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NVE
NORWEGIAN
WATER RESOURCES AND
ENERGY ADMINISTRATION

SMALL HYDRO ELECTRIC SCHEMES IN SOUTH AFRICA

Appraisal of the request for Norwegian support to conduct feasibility studies on 5 small projects in KwaZulu and Transkei

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Professor Jan Hesselberg, University of Oslo Section Manager Kjell Repp, NVE Senior Engineer Odd Arild Kilvik, NVE Chief Engineer Torodd Jensen, NVE	5 February 1996
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ABSTRACT

This report is based on a NVE mission to the Republic of South Africa (RSA) September 1995 regarding possible Norwegian support for feasibility studies on five small hydro electric power plants in KvaZulu and Transkei. The mission included meetings with Eskom, private consultants and research and development institutes in RSA relevant for the mission. Eskom organized a field visit to all five sites.

This report gives recommendations on further studies regarding the Jozini scheme in KvaZulu, the Lubisi and Tsitsa Falls schemes in Ttranskei. Further studies on the Mt. Fletcher and Endwe Poort schemes in Transkei are not recommended.

Information on socio-economy, hydrology, environment and technical/economical aspects is given for each scheme.

SUBJECT TERMS	RESPONSIBLE
Small Hydro South Africa	Egil Skofteland Head Office of International Cooperation

Head Office: Middelthunsgate 29
Postal Address: P.O. Box 5091. Maj.
N-0301 Oslo, Norway

Telephone: + 47 22 95 95 95
Telefax: + 47 22 95 90 00

Postgiro 0803 5052055

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ABBREVIATIONS

CEEM	Centre for Energy Efficiency and Management
CESSA	Centre for Energy Studies in Sub-Saharan Africa
CSIR	A South African company performing research and development to gain technology for competitiveness, development and decission making
DMEA	Department of Mineral & Energy Affairs
EDRC	Energy for Development Research Centre, University of Cape Town
EPRET	Energy Policy Research and Training Project
ERI	Energy Research Centre
Eskom	Electricity Supply Commission
NORAD	Norwegian Agency for Development Cooperation
NVE	Norwegian Water Resources and Energy Administration
RDP	Reconstruction and Development Programme
RSA	Republic of South Africa
TESCOR	A public company previously operating irrigation schemes and small hydro electric power plants. Today reduced to a small office owning plants, but not involved in operation. Small hydro operation and maintenance is handed over to Eskom

EXECUTIVE SUMMARY

1 General

The NVE Mission to South Africa took place in September 1995 and included meetings with relevant parties and site visits to the proposed project areas.

For small hydro implementation and operation Eskom has informed that the Department of Mineral & Energy Affairs (DMEA) will be the implementing agent. However, Eskom will still play a participatory role.

The proposed projects are located in remote areas. The implementation of the plants can promote an economic development in the neighbourhood of villages with a potential for growth. Some schools and clinics, however, which need electricity for enhanced education and other services are very isolated located. Connections to a local grid in **these cases** are very expensive, and it is therefore recommended to electrify them by means of supporting solar electrification programmes which are more economically viable than constructing transmission lines. These solutions will not introduce a potential for economic growth, but meet basic needs for light.

Eskom will be responsible for the implementation of solar electrification schemes and for the transfer of knowledge on the plants maintenance and operation to the local community.

2 The hydro power schemes (ranked after priority):

2.1 The Jozini scheme (KwaZulu)

The Jozini dam is a large dam built for irrigation and flood control. The dam creates a reservoir which can store more than the annual inflow. There is a documented need for irrigation schemes and improved drinking water supply in the area. Electricity could promote the development of such schemes.

The proposed hydro power station (3-10 MW) will utilize the head in the existing large dam and water released for irrigation and compensation flow in the Pongota river. The power scheme can compete with other alternatives for electricity supply including connection to the main grid. Approximate implementation cost NOK 20-40 mill depending on alternatives. No environmental impacts are expected. Existing information on hydrology is sufficient for development of the power station.

The hydro power scheme should be used for electrification of selected schools/clinics/market places which have a potential for growth. The scheme is well suited for a turn key development concept.

A ***feasibility*** *study with focus on socio-economy for improved understanding on the need for power is recommended. The feasibility study will also include design of the plant.*

2.2 The Lubisi scheme (Transkei)

The Lubisi dam is an existing large irrigation dam in the Indwe river. The village close to the dam has a potential for growth and electricity will improve the condition for development.

The proposed hydro power station (approximate 1.5 MW) will utilize the head in an existing large irrigation dam. It can compete with other alternatives for electricity supply including connection to the main grid. Approximate implementation cost NOK 15 mill. Environmental problems are not expected. The scheme is well suited for a turn key development concept.

A ***feasibility*** *study including socio-economy (focus on need for power), hydrology and technical/economical design is recommended.*

2.3 The Tsitsa Falls scheme (Transkei)

The village Shawbury close to the falls is the centre for schools and shops in the area and has a great potential for development. So far electricity has not reached the village. Only a small diesel generating unit is serving the main needs in the different school buildings. Plans are in progress for connecting the area to the main grid.

The water fall is impressive with 100 m head, hence development of the fall has to consider the environmental impacts.

The scheme can compete with connection to the main grid. The Tsitsa Falls have an option for small, medium or large hydro power development. Medium and large hydro will benefit the whole region. Approximate implementation cost small hydro (1.5 MW) NOK 22 mill. Approximate implementation cost large hydro (100-150 MW) NOK 600-700 mill.

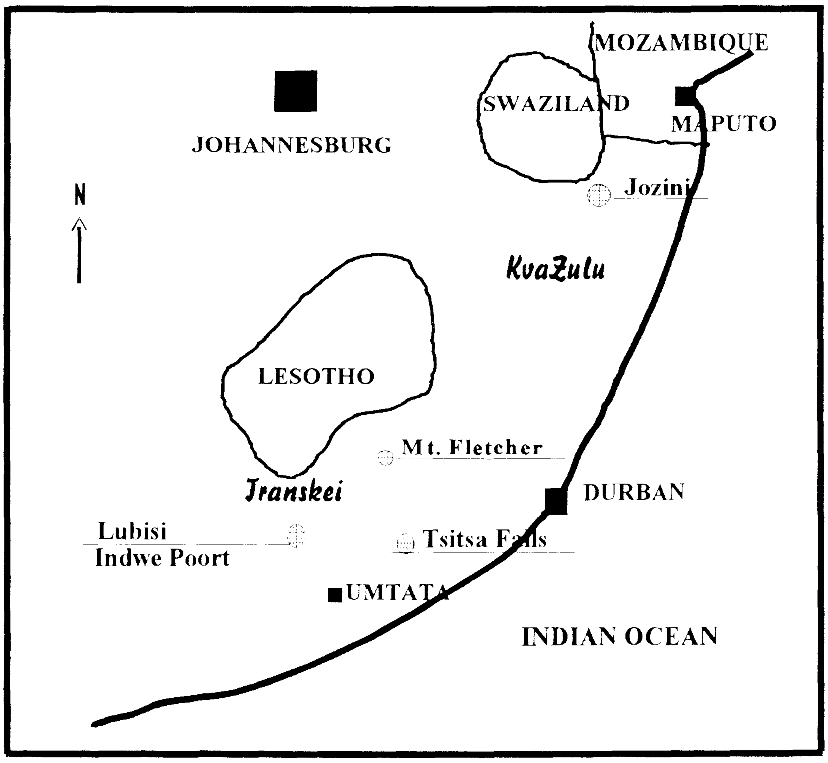
*A **pre-feasibility** study for all options is recommended including socio-economy, environment, hydrology and technical/economical design.*

2.4 The Indwe Poort and Mt. Fletcher schemes (Transkei)

These schemes are considered to be too expensive and cannot compete with electricity from the main grid.

Further studies are not recommended.

LOCATION MAP:



1 BACKGROUND

NORAD has received a request dated 3 March 1995 from Eskom to conduct a feasibility study for Jozini Dam small hydropower scheme in KwaZulu, Lubisi Dam, Indwe Poort, Mt.Fletcher and Tsitsa Falls small hydropower schemes in Transkei. NVE has been requested by NORAD in a letter dated 6 July 1995, to appraise the proposed schemes in order to improve NORAD's background knowledge before supporting the projects. The Terms of Reference for the NVE Mission to South Africa is found in appendix 1.

2 OBJECTIVE

The objective is to define projects which will contribute to improved quality of life for people in the rural areas. Focus is on making electricity available for lighting, water supply, irrigation and small scale industry. Target areas are put on schools, clinics and village centres which have a potential for development.

3 THE ELECTRICITY SITUATION IN SOUTH AFRICA

3.1 General

There is a decision on an accelerated national electrification programme in South Africa. Today only 45% of the South African population is connected to the electricity grid.

The generating of electricity in South Africa mainly depends on thermal power where coal fired plants are most common. Hydro power has been developed for peaking operation and in combination with a few irrigation dams. From the beginning of this century small hydro power plants were developed to feed large farms and local grids. Many of these small plants have been closed due to the possibility of connection to the main grid and expencive operation of the old plants.

The average domestic price for newly electrified households in South Africa (SA) is approximately 25 SA cent/kWh (~0.5 NOK/kWh). The connection fee is only 40 Rand (~75 NOK). There are several different domestic tariffs in SA, and time-of-use tariffs to reflect costs at different times for large customers and farmers. Time-of-use tariffs are under consideration for domestic users.

There is a large capacity of thermal power with a surplus of electric energy. New production capacity if sold to Eskom and connected to the main grid, will only be paid according to the marginal cost of adding more coal to the existing thermal plants. This cost is between 2-5 SA cents/kWh depending on transmission. A hydro power plant competing with extension of the main grid, will compete with the sum of:

- value of energy losses in the main grid
- cost for extension of the grid
- Eskom's average cost for production

The surplus situation will limit the construction of new capacity in foreseeable future. Some uncertainties, however, are connected to the vast electrification programme now being implemented. Connection of large numbers of households in the urban and the rural areas will reduce the load demand factor and thus increase the need for peaking power plants.

Hydropower is by far the most efficient resource for meeting peaking demand. The feasibility of small hydro power plants should therefore include a value of their peaking capacity.

3.2 Eskom's comments on electrification of rural areas and the small hydro electric power schemes.

Eskom supports integrated energy/rural development approach.

The best option must be selected from a financial, economic, technical, socio-political, environmental and legal perspective; inclusive of grid and other non-grid options.

Eskom has a neutral stance to the small hydro option at this stage and supports a study to test whether the option should be a rural electrification priority.

Eskom states that it is important that NORAD provides a commitment to fund the implementation of the projects with grant money before commencing with the studies, should the studies prove to be successful. Otherwise expactations will be raised which will not be met.

Eskom's stance on non-grid electrification:

* A grid solution will always be given preference to a non-grid. Taking into account the financial implications to the ministry/customer and resource constraints.

* Non-grid systems will not be promoted for areas which will be reached by the grid within 5 years, unless the ministry/customer requests otherwise.

* Eskom's non-grid effort will be concentrated on schools and clinics.

* Eskom will electrify schools and clinics using non-grid systems on a full cost recovery basis and only where:

  a) The ministry/customer or other external funders agree to pay the capital costs or the systems are earmarked for Eskom community development funds.

  b) The ministry/customer agree that the schools and clinics are priorities in terms of electrification and have budgets in place for the current costs.

* Eskom will not drive the implementation of residential non-grid electrification projects. Eskom will participate in residential non-grid projects planned and financed by bodies external to Eskom.

* Cognizance will always be taken of other alternative energy forms which can be combined with non-grid systems to ensure a best cost integrated energy solution for the customer.

* For solar energy systems to meet demands in schools and clinics Eskom will play a project management/facilitation role for provision of equipment, suitability of technology, system size and design, specification, establishment of a maintenance contract, placing of contracts, training of local contractors, projects supervision. Upon successful fulfillment of this role, Eskom will hand over the system to the ministry/customer who will then be responsible for the system.

4 MEETINGS/SITE VISITS

Appendix 2 informs about the travel, meeting programme and people met.

Information on socio economic conditions and viewpoints, hydrology and technical and economical aspects are based on information given in the meetings and available documents.

NVE has received information/copies of:

- Eskom's strategy for electrification of rural areas in connection with these projects (Appendix 4).
- Hydrology and maps, scale 1:50.000
- Information on local consultants
- Information on viewpoints from local development committees (included in the social-economy chapter)
- Information on research work in progress on energy for rural areas and energy efficiency in the country as a whole. (Appendix 3)

5 SOCIO ECONOMIC CONDITIONS AND VIEWPOINTS

(By professor Jan Hesselberg, University of Oslo)

5.1 General

South Africa today has an annual economic growth rate (3.5%) which is above the growth of population (2.1%). There has been a rapid drop in the black fertility rate during recent years. Although the economy is gradually improving, the legacy of the country's past will take time to overcome. The rate of unemployment is 40% among the black population and 6% for the white[1]. Only 7% of the youth entering the labour force every year obtain jobs in the formal sector. The rest must find their livelihood in the urban informal sector or remain in farming. In a study by the Bureau of Market Research (Umsa) found that the Eastern Cape Province has a rate of unemployment of 45%[2], the second highest in the country after the Northern Province.

Rural areas in South Africa are characterized by severe poverty, low productivity and limited access to land, gainful

[1]Sunday Times, Business Times, 17 September 1995

[2]The Star, 22 September 1995

employment and public services. Former Transkei and Kwa Zulu account for 48% (nearly 6 million people) of the country's rural population below the Minimum Living Level in 1990[3] (they have 35% of the population).

The areas visited by the team are all rural where farming and labour migration to towns and cities are the main sources of income. By providing infrastructure to the villages at and surrounding the sites for the hydro schemes, important incitements are given for local development. It is common understanding that the level of infrastructure (especially electricity, potable water and rural roads) has to be developed well in advance of production and other private sector economic activities. The provision of electricity would accordingly be of immense value as a means to start a positive development process in these areas.

One of the sites visited by the team, Lubisi, can be used as an example of a probably quite general application of energy sources for different domestic purposes. According to a survey made by CSIR (Pretoria) of the region in which Lubisi is located, 41% of the families use wood for cooking, 29% use paraffin and 24% use cow dung. For heating the figures are: wood 49%, paraffin 24%, and cow dung 20%; and for lighting - paraffin 55% and candles 39%[4]. The team met only complete enthusiasm from people, tribal authorities and officials regarding a possible provision of electricity to the areas surrounding the sites of the proposed hydro schemes. The question never arose of insufficient money for applying electricity to lighting people's homes. The low connecting fee of R 45 and the coupon system of charging for electricity use explain this fact. There is a restriction on the use of electricity. For houses of poor standard a pole is set in the ground at the wall of the house and a meter attached. A plug can be connected directly to the meter without any wiring of the house.

At present only 12% of the households in rural South Africa have access to electricity[5]. In rural Eastern Cape 2% have electricity, whereas the figure for former Transkei is 0.2%. In rural Kwa Zulu-Natal 7% use electricity. On average in the

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[3]Thom,C.1994. Energy for rural development, Energy for Development Centre, University of Cape Town, Paper no 6

[4]CSIR, Lubisi Dam Development Project. Request for finance document, Pretoria

[5]Davis M.1995. Overview of electrification statistics. Energy for Development Research Centre, University of Cape Town.

former homelands 4,8% of the households have access to electricity in densely populated places, whereas the figure for sparsely populated areas is 1,7%. It is thus to be expected that electrical appliances are virtually non-existent in most rural households. When electricity is provided, most households will not immediately be able to afford such appliances. It will take time for them to apply electricity to end-use purposes such as refrigeration, ironing, water- and space-heating. The first purposes after lighting will usually be radios, TVs and light cooking[6]. Even in electrified households other fuels make up a substantial portion of total energy expenditures (in urban areas 35% and in rural areas 65%). Additional loads outside of the household sector is therefore important to find/establish in order to create a larger demand for electricity in rural areas generally. It is said that rural areas have "twice the cost and half the sales" compared to urban electrification.

The use of electricity for other purposes than lighting, such as cooking and heating, will thus take some time before most of the population in an area can afford. According to Anton Eberhart of the EDRC (Energy for Development Research Centre, Cape Town), the rate of acceptance of electricity for non-lighting purposes was slower than expected in the Eastern Cape Province. People mainly use electricity **in addition** to firewood, whereas the rich substitute electricity for other energy sources more rapidly. This general conclusion on fuel-switching is somewhat modified according to availability of firewood in different areas. It can be said that South Africa is a multi-fuel economy in slow transition. One consequence of the slow acceptance rate apart from a low demand in the early phase of electricity provision, is that it may for instance take some time before the full environmental benefit of rural electrification will be visible in the landscape.

It is important to assist with additional development efforts in the villages in order to enable a more rapid application of electricity to other purposes than lighting. In view of the need to create a larger demand for electricity it is sensible to develop small hydro schemes as part of a broader programme of development.

5.2 Jozini hydro power and electricity supply scheme

At Jozini close to the dam there is a small service centre with grid electricity. Downstream of the dam and out on to the

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[6] Davis,M.1995. The institutional framework for electrification planning. Energy for Development Research Centre, University of Cape Town.

Makatini Flats the population is spread out on small farms. On average the region has only 29 persons per square km but with a concentration along the Pongolo river. Since the region belongs to a semi-arid climate type, farming is of the mixed category with both cattle/small-stock and cultivation of dry-land maize. The region has poor subsistence opportunities. Most farms are probably sub-subsistence meaning that a family cannot live on the farm alone. The area travelled by the team seems to be heavily grazed by cattle. As common in this part of Africa, land is communally controlled through traditional tenure. The farmer has use and inheritance right to the family crop land, but cannot sell it. Grazing land can be used freely. Labour migration is supplementing the income of the families, for some it is most probably the main source of money income. However, the team was told that now a few people had returned to the area because they could not find work in the cities. Only 2% of the work age population have formal wage employment locally.

Because of the money income derived from work elsewhere by one or more of the household members, it is to be expected that nearly all families will be able to afford the price of connecting to and using electricity for lighting. It may take some time before electricity will be used for other purposes. Since the density of population on the Flats is relatively low, firewood for cooking is available.

There is a need for lighting of clinics, community halls and schools. People expressed to the team that their priorities were electricity and water for drinking to the tiny "centres" in the area where these services were located together. Water is presently taken from the river Pongolo, from pans and wells. The water is often polluted by the run-off from the grazing areas for cattle and small-stock and in some places also a bit salty. By providing a few water taps spaced some hundred meters apart to the tiny "centres", a concentration of the settlement pattern in the region will occur. Such a development would be sensible for later grid electrification of the area.

It is thus the contention of the team that in a transition period, support (solar power and drinking water drawn by wind mills or diesel pumps; in some few cases grid extension may be more appropriate) should be provided to enable a selection of the "centres" to develop into small villages. Solar electricity requires a rather high initial capital outlay, and is thus not relevant for ordinary households. The same can be said for wind-pumping of water, which can have low reliability and must be accurately matched to borehole capacity. Experiences from South and Southern Africa show that especially water taps draw people from the farms to settle near schools. It is however important that these taps are some distance apart to allow the people space to keep kraals for their animals close by. The crop land can be a distance from the village. A study should be undertaken to decide on the appropriate "centres" to develop into small villages.

The third priority of the people the team met, was water for irrigation. The soil in the area was claimed to be good, but the rainfall too low and erratic. The community the team visited on the left bank of the river about 20 km downstream, maintained that sugar cane could be cultivated. These people had come to the area only a few years ago when there were some good rainfall years. Now they found it to be too dry for anything but maize and some beans.

The original plan when the dam was built, was also to irrigate the left bank. This has not been implemented, only the right bank has irrigation channels built during the 1970s. Moreover, the area irrigated is less than the potential according to available water. Electrical pumps can be an option for the large farms only. Normally electrical pumping is not economically viable and cannot compete with diesel pumping. This option is thus not of any help to the many small farmers.

The team learned that private interests would establish a sugar mill in the area if a sufficient amount of land (minimum 600 ha) where made available for irrigated sugar cane. At present there is a political debate on where this land is going to be allocated - on the Makatini Flats or on the west side of the mountain range, in the former "white farming area". The potential sugar mill operators were however not in favour of the latter because of the "long transport" of the sugar cane. It is of course possible to grow a number of crops if irrigated water is made available to the farmers. Cotton has been tried on the right bank but failed. More high value crops using the land intensively such as vegetables, is not a realistic option in the area since it is located far away from markets. Sugar cane seems to be the best crop besides maize, because there is no frost in this part of South Africa and the knowledge of cultivation of this crop is widespread. It must however be said that to provide the left bank with irrigation water will most probably be quite expensive, thus the cultivation will have to be heavily subsidized.

Although there is a general policy in South Africa now for cost recovery in new government projects, it is not known whether this policy will be fully implemented for irrigation projects. The farmers using irrigation water on the right bank must today pay 1 cent per cubic meter.

There is a long distance from the main centre by the dam, which has some government administrative functions, to the various communities out on the Makatini Flats. There is thus not one community that would benefit from a possible construction of a small hydro-electric scheme but many.

On the question of ability to manage, operate and maintain such a scheme, the team feels confident that the competence of organizing an association is available and that training may ensure that the operation will be successful given an agreement of cooperation and supervision with Eskom (agreement with Eskom necessary) during the first few years of the project. It is also probable that trained personnel will stay on in the area due to the existing group of skilled people already employed to maintain and run the dam. There is already an established association for development in the area - the Khulani Working Committee, Maputaland. The team met representatives of this committee at a meeting with people from the Momdabuya area. The meeting was held in their community hall.

In general, the impression is that people in the region have low incomes. Hunger could not be seen, people's clothes were normal for rural areas and the houses were built mostly of mud. Compared to the Transkei region, people in the Jozini area probably have less incomes and less means to improve themselves without outside support. Furthermore, malaria is a serious problem in this north-eastern part of South Africa. Statistics are available for 1993, and they show that in Igwavuma 4 556 people got malaria[7] in that year out of a population of 128 250. The death toll was 13 persons. Igwavuma was the hardest hit district because it boarders to Mozambique. In Ubombo 7 persons died out of a population of 103 446. Igwavuma and Ubombo constitute together the so-called Maputaland. In this region 56% of the population is below 18 years of age. As much as 47% are non-literate, and 25% are semi-literate. The team was told that the infant mortality rate is high in the region.

On the question of environmental consequences of a hydro scheme, the team cannot see any reason to fear for negative results. People did not mention any, either. In fact, they mentioned an environmental benefit if light was brought into the area because less firewood would be needed. Irrigation would also if extended to the left bank, improve the environment.

Monoculture of sugar cane in some areas would most probably be interspersed with maize and other crops for local consumption. The maize yield would undoubtedly at least double given irrigation.

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[7]Ingwavuma/ubombo in Kwa Zulu Natal. September 1995. Report made by the local authority at Jozini

Since grid electricity is available at the Jozini centre, grain milling and cold storage is already possible there if increased production in the area takes place. As a general rule, rural electrification will not be agriculture-driven in South Africa. Agricultural production and processing in remote areas cannot alone justify electrification, it would not be economic viable.

If NORAD decides to support the hydro scheme, other additional types of activities should be considered in the region to ensure that the poor will benefit. It may be an idea to enter into a joint programme with South Africa on a fifty/fifty basis (ie; Sentral Government, RDP etc).

Finally, it should be mentioned that the team was told that this area has been thoroughly studied in several dimensions, much data exist - but as yet very few projects have been implemented.

5.3 Tsitsa Falls hydro power and electricity supply scheme

The team visited the school centre in the village Shawbury close to Tsitsa Falls in the Bencuti district. The village grew up around a mission established there in 1909 and a church built in 1916. Today there are three schools in the village - a teachers training college, a high school and a junior secondary school. The village is fairly large with about 800 compounds or close to 4 800 people. In the district there is close to 50 000 people. It is situated in the region in such a way that it can easily become a service centre for the surrounding villages given better infrastructure such as electricity and water taps. At present there is no non-agricultural production activities. Local market sales exist. There are already plans for a shopping centre in the village; a large plot has been set aside for this purpose. The schools have electricity, and water is today provided by diesel pumps. The water is taken from the river. It is cleaned a little but not enough. In addition, water is taken from a reservoir in the mountains. This is however not well built and needs upgrading.

Due to this although spares infrastructure, the village is drawing people in from surrounding farms and is thus growing.

Most houses in the village are made of cement. The income for this is earned partly by labour migration. A large part of the households have a member working elsewhere in urban South Africa. The farming is mixed - a combination of cattle and maize cultivation. The area is fairly dry and almost without trees and bushes. A beginning of soil erosion on slopes can be seen in most areas around this and other villages in the region. Irrigation is here not an option regarding a possible construction of a dam because there are no cultivatable land downstream. A hydro scheme will provide the houses in the villages in the area with power for lighting and for many gradually also for cooking. This will be beneficial for the environment.

Peoples affordability levels to pay for electricity depend upon a number of factors which need to be assessed in detail. The present rate and the coupon system makes payment easy for some ordinary household use. Since Shawbury already is a centre of some sort, it is to be expected that as a result of electricity, small non-agricultural activities such as minor repair work of cars may be established. However, the area is remote from larger markets and thus no medium-sized production can be expected to locate their activities to the village in the foreseeable future.

Since the national grid is only 4 km away from Shawbury, and is planned to be extended within a few years, a construction of a hydro scheme may not seem to benefit the local people very much. On the other hand, the income that people may earn during a construction period, will create important local multiplier effects on other economic activities, especially if some of the work tasks are consciously made by labour intensive methods. Furthermore, investments may be made by the local people in production facilities because the village is in a phase of establishing itself as a key service centre in the region. On the negative side can be mentioned that often short term incomes are used for consumption and investments in cattle only. The increased pressure on grazing land may not be advisable.

The villages around Tsitsa Falls may be able to manage, operate and maintain a hydro scheme if training of operating personnel is included in the implementing budget. Training should, however, be carried out in cooperation with Eskom. An agreement with Eskom is necessary. In fact, it may even bring some skilled persons back from urban employment given the opportunity for a permanent job in the village. This will contribute to an empowerment of the local communities. Such a reverse brain flow is not unthinkable, although the normal experience is that whenever someone from a rural area receives special training, he ends up in a city where incomes are higher and lights brighter.

The committee on electricity in the village has already collected some funds in order to be able to approach RDP (the Reconstruction and Development Programme) with a request for an extension of the grid to the village.

At the meeting the team had with the headman, the chairperson of the electricity committee and representatives of ANC in Shawbury, it was made clear that there were no cultural feelings attached to the Falls. There were some burial grounds in the deep water downstream of the Falls. This aspect needs further investigation. Also other people in the village and in the village on the other side of the Falls, which the team did not visit, may have other opinions on this issue.

It should be mentioned that Tsitsa Falls is one of very few such falls in South Africa. The construction of a large dam upstream of the Falls for hydro power development of the falls and rapids downstream will therefore cause environmental impacts. There are no houses in the dam site area. The fields that may be put under water can be substituted with other fields. The cultivation of maize is done on a rotation basis with the land reverting to grazing in between. Although there may be limited grazing land, the land for cultivation does not seem to be in short supply.

5.4 Mt Fletcher hydro power and electricity supply scheme

The team did not visit this village but saw it clearly from the air. The village has a local grid based on diesel power. It is a fairly large settlement with several thousand people. It is an old mining settlement, and the houses are of better quality than other rural villages in the region. It is remote located, but there are plans for connecting it to the national grid within 5-10 years.

From the environmental point of view it seems unlikely to be severe problems regarding the dam site. There are no possibility for combining an irrigation scheme and the hydro power scheme.

Since the team did not visit the village, information on other possible problems and the opinions of the people are lacking.

5.5 Indwe Poort hydro power and electricity supply scheme

This area is close to the small town Lady Frere. This town is in a former white farming region. The town and region have electricity, tarred roads and even a narrow gauge railway. Two large irrigation dams exists in the catchment area. Downstream of the dams there are several villages of comparable standard to Shawbury. Many thousand people live in the surrounding villages.

Information is lacking on the options for irrigation and opinion of people.

5.6 Lubisi hydro power and electricity supply scheme

The village Lubisi is located close to the dam on both sides of the main road in this region. It is remote from small towns and thus markets. The national grid is not likely to reach this area during the coming years. The larger Lubisi region contains approximately 80 000 people, giving a population density of about 200 per square km. As much as 36% of the population is below 16 years.

The village Lubisi has the possibility to become a small service centre for the many villages surrounding the dam and possibly also for other villages. The favourable location explains this future prospects given provision of electricity and water taps. Handicrafts have not yet been commercialized in the region.

Through assistance from CSIR the people in Lubisi have managed to come together and establish a strong local community association called the Lubisi Dam Development Forum. This association has recently been accepted and their proposals for development efforts agreed upon by the Chief in Umtata. They have opted for a so-called "Section 21 company" (non-profit) and will get this registered with the Magistrate's Office. Forum has also mobilized people in the villages on the other side of the dam. They have clear ideas for priorities on development. This was presented to the team at a meeting with the local traditional authority and the Member of Parliament for the region. The use of electricity will thus probably gradually be used for other than just lighting purposes. The prospects for non-agriculture economic activities are limited, but the team got the impression that some smaller activities were likely to be established when electricity becomes available.

According to the standard of houses and the fact that many families have a labour migrant, people can afford the use of electricity in their homes. The team was told by the Rural Development Officer for the region that there was no undernutrition but some malnutrition in the area. This is due to a low degree of food variation, people rely mostly on maize.

As in most other areas of Transkei, people in the Lubisi region live on mixed farming of cattle/small-stock and dry-land maize cultivation. Although there is a small forest up on the mountain side where there is a national reserve, the area is treeless. Thus a hydro scheme will be environmental beneficial, especially later when people can afford to use electricity for cooking.

The successful mobilization of the people in the villages around the dam will in the opinion of the team ensure that management, operation and maintenance of a hydro electric power plant is possible using local resources. Training of operating personnel, however, must be included in the implemeting budget. Extensive training is necessary since the level of education in the region is low. About 37% of the population has no education at all.

Irrigation with water from the dam is today only carried out 9.5 km downstream through the Qamata Irrigation Scheme. The land on the edges of the dam is not used to grow for instance vegetables with bucket watering. It was mentioned that the irrigation downstream was successful on the production side, in fact so successful that some farmers had problems to sell their harvests.

5.7 Summary

The Jozini area is somewhat different from the places the team visited in the Eastern Cape Province. The economic situation for most people was better in Transkei. The land the Jozini and the Transkei areas are suitable for maize and cattle ranching. In the Jozini area sugar cane could also be grown but only under irrigation. Due to relatively sparse population, this area has more trees and bushes providing firewood. In Eastern Cape treelessness was the dominant feature together with some erosion problems. The carrying capacity regarding cattle and small-stock must here be close to the limit in some places and above the limit in others.

In both the Jozini and the Eastern Cape area people would be able to afford the cost of connection to the grid due to its cheap price, and to use it for lighting. The reason for this is the high degree of labour migration which provides most households with money income. Labour migration is also splitting the families. The result is, as is common for rural areas in the whole of southern Africa, a large number of female headed households. Unemployment is very high in rural areas. It was mentioned as the leading problem wherever the team went. Outright hunger is however not the issue, although poverty is rampant and some families probably also can be categorized as destitute. Information on the degrees of poverty is lacking, and specific studies are necessary to comment further on this issue. For women much time and effort is spent on fetching water.

On the question of management of hydro schemes, the team concludes that all the sites visited have the capacity to organize themselves, and through appropriate training operate small schemes in cooperation with Eskom or another company with similar knowledge. Undoubtedly, the schemes would act as important contributions towards empowerment of local communities. Although remote area power supply must be subsidized initially, it is advisable to undertake for social reasons as well as for the fact that it may constitute a push on the development process in general.

Common experience tells that the positive contribution by electricity provision to rural areas depends on the existence of the right preconditions and complementary development factors in a given area.

Availability of electricity is thus a necessary but not sufficient condition for development beyond a certain limited point. The main constraints to agriculture and business development in rural areas are of a structural kind and not primarily energy-related. Moreover, the question should always also be raised whether alternative uses of the funds would yield higher economic and welfare returns (e.g. housing, water supply, health, education, roads).

Rural electrification may have a positive environmental impact regarding the problem of soil erosion and used batteries. On the social side, women will gain considerably through less time and hardship spent on fetching firewood. Indoor air quality is often bad causing respiratory illnesses particularly in children. Electricity provision will be an important help in this respect given an improvement in household incomes enabling the purchase of electric appliances for cooking and space-heating.

Finally, the team wishes to express the need for baseline studies for later evaluation of projects that NORAD decides to go ahead with. It is however not sufficient only to have so-called before/after studies. Specialized studies are necessary on selected themes to ensure positive socio-economic impact of the hydro schemes, and the possibility of inclusion of other types of assistance to infrastructure and economic activities in the areas concerned.

Based on the information gained, the team is of the opinion that a joint effort by Norwegian researchers and CSIR (in agreement with Eskom) would best secure relevance and quality of a programme for systematic socio-economic and environmental evaluation. Such a programme is of particularly relevance when the objective is uplifting of people's quality of life.

6 HYDROLOGY

6.1 General

Hydrological records in the form of time series or monthly flow records are available from RSA Department of Water Affairs, Pretoria, and from Transkei Department of Agriculture and Forestry, Hydrology Sub-Division. Hydrological monitoring in Transkei has during the last ten years been carried out by Stephenson & Associates for the Transkei Department of Agriculture and Forestry. The company has in addition carried out a few more detailed hydrological studies covering the major runoff basins in Transkei, where long synthetic runoff series have been generated by rainfall-runoff modelling. The quality of the raw data seems to be highly variable, with a lot of gaps in the records and poor maintenance of weirs and gauging sections. In 1976 all gauges in Transkei were left to Transkei to attend, after which the monitoring started only in 1980, and only at some of the old gauging stations. For a number of years after 1976 there were under-qualified hydrological staff attempting to operate the Hydrology subdivision in the Department of Agriculture and Forestry, Transkei.

The availability of records from the catchment to Jozini Dam is unknown at present. The huge storage capacity of the reservoir minimizes the present need for hydrological data. Detailed hydrological studies are only necessary if larger hydropower or irrigation installations are considered.

The Transkei area has got one of the highest surface runoff per square kilometre of South Africa, mainly due to the high surrounding mountain ridges which explain the rather high annual rainfall compared to the rest of South Africa. It also has a high sediment loading, which is relevant for the Tsitsa Falls scheme. The mean annual rainfall varies between 600 and 1200 millimetres, while mean annual potential evaporation varies between 1300 and 1600 millimetres in the proposed project areas. The year is normally divided into one dry and one wet season, with the major part of the rain falling during the months from October-November to April.

The various rivers feeding the proposed schemes are therefore reasonably large, with a relatively high average flow. Due to the variable flow from summer to winter (i.e. high seasonality), only a fraction of the flow can be utilized without large storage capacity.

6.2 Jozini hydro power and electricity supply scheme

The Jozini Dam covers a catchment of 10.047 Km^2, of which more than half the area is within Swaziland. According to information from Dr. David Stephenson, professor of Hydraulic Engineering at the University of the Witwatersrand, Johannesburg, the mean annual rainfall of the catchment would be around 1000 millimetres. By using a minimum runoff coefficient of 0.1, the annual inflow to the reservoir would be in the size of 1000 Mm^3, or approximately 30-35 m^3/sec. With the huge existing storage capacity (2490 Mm^3) neither low flow or flood estimates have been considered necessary at this stage with the present proposed schemes. A more detailed hydrological study might have been beneficial, however, for future development planning in the area.

6.3 Tsitsa Falls hydro power and electricity supply scheme

According to the information received the catchment area to Tsitsa Falls is approximately 4200 km^2. This value is underestimated, as the drainage area to the river gauging station T3M06 a few kilometres upstream has been calculated to 4268 km^2. It is assumed, however that the flow contribution from the sub catchment between the two sites is negligible, and the flow records from T3M06 have therefore not been adjusted to the proposed dam site, but used directly.

Mean annual rainfall in the area has been estimated to 950 millimetres, while potential evaporation is approximately 1350 millimetres/year.

Mean annual flow has been calculated to 23 m^3/sec., or 737 Mm^3 (Appendices 4.1 and 4.2). Lowest mean monthly flow monitored was in September 1969, with approximately 40 l/sec. This low flow seems to be rather exceptional, however, and closer examination of the flow recession during the preceding months indicate that the value might be wrong. The second lowest mean monthly flow of 386 l/sec. was monitored during June 1979.

A dimensionless flow duration curve has been calculated on monthly flow data covering the periods 1951-79 and 1983-91, and is included as Appendix 4.3

6.4 Mt Fletcher hydro power and electricity supply scheme

There are no hydrological stations in the upper reaches of Tina River, where Mt Fletcher is located. The nearest one, T3M02, Kinira Drift, which probably possesses similar catchment characteristics, and therefore representative for the area, is not considered as very reliable (ref. Dr.Stephenson). A more detailed hydrological study would therefore be necessary prior to a detailed planning of a hydropower scheme.

Average rainfall in the approximately 900 km^2 large catchment of Mt Fletcher is 900 millimetres/year, while potential evaporation is 1350-1400 millimetres/year. Analyses of hydrological records (Appendices 4.4 and 4.5) from Kinira Drift during the periods 1948-79 and 1983-89 indicates a runoff coefficient of 0.13, which looks reasonable, or maybe a bit low, compared to a runoff coefficient of 0.18 at Tsitsa Falls. Transposing the values from T3M02 to Mt Fletcher indicate a mean annual flow of 3-4 m^3/sec., or 100-110 Mm^3, and a minimum flow slightly less than 100 l/sec. A dimensionless flow duration curve has been calculated, and is shown in Appendix 4.6.

Analyses of the runoff data from the station T2M05 (Appendices 4.7 and 4.8) further downstream in Tina river confirm the unreliability of the data from Kinira Drift. Specific runoff at T2M05 has been estimated to 4.4 l/sec. km^2, which transposed to Mt. Fletcher would give a mean runoff of approximately 4 m^3/s. Considering the special rainfall distribution in the area, the specific rainfall at Mt. Fletcher should be higher compared to T2M05. The indicated mean annual flow of 3-4 m^3/s at Mt. Fletcher could therefore probably be increased to 5 m^3/s. A dimensionless flow duration curve has been calculated, and is shown in Appendix 4.9.

6.5 Indwe Poort hydro power and electricity supply scheme

No information has been available on the hydrological station just downstream of the Indwe Poort Dam. According to Dr.Stephenson a more thorough study is necessary in order to establish accurately the inflow to the reservoir and the yield of the river at the proposed dam site. Such a study would include a thorough analysis of available rainfall records as well as all runoff stations in the surrounding area, which could be used for correlation and eventually hydrological modelling to assess the yield of the catchment.
The annual rainfall of the area has been estimated to 650 millimetres, while the potential evaporation is estimated to approximately 1600 millimetres/year.

Applying a runoff coefficient of 0.13 (same as Mt Fletcher, but probably too low) gives a mean annual runoff at the proposed dam site of 1.5-2 m^3/sec. Unfortunately no information have been available on the storage capacity of the Indwe Poort reservoir.

6.6 Lubisi Dam hydro power and electricity supply scheme

One hydrological station, S2R01, Lubisi Dam, has been in operation since 1968. The quality of the data is unknown, since no records have been available. Probably the same applies to this site as for the Indwe Poort. Rough analyses indicate a mean annual flow of approximately 3-3,5 m^3/sec.

6.7 Need for further data collection and analyses

The necessity for more detailed hydrological analyses for the various proposed schemes depend on the future water demand for irrigation and hydropower purposes. All values given above are assumed to be conservative, and represent safe yield for planning. It is proposed however, to carry out a detailed study of the hydrological regime of the catchments to the Indwe Poort and Lubisi Dam.

In order to get a more detailed and representative picture of the water balance in the Mzimvubu catchment, a new hydrological station should be established in the upper reaches of the Tina River, close to Mt Fletcher.
If it is decided to go ahead with the Mt Fletcher scheme a more thorough and detailed hydrological analysis should be carried out, including flood frequency analyses.

7 TECHNICAL - ECONOMICAL ASPECTS

7.1 General

A grid solution will always be given preference to a non-grid. Non-grid system means local production of electricity for one consumer. The electricity could be prodused by solar energy. Non-grid systems will <u>not</u> be promoted for areas which will be reached by the grid within 5 years. Eskom has a neutral stance with regard to the small hydro options. They will support a limited programme to test whether the option should be a rural electrification priority. The projects selected can therefore be looked upon as pilot projects.

All the five proposed schemes have been visited, however Mt. Fletcher and Indwee Falls have only been seen from helicopter. There have been meetings with local working committees at Jozini, Tsitsa Falls and Lubisi. The schemes are very different both in respect of electricity demand and technical solutions.

All projects have been subject to economical calculation of implementation cost, where NVE's experience on average cost for small hydro electric schemes have been used. The power output of the schemes has been chosen to exemplify the cost and is based on assumption on need for electricity in foreseeable future, water flow and approximate head. Consequently the given data on cost is only used to predict the feasibility of the schemes. The feasibility of the schemes will depend on the possibilities of increasing the load factor, especially to increase the load during night time.

The availability of local manpower for construction seems good for all sites. Most people living in these areas are travelling to seek jobs in the more urban part of the country. If jobs were available close to their homes, even for a short period, they would most probably take this option to earn money close to their families.

A new legislation on utilizing water from the rivers will be implemented in near future requiring environmental impact assessments for construction activities.

7.2 The Jozini hydro power and electricity supply scheme

7.2.1 General

The Jozini hydro electric project will utilize the head in an existing dam developed for flood control and irrigation. Pictures and drawing of the Jozini dam is presented in appendices 5-7. The dam is an arch dam 87 m high and regulates the Pongota river which flows into Mozambique. According to the operator of the dam, the Department of Water Affairs & Forestry, the reservoir has never been filled to the crest of the dam. <u>An agreement with Mozambique states the release of 4 m^3/s from the dam all year.</u> In addition up to 3 m^3/s is released into an irrigation channel. For irrigation the consumers have to pay SA 1 cent/m^3.

The hydro power plant could be a <u>10-20 MW peaking plant</u> according to available head and flow from the catchment area. However, this would be to design a plant feeding the grid with power not necessarily producing electricity for the local area. We have therefore concentrated on a plant utilizing the water which is already released for irrigation and compensation.

7.2.2 Option for hydro power construction

A hydro power station can utilize the compensation flow of 4 m^3/s and a head of 85 m from the normal water level to the river approximately 50m from the dam site. It has to be designed for flood water level downstream and a variation of head according to the use of water for irrigation, which can be increased in the future. An existing valve outlet from the dam can be utilized from where a penstock will be constructed down to the power station on the river bank. The potential is approximately 3 MW which can be operated all year and produce 25 GWh firm power.

The power station with option of utilizing 3 m^3/s released for irrigation would produce power when water is released. This station could be used for pumping water to irrigate new land on the left riverside. The station will utilize the existing penstock to the irrigation channel. The turbine will work on approximately 55m head which gives a capacity of 1.5 MW. The turbine has to be designed for a considerable variation of head since the water in the reservoir is used for irrigation.

7.2.3 Economic aspects

The cost for the plant utilizing 4 m^3/s is estimated to R 9.5 mill (NOK 19 mill). Based upon 40 years lifetime and 7% interest, the power production would cost R 0.04/kWh (NOK 0.08/kWh) including operation and maintenance cost.

The cost for the plant utilizing 3 m^3/s with tailwater level in the irrigation channel is estimated to R 6,5 mill (NOK ~12 mill). The energy production could be 13 GWh/year if 3 m3/s was released all year. The water, however, is only released in periods when irrigation is needed, thus power production will be lower.

It is expected that the load factor in the area is low. Pumping of water, proposed by the local committee, could be an option for increased load factor if pumped during night time to storage tanks.

The main grid is already feeding electrical equipment at the dam (22 kW line), hence the power stations could feed the main grid when power is not needed locally. The viability of the power stations depend on the possibilities of selling power to Eskom grid when local demand is lower than the capacity.

The area depends on transportation of electricity over long distances. There are plans for increased high voltage capacity, but a decision on this has still to be made. The area not electrified will be connected to the existing grid or the hydro power station which is more or less at the same site. The question is whether the hydro power plant can compete with energy prices from Eskom. Our calculations show that the hydro power plant can be a viable project.

Additional positive benefits will be:

- Production capacity on the end of a transmission line
- Reduced energy losses
- Local electricity security
- Energy production by a renewable resource with no air pollution and no local environmental impacts.

On the possible negative side is:

- Price per m^3 for water (the Department of Water Affairs & Forestry has put a price per m^3 water which is negotiable)
- Operation/maintenance if left to local organizations without proper training
- Establishment of a local organization can be difficult.

7.2.4 Infrastructure/land acquisition, rights

There are good roads to the area and the power station site. The 22 kW grid is close to the site. Acquisition of land should be negotiated with Department of Water Affairs & Forestry. According to given information payment for the hydro power plant's use of water is negotiable.

7.2.5 Environmental aspects

Because existing structures and regulation procedures are utilized, there will be no additional environmental impacts.

7.2.6 Local grid versus other sources of electricity

Locally the households, schools and clinics are very wide spread and electrification by grid connection would be very expensive. The connection fee for a household is only R 45. It may choose to consume electricity on an average of about R 10 per month. The initial cost of supplying the connection may be R 35.000 or higher (R 40.000 is the limit for connection cost). Ongoing service, energy and maintenance cost (perhaps R 25/month) far exceed the average monthly repayment. Rural grid electrification in this area has to be highly subsidized and give benefits to households which can afford electricity.

In order to support the need for improving activities in the clinics and schools in the area, solar electrification seems to be the best option. There is considerable experience on solar systems within Eskom. These solutions will solve the need for light for education and enhanced service in the clinics, but will not promote economic growth in the area. In addition to solar systems, a local grid, from the main grid or the hydro power station, should therefore be established to feed irrigation schemes and selected schools/clinics/market places with a potential of being a local village centre in the future.

7.2.7 Conclusions

Technically hydro power stations of wide range of capacity can be developed. A reasonable designed plant can also compete with marginal cost in the Eskom production/transmission system. A feasibility study in two phases is recommended:

Phase 1: Baseline studies on electricity consumption and social benefits of local electricity production

Phase II: Given the need for power, a technical/economical design of the powerstation(s) should be carried out sufficient for bidding on a turn key concept.

7.3 The Tsitsa Falls hydro power and electricity supply scheme

7.3.1 General

Tsitsa Falls has a great potential of more than being a local source for electricity. The area is planned to be electrified during the next five years, but no decision has been taken yet in Eskom. There is a school centre with potential of being a shopping/small workshop centre for the area presently without electricity except for a small diesel generating unit.

Pictures and copies of maps from the area are found in appendices 8-9.

The Tsitsa river at the falls has a catchment area of approximately 4,250 km^2. The mean annual flow has been calculated to 23 m^3/s or 737 $Mm^3/year$.

The scheme will utilize the minimum flow in a spectacular waterfall of approximately 100m.

7.3.2 Option for hydro power construction

7.3.2.1 Small hydro power station option

The small hydro power station will utilize the minimum flow in the Tsitsa river.

The small scheme will consist of a small weir in the river to lead the water into an intake and sediment chamber before entering a 300 m long almost vertical penstock. The powerhouse will be constructed on the bottom of the waterfall and equipped with a Francis unit of 1.5 MW, working on 120 m head and max flow 1.5 m3/s. Annual production is estimated to 12 GWh. The access to the power station will be a cableway.

7.3.2.2 Medium hydro power station option

The option for a medium hydro power scheme will include the construction of a rock fill dam. We have included the construction of a 50 m high dam with bitumen core creating a storage reservoir of 210 mill m3. This reservoir will inundate agriculture land to some extent.

Utilizing the head of the 50 m high dam, the water fall and rapids just downstream the water fall would create a head of 200 m. A 2000 m pressure tunnel (cross section 18 m^2) will lead the water to the power station. Access to the downstream area and the access tunnel for the underground powerhouse has to be constructed in difficult steep terrain, which will have a high cost. The power station could be equipped with two units (Francis turbines) of approximately 25 MW each. Annual energy production would be approximately 325 GWh. The plant could produce peak power to meet peaking demand in Umtata. The cost for the scheme is roughly calculated to R 215 mill (NOK 400 mill).

The implementation of the scheme will require construction of a 132 kV line to the area for connection to the high voltage grid system.

The option for a medium scheme is not further discussed because it is outside our Terms of Reference given by NORAD.

7.3.2.3 Large hydro power station option

The option for a large hydro power scheme will include the same dam as for the medium hydro power plant.

From the reservoir the water will be released into a pressure tunnel in order to utilize the head in the dam, the water fall and rapids in oxbows in the river creating a total head of 365 m. The 8100 m long pressure tunnel (cross section 18 m^2) should be blasted from downstream to reduce cost. Access to the downstream area and the access tunnel for the underground power house has to be constructed in difficult steep terrain, which will have a high cost.

The power station could be equipped with two units (Francis turbines) of approximately 45 MW each. For peaking capacity an output of 150-250 MW should be discussed. Annual energy production would be approximately 600 GWh. The cost for the scheme is roughly calculated to R 350 mill (NOK 600 mill). Full concrete lining of the tunnel will increase the cost by approximately R 45 mill (NOK 80 mill).

The implementation of the scheme will require construction of a 132 kV line to the area for connection to the high voltage grid system.

The option for a large scheme is not further discussed because it is outside our Terms of Reference given by NORAD.

7.3.3 Economic aspects- the small hydro electric plant

A rough cost estimate shows a construction cost of R 12 mill (NOK 22 mill), which according to 40 years life time, 7% interest and full use of available electricity production will give an energy price including operation/maintenance of approximately R 0.1/kWh (NOK 0.18/kWh).

In prior of implementing a small scheme, the large hydro options should be discussed.

7.3.4 Infrastructure/land acquisition, rights

There are good roads to the construction site area and no need for a road down to the power station. Information on need for land acquisition has not been given.

7.3.5 Environmental aspects

The plant will be a run of river plant utilizing the minimum flow in the river. The water fall is spectacular and great care has to be taken when developing it. A compensation flow to keep the landscape picture should be discussed. This may not be needed for a small hydro power plant since there normally will be much more flow in the river than the capacity of the plant. According to representatives for the local people there is no problem whereas cultural relics in developing the water fall for small hydro. Even a large hydro is acceptable if the local community will benefit. An implementation will probably draw the attention of the environmentalists, especially for large hydro development. By using the NORAD Booklet "Environmental impact assessment of development aid projects, No6, part II, section 3 - Checklist, there is the answer **no** to all questions for the small hydro. This depends, however, on careful construction and design of the hydro power plant to fit into the landscape.

A large scheme will have environmental impacts which must be studied.

7.3.6 Local grid versus other sources of electricity

There are plans for electrification, but no decission has been taken to electrify the area within 5 years. The high voltage grid is 10 km away. The extension of the main grid to the area will cost approximately R 0.5 mill (NOK 1 mill). In addition one should calculate transmission losses. The cost for the necessary local grid will be the same whether connected to the main grid or to the hydro power station.

For the time beeing, diesel units are powering the schools, clinics and shops.

7.3.7 Conclusions

The Tsitsa Falls can be developed for electricity production for local supply only or for regional supply. There are several options for hydro power development ranging from 1 MW to 200 MW depending on need for peak power and electric energy. Great care should be taken when developing the spectacular water fall. The small hydro scheme will do little harm to the environment.

A pre-feasibility study including all options for hydro power production is recommended.

7.4 The Mt. Fletcher hydro power and electricity supply scheme

7.4.1 General

The area has only been seen from the air, hence maps and information from Professor Stephenson have been the main source of information. Pictures and copies of maps from the area are found in appendices 10-11.

The scheme will utilize rapids in the Tina river close to Mt.Fletcher. Mt.Fletcher village already has a local grid serving schools, clinics and households. A diesel generating unit is powering the grid.

7.4.2 Option for hydro power construction

The hydro power station will utilize the flow in Tina river. The project will consist of a dam in the river, of approximately 10 m height in order to create a reservoir for daily operation. From the dam the water will flow through a sediment chamber before entering the penstock which will be approximately 2700 m long. The power station will release the water back into the river.

There are several options for constructing intake dams, but no obvious site where a storage reservoir can be created. The site selected is considered the best site for hydro power development in this part of the river.

The powerhouse can be equipped with a Francis unit of 2100 kW, working on 70 m head and max flow 3.5 m3/s. Estimated maximum energy production is 13 GWh.

7.4.3 Economic aspects

A rough cost estimate gives a construction cost of R 20 mill (NOK 38 mill), which according to 40 years life time, 7% interest and full use of available electricity production will give an energy price including operation/maintenance of approximately R 0.15/kWh (NOK 0.28/kWh). A low load factor in Mt.Fletcher will increase the cost per kwh.

There is proposed a plan for extending the main grid (132 kV) to Mt. Fletcher. The high voltage grid is now 30 km away. Implementation of the hydro power plant may reduce the pressure to construct the 132 kV line which will cost roughly R 5.5 mill (NOK 10 mill). The hydro power plant, however, can only meet the demand in Mt. Fletcher and will not contribute to electrification of other villages presently without electric energy. The reduction of losses and local security obtained by implementing a hydro power scheme seems not to be enough to justify the investment compared to the construction of a 132 kV line.

7.4.4 Infrastructure/land acquisition, rights

There are good roads to Mt.Fletcher. A road has to be constructed to the hydro power site area. The land which will be used for construction is barren land. Information on need for land acquisition has not been given.

7.4.5 Environmental aspects

The plant will be a run of river plant utilizing the flow in the river. During the low flow season (winter) it will dry out approximately 3 km of the river if not compensation water is released from the intake. It is not known whether there are fish in the river and if it is used for nutrition. It is anticipated that the construction will do little harm to the environment. During high flow season, migrating fish (if any) will not be able to pass the dam upstream without construction of a fish ladder. By using the NORAD Booklet "Environmental impact assessment of development aid projects, No6, part II, section 3 - Checklist, there is the answer **no** to questions no. 1,4,6,7 and 8. For questions no. 2,3 and 5 we have no information. However, it is not likely that a small scheme like this can seriously harm animal or plant life worthy of protection or conservation-worthy cultural relics if there are any.

7.4.6 Local grid versus other sources of electricity

There is already a local grid in Mt. Fletcher which is powered by a diesel unit. Connection to the grid is planned to be implemented within 5 years.

7.4.7 Conclusions

The Mt. Fletcher scheme has a too high energy cost compared to present tariff in the Eskom system. The energy production will depend heavely on the flow at any time, since options for reservoirs are limited. The operation of a hydro power scheme will have to be combined with the operation of diesel units. There are plans in progress for connecting the area to the main grid within 5 years. Further studies are not recommended.

7.5 The Indwe Poort hydro power and electricity supply scheme

7.5.1 General

The area has only been seen from the air, hence maps and information from Professor Stephenson have been the main source of information. Pictures and copies of maps from the area are found in appendix 12. The scheme will utilize rapids in the Indwe river at Indwe Poort.

7.5.2 Option for hydro power construction

The hydro power station will utilize the flow in Indwe river. An irrigation dam upstream the intake area, the "Doringrivierdam" built in the Guba river, a tributary to Indwe river should be looked upon for combining irrigation needs and power production needs.

The scheme will consist of a small dam in the river leading the water into an intake and sediment chamber before entering a 2100 m long penstock. The powerhouse will be equipped with a Francis unit of 700 kW, working on approximately 40 m head and max flow 2 m^3/s. Estimated maximum energy production is approximately 4 GWh.

7.5.3 Economic aspects

A rough cost estimate gives a construction cost of R 8 mill (NOK~15 mill), which according to 40 years life time, 7% interest and full use of available electricity production will give an energy price including operation/maintenance of approximately R 0.1/kWh (NOK~0.2/kWh). The low load factor, however, will increase the cost per kWh.

7.5.4 Infrastructure/land acquisition, rights

There are good roads to the construction site area. The land which will be used for construction is barren land. The need for land acquisition has not been given.

7.5.5 Environmental aspects

The plant will be a run of river plant utilizing the flow in the river and the water released from irrigation reservoirs in the catchment area. During the low flow season (winter) it will dry out approximately 3km of the river if not compensation water is released from the intake. According to local people there are no fishing activities in the river. It is therefore anticipated that the construction will do little harm to the environment. During high flow season, migrating fish (if any) should have the possibility to pass the small dam. By using the NORAD Booklet "Environmental impact assessment of development aid projects, No6, part II, section 3 - Checklist, there is the answer **no** to questions no. 1,4,5,6,7 and 8. For questions no. 2 and 3 we have no information, however, it is not likely that a small scheme like this can serious harm animal or plant life worthy of protection or conservation-worthy cultural relics if there are any.

7.5.6 Local grid versus other sources of electricity

There are no plans for electrification of the area in the near future. The main grid is 20 km away. The extension of the main grid to the area will cost R 1-1.5 mill (NOK 2-3 mill). In addition one should calculate transmission losses. The cost for the local grid will more or less be the same for both solutions.

7.5.7 Conclusions

The Indwe Poort scheme has a too high energy cost compared to present tariff in the Eskom system. Electricity production will depend on the flow at any time, since options for an intake reservoir is limited. Existing irrigation reservoirs in the catchment area could provide water for the power station in the low flow period if not used for irrigation. A connection to the main grid seems to be the best solution. Further studies are not recommended.

7.6 The Lubisi hydro power and electricity supply scheme

7.6.1 General

The Lubisi hydro electric project will utilize the head in an existing dam developed for irrigation.

Pictures and drawing of the Lubisi dam are presented in appendices 13 - 14. The dam is an arch dam and regulates the Indwe river. 9.5 km downstream of the dam is another small dam from where the irrigation water is distributed.

7.6.2 Option for hydro power construction

The power station will utilize the full head of the dam and down to an existing weir some 100 m downstream. Hence a penstock of approximately 100m has to be connected to the existing valve house. The power station will be located on the river bank 3-4 m above the water level at the weir. The full head will be utilized by the pressure pipe and the draft tube. The first phase would be to install a Francis unit working on approximately 40 m head and 1.5 m^3/s average flow. The unit has to be designed for the possible large variation of the water level in the reservoir. Approximate output and maximum production would be 500 kW and 4.4 GWh/year.

To meet further demand, especially during peaking hours, the scheme should be designed for a second unit with 1 MW output. Peaking production will require re-regulating weirs downstream the power station to minimize negative environmental impacts if necessary.

7.6.3 Economic aspects

A rough cost estimate gives a construction cost of R 5 Mill (NOK 9 mill) for a 500 kW plant prepared for the second phase (power station and penstock). The second phase is estimated to R 2.5 Mill (NOK 5 mill) for another 1 MW peaking plant.

The power station (500 kW) can produce power at a cost of R 0.1/kWh (NOK 0.2/kWh) if calculation is based on 40 years lifetime, 7 % interest and the assumption that all the possible electricity production can be utilized. Without special activities demanding power during night time, only 30-40% of the possible electricity production can be sold. This means a price of approximately R 0.3/kWh. Compared to the sum of transmission cost and Eskom production and main distribution cost it seems that the power station can compete with connection to the main grid. The possibility of peaking capacity at a later phase is positive in this connection.

The scheme can electrify villages close to the dam in the first phase.

7.6.4 Infrastructure/land acquisition, rights

The operator of the dam, the Department of water Affairs & Forestry in Transkei, informed that they would welcome a hydro electric scheme for local benefit. There will be no payment for water, but irrigation has first priority. Focus has therefore been put on utilizing water released for irrigation with option for peak power operation.

There are good roads to the area and access road to the dam site. No problems are expected connected to the use of land for the construction.

7.6.5 Environmental aspects

Existing structures will be utilized. There will be no additional environmental impacts for the 500 kW plant. The second phase with peaking operation can influence the flow in the river and biological life in a negative way. The problems, if any, can be solved by constructing re-regulation weirs. Also an existing downstream dam for distribution of irrigation water can be utilized for this purpose.

7.5.6 Local grid versus other sources of electricity

There are no plans in foreseeable future to electrify the area by connecting it to the main grid. The extension of the main grid to the area will cost R 1-1.5 mill (NOK 2-3 mill). In addition one should calculate transmission losses. The cost for the local grid will more or less be the same as for local production.

7.5.7 Conclusions

The Lubisi scheme can be developed to compete with extension of the main grid. It has a potential for peaking operation to meet the variation of demand locally. A feasibility study in two phases is recommended:

Phase 1: Baseline studies on electricity consumption and social benefits of local electricity production. A thorough hydrological study of the Lubisi catchement.

Phase II: Given the need for power and available water, a technical/economical design of the powerstation should be carried out sufficient for bidding on a turn key concept.

8 MAIN ITEMS OF THE TERMS OF REFERENCE FOR RECOMMENDED FEASIBILITY STUDIES

8.1 General

According to the conclusions in the report, the recommendations for Terms of Reference (TOR) is written with focus on the Jozini and the Lubisi hydro electric schemes and the Tsitsa Falls scheme.

The report also recommends support to low voltage electrification of remote schools and clinics in the selected areas by solar systems. This activity can be undertaken by Eskom which has considerable experience within this field, both regarding to purchasing of appropriate equipment and implementation/-operation including training. The need for a TOR in this respect is therefore considered unnecessary.

Specialized studies are necessary on selected themes to ensure positive socio-economic impact of the hydro schemes, and the possibility of inclusion of other types of assistance to infrastructure and economic activities in the areas concerned. Such a programme is of particularly relevance when the objective is uplifting of people's quality of life.

CSIR- Department of Technology for Development in Pretoria is a private company in South Africa, already involved in socio economic studies at Lubisi. Based on the information given, the team is of the opinion that a joint effort by Norwegian researchers and CSIR would best secure relevance and quality of a programme for systematic socio-economic and environmental evaluation. Cooperation would benefit both parties.

8.2 The Jozini and the Lubisi schemes

8.2.1 Socio Economic Studies

There is a need for further base line studies on the actual and future need for electricity. It is therefore recommended that a socio-economic study is carried out prior to technical-/economical feasibility studies.

To enhance the quality of the studies and improve the Norwegian - South African cooperation it is recommended that the TOR asks for the services of CSIR in cooperation with Norwegian social scientists.

Topics for this study would be:

- Electricity needed for irrigation
- Electricity consumption in villages. Because of the wide spread population at Jozini one special activity would be to define areas with a potential for growth, and produce development plans for these areas.
- Studies on commercial activities which could be introduced in order to increase the load factor of electricity consumption.
- Other developments to be included e.g. agriculture
- The number of people uplifted by the scheme
- Eskom's future involvment

This study could be completed after a period of 6 months including studies on both projects.

8.2.2 Hydrological studies

The size of the catchment to the Jozini Dam as well as the large storage capacity indicate that no further collection and analyses of hydrological data are necessary.

A thorough hydrological study of the Lubisi catchment must be carried out. The study should include the runoff station just downstream of the dam as well as other hydrological and meteorological stations in the catchment and neighbouring catchments.

Topics for this study would be:

- Inspection and quality controll of all hydrological records of the Transkei Department of Agriculture & Forestry, Hydrology Sub-Division and Department of Water Affairs, Pretoria
- Generate time series by various hydrological (e.g. models) and statistical methods
- Provide reliable estimates of average, low and high flow
- Estimation of sediment transport and reservoir siltation

A closer inspection of the records and data will reveal if additional stream gaugings and sediment transport measurement are necessary. This should be decided upon in the initial phase of the hydrological study.

The hydrology studies so far have been handled by Professor Stephensons firm which would be a natural partner for a Norwegian consultant.

8.2.3 Technical studies

After completion of the socio-economy and hydrological studies for the Jozini and the Lubisi schemes, the size of the power plants could be decided. Both Jozini and Lubisi are well suited for the "Turn key concept", which means a group of manufacturer of electro mechanical equipment and contractors offer a price for a complete project. The specifications for the complete project should be included in the feasibility study. This study could be a task for Norwegian and South African consultants in cooperation.

Necessary local transmission lines must be included in the feasibility studies.

The Terms of Reference for this activity would include:

- Detailed technical design of penstock and power stations including the use of existing valves in the dams.
- Specifications for the turbines working on different heads.
- In case of peak power production, document the impacts downstream of the river and propose solutions to minimize the negative impacts (re-regulating weirs etc.).
- Definition of a training programme for operation including information on South African companies which could undertake such a programme.

8.3 The Tsitsa Falls Scheme

A pre-feasibility study is needed which will include studies on:

Socio economic aspects

- Need for electricity locally
- Use of electricity for increased load factor
- Consequences of reduced agriculture land in case of a large dam.
- Potential for growth in nearby villages
- Social/health impacts during construction

Environmental aspects (in case of a medium or large scale hydro electric power plant should be developed).

- Dam site and area inundated
- The water fall (landscape)
- The affected area of the river between the intake and the outlet of the power station
- The river downstream the outlet of the power station in case of peak power operation

Hydrological aspects

- Inspection and quality controll of existing hydrological records
- Generate time series by various hydrological (e.g. models) and statistical methods
- Provide reliable estimates of average, low and high flow, including flood frequency analyses
- Estimation of sediment transport and reservoir siltation

Technical aspects regarding the small, medium or large hydro power plant.

- The small plant would include cost documentation on the construction of a small weir, penstock, power house with equipment and local 22 kV transmission line.
- The medium and large hydro power plants would include a study on geotechnical conditions (tunnel/dam), system analyses to decide the need for peaking operation, cost documentation on the size of the dam, tunnel, power station, access roads and electro mechanical equipment.

A Norwegian consultant company could cooperate with several local firms in South Africa.

APPENDICES

TERMS OF REFERENCE

for

THE NORWEGIAN WATER RESOURCES AND ENERGY ADMINISTRATION (NVE)

to undertake an appraisal of the request from ESKOM, South Africa for Norwegian support to conduct a feasibility study of mini hydro schemes in South Africa.

1. BACKGROUND

NORAD has received a request dated 3 March 1995 from ESKOM to conduct a feasibility study for five proposed mini hydropower schemes in South Africa. NORAD has responded that an independent appraisal of the projects would be required as basis for a decision regarding Norwegian support.

Four of the five sites in question are in Transkai Province while one is in KwaZulu. The rivers in Transkai have been monitored and investigated for different purposes over the last decade. Information on hydrology and identified dam sites are thus available. The sites for the mini hydropower schemes have been identified thorough a preliminary reconnaissance study financed by ESKOM and done by local consultants. The following main information can be given about the identified sites:

SITE	AREA	CAPACITY	GENERAL INFORMATION
Josini Dam	KwaZulu	Approx, 2 MW	The dam is supplying an irrigation scheme. It discharge at present 5m3/sek. It may be increase to 10 m3/sek if a decision to install turbines are made. Provision have been made in the dam for installing hydropower turbines.
Lubisi Dam	Transkei	Approx. 300 kW	The Lubisi Dam is a concrete arch dam on the Indwe River which feeds an irrigation scheme. The dam has a bottom outlet which would be the waterway for the turbines. it is assumed that it will be rather simple matter to install the turbines.
Indwe Poort	Transkei	Approx. 500 kW	There are a number of villages in the surroundings of the dam site, giving a relatively high population density. The steep part of the Indewe River allows building of a dam, which together with a penstock would give a 20 m head.

Mt Fletcher	Transkei	Approx. 1 - 5 MW	The Mount Fletcher town has a population of about 3000 people with no electricity at present. It seems possible to build a 20 m dam in the neighbouring Tiana River, giving a head of 20 m with a average flow of 1.5 m^3/sek.
Tsitsa Falls	Transkei	Approx. 1 -5 MW	

2. OBJECTIVE

The objective of the appraisal is to provide NORAD with necessary information, professional views and recommendations regarding the five proposed schemes, to get the necessary background to make a comparative assessment of the mini hydropower projects in relation to other pertinent energy projects. Although the current issue for NORAD is to decide whether or not to finance a feasibility study, which accordingly will be the basis for the decision to proceed to implementation, ESKOM has already indicated their intention to request NORAD for financing of the construction of the mini hydro schemes. Even though it is made clear that a possible NORAD financing of the study does not commit NORAD of any further financing participation in the implementation of the projects, a decision to finance the feasibility study may, by the South-African authorities, be interpreted as an intention from NORAD for further financial participation in the implementation. In the light of this, thoroughness of the appraisal is of great importance.

3. COLLECTION OF BACKGROUND INFORMATION

Background information may be available through:

3.1. Study of maps, collected data and reports prepared by local consultants. NORAD has only received limited documentation about the different schemes, but it is assumed that the Mission during its visit to South Africa will get access to more written information.

3.2. Meetings with ESKOM, and the different local consultants that have been involved with the preliminary studies regarding the schemes. ESKOM will prepare a meeting schedule with the these consultants. Meetings should also be held with the Energy for Development Research Centre (ERDC), University of Cape Town, who have been involved with the issue of rural electrification in South Africa from a socio economic point of view.

3.3. A site visit to each of the five proposed sites

4. SCOPE AND FOCUS

The following matters regarding the five propsed schemes should be addressed:

4.1. Technical aspects

- Infrastructure requirements during construction (Roads, power supply)
- Comments on the availability of local manpower for construction.

4.2. Hydrology

- Availability and reliability of data.
- Need for further data collection.

4.3. Construction.

A short description should be given about:

- Regulation works, dams and intakes
- Waterways
- Power station

4.4. Operation and Maintenance

- Ownership structure for the schemes both during construction and in the operation phase.
- Comments to made about training requirements for the operation and maintenance phase.

4.5. Land acquisition, rights.

Expected problems connected to acquisition of land, water rights, right of way.

4.6. Socio economic and cultural aspects

- Attitude from the local community towards development of the scheme and to turn to use of electric power.
- Ability in the local community to pay for electricity. Expected power market and attainable energy prices. Current tariff policy in South Africa.
- Possible social impact during and from the construction period

4.7. Economic aspects

- Indication of expected construction cost.
- Expected tariffs based on construction costs. Current ESKOM tariffs for supply from the main grid..
- Cost of development of mini hydropower schemes contra construction of a transmission line from the main grid.

4.8. Environmental aspects

Reference is made to the NORAD booklet "Environmental impact assessment of development aid projects, No. 6 Initial environmental assessment, Hydropower development." Brief answers should be given to the applicable questions in Part II, Section 3 - Checklist.

5. CONCLUSIONS AND RECOMMENDATION

Conclusions and recommendations should be given in respect of the following:

- Hydrology
- Socio economic issues
- Environment
- Cost and tariffs
- Mini hydropower schemes contra construction of transmission lines from the main grid.

Recommendation should also be given about the main issues to be covered in a feasibility study/detailed design phase. The main items of the Terms of References should be presented.

6. REPORTING

The report should be written in English and treat the five different schemes separately. All items mentioned in Section 4 above should be addressed. The presentation should be such that NORAD easily can draw conclusions regarding support to the feasibility study.

7. WORK SCHEDULE

The visit to South Africa should last for approximately two weeks and be made sometimes during the period 7 - 27 August 1995. The following detailed schedule is anticipated:

- Initial meetings and data collection in Johannesburg - 3 days
- Site visit to the five proposed sites - 5 - 6 days
- Follow up meetings in Johannesburg and possibly Cape Town - 3 days.

20 copies of the report should be forwarded to NORAD not later then 1 October 1995.

8. COMPOSITION OF THE APPRAISAL MISSION

The Mission should consist of four members with competence in hydropower engineering, hydrology, water resources, transmission and socio economic/cultural aspect in developing countries. The members should in addition have knowledge and experience within environmental aspects connected to hydropower development and energy tariffs.

The members have been nominate for the Mission:

Mr. Torodd Jensen - Hydropower Engineer - Head of Delegation
Professor Jon Hesselberg - Social Scientist
Mr. Kjell Rep - Hydrologist
Mr. Kilvik - Water Resources Engineer

Oslo 4 July 1995

Øistein Glømmi

Øistein Glømmi
Acting Head of Devision

TRAVEL AND MEETING PROGRAMME
PEOPLE MET

Travel and meeting programme:

There are no minutes from the meetings. However, information given in the meetings is included in the report.

14 September	:	Departure from Norway
15	:	Arrival Cape Town, meeting University of Cape Town (Appendix 4)
17	:	Arrival Johannesburg
18	:	Meeting Eskom, departure to Durban
19	:	Meeting Eskom, Durban, departure to the Jozini dam, meeting with chairman of Khulani, visit to schools and clinics, meeting with Khulani Working Committee in Jozini.
20	:	Meeting with the Department of Water Affairs in Jozini, dam visit, departure for Kogstad.
21	:	Visit Tsitsa Falls, meeting Eskom Umtata, Umtata Hydrology Office-Hydrology Group, meeting TESCOR for hydrology details and electrical grid network of former Transkei
22	:	Departure for Lubisi Dam, visit Indwe Poort and Mt. Fletcher sites with helicopter, meeting with Community Forum Lubisi, visit the NCORA hydro power station owned by TESCOR and operated by Eskom, departure for Johannesburg by air.
23-25	:	Report writing
26	:	Summing up meeting with Eskom, meeting Norwegian Embassy, ambassador Otterbech
27 September	:	Arrival Norway

APPENDIX 2-2

People met (meetings and visits organized by Eskom)

Mrs Diana Theron	Eskom, National Electrification Planning Manager, Electrification
Mr Rob Lines	Eskom, Hydro & Water Manager, Generation Group
Mr Rodney Buttle	Eskom Non Grid Electrification Manager
Mr Fanie du Plessis	Eskom corporate Hydro & Water Consultant
Mr Ed Bunge	Eskom (Durban), Customised pricing Agreement Manager
Mr Kenny Venkatasen	Eskom (Durban), Network Master Planning Manager
Mr Sipho Ngxungo	Khulani Working Committee in Jozini
Mr James C Perkins	Department of Water Affairs & Forestry
Mr Mel Fish	Eskom (Umtata), Senior Engineer Engineering Network
Mr Ron Wallace	Eskom (Umtata), Electrification Distribution Manager
Mr Naas du Preez	Eskom (Umtata), Electrification Manager - East London
Dr Shaker	Private contractor, electrification
Mr LE Moahloli	Dept. of Water Affairs, Engineering consultant
Mr Bill Cochrane	EB Cochrane
Mr David Stephenson	Wits University Water System research Group
Mr Mat Sexwale	CSIR, Project leader Renewable Energy Programme
Dr. Graham Wright	CSIR, Programme Manager renewable Energy

APPENDIX 3-1

MEETING UNIVERSITY OF CAPE TOWN 15 SEPTEMBER 1995

1 Meeting with Energy for Development Research centre (EDRC)

People met: The Director Anton Eberhard
Mr. Mark Davis

EDRC has up to now mainly been focusing on technical solutions for providing energy. This include both urban and rural areas. These solutions have been followed by economical evaluations.

EDRC has a large variety of activity and broad experience achieved from different research programmes. They have grouped the research functions into seven research programmes including research on following topics (among others): biomass for energy (fuel wood, raps etc), solar energy (PV voltage for lighting, pumping, hybrid systems with diesel etc.), efficient energy for brick production, energy information systems, human resources and employment. EDRC is also involved in the preparation of a new legal framework for electricity in Namibia as well as supporting the New National Electricity Regulator in their own country.

The following reports have been made available to NVE including reports from The Energy Policy Research and Training Project (EPRET):

- EDRC annual report 1994
- EPRET report no 8 (Farmworker families; towards equitable and adequate energy provision)
- EPRET report no 2 (Integrated energy planning; A methodology for policy analysis and research)
- EPRET report no 14a (restructuring the South African electricity supply industry)
- EPRET no 19 (Electricity pricing policy)
- ENERGETIC no 1 August 1995 (Newsletter of the Energy and Development Research Centre)
- EDRC March 1994; Guidelines from the IDT clinics electrification programme, 1993

2 Meeting with Energy Research Institute including centre for Energy Efficiency and Management.

People met: Professor R K Dutkiewicz
Senior Engineer Mark De Villiers

The Energy Research Centre (ERI) has a number of research centres and areas of major activity including:

- Centre for Energy Efficiency and Management (CEEM)
- Centre for Energy Studies in Sub-Saharan Africa (CESSA)
- Environment research with focus on air pollution studies

Their field of interests for hydro power is limited to micro hydro (less than 100 kW) and micro hydro in co-operation with wind and diesel units (hybrid power systems)

A study has started on the determination of the externality costs of the production of electricity by various generating methods.

CEEM provides background research for energy policies and is involved with the design of energy efficiency programmes for the government. It provides information and training programmes for the industry on energy efficiency and carries out energy analysis for consumers of energy. One interesting area is research on energy use in the clay industry. Attention is being given to the use of heat in the drying and firing processes for brick production.

Table 6.1 Monthly Runoff at Tsitsa Bridge, T3MO6

TSITSA BRIDGE, T3MO6 4267 km2

Monthly Total Runoff, Mm3, and Monthly Mean Runoff, m3/sec

Year	Oct		Nov		Dec		Jan		Feb		Mar		Apr		May		Jun		Jul		Aug		Sep		Annual total	Annual mean
	Mm3	m3/s	Mm3	m3/s	Mm3	m3/s	Mm3	m3/s	Mm3	m3/s	Mm3	m3/s	Mm3	m3/s	Mm3	m3/s	Mm3	m3/s	Mm3	m3/s	Mm3	m3/s	Mm3	m3/s	runoff, Mm3	runoff, m3/s
1951-52	29,8	11,13	13,9	5,363	17,1	6,384	24	8,961	60	24,8	35	13,07	21	8,102	11	4,107	6,2	2,392	5,6	2,091	4,2	1,568	8	3,086	235,80	7,48
	6	2,24	18	6,944	40	14,93	83	30,99	37	15,29	60	22,4	102	39,35	12	4,48	5,6	2,16	3,9	1,456	3,4	1,269	21,6	8,333	392,50	12,45
	36	13,44	51	19,68	118	44,06	56	20,91	135	55,8	180	67,2	65	25,08	35	13,07	31,3	12,08	3	1,12	3	1,12	10	3,858	723,30	22,94
	40	14,93	30	11,57	30	11,2	200	74,67	156	64,48	239	89,23	51	19,68	27	10,08	16	6,173	11	4,107	5,7	2,128	3,5	1,35	809,20	25,66
1955-56	13,2	4,928	8,8	3,395	30	11,2	10	3,734	200	82,67	200	74,67	83	32,02	40	14,93	20	7,716	3	1,12	2,9	1,083	8,3	3,202	619,20	19,63
	3,9	1,456	121	46,68	270	100,8	176	65,71	125	51,67	224	83,63	98	37,81	37	13,81	16	6,173	12	4,48	17	6,347	54	20,83	1153,90	36,59
	48,1	17,96	41	15,82	60	22,4	248	92,59	150	62	56	20,91	70	27,01	25	9,334	14	5,401	8,5	3,174	5	1,867	9,4	3,627	735,00	23,31
	6,45	2,408	99	38,19	130	48,54	109	40,7	121	50,02	83	30,99	52	20,06	153	57,12	41	15,82	43	16,05	24	8,961	21	8,102	882,45	27,98
	9,4	3,51	63	24,31	94	35,1	106	39,58	143	59,11	51	19,04	55	21,22	29	10,83	12	4,63	7,3	2,726	6,7	2,501	15	5,787	591,40	18,75
1960-61	20,3	7,579	40	15,43	200	74,67	150	56	100	41,34	100	37,34	90	34,72	50	18,67	10	3,858	5	1,867	20	7,467	1,7	0,656	787,00	24,96
	3,4	1,269	53	20,45	147	54,88	111	41,44	206	85,15	206	76,91	51	19,68	19	7,094	9,1	3,511	6	2,24	4,8	1,792	3,3	1,273	819,60	25,99
	6,4	2,389	80	30,86	122	45,55	277	103,4	190	78,54	452	168,8	159	61,34	31	11,57	17	6,559	22	8,214	9,1	3,398	5,2	2,006	1370,70	43,46
	43,5	16,24	177	68,29	97	36,22	102	38,08	81	33,48	75	28	57	21,99	26	9,707	96	37,04	34	12,69	15	5,6	21	8,102	824,50	26,14
	80,7	30,13	53	20,45	52	19,41	60	22,4	102	42,16	17	6,347	20	7,716	8,6	3,211	60	23,15	38	14,19	26	9,707	34	13,12	551,30	17,48
1965-66	50,2	18,74	124	47,84	30	11,2	113	42,19	239	98,79	29	10,83	13	5,015	20	7,467	7,8	3,009	8	2,987	6,3	2,352	13	5,015	653,30	20,72
	5	1,867	24	9,259	42	15,68	45	16,8	199	82,26	217	81,02	235	90,66	37	13,81	37	14,27	22	8,214	20	7,467	9	3,472	892,00	28,29
	9	3,36	20	7,716	40	14,93	90	33,6	70	28,94	20	7,467	30	11,57	4,5	1,68	3,5	1,35	3,6	1,344	3,7	1,381	5,5	2,122	299,80	9,51
	5,33	1,99	35	13,5	40	14,93	13	4,854	43	17,77	241	89,98	91	35,11	21	7,841	8,4	3,241	5,6	2,091	4,4	1,643	0,1	0,039	507,83	16,10
	40	14,93	30	11,57	50	18,67	40	14,93	100	41,34	8	2,987	5,7	2,199	5	1,867	2,59	0,999	3,9	1,456	55	20,53	54	20,83	394,19	12,50
1970-71	216	80,65	42	16,2	53	19,79	85	31,74	130	53,74	50	18,67	82	31,64	40	14,93	14	5,401	12,6	4,704	42	15,68	14	5,401	780,60	24,75
	112	41,82	77	29,71	96	35,84	179	66,83	330	136,4	264	98,57	72	27,78	30	11,2	21	8,102	9	3,36	5,98	2,233	4,55	1,755	1200,53	38,07
	8,2	3,062	39	15,05	17	6,347	15	5,6	92	38,03	84	31,36	98	37,81	22	8,214	6,5	2,508	4	1,493	5,4	2,016	3	1,157	394,10	12,50
	13,1	4,891	20	7,716	70	26,14	200	74,67	100	41,34	56	20,91	197	76	43	16,05	34	13,12	16	5,974	11,7	4,368	6,4	2,469	767,20	24,33
	3,9	1,456	29	11,19	60	22,4	14	5,227	20	8,267	161	60,11	24	9,259	9,5	3,547	5	1,929	5,1	1,904	10	3,734	18	6,944	359,50	11,40
1975-76	13,3	4,966	18	6,944	330	123,2	439	163,9	371	153,4	486	181,5	149	57,48	190	70,94	80	30,86	59	22,03	41,3	15,42	43	16,59	2219,60	70,38
	337	125,8	97	37,42	34	12,69	33	12,32	113	46,71	105	39,2	39	15,05	12	4,48	8,13	3,137	10	3,734	10,5	3,92	22	8,488	820,63	26,02
	30,8	11,5	71	27,39	46	17,17	166	61,98	79	32,66	69	25,76	182	70,22	53	19,79	17	6,559	9,1	3,398	7,3	2,726	23	8,873	753,20	23,88
	55	20,53	48	18,52	50	18,67	80	29,87	70	28,94	50	18,67	30	11,57	9	3,36	3	1,157	40	14,93	1,2	0,448	9,9	3,819	446,10	14,15
	12,5	4,667	11	4,244	46	17,17	37	13,81	49	20,25	91	33,98	17	6,559	10	3,734	1	0,386	2	0,747	2	0,747	100	38,58	378,50	12,00
1980-81																										
	8	2,987	35	13,5	94	35,1	200	74,67	51	21,08	150	56	55	21,22	17	6,347	12	4,63	5,7	2,128	3,3	1,232	4,4	1,698	635,40	20,15
	10,8	4,032	26	10,03	18	6,72	127	47,42	248	102,5	80	29,87	18	6,944	6,1	2,277	4,4	1,698	3,6	1,344	1,7	0,635	2,3	0,887	545,90	17,31
1985-86	100	37,34	101	38,97	194	72,43	150	56	91	37,62	69	25,76	16	6,173	10	3,734	5,2	2,006	5	1,867	5,3	1,979	10	3,858	756,50	23,99
	80	29,87	91	35,11	44	16,43	51	19,04	40	16,53	30	11,2	10	3,858	3	1,12	4,9	1,89	3,6	1,344	5,4	2,016	155	59,8	517,90	16,42
	194	72,43	72	27,78	54	20,16	77	28,75	36	14,88	37	13,81	37	14,27	720	268,8	19	7,33	13	4,854	7,2	2,688	30	11,57	1296,20	41,10
	10	3,734	38	14,66	80	29,87	111	41,44	324	133,9	108	40,32	101	38,97	39	14,56	18	6,944	15	5,6	7,5	2,8	3,9	1,505	855,40	27,12
	12,7	4,742	134	51,7	200	74,67	111	41,44	31	12,81	204	76,16	20	7,716	20	7,467	13	5,015	11,4	4,256	8,8	3,286	30	11,57	795,90	25,24
1990-91	50	18,67	12	4,63	20	7,467	40	14,93	132	54,56	33	12,32	12	4,63	6	2,24	5	1,929	3	1,12	3	1,12	5	1,929	321,00	10,18
	52	19,41	96	37,04	90	33,6	40	14,93	30	12,4	35	13,07	24	9,259	5	1,867	4	1,543	3	1,12	2	0,747	3	1,157	384,00	12,18
Qmean	46,74	17,45	56,28	21,71	84,34	31,49	109,68	40,95	126,16	52,15	122,50	45,74	66,62	25,70	48,31	18,04	18,12	6,99	12,51	4,67	10,99	4,10	20,66	7,97	722,92	22,92

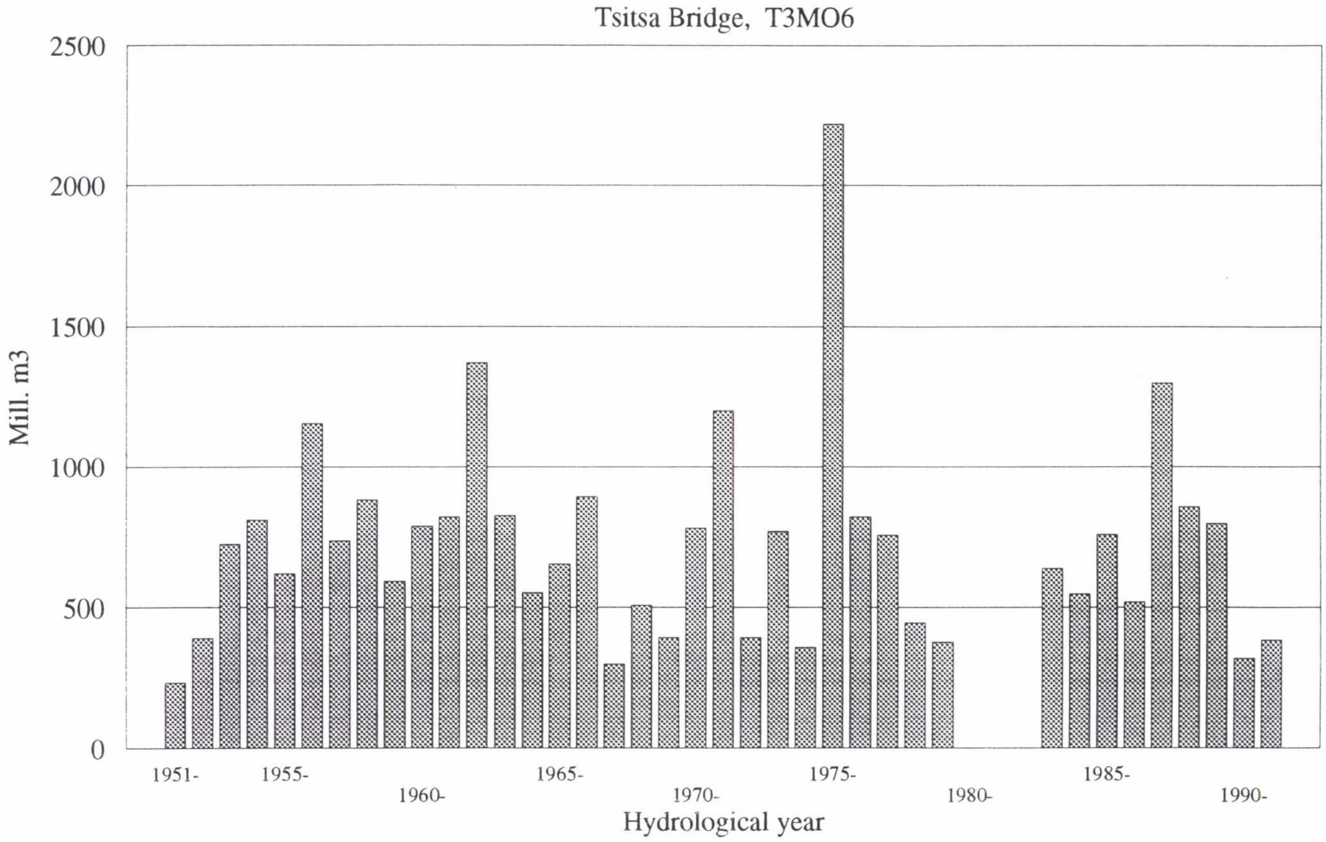


Figure 6.1 Annual Total Runoff at Tsitsa Bridge, 1951/52-1991/92

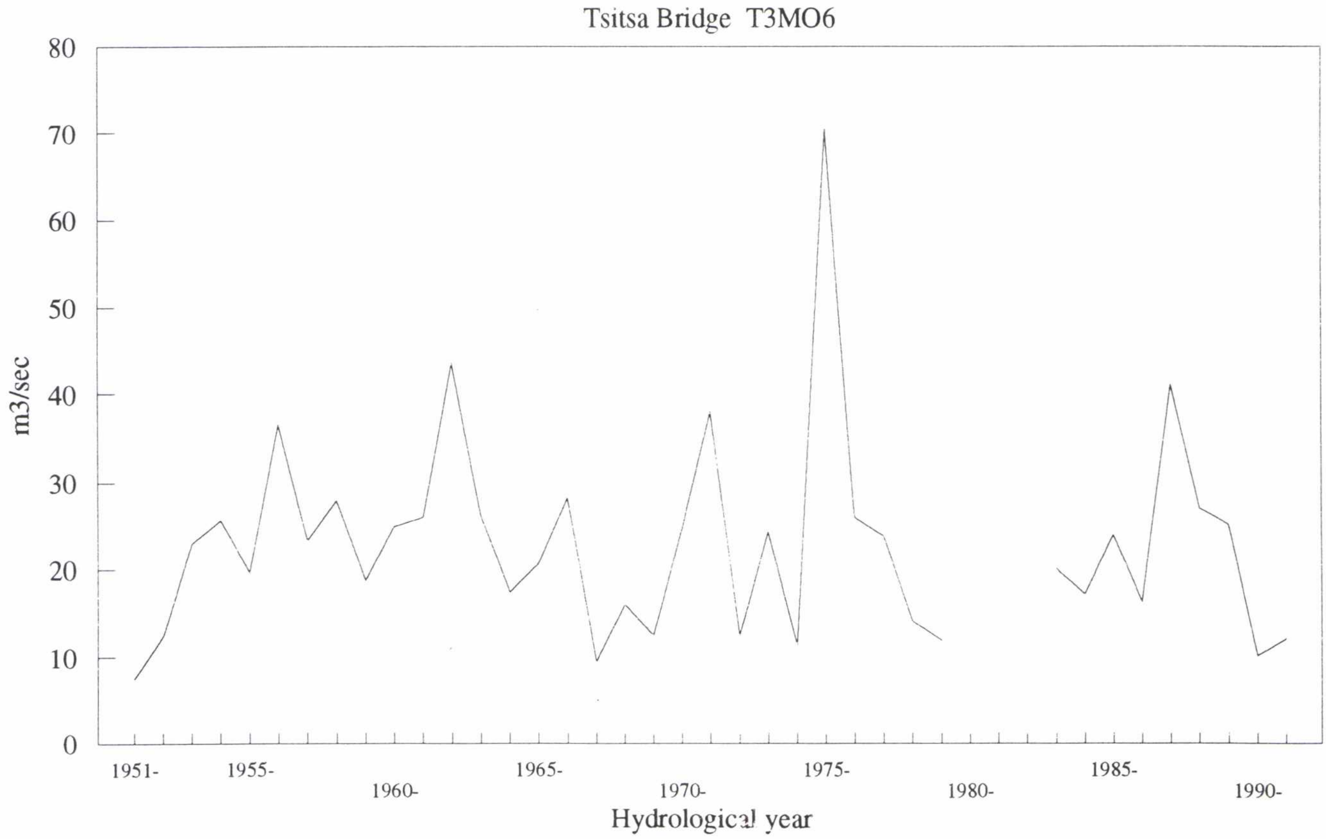


Figure 6.2 Mean Annual Runoff at Tsitsa Bridge, 1951/52-1991/92

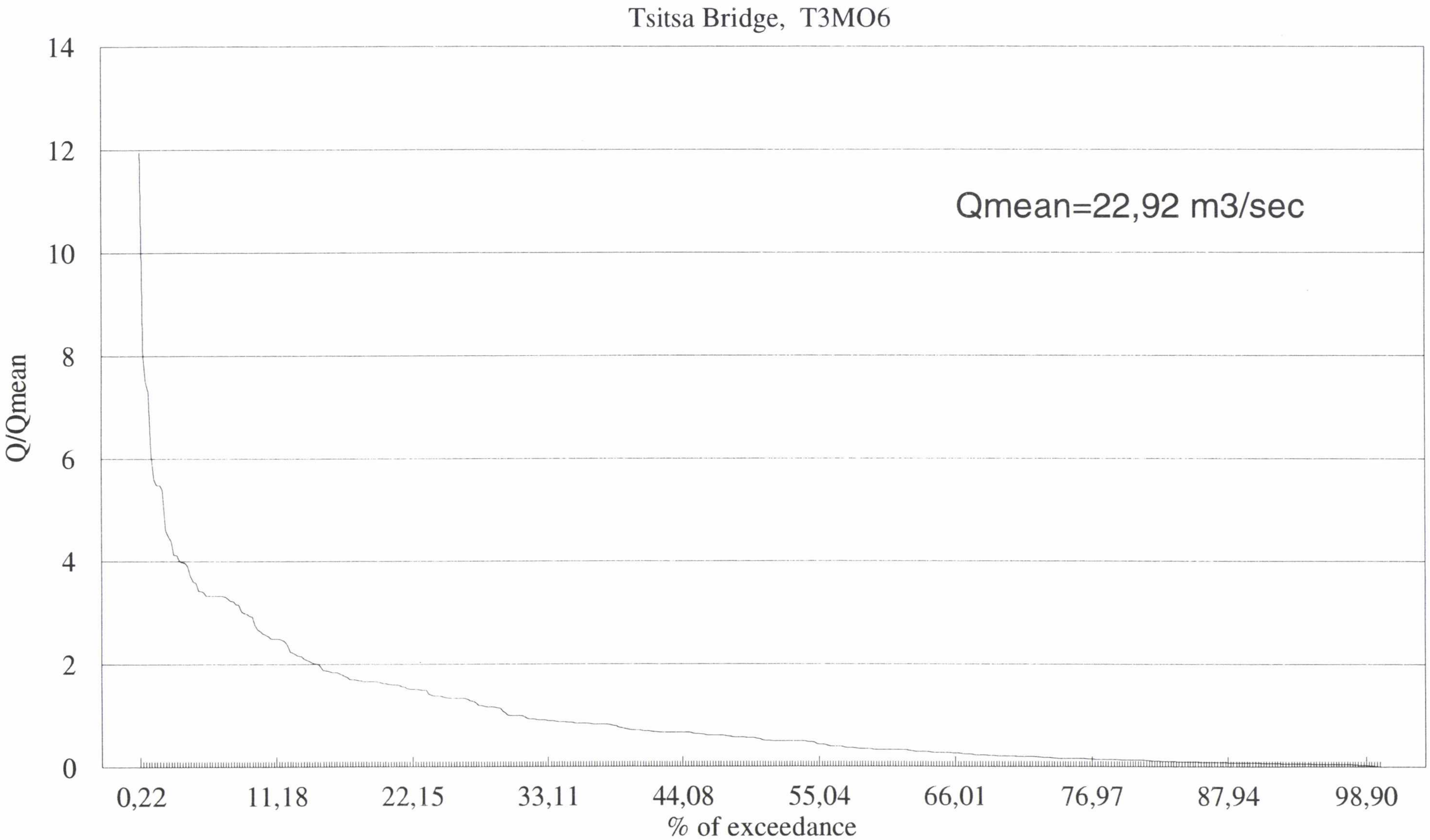


Figure 6.3 Non-dimensional flow duration curve, Tsitsa Bridge, T3MO6

APPENDIX 4.3

Table 6.2 Monthly Runoff at Kinira Drift, T3MO2

KINIRA DRIFT, T3MO2

2101 km2

Monthly Total Runoff, Mm3, and Monthly Mean Runoff, m3/sec

Year	Oct		Nov		Dec		Jan		Feb		Mar		Apr		May		Jun		Jul		Aug		Sep		Annual runoff Mm3	Mean annual runoff, m3/sec
	Mm3	m3/s	Mm3	m3/s	Mm3	m3/s	Mm3	m3/s	Mm3	m3/s	Mm3	m3/s	Mm3	m3/s	Mm3	m3/s	Mm3	m3/s	Mm3	m3/s	Mm3	m3/s	Mm3	m3/s		
	1,7	0,635	8,6	3,318	13	4,854	15	5,6	12	4,96	30	11,2	26	10,03	11	4,107	4,9	1,89	5,3	1,979	5,2	1,941	18	6,944	150,70	4,78
1950-51	8,1	3,024	5,1	1,968	14	5,227	23	8,587	13	5,374	12	4,48	6,4	2,469	2,3	0,859	1,83	0,706	1,59	0,594	1,89	0,706	4,6	1,775	93,81	2,97
	20,5	7,654	5,6	2,16	2	0,747	14	5,227	20	8,267	14	5,227	7,8	3,009	2	0,747	1	0,386	1	0,373	1	0,373	6	2,315	94,90	3,01
	2	0,747	5	1,929	12	4,48	10	3,734	12	4,96	12	4,48	29	11,19	6,2	2,315	3	1,157	2	0,747	2	0,747	11	4,244	106,20	3,37
	12,1	4,518	5,8	2,238	15	5,6	15	5,6	16	6,614	20	7,467	25	9,645	11	4,107	13,3	5,131	5,3	1,979	2,69	1,004	3,25	1,254	144,44	4,58
	14,1	5,264	23,1	8,912	26	9,707	30	11,2	20	8,267	21	7,841	9,9	3,819	6,39	2,386	3,7	1,427	3	1,12	1,91	0,713	1,2	0,463	160,30	5,08
1955-56	3,9	1,456	15,1	5,826	23	8,587	23	8,587	14	5,787	18	6,72	30	11,57	8,9	3,323	6,6	2,546	2,9	1,083	2	0,747	2,3	0,887	149,70	4,75
	1,5	0,56	19	7,33	30	11,2	8,7	3,248	15	6,2	30	11,2	23	8,873	5,7	2,128	3,3	1,273	3,7	1,381	4,3	1,605	13	5,015	157,20	4,98
	30	11,2	11	4,244	20	7,467	26	9,707	27	11,16	13	4,854	16	6,173	5,89	2,199	4,37	1,686	2,74	1,023	2	0,747	2	0,772	160,00	5,07
	1,4	0,523	8	3,086	14	5,227	21	7,841	11	4,547	20	7,467	8,7	3,356	30	11,2	13	5,015	8,8	3,286	5,11	1,908	3,2	1,235	144,21	4,57
	5,2	1,941	15	5,787	27	10,08	16	5,974	20	8,267	21	7,841	20	7,716	15	5,6	5,5	2,122	3,1	1,157	2,7	1,008	4,2	1,62	154,70	4,91
1960-61	5,8	2,165	22	8,488	31	11,57	32	11,95	29	11,99	24	8,961	40	15,43	14	5,227	7	2,701	3,91	1,46	2,9	1,083	1,9	0,733	213,51	6,77
	1,3	0,485	11	4,244	30	11,2	28	10,45	20	8,267	20	7,467	12	4,63	5,5	2,053	2,8	1,08	2,2	0,821	1,6	0,597	1,6	0,617	136,00	4,31
	3	1,12	11	4,244	12	4,48	40	14,93	26	10,75	40	14,93	26	10,03	7,6	2,838	4,7	1,813	9,6	3,584	4,3	1,605	1,9	0,733	186,10	5,90
	14,7	5,488	18	6,944	21	7,841	21	7,841	22	9,094	22	8,214	33	12,73	9,1	3,398	2,2	0,849	4	1,493	9,6	3,584	11,4	4,398	188,00	5,96
	8,5	3,174	12	4,63	29	10,83	11	4,107	18	7,44	6,5	2,427	11	4,244	2,6	0,971	17	6,559	20	7,467	20	7,467	19	7,33	174,60	5,54
1965-66	19,7	7,355	23	8,873	6,07	2,266	15	5,6	15	6,2	18	6,72	5,1	1,968	4,5	1,68	3,1	1,196	2,1	0,784	2,1	0,784	2,45	0,945	116,12	3,68
	2,6	0,971	11	4,244	7,9	2,95	27	10,08	15	6,2	20	7,467	20	7,716	17	6,347	18	6,944	11	4,107	6	2,24	3	1,157	158,50	5,03
	2,2	0,821	11	4,244	11	4,107	3,1	1,157	4,5	1,86	11	4,107	16	6,173	4,3	1,605	2,3	0,887	2,5	0,933	2,7	1,008	3,1	1,196	73,70	2,34
	5	1,867	11	4,244	14	5,227	14	5,227	31	12,81	68	25,39	46	17,75	5,2	1,941	2,9	1,119	2,1	0,784	1,6	0,597	1,1	0,424	201,90	6,40
	15,6	5,824	6,8	2,623	16	5,974	24	8,961	33	13,64	7,7	2,875	1,9	0,733	1	0,373	0,8	0,309	0,7	0,261	5,1	1,904	4,65	1,794	117,25	3,72
1970-71	35,3	13,18	8,1	3,125	7	2,614	43	16,05	48	19,84	21	7,841	27	10,42	7,6	2,838	2,9	1,119	4,6	1,717	3,6	1,344	1,7	0,656	209,80	6,65
	5,2	1,941	8,3	3,202	21	7,841	81	30,24	145	59,94	154	57,5	17	6,559	7,4	2,763	3,5	1,35	2,5	0,933	1,8	0,672	1,7	0,656	448,40	14,22
	5	1,867	6,3	2,431	3,2	1,195	1,9	0,709	22	9,094	9,9	3,696	20	7,716	3,7	1,381	1,9	0,733	1,4	0,523	2	0,747	0,9	0,347	78,20	2,48
	5	1,867	16	6,173	29	10,83	108	40,32	307	126,9	191	71,31	60	23,15	15	5,6	8,7	3,356	5	1,867	4,5	1,68	2,6	1,003	751,80	23,84
	1,9	0,709	23	8,873	49	18,29	23	8,587	128	52,91	137	51,15	16	6,173	5,2	1,941	3	1,157	2,5	0,933	1,7	0,635	11	4,244	401,30	12,73
1975-76	4,3	1,605	5,3	2,045	78	29,12	402	150,1	320	132,3	425	158,7	48	18,52	34	12,69	5,1	1,968	7,2	2,688	3,9	1,456	5,7	2,199	1338,50	42,44
	122	45,55	41	15,82	6	2,24	7,9	2,95	65	26,87	76	28,38	9,7	3,742	5,1	1,904	2	0,772	2,3	0,859	1,3	0,485	4,2	1,62	342,50	10,86
	16,4	6,123	40	15,43	10	3,734	90	33,6	30	12,4	15	5,6	80	30,86	8	2,987	2	0,772	2	0,747	2	0,747	10	3,858	305,40	9,68
	15	5,6	20	7,716	60	22,4	30	11,2	20	8,267	30	11,2	30	11,57	20	7,467	10	3,858	5,4	2,016	9,8	3,659	5,8	2,238	256,00	8,12
	5,7	2,128	3,9	1,505	15	5,6	41	15,31	50	20,67	52	19,41	10	3,858	9	3,36	8	3,086	1,4	0,523	0,8	0,299	1	0,386	197,80	6,27
1980-81																										
	6,9	2,576	14,9	5,748	39	14,56	81	30,24	16	6,614	34	12,69	5	1,929	9	3,36	9	3,472	3,5	1,307	2,3	0,859	4,3	1,659	224,90	7,13
	3,9	1,456	8,5	3,279	6,11	2,281	4,4	1,643	128	52,91	41	15,31	4,5	1,736	2,7	1,008	2,2	0,849	1,7	0,635	0,9	0,336	0,7	0,27	204,61	6,49
1985-86	32	11,95	11	4,244	73	27,26	25	9,334	67	27,7	21	7,841	6,1	2,353	5,1	1,904	4,8	1,852	6,1	2,277	8	2,987	10	3,858	269,10	8,53
	22	8,214	63	24,31	28	10,45	28	10,45	11	4,547	13	4,854	9,3	3,588	5	1,867	5	1,929	4,1	1,531	3	1,12	90	34,72	281,40	8,92
	10	3,734	53	20,45	8,5	3,174	9,3	3,472	122	50,43	199	74,3	6	2,315	6,2	2,315	2,5	0,965	2,6	0,971	2,6	0,971	27	10,42	448,70	14,23
	36	13,44	18	6,944	25	9,334	25	9,334	138	57,04	70	26,14	40	15,43	18,4	6,87	10	3,858	10	3,734	16	5,974	20	7,716	426,40	13,52
	12,4	4,63	50	19,29	20	7,467	21	7,841	8	3,307	10	3,734	25,4	9,799	4,1	1,531	7,5	2,894	7,4	2,763	14	5,227	2	0,772	181,80	5,76
1990-91	2	0,747	1	0,386	20	7,467	40	14,93	125	51,67	14	5,227	2	0,772	1	0,373	1	0,386	1	0,373	1	0,373	1	0,386	209,00	6,63
	31	11,57	16	6,173	60	22,4	11	4,107	16	6,614	10	3,734	5	1,929	1	0,373	1	0,386	1	0,373	1	0,373	1	0,386	154,00	4,88
Qmean	13,77	5,142	16,64	6,418	23,29	8,697	37,23	13,9	53,99	22,32	49,28	18,4	20,85	8,042	8,567	3,199	5,285	2,039	4,231	1,58	4,173	1,558	7,986	3,081	245,29	7,78

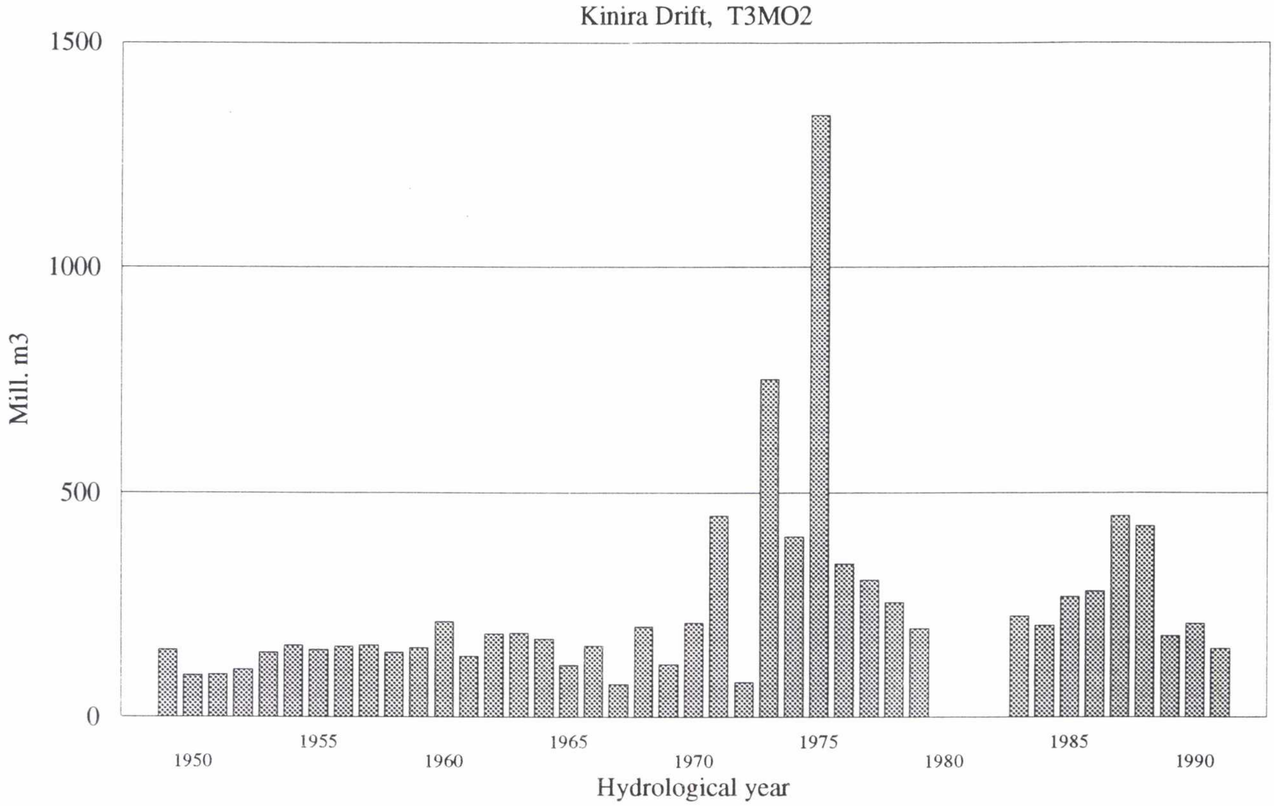


Figure 6.4 Annual Total Runoff at Kinira Drift, 1949/50-1991/92

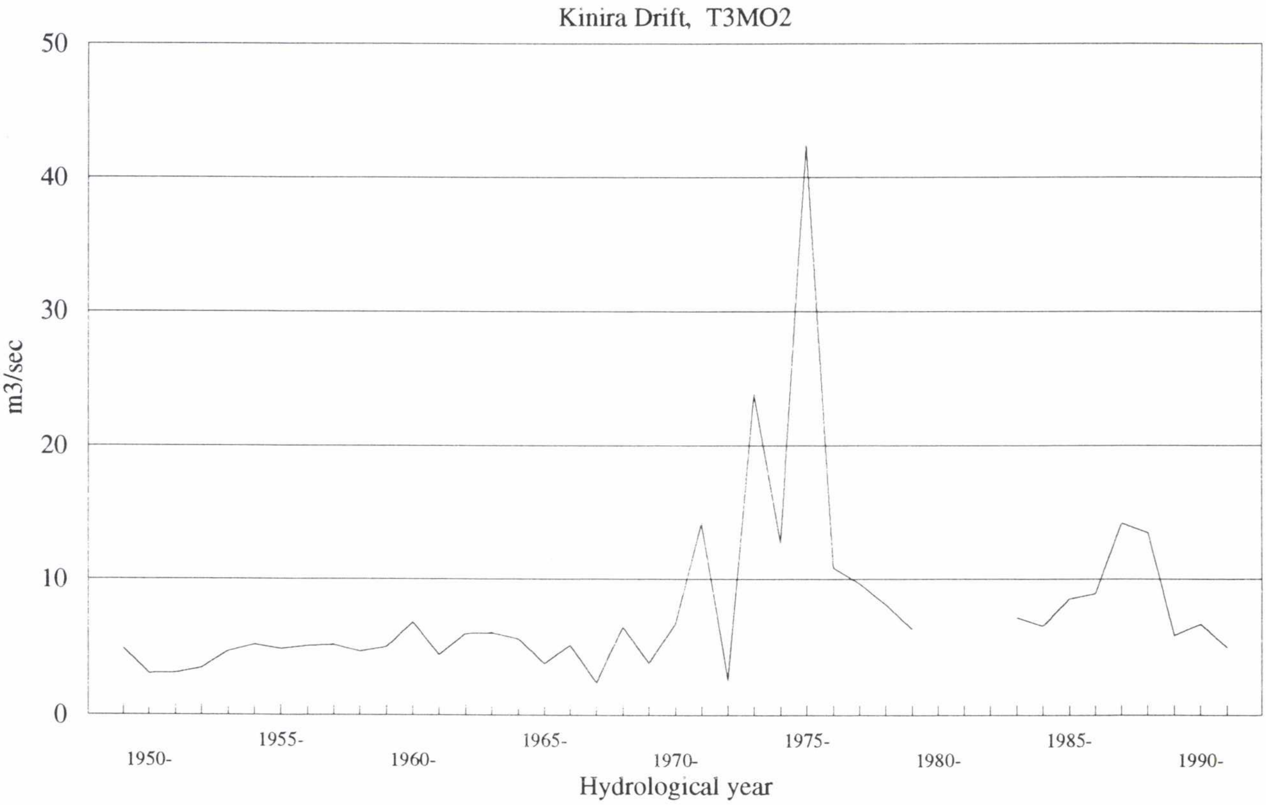


Figure 6.5 Mean Annual Runoff at Kinira Drift, 1949/50-1991/92

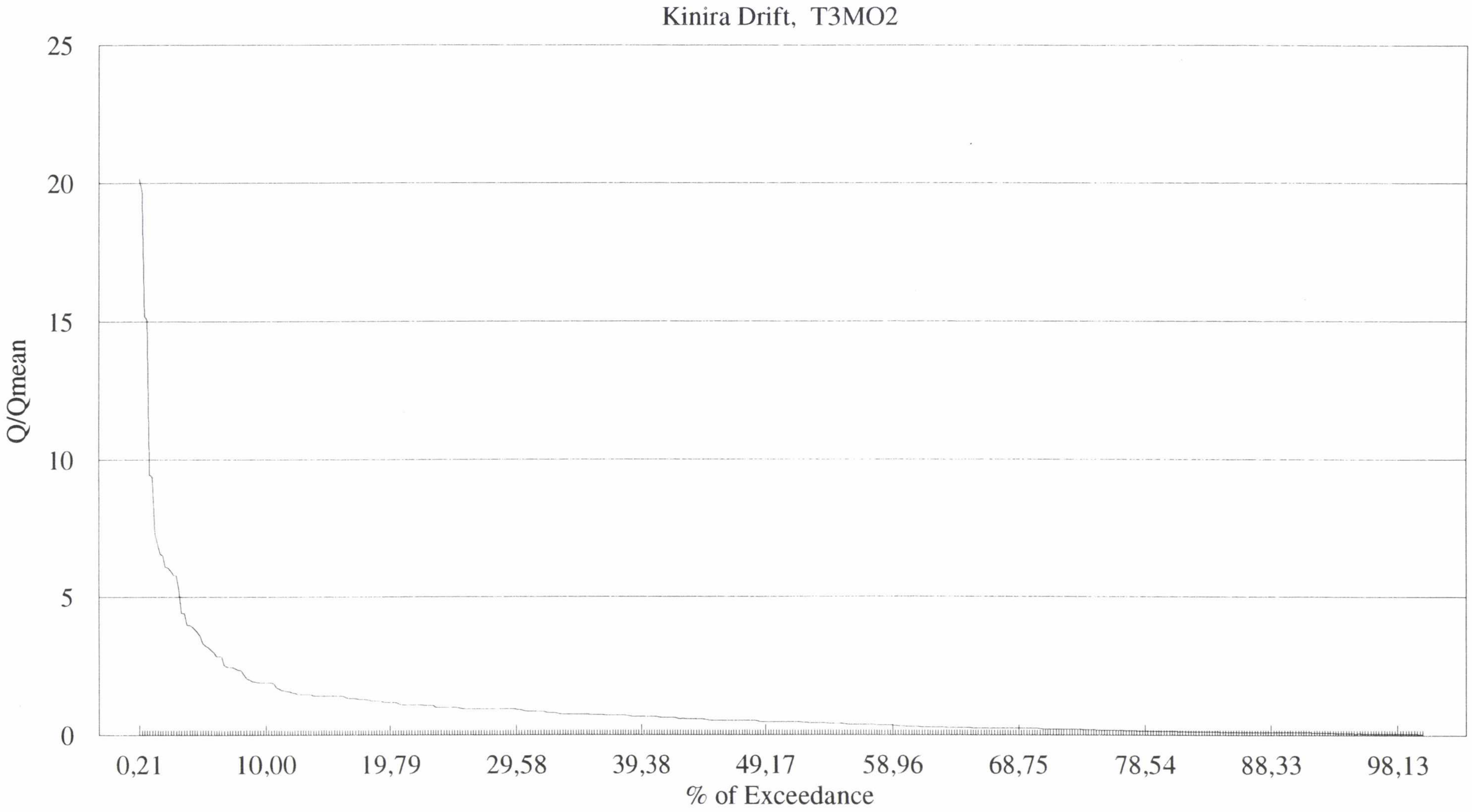


Figure 6.6 Dimensionless Flow Duration Curve, Kinira Drift

Table 6.3 Monthly Runoff at Tina River, T2MO5

Tina River T3MO5 2597 km2

Monthly Total Runoff, Mm3, and Monthly Mean Runoff, m3/sec

	Oct		Nov		Dec		Jan		Feb		Mar		Apr		May		Jun		Jul		Aug		Sep		Annual total runoff, Mm3	Annual mean runoff, m3/s
	Mm3	m3/s	Mm3	m3/s	Mm3	m3/s	Mm3	m3/s	Mm3	m3/s	Mm3	m3/s	Mm3	m3/s	Mm3	m3/s	Mm3	m3/s	Mm3	m3/s	Mm3	m3/s	Mm3	m3/s		
1951-52	54,90	20,50	12,90	4,98	5,00	1,87	8,90	3,32	88,00	36,38	85,00	31,74	17,20	6,64	6,90	2,58	0,60	0,23	2,00	0,75	1,00	0,37	10,00	3,86	292,40	9,27
	8,00	2,99	10,00	3,86	30,00	11,20	28,00	10,45	45,00	18,60	19,00	7,09	37,00	14,27	1,00	0,37	1,00	0,39	1,00	0,37	10,00	3,73	20,00	7,72	210,00	6,66
	20,00	7,47	30,00	11,57	40,00	14,93	30,00	11,20	40,00	16,53	30,00	11,20	8,00	3,09	20,00	7,47	8,00	3,09	1,00	0,37	0,10	0,04	0,00	0,00	227,10	7,20
	20,00	7,47	15,00	5,79	15,00	5,60	70,00	26,14	87,00	35,96	121,00	45,18	17,50	6,75	10,80	4,03	6,40	2,47	7,20	2,69	4,70	1,75	3,10	1,20	377,70	11,98
1955-56	10,30	3,85	19,20	7,41	20,00	7,47	10,00	3,73	50,00	20,67	60,00	22,40	10,00	3,86	13,20	4,93	11,70	4,51	6,60	2,46	4,30	1,61	3,80	1,47	219,10	6,95
	1,70	0,63	55,00	21,22	221,00	82,51	130,00	48,54	128,00	52,91	140,00	52,27	46,00	17,75	15,30	5,71	6,20	2,39	6,30	2,35	11,90	4,44	56,40	21,76	817,80	25,93
	40,00	14,93	21,60	8,33	35,50	13,25	134,00	50,03	77,00	31,83	31,00	11,57	41,00	15,82	16,60	6,20	11,60	4,48	7,30	2,73	5,20	1,94	5,00	1,93	425,80	13,50
	20,00	7,47	100,00	38,58	32,40	12,10	58,00	21,65	55,00	22,73	41,00	15,31	14,00	5,40	142,00	53,02	20,50	7,91	15,10	5,64	10,10	3,77	10,80	4,17	518,90	16,45
	8,48	3,17	24,90	9,61	39,40	14,71	39,00	14,56	48,00	19,84	28,00	10,45	31,00	11,96	14,80	5,53	6,15	2,37	4,50	1,68	3,80	1,42	8,50	3,28	256,53	8,13
1960-61	9,60	3,58	34,60	13,35	74,00	27,63	51,00	19,04	46,00	19,01	44,00	16,43	159,00	61,34	18,20	6,80	11,90	4,59	7,10	2,65	5,50	2,05	3,50	1,35	464,40	14,73
	2,80	1,05	16,00	6,17	26,00	9,71	54,00	20,16	145,00	59,94	91,00	33,98	18,00	6,94	11,30	4,22	6,00	2,31	4,70	1,75	3,80	1,42	3,20	1,23	381,80	12,11
	4,20	1,57	27,80	10,73	48,00	17,92	120,00	44,80	77,00	31,83	236,00	88,11	83,00	32,02	17,50	6,53	10,70	4,13	17,50	6,53	8,90	3,32	4,80	1,85	655,40	20,78
	37,80	14,11	121,00	46,68	75,00	28,00	61,00	22,77	36,00	14,88	21,00	7,84	20,00	7,72	5,00	1,87	40,00	15,43	2,00	0,75	2,00	0,75	10,00	3,86	430,80	13,66
	40,00	14,93	20,00	7,72	20,00	7,47	30,00	11,20	30,00	12,40	20,00	7,47	15,00	5,79	10,00	3,73	5,00	1,93	40,00	14,93	15,00	5,60	8,70	3,36	253,70	8,04
1965-66	31,60	11,80	27,90	10,76	25,00	9,33	60,00	22,40	40,00	16,53	5,00	1,87	9,00	3,47	30,00	11,20	5,00	1,93	5,00	1,87	5,00	1,87	10,00	3,86	253,50	8,04
	5,00	1,87	20,00	7,72	20,00	7,47	40,00	14,93	30,00	12,40	90,00	33,60	40,00	15,43	20,00	7,47	6,00	2,31	18,70	6,98	7,80	2,91	6,20	2,39	303,70	9,63
	5,00	1,87	20,00	7,72	25,00	9,33	35,00	13,07	40,00	16,53	50,00	18,67	20,00	7,72	9,00	3,36	9,00	3,47	5,00	1,87	3,00	1,12	8,00	3,09	229,00	7,26
	15,00	5,60	20,00	7,72	20,00	7,47	25,00	9,33	50,00	20,67	30,00	11,20	20,00	7,72	20,00	7,47	8,00	3,09	5,00	1,87	4,00	1,49	5,00	1,93	222,00	7,04
	20,00	7,47	20,00	7,72	30,00	11,20	20,00	7,47	50,00	20,67	3,10	1,16	3,20	1,23	3,50	1,31	2,60	1,00	3,10	1,16	23,00	8,59	18,00	6,94	196,50	6,23
1970-71	89,00	33,23	14,00	5,40	16,50	6,16	41,00	15,31	76,00	31,42	31,00	11,57	44,00	16,98	19,60	7,32	7,20	2,78	9,00	3,36	19,50	7,28	8,60	3,32	375,40	11,90
	62,00	23,15	46,00	17,75	32,00	11,95	103,00	38,46	52,00	21,49	50,00	18,67	20,00	7,72	5,00	1,87	5,00	1,93	5,00	1,87	4,00	1,49	1,00	0,39	385,00	12,21
	20,00	7,47	50,00	19,29	60,00	22,40	40,00	14,93	60,00	24,80	40,00	14,93	20,00	7,72	5,00	1,87	5,00	1,93	5,00	1,87	5,00	1,87	10,00	3,86	320,00	10,15
	5,00	1,87	1,40	0,54	23,60	8,81	200,00	74,67	100,00	41,34	60,00	22,40	116,00	44,75	27,30	10,19	17,90	6,91	14,20	5,30	10,50	3,92	20,00	7,72	595,90	18,90
	1,20	0,45	32,00	12,35	65,40	24,42	23,00	8,59	25,00	10,33	30,00	11,20	20,00	7,72	10,00	3,73	5,00	1,93	5,00	1,87	5,00	1,87	10,00	3,86	231,60	7,34
1975-76																										
1980-81																										
	5,20	1,94	13,00	5,02	51,40	19,19	79,00	29,50	28,00	11,57	6,80	2,54	45,00	17,36	8,10	3,02	5,50	2,12	3,70	1,38	3,70	1,38	6,10	2,35	255,50	8,10
	8,80	3,29	20,00	7,72	14,00	5,23	51,00	19,04	208,00	85,98	44,00	16,43	7,70	2,97	1,70	0,63	1,80	0,69	2,20	0,82	1,90	0,71	1,20	0,46	362,30	11,49
1985-86	30,00	11,20	20,00	7,72	110,00	41,07	105,00	39,20	65,00	26,87	31,30	11,69	9,80	3,78	6,40	2,39	6,40	2,47	2,00	0,75	30,00	11,20	10,60	4,09	426,50	13,52
	25,00	9,33	95,00	36,65	31,00	11,57	38,00	14,19	14,00	5,79	29,80	11,13	12,90	4,98	5,00	1,87	4,40	1,70	4,90	1,83	11,90	4,44	64,00	24,69	335,90	10,65
	10,00	3,73	65,00	25,08	26,00	9,71	108,00	40,32	150,00	62,00	120,00	44,80	44,00	16,98	16,80	6,27	14,70	5,67	10,80	4,03	5,00	1,87	5,00	1,93	575,30	18,24
	20,00	7,47	40,00	15,43	50,00	18,67	30,00	11,20	70,00	28,94	77,20	28,82	58,00	22,38	24,10	9,00	18,70	7,21	10,10	3,77	5,00	1,87	3,00	1,16	406,10	12,88
	10,00	3,73	97,00	37,42	105,00	39,20	20,00	7,47	20,00	8,27	98,00	36,59	20,00	7,72	12,40	4,63	9,10	3,51	10,60	3,96	8,00	2,99	5,00	1,93	415,10	13,16
1990-91	12,00	4,48	6,00	2,31	60,00	22,40	90,00	33,60	100,00	41,34	30,00	11,20	8,00	3,09	5,00	1,87	4,00	1,54	4,00	1,49	3,00	1,12	3,00	1,16	325,00	10,31
	40,00	14,93	27,00	10,42	85,00	31,74	13,00	4,85	16,00	6,61	9,00	3,36	8,00	3,09	3,00	1,12	3,00	1,16	2,00	0,75	2,00	0,75	3,00	1,16	211,00	6,69
Qmean	20,99	7,84	34,62	13,35	46,40	17,32	58,94	22,00	65,03	26,88	54,61	20,39	31,58	12,19	16,20	6,05	8,61	3,32	7,50	2,80	7,38	2,76	10,47	4,04	362,33	11,49

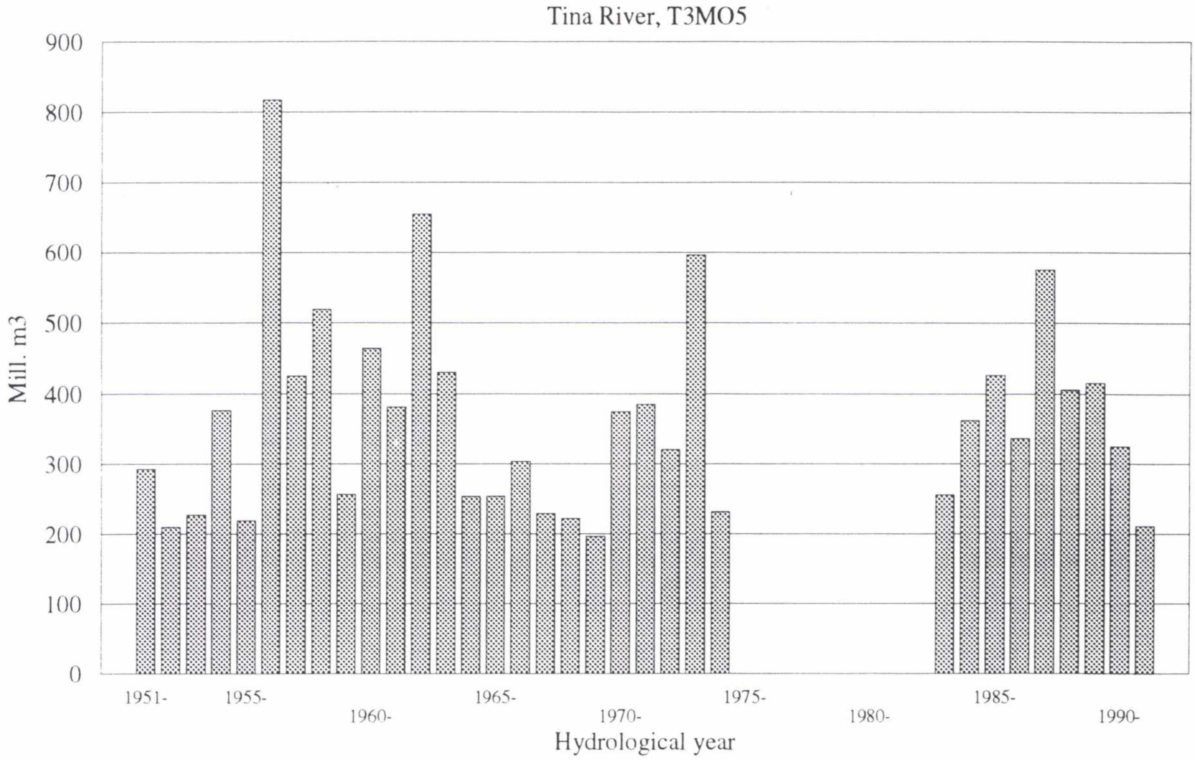


Figure 6.7 Annual Total Runoff at Tina River, 1951/52-1991/92

Figure 6.8 Mean Annual Runoff at Tina River, 1951/52-1991/92

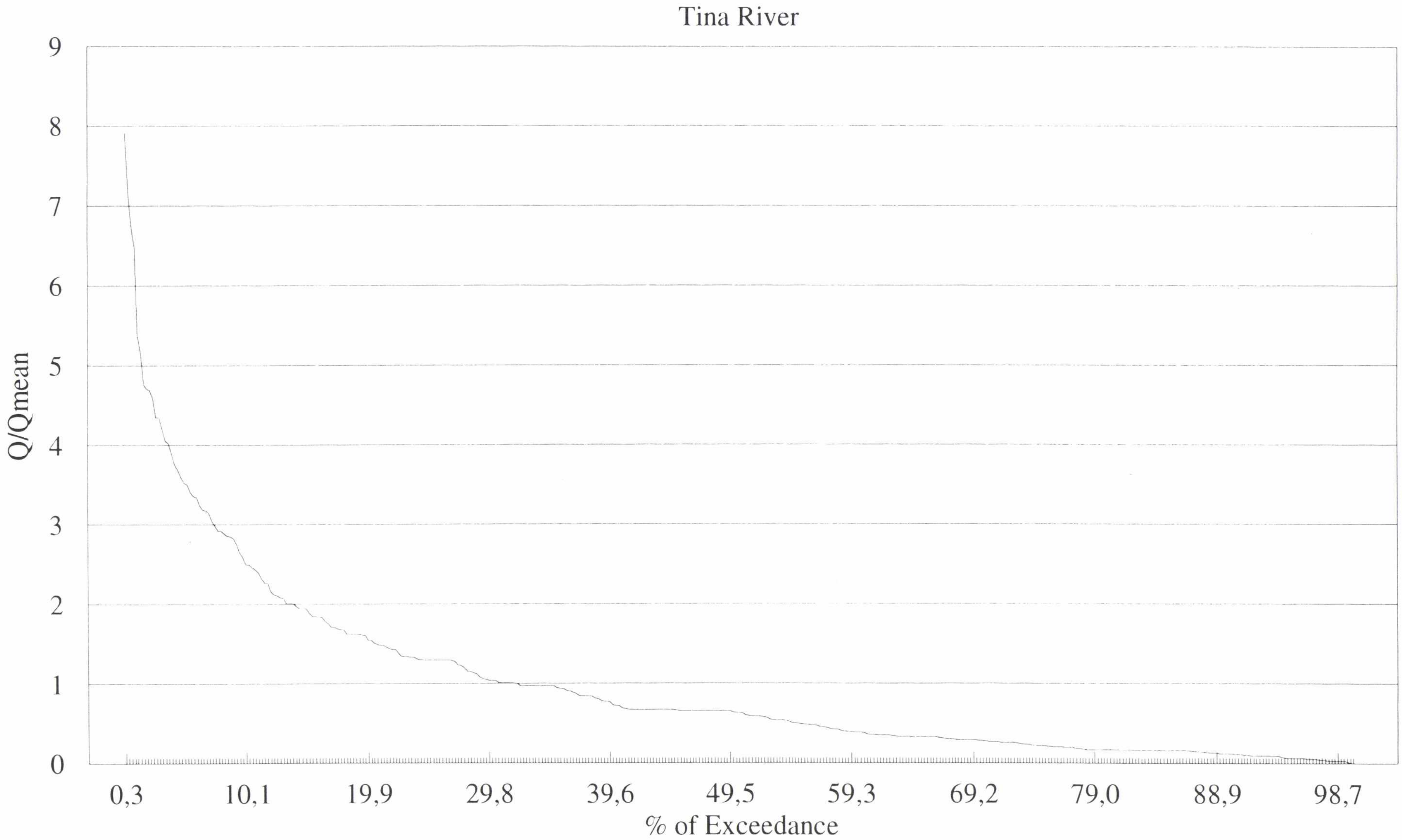
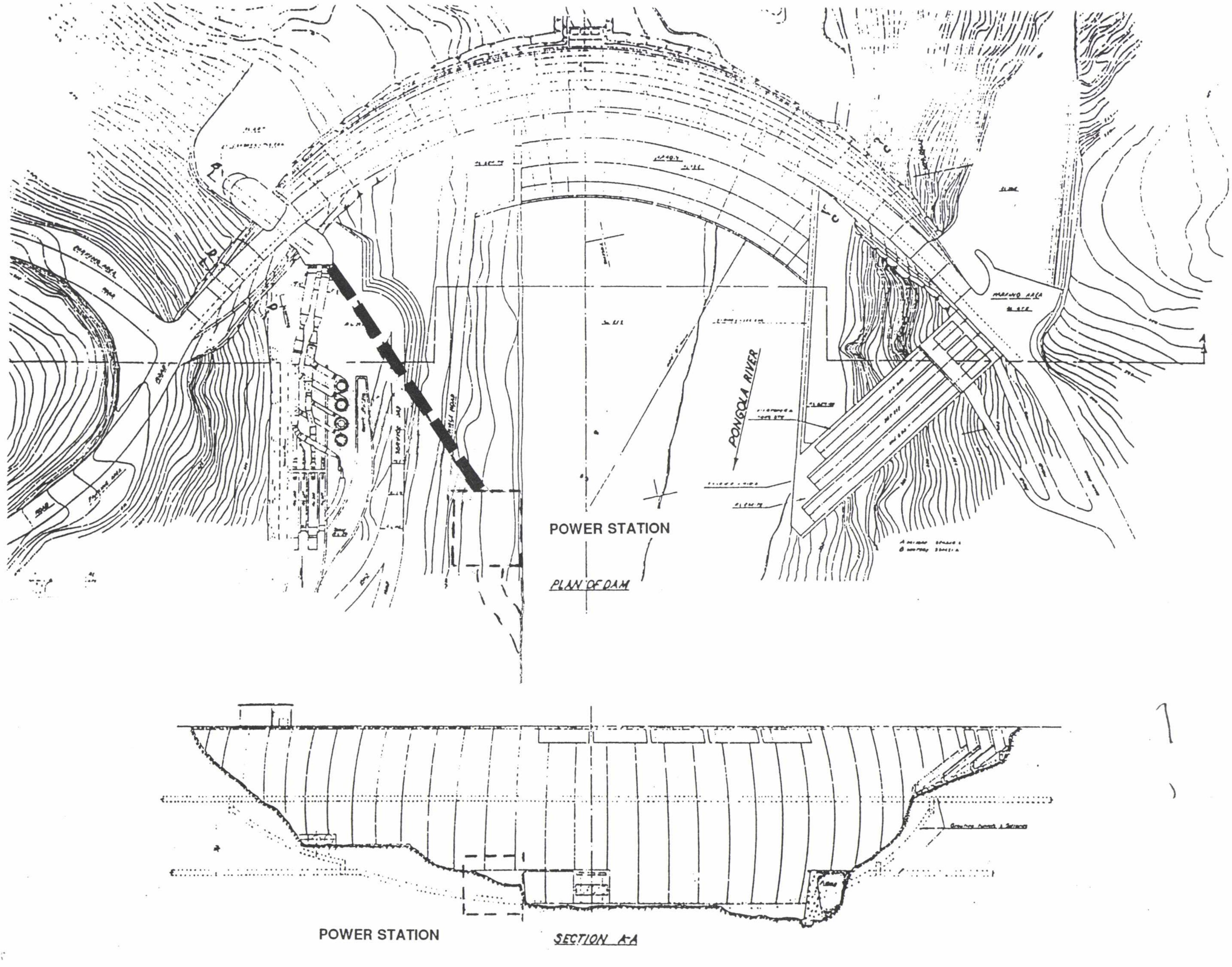


Figure 6.9 Non-dimensional flow duration curve, Tina River, T3MO5

APPENDIX 4.9

APPENDIX 5

JOZINI

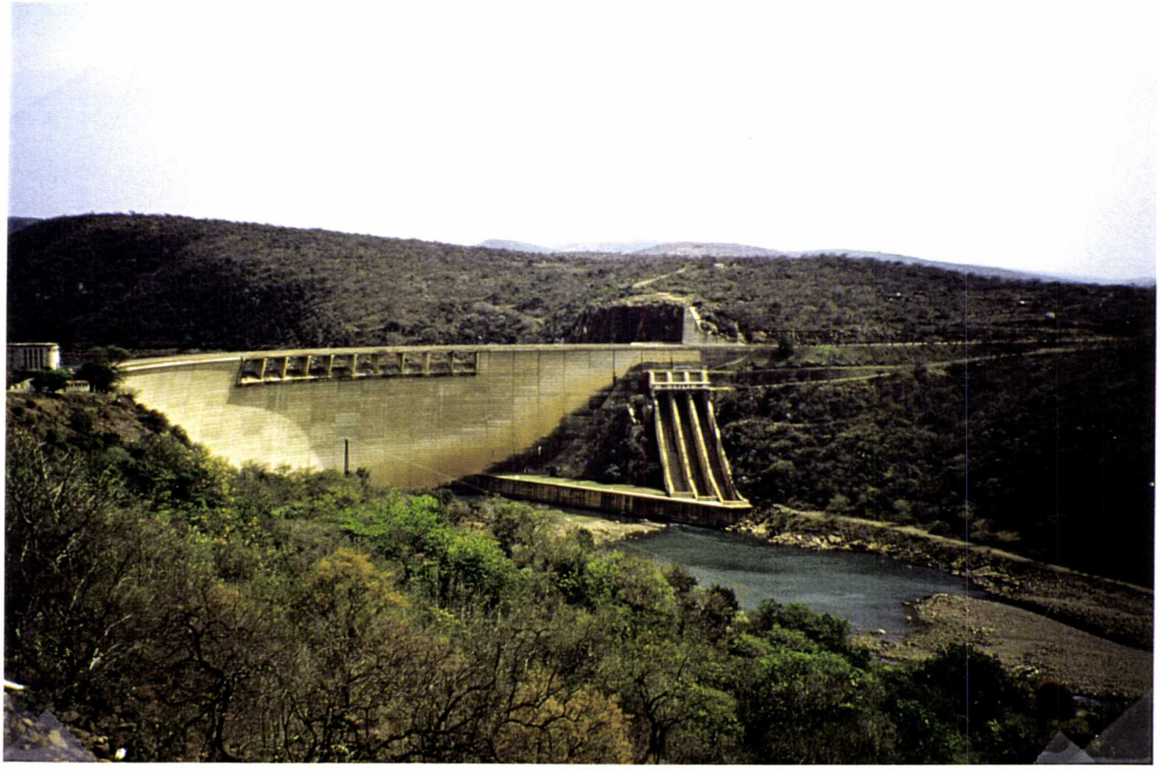


APPENDIX 6

The Jozini scheme

Picture 1: The Jozini dam is an arch dam, 87 m high and regulates the Pongota river which flows into Mozambique. 3 m3/s is released for irrigation. Only a small part of the dam's capacity is utilized.

Picture 2: 4 m3/s is released to secure a minimum flow into Mozambique.

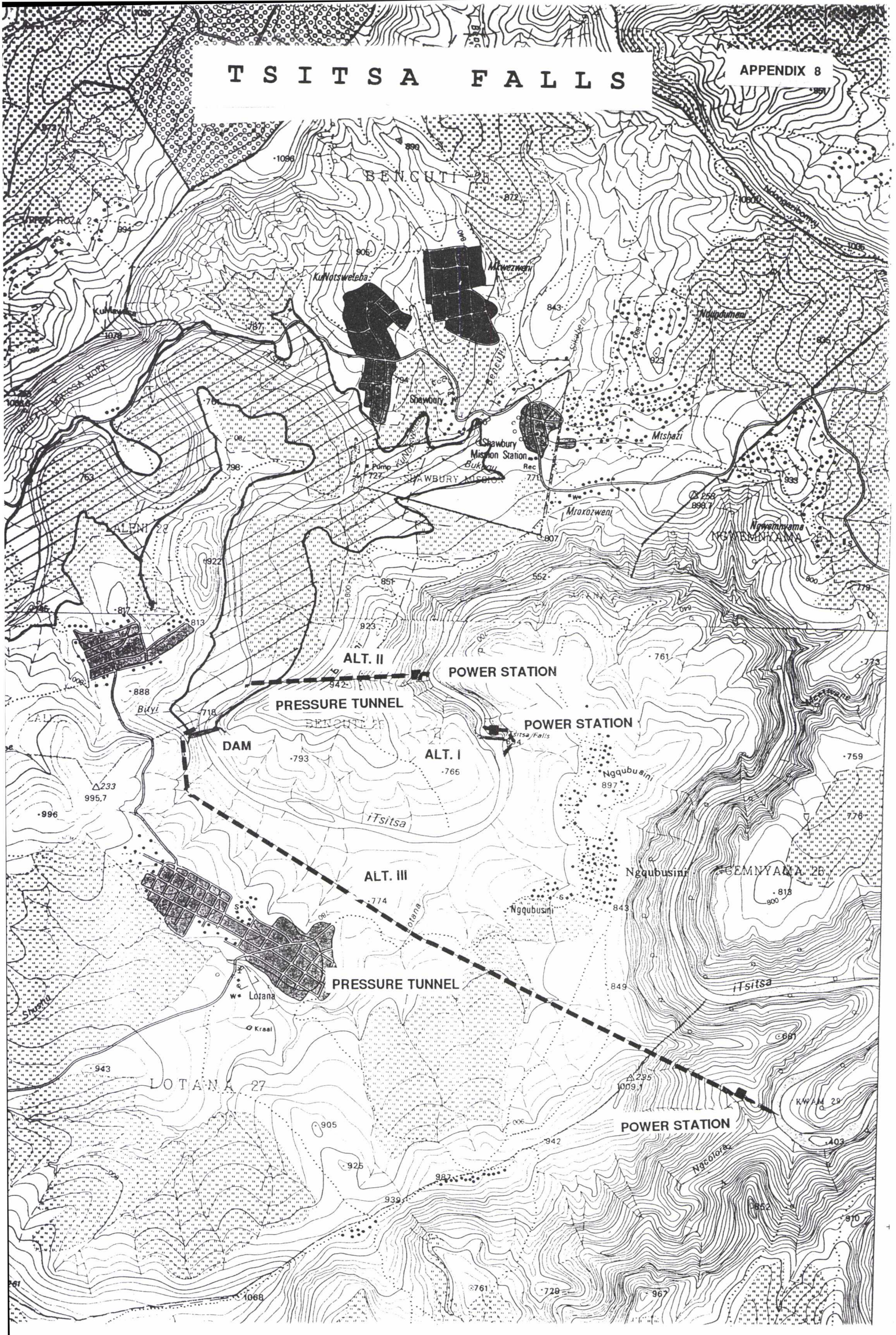


APPENDIX 7

The Jozini scheme

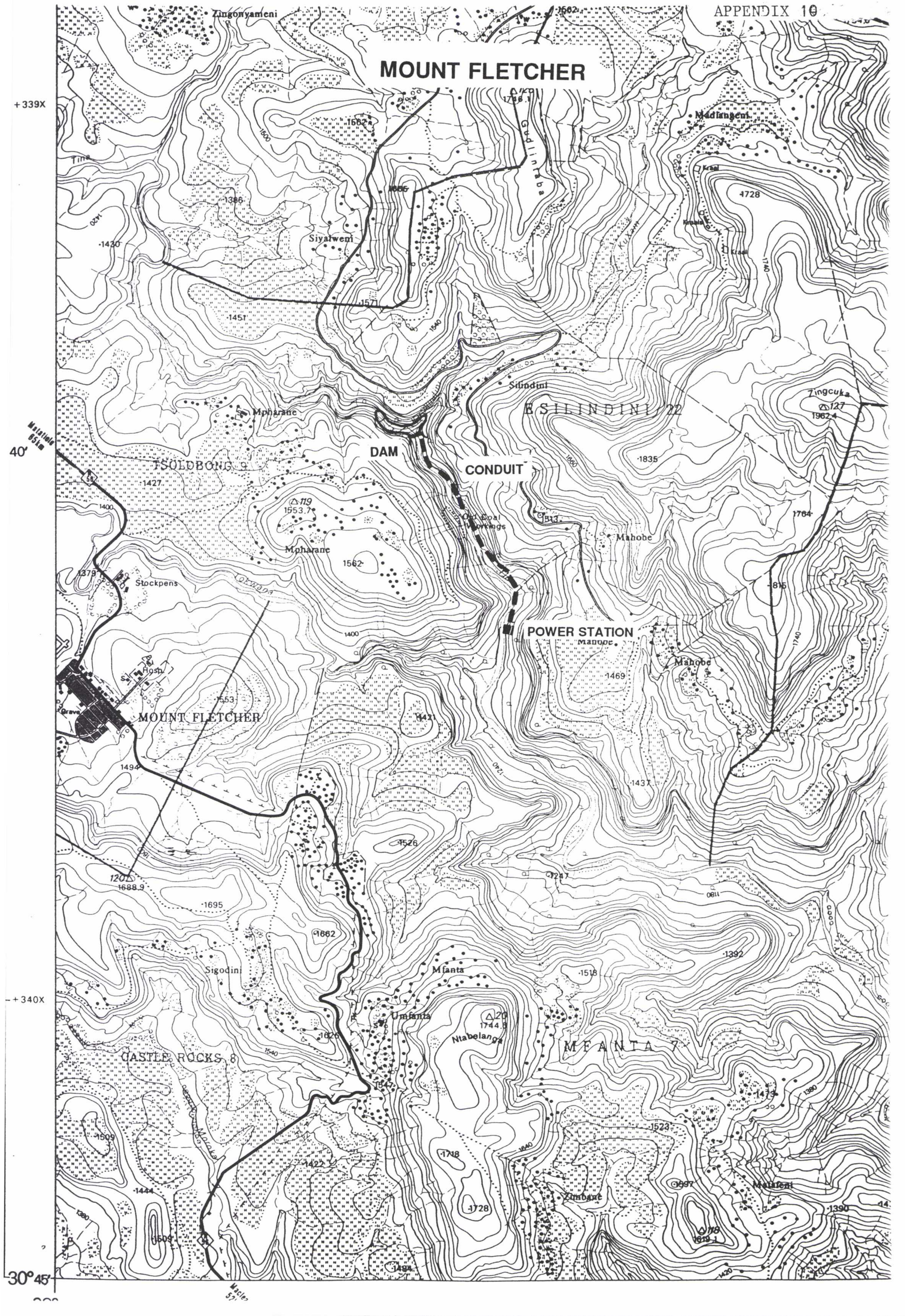
Picture 1:
The irrigation channel (3 m3/s is released, the capacity is much greater). The river has natural ponds which will re-regulate the water folw from peak power operation. One power station utilizing 4 m3/s could be built with tailwater in the river. One power station utilizing the irrigation water could be built at the existing reduction valves for irrigation water.

Picture 2:
Lack of water downstream the dam creates a market for drinking water.


TSITSA FALLS
APPENDIX 8
BENCUTI 25
KuNotsweleba
Mtwezweni
Shawbury
Shawbury Mission Station
SHAWBURY MISSION
Mtshazi
Mroxozweni
NGWEMNYAMA 25
ALENI 22
ALT. II
POWER STATION
PRESSURE TUNNEL
POWER STATION
Tsitsa Falls
DAM
ALT. I
Ngqubusini
iTsitsa
ALT. III
Ngqubusini
PRESSURE TUNNEL
Lotana
Kraal
LOTANA 27
POWER STATION
iTsitsa
KWAM 29
Ngcolora
Bityi

The Tsitsa Falls Scheme

Picture 1:	The spectacular falls is 100m high.
Picture 2:	The village Shawbury includes schools, clinic and shops. The buildings are powered by a diesel unit. The development of the falls can supply the area with electricity.

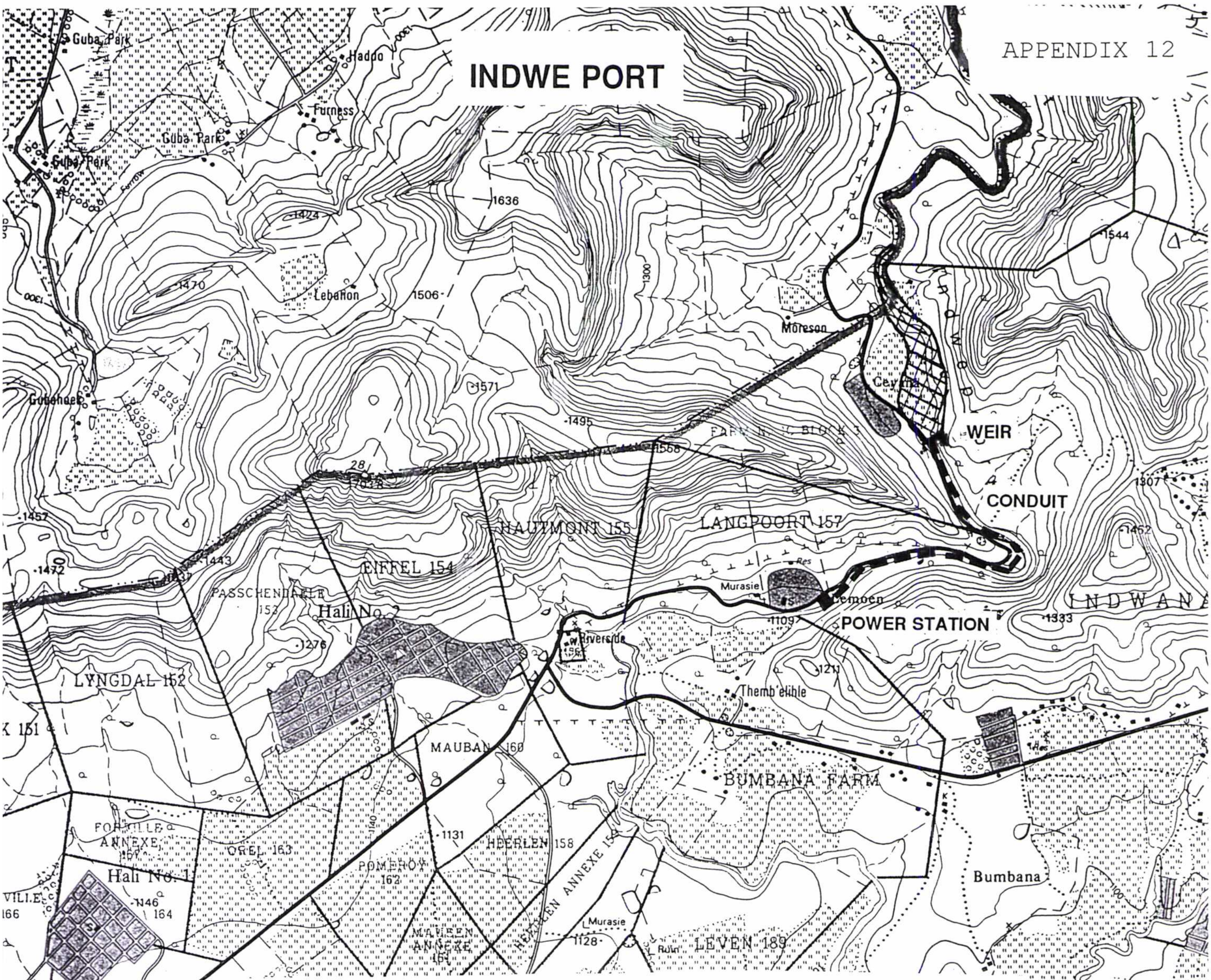

MOUNT FLETCHER
DAM
CONDUIT
POWER STATION
Zingonyameni
Siyalweni
Mpharane
TSOLOBONG 9
Old Coal Workings
Silindini
ESILINDINI 22
Zingcuka
Mahobe
Stockpens
Hosp
MOUNT FLETCHER
Sigodini
Mfanta
Umfanta
Ntabelanga
MFANTA 7
CASTLE ROCKS 8
Zimbane
Madlangeni
+339X
+340X
40'
30°45'

APPENDIX 11

The Mt. Fletcher Scheme

Picture 1: The damsite area in the Tina river

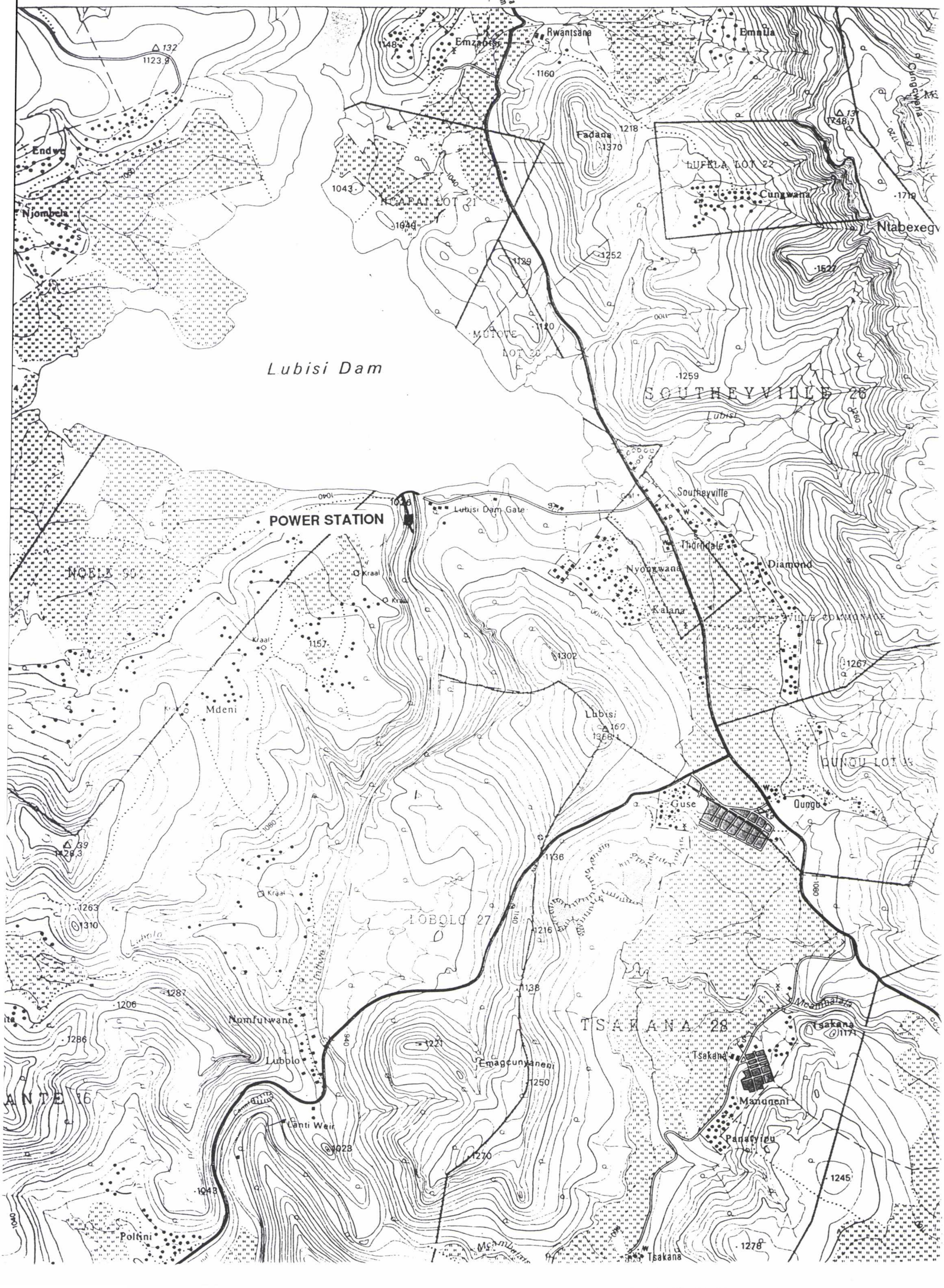
Picture 2: The existing local electricity supply is powered by a diesel unit. There are plans for connection to the grid.



The river area which will be dried out by the scheme in low flow periodes. Intake dam in front of the picture. The power station will be located at the other end of the oxbow.

1:50 000

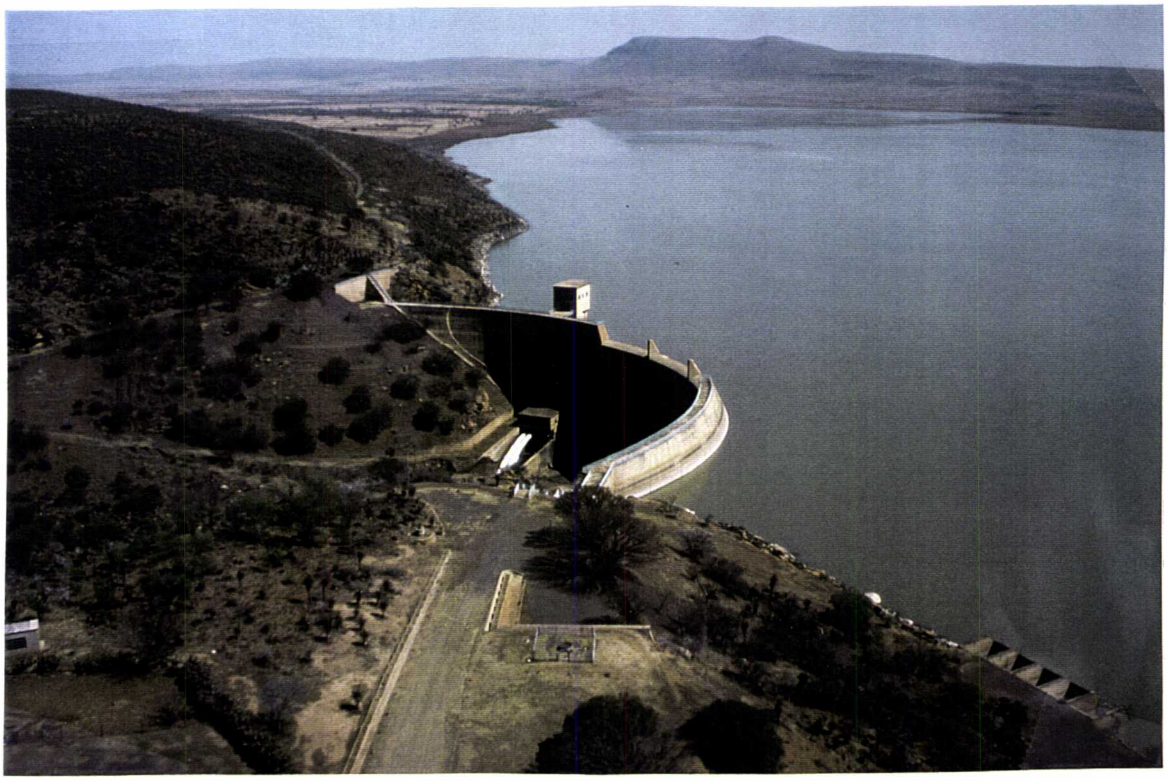
LUBISI



APPENDIX 14

The Lubisi Scheme

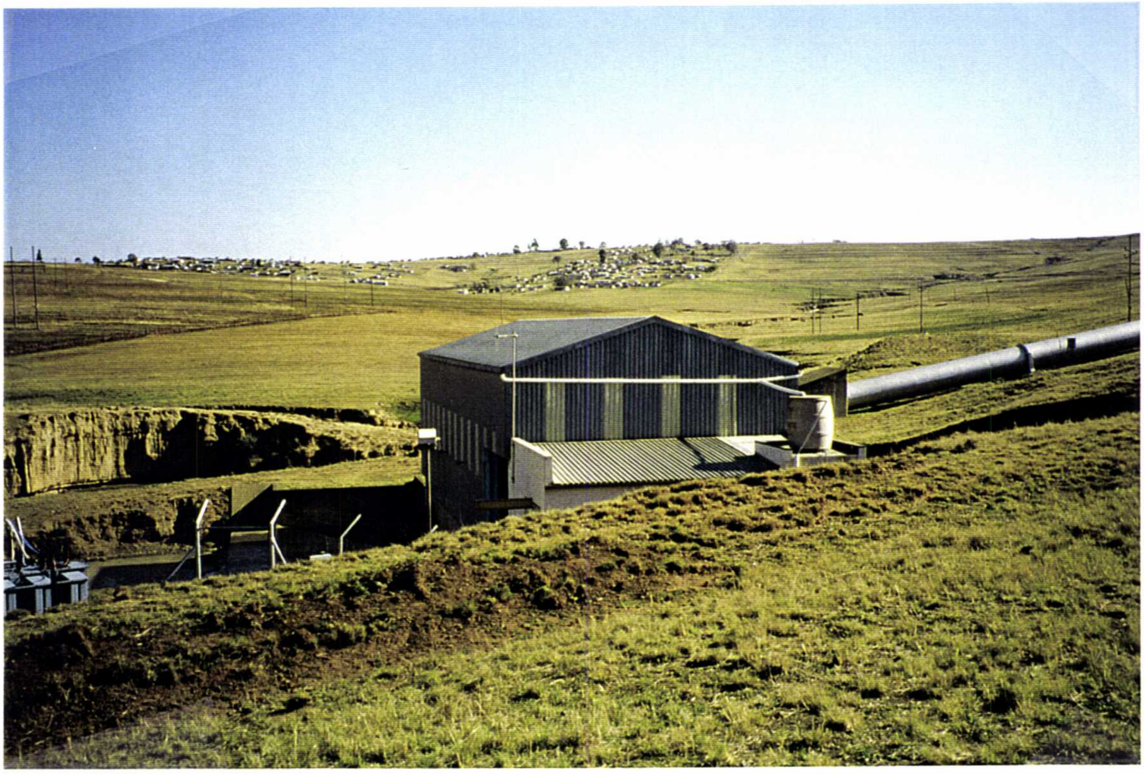
Picture 1/2: The dam is an arch dam, approximately 40 m high. Water is released for downstream irrigation. The hydro power station will utilize the head in the dam and rapids 50m downstream the dam.



APPENDIX 15

The NCORA hydro power station (3 units, two 500 kW each, one 1500 kW). Working head 46.2 m.

The power station is developed as part of an irrigation scheme. The turbines are second hand and have been taken from another power station in South Africa. It is owned by TESCOR, but runned by ESKOM. The station proved to be very well maintained. Several similar examples can be found which states that training for operation/maintenance can be undertaken in South Africa.



APPENDIX 16

AVAILABLE DOCUMENTS, REPORTS

Eskom guide:
Minimum requirements for the connection of non-Eskom generating plant to the Eskom distribution system. July 1995.

CSIR:
The RDP and Rural Development, facing the real challange. Case the Lubisi Dam Project

CSIR/WNNR:
Lubisi Dam Development Project, Request for finance document, September 1995

Zimele Rural Development:
Annual Report 1994/1995

KHULANI, A development committee for Ubombo/Ingwavuma (Maputaland):
Basic information on the Jozini area, September 1995 (two books)

KHULANI:
Letter to NVE 16 October 1995, including GPS information

Pieterse Lotz & Vennote/Partners:
Preliminary planning proposal for bulk power infrastructure in Maputaland (Makhatini flats), 6 March 1995

Energy Research Institute:
The potential for small-scale hydro plant, R. K. Dutkiewicz

EDRC, 15 March 1994:
Electricity for rural institutions; gudelines from the IDT clinics electrification programme, 1993

Republic of Transkey, Department of Works and Energy. Stephenson Associates in Conjuction with Eskom, September 1991:
Review of hydrology of the Mzimvubu Basin