



Republic of South Africa
Department of Water Affairs and Forestry

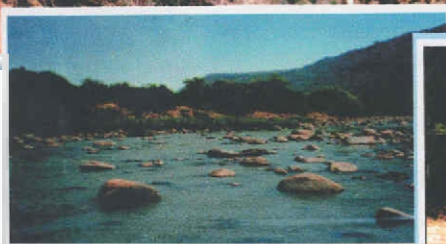
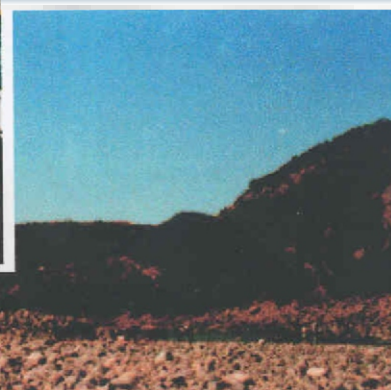


THUKELA WATER PROJECT FEASIBILITY STUDY

INSTREAM FLOW REQUIREMENTS:

SUMMARY REPORT

MARCH 2000



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INSTREAM FLOW REQUIREMENT STUDY: SUMMARY REPORT (1995 – 2000)

March 2000

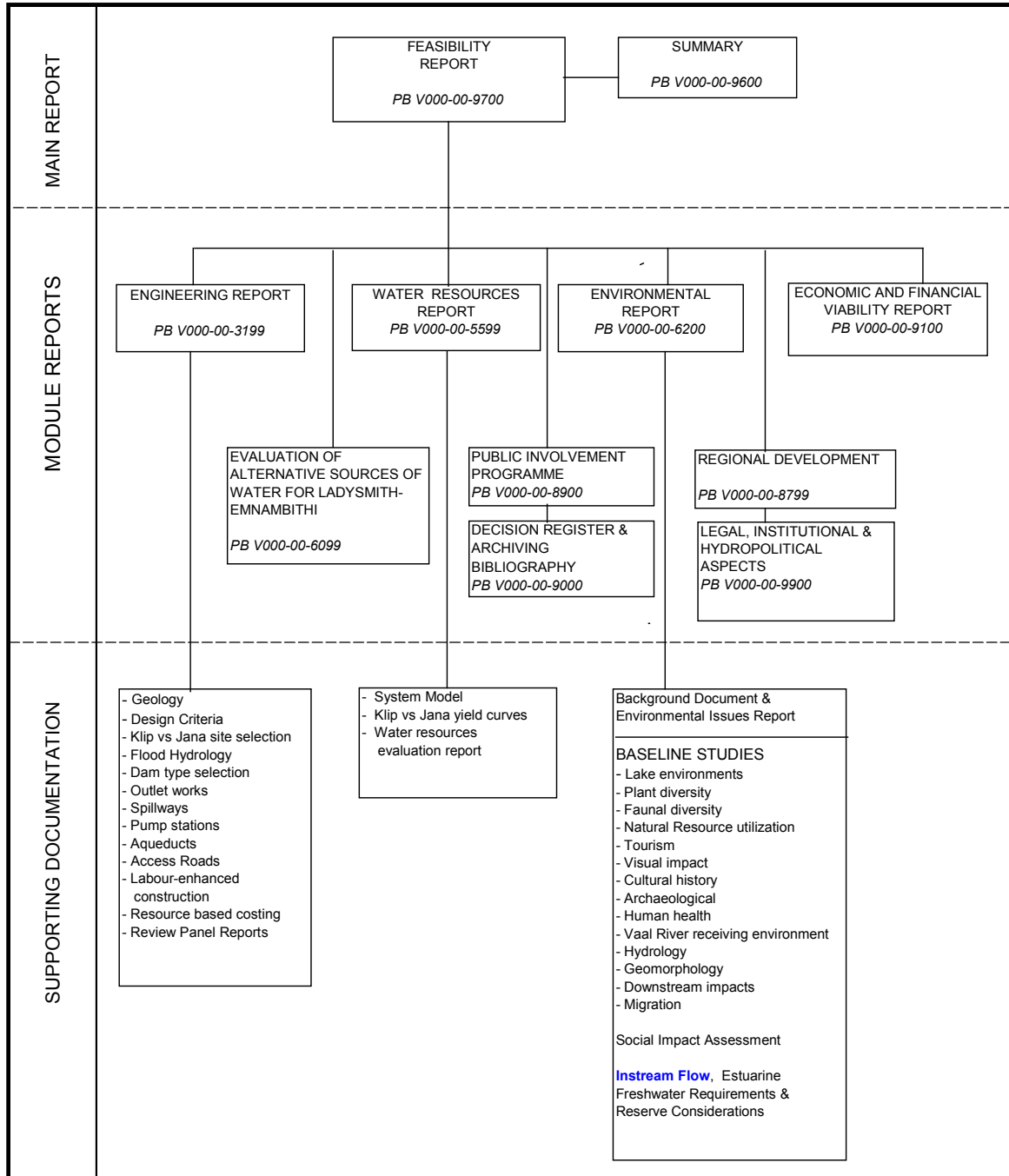
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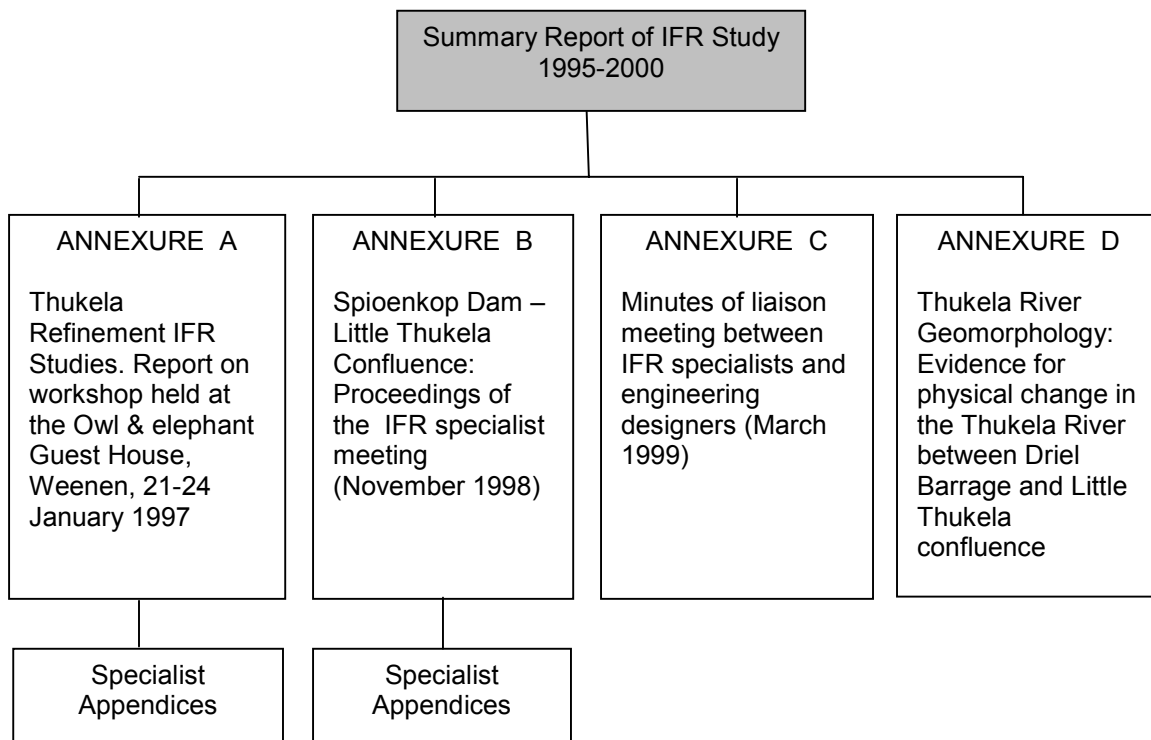
STRUCTURE OF REPORTS



THUKELA WATER PROJECT FEASIBILITY STUDY

INSTREAM FLOW REQUIREMENT STUDY: SUMMARY REPORT (1995 – 2000)

REPORT STRUCTURE



**THUKELA WATER PROJECT FEASIBILITY STUDY
INSTREAM FLOW REQUIREMENT STUDY SUMMARY REPORT**

IWR ENVIRONMENTAL

MARCH 2000

Approved for IWR Environmental by:

.....

D Louw: Team Leader & Director

PREFACE

This Module Report reviewing the Instream Flow Requirements associated with the Thukela Water Project proposals that emanate from the Feasibility Studies was prepared by IWR Environmental and their team of specialists. The authors were appointed to undertake one of 15 modules in the Feasibility Study and obtained information from and liaised, inter alia, with investigating teams assigned to the other modules. The report was prepared under the direction of the Project Management Team.

The report has been accepted as representing the outcome of the terms of reference assigned to IWR Environmental and has been used as an important source document for the preparation of a Main Feasibility Report on the Thukela Water Project. All the views, findings, interpretations and recommendations of the authors may not necessarily have been included in full in the Main Feasibility Report.

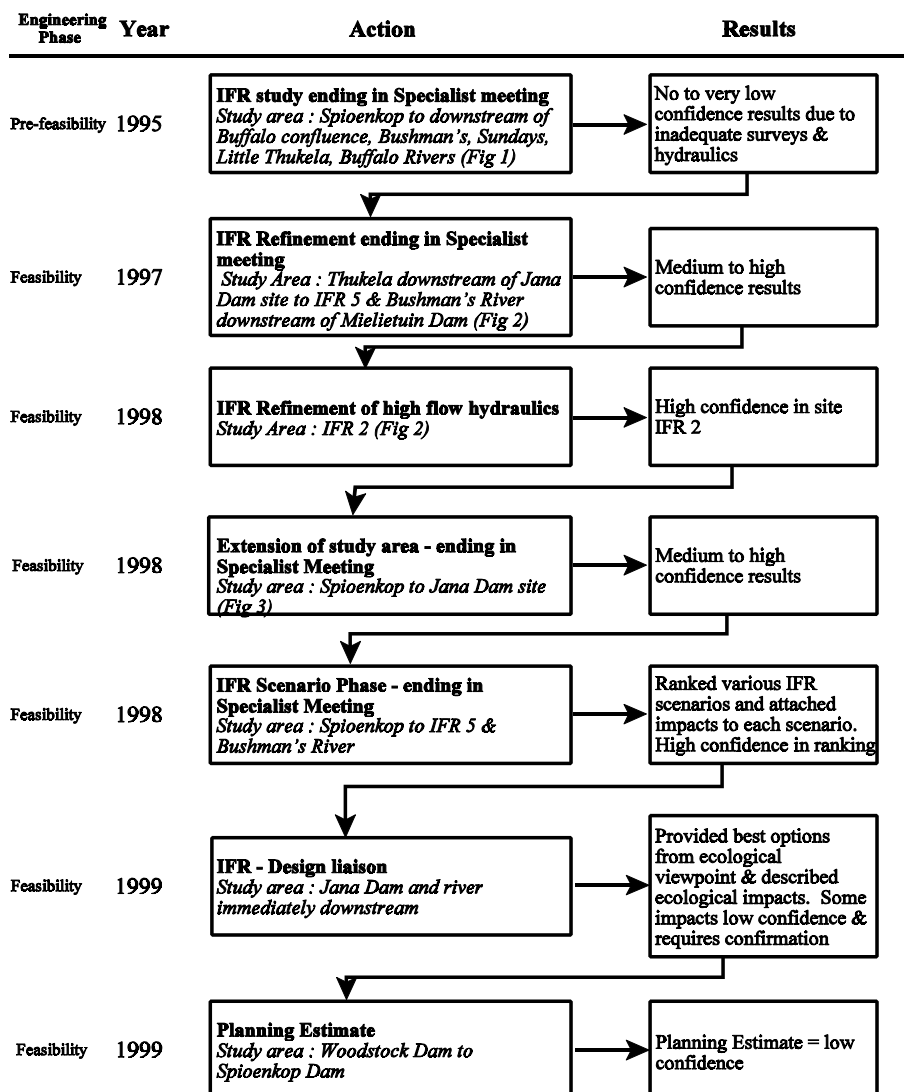
SUMMARY

In 1994 the Department of Water Affairs and Forestry (DWAF) initiated the Vaal Augmentation Planning Study (VAPS) to determine the merits of alternative water resource development options to follow Phases 1A and 1B of the Lesotho Highlands Water Project (LHWP). The VAPS is part of ongoing water resource development and management planning at a national level. The subsequent Thukela Water Project Feasibility Studies was initiated in 1997 as a confirmation of the VAPS in order to further investigate the feasibility of possible water resource development of the Thukela River Catchment. An Instream Flow Requirement (IFR) study was initiated during 1995 as part of the VAPS study and various IFR actions have taken place since 1995.

The IFR actions that were undertaken are the following:

- 1995 IFR Study
- 1997 IFR Refinement
- 1998 IFR Refinement - high flow calibration
- 1998 - Extension of IFR study area
- 1998 - Scenario IFR phase
- 1999 - IFR / Design liaison
- 1999 - Planning estimate: Woodstock Dam to Spioenkop Dam
- 1999 - Evidence for physical change in the Thukela River between Driel Dam and the Little Thukela confluence.

The interlinkages between the various studies are described in the flow diagram below.



The results of the various actions are documented in various reports (referenced later), and *this report* serves as a summary of the results generated by the various studies.

The medium to high IFR confidence results are summarised in the following table:

The values in the table represent Instream Flow Requirements (IFRs) at these positions in the river system. These values include natural flows required and their distribution (and volumes) over the course of a normal rainfall year and during an abnormally dry or drought year. Apart from the normal river flow released as part of the operation of the dam, special releases from a future dam(s) may be required at certain times of the year to meet these requirements.

	IFR A		IFR 2		IFR 5		IFR 3A		IFR 3B	
	X 10 ⁶ m ³	% OF MAR	X 10 ⁶ m ³	% OF MAR	X 10 ⁶ m ³	% OF MAR	X 10 ⁶ m ³	% OF MAR	X 10 ⁶ m ³	% OF MAR
MAINTENANCE LOW FLOWS	166	18.2	162.22	10.7	250.92	11.62	51.24	18.11	55.68	17.79
MAINTENANCE HIGH FLOWS	86	9.5	143.04	9.42	157.84	7.31	28.24	9.98	32.36	10.34
TOTAL	252	27.7	305.26	20.1	408.76	18.92	79.48	28.09	88.04	32.03
DROUGHT LOW FLOWS	64	7.1	70.1	4.61	106.14	4.91	24.35	8.6	26.05	8.32
DROUGHT HIGH FLOWS	17	2.7	50.43	3.32	44.79	2.07	5.38	1.9	5.98	1.91
TOTAL	81	9.8	120.53	7.93	150.93	6.99	29.72	10.50	32.03	10.23

The National Water Act (No 36 of 1998) requires that the Reserve (Ecological and Basic Human Needs) be quantified before allocating water to other new users. The IFR study, even though initiated before the Ecological Reserve came into place, does include some of the steps required for the Reserve and an analysis has been made of the steps required to upgrade the existing IFR results so that it may be regarded as the Ecological Reserve. These actions mostly centre around the need for:

- stakeholder input into the setting of the Environmental Management Class;
- the Water Quality Reserve
- the Groundwater Reserve.

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- Annexure B** : Thukela IFR Study : Spioenkop Dam - Little Thukela Confluence : Proceedings of the IFR specialist meeting. (November 1998)
- Annexure C** : Thukela IFR Study : Minutes of liaison meeting between IFR specialist and designers (Mar 1999)
- Annexure D** : Thukela River Geomorphology : Evidence for physical change in the Tugela River between Driel Dam and the Little Tugela confluence.

CHAPTER 1 : INTRODUCTION

In 1994 the Department of Water Affairs and Forestry (DWAF) initiated the Vaal Augmentation Planning Study (VAPS) to determine the merits of alternative water resource development options to follow Phases 1A and 1B of the Lesotho Highlands Water Project (LHWP). The VAPS is part of ongoing water resource development and management planning at a national level. The subsequent Thukela Water Project Feasibility Studies was initiated in 1997 as a confirmation of the VAPS in order to further investigate the feasibility of possible water resource development of the Thukela River Catchment. An Instream Flow Requirement (IFR) study was initiated during 1995 as part of the VAPS study and various IFR actions have taken place since 1995.

The IFR actions that were undertaken are the following:

- 1995 IFR Study (Pre-feasibility Study)
- 1997 IFR Refinement (Feasibility Study)
- 1998 IFR Refinement - high flow calibration
- 1998 - Extension of IFR study area
- 1998 - Scenario IFR phase
- 1999 - IFR/Design liaison
- 1999 - Planning estimate: Woodstock Dam to Spioenkop Dam
- 1999 - Evidence for physical change in the Thukela River between Driel Dam and the Little Thukela confluence.

The above actions were applicable for different study areas and the results were of various levels of confidence. The actions have also been documented in various reports, minutes, appendices etc and are at different stages of finalisation. This summary report serves to integrate all the information available (with specific emphasis on the final usable result) in the various documents.

The documents from which this report was summarised are the following:

Date	Author	Title	Status	Available from this source
Jan 1997	Department of Water Affairs and Forestry, South Africa	Thukela - Vaal Transfer Scheme, Interim Study, Instream Flow Requirements	Final	Department of Water Affairs and Forestry
Aug 1997	WJ Muller, IWR, Rhodes University	Thukela Refinement IFR Studies (Southern Tributaries) Report on a Workshop held at the Owl and Elephant Guest House, Weenen, 21 - 24 January 1997	Final Draft	Thukela Water Project
Nov 1998	Edited D Louw	Starter Document : IFR	n/a	Appendix of next report
Nov 1998	D Louw, IWR Environmental	Thukela IFR study : Spioenkop Dam - Little Thukela : Proceedings of the IFR specialist meeting	Final Draft	Thukela Water Project IWR Environmental
Mar 1999	-	Minutes of meetings	n/a	Thukela Water Project
Dec 1999	R Wadeson, IWR Environmental (PMB)	Evidence for physical change in the Thukela River between Driel Dam and the Little Thukela confluence.	Draft	Thukela Water Project

CHAPTER 2 : 1995 IFR STUDY

2.1 BACKGROUND & PURPOSE

In 1994 the Department of Water Affairs and Forestry (DWAF) initiated the Vaal Augmentation Planning Study (VAPS) to determine the merits of alternative water resource development options to follow Phases 1A and 1B of the Lesotho Highlands Water Project (LHWP). The VAPS is part of ongoing water resource development and management planning at a national level.

A Pre-feasibility Study was initiated and concluded in 1996. As part of the Pre-feasibility Phase, an Integrated Environmental Management (IEM) study was initiated. The IEM process included a rudimentary or reconnaissance level Environmental Assessment (EA) which required an IFR study to identify the impacts of the proposed developments on the riverine ecosystem. The IFR study is phased and linked to the engineering Pre-feasibility and Feasibility Phases. The IFR actions which are required during the Pre-feasibility Phase and which were undertaken are the following:

- Initial pre-specialist meeting investigations, i.e.,
 - Selection of study area
 - Habitat Integrity Assessment
 - Selection of IFR sites
 - Fish, Geomorphology, Riparian vegetation, Aquatic invertebrates, Social utilisation and Water Quality data collection and surveys.
 - Hydrological and hydraulic modelling
 - Determination of Environmental Management Class (EMC)
- Specialist Meeting
- Report documenting the proceedings

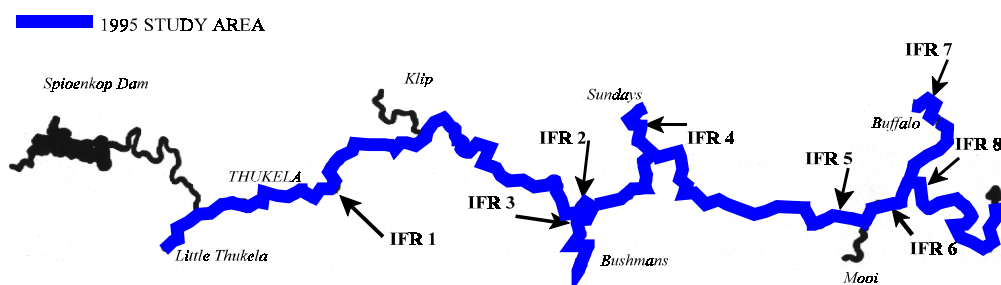
2.2 STUDY AREA

The study area and IFR sites selected are illustrated in Fig 1. The study area included the following:

- Thukela River downstream of the Little Thukela confluence to a point about 30 km downstream from the Buffalo River confluence.
- The Bushman's River downstream of the Wagendrft Dam
- The Sundays River (focus on the downstream section)
- The Buffalo River (focus on the downstream section)

The study area was represented by eight IFR sites of which five were in the main Thukela River. One site each was situated in the tributaries. The arrangement was made prior to the study that the tributary's IFRs would be at a coarse scale as the length and physical/ecological changes along these rivers would require more than one IFR site. It was concluded that if further investigations took place in the tributaries, additional IFR sites would be required during a refinement process.

Fig 1 : 1995 STUDY AREA AND IFR SITES



2.3 RESULTS & CONFIDENCE

During the IFR specialist study it became apparent that both the cross-sectional surveys and the hydraulic analysis were inadequate and could not be used with any confidence to derive meaningful ecological information from the relationships between flow rate and hydraulic parameters such as depth, wetted perimeter and velocity. The final results were therefore worthless until the hydraulic analysis was substantially refined or repeated in its entirety.

No to low confidence was attached to the IFR results and they were consequently NOT used in the Pre-feasibility Phase hydrological modelling.

2.4 FURTHER WORK RECOMMENDED

The recommended further work, in order of high priority to low priority recommended was as follows:

- Cross-sectional re-surveys of all sites
 - Repeat of hydraulic calculations for all the sites
 - Relocate IFR 2 (it was not representative of the gorge)
 - Additional IFR sites in the tributaries
 - Model IFRs to determine available yield
 - Design a monitoring protocol.
-

CHAPTER 3 : 1997 IFR REFINEMENT

3.1 BACKGROUND & PURPOSE

The Thukela Water Project (TWP) Feasibility Study is intended to include an evaluation of all factors which may affect the viability of development proposals on the Thukela River to a sufficient degree of detail to:

- Identify all the technical issues likely to affect implementation and to define and evaluate all the actions required to address these issues.
- Provide an estimate of cost with sufficient accuracy and reliability to ensure that management decisions can be made with confidence.

A much more sophisticated IEM investigation formed part of the Feasibility Study, which included a feasibility level Environmental Assessment (EA) and the specialist IFR study as part of this EA. The IFR study actions that normally take place during a Feasibility phase are the following:

- Refinement of the results generated at the IFR specialist meeting.
- Scenario phase during which an investigation of different scenarios of IFRs, their impact and ranking take place.
- Preliminary recommendations regarding the design of the proposed development.
- Design of a monitoring programme.

Linked to the confidence and results of the 1995 Pre-feasibility IFR study the following actions were undertaken during the IFR refinement study during the TWP Feasibility Phase:

- Resurvey of the relevant sites.
- New hydraulic modelling and hydraulic calibration data collection spanning two seasons.
- Additional sites and relocation of sites where necessary.
- Additional specialist studies where necessary.
- Specialist meeting to adjust the IFR results according to the new information generated during the refinement.

3.2 STUDY AREA

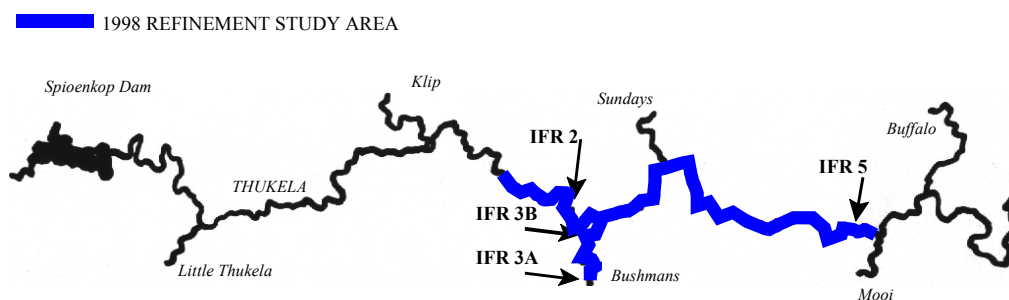
The study area and the IFR sites selected at feasibility level are illustrated in Fig 2. The Feasibility Study only focussed on the more upstream section of the Thukela River and its tributaries. The study area included the following:

- Thukela River downstream of the Jana Dam site to IFR 5 (downstream of the Sundays River confluence) in the Thukela River.
- The Bushman's River downstream of the Wagendrift Dam.

The Thukela River downstream of IFR 5, the Sundays and Buffalo Rivers were therefore not part of the refinement study.

The study area was represented by four IFR sites of which two were in the main Thukela River. Two sites were situated in the Bushman's Tributary. IFR 5 was exactly similar to the 1995 study, IFR 2 (in the Thukela) and IFR 3 (changed to IFR 3B) in the Bushman's River was relocated and a new additional site in the Bushman's River upstream of IFR 3B and downstream of Wagendrift Dam (IFR 3A) was selected. (See Fig 2)

Fig 2 : 1998 REFINEMENT STUDY AREA AND IFR SITES



3.3 RESULTS & CONFIDENCE

The Ecological Management Class (EMC) for the Thukela and the Bushman's River was selected as a B/C (i.e. largely natural to moderately modified).

The results generated for the Thukela and Bushman's River to maintain the EMC are presented in Chapter 9. A medium to high confidence was attached to the results.

3.4 FURTHER WORK REQUIRED

The recommended further work in order of high priority to low priority, was as follows:

- Incorporate additional flood data obtained into the hydraulic modelling. Flood flows occurred during the IFR Refinement Specialist meeting. These flows were measured from bridges and the associated water level surveys undertaken. (If these flows were to be incorporated in the hydraulic modelling to adjust the rating curve and the associated IFR results, the overall confidence of the IFR results would increase).
- Model IFRs to determine available yield.
- Preliminary input into design.
- Design a monitoring protocol.

The work associated with the first three bullets was conducted during the Feasibility study and the findings are provided in this report.

CHAPTER 4 : 1998 IFR REFINEMENT - HIGH FLOW CALIBRATION

4.1 BACKGROUND & PURPOSE

During the 1997 IFR Refinement specialist meeting (21 - 24 January 1997) floods occurred at the IFR sites on the Thukela and Bushman's Rivers. No flood data were available for the refinement study and consequently the opportunity was taken to measure surface flow velocities from the high-level bridges downstream of IFR 2 in the Thukela and across the Bushman's River at the town of Weenen. Stage levels were also recorded at the river cross-sections at IFR 2 and 3B during the specialist site visits. In order to estimate the flood discharges and utilise the additional rating data, it was, however necessary to survey the bridge profiles from which the flow measurements were taken - a task undertaken in September 1998. The refinements to the rating relationships and changes to the January 1997 recommended discharges based on the refined hydraulics were then undertaken.

4.2 STUDY AREA

The study area was the same as that for the 1998 IFR. The high flow calibration was only relevant to IFR 2 and 3B, as 3A was not visited on the same day that the flow measurement was undertaken. No stage levels were therefore available for this site.

4.3 RESULTS & CONFIDENCE

The highest flow previously measured was 28,9m³/s (Thukela River, IFR 2). The new high flows that could be used for hydraulic calibration purposes were 145m³/s and 312m³/s. This resulted in changes in the high flows recommended during the 1997 refinement studies. The range of changes are as follows:

IFR 2 :

• 30 m ³ /s	Y	31 m ³ /s
• 60 m ³ /s	Y	67 m ³ /s
• 100 m ³ /s	Y	118 m ³ /s
• 200	Y	255 m ³ /s

The resulting IFRs incorporating the above changes had a high confidence evaluation.

These results are incorporated in the IFR tables in Chapter 8.

No changes were made to the IFR results in the Bushman's River.

4.4 FURTHER WORK REQUIRED

Flood measurements in the Bushman's River to increase the confidence in high flow recommendations should be undertaken if possible. However, the high flows recommended do not pose any problems for releases and this information requirement does not have a high priority.

CHAPTER 5 : 1998 - EXTENSION OF IFR STUDY AREA

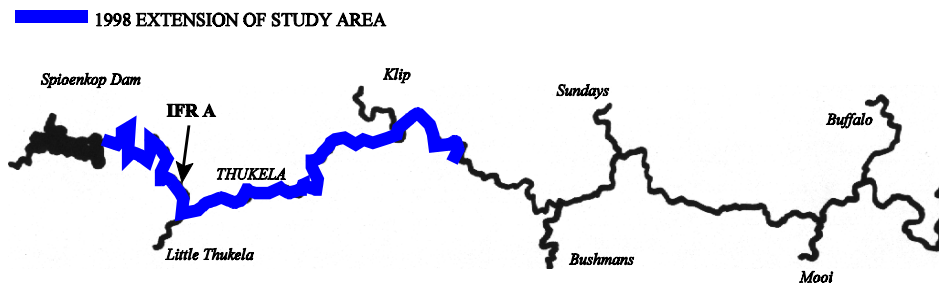
5.1 BACKGROUND & PURPOSE

The sizing of Jana Dam is influenced by the effect of the IFR on the estimated yield. To determine the yield accurately, the operation of the upstream Spioenkop Dam and the proportion of the IFR which it should supply for the reach downstream of the dam needed to be determined. An IFR for this reach was therefore required.

5.2 STUDY AREA

The study area was the Thukela River downstream of Spioenkop Dam to the Jana Dam site. This area was represented by one IFR site (IFR A). (See Fig 3)

Fig 3 : 1998 EXTENSION OF STUDY AREA



5.3 RESULTS & CONFIDENCE

An EMC class of B (largely natural) was allocated to this section of the river. The IFR results were in the medium to high confidence range. However, it must be noted that the evaluation is dependant on the accuracy of the statement that there is a long-term trajectory of change (i.e. degradation) of the river (specifically in its fluvial geomorphology) taking place due to the present operation of the dam. This implies that even though the dam has been operated for the last 30 years at volumes lower than the IFR requirements, continued operation of the dam would in the long-term not maintain the present ecological state.

5.4 FURTHER WORK REQUIRED

The IFR influences the yield of Spioenkop Dam considerably. As the IFR is based on the assumption that there is presently a long-term degradation in the geomorphology of the river, it will be necessary to confirm this by undertaking a geomorphological modelling study. This study was conducted during November 1999 as part of the Feasibility Study.

CHAPTER 6 : 1998 - SCENARIO IFR PHASE

6.1 BACKGROUND & PURPOSE

The IFR results for the Thukela River downstream of IFR A down to and including IFR 5 need to be included in the system analysis to determine the effect on the yield of the system. During a Scenario specialist meeting the results of the system analysis were presented to the IFR specialists. This included a range of different scenarios, which might hold significant advantages or disadvantages to the yield of the system. The advantages and disadvantages from an ecological viewpoint were determined.

6.2 STUDY AREA

The Thukela River, specifically IFR A was used to evaluate the ecological impacts. As the Scenario specialist meeting immediately followed the IFR A specialist meeting, this site was the easiest to relate to. However, the impact must be seen as relevant for the whole area.

6.3 RESULTS & CONFIDENCE

The IFR results for IFR A, 2, 5, 3a & 3b were modelled using the Water Resources Yield Model (WRYM). The water available after supplying the IFRs served as the available yield for the users.

IFR scenarios were then formulated and these were evaluated from an ecological viewpoint and the possible impacts on the river described.

The scenarios were the following:

Scenario 1 : Extended Drought

Maintenance flows and the assurances of maintenance flows stayed the same in this scenario. However, the occurrence of drought flows doubled. Therefore, if the drought flows at IFR A occurred 7% of the time (as was determined by the IFR model), it will now occur 14% of the time.

This scenario would result in a lowering of the EMC of the river.

Scenario 2 : 10% reduction of all flows

All flows were reduced by 10%. The impacts were evaluated by converting the recommended flows (IFR) to depths and the other relevant hydraulic parameters. The decrease in habitat was then evaluated.

This scenario would result in a lowering of the EMC by half a class (10 % vs 20% for a full class) in the long-term.

Scenario 3 : Dry season decrease of assurance

The scenario consists of

- the summer flows (December to March) to be maintained at the assurance set during the IFR determination;
- winter flows with a decreased assurance compared to the assurance set during the IFR determination. Flows in the month of August therefore were specified to have an assurance of 60 % and will now have an assurance of 30 %. The other months will proportionately decrease;
- High flows stay the same.

The changes in measurable parameters (eg. depth, velocity, wetted perimeter) are relatively low, and the resulting impacts on the riverine ecosystem are therefore difficult to quantify with any confidence.

The impact on the riverine ecosystem is of a resolution that is difficult to quantify. No short term

change in EMC is expected.

Ranking of scenarios

The scenarios in the order of least to most damage to the riverine ecosystem are as follows:

- Scenario 3
- Scenario 2
- Scenario 1

It must be noted that Scenario 3 is by far the least deleterious of the three scenarios.

High confidence was attached to the ranking of the scenarios.

6.4 FURTHER WORK REQUIRED

The results of the IFR A and the refined IFR 2 must be incorporated into the WRYM model.

CHAPTER 7 : 1999 - DESIGN/IFR LIAISON

7.1 BACKGROUND & PURPOSE

Some flexibility exists in the design of Jana Dam for incorporating features which could hold a range of implications for the riverine ecology.

A Jana dam design scenario which entailed

- concrete dam (160 m high)
- two bottom outlets that can release in total 300m³/s and need to be tested on a monthly basis (worst case scenario)
- multilevel outlets that can release 80m³/s in total
- tailpond dam (27 m high, 300 m long, 100 m wide and with no operable sluices)

was discussed at a specialist meeting. The ecological issues were identified and where applicable, options different from the above (eg tailpond dam vs plunge pool) was discussed.

7.2 STUDY AREA

The study area was the riverine ecosystem downstream from Jana and Mielietuin Dams to IFR 5.

7.3 RESULTS & CONFIDENCE

The design and operation issues from an ecosystem viewpoint are closely related. Some operation issues were discussed, and although not relevant to *design* specialist meeting, the issues were noted. Low confidence is reflected in question marks where impacts are evaluated.

7.3.1 Tailpond Dam vs Plunge Pool

- Stratification : One of the major problems is the temperature of releases due to stratification in the dam. In summer, water temperatures at the bottom of the dam may be considerably colder than at the surface or in the river. The tailpond dam would allow mixing of the water released from the dam, allowing the temperature to adjust to a situation more similar to the river temperature. The possibility of stratification in the tailpond dam however also has to be investigated and whether, under certain operating scenarios, this could negatively influence the flow to the river. However, the plunge pool option will allow for no mixing or adjustment and the impact on temperature compared to the tailpond dam is probably much higher. This impact will especially be critical during the summer when the temperature of the monthly 'testing' release will be much colder than the ambient water temperature. The confidence is low in these assumptions as a water quality modeling study needs to be undertaken to confirm this.

Impact of tailpond dam **LOW?** *Impact of plunge pool* **VERY HIGH?**

- Fluvial geomorphology : The tailpond dam will attenuate the release and dissipate the energy considerably. Without the tailpond dam, significant erosion and aggradation will take place in the river reach downstream of the dam. The 300m³/s releases from the bottom outlet without a tailpond dam could have significant impacts on the channel geomorphology and hydraulic habitats. Seasonally during winter, the vegetation could be reduced so that banks might be more unstable than during summer and the releases could cause erosion. Also, the consequences on biotopes could be significant as this would be an unnatural flooding regime, with large floods, and no other medium and small floods. The suite of actions that take place to maintain these habitats would be disrupted by such an unnatural flooding regime. These high-flow releases could however be 'caught' completely in the tailpond dam (if not full) and would then have no impacts downstream.

Impact of tailpond dam **LOW - NONE** *Impact of plunge pool* **VERY HIGH?**

- Instream biota : The tailpond dam will be biologically impoverished due to the large dam releases into the tailpond dam. A plunge pool could have major negative effects, as the biota immediately downstream of the dam wall will be wiped out by the releases. As

there is nothing to prevent biota moving back into the impacted river stretch (through migration eg), this could create a repetitive scenario.

Impact of tailpond dam *NONE* *Impact of plunge pool* *VERY HIGH?*

7.3.2 Tailpond dam operable vs tailpond dam not operable

The design of the tailpond dam is such that, at present, operation will be on a stand-alone basis and does not include operable sluices. This could however have negative ecological consequences. At some stages the 300m³/s would need to be caught in the tailpond dam and, if the tailpond dam at that stage is full and flow cannot be released from the tailpond dam, the tailpond dam will not be able to mitigate the possible unseasonal release. This design of the tailpond dam will therefore require additional engineering investigation.

Impact *LOW* *Impact* *HIGH?*

7.3.3 Flood release - combination between bottom and multi-level outlets

A yearly flood of 255m³/s is required according to the IFR recommendations. To enable such a release, a combination other than two 150 m³/s from the bottom outlet might be required. However, this is not a major engineering issue. At this stage there are no specific reasons to change this. The water quality problems associated with the bottom release are independent of the sizes from the two outlets.

7.3.4 Initial operating when dam starts storing water

Quantity : The initial closing of the dam could cause problems with a no-flow or low flow situation with limited releases. This is an engineering issue that can be addressed. The IFR specialists emphasized that the river should not stop flowing, even for short period.
Quality : The issue of dam basin clearing was discussed as this could have implications on the initial water quality of the dam. This needs to be investigated and is an operation issue, not design. The IEM team would consider this matter further.

7.3.5 Attenuation of floods

Attenuation of required floods at points downstream of the dam is a major problem. Larger releases from the dam might be required to achieve the required peak at downstream sites but these may have undesirable effects nearer to the dam.

7.4 FURTHER WORK REQUIRED

Certain operational issues and some engineering issues such as the possibility and necessity of adjusting the tailpond dam into a more operable structure must be investigated. These issues must then be brought to the larger IEM group for their input.

A water quality modeling study of the dam and tailpond dam has to be undertaken and this will quantify the relevant assumptions made.

CHAPTER 8 : 1999 - PLANNING ESTIMATE : WOODSTOCK DAM TO SPIOENKOP DAM

8.1 BACKGROUND & PURPOSE

It was found that for accurate yield modelling, as well as to distribute the IFR proportionately, an IFR estimate was required downstream of Woodstock Dam. Due to time constraints, the Planning Estimate method was undertaken which provides a conservative and low confidence answer.

8.2 STUDY AREA

The study area is the Thukela River downstream of Woodstock Dam to the Spioenkop Dam. A hypothetical point is selected for a Planning Estimate and this would be near the inflow of Spioenkop Dam.

8.3 RESULTS & CONFIDENCE

An estimate based purely on visual observations by one specialist in the area was made regarding the Environmental Management Class which resulted in a low confidence class B. As there is no chance of the river being a class higher, i.e. A = pristine, a lower class C/B was also investigated. The IFR results for class B and B/C class are presented in Chapter 9. As the method used is the Planning Estimate, the confidence is by definition low.

8.4 FURTHER WORK REQUIRED

A detailed IFR study is required.

CHAPTER 9 : 1999 : EVIDENCE FOR PHYSICAL CHANGE IN THE THUKELA RIVER BETWEEN DRIEL DAM AND THE LITTLE THUKELA CONFLUENCE

9.1 BACKGROUND & PURPOSE

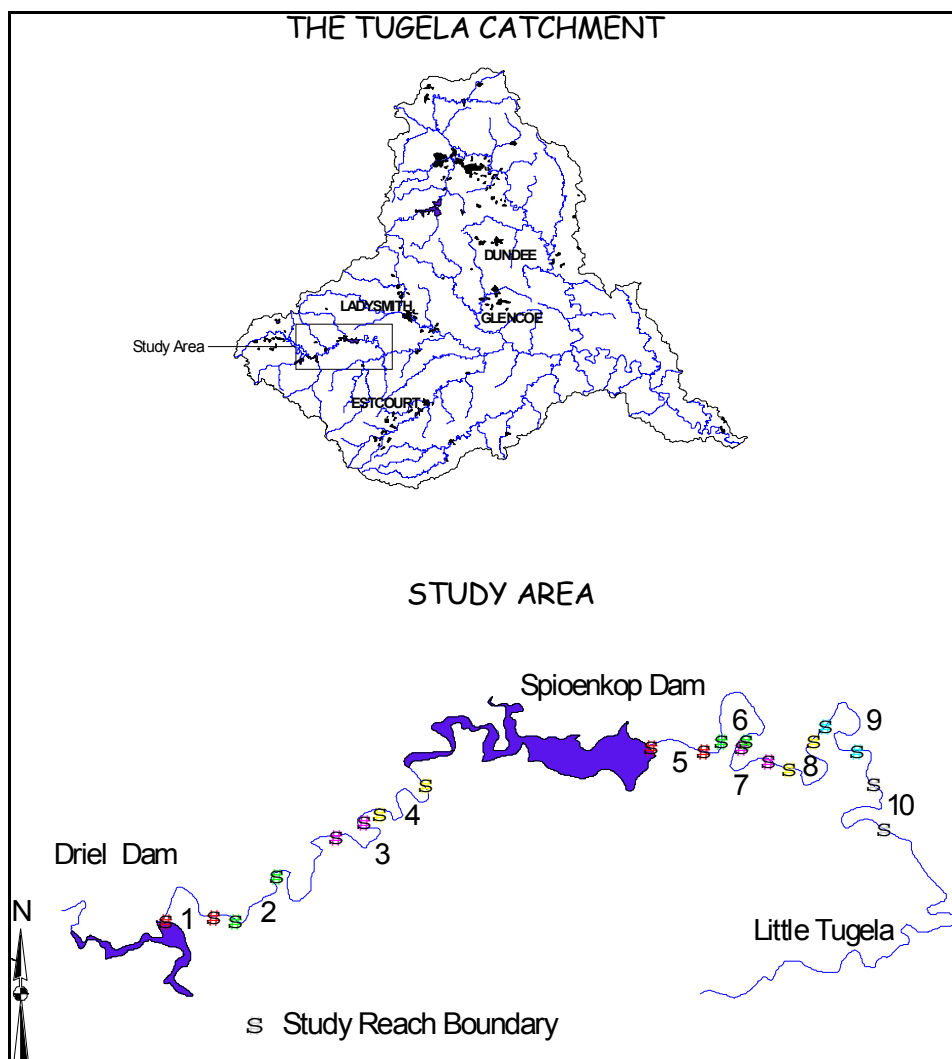
During the IFR determination work on this section of the Thukela river it was suggested by the geomorphological specialist that the channel morphology was in a state of change as a result of instream impoundments. Cursory evidence indicated that increased catchment erosion together with reduced flows was causing channel aggradation and the gradual loss of instream habitat. The primary motivation for ecological flow requirements were thus based on the geomorphological requirements of the channel.

In 1999 a more detailed geomorphological study was commissioned by DWAF to try and

determine the natural progression for morphological change in this part of the river and the affect of dams on channel morphology. The technique used for this study was simply an aerial photographic analysis of channel morphology over a period of time which included the pre- and post-dam eras.

The study had as its focus an area between Driel Dam and the Little Thukela confluence. This area includes a section of the Thukela river below the Spioenkop dam (Figure 4).

Fig 4 : Thukela Catchment and Study area



9.2 METHODS

The method utilised in this study was to obtain a succession of aerial photographs for the study area and to compare the physical form of the channel over time. Four sets of photographs were obtained. The first period was for 1944 which is the earliest available photographic record and shows the river in its pre dam form. The second period is for 1964, also pre dam. The third period is for 1985, post dam but prior to the 1987 floods. The final set is for the most recent available aerial photography which was flown in 1996. For some consistency the records were photographically adjusted to an approximate scale of 1:10 000. This is a large enough scale to allow the recognition of various features in the channel. 10 sections of the river were selected, 4 between Driel dam and Spioenkop dam and 6 between Spioenkop dam and the Little Thukela confluence.

9.3 RESULTS AND CONFIDENCE

Section 1: demonstrates a change in width and depth as lateral bars develop. There is no change in channel pattern as the river is entrenched into the landscape.

Section 2: there is evidence of sediment accumulation over time. This section of the river is getting narrower and shallower in places.

Section 3: the active channel appears to be getting narrower due to sediment accumulation and reduced discharges. The most significant change occurs from 1985 to 1996.

Section 4: aggradation is demonstrated by channel narrowing as lateral bars develop and by loss of depth as transverse bars fill the channel width.

Section 5: there have been small changes in the channel immediately below Spioenkop dam, there are virtually no sediment inputs from tributaries in this section.

Section 6: sedimentation appear to be occurring in this section, particularly downstream of small tributary inputs from the northern banks of the river. As with previous sections of the river, the most significant impact occurs post dam construction.

Section 7: there is evidence of bar growth post dam construction but this appears to have stabilised by 1996.

Section 8: sediment aggradation and channel constriction is the dominant process in this section.

Section 9: post dam construction appears to have caused reductions in stream flow and therefore increased sediment accumulations.

Section 10: this section of the river appears to act naturally as a sediment accumulation zone.

The available photographic evidence indicates that many physical changes occurred in this river after 1964. This would suggest that some geomorphic thresholds were crossed causing changes in channel morphology. It seems reasonable to suggest that the catalyst for change was the construction of Driel and Spioenkop dams.

The geomorphological response to this regulation has primarily been the deposition of sediment along the channel margins. Other changes that have occurred are the deposition of sediment in the channel causing a loss in depth, and deposition on or behind existing bars causing bar growth.

The fact that there has been little change in channel pattern serves to illustrate the stability of the Thukela system. The river appears to be entrenched in a historical flood plain and therefore confined within a "macro" channel. The reason for entrenchment is likely to be as a result of an increased energy gradient due to tectonic uplift. There is an area of rejuvenation in the channel long profile immediately downstream of this study area.

9.4 FURTHER WORK REQUIRED

The motivation for various flows in the IFR workshop was primarily to maintain the present physical characteristics of the channel. Flows were requested utilising velocity requirements for the movement of sediment. The velocities required to move various sediments were based on fairly simplistic and generalised data. To ensure that further sedimentation does not take place it is necessary to collect data on bed load particle size distribution and then run the sediment model of Dollar (2000).

CHAPTER 10 : CONCLUSIONS

10.1 FINAL IFR RESULTS

The medium to high confidence IFR results which incorporate all the refinement changes, as well as the result of the Planning Estimate, are presented in the following tables.

Table 1 : IFR 5 (Thukela River, Tugela Ferry)

VIRGIN MAR : 2160

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	TOTAL 10 ⁶ m ³	% of MAR
IFR MAINTENANCE LOW FLOWS														
FLOW (m ³ /s)	4.3	7.7	10.7	13	15	13	10.2	7.3	5	3.6	3.1	3	250.9	11.6
DEPTH (m) section	0.77	1	1.01	1.1	1.1	1.06	1	0.93	0.81	0.72	0.68	0.7		
VOLUME (10 ⁶ m ³)	11.5	20	28.7	34	37	34.8	26.4	19.6	13	9.6	8.3	7.8		
IFR MAINTENANCE HIGH FLOWS														
FLOW (Instantaneous peak m ³ /s)	15	20	30 70	30 80	60 200	30 60	30						157.84	7.31
DEPTH (m) section	1.1	1.2	1.3 1.7	1.3 1.8	1.6 2.48	1.3 1.64	1.3							
DURATION (days)	4	4	4 6	4 7	6 15	4 6	4							
VOLUME (10 ⁶ m ³)	2.1	2.2	16.1	19	99	15.8	3.6							

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	TOTAL 10 ⁶ m ³	% of MAR
IFR DROUGHT LOW FLOWS														
FLOW (m ³ /s)	1.9	3.1	4.6	5.6	6.4	5.6	4.4	2.8	2	1.4	1.4	1.4	106.1	5
DEPTH (m) section	0.57	0.7	0.8	0.9	0.9	0.85	0.78	0.66	0.58	0.51	0.51	0.5		
VOLUME (10 ⁶ m ³)	5.1	8	12.3	15	16	15	11.4	7.5	5.2	3.7	3.7	3.6		
IFR MAINTENANCE HIGH FLOWS														
FLOW (Instantaneous peak m ³ /s)		20	30	30	100	30	30						44.79	2.07
DEPTH (m) section		1.2	1.3	1.3	1.9	1.3	1.3							
DURATION (days)		4	4	4	7	4	4							
VOLUME (10 ⁶ m ³)		3.1	4.6	4.4	24	4.4	4.6							

Table 2 : IFR 2 (Thukela River, Gorge)

Virgin MAR : 1519

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	TOTAL 10 ⁶ m ³	% of MAR
IFR MAINTENANCE LOW FLOWS														
FLOW (m3/s)	3	5	7	8	9	8	7	5	3.5	2.5	2	2	162	11
DEPTH (m) section	0.8	0.9	0.98	1	1	1.01	0.98	0.91	0.84	0.76	0.71	0.7		
VOLUME (10 ⁶ m ³)	8	13	18.7	21	22	21.4	18.1	13.4	9.1	6.7	5.4	5.2		
IFR MAINTENANCE HIGH FLOWS														
FLOW (Instantaneous peak m3/s)	13	20	31 67	31 80	255 55	55 31	31						143.04	9.42
DEPTH (m) section	1.14	1.3	1.44 1.8	1.4 1.9	2.7 1.69	1.69 1.44	1.44							
DURATION (days)	4	4	4 5	4 5	10 5	5 4	4							
VOLUME (10 ⁶ m ³)	1.8	2.7	17.2	20	83	14.3	4.4							

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	TOTAL 10 ⁶ m ³	% of MAR
IFR DROUGHT LOW FLOWS														
FLOW (m3/s)	1.3	2	3	3.5	4	3.5	3	2	1.5	1	1	1	70	4.6
DEPTH (m) section	0.62	0.7	0.8	0.8	0.9	0.84	0.8	0.71	0.65	0.57	0.57	0.6		
VOLUME (10 ⁶ m ³)	3.5	5.2	8	9.4	9.7	9.4	7.8	5.4	3.9	2.7	2.7	2.6		
IFR MAINTENANCE HIGH FLOWS														
FLOW (Instantaneous peak m3/s)		20	31	31	118	31	31						50.43	3.32
DEPTH (m) section		1.3	1.44	1.4	2.1	1.44	1.44							
DURATION (days)		4	4	4	7	4	4							
sVOLUME (10 ⁶ m ³)		3.3	5.1	4.7	28	4.7	4.9							

Table 3 : IFR 3A (Bushman's River, Weenen Nature Reserve) Virgin MAR 283

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	TOTAL 10 ⁶ m ³	% of MAR
IFR MAINTENANCE LOW FLOWS														
FLOW (m3/s)	1	1.8	2.2	2.5	3	2.5	2	1.5	1	0.7	0.7	0.7	51.2	18.1
DEPTH (m) section	0.46	0.6	0.58	0.6	0.6	0.62	0.57	0.52	0.46	0.41	0.41	0.4		
VOLUME (10 ⁶ m ³)	2.7	4.7	5.9	6.7	7.3	6.7	5.2	4	2.6	1.9	1.9	1.8		
IFR MAINTENANCE HIGH FLOWS														
FLOW (Instantaneous peak m3/s)	5	12	20 10	30 10	60 10	20 10	10						28.24	9.98
DEPTH (m) section	0.75	1	1.18 0.9	1.4 0.9	1.8 0.93	1.18 0.93	0.93							
DURATION (days)	2	3	3 3	3 4	5 3	3 3	3							
VOLUME (10 ⁶ m ³)	0.5	1.6	4	5.4	12	3.9	1.2							

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	TOTAL 10 ⁶ m ³	% of MAR
IFR DROUGHT LOW FLOWS														
FLOW (m3/s)	0.5	0.8	1	1.2	1.3	1.2	0.9	0.7	0.5	0.4	0.4	0.4	24.4	8.6
DEPTH (m) section	0.37	0.4	0.5	0.5	0.5	0.48	0.44	0.41	0.37	0.34	0.34	0.3		
VOLUME (10 ⁶ m ³)	1.3	2.1	2.7	3.2	3.1	3.2	2.3	1.9	1.3	1.1	1.1	1		
IFR MAINTENANCE HIGH FLOWS														
FLOW (Instantaneous peak m3/s)		5	8	8	12	8							5.38	1.9
DEPTH (m) section		0.8	0.87	0.9	1	0.87								
DURATION (days)		2	3	3	3	3								
VOLUME (10 ⁶ m ³)		0.5	1.1	1.1	1.7	1.1								

Table 4 : IFR 3B (Bushman's River, Darkest Africa) Virgin MAR : 313

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	TOTAL 10 ⁶ m ³	% of MAR
IFR MAINTENANCE LOW FLOWS														
FLOW (m3/s)	1.1	2	2.5	2.7	3.3	2.8	2.2	1.6	1.1	0.77	0.77	0.8	55.68	17.8
DEPTH (m) section	0.54	0.6	0.63	0.6	0.7	0.64	0.62	0.59	0.54	48	0.48	0.5		
VOLUME (10 ⁶ m ³)	2.9	5.2	6.7	7.2	8	7.5	5.7	4.3	2.9	2.06	2.06	2		
IFR MAINTENANCE HIGH FLOWS														
FLOW (Instantaneous peak m3/s)	5.5	13	11 22	11 33	11 67	11 22.2	11.1						32.36	10.34
DEPTH (m) section	0.73	0.9	0.85 1	1.3 1.8	1.3 2.24	1.29 1.77	1.29							
DURATION (days)	2	3	3	3 4	3 4	3 3	3							
VOLUME (10 ⁶ m ³)	0.5	1.8	4.4	7.1	13	4.3	1.4							

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	TOTAL 10 ⁶ m ³	% of MAR
IFR DROUGHT LOW FLOWS														
FLOW (m3/s)	0.55	0.9	1.1	1.3	1.4	1.3	1	0.7	0.5	0.4	0.4	0.4	26.05	8.32
DEPTH (m) section	0.42	0.5	0.5	0.6	0.6	0.57	0.52	0.48	0.42	0.39	0.39	0.4		
VOLUME (10 ⁶ m ³)	1.5	2.3	2.9	3.5	3.4	3.5	2.6	1.9	1.3	1.1	1.1	1		
IFR MAINTENANCE HIGH FLOWS														
FLOW (Instantaneous peak m3/s)		5.5	8.8	8.8	13	8.9							5.98	1.91
DEPTH (m) section		0.7	0.81	0.8	0.9	0.81								
DURATION (days)		2	3	3	3	3								
VOLUME (10 ⁶ m ³)		0.6	1.2	1.2	1.9	1.2								

Table 5 : IFR A (Thukela River, Skietdrift)

VIRGIN MAR : 878

IFR MAINTENANCE LOW FLOWS	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	TOTAL 10⁶m³	% of MAR
FLOW (m3/s)	2.8	4	6	8	10	9.5	7	4.5	3.5	2.9	2.5	2.6	165.47	18.2
DEPTH (m) section	0.27	0.3	0.4	0.5	0.5	0.51	0.44	0.35	0.31	0.28	0.26			
FDC% (VIRGIN)	61	90	92	96	95	92	88	84	90	89	90	64		
VOLUME (10 ⁶ m ³)	7.5	10	10.1	21	24	25.5	18.1	12.1	9.1	7.8	6.7	6.8		
IFR MAINTENANCE HIGH FLOWS														
FLOW (Instantaneous peak m3/s)		30 20	40 25	50 30	150 30	50 25	40						86	9.5
DEPTH (m) section		0.9 0.7	1.05 0.8	1.2 0.9	2.1 0.91	1.18 0.83	1.05							
DURATION (days)		3 3	4 3	4 3	4 3	4 3	4							
FDC% (VIRGIN)		24 38	30 50	34 58	13 74	34 65	17							
VOLUME (10 ⁶ m ³)		6.5	9.6	12	41	11.1	6.5							

IFR DROUGHT LOW FLOWS	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	TOTAL 10⁶m³	% of MAR
FLOW (m3/s)	1.5	1.8	2.4	2.9	3.3	3.1	2.4	1.8	1.6	1.3	1.2	1.3	64.29	7.1
DEPTH (m) section	0.2	0.2	0.25	0.3	0.3	0.29	0.25	0.22	0.21	0.19	0.18	0.2		
FDC% (VIRGIN)	100	99	100	100	100	100	100	100	100	100	100	99		
VOLUME (10 ⁶ m ³)	4	4.7	6.4	7.8	8	8.3	6.2	4.8	4.1	3.5	3.2	3.2		
IFR MAINTENANCE HIGH FLOWS														
FLOW (Instantaneous peak m3/s)		12	14	16	50	14							16.6	2.7
DEPTH (m) section		0.6	0.62	0.7	1.2	0.62								
DURATION (days)		3	3	3	3	3								
FDC% (VIRGIN)		58	72	82	52	83								
VOLUME (10 ⁶ m ³)		1.6	1.8	2	9.5	1.7								

The overall % of the MAR over a time series that includes maintenance and drought flows is 26.2%.

Table 6 : Planning Estimate - Reach downstream from Woodstock Dam : B EMC : Planning Estimate

Annual flows (Million cubic metres or index values):

MAR	825.167
Total IFR	296.904 (35.98% MAR)
Maintenance low flow	200.389 (24.28% MAR)
Drought low flow	60.507 (7.33% MAR)
Maintenance high flow	96.515 (11.70)

Monthly distributions (million cubic metres)

Distribution Type : Drakensberg

MONTH	LOW FLOWS		HIGH FLOWS
	MAINTENANCE	DROUGHT	MAINTENANCE
OCT	8.54	3.01	2.3
NOV	15.18	5.44	9.72
DEC	19.25	6.16	18.18
JAN	28.42	8.53	9.09
FEB	35.3	9.83	44.34
MAR	37.24	10.15	9.09
APR	22.24	6.22	3.8
MAY	10.91	3.28	0
JUNE	6.82	2.23	0
JULY	5.45	1.92	0
AUG	4.81	1.69	0
SEP	5.36	1.82	0

Table 7 : Planning Estimate - Reach downstream from Woodstock Dam : C/B EMC : Planning Estimate

Total IFR	239.169 (28.98% MAR)
Maintenance low flow	160.801 (24.28% MAR)
Drought low flow	60.507 (7.33% MAR)
Maintenance high flow	78.368 (9.50)

Monthly distributions (million cubic metres)

Distribution Type : Drakensberg

MONTH	LOW FLOWS		HIGH FLOWS
	MAINTENANCE	DROUGHT	MAINTENANCE
OCT	7.13	3.01	1.87
NOV	12.71	5.44	7.9
DEC	15.75	6.16	14.76
JAN	22.97	8.53	7.38
FEB	27.5	983	36.01
MAR	29.61	10.15	7.38
APR	17.76	6.22	3.08

MONTH	LOW FLOWS		HIGH FLOWS
	MAINTENANCE	DROUGHT	MAINTENANCE
MAY	8.82	3.28	0
JUNE	5.61	2.23	0
JULY	4.55	1.92	0
AUG	5.01	1.69	0
SEP	4.44	1.82	0

10.2 COMPARISON BETWEEN THUKELA IFR STUDY & ECOLOGICAL RESERVE PROCEDURES

The supreme law of the Republic is the Constitution of the Republic of South Africa (Act No. 108 of 1996). This includes the Bill of Rights, which is human-centred. The two rights most directly relevant to water are:

- C Section 27: the right of access to sufficient food and water; and
- C Section 24: the right to an environment not harmful to health and well being, and to have the environment protected for the benefit of present and future generations.

The White Paper on a National Water Policy for South Africa was approved by Cabinet in April 1997, and incorporates the constitutional requirements described above, as “the Reserve”. “The Reserve” has subsequently been codified as a legal requirement in the National Water Act (No 36 of 1998) which was signed into law by the President on 28 August 1998.

The priorities in the use of water are the following:

- C The Reserve, i.e. basic human needs and ecosystem protection. These are the only two rights to water, and the Reserve may not be allocated to other users.
- C International obligations
- C All other uses require authorisations

It is therefore necessary to quantify the Reserve before allocating water to other new users. In some areas it is possible that allocations of water to existing users may need to be adjusted to meet the requirements of the Reserve.

The new Act was signed into law during August 1998, i.e. well after the IFR study on the Thukela River was initiated. DWAF is at present determining methods to determine the Ecological Reserve and a generic seven step procedure has been identified. The method acceptable to determine the quantity Ecological Reserve is the Building Block Methodology, i.e. the same method used for the Thukela study.

The seven steps are described below and an analysis of what needs to be added to the present IFR study for the results to constitute the Ecological Reserve follows:

- Step 1 : Delineate geographical boundaries or resource
- Step 2 : Eco-regional or geo-regional type
- Step 3 : Determine reference conditions
- Step 4 : Determine present state
- Step 5 : Determine EMC
- Step 6 : Set the Ecological Reserve (quality & quantity)
- Step 7 : Monitoring

10.2.1 Thukela River downstream of IFR 5

Steps 2 to 7 are still required.

10.2.2 Thukela River from Jana Dam site to IFR 5 & Bushmens River from Mielietuin Dam to the Thukela confluence

Steps 1 to 4 have been undertaken for the quantity aspects.

Step 5 has been undertaken but without the required public input.

Step 6 has been undertaken for quantity aspects for an estimated EMC.

To enable the existing results to conform to the procedures for determining the Ecological Reserve, the following is required:

- A stakeholder process must be initiated to provide input into the selection of the EMC.
- If the resulting EMC is different to the EMC on which the IFR is based on, Step 6 will require re-evaluation
- A water quality Ecological Reserve must be set.
- The ground water Reserve must be set.
- A monitoring procedure must be designed and initiated.

10.2.3 Thukela River downstream of Spioenkop Dam to the Jana Dam site

Steps 1 to 3 have been undertaken for the quantity aspects.

Step 4 has been undertaken, but low confidence is attached to the results

Step 5 has been undertaken but without the required public input.

Step 6 has been undertaken for quantity aspects for an estimated EMC.

To enable the existing results to conform to the procedures for setting the Ecological Reserve, the following is required:

- A stakeholder process must be initiated to provide input into the selection of the EMC.
- Reference conditions with emphasis on the geomorphological aspects must be established.
- Based on the results of the above reference conditions and the stakeholder process, Step 6 might require re-evaluation.
- A water quality Ecological Reserve must be set.
- The ground water Reserve must be set.
- A monitoring procedure must be designed and initiated.

10.2.4 Thukela River downstream of Woodstock Dam to Spioenkop Dam

As a Planning Estimate has been determined which does not constitute the Ecological Reserve, all seven steps will have to be undertaken.