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Man and the Pongolo floodplain

J Heeg and C M Breen

A report of the Committee for Inland Water Ecosystems
National Programme for Environmental Sciences

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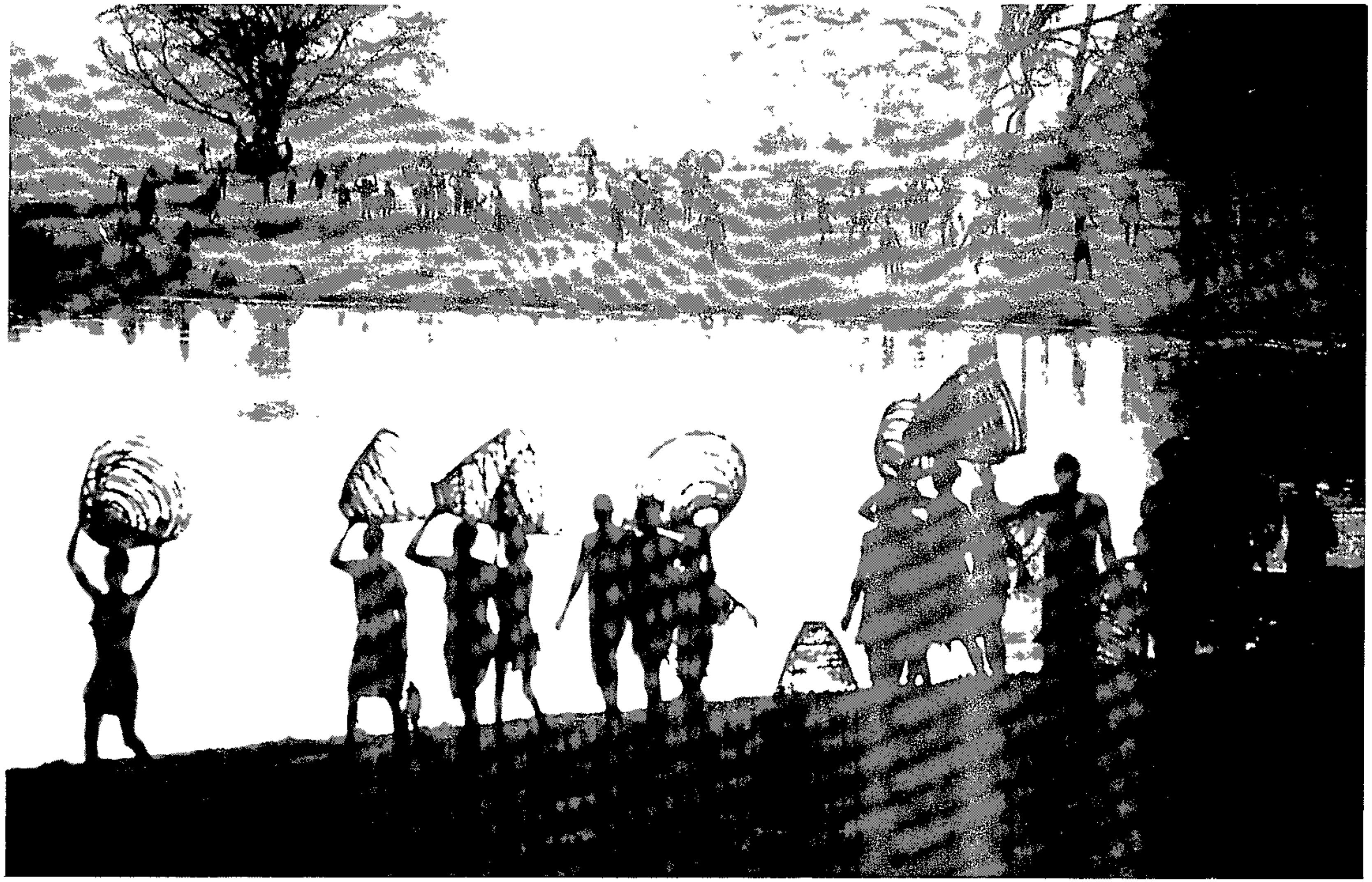


GOING HOME: Sunset on Tete Pan. (Photo: K H Rogers)

PREFACE

Long protected by nagana, malaria, and sandy soils which made access by motor-vehicles difficult, the Pongola floodplain was one of the last remaining undisturbed areas in South Africa. Then the tsetse flies were eradicated, malaria was controlled, and roads were built. Now the Pongola River itself has been harnessed by the construction of the large Pongolapoort Dam, and in the not too distant future the floodplain will be surrounded by irrigated lands. The population in the area will increase and some agriculturally-orientated industries may be established.

It is not difficult to visualise the dramatic changes that will take place. The floodplain and associated pans are the product of the flow and sediment regime of the river. This regime will be radically changed, and the location and shape of the waterways will tend towards new equilibrium conditions over a long period of time. More immediate consequences will be those related to the frequency and timing of flooding which is vital for the maintenance of the diverse fish and plant life found nowhere else in South Africa. The local population whose ancestors took refuge in this inhospitable environment will now have to make radical changes in their way of life, from primitive subsistence agriculture with fish providing the main source of protein, to sophisticated farming methods. This adaptation may be the most traumatic change of all.

With these problems in mind the Committee for Inland Water Ecosystems of the National Programme for Environmental Sciences launched a study of the Pongola floodplain system. Initially, the emphasis was on the ecological aspects, with the planned conservation of the system as the principal objective. However, it was soon realised that the need for conservation could not be separated from the need for planned development on a much broader front, and that the authorities responsible for this development would require information not only on the ecological interactions, but also those between the present inhabitants and the floodplain, and, looking towards the more distant future, the effect of future development on these complex interrelationships.

In January, 1978 a workshop was held on the theme 'Man and the Pongola floodplain', which was attended by representatives from all the research organisations, government and provincial authorities, and others who had an interest in the area. This report is to a large extent a synthesis of the information presented at the workshop prepared by the two authors who themselves played a major role in the research programme.

Much has been accomplished, but the research is by no means complete. Within a few months trial releases of water will be made from the dam to determine to what extent natural flooding can be simulated in order to achieve optimum benefit to the natural system and the inhabitants who depend on the floodplain. Further development will be a gradual process, and if it is founded on the knowledge available in this report, modified where necessary by subsequent research and experience, it should be possible to conserve a significant part of the floodplain in its present condition for all time while simultaneously providing a higher standard of living for all those who depend on the floodplain for their livelihood.

ACKNOWLEDGEMENTS

The authors gratefully acknowledge the financial assistance and logistic support received from the South African Council for Scientific and Industrial Research and the University of Natal. Our own research on the Pongolo Floodplain would not have been possible without this substantial assistance, nor could a workshop with so wide a representation have been held. Dr R G Noble of the Cooperative Scientific Programmes unit has played a key role both in initiating the floodplain research programme and in finding the necessary funds to keep it going. His enthusiasm, encouragement and efforts in a variety of spheres are much appreciated.

All those who attended the workshop have made valuable contributions to this final synthesis, and to acknowledge each of these separately would be merely to repeat the list of participants. We therefore extend to all participants our grateful thanks. There are, however, a number of our colleagues whose contributions have been such that without them our understanding of the floodplain and appreciation of its importance would have been significantly curtailed. We therefore gratefully acknowledge the substantial contributions made by Mr W J R Alexander and his colleagues (Directorate of Water Affairs), Mr M M Coke (Natal Parks, Game and Fish Preservation Board), Mr M Hensley (University of Fort Hare), Mr P B N Jackson (J L B Smith Institute of Ichthyology), Dr R R Maud (Department of Geology, University of Natal), Mr J L Ribbeiro-Torres (Department of African Studies, University of Natal) and Dr S J M Blaber, Dr H M Kok, Messrs P M Colvin, H D Furness, C F Musil, K H Rogers, G C B Walley, Mrs T Everson and Mrs F E J Rogers, who all, at various times, formed part of our research team.

Finally our sincere thanks to Miss Marijke Swierstra of CSP for her untiring efforts in organising the workshop and to Mrs N M Cook who coped so valiantly with the flood of typing and duplicating during the course of our discussions and the preparation of this report.

ABSTRACT

This report comprises a synthesis of contributions to a workshop on Man and the Pongolo held at the University of Natal, Pietermaritzburg in February 1978. Studies on the ecology of the Pongolo floodplain, encompassing its fauna, flora and human population, have stressed not only its unique nature, but also its essential role in the day-to-day existence of the people of western Maputaland. The building of the Pongolapoort Dam will permit the realisation of the agricultural potential of the alluvial soils of the area, but will, unless timely steps are taken, also deprive the floodplain of the water on which its continued existence depends. The value of the floodplain has not been taken into account in any planning to date. On the basis of existing knowledge preservation of the floodplain is not merely desirable, but necessary at least in the short and medium term. Recommendations for the rational conservation of the floodplain are made to assist in the future planning of the area.

SAMEVATTING

Hierdie verslag omvat 'n samestelling van bydraes tot 'n werksessie oor Die mens en die Pongolo wat in Februarie 1978 by die Universiteit van Natal, Pietermaritzburg plaasgevind het. Ekologiese studies, wat die fauna, flora en inheemse bevolking van die Pongolovloedplein behels, beklemtoon nie net die unieke aard van hierdie ekosisteem nie, maar ook die rol wat dit in die alledaagse lewens van die mense van westelike Maputaland speel. Die bou van die Pongolapoort Dam sal toelaat dat die landboupotensiaal van die streek verwenselik word, maar, tensy daar vroegtydig stappe gedoen word, sal dit essensiële water van die vloedplein ontneem. Huidige kennis dui daarop dat die instandhouding van die vloedplein nie slegs wenslik is nie, maar wel noodsaaklik is in die kort- en mediumtermyn. Aanbevelings word derhalwe gemaak vir die beredeneerde bewaring van die vloedplein, om behulpsaam te wees in die toekomstige beplanning van die landstreek.

INTRODUCTION

The Pongolapoort (Jozini) Dam impounds the water of the Pongolo River and thus alters the flooding regime downstream. This affects the floodplain ecosystem. Floodplain ecosystems develop in response to flooding patterns and their cycles of plant growth, fish migration and breeding, and utilization by humans are flood dependent. The consequences for the Pongolo floodplain of changes in magnitude, frequency and duration of flooding have been studied for a number of years.

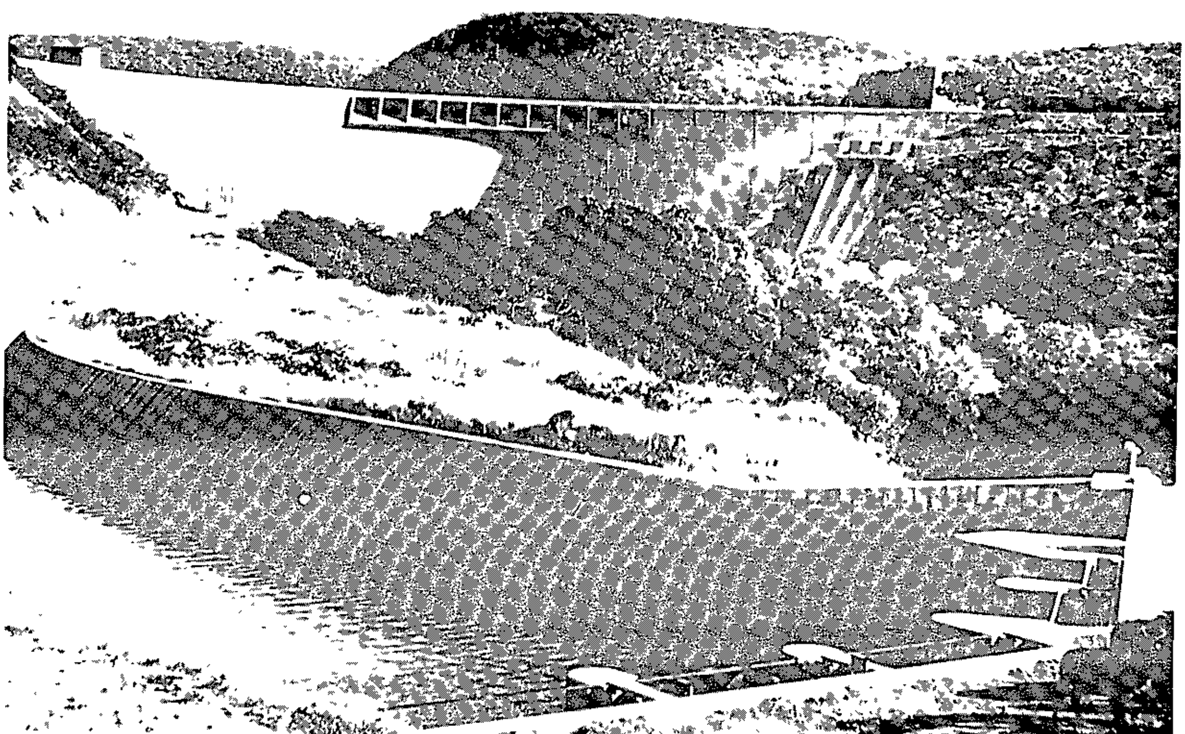
The objective of the Workshop on Man and the Pongolo held at the University of Natal in Pietermaritzburg from 31 January to 2 February 1978 was to review the present state of knowledge of the Pongolo River, its floodplain and immediate environment with a view to:

- predicting the likely impact of the Pongolapoort Dam and associated development on the floodplain,
- establishing management requirements for minimizing such impact,
- investigating means of maximizing benefits which would accrue from both agricultural development and the maintenance of the floodplain.

This report presents information which the Workshop considered should be taken into account in the planned development of Maputaland.

PLATE 1. The old and the new.

(a) Namanini Pan is one of some 90 pans of various sizes located on the Pongolo floodplain. Such pans constitute about 2 600 hectares of the total floodplain area of 10 000 hectares and are an important source of water, fish and other resources exploited by the 40 000 people living on the adjacent Makatini Flats. (Photo: H M Kok)



(b) Pongolapoort dam with irrigation canal in the foreground. The 91,5 metre high wall across the Pongolapoort, which impounds the Pongolo River, gives the dam a storage capacity of 2 500 million cubic metres of irrigation water and can provide an assured annual duty of 1 220 mm to 48 000 hectares. (Photo: K H Rogers)

DESCRIPTION OF THE AREA

The Pongolo River arises at some 2 200 m above mean sea level near Wakkerstroom and descends steeply through the major portion (7 081 km^2) of its catchment to the west of the Lebombo Mountains (see Figure 1). It passes between the Lebombo and Ubombo ranges through a narrow gorge, and the lower reaches of the river lie on the Maputaland Plain east of the mountains. Here it has a slope of 1 in 3 000; the abrupt change in gradient stems the flow rate of the river on the plain, causing a deposition of part of the sediment load and the flooding of extensive areas adjacent to the river course.

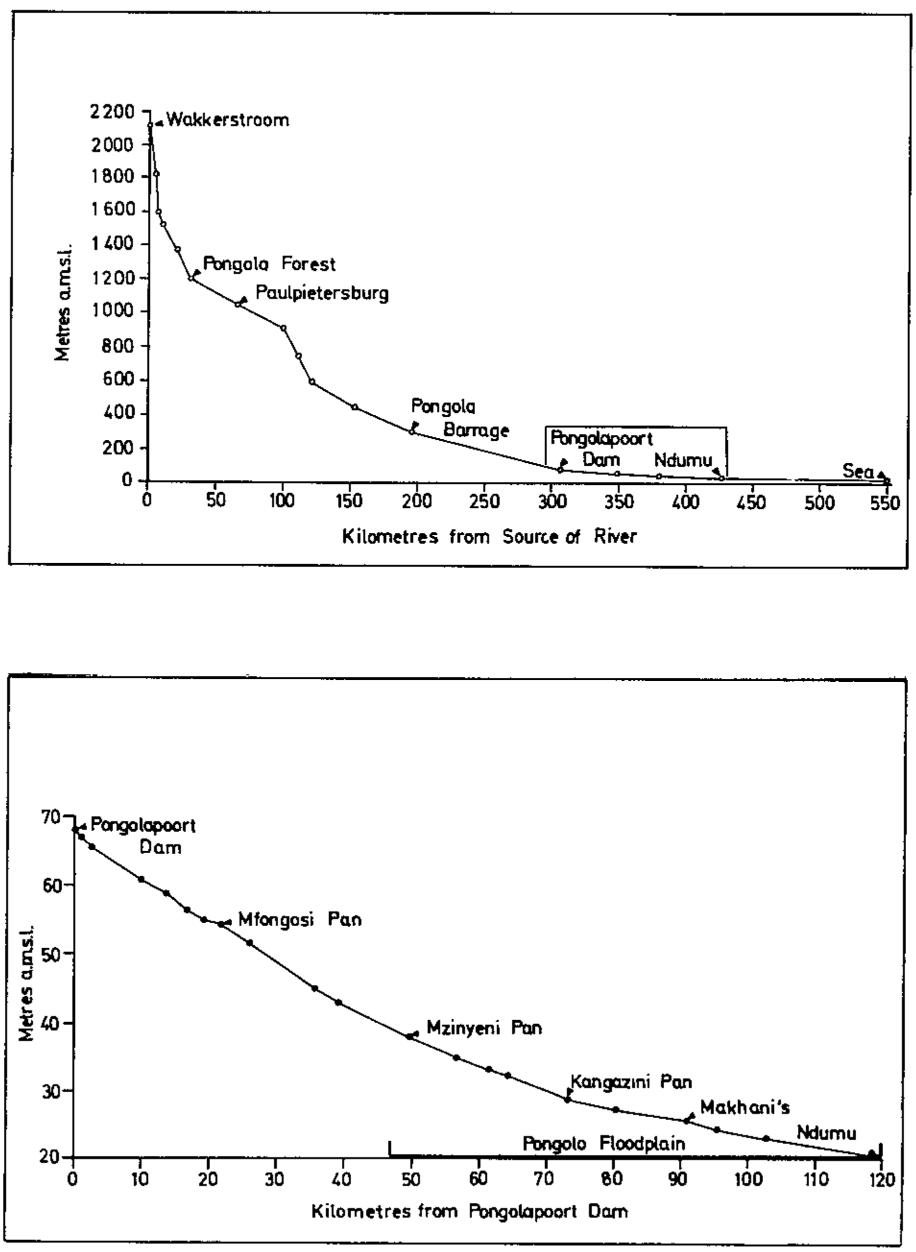


FIGURE 1. Profile of the course of the Pongolo River.

The area discussed in this report lies adjacent to the Pongolo River on the Maputaland Plain, and consists of two distinct ecosystems. The first, the Pongolo floodplain, is directly dependent upon the seasonal floodwaters of the Pongolo River and comprises the river course and those areas adjacent to it which are inundated during floods. The second, the Makatini Flats, is the area adjoining the floodplain on both sides of the river. It includes almost all irrigable soils available to the proposed Pongolapoort irrigation canal system and is therefore the area in which future agricultural development will take place. These two ecosystems are interlinked in that developments on the Makatini Flats will inevitably impinge on the Pongolo floodplain. The resident human population which currently uses the floodplain lives beyond the normal reach of the floodwaters, and their homesteads are therefore located on the Makatini Flats. Figure 2 shows the extent of these two ecosystems and their locations.

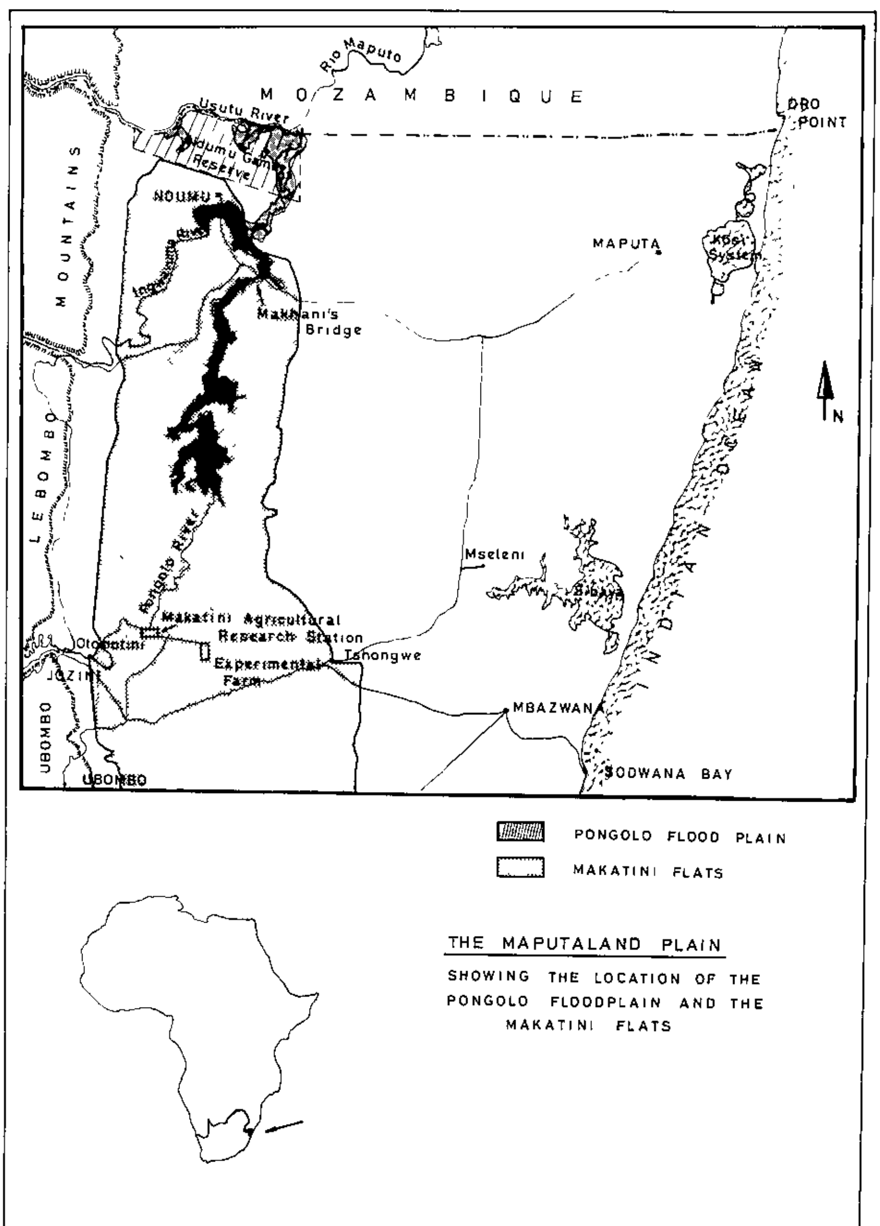


FIGURE 2. The Maputaland Plain showing the location of the Pongolo floodplain and the Makatini Flats.

Geology and geomorphology

The geological history of the Maputaland Plain, to which the characteristics of the Pongolo floodplain and the Makatini Flats are attributable, is one of changes in sea level over the past 100 million years.

The Lebombo Mountains, which form the western boundary of the Maputaland Plain, comprise acid volcanic rocks, rhyolite and dacite, which were tilted eastward when Gondwanaland broke up in upper Jurassic times. At this time the sea extended to the Lebombo Mountains whose seaward inclined eastern slopes extended well below sea level. On these submerged slopes a flat-lying wedge of mainly marine sedimentary rocks was laid down during Cretaceous times. The lower portion of this Cretaceous formation comprises conglomerates while the upper portion consists of siltstones, sandstones, shales and limestones. A period of erosion followed the deposition of the cretaceous sediments and on their eroded but nearly flat surface there was laid down, in late Miocene times, a thin covering of conglomerates and sandy limestones. In places at Ndumu Hill and the hill to the south of it, weathering of the limestones has given rise to a deep red sand which forms part of the Berea red sand formation. About 250 000 years ago, during the Pleistocene, sandy material which forms the Port Durnford beds was deposited over the nearly flat surface of the Miocene rocks. At this time a series of general lowerings of sea level occurred, causing the coastline to shift progressively eastward. At each position where the shoreline was located for any length of time through sea level being static, a system of longshore dunes developed. It is these dunes with their typical north-south orientation, subsequently much modified by wind action in places to produce the sands of recent age, which characterize the landscape of the Maputaland Plain.

The lowering of sea level, with its consequent eastward shift of the shoreline and successive series of longshore dunes, had a profound effect on the rivers of the area. The dunes formed a barrier to an eastward flow of the Pongolo, setting it on its present northerly course across the plain parallel to the Lebombo Mountains. This allowed it to capture the flow of the Usutu and Ingwavuma Rivers as well as that of the minor streams of the eastern Lebombo. The sea level changes also affected flow velocities of the rivers of the area, causing them to deposit alluvial material at successively different levels. This alluvium now occurs in the form of river terraces, the youngest of which is the lowest.

Apart from the general lowering in sea level during the past 250 000 years, there have been periods of extreme lowering coincident with Pleistocene glacial periods. Sea levels at about 100 m below present level occurred some 120 000 and 30 000 years ago (Riss and Würm glacial periods) and during these periods the Pongolo River incised its course deeply into the comparatively soft underlying Cretaceous sediments. With the return of sea level to somewhat above present level after both these extreme lowerings, the incised river valleys became filled with alluvium. The latest, as yet incomplete, infilling of the incised former valleys forms the present day Pongolo floodplain.

A geological cross-section summarizing the geological history of the Pongolo floodplain and its immediate surroundings is given in Figure 3. The major geological features of the Maputaland Plain are shown in Figure 4.

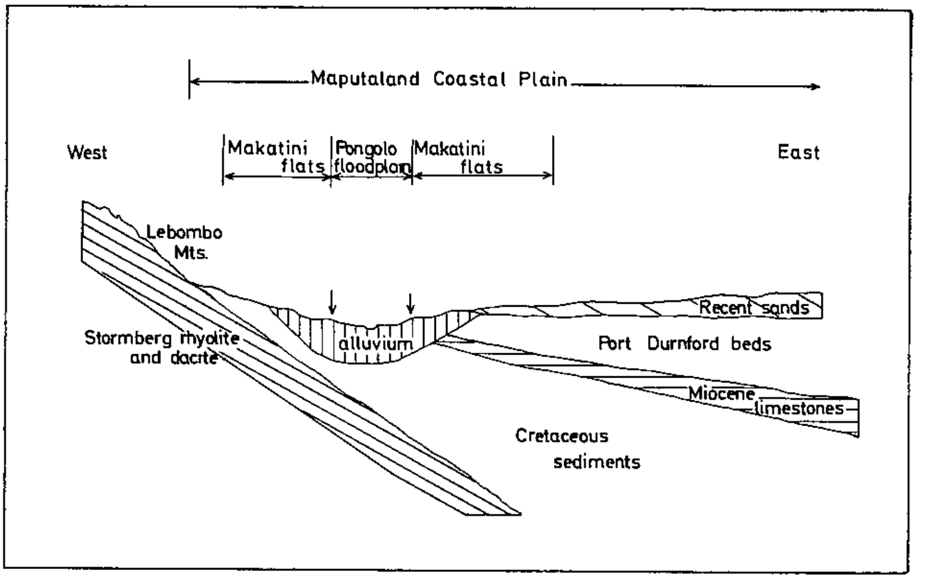


FIGURE 3. Geological section through the Maputaland Plain.

Climate

The Maputaland Plain represents the northern extreme of the climatic region described by Schulze (1965) as warm to hot, humid sub-tropical. While the area receives some rain throughout the year, the winters are distinctly drier than the summers; the plain is frost-free and has high summer temperatures. Detailed weather data from the Makatini Agricultural Research Station show the seasonal pattern of change in the various climatic parameters which determine the agricultural potential of the Makatini Flats and which influence the ecology of the floodplain (see Table 1). Rainfall data are available from the Makatini Agriculture Research Station and from a number of subsidiary stations in the area (Table 2).

The mean annual rainfall for the weather stations shown in Table 2 varies from 485 mm to 642 mm, with an overall average of 574 mm, while the mean for the two stations situated on the floodplain, Mamfene and Mzinyeni, is only 519 mm. The adjacent Lebombo Mountains receive a considerably higher rainfall (850 mm at Ingwavuma) but little of this finds its way to the floodplain; only some of the floodplain pans located to the west of the Pongolo River and to the south of the Ingwavuma catchment (ie Mayazela, Mfongozi, Mzinyeni and Ntunte) have feeder streams originating in the high rainfall belt of the Lebombo range.

Evaporation, as measured at the Makatini Agricultural Research Station, is unexpectedly high, presumably due to a large advective component caused by arid surroundings, high temperatures and a very high run of

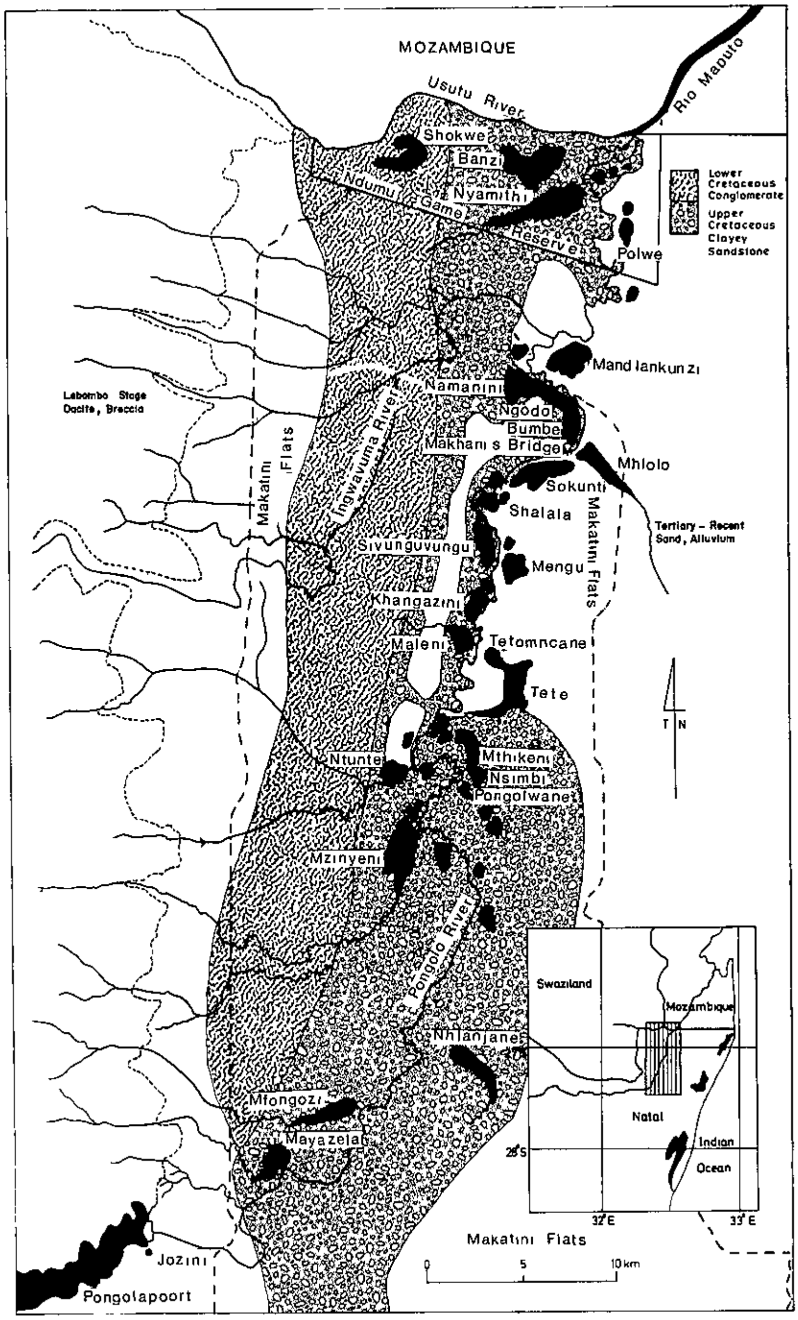


FIGURE 4. Geological map of the Pongolo floodplain and its immediate surroundings.

wind. The whole area is subject to considerable wind, particularly during the period September to December when the average daily run is 230 to 240 km day^{-1}. Wind is important not only because of its influence on evaporation, but also on turbulence in the pans, wind erosion (particularly on the sandy soils) and its potential effect on crops and sprinkler irrigation. It has been shown that the frequency and force of winds are of sufficient magnitude to cause mechanical damage and scorching to field and horticultural crops. The main wind directions

TABLE 1. Climatic data measured at the Makatini Agricultural Research Station.

	Temperature (°C) Mean Max	Mean Min	Mean	Mean Highest Max	Mean Lowest Min	Mean Grass Min	Rainfall (mm)	Class A pan evaporation (mm)	Wind (km day^{-1})	Sunshine (hrs day^{-1})	Relative humidity percent 08h00	14h00
July	25,4	8,3	16,8	31,7	2,3	5,7	12,1	136	149,3	8,0	86	39
August	26,7	11,4	19,0	34,4	4,2	8,5	6,9	187	190,4	8,2	78	39
September	28,2	14,5	21,3	36,4	7,5	12,5	46,9	220	240,8	7,4	70	40
October	29,0	17,0	23,0	39,8	11,3	-	43,7	229	231,6	6,6	72	48
November	29,4	18,4	23,8	37,6	12,4	-	64,9	227	238,7	6,6	71	51
December	31,2	20,1	25,6	38,4	14,5	-	60,8	266	233,3	6,9	72	51
January	32,5	21,3	26,8	40,3	16,3	-	75,9	276	190,2	7,4	74	51
February	31,2	20,5	25,8	36,4	15,1	-	105,6	225	211,4	7,2	76	54
March	30,5	19,6	25,0	36,3	14,8	-	73,4	208	180,5	7,6	81	54
April	28,4	16,6	22,4	33,3	11,7	14,7	54,2	159	150,1	7,3	84	53
May	26,8	12,9	19,8	33,0	6,2	10,6	23,6	137	168,7	7,8	86	48
June	25,0	8,4	16,6	30,9	3,5	5,7	4,6	118	127,0	8,1	86	40
Year	28,7	15,8	22,1	-	-	-	572,6	2388	192,7	7,4	78	47
Period from	1966	1966	1966	1966	1966	1966	1966	1966/ 1967	1969	1966	1966	1966
to	1975	1975	1975	1975	1975	1975	1975	1974/ 1975	1973	1975	1975	1975

TABLE 2. Rainfall stations measured on or near the Pongolo floodplain.

Station	Latitude	Longitude	Altitude (m)	Mean annual rainfall (mm)	No of years of record
Pongolapoort Dam	27°26'S	32°04'E	293	519	14
Makatini Agricultural Research Station	27°24'S	32°11'E	73	571	9
Mamfene	27°23'S	32°12'E	69	553	17
Mzinyeni Pan	27°12'S	32°13'E	55	485	12
Ndumu	26°56'S	32°15'E	75	617	51
Ndumu Game Reserve	26°54'S	32°18'E	122	632	16
Otobotini	27°25'S	32°06'E	91	642	52
Mean				574	

recorded over the three year period 1965-1968 were north to north-east (31,5 per cent) and south to south-west (31,9 per cent) with the northerly winds predominating during August to December and the southerly winds prevailing during January to July (except April).

A study of climatic tolerability for humans has shown the Makatini Flats to have a higher "Discomfort Index" than other stations investigated in the Republic of South Africa. Serious to acute discomfort is experienced between December and March and only between mid-June and late July can the climate be described as comfortable (Figure 5).

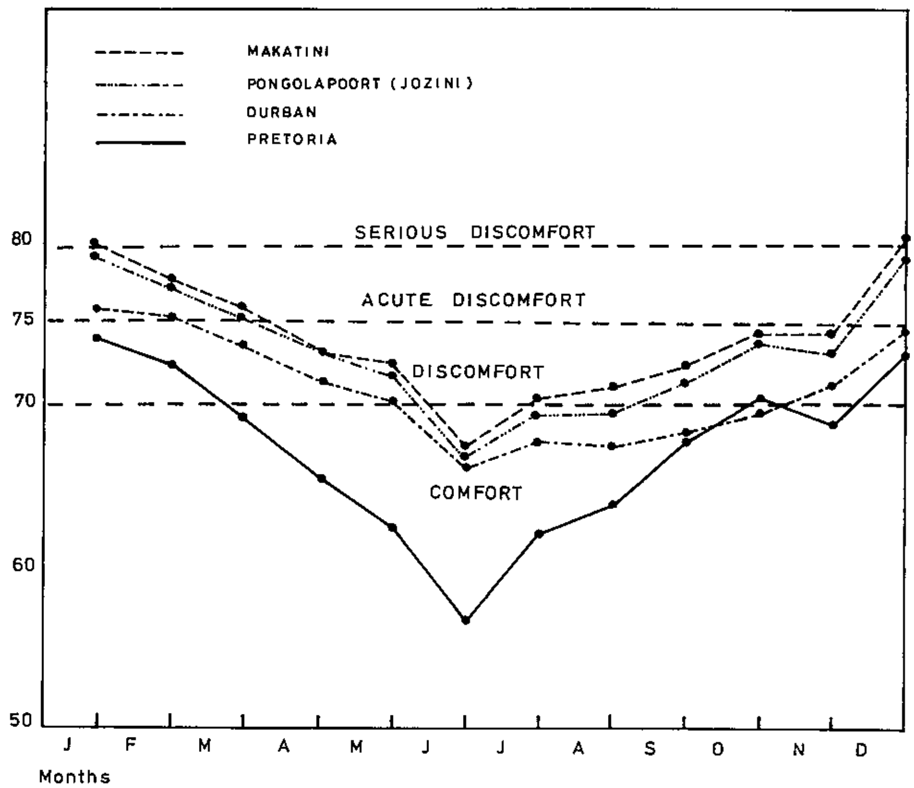


FIGURE 5. Discomfort indices at Pongolapoort (Jozini), the Makatini Agricultural Research Station, Durban and Pretoria measured at 14h00 SAST (Department of Planning 1969).

The Pongolo floodplain

The most extensive coastal plain in the high rainfall areas of South Africa is the Maputaland Plain, along the western and southern margins of which the Pongolo and Mkuzi floodplains respectively are located. While both floodplains are of considerable interest and potential value, that of the Pongolo, by virtue of its extent, current utilization by the resident population, and considerably higher biological diversity as an extension of a more northern tropical biota, can safely be considered the more important.

The Pongolo floodplain (Figure 6) extends from just downstream of the Pongolapoort Dam, where it is very narrow, to the confluence of the Ponglo and Usutu Rivers. It comprises a low-lying area adjacent to the river with numerous depressions (the floodplain pans) which retain floodwater for varying lengths of time. When an aggrading river overflows its banks during a flood, most of the sediment is deposited on or adjacent to the river bank forming a natural levee. Consequently, the alluvial plain generally slopes away from the river banks creating slackwater areas which retain water when the flood recedes. The meander pattern of the river changes with time. Occasionally these meanders are cut off when the river takes a new course forming oxbow lakes or pans which are separated from the river by the new levees.

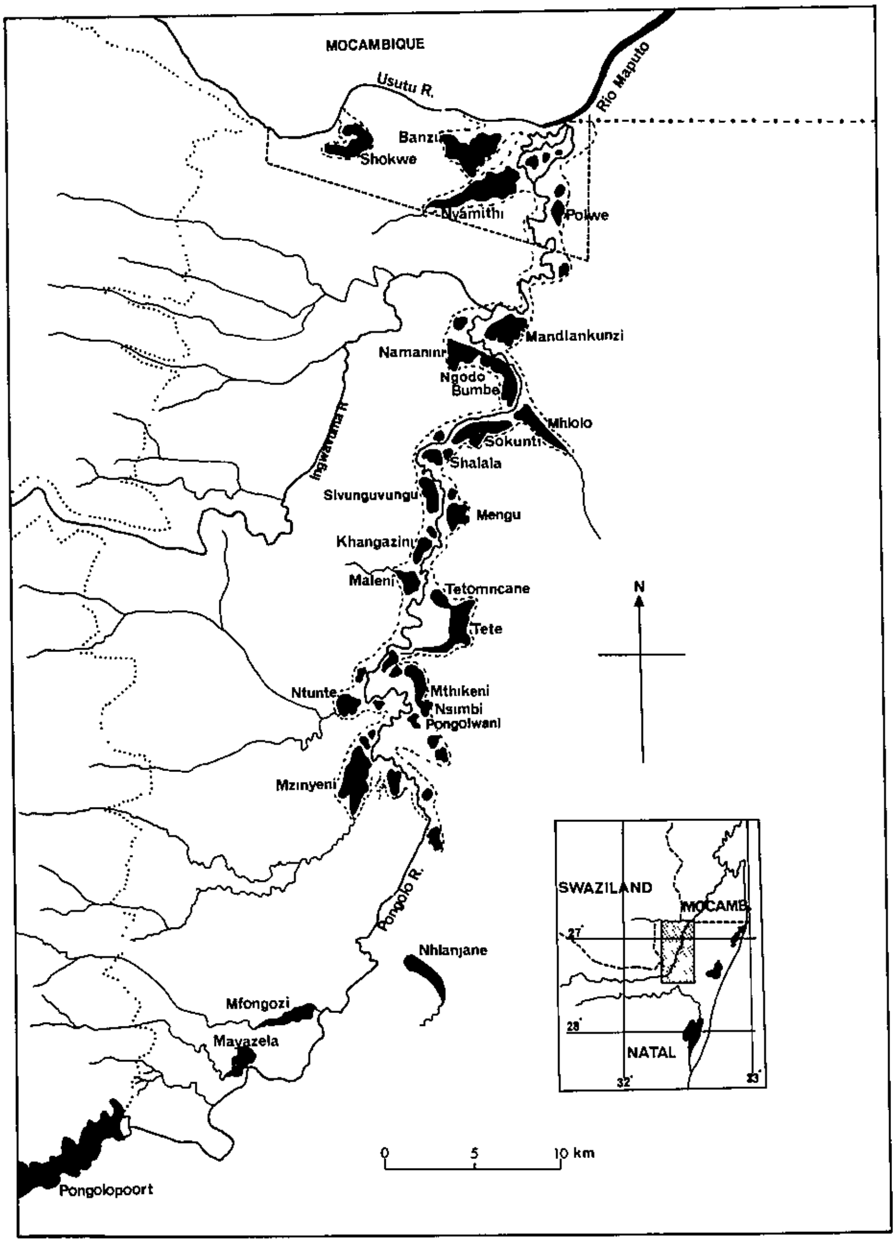


FIGURE 6. The Pongolo floodplain showing the major pans and the area inundated by floods.

There are some 65 named and at least 25 unnamed pans of varying size, permanence and importance within the 13 000 hectare area which comprises the Pongolo floodplain. At maximum retention level, ie immediately after floodwaters of a flood sufficient to inundate the full extent of the floodplain have receded, they have an estimated collective area of 2 600 ha. Strictly speaking, some of these are part of the Usutu system but they are nonetheless closely linked to and influenced by the Pongolo River. The southern 25 km of the Pongolo floodplain, while including a few pans of significant proportions (Mayazela, Mfongozi, Nhlanjane) is narrow and almost restricted to the main river course and its associated lower terraces. Many of these southern pans owe their existence almost entirely to feeder streams and their own catchments, and only receive water from the Pongolo River during exceptionally high floods. At a latitude of approximately 27°15'S the floodplain widens, and its width varies between 0,8 and 4,8 km over the 50 km to the Mozambique border. While some of the pans in this northern sector of the floodplain have local catchments, they are all under the direct influence of the Pongolo River and dependent on its floodwaters for the bulk of their water supply.

Vegetation

Tinley (1976) divides that part of the vegetation in the immediate vicinity of the Pongolo floodplain into five principal types:

- Sand forest occurs in isolated patches which have a north-south orientation. This community is a dry form of the coastal dune forest and its present distribution probably denotes the original location of successive lines of coastal dunes marking the retreat of the sea. *Newtonia hildebrandtii*, *Hymenocardia ulmoides* and *Erythrophleum lasianthum* are the dominant trees within this community.

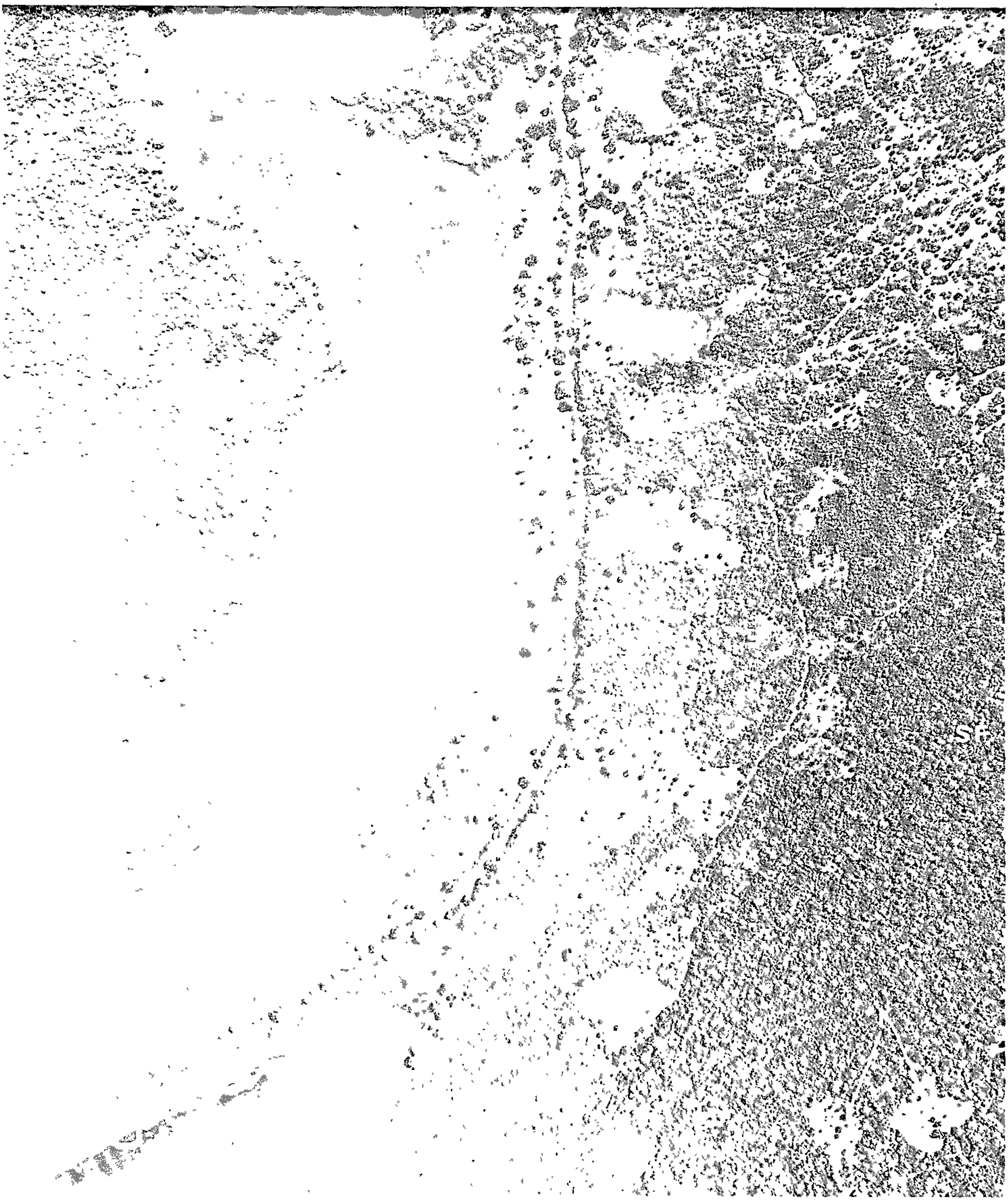
- Woodland is found on sandy soils on both sides of the river. In the east, it is dominated by *Terminalia sericea* in association with *Strychnos spinosa* and *Acacia burkei*. On the western bank a mixed woodland occurs in which *Combretum zeyheri* is dominant.

- *Acacia* tree and bush vegetation is characteristic of clay and loamy soils abutting on the margins of the floodplain. This community comprises several *Acacia* species, as well as *Spirostachys africana* (umThombothi).

- Riparian forest occurs along the banks of the river. Although much disturbed by clearing in many localities, some good stands remain. It is dominated by *Ficus sycomorus* (wild fig), which may reach a height of 18 m. and *Rauvolfia caffra*. Other large trees in this community include *Syzygium guineense* and *Trichilia emetica*.

- The aquatic and marginal pan vegetation includes that component which is directly influenced by flooding and will be described in detail in a later section.

The forest and the floodplain vegetation are of particular importance to the population in providing the only local source of material for hut and kraal construction as well as a variety of foodstuffs.



Human links with the floodplain

Of the total black population of the Ingwavuma and Ubombo districts, 96 per cent claim to be Zulus. Most if not all of these are, if judged by their social customs and political structure, descended from the original inhabitants of the coastal plain, the Tembe-Thonga, a Tsonga-Shangaan speaking people, whose distribution once extended from St Lucia in the south to the Save River in the north. This area has, since the beginning of the nineteenth century, been subjected to numerous incursions by Nguni speaking peoples and it is, therefore, not surprising that the original inhabitants have been strongly influenced by their contact with these peoples, even to the extent of having adopted Zulu nationality.

Contrary to expectations, particularly in view of the close contact between the original inhabitants of the coastal plain and the Zulus over the past 200 years, assimilation into Zulu culture has not been complete, since close contact has been maintained throughout with their kinsmen in southern Mozambique. This contact has helped to maintain local traditions, even though Zulu was the official language and medium of instruction in local mission schools. Although the frontier has now been closed, some contact is still being maintained through one-day visits across the border. A further contributing factor to the partial retention of cultural traditions is attributable to the nature of the coastal plain environment. The prevalence of nagana and malaria made the area unattractive to the Zulu, whose presence in the surrounding areas confined the Tembe-Thonga to the coastal plain where they have adapted to the physical environment in terms of their mode of subsistence.

Approximately 36 per cent of the total population of Maputaland, ie 40 000 people, are resident in the area immediately around the floodplain and have close links with it (Figure 7). They use the productive areas subject to intermittent inundation both for cultivation and for grazing during the dry winter months. The pans are an important source of fish and are linked to aspects of social life.

PLATE 2. Features of the Pongolo floodplain. An aerial view of a section of the floodplain, showing some of its distinctive characteristics. Bumbe Pan (P) is a typical ox-bow lake lying adjacent to the Pongolo River (R). A marginal meadow of the grass Cynodon dactylon, typical of many of the floodplain pans can be seen at the upper end of the pan. Note the extensive cultivation between river and pan (C) which has resulted in the removal of almost all the riparian forest (F), and the spread of cultivation into the unproductive scrubland (S). Homesteads or kraals (K) are located on high ground beyond the reach of the annual summer floods. The sand forest (SF) is a modified form of the dune forest typical of the Maputaland coast. It comprises species adapted to rapidly draining sandy soils of low nutrient status and therefore has a low productivity and carrying capacity. (Photo: Department of Land Surveying, University of Natal)

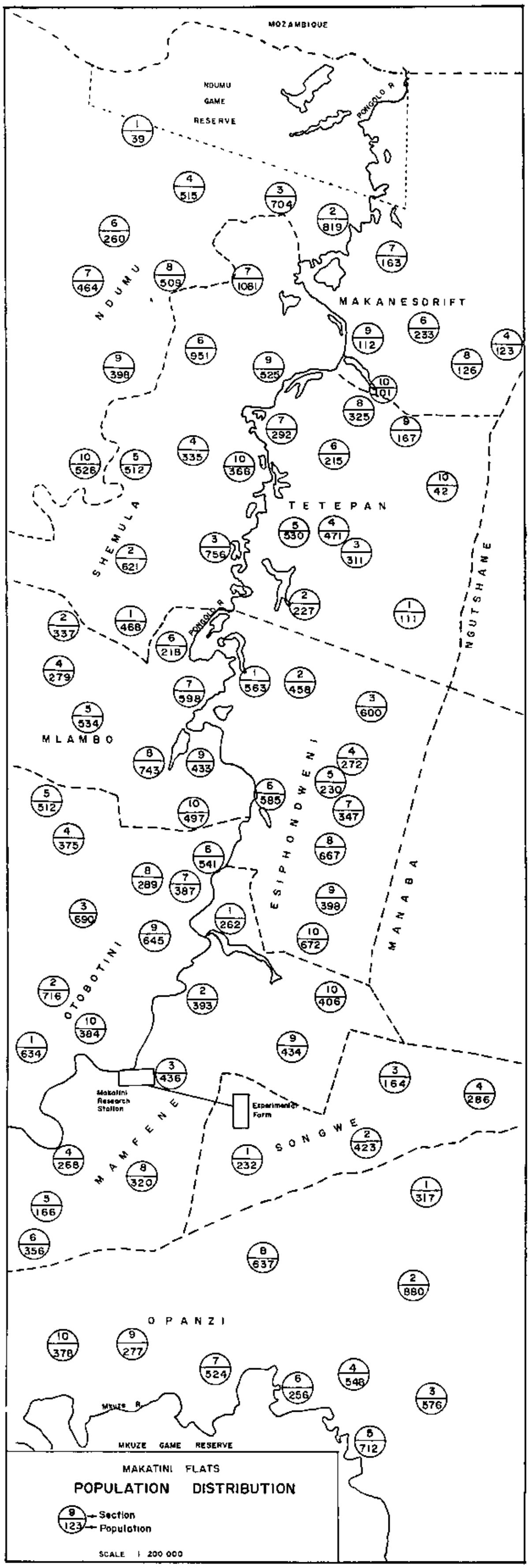


FIGURE 7. Distribution of population around the Pongolo floodplain.

The Pongolapoort Dam and proposed Makatini Flats irrigation scheme

The Pongolapoort Dam was constructed at the eastern end of the narrow gorge separating the Lebombo and Ubombo ranges (Figure 6). It has a wall height of 69,8 m, a capacity of 2 500 x 10^6 m^3 at full supply and a mean assured yield of 862 x 10^6 m^3 y^{-1}. This is sufficient to provide an assured annual duty of 1 220 mm to approximately 48 000 ha. The area of good to satisfactory irrigable soils which it can supply is of about the same order. This irrigable area, lies primarily on the Makatini Flats flanking the Pongolo River.

Implementation of the scheme will have a profound effect on the development potential of Maputaland in general and the Makatini Flats in particular. Development of the area is bound to affect the floodplain and its resident population.

HYDROLOGY OF THE PONGOLO RIVER AND ITS FLOODPLAIN

Three parameters of the natural hydrological regime are of importance in considering the provision of water to the floodplain: the volume of water delivered by the river, the rate of flow and the duration of flow rates. The volume of flow will also determine the rate at which the store in the dam is replenished against the draw-down for irrigation. Data on all three parameters are available from the gauging station at Golela for the period 1929 to 1976, and these have been compiled here in order to assess the requirements of the floodplain in terms of the established flooding regime and to pinpoint the gaps in knowledge.

River flow volumes

The mean annual rainfall in the portion of the catchment west of the Lebombo Mountains is 864 mm, of which 692 mm (80 percent) falls during the period October to March. This precipitation is calculated to yield a mean annual run-off of 1068 million cubic metres (Redman 1974). The measured mean annual river flow was 1082 million cubic metres measured at Golela for the period 1929 to 1976 with a considerable variation ranging from the lowest recorded volume of 309 x 10^6 m^3 for the hydrological year 1930/31 to 3295 x 10^6 m^3 for 1938/39. The monthly records for the full 47 year period are set out in Appendix 1 and are summarized in Figure 8.

Figure 8(a) shows the data subjected to normal statistical treatment, giving mean values and 99 per cent confidence limits of the mean for each month based on available data. Recorded maxima and minima are also shown, together with the flow which can statistically be expected to be exceeded in that particular month only once in every 100 years. These data are, however, heavily weighted by the upper extremes, since maximum flow can equal five times the mean, whereas zero flow has never been recorded. The data therefore tend to have a long range of values higher than the mean (ie skewed to the right) and, in addition, have a fairly wide range of commonly occurring values on either side of the mean (ie platykurtic). Coefficients of variation (C_v) are also high and erratic.

The inadequacy of normal statistical methods in considering data of this nature can be seen in Figure 8(a) where the one in 100 year expectation for each month has already been exceeded in ten out of twelve instances during the 47 years. Statistical methods do, however, exist whereby the effect of long-term extremes which occur relatively rarely are given a lower weighting than more commonly occurring values. A conversion of the data by one of these methods is shown in Figure 8(b). This gives a more realistic picture of the the short-term river flow expectations, with an estimated median annual flow of 1025 x 10^6 m^3, some five per cent lower than the recorded arithmetic mean, and an expectation that the flow in 50 per cent of years (one year in two) will be between 690 x 10^6 a^{-1} and 1360 x 10^6 y^{-1}. The flow can be expected to be less than 690 x 10^6 m^3 y^{-1} during one in every four years, which agrees well with the recorded data in Appendix 1.

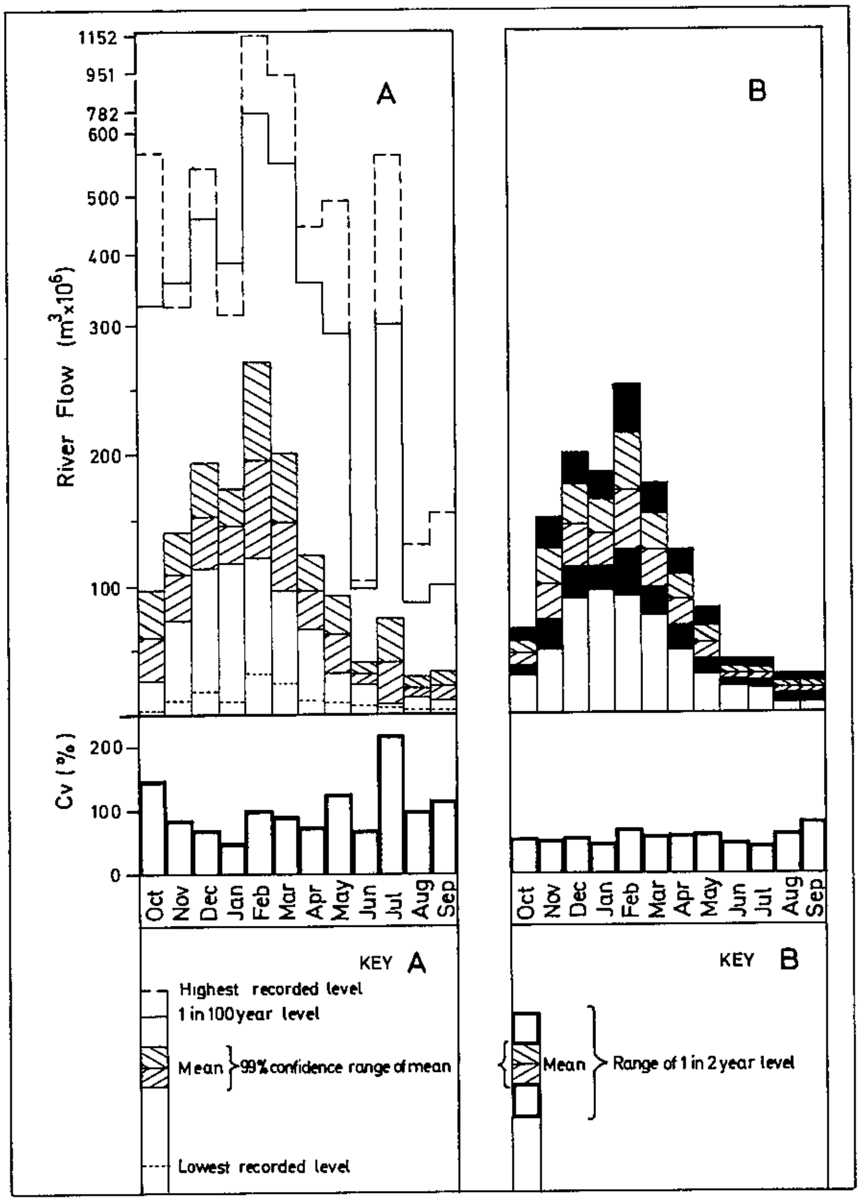


FIGURE 8. Analysis of seasonal fluctuations in flow of the Pongolo River. (See text for explanation)

Figure 8(b) also shows the seasonality of the river flow. As expected from the rainfall figures, the major portion of the flow, some 70 per cent of the total, can be expected during the period November to March, with the greatest volume (17,5 percent) flowing during February. Although June to September is, typically, the period of lowest flow, accounting for approximately 10,5 per cent of the annual flow, floods of considerable magnitude have been recorded in July on three occasions during the 47 year period. The fourth highest monthly flow ever recorded, 563 x 10^6 m^3, occurred in July 1963.

Flow rates and flood durations

Inundation of the floodplain is dependent upon rate and duration of flow as well as the volume of water carried by the river. Average daily flow rate maxima and minima recorded over the period 1929 to 1976 are given in Appendices 2 and 3. These data are summarized in Figure 9, which shows the mean maxima and minima together with a range within which the flow rate would fall if it were constant, ie the minimum rate which the volumes of water shown in Figure 8 would demand. The fact that the mean maxima and minima fall outside this range and that the recorded extremes deviate from it to an even greater extent illustrates clearly that the flood season is characterized by several flood peaks of relatively short

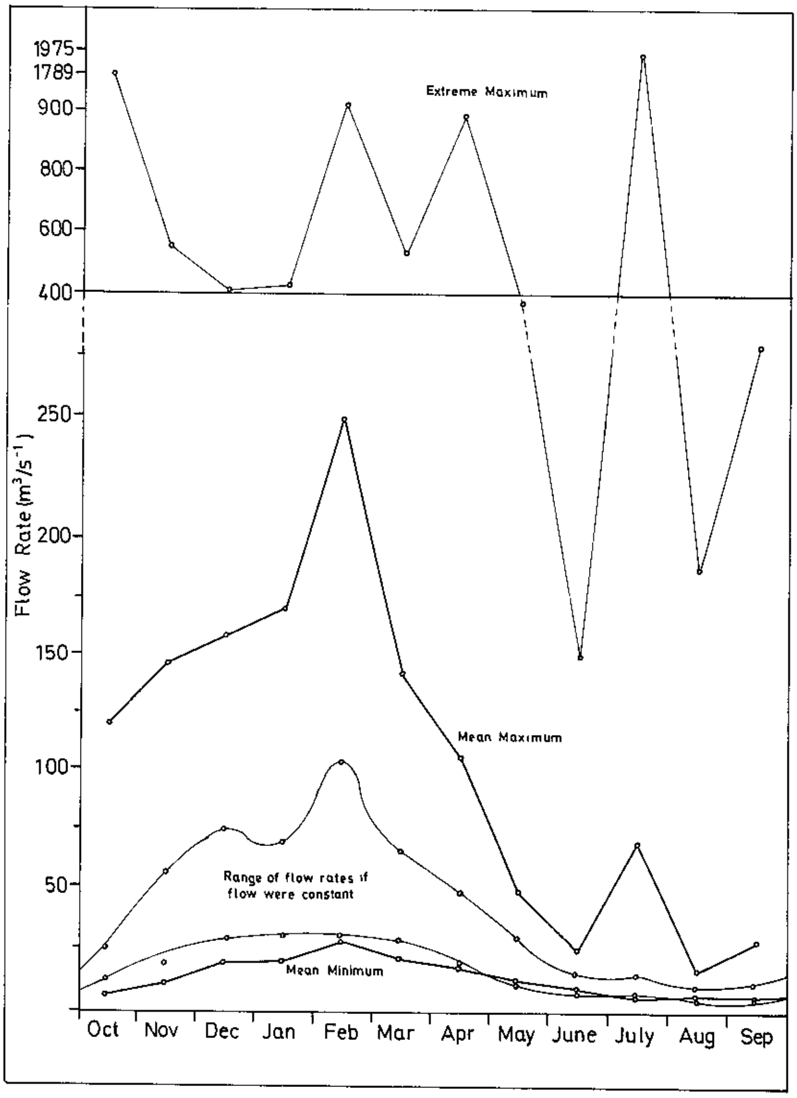


FIGURE 9. Average daily flow rate maxima and minima in the Pongolo River. (See text for explanation)

duration, rather than a constant flow. Figure 9 also shows the extremes which have been recorded during July; on 4 July 1963, the average flow rate for the day was 1 975 cubic metres per second (cumecs) and this flood peaked at 5 009 cumecs. However, despite these occasional "unseasonal" floods of high magnitude, the highest average daily rate coincides with the highest volume flow in February.

Sediment loads

The sediment content of the Pongolo River is low, amounting to only 0,15 per cent of flow, or 2,1 x 10^6 m^3 y^{-1}. No information is available on the particle size composition of this suspended material. The reduced velocity of the river once it has overflowed its banks to inundate the floodplain will reduce the carrying capacity of the water, and an unknown fraction of particulate matter carried will be deposited.

Hydrology of the floodplain

The duration of inundation of the floodplain is dependent upon the number of days a pan is in contact with the river. Records have been kept (summarized in Table 3) of the estimated flow released from the dam at which individual pans are in contact with the river. No data are, unfortunately, available on how long a given flow rate needs to be

TABLE 3. Inundation of Pongolo floodplain pans in relation to river flow resulting from releases from the Pongolopoort Dam.

Pan	Area (ha)	7	28,3	56,6	84,9	141,5	198,2	300+
Mayezela	25,8							X
Mfongozi	20,5							X
Nhlanjane	37,9							X
Nzila	14,2				X	X	X	X
Mzinyeni	74,2	X	X	X	X	X	X	X
Ebugubugwini	8,8						X	X
Pongolwane	9,9						X	X
Matutwana	27,1					X	X	X
Stutshanene	9,6					X	X	X
Nsimbi	15,7					X	X	X
Mthikeni	45,4				X	X	X	X
Pokolo	14,2				X	X	X	X
Somtshatsha	11,0					X	X	X
Mlawanyana	17,7					X	X	X

TABLE 3 (continued).

Pan	Area (ha)	7	28,3	56,6	84,9	141,5	198,2	300+
Ntunte	23,5					X	X	X
Subane	59,7				X	X	X	X
Tete	115,9			X	X	X	X	X
Tetemcani	23,9			X	X	X	X	X
Ndugozabo	14,5				X	X	X	X
Ulusundu	50,4				X	X	X	X
Maleni	46,5				X	X	X	X
Kangazini	74,0				X	X	X	X
Mengu	32,2				X	X	X	X
Siuunguvungu	40,4				X	X	X	X
Shalala	49,2						X	X
Sokunti	101,0			X	X	X	X	X
Mhlolo	56,0					X	X	X
Singulungwane	14,1					X	X	X
Bumbe	58,4		X	X	X	X	X	X
Ngodo	22,1		X	X	X	X	X	X
Namanini	63,4		X	X	X	X	X	X
Mandlankunzi	255				X	X	X	X
Ulujwe	37,5				X	X	X	X
Nhlanjane	16,8					X	X	X
Polwe	22,9				X	X	X	X
Nyamithi	183,4				X	X	X	X
Bakabaka	23,2				X	X	X	X

sustained before such contact is made. Figure 10 represents the flow intensity exceedance records in Appendix 4; the uncorrected data are shown in Figure 10(a) while Figure 10(b) shows the same data corrected for skewness and includes the probable one in two year expected range. From Table 4 and Figure 10(b) the number of days in the year during which the major pans of the system are likely to be in contact with the river can be computed. This is shown in Figure 11. Figure 12 shows the total pan area flooded at a given flow intensity as well as the number of days during which a given pan area will be inundated in an average year. The figures do not, unfortunately, include the marginal area flooded at each flow intensity; from the point of view of biological production this constitutes an important parame

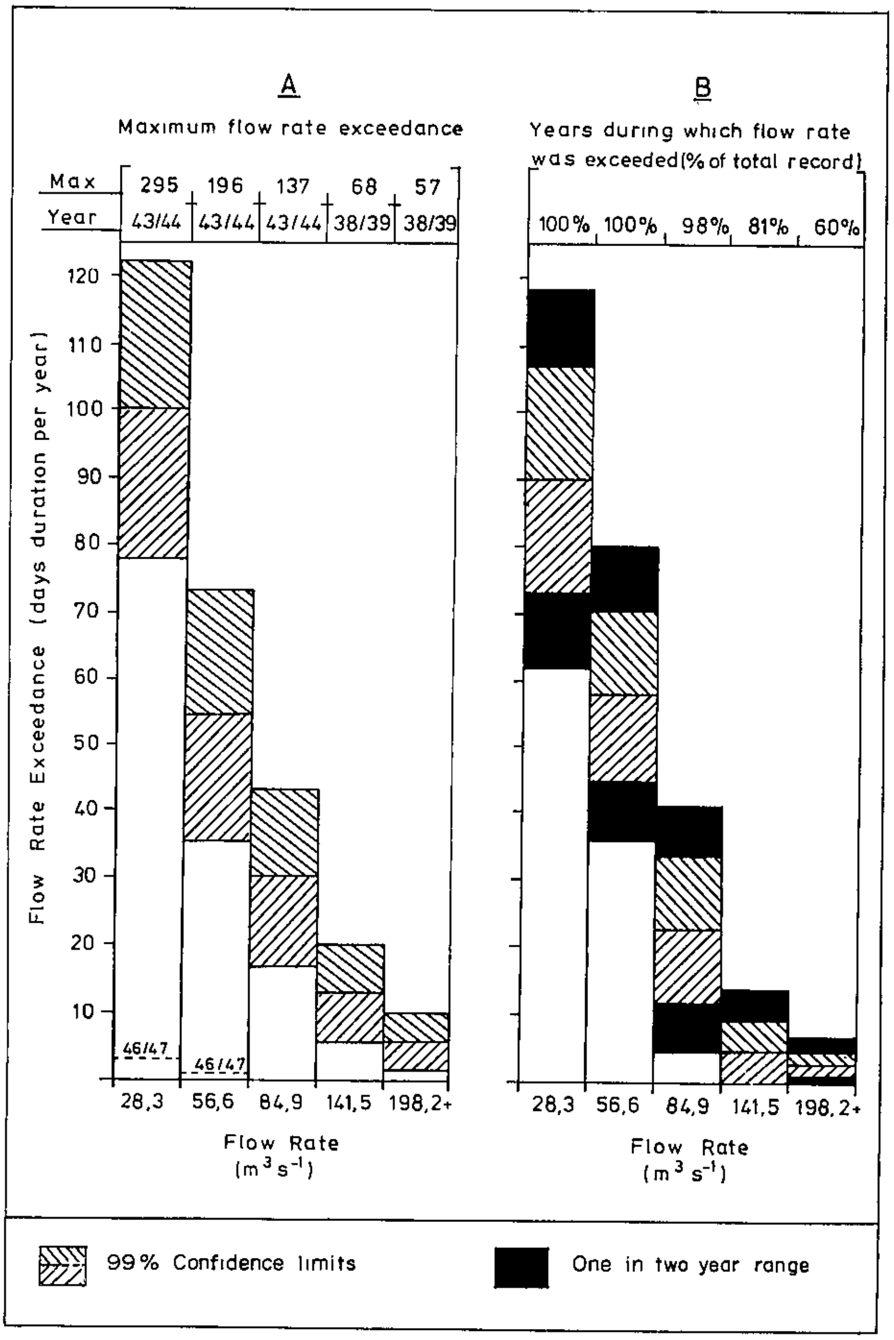
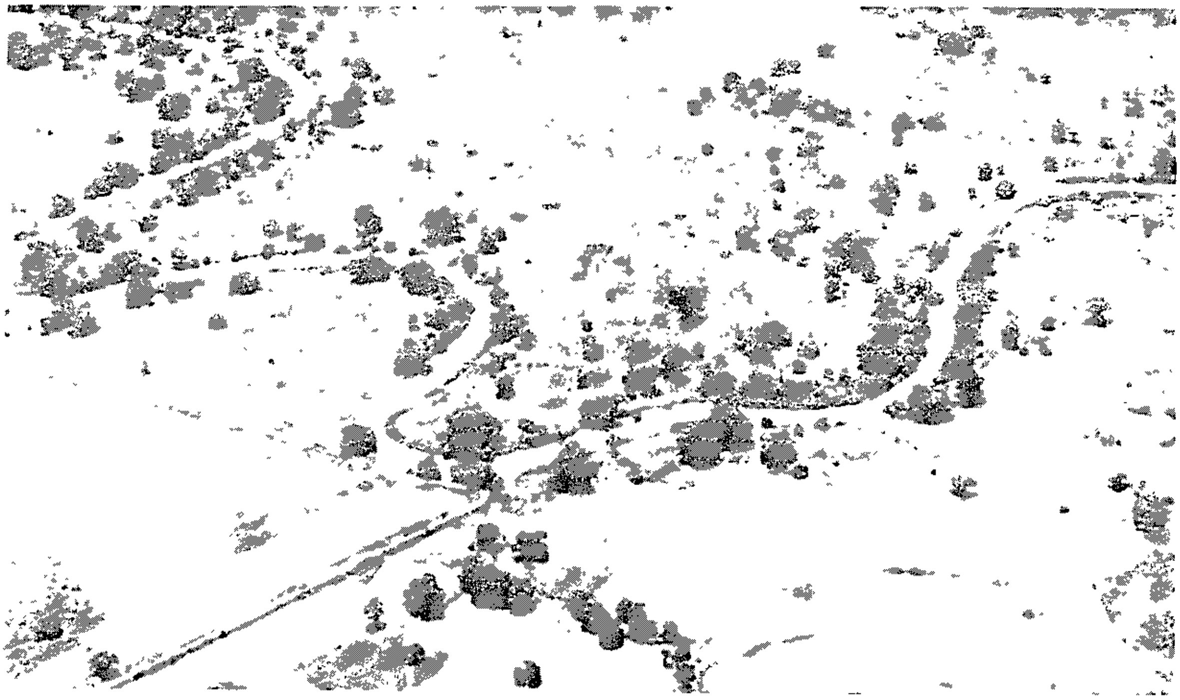


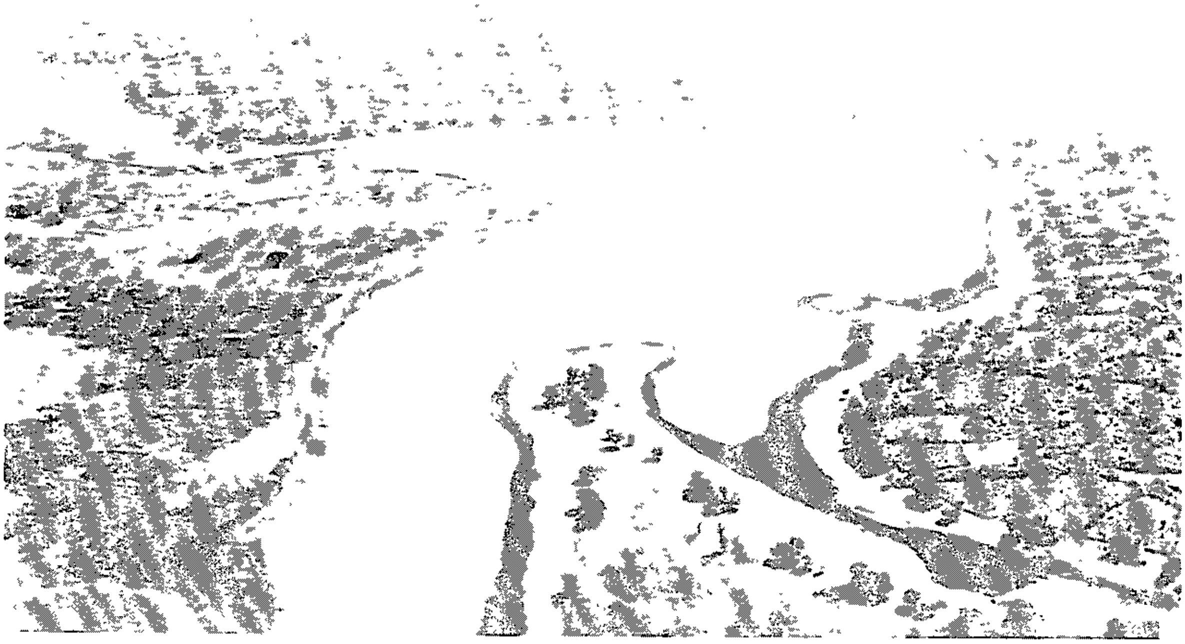
FIGURE 10. Analysis of numbers of days per year during which different flow rates have been exceeded. (See text for explanation)

Breen et al (1978) have conducted a preliminary bathymetric survey of some of the more important floodplain pans. Figure 13 shows the relationship between water depth and area relative to the maximum retention level of each pan. From this figure it can be seen that those pans which have extensive floodable margins due to the flatness of the surrounding marginal land are all flooded at a river flow rate of 85 cumecs or less. These pans can, therefore, be expected to be inundated for five days or longer during three years in every four, and in excess

PLATE 3. Pongolo floodplain during the dry and rainy seasons.



(a) Tete and Tetomncani pans seen from the air during winter. Note the exposed marginal meadows and floodplain cultivation. (Photo: C M Breen)



(b) The floodplain inundated by an 85 cumec flood. Note the extensive spread of the silt-laden floodwaters beyond the confines of the river channel. Much of the nutrient rich silt is deposited on the floodplain as the flow rate of the water is reduced by the gradual slope of the coastal plain. (Photo: M Coke)

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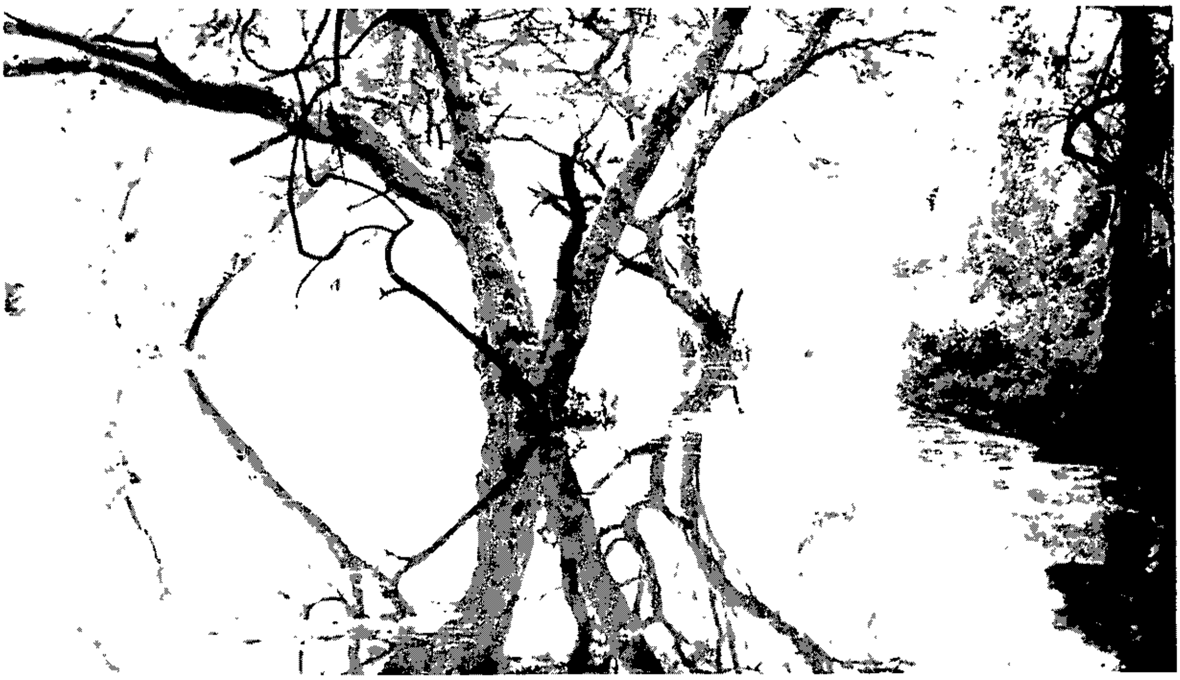
page 22 - plate 3, legend a and b transpose.

PLATE 4. North-east corner of Tete pan. (Both photographs were taken from the same point; comparison between them gives an appreciation of the extent of the inundation by a flood of this magnitude)



(a) Water level at the peak of an 85 cumec flood. (Photo: M Coke)

(b) Upon retreat of the floodwaters, leaving the pan at maximum retention level. (Photo: M Coke)

TABLE 4. Volumes of water contained in various basins during and immediately after floods.

	Volume $M^3 \times 10^6$	
Pan	MRL (Maximum retention level)	HFL (High flood level)
Kangazini	0,091	1,142
Namanini	0,201	1,206
Mthikeni*	0,103	2,500
Tetomncane$^+$	0,165	3,625
Maleni	0,0676	0,319
Tete$^+$	1,105	3,625
Nsimbi*	0,340	2,500
Sivunguvungu	0,445	1,064
Shalala	0,598	1,253
Mandlankunzi	4,258	8,545
Mhlolo	0,483	1,626
Mengu	0,356	0,771
Sokunti	3,008	4,783

$^+$*These basins coalesce during floods.

of 40 days once in every four years. A number of the more important pans, notably Mzinyeni, Tete, Tetomcani and Namanini are normally flooded for much longer periods, allowing adequate time for the utilization of flooded terrestrial vegetation by the aquatic fauna. The pans requiring a river flow rate in excess of 85 cumecs before receiving water all lie in more steep-sided depressions and are as a result flooded less frequently and for shorter durations.

In order to assess the cost, in terms of potential irrigation water, of maintaining the floodplain ecosystem, the volume of water required to raise the water level of the pans to High Flood Level, ie the level which the floodwaters normally reach, needs to be established. To date the only relevant data are those of Breen et al (1978) which are summarized in Table 4. These are incomplete, inasmuch as they cover only a few selected, though important pans. A more detailed knowledge of the volumes required to be retained on the floodplain will undoubtedly be prerequisite to the design of engineering measures aimed at rationalizing the water supply to the ecosystem.

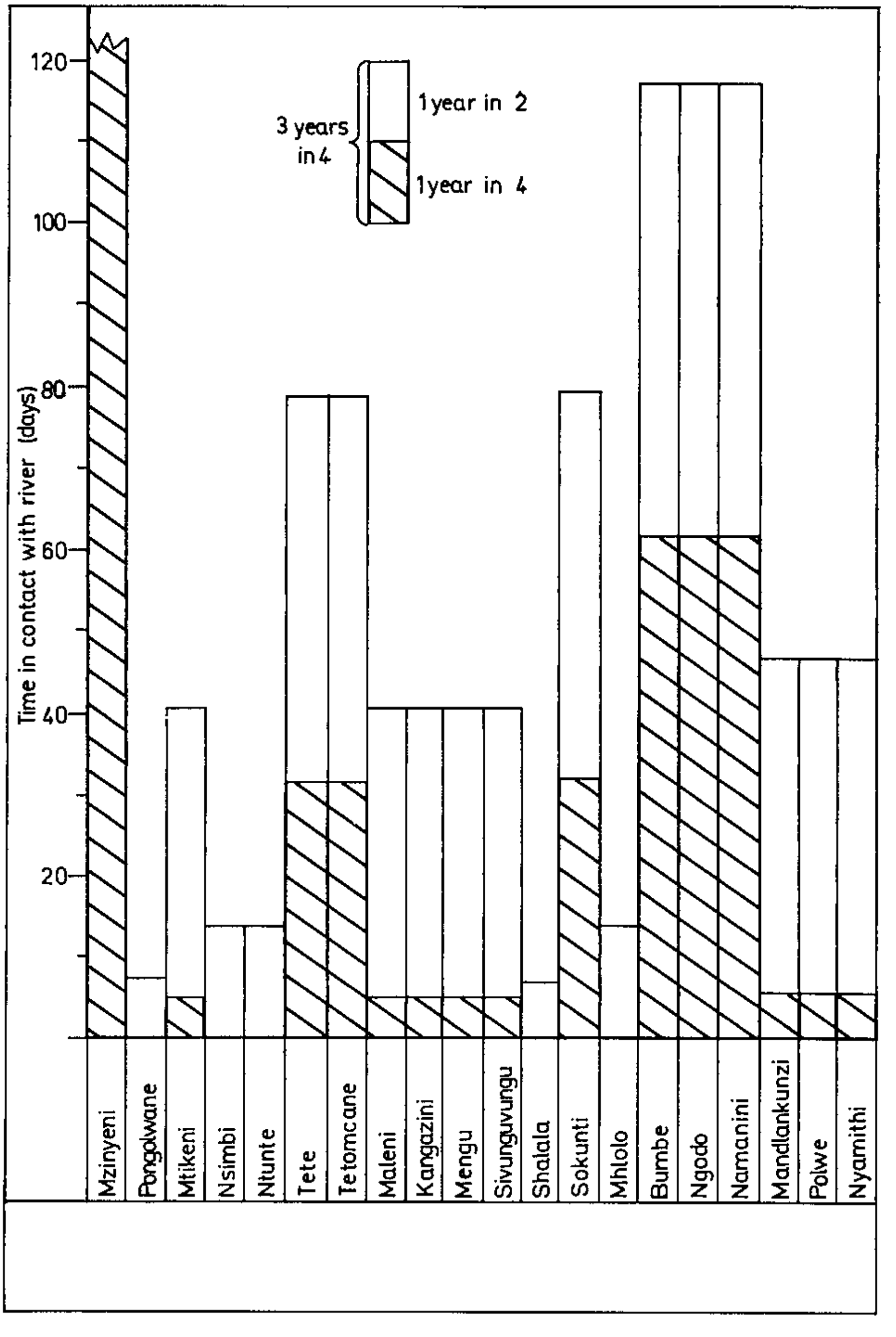


FIGURE 11. Numbers of days per year during which different Pongolo floodplain pans were in contact with the river.

Effects of the dam on hydrology and hydraulics

The major effect of the dam on the floodplain will be the interception of all low flows. Very high flows will pass through without much attenuation. Controlled releases will be necessary for satisfying existing rights as the Pongolo as an international river, and return flows from the settlement and development areas will have to be taken into account.

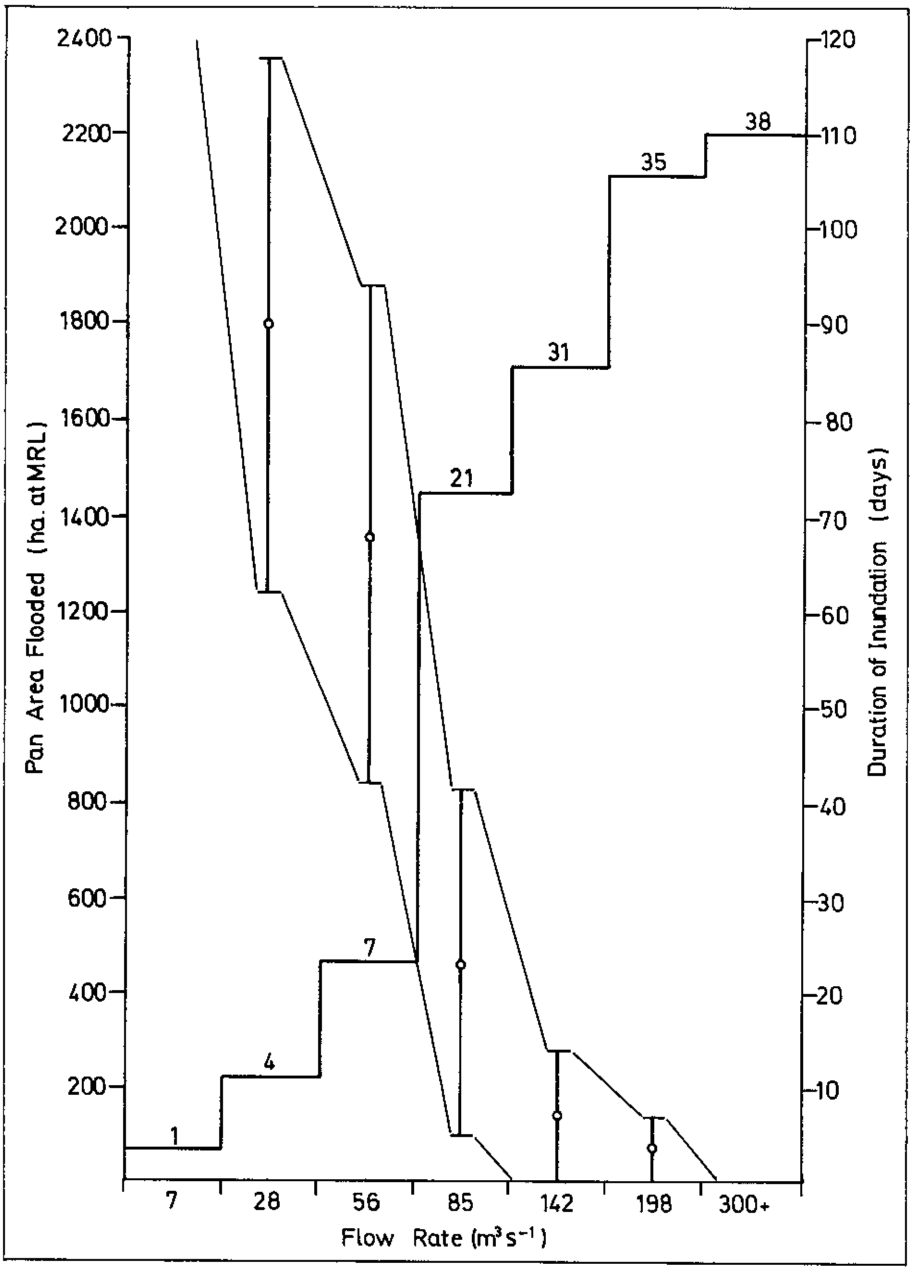


FIGURE 12. Expected area of Pongolo pans flooded and expected duration of flooding as a function of river flow rate. The figures on the area histogram denote the number of pans receiving water.

Overspill

The percentage probability that there will be no overflow from the dam during a given month at different levels of utilization is shown in Table 5. More detailed information is given in Appendices 5 to 7. Any water required for the maintenance of the floodplain over and above the overspill would need to be met by controlled releases and would, therefore, have to be deducted from the yield of the dam, which is approximately 860 x 106 m^3 y^{-1}.

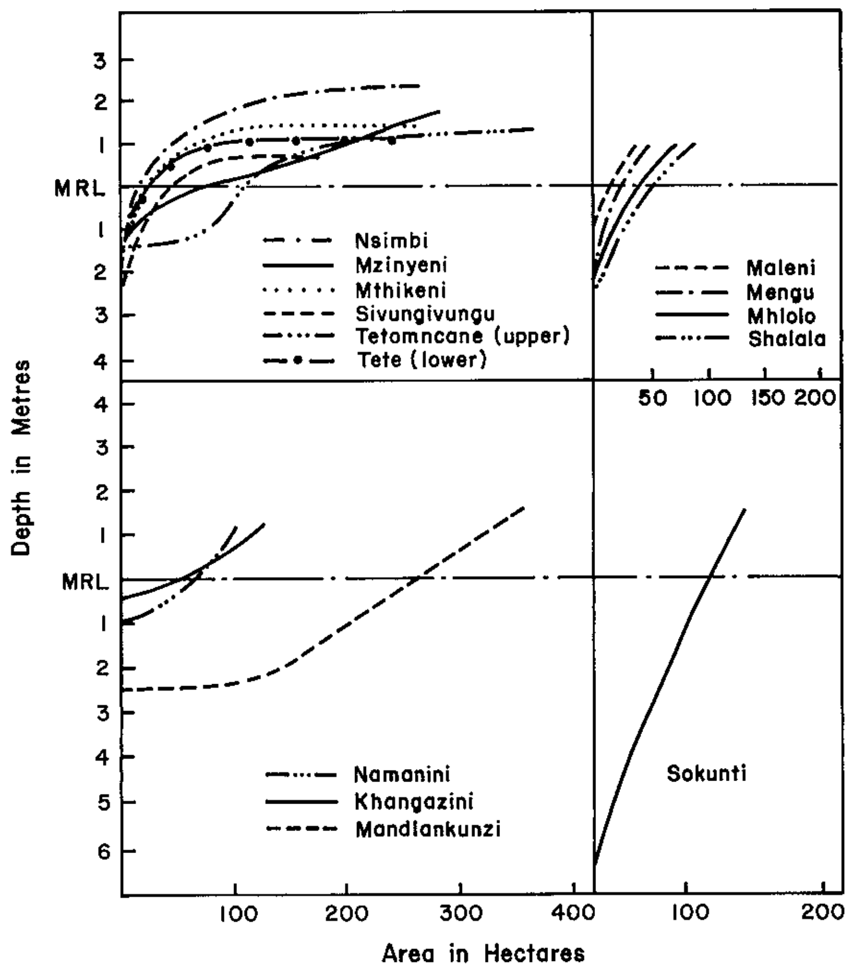


FIGURE 13. Relationship between Pongolo pan water depth and area and maximum retention levels of different Pongolo pans.

Effect on the hydraulic regime of the floodplain

While steady state flows required to fill the various floodplain pans are known (see Table 3), it is not at this stage possible to define the hydraulic regimes (both steady and unsteady state) required to produce various conditions on the floodplain. A computer simulation model of the floodplain will provide predictions of water level fluctuations on the floodplain as a function of changing river flow. This will permit the formulation of controlled discharge patterns for optimal water use in floodplain management and to assess the cost of different management options.

Effect on sediment movement

The estimated trap efficiency of the dam is approximately 95 per cent and only very fine particles will be transported through the reservoir. Essential nutrients are carried on the surface of sediment particles, which previously were deposited on the floodplain. These contributed to productivity of the floodplain as well as the fertility of agricultural lands and marginal meadows, but will now largely be trapped in the lake.

TABLE 5. Percentage probability of no overflow from the Pongolapoort Dam for the hydrological year.

Month	Percentage probability of no overflow at: 25% utilization	50% utilization	100% utilization
October	62	83	91
November	36	68	87
December	21	43	87
January	8	32	85
February	0	15	79
March	8	19	79
April	15	26	81
May	26	53	91
June	49	83	96
July	60	91	98
August	81	96	98
September	85	96	96

A further consequence of the interruption in sediment transport and the change in flow patterns will be an increase in the difference between sediment deposition and erosion and the consequent deformation of the river channel downstream of the dam. During the initial stages of impounding, both release and overspill will cause the main channel of the river to be eroded to a steeper gradient. A lowering of the river bed through erosion will, depending on its extent downstream, result in larger flow rates being required to fill the pans than are at present necessary.

WATER QUALITY OF THE PONGOLO SYSTEM

Any interference with the normal flow regime of a river may affect the concentration of solids dissolved in the river water and thus the quality of that water. Such changes in dissolved solids can have an effect on the irrigation potential of the water, and, in the case of the Pongolo, may affect conditions in the floodplain as well. Furthermore, additional human settlements in close proximity to the river and the discharge of effluents from, for instance, sugar mills into the river course may result in localized inputs of toxic chemicals and organic matter, which can have serious adverse effects on the quality of the downstream water on which both the resident population and the floodplain are dependent. Water borne health hazards constitute yet another aspect of water quality with a direct bearing on both development and conservation.

Dissolved solids

A feature of the rivers of northern Natal and Zululand, notably the Pongolo, Mkuzi and Mfolozi, is a high concentration of dissolved solids, particularly during periods of low river flow. Figure 14 shows the relationship between flow rate and the concentration of salts for the Pongolo River, the lowest salt content having been recorded at the highest flow rate. The composition of the dissolved solids during the dry season (Table 6) is characterized by high concentrations of both sodium and chloride, thought to result from the entry of underground seepage water into the river (Archibald *et al* 1969). Groundwater of similar composition is characteristic of fairly flat bush-clad Lowveld areas (Van Wyk, 1963) and the Pongolo River acquires the characteristic high sodium and chloride content only where its course passes through such areas (Archibald *et al* 1969).

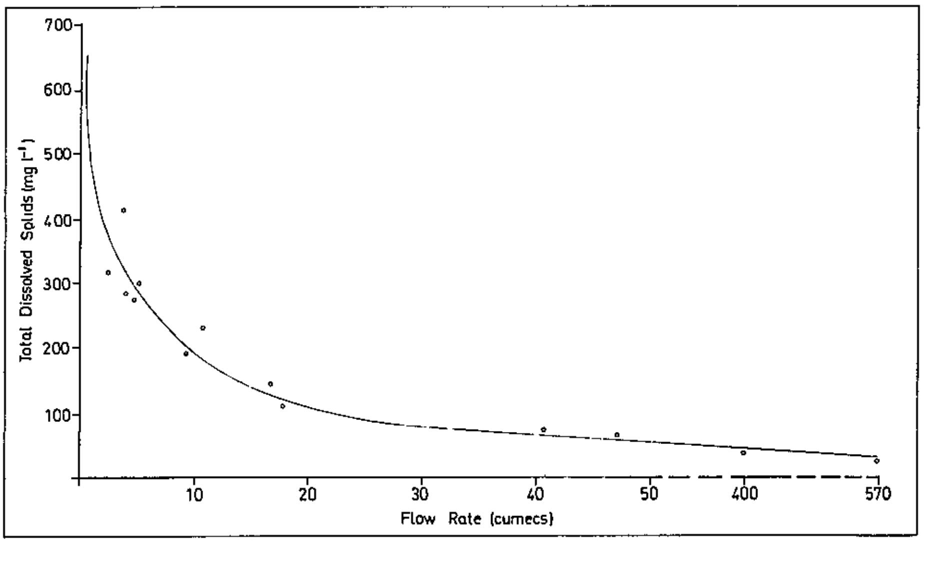


FIGURE 14. Relationship between flow rate salt concentrations in the Pongolo River.

During the rainy season, surface run-off contributes the major fraction of the volume flow in the river, resulting in not only a considerable dilution of the dissolved solids, but also a marked reduction in both sodium and chloride relative to calcium and bicarbonate, the more typical dominant ions in freshwater. Floodwaters will contribute the greatest volume of water impounded in the Pongolapoort Dam, and their diluting effect on the water stored from the much lower dry season flow should ensure a good quality irrigation water throughout. Archibald et al (1969) have predicted that the dissolved solids in the impounded water would be of the order of 200 mg l^{-1}, and Heeg et al (1978) have found it to fluctuate between 100 and 125 mg l^{-1}, which represents a quality suitable for most purposes including irrigation and domestic use.

Studies on the dissolved solids of the floodplain pans by Du Preez (1967) and Heeg et al (1978) have shown salinization to be a potentially serious problem. Seepage water from sediments overlying the marine Cretaceous deposits on the Maputaland Plain results in the water of several important pans taking on the characteristics of dilute seawater, which then becomes concentrated due to evaporation. Nyamithi, Mhlolo and Tete pans are particularly affected in this way (Table 7), and are dependent upon an annual flushing out by floodwaters of low dissolved solid content for retaining their freshwater characteristics. Figure 15 shows the effect of concentration and flushing in Mhlolo pan.

The effect of raised salinities on the fauna and flora of the floodplain pans has not been studied in detail. It is known that the important water plant, Potamogeton crispus, upon which much of the productivity of the floodplain depends, is adversely affected by salt concentrations in excess of 4 000 mg l^{-1} and that all oligochaete worms and freshwater mussels disappear at these salinities. The plankton community, too, takes on a different composition, and it has been reported from Lake Chilwa

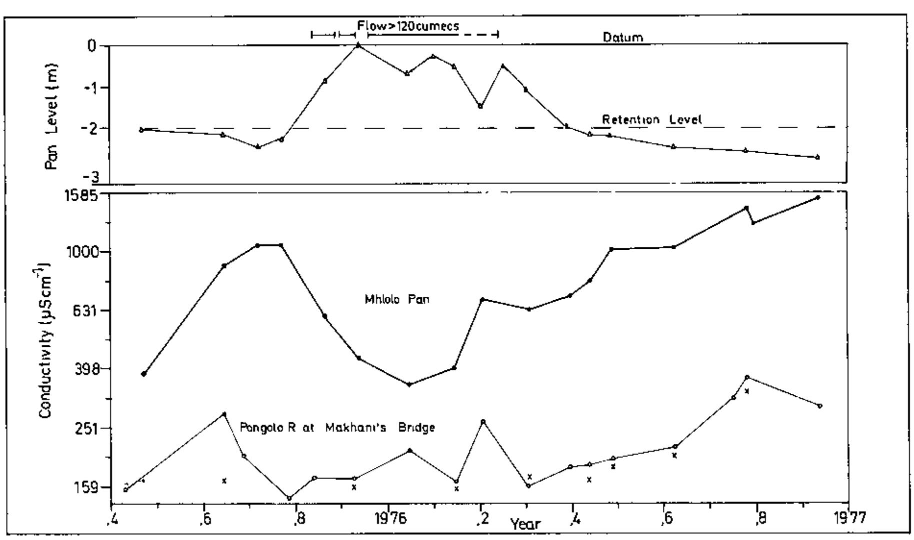


FIGURE 15. Fluctuations in dissolved solids concentration in Mhlolo pan, showing effects of concentration and flushing.

TABLE 6. Concentration (mg l^{-1}) and composition of the dissolved solids in Pongolo River water during dry and rainy seasons (Modified from Archibald *et al* 1969). Note marked increase in total dissolved solids, sodium and chloride once the river reaches the Lowveld during the dry season.

	Commondale (Middleveld)		Pongolo Settlement (Lowveld)		Golela (Lowveld)		Pongolapoort (Lowveld)		Makhani's Bridge (Coastal Plain)	
Season	Dry	Rainy	Dry	Rainy	Dry	Rainy	Dry	Rainy	Dry	Rainy
Total dissolved solids	65	49	636	137	617	241	970	110	582	104
Sodium	6	3	157	14	165	30	172	12	135	17
Calcium	8	4	32	10	34	10	30	6	33	8
Magnesium	3	3	38	6	9(?)	10	30	7	33	7
Chloride	3	3	97	7	149	21	185	9	165	17
Bicarbonate	52	31	522	74	452	112	348	73	331	92
Sulphate	3	2	32	7	16	11	11	17	33	9

TABLE 7. Composition of the dissolved solids of floodplain pans prone to salinization compared with those of typical freshwater and seawater. Similarities between equivalent ratios are indicative of similarities in composition. Note greater similarities of pans to seawater than to freshwater.

	Typical freshwater (Rodhe 1959)	Nyamithi inflow (Du Preez 1967)	Nyamithi mid pan (Heeg *et al* 1978)	Tete (Du Preez 1967)	Mhlolo (Heeg *et al* 1978)	Seawater
Total dissolved solids (mg l^{-1})	Variable	11 290	5 630	3 627	1 933	34 330
Sodium mg l^{-1}	Variable	2 645	1 400	797	470	10 813
Equivalent proportion	0,16	0,57	0,69	0,51	0,65	0,79
Calcium mg l^{-1}	Variable	468	73	310	94	410
Equivalent proportion	0,66	0,12	0,04	0,25	0,14	0,03
Magnesium mg l^{-1}	Variable	761	290	181	80	1 303
Equivalent proportion	0,18	0,31	0,27	0,24	0,21	0,18
Chloride mg l^{-1}	Variable	6 110	2 284	2 094	760	19 440
Equivalent proportion	0,10	0,86	0,86	0,91	0,74	0,90
Bicarbonate mg l^{-1}	Variable	305	387	165	344	143
Equivalent proportion	0,74	0,02	0,08	0,04	0,20	0,01
Sulphate mg l^{-1}	Variable	1 153	-	163	-	2 713
Equivalent proportion	0,16	0,12	-	0,05	-	0,09

(Kalk and Schulten-Senden 1977) that at concentrations of 11 500 mg^{-1} all zooplankton had disappeared. The use of irrigation seepage water to maintain water levels in the floodplain pans without the release of good quality water in the form of a simulated flood to effect a periodic flushing out of the system is expected to lead to a build-up of salts in the pans and elimination of the existing fauna and flora.

Sediments

The sediment load of the Pongolo River is regarded as low and will be reduced even further as a consequence of storage in the Pongolapoort Dam. The effect of this will be an improvement in the water quality for domestic purposes but it is also likely to have detrimental effects on the floodplain. Plant nutrients adsorbed onto silt particles are a source of replenishment for those lost during flooding. These silt-borne nutrients particularly favour the growth of rooted plants such as *Potamogeton crispus*, *Cynodon dactylon* and *Cyperus fastigiatus* upon which so much of the productivity of the floodplain depends.

Increased organic input

Agricultural development, particularly if this entails sugar cane growing, may affect water quality through the input of effluent from processing plants. The data provided by Archibald *et al* (1969) for stations immediately upstream and downstream from the Pongola Barrage (see Figure 1) show clearly the effects which increased organic input can have. Downstream from the Barrage the dissolved oxygen of the water was reduced to 28 per cent saturation, the faunal diversity was low, changing from 17 species above the Barrage to only four species, all oligochaete worms which are tolerant of low oxygen concentrations. The river recovered from this organic pollution within 30 km, but if such material from a mill on the Makatini Flats were to find its way into any one of the floodplain pans it would be likely to have a prolonged effect and adversely affect fish production and the utilization of the water for domestic and stock watering purposes.

Toxic chemicals

The input of toxic chemicals (insecticides, nematocides, weedicides) into the aquatic system will almost inevitably increase with agricultural development, entering the water bodies through soil seepage and spray drift. Apart from the harm these can do to aquatic organisms, they are also likely to constitute a health hazard to people dependent upon the water and the fish. The risk of toxic chemicals having harmful effects can be minimized if direct introduction into the water is prevented. Thus the siting of cattle dipping tanks well away from the floodplain pans, the prevention of direct inputs of toxic effluents and prohibiting the washing of spraying equipment in any important natural waters will all go a long way to keeping chemical pollution down to an acceptable level

Fertilizers

The irrigation scheme will produce tail waters which are likely to contribute signifcant quantities of plant growth nutrients and, while these may more than compensate for the loss of silt-borne nutrients, they are likely to favour the growth of phytoplankton, including potentially toxic Microcystis, instead of rooted hydrophytes which are at present dominant.

Water borne health hazards

All natural waters are pontential health hazards, particularly when surrounded by human settlements. Bacterial counts, including intestinal bacteria, for the Pongolo River are described as exceptionally low (Archibald et al 1969) but all of their sampling was confined to the west of the Lebombo Mountains, and thus may well not be representative of the floodplain. The most important health hazards associated with the floodplain system include typhoid, bilharziasis and malaria.

Typhoid

An outbreak of typhoid on the Makatini Flats in 1969 necessitated extensive innoculations. In the summer of 1969/70 impounding of the Pongolo commenced with a release of only 0,6 cumecs to the lower river. These conditions obliged the resident population to dig in the riverbed for drinking water and in July, 1970, it was reported that another outbreak of typhoid was imminent as a consequence of the poor quality of available drinking water. A release of water from the dam alleviated the problem (Coke 1970).

To prevent a recurrence of the above incident,it is necessary to make adequate provision for the water requirements of the population or adequate maintenance of the floodplain.

Bilharziasis

Bilharziasis or bilharzia is a disease of man and domestic animals caused by parasitic worms (schistosomes). These parasites undergo a complicated life cycle which involves certain aquatic snail species as intermediate hosts. They develop to an infective stage within the snail host, after which they pass into the water, and man and domestic animals are infected if they come into contact with water containing these infective schistosome larvae. Reinfection of the snail population results from excretory products from infected persons or animals being discharged into a water body where the host snails are present.

The intermediate snail hosts abound in the floodplain pans, and are the dominant snail species in some pans. A survey by the Bilharzia Field Research Unit of the Medical Research Council has found an extremely high incidence of infection among the resident population and it is evident, therefore, that the area is a dangerous bilharziasis region. Under the present social system little can be done to prevent or minimize the incidence of the disease.

Malaria

Maputaland is an endemic malaria area in which the Department of Health and KwaZulu health authorities are conducting an active control programme. This is a mosquito borne disease and relates to the floodplain only inasmuch as waterbodies provide breeding sites for the carrier mosquitoes. Mosquito larvae occur in only very small numbers in the floodplain pans, where they are preyed up by fish and invertebrate predators. Shallow isolated temporary pools left by receding floods or filled by rain, as well as discarded containers which can hold water, are probably the main mosquito breeding sites. Present control measures include the spraying of such breeding sites with insecticide as well as the hospitalization and treatment of confirmed malaria cases.

Groundwater

Van Wyk (1963) describes the groundwater associated with the Cretaceous beds of the Zululand coastal plain as highly mineralized chloride water with a total dissolved solids content in excess of 3 500 mg l^{-1} (average 5 000 mg l^{-1}) and a chloride content exceeding 30 per cent of the toal dissolved solids. Heeg et al (1978) have suggested that this total dissolved solids content is probably an underestimate, as du Preez (1967) recorded 11 290 mg $l^{-1}$for seepage water entering Nyamithi pan. Orpen (1972) has carried out a detailed survey of groundwater in the Mjinde area near Makatini Agricultural Research Station. Seven boreholes were sunk to depths between 20 and 50 m over an area of several kilometres. The yields of six of these boreholes ranged between 0,06 and 0,13 l s^{-1} (50-100 gallons per hour) while one gave a moderate yield of 1,0 l s^{-1} (800 gallons per hour). As expected, the quality of the water was poor, ranging from 1 000 to 24 000 mg l^{-1} total dissolved solids.

The geological formations on and around the floodplain militate against the use of groundwater to make up for the cessation of flooding.

THE PONGOLO FLOODPLAIN ECOSYSTEM

The Pongolo floodplain ecosystem presents a complex pattern of interacting flood dependent components. The components of the ecosystem are derived from two principal sources, the land-based or terrestrial source and the aquatic source. Because fluctuating water levels intermittently incorporate terrestrial components into the aquatic system, the productivity of both systems is governed by the processes which occur under both flooded and non-flooded conditions.

As in all ecosystems there are two levels of production, the primary producers (or plants) which trap solar energy and the secondary producers (animals and decomposer microbes) which in turn are dependent on this energy source. In this way, energy enters the system via the plants and then after a series of transfers is ultimately lost as heat. Nutrients also enter primarily through the plants but tend to be recycled through the processes of growth and decay.

Primary producers - terrestrial

Six communities have been recognized on the floodplain and may be grouped according to their relative periods of exposure and inundation:

- The *Acacia xanthophloea* - *Dyshoriste depressa* community. It occupies a total area of some 128 hectares and occurs near the edge of the floodplain under drier conditions than any of the other communities. Here it forms a narrow belt along the eastern and western margins of the ecosystem.

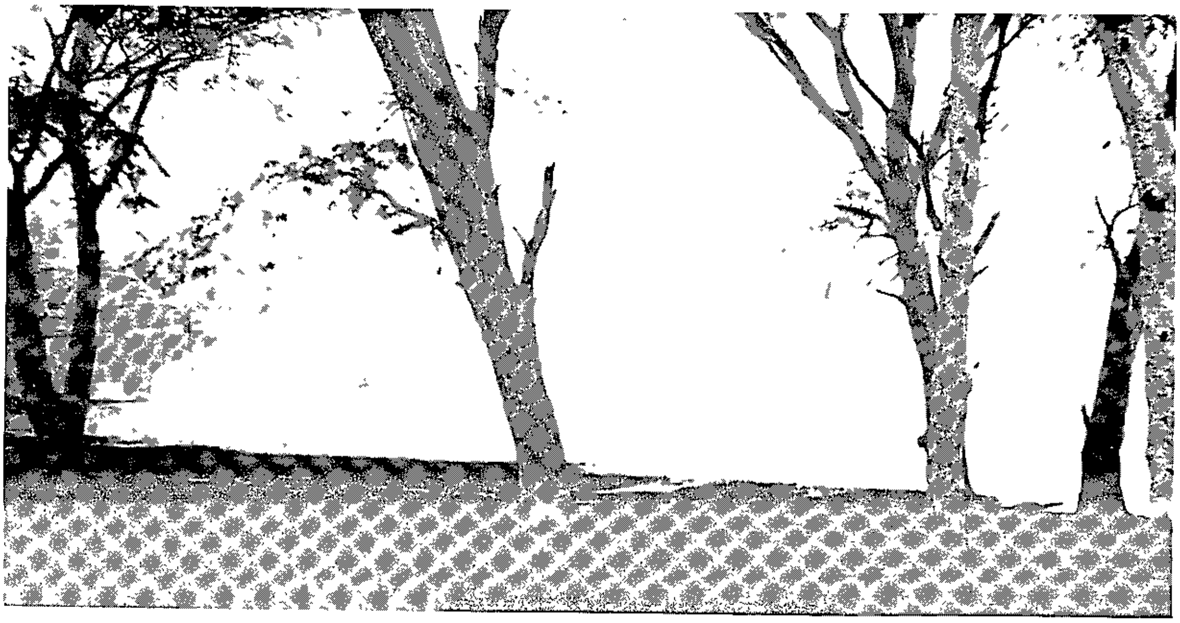
- The *Ficus sycomorus* - *Rauvolfia caffra* community grows only along the levees of the Pongolo and Usutu rivers. This riparian forest is well developed along both these rivers in the Ndumu Game Reserve, where it occupies an area of 246 ha. Outside the reserve it has suffered considerable cutting and burning and is mostly present in a degraded form with only about 160 ha remaining recognizable.

- The *Cynodon dactylon* community occurs on areas which regularly experience alternate inundation and exposure, being particularly well developed around pans which are shallow and thus have substantial margins subject to periodic flooding (eg Namanini and Mthikeni pans). Extensive *C. dactylon* "lawns" or "meadows" are formed around such pans, and these have a total area of approximately 171 ha on the floodplain. The major localities are around Namanini (42 ha), Mthikeni-Nsimbi (27 ha) and Ngodo (32 ha) pans.

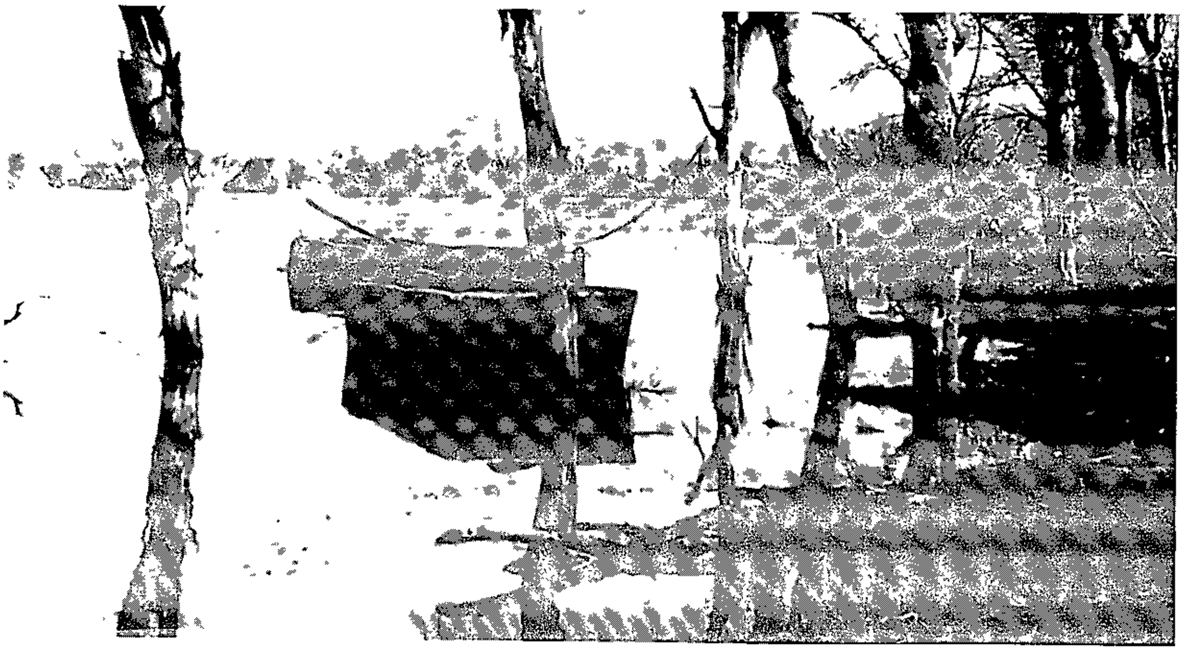
- The *Cyperus fastigiatus* - *Echinochloa pyramidalis* community tends to occupy marshy areas rather than pan margins. This community covers 2 471 ha, with particularly extensive stands west of the Tete and Nsimbi pans and in the Ndumu Game Reserve.

- Two *Phragmites* species occupy the wettest areas. *P. australis* prefers flat, swampy areas while *P. mauritianus* favours river

PLATE 5. The importance of the natural flooding regime to floodplain vegetation.



(a) Fever trees (Acacia xanthophloea) with a groundcover of Dyschoriste depressa at Tete Pan, are a feature of the floodplain edge where the water table is high. Although this plant community is subject to regular flooding, inundation is infrequent and of short duration. (Photo: C M Breen)



(b) Fever trees at Mzinyeni Pan killed as a result of attenuated floods released during the construction of the Pongolapoort Dam. The lateral surface roots of these trees were submerged for a prolonged period instead of the brief inundation normally experienced under the natural flooding regime, and were killed as a result. (Photo: C M Breen) banks, inlet-outlet channels and pan margins where there is a fluctuation in water level. The two Phragmites communities together account for approximately 234 ha of the floodplain, about 65 percent being P. australis, mainly in the Ndumu Game Reserve.

The remainder of the floodplain is made up of areas disturbed principally by cultivation. These areas form the basis for subsistence agriculture on the floodplain. Figure 16 shows the distribution of the communities in relation to pan and river water levels. Figure 17 shows their distribution on the floodplain.

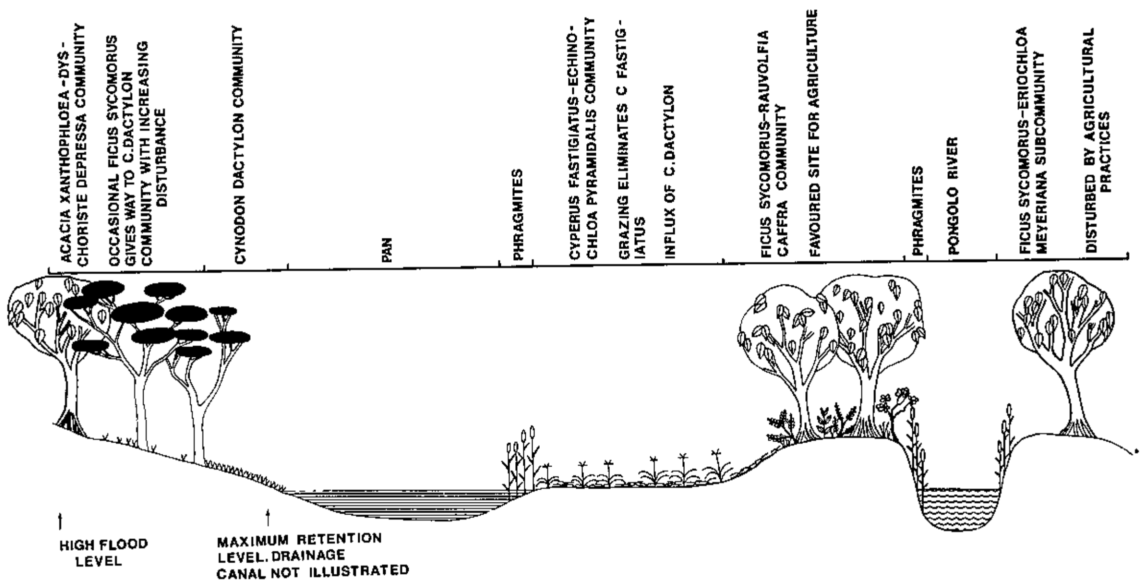


FIGURE 16. Diagramatic section across the Pongolo floodplain showing the distribution of different plant communities.

Primary producers - aquatic

The aquatic flora can be broadly divided into two types:

- Algal communities, which may be either free in the water column (phytoplankton) or attached to larger plants, stones and other substrates (epiphyton). The composition of the phytoplankton community is similar to that found in mesotrophic waters, consisting essentially of blue-green algae (Cyanophyta) and the diatom Melosira granulosa. The epiphyton has not been studied beyond establishing that substantial amounts do occur in the system, and that this community fixes an appreciable amount of atmospheric nitrogen.

- Hydrophyte communities, which may be either permanent or seasonal. Permanent hydrophyte communities consist mainly of Trapa bispinosa (water chestnut) and various water lilies (Nymphaea spp). These are best developed in those pans where the water level is not subject to extensive seasonal fluctuations. The seasonal communities consist largely of Potamogeton crispus and Najas pectinata and occur in those pans where a reasonable depth of water is retained over the dry season.

Primary productivity and nutrient cycling

The extent of the contribution to the energy flow of the floodplain pan system by the above communities has not been established in every instance. However, each is an integral part of the ecosystem as a whole, and its rôle can often be inferred even if it has not been quantified.

The terrestrial communities

The high-lying Ficus sycomorus - Rauvolfia caffra and Acacia xanthophloea - Dyschoriste depressa communities are not major contributors to the pans for three reasons:

- under normal flooding conditions they are infrequently flooded,
- the duration of their being flooded is short, and,
- the field layer is sparse and thus the amount of decomposable material is small.

However, the fruits of F. sycomorus and the seeds of A. xanthophloea are seasonally found in considerable quantities in the stomachs of omnivorous fish species, and hence make some contribution to the secondary production of the pans. Their contribution to the rest of the floodplain has not been assessed.

The Cyperus fastigiatus - Echinochloa pyramidalis community is also likely to make a small contribution to aquatic secondary production when flooded, although E. pyramidalis is certainly grazed by the herbivorous fish Tilapia rendalli. However, its contribution to terrestrial grazers is considerable, as research on the diet of hippopotamuses indicates that it is well utilized and it also provides valuable grazing for cattle.

The two Phragmites communities are likely to be of minor importance for energy flow through the ecosystem, except perhaps in the Ndumu Game Reserve. However, these reeds are extensively harvested for roofing material and the young sprouts are grazed by cattle.

The terrestrial community of greatest significance to the productivity of the floodplain pans is, without doubt, the Cynodon dactylon community, which occurs extensively around certain pans. It survives inundation as viable rhizomes and shoots, even though the latter lose all their leaves, and develops rapidly on re-exposure as the floodwaters recede. With abundant water, such as immediately following exposure, production is extremely high (23 kg ha^{-1} d^{-1} dry mass), but most of this is consumed by terrestrial grazers. As the plants are subjected to increasing water stress, productivity decreases but the grass also becomes less palatable, so that grazing pressure is reduced. Although up to 15 kg ha^{-1} d^{-1} may be removed through grazing, by the end of the

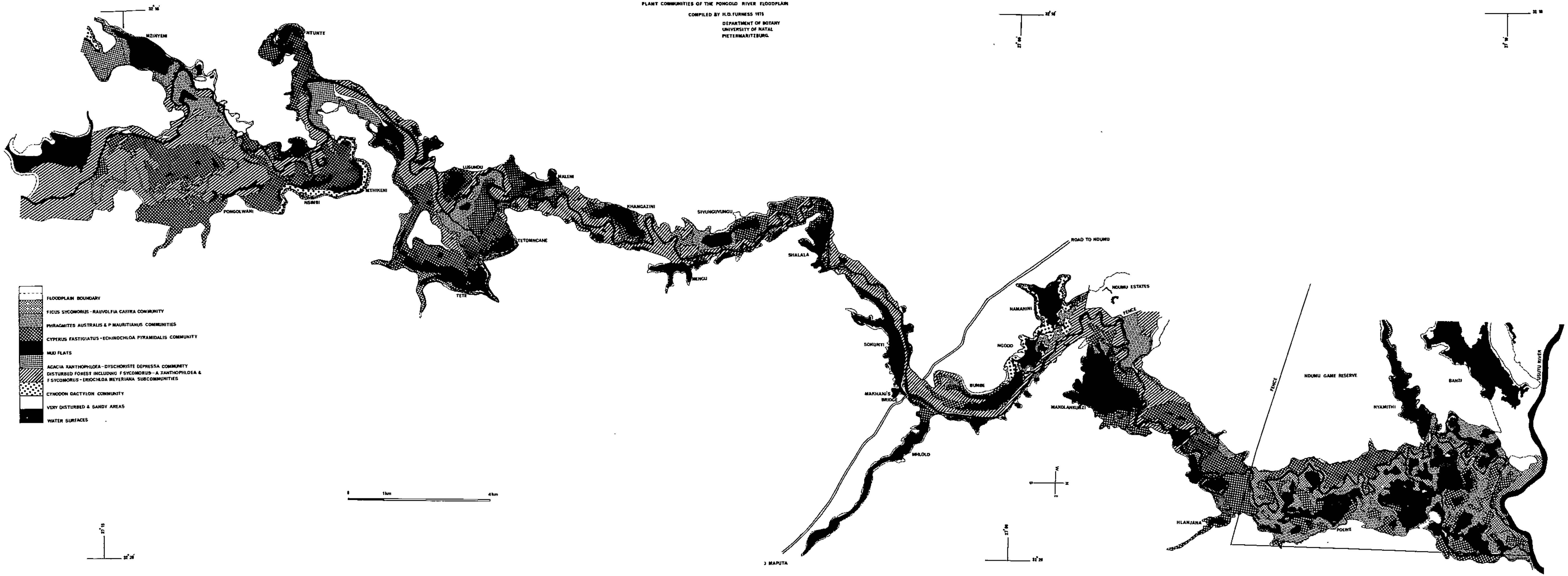

PLANT COMMUNITIES OF THE PONGOLO RIVER FLOODPLAIN
COMPILED BY H.D. FURNESS 1975
DEPARTMENT OF BOTANY
UNIVERSITY OF NATAL
PIETERMARITZBURG
FLOODPLAIN BOUNDARY
FICUS SYCOMORUS - RAUVOLFIA CAFFRA COMMUNITY
PHRAGMITES AUSTRALIS & P MAURITIANUS COMMUNITIES
CYPERUS FASTIGIATUS - ECHINOCHLOA PYRAMIDALIS COMMUNITY
MUD FLATS
ACACIA XANTHOPHLOEA - DYSCHORISTE DEPRESSA COMMUNITY
DISTURBED FOREST INCLUDING F SYCOMORUS - A XANTHOPHLOEA & F SYCOMORUS - ERIOCHLOA MEYERIANA SUBCOMMUNITIES
CYNODON DACTYLON COMMUNITY
VERY DISTURBED & SANDY AREAS
WATER SURFACES
MZINYENI
NTUNTE
PONGOLWANI
NSIMBI
MTHIKENI
MALINI
KHANGAZINI
SIYUNGUVUNGU
TETOMNCANE
TETE
SHALALA
ROAD TO NDUMU
NDUMU ESTATES
FENCE
NAMANINI
NGODO
SOKUNTI
BUMBE
MHLOLO
NDUMU GAME RESERVE
NYAMITHI
BANZI
USUTU RIVER
HLANJANA
POLWE
MAPUTA
1km
4km

FIGURE 17. Vegetation map of the Pongolo floodplain.

dry season some 825 kg ha^{-1} is inundated by floodwaters, and since only 195 kg ha^{-1} remains at the time of re-exposure, the difference (ca 630 kg ha^{-1}) is either utilized directly by aquatic herbivores or enters the decomposer cycle as detritus.

In a pan such as Namanini approximately 34 tonnes of C. dactylon is submerged annually, representing an input of 26 tonnes. Within the relatively short time of 30 days, half of this material has disappeared, including 0,5 tonnes of nitrogen, most of which is released in the first four days. The latter will often be released when water is flowing through the pans, so that nitrogen may well be lost from the system during floods. There can be little doubt that in pans such as Namanini, where an extensive marginal meadow is periodically inundated, this terrestrial component is particularly important to its general productivity.

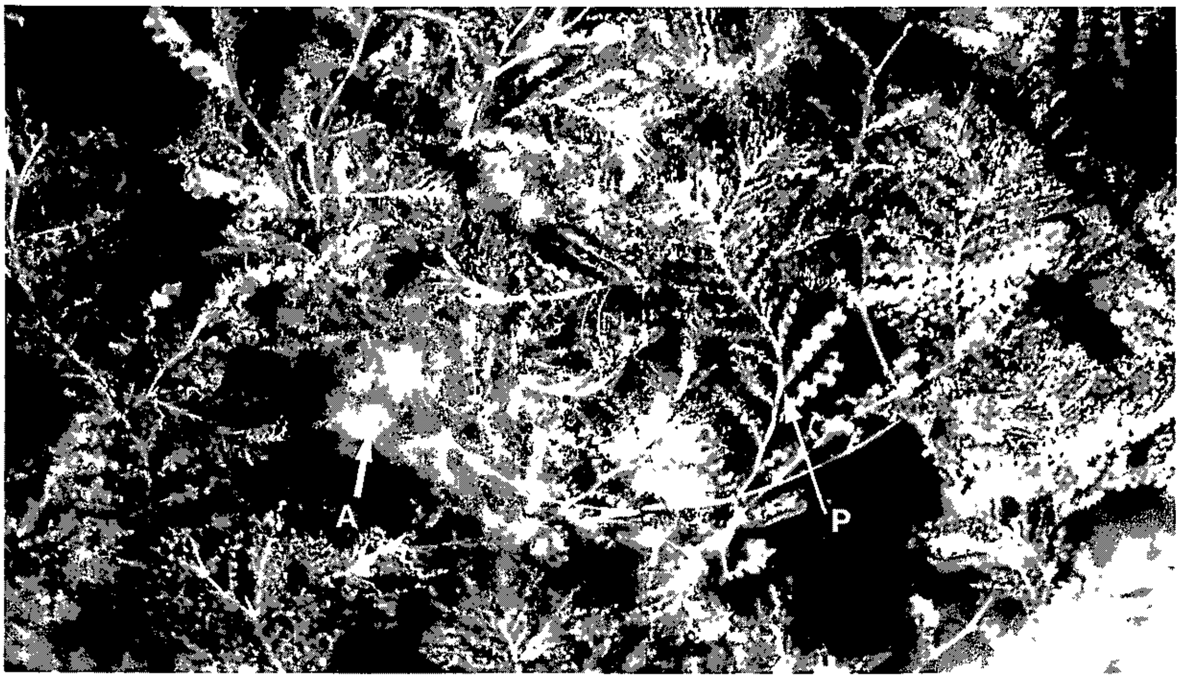
The aquatic communities

While phytoplankton must play a role in the primary productivity of the system, no attempt has, as yet, been made to quantify its contribution. The large blue-green algal component includes species known to be nitrogen fixers, and these are likely to contribute materially to the overall nitrogen budget. The epiphyton community occurring on Potamogeton crispus has been found to have a considerable nitrogen fixing potential, with a maximum fixation rate of 23 mg N m^{-2} 24 h^{-1} having been recorded and a total fixation of 1,27 g N m^{-2} for a period of four months. On the basis of these values, this community could be responsible for adding 1,14 tonnes to the nitrogen pool of Tete pan. Preliminary investigations into the epiphyton standing crop showed the dry mass of the organic component of this community to amount to some 19 per cent of the dry mass of the non-reproductive parts of the P crispus on which it was growing. Considering that the epiphyton is constantly grazed by snails, and that turnover times measured elsewhere range between 14,4 and 22 days, its annual production is likely to exceed that of P crispus. Epiphyton is also known to occur on other submerged aquatics, as well as on Cynodon dactylon once it is inundated.

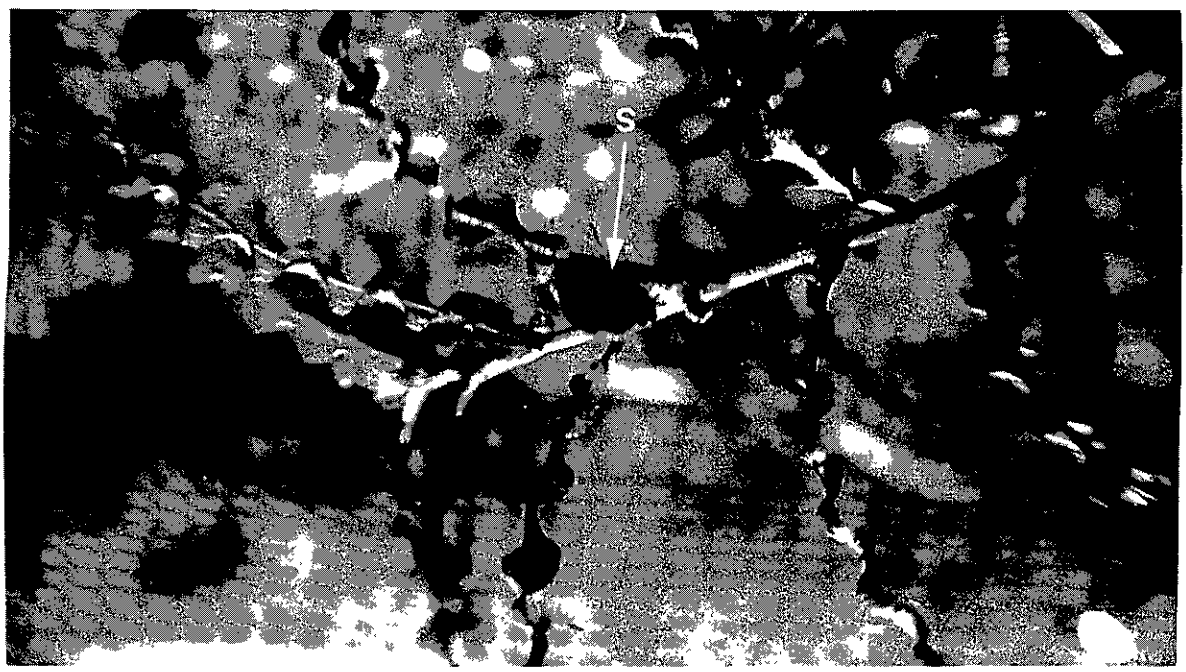
Because flooding is typically a summer phenomenon, input into the pans from terrestrial plants occurs almost exclusively during this season. The permanent aquatic communities (Nymphaea, Trapa) provide a continuous input in pans with a relatively stable water level (eg Mhlolo) and are likely to be particularly important between seasons. However, in most instances, they do not cover extensive areas and the major contribution by hydrophytes comes from the seasonal winter growth of Potamogeton crispus, which provides an input when that from all other sources is at a minimum.

P crispus, although it produces seeds in considerable numbers, develops principally from dormant vegetative propagules (turions). These propagules are extremely sensitive to desiccation, so that P crispus only develops a substantial standing crop in those pans which do not dry out. Germination of the turions is inhibited by high temperatures and it is only when water temperatures begin to fall during April that germination commences. This produces within a short time dense growths of this

PLATE 6. Aquatic primary production in the floodplain pans.

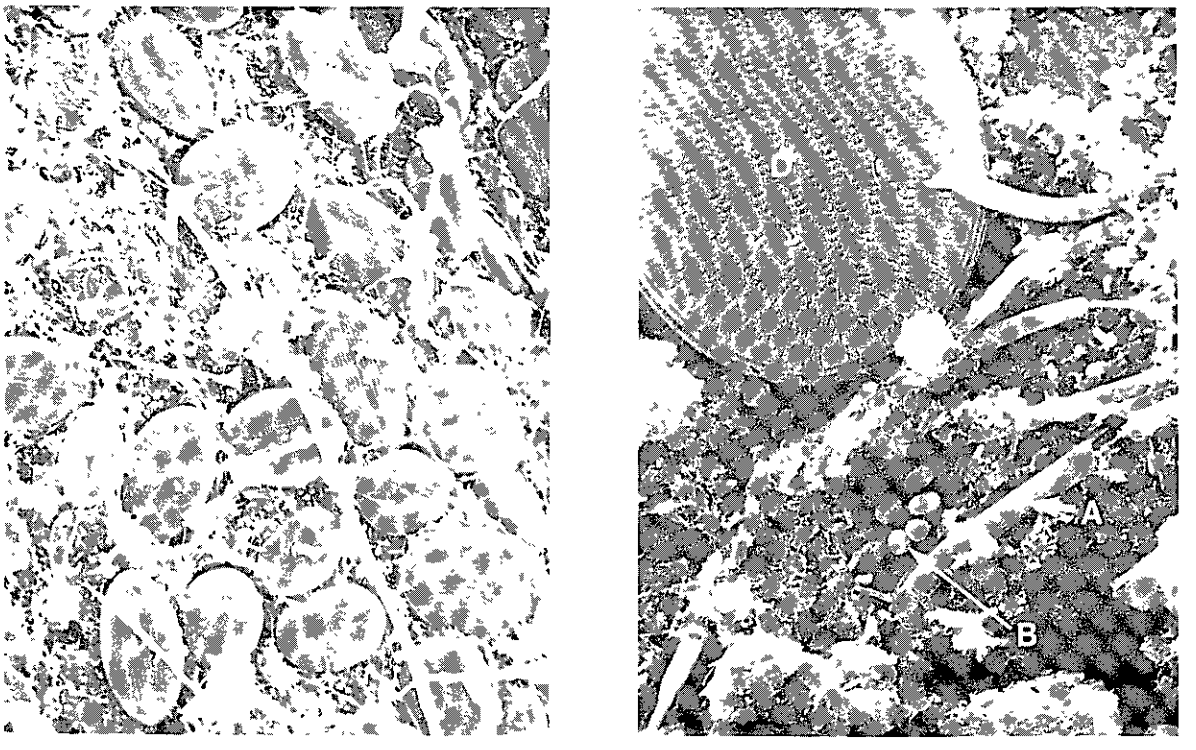


(a) Potamogeton crispus (P), the most important aquatic macrophyte in the pans during the dry (winter) season, showing a dense growth of filamentous epiphytic algae (A). The epiphyton which grows on the leaves of P cripsus constitutes the base of a number of food chains during the winter months. (Photo: K H Rogers)



(b) A freshwater snail (Bulinus natalensis) (S) grazing the epiphyton growth on P crispus. Snails do not feed on the macrophytes until these become senescent and plant tissues begin to degenerate, after which they play an important role in the breakdown of the plant material. (Photo: K H Rogers)

PLATE 7. The epiphyton growth on the leaves of P crispus.



(a) Scanning electron micrograph (magnification x 850) showing diatoms (D) and filamentous algae (A). (Photos: Electron Microscope Unit, University of Natal, Durban)

(b) Further magnification to 3 000 times shows colonies of bacteria (B)

submerged plant. These restrict wave action and reduce turbulence so that the water becomes progressively clearer, which is probably an important factor governing the development of the epiphyton community.

The standing crop of P crispus varies from year to year and may be influenced by the activities of water fowl, particularly white-faced whistling duck (Dendrocygna viduata) which graze extensively on the turions when these are produced in late winter. Duck represent a major consumer of living P crispus which is also eaten by the fish Tilapia rendalli; snails only appear to attack the plant when it becomes senescent, but browse extensively on the epiphyton which grows on the living leaves. Individual P crispus plants appear to have a life span of approximately five months and at the end of the growing season the remaining standing crop, which may be as much as 110 g m^{-2} dry mass, enters the decomposer cycle once senescence has set in.

P crispus is a rooted plant and it seems likely that it derives some of its nutrients from the sediments at the bottom of the pans, since it has been shown that the phosphorus content of the surface sediments decreases as the standing crop of P crispus increases. It is estimated that 0,17 tonnes of phosphorus is bound up in the P crispus crop in a water body such as Tete pan. In this way it serves to increase the movement of inorganic nutrients through the system.

The importance of P crispus in the productivity of the system can be assessed from a consideration of Tete pan, which has a total area of 86 ha. The standing crop in September was 42,8 g m^{-2}, respresenting some 34,95 tonnes of dry plant material. Since only the vegetative portion of the plant decomposes, 27,18 tonnes of potentially decomposable material is put into the system. This disappears at a rate of 1 percent per day, so that by the beginning of summer this material has all been transferred to other components of the system. If the floods occur before this has taken place, there will be a loss of nutrients, particularly phosphorus, from the pans.

Factors influencing primary productivity

The factors to be considered here are those which are likely to arise from the presence of the Pongolapoort Dam, and which are thus subject to manipulation.

Alterations to the flooding regime

The Phragmites communities can tolerate a wide flooding range, but it would be desirable to keep the flooding pattern regular on an annual basis. Acacia xanthophloea is sensitive to prolonged inundation, as witnessed by the considerable mortality of these trees following attennuated floods during 1974. The Cyperus fastigiatus - Echinochloa pyramidalis community must have an annual flood, but also cannot tolerate long periods of complete inundation; two months is considered the maximum tolerable period of submergence if this community is to be maintained. Since it is found in marshy areas, the inundation pattern should be such that the likelihood of drying out during the period between flooding and the summer rains is minimal. There is evidence to suggest that this community is decreasing in extent to be replaced by Cynodon dactylon in better drained localities.

The C. dactylon lawns also need an annual period of flooding, and here the rate of drying out after flooding is critical to the productivity of the system. If the floods recede too quickly, early water stress results and the lawns are also subjected to earlier and more extensive grazing pressure from cattle, both of which are detrimental to productivity. Such a rapid drying out would result from a sudden complete shut-down after a simulated flood. This has occurred on occasions and has resulted in overgrazing which interferes with the productivity of the lawns. The recommended rate of exposure is for a drop in water level between high flood level and maximum pan retention level of not less than two months. Anything less would be detrimental.

The maintenance of both the seasonal and the permanent hydrophyte communities requires a summer flooding regime associated with relatively stable conditions during winter. Where such winter stability is not preserved (eg Khangazini pan), P crispus is rapidly diminished, and with it the numbers of waterfowl and the overall secondary productivity. The permanent hydrophyte communities require water level stability and as such are adversely influenced by prolonged periods of high floods.

Changes in sediment load

The influence of the dam on the transport and deposition of sediment by floodwaters is an important consideration. Prior to the construction of the dam, it is likely that the floodplain operated as a flow-through ecosystem in that nutrient losses resulting from flushing were replaced by those carried in with the sediment. The dam acts as a silt trap and reduces the sediment load of the floodwaters. A gradual decline of productivity of the system results with a net annual loss of nutrients.

Changes in dissolved solids

Many of the pans, particularly Nyamithi, Mhlolo and Tete show an increase in dissolved solids, particularly sodium and chloride ions, during the dry season. There is a likelihood of an increase in the salinity of pans if the saline seepage water from irrigation development should reach them. Although most of the plant communities have a marked tolerance of raised salinities, levels may be reached where the composition of the flora will be affected. P crispus turions will not germinate at salinities above 5 000 mg l^{-1} and the growth of established plants is impaired at this concentration.

Secondary producers - invertebrates

From a study of the diets of the fish of the system, it is apparent that most of the invertebrates present in the pans are utilized by one or other fish species. The invertebrates can be divided into those which are free-swimming in the water column (zooplankton) and those which live on the bottom or on plants (zoobenthos).

The species composition of the zooplankton community differs from pan to pan, with rotifers or cladocerans generally being dominant. In most pans the structure of this community is similar to that which is normally dependent upon a detritus based food resource, with Ceriodaphnia as the dominant cladoceran genus and small rotifers which feed on bacteria featuring prominently. Species which normally feed on phytoplankton do occur, but only form a significant component of the zooplankton community in clear, deeper and less productive pans such as Mengu. No data are available on zooplankton standing stocks or production rates.

The benthic invertebrates appear to be more important in the trophic economy of the pans than is the zooplankton when judged by their presence in the diets of the most important fish species. The zooplankton is likely to feature more prominently in the diets of juvenile fishes, which have not as yet been studied in this connection. For convenience the zoobenthos may be divided into two categories: that which is associated with vegetated or barren pan margins, including flooded terrestrial vegetation such as the C dactylon lawns and that found on the offshore bottom sediments. Some snails and other invertebrates associated with submerged hydrophytes also occur.

The invertebrate fauna of the offshore sediments, or mid-pan benthos, consists largely of an infauna (those that burrow in the sediment) comprising freshwater mussels, oligochaete worms (mainly *Branchiura sowerbyi*) and the larvae of chironomid midges and of *caddis flies* (*Dipseudopsis* spp). The epifauna (those living on hydrophyte and *sediment surfaces*) includes snails, which feed on the epiphyton growing on *P crispus* during the latter's growth season, and the predaceous nymphs of *dragonflies* which probably feed on the rich infauna. The infauna is dependent on an input of dead plant and/or animal material and its associated microbial flora, thus forming part of the detritus food chain.

The marginal benthos is much more diverse than that of the mid-pan sediments. While all the mid-pan species are represented here, their density is lower and the community is dominated by a variety of aquatic insects, freshwater shrimp (*Caridina nilotica*) and a large number of snails. Both *C nilotica* and *various snail* species feed mainly on the epiphyton growth *on submerged* vegetation.

The standing stock biomass of the benthic invertebrates remains high throughout the year, although there are apparent seasonal fluctuations which may be connected with the input of organic material from both the terrestrial and submerged aquatic primary producers. Superimposed on this are variations in density of the fauna, particularly that of vegetated margins, resulting from changes in water level. A drop in water level decreases the width of the marginal belt of submerged vegetation, thus compressing the total biomass into a more restricted area. Differences in the mid-pan benthic biomass of different pans appears to be related to vegetation; pans which support an appreciable growth of submerged macrophytes (eg Mhlolo, Mthikeni) maintain a significantly greater biomass of mid-pan benthos than those pans which do not (eg Namanini). Fluctuations in biomass of these invertebrates in the pans in which hydrophytes are an important component appear to be related to the input of detritus from these plants.

Studies on the actual production rates of benthic invertebrates have yielded reasonably reliable results for only one species, the oligochaete *Branchiura sowerbyi*. The rates were shown to vary seasonally, probably *in response to the* detritus inputs into the mid-pan system, giving mean annual values ranging from 5.9 mg dry wt m^{-2} y^{-1} or 92.97 J M^{-2} y^{-1} for Mzinyeni Pan to 21.1 mg y^{-1} or 330.13 J M^{-2} y^{-1} for Mhlolo Pan. These values, and the turnover rates derived from them, are comparable with rates of up to 393 J m^{-2} y^{-1} for oligochaetes in the enriched Lake Ontario (Johnson & Brinkhurst, 1971).

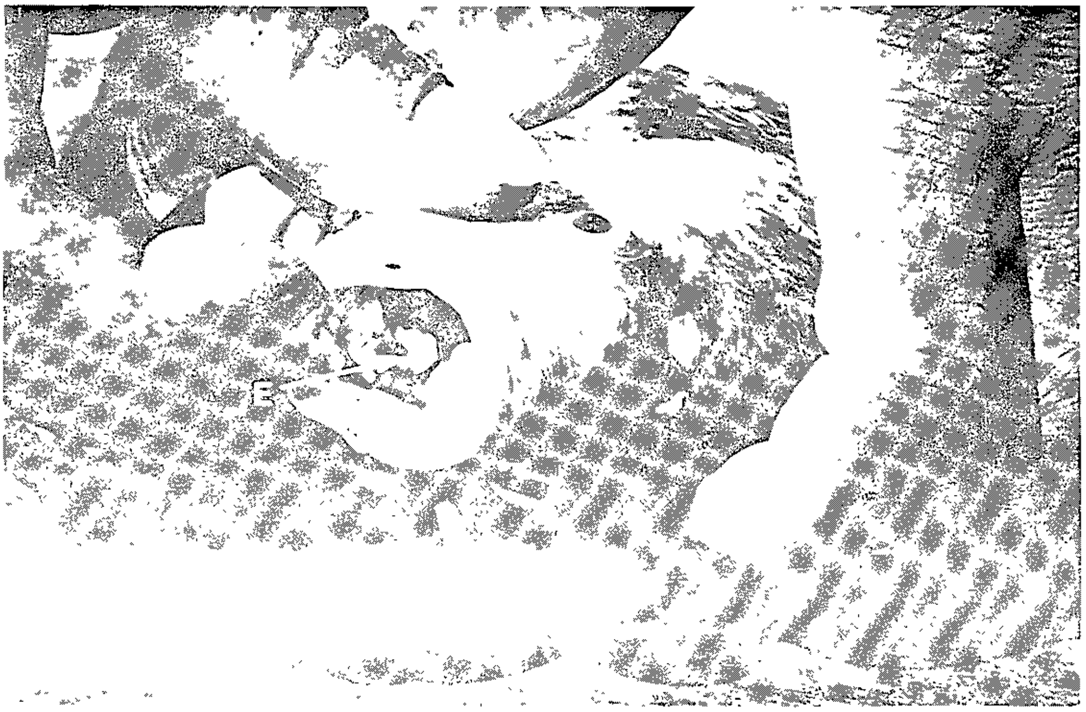
Secondary producers - fish

The Pongolo floodplain has one of the most diverse fish faunas in the Republic of South Africa, 48 fish species having been recorded from the system to date (see Appendix 8). Several of these are important as human food and are currently exploited at a subsistence level by the local population.

The pans differ from one another in depth, permanence, turbidity, composition of dissolved solids, aquatic vegetation and fish species composition (Table 8).

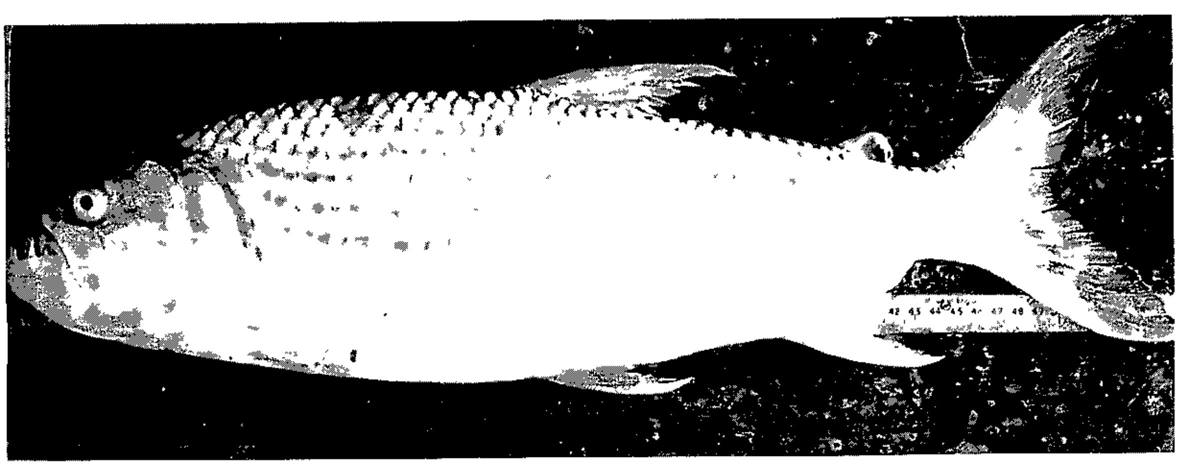
PLATE 8. Some fishes of the Pongolo floodplain.

(a) A typical seine net haul from Mzinyeni Pan comprising imberi (Alestes imberi) (I), rednose labeo (Labeo rosae) (L), butter catfish (Eutropius depressirostris) (B) and Mozambique tilapia (Sarrotherodon mossambicus) (T). (Photo: H M Kok)



(b) Mozambique Tilapia (Sarrotherodon mossambicus) with a brood of eggs (E) in its mouth. This species cares for its eggs and young by carrying them in this way and thus protecting the most vulnerable stages in the life cycle from predation. It is one of the few floodplain fish species not dependent upon flooding for breeding. (Photo: H M Kok)

(c) A fifteen kilogram female Sharptooth Catfish or common barbel caught in Mzinyeni Pan. Catfish are a highly prized food fish on the floodplain. (Photo: H M Kok)



(d) Tigerfish (Hydrocynus vittatus), active predators and renowned fighters when caught on rod and line, are much sought after by anglers. This two kilogram specimen from Sokunti Pan is about half the mass of the largest recorded from the floodplain. (Photo: H M Kok)

TABLE 8. Characteristics and dominant fish species of selected pans on the Pongolo floodplain.

Pan	Characteristics	Dominant fish species
Mzinyeni	Shallow, turbid, with very little aquatic vegetation	Common barbel (*Clarias gariepinus*) Mozambique tilapia (*Sarotherodon mossambicus*) Red-nose labeo (*Labeo rosae*)
Tete	Shallow, clear, with abundant aquatic vegetation	Red-breasted tilapia (*Tilapia rendalli*) Mozambique tilapia (*Sarotherodon mossambicus*)
Sokunti	Deep, turbid, with little aquatic vegetation	Tigerfish (*Hydrocynus vittatus*) Red-nose labeo (*Labeo rosae*) Common barbel (*Clarias gariepinus*)
Mhlolo	High conductivity, shallow, clear, with abundant aquatic vegetation	Mozambique tilapia (*Sarotherodon mossambicus*)
Nhlanjane	Very infrequently flooded, own catchment is source of water	Common barbel (*Clarias gariepinus*)

The very large number of species which occur in the floodplain ecosystem is likely to be due to a super-abundance of food. Notwithstanding this, and the fact that all the fish species exploit a number of different food items, each shows a distinct preference for a specific type of food, which avoids unnecessary competition during winter when pan water levels are low and food is less abundant. A measure of resource partitioning is therefore apparent from a study of the diets of the different species. The preferred food items of the more important fish species are shown in Table 9.

Where species appear to compete for the same resource, it is usual to find a degree of specialization by the individual species to a particular component of that resource. Thus both the churchill and the bulldog (both belong to the family Mormyridae) feed exclusively on aquatic larval insects, but they exploit different size ranges of prey. This is even more strikingly shown by three of the catfish species, all of which feed on mussels to a significant extent. The common barbel takes almost only large mussels (family Unionidae) and the blunt-tooth catfish takes a smaller mussel species (*Corbicula africana*) which it crushes before swallowing, while the squeaker takes only very small bivalves (*Pisidium*, *Eupera* and juvenile *Corbicula*). The most abundant tilapia, the Mozambique tilapia, is primarily an algal and microbial feeder, whereas the red-breast tilapia feeds on plants. Even among the piscivores some partitioning is apparent, but here separation is temporal and spatial.

TABLE 9. Food preferences of some Pongolo floodplain fishes.

Species	Preferred food item
Mozambique tilapia (Sarotherodon mossambicus)	Algae and mud
Red-breasted tilapia (Tilapia rendalli)	Aquatic and inundated terrestrial plants
Red-spotted labeo (Labeo rubropunctatus)	Epiphyton
Red-nose labeo (Labeo rosae)	Detritus
Common barbel (Clarias gariepinus)	Omnivorous (mainly piscivorous)
Blunt-tooth barbel (Clarias ngamensis)	Freshwater mussels
Butter barbel (Eutropius depressirostris)	Omnivorous (mainly piscivorous)
Squeaker (Synodontis zambezensis)	Insects, worms, etc
Churchill (Petrocephalus catastoma)	Small insect larvae
Bulldog (Marcusenius macrolepidotus)	Large insect larvae
Imberi (Alestes imberi)	Seeds and plankton
Tigerfish (Hydrocynus vittatus)	Fish
Tank goby (Glossogobius giurus)	Fish

Tigerfish and butter barbel are both open water predators, but the former feeds during the day and the latter at night, also augmenting its fish diet with other food items. Similarly, both the tank gobies and the common barbel are bottom feeding piscivores, but the latter makes extensive use of other resources from time to time.

In view of the fact that all possible food resources for fish within the floodplain ecosystem appear to be utilized, the introduction of exotic species would be unlikely to serve any purpose.

Fish stock recruitment

The Pongolo floodplain pans serve as a breeding habitat for all the important fish species of the system as witnessed by the abundance of newly hatched fish which appear every year immediately following the floods. While there is certainly a high degree of pan endemism within the system, with many adult fish remaining in a particular pan over the whole flooding period, the river, when in flood, does provide a route for interpan migration and the supplementing of the breeding stock of a pan by the recruitment of immigrants from other localities. That upstream migrations occur in response to flooding can be construed from the considerable aggregations of adult fish of all species in the stilling pool below the dam wall immediately following the cessation of a released flood. Since any exploitation of the fish fauna of the pans will inevitably involve the removal of fish of breeding age, only pan-river contact will provide the necessary migration route whereby the breeding stock can be replenished through immigration.

Several species of fish are stimulated to spawn by the flooding of the system. In some, including important species from an exploitation point of view (eg tigerfish, mudsuckers, catfishes), spawning appears to be totally flood dependant. In these species, the reproductive organs mature in summer, presumably in response to raised water temperatures, but there is no evidence of spawning before the advent of the summer floods. Such synchronization of spawning with flooding holds distinct advantages for the eggs and juveniles, providing protection against fish predators which cannot feed effectively in the shallow water and sufficient shelter among the inundated vegetation to reduce the risk of being taken by birds. The flooded margins are also rich in invertebrates which range in size from microscopic to several centimetres, thus providing for the food requirements of the young fish from hatching until they reach a size where their swimming ability renders them less prone to predation and they can leave the shallows to forage elsewhere. Since the rate of growth of young fish is known to depend on the available food supply, the richness of the marginal benthic fauna promotes a rapid increase in size. The dependence of juvenile fish, and therefore ultimately the total fish stock, on the flooded margins further stresses the undesirability of too rapid a dropping of the water level following a flood. For the fish populations to benefit fully from this nursery habitat, inundation of the margins must be sustained to allow the young to fully exploit the food and shelter provided.

Species such as the Mozambique and red-breast tilapias, which are both nest builders and show parental care for both eggs and young, are not flood dependent in their spawning but breed with the onset of increasing water temperatures. However, parental care extends only to the very young juveniles, and individuals of both these species which have attained a length of 10 to 15 mm abound in the flooded margins. The annual cycle of fish recruitment is summarized in Figure 18.

Secondary producers - other vertebrate animals of the floodplain

Other elements of the vertebrate fauna of the floodplain play a less obvious but nonetheless significant rôle in the dynamics of the ecosystem, either contributing to its productivity or utilizing its resources.

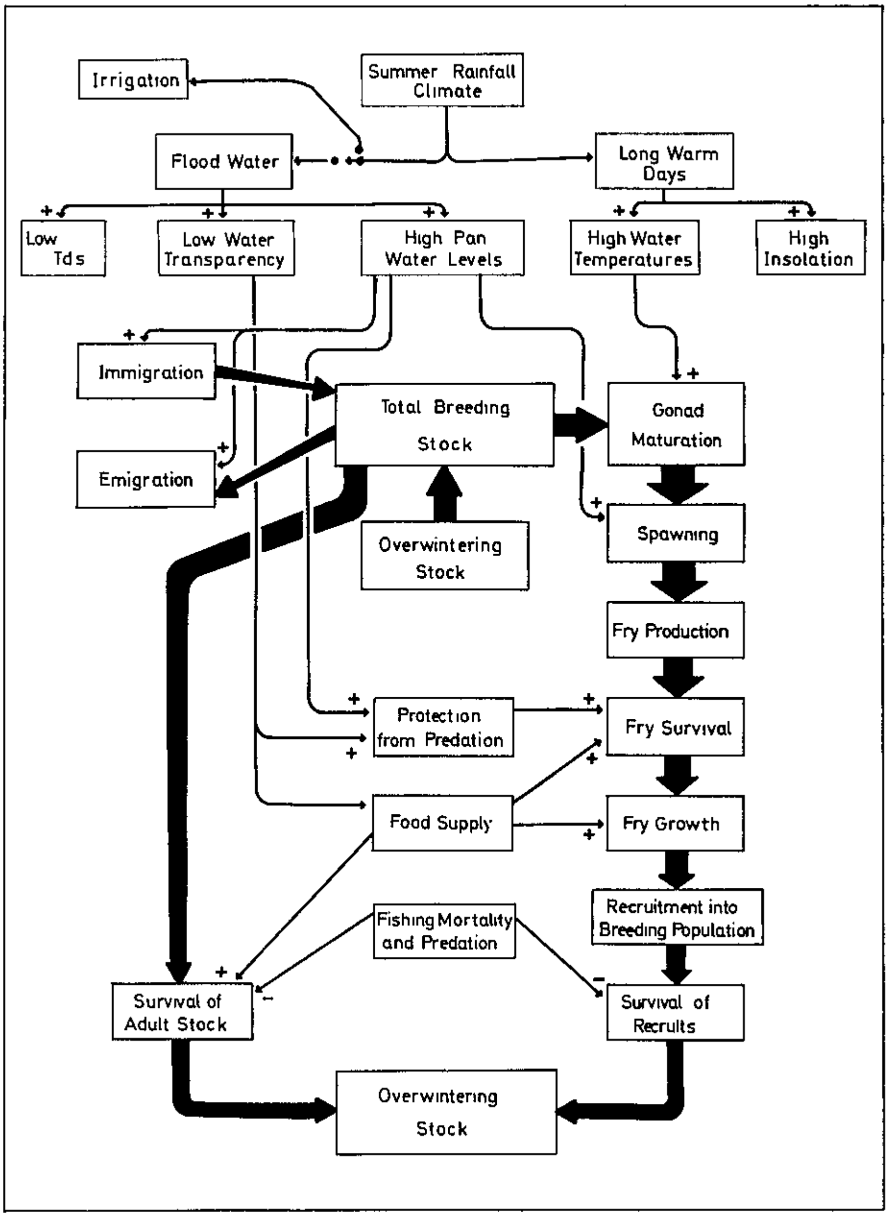


FIGURE 18. Annual cycle of fish recruitment on the Pongolo floodplain. Note effect of high water temperatures on gonad maturation and effect of high water levels on spawning.

Crocodiles

Crocodiles are primarily piscivorous and thus utilize a portion of the fish production of the system. There are an estimated 300 crocodiles on the floodplain, the average length of these being 2,5 m. Based on Whitfield's (1977) experimental feeding data, these reptiles would remove approximately 16 tonnes of fish from the system annually. In this they would be in direct competition with man, but since the bulk of the crocodile population is to be found in the Ndumu Game Reserve, their effect on that part of the floodplain currently utilized for fishing is not likely to be great.

Birds

The floodplain supports a variety of birdlife which utilizes it either as a feeding or breeding habitat. Ducks and pelicans feed on the pans during winter and spring, but their degree of dependence on the system cannot readily be assessed. A total of 30 endangered bird species included in the South African Red Data Book (Siegfried et al 1976) of which only the water birds are listed below, are known to occur on the floodplain.

White pelican	-	Pelicanus onocrotalus
Goliath heron	-	Ardrea goliath
Rufous-bellied heron	-	Ardrea rufiventris
White-backed night heron	-	Gorsachius leuconotus
Openbill stork	-	Anastomus lamelligerus
Wood stork	-	Ibis ibis
Woolly-necked stork	-	Dissoura episcopalis
Greater flamingo	-	Phoenicopterus rufer
Lesser flamingo	-	Phoenicopterus minor
White stork	-	Ciconia ciconia
African fish eagle	-	Haliaëtus vocifer
Lesser Jacana	-	Microparra capensis
Fishing owl	-	Scotopelia peli
White-winged plover	-	Hemiparra crassirostris
Caspian tern	-	Hydroprogne caspia

To what extent the above species are dependent on the Pongolo floodplain for their continued survival in South Africa is not known, but at least two of them make extensive use of the system. White pelican (Pelicanus onocrotalus) from the breeding colony on Lake St Lucia are known to feed on the floodplain from time to time, and in the breeding season carry fish from the floodplain to their young over a distance of 100 km (Whitfield 1977). Because their presence is transient, and also because they do not necessarily return to a particular pan to feed, the extent of their rôle as exploiters of the fish resources cannot be quantified. However, the fact that they have been observed on the system on many occasions, and that it appears necessary for them to undertake the long flight from St Lucia when feeding young, suggests that the Pongolo floodplain is important to the maintenance of the only breeding colony within our borders.

The extensive Phragmites australis stands in the Ndumu Game Reserve is one of two known breeding localities of the openbill stork (Anastomus lamelligerus) within the borders of the Republic and the Pongolo floodplain is one of the few areas where this rare bird can be regularly seen. This species is dependent on the floodplain for both breeding and feeding, since its diet is restricted to large molluscs (mussels and large snails) which need to occur in sufficient abundance and in shallow water for the birds to be able to obtain sufficient food. Suitable conditions for the openbill stork are thus almost entirely confined to productive floodplains.

Non-endangered species also play major rôles in the dynamics of the floodplain. White-faced duck (Dendrocygnus viduata) occur in large flocks during the peak of the Potamogeton crispus growing season. As many as 8 000 of these duck may be present on the 86 ha Tete pan during September, all feeding exclusively on P crispus turions. This species normally occurs in small aggregations throughout Transvaal and Natal. The large flocks which temporarily invade the Pongolo floodplain are indicative of its importance as a winter feeding ground.

Heronries of the cattle egret (Bubulcus ibis) are located in the Phragmites stands of the floodplain. These birds feed on terrestrial insects. The faeces may be locally significant in introducing plant nutrients into the system since large numbers of egret roost in the heronries at night.

Mammals

The mammallian fauna of the floodplain and its surroundings is, today, sadly depleted. Past records and the remnant of this faunal component which is preserved in the Ndumu Game Reserve indicate that the Maputaland Plain once harboured a large variety of game animals. Indeed, it was a favoured hunting ground during the 19th century. Early accounts of travels in the area all comment on this abundance of wildlife, and elephant (which still enter the area from Mozambique), rhinoceros, buffalo, kudu, nyala, bush pig, baboons and small antelope (presumably duiker and steenbuck) were reported as abundant in the area as late as 1887 (Saunders 1887).

Hippopotamus (Hippopotamus amphibius) have a direct influence on the system. There are at present about 220 of these animals on the floodplain, the majority of which confine themselves to the Ndumu Game Reserve. Some 40 to 50 may take up residence in pans outside the reserve during the summer, but many of these return in winter when pan levels drop. Hippopotamus are important to the system in that they replenish the detritus pool to some extent through feeding on the terrestrial vegetation during the night and defaecating in the water by day. Based on feeding studies by Field (1970) and assuming an assimilation efficiency of 35 percent, each hippopotamus would contribute between 4,2 and 5,2 tonnes of detritus to the pans annually, giving a total of between 1 774 and 2 184 tonnes for the system as a whole.

Cattle and goats occur in the area in considerable numbers. During winter the marginal Cynodon dactylon meadows provide grazing for these animals and the pans are utilized as a source of drinking water for this stock. Some faecal material from these animals finds its way into the aquatic system detritus pool as well.

Functioning of the ecosystem

Figure 19 summarizes the major seasonal events in the ecosystem. Spring is characterized by a peak in the standing crop of Potamogeton crispus, which with the approach of summer enters a phase of senescence. During this period, the P crispus provides the major source of energy for the secondary producers. Part of this, mainly the reproductive structures, is consumed by waterfowl and eventually leaves the system when they

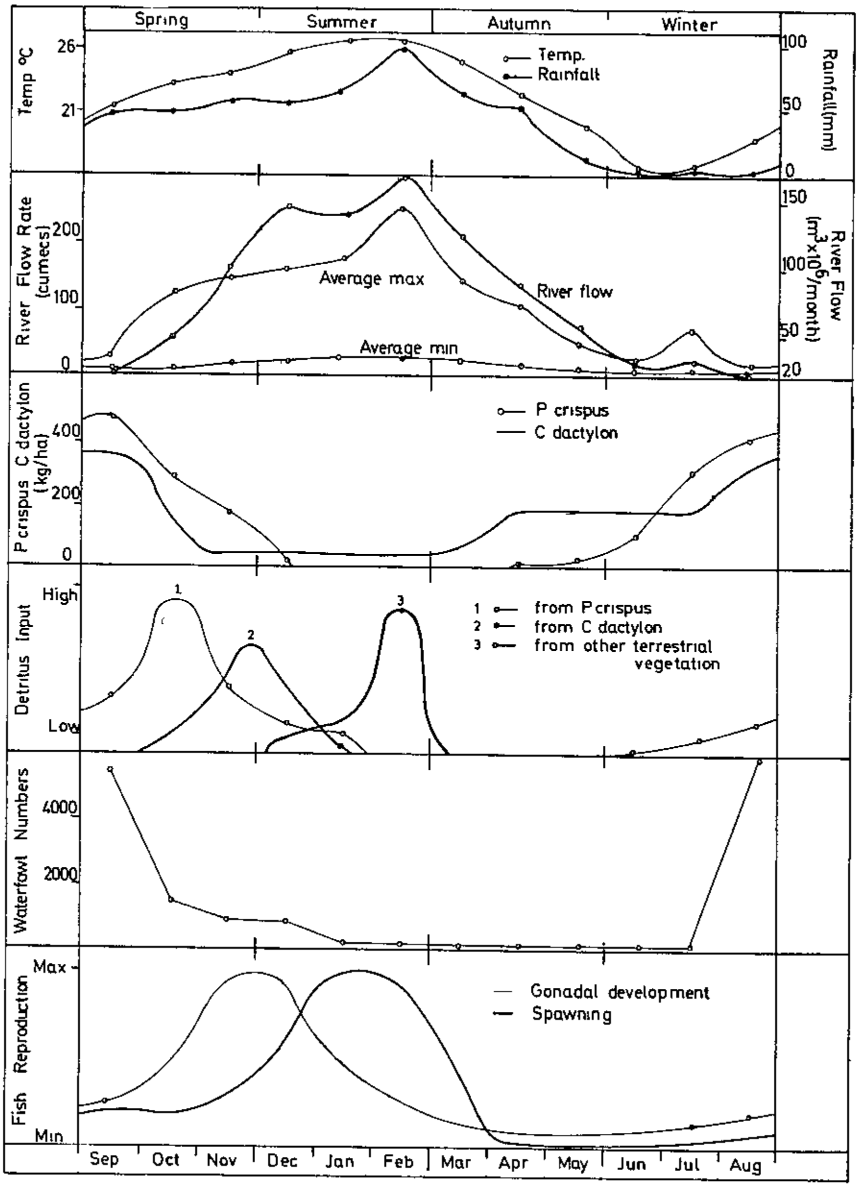


FIGURE 19. Seasonal fluctuations in standing crop of different components on the Pongolo pan ecosystem.

emigrate. Most of the remainder is consumed by snails and other invertebrates and is then transferred to fish and waterfowl. Senescence, decay and grazing all release nutrients into the water. Some of these nutrients become incorporated into the sediments and the remainder may be either taken up by primary producers or flushed from the system during floods. At this time, pan levels are low and the extensive Cynodon dactylon lawns are fully exposed. They thus are contributing to the terrestrial grazers and not to the aquatic system.

In spring, temperatures rise and gonad development in fish is initiated. Whilst some species, notably the Mozambique and red-breast tilapias, begin to spawn at this stage, the majority will not spawn until flood conditions arise.

The advent of the rainy season stimulates production in the grasslands and by November the first floods have normally arrived. At this stage the input from the Potamogeton crispus is almost complete and the primary producer component in the pans is at a low level.

During the summer months, there is a progressive increase in the magnitude and duration of successive floods. Not all pans are therefore flooded simultaneously, but fish gain access to and egress from a particular pan as soon as it joins the river. Thus pan to pan and upstream migrations occur at this time, often as a prelude to spawning. The inundation of marginal land around the floodplain pans stimulates spawning in many of the important fish species. The turbid floodwaters probably inhibit the productivity of the primary producers in the pans. However, the energy input into the pans increases as a result of inundation of terrestrial species. Not only are extensive tracts of terrestrial vegetation, notably C dactylon meadows, submerged and thus made available to the aquatic component of the system, but leaves, fruits and seeds are carried into the pans by the floodwaters as well. A rich and varied invertebrate fauna rapidly develops in the flooded margins, providing a source of food for young fishes. A floodplain pan, when connected to the river, is an open-ended system. High concentrations of dissolved solids resulting from mineralized seepage water and evaporation during the dry season which have accumulated in the pans are flushed out by the summer floodwaters and part of the plant nutrients resulting from the decomposition of plant material will be lost in the same way. A replenishment of the phosphorus pool comes from the phosphorus adsorbed onto silt particles which are carried in by the floods, while the nitrogen lost is presumably made good by nitrogen-fixing bacteria and blue-green algae growing on the submerged C dactylon.

Autumn sees a progressive reduction in river flow and pan levels drop to their maximum retention levels. With the receding floodwaters, the invertebrate fauna of the pan margins becomes more concentrated and the surviving young fish of the year are able to continue feeding in these margins well into the winter. With a drop in temperatures and daily wind run during autumn comes a lowering of both water temperature and suspended solids in the pans. A water temperature of 20°C coupled with good light penetration provides favourable conditions for the germination of P crispus turions. Thus, as the input from terrestrial sources dwindles, aquatic primary production is augmented by the growth of P crispus and the food supply for aquatic grazers is thus maintained. As pan levels drop, so the C dactylon, which has been dormant during the period of inundation and lost most of its aerial stems and leaves, recommences growth from viable underground stolons. Not suffering water stress in the now near saturated soil on the newly exposed areas, this grass has a very high rate of production which contributes to the available grazing for stock.

As winter progresses and conditions become drier, production of C dactylon is lowered because of both drier conditions and grazing pressure. However, continuously falling water levels, now to below maximum retention level, expose more of the substrate on which grass and annual plants can grow. At this time the standing crop of P crispus and its associated epiphyton is building up and it therefore takes over from C dactylon as the major source of energy for the secondary producers.

This attracts large flocks of white-faced duck which come in to feed on the P crispus turions. In so doing, they increase the rate of nutrient cycling and add to the detritus pool, as do hippopotamus in those pans deep enough to accommodate them.

The influence of environmental conditions on the energy flow between the ecosystem components described above are represented diagramatically in Figures 20 and 21 for summer and winter respectively.

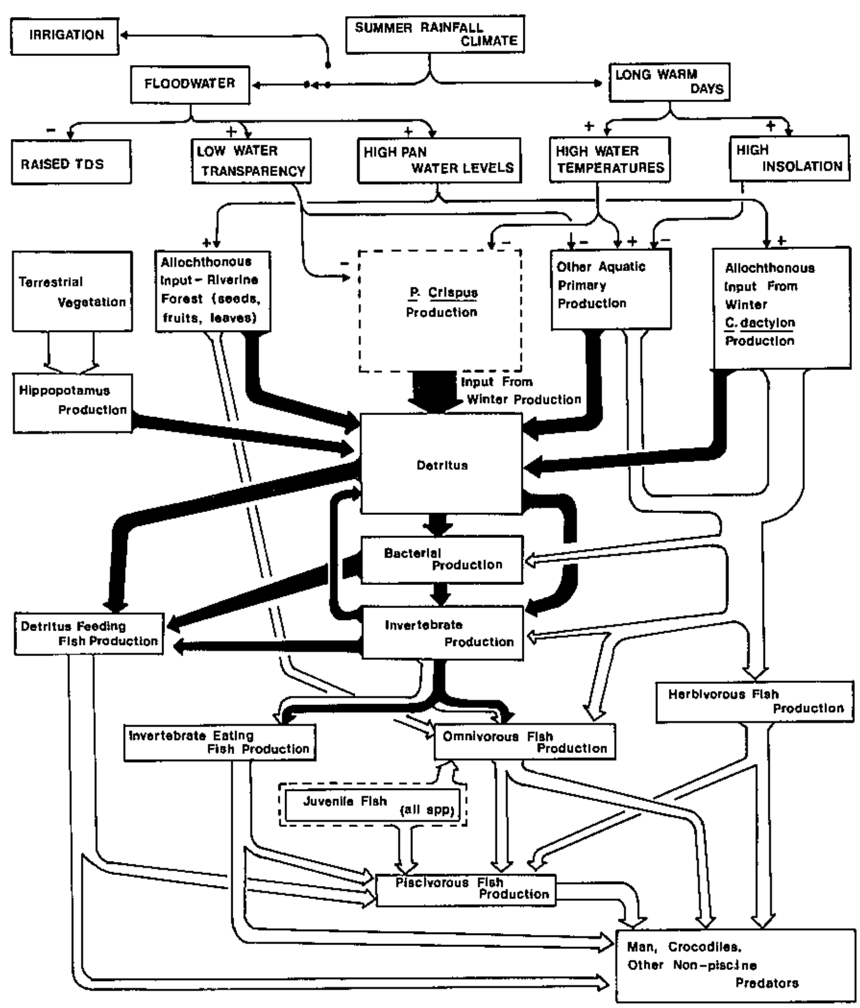


FIGURE 20. Interrelationships of the climatic, hydraulic and biological components of the Pongolo Floodplain ecosystem during summer. There are two main energy pathways through the system: a grazing pathway which has as its basis living plant material, and a detritus pathway (denoted by black arrows) based on dead plant and animal material, plus associated bacteria. Note that inputs of all allochthonous material is totally dependent on raised pan levels. Deviation of water for irrigation purposes will, therefore, exclude these energy sources from the system (see Figure 22).

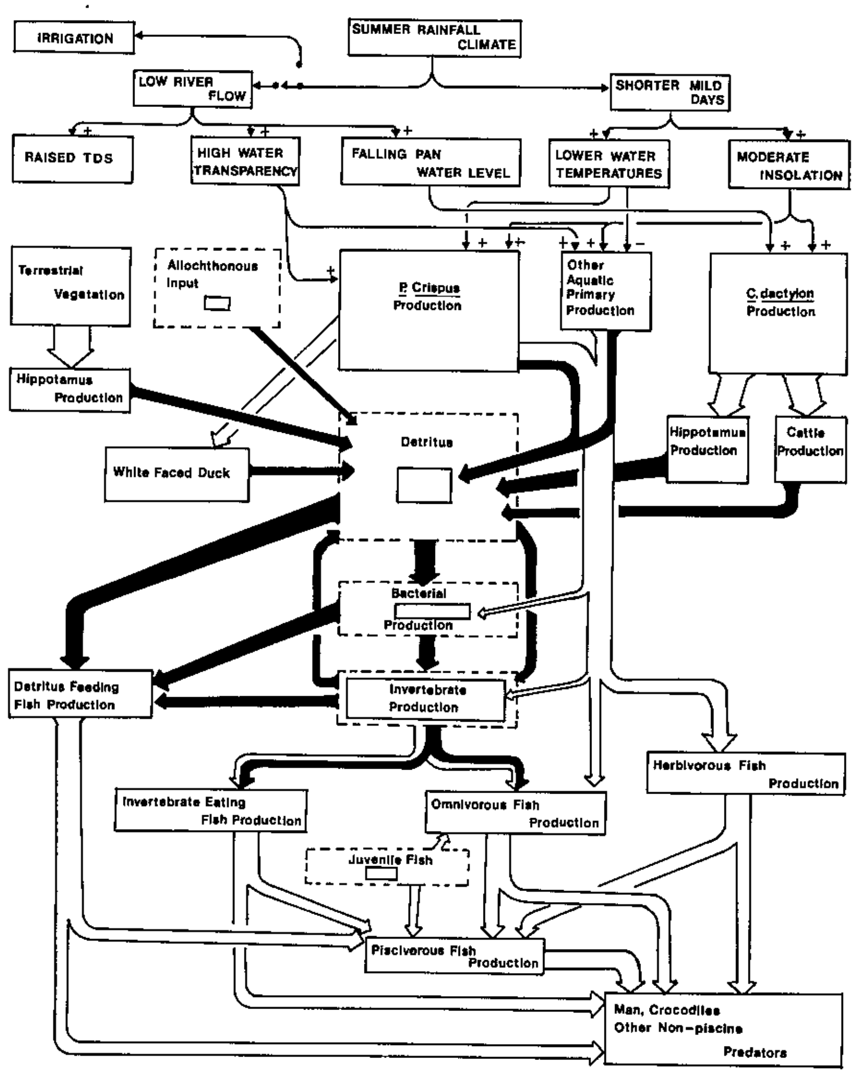


FIGURE 21. Interrelationships of the climatic, hydraulic and biological components of the Pongolo Floodplain ecosystem during winter. Allochthonous inputs are considerably reduced, and the winter growth of Potamogeton crispus forms the main basis for grazing food chains. Cynodon dactylon production is largely grazed by terrestrial animals, but the fraction remaining when the next summer floods arrive will contribute to the aquatic system during the following summer (see Figure 20).

Flood dependence of the system

Apart from the obvious dependence of the floodplain ecosystem on the annual Pongolo floodwaters for an adequate supply of water to fill the pans, important components of the system are geared to the seasonal flooding for their survival and input into the food web.

Among the primary producers, Potamogeton crispus depends on the floods not only to maintain a water level sufficient for growth, but also to flush out the dissolved salts which have accumulated over winter. This key primary producer has been shown to be intolerant of salinities of 5 000 mg l^{-1} or higher, a concentration which can readily be reached in some of the pans if they are not flushed out every year. Such high salinities not only inhibit germination of turions, but also retard the growth of established plants. The input of energy from Cynodon dactylon, Echinochloa pyramidalis and Cyperus fastigiatus into the aquatic system is directly dependent upon seasonal fluctuations in water level, allowing for growth when levels are low and exploitation when inundated. Without flooding, E pyramidalis and C fastigiatus are likely to disappear altogether with drying out of the marshy areas. C dactylon and other terrestrial floodplain vegetation may persist for a time, but without its assured water supply production will be greatly reduced. Subsequent grazing and trampling would create unstable conditions around the pans, leading to erosion and infilling of these shallow depressions.

Replenishment of the phosphate pool will be reduced with the cessation of floods, since less particulate matter carrying this essential plant nutrient will reach the pans. Should phosphate become the nutrient limiting growth rates of all primary producers, primary production will be diminished.

Reduced primary production must inevitably result in reduced secondary production. The rich and varied invertebrate fauna which inhabits the flooded margins will suffer a considerable reduction with the disappearance of a major portion of its habitat, thus diminishing the food supply for young fishes. The mid-pan invertebrates are, for the most part, dependent upon plant detritus from various sources and, should the input from C dactylon and other terrestrial plants cease, and that from P crispus become markedly less, these animals will receive food material only from hippopotamus faeces and from such marginal plants which may encroach into the shallow water. Hippopotamus too will abandon the pans once these become too shallow. The concentration of dissolved solids also has an effect on the invertebrate fauna. Oligochaete worms and mussels disappear from the pans when salinities are raised, and the composition of the zooplankton changes markedly.

Fish will be affected by the cessation of flooding in several ways. Spawning in all the important fish species, with the exception of the cichlids (tilapias), will be inhibited and the recruitment of adults into the pans will be precluded by the lack of migration routes. Flood dependent spawning is an effective adaptation, particularly in fish species inhabiting a floodplain, since it ensures that spawning will take place only when adequate food and shelter for the young fish is present in the habitat. During normal drought years there will be little or no spawning and resorption of the reproductive organs will provide reserves to tide the adult fish over the lean winter which follows. However, a complete cut-off of floods in consecutive years will preclude all spawning by the flood dependent species and they will gradually disappear from the system. An increase in the dissolved solids of the pans will also have a direct effect on some fish species. Both the churchill and the bulldog rely on the production of an electric field around themselves in order to locate prey, a mechanism which cannot work in water of a high electrical conductivity resulting from increased dissolved salts in the water. Apart from a reduction of food material originating in and around the pans, cessation of flooding will also eliminate the import of food materials, notably seed and the fruits of Ficus sycomorus, into the pans.

Species such as the butter barbel and the imberi utilize these as food to a considerable extent and will thus be deprived of important (even if seasonal) components to their diets.

Crocodiles and birds are dependent upon components of the aquatic system already mentioned for their presence in the floodplain ecosystem and will, if deprived of these, themselves disappear. The maintenance of the whole ecosystem therefore hinges on a regular supply of floodwater, sufficient in magnitude to flush out the system and to allow for fish migration, and sufficient in duration to allow an adequate transfer of energy rich organic material from the terrestrial to the aquatic components.

Figures 22 and 23 show the effects of the cessation of flooding on the Pongolo floodplain ecosystem.

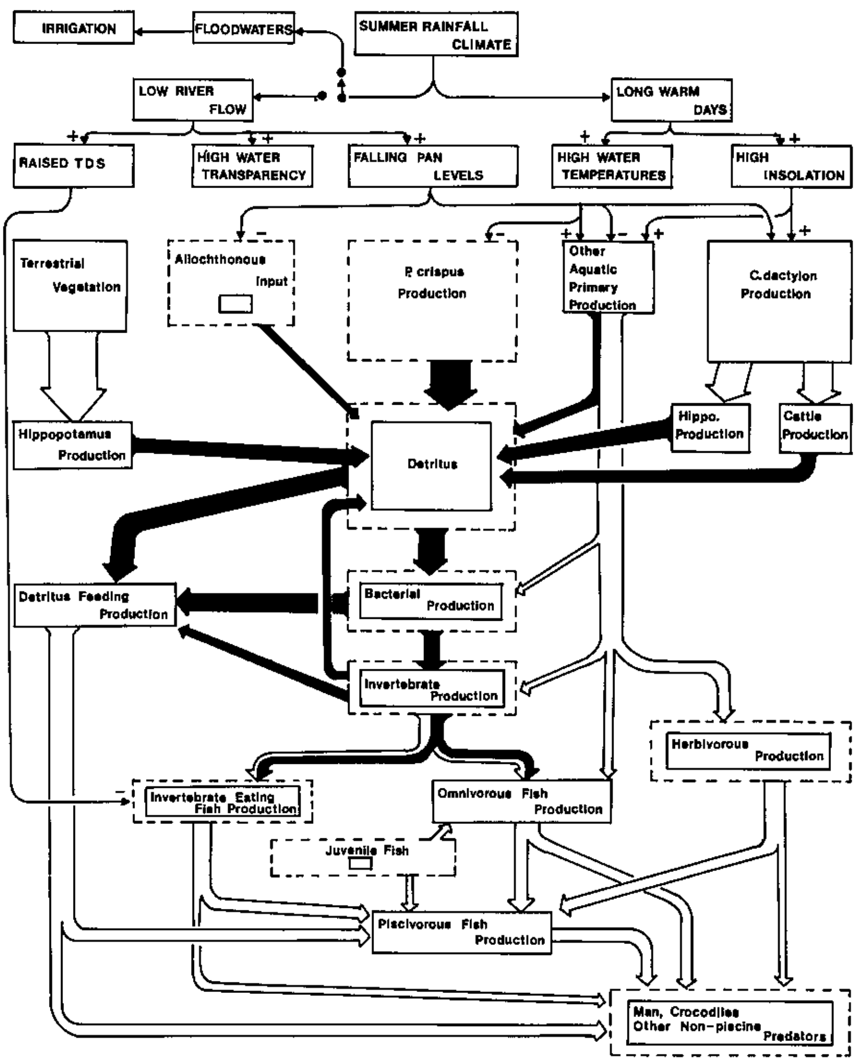


FIGURE 22. Effect on the summer energy flow pattern and fish production of the Pongolo Floodplain ecosystem resulting from diversion of floodwaters for irrigation purposes. Apart from the drying up of several pans, allochthonous input remains at or falls below winter levels, and without the Potamogeton crispus production typical of winter, the grazing pathways are severely curtailed. Most fish species will not spawn unless terrestrial vegetation is flooded.

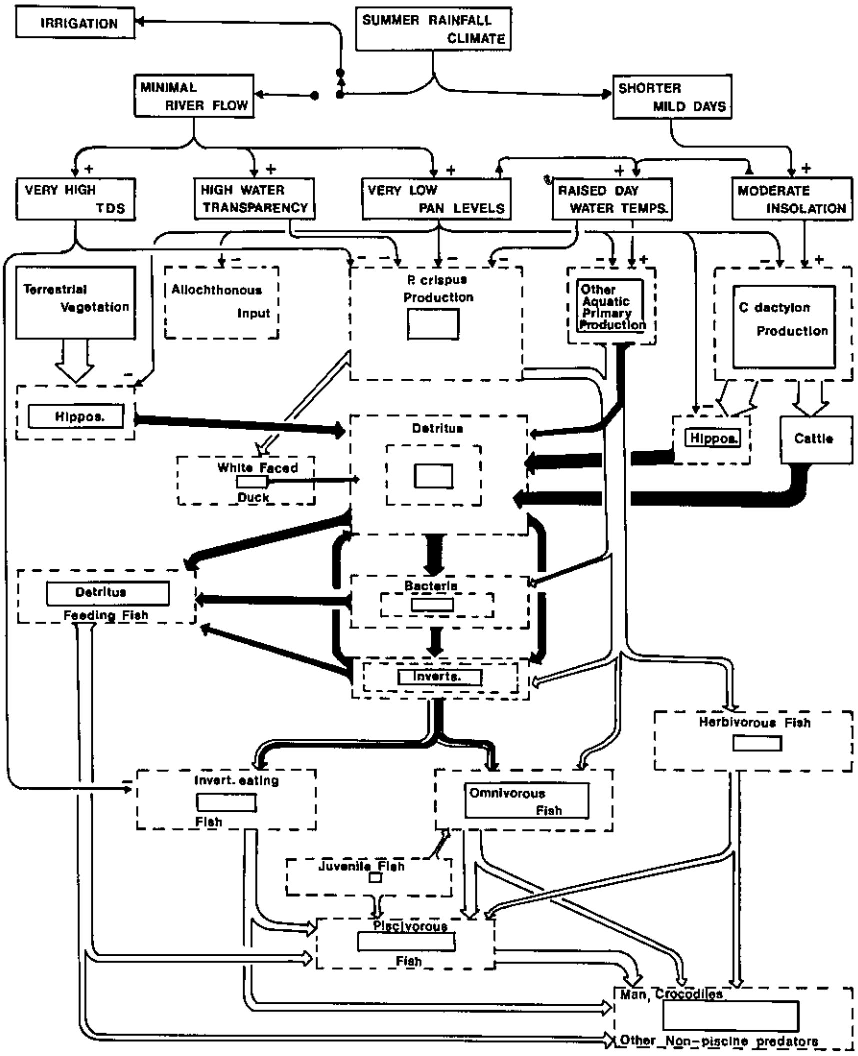


FIGURE 23. Effect on the winter energy flow pattern and fish production of the Pongolo Floodplain ecosystem resulting from diversion of floodwaters during the preceding summer. Potamogeton crispus production is restricted due to low water levels while that of Cynodon dactylon is reduced as a consequence of having received no flood irrigation. Hippopotamus leave the pans as a result of low water levels and waterfowl abandon the area through lack of food. With the diminishing detritus pool, all production runs down. C dactylon meadows will disappear entirely within a few years, thus eliminating valuable winter grazing.

MAN AND THE PONGOLO

The Tembe-Thonga people form the bulk of the population inhabiting the immediate environs of the Pongolo. They have been there a long time and have evolved a pattern of living which is dependent upon the manifold natural resources of the area. The benefits they presently derive, or could potentially draw from these existing resources should be borne in mind in planning future development and modernization.

The people and their socio-economic structure

Early records show clearly that the Tembe-Thonga, who are supposed to be an offshoot of the Calanga or Karanga peoples, have been settled around Delagoa Bay for many centuries. Like the Zulus, they are divided into a number of chieftainships. However, they were never united under a Paramount Chief and the clan structure has remained stronger among them than among the Zulus. Clan chiefs usually appoint members of their own family as district izinDuna and choose sub-district headmen from among the original families living in the sub-district. The district inDuna and the subdistrict inDuna play the most important rôle in the everyday life of the average tribesman and in the socio-economic life of the group. The inDuna controls access to all natural resources such as land, wild fruits and fishing rights in the area under his jurisdiction. The district inDuna's court, although not recognised by the administration, is the most important judicial institution in the Tembe-Thonga society.

Control over the natural resources of an area by headmen has its roots in the history of the Tembe-Thonga. Confined to an area of low agricultural potential a form of shifting horticulture on the alluvial soils of the floodplain has developed. Crops were planted on the banks of the pans or, during periods of drought, in the pans themselves. In addition fish formed one of the main sources of protein (the eating of fish further distinguishing the floodplain inhabitants from the Zulu). Both crop growing and the floodplain fishing are subject to the vagaries of the climate and flooding regime. Consequently the right to exploit these resources needed to be controlled in a manner that led to their equitable partitioning.

Recent population growth has led to increased exploitation of natural resources. This is evidenced by degration of the vegetation. A rough estimate of population growth can be derived from a comparison between the 1960 and 1970 census for the black population of the Ingwavuma and Ubombo magisterial districts. These give a population growth rate of 13,8 per cent over the decade, as shown in Table 10.

Up to now employment opportunities in Maputaland generally have been very limited and a considerable proportion of the able-bodied men and some women are compelled from time to time to find work outside their home districts as migratory workers. As shown in Table 10, the increase in the male population over the decade was only six per cent, compared with 19,7 per cent for females, and the male : female ratios were 0,8:1 and 0,7:1 for 1960 and 1970 respectively. This discrepancy can only be attributed to between 18 and 19 per cent of the male population having

TABLE 10. Total black populations resident in the Ingwavuma and Ubombo districts in 1960 and 1970.

Year and district	Males	Females	Total
1960			
Ingwavuma	30 998	38 562	69 360
Ubombo	11 968	14 401	26 369
Total in 1960	42 966	52 963	95 929
1970			
Ingwavuma and Ubombo	45 548	63 416	108 964
Increase 1960 to 1970	2 582	10 453	13 035

been employed outside the area during 1960 and this fraction having increased to 28 per cent by 1970. Most people interviewed have worked near Empangeni, Richard's Bay and elsewhere on the North Coast and some have been employed as far afield as Durban and the Witwatersrand.

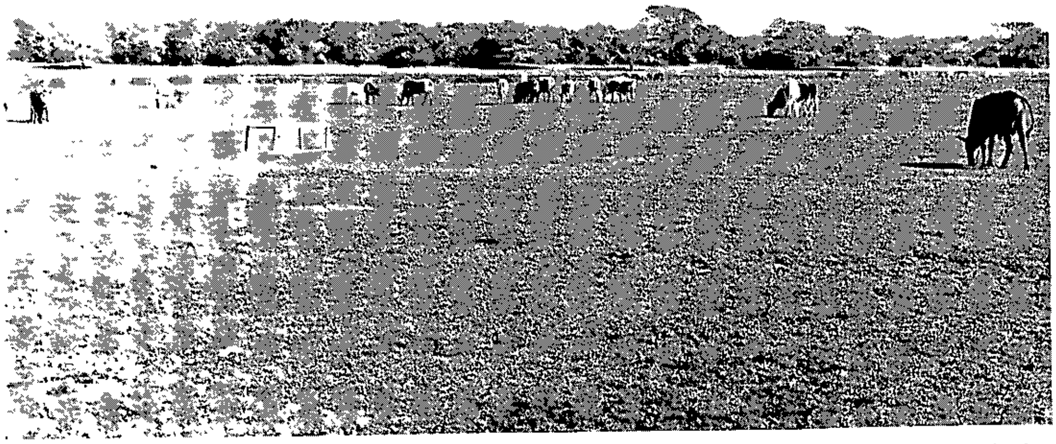
The inhabitants of the Makatini Flats surrounding the floodplain are probably all Tembe-Thonga who have adopted Zulu nationality. They comprise about 35 per cent of the total black population of Maputaland. Table 11 gives details of their distribution.

Current utilization - agriculture

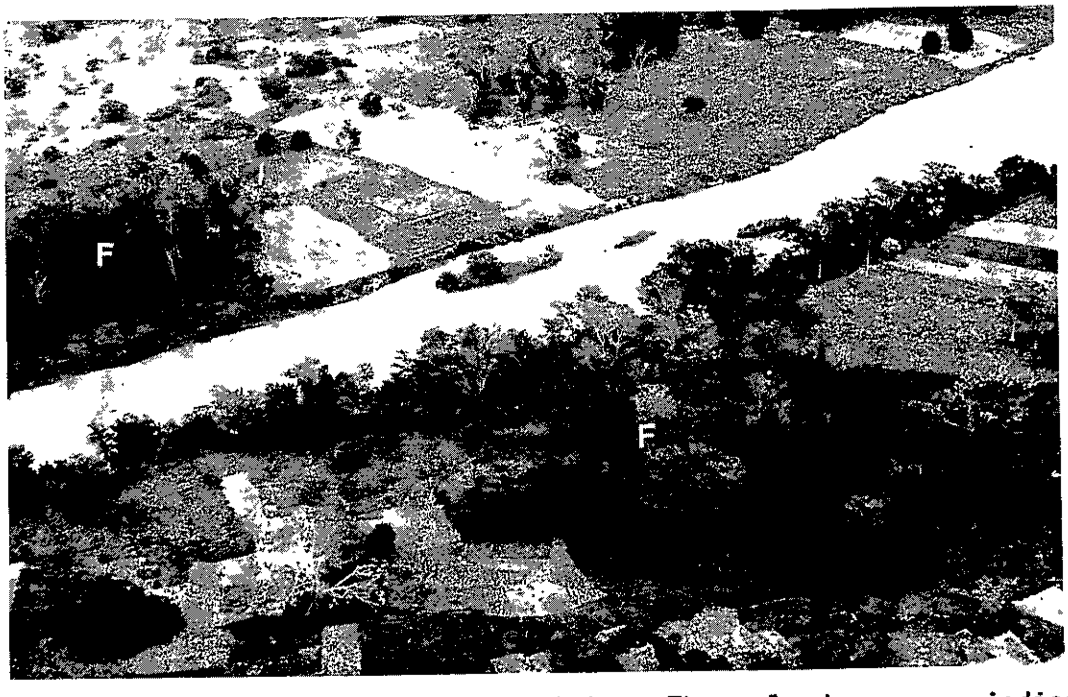
Maize, groundnuts, pumpkins, sorghum, tomatoes, tuber crops and sugar cane are all traditionally grown within the floodable area on a subsistence basis. During most normal years the local population is, therefore, almost self sufficient. Periodic inundation of the floodplain is necessary for this essential food production in that the floodwaters that bring in nutrient rich sediment prepare the soil for ploughing and provide the necessary water for plant growth in an area where evaporation exceeds precipitation. With normal flooding the people often raise two crops per season. The lands are situated at a level where they are repeatedly inundated for only short periods of time and both flood reductions and the attenuation of high floods can therefore completely destroy a planting.

Although cattle are still a symbol of wealth and were formerly seldom sold or slaughtered, they are now more often disposed of and stock sales are held regularly. Goats are increasingly in evidence in the area.

PLATE 9. Subsistence agriculture on the Pongolo floodplain.



(a) Cattle grazing on the Cynodon dactylon meadows at Namanini Pan. These meadows, which are subject to periodic inundation, have an extremely high annual production, and provide important winter grazing. Exclosures (E) which prevent grazing by cattle were used to assess this production. (Photo: H D Furness)



(b) Subsistence lands on the floodplain. These lands are periodically flooded during the summer season, when they also receive an input of nutrient-rich silt. Floods thus provide both irrigation and fertilization. Note the extent to which riparian forest (F) has been removed. (Photo: H D Furness)

(c) and (d) The productivity of the floodplain lands is illustrated by these two stands of maize. The maize shown in (c) (right), growing on the floodplain was photographed on the same day as that in (d) (below), grown beyond the reach of the floods. The floodplain lands often yield two crops in a season, and surplus maize is bartered or sold off the floodplain.
(Photos: K H Rogers)

TABLE 11. Population of the Makatini Flats and surrounding area (1973) excluding those people living in the Lebombo Mountains.

District and area	Kraals	Huts	Persons
Ingwavuma			
Ndumu	896	2 670	4 540
Shemula	830	4 567	6 215
Mlambo	700	2 259	4 246
Makani's Drift	395	957	2 297
Tete pan	565	1 291	2 691
Otobotini	677	2 465	5 173
Ubombo			
Siphondweni	689	2 082	4 787
Tsongwe	222	585	1 253
Mamfene	579	2 031	3 408
Ophansi	753	3 229	5 105
Total	6 303	22 136	39 715

There appears to be an increase in stock theft for sale and slaughter. The *Cynodon dactylon* meadows which surround many of the pans are extremely important as winter grazing for the livestock of the area, and these are entirely dependent upon periodic flooding for their maintenance.

It is evident that all the most suitable sites for cultivation on the floodplain are currently being exploited and there is increasing utilization of the less productive dry land sites in the sand forests. In addition, overgrazing is apparent on the floodplain. Improved returns from subsistence agriculture will only be achieved by an improvement in farming practice.

Current utilization - fisheries

The importance of fishing in the social life of the Tembe-Thonga suggests that most of the population on the Makatini flats eat fish. In the past, it could well have represented their major source of animal protein.

A variety of fishing methods are practiced by Tembe-Thonga of all age groups:

- The most spectacular method is isiFonya fishing. Here a line of people, all wielding baskets is formed right accross a pan and the fish are driven towards the shallows by the moving line, all thrusting their baskets into the water. The dome-shaped basket is made of sticks positioned about 1 cm apart The base of the basket, which is open, has a diameter of between 0,5 and 1 m and the height is not more than the arm length of the owner. Captured fish are extracted through a hole at the apex (see Plates 10 and 11).

- The mona-basket (Plate 11a) is a valved trap constructed out of reeds, often placed in a specially constructed reed fence barring a water course. This form of fishing is more commonly used during floods, when fish are migrating into and out of pans. Single baited baskets are sometimes used in the floodplain pans.

- A very primitive form of seine netting is practised by women and children, who make long bundles of grass and weeds and push these through the shallows thus driving numbers of small fingerlings towards the edge of the pan and then catching these by hand. Occasionally women may drag a length of fabric through the shallow water in order to catch small fish.

- Modern techniques include line fishing (with or without a rod) and gill netting. The latter technique is restricted to a few individuals, possibly controlled by the local inDuna.

These fishing methods are to some extent complementary to one another, since they catch different sizes and species of fish.

It has been estimated that the population harvests about 400 tonnes of fish from the floodplain each year and that the potential yield could lie between 500 and 750 tonnes per annum. The fishery is therefore regarded as being under-utilized at present.

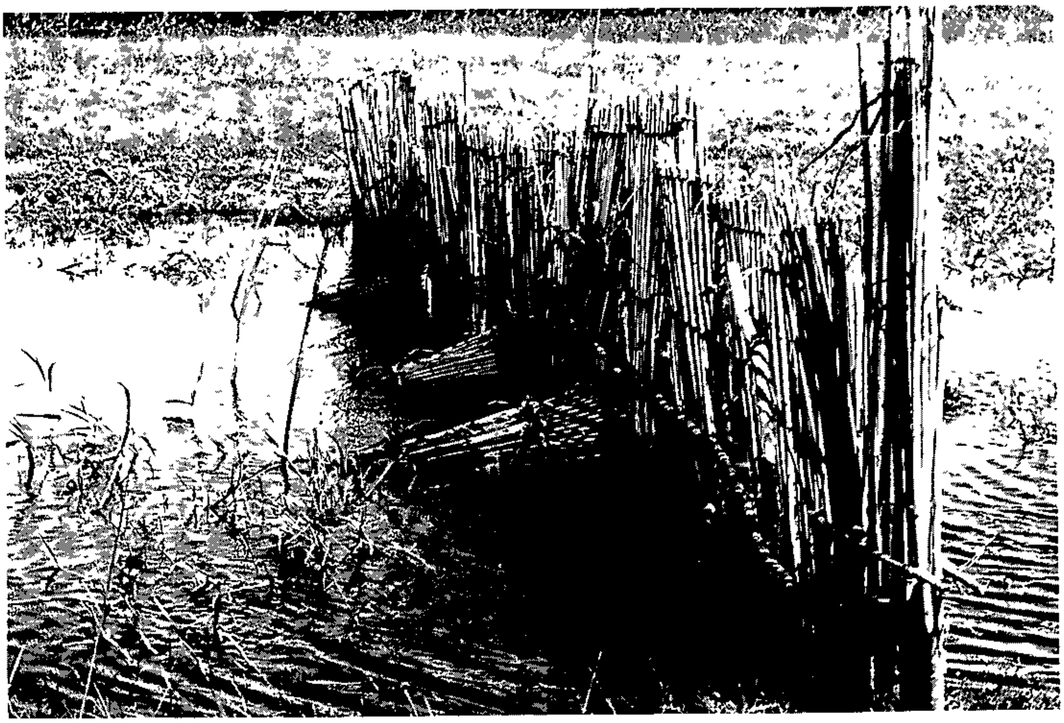
Current utilization of other resources

Much of the building material used in hut construction is obtained from the floodplain and surrounding forest. Most important are poles, reeds for roofing, and sedges for mats and baskets.

Food resources are supplemented by water plants, particularly water lily tubers (*Nymphaea*) and water chestnuts (*Trapa*) and the fruits of *Strychnos* and *Landolphia* from the forests. These are utilized when there is crop failure or between season. The fermented sap (ubuSulu) of the ilala palm (*Hyphaene*) is widely drunk and traded. Game in general is very scarce, but a limited amount of waterfowl trapping is practised (Plate 12). Hippopotamus, which are culled from time to time by the Natal Parks, Game and Fish Preservation Board, provide another protein source.

Increasing demand by the growing population is reducing the availability of most natural resources of food and building material resulting in an

PLATE 10. Fishing methods.



(a) Valved basket traps (uMona) are extensively used to catch fish throughout Maputaland. Allocation of rights to set fish traps is the responsibility of the local headman. (Photo: K H Rogers)

(b) Fonya baskets are used in large fishing drives, often with several hundred participants (see Plate 11) called together by the local headman. Small groups of youths and women can, however, frequently be seen using the baskets to catch daily fish requirements. (Photo: J Heeg) increased dependence on materials imported onto the Makatini Flats. Large scale agricultural development will aggravate this situation even further.

Future development - agriculture

On the Makatini Flats, the quantitity and quality of available water, the climate, the topography of the land, and the nature of the soils are favourable for agricultural development, and some are very favourable. Frost free winters make the area eminently suitable for sub-tropical crops; experiments conducted at the Makatini Agricultural Research Station over a number of years have shown that sustained high yields can be obtained from a variety of such crops. Proven success has been achieved with citrus, winter vegetables, sugar cane, cotton, rice, groundnuts, certain types of tobacco, maize, beans, sorghum, soya beans, cassava and winter wheat.

Those soils considered to be irrigable fall into three broad categories based on their permeability:

- the clayey, slowly permeable, soils consist mainly of the Oakleaf, Shortlands and Bonheim forms and are optimally suited to the growing of rice, sugar cane, cotton, sorghum and wheat.

- the loamy soils are medium textured, consisting mainly of the Hutton, Oakleaf, Dundee and Shortlands forms. Optimal productivity can be obtained from a wide range of crops on these soils, the more important being sub-tropical fruits, sugar cane, cotton, winter vegetables, citrus, wheat and sorghum.

- the sandy soils, coarse textured members of the Clovelly, Oakleaf, Hutton and Kroonstad forms, which provide optimal soil conditions for the growing of groundnuts, cassava, certain types of tobacco, citrus and winter potatoes. Sustained high yields have also been obtained from sugar cane, but because of the danger of widespread nematode infestation, these soils must be regarded as sub-optimal for this crop.

During the planning and production phases of irrigation schemes considerable attention needs to be given to the drainage aspect. This is particularly true for any scheme on the Makatini Flats with its long gentle slopes. Salt accumulation in the deeper layers of certain soils and the salinity in the underlying Cretaceous rocks together with the rapid permeability of the sandy soils have the potential for bringing additional saline seepage water to the floodplain.

Future development - fishing and fish farming

The potential fish production of the Pongolo floodplain is extremely difficult to assess because there is almost no information on the amount of fish removed by the local population or on the area's standing stock of fish. Experimental fishing in selected pans on a regular monthly basis has been carried out over a period of three years and this has given a measure of the catch which can be expected for a particular

PLATE 11. Subsistence fishing on the Pongolo floodplain.

(a) Fonya drive on Mtigi Pan using the valved basket. The line of 200 participants, predominantly men and boys in the 1950's, extends from shore to shore across the pan. In the 1970's participants were chiefly womenfolk and groups of up to 800 have been recorded by Poultney (1980). (Photo K L Tinley)

(b) Close up on a fonya drive, Namanini Pan, showing the fonya baskets being used to capture the herded fish. Inhabitants of the Okavango use baskets and fishing methods similar to those of the people of Maputaland. (Photo: K H Rogers)

(c) Fonya catch, Namanini Pan. Catfish (Clarias species) are frequently caught in fonya drives because of their sluggish habit. This photograph was taken shortly after the first floodwaters had entered the pan, the fish caught being immigrants from elsewhere in the system. As Namanini is one of the first pans to receive floodwaters, it is likely that these fish came from downstream, probably north of the Mozambique border. (Photo: K H Rogers)

(d) Barbel biltong. The preservation of fish by sun drying is a custom which the amaThonga share with the fishing people of the Okavango and the Zambezi floodplain. (Photo: M Coke)

PLATE 12. Wildfowl utilization.

(a) White faced whistling duck (Dendrocygna viduata) gather on the floodplain pans in large numbers to feed on the abundant Potamogeton crispus during winter. The duck, which have attained a density of 93 per hectare on Tete Pan, form another important source of protein for the local inhabitants. (Photo: H M Kok)

(b) Duck trap consisting of a closely set fence of Cyperus stalks with a number of narrow openings, each furnished with a noose (N). (Photo: H M Kok) fishing effort, but it does not give a direct indication of actual fish production. Inferential methods, comparisons with known statistics from other tropical African floodplain fisheries and indirect evidence from the local fishery can, however, all be used together with the results of experimental fishing to estimate the value of the fishery. While these cannot give a precise assessment of the Pongolo fishery potential, they can indicate an order of magnitude which may be used with some confidence.

A floodplain fishery which is comparable with the Pongolo is that of the lower Shire River in Malawi. This produces some 8 000 tons per annum, which is the equivalent of 65 kg $ha^{-1}a^{-1}$. Of the total yield, some 85 per cent comprises barbel (Clarias) and tilapias (Hastings 1973) and the catches per unit effort from the Shire are comparable with those obtained in the experimental fishing on the Pongolo. Welcomme (1975) has examined the commercial catches from twelve African floodplains ranging from the Shire in the south to the Niger Delta in the north and including the Barotse and Kafue floodplains of Zambia. From his studies he deduced that the expected mean catches from all African floodplains range from 30,55 kg $ha^{-1}a^{-1}$ for the least productive to 68,51 kg $ha^{-1}a^{-1}$ for the most productive, with an average of 49,53 kg $ha^{-1}a^{-1}$, the area applicable being the maximum area flooded in each case. Applying these figures to the Pongolo floodplain, with a maximum floodable area of 10 416 ha, gives an average of 516 t a^{-1}, with a minimum of 318 and a maximum of 714 t a^{-1}.

The above figures find some substantiation in a consideration of the present subsistence fishery. About 40 000 people have access to the floodplain as a source of animal protein. These people show no signs of malnutrition and are, therefore, likely to be receiving adequate animal protein in their diet. Indeed the nutritional status of the people of Maputaland is known to be the highest for any rural black population in Natal (Department of Dietetics and Home Economics, University of Natal). They fish at no great effort all the year round, thus fish must make a substantial contribution to their diet. If each individual were to consume 10 kg live weight of fish per year, which, allowing for the inedible fraction, would account for some 10 per cent of his annual protein requirement, then the population would extract 400 tonnes from the system each year. The experimental fishing, undertaken over and above the subsistence fishery during the period 1974 to 1977, showed no signs of diminution of catch, which would indicate overfishing, thus it may be confidently assumed that the application of Welcomme's mean figure of 516 t a^{-1} is safe, but probably conservative, estimate of the value of this particular fishery. Based on available catch per unit effort data, the Pongolo floodplain may well be comparable with the Shire fishery, which is productive enough to be above Welcomme's average, in which case the fishery could yield some 680 t a^{-1}.

There can be no doubt that the potential fish yield of the floodplain system exceeds the current demand made on it by the subsistence fishery and commercial exploitation. Providing fish to people living away from the floodplain may therefore be a viable proposition. Such a fishery would need to be controlled by issuing only a limited number of licences on a year to year basis to prevent over-exploitation. A pilot scheme encompassing all aspects of a commercial enterprise should be started not only to establish the feasibility of such an enterprise, but also to provide basic information for the setting of catch limits and mesh sizes. Further studies to determine the subsistence level of utilization should be carried out concurrently with such a pilot scheme.

A value on the water required to produce the above quantities of fish can be arrived at on the basis of market replacement value, ie the cost of purchasing fish from elsewhere if fish production on the floodplain were to cease. At a replacement cost of R1,00 per kg, the opportunity cost of the necessary water is between R516 800 for an annual yield of 516 t and R680 000 for a yield of 680 t a^{-1}. This means that if the water is used for irrigation it would have to make a net profit of between R172 and R227 ha^{-1} on 3 000 ha.

Fish farming

The floodplain is totally unsuited to aquaculture. The construction and management of permanent ponds in an area subject to periodic flooding is not feasible and the release of enriched or saline water from ponds into the pans or river is undesirable.

Great possibilities do, however, exist for the incorporation of fish farming into the proposed irrigation schemes envisaged for the Makatini Flats. The Rensburg soils, because of their clay and salt content, are unsuitable for irrigation agriculture but they are eminently suitable for fish culture. A possible area is situated south of the Makatini Agricultural Research Station and between the research station and the Jozini road. It is estimated that a pond of 1 ha, properly managed in accordance with modern aquacultural methods, will readily yield between one and three t a^{-1} of fish. A reasonable price, ex pond, would be 75c kg^{-1}, giving a return of R750 t^{-1} each year or up to R2 250 ha^{-1} of pond each year. The return is not net profit, of course, since the ponds need to be managed and enriched. However, such a system could be complementary with agriculture and not compete with it either for water or for irrigable soils.

Suitable species for aquaculture already occur locally, particularly the Mozambique tilapia (*Sarotherodon mossambicus*), the catfish or barbel (*Clarias gariepinus*) and the red-breasted tilapia (*Tilapia rendalli*); flat head mullet (*Mugil cephalus*) are available for stocking from nearby Lake St Lucia. All of these species can tolerate water of considerable salinity, thus irrigation seepage water may be used for this purpose.

Future development - tourist potential

There can be no doubt that the floodplain, as it exists today, has considerable potential for tourism. The area has an abundance of bird life and still supports populations of hippopotamuses and crocodiles. The essentials for the development of a small but profitable tourist industry exist in the area.

The Ndumu Game Reserve is already established in the area, and has proved popular with wildlife enthusiasts, particularly those with an interest in bird life. The reserve harbours a variety of game, although not all species known to have been present in Maputaland in the past are represented. Reintroductions could be effected, but this would probably require an extension of the reserve's borders into the sparsely populated adjacent sand forest area to the east of the present boundaries. It is doubtful whether any further game reserves per se can be established on the floodplain until other arrangements are made for the local population, since the land is occupied and too valuable in terms of human subsistence.

Game reserves, because of their restricted area and frequent lack of adequate predator populations, require careful management and frequent culling of herbivore populations in order to maintain the quality of the range. Such culling not only provides food but can be turned to profit by allowing controlled hunting as is the current practice in the provincial game reserves of the Orange Free State. Additional controlled hunting areas could also be established outside the reserves, and on the floodplain itself necessary culling operations could allow the hunting of species not available elsewhere in South Africa, notably hippopotamus and crocodile.

The provision of limited rustic accommodation and basic facilities for angling (ie boats and motors for hire) should prove popular with the discerning angler who will be able to enjoy his sport in unique surroundings. One or two such facilities at selected pans are likely to prove attractive, as the variety of angling fishes available is unsurpassed in South Africa, and includes the much sought after tigerfish, Hydrocynus vittatus.

A more intensive recreational angling complex can be established on the Pongolapoort Dam. The lake would need to be stocked with tigerfish if it is to draw anglers, since this species does not breed in the lake (Kok, Blaber and Walley 1978). Such stocking would need to take place annually and for this the floodplain pans are the only source of young fish which would make this an economical proposition. The lake, by virtue of its size, can support competitive angling, which could lead to more extensive recreational development with a hotel complex, caravan park and other recreational needs.

Tourist development will bring in revenue and provide both direct and indirect employment, including the production and sale of traditional arts and crafts. The whole area along the national road, from the Pongolo to the coast, includes several reserves (Mkuzi, Umfolozi, Hluhluwe) and resorts (Lake St Lucia, Sodwana Bay) thus a steady flow of visitors is assured. However, a measure of caution is required in extending existing tourist routes to include the Pongolo floodplain. The development of the tourism in that area, because of the fragile nature of the ecosystem and its importance in the lives of the inhabitants, should be such as to impinge minimally on both the habitat and the people. For this reason access to the floodplain should be restricted, with only a limited number of visitors allowed at any one time. This need not incur any great loss in potential revenue, since the desirable and discriminating visitor will be glad to pay more for the privacy which such a system will afford.

IMPACT OF DEVELOPMENT

This document has presented evidence on the suitability of the Makatini Flats for agricultural development, based on irrigation from the Pongolapoort Dam. That such development is both feasible and desirable is beyond question. It remains therefore:

- to assess the potential impact of development on the floodplain and its immediate surrounding;
- to consider methods whereby the impact of development may be minimised;
- to define development options in respect of these impacts;
- to assess the cost: benefit aspects of implementation of the development of the area.

Key factors

The floodplain and those people currently deriving a living from it will be affected by three major environmental changes:

Reduction in water availability

Water is required for domestic and agricultural needs as well as for the maintenance of the floodplain, in which it is the most important factor. It should be clear, from what has gone before, that the water is required in the form of simulated floods if it is to maintain the present level of productivity of the floodplain. Deviation from the natural pattern can result in:

- decreased energy flow, nutrient input and consequently lowered productivity;
- cessation of recruitment of fishes, including desirable food and angling species;
- cessation of flood irrigation of subsistence lands;
- loss of winter pastures;
- loss of plant food and building sources eg Nymphaea, Trapa, Phragmites.

Deterioration in water quality

Whatever water is available to the floodplain and the downstream population must be of such quality as to have no detrimental effects on man, plants or animals. Water availability, population density and development, whether agricultural or industrial, can all have an effect on this. The main factors influencing water quality are discussed in Chapter 4.

Decrease in available land

There is clear evidence that all land suitable for subsistence agriculture is at present occupied and that even the natural population increase is forcing people into sub-optimal areas of lower productivity. The land, which is either fragile and subject to erosion or unproductive, is therefore already overutilized. In addition, the area is overstocked with livestock as evidenced by the overgrazing in most parts of the floodplain.

The availability of an irrigation scheme will materially increase the carrying capacity of the land, both in terms of people and of livestock. However, the development is going to be costly and the nature of the soils is such that the application of irrigation water will require considerable expertise. Initialy estate development is likely to be the preferred option. Such development, while it will absorb part of the population which it must inevitably displace, is bound to necessitate the removal of the remainder to other suitable subsistence areas. It is very likely that the labour force for estate and infrastructure development will comprise men who at present export their labour (ie the migrant labour component which is so clearly reflected in the population census figures). This population shift will probably affect the increased production potential; people displaced will have to be resettled on land rendered productive by the irrigation scheme so as to permit estate development.

However, while the irrigation scheme will probably provide the answer to the land availability problem for the present, and perhaps even the immediate future, there is no permanent solution which permits subsistence land tenure for all who might desire or require it, except in the unlikely event of a drastic reduction in the population growth rate. Urbanization of the surplus population is therefore the only answer. This in itself poses considerable problems, particularly the provision of employment to the newly urbanized communities. The transition to urban living will prove a difficult one for the Tembe-Thonga, whose whole lifestyle is still closely linked to their subsistence economy, and this applies particularly to those living around the floodplain. Their transition to urbanization will perforce have to be gradual and guided, thus the existing pattern of subsistence agriculture will have to be phased out gradually.

There have been persistent rumours over the past twelve years of an impending relocation of Zulu people from elsewhere onto the Makatini Flats. These people are supposedly to come from regions such as the Drakensberg river catchments, the Paulpietersburg area and others. Should these rumours be founded on actual pre-emptive planning which is not, as yet, official policy, the concept should be abandoned. The area is too fragile to withstand even the impact of natural population increases for any length of time; artificial increases can only hasten the destruction of the natural resources of the area and cause serious discontent among the existing population. Because of the ethnic differences between the people of Maputaland and the rest of the Zulu nation, such discontent may well develop into friction, which must be avoided in a sensitive international border area such as this.

Agricultural development

Development of the area may be divided into three phases: Construction; development and maintenance. In the context of this study, the construction phase has been completed in so far as the waters of the Pongolo River are already impounded. The development phase, during which the agricultural potential of the Makatini Flats is realised, has not yet started as the first canal does not extend much beyond the foot of the mountains. Once operational, the project enters the phase where the rate of development is slower, and the emphasis shifts to maintenance of the enterprise as a profitable business.

Although there is a degree of interaction between these phases and their impact on the floodplain ecosystem, they are for convenience, detailed separately in Tables 12 and 13.

The impact of the constructional phase (Table 12) on the components of the floodplain has been considerable. There have been marked changes in the flooding of regime, including both extended floods, which have destroyed pan edge communities, and dry periods which have increased the incidence of human disease and have had a detrimental effect on the marshland communities. This impact can be minimised by a programme of controlled releases, with or without weirs in the river. Since use of water in this manner competes with agriculture for the water stored in the Pongolapoort Dam, it has therefore to be assessed on a cost: benefit basis.

Other impacts of the constructional phase are of a more long-term nature and will only become fully evident once agricultural development commands some, or all, of the mean assured yield of the impoundment. However, their probable impact and possible remedial measures may be suggested and are detailed in Table 12.

The impact of development of the agricultural land is, in some instances, similar to that resulting from the impoundment of the waters. This is so since once the demand for water has been created, the hydrological regime will change, and the rate and extent of change will be dependent upon the rate and extent of agricultural development. Because of the variety of activities associated with the development phase, together with the fact that it covers a much larger area than that involved in the construction phase, the potential impact of this phase on the floodplain is considerable (Table 13). Minimisation of these impacts provides further competition for the water from the impoundment because, not only are floods still required, but they may be required to run for longer periods to effectively dilute and flush away effluents of various types such as saline seepage waters and salts which have accumulated in the pans. Whilst it may be possible to utilize effluents in aquaculture, it should be realised that this is unlikely to provide a complete solution to the problem.

TABLE 12. An analysis of the major impacts of the constructional phase on the floodplain ecosystem.

Development	Probable effect	Probable consequence	Remedial measures	Monitoring needs
Construction	Changes in hydrological regime			
	i) Attenuation of floods - extended inundation	i) Primary producers: deterioration of riverine forest and pan edge ii) Secondary producers: reduced input from C. dactylon, reduced agricultural production iii) Human population: reduced agricultural production	i) Programmed controlled reservoir releases ii) Flow diversion measures	i) Monitoring viability of pan edge communities.
	ii) Creation of non-flow conditions	i) Primary producers: reduced productivity of meadows; drying out of pans, reduced P crispus. ii) Secondary producers: reduced migration; reduced breeding; reduced production. iii) Human population: reduced protein sources; increased water borne diseases; reduced water quality.	i) Controlled minimum releases; ii) Controlled maximum releases for flooding iii) Provision of inflatable weirs to permit flooding under low-flow conditions iv) Pumping into pans.	i) Monitoring of production of marginal meadows and P crispus standing crop. ii) Monitoring fish breeding.
	iii) Retention of sediments and associated nutrients	i) Primary producers: decreased production. ii) Secondary producers: no direct effects iii) Human population: reduced agricultural production. iv) Scouring: erosion of banks; new channels; draining of pan v) Deposition: altered deposition pattern silting.	i) Releases from scour gates ii) Construction of revetments iii) Channelization and dredging	i) Monitoring production of marginal meadows. ii) Aerial reconnaisance and and photography
	iv) Reduced ground water levels: reduced basic flow; water table; increased saline seepage inflow.	i) Primary producers: reduced viability of riverine forests ii) Secondary producers: reduced grazing. iii) Human population: reduced agricultural production; reduced water quality; increased water borne diseases.	i) Controlled releases.	i) Monitoring viability of riverine forest and agricultural production.
	v) Thermal stratification of water in the impoundment	i) Primary producers: unseasonal stimulation of growth; reduction in winter production ii) Secondary producers: death following release of anoxic water into river; indirect effect of reduced primary production; reduced breeding.	i) Selective releases	i) Monitoring of thermal and oxygen stratification in the impoundment

TABLE 13. An analysis of the major impacts of agricultural development phase on the floodplain ecosystem.

	Probable effect	Probable consequences	Remedial measures	Monitoring needs
1. Development of agriculture	i) Infrequent flooding	i) Primary producers: reduced pan margins and aquatic vegetation ii) Secondary producers: reduced fish breeding and production; disappearance of certain species. iii) Human population: reduced winter grazing; reduced protein source; increased water-borne diseases; reduced construction material (eg reeds); reduced tourist potential.	i) Controlled maximum releases. ii) Controlled minimum release associated with with system of adjustable weirs. iii) Pumping into pans.	i) Monitoring pan margin vegetation. ii) Monitoring fish breeding.
	ii) Nutrient enriched run-off or seepage into pans (including organic matter and silt	Primary producers: probable increase in algal growth decrease in hydrophytes; decrease in water quality; increase in marginal meadow production. ii) Secondary producers: increase in production; decrease in species composition; possible anaerobic conditions. iii) Human population: possible increased fish production; increased possibility of toxic algae; decreased water quality; reduced tourist potential.	i) Diversion of surface run-off. ii) Retention for controlled discharge during floods ii) Retention for aquaculture, principally fish culture.	i) Monitoring primary production patterns and nutrient loading. ii) Monitoring water quality.
	iii) Saline seepage water	i) Primary producers: reduction in species composition. ii) Secondary producers: marked reduction in species composition - invertebrates, fish and birds. iii) Human population: reduced water quality; reduced tourist potential.	i) Retention for controlled discharge during floods. ii) Retention for aquaculture, principally fish culture.	i) Monitoring salinity. ii) Monitoring species composition.
	iv) Mill effluents including oil from machinery; fermentation wastes; increased nutrients; increased microbial flora; chemical toxins.	i) Primary producers: deterioration in downstream conditions; change in species composition; ii) Secondary producers: marked increase in bacterial production; decreased dissolved oxygen; reduced species composition and fish production. iii) Human population: reduced water quality: increased health hazard; decreased tourist potential.	i) High quality effluent treatment. ii) Utilization in irrigation. iii) Utilization of enriched water in agriculture.	i) Monitoring effluent water quality and bacterial content. ii) Monitoring fate of effluent.

TABLE 13 (cont). An analysis of the major impacts of agricultural development phase on the floodplain ecosystem.

2.Associated Developments 1) Population influx				
a) Rural	i) Increased population in vicinity of water supply	i) Increased health hazards.		
	ii) Increased utilization of floodplain and surroundings. See settlements below.	ii) Overutilization of floodplain natural resources Primary and secondary producers. iii) Overutilization of surrounding areas for grazing cultivation and construction materials.	i) Provision of treated water supply. ii) Educational programme iii) Provision of medical aid (clinics) iv) Provision of employment v) Provision of alternative sources of construction materials.	i) Monitoring health of population. ii) Monitoring utilization of floodplain and immediate surrounds.
b) Urban	i) Population concentrations with unhygienic conditions	i) Primary and secondary producers as for nutrient enrichment in agriculture above.		
	ii) Increased domestic effluents	ii) Human population: increased health hazard, particularly bilharziasis, malaria, typhoid and hookworm Decreased tourist potential. iii) Domestic stock: increased hazard of foot and mouth and rabies and other stock diseases.	i) Provision of suitable facilities. idi) High quality treatment of effluent. iii) Utilizatiun of effluent in agriculture - irrigation. iv) Fencing of open water near settlements. v) Provision of treated swimming facilities vi) Mosquito control; isolation of malaria cases. vii) Control of movement of livestock. viii) Regular dipping ix) Restriction of wildlife movements.	i) Monitoring water quality bacterial counts. ii) Monitoring human population for bilharzia iii) Monitoring snail population. iv) Monitoring and control of mosquito breeding sites. V) Monitoring of livestock condition and movements.
ii) Infra-structure a) bridges and cause-ways.	i) Impedence of flow re-channeling of water course.	Refer to impoundment above.	i) Construction of high-level bridges	i)Surveilance for signs of new courses
b) canals	ii) Increased breeding areas for mosquitoes, snails etc.	i) Human population: increased health hazard	ii) Avoidance of causeway construction.	
3. Exploit-ation of fisheries resources	i) Over exploitation	i) Reduction in productivity. ii) Elimination of certain species.	i) Fencing of canal systems. ii) Mosquito control	i) Monitoring snail and mosquito populations.
	ii) Introduction of exotics	i) Elimination of indigenous species of fish and other organisms.	i) Control fishing under licence.	i) Monitoring catches.
			i) No possible solution: aquaculture utilizing exotic species to be restricted to areas off the floodplain.	i) Control over culture harvesting and disposal of exotic species

Although also true of the construction phase, but to a lesser extent, the development phase has considerable potential to influence the health and way of life of the local inhabitants. Whilst some of this impact will undoubtedly be beneficial, some will be adverse. It will therefore be desirable to implement certain control measures to minimise impact as well as to initiate effective monitoring programmes, irrespective of whether conservation of the floodplain is regarded as the development objective or not.

The impact during the maintenance phase reflects the effectiveness of the control measures applied during the construction and development phases, and the monitoring programmes will have to be kept fully operational so that timely remedial action may be taken as and when required. Since decisions for remedial action must be based upon ecological interpretation of cause and effect relationships, it will be necessary to create a post for a suitably trained ecologist, whose task it will be to design monitoring programmes, assess their results and to direct remedial action as and where necessary.

Urbanization and general infrastructure

The impact of urbanization and of an extension of the general infrastructure of the area is already implicit in the analysis of the effects of agricultural development, the main difference being that population concentrations provide substantial point sources of pollution and disease.

Health services and effective effluent control through the establishment of proper sewage works are the only possible counter measures. The use of raw or semi-treated sewage as fertilizer is not recommended for the area.

DEVELOPMENT OPTIONS AFFECTING THE FLOODPLAIN

There are four development options for the Makatini Flats, all of which merit consideration. These are:

- implementation of agricultural development without regard for its impact on the floodplain, leading to change and eventual disappearance of the floodplain ecosystem,

- implementation of agricultural development within the constraints imposed by the need for continued subsistence agriculture, at least until such time as the population becomes largely independent of the floodplain for subsistence,

- implementation of agricultural development but within the constraints of the maintenance of key floodplain ecosystem processes, and with subsistence agriculture constrained so that its impact on the floodplain is reduced, and,

- implementation of a programme to conserve the floodplain with both organised and subsistence agriculture constrained by conservation needs.

In evaluating these options, the immediate interests of the people living on the Makatini Flats must be paramount, at least in the short term. An estimated 35 926, some 27% of the population of Maputaland, are resident in the immediate vicinity of the floodplan and may, therefore, be assumed to have subsistence rights on the system. Whilst it is likely that many of these people will benefit either directly or indirectly from employment in the proposed agricultural developments, it seems unlikely that they, or their families, will willingly forfeit these rights. In the course of our studies on the floodplain we have heard frequent expressions of discontent arising from the changed flooding regime during the construction phase of the dam. The cessation of flooding would be far more serious; it would, in effect, be a removal of subsistence rights enjoyed for centuries.

On this basis alone we consider it imperative that an equitable partitioning of the water stored in the Pongolapoort Dam be effected at least during the development phase. In the initial stages of development there need be no conflict of interests, since the supply of water will exceed the demand and the floodplain will serve as an additional source of agricultural produce. It is, in any event, doubtful whether the protein producing potential of the floodplain can be lightly dismissed, since agricultural development will change the whole pattern of subsistence agriculture. Through its utilization of existing grazing land the proposed developments will restrict subsistence agriculture to crop growing, and the population will, of necessity, have to revert to fish as its main protein source. In this connection it must be remembered that the proposed agricultural crops are seen as generating cash flow, and are not intended for local consumption. If the increased money in circulation has to go towards the purchase of foodstuffs brought in from elsewhere to replace that which was freely available before development, this can hardly be considered a gain for the local population.

The conclusion that the floodplain should be maintained in its present form until there is genuine conflict in the demand for water is, therefore, inescapable, and it is essential that a rational programme of water releases, which takes account of the requirements of the floodplain, should be implemented without delay.

The implementation of a programme of conservation in the generally accepted sense of the term will deprive the resident population of their subsistence rights without providing an alternative. This approach too cannot be considered feasible at this point in time.

In the short term, therefore, the only development options which seem to be reasonable are those which take cognisance of the needs of subsistence agriculture as well as maintaining the protein producing potential of the floodplain. Since the floodplain is deteriorating steadily under the impact of both the altered hydrological regime and the expanding demands of subsistence agriculture, some form of control over its utilization needs to be implemented. However, it must be recognised that such control cannot be effected until alternative opportunities are provided whereby the family requirements for food are met. Agricultural development in conjunction with a policy of floodplain preservation is likely to prove to be the only means whereby the continued existence of the floodplain as a viable ecosystem can be assured.

In the long term, ie when the demand for water by irrigation agriculture approaches the assured yield of the dam, the desirability of continued maintenance of the floodplain will again come into question. At this time subsistence agriculture may well have outlived its usefulness, since its water usage is bound to prove inefficient when compared with agriculture based on modern agronomic and horticultural methods. This will, of course, only be possibe if all those dependent upon subsistence agriculture have been absorbed into any proposed agricultural and urban developments. Provided that a degree of research effort is maintained in the intervening period, alternative means for the maintenance of the floodplain will have been more precisely defined and evaluated by that time, and the whole situation, including the present proposals, will have to be reviewed.

In summary, then, the only development option which is feasible in the immediate future is the implementation of agricultural development within the constraints of the requirements of both subsistence agriculture and the maintenance of key ecosystem processes. In the more distant future, preservation of the floodplain is likely to be divorced from the needs of the people, and becomes purely a conservation issue, which needs to be evaluated on its own merits.

CONSERVATION OF THE PONGOLO FLOODPLAIN

While preservation of the floodplain in the immediate future can be amply justified, its conservation as a long term policy needs to be considered, at least in principle, as soon as possible. Through realizing the asset value of the floodplain early in the development of Maputaland a timely and realistic assessment can be made of its worth long before its interests will come into direct conflict with those of agriculture. To this end, we include an evaluation of the implication of conservation as development option both during and after the development phase.

Justification for conservation of the Pongolo floodplain

To arrive at an objective assessment of whether conservation of the floodplain is worthy of consideration, it becomes necessary to consider whether conservation is, in itself, a justifiable objective and whether the Pongolo Floodplain in particular warrants conserving. These are, of necessity, value judgments which will need to be supplemented by some form of cost-benefit analysis.

Is conservation a justifiable objective?

While conservation must necessarily take second place to human needs for food and other commodities, its importance to a country can be assessed in terms of both public monies devoted to conservation and private organizations which foster the conservation aim. In the Republic of South Africa there are five fully fledged public bodies concerned in conservation (National Parks Board, Nature Conservation Departments of the Cape, Orange Free State and Transvaal Provincial Administrations, and the Natal Parks, Game and Fish Preservation Board) as well as subsidiary sections within government departments. In addition, the Wild Life Society of Southern Africa (18 000 members) and the S A Wildlife Foundation represent private interest in conservation, and there are several other organizations which, though having more narrowly specific spheres of interest, are broadly conservation oriented, eg Wildlife Management Association of S A, South African Ornithological Society, etc. The need for conservation is therefore recognised by both government and private individuals.

Is the Pongolo floodplain worth conserving?

Conservation of the Pongolo Floodplain can be justified in terms of uniqueness, scientific interest and aesthetic worth. In addition its role extends beyond its own boundaries to other adjoining and more distant ecosystems. The more important reasons for conserving it are listed below.

- It is the only major floodplain incorporating a series of pans within the borders of South Africa, and is, therefore, unique.

- Along its western boundary the floodplain vegetation gives way to Sand Forest, a unique vegetation type, now rapidly disappearing as a result of encroaching subsistence agriculture.
- It is the southern distribution limit of several tropical aquatic organisms, notably fish, and is therefore of considerable scientific interest.
- It is an important winter feeding ground for large numbers of waterfowl which are dispersed at other times of the year and therefore serves to maintain the avifauna of other systems.
- The natural beauty of the floodplain, together with many rare species included in the biota, make it potentially one of the most aesthetically pleasing and interesting conservation areas in South Africa.

Thus, on the available evidence, and economic and human interests apart, the Pongolo Floodplain is worthy of, and should be given, a high priority rating for conservation.

Nature and extent of conflicting interests

In this context it must be stressed that not all parts of the floodplain need be given equal priority for conservation. The area between the Mthikeni-Nsimbi complex and the Pongolo-Usutu confluence is the most important, and, with the exception of an area south of Mthikeni-Nsimbi, the major fraction of the irrigable soils occur off the floodplain. There is, therefore, no likelihood of competition between agriculture and conservation for land. Where proposed agricultural developments would impinge directly on the floodplain pans, or where buffer zones along the floodplain margin for the prevention of excessive visual and noise impact are needed, alternative suitable land is available.

Water availability has already been shown to be the major limiting factor in agricultural development, there being sufficient arable land to utilize 114% of the mean assured yield. Even using a 10% risk factor, agriculture could use the total water supply. The amount of water required to maintain the floodplain pans at maximum retention level is estimated at 26 million cubic metres per year, based on an estimated annual evaporation of 2 000 mm and a rainfall of 600 mm per year and allowing for seepage losses. However, much of the productivity of the floodplain pans results from inundation, and the amount of water required to inundate the area between the levees and the adjoining high-lying areas for a reasonable period of time is of the order of 100 million cubic metres a year. This total of 126 million cubic metres per year, or 14,6% of the mean assured yield may be considered as an absolute minimum for the maintenance of the floodplain ecosystem in terms of our present knowledge.

Optimization of water use

The value of the potential yield from the development of irrigation farming on the Makatini Flats is considerable, and thus places an equally high premium on any water from the Pongolapoort Dam which is used for other purposes. However, the floodplain too has a current and potential monetary value which justifies its preservation, and research efforts should now be directed at reconciling the conflicting demands on the available water. It is estimated that the complete utilization of all the potentially productive land will take between 20 and 50 years, thus there is no immediate clash of interests between the irrigation requirements and those of the floodplain. This period affords an opportunity for research into alternative flooding strategies. The natural flooding regime uses flowing water to flood marginal areas and is, therefore, wasteful. A more economical means of provinding the necessary inundation of the whole floodplain, including the agricultural lands needs to be devised, and should include means for countering as many of the other adverse effects of the agricultural and associated developments as possible.

The most promising suggestion put forward to date is the use of inflateable weirs. These, if positioned strategically at points along the river course will allow water to be diverted onto the floodplain without the downstream losses incurred by the present flow through system. Prerequisite to this is the construction of a hydraulic model of the system which will establish relationships between river flow and flood levels, and will provide a means for testing the effects of this and other engineering alternatives for the optimization of the use of available water resources. Such a model can safely be regarded as the immediate research need. It should take account the possibility that the Ingwavuma and Usutu Rivers are likely to be impounded in the future and thus allow for the total water requirements of the floodplain having to be provided from the Pongolapoort Dam.

On the basis of the predictions obtained from the model, it should be possible to devise a method whereby the water levels on the floodplain can be selectively raised and maintained without the wastage of a flow-through system. Subsequent lowering will effect necessary flushing where required and depending on how finely adjustable a control is possible, irrigation of subsistence lands should also be feasible. Such a system which can control the residence time of the water on the floodplain may well have advantages over the natural system in that it can provide controlled flooding when required and possibly minimise nutrient losses.

Any controlled flooding regime must serve the following functions if it is to be useful in maintaining the floodplain: removal of accumulated unutilizable wastes, stimulation of fish migration and spawning, submergence of marginal vegetation for a sufficiently long period to allow assimilation into the aquatic system and the provision of flood irrigation to cultivated lands on the floodplain. The following seems a likely pattern to begin with, and experimental changes aimed at optimization should follow.

1. Raise to flood all pans in December, hold 3 days, drop to normal river level to drain and follow by 2 days at 56 cumec flow and 4 days at 28 cumec flow. This should effect flushing and allow fish migration.

2. Raise to flood Tete, oscillate water level about this point to flood subsistence lands. Such oscillations would probably range between flooding Mthikeni at highest level and maintaining the Namanini-Bumbe-Ngodo complex at high flood level, and can probably, with the use of inflatable weirs, be done on base flow and overspill alone, although some water release may be necessary.

3. Raise level to flood all pans during February, hold for 5 days and return to 2 above.

4. Drop to level of Namanini-Bumbe-Ngodo during March. Oscillate about this point, raising to level of Tete perhaps once or twice.

5. Unimpeded flow April - November.

This involves an annual water release estimated at 41 million cubic metres. Water availability will dictate whether the flooding season should be extended. If this is possible earlier low-level floods in November would be an advantage.

It will be necessary to carefully monitor the system throughout until the agricultural and other developments are fully implemented. The monitoring needs have been set out in Tables 12 and 13, and any symptoms of environmental degradation which may be revealed will have to be countered. This may involve changes in the flooding regime set out above.

THE COST OF CONSERVING THE PONGOLO FLOODPLAIN

In assessing the cost of conserving the Pongolo Floodplain its total asset value must be offset against the loss of profits from agriculture. Such an assessment must therefore take into account all gain from the floodplain, whether current or potential, and weigh this against the value of the water needed for its maintenance. Figure 24 shows, in simplified form, the interaction of the dam, the floodplain, proposed developments and the floodplain population. From this it is clear that, in terms of exploitable resources, a value needs to be put on the losses to agriculture and the gains from the fishery and from tourism if the floodplain is conserved and these must be considered together with the impact on the subsistence economy.

Losses to agriculture

The original objective of the Pongolapoort Dam was to increase sugar production, which, on the Makatini Flats, will have an annual irrigation water requirement of 1 600 mm, or 16 000 m^{3}ha^{-1} which can be expected to yield a net profit of some R200 ha^{-1}y^{-1}. The water requirements for maintaining the floodplain have been estimated at 126 x 10^6 m^3, which figure can be reduced to an estimated 42 x 10^6 m^3 with inflatable weirs (note: these figures are tentative and need to be confirmed by the hydraulic survey and model). On this basis the loss in agricultural production has been estimated for both flooding methods as set out in Table 14.

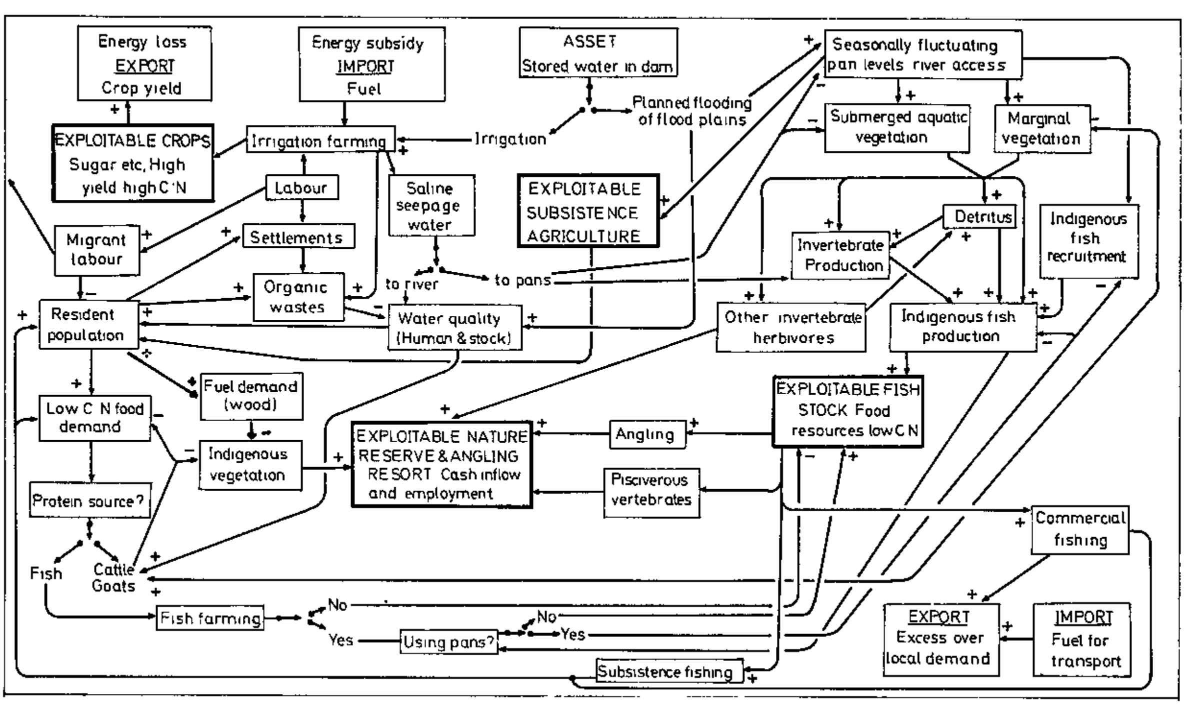


FIGURE 24. Interactions of the Pongolapoort Dam, irrigation and subsistence agriculture and the Pongolo Floodplain.

TABLE 14. Valuation of water required to maintain the Pongolo Floodplain.

Option for provision of water	Equivalent area which could be irrigated	Value of water on a profitability of R200 $ha^{-1}y^{-1}$	Annual cost as % of annual profit	Annual Cost as percentage of agricultural development cost	Annual cost as percentage of total development cost
Floods without weirs	7875 ha	R1,575 x 10^6	30%	1,1%	0,78%
Floods with weirs	2625 ha	R525 000	10,5%	0,4%	0,26%

While the cost of maintaining the floodplain without some means of controlling residence time on the floodplain is unacceptably high at 30% of projected profits, with the use of inflatable weirs, at a cost of 10,5% of profits, conservation does merit further consideration. Even this figure is open to question, since the profitability of agriculture has not taken into account the cost of providing the water (ie the cost of the dam, infrastructre and canal system) on which some R24,3 x 10^6 has been spent to date and a further R35 x 10^6 is earmarked for completion of the canal system. This means that, in real terms, the total expected profits must effectively be reduced by 30% implying that irrigation-based development at least is subsidized to this extent. However, the dam is a fait accompli and must be made to yield a maximum return, therefore this anomaly will not be taken into account in the assessment.

Asset value of the floodplain

An evaluation such as this can initially take account only of those assets on which a cash value can be placed. Scientific interest and aesthetic values can then be weighed against any shortfall.

Value of the fishery

In Chapter 8 we estimated that 516 tonnes of fish per annum was a safe but probably conservative estimate for the sustainable yield of the floodplain fishery. This, at a replacement cost of R1,00 per kg, represents a cash value of R516 800 with a possible maximum of R618 000.

Conservation of the floodplain may place some constraints on the amount of fish which can be removed, and such fish as are taken from the system for sale are unlikely to realise more than 50c per kg. A conservative estimate of the potential cash yield of the fishery can therefore be set at R200 000, ie 400 tonnes at 50c per kg.

Value of subsistence agriculture

The value of the floodplain in the subsistence economy of the people of western Maputaland has been stressed throughout this report. These people have the highest nutritional status of all rural black populations in Natal (Dept of Dietetics and Home Economics, University of Natal, personal communication) which can be attributed to a balanced and varied diet, a large part of which currently derives from subsistence agriculture.

Consequent upon agricultural development and a reduction in available grazing, it is inevitable that the population as a whole will become increasingly dependent upon cash income. However, only a relatively small proportion of these people will be gainfully employed in the major agricultural developments and those who remain unemployed will become increasingly dependent upon crop growing for their subsistence. No mention has yet been made of the allocation of small holdings under irrigation to absorb these people, but whatever measures are taken the natural increase in the population, and the permanent return of migrant workers is bound to leave at least some people which have not been catered for. Conservation of the floodplain does not exclude rational subsistence agriculture, and we expect that there will be subsistence farmers on the floodplain for the foreseeable future.

The retention of between 10 and 20 percent of the present population on the floodplain does not seem to us to be inconsistent with conservation. Indeed, these people have for centuries been part of the ecosystem. This would represent, maximally, some 8 000 people or 800 families. Then, even being conservative and assuming the annual produce from the environment to be R750 per family per year, the value of subsistence agriculture will be R600 000 per annum. In practice, of course, this figure will, in the early stages of development, be of the order of R2,5 x 10^6 per annum and will only become reduced as and when alternative means of livelihood become available.

Value of the potential for tourism

With the Ndumu Game Reserve nearby and the possibility of tourist amenities being developed on the coast, the floodplain must be seen as a valuable tourist attraction because it provides something completely different from all existing reserves. Apart from angling, there exists the potential for wilderness trails, and, should the existing Ndumu Game Reserve be extended and controlled hunting areas be introduced, there is even room for a hotel. Indeed, a hotel suitably designed to blend into the natural surroundings and located on Ngodo pan would be remarkably similar to the highly successful hotel on Lake Naivasha in Kenya.

Because of the trying climatic conditions in Maputaland, the most favourable time to visit the floodplain would be during the cooler months April to September. At this time angling and the avifauna are at their best, and the marginal meadows around the pans are exposed. This season, on the basis of chalet accommodation for 200 people, gives a total of 36 000 visitor days per year. Assuming that each visitor spends R5 per day on boat hire, chalet hire, gillies, guides, and cooks the gross income would be R280 000 per annum. It is difficult to assign a profit margin to such a development, but a net profit of R25 000 on a gross income of R280 000 (13,8%) does not appear to be unreasonable. Both profit and turnover can be increased by adopting a higher density accommodation policy, but this is not recommended in the initial stages. A suitably designed hotel will materially add to the profits but the demand for hotel accommodation over the summer season may be low. However, bearing in mind the profitability of licenced premises, an hotel catering for 50 guests may well equal the profits derived from the rustic chalet accommodation.

Cost - benefit analysis

Table 15 summarises the losses and gains likely to result from a policy aimed at conservation of the floodplain. Evaluating the development options in tne light of this analysis, it would seem to us that a policy of conservation which places limited constraints on agricultural development and encourages a gradual exodus from the floodplain through the provision of incentives to move (employment in agriculture, small holdings under irrigation, urbanization, etc) provides the best solution.

TABLE 15. Summary of likely losses and gains derivable from conservation of the Pongolo Floodplain.

LOSSES			GAINS		
Source	Amount (R x $10^6 a^{-1}$)		Source	Amount (R x $10^6 a^{-1}$)	
	Assessed likely maximum	Achievable minimum		Assessed likely minimum	Possible maximum
Agriculture (Table 9)	R1,575	R0,525	Fisheries (P)	R0,200	R0,680
			Subsistence agriculture (P)	R0,600	R2,500
			Tourism (P)	R0,25	R0,050
Total	R1,575	R0,525	Total	R0,825	R3,270

If implemented so as to minimize both agricultural losses through the provision of weirs and floodplain damage through encouraging a number of people to move, this policy would probably yield a small net profit of some R300 000 per annum in real terms, or if the hidden asset of a smaller-scale subsistence agriculture is excluded, a loss of R300 000. These figures do not of course, include the cost of the inflatable weirs or of their installation. This, when considered in the context of the cost of the dam, canals and proposed agricultural development would be a very small amount. The figures also do not take account of the cost of relocating the people of the floodplain, but this represents an expense which would in any event be incurred if flooding were to cease.

Finally, this analysis, whether in the interpretation of the policy makers it reflects a gain or a loss, should be weighed also against those assets of the floodplain which cannot be assessed in monetary terms: uniqueness and aesthetic worth. Once destroyed the floodplain cannot be reclaimed or restored. Any decision to sacrifice this unique and beautiful system in the face of undoubted need for development in Maputaland must be taken in the full knowledge of its value and cannot therefore be taken lightly.

SUMMARY

The Pongolo Floodplain, as a natural ecosystem, is unique in the Republic of South Africa. Its biota, which includes tropical and other rare species, is adapted to the changing water levels of the floodplain. The productivity of the whole system is dependent upon the annual summer floods. The people living on the Makatini Flats, the area immediately surrounding the floodplain, have depended on its natural resources for centuries, and the floodplain still plays a key role in their subsistence economy. A rapidly expanding human population has utilized all land on the floodplain which is suitable for subsistence agriculture, and is now encroaching on marginal, less productive land and destroying natural vegetation for little return.

The Pongolapoort Dam has greatly increased the agricultural potential of the Makatini Flats. While the developments resulting from it will have the effect of removing some people from the floodplain, and proposed gradual urbanization will further reduce the floodplain population in the long term, the rate of population increase is such that at least some people will still cling to their subsistence rights for many years to come. For this reason the floodplain will need to be preserved at least until alternative means of livelihood are found for all these people if serious discontent in a sensitive international border area is to be avoided. The effect on the floodplain ecosystem, including the human population, impoundment, agricultural development, urbanization and associated infrastructre have been considered in this report and necessary steps for countering these have been put forward.

All development plans for western Maputaland have, to date, been centred on the enhanced agricultural potential resulting from the Pongolapoort Dam. The asset value of the floodplain has not yet been considered in any of the development plans, largely because none of the planners have ever visited it. A means for its conservation with minimal losses to agriculture is suggested, and a provisional cost - benefit analysis suggests that conservation as a form of land use can be justified not only in terms of aesthetic worth and uniqueness but in monetary terms as well, provided its tourist potential is realized and the natural fishery is rationally exploited.

RECOMMENDATIONS

The situation in western Maputaland is one of a rapidly increasing population living in a subsistence economy bolstered by earnings from migrant labour. Population pressure on natural resources, chiefly derived from the Pongolo Floodplain, makes it imperative that both agriculture and a planned policy of urbanization be implemented. However, the implementation of these proposals in such a way as to preserve the Pongolo Floodplain ecosystem would, in our opinion, not only prove profitable and rewarding, but will also enhance the reputation of the Republic as a country in which concern for the natural environment, the preservation of renewable natural resources, and, above all, respect for the traditional rights and modes of life of all its inhabitants form an integral part of national policy. To this end, we submit the recommendations set out below:

(1) That a policy of adequate summer flooding for the maintenance of the floodplain and of subsistence agriculture be initiated immediately and continued while alternative means of providing water are investigated and the future of the floodplain decided.

(2) That a decision on the future role of the Pongolo Floodplain in the proposed development of western Maputaland be taken as a matter of urgency. If preservation of the floodplain is considered justified on the strength of this report, then 3 to 12 apply.

(3) That constraints be imposed on further expansion of subsistence agriculture into unproductive areas to minimize environmental damage, and that the demands for subsistence rights be channelled into controlled exploitation of the natural fishery.

(4) That the development of an hydraulic model of the floodplain be made an urgent priority, and that this model take account of the water needs of the whole floodplain in the event of the Ingwavuma and Usutu Rivers being impounded in Swaziland. Prof Midgley of the University of the Witwatersrand should be consulted in this connection.

(5) That the suitability of various engineering structures such as inflatable weirs be investigated as soon as the hydraulic model can provide the necessary data, and that the optimal structures be installed as soon as possible to minimize unnecessary wastage of irrigation water. Mr W J R Alexander of the Research Division of the Dept of Environmental Affairs should be consulted.

(6) That the total fish resources and potential for fish production be rationalized towards optimal utilization in conjunction with the constraints imposed on subsistence agriculture. This should involve investigations into fish culture in consultation with the Fisheries Development Corporation, the stocking of the Pongolapoort Dam in consultation with the Natal Parks, Game and Fish Preservation Board, the subsistence fishery and exploitation of the natural fishery for profit. We recommend that Mr P B N Jackson of the J L B Smith

Institute of Ichthyology, Rhodes University, Grahamstown be approached to act as overall consultant in all matters relating to fish culture and fishery exploitation.

(7) That agricultural development which is labour intensive be given priority in the planning, so that people whose subsistence rights have been infringed and those subsistence farmers at present on marginal lands can be gainfully employed.

(8) That the very limited constraints suggested in this report be rigidly imposed on all development in the vicinity of the floodplain and that a system of environmental monitoring by a trained ecologist be instituted as soon as possible. We willingly make ourselves available for consultation to whoever is made responsible for such a monitoring programme.

(9) That relocation, where necessary, and urbanization be carried out in consultation with suitably qualified social scientists on a planned basis and with adequate incentives of an alternative means of livelihood. The Human Sciences Research Council should be consulted in this matter.

(10) That relocation of people from elsewhere onto the Makatini Flats not be even contemplated until the local inhabitant needs have all been catered for and provision has been made for the projected increase in the local population. Ethnic differences, and the tribal ties of the people of Maputaland with those in Mozambique, could create a highly inflamable situation in a sensitive international border area should any land dispute arise.

(11) That the tourist potential of the Pongolo Floodplain and of the Pongolapoort Dam be considered as part of the overall plan for the development of tourism in northern Natal and KwaZulu in general and Maputaland in particular.

(12) That the appointment of a warden for the area, who will work in close cooperation with ecologists and the various consultants and developers be made an urgent consideration.

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Appendix 1. Monthly flow record for the Pongolo River over the period October 1929 to September 1976

YEAR	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEPT	TOTAL
29/30	98.	112.	143.	178.	92.	139.	53.	39.	28.	29.	22.	18.	951.
30/31	13.	25.	48.	41.	82.	29.	24.	11.	9.	12.	8.	6.	309.
31/32	5.	41.	50.	69.	61.	214.	39.	52.	18.	11.	10.	15.	584.
32/33	33.	58.	198.	88.	54.	51.	21.	10.	8.	11.	7.	5.	544.
33/34	9.	110.	271.	315.	259.	202.	145.	52.	33.	30.	48.	25.	1500.
34/35	17.	86.	323.	159.	57.	80.	65.	87.	23.	19.	14.	13.	944.
35/36	9.	11.	30.	206.	174.	88.	120.	88.	65.	36.	21.	18.	866.
36/37	19.	328.	96.	273.	563.	152.	102.	51.	33.	28.	21.	28.	1693.
37/38	40.	29.	67.	75.	97.	125.	102.	39.	32.	29.	18.	15.	669.
38/39	120.	79.	224.	226.	1152.	951.	199.	144.	62.	51.	39.	47.	1295.
39/40	85.	301.	226.	249.	127.	75.	215.	172.	104.	58.	36.	67.	1715.
40/41	95.	310.	305.	238.	259.	168.	145.	45.	23.	23.	18.	9.	1642.
41/42	19.	33.	159.	166.	105.	254.	85.	35.	74.	29.	23.	24.	1006.
42/43	131.	218.	357.	210.	88.	295.	453.	250.	58.	276.	132.	101.	2608.
43/44	324.	338.	237.	229.	457.	245.	153.	84.	63.	44.	29.	39.	2244.
44/45	94.	52.	39.	99.	47.	184.	62.	34.	27.	20.	16.	12.	685.
45/46	12.	10.	19.	94.	177.	126.	170.	30.	19.	14.	12.	27.	710.
46/47	61.	174.	130.	87.	163.	107.	50.	28.	19.	19.	16.	15.	869.
47/48	35.	58.	125.	240.	485.	296.	121.	44.	28.	9.	16.	23.	1479.
48/49	35.	89.	97.	130.	112.	74.	95.	81.	42.	22.	14.	17.	810.
49/50	61.	108.	226.	134.	53.	144.	114.	59.	37.	26.	26.	21.	1009.
50/51	14.	33.	126.	187.	81.	145.	123.	40.	26.	24.	60.	42.	900.
51/52	94.	47.	125.	54.	53.	24.	27.	15.	16.	14.	9.	6.	485.
52/53	17.	60.	134.	58.	94.	80.	73.	25.	16.	13.	9.	9.	593.
53/54	14.	62.	90.	81.	141.	121.	108.	88.	39.	27.	12.	12.	796.
54/55	50.	97.	103.	149.	508.	283.	58.	30.	28.	31.	17.	18.	1372.
55/56	30.	44.	159.	121.	445.	228.	67.	40.	29.	18.	11.	19.	1212.
56/57	37.	165.	181.	113.	118.	92.	86.	48.	31.	122.	45.	155.	1194.
57/58	566.	148.	20.	299.	190.	79.	81.	492.	25.	34.	15.	35.	1983.
58/59	43.	177.	255.	143.	128.	51.	17.	35.	17.	12.	9.	18.	906.
59/60	29.	69.	92.	42.	92.	77.	42.	19.	31.	20.	23.	19.	556.
60/61	67.	201.	542.	10.	104.	85.	131.	54.	42.	28.	23.	15.	1304.
61/62	34.	55.	182.	123.	89.	62.	40.	23.	13.	10.	7.	7.	644.
62/63	15.	142.	172.	135.	85.	49.	48.	18.	41.	563.	59.	33.	1361.
63/64	32.	123.	71.	117.	96.	26.	24.	13.	10.	9.	7.	9.	533.
64/65	53.	238.	152.	100.	100.	26.	19.	11.	14.	11.	6.	11.	741.
65/66	11.	24.	24.	125.	207.	35.	14.	15.	11.	6.	4.	5.	482.
66/67	13.	12.	74.	89.	401.	162.	72.	38.	24.	16.	11.	10.	921.
67/68	8.	171.	134.	77.	39.	81.	44.	24.	19.	17.	15.	12.	641.
68/69	3.	34.	64.	72.	31.	109.	98.	75.	18.	12.	5.	5.	527.
69/70	104.	60.	93.	98.	120.	42.	11.	9.	11.	9.	8.	4.	571.
70/71	37.	38.	107.	177.	55.	23.	112.	53.	14.	11.	4.	5.	636.
71/72	50.	126.	257.	258.	216.	239.	123.	71.	44.	29.	19.	11.	1444.
72/73	13.	12.	38.	50.	214.	85.	211.	58.	30.	21.	50.	28.	810.
73/74	91.	88.	103.	218.	270.	88.	76.	48.	19.	26.	13.	11.	1051.
74/75	13.	153.	296.	236.	269.	203.	109.	59.	33.	26.	17.	37.	1452.
75/76	44.	95.	275.	199.	364.	205.	177.	119.	52.	38.	29.	14.	1612.
TOTAL	2794.28	5043.60	7240.83	6837.55	9175.76	5700.88	4530.78	2958.83	1506.15	1941.69	1036.49	1091.08	50857.91
MEAN	59.45	107.31	154.06	145.48	195.23	142.57	96.40	62.95	32.05	41.31	22.05	23.21	1082.08

Appendix 2. Pongolo River maximum daily average flow in $m^3\ s^{-1}$

YEAR	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEPT	TOTAL
29/30	67	150	150	407	117	345	43	17	16	11	9	7	1 339
30/31	7	21	50	20	198	21	16	6	3	5	4	3	354
31/32	3	34	114	424	150	413	21	72	15	4	4	58	1 312
32/33	86	81	248	54	103	54	19	5	3	8	3	2	666
33/34	13	248	413	272	223	293	150	29	15	21	40	12	1 729
34/35	8	103	413	413	-	/49/	57	99	10	8	6	9	/1 175/
35/36	8	9	34	310	150	76	133	160	54	16	11	15	976
36/37	10	954	95	272	888	90	103	29	15	12	8	34	2 510
37/38	58	95	76	150	114	122	108	20	15	21	8	10	797
38/39	392	95	165	277	926	531	748	127	32	21	17	47	2 878
39/40	150	310	198	248	150	80	310	381	127	32	17	103	2 106
40/41	198	248	248	198	248	150	150	32	12	12	7	6	1 509
41/42	21	49	175	150	198	198	103	19	150	12	9	11	1 095
42/43	198	310	310	198	150	198	888	150	103	310	94	51	2 960
43/44	482	272	186	156	494	402	114	100	42	21	12	42	2 323
44/45	87	34	23	74	22	194	57	17	11	9	7	6	541
45/46	7	12	17	120	194	120	281	21	9	6	5	57	849
46/47	-	-	-	-	-	-	-	-	-	-	-	-	-
47/48	-	103	217	127	355	211	80	21	12	-	7	42	1 175
48/49	40	120	-	-	-	-	-	-	-	-	-	-	/160/
49/50	-	-	-	-	-	193	128	32	16	12	13	11	405
50/51	15	57	131	148	96	106	105	26	11	18	187	34	934
51/52	88	38	172	38	60	17	18	9	12	10	5	3	470
52/53	91	86	166	56	163	70	92	14	9	9	5	7	768
53/54	20	78	77	54	107	57	43	42	16	14	8	12	528
54/55	56	128	151	236	678	332	42	14	12	13	8	8	1 678
55/56	34	53	164	167	900	219	50	19	14	9	7	11	1 647
56/57	104	132	99	87	160	69	56	44	20	122	23	280	1 196
57/58	1 798	174	/37/	-	-	-	-	-	-	-	-	-	/2 009/
58/59	-	-	-	96	88	32	11	46	9	6	/8/	25	/321/
59/60	57	/80/	/127/	/63/	113	70	/58/	/28/	-	-	-	-	/596/
60/61	-	-	-	43	75	71	91	41	23	14	18	18	/394/
61/62	/54/	/47/	-	161	152	70	33	17	7	6	5	6	/558/
62/63	12	119	271	126	150	62	35	10	69	1 975	33	20	2 882
63/64	39	110	63	159	87	17	21	8	6	5	5	4	524
64/65	152	554	151	81	103	19	16	8	15	7	6	8	1 120
65/66	15	42	32	145	491	34	12	17	8	4	2	6	808
66/67	23	14	125	59	557	171	43	24	13	8	6	16	1 059
67/68	19	265	142	36	44	64	24	13	9	8	7	6	637
68/69	/5/	55	86	105	17	112	87	38	13	8	6	8	/540/
69/70	104	99	79	/104/	115	50	14	9	6	5	8	6	/599/
70/71	76	43	60	149	45	40	99	85	15	9	6	9	636
71/72	101	187	314	318	342	170	93	39	24	14	9	7	1 618
72/73	10	16	23	85	322	101	212	37	16	12	33	82	949
73/74	71	61	62	346	334	61	80	26	/13/	-	/10/	7	/1 071/
74/75	19	313	304	300	286	176	95	50	15	13	9	92	1 672
75/76	63	272	346	157	334	225	198	151	27	18	14	12	1 817
TOTAL	4 802	6 144	6 150	7 022	10 499	6 106	4 579	2 124	1 029	2 848	691	1 213	
AVERAGE	120	146	158	171	250	142	106	49	25	69	17	28	

NB. PERIODS OF NO OR INCOMPLETE RECORD WERE NOT TAKEN INTO ACCOUNT

Appendix 3. Pongolo River minimum daily average flow in $m^3 s^{-1}$

YEAR	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEPT	TOTAL
29/30	27	24	27	17	21	23	17	12	9	11	7	7	202
30/31	3	3	7	11	12	6	6	3	3	3	3	1	61
31/32	1	1	3	3	5	18	5	7	4	4	3	3	57
32/33	3	4	17	15	8	7	4	3	3	3	2	2	71
33/34	1	3	29	50	58	34	29	15	11	8	9	8	255
34/35	5	11	40	21	-	/21/	14	10	8	5	5	4	/144/
35/36	2	1	2	8	4	19	21	16	16	11	6	5	111
36/37	5	9	19	21	90	29	29	15	12	8	8	5	250
37/38	8	4	7	11	16	16	16	11	11	8	6	4	118
38/39	4	13	21	34	150	103	37	21	20	18	10	12	443
39/40	11	17	21	21	19	17	21	21	16	17	12	11	204
40/41	13	40	21	21	58	40	32	12	10	7	6	3	263
41/42	4	4	11	16	16	5	14	9	12	9	8	8	116
42/43	9	9	58	21	16	40	21	58	21	21	19	28	321
43/44	23	23	23	26	74	38	25	19	16	12	10	8	297
44/45	11	11	11	14	12	12	17	10	9	6	5	4	122
45/46	3	2	2	2	19	17	21	8	6	5	4	3	92
46/47	-	-	-	-	-	-	-	-	-	-	-	-	-
47/48	-	5	16	57	76	38	21	12	10	-	5	5	/245/
48/49	5	5	-	-	-	-	-	-	-	-	-	-	/10/
49/50	-	-	-	-	-	22	22	16	14	8	8	6	/96/
50/51	2	6	15	20	5	20	14	11	9	6	4	9	121
51/52	9	6	9	10	9	5	6	3	3	4	2	2	68
52/53	1	3	14	7	6	14	13	8	5	3	2	2	78
53/54	1	4	21	23	11	38	40	16	14	4	3	2	177
54/55	7	20	12	14	57	43	14	10	9	7	6	5	204
55/56	5	8	19	13	12	31	16	11	9	4	3	4	135
56/57	4	30	46	26	15	20	23	11	8	13	11	13	220
57/58	35	26	/32/	-	-	-	-	-	-	-	-	-	/93/
58/59	-	-	-	32	24	11	5	5	5	4	3	2	/91/
59/60	2	/8/	/13/	/8/	12	12	/10/	/12/	-	-	-	-	/77/
60/61	-	-	-	/38/	24	18	31	15	12	7	5	3	/153/
61/62	4	/12/	-	/17/	19	10	6	5	4	3	1	1	/82/
62/63	1	2	12	18	16	9	10	3	3	10	16	8	108
63/64	5	16	9	10	13	5	4	4	2	2	1	2	73
64/65	1	20	22	21	16	4	4	1	2	3	1	2	97
65/66	1	1	3	10	28	4	2	2	3	1	1	1	57
66/67	0	1	2	16	35	26	14	10	7	4	2	1	118
67/68	1	23	31	22	8	14	13	7	6	5	5	3	138
68/69	/1/	1	12	9	2	10	17	11	7	4	2	1	/77/
69/70	3	15	26	11	20	6	3	2	3	2	1	1	93
70/71	2	5	2	16	16	7	15	14	8	4	3	2	94
71/72	2	20	36	26	21	52	27	19	13	9	5	2	232
72/73	2	2	7	7	4	14	39	16	9	5	/9/	3	/117/
73/74	26	23	30	23	44	18	20	10	/11/	-	/5/	2	/212/
74/75	2	2	49	31	57	37	28	16	11	7	5	4	249
75/76	10	9	27	47	63	36	30	27	16	11	9	4	289
TOTAL	264	432	739	781	1 191	948	766	515	379	286	227	206	
AVERAGE	6	11	19	20	28	22	18	12	9	7	6	5	

Appendix 4. Pongolo River flow rate exceedance (days duration per year).

Year \ Flow Rate (cumecs)	28.3	56.6	84.9	141.5	198.2	283.2	424.8
1929/30	116	43	22	7	4	2	0
30/31	18	5	1	1	1	0	0
31/32	40	29	13	7	5	2	0
32/33	78	22	11	3	2	0	0
33/34	172	128	52	28	15	0	0
34/35	119	27	11	10	7	3	0
35/36	113	48	26	6	4	1	0
36/37	166	98	64	33	21	10	4
37/38	93	26	12	1	0	0	0
38/39	210	139	107	68	57	47	27
1939/40	148	119	63	42	25	3	0
40/41	197	149	78	40	14	0	0
41/42	98	78	44	14	3	0	0
42/43	195	189	114	56	24	7	4
43/44	295	196	137	62	22	7	4
44/45	68	32	13	4	0	0	0
45/46	70	63	28	4	1	0	0
46/47	3	1	0	0	0	0	0
47/48	138	101	68	28	15	6	0
48/49	11	5	3	0	0	0	0
1949/50	47	14	10	2	0	0	0
50/51	110	55	22	2	0	0	0
51/52	58	22	7	2	0	0	0
52/53	69	28	13	3	0	0	0
53/54	148	25	9	0	0	0	0
54/55	119	70	43	24	17	7	4
55/56	109	56	31	16	8	6	5
56/57	63	54	19	1	0	0	0
57/58	98	50	42	17	10	4	3
58/59	62	21	3	0	0	0	0
1959/60	69	25	10	0	0	0	0
60/61	69	21	1	0	0	0	0
61/62	56	12	5	2	0	0	0
62/63	84	44	19	4	2	0	0
63/64	108	38	16	7	4	4	3
64/65	94	37	21	8	2	2	1
65/66	48	21	13	5	2	1	1
66/67	96	41	31	19	8	2	1
67/68	86	19	9	4	2	0	0
68/69	58	16	6	0	0	0	0
1969/70	89	32	11	0	0	0	0
70/71	77	25	9	1	0	0	0
71/72	138	82	56	22	9	5	0

Appendix 5. Monthly spillage in 10^6m^3 assuming utilisation equal to 25% of assured yield (216 $10^6m^3y^{-1}$)

YEAR	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEPT	TOTAL
29/30	70.	87.	123.	167.	73.	115.	28.	12.	2.	2.	0.	0.	679.
30/31	0.	0.	0.	12.	62.	2.	0.	0.	0.	0.	0.	0.	77.
31/32	0.	0.	0.	0.	7.	187.	20.	30.	0.	0.	0.	0.	244.
32/33	0.	0.	167.	67.	44.	23.	0.	0.	0.	0.	0.	0.	301.
33/34	0.	0.	235.	292.	235.	181.	121.	24.	7.	9.	25.	0.	1129.
34/35	0.	48.	305.	134.	35.	52.	39.	64.	0.	0.	0.	0.	677.
35/36	0.	0.	0.	122.	160.	63.	93.	65.	38.	10.	0.	0.	551.
36/37	0.	305.	66.	264.	570.	124.	75.	24.	6.	2.	0.	0.	1435.
37/38	7.	0.	73.	52.	80.	96.	79.	11.	17.	4.	0.	0.	419.
38/39	68.	47.	255.	203.	1161.	937.	170.	119.	36.	27.	10.	26.	3058.
39/40	56.	293.	198.	224.	101.	77.	189.	153.	90.	31.	9.	38.	1461.
40/41	70.	296.	279.	212.	231.	141.	132.	17.	1.	0.	0.	0.	1378.
41/42	0.	0.	99.	166.	78.	233.	57.	23.	50.	2.	0.	0.	707.
42/43	106.	205.	339.	183.	69.	283.	454.	228.	12.	262.	109.	77.	2386.
43/44	306.	322.	209.	206.	447.	219.	127.	56.	65.	17.	0.	14.	1968.
44/45	60.	31.	7.	87.	24.	172.	49.	7.	0.	0.	0.	0.	441.
45/46	0.	0.	0.	22.	167.	97.	142.	2.	0.	0.	0.	0.	430.
46/47	0.	144.	102.	60.	145.	85.	26.	1.	0.	0.	0.	0.	563.
47/48	0.	13.	107.	214.	464.	270.	95.	16.	1.	0.	0.	0.	1180.
48/49	0.	46.	74.	128.	97.	50.	77.	63.	18.	0.	0.	0.	553.
49/50	3.	84.	220.	106.	32.	121.	91.	32.	10.	1.	0.	0.	699.
50/51	0.	0.	88.	169.	52.	117.	102.	13.	0.	0.	42.	12.	594.
51/52	70.	14.	115.	29.	32.	0.	0.	0.	0.	0.	0.	0.	260.
52/53	0.	0.	77.	34.	77.	52.	52.	1.	0.	0.	0.	0.	294.
53/54	0.	0.	38.	58.	130.	92.	82.	69.	12.	1.	0.	0.	482.
54/55	5.	79.	72.	140.	488.	270.	31.	5.	1.	4.	0.	0.	1094.
55/56	0.	21.	138.	90.	447.	200.	38.	18.	2.	0.	0.	0.	954.
56/57	0.	124.	165.	87.	113.	68.	62.	21.	5.	105.	19.	149.	918.
57/58	557.	117.	0.	279.	170.	46.	57.	464.	0.	7.	0.	0.	1699.
58/59	12.	155.	236.	126.	118.	20.	0.	0.	0.	0.	0.	0.	666.
59/60	0.	0.	68.	11.	84.	60.	15.	0.	0.	0.	0.	0.	238.
60/61	25.	185.	529.	0.	80.	60.	119.	27.	25.	2.	0.	0.	1051.
61/62	0.	31.	150.	94.	63.	38.	15.	0.	0.	0.	0.	0.	392.
62/63	0.	23.	144.	112.	66.	35.	22.	0.	7.	550.	30.	2.	992.
63/64	11.	99.	39.	113.	74.	0.	1.	0.	0.	0.	0.	0.	338.
64/65	0.	154.	129.	68.	73.	0.	0.	0.	0.	0.	0.	0.	424.
65/66	0.	0.	0.	23.	188.	5.	0.	0.	0.	0.	0.	0.	216.
66/67	0.	0.	0.	0.	382.	136.	54.	16.	0.	0.	0.	0.	588.
67/68	0.	42.	106.	48.	20.	67.	17.	0.	0.	0.	0.	0.	341.
68/69	0.	0.	0.	11.	9.	86.	77.	53.	0.	0.	0.	0.	236.
69/70	29.	35.	73.	63.	95.	12.	0.	0.	0.	0.	0.	0.	307.
70/71	0.	0.	0.	149.	25.	0.	84.	25.	0.	0.	0.	0.	283.
71/72	0.	44.	234.	238.	213.	219.	97.	53.	18.	4.	0.	0.	1120.
72/73	0.	0.	0.	0.	195.	61.	185.	31.	3.	0.	17.	0.	492.
73/74	67.	58.	83.	206.	252.	64.	51.	21.	0.	0.	0.	0.	803.
74/75	0.	73.	276.	225.	250.	179.	84.	32.	7.	0.	0.	0.	1126.
75/76	19.	65.	255.	180.	345.	181.	152.	92.	26.	11.	2.	0.	1336.
TOTAL	1550.06	3274.23	5872.56	5481.57	8323.93	5595.50	3460.04	1887.65	500.67	1050.60	263.81	318.20	37578.82
AVERAGE	32.98	69.66	124.95	116.63	177.10	119.05	73.62	40.16	10.65	22.35	5.61	6.77	799.55

Appendix 6. Monthly spillage in $10^6 m^3$ assuming utilisation equal to 50% of assured yield (431 $10^6 m^3 y^{-1}$)

YEAR	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEPT	TOTAL
29/30	57.	64.	105.	149.	55.	97.	10.	0.	0.	0.	0.	0.	537.
30/31	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
31/32	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
32/33	0.	0.	0.	0.	13.	5.	0.	0.	0.	0.	0.	0.	18.
33/34	0.	0.	74.	274.	217.	163.	103.	6.	0.	0.	0.	0.	838.
34/35	0.	0.	268.	116.	17.	34.	21.	46.	0.	0.	0.	0.	502.
35/36	0.	0.	0.	0.	121.	45.	75.	47.	20.	0.	0.	0.	309.
36/37	0.	225.	48.	246.	552.	106.	57.	6.	0.	0.	0.	0.	1239.
37/38	0.	0.	0.	0.	59.	78.	61.	0.	0.	0.	0.	0.	198.
38/39	0.	21.	237.	185.	1143.	919.	152.	101.	18.	9.	0.	0.	2785.
39/40	38.	275.	180.	206.	83.	59.	171.	135.	72.	13.	0.	12.	1245.
40/41	52.	278.	261.	194.	213.	123.	114.	0.	0.	0.	0.	0.	1234.
41/42	0.	0.	0.	122.	60.	215.	39.	5.	32.	0.	0.	0.	473.
42/43	36.	187.	321.	165.	51.	265.	436.	210.	54.	244.	91.	59.	2119.
43/44	288.	304.	191.	188.	429.	201.	109.	38.	27.	0.	0.	0.	1775.
44/45	25.	13.	0.	58.	6.	154.	31.	0.	0.	0.	0.	0.	286.
45/46	0.	0.	0.	0.	17.	79.	124.	0.	0.	0.	0.	0.	220.
46/47	0.	21.	84.	42.	127.	67.	8.	0.	0.	0.	0.	0.	349.
47/48	0.	0.	0.	174.	447.	252.	77.	0.	0.	0.	0.	0.	950.
48/49	0.	0.	0.	104.	80.	32.	59.	45.	0.	0.	0.	0.	320.
49/50	0.	0.	199.	88.	14.	103.	73.	14.	0.	0.	0.	0.	491.
50/51	0.	0.	0.	124.	34.	99.	84.	0.	0.	0.	0.	0.	341.
51/52	29.	0.	93.	11.	14.	0.	0.	0.	0.	0.	0.	0.	148.
52/53	0.	0.	0.	0.	0.	8.	34.	0.	0.	0.	0.	0.	42.
53/54	0.	0.	0.	0.	49.	74.	64.	51.	0.	0.	0.	0.	238.
54/55	0.	0.	43.	122.	470.	252.	13.	0.	0.	0.	0.	0.	899.
55/56	0.	0.	26.	72.	429.	182.	20.	0.	0.	0.	0.	0.	729.
56/57	0.	19.	147.	69.	95.	51.	44.	3.	0.	73.	1.	131.	633.
57/58	539.	99.	0.	243.	152.	28.	39.	446.	0.	0.	0.	0.	1547.
58/59	0.	67.	218.	108.	100.	2.	0.	0.	0.	0.	0.	0.	495.
59/60	0.	0.	0.	0.	0.	8.	0.	0.	0.	0.	0.	0.	8.
60/61	0.	82.	511.	0.	44.	43.	101.	9.	7.	0.	0.	0.	796.
61/62	0.	0.	76.	76.	45.	20.	0.	0.	0.	0.	0.	0.	217.
62/63	0.	0.	23.	94.	48.	17.	4.	0.	0.	503.	12.	0.	700.
63/64	0.	59.	21.	95.	56.	0.	0.	0.	0.	0.	0.	0.	231.
64/65	0.	0.	106.	50.	55.	0.	0.	0.	0.	0.	0.	0.	211.
65/66	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
66/67	0.	0.	0.	0.	169.	118.	36.	0.	0.	0.	0.	0.	323.
67/68	0.	0.	61.	30.	2.	49.	0.	0.	0.	0.	0.	0.	143.
68/69	0.	0.	0.	0.	0.	0.	0.	4.	0.	0.	0.	0.	4.
69/70	0.	0.	11.	45.	77.	0.	0.	0.	0.	0.	0.	1.	134.
70/71	0.	0.	0.	0.	0.	0.	21.	7.	0.	0.	0.	0.	28.
71/72	0.	0.	153.	220.	195.	201.	79.	35.	0.	0.	0.	0.	883.
72/73	0.	0.	0.	0.	56.	43.	167.	13.	0.	0.	0.	0.	279.
73/74	0.	38.	65.	189.	234.	46.	33.	3.	0.	0.	0.	0.	609.
74/75	0.	0.	224.	207.	232.	161.	66.	14.	0.	0.	0.	0.	905.
75/76	0.	0.	220.	170.	327.	163.	134.	74.	8.	0.	0.	0.	1096.
TOTAL	1064.08	1752.27	3966.01	4236.68	6584.93	4560.80	2659.28	1312.90	238.84	843.55	104.57	202.38	27526.30
AVERAGE	22.64	37.28	84.38	90.14	140.10	97.04	56.58	27.93	5.08	17.95	2.22	4.31	585.67

Appendix 7. Monthly spillage in $10^6 m^3$ assuming utilisation equal to 100% of assured yield (862 $10^6 m^3 y^{-1}$)

YEAR	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEPT	TOTAL
29/30	24.	31.	71.	116.	22.	63.	0.	0.	0.	0.	0.	0.	327.
30/31	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
31/32	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
32/33	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
33/34	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
34/35	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
35/36	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
36/37	0.	0.	0.	0.	74.	73.	24.	0.	0.	0.	0.	0.	171.
37/38	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
38/39	0.	0.	9.	0.	1058.	885.	119.	67.	0.	0.	0.	0.	2129.
39/40	0.	140.	147.	173.	49.	26.	138.	101.	39.	0.	0.	0.	813.
40/41	0.	188.	228.	160.	180.	90.	80.	0.	0.	0.	0.	0.	925.
41/42	0.	0.	0.	0.	0.	31.	5.	0.	0.	0.	0.	0.	37.
42/43	0.	27.	287.	131.	17.	232.	403.	177.	20.	211.	58.	26.	1589.
43/44	255.	271.	157.	155.	395.	168.	75.	5.	0.	0.	0.	0.	1481.
44/45	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
45/46	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
46/47	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
47/48	0.	0.	0.	0.	16.	218.	44.	0.	0.	0.	0.	0.	278.
48/49	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
49/50	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
50/51	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
51/52	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
52/53	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
53/54	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
54/55	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
55/56	0.	0.	0.	0.	0.	62.	0.	0.	0.	0.	0.	0.	62.
56/57	0.	0.	0.	0.	0.	0.	11.	0.	0.	0.	0.	42.	53.
57/58	506.	66.	0.	177.	119.	0.	0.	413.	0.	0.	0.	0.	1280.
58/59	0.	0.	52.	75.	66.	0.	0.	0.	0.	0.	0.	0.	193.
59/60	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
60/61	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
61/62	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
62/63	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
63/64	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
64/65	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
65/66	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
66/67	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
67/68	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
68/69	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
69/70	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
70/71	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
71/72	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
72/73	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
73/74	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
74/75	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
75/76	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
TOTAL	784.16	722.36	942.01	986.05	1996.78	1848.98	899.93	763.16	59.44	210.63	57.80	67.94	9339.24
AVERAGE	16.68	15.37	20.04	20.98	42.48	39.34	19.15	16.24	1.26	4.48	1.23	1.45	198.71

Appendix 8. Checklist of the fish species of the Pongolo River system.

The taxonomic and vernacular nomenclature used follows that of Jackson (1975) unless otherwise stated.

The recorded ichthyofauna of the Pongolo system comprises 50 species representing 15 families as listed below.

* denotes species not recorded from the floodplain.

\+ denotes marine immigrant species.

SCIENTIFIC NAME	COMMON NAME
Family : Mormyridae	
Petrocephalus catastoma (Gunther, 1866).	Churchill
Marcusenius macrolepidotus (Peters, 1852).	Bulldog
Family : Characidae	
Hydrocynus vittatus Castelnau, 1861.	Tigerfish
Alestes imberi Peters, 1852.	Imberi
Micralestes acutidens (Peters, 1852).	Silver robber
Family : Cyprinidae	
* *Barbus polylepis* Boulenger, 1907	Small scale yellowfish
Barbus marequensis A Smith, 1841	Large scale yellowfish
Barbus trimaculatus Peters, 1852	Threespot barb
Barbus paludinosus Peters, 1852	Straightfin barb
Barbus afrohamiltoni Crass, 1960	Hamilton's barb
Barbus argenteus Gunther, 1866	Rosefin barb
Barbus anoplus Weber, 1897	Chubbyhead barb
Barbus unitaeniatus Gunther, 1866	Longbeard barb
Barbus viviparus Weber, 1897	Bowstripe barb
Barbus annectens Gilchrist & Thompson, 1917	Broadstripe barb

Barbus toppini Boulenger, 1916	East coast barb
Barbus radiatus Peters, 1853	Beira barb
* *Varicorhinus nelspruitensis* Gilchrist & Thompson, 1911	Incomati chiselmouth
Labeo cylindricus Peters, 1852	Redeye labeo
Labeo molybdinus du Plessis, 1963	Leaden labeo
Labeo rubropunctatus Gilchrist & Thompson, 1913	Redspotted labeo
Labeo rosae Steindachner, 1894	Rednose labeo
* *Barilius zambezensis* (Peters, 1852)	Barred minnow
Engraulicypris brevianalis (Boulenger, 1908)	River sardine

Family : Clariidae

Clarias gariepinus (Burchell, 1822)	Sharptooth catfish
Clarias ngamensis Castelnau, 1861	Blunttooth catfish

Family : Schilbeidae

Eutropius depressirostris (Peters, 1852)	Butter catfish

Family : Mochokidae

Synodontis zambezensis Peters, 1852	Brown squeaker
* *Chiloglanis anoterus* Crass, 1960	Pennant-tail catlet
* *Chiloglanis emarginatus* Jubb & le Roux, 1969	Pongola rock catlet
Chiloglanis paratus Crass, 1960	Sawfin rock catlet
Chiloglanis swierstrai van der Horst, 1913	Lowveld rock catlet

Family : Amphiliidae

* *Amphilius platychir* Gunther, 1864	Rhodesian mountain catfish
* *Amphilius natalensis* Boulenger, 1917	Natal mountin catfish

Family : Anquillidae

Anquilla bicolor bicolor McClelland, 1845	Shortfin eel
Anquilla marmorata Quoy & Gaimard, 1824	Madagascar mottled eel
Anquilla mossambica Peters, 1852	Longfin eel
Anquilla nebulosa labiata Peters, 1852	African mottled eel

Family : Cyprinodontidae

Nothobranchius orthonotus (Peters, 1844)	Spotted killifish

Family : Cichlidae

Sarotherodon mossambicus (Peters, 1852)	Mozambique tilapia
Tilapia rendalli swierstrai Gilchrist & Thompson, 1917	Southern redbreast tilapia
Tilapia sparmanni A Smith, 1840	Banded tilapia
Pseudocrenilabrus philander (Weber, 1897)	Southern mouthbrooder

Family : Gobiidae

Platygobius aeneofuscus (Peters, 1852)	Freshwater goby
Glossogobius giurus (Hamilton-Buchanan, 1822)	Tank goby
Mugilogobius pongolensis Kok & Blaber, 1977	Blue-spot goby

Family : Carcharhinidae

+ *Carcharhinus leucas* (Muller & Henle, 1941)	Zambezi shark

Family : Elopidae

+ *Megalops cyprinoides* (Broussonet, 1782)	Oxeye tarpon

Family : Sparidae

+ *Acanthopagrus berda* (Forskal, 1775)	River bream

Family : Mugilidae

+ *Mugil cephalus* Linnaeus, 1958	Flathead mullet

Appendix 9. List of participants.

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Mr W D Densham, Natal Parks, Game and Fish Preservation Board
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