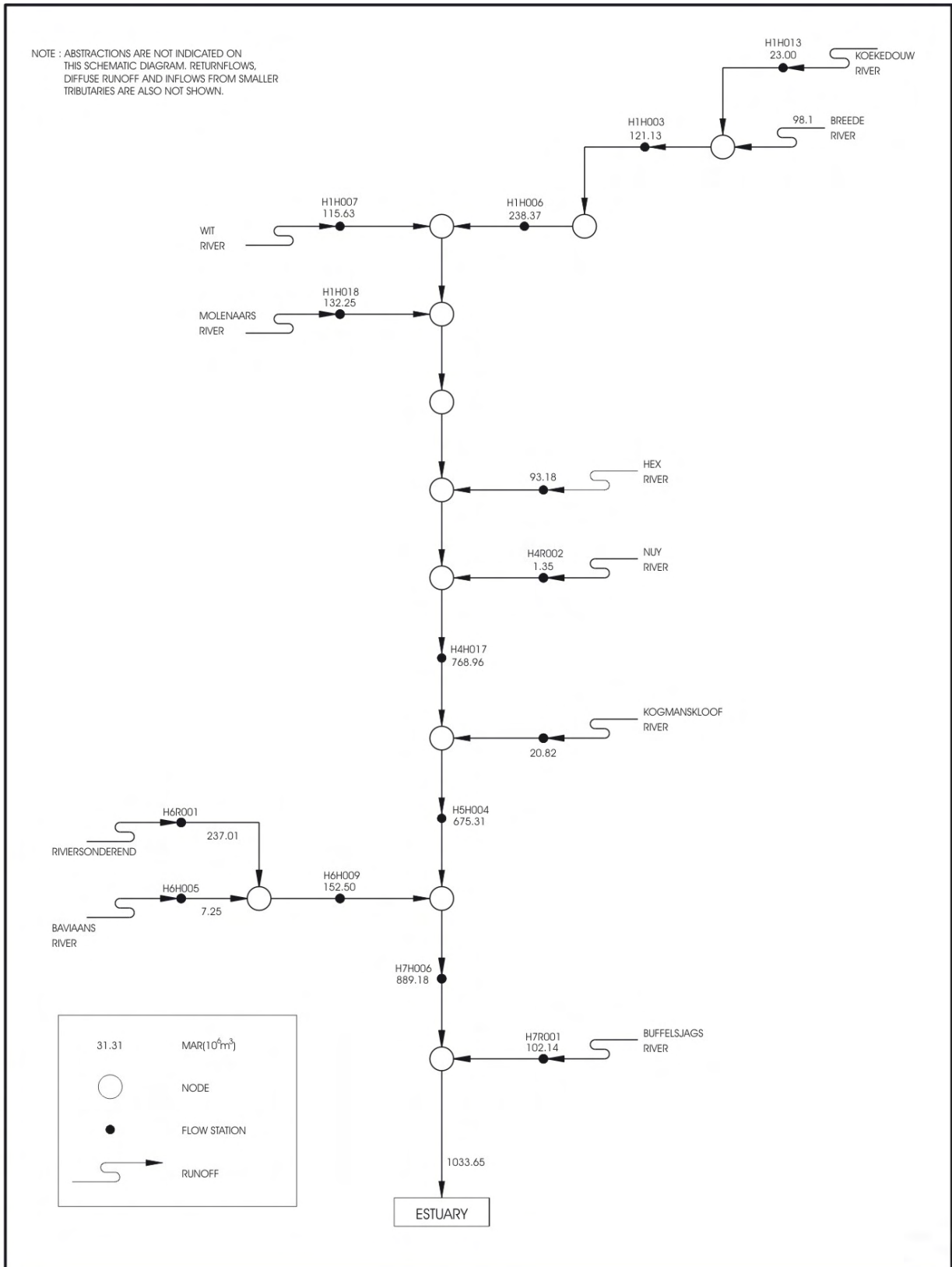


Figure 7.3 : Schematic representation of naturalised flows in the Brede River



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Figure 7.4 : Schematic representation of present day (2000) flows in the Breede River (1927 - 1990)

Increases in nitrogen and phosphorus levels above those that could be expected under unimpacted conditions are ascribed to increased farming activities which result in elevated nutrient concentrations in the irrigation return flows. It is concluded that management strategies for the application of fertilisers should be implemented to ensure that as little nitrogen and phosphorus as possible reaches the rivers in the return flows.

Very little information on the occurrence of algal blooms in the catchment exists, and a reporting system for water bailiffs should be initiated to quantify the extent of these occurrences.

The water quality monitoring points that were used for the trend analyses, are shown on Figure 7.6 overleaf.

Trend analysis has once again highlighted environmental and irrigation concerns about rising salinity levels (mainly sodium and chloride) in the Middle and Lower Breede River.

Downstream of Greater Brandvlei Dam, the Breede River valley is underlain by shales of marine origin. This results in highly saline return flows from irrigation and canal seepage. These return flows cause the progressive deterioration of water quality in a downstream direction. In the lower Riviersonderend valley irrigation on shales is at present too limited to create sufficient return flows to have any significant effect on water quality. Consequently the Riviersonderend is able to dilute the salinity in the Lower Breede River. Figure 7.5 shows the spatial distribution and magnitude of total dissolved salts as measured at water quality monitoring points.

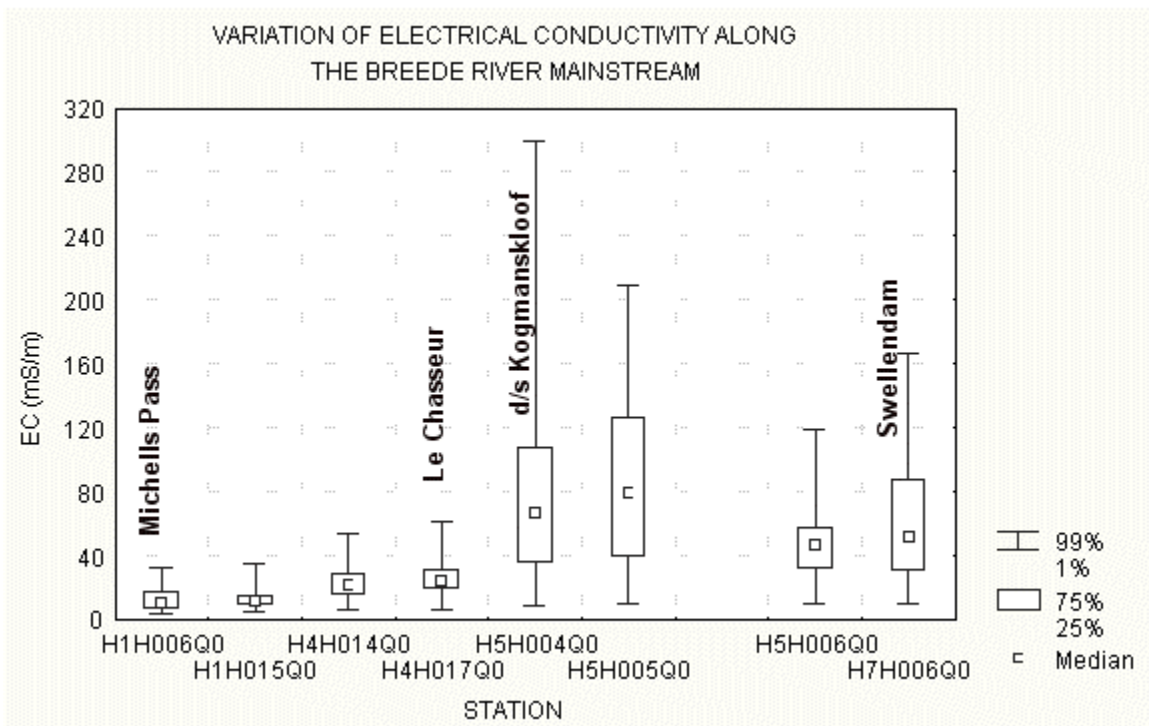
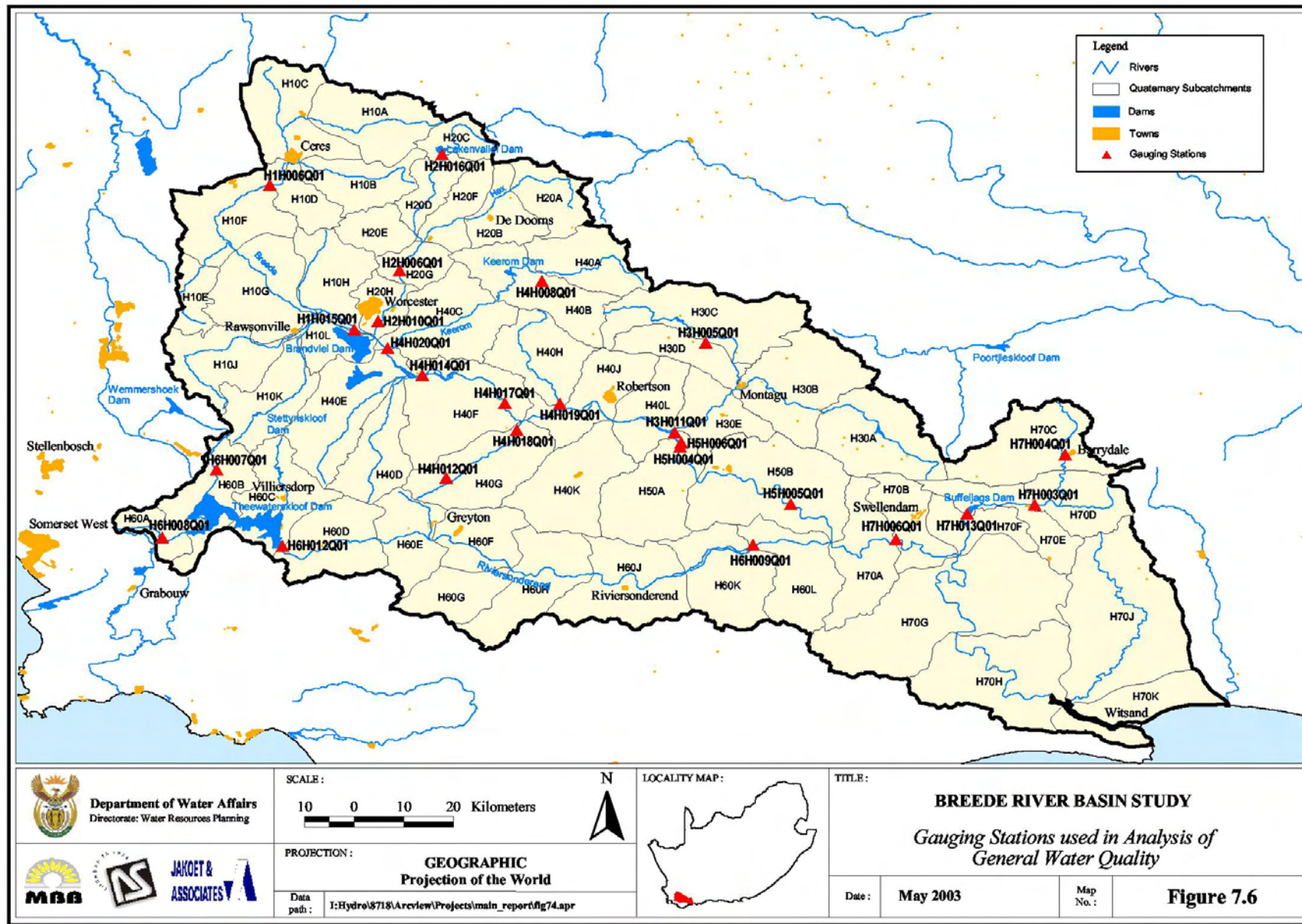


Figure 7.5 : Spatial variation of electrical conductivity along the Breede River



From Robertson onwards, freshening releases are necessary to maintain acceptable water quality for irrigation. Beyond Bonnievale, downstream until the confluence with the Riviersonderend River, the water is generally unsuitable for irrigation.

Salinity levels in the Middle Breede River are currently controlled by providing sufficient freshening releases from Greater Brandvlei Dam to ensure that the salinity level at the Zanddrift canal intake, directly upstream of the confluence of the Breede and Kogmanskloof Rivers, does not result in electrical conductivity readings exceeding 70 mS/m for at least 50% of the volume of irrigation water supplied during the irrigation season. For the remaining 50% of the volume supplied, electrical conductivity is allowed to fluctuate between 70 and 120 mS/m. While this system has proved highly effective, freshening releases totalling some 20 million m³ are required on average each year as dilution to meet the salinity targets. It has been estimated (DWAF, 1988) that the freshening requirement could rise to as much as 46 million m³/a if the potential irrigation in the Middle Breede River is fully developed. It would therefore be preferable for expansion to take place in areas such as the Upper Breede, where the soil is less saline, or where return flows would not be detrimental to other users, i.e. near the Estuary. From a water conservation perspective, salinity alleviation by means of freshening releases only is not considered to be a long-term solution.

Farmers who obtain water from the Zanddrift canal have expressed concern about the use of electrical conductivity (EC) as the only measure of salinity for operating the system. They believe that the constituents that make up the electrical conductivity (chlorides in particular) should be investigated more thoroughly. According to them the crucial periods for their produce are during September, March and April. These are the months when the crops are particularly sensitive to elevated chloride levels and a lower Target Salinity Limit should possibly be introduced for these months.

Several measures to improve water quality were investigated, and are described further in Section 8.6.

7.2 GROUNDWATER RESOURCES

The objectives of the groundwater component of the Study have been to assess the significance and distribution of groundwater resources in the Breede River catchment, to estimate the amount of abstraction and degree of stress it may be causing, and to indicate the scope for further development of groundwater resources. This was achieved by a review of all available literature and obtaining yields and quantities from all significant groundwater schemes. The characterisation of important aquifers and the assessment of the groundwater balance (recharge versus consumption) allowed for identification of further groundwater potential.

The geohydrology of the Breede River catchment is controlled by the occurrence of the rocks of the Table Mountain Group (which form the mountainous areas), the occurrence of high levels of faulting and folding in the syntaxis area of the upper catchments and the variable rainfall, being highest in the mountainous areas in the west. These factors result in a catchment with highest

groundwater potential in the west, where recharge, yields and abstraction potential are greatest and the quality is the best. As a result of these factors, the western half of the catchment is also the area with the greatest groundwater use.

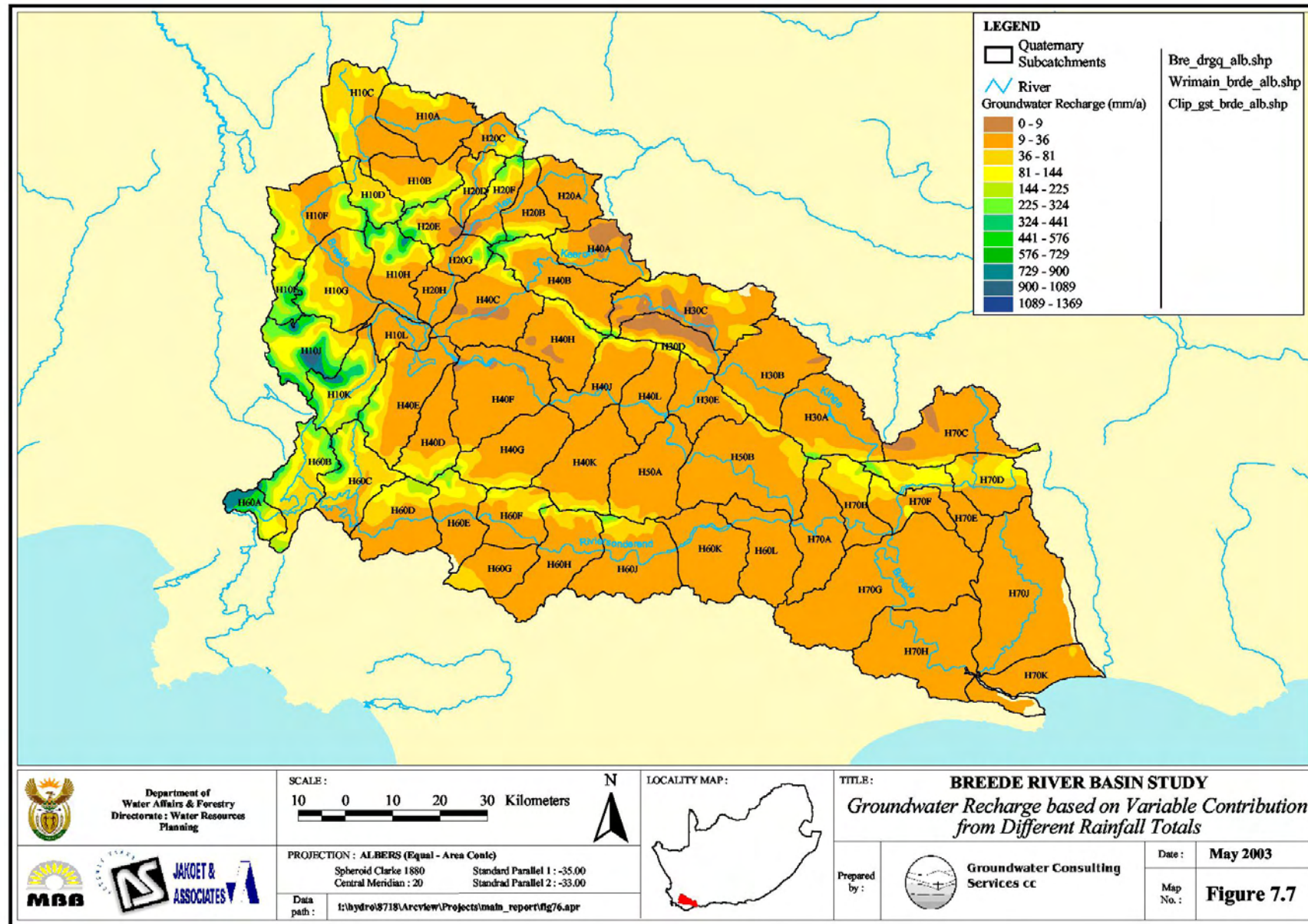
Total groundwater use in the catchment is about 100 million m³/a, far less than the annual recharge for the catchment of 640 million m³/a. The majority of this recharge (75%) takes place in the western 29% of the catchment (Figure 7.7). A significant component of recharge that occurs in the mountains rapidly becomes baseflow that feeds streams and recharges the alluvial aquifers in the valley bottoms. Other recharge mechanisms include throughflow (or upflow) from the TMG to Malmesbury, Bokkeveld and alluvial aquifers and direct precipitation.

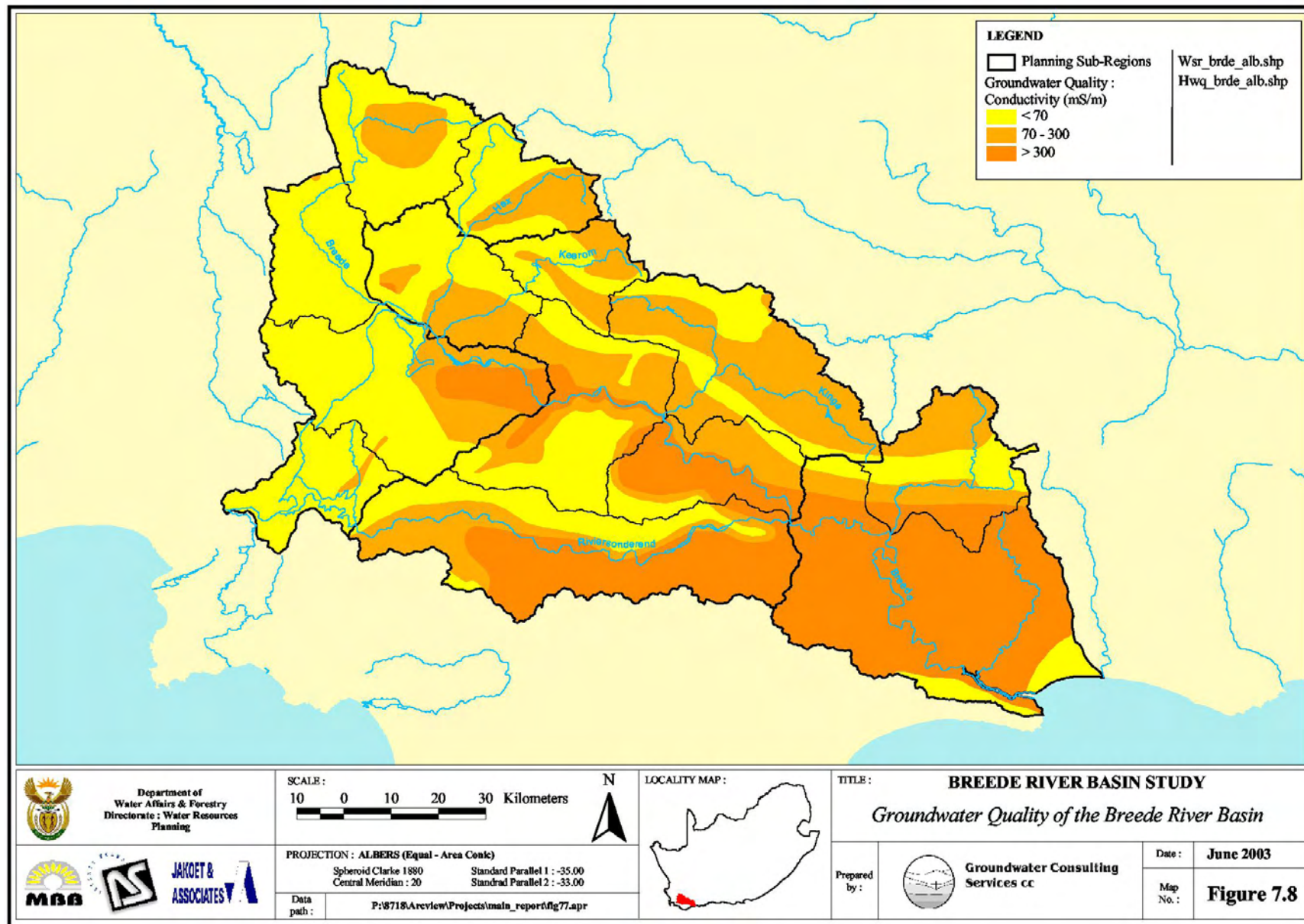
Fractured and confined to semi-confined aquifers occur within the consolidated rocks of the Breede catchment. In these aquifers, the groundwater is usually under pressure and artesian conditions may be present where the piezometric surface is above ground level. Other important aquifers found in the catchment are unconsolidated sand deposits that make up the alluvial aquifers. Groundwater levels in the alluvial aquifers are close to surface and yields of from 10 – 15 ℓ/s are common from shallow (<30m) boreholes supplying irrigation schemes in the valleys.

The fractured aquifers are less extensively used in the Upper Breede catchments because of difficulty in accessing drilling sites on the rugged terrain. Boreholes in these aquifers are usually deeper than those drilled in the alluvium. The groundwater quality in all aquifers in the upper Breede is generally excellent (<70 mS/m). As one moves down the catchment, the quality deteriorates, particularly in poorly transmissive rocks such as the Bokkeveld and Karoo (Figure 7.8). A way to increase the groundwater production in irrigation areas is to mix marginal quality groundwater with less saline surface water. There is limited information of chemical indicators other than EC but it is expected that the alluvial aquifers may have elevated concentrations of nitrate as a result of fertilisation and irrigation of vineyards that are mostly situated on alluvium in the valleys.

Groundwater is not considered to contribute significantly to the salinisation of the water in the Middle Breede River. A review of the literature on salinisation in the Middle Breede Catchment concludes that groundwater contributes as little as 1% - 2% of the salt load to the river.

Assessment of the land under irrigation and average water requirements per crop provide an estimate of the total water demand for irrigated agriculture in the Breede Catchment. The percentage of irrigation supplies made up by groundwater is estimated at 32% in the Upper Breede Catchment. Irrigation use of groundwater in the Middle Breede Catchment is around 18 million m³/a. Groundwater consumption in the Lower Breede is predominantly domestic and stock watering and is estimated to comprise approximately 4 million m³/a.





The groundwater contribution to river flow or baseflow in selected sub-catchments was assessed using several hydrograph separation techniques. The results indicate that the baseflow in the Upper and Middle Breede River catchment is about 10%, using the linear interpolation method. Gauged river flow data give higher percentages for the groundwater component of river flow than synthetic naturalised sequences, possibly indicating the role of irrigation return flow in developed catchments (e.g. the Hex River) in the Upper Breede. This interrelated nature of surface and groundwater resources means that, on a catchment-wide scale, estimates of surface water development potential represent the major part of total catchment resources. In view of the scarcity of good surface water storage sites, the use of deep groundwater bodies to provide seasonal storage could very well add to this potential, but very little is known about the impacts that this may have at a wider, regional scale.

Due to the generally poor transmissivity of aquifers in the Breede catchment, conventional groundwater schemes are not able to deliver the volumes of water typical of regional surface water schemes. For example, a 64 borehole wellfield on the eastern side of the Rawsonville alluvial aquifer is estimated to be able to deliver only about 5 million m³/a. The unit cost of water is estimated at R1,16 / m³, delivered to Greater Brandvlei Dam during the winter months. However, future in-basin water resource developments are likely to take place incrementally, in the form of schemes supplying individual municipalities or groups of farms. At this scale, groundwater developments are viable, and in some areas, preferable alternatives to surface water developments. Aquifers that could be exploited for irrigation in various regions of the Breede catchment are indicated in Report PH 00/00/2502 *Groundwater Assessment*.

The City of Cape Town (CCT) is currently investigating the possibility of extracting water from deep boreholes in aquifers of the TMG. One such area is to the south-west of Theewaterskloof Dam. The CCT estimates indicate that 15 million m³/a could be abstracted from 10 deep boreholes in this area and pumped into Theewaterskloof Dam when storage capacity is available in the dam. It is not yet known what the effects of these wellfields (if developed) would be on surface water yields.

7.3 WATER RESOURCES DEVELOPMENT POTENTIAL

The future use of the water resources of the Breede River will require trade-offs between development and conservation with, as a point of departure, conservation receiving preference. Estimates of the yields available from new developments after provision of ecological water requirements (EWRs) have shown that previous assessments of water resources development potential in the Breede catchment will probably have to be downscaled dramatically. Reserve requirements have become the critical aspect in terms of water availability, and will greatly affect the further availability of water from the Breede River.

In terms of total system yield, it was found that the EWRs of the lower reaches of the Breede River would limit the catchment-wide amount of surplus water that would be available for further abstraction and use during the dry summer months, while the requirements of the Estuary limit the quantities of water that are available for storage during some of the high runoff winter

months. Unlike many other developed coastal systems, the EWRs of the Lower Breede River and its Estuary are of the same order of magnitude. Selection of a lower ecological Reserve category for one of these two components would therefore not significantly increase the yield potential of the system.

The recommended flow requirements for the Lower Breede River are aimed at improving the present condition of the River (a Category "C" river) to a Category "B/C", while the recommended estuarine requirements are aimed at maintaining its "B" category present status.

The Ecological Reserve determinations that were carried out for the BRBS provide site-specific recommendations of EWRs. These recommendations will form the departure point for the setting of a preliminary Reserve. Before a comprehensive determination of the Reserve can be set, a separate stakeholder consultation process must take place.

In order to inform this process, the effects that potential adjustments to the recommended EWRs may have on the future availability of water were investigated. The consequences of deviating from the recommended environmental management categories were also investigated. It may, for instance, be possible to "unlock" significant yield potential by reducing the ecological Reserve category at one or two system-critical sites. Similarly, it may be possible to upgrade recommended ecological Reserve categories in certain conservation-worthy subsystems without adversely affecting system yield. These are the type of scenarios to be analysed when decisions are finally made on the quantities of water available for water use licences.

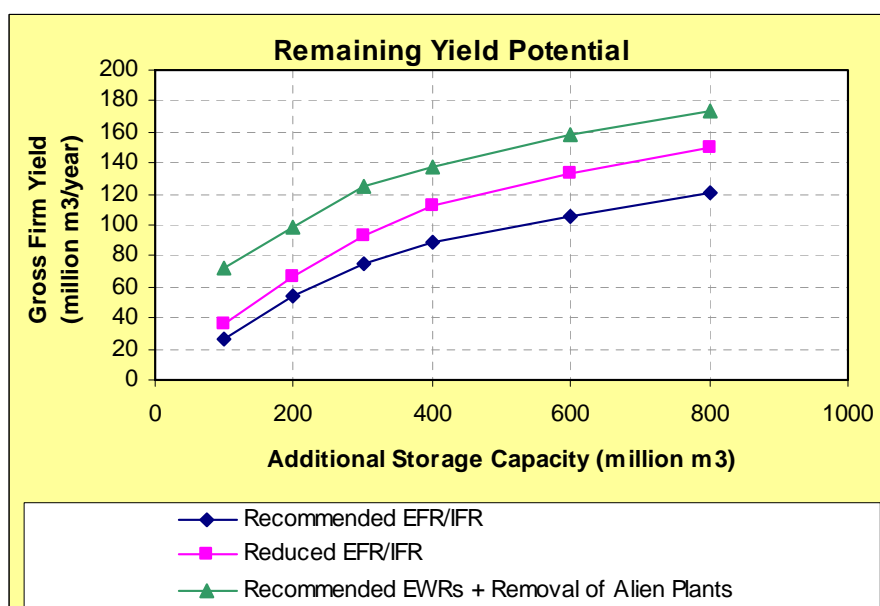


Figure 7.9 : Remaining yield potential

The effect of selecting a lower Reserve category (a "C" Category) for both the Lower Breede River and the Estuary on the yield potential of the system was investigated, and is illustrated in Figure 7.9. It must be noted that the Breede River Estuary is rated as a 'highly important' estuary due to its size, habitat diversity, and biodiversity and functioning importance on a national scale. This rating implies that selection of a lower category would represent a significant departure from

a desirable estuarine condition. However, it is believed that a more realistic scenario, making specific provision for flows to the Estuary required at critical times, could substantially reduce the EWR while still maintaining the present condition of the Estuary. It is imperative that a further scenario for the determination of the Estuary EWR be investigated prior to the stakeholder consultation process.

Figure 7.9 also illustrates the dramatic effect that current levels of alien invasive vegetation have on available system yield. Should the (admittedly distant) goal of eradicating all invasive plants in the catchment be achieved, an additional yield of some 50 million m³/a could be made available for further allocations to the environment, or for consumptive use.

The extent to which the potential yields shown in Figure 7.9 could be realised, depends largely on the availability of economical and environmentally acceptable dam sites. These sites need not be situated in main river channels, and could be located off-channel, as is the case with Greater Brandvlei Dam, and numerous farm dams throughout the catchment. The Breede River catchment is characterised by its steep tributary rivers, which flow into the broad, relatively flat topography of the main river valley. Significant undeveloped, economical dam sites are therefore few and far between.

To provide an indication of the maximum development potential in the catchment, an estimate can be made of storage capacities, which may be developed in future. These dams may be of different sizes to those that are discussed in Section 8 below, and are not necessarily economic, or attractive options for implementation at present, but could be considered in the event of improvements in future economic conditions and changes in demand patterns:

- In the Upper Breede catchments, significant storage capacity is available in Michell's Pass (30 million m³), the Lower Wit River (90 million m³), and in a raised Stettynskloof Dam (a further 35 million m³); totalling 155 million m³.
- In the Middle Breede, the existing unused capacity in Greater Brandvlei Dam can be utilised (130 million m³). Significant storage capacity is available at the Le Chasseur site, but the storages in the Upper Breede, combined with the spare capacity in Greater Brandvlei Dam would develop the major portion of remaining system yield in the Upper Breede (taking the recommended EWRs into account). While it is technically possible to raise Greater Brandvlei Dam, the recommended EWRs would limit diversions into the dam.
- In the Lower Breede, a large dam at the Bromberg site (100 million m³) would develop the remaining yield potential of the Rivieronderend River. The existing Buffeljags Dam in the Buffeljags River is sited at a point where the mean annual runoff is about 100 million m³/a. The existing dam has a capacity of only 5,7 million m³, and could be raised to provide an additional 19 million m³ of storage. While a larger dam could be constructed at this point, the aforementioned developments, and the estuarine flow requirements would cancel out any additional yield benefits. The Buffeljags Dam seems suitable for managing salinity levels in the estuary.

The dams listed above, represent a total storage capacity of about 400 million m³. In an effort to quantify the remaining water resources potential in the Breede catchment, it is assumed that it might be possible to provide between 300 and 400 million m³ of additional storage capacity in the catchment, depending on environmental concerns regarding dam construction. Assuming that the Minister eventually accepts the Reserve categories as recommended by the ecological scientists, this storage volume would increase the system yield by 75 million m³/a. If lower Reserve categories are adopted, the system yield could be increased by a further 20 million m³/a. Removal of most of the invasive alien plants in the catchment could recover about 45 million m³/a of "lost" yield. An optimistic maximum value of potential water supply remaining is therefore about 140 million m³/a. It is possible that a significant portion of this potential yield could be developed from groundwater sources in the Upper Breede and Hex River catchments.

This estimate of remaining water resources development is considered to represent a near maximum potential, and should be reduced to allow for reductions in dam capacities on account of environmental impacts, economic considerations and evaporative losses.

8. POSSIBLE FURTHER DEVELOPMENT OPPORTUNITIES

8.1 EVALUATION OF DEVELOPMENT OPTIONS

Only after the means to achieve optimum resource utilisation had been identified, can options for the further development of the water resources to meet future water requirements be explored. In this regard, it is firstly necessary to identify opportunities to address poverty and past inequities through the development of water and agricultural resources for resource poor farmers. This aspect was discussed in Section 5. Further development of the water resources of the Breede River catchments may in future be required for increased transfers to the Berg Water Management Area, and also to meet increasing urban and agricultural water requirements in the Breede River. This section presents a range of development options that could be utilised for these purposes and discusses the engineering costing and evaluation, and the potential environmental implications of these schemes.

Much of the risk in agricultural development projects arises from factors that cannot be assessed at the time of implementation. Obvious examples are the future prices of produce and resulting income. Schemes which can be adapted in the light of experience and changed conditions, and which can be expanded in phases if circumstances appear favourable, allow for management of these risks. In the Breede catchment, this would favour the development of "more and smaller" schemes such as some of the developments listed in Table 5.2, and other schemes considered in earlier investigations. Water user associations will have to raise their own loans for the development of new irrigation schemes, and in most instances, would not be in a position to raise the finances that would be required for the development of large schemes intended for exclusive use by irrigated agriculture.

Given these development parameters, the development of a conventional implementation plan describing the sequential implementation of a series of water resources developments (usually large), to meet future in-basin requirements, would be futile. The approach that was followed in the Study was therefore to identify favourable development options, and to compare these on their individual merits in order to make recommendations as to the options that should receive priority attention. However, the cumulative impact that increasing numbers of small schemes may have on the natural environment must continually be re-assessed. The Study provides some guidance to address this issue, by quantifying the extent to which water resources could be developed without impacting on minimum ecological flow requirements in the catchment.

A similar situation exists when assessing options for the transfer of water to the Berg Water Management Area. The investigations of these options provide an indication of the scope and cost of schemes to transfer water out of the Breede River catchment. However, the sequence and timing of implementation of any transfer schemes can only be determined through comparison with further development options in the Berg Water Management Area for meeting the water demand of the GCTMA.

A wide range of water supply options that were investigated in the past, as well as some new possibilities, were assessed at a reconnaissance level to identify the more favourable developments. The larger regional schemes (with yields in excess of 10 – 15 million m³/a) were evaluated from financial and technical, socio - economic and environmental perspectives. There are numerous smaller "local" water supply development possibilities with individual yields of generally less than 10 million m³/a. Assessments of these local schemes were limited to the preparation of cost estimates of a representative sample to provide input to financial viability assessments of irrigated agriculture, and comment on the potential accumulative environmental impact of the development of large numbers of the smaller schemes.

Following the broad-brush assessments carried out during the Preliminary Phase of the Study, the regional scheme configurations were progressively refined to arrive at near economical sizes, and to allow for the mitigation of environmental and/or social concerns where possible. In some instances, serious environmental or social concerns could not be adequately addressed through the re-configuration of the schemes, and influenced the ranking of the final list of development options.

The yields of the regional schemes were determined by utilising flows that are surplus to recommended ecological flow requirements as defined at the nearest downstream IFR site (or where applicable, the ecological flow requirements of the estuary), and surplus to existing yields. These yields and the corresponding unit reference values (URVs) of the schemes investigated are summarised in Appendix B.

In some instances, the sequential construction of two or more of these schemes would impact on the system yield in ways that were not taken into account in the individual assessments of the schemes.

8.2 SMALL DEVELOPMENTS FOR LOCAL WATER SUPPLY

As discussed in Section 8.1, it is anticipated that the future development of irrigated agriculture will take place in relatively small "affordable" increments. Water schemes associated with these new developments will typically consist of groundwater abstraction schemes or off-channel storage dams fed from adjacent rivers, and will rarely include dams in the main stem of the Breede River or its major tributaries. Some opportunities exist to increase the capacities of existing infrastructure.

Assessments of local schemes were aimed at providing input to financial viability assessments of irrigated agriculture (Section 5.2), and were limited to the preparation of cost estimates of a representative sample to provide estimates of the cost of new agricultural water supplies in each of 13 producer areas in the catchment. These schemes are discussed in Report PH 00/00/1802 *Agricultural Water Demand*. A selection of the schemes is presented in Table 5.2, Section 5.2, dealing with the potential expansion of irrigated agriculture.

When viewed in isolation, the environmental impacts of new local water supply schemes are likely to be small compared to the impacts of the larger regional schemes. However, the development of increasing numbers of small water supply schemes will have a cumulative impact that will have to be monitored on an ongoing basis. Many of these schemes are based on run-of-river abstractions, which could place additional strain on the already depleted summer low flows in the system. The schemes that were assessed comprise of a mixture of schemes that are designed to increase assurance of supply to existing irrigated areas, and schemes for irrigation water to supply previously undeveloped areas with good soils. The latter developments are generally located in higher lying areas on the fringes of existing developments in valley floors, and will encroach on pristine mountain fynbos areas.

8.3 REGIONAL DEVELOPMENTS IN THE UPPER BREEDE RIVER

The three regional schemes that were identified in the Upper Breede River would mainly be focussed on augmenting the supplies of the Berg Water Management Area, although one scheme could also serve irrigation in the Upper Breede River valley.

- (a) A weir in Michell's Pass downstream of the confluence with the Witels could divert winter flows via a canal into the Klein Berg River and thence via the existing diversion weir and canal into Voëlvlei Dam to augment the supply to the Greater Cape Town Metropolitan Area. The water could also be allowed to flow into the Berg River, and on to Misverstand Dam, from where it could be diverted to the West Coast demand centres.

The final configuration would require the construction of a small weir on the Dwars River to lift the water out of the river channel to the canal off-take. The weir would be small enough to prevent inundation of the Witels tributary, and environmental concerns should therefore be limited to the local terrestrial impacts associated with the weir and inundated area and with the canal route through existing farms. Environmental impacts outside the Breede River catchment will need to be assessed in subsequent studies.

- (b) A dam in the lower reaches of the Wit River with a capacity of approximately 24 million m³ could be used to supply water for irrigation in the neighbouring Slanghoek valley, and along the left bank of the Breede River in the direction of the Jan du Toits River. Alternatively, the scheme could be used to transfer water to the GCTMA and West Coast by pumping water from the Wit River to the Klein Berg River. This water would be used in the same way as water from the Michell's Pass scheme. The dam would inundate about 5 km of the historic Bainskloof Pass downstream of Tweede Tol.

In the event that this scheme is seriously considered for implementation in the future, the environmental impact as presently assessed contrasted with the yield potential of the scheme may present water resources managers with a difficult decision.

- (c) A 1,2 m diameter pipeline was laid through the Huguenot Tunnel during its construction. DWAF originally envisaged that a 27 m high dam with a capacity of about 1 million m³

would be constructed on the Elandspad tributary of the Molenaars River to divert winter flows into this pipeline and thence to the Dasbos portal of the Riviersonderend-Berg River Tunnel System. This scheme aroused deep concerns on environmental grounds.

A more likely option to utilise the Huguenot Tunnel pipeline would be a scheme comprising a small off-channel pump sump to abstract water from the Molenaars River during high flow events. The sump and pump station would be sited a short distance downstream of the confluence with the Elandspad River, and could deliver water via the tunnel pipeline and a new gravity main to the proposed Berg River (Skuifraam) Dam. High environmental flow requirements have been recommended for the Molenaars River, resulting in a relatively small exploitable yield of about 27 million m³/a. This yield may not justify the long and expensive pipeline envisaged, but other applications for this water may be suitable. The scheme would reduce both the existing yield of Greater Brandvlei Dam and the potential for augmentation.

The locations of the three schemes are indicated on Figure 8.1 overleaf.

8.4 GREATER BRANDVLEI DAM

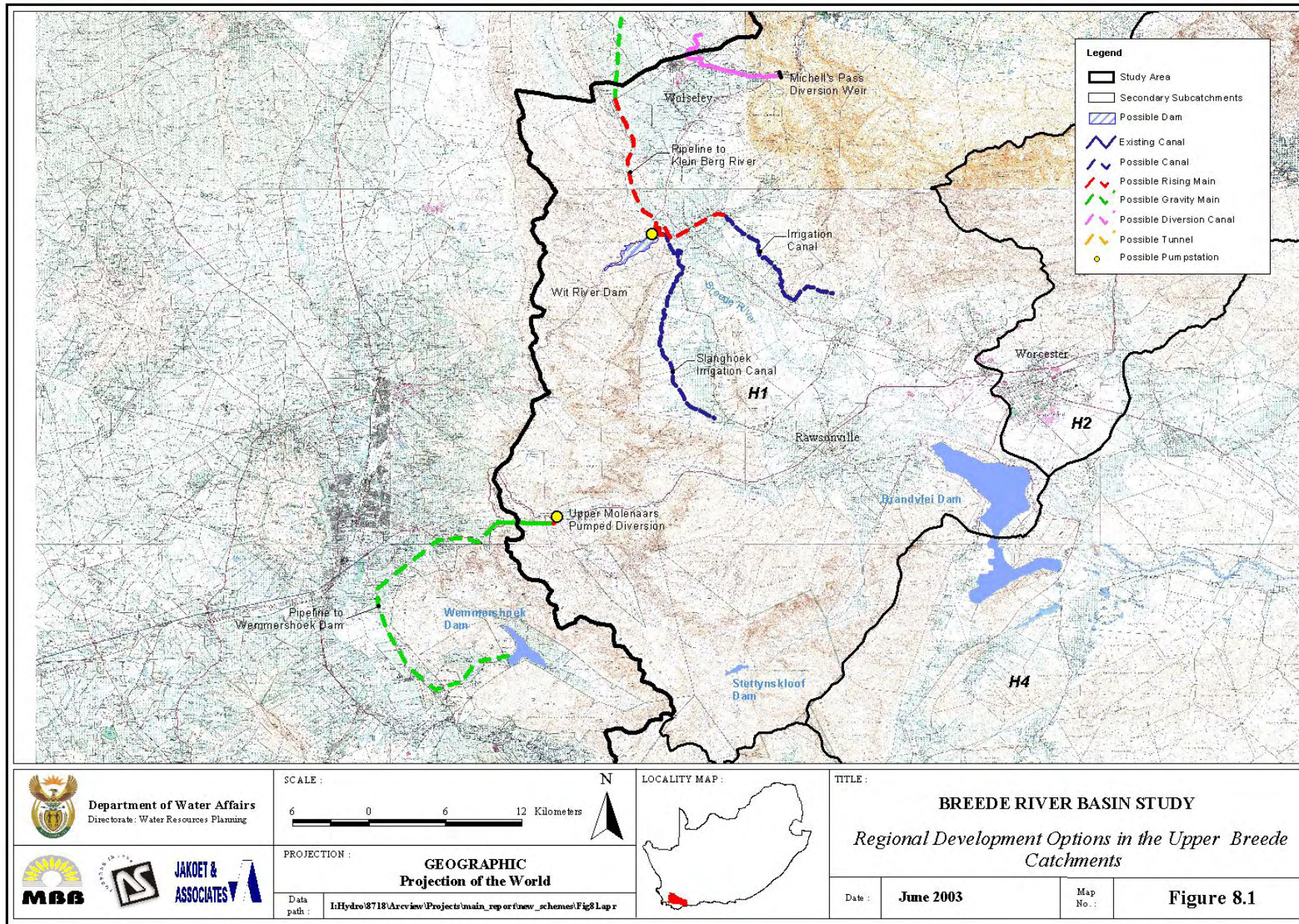
8.4.1 General

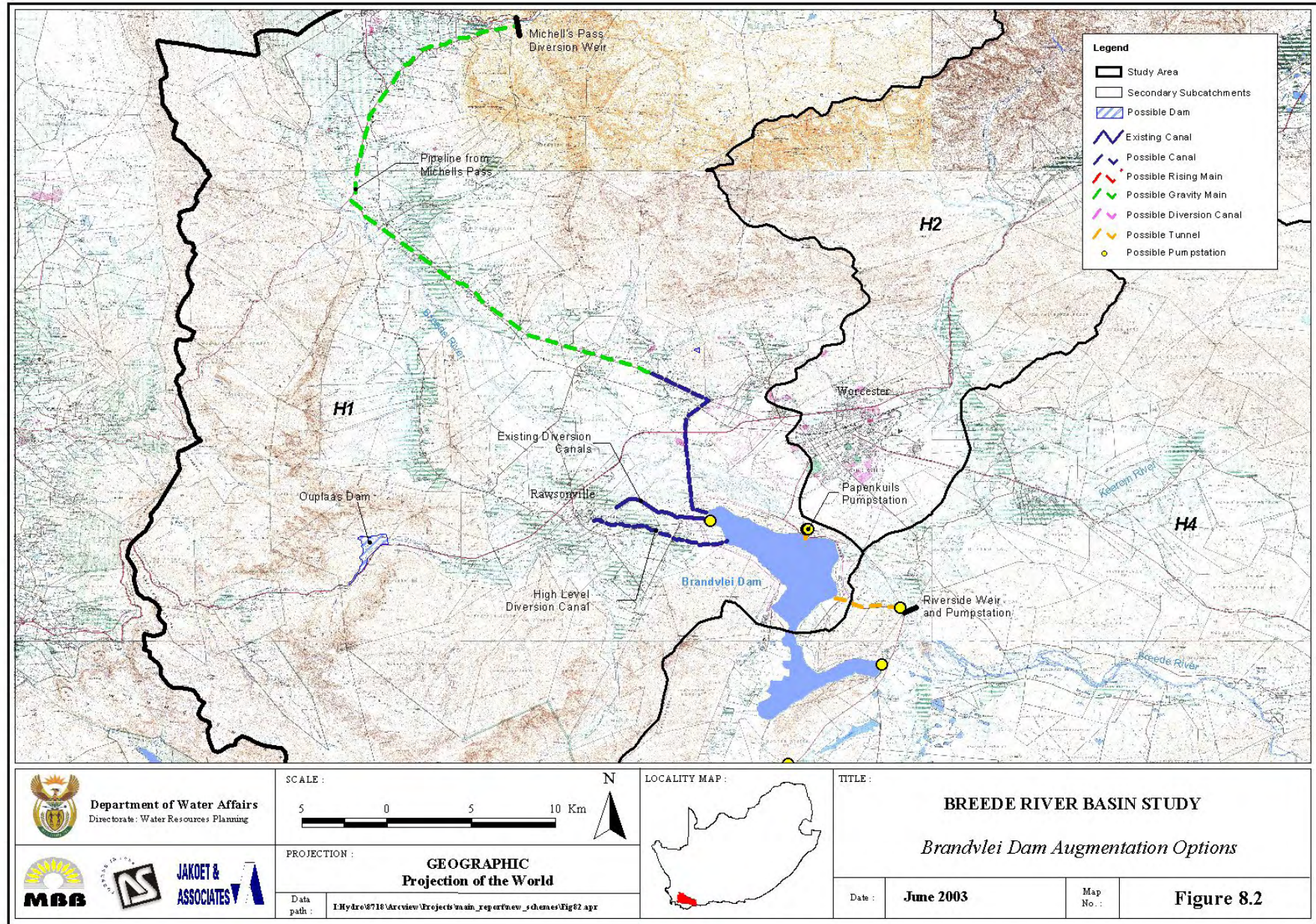
The Greater Brandvlei Dam is the single largest water resource development in the catchment. The dam is currently filled with gravity diversions from the Holsloot and Smalblaar Rivers up to a level of 207 m above sea level, corresponding to a capacity of 342 million m³.

Water from Greater Brandvlei Dam is mainly used for irrigation along the Breede River downstream of the dam. Freshening releases are also made from the dam to manage salinity levels in the middle reaches of the Breede River. The present yield of the dam (operated at RL 207.12 m to which the feeder canals can fill the dam), is estimated at about 115 million m³/a, and is virtually fully subscribed.

A further 133 million m³ of storage is available up to the full supply level of 210,5 m. Water can be pumped into this storage zone by means of the 5 m³/s Papekuils pump station. To raise the water level each year from 207 m to 210,5 m would require the pump station to operate at full capacity continuously for 10 months. This is clearly not possible under present circumstances.

By increasing the quantity of water that can be fed into the dam, better use can be made of the existing dam storage capacity, providing the most economical means of increasing the yield of the system by a substantial margin. The possibility of raising the dam wall to further increase the storage capacity of the dam has previously been considered (the so-called "Phase 2 development"). Yield analyses carried out for the BRBS have indicated that the recommended EWRS would preclude this option. The options for augmenting the supply to Greater Brandvlei Dam are indicated on Figure 8.2, and described below:





8.4.2 Augmenting Diversions to Greater Brandvlei Dam

- (a) The capacity of the existing diversion canals from the Smalblaar and Holsloot Rivers to Greater Brandvlei Dam can be increased to reach the current FSL of RL 207,12 m earlier in the wet season. A low lift pump station will also have to be constructed to lift the water from the existing canal into the dam once the level of RL 207.12 m is exceeded. Environmental concerns do not appear to be serious.
- (b) An additional high level canal, that will divert water from the Smalblaar and Holsloot Rivers into Greater Brandvlei Dam under gravity up to the maximum FSL of 210.5 m, could be constructed. There may be concerns related to disturbance of farming operations along the route of the canal.
- (c) A high level canal can be constructed to transfer water from the Dwars River in Michell's Pass to Greater Brandvlei Dam. Environmental concerns associated with this scheme relate to the barrier effect that the canal would create between the left bank of the Breede River, and natural vegetation on the valley flanks.
- (d) The existing pump station at Papenkuils in the Breede River adjacent to Brandvlei Dam has a capacity of 5 m³/s. This capacity can be upgraded by a further 15 m³/s to enable the filling of the pumped storage zone in Greater Brandvlei Dam during most winters. Daily diversion analyses have indicated that, with this pumping capacity, balancing storage in the Breede River would not be required. Concerns around the inundation of the Papenkuils wetland by the construction of a balancing weir can therefore be allayed.
- (e) For a similar pumping capacity, a new pump station located further downstream at Riverside, could also utilise the additional flows from the Hex and Nuy Rivers, and would substantially improve on the yield that can be developed at the Papenkuils site. The scheme would however be about twice as expensive as the Papenkuils option, mainly due to the longer rising main, and the new pump station that would be required.
- (f) A 30 million m³ dam could be constructed at the Ouplaas site on the Molenaars River to contain floods for subsequent release over an extended period to increase the efficiency of existing canal diversions. A low lift pump station will also have to be constructed to lift the water from the existing canal into the dam once the level of RL 207.12 m is exceeded. This scheme is likely to have a significant environmental impact as a result of the inundation of a unique tributary delta supporting a number of red data species. The yield of this scheme would be reduced should the off-channel pumping sump in the upper Molenaars River be constructed.
- (g) The possibility of utilising the alluvial groundwater aquifer upstream of Greater Brandvlei Dam to provide temporary storage of flood waters for later pumping into Greater Brandvlei Dam was also investigated. It was found that, even if a 15 caisson wellfield were to be

developed, that the transmissivity between the river and the aquifer might be limited to less than 5 million m³/a, making this an unattractive option.

8.4.3 Utilising Additional Yield from Greater Brandvlei Dam

The additional yield of the Greater Brandvlei Dam could be used in a number of different ways for further agricultural development in the Middle Breede or Upper Breede. These possibilities include the following :

- (a) Existing supplies from the lower reaches of the Hex River to the Worcester-East and Overhex areas could be replaced by a supply from Greater Brandvlei Dam. Such an arrangement would release previously committed water for development in the Lakenvallei and Hex River Valleys, and would have the added benefit of improving the reliability of supplies to the Worcester-East and Overhex areas.
- (b) The additional yield could be used for irrigation expansion in the Middle Breede, downstream of Greater Brandvlei Dam. By using the existing distribution system to convey the additional water during off-peak periods, infrastructure development would be limited to the provision of on-farm storage dams to store water for peak time use in extended areas. Variations of this option have been investigated as part of the assessment of local schemes. Extension of irrigated areas in the Middle Breede is likely to increase saline return flows.
- (c) Additional yield from Greater Brandvlei Dam could also be used to supply water for irrigation in the areas to the north-west of Worcester (hereinafter referred to as the "Worcester" Irrigation Scheme). Such a scheme would require a pump station at Brandvlei Dam, from where water would be pumped via a rising main to a small earthfill dam on the lower slopes of the Fonteintjiesberg. From this dam, which would provide balancing storage, water would be supplied for irrigation via a feeder canal routed around the south-western spurs of the Waaihoek Mountains.

Cost estimates and environmental comment were prepared for the last scheme described above, in order to assess the effects of an agricultural development that would utilise most of the additional water supply from Greater Brandvlei Dam.

- (d) The additional yield of the Greater Brandvlei Dam could also be transferred to Theewaterskloof Dam and thence via the Riviersonderend-Berg Tunnel System to the Berg WMA. The transfer scheme would comprise two pump stations, a canal, a tunnel and a pipeline to transfer the water between the two dams. Environmental impacts include potential erosion due to the discharge of water into the Elands River, which would feed the water into Theewaterskloof Dam, and the effects of mixing Greater Brandvlei water with the water entering Theewaterskloof naturally.

8.5 REGIONAL DEVELOPMENTS IN THE MIDDLE BREEDE RIVER

- (a) A dam site has previously been identified at Le Chasseur on the Breede River main stem, approximately halfway between Worcester and Robertson. A dam at Le Chasseur could be used to divert water into irrigation canals serving downstream users presently supplied from Greater Brandvlei Dam. The reduction in demand on Greater Brandvlei would make a similar amount of water available for transfer to Theewaterskloof Dam, and on to the GCTMA, or for irrigation upstream of Le Chasseur. A further option is to continue the present use of Greater Brandvlei Dam, and to utilise Le Chasseur Dam to irrigate new areas downstream. If the dam has a large capacity, saline irrigation return flows from upstream irrigation would not be sufficient to cause salinity problems in the Le Chasseur reservoir.

Due to the flat gradient of the river in this area, even a relatively low dam wall would cause the inundation of large areas of presently irrigated land. Costs associated with the expropriation of property and the replacement of the farms through new irrigation developments would lead to a very high capital cost. The practicalities of funding such a scheme, combined with the inherent risk associated with agricultural developments, would in all likelihood preclude the development of such a scheme for agricultural use only. It is conceivable however, that this scheme could in the distant future become viable as a means of augmenting the quantity of water available for transfer from Greater Brandvlei Dam to the GCTMA, while maintaining and improving the water supply to Breede River irrigators.

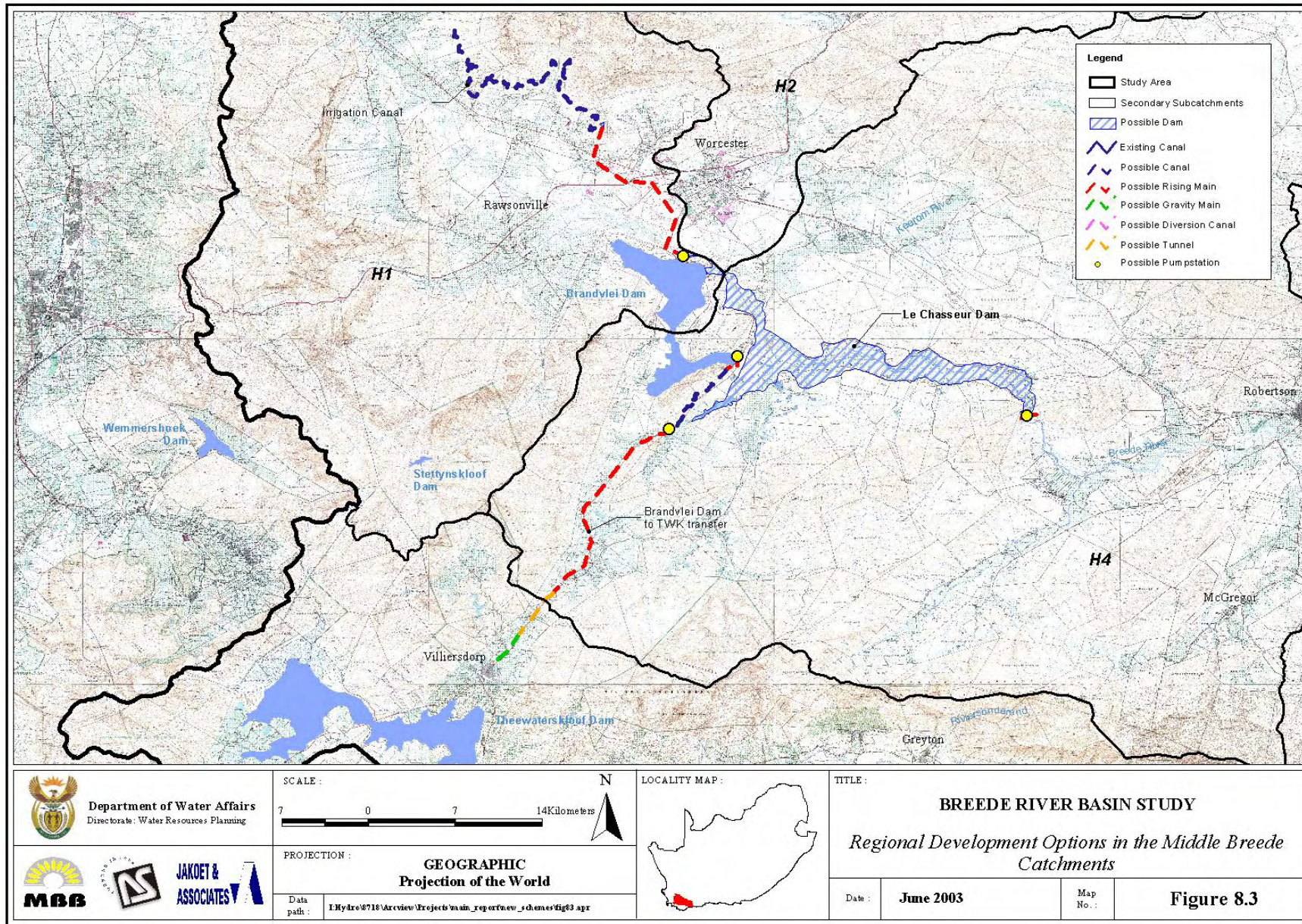
Some of the more obvious concerns regarding this scheme include :

- high social impacts associated with the relocation of farming communities in the dam basin;
- limited opportunities for the phased implementation of the scheme to reduce overall risk;
- reduced yields that may be available from this dam due to releases that may be required to meet estuarine flow requirements, and to a lesser extent due to future upstream developments.

At this stage, it is anticipated that, rather than constructing a dam at Le Chasseur, it would be possible to mobilise substantial volumes of water through the augmentation of the yield of Greater Brandvlei Dam and through developments in the upstream catchments, with significantly smaller risk and social implications.

- (b) There is an alternative dam site at Skurwekop, about 25 km downstream of Le Chasseur that might be more economical but lacks certain advantages of the Le Chasseur site.

The development options in the Middle Breede region are shown on Figure 8.3



8.6 SALINITY ALLEVIATION IN THE MIDDLE BREEDE RIVER

Salinity levels in the Middle Breede affect economic growth in the area because of its negative effect on crop yields. Alleviation measures include the current practice of making freshening releases from Greater Brandvlei Dam, the possible construction of new conveyance systems, end-of-line treatment and optimum management strategies.

- (a) The construction of new conveyance systems would replace the current water distribution infrastructure with a system of high level canals that would supply existing and future irrigation developments with good quality water directly from Greater Brandvlei Dam. This option would reduce losses incurred in the existing antiquated canals, reduce farmers' pumping costs and eliminate the need for freshening of river flows in the Middle Breede, but is a capital-intensive solution, and would merely shift the salinity problem from an upstream to a downstream position, where its impact may be intensified.
- (b) A meaningful short-term solution could be achieved through the construction of return flow interceptor drains, combined with the freshening release strategy. The life span of this solution could be extended through disposing of the saline return flows by evaporation (preferable), or diverting these into a canal leading to a temporary storage dam for release during winter below the irrigated areas. Yield assessments have shown that this option could reduce the impact of freshening releases on the yield of Greater Brandvlei Dam by about 12 million m³/a. Further detailed investigations should be carried out to optimise and cost this option, taking into account the current salinity profile in the Breede River between Robertson and Bonnievale, and making use of detailed soil surveys that are available for this area.
- (c) In addition to the physical alleviation measures described above, further development of irrigation in areas producing highly saline return flows should be actively discouraged. It is recommended that, based on the soils investigations carried out for this study, these areas be demarcated on a map, and that the Catchment Management Agency make use of regulatory and financial instruments at its disposal to influence further irrigation development in the demarcated areas. The occurrence and characteristics of these soils (mainly sodic, and saline-sodic soils located on Bokkeveld shales and Tertiary sediments) are described in Report PH 00/00/1902 *Evaluation of Soil and Climate Suitability for Irrigated Agriculture*.

The measures at the disposal of the CMA include :

- Conditional approval of new water use licenses, subject to approval of plans for the disposal of saline return flows. The CMA may even consider the possibility of discontinuing the issuing of new water use licenses in demarcated areas.
- Penalties, which can be implemented for offences in terms of water use regulations or licensing conditions. CMAs may recover costs incurred to implement remediation strategies where a directive has not been complied with.

- Pricing strategy, which could allow for an increased price of water supply to demarcated areas.

8.7 THE RIVIERSONDEREND CATCHMENT

- (a) As discussed in Section 6 above, the clearing of alien invasive vegetation, followed by regular maintenance, would provide a cost efficient means of increasing flows in the Riviersonderend River. (Cost estimates of clearing operations are of the order of 10% to 20% of the costs of new infrastructure that would be required to make the same quantities of water available.)
- (b) The Theewaterskloof Dam would provide part of the conduit for water transferred from Greater Brandvlei Dam to the GCTMA. The Theewaterskloof Dam could be raised at relatively low cost to increase the yield from its own catchment and/or to balance the inflow from Greater Brandvlei Dam against the seasonal demand of the GCTMA. However, the Study has found that, due to the intensive development around the dam, the large size of the existing dam, and shortfalls in the recommended EWRs downstream of the dam, very little additional yield could be made available in this manner. This option was therefore discarded during the final phase of the study.
- (d) The Bromberg Dam on the lower Riviersonderend River could fully develop the resources of the river, at a point where the present day mean annual runoff is about 152 million m³/a. The dam would be utilised for irrigation in the region of the confluence of the Riviersonderend and Breede Rivers. The configuration analysed consists of a dam with a storage capacity of about 100 million m³, a yield of about 22 million m³/a, two pump stations with rising mains, and two canals totalling about 61 km in length. Should a dam of this size be constructed, the cost would be high due to the need to relocate a long stretch of the N2 highway, and a further concern being the need to relocate the Stormsvlei community. Both of these concerns could be allayed by reducing the size of the scheme. The poor yield of the scheme could be significantly improved by removal of invasive alien plants in the catchments upstream of the dam.
- (e) An alternative to this scheme would be to raise the existing Reenen Weir at the Bromberg site by about 4 m, in order to regulate flows in the lower Riviersonderend River, thereby improving the efficiency of irrigation water use in this area. This is a relatively small scheme (delivering an additional yield of about 0,5 million m³/a), and was not assessed in detail.

8.8 THE LOWER BREEDE REGION

- (a) The existing Buffeljags Dam is sited as far downstream as is practical, at a point where the mean annual runoff is about 100 million m³/a. The existing dam has a capacity of only 5,7 million m³, and supplies 11 million m³/a for irrigation along the lower reaches of the Buffeljags River. It may be possible to raise the dam by 10m, which could yield an additional supply of about 11 million m³/a, after allowing for ecological flow releases to the

Lower Breede and the Estuary. The water, which is of good quality, could be used to expand irrigation downstream of the dam.

- (b) An alternative use of the raised Buffeljags Dam would be to provide storage for some of the winter high flows that are surplus to the flow requirements of the estuary. A portion of this water could be released during the summer to manage salinity levels in the estuary. The remainder of the stored water could then be made available for upstream development.
- (c) In addition to the raising of Buffeljags Dam, a new weir upstream of the Buffeljags Dam, which could possibly benefit the Suurbraak Community, may be practical.

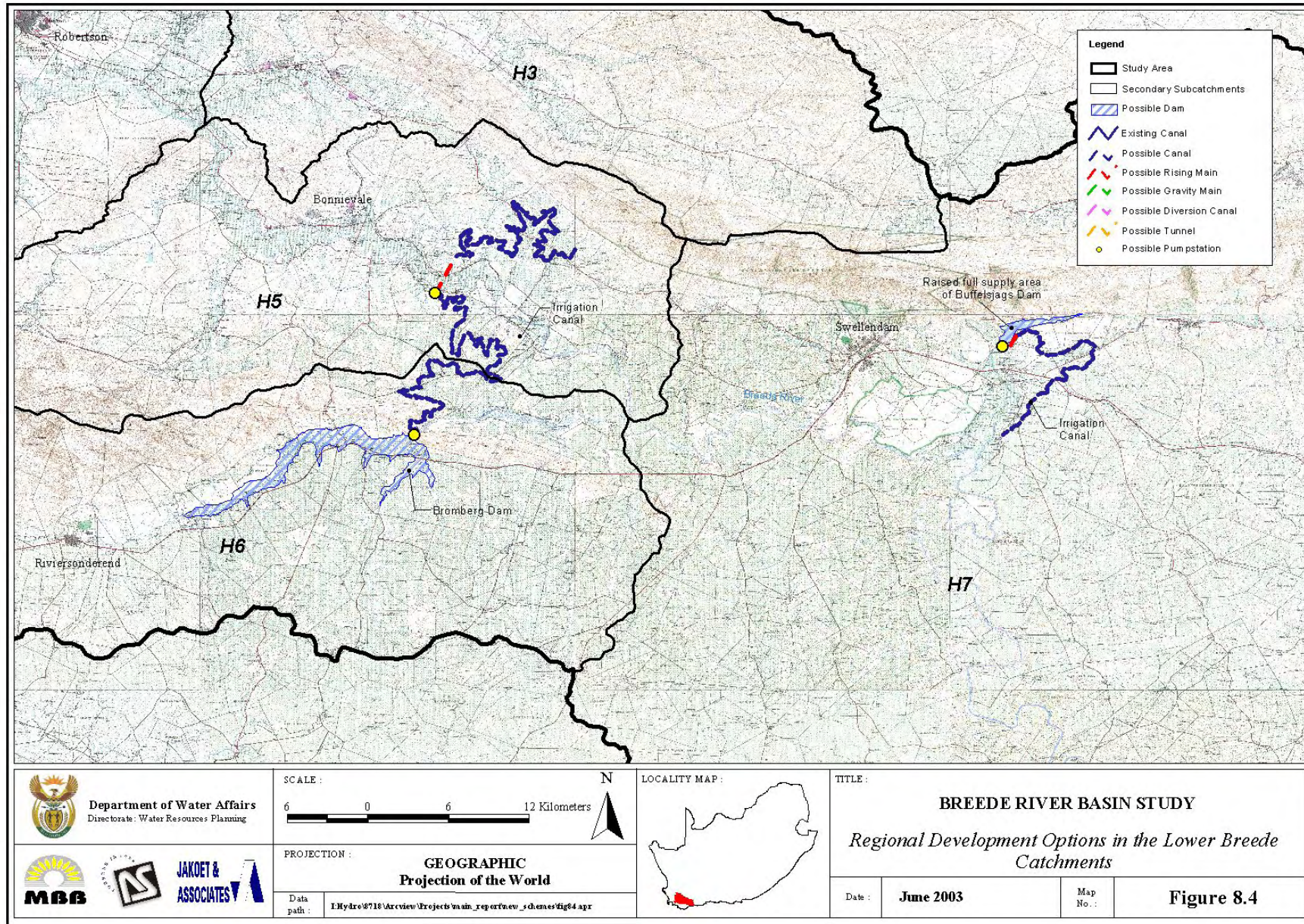
Development options in the Riviersonderend and Lower Breede are shown on Figure 8.4.

8.9 COMPARATIVE EVALUATION OF REGIONAL WATER SUPPLY OPTIONS

The original terms of reference for the study provided for the evaluation of development options according to financial and technical viability, accompanied with comment from environmental and social perspectives. As a late addition to the Study, the evaluation of development options was broadened to include multi-criteria decision analysis (MCDA). This enabled weighting to be assigned to the various criteria used to evaluate schemes.

The MCDA was structured to rate financial and technical considerations, socio-economic considerations, and natural environment concerns associated with the different options:

- Financial and technical criteria included yields and costs of schemes, reliability of cost estimates, constraints on capital finance, and affordability.
- Socio-economic criteria included job creation opportunities, primary and secondary economic benefits, support to resource poor farmers, resettlement impacts, and impacts on recreation tourism.
- Natural environment criteria were selected to evaluate the effect of the developments on rivers, groundwater, estuaries, the terrestrial environment, and on the aesthetics of the area.



The development options were evaluated within three broad groupings: irrigation schemes; urban transfer schemes, and alternative schemes for the augmentation of Greater Brandvlei Dam. The results of the evaluation are summarised in Figures 8.5 to 8.7. It must be noted that the comparisons of the schemes were based on the reconnaissance level configurations conceived for the Study. Some of the schemes that were found to be relatively unattractive could very well be modified to address the concerns that were identified, thereby achieving a much improved rating, while on the other hand detail study could show costs and disbenefits greater than presently thought. Nevertheless, MCDA at this early stage may serve to highlight aspects that need to be given particular attention in subsequent investigations.

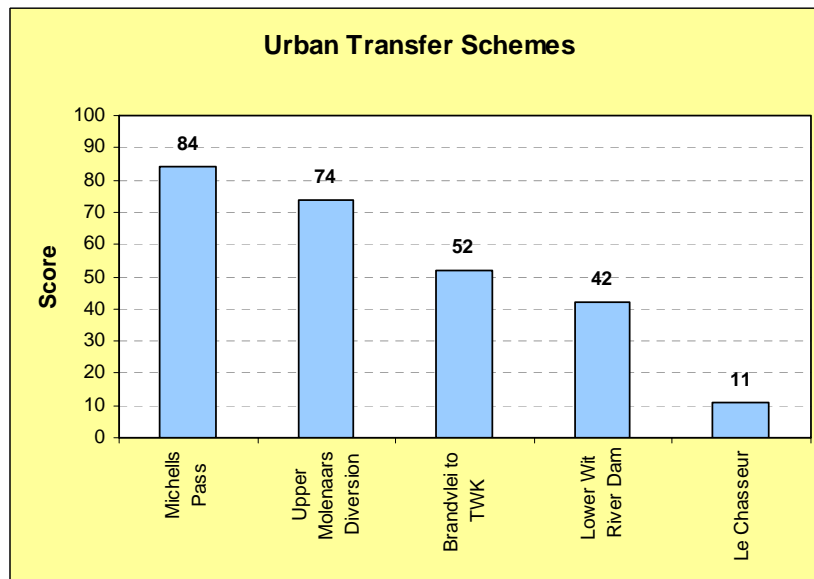


Figure 8.5 : Ranking of Greater Brandvlei Augmentation Schemes

On the basis of low environmental impact and a relatively inexpensive cost of water, enlarging of the existing Papekuils pump station appears to be the most attractive option to augment the supply from Greater Brandvlei Dam (Figure 8.5). This option is followed by a cluster consisting of the enlargement of the existing diversion canals, combined with the construction of a low-lift pump station; a new high level canal from the Smalblaar River; or a new pump station in the Breede River at Riverside. The construction of Ouplaas Dam, and a high level canal from Michell's Pass appear to be the least favourable options for augmentation of Greater Brandvlei Dam, due to higher costs, and environmental concerns.

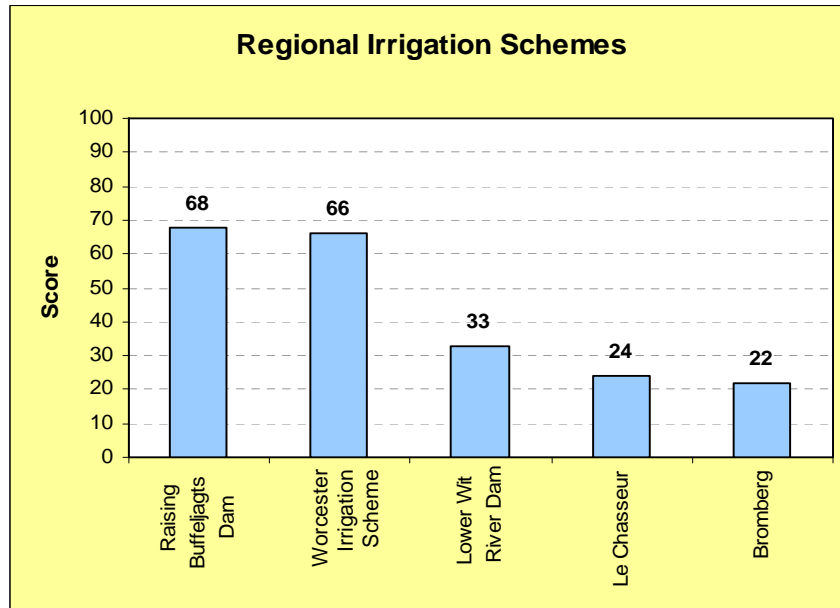


Figure 8.6 : Ranking of regional irrigation schemes

As shown in Figure 8.6, the two most favoured irrigation options are the Buffeljags scheme as described in Section 8.8 (a), and the Worcester scheme as described in Section 8.4.3 (c). These are the smallest and largest schemes (in terms of yield), respectively. Environmental and social concerns influenced the relatively poor overall rating of the remaining three schemes. The low rating of the Bromberg scheme would improve significantly if a smaller scheme is conceived and if the yield were to be increased by clearing the alien vegetation. The Buffeljags scheme, operated mainly as a means to alleviate salinity in the upper part of the estuary and hence to permit increased allocations to irrigators from other schemes, has not been evaluated.

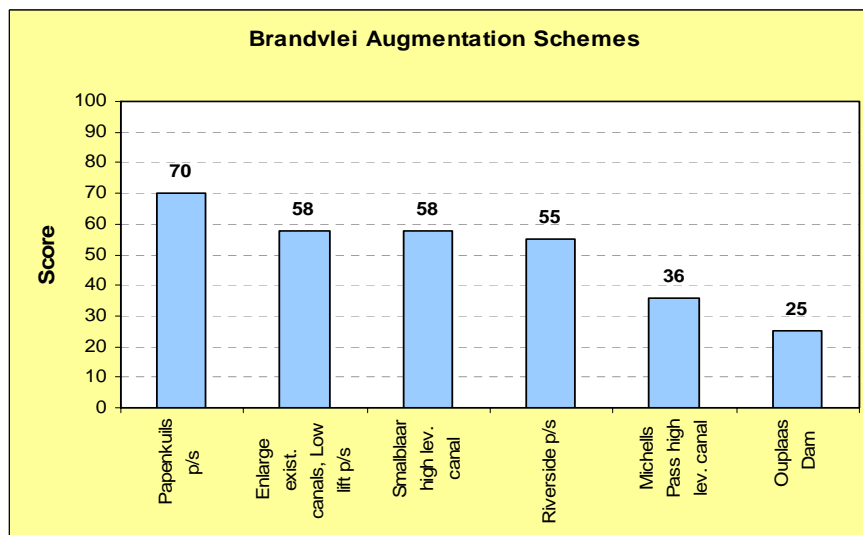


Figure 8.7 : Ranking of urban transfer schemes

8.10 DISCUSSION OF TRANSFER OPTIONS

The schemes for transferring water to the Berg Water Management Area considered in the Study are the following :

TABLE 8.1 : TRANSFER SCHEMES

SCHEME NAME	MAXIMUM YIELD (Mm ³ /a)	URV (c/m ³)**
Michell's Pass diversion	53	11
Upper Molenaars diversion	27	82
Lower Wit River diversion	30	87
Brandvlei-Theewaterskloof scheme	41	114*

* Inclusive of the cost of increasing the yield of Greater Brandvlei Dam correspondingly by means of the 20m³/s Papenkuils pump station.

** URVs exclude the cost of additional bulk conveyance infrastructure to deliver transferred water to the GCTMA, should this be the destination point.

The Water Resources Yield Model of the Breede River catchment has not been linked to the Model that has been developed for the Western Cape System. The yields shown in Table 10.1 are therefore approximations of the true yield benefit to the Western Cape System, and were estimated by determining the average annual transfer volume that would be available during the critical drought period of the Western Cape System (hydrological years 1968/69 – 1974/75). It is a recommendation of this study that the two systems models be linked to obtain the true marginal yields of schemes to be taken into feasibility studies.

The Michell's Pass Scheme is by a large margin the most economical transfer scheme. Moreover, the environmental impact is considered small. The unit reference value is substantially lower than that of any alternative option for supply to the Berg Water Management Area. The substantial yield, taken together with other means of increasing the yield of Voëlvelei Dam, will probably exceed local demand and require that a second pipeline to Cape Town be constructed. This would increase the effective URV substantially. This supply would be integrated into the GCTMA system, depending ultimately on other developments in the Lower Berg River. If the scheme is implemented at an early date and it is later found to be impacting to an unacceptable extent on supplies in the Breede River catchment, water transfers could easily be moderated as desired. The diversion of 53 million m³/a from the river in winter would not affect water supplies in the Breede River catchment as at present, but would reduce slightly the yield of the enlarged Papenkuils pump station, if this scheme were implemented to augment the yield of Greater Brandvlei Dam.

The other schemes listed above, in addition to being much more expensive than the Michell's Pass diversion, all have more serious impacts on the environment and on in-basin supplies. There is a further small potential transfer scheme that has not been studied but which appears to be economical and to have relatively small environmental impact. This entails increasing the capacity of the existing "Gawie se Water" diversion from the Upper Wit River to increase the

quantity of water released in winter into the Berg River catchment. Another potential transfer scheme to augment the supply to the GCTMA is development of the Table Mountain Group aquifer, which is under investigation by the City of Cape Town. There are also other options for augmenting water supplies in the GCTMA, not involving the Breede River catchment, which might be more attractive than the remaining transfer schemes listed above.

The Michell's Pass and Upper Molenaars diversions appear to be the more favourable transfer options as shown in Figure 8.7. The relatively high score assigned to the Michell's Pass scheme is due to it being the cheapest scheme by a large margin, while scoring relatively highly on other criteria. The Upper Molenaars scheme is placed second due to it being a relatively small and expensive scheme, despite being preferred to the Michell's Pass scheme on most other criteria.

Further assessment of transfer schemes needs to take into account the costs and impacts incurred outside the Breede River catchment, which have not been considered in this Study. Schemes transferring water through Theewaterskloof Dam in particular are likely to present difficulties.

8.11 POTENTIAL EFFECTS OF TRANSFERS ON IN-BASIN WATER RESOURCE DEVELOPMENTS

In view of the uncertainty as to how, whether, and if so, when water will be transferred to the Berg WMA, the question arises of how the uncertainty could affect development in the catchment. Small schemes are unlikely to be affected at all.

The two most favourable regional options, by a wide margin, are the Buffeljags and Worcester irrigation schemes. (With regard to the latter, it needs to be remembered that this scheme is just one of a number of possible in-basin developments that could utilise the augmented yield of Greater Brandvlei Dam – see Section 8.4.3). The Buffeljags scheme will be largely unaffected by transfers from the Upper Breede catchments. In regard to the Worcester (or similar) schemes, the preferred option for the necessary increase in the yield of Greater Brandvlei Dam is by way of the Papekuils pumping scheme. Implementation of the Michell's Pass transfer scheme would affect the yield of the pumping scheme slightly. If and when the latter is implemented, it would need to be verified that its viability would not be affected by the Michell's Pass diversion. A similar situation applies in regard to the Upper Molenaars scheme. The latter would affect the yield of Greater Brandvlei Dam more directly if it were planned to increase the inflow to the Dam from the Molenaars River. On the other hand, implementation of the Greater Brandvlei transfer scheme would virtually preclude the Worcester scheme, or other sizeable irrigation developments that could be supplied from the augmented yield of Greater Brandvlei Dam.

In order to clarify the situation within a reasonable time, a limited time should be allowed for clarification of whether the Greater Brandvlei transfer scheme should be retained as an option. Alternatively, it may be considered that sufficient information has already been assembled to rule it out.

In conclusion, it is considered that individually, the Molenaars and Michell's Pass transfer schemes would not shut out in-basin agricultural development that can realistically be achieved. Further investigations should be carried out to define the configuration of components of these schemes that would be required outside the Breede River catchment, and to evaluate the costs and impacts associated with these.

With regard to in-basin water resource developments, the continuing incremental development of irrigated agriculture through the expansion of existing farms and the establishment of new schemes supplied from small, local water resources developments will benefit the economy of the region. Provided that these developments are shown to be economically viable, and to embrace the concepts of environmental protection and WCDM, licensing of water use should not be unnecessarily constrained.

Further investigations should be carried out to determine the best use of water from the augmented yield of Greater Brandvlei Dam (various irrigation developments), and from the raised Buffeljags Dam (irrigation development or management of ecological flow requirements in the Lower Breede River).

9. THE BREEDE RIVER AS A REGIONAL WATER RESOURCE

9.1 INTRODUCTION

The focus of the Breede River Basin Study is on the water resources of the catchment, how these are used, what opportunities and constraints are influencing further development of the land and water in the catchment, and how water resources could further be harnessed and used. However, the Breede River catchment cannot be viewed in isolation and any further development must be considered both in the context of Western Cape region and also the wider needs of the country.

The Study provides information that will be needed to develop strategies for the local development of the water resources of the Breede River, and to plan possible transfers. Development of these local strategies will follow the Basin Study, and will form the basis for the operations of the future Breede Catchment Management Agency. Furthermore, the regional sharing and allocation of water resources through inter-basin transfers bring national economic interests into play, which have to be taken into account together with the needs of water user groups in affected catchments. The Western Cape has been described as an oasis, separated from the remainder of the country by semi-desert. It would be implausible to suggest that transfer of water, on any significant scale and in either direction, will be contemplated over the eastern watersheds of the Olifants, Breede and Palmiet Rivers. The national interests in regard to the use of the Western Cape's water resources relate to its contribution to the economy of the country, the job opportunities provided, and the foreign exchange earned.

In recognition of the above, the Study included two components that were geared toward an improved understanding of the regional issues that will affect future decisions on the sharing and allocation of water resources in the Western Cape:

- The DWAF Strategic Environmental Assessment (SEA) Team was involved in the Study to promote the integrated environmental management principles that are embodied in a SEA process. The SEA team facilitated a strategic work session at which participants from a range of local and national Government departments, development agencies, Breede River stakeholders and study team members discussed issues affecting the regional development and use of water resources.
- The Regional Economics component of the Study focussed on the development of a regional economic model that would help explore the economic implications of water resource allocations between the Breede and Berg Water Management Areas. This exercise provided preliminary comment on the benefits and disbenefits of water transfers from the Breede WMA to the Berg WMA.

By way of introducing the management approaches that could be included in the process of developing interim water resource management strategies and an eventual CMS for the Breede WMA, the outcomes of these two study components are discussed in the remainder of this section.

9.2 STRATEGIC PERSPECTIVES

The major points raised at the strategic work session are paraphrased here to indicate the type of issues that will have to be taken into account when strategies for the future development of water resources in the Western Cape are developed.

- By 2015 the Cape Metropolitan Area could require more water than can realistically be drawn from the surface and groundwater resources of the Berg WMA and the Palmiet River. The options then would include re-use of effluent, desalination of seawater and transfers from the Breede and Olifants catchments.
- Agriculture has an important place - and entails very important feedback loops (tourism, manufacturing, jobs) in the overall health of the regional economy. An aspect that needs to be evaluated is the contribution of irrigated agriculture to the overall welfare. It has been suggested from time to time that irrigation should be curtailed or reduced in order to release water for domestic and industrial purposes. It may be that judicious expansion of irrigation would be the wiser course. A problem here is that, left to market forces, urban and industrial users would be in a position to buy out the water rights of irrigators. Hence a method of allocating water that takes full account of the public benefit of competing usage needs to be evolved.
- Agriculture will need to improve its water use efficiencies. Other than by reducing allocations per hectare, the best incentive for irrigation to improve efficiency is the prospect of increased profit through expansion of irrigated area, without increasing the supply of water. Efficiency can also be improved substantially by reducing losses in communal transmission and distribution systems. Costs and benefits need to be established in each case.
- The development of agriculture as a sector can probably best be achieved by combining the expertise, infrastructure and finance of the existing sector with the legitimate demands of the emerging sector for water for equity and development.
- The risks of over-investment (of water) in agriculture must be born in mind. Agriculture could be allocated water on the basis of time-limited licenses.
- Tourism is an extremely important income generator – and will become more so if the declines in agri-business sectors cannot be stemmed.
- Development of the industrial sector should be towards low water users (e.g. Information Technology) rather than high water users at the expense of agriculture. However, market forces will probably dictate the direction of this evolution, and can only be influenced to some extent by structuring of water tariffs.
- Global warming is a reality and could affect development in a number of ways.
- The local and national consequences of a severe drought, resulting in loss of high value crops and even destruction of orchards and vineyards, need to be taken into account when establishing criteria for the reliability of irrigation water supply.
- Irrespective of any future water resources development, it is essential that significant progress is made with water demand management in all sectors to ensure the future well-being of the region.

9.3 REGIONAL ECONOMICS OF WATER TRANSFERS

9.3.1 Development of a Regional Economics Model

As part of the Regional Economics component of the Study, a basic economic model was developed which attempts to find a means to contribute to the key question of "where should the GCTMA's future sources of water supply come from and what proportion of this water if any should come from the Breede River catchment?". The nature of this question implies that other potential supply areas, particularly the Palmiet and areas of the Berg WMA outside of the GCTMA need to be brought into consideration when evaluating the role of the Breede and Olifants catchments in supplying water to the GCTMA.

An early draft of an economic model was based on the concept of maximising private and public benefit of water use in the region. After some discussions this was modified in an attempt to develop a model more consistent with standard economic approaches to resource allocation. The revised model follows a simplified economic optimisation approach in that it takes the demand from the GCTMA as fixed at any point in time, and assumes that the GCTMA users will purchase water at any price, i.e. a totally inelastic demand. The model then determines an optimal supply schedule based on a "supply curve" constructed from the least cost of supply from the surrounding catchments (Berg, Breede and Palmiet) over a 20 year period. Costs of supply are made up of resource development costs plus opportunity costs of supply, i.e. those costs that would be incurred if users in any year are denied access to water that they currently use, due to transfers out of their catchment.

The model has a number of limitations in its present form. These include the way that it deals with the Reserve (an economic value is not attached to water for the environment), and inefficiencies in the economy (such as unemployment). To realise its full potential as a decision support tool, these limitations should be addressed, and input data must be sourced for the Palmiet catchment and Berg WMA, ideally as a research project.

9.3.2 Public and Private Benefits of Water Transfers

The process of developing the economic model has stimulated a debate in the study team around the public and private benefits of water transfers from the Breede WMA to the Berg WMA. Preliminary comment arising out of the debate is summarised below.

At the extremes, the decision to transfer water can be taken from a completely private benefit or a completely public benefit point of view. The private benefit approach would be based on the willingness of potential users to pay for water. Essentially the highest bidding user or group of users wins and the water goes to them preferentially.

The public benefit argument looks at water use from the point of view of the public in general and focuses on the environmental, social and economic benefits achieved through using water. Water would be allocated to the user or group of users that offer the maximum public benefit.

In reality a mix of private and public benefit analysis needs to be applied. However, the values of public benefits can seldom be established at a level comparable with those of private benefits. A range of values needs to be placed on the public benefit of each supply option, in order to, as a first step, ascertain whether this consideration could re-rank the supply options.

Water use in the Breede River catchment

Urban use (domestic and industrial) is relatively small. Total quantities are not large enough for this to be major factor in transfer decisions. Potential supply options would not materially affect the future supply to any town.

Agricultural use: Further allocations of water to agricultural users will achieve a public benefit based on increased employment, increase in gross domestic product and, possibly, increase in foreign exchange. There will also be a private benefit for the farmer who will receive returns on his investment. The extent of such benefit will depend on the type of agriculture.

Environmental use: Any abstractions from the catchment will negatively affect its environmental status. Therefore there is a reduction in overall public benefit through such abstractions.

Water use and public benefit in the Cape Metro

For the purpose of discussion, current water use in the Cape Metro can be split roughly as follows :

TABLE 9.1 : CURRENT WATER USE IN THE CAPE TOWN METROPOLITAN AREA

Category	Relative public benefit per m ³	Proportion of total use
Urban Domestic – basic level (subsistence)	Very high	1%
Urban Domestic – intermediate use level	High	2%
Urban Domestic – high use level	Very small	19%
Urban Domestic – luxury use level	Zero	19%
Industrial and commercial	Moderate to high	9%
Agriculture - High employment, high value added	Moderate to low	25%
Agriculture - Lower employment and value added	Low	25%
Total		100%

The qualitative assessment of the relative public benefit of the various categories is open to debate. So, for example it could be argued that a higher public benefit should be accorded to the "high" and "luxury" levels of urban domestic water use, as these categories are associated with "quality of life", and contribute to the attractiveness of a city as an investment and settlement destination. Together, the two categories make up 38% of total water use, and the public benefit weighting attached to these will significantly influence an overall assessment of the net public benefit of water transfers.

If the weightings in Table 9.1 are accepted for illustrative purposes, it can be argued that the amount of water needed to provide for use with high to moderate public benefit is relatively small (about 25%). The remainder generates relatively low public benefit. In considering the marginal use (next amounts of water used) there is the choice of (1) assuming that the mix of use categories will be about the same or (2) assuming that it will be more on the low public benefit end. The probability is that it will be the latter: the high public benefit use is largely satisfied and the marginal increase will be in the low public benefit bracket.

Public disbenefit of transfer from the Breede River catchment

The assessment of public benefit of transferring water to the Cape Metro has been illustrated. What is more difficult to assess is the marginal 'disbenefit' of taking it from the Breede River catchment. If the 'disbenefit' is to be borne by the agriculture sector, in the sense that they will not be able to expand, then this depends on the type of agriculture being forfeited. If the 'disbenefit' is to be borne by the environment then much depends on the status of the rivers and how this will change.

Allocation decision process

Because public benefit (or more particularly public disbenefit in the Breede River catchment) cannot be assessed accurately, there is a danger that private benefit considerations may dominate. Furthermore, since industries, commerce and high-income households see much greater private benefits per cubic metre of water than agriculture, they may be able to outbid agriculture for water, and being represented by a strong local government, may be in a better position to finance major schemes. Consequently, depending on the cost of transfer compared with in-basin use, the latter may be found to be the less favourable alternative if the public disbenefit is not assessed as substantial.

10. RECONCILIATION OF WATER REQUIREMENTS AND AVAILABILITY

10.1 CURRENT YIELD BALANCE

The BRBS has improved on previous estimates of water availability and water requirements in the Breede catchment. This information will form the basis of the detailed water reconciliation strategies that will be developed as part of the DWAF ISP process. The current yield balance (Year 2000) in the Breede catchment is the departure point of these strategies, and is discussed in the remainder of this section. The yield balance is calculated by comparison of water availability at 98% assurance, with equivalent water requirements at 98% assurance.

Water Availability

The estimated available yield is shown in Table 10.1. The yield consists of surface and groundwater yields, estimated re-usable return flows, impacts on the yield due to water use by alien plants, provisional Reserve requirements, and estimates of river channel losses.

As mentioned in Section 7, acceptance of the classification assumptions and Reserve determinations done by the team of ecological scientists would greatly reduce the potentially exploitable water from the Breede River catchment. In terms of the present availability of water, investigations have shown that, with the exception of the Riviersonderend River, the recommended requirements could be met without impacting significantly on the availability of supplies. Should the provisional Reserve be implemented in the Riviersonderend River, it would result in an impact on the yield of the system of about 85 million m³/a (at 98% assurance). The provisional Reserve is based on the requirement that Category E systems (such as the Riviersonderend River) have to be restored to at least a Category D system, but to achieve this the shortfall would have to be replaced from other sources, and the cost would be very high. For the purposes of estimating the remaining water resources exploitation potential of the Breede River catchment, it was assumed that present day flows would not be further reduced in months when deficits occur, but that the present condition of the Riviersonderend River would not be upgraded. It is, however, essential that this aspect of RDM policy be reviewed, and that the implications associated with meeting this requirement be explored in the ISP and CMS strategy development process.

TABLE 10.1 : WATER AVAILABILITY IN THE BREEDE CATCHMENT (million m³/a, Year 2000)

SUB-AREA	SURFACE WATER	GROUND-WATER	USABLE RETURN FLOWS		IMPACT ON YIELD		LOCAL YIELD	TRANS-FERS IN	AVAILABLE YIELD (1:50 YEAR)
			IRRI-GATION	URBAN	RESERVE	ALIEN PLANTS			
UPPER BREEDE	432	94	74	12	(16)	(30)	566	0	566
RIVIER-SONDEREND	264	5	9	1	0*	(15)	264	24	288
LOWER BREEDE	61	4	7	0	0	(9)	63	13	76
TOTAL	757	103	90	13	(16)	(53)	894	37	930

* Assuming the Riviersonderend River will not be restored to a Category D River.

Water Requirements

Table 10.2 shows the sectoral water requirements within the Breede catchment at the Year 2000 level of development.

TABLE 10.2 : REQUIREMENTS IN THE BREEDE CATCHMENT (million m³/a, Year 2000)

SUB-AREA	IRRIGATION	URBAN	BULK INDUSTRIAL	RURAL	AFFORESTATION	RIVER LOSSES	LOCAL REQUIREMENTS	TRANSFERS OUT	TOTAL REQUIREMENT
UPPER BREEDE	495	23	0	4	0	5	527	22	549
RSE	91	2	0	2	1	0	96	192	288
LOWER BREEDE	72	1	0	1	0	0	74	0	74
TOTAL	658	26	0	7	1	5	697	214	911

Reconciliation of Requirements and Availability

Table 10.3. shows the yield balance for the Breede catchment at the Year 2000 level of development.

TABLE 10.3: COMPARISON OF REQUIREMENTS AND AVAILABILITY (million m³/a, Year 2000)

SUB-AREA	AVAILABLE WATER (1:50 YEAR)			WATER REQUIREMENTS (1:50 YEAR)			BALANCE
	LOCAL YIELD	TRANSFERS IN	TOTAL	LOCAL REQUIREMENTS	TRANSFERS OUT	TOTAL	
UPPER BREEDE	566	0	566	527	22	549	17
RIVIERSONDEREND	264	24	288	96	192	288	0
LOWER BREEDE	63	13	76	74	0	74	2
TOTAL	894	37	930	697	214	911	19

The surplus that is shown in the Upper Breede relates mainly to portions of the yields of the Koekedouw Dam near Ceres, and the Stettynskloof Dam in the Holsloot River. The small surplus in the Lower Breede is due to inflows from upstream, and also from some spare yield that is available from the Buffeljagts Dam near Swellendam. If the provisional Reserve for the Riviersonderend River were to be implemented, the overall surplus of 19 million m³/a would be reduced to a large deficit of about 66 million m³/a.

10.2 RECONCILIATION OF FUTURE WATER REQUIREMENTS AND AVAILABILITY

The future utilisation of the water resources of the Breede River catchment cannot be viewed in isolation and must be considered in the context of the Western Cape region as a whole. It is one of the recommendations of the BRBS that reconciliation of water requirements and water availability in the Breede and Berg WMAs be done as part of an integrated follow-up study. The BRBS has put in place much of the information that will be needed to, in the mean time, develop strategies for the local management and future use of the water resources of the Breede River

catchment itself. In doing so, it was necessary to at least develop some understanding of the wider regional issues that will affect future decisions on the sharing of water resources in the Western Cape. The following broad water use scenarios were identified, which could form a departure point for the reconciliation of future regional water requirements and water availability:-

- Urban demand growth is given priority (i.e. meeting future demands for water from the WCWSS and urban demands within the Breede River catchment).
- Development for resource poor farmers gets priority.
- Tourism and conservation are given strong emphasis.
- The existing irrigation sector continues to develop to a greater or lesser extent.
- Balanced development.

The agricultural development scenarios (prioritisation of developments for resource poor farmers, and commercial irrigated agriculture continues to develop) can conceivably be combined as one scenario – this being the most plausible way forward for the agricultural sector.

Reconciliation of future water requirements and availability in the Breede and Berg WMAs will have to be based on the relative benefits of water use by different sectors in the region, including the natural environment. Some considerations with regard to the reconciliation of future water requirements and water availability are outlined in the following sections.

Water Availability

Future water availability will be largely depend on the degree to which water use by invasive alien plants can be controlled on the one hand, and the levels at which the Reserve is eventually set. As previously mentioned, a possible maximum value of potential water supply remaining is about 140 million m³/a.

Future Water Requirements (2030)

It appears unlikely that Breede River irrigation demand will increase by more than 75 million m³/a in 2030. Allowing for an increase in urban water requirements of about 17 million m³/a, the total additional in-basin water requirement by the year 2030 could therefore be of the order of 90 million m³/a.

Reconciliation of Future Requirements and Availability

From the above, it appears that there may be an opportunity to enable a significant quantity of water (about 50 million m³/a) to be transferred from the Breede River catchment without impacting on in-basin water requirements prior to 2030. In reality, the water supply that would be required during final stages of agricultural growth is likely to come at a higher price than agriculture can afford. If no, or very little expansion of commercial irrigation is authorised, the upper limit for transfers could therefore be of the order of 90 million m³/a.

Possible Reconciliation Interventions

The effective implementation of WCDM measures is of prime importance, and should be the first intervention. BRBS estimates of future water requirements have already been reduced to account for the effect of WCDM.

The development of water supplies for irrigation is likely to facilitate provision of the relatively small quantities needed to augment the water supplies of the various towns in the Breede catchment.

Supplementary water supplies to meet future WCWSS demands (after the Berg Water Project) could be derived from several sources in and around the Berg WMA. Options within the Berg WMA would have advantages and should be considered first, but these local options would become more expensive as the more economical ones are developed and exploited. In the medium term future, transfers to the Berg WMA through the relatively inexpensive Michell's Pass diversion scheme (53 million m³/a) or even the Molenaars diversion scheme (27 million m³/a) could be developed ahead of more expensive schemes in the Berg WMA. In the longer term, the benefits of transfers from any area where surplus water may exist would be weighed against the cost of desalination.

The implementation of the Greater Brandvlei – Theewaterskloof – Berg WMA transfer scheme would virtually preclude sizeable irrigation developments that could be supplied from the augmented yield of Greater Brandvlei Dam. A limited time should be allowed for clarification of whether the Greater Brandvlei transfer scheme should be retained as an option.

Further investigations should be carried out to determine the best use of water from the raised Buffeljags Dam (irrigation development or supply of ecological water requirements in the Lower Breede River).

11. MANAGEMENT APPROACHES AND STRATEGIES

11.1 INTRODUCTION

The devolution of catchment management functions from DWAF to the future Breede River CMA will be a phased over a period of about ten years to match the establishment of capacity within the CMA. In the mean time, DWAF will have to take responsibility for and later assist with water resource management in the WMA. The Department's ISP process is intended to develop interim water resource management strategies to be followed by DWAF until such time as the CMA can take over with its own CMS. The baseline information provided by the BRBS should feed into this process, and presumably also into the eventual CMS. The following is an abbreviated list of the issues and broad management approaches that were identified in the BRBS:

11.2 THE RESERVE

The setting of ecological classes and the implementation of the Reserve could have a significant effect on the availability of water for other users. The BRBS assessments of water availability were based on the classifications and ecological water requirements (nearly 1000 million m³/a or, 53% of MAR) suggested by the ecological scientists on the study team. It is difficult, if not impossible to do meaningful planning without clear DWAF policy regarding the setting of the Reserve and its implementation. At present there are no precedents to go by. It is therefore important that ongoing progress be made in this regard, possibly by including policy statements on this issue in the second edition of the NWRs. Other issues that relate to the implementation of the Reserve in the Breede catchment include:

- The protocol for estuarine Reserve determination should be reviewed, and if possible, amended to introduce a flexible, iterative means of refining the estimates of ecological water requirements.
- Further studies should be undertaken to fully assess the potential impacts of future developments in the feeder rivers of the Papekuils Wetland, and to facilitate management of this wetland system. The possibility of mechanical intervention to rehabilitate the system by, for example, diverting flows from the main channel of the Breede River into the wetland, should be investigated. Further work should also be done to determine the volumetric quantities, seasonal distribution, and assurances of the ecological flow requirements that are associated with the frequencies and levels of inundation that were determined during the course of this study. The relative contributions of groundwater and surface water to these requirements should be quantified.
- The financial and socio-economic implications of restoring the Riviersonderend River to a Category D river should be explored. In a wider context, consideration should be given to the concept of identifying and balancing the distribution of localised "sacrificial" and "conservation-worthy" systems within a wider regional biosphere.

- Environmental monitoring should be implemented to evaluate the validity of the Reserve provision.
- With the exception of IFR Site 4 (in the Lower Breede River), all IFR Sites are located near a DWAF flow gauging station. These stations should form the basis of a compliance monitoring network that could be expanded to include other stations as the Reserves are extrapolated into the remainder of the catchment.
- The parallel application of the BBM and DRIFT methodologies in the Breede catchment has shown that DRIFT produces time series of riverine ecological water requirements that are more closely aligned with present day flows in the system than those produced with the BBM. The disparity between the two sets of estimates was most pronounced at the downstream end of the system (IFR Site 4), where the DRIFT sequence indicated that present flows in the system are sufficient to meet provisional Reserve Requirements, whereas the BBM sequence indicated a substantial shortfall of about 76 million m³/a.

11.3 YIELD BALANCES

According to study estimates, groundwater use in the Ceres catchment exceeds the available allocation in this area. Licensing of further surface and groundwater abstractions during the summer months should therefore be avoided. There may be further potential for groundwater use by means of artificial recharge of aquifers during the winter months, or abstractions from confined or deep aquifers, but this will have to be verified by means of further studies.

Water use in the catchment of the Theewaterskloof Dam, releases for downstream irrigators, and supplies to the Berg WMA via the tunnel system have taken up the maximum yield of the upper Riviersonderend catchment, and licensing of new water use in this catchment should also be restricted. Future water availability in the Riviersonderend catchment downstream of Theewaterskloof Dam will largely depend on the degree to which invasive alien plants can be eradicated in this area, as well as on the level of the Reserve that will be set for the river.

In the Hex River catchment, water resource developments have taken up the major portion of the potentially exploitable yield. Limited amounts of water could still be made available through groundwater developments, provided that these do not further reduce summer flows, or by means of storing surplus winter runoff.

Prior to commencement of the study, a number of transfer options from the Breede to the Berg WMA were investigated. The sizes of the transfers ranged up to 100 million m³/a. The investigations carried out for the BRBS have shown that some transfer of water to the Berg WMA would be acceptable from the Breede development perspective. Assessment of transfer options should be refined in an integrated regional water resource study. In the mean time, an element of conservatism should be built into decisions on water allocations for transfers.

The wide spread in the growth scenarios for Breede River irrigation is indicative of the uncertainties around the future of the sector. The risk associated with over-investment in

irrigation water supplies is therefore high. At the other extreme, the reservation of all the remaining water in the Breede catchment for future demands for water from the WCWSS would preclude its use for irrigation in the interim, and would entail substantial loss of opportunity. This issue should be further addressed in the Breede ISP, but it will only be possible to make final decisions on the allocation of water after more detailed further regional studies and comparisons.

11.4 RESOURCE POOR FARMERS

The development and support of resource poor farmers must receive highest priority. The large number of resource poor farmer developments in the Breede River catchment that have already been registered with the Department of Land Affairs indicate a substantial demand for the redressing of past inequities. It is essential that a strategy with clearly defined targets be put into place to guide this process. A development model that encourages support and skills transfer from existing commercial farmers could have many advantages in the long run. Incentives could be provided through a licensing policy that would limit (or at least favour) the issuing of new licenses for irrigation water use to joint partnerships between existing and emerging farmers.

11.5 WATER CONSERVATION AND DEMAND MANAGEMENT

Elimination or reduction of water use by invasive alien plants represents by far the most viable means of unlocking water resources for the benefit of the environment and future consumptive water needs in the catchment. Clearing efforts should be sustained, and if possible, intensified. There is also considerable scope for water savings in the irrigated agriculture and urban sectors, and the importance of establishing a WCDM culture in the catchment cannot be over-emphasised. Measures that should be implemented in the Breede catchment include:

- In towns where water shortages are being experienced or where shortages are imminent such as De Doorns, Bonnievale, and to a somewhat lesser extent Robertson, Ashton, Villiersdorp and Riviersonderend, the implementation of WCDM measures should receive priority attention.
- The yields of virtually all the existing irrigation water supply schemes in the catchment are fully committed. Farmers should be encouraged to use water more efficiently, thereby making water available for resource poor farmers or even for some limited expansion of existing operations, by implementing WCDM measures.
- Real-time monitoring systems should be installed at selected points on the Breede River, the Riviersonderend River, and on the major canal systems and pumping schemes to improve the efficiency of releases from dams.
- Water user databases maintained by Water User Associations (WUAs) must be modified to include information necessary for the successful implementation of WCDM measures.
- DWAF should promote the concept of managing irrigation water supply schemes on the basis of compulsory weekly demand projections, based on reliable soil moisture and crop water demand data.

- A workshop should be arranged to decide on, and adopt a set of benchmarks and benchmark values for efficient water use on irrigated crops. Such a workshop should include all role players in irrigated agriculture in the Breede WMA.
- The pilot study that was planned by DWAF for the testing of its Agricultural WCDM Implementation Guidelines in the Breede WMA should now be in order to gain a quantitative picture of the scope for WCDM in the area.
- Bulk water meters must, as a matter of urgency, be installed on all urban water supply schemes from which supplies are not currently measured. Meters should also be installed to record water consumption at zone level, and volumes recorded meticulously.
- Procedures for the comparison of bulk-metered consumption with the totals of individual water meters should be instituted to quantify "unaccounted for water" and system losses in urban water supply systems.
- Municipalities should be encouraged to implement structured water tariff systems that will promote the efficient use of water. This should be supplemented by informative billing to empower water users to improve their own water use efficiencies.
- A programme to educate local government water services officials and councillors on the need for, and importance of the implementation of WCDM measures should be initiated as a matter of urgency.
- Municipalities should be required to record and report on the per capita and per household water consumption in the water use zones in their respective service areas. This will provide a measure of progress made with the implementation of WCDM, and will also assist in the identification of areas that should receive priority attention.

11.6 WATER QUALITY

In the past, the general water quality in the Breede River catchment was not considered to be a major concern, except for the rising salinity in the Middle Breede River and its tributaries. The occurrence of algal blooms under low flow conditions at certain locations within the Middle Breede River, clogging of canals by filamentous algae and aquatic weed, and point pollution from, in particular, distilleries, cheese factories, and textile factories have been identified as additional problems. Several measures to improve water quality were investigated, leading to the following recommendations:

- Management strategies for the application of fertilisers should be developed and implemented to reduce nitrogen and phosphorus loads in rivers.
- Very little information on the occurrence of algal blooms in the catchment exists, and a reporting system for water bailiffs should be initiated to quantify the extent of these occurrences.
- For the purposes of improving crop quality and yields in the Middle Breede River, the possibility of lowering the target salinity limits at the Zanddrift canal offtake in certain months should be considered.
- Meaningful short-term salinity alleviation could be achieved through the construction of return flow interceptor drains, combined with the freshening release strategy. Further

detailed investigations should be carried out to optimise and cost this option, taking into account the current salinity profile in the Breede River between Robertson and Bonnievale, and making use of detailed soil surveys that are available for this area.

- Further development of irrigation in areas producing highly saline return flows should be actively discouraged. It is recommended that, based on the soils investigations carried out for this study, these areas be demarcated on a map, and that the future CMA make use of regulatory and financial instruments at its disposal to influence further irrigation development in the demarcated areas. These measures could include the conditional approval of new water use licenses, penalties for offences in terms of water use regulations or licensing conditions, and a pricing strategy that would allow for an increased price of water in demarcated areas.

12. THE WAY FORWARD

The study has highlighted the need for the development of a strategy for the integrated management of the water resources of the Breede River catchment, together with those of the Berg River catchment. The strategy development process will be initiated through the Department's Internal Strategic Perspectives (ISP) process, which is intended to develop interim water resource management strategies to be applied by DWAF until such time as the CMA can take over.

The study provides much of the information that would be needed to inform the strategy about the local development of the water resources of the Breede River and about possible transfers. However, the following additional information would among others be needed to develop compatible catchment management strategies for the Berg and Breede WMAs:

- Assessment of the economic and social benefits of water usage for irrigation in the Breede WMA, and comparison of these with the benefits associated with transferring water to the Berg WMA. This information is required to inform decisions on possible eventual transfers.
- Evaluation, comparison and prioritisation of options for the further development of water supplies to meet the needs of the Berg WMA, in order to give the transfer options (especially the Michell's Pass and Molenaars diversion schemes) their correct positions in an implementation schedule.

Setting the Reserve for the Breede River and its tributaries in order to clarify the potential for the further development of the water resources. It is suggested that this should include a review of the RDM policy to take into consideration the concept of localised "sacrificial" and "conservation-worthy" sub-systems. Thereafter, a public participation process taking account of both the impacts of further abstractions on the environment as well as the benefits of further developments, will be needed.

13. RECOMMENDATIONS

The main recommendations of the Study that have been discussed in the body of this Report, are summarised here for ease of reference. These suggested recommendations should be considered further in the Breede WMA ISP process.

	REFER TO SECTION
1. The protocol for estuarine Reserve determination should be reviewed, and if possible, amended to introduce a flexible, iterative means of refining the estimates of ecological flow requirements.	3.7
2. Further studies should be undertaken to fully assess the potential impacts of future developments in the feeder rivers of the Papenkuils Wetland, and to facilitate management of the system. The possibility of mechanical intervention to rehabilitate the system by, for example, diverting flows from the main channel of the Breede River into the wetland, should also be investigated. Further work should also be done to determine the volumetric quantities, seasonal distribution, and assurances of the ecological flow requirements that are associated with the frequencies and levels of inundation that were determined during the course of this Study. The relative contributions of groundwater and surface water to these requirements should also be quantified.	3.8.4
3. The financial and socio-economic implications of restoring the Riviersonderend River to a Category D river should be explored. In a wider context, consideration should be given to the concept of identifying and balancing the distribution of localised "sacrificial" and "conservation-worthy" systems within a wider regional biosphere.	3.8.4
4. Environmental monitoring should be implemented to evaluate the validity of Reserve provision.	3.8
5. The possibility of limiting the issuing of new licences in the Ceres catchment and in the catchments of the Upper Breede River to periods of surplus should be considered.	3.8
6. According to study estimates, groundwater use in the Ceres catchment exceeds the available allocation in this area. The potential impacts of proposed groundwater schemes on river flows should therefore be investigated prior to the approval of licenses for such schemes.	3.8

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| 7. | With the exception of the IFR Site 4 (in the Lower Breede River), all IFR Sites are located near a DWAF flow gauging station. These stations should form the basis of a compliance monitoring network that could be expanded to include other stations as the Reserves are extrapolated into the remainder of the catchment. | 3.8 |
| 8. | For environmental monitoring purposes, correlations will have to be established between the flows measured at stations H7H006 (Swellendam) and H7H013 (Buffeljags River), and flows at the head of the Estuary. | 3.8 |
| 9. | The towns of Robertson, Ashton, Villiersdorp and Riviersonderend will have to start planning for increased water supplies in the near future. In towns where water shortages are being experienced or where shortages are imminent such as De Doorns and Bonnievale, the implementation of WCDM measures should receive priority attention. | 4. |
| 10. | There is a need for a programme to educate, train and support resource poor farmers in the catchment. An implementing agent (perhaps a NGO) would be required to drive such a programme, to assist new farmers, and to facilitate access to available support. | 5.4 |
| 11. | The suitability of flow measuring devices developed for Water Research Commission projects to local conditions should be tested at pilot sites in the Breede River catchment. | 6.2 |
| 12. | Real-time monitoring systems should be installed at selected points on the Breede River, the Riviersonderend River, and on the major canal systems and pumping schemes to improve the efficiency of releases from dams.. | 6.2 |
| 13. | Water user databases maintained by Water User Associations (WUAs) must be modified to include information necessary for the successful implementation of WCDM measures. | 6.2 |
| 14. | The Department of Water Affairs and Forestry should promote the concept of managing irrigation water supply schemes on the basis of compulsory weekly demand projections, based on reliable soil moisture and crop water demand data. | 6.2 |

**REFER TO
SECTION**

15. The yields of virtually all the existing irrigation water supply schemes in the catchment are fully committed, and water users should be encouraged to "create" water for new developments and for expansion of existing operations by implementing WCDM measures on existing farms. 6.2
16. A workshop should be arranged to decide on, and to adopt a set of benchmarks and benchmark values for efficient water use on irrigated crops. Such a workshop should include all role players in irrigated agriculture in the Breede WMA. 6.2
17. The pilot study that was planned for the testing of the Department of Water Affairs and Forestry's Agricultural WCDM Implementation Guidelines in the Breede WMA should be undertaken as a matter of urgency in order to gain a quantitative picture of the scope for WCDM in the area. 6.2
18. Bulk water meters must, as a matter of urgency, be installed on all urban water supply schemes from which supplies are not currently measured. Meters should also be installed to record water consumption at zone level, and volumes recorded meticulously. 6.3
19. Procedures for the comparison of bulk metered consumption and the totals of individual water meters, should be instituted to quantify "unaccounted for water" and system losses in urban water supply systems. 6.3
20. Municipalities should be encouraged to implement structured water tariff systems that will promote the efficient use of water. This should be supplemented by informative billing to empower water users to improve their own water use efficiencies. 6.3
21. A programme to educate local government water services officials and councillors on the need for, and importance of the implementation of WCDM measures should be initiated as a matter of urgency. 6.3
22. Municipalities should be required to record and report on the per capita and per household water consumption in the water use zones in their respective service areas. This will provide a measure of progress made with the implementation of WCDM, and will also assist in the identification of areas that should receive priority attention. 6.3

**REFER TO
SECTION**

23. Elimination or reduction of water use by invasive alien vegetation represents by far the most beneficial means of unlocking water resources for the benefit of the environment and future consumptive water needs in the catchment. Clearing efforts should be sustained, and if possible, intensified. 6.4
24. Management strategies for the application of fertilisers should be implemented to reduce nitrogen and phosphorus loads in rivers. 7.1.2
25. Very little information on the occurrence of algal blooms in the catchment exists, and a reporting system for water bailiffs should be initiated to quantify the extent of these occurrences. 7.1.2
26. For the purposes of improving crop quality and yield in the Middle Breede River, the possibility of lowering the target salinity limits at the Zanddrift canal offtake in certain months should be considered. 7.1.2
27. Future groundwater exploitation, especially for any large-scale schemes, could be located on the alluvial, Bokkeveld or TMG aquifers of the western part of the catchment. Abstraction schemes in the eastern half of the catchment would have to exploit the TMG aquifers, since the water of other aquifers is generally too saline for irrigation. 7.2
28. Meaningful short-term salinity alleviation could be achieved through the construction of return flow interceptor drains, combined with the freshening release strategy. Further detailed investigations should be carried out to optimise and cost this option, taking into account the current salinity profile in the Breede River between Robertson and Bonnievale, and making use of detailed soil surveys that are available for this area. 8.6
29. Further development of irrigation in areas producing highly saline return flows should be actively discouraged. It is recommended that, based on the soils investigations carried out for this study, these areas be demarcated on a map, and that the Catchment Management Agency make use of regulatory and financial instruments at its disposal to influence further irrigation development in the demarcated areas. These measures could include the conditional approval of new water use licenses; penalties for offences in terms of water use regulations or licensing conditions, and a pricing strategy that would allow for an increased price of water in demarcated areas. 8.6

**REFER TO
SECTION**

30. The Water Resources Yield Model of the Breede River catchment has not been linked to the Model that has been developed for the Western Cape System. The yields of transfer schemes that were determined in the BRBS are therefore approximations of the true yield benefit to the Western Cape System. The two system models should be linked to obtain the true marginal yields of transfer schemes to be taken into feasibility studies. 8.10
31. Further investigations should be carried out to define the configuration of components of the Molenaars and Michell's Pass transfer schemes that would be required outside the Breede River catchment, and to evaluate the costs and impacts associated with these. 8.10
32. The implementation of the Greater Brandvlei – Theewaterskloof – Berg WMA transfer scheme would virtually preclude sizeable irrigation developments that could be supplied from the augmented yield of Greater Brandvlei Dam. A limited time should be allowed for clarification of whether the Greater Brandvlei transfer scheme should be retained as an option. Alternatively, it may be considered that sufficient information has already been assembled to rule it out. 8.11
33. The continuing incremental development of irrigated agriculture through the expansion of existing farms and the establishment of new schemes supplied from small, local water resources developments will benefit the economy of the region. Provided that these developments are shown to be economically viable, and to embrace the concepts of WCDM, licensing of water use should not be unnecessarily constrained. 8.11
34. Further investigations should be carried out to determine the best use of water from the augmented yield of Greater Brandvlei Dam (various irrigation developments), and from the raised Buffeljags Dam (irrigation development or management of ecological flow requirements in the Lower Breede River). 8.11
35. The Water Allocation Model that was developed as part of the study, has a number of limitations in its present form. These include the way that it deals with the Reserve, and inefficiencies in the economy. To realise its full potential as a decision support tool, these limitations should be addressed, and input data must be sourced for the Palmiet catchment and Berg WMA, ideally as a research project. 9.3.1

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Appendix A

**Reports of Previous Studies
in the Breede River Catchment**

A - 1

REPORT NO.	YEAR	TITLE	AUTHOR INSTITUTION	AUTHOR INDIVIDUALS	LANGUAGE	STUDY ASPECT	COMMENTS	AVAILABILITY
PH000/00/0192	May-95	Breede River Hydrological Study and System Analysis: Terms of Reference	DWAF: Directorate of Project Planning	A.P. Van der Merwe G.J. Grisp P.D. Pyke P.H. van Niekerk	English	Water Resources Land-Use and Agriculture Environment General	The report describes the tasks to be performed and the objectives of the BRHS & BRSA	Ninham Shand library
PH000/00/0292	Jun-95	Breede River Hydrological Study: Evaluation and Calibration of Gauging Stations	Ninham Shand Consulting Engineers	G.R.Basson	English	Water Resources	Series of 5 volume reports on the calibration and evaluation of flow gauging stations in the Breede River catchment.	Ninham Shand library
PH000/00/0392	Jun-95	Breede River Hydrological Study: Procedure for the Evaluation of Farm Dams	DWAF: Directorate of Project Planning	A.P. van der Merwe G.J. Grisp P.D. Pyke P.H. van Niekerk F.J. Joubert	English	Water Resources Land-Use and Agriculture	Data and methodology followed to estimate the full supply level, full supply capacity and area capacity characteristic curves for farm dams within Breede River catchment can be obtained from the report	Ninham Shand library
PH000/00/0492	May-95	Breede River Hydrological Study: Climate Conditions of H1, H2, H3, H4 and H5	DWAF: Directorate of Project Planning	F.P. Cornelius J.M.Stassen P.D. Pyke P.H. van Niekerk	English	Water Resources	Two reports (Vol. I & II). Volume I is a text which describe the methods of acquiring rainfall and evaporation data, the calculation of catchment rainfall and patching of missing data. Volume II is appendices document for the presentation of the results.	Ninham Shand library
PH000/00/0592	Apr-95	Breede River Hydrological Study: Assessment of Irrigation, Afforestation and Municipal Water Demands	DWAF: Directorate of Project Planning	A.P. van der Merwe G.J. Grisp P.D. Pyke P.H. van Niekerk F.J. Joubert	English	Land-Use and Agriculture Water Resources Group	The report describes the procedure used to determine the historical irrigation, urban and afforestation water demands for the BRHS.	Ninham Shand library
H000/00/0690	Jun-90	DISA User's Guide	Ninham Shand Consulting Engineers	J.Beuster A.Gorgens A.J. Greyling	English	Water Quality Group Environmental Group Land-Use and Agriculture Group	It is a user guide of the Daily Irrigation Hydro- salinity model (DISA).	Ninham Shand library
H000/00/0790	Jul-90	Breede River System: Development of Daily Hydrosalinity Model (DISA)	Ninham Shand Consulting Engineers	J.Beuster A.Gorgens A.J. Greyling	English	Water Quality Group Environmental Group Land-Use and Agriculture Group	The model was initially developed and utilized for the Middle Breede River.	Ninham Shand library
PH000/00/0792	May-95	Breede River Hydrological Study : Description of Water Infrastructure and Operating Rules	DWAF: Directorate of Project Planning	A.P. van der Merwe G.J. Grisp P.D. Pyke P.H. van Niekerk F.J. Joubert	Afrikaans	Water Resources Group Land-Use and Agriculture Group Environment Group	The report provides a description of the existing water supply infrastructure in the Breede River catchment, and describes in broad outline the water users and the operating rules used.	
PH000/00/0892	May-95	Breede River Hydrological Study Hydrological Investigation: Calibration and Flow Generation	DWAF: Directorate of Hydrology	F.P. Cornelius J.M.Stassen P.D. Pyke P.H. van Niekerk	English	Water Resources Group	Two Reports (Vol. I & II). They describe the process of streamflow generation for the Upper and Middle Breede River catchments. Vol. I is a text documents showing the methods of model calibration and verification. Vol II shows the results in a form of appendices.	Ninham Shand library
NH000//RIQ0888	Jun-88	Breede River Salination Program (BRSRP) 1st Internal Report on the Salinity of the Breede River and its Tributaries between Brandvlei Dam and H5M04.	DWAF: Hydrological Research Institute.	S.W. Kienzle W.A. Flugel	English	Land-Use and Agriculture Group Water Resources Group	Summary of daily data up to September 1987	
NH400//GIQ/1088	Jul-88	Breede River Salination Program (BRSRP) : 2nd Internal Report. Soil Salination and Associated Shallow Groundwater Dynamics of the Alluvial Robertson Irrigation Scheme.	DWAF: Hydrological Research Institute.	S. Volkman W.A. Flugel	English	Land-Use and Agriculture Group Water Resources Group		
NH000//RIQ0589	Mar-89	Breede River Salination Program (BRSRP) 3rd Internal Report on the Salinity of the Breede River and its Tributaries between Brandvlei Dam and H5M04.	DWAF: Hydrological Research Institute.	S.W. Kienzle	English	Land-Use and Agriculture Group Water Resources Group	Summary of daily data for the hydrological year 1987/88	

REPORT NO.	YEAR	TITLE	AUTHOR INSTITUTION	AUTHOR INDIVIDUALS	LANGUAGE	STUDY ASPECT	COMMENTS	AVAILABILITY
NH000/RIQ0590	Jun-90	Breede River Salination Program (BRSRP) : 7th Internal Report . Hydro-Chemistry of Surface Water in the Upper and Middle Parts of the Breede River Catchment	DWAF: Hydrological Research Institute.	S.W. Kienzle	English	Water Resources Group Environment Group	Part 1. Presentation of Hydrochemical Data	
NH000/RIQ0390	Mar-90	Breede River Salination Program (BRSRP) : 5th Internal Report on the Salinity of the Breede River and its Tributaries between Brandvlei Dam and H5M04.	DWAF: Hydrological Research Institute.	S.W. Kienzle	English	Land-Use and Agriculture Group Water Resources Group	Summary of daily data for the hydrological year 1988/89.	
NH000/RIQ1390	Jul-90	Breede River Salination Program (BRSRP) : 8th Internal Report on the Salinity of the Breede River and its Tributaries between Brandvlei Dam and H5M04.	DWAF: Hydrological Research Institute.	S.W. Kienzle	English	Land-Use and Agriculture Group Water Resources Group	Summary of daily data for the hydrological year 1989/90	
PH000/00/0588	Oct-88	Hydrosalinity Modelling of the Breede River	DWAF: Directorate of Project Planning	A.M. Schreuder S.F. Forester H.A. Smit P.H. Van Niekerk	English	Land-Use and Agriculture Group Water Resources Group	Planning Options for the Breede River	
PH000/00/0488	Oct-88	Hydrosalinity Modelling of the Breede River	DWAF: Directorate of Project Planning	A.M. Schreuder S.F. Forester H.A. Smit P.H. Van Niekerk	English	Land-Use and Agriculture Group Water Resources Group	Available Data	
PH000/00/0388	Apr-88	Hydrosalinity Modelling of the Breede River	DWAF: Directorate of Project Planning	A.M. Schreuder S.F. Forester H.A. Smit P.H. Van Niekerk	English	Land-Use and Agriculture Group Water Resources Group	Technical Description of the Greater Brandvlei Dam Government Water Scheme	
H000/00/0890	Jul-90	Breede River System: DISA Salinity Predictions for Various Planning Scenarios	Ninham Shand Consulting Engineers	J.Beuster A.H.M Gorgens A.J. Greyling	English	Land-Use and Agriculture Group Environmental Group	The DISA model was implemented to evaluate a number of planning options for the Breede River between Greater Brandvlei Dam and Zanddrift to predict the potential effect on future salinity patterns.	Ninham Shand library
PH 100/00/0690	Oct-90	Preliminary Report on the Need for a Dam on the Molenaars River	Ninham Shand Consulting Engineers	C.A. Carter R. Blackhurst	English	Schemes Development Group Hydrology and System Analysis Group	The report provides a review of proposal to augment the supply to greater Cape Town through three alternative schemes. One of the proposed schemes is to build a dam on the Molenaars River. The results of scheme evaluations show that it is unnecessary to reserve the site for a large dam which might not be cost-effective and feasible.	Ninham Shand library
H400/00/0190	Jun-90	Nuy River Irrigation Board: Yield Analysis of Keerom Dam	Ninham Shand Consulting Engineers	A.J. Shelly	English	Yield Analysis and Hydrology Group Land-Use and Agriculture Group	The report aimed to evaluate the firm yield from the dam before and after raising the wall of the dam. The dam was used to serve the Nuy irrigation board	Ninham Shand library
White Paper W.P.J-' 72	Jun-72	Report on the Proposed Greater Brandvlei Dam Government Water Scheme Prepared in Terms of Section 58 of the Water Act, 1956 (Act 54 of 1956)	DWAF: Secretary for Water Affairs	J.P. Kriel	English	Schemes Development Group	The report gives consolidated description of the proposed scheme together with design details cost estimates, financial and time completion of the project.	Ninham Shand library
White Paper	Mar-81	Supplementary Report on the Proposed	DWAF: Director-General of Water Affairs	J.F. Otto	English	Schemes Development Group	The report prepared in the light of cost increases	Ninham Shand library
W.P.M-' 81		Greater Brandvlei Government Water Scheme : Prepared in Terms of Section 58 of the Water Act, 1956 (Act 54 of 1956)	Forestry and environmental Conservation				of the already approved schemes of greater Brandvlei dam described in White Paper W.P.J - ' 72.	
P H000/00/0286	Feb-86	Hydro-salinity modelling of the Breede River: Review and future strategy	DWAF: Directorate of Planning and Hydrological Research	S.F. Forester H.A. Smit C. Triebel	English	Land-Use and Agriculture Group Water Quality Group	The Report describes the state-of-knowledge concerning irrigation and river salination in the upper Breede river up to its point of confluence with the Riviersonderend.	Ninham Shand BRBS library Contact person : Julie Phone : (021)4245544

REPORT NO.	YEAR	TITLE	AUTHOR INSTITUTION	AUTHOR INDIVIDUALS	LANGUAGE	STUDY ASPECT	COMMENTS	AVAILABILITY
								(on loan from Gerrit van Zyl)
1966-0161	Feb-66	First geological report on the Koekedouw Dam Site in the Koekedouw River, Ceres	Department of Mineral and Energy Affairs	H.N. Visser	English	Geology/Groundwater Group Schemes Development Group	It is an investigative geological report aimed at examining the possibilities of increasing the height of the existing dam site or building a larger dam immediately downstream.	Ninham Shand BRBS library Contact person : Julie Phone : (021)4245544 (on loan from Gerrit van Zyl)
1976-0359	Sep-76	Brede River Development Scheme; Koekedouw Upper Dam Site - Ceres	Department of Mineral and Energy Affairs	A.Dick	English	Schemes Development Group Geology/Groundwater Group	It is an investigative planning report of preliminary nature, intended to assist cost estimate and construction material needed as well as foundation conditions.	Ninham Shand BRBS library Contact person : Julie Phone : (021)4245544 (on loan from Gerrit van Zyl)
442/3029	Apr-77	Report on the Augmentation of the Stettynskloof Water Supply Scheme	Ninham Shand Inc. Consulting Engineers	Unspecified	English	Scheme Development Group Water Demand and Hydrology Group	It is an investigative report carried to augment the supply to Worcester from the existing Stettynskloof water scheme	Ninham Shand BRBS library Contact person : Julie Phone : (021)4245544 (on loan from Gerrit van Zyl)
P0850/01/0178	Mar-78	Boesmansrivierskema Vergelyking tussen 'n alternative pomp en damskeema vir die Boesmansrivier-besproeiingsdistrik (Robertson)	DWAF : Directorate of Project Planning	F.C. Koek P.F. Pretorius T.P.C. Robbroeck	Afrikaans	Engineering Costing/Evaluation Group Land-Use and Agricultural Group	The report compares two proposal options for expanding the irrigation supply to the Boesmans irrigation boards.	Ninham Shand BRBS library Contact person : Julie Phone : (021)4245544 (on loan from Gerrit van Zyl)
P0850/01/076	Sep-76	Boesmans River Irrigation Board Report and Recommendation on Alternative Pump or Storage Scheme	DWAF: Directorate of Project Planning	A. Bekker H. Muller J. de Kock	English/Afrikaans	Land-Use and Agricultural Group Engineering Costing/Evaluation Group Water Demand and Hydrology Group	The report compares two proposal options for expanding the irrigation supply to the Boesmans irrigation boards. The methods of evaluation followed in the report based on cost - effectiveness and sustainability of the supply during dry periods.	Ninham Shand BRBS library Contact person : Julie Phone : (021)4245544 (on loan from Gerrit van Zyl)
Unspecified	Aug-86	Sanddrift State Water Scheme: System Analysis of Rode Elsberg and Lakenvallei Dam	DWAF: Directorate of Hydrology	K. Moore	English	Hydrology and System Analysis Group	Stochastic analysis and determination of system yield.	Ninham Shand BRBS library contact person : Julie phone : (021)4245544 (on loan from Gerrit van Zyl)
PH200/00/0186	Aug-86	Sanddriftrivier-Staatswaterskema Onderzoek na Moontlikhede om Meer Aanvullende Besproeiingswater aan die Bo-Hexriviervallei Beskikbaar te Stel	DWAF: Directorate of Hydrology	S.T. Muller G. van Zyl H.A. Smit C. Triebel	Afrikaans	Water Resources Group	Investigation report on the possibility of providing more surplus water to the Hex river valley.	
PG 400	Dec-88	Cost of Transferring Water by Pump and Pipeline from Kwaggaskloof Dam to Theewaterskloof Dam	DWAF: Directorate of Project Planning	C.J.Littlewort H.A.Smit P.J. van Niekerk	English	Engineering Costing/Evaluation Group Schemes Development Group	The basic objective of the report is to provide some cost estimate for the proposed scheme of pumping water from Kwaggaskloof to the Theewaterskloof dam. Some design parameters and calculation procedures are also presented in the Report	Ninham Shand BRBS library Contact person : Julie Phone : (021)4245544 (on loan from Gerrit van Zyl)
1358/3668	Nov-87	Verslag oor Voorgestelde Pomskeema vir Besproeiingswater uit Groter Brandvlei	Ninham Shand Inc. Consulting Engineers	Unspecified	Afrikaans	Land-Use and Agriculture Group	Description of the proposed pumping scheme for the Worcester-East Water Board Irrigation Design Report	Ninham Shand BRBS library Contact person : Julie Phone : (021)4245544 (on loan from Gerrit van Zyl)
708/3668	Jan-82	Bepanningsverslag oor die Voorgestelde Pomskeema vir Besproeiingswater uit Groter-Brandvleidam	Ninham Shand Inc. Consulting Engineers	Unspecified	Afrikaans	Land-Use and Agriculture Group	Description of the proposed pumping scheme for the Worcester-East Water Board Irrigation Planning Report	Ninham Shand BRBS library Contact person : Julie Phone : (021)4245544 (on loan from Gerrit van Zyl)
1331B	Jul-83	Loodsondersoek na die Lewensvatbaarheid van die voorgestelde watervoorsieningskema vir Worcester oos Besproeiingsdistrik	Ninham Shand Inc. Agriplan J.J.N. Lambrechts	Unspecified	Afrikaans	Land-Use and Agriculture Group	Feasibility of the proposed pumping scheme for the Worcester-East Water Board Irrigation Pilot Investigation	Ninham Shand BRBS library Contact person : Julie Phone : (021)4245544 (on loan from Gerrit van Zyl)
820/75/1	Unspecified	Hex River Valley: Supplementary Water Supply	DWAF: Directorate of Project Planning	J.H. Potgieter	Afrikaans	Land-Use and Agriculture Group Engineering Costing/Evaluation Group	The report evaluates four proposal options for supplementing the irrigation water to the Hex River Valley. It is a summary report for Report 820/2 Vol. 1	Ninham Shand BRBS library Contact person : Julie Phone : (021)4245544 (on loan from Gerrit van Zyl)
Unspecified	Sep-81	An Investigation of the Water Requirements of Eleven Municipalities in the Upper Half of	DWAF: Directorate of Planning	D.A. Lynch	English	Land-Use and Agriculture Group	The report presents the findings of an investigation into the water requirements of the eleven largest municipalities in the Breede River catchment	Ninham Shand BRBS library Contact person : Julie Phone : (021)4245544

REPORT NO.	YEAR	TITLE	AUTHOR INSTITUTION	AUTHOR INDIVIDUALS	LANGUAGE	STUDY ASPECT	COMMENTS	AVAILABILITY
		the Breede River Catchment						(on loan from Gerrit van Zyl)
PG100/00/1096	Feb-96	The Riviersonderend: Situation Assessment with Specific Reference to the Effect of Theewaterskloof Dam on the Riverine Ecosystem	Southern Waters Ecological Research and Consulting CC.	G.Ractliffe K. Snaddon C. Brown	English	Environmental Group (EFR)	Study aimed to provide a preliminary ecological assessment of the possible impact that may accompany a reduction or alteration in the hydrological regime of the river, which could result from the rising of Theewaterskloof Dam.	
EH7 00/00/0188	Sep-88	Situation Report on the Water Quality Problem at the Bontebok National Park in the Breede River Catchment	DWAF: Scientific Services Directorate of Pollution Control	A.M. Schreuder S.F. Forster	English	Water Quality Group	Water Quality Management Report	
H000/RIH/0387	Dec-87	Mapping the Extent of Irrigated Land in the Breede River Catchment with the Aid of Satellite Imagery	DWAF: Directorate of Scientific Services Hydrological Research Institute	U. Lourens B. Brown A. Seed	English	Land-Use and Agriculture Group	A method of clustering and classification is used to map areas under irrigation. An area of 2000 ha in the vicinity of Robertson was taken as a representative sample of agriculture in the catchment as a whole.	
77/04283/21	Mar-88	A Pilot Study of the Irrigated Areas Served by the Breede River (Robertson) Irrigation Canal	Murray Biesenbach & Badenhorst Consulting Agricultural & Civil Engineers	Unspecified	English	Land-Use and Agriculture Group	Technical Report submitted to and funded by the Water Research Commission	
H100/00/019	Nov-91	Prognosis of the relevant environmental Impacts of the Ouplaas Dam	DWAF: Directorate of Design Services	M.D. Louw	English	Environmental Group	Preliminary EIA of Ouplaas Dam	
H100/00/0194	Jun-94	Michell's Pass Diversion	DWAF: Directorate of Design Services Sub-directorate of Environmental Studies	M.D. Louw	English	Environmental Group	Preliminary EIA of Michell's Pass Dam Diversion Scheme	
P0810/08/0178	Jun-78	Groter-Brandvlei Dam: Ondersoek na die moontlikheid dat die huidige dam ook water aan die Klaasvoogdrivier -Hoofbesproeiingsraad kan voorsien	DWAF: Directorate of Planning	F.C. de Kock P.F. Pretorius T.P.C. Van Robbroeck	Afrikaans	Land-Use and Agriculture Group Water Resources Group	The report investigates the possibility that the greater Brandvlei Dam can also supply water to the Klaasvoogdsriver- Head Irrigation Board	
P0810/08/0276	Nov-76	Groter-Brandvlei Dam: Holsloot - Smalblaar Toevoerkanaal. Verslag oor die Ekonomiese Vergelyking Tussen Die Hoevlak- En Laevlak-toevoerkanale	DWAF: Directorate of Planning	F.C. De Kock	Afrikaans	Engineering Costing/Evaluation Group Land-Use and Agriculture Group	The report provide economic comparisons for two options aimed to optimise the carrying capacity of the inlet channel diverting water from Holsloot and Smalblaar rivers to Brandvlei dam. (Interim Report)	
P0810/08/0277	Mar-77	Groter-Brandvleidam: Holsloot - Smalblaar Toevoerkanaal. Verslag oor die Ekonomiese Vergelyking Tussen Die Hoevlak- En Laevlak-toevoerkanale	DWAF: Directorate of Planning	F.C. De Kock P.F. Pretorius T.P.C. Van Robbroeck	Afrikaans	Engineering Costing/Evaluation Group Land-Use and Agriculture Group	The report provides economic comparisons for two options aimed at optimising the carrying capacity of the inlet channel diverting water from Holsloot and Smalblaar rivers to Brandvlei dam. (Final Report)	Ninham Shand BRBS library Contact person : Julie Phone : (021)4245544 (on loan from Gerrit van Zyl)
445/2902	Mar-77	Verslag oor die Voorgestelde Verbetering en Uitbreiding van die Waterskema	Ninham Shand Inc. Consulting Engineers	Unspecified	Afrikaans	Water Resources Group	The report investigates the possibility of upgrading the existing water supply scheme of Montague Municipality.	Ninham Shand BRBS library Contact person : Julie Phone : (021)4245544 (on loan from Gerrit van Zyl)
PH000/00/0181	Sep-81	Breerivier Ontwikkeling: 'n Voorgestelde Langtermyn Waterplan	DWAF: Directorate of Planning	P.F. Pretorius C. Triebel	Afrikaans	All Groups	The report gives a proposal for long term planning of water supply to the Breeriver Valley	Ninham Shand BRBS library Contact person : Julie Phone : (021)4245544 (on loan from Gerrit van Zyl)
PG100/06/0385	Apr-85	The Lower-Berg River System Computer Program	DWAF: Directorate of Planning	Unspecified	Afrikaans	Water Resources Group	Three volumes: Volume 2 : The proposed Voelvlei Scheme excluding the Berg River Volume 3: the proposed Voelvlei Scheme including Berg River Volume 1: Appendices	Ninham Shand BRBS library Contact person : Julie Phone : (021)4245544 (on loan from Gerrit van Zyl)
P810/08/0181	Sep-81	Greater Brandvlei Scheme Geraamde Toekomstige Waterbehoefes en die Lewerings-Potensiaal van die Skema	DWAF: Directorate of Planning	F.C. De Kock P.F. Pretorius C. Triebel	Afrikaans	Water Resources Group Water Demands Group	Estimated future water demands and the supply potential of the greater Brandvlei scheme	Ninham Shand BRBS library Contact person : Julie Phone : (021)4245544 (on loan from Gerrit van Zyl)

REPORT NO.	YEAR	TITLE	AUTHOR INSTITUTION	AUTHOR INDIVIDUALS	LANGUAGE	STUDY ASPECT	COMMENTS	AVAILABILITY
P0810/01/0179	Jan-79	Upper Breede River Catchment Study of water Supply from the Greater Brandvlei Dam	DWAF: Directorate of Planning	D. Basson P.F. Pretorius F.C. Kock T.P.C van Robbroeck	Afrikaans	Land-Use and Agriculture Group Water Resources Group	The study compares two irrigation schemes for the Upper Breede River Catchment between Michell's Pass and Worcester in the Tulbagh area	Ninham Shand BRBS library Contact person : Julie Phone : (021)4245544 (on loan from Gerrit van Zyl)
Unspecified	Dec-84	Hydrological Investigation of the Runoff from the Koekedouw River Catchment in the District of Ceres	DWAF: Directorate of Planning Division of Hydrology	K. Moore	English	Hydrology and System Analysis Group	Hydrology/yield analysis at Ceres Dam:HIR03 Hydrology and yield analysis for two proposed dam sites.	Ninham Shand BRBS library Contact person : Julie Phone : (021)4245544 (on loan from Gerrit van Zyl)
Unspecified	Feb-82	Hydrology of Wit River in Bainskloof	DWAF: Directorate of Planning Division of Hydrology	L. de. Kock	Afrikaans	Hydrology and System Analysis Group		Ninham Shand BRBS library Contact person : Julie Phone : (021)4245544 (on loan from Gerrit van Zyl)
P0810/01/0177	Sep-77	Bo-Breerivierontwikkeling: Ondersoek na Watervoorsiening Uit Dwarsrivier Michell'spas Dam En Kanale	DWAF: Directorate of Planning	Unspecified	Afrikaans	Water Resources Group Land-Use and Agriculture Group	Investigation into water supply from Dwarsrivier Michell's Pass Dam and Canal	
P0810/01/0279	May-79	Bo-Breerivierontwikkeling: Ondersoek na 'n Waterskema vir Besproeiing	DWAF: Directorate of Planning	T.P.C. Van Robbroeck B.W. Bonthuys F.C. Kock P.F. Pretorius	Afrikaans	Land-Use and Agriculture Group	The report investigates the most feasible water supply scheme for irrigation in the upper Bree river valley.	Ninham Shand BRBS library contact person : Julie phone : (021)4245544 (on loan from Gerrit van Zyl)
P0810/08/0176	Aug-76	verslag oor die Verspreiding van Besproeiingswater in die Breerivervallei Benede Groter Brandvlei	DWAF: Directorate of Planning	P.F. Pretorius J.M. Kock	Afrikaans	Land-Use and Agriculture Group Water Resources Group	A planning report investigating 3 alternative schemes supplying water for irrigation to the Bree River Valley between Brandvlei Dam and Riviersonderend	Ninham Shand BRBS library Contact person : Julie Phone : (021)4245544 (on loan from Gerrit van Zyl)
P0810/10/0177	Aug-77	Goudini-Rawsonville Distrikte Ondersoek na die Molenaarsrivier vir Watervoorsiening aan die Goudini - Rawsonville Gebied	DWAF: Directorate of Planning	J.S. Knoesen F.C. Kock P.F. Pretorius	Afrikaans	Water Resources Group Schemes Development Group	The report discusses the possibility of constructing a dam on the Molenaars River in Du Toits Kloof for the purpose of water supply to the Goudini -Rawsonville area	Ninham Shand BRBS library Contact person : Julie Phone : (021)4245544 (on loan from Gerrit van Zyl)
GH 3186	May-81	Geohydrological Investigation Bree River Valley Between Wolseley and Brandvlei Dam	Department of Environmental Affairs Directorate of Water Affairs	P.N. Rosewarne	English	Water Resources Group Environmental Group	The report investigates the delineation of the aquifers in the area and assesses the ground and surface water resources in the area with a view to determining areas of deficiency and any areas for future exploitation.	Ninham Shand BRBS library contact person : Julie phone : (021)4245544 (on loan from Gerrit van Zyl)
P0840/05/0176	Jan-76	McGregor Besproeiingsraad Ondersoek na Moontlike Dam in die Houtbaaisrivier vir Watervoorsiening aan McGregor Besproeiingdistrik	DWAF: Directorate of Planning	J.M. Kock P.F. Pretorius	Afrikaans	Land-Use and Agriculture Group	The report investigates the possibility of constructing a dam in the Houtbaai River to provide adequate and stable water supply for future irrigation developments in the area.	Ninham Shand BRBS library contact person : Julie phone : (021)4245544 (on loan from Gerrit van Zyl)
WRC196/2/93	Feb-93	Data Acquisition and Evaluation of Soil Conditions in Irrigated Fields in the Breede River Valley	University of Stellenbosch Dept. Of Soil- and Agricultural Water Science	J.H. Moolman W.P de Clercq	English	Land-Use and Agriculture Group	Submitted to Water Research Commission	
GH 3683	Mar-90	The Groundwater Contribution to the Salt Load and Flow Volume of the Breede River in the Robertson Area	DWAF: Directorate of Geohydrology	J.L. Jolly	Afrikaans	Water Quality Group Land-Use and Agriculture Group Environmental Group		
H000/00/0186	Apr-86	A Report on Initial fieldwork Concerning the Salination of the Breede River	DWAF: Directorate of Scientific Services Hydrological Research Institute	G.J. Howard	English	Land-Use and Agriculture Group Water Resources Group		
H000/00/0184	Jan-84	Breede River Management Project Project B-N3/0209	DWAF: Directorate of Scientific Services Hydrological Research Institute	R.S. Blake	English	Water Resources Group Land-Use and Agriculture Group	Processing of Release Data From Brandvlei and Kwaggaskloof Dams	
H000/00/0284	Feb-84	Breede River Management Project Project B-N3/0209	DWAF: Directorate of Scientific Services Hydrological Research Institute	R.S. Blake	English	Land-Use and Agriculture Group Water Resources Group	Evaluation of Breede River Irrigation System Operation	
H000/00/0183	Oct-83	Breede River Management Project	DWAF: Directorate of Scientific	R.S. Blake	English	Land-Use and Agriculture Group	Processing of Electrical Conductivity Data From Breede River	

REPORT NO.	YEAR	TITLE	AUTHOR INSTITUTION	AUTHOR INDIVIDUALS	LANGUAGE	STUDY ASPECT	COMMENTS	AVAILABILITY
		Project B-N3/0209	Services Hydrological Research Institute			Water Resources Group	Water Conservation Board	
H000/00/0484	Unspecified	Breede River Management Project Project B-N3/0209	DWAF: Directorate of Scientific Services Hydrological Research Institute	R.S. Blake	English	Land-Use and Agriculture Group Water Resources Group	Canal Flow Data Processing and Analysis	
H400/xx/0289	Jan-89	A Pilot Study of the Irrigated Areas Served by the Breede River (Robertson) Irrigation Canal	MBB Inc Consulting Agricultural and Civil Engineering	Unspecified	English	Land-Use and Agriculture Group	Part II: Appendices	
P0810/08/0178	Jun-78	Groter-Brandvlei Dam Ondersoek na die moontlikheid dat die huidige dam ook water aan die Klaasvoogdsrivier - Hoofbesproeiingsraad kan Voorsien	DWAF: Planning Division	Unspecified	Afrikaans	Land-Use and Agriculture Group Water Resources Group	Investigation into the possibility of supplying water to the Klaasvoogds River Irrigation Board from the greater Brandvlei Dam.	Ninham Shand BRBS library Contact person : Julie Phone : (021)4245544 (on loan from Gerrit van Zyl)
P080/00/0180	Unspecified	Groter-Brandvlei-Staatswaterskema Voorlopige Ondersoek na die Voorgestelde Nuy-Nonna Pumpschema	DWAF: Planning Division	Unspecified	Afrikaans	Schemes Development Group Engineering Costing/Evaluation Group	Preliminary investigation into the proposed Nuy-Nonna Pumping Scheme	
P0810/35/0180	Aug-80	Elandsrivier-Theewaterskloof Uitkering Moontlike Uitkering van Surpluswater uit die Elandsrivier via die Dutoitskloof Padtonnel na die Theewaterskloofprojek	DWAF: Planning Division	G. Verwey F.C. Kock P.F. Pretorius T.P.C. van Robbroeck	Afrikaans	Water Resources Group Environmental Schemes Development	Possible releases of surplus water from the Elands River via the Du Toitskloof tunnel to the Theewaterskloof project.	
P081/41/0176	Dec-76	Brandvlei Gevangenis-Watervoorsiening Ooreenkoms met Gevangeniswese oor Waterregte en Vergoeding	DWAF: Planning Division	P.F. Pretorius A.P. Bekker	Afrikaans	Legal Aspects Group	Brandvlei Prison: Agreement with prison authority on water rights	
P0810/01/0279	May-79	Bo-Breerivierontwikkeling Ondersoek na 'n Waterskema vir Besproeiing	DWAF: Planning Division	Unspecified	Afrikaans	Land-Use and Agriculture Group Water Resources Group Schemes Development	Investigation into water system for irrigation	
H100/xx/0176	Sep-76	Wolseley Municipality: Report on Drinking Water Supply	Robert Leslie & Partners Consulting Engineers	Unspecified	Afrikaans	Water Demands Group		
P0810/02/0176	Oct-76	Ondersoek na Watervoorsiening aan Ceres Distrik Alternatiewe Terreine op die Koekedouwriver	DWAF: Planning Division	T.P.C. van Robbroeck P.F. Pretorius D. Basson	Afrikaans	Water Resources Group Water Demands Schemes Development	Investigation into water supply to Ceres district Alternative areas on Koekedouw River	
Unspecified	Dec-84	The Gentle Art of Re-Perceiving One Thing or Two Learned While Developing Planning Scenarios for Royal Dutch/Shell	Harvard Business School Division of Research	Pierre Wack	English	Water Resources Group		
V/1-1102/51/001		ROIP: Elandsrivier - Theewaterskloof - Uitkering Klein Drakenstein Dam	DWAF: Environmental Studies	M D Louw	Afrikaans	Environmental		
	Non 91	Prognosis of the relevant environmental impacts of the Elands River/ Dasbos Tunnel Pipeline	DWAF: Environmental Studies	M D Louw	English	Environmental		
V/H102/51/E003	Jul-94	ROIP: Molenaars Diversion Weir	DWAF: Environmental Studies	M D Louw	English	Environmental		
Unspecified	Sep-94	Molenaars River: Situation Assessment of the Riverine Ecosystem	Southern Waters	G. Ractliffe & C Brown	English	Environmental		
Unspecified	Jul-88	Du Toits Kloof Environmental Impact Assessment	Hill Kaplan Scott		English	Environmental		

REPORT NO.	YEAR	TITLE	AUTHOR INSTITUTION	AUTHOR INDIVIDUALS	LANGUAGE	STUDY ASPECT	COMMENTS	AVAILABILITY
Unspecified	Dec-96	Environmental Impact Assessment of the Proposed Titus River Irrigation Scheme	Ninham Shand/ Agro-Water		English	Environmental		Ninham Shand library
Unspecified	Aug-96	Titus River: Assessment of Conservation Status and potential impacts of the Titus River Irrigation Scheme on the riverine ecosystem	Southern Waters	G. Ractliffe & C Brown P Ackerman	English	Environmental		
		ROIP: Michell's Pass Dam	DWAF: Environmental Studies	P Ackerman	English	Environmental		
Unspecified	Apr-89	The Role of Groundwater in the Mineralization of the Breede River in the Area Between Worcester and Robertson	DWAF: Directorate of Geohydrology	J.L. Jolly	English	Water Quality Group Land-Use and Agriculture Group Environmental Group		
PH100/08/0385	Mar-85	Breede River Greater Brandvlei Dam Complex The Phasing of Installation of Pumps and Other Components of the Proposed Scheme	DWAF: Directorate of Project Planning	Unspecified	English	Schemes Development Group		
Unspecified	Mar-89	Extended Summary on the Operational and Planning Alternatives for the Breede River	DWAF: Directorate of Water Pollution Control	S.F. Forester	English	Water Quality Group Environmental Group	Water quality management report presented at a meeting of the Task Group for the Breede River of the Co-ordinating Committee for salinity research on 24 April 1989 at Elsenburg.	
H400/xx/027	Aug-79	The Development and Evaluation of Geophysical Techniques for Determining the Groundwater Potential of the Breede River Area between Brandvlei Dam and Witbrug	CSIR: Geophysics Division National Physical Research Laboratory	J.S.V. Van Zijl R. Meyer R. Huysen N.P.R.L.	English	Groundwater Group Surface Water Group	Presented for a discussion at the Steering Committee meeting on August 28, 1979.	
H200/06/0188	Jan-88	Lakenvlei Dam Capacity Determination	DWAF: Directorate Survey Services	Unspecified	Afrikaans	Water Resources Group Infrastructure Land-Use and Agriculture Group		
H400/02/800	Feb-80	Keerom Dam Capacity Determination	DWAF: Planning Division	Unspecified	Afrikaans	Water Resources Group Land-Use and Agriculture Group Infrastructure	Hydrographic Survey	
H400/10/0885	Oct-85	Moordkuil Dam Capacity Determination	DWAF: Planning Division	Unspecified	Afrikaans	Water Resources Group Land-Use and Agriculture Group Infrastructure	Hydrographic Survey	
H400/06/083	Jun-83	Klipberg Dam Capacity Determination	DWAF: Planning Division	Unspecified	Afrikaans	Water Resources Group Land-Use and Agriculture Group Infrastructure	Hydrographic Survey	
H200/07/H001	Jan-83	Roodeelsberg Dam Capacity Determination	DWAF: Planning Services	Unspecified	Afrikaans	Water Resources Group Infrastructure Land-Use and Agriculture Group	Hydrographic Survey	
H400/00/0179	Jan-79	Pietesfontein Dam Capacity Determination	DWAF: Directorate Survey Services	Unspecified	Afrikaans	Water Resources Group Land-Use and Agriculture Group Infrastructure		
H400/00/0279	Feb-79	Poortjieskloof Dam Capacity Determination	DWAF: Directorate Survey Services	Unspecified	Afrikaans	Water Resources Group Land-Use and Agriculture Group Infrastructure		
P0810/08/0175	Dec-75	Greater Brandvlei Dam Holsloot-Smalblaar Feeder Canal	DWAF: Directorate of Planning	T.P.C. Van Robbroeck	Afrikaans	Water Resources Group Infrastructure		
P0810/36/0180	Jul-80	Ceres Development Water Control Area Determination of Water Rights of	DWAF: Planning Division	Unspecified	English	Legal Aspects Group		

REPORT NO.	YEAR	TITLE	AUTHOR INSTITUTION	AUTHOR INDIVIDUALS	LANGUAGE	STUDY ASPECT	COMMENTS	AVAILABILITY
		Properties Riparian to the Titus River						
H600/00/0197	Jan-97	Theewaterskloof Dam: Proposal by DWAF to Raise the Full Supply Level by One Metre using Flood Gates	D. Hofmeyr Consulting Economist: Farm Valuations and Planning of Finance and Labour		English	Engineering Costing/Evaluation Group	Comments from Interested and Affected Parties in Theewaterskloof catchment	
H400/00/0187	Apr-87	Field Investigations in the Robertson Irrigation Scheme	DWAF: Directorate of Scientific Services Hydrological Research Institute	W.A. Flugel G.J. Howard	English	Land-Use and Agriculture Group		
H400/00/0184	Jan-84	Greater Brandvlei Dam Government Water Scheme: Papenkuils Valley Barrage	Binnie & Partners Consulting Engineers	Unspecified	English	Engineering Costing/Evaluation Group	Structural Design Report	
H400/00/0182	Jun-82	Greater Brandvlei Dam Government Water Scheme: Gates and Operating Machinery for Papenkuils Valley Barrage	Binnie & Partners Consulting Engineers	Unspecified	English	Engineering Costing/Evaluation Group	Structural Design Report	
H400/xx/0189	Jan-89	A Pilot Study of the Irrigated Areas Served by the Breede River (Robertson) Irrigation Canal	MBB Inc Consulting Agricultural and Civil Engineering	Unspecified	English	Land-Use and Agriculture Group	Part 1: Technical Report Submitted to the Water Research Commission	
Unspecified	Nov-91	Wit River Water Supply Scheme: Preliminary	Ninham Shand		English	Environmental		Ninham Shand library
Unspecified	Aug-94	Upper Wit River, Situation Assessment of the Riverine Ecosystem	Southern Waters	C Brown & R Tharme	English	Environmental		
P G100/00/1096		Riviersonderend Situation Assessment			English	Environmental		
Unspecified	Feb-98	Management Plan for the Upper Riviersonderend Catchment	CSIR		English	Environmental		Ninham Shand library
Unspecified	Aug-98	Alien invading plants and water resources in South Africa: A Preliminary Assessment	Water Research Commission	DB Versveld, DC le Maitre & R A Chapman	English	Environmental		Ninham Shand library
N/H000/00/RIH/0387	Dec-87	Mapping the Extend of Irrigated Land in the Breede River Catchment with the aid of Satellite Imagery	DWAF: Scientific Services Hydrological Research Institute	U. Lourens B. Brown A. Seed	English			Ninham Shand BRBS library contact person : Julie phone : (021)4245544 (on loan from Gerrit van Zyl)
H003-93	93	Riviersonderend - Bergrivierskema Klein Drakenstein Dam Bo Molenaarsrivier - Uitkering	Departement van Waterwese	M D Louw	Afrikaans			Ninham Shand BRBS library contact person : Julie phone : (021)4245544 (on loan from Gerrit van Zyl)
Unspecified	Jun-94	Michell's Pass Diversion	DWAF: Design Services	M D Louw	English	Environmental		Ninham Shand BRBS library contact person : Julie phone : (021)4245544 (on loan from Gerrit van Zyl)
Unspecified	Jul-94	Molenaars Diversion Weir	DWAF: Design Services	M D Louw	English	Environmental		Ninham Shand BRBS library contact person : Julie phone : (021)4245544 (on loan from Gerrit van Zyl)

Appendix B

Yields and Unit Reference Values of Schemes

BREEDER RIVER BASIN STUDY: SCHEME DEVELOPMENT OPTIONS				
SCHEME	Capital Cost (R Million)	URV (R/m ³)	Yield (Mm ³ /a)	Comparative Evaluation (Note 1.)
UPPER BREEDER				
MICHELLS PASS (GCTMA)				
Diversion: 4 m ³ /s	51	0.14	35.7	
Diversion: 8 m ³ /s	56	0.11	52.5	X
Diversion: 12 m ³ /s	61	0.11	59.6	
LOWER WIT RIVER DAM				
Irrigation (Breede River Valley)				
Storage capacity: 12 Mm ³	104	0.90	12.0	
Storage capacity: 24 Mm ³	184	0.83	23.4	X
Storage capacity: 50 Mm ³	290	0.87	35.1	
Storage capacity: 86 Mm ³	416	1.00	43.3	
Transfer to Lower Berg River (GCTMA)				
Storage capacity: 12 Mm ³	160	1.12	14.9	
Storage capacity: 24 Mm ³	238	0.87	29.5	X
Storage capacity: 50 Mm ³	313	0.90	37.8	
Storage capacity: 86 Mm ³	425	1.03	45.1	
Irrigation and Transfer				
Storage capacity: 24 Mm ³	247			
Irrigation		0.78	13.3	
Transfer		1.17	13.3	
UPPER MOLENAARS DIVERSION (GCTMA)				
Diversion : 5 m ³ /s	213	0.82	27.2	X
AUGMENTATION OF BRANDVLEI DAM				
INCREASE CAPACITY OF EXISTING CANALS / NEW LOW LIFT PUMPSTATION				
+ 10 m ³ /s	91	0.68	16.9	
+ 25 m ³ /s	126	0.67	23.2	X
HIGH LEVEL DIVERSION CANAL FROM SMALBLAAR & HOLSLOOT RIVERS				
Diversion: 5 m ³ /s	35	0.48	7.0	
Diversion: 10 m ³ /s	40	0.26	14.6	
Diversion: 25 m ³ /s	53	0.22	23.2	X
OUPLAAS DAM				
Existing canals & low lift pumpstation	190	0.83	24.8	X
Increase existing canals by 10 m ³ /s & low lift pumpstation	223	0.94	25.9	
HIGH LEVEL DIVERSION FROM MICHELLS PASS				
Diversion: 8 m ³ /s (Pipeline)	543	2.45	20.9	
Diversion: 8 m ³ /s (Canal)	230	1.04	20.9	X
PAPENKUILS WEIR AND PUMPSTATION (20 m³/s)				
No storage	38	0.15	44.2	X
Storage capacity: 7.8 Mm ³	60	0.18	49.0	
Storage capacity: 20 Mm ³	65	0.18	52.5	
Storage capacity: 27.8 Mm ³	67	0.18	58.4	
RIVERSIDE WEIR AND PUMPSTATION (20 m³/s)				
Storage capacity: 7.8 Mm ³	240	0.38	81.8	X
Storage capacity: 20 Mm ³	251	0.39	83.7	
Storage capacity: 27.8 Mm ³	258	0.38	88.0	
DIRECT IRRIGATION FROM BRANDVLEI DAM (Local Irrigation)				
Canal (Papenkuijs pumpstation (no storage) used to augment GBD - Cost excluded)	263	0.85	44.2	X
Pipeline (Papenkuijs pumpstation (no storage) used to augment GBD - Cost excluded)	405	1.15	44.2	
LINK GREATER BRANDVLEI DAM TO THEEWATERSKLOOF DAM (GCTMA)				
Papenkuijs pumpstation (no storage) used to augment GBD - Cost excluded	267	0.98	41.0	
Papenkuijs pumpstation (no storage) used to augment GBD - Cost included	304	1.14	41.0	X
MIDDLE BREEDER (Le Chasseur Dam)				
Supply Existing Irrigation - Surplus Water transferred from GBD - TWK (GCTMA)				
	545	1.76	60.00	X
New Irrigation in Middle Breeder River Valley				
With EFR	436	1.07	40.30	X
No EFR	476	0.98	50.10	
RIVIERSONDEREND (Bromberg Dam) (Local irrigation)				
With EFR:				
Storage capacity: 159 Mm ³	351	1.49	24.40	
Storage capacity: 100 Mm ³	302	1.44	21.90	X
Storage capacity: 50 Mm ³	217	1.79	12.20	
No EFR:				
Storage capacity: 100 Mm ³	319	1.17	29.30	
LOWER BREEDER (Raising Buffeljagts Dam) (Local irrigation)				
With EFR	80	0.75	10.80	X
No EFR	84	0.64	13.30	
NOTE 1. These scheme alternatives are referred to in the text of the Summary Report, and were ranked using multi-criteria decision analysis				
NOTE 2. This list excludes numerous smaller local schemes (including groundwater schemes) that were also assessed in the Study.				