ECOLOGICAL AND ECONOMIC EVALUATION OF WETLANDS IN THE UPPER OLIFANTS RIVER CATCHMENT, SOUTH AFRICA

By

RW Palmer, J Turpie, GC Marnewick and AL Batchelor

Report to the Water Research Commission on the Project

"Ecological and economic evaluation of wetlands in the Upper Olifants River Catchment, with reference to their functions in the catchment and their management"

Project Leader: RW Palmer, Afridev Consultants

WRC Report No: 1162/1/02
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Project Leader Palmer, R. W., AfriDev Consultants

Specialist Team:

Batchelor, A. L., Environmentek, CSIR (Water quality)
Coleman, T., Wates Meiring & Barnard (Hydrology)
Engelbrecht, J., Mpumalanga Parks Board (Fish)
Grundling, P-L., Ihlaphosi Enviro Services (Capacity Building)
Grundling, A., Ihlaphosi Enviro Services (Capacity Building & Surveys)
Jacobsen, N. H. G., Freelance (Amphibians, reptiles and mammals)
Marneweck, G. C., Wetland Consulting Services (Wetland Inventory and Classification)
Matthews, G., Wates Meiring & Barnard (Hydrology)
Muller, J., Environmentek, CSIR (GIS)
Palmer, R. W., AfriDev (Aquatic invertebrates)
Turpie, J., Freelance (Resource Economics and Birds)
van Zyl, H., Independent Economics Researchers (Economics)
Vink, D., Environmentek, CSIR (GIS)

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ISBN No :

DISCLAIMER

This report is based on best available scientific knowledge and understanding of wetland values and functions at the time of writing, and concerns the specific wetland types found in the Upper Olifants River Catchment (UORC). It is inevitable that some of the statements, conclusions and recommendations made in this report may turn out to be invalid as new information and new methods of assessment become available. The classification system as well as the mapping method used and scale at which the wetlands were captured and mapped were intended to meet the objectives for this project. The accuracy of the wetland areas and boundaries are therefore limited to the scale at which the information was captured. The map is thus not intended for use at any finer scale of resolution. In addition, this report is and was not intended to be a definitive study of the wetlands of the UORC. The report has been reviewed by the Water Research Commission (WRC) and approved for publication. Approval does not signify that the contents necessarily reflect the views and policies of the WRC or members of the Project Steering Committee. Mention of trade names or commercial products do not constitute endorsement or recommendation for use.

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The Steering Committee responsible for this project, consisted of the following persons:

Dr SA Mitchell	Water Research Commission (Chairman)
Dr S Mkhize	Water Research Commission
Mr JF Taljaard	Water Research Commission (Secretary)
Dr M Aken	Anglo Coal Environmental Services
Dr ME Ligthelm	Department of Water Affairs and Forestry, Nelspruit
Mr CM Chunda (for Dr ME Ligthelm)	Department of Water Affairs and Forestry, Nelspruit
Mr M Lizamore (for Dr ME Ligthelm)	Department of Water Affairs and Forestry, Nelspruit
Ms G Munro	Department of Water Affairs and Forestry, Pretoria
Dr WR Harding	Southern Waters
Mr A Linström	Mpumalanga Parks Board
Mr LM Nengovhela (for Mr JNJ Viljoen)	Matla Environmental Services and Olifants River Forum
Dr AS Parsons	Chamber of Mines
Ms C Thirion	Institute of Water Quality Studies, Pretoria
Mr M Mander	University of Natal

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Mr JP Bloemsma	Anglo Coal, Marshalltown
Mr D Klein	National Department of Agriculture, Pretoria
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Mr R Meiswinkel	Onderstepoort Veterinary Institute, Onderstepoort
Mr G Pool	National Department of Agriculture
Mr T Poulter	Working for Water Programme, White River
Mr X Prevost	Department of Minerals and Energy
Dr Rezin	Veterinarian, Witbank
Mr J Schoeman	Agricultural Research Council
Mr B Swart	Mpumalanga Parks Board
Mr B van Zyl	Anglo Coal

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EXECUTIVE SUMMARY

This report provides a preliminary assessment of the ecological and economic values of wetlands in the Upper Olifants River Catchment (UORC). In doing so, the report provides the basis for developing a strategic framework for the conservation and management of these wetlands. The wetlands were classified on the basis of hydro-geomorphic determinants. A detailed digital map, captured at a scale of 1:50 000 and reproduced at a scale of 1:160 000, showing the distribution of various wetland types in the UORC, accompanies the report.

We acknowledge that the study has underestimated the values of these wetlands because:

(1) The study focussed exclusively on uses of wetlands within the UORC, and did not consider their values for users lower down in the catchment (ie downstream of Loskop Dam). Demands for water in the lower reaches far exceed water availabilty, and the wetlands in the UORC are considered important in providing steady flows for downstream users.

(2) Most of the wetlands in the UORC are currently degraded, and their values would presumably have been higher under pristine or near pristine conditions.

(3) The study focussed on the main uses of wetlands, and did not consider all uses, such as the harvesting of medicinal plants.

(4) The study did not consider the values of any wetlands dominated by Phragmites reeds or bulrush (Typha). These would undoubtedly play an important role in flood attenuation, and possibly also water quality improvement. These wetland types were largely restricted to a few, disturbed areas in the vicinity of Witbank, and were therefore excluded from this study.

Rationale

The need to assess the values of wetlands in the UORC arose because many wetlands in the area face irreversible degradation due to developments in the catchment, and because wetlands are increasingly recognised as of areas of considerable economic and ecological importance. Whether the degradation and loss of wetlands in the UORC is reason for concern was uncertain, as neither the ecological nor the economic value of these wetlands was known. If decisions regarding the conservation versus development of wetlands in the area are to be optimal for society, then it is necessary to develop an understanding of the sorts of costs and benefits that need to be traded off.

Aims

The primary aims of this project were:

- *To produce an inventory of wetlands in the Upper Olifants River Catchment (upstream of the Olifants and Klein Olifants River confluence).*
- *To classify these wetlands in terms of their functional and ecological type and importance.*
- *To assess the net economic value derived from these wetlands, based on a desktop evaluation of the goods and services they provide, and the opportunity cost of conserving them.*

The project also aimed to create awareness and understanding of the wetlands of the UORC among local communities and users, and to build capacity around wetland management and conservation.

Approach

The study relied mainly on existing information, supplemented by limited fieldwork and limited liaison with stakeholders. It was recognised from the outset that a desktop study would not provide definitive information on the conservation or economic values of the wetlands, but that it would provide ball-park estimates and guidance to future, more detailed studies.

Methods

The study ran for two years, with the first year and a half focussing on the mapping and classification and inventory of wetlands, and subsequent ground-truthing. This was followed by a number of specialist studies as follows:

- *Review of policy and legislation relating to wetlands.*
- *Multiple variable and spatial analysis to investigate the main drivers of wetland distribution and land use patterns.*
- *Hydrological modelling to investigate the impacts of wetlands on stream flow hydrological characteristics.*
- *Desktop water quality assessment.*
- *Desktop biodiversity studies, including review of data on plants, aquatic invertebrates, amphibians, reptiles, birds and mammals associated with wetlands.*
- *Resource survey of direct use values of wetlands (e.g. harvesting food, medicinal plants etc).*
- *Assessment of indirect use values of wetlands (e.g. water purification, flow regulation etc).*

The study focussed on the non-consumptive values of these wetlands, particularly their role in water quality improvement and flow regulation. The study did not attempt to estimate the existence value of the UORC wetlands due to the extensive resources required for a Contingent Valuation or similar stated-preference valuation study. However, it is probable that the existance value is low, particularly because the wetlands in the UORC are small and numerous.

Wetland Classification, Mapping and Inventory

A 1:50 000 scale digital map of wetland types in the UORC showed that wetlands, including dams, cover 9,9% of the UORC (or 64 813 ha). A total of 17 hydro-geomorphic wetland types were recognised, and these were grouped into six main categories shown in Figures A-C and Table A.

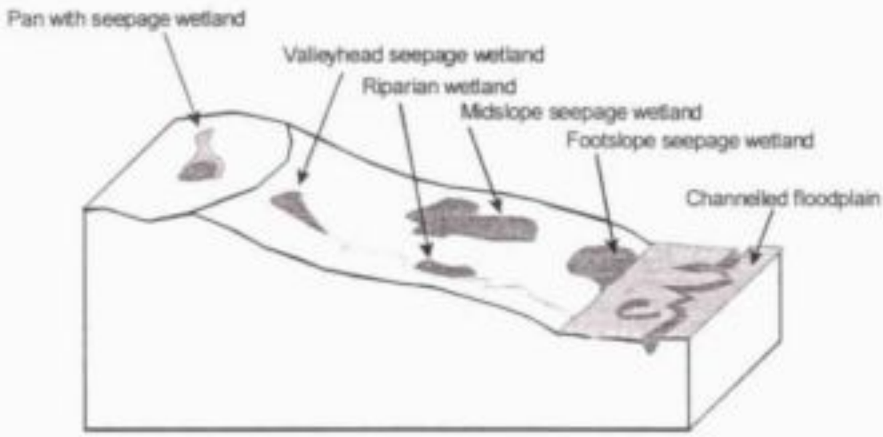

Figure. A. Diagrammatic representation of various wetland types, highlighting channelled floodplain and hillslope seepage wetlands.

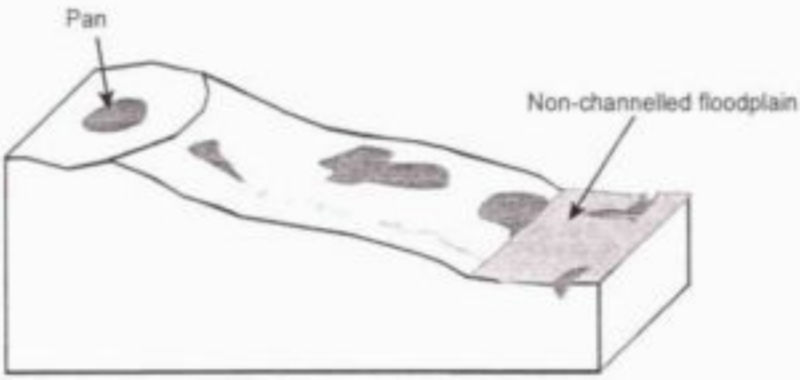

Figure. B. Diagrammatic representation of non-channelled floodplan wetland and pan without seepage wetland.

Figure. C. Diagrammatic representation of crest seepage and footslope seepage wetlands.

Table A. Percentage of total wetland area covered by various wetland types in the Upper Olifants River Catchment.

WETLAND TYPE	*% of total wetland area*
NON-FLOODPLAIN RIPARIAN	
1. Drainage lines with riparian zones	*22,4*
2. Channelled riparian wetlands	*3,2*
3. Non-channelled riparian wetlands	*0,6*
FLOODPLAIN RIPARIAN	
4. Seasonally inundated channelled valley bottom floodplains with footslope seepage wetlands	*17,7*
5. Seasonally inundated valley bottom floodplains without footslope seepage wetlands	*0,7*
6. Seasonally inundated non-channelled valley bottom floodplains	*1,6*
7. Temporarily to seasonally inundated channelled valley bottom foodplains	*1,2*
HILLSLOPE SEEPAGE	
8. Footslope seepage wetlands	*12,9*
9. Midslope seepage wetlands	*12,1*
10. Valleyhead seepage wetlands	*3,1*
11. Crest seepage wetlands	*0,04*
PANS	
12. Permanently wet pans	*5,4*
13 Non-permanently wet pans	*3,8*
14. Seepage wetlands associated with pans	*2,1*
OTHER NON-RIPARIAN	
15. Wet grasslands	*1,64*
ARTIFICIAL WETLANDS	
16. Dams and weirs	*10,55*
17. Other artificial wetlands	*0,89*

The most common wetlands in the area were drainage lines with riparian zones, followed by seasonally inundated channelled valley bottom floodplains with footslope seepages.

Geology

The highest concentrations of wetlands are associated with the distribution of dolerite intrusions within the Vryheid sediments in the southern section of the UORC. The structural control of the geological lithologies in terms of landform and wetland keypoints contributed to the high concentration of wetlands in these areas. The smaller non-pan wetlands occur in the southern, central and northwestern portions of the catchment.

Soils

Katspruit and Rensberg soil forms associated with the floodplains are usually not used for cultivation. Instead these areas are used predominantly for livestock grazing and some areas are mowed and baled. By contrast, most of the more sandy soils and soil forms associated with the seepage wetlands (particularly the Avalon, Pinedene and Westleigh soil *forms) are extensively cultivated. Cultivation is preferred where saturation is not extensive or where hydric conditions are not well expressed such as in the more intermittently saturated part of these seepage systems. As a result of the agricultural value of the soils associated with many of the seepage areas have been heavily impacted by cultivation.*

ECOSYSTEM SERVICES

Flow Regulation

The hydrological characteristics of a typical quaternary catchment of the UORC (B11C) was modelled with and without wetlands. The model assumed grassland cover for wetlands, as this is the most common wetland vegetation in the UORC. The results are likely to have been significantly different had the model assumed cover by Phragmites reeds or bulrush (Typha). [These are restricted to a few, disturbed wetlands in the vicinity of Witbank, and were therefore not taken into consideration during this study.]

The results of the modelling showed that wetlands have a higher effect on the runoff for lower flows than they do for higher flows. Furthermore, evaporation from wetlands during wetter period results in higher evaporation losses as there is more water available for evapotranspiration. The baseflow and baseflow storage differences are more marked for the low-flow period than the high-flow period, as there is more water contributing to baseflow during wetter months.

Water Purification

Wetland systems in the UORC are complex, with the complexity compounded by differences in position in the landscape, water quality, hydraulics, hydrological characteristics and landuse. An understanding of the water balance and nutrient mass balance is critical in attributing a water quality improvement capacity to wetlands. There are no data on any of the systems individually, or even collectively, to provide an indication of the role besides anecdotal, that the systems are playing with respect to nutrient removal. The most important findings were as follows:

Floodplains

Floodplain wetlands are unlikely to markedly reduce the concentrations of soluble nutrients as the contact period between wetland biota and water/substrate is short during flood periods. If floodwaters are retained in floodplain wetlands, typically in depressions, the total volume and hence mass of nutrients that are retained is likely to represent only a small fraction of the nutrients exported during any one flood event. The behaviour of nutrients in these systems, once water levels have receded, would be similar to those recorded for pans. If the dominant source of phosphates in the UORC is associated with sediment, then sedimentation is likely to be an important process for nutrient removal in floodplain systems.

Pans

Nutrient cycling and removal within a pan environment is likely to be the dominant process, rather than nutrient loss. With respect to nitrogen, a portion will be lost through volatilisation if the pH exceeds 8, and some will be lost to the atmosphere via nitrification/denitrification. Plants will take up some, but this is likely to be short-term removal unless the plants are harvested and removed from the system. If grazed, some of the nitrogen will be returned in the waste of the grazer. It is likely that as the solutes in the *pans concentrate through evaporative losses that the relative importance of each one of the processes is likely to change, for example as the pH and salinity increase, ammonia volatilisation could replace nitrification/denitrification as the dominant process. Phosphates precipitation is likely to be the dominant removal process as calcium/phosphate type complexes form, particularly at higher pH's. The concentration in pan waters is likely to reflect some form of equilibrium between precipitated phosphates and release of phosphates from the predominantly anaerobic sediments. Unless pans leak (which they are suspected of doing), nutrients will accrete in pan systems with loss being dependent on the rate of diagenesis within the pan sediments.*

Seepage Wetlands

Seepage wetlands offer the potential to remove oxidised substances as flows typically move through reducing areas before emerging into areas with a higher redox. Flow direction through seepage wetlands will have an influence on the transformation processes, with a higher removal propensity in those systems with a vertical flow component. When permanently flooded, seepage systems would perform typical functions documented for constructed free water surface wetlands, such as organic transformation, suspended solids removal, limited ammonia removal, nitrate removal, limited sulphate removal and metals removal.

BIODIVERSITY VALUES

Plants

The available information on plants in the wetlands of the UORC indicates that plants species diversity is exceptionally high. A total of 354 indigenous plant species, and a further 59 exotic species, has been reported in these wetlands. The Nylsvlei wetland, by comparison, supports about 60 species of plant in total. There also appears to be considerable local and regional variability in plant species composition and richness among and within the different wetland types.

Of the wetland types in the UORC, the hillslope seepage wetlands are the most impacted by agricultural practices. It is likely that a large portion of the plant species diversity that was naturally associated with these systems has been lost. With respect to the pans, there is very little information on how the plant species richness and composition change in relation to the natural hydrological and water quality dynamics of these systems.

Although Red Data Book listed plant species do occur in the systems, only a few were recorded in the field surveys of these systems and reported in the reports examined. Considering the diversity of habitats among all the systems, the likelihood of the occurrence of others cannot be ruled out.

Aquatic Invertebrates

Available data on aquatic invertebrates in the UORC indicates that the fauna comprises mostly widespread, common and hardy taxa. However, their abundance and high productivity are important in maintaining large populations of higher trophic levels, particularly birds. Most insect species have good dispersal abilities, and are capable of rapid recolonisation. However, their ability to recolonise disturbed areas depends on the presence of undisturbed refugia. This highlights the need to designate wetland areas worthy *of special protection. Most of the crustacea and common snail species are adapted to temporary drying. Permanently inundated conditions, such as found in dams and weirs, leads to reduced diversity, and replacement by species that are sensitive to drying. This highlights the importance of maintaining a mosaic of intermittent, seasonal and permananent systems.*

Fish

The wetlands of the UORC are characterised by a low diversity of fish fauna, historically with 11 indigenous species, but presently with eight indigenous, three exotic species and three translocated indigenous species. The presence of several large impoundments in the area, which restricts the movement of fish, may limit the available habitat and numbers of fish and fish species in the area. Where suitable habitat is still available, e.g. pools in the lower Viskuilespruit, large numbers of small-scale yellowfish (Barbus polylepis) are still present.

Amphibians, Reptiles & Mammals

The wetlands of the UORC are characterised by a low diversity of herpetofauna and mammal fauna, with few rare or endangered species. The naturally low diversity has been aggravated by large-scale habitat degradation, coupled with the use of pesticides, particularly treated seeds, reducing the amount of available prey. An important attribute of these wetlands is that they provide pathways of genetic interchange, linking populations of amphibians and aquatic reptiles and mammals.

Birds

Birds are the most conspicuous faunal element of the UORC wetlands. The variety of habitats offered by the different types of wetlands results in a large diversity of birds using the area, and their large aggregate area probably means that many of the waterbird populations are significant in terms of their overall numbers. These include populations of Red Data species such as Greater and Lesser Flamingo as well as of a former Red Data species, the Grass Owl. The latter three species are all highly sensitive to disturbance.

Although all of the major wetland types provide complementary habitats for birds, pans probably constitute the most important wetland type in the area. Because most waterbird species are opportunistic, the diversity and numbers of birds using artificial wetlands is also high. The construction of dams in the area thus adds to waterbird numbers in the area, but does not contribute to the conservation of rare species.

LAND USE, WETLAND USERS AND THREATS

Land use pattern

By far the largest land use in the area is dryland commercial agriculture (mainly maize farming) at 37%, followed by mining and quarrying, forest plantations and urban residential land use at 5%, 2%, and 1% respectively.

Users

An initial meeting with stakeholders, held in Witbank concluded that the main users of wetlands in the area are Agriculture and Mines. The uses of wetlands by these sectors were *therefore investigated in detail in this study. Other users of wetlands were identified and considered, but not to the same level of detail.*

Threats

Major threats to the wetlands in the area include total destruction due to coal mining or agriculture, and changes in hydrological characteristics and water quality due to damming and effluent from agriculture, mines, power stations, industry and urban environments, and increasing demands for water. There is considerable evidence that catchment modification including overgrazing, damming and the effects of roads and road bridges have all contributed to channel erosion and incision in the main rivers in many areas of the catchment. This in turn has tended to reduce the flooding frequency, and as a result the associated floodplain wetlands show signs of desiccation and degradation. As a result of the combination of threats, very few wetlands in the catchment remain in a natural state or reflect reference conditions.

Legislation and Protection

Although current environmental legislation in South Africa emphasises the importance of wetlands, no area within the UORC is conserved in any formal way. Furthermore, there is often inequitable enforcement of the regulations due to inconsistencies in practise among developers, and because of the uncertainties in predicting the long-term impacts of development, particularly coal mining.

DIRECT USE VALUES

Based on our rough estimates, the wetlands of the UORC could generate as much as R70 to 86 million per year in terms of direct use value. Pans appear to be the most valuable wetlands in terms of direct use values, followed by seepage wetlands and artificial wetlands. Riparian wetlands provide considerably less direct use value. The main direct use values are described below.

Harvesting Food, Medicinal Plants and Building Materials

Based on quantitative studies of the consumptive use values of wetlands elsewhere, and adjusting for the different socio-economic environment of the study area, we estimate that the wetlands in the UORC are currently worth in the order of R10 - R100 per ha per year in terms of resource harvesting.

Fishing

Fishing is one of the largest recreational activities in the UORC, and at least 18 angling clubs can be found in the towns within the catchment. We estimate that up to R16,5 million per year is spent on fishing within the catchment. Most fishing in the catchment takes place in dams and pans. These are estimated to be worth R1 690 and R276 per ha per year respectively.

Bird Watching

Estimates of the total annual birding-related expenditure by birders in the UORC were based on average expenditure on (1) birding gear, and (2) other birding trip related costs. We estimate that R1 855 440 per year is spent on birding within the catchment. About 40% of the birding takes place at dry land sites, 20% at rivers, 20% at dams and 20% at *wetlands dams and pans. Dams are estimated to be worth about R54 per ha per year, pans are worth R47 per ha and all other natural wetlands are worth R2 per ha in terms of birding. These averages would only apply to particular wetlands if the value were evenly spread across all wetlands. In reality, it is to be expected that the value is patchily distributed and strongly influenced by particular site attributes such as size and habitat diversity.*

Waterfowl Hunting
No estimates were made for the value of waterfowl hunting, partly because it was not considered an important economic activity in the catchment, and partly because it has been illegal to hunt waterfowl in the UORC for the past ten seasons.

Water for Cattle
Permanent wetlands can save a farmer from having to distribute livestock drinking water. We estimate that an average perennial pan would save 500m of piping at a cost of R7 per m, a reservoir at an average cost of R8 000 and a trough at an average cost of R750. The total capital cost saved by the average pan would thus come to R12 250. Seeing that there are 149 permanently wet pans in the UORC, their combined maximum value is R1 825 250. This translates into a per hectare value of R522 which can be converted into an annual value of R42 (using an 8% discount rate).

Storage and Evaporation of Mine Water
A storage dam with a 5 million m^3 capacity costs about R15 million to construct. This money could be saved if pans were used to store this water instead. Taking the average capacity of pans in the UORC into account, we estimate that using pans to store mine water could result in a total saving of R36 000 per ha of pan, or a R2 800 annual saving. This value however, is only realised if a wetland is on a mining property and not underlain by coal.

Grazing for Livestock
The main value of wetlands for livestock grazing in the UORC is a short (six week) period towards the end of winter, when wetlands provide the only available good grazing. Once the summer rains start, grazing takes place throughout the area, and the wetlands do not have any particular benefits for grazing. Generally, seepage wetlands are the wetland type most commonly grazed, and these are estimated to be about twice as productive as natural veld. We estimate that the annual value of wetland grazing lies in the order of R1 800 per ha for natural seepage systems, and between R1 800 per ha and R2 400 per ha for seeded seepage systems.

Livestock Diseases
Wetlands in the UORC are directly associated with a number of important diseases of livestock, and as such, represent a "negative" wetland value. The most important diseases are nematodes, internal parasites associated with aquatic snails and arboviruses associated with Culicoides midges. Most livestock owners in the UORC spend considerable amounts of money vaccinating and dosing cattle and sheep regularly against these diseases, particularly in summer. In addition, many farmers tend to remove their livestock from wetland areas during summer (February to April) so as to reduce rates of infection.

Crop Production

We were unable to estimate values of crop production from wetlands by interviewing farmers because it is illegal to cultivate wetlands. However, it is certain that large areas of hillslope seepage wetlands have been drained and cultivated.

INDIRECT USE VALUES

The indirect use value of the wetlands could not be estimated in monetary terms, but were considered to be fairly low. The preliminary findings of this study provide a major deviation from general beliefs about the economic services provided by wetlands, and illustrate the potential danger of transferring the benefits of one wetland system to another on the assumption that all wetlands provide similar goods and services. The classification exercise in this study alone has demonstrated the wide variety of functional types of wetlands that occur in the UORC, and these are undoubtedly vastly different in function from many of the wetlands for which more accurate measures of functional value have been made.

Hydrology

Based on limited modelling and available data, it appears that the wetlands of the UORC have little impact on flow regulation or flood attenuation. Instead, it appears that hydrological characteristics have a major impact on the wetlands. It should be stressed that the modelling exercise did not consider other factors, such as the soil binding properties of floodplain vegetation (many being clonal with extensive rhizome systems), which is important for protecting the floodplain soils and even the channel banks from erosion during flooding.

Water Quality

The water purification functions of the wetlands in the UORC are considered to be limited to a small amount of removal of certain contaminants by seepage wetlands only, and their sediment retention function is unknown, but thought to be negligible. There is danger in citing these preliminary findings, as detailed data collection and modelling may still prove otherwise. Moreover, we have not investigated all possible values, such as carbon sequestration.

SYNTHESIS

Ecological Values of Wetlands

The main ecological value of the UORC wetlands lies in the sheer abundance of wetland habitat in the region. Taken alone, most of the wetlands are small and disjunct. This is probably the single most important ecological factor that has promoted the degradation of the wetlands, as they prove insignificant in environmental impact assessment studies. If the wetlands of the study area were seen as a single system (65 000 ha), they may be treated differently in terms of a conservation strategy.

Another factor that adds to the aggregate biodiversity value of the wetlands is their diversity of types, providing a high variety of wetland habitats. The fact that 17 wetland types could be distinguished in the study area is of conservation significance alone.

In terms of biodiversity value, pans are generally the most important type of wetlands in the UORC, largely due to their seasonality in water level and variety of habitats. Riparian wetlands are the next most important category, followed by seepage wetlands. Conservation planning needs to take irreplaceablity, complementarity and connectivity of the wetlands into account. Ideally, more detailed data on individual wetlands as well as the linkages between systems is required in order to set conservation priorities in an efficient manner.

Economic Values of Wetlands

A crude estimate was made of wetland values in this study, but the estimates suggest that, despite the wetlands having little or no indirect use value, their direct use value is not insubstantial. Different types of wetlands are estimated to be worth R1 000 to R32 000 per ha in present terms. The presence of a wetland may also preclude the use of the land for other purposes, and this represents an opportunity cost, valued as the lost income that could have been generated by that activity.

A rough estimate of agricultural opportunity costs may be obtained from land prices, which generally reflect the expected future income streams from land. In the UORC, the average opportunity cost for wetlands that can be drained would be in the middle of the range of values for grazing land (i.e. R725 per ha) and the lower end of the range for cultivated land (R1 500 per ha).

The opportunity costs of mining in the UORC are highly variable, as the value of the mineral rights depend on the size, quality, location, ease of extraction of the coal, as well as the coal price and state of the coal market. Values may range from as low as 30c per ton of coal up to about R4 per ton, representing a difference factor of 13. For the purposes of this study, R1 per ton, and an average yield of 45 000 tons per ha, were agreed upon as acceptable averages. This implies that the average hectare of wetland underlain by coal deposits has an opportunity cost of R45 000 (R1 per ton X 45 000 tons per ha) plus the agricultural value of surface land as described above.

To illustrate the substantial difference between using mineral rights values and gross income for coal to estimate values, the gross income of a hectare of coal was estimated by Anglo Coal to be between R4 and R9 million. However, using the gross income from coal would be an incorrect reflection of the true value of the resource as it would also capture the return to capital and labour required to extract and process the coal. The value of mineral rights is thus theoretically the best reflection of the returns from the resource itself.

Trade-offs between Conservation and Conversion

Recognising that the opportunity costs also differ from wetland to wetland, it makes sense to allow conversion of those wetlands for which the opportunity costs of conservation are high and the (non-monetised or monetised) biodiversity value is low, and to promote conservation where the opposite is true. Where the conservation value of the wetlands is relatively low in monetary terms, as seems to be the case in the UORC, there could be excessive pressure for conversion if this is the only criterion for decision-making. However, it would be incorrect to base decisions solely on a comparison of incomplete total values with opportunity costs. The optimal amount to conserve, and the decision of which wetlands to conserve, will need careful consideration of all these factors. Because of the difficulties in monetising all value, the precautionary principle should still apply, in that enough wetland area should be conserved to maintain ecosystem integrity and viable populations.

Rehabilitation

The conversion of a wetland to mining does not necessary lead to the total loss of the wetland in perpetuity. Rehabilitation is possible, although usually to a poorer quality wetland than existed previously. Although mines are required to rehabilitate land beyond the point where externalities no longer occur, the extra money that they are spending on comprehensive rehabilitation is likely to far outstrip the future productive value of the land.

CAPACITY BUILDING

Various activities contributed towards capacity building during this project. These included a mini-symposium for teachers, a secondary school wetlands project and participation by tertiary level students.

Teachers

A one-day Symposium for teachers of the Elukhanyisweni Secondary School in Witbank was held at Colbyn Valley Wetland on the 12th April 2001. The symposium was attended by 8 teachers, 11 learners, 3 guides and 4 presenters. This was followed by a field outing to the Colbyn Valley Wetland.

Secondary Schools

The Elukhanyisweni Secondary School in Witbank was identified to participate in the capacity building exercise together with the Mosstrosity (Friends of Colbyn) Environmental Group of the C R Swart High School in Pretoria. The latter is a successful wetland environmental club, comprising learners. Forty learners from both schools, as well as 4 teachers from Elukhanyisweni Secondary School, including the principal, Mrs Buyi Nkosi attended the field trip. Learners expressed their gratitude for the project for enriching their life experiences, and wished the project to continue at their school. The success of this awareness and capacity building campaign was also reflected by contributions that the learners made in the week following the visit. These included a scale model of a traditional hut built with "pseudo-wetland" vegetation, various wetland essays and related posters, hand painted and drawn by the learners. The posters reflected channelled and urban wetlands and the Olifants River in a multi-landuse setting.

Tertiary Students

Tertiary level students that participated in the project included the following:

- *Mr Calvin Chirwa, a geographer who has some GIS training, assisted with the GIS work. The project provided him with exposure and some experience with regard to the practical application of his undergraduate studies by participating as part of the capacity building team.*
- *Two students from the University of Venda participating in the Wetland Rehabilitation projects of Working for Water Programme, Mr Eric Munzhedzi and Mr Mpho Nanngambi, participated as field guides during the excursion of the Colbyn Wetland.*
- *Mr Cain Chunda of Department of Water Affairs and Forestry (DWAF) Nelspruit was invited and participated in the first Wetland Awareness Meeting between the Teachers of the Elukhanyisweni Secondary School (Witbank) and the Learners from C R Swart High School (Colbyn Valley Wetland). Mr Chunda intends to use the wetlands*

in the UORC as the focus of his Masters thesis in Water Management with University of Pretoria.

TECHNOLOGY TRANSFER

Members of the study team attended and introduced this project to the following meetings of professional organisations during the course of the project:

- *International Association of Impact Assessors (Witbank, May 2000)*
- *Controlled Release Scheme (SACE Recreation Club, May 2000)*
- *Banke Farmers Union Meeting (Middelburg, September 2001)*
- *Matla Coal Environmental Forum (Matla Mine, December 2001)*
- *Key Stakeholders (Witbank: May 2000 and February 2002)*

ARCHIVING OF DATA

This report and its associated digital map contains the most important information collected during this study. As this study was based mainly on a desktop assessment, there was not much additional data collected. Additional data that were collected during this study has been kept mainly by the respective authors as follows:

- *Data layers developed for the analysis of physioregions (J. Muller, CSIR)*
- *Detailed data on individual wetlands used for classifying wetlands and ground-truthing the maps* and the original data collected and used for compiling the map *(G. C. Marneweck, Wetland Consulting Services)*
- *Questionaire forms completed by farmers (J. Turpie, UCT)*
- *School posters and completed activity sheets (R. W. Palmer, AfriDev)*

RECOMMENDATIONS

1. Recommendations for Management and Policy Formulation

Strategic Environmental Management Plan

It is recommended that a Strategic Environmental Management Plan should be developed for the UORC. The central component to such a plan would be active involvement of key Stakeholders in setting environmental objectives and priorities, and addressing environmental policy and regulatory failure. A key component to such a plan would be the development of a conservation plan specifically for wetlands, in which wetlands would be zoned in terms of their ecological importance, future uses and threats. The plan should be based on an ecosystem approach to conservation, in which irreplaceablity, complementarity and connectivity of the wetlands are taken into account.

The present study has provided a basic framework for such a plan, but more detailed studies are needed to evaluate and categorise the different wetland types according to their current status, ecological and economic values, key threats and management needs. This will require more detailed understanding of the key drivers, functions, biodiversity values and uses of each wetland type.

Monitoring

It is strongly recommended that appropriate environmental and social indicators should be developed to monitor conditions in the catchment. In particular, indicators designed specifically for the wetlands of the UORC should be developed, and a monitoring plan that details the aims, frequency and distribution of monitoring should be developed and implemented as part of the Environmental Management Plan.

Rehabilitation

We suggest that some of the money that is spent on rehabilitation of mining areas in the UORC could be used more effectively for other more critical environmental improvements that are urgently needed in the catchment, such as wetland and river rehabilitation. This means that the standards that are set for rehabilitation could be relaxed, but in doing so, the 'debt to society' owed by coal mining companies in the form of rehabilitation expenditure could be optimised.

2. Recommendations for Future Research

Biodiversity

We recommend further studies should investigate the processes underlying the formation, maintenance and dynamics of plant species diversity of wetlands in the UORC, particularly in relation to groundwater and the variability in surface water supply and quality in pans. Attention should also focus on the reasons for the considerable degree of local and regional variability in plant species composition among and within the different wetland types. Understanding the processes underlying this will assist in the development of rehabilitation *methods, assist in ecological Reserve determinations for these systems, and help in predicting and mitigating the impacts of water abstraction or storage by mines.*

Mass Balance

We recommend that a mass balance approach should be used to understand the water quality dynamics in wetland systems. Particular attention should focus on the water quality dynamics of pans in the UORC, the extent to which they leak, and the ecological implications of using them to store mine water.

Further Inventories

The present study has provided valuable insights into the functions and values of wetlands in the UORC. It is recommended that similar inventories of wetlands are undertaken in other priority catchments that are under threat as a result of water resource or other developments or activities (e.g. the wetlands in the adjacent Wilge River Catchment).

3. Recommendations for Capacity Building

The present study generated considerable interest among teachers and children living within the catchment. It is recommended that this interest and enthusiasm should be encouraged by the following activities:

- *Assisting the Elukhanyisweni Secondary School in the establishment, management and expansion of their own Environmental Group;*
- *Assisting with the development of an environmental library/centre at the school and to forward any information on wetland and environmental related subjects;*
- *Surveying the Lynnville Wetland in the Kaal Spruit, near the school, for rehabilitation and job creation purposes in the community around the Elukhanyisweni Secondary School;*
- *Expanding the awareness and capacity building exercises to other schools in the UORC;*
- *Awarding prizes to the best posters/essays or models that have been produced and/or written by the learners after the wetland programme; and*
- *Monitoring the success of the programme over a limited period of time to ensure their self-confidence and own growth.*

Furthermore, we recommend that future emphasis should be placed on building capacity within relevant regulatory institutions and other organisations, and in doing so, narrow the gap between environmental policy and its implementation.

ABBREVIATIONS

ACRU	Agricultural Catchment Research Unit
amsl	Above Mean Sea Level
CARA	Conservation of Agricultural Resources Act
CMA	Catchment Management Agency
CITES	Control of International Trade of Endangered Species
CSIR	Council for Scientific and Industrial Research
DWAF	Department of Water Affairs and Forestry
EMP	Environmental Management Programme
NEMA	National Environment Management Act
PCA	Principal Component Analysis
UORC	Upper Olifants River Catchment (including the Upper Olifants and the Klein Olifants River Catchments).
WRC	Water Research Commission

TERMINOLOGY

Absorbtion	The penetration of substances into the bulk of the solid or liquid.
Adsorption	The surface retention of solid, liquid or gas molecules or ions by a solid or liquid.
Aeolian	Pertaining to wind.
Allochthonous	Generated from outside the system in question.
Anion	Negatively charged ion (e.g. Cl^-).
Apedal	Materials that are not well aggregated in a microstructure so that well-formed peds cannot be detected macroscopically.
Aquifer	A geological formation which has structures or textures that hold water or permit appreciable water movement through them.
Benthic	Relating to or occurring on the bottom underlying a body of water.
Benthos	Bottom-dwelling biota.
Biodiversity	The structural, functional and compositional attributes of an area, ranging from genes to landscapes.
Biofilm	An assemblage of micro-organisms attached to a surface.
Biota	A collective term for all the organisms (plants, animals, fungi and bacteria) in an ecosystem.
Biotope	The place in which a certain assemblage of organisms live.
Catchment	The area from which any rainfall will drain into the watercourse or watercourses or part of a watercourse, through surface flow to a common point or common points.
Chroma	The relative purity, strength, or saturation of a colour, directly related to the dominance of the determining wavelength of the light and inversely related to the greyness.
Clastic	Composed of fragments of rocks and minerals. A term applied to rocks or sediments composed principally of fragmented material derived from pre-existing rocks.

Conjoint valuation	A valuation method which assesses the influence of component attributes on the overall value of a commodity, by asking respondents to rank or score different commodities which varying levels of component attributes
Contingent valuation	A stated preference valuation method using questionnaires whereby respondents express a willingness to pay, or accept compensation for an environmental or other change.
Cumulative Impact	An action that in itself is not significant but is significant when added to the impact of other similar action.
Denitrification	A microbial process which, in the presence of carbon, results in the reduction of nitrates (NO_3^-) via nitrites (NO_2^-) to N_2 (g).
Diagenesis	The changes that occur in sediments after their initial deposition, including compaction, replacement, cementation and recrystalisation.
Dyke	A tabular body of igneous rock that cuts across the structure of adjacent rocks or cuts massive rocks.
Ecological Process	Processes that make an ecosystem function. For aquatic systems, ecological processes include photosynthesis, nutrient cycling, sediment transport, succession, disturbance, decomposition of organic material and specific aspects of the life cycles and habitat requirements of the biota, such as population growth, feeding and dispersal.
Ecoregion	A modelled physiographic area based on pre-defined regional characteristics such as rainfall, topography and vegetation.
Endemic	Occurring in a specified locality, not introduced.
Endorheic	A depression in a closed drainage system with no obvious surface water outflow.
Evapotranspiration	Loss of water from the soil by evaporation from the surface and by transpiration from the plants growing thereon.
Eurytopic	Having a wide range of geographical distribution.
Eutrophication	The process whereby high levels of nutrients result in excessive growth of plants.
Externality	A negative impact of any action which is not compensated or a positive action which is not rewarded.
Flood plain	Extensive lateral accumulation of finer sediment as a result of flood deposition by lateral or vertical accretion. The active floodplain is associated with the bank full flow condition of all.
Fluvial	Of or pertaining to rivers. Produced by river action, as in fluvial deposits.
Gleycutanic	A subsurface diagnostic horizon of the 1977 SA soil classification system; it indicates cutanic character superimposed on marked evidence of gleying.
Habitat	The place in which a plant or animal lives.
Hedonic pricing	A valuation method that isolates the influence of the input to be valued from other factors affecting value by using multiple regression analysis.
Hydric	When used in association with soil, implies that soil in its natural or undrained state is saturated with water, at or near the surface for significant periods during the growing season.

Hydrolysis	A chemical reaction between water and a salt resulting in the formation of a hydroxide and a weak acid
Hydromorphic	A suborder of intrazonal soils, consisting of seven great soil groups all formed under conditions of poor drainage in marshes, swamps, seepage areas or flats.
Instream habitat	The physical structure of a watercourse and the associated vegetation in relation to the bed of the watercourse.
Key Point	Geological feature which exerts an influence on upstream hydrological processes often resulting in the formation of a wetland.
Lacustrine	Related to, formed in, or growing in lakes.
Ligands	In chemistry, a complex consisting of a central group (such as an ion) in close association with other atoms or molecules, the latter are termed ligands.
Moraine	An accumulation of drift with an initial topograpghic expression of its own, built within a glaciated region chiefly by the action of glacial ice.
Nitrification	A microbially mediated process in which nitrogen in the reduced. Typically, ammonium nitrogen is oxidised to nitrate nitrogen.
Opportunity cost	The net benefit of the best alternative activity.
Orthic	A surface horizon that does not qualify as organic, humic, vertic or malinic topsoil horizons.
Oxidation	A chemical reaction involving the transfer of electrons, for example Fe^{++} to Fe^{+++}.
Palustrine	Growing in marshes or swamps.
Peat	A dark brown or black residium produced by the partial decomposition and disintegration of mosses, sedges, trees and other plants that grow in wet places.
Plinthic	A mottled and concretionary (iron and manganese oxides) horizon that is non-indurated and non-calcerous.
Pyroclastic	A term applied to clastic rock material formed by volcanic explosion or aerial expulsion from a volcanic vent.
Red Data Book	A book that lists species that are threatened with extinction. The concept was initiated by the International Union for the Conservation of Nature, and has since become adopted by many countries. The "Red" stands for "Danger". The categories reflect the status of the species only within the area under review, and it is sometimes the case that species which are threatened in one region may have secure populations in other areas.
Stenotopic	Having a restricted range of geographical distribution.
Redox potential	A state indicating the potential for electron transfer.
Reduction	The opposite of oxidation.
Rhizosphere	The zone of soil immediately adjacent to plant roots in which the kinds, numbers, or activities of microorganisms differ from that of the bulk soil.
Riparian	The area of land adjacent to a stream or river that is influenced by stream/river induced or related processes.
Riparian habitat	The physical structure and associated vegetation of the areas associated with a watercourse which are commonly characterised

	by alluvial soils, and which are inundated or flooded to an extent and with a frequency sufficient to support vegetation of species with a composition and physical structure distinct from those of adjacent land areas. This includes wetlands and non-wetlands whose vegetation depends on river influenced ground water for growth and reproduction.
Sequester	The process of forming coordination complexes of an ion in solution. This often involves the formation of chelate complexes, and is used to prevent the chemical effect of an iron without removing it from the solution.
Sill	A tabular igneous intrusion, approximately uniform in thickness, and relatively thin compared to its lateral extent that parallels the structure of its surroundings.
Stenotopic	Having a narrow range of geographical distribution.
Surficial	A term used to describe on or close to the surface.
Vertic	A horizons that have both a high clay content and a dominance of smectitic clay minerals which have the capacity to swell and shrink in response to moisture changes.

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1. INTRODUCTION

1.1 Background and Rationale

Wetlands are an important feature of the Upper Olifants River Catchment (UORC), yet there has been no serious attempt to map their distribution, understand how they function, or evaluate their conservation or economic values. The need for such a study is urgent because wetlands in the UORC are under threat from large-scale changes in hydrological characteristics and water quality caused by surface and underground coal mining, power stations, industry, urban environments and agricultural developments. Furthermore, water demands in the middle and lower Olifants River Catchment are estimated to exceed water availability by over 150%, and wetlands in the UORC are perceived to play an important role in regulating flows for downstream users (Lizamore, M, DWAF, Nelpruit).

Whether the degradation of wetlands in the UORC is reason for concern is uncertain, as neither the ecological nor the economic value of these wetlands was known. If decisions regarding the conservation versus development of wetlands in the area are to be optimal for society, then it is necessary to develop an understanding of the sorts of costs and benefits that need to be traded off.

Current thinking generally considers wetlands to be important both on ecological and economic grounds. Environmental legislation in South Africa therefore provides special protection for wetlands. In the UORC, legal protection of wetlands can potentially "sterilise" coal reserves, and this has significant financial implications.

To estimate the economic value of wetlands, it is necessary to understand their structural and functional characteristics, as it is these that translate into the economic goods, services and attributes they provide. To understand this for an area with hundreds of wetlands, such as the UORC, it is necessary to generalise. This in turn requires a clear definition of wetlands and classification system, and the latter requires an appropriately detailed inventory of wetlands in the area.

This report presents the results of a preliminary, largely desktop study to determine the likely biodiversity importance, functional importance and nature and magnitude of the costs and benefits of conservation versus alteration of the wetlands of the UORC. Some of the conclusions differ significantly from the generally held notions of wetland values, and this highlights the dangers of extrapolating attributes of one wetland system to wetlands elsewhere.

1.2 The Definition and Classification of Wetlands

Perceptions and definitions of wetlands vary widely, and it was therefore essential to decide on a working definition at the outset of this study. It was recognised that this study would need an innovative approach to the definition and classification of the wetlands of the UORC. Because the study was aimed at quantifying the functions, the classification system needed to consider those attributes of the various wetland types in the UORC that could be related to functionality.

Previous attempts to classify wetlands in the Transvaal Highveld, which includes the UORC, was aimed at understanding the distribution of birds, and focussed on pans (Allan, 1987a & b). This classification system was found to vary, as the same pan could be classified differently, depending on when the pan is visited. It was therefore necessary to develop a classification system based on fundamental processes of wetland development that would remain constant over time.

The structure and physiognomy of a wetland is determined by the interaction of the quality and quantity of inflows and outflows, the geological characteristics, soils and topography, the climate and how they are used or managed. Water feeding wetlands may be rainwater, surface water, groundwater or a combination of these. Outflows include evaporation, evapotranspiration, surface flows or groundwater flows. These fundamental processes therefore formed the basis of the classification system used in this report.

Definition of Wetlands

The term "wetland" is a general term that describes a variety of very different and complex aquatic ecosystems, including springs, seeps, floodplains, vleis, pans, dams, weirs, evaporation ponds and water treatment works. Their common feature is that they develop in areas where soils are saturated with water for varying lengths of time. According to the National Wetland Classification System (Wetland Conservation Programme, National Department of Environmental Affairs and Tourism), all the natural wetlands in the UORC area are classified as palustrine[1] persistent emergent wetlands. Clearly, a more detailed system of classifying wetlands in the UORC was needed for this study.

In this report, wetlands are defined in accordance with the National Water Act as "Land which is transitional between terrestrial and aquatic systems where the water table is usually at or near the surface, or the land is periodically covered with shallow water, and which land in normal circumstances supports or would support vegetation typically adapted to life in saturated soil".

Rivers

Rivers are excluded from the definition of a wetland in this report, although riparian zones, floodplains and other marginal areas of rivers are included.

Pans

Our report distinguishes between permanent and seasonal pans only. However, it is recognised that all the pans in the area do dry up at times, and that some pans may be inundated only intermittently.

[1] Palustrine wetlands are vegetated wetlands including marshes, swamps, ponds, pans, vleis, and springs. They may be situated along river channels, lake shores and estuaries or in isolated catchments.

1.3 Ecological and Economic Values of Wetlands

Historically, wetlands have generally been considered as undesirable - the spawning grounds of human diseases, the homes of predators and parasites, and places where crops don't grow. Wetlands have therefore generally been considered as areas with little or no value. With advances in water resource management and ecological economics, this view has changed, and wetlands are now recognised as providing highly valuable "goods and services" that contribute significantly to local, regional and national economies. The degree to which this is the case is depends on numerous factors, in particular the nature, size and type of wetland, as well as its location and linkages with other systems.

The value of wetlands lies in their supply of goods and services that are 'consumed' by society, and their attributes, which are 'appreciated' by society (Table 1.1). Goods are the tangible products provided by these areas, such as grasses that can be harvested, and services encompass benefits such as those associated with ecosystem functioning, for example, water purification. Wetlands also have attributes, such as biological diversity, which contribute to their recreation value, or sense of place, contributing to the overall quality of life of catchment residents.

Goods, services and attributes all contribute to the total value of an environmental amenity. In the environmental and resource economics literature, the total economic value of environmental amenities such as wetlands is categorised into different types of value to simplify the description and measurement of value (Figure 1.1). These values are described in more detail below.

Table 1.1. A comparison of ecological and economic characteristics of ecological systems (adapted from Aylward & Barbier, 1992).

System characteristics	Ecosystem characteristics	Economic characteristics
Standing Stocks	Structural components	Goods
Energy Flows	Environmental functions	Services
Organisation	Biological and cultural diversity	Attributes

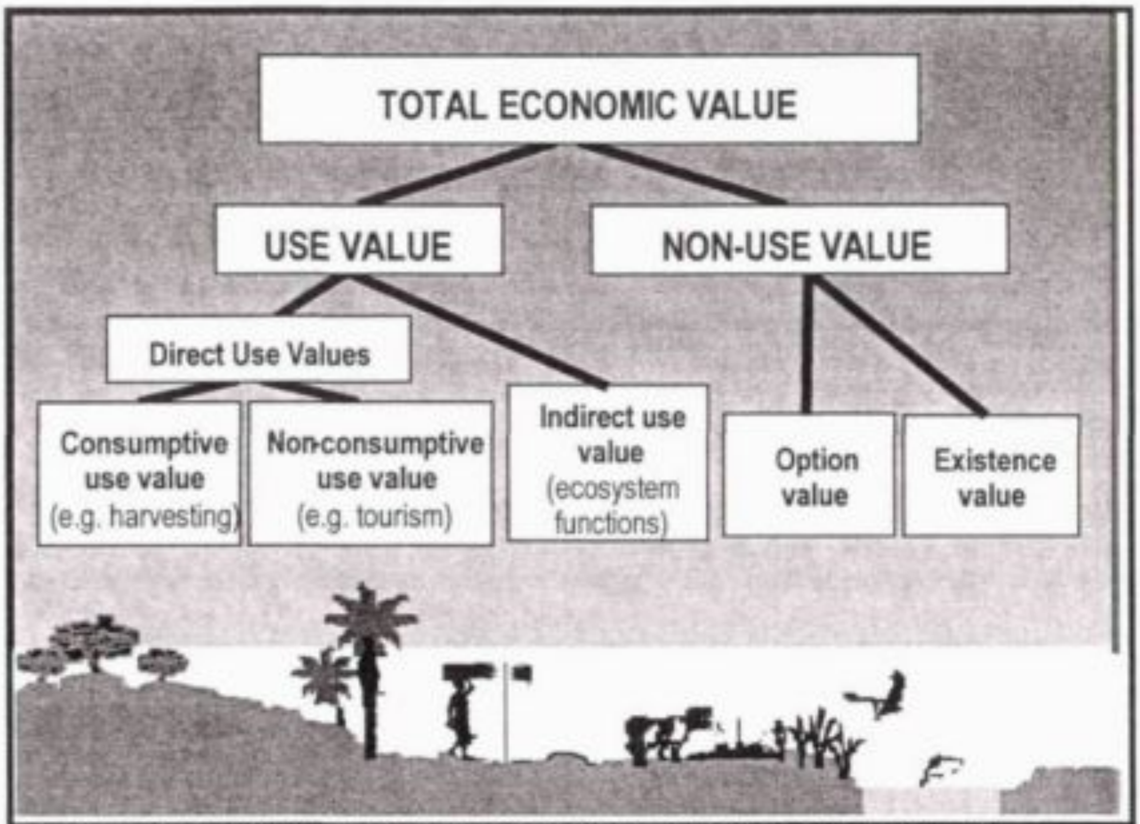


Figure 1.1. Conventional classification of the values of environmental amenities.

1.3.1 Consumptive Use Values

Consumptive use value is the value associated with direct harvest of 'goods', or natural resources, from an area. Typical resources harvested from wetlands include sand (used for building), clay (used for brick-making and pottery), grasses (used for livestock grazing, thatching or basket making), medicinal plants, fishes (for eating) and birds (for shooting or eating). The value of this consumptive use is the gross monetary value of the harvest net of harvesting costs.

1.3.2 Non-consumptive Use Values

Non-consumptive use value is the value obtained from any use of a resource which does not involve the removal of goods. This includes the value of most recreation (e.g. bird watching), and also includes the educational and scientific value of wetlands.

1.3.3 Indirect Use Values - Ecosystem Functions

Indirect use values are the benefits obtained from ecological functions, or 'services', of wetlands. Thus, in the context of wetlands, the magnitude of these values often depends on the ecological integrity of the wetlands, or the degree to which they are altered or transformed. Some of the values associated with ecosystem functions have been identified from the international literature as follows:

- **Controlling floods**. Certain wetland types are capable of attenuating flood peaks, and this can be important in reducing the damage caused by floods.

- **Flow augmentation**. Wetlands are considered important in maintaining river base flows, and this can be important in maintaining flows during drought periods.
- **Storing water**. Some wetlands store large volumes of water, and are therefore important as water sources and/or water storage facilities.
- **Waste treatment**. Wetlands are often considered important in nutrient recycling and detoxification of chemicals, and are therefore considered to improve water quality.
- **Reducing water borne diseases**. Wetlands are often considered to reduce the abundance of water-borne pathogens, such as cholera and Giardia.
- **Trapping sediments**. Certain wetland types are capable of trapping sediments, and this is considered important in reducing erosion and soil loss.
- **Trapping carbon**. Permanently anaerobic conditions in a wetland can result in the accumulation of large amounts of carbon in the form of peat. Carbon locked in this material is prevented from contributing to levels of carbon dioxide and other greenhouse gases in the atmosphere.
- **Providing habitats for flora and fauna**. Wetlands are often important nodes of biological diversity, and therefore can play important roles in ecological and evolutionary processes, such as providing migration corridors, and refugia during droughts or fire.

1.3.4 Option and Existence Values

Option value, sometimes called future use value, is the value that people place on retaining the option to use a resource in the future, irrespective of whether it is any use to them at present. The value is variously described as a use value or a non-use value, but its classification is not important in the issue of valuation.

Existence value is the value of knowing that a resource exists, even if that resource is remote and is never used directly. Existence value is often expressed as peoples' willingness to pay for the conservation of endangered species in far-off places. This would include conservation value as perceived by society.

1.3.5 Total Economic Value

Whether or not the different types of values associated with natural resources can actually be summed is a contentious issue. In particular, expressed existence values are fairly difficult to decouple from other types of values. It is also necessary to recognise that many of the values identified are conflicting values or trade-offs. For example, the value of grazing or thatching may compete, if livestock graze the same species used for thatching. Similarly, the recreational value of a wetland may conflict with its conservation value.

1.3.6 Specificity of Values

Wetlands are not uniform, and different wetlands, even within the same classification, will yield different values. The value will be a function of a number of factors such as size, degree of ecological functioning, cleanliness, location, proximity of substitute areas, etc. For this reason, average values yielded by a broad valuation of wetlands may not reflect the variation at a local level.

A critical evaluation of these 'goods and services" shows that not all wetlands types are capable of providing them, or providing them all of the time, and that the issues are far more complex. For example, a detailed study of the water quality in the Landau wetland near Witbank suggested that this wetland is capable of removing sulphates when flows are low, but that the wetland becomes a significant source of sulphates (i.e. pollution) when flows are high (Batchelor, 1992). Likewise, wetlands that provide habitats for bilharzia snails or malaria vectors, for example, can significantly increase the incidence of disease, rather than reduce them. The values of wetlands therefore need to be carefully considered.

The correct identification of wetland values has important implications for wetland management. If sulphate reduction is identified as an important value of a wetland system, for example, then the mechanisms of sulphate reduction in the wetland need to be understood to allow predictions to be made on how the capacity of the wetland to reduce sulphate may be altered through increased sulphate loadings, changes in hydrological characteristics and so on.

An initial meeting of Stakeholders and specialists on this project, conducted in May 2000, concluded that wetlands in the UORC play an integral role in surface water quality and the hydrological characteristics in the catchment. These wetlands were also considered to provide important habitats for plants and birds, particularly migrating species. The wetlands were not considered particularly important for most other fauna, and they were not considered particularly beautiful. This study therefore focussed on the indirect (i.e. functional) values of wetlands, particularly their role in the hydrological cycle and water quality improvement.

1.4 Understanding Wetland Functions

Water is the driving force in the formation and maintenance of wetlands and, as such, knowledge of wetland hydrological characteristics is basic to understanding, quantifying, and evaluating wetland function and processes (Greeson, Clark & Clark, 1979). Despite this there is still a lack of understanding of these processes, and this is shown in the contradictions found in the literature associated with various wetland studies, such as the following:

- Balek and Perry (1973) found that peak discharge increased with and increase in the area of a wetland, whereas Bullock (1992) found that there was no significant influence of dambos [wetlands] on flood discharges;
- Schulze (1979) in a study on the water resources of the Natal Drakensberg, found that wetlands regulated flow effect especially during the dry seasons,

whereas Bullock (1992) found a decrease in dry season flows with an increase in wetland area;

- Balek and Perry (1973) found there was a decrease in water yield with an increase in percentage of dambos (vlies) in a catchment, whereas Bullock (1992) reported inconsistent water yield results with respect to an increase in the percentage of dambos in a catchment.

The reason for these contradictions is partly because there have been few quantitative studies, and partly because hydrological processes vary markedly from site to site, and from one wetland type to another. Therefore considerable effort was made in this study to classify wetlands according to their fundamental hydrological functioning.

1.5 Identification of Conservation Priorities

Conservation priorities may be assessed on the basis of ecological and biodiversity values, or in terms of economic values. Ideally, these priorities should be assessed on the basis of both, as not all aspects of biodiversity value can be adequately translated into economic value, particularly in a desktop study such as this, and equally, assessments devoid of estimates of economic value lack power in conventional decision-making processes. This study therefore took a two-pronged approach, assessing both the conservation value of wetlands in terms of their biodiversity and functional characteristics, and in terms of their economic values. These characteristics and values are then discussed in the context of alternatives to wetland conservation.

1.6 Aims of the Study

The primary aims of this project were:

- To produce an inventory of wetlands in the Upper Olifants River Catchment (upstream of the Olifants and Klein Olifants River confluence).
- To classify these wetlands in terms of their functional and ecological type and importance.
- To assess the net economic value derived from these wetlands, based on a desktop evaluation of the goods and services they provide, and the opportunity cost of conserving them.

The project also aimed to create awareness and understanding of the wetlands of the UORC among local communities and users, and to build capacity around wetland management and conservation.

1.7 Target Groups

The target groups for this research included the following:

- Chamber of Mines
- Coal Mining Industry
- Conservation agencies (e.g. Mondi Wetlands Project)
- Department of Environment and Tourism
- Department of Minerals and Energy
- Department of Water Affairs and Forestry
- Escom
- Mpumalanga Parks Board
- Olifants River Forum
- Water Boards

1.8 Potential Applications

The results of this research have the following potential applications:

- Strategic planning of developments within the UORC;
- Evaluating potential impacts of proposed developments;
- Assessing cumulative impacts of proposed developments;
- Assessing license applications of proposed developments;
- Assisting with the preparation of Environmental Management Plans;
- Classifying significant resources, as required in the National Water Act (Act No 36 of 1998: National Water Act, 1998); and
- Contributing to the national database and inventory of wetlands.

Although the information contained in this report may be of use in the above-mentioned applications, it should only be considered in the context and at the scale for which it was intended. This report is and was not intended to be a definitive study of the wetlands of the UORC. As such it does not preclude the future requirement for detailed wetland assessments which may arise to address the requirements of new development activities in the area.

1.9 Structure of this Report

This report starts with a brief review of the legal aspects pertaining to wetland management in South Africa. This is followed by a description of the study area, focussing on geology and soils. The methods are then described, detailing the main sources of information used, the assumptions made and limitations of the study.

The report then describes the mapping and classification of wetlands in the UORC, in which a modification of the hydro-geomorphic classification developed for application in the United States of America is presented. The ecological values of the wetlands are described in terms of the biodiversity that is likely to be associated with the different wetland types. The report then considers the economic values of wetlands, in which consumptive values (e.g. harvesting of resources), non-consumptive values (e.g. bird watching), and indirect use values (e.g. water storage and supply) and considered separately.

A general discussion follows in which the tradeoffs between wetland conservation and alternative land uses are considered. The final chapter addresses the capacity building activities that took place during this study. The main focus in this regard was a one-day symposium on wetlands for teachers, and the subsequent mobilisation of a wetlands awareness programme at the Elukhanyisweni Secondary School, in Witbank.

The report concludes with a number of statements, some of which are contrary to the traditional views on wetland values. The report ends with a few, specific recommendations that are considered to be the most important areas for future actions.

2. LEGAL AND POLICY CONTEXT

2.1 Summary of Main Legal Aspects

The following section summarises of some of the more important legal aspects pertaining to wetland management and conservation in South Africa.

2.1.1 The Constitution

The Constitution of the Republic of South Africa contains broad provisions concerning environmental rights and state obligations to enforce them. The environmental right (Section 24 of the Constitution) provides that "everyone has the right -

(a) to an environment that is not harmful to their health or well-being; and
(b) to have the environment protected, for the benefit of present and future generations, through reasonable legislative and other measures that:
   - prevent pollution and ecological degradation;
   - promote conservation;
   - secure ecologically sustainable development and use of natural resources while promoting justifiable economic and social development."

Wetlands are essential to ecological health, and this in turn has a direct bearing on human health, and so the implied mandate on all organs of State to take reasonable steps to ensure wetland health (Winstanley, 2001).

Furthermore, the majority of people in South Africa still adhere to the basic principles of indigenous or customary law. In terms of the Constitution, indigenous law forms part of the legal system in South Africa. Furthermore, the Constitution recognises the right to culture, and therefore the right for people to use flora and fauna for medicinal or spiritual purposes (Vorster undated). Indigenous laws are based largely on public participation, but originate from the ancestors, who tend to reside in rivers and wetlands. Accordingly, rivers and wetlands and their associated resources, tend to be treated with spiritual reverence and respect.

2.1.2 Agenda 21

Agenda 21 is an action plan for sustainable development, aimed at integrating economic, social and environmental objectives (Department of Environmental Affairs and Tourism, 1998). The plan was adopted by more than 178 Governments, including South Africa, at the United Nations Conference on Environment and Development in Rio de Janeiro in 1992. The plan recognises water as a social and economic good with a vital role in providing human needs, food security, poverty alleviation and protecting ecosystems. The overall environmental health objective of Agenda 21 is to "evaluate the consequences of the various users of water have on the environment, to support measures aimed at controlling water-related diseases, and protect ecosystems". High priority is placed on the formulation and implementation of policies and programmes for integrated catchment management, where cost recovery and the equitable and efficient allocation of water is stressed.

The UN General Assembly has called for a Summit to review 10-years of progress achieved in the outcome of the Rio Conference. The Summit, to be called the World Summit on Sustainable Development, will take place in 2002 and will be hosted by South Africa.

2.1.3 The Ramsar Convention

The Convention on Wetlands of International Importance especially as Waterfowl Habitat, commonly referred to as the Ramsar Convention from its place of adoption in Iran in 1971, is an inter-governmental treaty that provides the framework for international co-operation for the conservation of wetland habitats. South Africa took a leading role in the development of the Convention and became the fifth contracting party to the Convention in 1975 and the National Department of Environmental Affairs and Tourism is responsible for the implementation of the Convention (Cowan, 1995). The broad aims of the convention are to stem the loss of wetlands, to ensure their conservation and wise use, and to promote the special protection of listed wetlands. Although South Africa has designated 17 wetlands to the List of Wetlands of International Importance in terms of the Convention, none of these are found in the UORC. However, contracting parties to the Convention accept general obligations relating to the conservation and wise use of all wetlands throughout their territory.

The National Department of Environmental Affairs and Tourism has set up a number of initiatives relating to meeting the obligations of the Ramsar Convention. Two of these include the Wetland Conservation Programme and Working for Wetlands. Information on these two initiatives has been extracted from the Wetland Conservation Programme web site at www.ccwr.co.za. The Wetland Conservation Programme also deals with aspects concerning aquatic ecology under the Convention on Biological Diversity. The programme is aimed at building on past efforts to protect wetlands in South Africa against degradation and destruction, while striving for their wise and sustainable use through trying to ensure that their ecological and socio-economic functions are sustained.

More recently (July 2000), a national wetland rehabilitation initiative was launched under the banner of the multi-departmental Working for Water Programme. The initiative, dubbed "Working for Wetlands", stems from the recognition that efforts aimed at conserving South Africa's biodiversity need to focus on the rehabilitation of degraded ecosystems as well as safeguarding those still in good condition. The focus on wetlands complements the alien plant eradication activities of the Working for Water Programme, and recognises the important role that these ecosystems play in managing the country's water resources.

Working for Wetlands has taken advantage of the expertise and infrastructure built by the Working for Water Programme to establish a National Wetland Rehabilitation Programme. This programme reflects the multi-departmental character of the Working for Water Programme by using the administrative systems of the Department of Water Affairs and Forestry for financial management and project implementation, and technical skills within the Department of Environmental Affairs and Tourism for identifying, planning and monitoring rehabilitation projects. Although the role of the other key partner in Working for Water, the National Department of Agriculture, has yet to be formalised within the context of Working for Wetlands, staff from this department are actively involved in providing technical advice to individual projects. One of the driving forces behind the formation of Working for Wetlands, the Mondi Wetlands Project, is also a key partner in the programme, providing technical support and training.

2.1.4 National Environmental Management Act (Act No. 107 of 1998)

The following section was extracted from Winstanley (2001). The National Environment Management Act ("NEMA") is an overarching statute regulating various aspects of natural resource use, integrated environmental management and pollution control. Its definition of the environment includes the land and water of the earth; micro-organisms, plant and animal life or a combination of those things; and the interrelationships among them [Section 137 (1)]. Underpinning NEMA are a number of national environmental management principles which apply to the actions of all organs of State that may significantly affect the environment (Section 2). These are therefore the test against which administrative action which may affect the environment must be measured.

According to NEMA, development must be socially, environmentally and economically sustainable. Sustainable development requires the consideration of all relevant factors including the following:

- That the disturbance of ecosystems and loss of biological diversity are avoided, or, where they cannot be altogether avoided, are minimised and remedied;
- That pollution and degradation of the environment are avoided, or, where they cannot be altogether avoided, are minimised and remedied;
- That development, use and exploitation of renewable resources and the ecosystems of which they are part do not exceed the level beyond which their integrity is jeopardised;
- That a risk-averse and cautious approach is applied, which takes into account the limits of current knowledge about the consequences of decisions or actions;
- That negative impacts on the environment and on people's environmental rights be anticipated and prevented, and where they cannot be altogether prevented, are minimised and remedied;
- That the costs of remedying pollution, environmental degradation and consequent adverse health effects and of preventing, controlling or minimising further pollution, environmental damage or adverse health effects must be paid for by those responsible for harming the environment; and
- That sensitive, vulnerable, highly dynamic or stressed ecosystems, such as coastal shores, estuaries, wetlands, and similar systems

require specific attention in management and planning procedures, especially where they are subject to significant human resource usage and development pressure.

2.1.5 National Water Act (Act No. 36 of 1998)

The primary purpose of the National Water Act is to manage and control South Africa's water resources. In terms of this act, all water, wherever it occurs in the water cycle, is a resource common to all, but subject to national control. Accordingly, there is no ownership of water, but only a right to use it. The quantity, quality and reliability of water required to maintain the ecological functions on which humans depend is reserved so that the use of water does not compromise the long-term sustainability of aquatic and associated ecosystems. Ultimately, the Minister of Water Affairs and Forestry is responsible for the protection, use, development, conservation, management and control of the water resources of South Africa on a sustainable basis. However, the day to day management of water resources has been delegated to Catchment Management Agencies (CMAs), although most of these are still in the process of forming.

In managing South Africa's water resources, a number of factors must be taken into consideration. Those most relevant to wetlands are:

- Meeting the basic human needs of present and future generations;
- Promoting the efficient, sustainable and beneficial use of water in the public interest;
- Facilitating social and economic development;
- Providing for growing demands for water use;
- Protecting aquatic and associated ecosystems and their biological diversity;
- Reducing and preventing pollution and degradation of water resources; and
- Meeting international obligations.

The National Water Act also controls the right to:

- Take or use water;
- Obstruct or divert a flow of water;
- Affect the quality of any water;
- Receive any particular flow of water;
- Receive a flow of water of any particular quality; or
- Construct, operate or maintain any waterwork.

These controls may regulate activities which degrade wetlands (Winstanley, 2001). For example, impacting on the water quality of a wetland by discharging of effluent generated in an industrial process would be an activity regulated by the National Water Act. Similarly, the diversion of the flow of water for the purposes of, for example mining, may also be the subject of control by this Act. The diversion of the flow of water for the purposes of rehabilitation, even of a wetland, may also be the subject of control by this Act (Winstanley, 2001). Furthermore, the definition of

"Water use" also includes altering the bed, banks, course or characteristics of a watercourse (Winstanley, 2001).

2.1.6 Environmental Conservation Act (Act No. 73 of 1989)

The Environment Conservation Act ("ECA") was intended to be an overarching piece of legislation aimed at environmental management in the broadest sense (Winstanley, 2001). It has, to a large extent been repealed and replaced by NEMA (Winstanley, 2001). Perhaps the most important remaining provisions of the ECA are those concerning the power of certain officials to require remediation, and the Environmental Impact Assessment Regulations (Winstanley, 2001). In terms of the ECA, the Minister of Environmental Affairs and Tourism is entitled to identify activities that he or she believes may have a substantial detrimental effect on the environment (Section 21). No one may carry out such an identified activity without the prior written permission of a competent authority (Section 22). Permission may not be granted without compliance with (or exemption from) the EIA regulations. The identified activities encompass a number of human/development undertakings that are likely to have an adverse impact on wetlands (see GNR 1182 in *Government Gazette* 18261 on 5 September 1997). They also potentially include activities that may be undertaken in the rehabilitation of wetlands (Winstanley, 2001).

2.1.7 Conservation of Agricultural Resources Act (Act No. 43 of 1983)

The following section was extracted from Winstanley (2001). The main focus of the Conservation of Agricultural Resources Act ("CARA") is upon agricultural resources but it has indirect implications for wetlands, especially insofar as they play a positive role in agricultural activities. It is also one of the primary statutes through which agricultural activities which negatively affect wetlands may be regulated. Of particular importance are the recently promulgated regulations. The stated object of CARA is to provide for the conservation of the natural agricultural resources of South Africa by maintaining the production potential of land, by combating and prevention of erosion and weakening or destruction of the water sources, and by the protection of the vegetation and the combating of weeds and invader plants (Section 3). Accordingly, CARA considers the resources land, water and the related aspects of the veld and the vegetation.

CARA also regulates rehabilitation of wetlands insofar as that activity falls under the definition of "conservation" which, in relation to the natural agricultural resources, includes the protection, recovery and reclamation of those resources (Section 1). The Minister of Agriculture may prescribe control measures with which all land users must comply (Section 6). Section 6 includes the control measures that are relevant to wetlands, namely:

- The irrigation of land;
- The prevention or control of waterlogging or salination of land;
- The utilisation and protection of vleis, marshes, water sponges, water courses and water sources;
- The regulation of the flow pattern of run-off water;
- The utilisation and protection of vegetation;
- The control of weeds and invader plants;

- The protection of water sources against pollution on account of farming practices; and
- Any other matter which the Minister may deem necessary or expedient in order that the objects of CARA are achieved.

The Minister has published a number of control measures. These include those in accordance with section 6(2) concerning the utilisation and protection of vleis, marshes, water sponges and water courses (Regulation 7), regulation of the flow pattern of water (Regulation 8), restoration and reclamation of eroded land (Regulation 9) and restoration and reclamation of disturbed or denuded land. With the Minister's co-operation, these may be employed to compel wetland protection or rehabilitation, where this is appropriate.

The mining of peat is also controlled by CARA and the Department of Agriculture's Directorate for Land and Resources Management (DLRM) is responsible for the implementation of this component of the Act. Permission to mine peat is granted by Article 7 of CARA.

2.1.8 Minerals Act (Act No. 50 of 1991)

In terms of this act, an Environmental Management Programme (EMP) is required before any proposed mining can be authorised. The EMP must include plans for the rehabilitation of any areas disturbed by mining. Provision is also made in this act for an Environmental Impact Assessment to be carried out, pending the approval of the EMP report. A standard Aide-Mémoire is intended to assist in the compilation of the EMP.

2.2 Conclusions

There is no single wetland policy in South Africa, but there are several legal instruments that govern the use and management of wetlands in the country. The legislation emphasises the importance of protection and sustainable use of wetlands and their associated resources. The large-scale destruction of wetlands, particularly in the UORC, clearly indicates a gap between the legislation and its implementation. Some of the reasons for this are that:

1. There is often inequitable enforcement of the regulations due to inconsistencies in practise among developers,
2. There is great uncertainty in predicting the long-term impacts of development (Wates, 1997). This is particularly true for the developments in the UORC, where the long-term implications of large-scale surface and underground coal mining are largely unknown.
3. The financial and human resources required to adhere to the new regulations is often limited. In some cases the costs of rehabilitation far outstrip the value of the land.
4. No area or wetland within the UORC is conserved in any formal way.

3. STUDY AREA

This study comprises the upper catchment (watershed) of the Olifants and Klein Olifants Rivers, upstream of their confluence, referred to in this report as the Upper Olifants River Catchment (UORC). The total area of the two catchments is estimated at 6 485 km^2 (Appendix A). The area includes the towns of Witbank, Middelburg, Hendrina, Davel, Bethal, Trichardt, Kinross and Oogies (Figure 3.1).

The study area covers all or portions of twenty-one 1:50 000 scale topographic map sheets. The area has been divided into 14 sub-catchments, referred to as quaternary catchments (Figure 3.2; Appendix A).

The altitude of the UORC ranges from 1 260 to 1 820 m amsl, with most of the area higher than 1 500 m amsl. Gently undulating plains with moderate relief dominate the topography. The study area falls within the following two Ecoregions described by Kleynhans et al. (1998):

- ***Highveld Ecoregion:*** Most of the UORC falls within the Highveld Ecoregionm characterised by gently undulating grasslands with numerous wetlands, and underlain the Vryheid formation Karroo Series sediments (Fig. 3.1).
- ***Central Highlands Ecoregion:*** The lower portion of the catchment is situated within the Central Highlands Ecoregion (Fig. 3.1). Here the rivers cut through the Karoo sediments to expose, in impressive and largely inaccessible gorges, complexes of older rock types of the Bushveld Igneous Complex and the Transvaal Sequence. The vegetation consists mainly of bushveld, with isolated patches of indigenous forest.

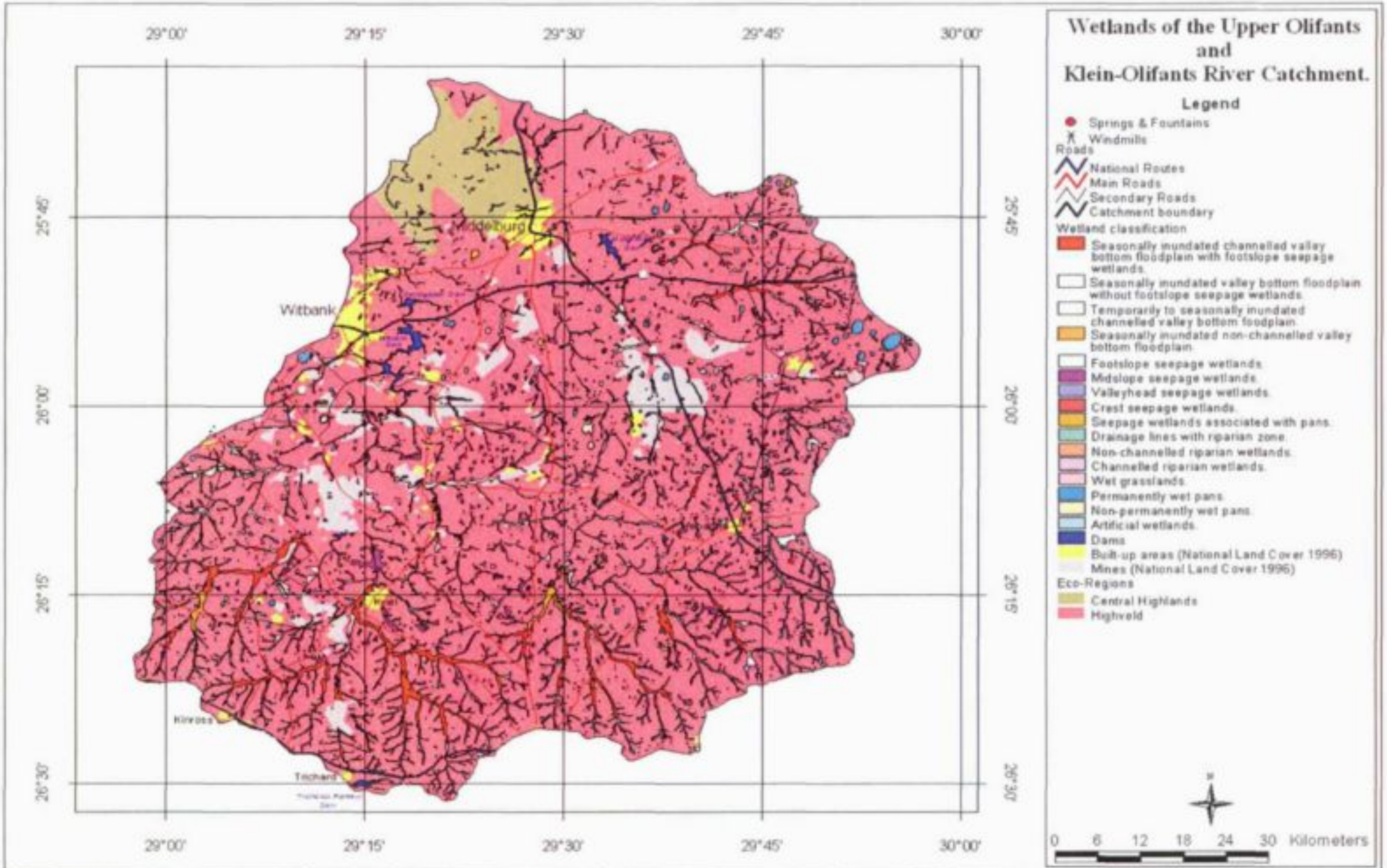


Figure 3.1. Map of the Upper Olifants River Catchment, showing towns, roads, ecoregions, mining areas and wetlands.

Air temperatures are generally cool, particularly towards the east. The mean annual air temperature ranges between 14 and 16°C. The area experiences occasional snow, and frost typically occurs for about 90-120 days each year between May and August (Schulze, 1997). The Mean Annual Precipitation (MAP) of the area is relatively high, and ranges from 671 to 707 mm per annum (Appendix A). Most of the rain falls in summer, particularly early summer (December). Variation in rainfall between years is moderate (CV = 25-30%) (Schulze, 1997).

Evaporation is more than double the rainfall, and ranges between 1 500 and 1 650 mm per annum (Midgley et al., 1994). Consequently, many of the endorheic pans in the area hold water seasonally, filling by the end of summer and drying up by the end of winter.

Developments in the UORC have reduced runoff by 58% from that of natural conditions (Palmer, 2001). The total naturalised (virgin) Mean Annual Runoff (MAR) for the area is estimated as 228,5 $\times 10^6$ m^3 per annum (Midgley et al., 1994). Natural sources of salinity in the UORC are minimal, so nearly all sources of salinity (apart from that occurring naturally in pans) are anthropogenic.

4. METHODS

4.1 Overall Approach

This study was largely a desktop study, relying mainly on existing information, supplemented by limited fieldwork, limited telephonic and face-to-face interviews with farmers, mining companies, power stations and other relevant land users, and a small amount of public consultation with stakeholders. It was recognised from the outset that a desktop study would not provide definitive information on the conservation or economic value of the wetlands, but that it would provide qualitative or ball-park estimates and guidance for future, more detailed studies.

The study was conducted with a view to providing enough information to make a preliminary assessment of the ecological and economic value of the wetlands of the area, to be presented in such a way that would be useful to land use planners and management agencies. Stakeholders involved in the analysis of conservation and economic values thus played an important role in setting the research agenda for the study. The study included the following key steps, each of which provided input towards the overall assessment of conservation and economic value:

1. Reconnaissance field visit and public consultation;
2. Inventory and mapping of wetlands;
3. Classification of wetlands into basic functional types on the basis of hydro-geomorphic determinants and existing biophysical data;
4. Interpretation of patterns of wetland distribution and type in terms of physical parameters such as geological characteristics, soils and physiographic area;
5. Modelling- and literature-based analysis of the functional importance of wetlands, especially in terms of influence on water quality and catchment hydrological characteristics;
6. Literature-based assessment of the biodiversity and conservation importance of each of the different types of wetlands, and of the wetland system as a whole;
7. Description of the anthropogenic characteristics of the landscape and the current threats to the wetlands;
8. Primarily desktop estimation of some of the economic values of the wetlands based on study findings; and
9. Assessment of the implications of conservation values, economic values and opportunity costs of conservation on decisions about the future of the wetlands.

In addition, a capacity building component was integral to the entire study.

Valuation studies rely on quantitative information, but there was limited scope for fieldwork or detailed surveys during this project. Much of the effort in the study was therefore directed at the understanding of the functioning of the different types of wetlands in the study area. This was achieved using a model and literature-based approach.

4.2 Information Sources

Information for this project was obtained from a wide range of sources including:

- Published and unpublished reports (see References at the end of this report);
- GIS Databases (CSIR and DWAF);
- Water quality and water flow databases (DWAF);
- Aerial photographs, ortho-photographs and maps;
- Discussions with key personnel in regional and government departments (Institute for Water Quality Studies, Department of Environment and Tourism, Mpumalanga Parks Board), mining companies (Amcoal, Ingwe, SASOL), and engineering companies (e.g. Jones & Wagener);
- Interviews with farmers, environmental officers at mining companies and power stations, and various other land users.

Each of the research steps outlined above, together with the information sources used and the limitations involved is described in more detail in the following sections.

4.3 Reconnaissance Visit and Public Consultation

The study started with the team of specialists visiting some representative wetlands, followed by a one day planning meeting on 11 May 2000. The aims of the field visit and planning meeting were:

- To introduce the team members to each other and in doing so, provide a basis for team building and co-ordination;
- To familiarise the team members with the study area and the different types of wetlands;
- To identify key issues; and
- To design a programme to ensure that the data collected will contribute meaningfully to the classification of wetlands and the cost-benefit analysis.

Areas visited included the Greenside Colliery Pan, Rietspruit, Steenkoolspruit and Viskuile. The field visit was invaluable, as most team members had different perceptions of what comprised a wetland. The field visit therefore enabled team members to "calibrate" themselves in terms of the different wetland types. This is likely to have been important in eliminating potential confusion over what constituted a wetland in later stages of the project.

Invitations were sent to about 160 selected stakeholders to attend a meeting at the SACE Recreation Club, Witbank, on 12th May 2000. The aims of the meeting were:

- To provide an opportunity for team members and stakeholders to meet one another;
- To identify stakeholder needs and interests;
- To identify wetland users;
- To identify and prioritise wetland uses; and
- To identify sources of information.

The invitations were sent to 65 people from the agricultural sector, 47 from the mining industry, 18 from the water sector, 13 from the environmental sector, and 13 from the power sector (Appendix G). The meeting was attended by 22 stakeholders and 11 members of the study team (Appendix G). Stakeholders attending the meeting were mainly from the mining industry (6), water sector (5) and power sector (4). Two people only from institutional agriculture attended, apparently because of a clash with an important agricultural meeting.

After presentations on the ecological evaluation of wetlands (G.C. Marneweck) and the economic evaluation of wetlands (J. Turpie), the meeting broke into smaller groups that represented the different wetland user groups, and each group first discussed and then presented a prioritised list of wetland uses. This was followed by a discussion of sources of available information.

A feedback meeting, in which the key results of the study were presented to Stakeholders, was held in Witbank on 20th February 2002. The meeting was attended by 25 stakeholders and 4 members of the study team (Appendix G). Stakeholders attending the meeting were mainly from the mining industry (10), water sector (3) and power sector (3). Two people only from agriculture attended the meeting.

4.4 Wetland Classification

A system for wetland classification in the UORC was developed by G. C. Marneweck and A. L. Batchelor, based on a modified version of the hydro-geomorphic classification developed for application in the United States (Brinson, 1993). The classification took the following into consideration:

4.4.1 Importance of Hydrology

Understanding the nature of flows into and out of a wetland is critical for understanding the hydrological functions of a given wetland (Brinson, 1993). The hydrological regime, which comprises the frequency, depth, duration and timing of wetting, is usually the main factor that drives the ecosystem processes and dynamics of a wetland ecosystem. A key determinant of the hydrological regime is the landform setting, as landform influences local patterns of water movement (surface and sub-surface) as well as the extent to which wetlands are open to lateral exchanges of water, sediment, nutrients and pollutants.

4.4.2 Importance of Landscape

Within a spatially linked wetland system, there is often a division of wetland units or components based on landform settings and geomorphological characteristics. These may represent different hydro-geomorphic units within the same wetland which add a dimension of complexity to the wetland functions. How these units are linked and interact with each other and the surrounding landscape will affect the functional characteristics of the wetland system in general. It can also be argued that despite being spatially linked, each hydro-geomorphic unit within the wetland system may be performing different functional roles in a particular section of the sub-catchment. The classification system therefore needed to consider the division of spatially linked wetland units into hydro-geomorphic units. Kotze (1999) has also highlighted the importance of where a wetland occurs in the landscape, as well as its form in terms of functionality. Aspects of this, as well as of those relating to topographic and landform settings as described by Kotze, Breen and Klugg (1994) were also used in the classification.

4.4.3 Hydro-Geomorphic Units

Figure 4.1. illustrates how a wetland may be divided into different hydro-geomorphic units. In this schematic example, the wetland complex consists of nine wetland units. Units 1 - 7 comprise one spatial "wetland" because all these units are linked. However, delineating them all as one wetland would not recognise the role of each hydro-geomorphic unit in the overall functioning of the wetland system.

4.4.4 Functional Classification

Based on an understanding of how water moves through each of the wetland types occurring in the region, generalities about the functioning of the different wetlands units were inferred. This was based on desktop and field indicators which were considered to be sufficient for the level of detail required for the purposes of this project. For example, a general statement that could be made for a particular wetland type could be that because it develops at the point of discharge of a confined seepage area or spring on the side or bottom slopes of a hill, it is unlikely to positively influence flood hydrographs (reduce the peak discharge and attenuate flows) in the nearest watercourse. The reasons for this may be that flow rate is governed by the slope, the roughness and the porosity of the system, and are unlikely to differ much from the adjacent habitat. Indeed, flow rates may be higher across a hill slope wetland because the soils in the wetland are already saturated, whereas in the adjacent grassland the soil would still have to reach field capacity before runoff occurs.

Initially these hydro-geomorphic units were not easily identified from aerial photographs. It was only once we had a better understanding of the type of systems occurring in the area that these aspects could be delineated from the aerial photographs. Cartographic information contained on the 1:50 000 scale topographic sheets were used to assist with this. For example, contours provided information on where the wetland component occured in relation to the overall topography (e.g. slope, valleyhead or valley bottom) and this together with other factors such as slope, provided clues about how water may enter, move through and exit a system. This, in turn, helped us to understand and ascribe hydrological and biogeochemical functions to the units and each system as a whole.

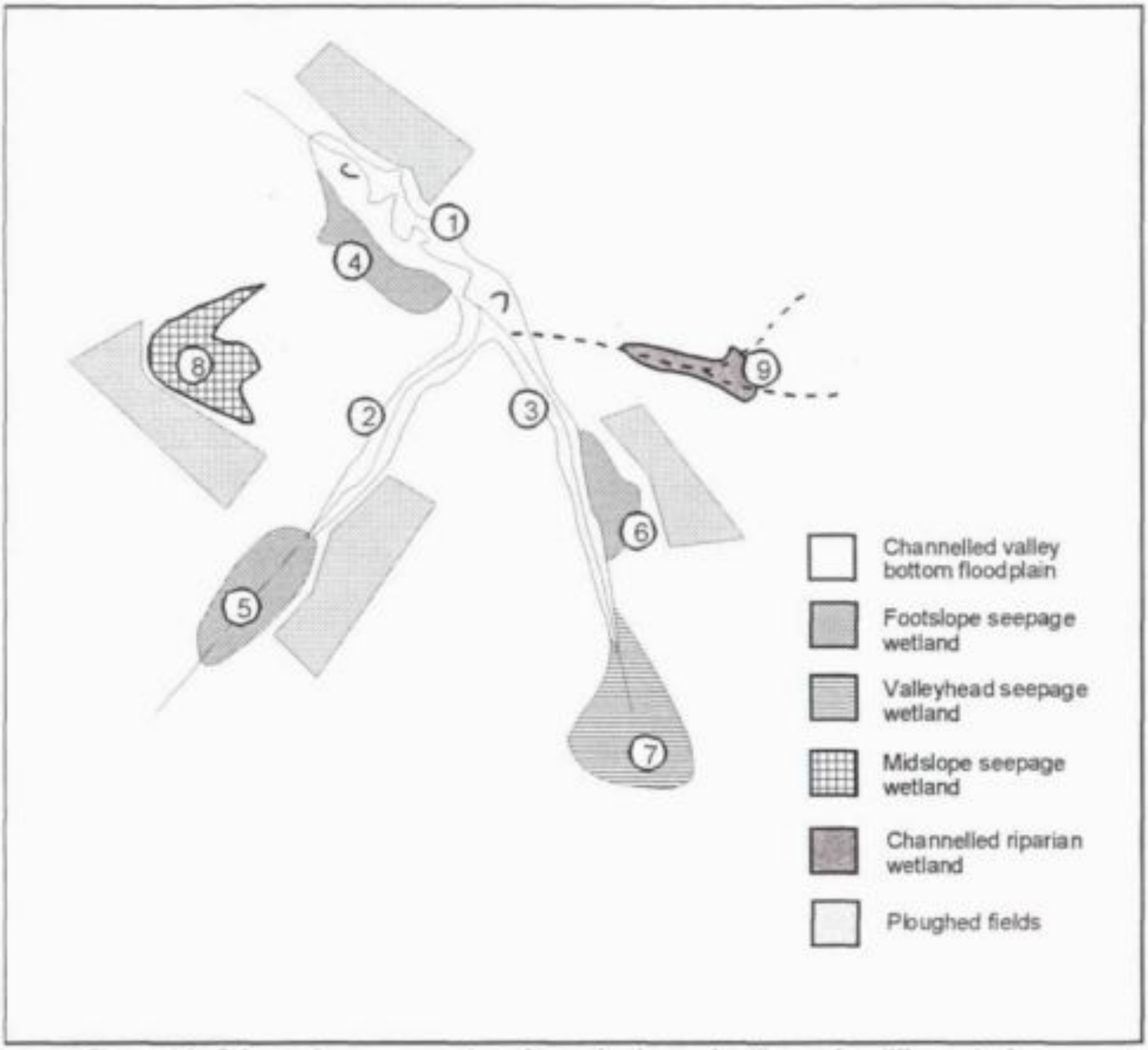


Figure 4.1. Schematic representation of a wetland complex illustrating different hydro-geomorphic units.

In Figure 4.1, Units 1- 7 represents separate hydro-geomorphic units. Not all these units perform the same functional roles. For example, Unit 1 (the channelled valley bottom floodplain) is likely to be important for flood attenuation. However it is unlikely to be important for water quality enhancement because most of the time the water flowing through the system is restricted to the active channel. Even during flooding, the lack of sufficient retention time may mean that this unit still plays only a limited role in water quality enhancement.

By contrast, the footslope seepage wetland associated with the floodplain (Unit 4) is unlikely to be important for flood attenuation, but is probably important for water quality enhancement as this unit is situated downstream of cultivated lands, and receives sub-surface seepage water and surface runoff from the lands. The characteristics of this seepage area also mean that water retention times in the wetland may be higher than in the floodplain, thereby also increasing the likelihood of water quality enhancement. The footslope seepage wetland may also be responsible for the maintenance of the section of floodplain wetland immediately downstream of the seepage area, and as such would also be providing a different biological function to the floodplain system.

Both the floodplain (Unit 1) and the footslope seepage area associated with the floodplain (Unit 4) may play a minor role in flow augmentation to the watercourse. In contrast the footslope seepage wetlands (Units 5 and 6) may be more important for flow augmentation than the footslope seepage wetland associated with the floodplain (Unit 4). This is because the seepage water from Unit 4 that reaches the floodplain travels over an extensive area of mixed grass/sedge meadows on the floodplain before reaching the water course, and is therefore subjected to considerable evapotranspiration losses.

By contrast the seepage water from Units 5 and 6 drain more directly into the water course. At the same time this role may be different between Units 5 and 6 as Unit 5 has no riparian wetland associated with it, and as such the evapotranspiration losses are likely to be less. Obviously this is also dependent on the extent and magnitude of the sub-surface seepage in all these seepage wetlands and whether or not the sub-surface seepage is linked to perched water tables or ground water aquifers. At the same time, the footslope seepage wetland at Unit 6 may be more important for flow augmentation but less important for water quality enhancement than the footslope seepage wetland (Unit 4) because of the lack of agricultural lands in the immediate vicinity of the unit. Unit 6 may also be more important than Unit 5 in terms of water quality enhancement because it is surrounded by cultivated land compared to Unit 5, where the seepage area only receives nutrient inputs from a portion of the cultivated lands.

Similarly, the midslope seepage wetland (Unit 8) may be more important for water quality enhancement than Unit 6, despite them both being surrounded by cultivated lands. This may depend on the extent of development of anaerobic conditions in these units, and the water retention times in any of the units. Clearly many more scenarios are possible, but these few were used to illustrate the point that identifying the units and how water moves through a wetland system is key in understanding functions.

4.4.5 Wetland Types Considered

Wetlands in the UORC were divided into riparian, non-riparian and artificial wetlands, and further divided on the basis of landform type, geomorphic setting and the nature of the flows into and out of the systems i.e. hydro-geomorphic units, as outlined below. The details of this classification are described in the results.

4.5 Mapping and Inventory of Wetlands

Wetlands in the UORC were mapped by G.C. Marneweck, with assistance from A. Grundling. The area mapped included twenty-one 1:50 000 scale topographic maps, using 209 aerial photographs. A draft map was produced, and between September and December 2000, field verification of sections of the map was undertaken. Representative wetlands in the high elevation, moist, cool, flat and high elevation, dry cool flat ecoregions were visited, and data on these areas were collected.

4.5.1 Data Sources and Mapping Techniques

Black and white aerial photographic prints at a scale of 1:50 000 and in non-stereo format were obtained from the Chief Directorate: Surveys and Mapping. The job and print numbers of the black and white prints used in the survey are shown in Appendix E. The photographs used for the delineation of wetlands were taken between May and July 1991. The boundaries of the wetlands were delineated on transparent film overlays on the aerial photographic prints. The delineated wetland boundaries were then manually transferred from the overlays onto 1:50 000 scale topographic map sheets of the area. This information was then digitised by D. Vink (CSIR).

Experience gained in other wetland mapping projects (Marneweck, Grundling & Grundling, 1999), showed that black and white aerial photographic prints at a scale of 1:50 000 or larger (1:30 000) provide a reasonably reliable indication of wetland signatures for this level of mapping. Manual transfer mapping was also shown to be both relatively cost-effective for the purpose of mapping wetlands at a scale of 1:50 000 over extensive areas such as this study area.

The use of stereo imagery would have been preferable for the mapping, as stereoscopic coverage allows one to assess topographic relief, and this enhances the accuracy of remote mapping. However, budget constraints did not allow this and as a substitute, the 1:50 000 scale photographs were used in combination with 1:50 000 scale topographic sheets to relate wetland signatures to topographic relief.

Additional information on four wetlands near Witbank was provided by Anton Linström of Mpumalanga Parks Board, Lydenburg.

4.5.2 Spatial Scale

Because of the large size of the study area, the project focussed at the scale of the catchment, and mapping was therefore undertaken at a scale of 1:50 000. The major limitation with the scale and the method used is that the wetland boundaries may not be accurate to more than tens or even hundreds of metres. In addition, certain wetland types are not as accurately captured as others both in terms of number and extent. This is mostly due to scale-dependent factors, such as the wetlands simply being too small to be seen on the aerial photographs.

4.5.3 Pans

For the purposes of this study, there were too many pans for detailed classification. This is because the method of classifying wetlands used in this study relied on features that could be seen on aerial photographs. The main features needed to classify pans (such as depth and water quality) cannot be determined from aerial photographs, which together with the dynamic nature of pans, makes them impossible to classify in detail using remote methods. Therefore, three types of pans only are shown, namely perennial, non-perennial and pans associated with seepage areas. Furthermore, many pans smaller than 5 ha were not mapped because of the scale and resolution of this study. However, some of these were identified from the digital topographic sheets.

4.5.4 Artificial Wetlands

The identification of artificial wetlands was difficult, and only those that are known to exist, or for which there is information available, were mapped. Water diversion and pollution control systems, including pans used for pit storage, were included where these were easily identified or associated with existing mining operations. Besides dams and water works, it was not possible to capture or differentiate most of the other artificial wetlands that may have developed as a result of anthropogenic influences. These include those that may have developed as a result of road construction and subsidence from underground mining and so on. Consequently, the representation of these types of artificial systems is highly inaccurate.

4.5.5 Temporal Changes

The intention of this project was to classify wetlands according to their present conditions only. Considerable value could have been added to the project by knowing what the reference (virgin) conditions were – i.e. what the distribution and condition of wetlands in the area was before development. However, it was not possible to delineate reference conditions with any degree of accuracy because: (1) the resolution of the aerial photographs is not fine enough, partly because the area was already disturbed when the first aerial photographs were taken in 1991; (2) the identification of seepage areas without subsequent ground-truthing was difficult; and (3) extensive development has taken place in the catchment. Therefore, no estimate of wetland loss or addition due to development in the study area was or could be made. However, anecdotal evidence suggests that for certain wetland types, mainly the seepage systems, as much as 50% of the seepage wetland area may have been altered significantly or lost, mainly due to agricultural practices.

It is also important to note that wetlands are dynamic systems that change in nature and function over time. Water levels and water temperatures rise and fall, and populations of flora and fauna change in response to these and other changes. Channels may shift in response to sedimentation or erosion and new channels to form elsewhere. Dynamic variation in wetlands means that their functions and values may also be constantly changing, and the limitations of a once-off, static analysis of the UORC wetlands must be recognised in this context.

Changes in wetland boundary signatures with season may also affect the accuracy of mapping. Considering the scale at which the systems were mapped (1:50 000) and because black and white photography as opposed to true colour were used, this is unlikely to be a major problem in this study. The aerial photographs used in this assessment were taken during May, June and July 1991, all during the winter months. From experience with wetland mapping on this and other projects (Marneweck et al., 1999 and from work undertaken by G. Marneweck on the Pilot Study for the National Wetland Inventory), wetland boundary mapping in cultivated areas in winter has some advantages over summer mapping. This includes easier boundary identification in agricultural lands. Masking of wetland signatures by burnt areas provides the major drawback to remote mapping at this time of year.

4.5.6 Ground-truthing

A total of 30 wetlands was sampled in detail and an additional 86 were visited to ground-truth, correct and verify the aerial photographic interpretation. Experience from other work undertaken in the area (Marneweck, 1998, 1999, 2001; Marneweck & Batchelor, 2001) was also used to assist with this aspect of the study. At each of the wetlands sampled, the following information was recorded:

- Wetland unit type;
- Topographic setting;
- Slope;
- Vegetation cover types;
- Dominant vegetation;
- Estimates of plant species diversity;
- Wetting regime;
- Hydrological drivers;
- Keypoints or substrate;
- Soil forms;
- Special habitats;
- Red Data Species;
- Other special flora and fauna;
- Adjacent land-uses;
- Land-use within wetland;
- Notes on degradation; and
- Anecdotal evidence of the functions the wetland is likely to perform.

To get an idea of boundary accuracy, as well as to verify whether certain areas identified on the aerial photographs were in fact wetlands, data were collected at these sites on the soils and vegetation. These data were used to determine whether or not the area met the criteria for classification as a wetland. The criteria, as specified by Kotze and Marneweck (1999), were applied in the determination.

Where possible during the detailed sampling, hydric indicators were related to hydrological conditions in terms of the criteria for distinguishing different soil saturation zones within a wetland as described by Kotze et al., (1994). Notes were also made on the degree of soil mottling and rhizosphere oxidation conditions.

4.6 Wetland Patterns in Relation to Geology, Soils and Physioregions

4.6.1 Geology

Geological characteristics of the UORC were described by P.-L. Grundling. Wetland distribution, type and size were then interpreted in the light of the influence of geology.

4.6.2 Soils

Soils of the area were described by G. Marneweck on the basis of literature review and observation during field and other surveys.

4.6.3 Physioregions

The landscape ecology assessment for this project was carried out by G. Muller and D. Vinke (CSIR), and comprised defining the spatial patterns and processes of the landscape (biophysical aspect), and the impact of human settlement in the area (human aspect). The biophysical aspect of the study involved delineating homogeneous bio-geographic areas, or physioregions, based on physical parameters such as climate, slope, soils and elevation. The human aspect of the study involved the description of the landscape according to current human land uses and the impact on the natural environment.

The analysis was conducted using a Geographic Information System (GIS) so that the wetland classification could be overlain and analysed with the physioregions and current land use data. The projection used for analysis was Albers Equal-Area to allow for correct area calculations needed in the assessment. Data for the study were prepared in a raster format with a 500 x 500 m grid cell size. Datasets in vector format were converted to raster format, and existing grid information at different resolutions (e.g. 1 km x 1 km grid cell size) were re-sampled to 500 x 500 m to provide a common platform for analysis. The finer resolution cell size was maintained so as not to loose the benefit of the more detailed information.

Multivariate analysis, which explores the complex and sometimes obscure relationships between many input variables, was used to identify physioregions in the study area. Multivariate analysis functions take into account the joint statistical distributions of multiple input variables. For example, multivariate cluster analysis will cluster cell locations into similar groups based on the joint distribution of slope, aspect, and distance from streams.

Distribution maps of key environmental variables, which represent the physical parameters of the landscape were collated (Table 4.1). To reduce the number of data to be analysed, a stratified random sampling of datasets was conducted. For

This prevents bias towards a dataset with high numerical values. The following formula was used to convert data to a range between 320 and 460:

$$Z = (X - oldmin) * (newmax - newmin) / (oldmax - oldmin) + newmin,$$

where Z is the output grid with new data ranges, X is the input grid, oldmin is the minimum value of the input grid, oldmax is the maximum value of the input grid, newmin is the desired minimum value for the output grid, and newmax is the desired maximum value for the output grid.

Table 4.1. Key environmental variables used for factor analysis.

Feature	Attributes and/or description	Continuous or Discrete	Original format
Baseflow (i.e. groundwater component of river flow)	Mean annual flow (mm)	Continuous	Polygon
Depth to groundwater level	Mean depth (m)	Continuous	Polygon
Elevation	Height (m)	Continuous	DEM derived from 20 m contour interval, 500 x 500 m grid generated
Geology	Lithology type	Nominal	Polygon
Growth days	Ratio of precipitation to potential evaporation (days)	Continuous	grid 1 x 1 km
Precipitation: mean	Annual (mm)	Continuous	grid 1 x 1 km
Precipitation: median	Annual (mm)	Continuous	grid 1 x 1 km
Slope	Calculated from elevation model (percent rise)	Continuous	grid 500 x 500 m
Soil fertility	Soil fertility derived from primary lithology (H,M,L)	Ordinal	Polygon
Soil depth	Depth of A horizon	Continuous	Polygon
Temperature: Maximum	Annual (°C)	Continuous	grid 1 x 1 km
Temperature: Minimum	Annual (°C)	Continuous	grid 1 x 1 km
Temperature: Mean	Annual (°C)	Continuous	grid 1 x 1 km
Recharge to groundwater	mm per annum	Continuous	Polygon
Topographic index	Derived from elevation model. Indicates concave, convex, and flat slopes.	Nominal	grid 500 x 500 m

Fifteen key environmental variables were analysed by factor analysis, with the Principal Component Analysis (PCA) method as a means of data simplification and reduction. The goal of PCA is to summarise a multivariate data set as accurately as possible using a few components (Jongman *et. al.*, 1987). PCA is similar to linear regression models, except that it predicts the relationship (covariation) between many variables. The regression line indicates best prediction, whereas the component line indicates best association (Systat 8.0, 1998). The PCA was performed using a varimax rotation and a minimum eigenvalue of one. The varimax rotation (an orthogonal rotation that minimises the number of variables that have high loadings on each factor) simplifies the interpretation of factors.

A correlation analysis was also performed on all fifteen variables, to determine whether variables that had been used in the derivation of other variables were highly correlated. When this was the case, these variables were excluded from further analysis. For example the growth day surface is derived from precipitation and evaporation, and is highly correlated with median and mean precipitation surfaces as well as temperature values. Therefore all precipitation and temperature variables were removed and only the growth day variable included for further analysis. Any variable with a factor loading of less than absolute value 0.6 was also removed. To further minimise the defining set of variables, those variables selected in the preceding process that had loading factors of less than 0.6 were again excluded, and a second pass PCA performed, using the same rotation and eigenvalue parameters.

A multivariate unsupervised cluster analysis was then performed using the results of the PCA to cluster the data into natural groupings or homogeneous physioregions. The Arc/Info ISOCLUSTER command was used, a routine which uses a modified iterative clustering procedure that calculates the minimum Euclidean distance when assigning each candidate cell to a cluster.

The number of cluster classes is supposed to be specified by the user beforehand. However, this was unknown at the outset of the analysis, so a conservatively high number of classes were entered for the initial ISOCLUSTER routine. The results were then analysed and the routine rerun until the number of clusters became stable. A generalised form of scattergrams (ellipse) was derived to analyse the output of the ISOCLUSTER routine to determine the optimum number of classes or clusters. A good cluster should have little overlap between the clusters in multivariate space. To determine whether there is overlap between clusters, all scattergram combinations must be viewed. Since the clusters are determined from multivariate space, what may appear to be significant overlap between two or more classes in one scattergram combination may contain no overlap in another scattergram combination. The worst case scenario is when certain classes or clusters overlap on all scattergram combination, indicating that the classes or clusters are not distinct from one another. As this is not the case with the results in this study, the number of classes generated, were found to be acceptable.

4.7 Functional Assessment: (I) Hydrology

An assessment of the key hydrological functions of the different types of wetlands in the UORC was carried out by G. Matthews and T. Coleman, using a modelling approach.

4.7.1 Data Sources

There are nine gauging stations registered by the DWAF in the UORC (Table 4.2). Most of these have limited data periods, or are situated downstream of Witbank and Middelburg Dams, and are therefore of limited use for this study.

Table 4.2. Summary of flow gauging stations in the Upper Olifants River Catchment.

Station	River	Name	Start	End	Reliability
B1H001	Olifants	Mooifontein	1904	1951	Medium
B1H002	Spookspruit	Elandspruit	1956	-	Medium
B1H003	Klein Olifants	Rondebosch	1957	1967	Medium
B1H004	Klipspruit	Zaaihoek	1959	-	Medium
B1H005	Olifants	Wolwekraans	1972	-	Medium
B1H010	Olifants	Witbank Dam	1953	1979	Medium
B1H012	Klein Olifants	Middelburg Dam (Inlet)			Medium
B1H015	Klein Olifants	Middelburg Dam (Outlet)	1978	-	Medium
B1H017	Steenkoolspruit	Aangewys	1989	-	Medium

4.7.2 Assumptions and Limitations

Modelling the exact extent and influences of wetlands on the hydrological characteristics of these catchments is difficult owing to the complexities of hydrology of the catchment and the varying nature of the hydrological processes of wetlands.

The hydrological characteristics of wetlands are notoriously difficult to measure. There are many reasons for this. For example, wetlands are often situated in areas where groundwater contributions are significant. Furthermore, evaporation and evapotranspiration from wetlands may impact significantly on wetland hydrology, and both are difficult to measure, particularly because they are highly variable in both space and time.

Although the contribution of groundwater inputs and evaporative losses from the wetland systems in the UORC is little understood, these were modelled using the ACRU Agrohydrological Model. Owing to limitations associated with ACRU when it comes to the modelling of wetlands, the following assumptions were made:

Flood Attenuation
We assumed that wetlands in the UORC have limited effect on flood attenuation because of the channel morphology and the location of the wetlands. However, when floodwaters overtop the channel, they disperse laterally, and hence attenuate the flood. We also assumed that removal of the wetland vegetation from the riparian areas would result in an increase in the flood peak, as the vegetation impedes the flow of the floodwaters. This would hold true for smaller flood events, as the larger events would flatten the vegetation occurring along the channel length and thus result in less attenuation of flood waters. Other physical characteristics that could lead to attenuation of a flood peak include storage capacity of the wetland soils and the floodplain area.

The model assumed grassland cover for wetlands, as this is the most common wetland vegetation form in the UORC. The results are likely to have been significantly different had the model assumed cover by *Phragmites* reeds. The later are restricted to a few, highly distrubed wetlands in the vicinity of Witbank, and were therefore not considered during this study.

Streamflow Regulation
It was assumed that streamflow regulation would be directly related to the number of times the channel is breached and the amount of water augmenting the transient water from surrounding catchment runoff. It was assumed that the effect would be more pronounced on the receding limb of the hydrograph.

Wetlands play a major role in the hydrological system, as they have the ability to store transient water. Wetland type and location would be the main factor that effects the behaviour of this transient water. The wetland streamflow regulation would only come into play when the transient water in the wetland is augmented by channel breaching during flood events, or from runoff from the surrounding catchment.

Because of wetland geomorphology, the regulatory effect would be more pronounced on the receding limb of a storm event, where the water yield would be higher on a day for the wetland scenario than it would be for the non-wetland scenario.

Evaporation Losses
It was assumed that evaporation losses from wetlands would be high, as the rate of lateral movement of the transient water passing the wetland is slow, thus allowing for high levels of evapotranspiration. Values used in the model are shown in (Table 4.3).

Table 4.3. Mean monthly A-pan Evaporation used in the modelling. [Data from Schulze (1997).]

J	F	M	A	M	J	J	A	S	O	N	D	Total
205	171	174	142	122	101	113	154	189	212	207	215	2005

For modelling purposes, it was assumed that the plants present in the wetland only use water from the riparian zone and do not use water directly from the stream. A large portion of catchment soil moisture percolates down to the riparian zone, causing this area to have a high soil moisture content. Plants growing in this riparian zone have access to high levels of soil moisture via their roots and therefore are thought to evapotranspire more so than the plants found outside the riparian zone.

The lateral moving transient water found in the valley bottom floodplain and footslope wetlands diffuses slowly towards the channel owing to the flat topography associated with floodplains. This slow movement would allow for a high level of evapotranspiration, thus lowering the water yield from the catchment.

The ACRU Model relates transpiration to an average monthly crop coefficient. The crop coefficient allows for the fraction of water evapotranspired by certain vegetation types under conditions of maximum evaporation in relation to that evaporated by an A-pan in a given period.

For the simulations the crop coefficients for Sedge meadows were used for the wetland area, and those for veld conditions were used for the Non-wetland Scenario area and the Contributing area in the Wetland Scenario. These crop coefficients are listed in Table 4.4.

Table 4.4. Monthly Crop Coefficients used in the ACRU Simulations (Smithers and Schulze, 1995).

	J	F	M	A	M	J	J	A	S	O	N	D
Sedge Meadows	.80	.80	.80	.70	.60	.50	.40	.40	.40	.50	.60	.70
Veld	.76	.70	.48	.36	.32	.29	.26	.26	.29	.33	.48	.71

Spatial Differences

All wetland types found in the catchment, excluding pans, were assumed to have the same hydrological properties. Furthermore, a general channel cross section was assumed throughout quaternary catchment B11C. However, seasonally inundated channelled valley bottom floodplain wetlands with footslope seepage wetlands were assumed to be associated with floodplain geomorphology. The rest of the wetland types were assumed to be on the catchment slope.

4.7.3 Modelling Approach

The modelling aimed to establish the effects of the wetlands on the hydrology of the UORC. This exercise was made difficult because the total catchment area covers an extensive area of about 6 485 km^2. The ACRU model was used to simulate the hydrological responses in quaternary catchment B11C. This quaternary catchment was chosen because of its location where the land use was still relatively virgin and the weir B1H017 was located at its outlet. The Bethal Municipality rain gauge (0478837W) was used for the simulations. The simulation was run for the period 1949 to 1999. The MAP of the Bethal rain gauge is 652 mm.

A typical quaternary catchment (B11C) was chosen for a detailed modelling exercise (Figure 3.2). A total of 13.8% of this catchment (385 km^2) was covered by wetlands (Table 5.4). For the purposes of the study all these wetlands were assumed to have the same hydrological characteristics, and the surrounding catchment was assumed to be relatively homogenous. The ACRU modelling approach involved running two scenarios, one with wetlands and another without wetlands as described below.

With Wetlands Scenario

The wetland scenario involved modelling the catchment in its present land use status, i.e. as represented by the flow values taken at B1H017, which are inclusive of the hydrological effects the wetlands have on the system. The concepts used in ACRU when modelling wetlands are depicted in graphically in Figure 4.2. A subcatchment was defined for all the wetlands occurring in B11C, with an area of 53 km^2 (calculated from the GIS based maps generated by the CSIR). The soils and vegetation parameters for the "contributing area" and wetland subcatchment were adjusted so that the ACRU model could simulate the hydrological processes.

Surface flow from the "contributing area" could not be directly routed through the wetlands and therefore this was taken to pass directly into the channel. The assumption was made that the majority of the surface flow would have passed into the channel along the main channel tributaries. The main wetland types associated with the tributaries in B11C are Temporarily to Seasonally Inundated Channelled Valley Bottom Floodplain Wetlands. It was assumed that no floodplain geomorphology is associated with these wetlands, and therefore the surface flow was direct to the channel. The surface flow generated in the wetland subcatchment was affected by the sedge meadows associated with wetlands.

Overtopping discharges from the channel were calculated using an assumed general incised channel dimensions and Manning's equation:

$$Q_p = \frac{1}{n} A^{\frac{5}{3}} P^{-\frac{2}{3}} S^{\frac{1}{2}}$$

Where Q_p is the maximum flow rate of the channel through wetland (m^3/s), *A* is the cross-sectional area of full channel (m^2), *P* is the wetted perimeter of the cross-section (m), and *S* is the average catchment slope (m.m^{-1}). This discharge was calculated as being 9.2 m^3/s. This overtopping discharge was the discharge that needed to be reached for the channel to burst its banks and for the wetlands occurring in the riparian zone to be inundated by floodwater.

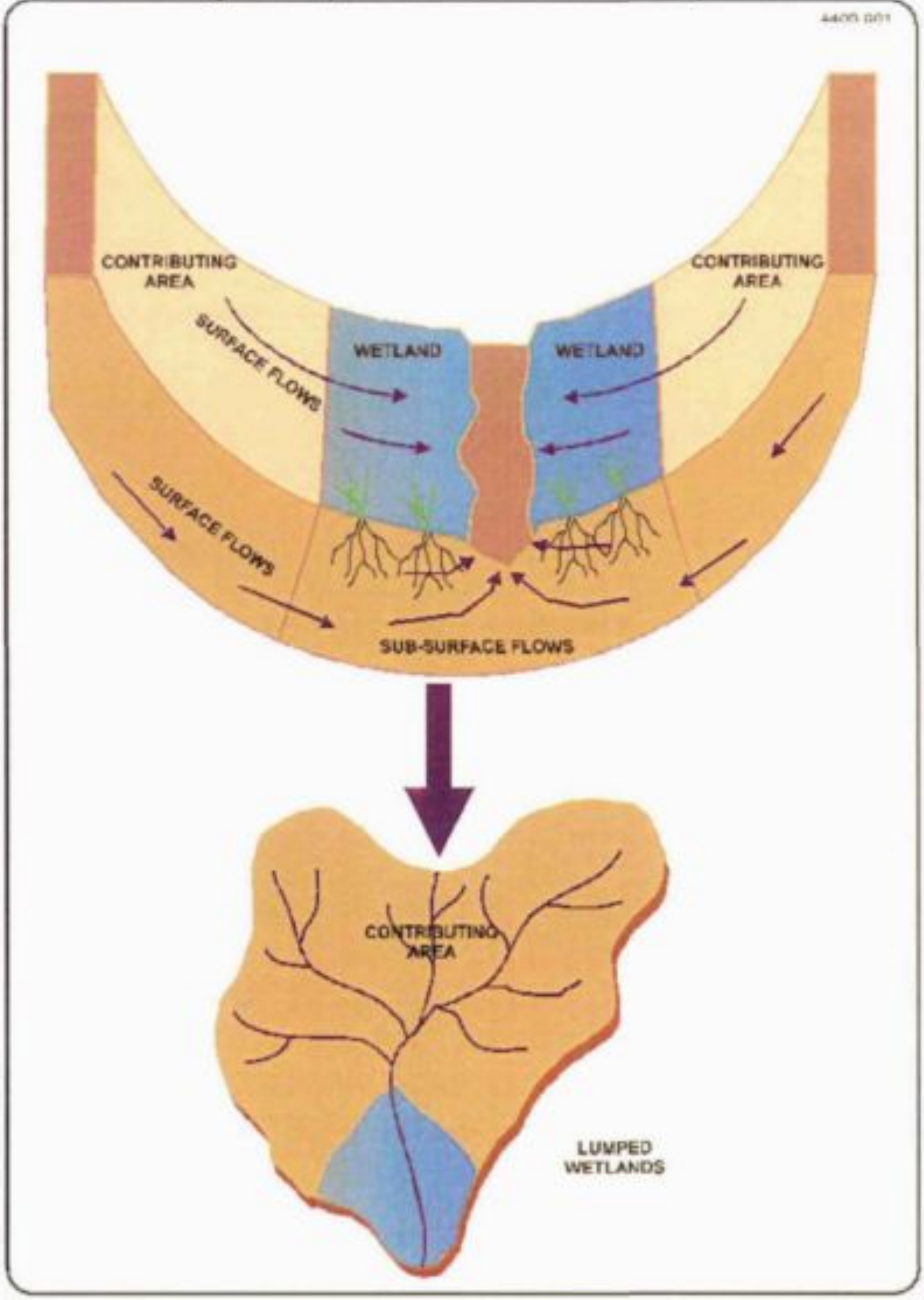


Figure 4.2 ACRU Wetland modelling concepts.

The wetland routine in ACRU is depicted in Figure 4.3. The ACRU modelling process routes the contributing area's surface flows into the wetland zone subcatchment as surface flow, and baseflow from the contributing area is routed into the riparian zone as subsurface flow. For modelling it was assumed that the entire baseflow from the "contributing area" was routed into the wetland subcatchment's baseflow. This allowed for simulation of the lateral slope baseflow movement, thus allowing for an increase in water content in the riparian zone. This increase in soil water content would allow for the simulation of the increase in water losses, due to evapotranspiration from the wetland sedge meadows from very moist soils. The remaining riparian baseflow water is then routed along with the surface flows from the riparian subcatchment as downstream surface flow.

The free-standing water in the wetland was modelled as a shallow reservoir that was located at the outlet of the wetland subcatchment. This "reservoir" was modelled separately from the rest of the catchment. The outflow from the reservoir was defined by a hypothetical spillway, which for the purposes of the study was assumed to be 50% of the length of the channel along which the Wetland Type A occurred (Seasonally Inundated Channelled Valley Bottom Floodplain Wetlands with Footslope Seepage Wetlands). For quaternary catchment B11C this was found to be 23,2 km. The surface area of the wetland "reservoir" at full capacity was taken as 50% of the total area of Wetland Type A.

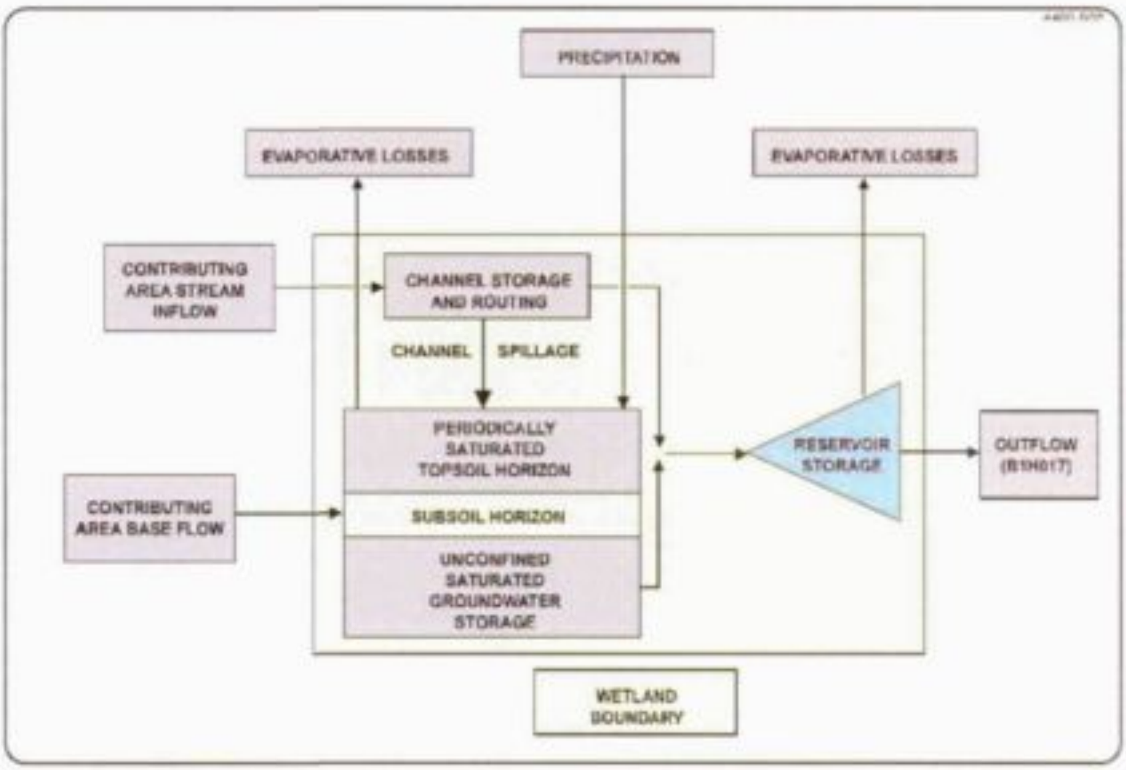


Figure 4.3 Schematic diagram depicting flow routing in the ACRU wetland routines.

Non-wetland Scenario

The non-wetland scenario involved modelling the catchment where the current wetlands found in the catchment are removed and the area modelled as if found under typical veld conditions of the quaternary B11C. For this scenario the wetlands were "removed" from the catchment and replaced with the dominant veld type found within the quaternary catchment. It was also assumed that surface flow passed directly into the channel and there was no effect on this water movement by the floodplain.

4.7.4 ACRU Model Calibration

The ACRU model was run for both these scenarios over a period of 51 years (i.e. 1949 to 1999). When modelling quaternary catchment B11C with the ACRU model, the following approach was adopted.

Calibration of surface flow process in B11C was attempted using the weir found at Aangewys (B1H017). The raw data for B1H017 were obtained from the Department of Water Affairs and Forestry (DWAF). These data extended from December 1989 to February 2000.

Problems were experienced with exact calibration, as B1H017 is flooded at a level of 0,82 m, which has an equivalent flow of 8,26 m^3/s. Thus there were no recorded values for the larger storm events. These problems were further expounded because the aerial distribution of the rainfall over the catchment was not adequately depicted. For these reasons there was no strong correlation between the measured values at B1H017 and the simulated daily values.

The Median Annual Simulated Runoff for the quaternary catchment B11C ranges from 40 to 60 mm (Schulze, 1997). The Median Annual Simulated Runoff that was generated by ACRU for the quaternary catchment for the wetland and non-wetland scenarios was 43,9 and 59,3 mm respectively.

The general slope of the hydrograph recession limbs obtained from B1H017 and those obtained from the ACRU wetland simulations were used as an indication of hydrological responses occurring in the catchment. Figure 4.4 shows the observed (B1H017) and simulated daily flow curves for certain storms occurring in the catchment for the period December 1989 to February 2000. These storm periods were selected as the daily simulated streamflow that closely followed that of the observed daily values taken at B1H017. It was therefore assumed that the rainfall during these periods recorded at the Bethal raingauge (0478837W) represented the aerial distribution of the rainfall over the entire catchment.

The similarity in the general slope of both the simulated and observed hydrograph recession limbs for all the four storm periods was used as an indication of the hydrological responses occurring within the catchment under the present conditions (ie. wetlands in place).

Taking into account the complex nature of the wetland hydrological study, the above variables were assumed to be adequate to allow for the simulated scenarios to be taken as indicative of the hydrological processes occurring in B11C quaternary catchment.

It is important to note that the ACRU values that exceeded 8,26 m^3/s were cropped so as to match the observed data at B1H017. From these curves the following assumptions were made:

- The peaks of the simulated and observed hydrographs are not congruent as a single representative raingauge (Bethal, 0478837W) was used for the modelling of the quaternary catchment, and thus the varying areal distribution of rainfall within the catchment is not accurately represented.
- As a result of the wetland hydrology and geomorphology, the regulatory effect that the wetland would have on streamflow would be more pronounced on the receding limb of a hydrograph. The close correlation in slope of the recession limbs of both the observed and simulated flow curves is an indication that the ACRU model is simulating the hydrological effects of the wetlands on the catchment hydrology adequately.

Taking into account the complex problems associated with the modelling of quaternary catchment B11C, the above variables were assumed to be adequate to allow for the simulated scenarios to be taken as indicative of the hydrological processes occurring in the catchment.

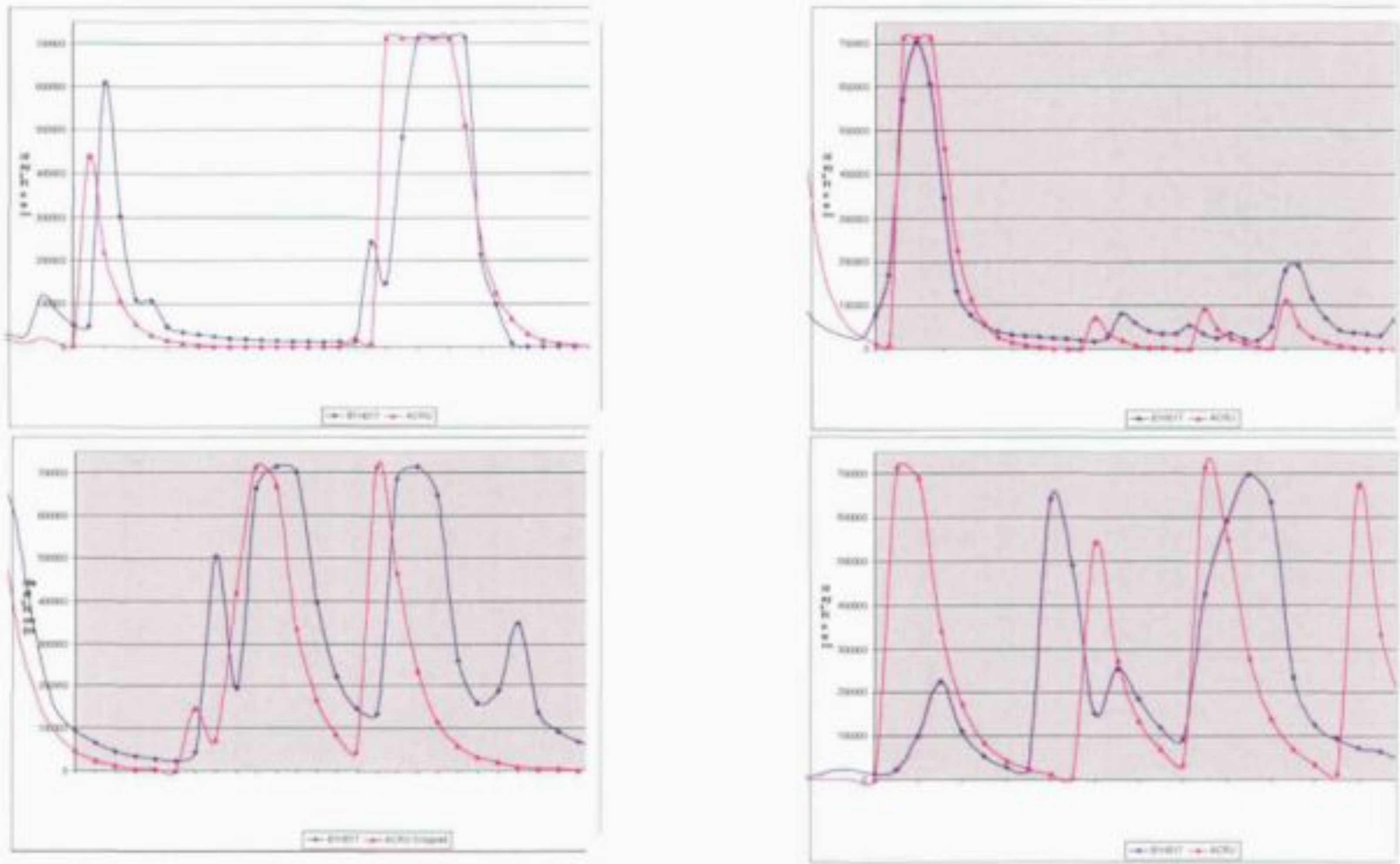


Figure 4.4 The observed (B1H017) and simulated daily flow curves for selected storms occurring in the catchment for the period December 1989 to February 2000.

4.8 Functional Assessment: (II) Water Quality

An assessment of the potential water purification capacity of different types of wetlands in the UORC was carried out by A. L. Batchelor. To assess the value of wetlands in removing nutrients and improving water quality, a mass balance in the transfer of nutrients into and through a wetland system is needed. This requires accurate measurement of discharges. However, wetlands are often situated in areas where groundwater contributions are significant, but these inputs are difficult to measure. A drop in nutrient levels downstream of a wetland may simply be caused by dilution, and have nothing to do with processes within the wetland itself. Wetlands are extremely complex and dynamic systems, and quantification of nutrient flows was not possible in a study of this nature.

Nevertheless, an attempt was made at the landscape level to determine the role that different wetlands might play in the UORC. A paired catchment approach was adopted, with the selection of the catchments based on their geological and structural similarity, as well as the availability of both hydrological and water quality data.

The approach used to assess the importance of the contribution of wetlands to nutrient removal was:

i) to provide a generalised description of processes related to nutrient removal;
ii) to examine these principles in relation to three principle wetland types - pans floodplains and seepage wetlands; and
iii) based on these observations, to quantify, if possible, the nutrient removal capacity of the wetlands in the catchment.

Water quality and flow data were obtained from DWAF. The period for which data were available for comparison was restricted to a very limited period, the 91/92 to the 95/96 hydrological periods. The two stations that represent the catchments were 21Q01 and 18Q01. The difference between the two catchments is the loss of wetland area in 21Q01 due to changes in land use, from predominantly agriculture to mining, sand winning and agriculture.

4.9 Functional Assessment: (III) Sediment Trapping

Donkin (1994) summarised the efects wetlands have on sediment deposition as follows:

- Wetlands generally occupy relatively flat areas and support a variety of vegetation types. Flow velocity would be reduced as a result of the decrease in slope on entering a wetland and the frictional affects associated with the vegetation growth. This reduction in velocity would result in sediments being deposited.

- Wetland vegetation binds the deposited sediments thus decreasing the chance of resuspension.
- Wetland vegetation decreases wave action that could result in resuspension and redistribution of sediments.
- A long-term effect of increased sedimentation would be an increase in plant density present in the wetland as a result of an increased medium for plant growth.
- Sedimentation would result in an increase in wetland elevation. A consequence of this is that the hydrological regime of the wetland could be altered.
- Changes in wetland elevations could cause channel deviations, which affects the distribution of sediments and associated nutrients and toxins which in turn could affect the water quality in the channel.

4.10 Wetland Biodiversity

Desktop studies were carried out on wetland plants (G.C. Marneweck and N. H. G. Jacobsen), invertebrates (R. W. Palmer), fish (J. Engelbrecht), birds (J. Turpie) and on amphibians, reptiles and mammals (N. H. G. Jacobsen). Each study attempted to identify as many species of flora and fauna as possible that are associated with wetlands of the UORC, based on available literature and limited surveys conducted during this study. The study was restricted to aquatic species, or species closely associated with water. It is likely that many species may have been overlooked because of limited collecting among certain groups (e.g. Lepidoptera), limited collecting in certain areas (e.g. Viskuile), and because the time of collecting was inappropriate (e.g. winter collecting or after burning may miss species). Information sources and limitations of the component studies are detailed below.

4.10.1 Wetland Vegetation

Information on the plant species occurring in the wetlands of the UORC is limited, and there is no information available relating specifically to the plant species composition or richness for the different wetland types classified for the purpose of this study. As a result, wetland plant species lists for the main groups of wetland types, viz. floodplains, seepage systems, riparian zones and pans, were compiled based on experience and available information from previous work by G. C. Marneweck and N. H. G. Jacobsen in the UORC. Additional information on plant species occurring in the wetlands was obtained from other available reports that were compiled as part of other investigations of wetlands in the UORC. Usually these data could not be related to the specific wetland types identified as part of this study, but rather to the broader wetland types such as floodplains and pans. Reports that were made available by M. Aken of Anglo Coal Environmental Services and that were used in the compilation of the plant species lists included: Myburgh, Breytenbach, Panagos and Buijs (1998); Loxton, Venn and Associates (1998) and Eco-Info cc, (1999).

The plant species lists compiled for each main wetland type in this report, while assumed to provide at least a preliminary regional database of plant species occurring in the wetlands of the UORC, should not be considered as complete or fully representative of each wetland type. Rather they should be seen to provide a baseline dataset of the plant species occurring in the wetlands of the area. Many more species as well as similarities and differences in species composition between the wetland types can be expected as more data becomes available as and when more work is undertaken in this field.

4.10.2 Aquatic Invertebrates

Available information on the aquatic invertebrates in the UORC is largely limited to invertebrates found in pans and rivers. Information available on invertebrates inhabiting other wetland types is largely anecdotal. Furthermore, there is no information available on aquatic invertebrates before large-scale development in the catchment, or before coal mining in the area, which started in the early 1900's. It was therefore not possible to assess the importance of the various wetland types identified during this study in terms of invertebrate biodiversity.

The most detailed information on aquatic invertebrates in the area was collected from selected pans and the nearby Lake Chrissie (Hutchinson et al., 1932). This study examined the species composition and abundance of invertebrates (mainly zooplankton) in relation to pan water quality and habitat availability. Some years later, in 1956, aquatic invertebrates in an unpolluted stream near Witbank, the Sadelboom Stream (adjacent to the current study area), was compared to the fauna in the Klipspruit, a nearby stream polluted by acid mine drainage (Harrison, 1958, 1965). Between 1957 and 1978, a detailed study of the distribution of aquatic snails in the UORC was undertaken by the University of Potchefstroom (Pretorius et al., 1980). Other available information on aquatic invertebrates in the UORC includes biomomitoring data on rivers (Ecosun, 2000), and snap surveys of crabs (Cook, 1997), dragonflies (Pinhey, 1984; Samways, 1999), copepoda (Rayner & Heeg, 1994), and various baseline environmental and impact assessment studies (e.g. Chutter & Engelbrecht, 1997; Toerien et al., undated; Ecosun, 2000; Loxton Venn & Associates, 1997, 1999; Diedericks & Nel, 1999a & b).

4.10.3 Fish

Information on fishes used in this report consists mainly of studies relating to taxonomy and distribution patterns (Gilchrist & Thompson, 1913; Groenewald, 1958; Jubb, 1967; Gaigher, 1969, 1976; Gaigher & Pott, 1973; Skelton, 1993, Mpumalanga Parks Board data base and National River Health Programme surveys). Additional sampling was done in areas with little or no information, using a small seine net and electro-narcosis (e.g. Viskuile).

4.10.4 Birds

There are few published or unpublished accounts of the birds of the UORC wetlands. Information on birds was extracted from the South African Bird Atlas

(Harrison et al., 1997), and from several impact assessment reports (Batchelor, 1992; Loxton, Venn & Associates, 1997, 1998a&b; Clean Stream Environmental Services, 2000; L&W Environmental, 1999; Chutter & Engelbrecht, 1997; Hoare, 1999). Barnes and Tarboton (1998) list the Amersfoort-Bethal-Carolina District and the Chrissie Pans as important bird areas, and provides brief descriptions and lists and counts of important species in each area. The former area falls partly within the study area, but the Chrissie Pans fall outside the area. In addition, Allan and Brown (1991) conducted a study of the wetlands in the Lake Chrissie area, which is similar in many respects to the study area. Cowan (1995) and Cowan (1999) provide general information on wetlands and wetland birds, including grebes, pelicaniformes, and migratory birds, but nothing specific to the study area. The published Co-ordinated Waterbird Counts do not cover the wetlands within the study area, but cover several of the Chrissie wetlands and Witbank Dam, although co-ordinated waterbird counts have recently been started on several wetlands in the study area.

4.10.5 Amphibians, Reptiles and Mammals

The available ecological data on wetland herpetofauna and mammals are meagre and mainly based on anecdotal material together with a few more detailed zoogeographic studies. The lists compiled during this study reflect this knowledge and should be seen as an interim, less desirable state of the art. The current frog atlas project (Harrison & Burger, 1999) will dramatically increase the known distribution of species and provide an improved base for further studies.

4.11 Landuse, Wetland Uses and Threats

A GIS analysis of current landuses was carried out by G. Muller and D. Vinke. This involved the description of the landscape according to current human land uses. The pattern of a landscape can be explained through analysis of fragmentation and compositional diversity. The 1:250 000 National Land cover/land use dataset was used to provide the basic statistics on current land uses in the study area (Appendix B). Land use encroachment on the wetlands, was determined by buffering the digitised wetlands by a distance of 0,5 km and then intersecting the national land cover dataset with the buffered wetlands (Appendices C & D). This method identifies land uses directly adjacent to the wetlands and the approach provides an idea of possible threats to wetlands through land conversion or degradation. Wetland uses and threats were briefly assessed in terms of the GIS analysis, contact with stakeholders, literature review, and informal interviews.

4.12 Economic Analysis

The economics component of the study was carried out by J. Turpie and H. van Zyl, using inputs from team members. The main aim was to describe the net economic value derived from the wetlands, based on an evaluation of the goods and services they provide, and the opportunity cost of conserving them. To start with, the goods and services provided by wetlands had to be identified. This involved a brief review of the literature on the subject, an exploratory field trip to the study area and consultation among team members and stakeholders.

Valuation methods can be divided into three main categories: market-value approaches, surrogate-market approaches and simulated market approaches. Whereas surrogate- and simulated-market approaches may measure the demand for wetlands, and hence willingness to pay, market value approaches are based on prices and do not necessarily include consumer surplus. The latter group of techniques therefore normally underestimate benefits.

The methods available to value economic goods and services of wetlands are no different from the methods used to value any other type of environmental assets. Different types of value are each measured with a different choice of methods (Table 4.5). The number of possible methods that can be used to measure the different types of values also decreases from left to right along the columns in Table 4.5. The published literature tends to pigeonhole environmental valuation techniques into discrete methods. However, it is important to note that many of the 'methods' mentioned in the literature do not stand alone as valuation techniques, but form part of an overall approach, often involving the combination of different methods, and innovation, where appropriate.

Table 4.5. Commonly-used natural resource valuation methods, and the types of value which they are generally used to measure.

	Direct use values		Indirect use values	Option and non-use value
	Consumptive	Non-consumptive		
Market value approaches				
Market price/ shadow price/ surrogate price methods	✓✓	✓		
Net Factor Income	✓✓	✓		
Production Function	✓✓	✓		
Replacement Costs etc	✓	✓	✓✓	
Surrogate market approaches				
Travel Cost Method	✓	✓✓		
Hedonic Pricing	✓	✓✓	✓✓	
Simulated market approaches				
Contingent Valuation Methods	✓✓	✓✓	✓	✓✓
Conjoint Valuation	✓	✓	✓	✓

This study required innovation and is largely a qualitative valuation of wetlands, since the desktop approach of the study, even with the opportunity for cursory field data collection, made it difficult to implement any of these methods to a statistically satisfactory degree.

Although the wetlands in the UORC yield all the types of value described in Chapter 1, some of these values could not be investigated due to lack of existing data and the types of methods involved in their estimation, which were not suited to a desktop study. In particular, option, existence and education values could not be estimated specifically for the study area. We thus focussed on use values. The following good and services were chosen for evaluation:

DIRECT USE VALUES

Consumptive use values

- Harvesting of Grass, Herbs, Plants and Building Materials
- Water for livestock
- Livestock Grazing
- Storage and Evaporation of Mine Water

Non-consumptive use values

- Bird watching
- Recreational fishing
- Recreational waterfowl hunting

INDIRECT USE VALUES

- Flow regulation
- Water Purification
- Sediment trapping

The importance of the biodiversity supported by the wetlands was also considered qualitatively. Biodiversity was not valued directly, but rather captured through the valuation of goods and services that derive their value from biodiversity. Once goods and services had been chosen, the process of attaching values to them commenced.

Ideally, each wetland should be valued separately, as the complexity of the study increases exponentially with an increase in size and complexity of the area to be valued. However, this study attempted a broad-brush valuation of all wetlands in the study area. This, together with limited time, data and budget constrained the available valuation technique choices to market techniques only. Fortunately this was not a significant constraint as only use values, which are suited to valuation using market techniques, were considered. Information sources included the literature, interviews and a survey. Table 4.6 lists the valuation methods used for each value category and is followed by a brief description of the methods and specific information sources used. Methods used are described in more detail below.

Table 4.6. Value categories and valuation methods used.

Value categories	Valuation methods used
Direct use values	
Harvesting of Grass, Herbs, Plants and Building Materials	Market prices and surrogate prices for goods
Water for livestock	Replacement costs of alternative water supply infrastructure
Livestock Grazing	Surrogate prices for fodder
Storage and Evaporation of Mine Water	Replacement costs of mine dams
Bird watching	Survey of expenditure by participants and benefit transfer
Recreational fishing	Survey of expenditure by participants
Recreational waterfowl hunting	Survey of expenditure by participants
Indirect use values	
Flow regulation	Replacement costs, damage cost avoided
Water Purification	Replacement costs
Sediment trapping	Replacement costs

4.12.1 Estimation of Direct Use Values

Harvesting of Grass, Herbs, Plants and Building Materials

For all harvested resources, the annual gross use value can simply be calculated as follows:

$$\text{Annual use value} = Q \times (P-C)$$

Where Q is the quantity of units used annually, P is the unit price and C is the unit cost of harvesting. There are no existing data on the quantities of any resources harvested from the UORC wetlands. Quantities and prices were estimated on the basis of key informant interviews and a survey of users on farms in the area (Appendix F). Unfortunately study resources only allowed for the surveying of 22 farms which is a very small sample size. Harvesting costs, which comprise labour costs and transportation as well as the costs of harvesting equipment, were assumed to be negligible.

Water for Livestock

In terms of agricultural use, wetlands theoretically have the potential to obviate the construction of water distribution infrastructure. The validity of this hypothesis was investigated with the help of agricultural extension officers in the area. The replacement cost method was used, whereby the cost of replacing the function by artificial means was estimated. Extension officers also provided the figures necessary for the estimation of the replacement costs of water supply infrastructure.

Livestock Grazing

Wetlands are said to provide grazing for livestock in the area. Wetland grass production thus provides an input into livestock production, and ideally should be valued by using a production function. However, since the construction of a production function requires a thorough understanding of functional relationships based on sufficient, detailed agricultural data, this approach could not be used here. Instead, we apply the replacement cost method, in which the value of fodder production by wetlands is valued in terms of the price of an equivalent quantity of harvested fodder. Production estimates were provided by G.C. Marneweck and A.L. Batchelor, based on existing literature on the production of the common species involved and the known wetland conditions.

Storage and Evaporation of Mine Water

Mines are interested in wetlands mainly because they offer the opportunity for water storage and evaporation. The replacement cost of dam construction sourced from Anglo Coal was used to give an indication of the storage benefits provided by wetlands

Bird Watching

To determine the value of bird watching, an estimate of the annual expenditure by birders in the area was made. The Middelburg and Witbank bird clubs were contacted to generate a reasonable estimate of the number of birders and annual birding trips in the area. These numbers were then multiplied by a cost per trip taken from the literature on the value of birding in South Africa (Turpie & Ryan, 1999).

Recreational Fishing

To determine the value of recreational fishing, an estimate of the annual expenditure by fishers in the area was made. The Mpumalanga Parks Board was contacted to generate a reasonable estimate of the number of fishers in the area based on licence sales adjusted upward for un-licensed fishing. These numbers were then multiplied by an annual average number of trips and a cost per trip estimate. In addition, annual sales figures of fishing equipment in the area was sourced from 13 fishing shops by J. Engelbrecht, and an estimate was made of the proportion of annual expenditure specifically devoted to fishing in the study area. The use of two different approaches allowed for the comparison of estimates thereby improving confidence in results.

Recreational Waterfowl Hunting

To determine the value of recreational waterfowl hunting, an estimate of the annual expenditure by hunters in the area was made. The Mpumalanga Parks Board was contacted to generate a reasonable estimate of the number of hunters in the area based on licence sales adjusted upward for un-licensed hunting. These numbers were then multiplied by an annual average number of trips and a cost per trip estimate.

4.12.2 Estimation of Indirect Use Values

Wetlands are thought to perform numerous ecosystem functions that have an input into economic production, or provide a cost savings by performing a function that would otherwise have to be performed by artificial means. The latter types of services can best be valued in terms of the costs that would be incurred to replace these functions if they were lost. The former are best valued in terms of the change in productivity that would result from their loss. In initial meetings, the study team decided to investigate three of these functions that were likely to be most important in the in context of the UORC wetlands: flow regulation, water purification and sediment trapping.

Flow Regulation: Winter Flow Augmentation and Flood Attenuation
It is commonly asserted that wetlands capture and store water during the rainy season, and release it gradually during the dry season. This would enhance stream flow during the dry season, alleviating stress to productive entities such as crops and livestock, as well as helping to maintain biodiversity and functioning of aquatic systems. In addition, the capture of wet season flows by wetlands helps to ameliorate the impacts of flooding, and thus flood attenuation is often cited as a particularly valuable service provided by wetlands. To ascertain the extent to which these functions are performed by the UORC wetlands, the team's hydrologists were asked to model the flow of water in the catchment with and without the presence of wetlands in the catchment. Following this, we wanted to determine whether different types of wetlands were better at performing these functions than others. Similar exercises were thus also requested from the modelling team, but in this case removing each particular type of wetland in the catchment, to ascertain the influence of this wetland type on streamflow from the catchment. The wetland types considered were three major groupings of seepages, pans and floodplains.

The value of the winter flow augmentation is its value as input into productive activities (i.e. its contribution to final outputs). The value of flood attenuation is the costs saved in terms of flood damages avoided. Thus the outputs requested included an update of flooding contours under a no-wetlands scenario, which would then be overlaid on GIS coverages of infrastructure. Damage costs are the costs or replacing the infrastructure multiplied by the probability of its being lost to flooding. The latter analyses were not performed, however, due to the outputs of the modelling exercise (see results).

Water Purification
Allan Batchelor was requested to estimate the uptake of excessive nutrients by the different broad groupings of wetlands listed above. This uptake capacity would then be valued at the commercial cost of removing such nutrients in a wastewater treatment facility.

Sediment Trapping
The modelling team were asked to estimate the sediment yield of the catchment that lands up in major dams (e.g. Witbank Dam), with and without the presence of the wetlands in the catchment. The next step was to only remove certain types of wetlands to see how much each of these affected sediment transport. Sediment deposition in dams reduces the lifespan of the dam, by slowly reducing its water holding capacity. Thus, if sediment deposition was more rapid without the wetlands, then the change in lifespan of the dam can be calculated, and the economic implications are calculated in terms of the costs of having to replace the dam earlier than planned. Again, the latter analysis was not performed, due to the outputs of the sediment modelling exercise.

4.12.3 Estimation of Opportunity Costs of Conserving Wetlands

The valuation component of this report deals with the values associated with wetlands that have been conserved to varying degrees. Conservation is, however, not the only available land use option for wetlands in the area. They can be converted to other uses, notably agriculture and coal mining. This means that conservation carries an opportunity cost. Attaching values to the conversion option involved the calculation of the value that would be foregone by not converting to the next best land use option thus determining the opportunity cost of conservation.

For wetlands with agricultural potential, the total opportunity cost could have been estimated by calculating foregone yearly income for the long term and generating a discounted present value of this income. There was, however, an easier way whereby land prices sourced from la local estate agent were simply used. This was possible as land prices reflect the expected future income streams from land in a well-functioning market, as is likely to be the case in much of the study area.

Where coal mining is the next best use of a wetland area, property prices are an inadequate reflection of opportunity costs. This is because property prices only capture the value of the top layer of ground. For a true reflection one has to add the value of underground minerals reflected in the value of mineral rights. With the help of Anglo Coal, a value of mineral rights per hectare was established based on market averages.

4.12.4 Assumptions and Limitations

All values are subjective, as they depend on the choices that humans make and the complex dynamic between supply and demand. Some of the problems with economic valuation are discussed below, and include differences between *users*, the importance of identifying *uses*, and choosing an appropriate *currency*. Various methods have been developed to address these problems. Although there is, and will never be, a final answer to what a particular wetland may be worth, the methods do provide a useful framework for identifying and prioritising the key issues.

Apart from the general theoretical limitations of valuation, the main sources of limitation for the study were its broad scope, limited data availability and limited budget. In terms of scope, the study attempted to generate per hectare values for all wetlands in the study area. This necessitated numerous assumptions and generalisations despite it being inadvisable to aggregate individual wetlands values due to the significant variation that can occur between wetlands. Results thus need to be viewed strictly as preliminary indicators of overall values at a broad level. The successful estimation of environmental values (particularly for ecosystem functions) is highly dependent on sufficient data on biophysical processes, and this in turn is dependent on comprehensive field studies. Finally, budget constraints meant that the study had to remain a primarily desktop exercise.

Subjectivity of Value
Different people have different values, and these may change in time, so it is impossible to provide a unifying definition of ecosystem value (Bingham et al., 1995). Economists may value wetlands in terms of money, farmers may value wetlands in terms of grazing potential, whereas ecologists may value wetlands in terms of ecological functions, such as their importance as migration corridors. The same individual may also express different values, depending on whether they are responding in their personal capacity or their work capacity (Bingham et al., 1995). Furthermore, the term "value" encompasses utilitarian, aesthetic and moral assessments, and the later are difficult to quantify. In simple terms, value refers to the importance and desirability of a resource, and the overall economic value = value per individual x the number of individuals.

Sources of Value
Another problem with economic valuations of natural resources in particular is that the value of a resource needs to be recognised to be valued. Often the values of natural resources are not recognised due to a lack of information. For example, it has only been in recent years that wetlands have been recognised for their ability to neutralise acids. Furthermore, the socio-economic consequences of proposed physical changes to ecosystems are very often unknown. This makes them impossible to quantify.

Currencies
There are various ways of measuring value. These include the price that people are prepared to pay for something (i.e. monetary value), the laws and policies of a country (i.e. societal value), and the feelings, morals and beliefs of a person. Certain values may be relatively easy to quantify and translate into monetary terms, whereas other values are more difficult to quantify. For example, the harvesting and sale of fish or reeds from a wetland may be easy to quantify, but the value of the biodiversity or scenic beauty of an area may be more difficult, and some may say impossible, to quantify.

Another danger of monetary valuation is that money can be used to make decisions in situations where broader human values, including non-monetary values, may be more appropriate (Bingham et al., 1995). For example, many environmental problems involve issues of equity within the current and future generations. Clearly, monetary valuation has limitations in such situations.

Spatial Changes
Estimates made in this study are presented on a per hectare basis for different types of wetlands. Of course there will be tremendous spatial variability in the use of wetlands depending on their density in an area, their proximity to potential users, their size, and other influencing factors. It must be stressed, therefore, that the average values given may not necessarily be typical in any part of the study area.

Temporal Changes
The benefits and costs of wetland conservation or conversion are not just felt in the present, but to varying degrees in the future. The path of these costs and benefits

over time can only be estimated, as there is no certainty as to the needs and preferences of future generations. A stream of costs and benefits over a period of years is frequently expressed as a net present value, a concept which is comparable to the quoting the price of land per ha, which reflects it expected future earnings. To calculate present value, the values expected in future time periods are discounted to account for the fact that values gained in the future are generally held to be less important than values gained in the present. This becomes clearer if one considers that present income can be invested at a positive interest rate. The discount rate is thus usually similar to the prevailing real rate of interest, and a high discount rate gives lower weight to values accruing in the future. In this study, a discount rate of 8% is used. The time period for analysis is 20 years, as beyond this, discounted values are very small.

Following common practice, it is assumed that current annual values do not change over time. However, this is a flawed assumptions with regard to wetlands, as these are dynamic systems, and values must therefore change over time. Furthermore, the way on which wetlands are used or managed today may affect their ability to continue producing the same goods and services in the future. This means that people's options to benefit from the goods and services in the future may be compromised.

Data Availability

The biggest limitation of this study was the lack of available data. Few resource economics studies have been carried out in South Africa to date, so there is little basis from which to transfer existing knowledge to desktop studies. Furthermore, certain information was difficult to obtain particularly where companies or individuals were reluctant to disclose information that may be considered confidential. Moreover, quantitative understanding of the functioning of wetlands is also limited, and available species lists of flora and fauna are far from complete.

5. WETLAND CLASSIFICATION, MAPPING AND INVENTORY

G.C. Marneweck, & A.L. Batchelor

5.1 Definitions and Hydrological Components of the Different Wetland Units

In total, 17 hydro-geomorphic units or types of wetlands were recognised in the study area. These are depicted diagrammatically in Figures 5.1 to 5.3, and definitions of the units are given in Tables 5.1. and 5.2. Generalisations about the attributes of each of the types of wetland units recorded in the study area are detailed in Appendix Q.

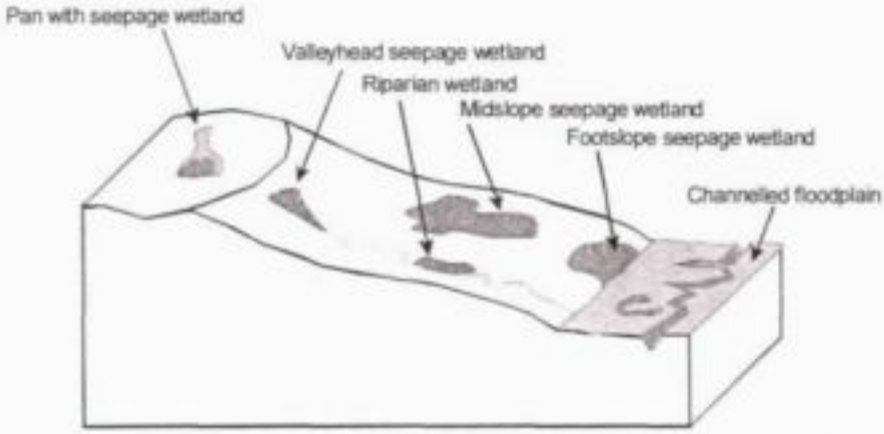


Figure 5.1. Diagrammatic representation of various wetland types, highlighting channelled floodplain and hillslope seepage wetlands.

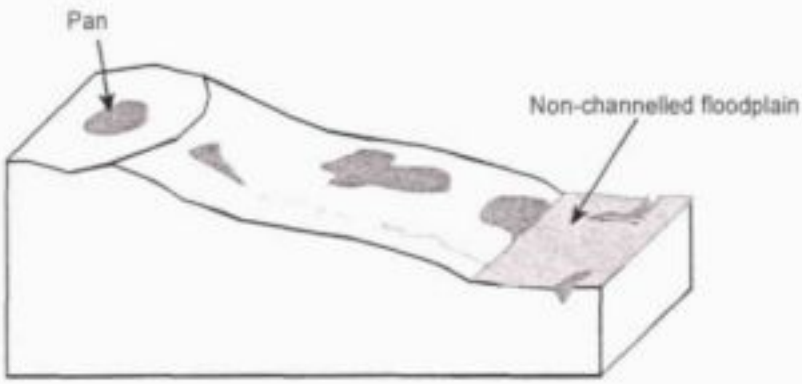


Figure .5.2. Diagrammatic representation of non-channelled floodplain wetland and pan without seepage wetland.

Figure 5.3. Diagrammatic representation of crest seepage and footslope seepage wetlands.

Table 5.1. Classification of Wetland Types.

Group	No.	Description
Non-floodplain riparian	1	Drainage lines with riparian zones.
	2	Channelled Riparian wetlands.
	3	Non-channelled riparian wetlands.
Floodplain riparian	4	Seasonally inundated channelled valley bottom floodplain wetlands with footslope seepage wetlands.
	5	Seasonally inundated valley bottom floodplain without footslope seepage wetlands.
	6	Seasonally inundated non-channelled valley bottom floodplain.
	7	Temporarily to seasonally inundated channelled valley bottom floodplains.
Hillslope seepage	8	Footslope seepage wetlands.
	9	Midslope seepage wetlands.
	10	Valleyhead seepage wetlands
	11	Crest seepage wetlands.
Pans	12	Permanently wet pans.
	13	Non-permanently wet pans.
	14	Seepage wetlands associated with pans.
Other non-riparian	15	Wet grasslands.
Artificial wetlands	16	Dams
	17	Other artificial wetlands.

Table 5.2. The definition of the different wetland units recorded during the study in relation to wetland type, topographic setting and hydrologic components (table and classification modified from Brinson, 1993).

TYPE		UNIT	TOPOGRAPHIC SETTING	DEFINITION	HYDROLOGIC COMPONENTS		
					Inputs	Throughputs	Outputs
RIPARIAN	NON-FLOODPLAIN	1. Drainage lines with riparian zones	Valley bottom	Incised stream channel along a watercourse, which may be shallow or deep but which has clearly defined margins, lacks a well defined and extensive floodplain, has an associated narrow band of riparian vegetation and may or may not be associated with footslope seepage wetlands	Overland flow from catchment runoff, channel flow and lateral seepage from associated footslope seepage wetlands.	Channel flow	Channel flow
		2. Channelled riparian wetlands	Valley bottom	Riparian wetland with little relief which is characterised by seepage and surface flow influenced by stream related processes in an incised stream channel along a watercourse.	Channel flow and lateral seepage.	Channel flow	Channel flow
		3. Non-channelled riparian wetlands	Valley bottom	Riparian wetland with little relief which is characterised by seepage and diffuse surface flow by stream related processes in a section of stream without a clearly defined channel.	Diffuse flow from upstream channel flow and seepage.	Diffuse flow	Channel flow
	FLOODPLAIN	4. Seasonally inundated channelled valley bottom floodplains with footslope seepage wetlands	Valley bottom	A broad riparian zone of low relief (up to hundreds of metres) characterised by the alluvial transport and deposition of material, oxbows, adjacent footslope seepage wetlands, and a well defined but meandering shallow stream channel allowing seasonal inundation.	Channel overspill during flooding, tributary supply, lateral surface flow from adjacent slopes and from footslope seepage wetlands[3]	Diffuse surface flow, particularly during flood events, and seasonally due to flows from lateral seepage areas. Channel flow.	Channel flow.

TYPE		UNIT	TOPOGRAPHIC SETTING	DEFINITION	HYDROLOGIC COMPONENTS		
					Inputs	Throughputs	Outputs
		5. Seasonally inundated channelled valley bottom floodplains without footslope seepage wetlands	Valley bottom	A broad riparian zone of low relief (up to hundreds of metres) characterised by the alluvial transport and deposition of material, oxbows, and a well defined but meandering shallow stream channel allowing seasonal inundation.	Channel overspill during flooding, tributary supply and lateral surface flow from adjacent slopes.	Diffuse surface flow during flood events and channel flow.	Channel flow
RIPARIAN	FLOODPLAIN	6. Seasonally inundated non-channelled valley bottom floodplains	Valley bottom	A broad riparian zone of low relief (up to hundreds of metres) characterised by the alluvial transport and deposition of material, oxbows, adjacent footslope seepage wetlands, but without a defined stream channel allowing diffuse flow over the wetland surface most of the time.	Diffuse flow from upstream channel spillage and lateral flow from adjacent slopes.	Diffuse surface flow during flood events and from upstream channel flow.	Channel flow
		7. Temporarily to seasonally inundated channelled valley bottom foodplains	Valley bottom	A broad riparian zone of low relief (up to hundreds of metres) characterised by the alluvial transport and deposition of material, oxbows, and a well defined deeply incised stream channel allowing only temporary inundation during large infrequent flooding events.	Channel overspill during flooding, tributary supply, lateral surface flow from adjacent slopes and lateral sub-surface flow from footslope seepage wetlands.	Diffuse surface flow (particularly during flood events) and diffuse seepage flows seasonally. Channel flow.	Channel flow
NON-RIPARIAN	HILLSLOPE SEEPAGE WETLANDS	8. Footslope seepage wetlands	Hillslopes but restricted to those near the valley bottom.	Concave or convex slopes which are characterised by the colluvial (transported by gravity) movement of materials and are situated immediately above riparian areas.	Predominantly groundwater and interflow.	Interflow & diffuse surface flow.	Variable
		9. Midslope seepage wetlands	Hillslopes but more toward the middle sections of the slopes.	Concave or convex slopes which are characterised by the colluvial (transported by gravity) movement of materials and are situated towards the middle sections of the hillslopes.	Predominantly groundwater from perched aquifers and interflow.	Interflow & diffuse surface flow.	Variable

TYPE		UNIT	TOPOGRAPHIC SETTING	DEFINITION	HYDROLOGIC COMPONENTS		
					Inputs	Throughputs	Outputs
		10. Valleyhead seepage wetlands	Hillslopes but mainly at the heads of the valley.		Predominantly groundwater from perched and main aquifers and interflow.	Interflow & diffuse surface flow.	Variable but predominantly streamflow.
		11. Crest seepage wetlands	Hillslopes normally above rocky outcrops at the crest of the hills where the soils are shallow.	Concave shallow slopes which are characterised by the presence of shallow bedrock.	Predominantly interflow.	Seepage flow at the bedrock contact.	Variable

TYPE		UNIT		LANDFORM SETTING[1]	DEFINITION	HYDROLOGIC COMPONENTS		
						Inputs[3]	Throughputs	Outputs
NON-RIPARIAN	PANS	12.	Permanently wet pans	Mainly on top of the drainage divides.	A basin shaped area with a closed elevation contour that allows for the permanent accumulation of surface water. An outlet is usually absent.	Variable but predominantly runoff from adjacent slopes.	Flow usually contained and stored.	Evapo-transpiration
		13	Non-permanently wet pans	Drainage divides and hillslopes.	A basin shaped area with a closed elevation contour that allows for the non-permanent (seasonal or temporary) accumulation of surface water. An outlet is usually absent.	Variable but predominantly runoff from adjacent slopes.	Flow usually contained and stored.	Evapo-transpiration
		14	Non-permanently wet pans	Hillslopes	A basin shaped area with out a closed elevation contour that allows for the non-permanent (seasonal) accumulation of surface water from adjacent seepage areas. An outlet usually occurs.	Variable but predominantly runoff and sub-surface seepage from adjacent slopes.	Storage, Interflow & diffuse surface flow.	Evapo-transpiration, interflow and channel flow
	OTHER	15	Wet grasslands	Hillslopes	A grassland which may be wetted seasonally for short periods but does not develop more permanent signs of hydric conditions.	Variable but may include seepage and rainfall.	Diffuse flow	Variable
ARTIFICIAL WETLANDS		16.	Dams	Valley bottom	An artificially created open water body within a drainage line or stream.	Channel flow.	Channel flow	Channel flow
		17.	Other artificial wetlands	Varied, but mainly valley bottom.	An artificially created or extended wetland area which may or may not be riparian.	Variable	Variable	Variable

5.2 Overall Inventory of Wetlands in the UORC

The overall distribution and pattern of wetland types in the study area is shown in Figure 3.2. A more detailed map in both hard copy and digital format has been prepared, and is available from the WRC. The number of each of the types of hydro-geomorphic wetland units recorded and their extent are summarised in Table 5.3. Details of the amount of each wetland type are given for each of the quaternary catchments within the study area in Table 5.4.

The total wetland area as delineated by the 1: 50 000 scale mapped wetlands comprise 64 813 ha (Table 5.3). This value includes dams (or waterbodies as classified in the 1996 National Land Cover) at 6 840 ha. This value is slightly larger than the national land cover value, but is most likely due to scale discrepancies. A total of 57 969 ha are therefore defined as wetlands (excluding dams), a much higher value than that represented by the national land cover database; as much as 56 334 ha more. Scale discrepancies are a reason, but the more likely reasons are due to better signature and boundary identification from aerial photograph interpretation of larger scale imagery and the identification of more obscure or lesser known wetland types.

5.2.1 Field Verification of Maps

Field verification showed that certain categories of wetlands were not easily identified at a scale of 1:50 000, despite the reasonably good quality of the aerial photographs. The main categories affected were the hillslope seepage wetlands. These included the valleyhead and midslope seepage areas and hydromorphic grasslands in particular. This appears to be as a result of masking of the signatures by landscape modification. Cultivated fields and planted pastures, for example, caused numerous problems in this regard, particularly fallow lands and old fields that were being re-colonised by grassland species. Often the signatures were masked by the various shades of grey in these areas, or it was simply too difficult to decide whether or not the area was a wetland or alternatively, where the boundaries lay. In addition, the valleyhead and midslope systems were not necessarily associated with drainage lines, which further complicated the matter.

Accuracy

The map of wetlands that accompanies this report may usually only be accurate to 100 m on the ground, and this may extend to hundreds of metres taking into account inherent ortho-rectification errors involved in the data capture and transfer to electronic format. This is despite that the captured boundaries were transferred to ortho-rectified topographic map sheets. More detailed boundary mapping of individual wetlands in the UORC has confirmed this. The map does however provide high confidence with respect to the identification of wetlands as well as where they occur and this was verified through ground truthing.

In addition to the low level of accuracy with respect to the boundaries of the wetlands in places, certain wetland types are not as accurately captured as others. This is in terms of both number and extent and is mostly due to scale dependent factors such as that the wetlands were simply too small to be seen on the aerial photographs. Other factors also influenced this such as if sections of the ground had been burnt when the photographs were taken. Thus larger floodplain areas, for example, are more accurately represented in terms of extent, than seepage areas. More detailed mapping of individual wetlands in the UORC has also confirmed this.

Ground truthing also showed that the extent of certain wetland types, particularly the midslope and valleyhead seepage systems, is vastly underestimated on the map. At a gross estimate, as much as 50% of the area of these systems may not be depicted on the map because the signatures and boundaries were masked on the aerial photographs. This was mainly due to many of these systems having been drained and ploughed, particularly when they were associated with the more arable Avalon soil form. This made it very difficult to identify their extent and boundaries remotely. The extensive cultivation in many of the wetland systems also affected the top 50 cm of the soil profiles making the identification of hydric indicators difficult. This also made field verification of some of the wetland boundaries (particularly the hillslope seepage wetlands) very difficult and as a result more accurate boundary delineation at a higher resolution of mapping would require extensive fieldwork.

Many of the drainage lines with riparian zones included narrow floodplains as well as relatively narrow footslope seepages along the valley bottoms. These areas as well as differences in the extent of these linearly along the valley bottoms could not be distinguished remotely at a scale of 1:50 000. As a result, a mapping convention was applied and all combinations of these were simply lumped together and classified as drainage lines with riparian zones. Classifying these areas at a finer resolution (for example 1:10 000) would probably result in these areas being separated out and this would usually add to the extent and number of footslope seepage wetlands. The same can be said for the channelled valley bottom floodplain areas with footslope seepage wetlands. At a finer resolution of mapping, the footslope seepage wetlands could probably be separated out thus again increasing the number recorded at 1:50 000 scale. These type of wetland mapping constraints are well recognised (Tiner, 1999) and their limitations need to be understood with respect to interpretation of the mapping results and with respect to the overall functional assessment.

Although few wet grasslands and crest seepage wetlands were recorded, the numbers are unlikely to reflect actual numbers occurring in the study area. The mapping resolution and technique was inadequate for picking up these systems since most are small and have marginal hydric indicators. Many more of both these types of systems are expected to occur since only the larger ones were identified during mapping. The cumulative contribution of these additional systems may have an influence on the wetland area estimates given but for the purposes of this report they are accepted as has been recorded.

Windmills

Evidence from field visits suggested that the location of these systems may often be identified by looking for windmills, particularly near the top of a drainage divide. In an attempt to indicate where these systems may occur, all the windmills on the 1:50 000 topographic map were captured and included on the wetlands map. Examination of the map shows that many of these are located almost in clusters along drainage divides, often in the vicinity of delineated seepage wetlands and where ground water occurs close to the surface, either as deep or perched aquifers. Windmills may thus provide clues as to the original extent of these seepage wetland systems.

Table 5.3. The number and extent of the different wetland types recorded in the Upper Olifants River Catchment.

Wetland Type	Number of wetlands	% of total number of wetlands	Area (ha)	% of total wetland area
NON-FLOODPLAIN RIPARIAN				
1. Drainage lines with riparian zones	710	15,95	14 538	22,43
2. Channelled riparian wetlands	35	0,79	2 083	3,21
3. Non-channelled riparian wetlands	2	0,04	356	0,55
TOTAL	**747**	**16,78**	**16 977**	**26,19**
FLOODPLAIN RIPARIAN				
4. Seasonally inundated channelled valley bottom floodplains with footslope seepage wetlands	26	0,58	11 454	17,67
5. Seasonally inundated valley bottom floodplains without footslope seepage wetlands	3	0,07	483	0,74
6. Seasonally inundated non-channelled valley bottom floodplains	2	0,04	1 034	1,59
7. Temporarily to seasonally inundated channelled valley bottom foodplains	5	0,11	794	1,22
TOTAL	**36**	**0,81**	**13 765**	**21,24**
HILLSLOPE SEEPAGE				
8. Footslope seepage wetlands	192	4,31	8 382	12,93
9. Midslope seepage wetlands	370	8,31	7 824	12,07
10. Valleyhead seepage wetlands	108	2,43	2 037	3,14
11. Crest seepage wetlands	3	0,07	25	0,04
TOTAL	**673**	**15,12**	**18 268**	**28,19**
PANS				
12. Permanently wet pans	149	3,35	3 496	5,39
13 . Non-permanently wet pans	498	11,19	2 479	3,82
14. Seepage wetlands associated with pans	65	1,46	1 346	2,08
TOTAL	**712**	**16,01**	**7 321**	**11,30**
OTHER NON-RIPARIAN				
15. Wet grasslands	7	0,16	1 066	1,64
TOTAL	**7**	**0,16**	**1 066**	**1,64**
ARTIFICIAL WETLANDS				
16. Dams and weirs	2 237	50,26	6 840	10,55
17. Other artificial wetlands	39	0,88	576	0,89
TOTAL	**2 276**	**51,13**	**7 416**	**11,44**
GRAND TOTAL	**4 451**		**64 813**	

Table 5.4. Percentage catchment area of the wetland types per quaternary catchment.

Quaternary Catchment		WETLAND TYPE (%)																	
		Non-floodplain riparian			Floodplain Riparian				Hillslope Seepage				Pans			Other	Artificial wetlands		
Number	Area (km^2)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	Total (%)
Olifants River Catchment																			
B11A	**945**	2,88	0,09	0,19	3,46	-	0,61	0,30	1,45	1,85	0,67	-	0,29	0,16	0,12	-	0,58	-	**12,66**
B11B	**435**	2,48	-	-	-	1,11	-	0,30	1,16	0,92	0,36	-	0,05	0,21	0,03	0,06	1,11	0,07	**7,86**
B11C	**385**	5,54	-	-	6,77	-	-	-	0,46	0,77	0,11	-	0,04	0,09	-	0,18	0,53	-	**14,49**
B11D	**551**	3,35	0,17	-	3,76	-	-	0,69	0,38	2,75	0,13	-	0,10	0,17	0,04	-	1,58	0,12	**13,26**
B11E	**467**	2,25	0,30	0,39	4,94	-	0,97	-	1,15	0,70	0,13	-	0,30	0,55	0,09	0,62	1,22	0,06	**13,67**
B11F	**428**	2,12	1,76	-	-	-	-	-	2,66	1,22	0,57	-	0,13	0,60	0,28	0,05	1,15	0,15	**10,68**
B11G	**368**	0,52	0,73	-	-	-	-	-	0,12	0,81	0,19	-	0,95	0,67	0,04	-	3,94	0,57	**8,54**
B11H	**246**	2,12	-	-	-	-	-	-	0,98	0,57	0,03	-	0,71	0,86	0,36	-	0,81	-	**6,44**
B11J	**269**	1,28	-	-	-	-	-	-	0,13	0,29	0,22	-	-	0,10	0,39	-	1,75	0,01	**4,17**
Sub-Total																			
Klein Olifants River Catchment																			
B12A	**405**	3,30	1,23	-	-	-	-	-	2,32	1,73	0,30	0,04	0,42	0,22	0,13	-	0,44	-	**10,14**
B12B	**659**	1,25	0,35	-	0,13	-	-	-	2,31	1,52	0,41	-	0,59	0,76	0,33	0,82	0,68	0,18	**9,34**
B12C	**529**	1,30	-	-	2,08	-	-	-	2,15	0,77	0,21	-	0,98	0,48	0,47	-	1,28	0,02	**9,74**
B12D	**362**	1,41	-	-	-	-	-	-	0,42	0,47	0,07	-	0,51	0,23	0,11	-	0,41	0,10	**3,73**
B12E	**436**	0,82	-	-	-	-	-	-	0,86	0,20	0,37	0,02	-	0,16	-	-	0,20	0,01	**2,63**
Sub-Total																			

5.3 Abundance and Distribution of Different Wetland Types

The most frequently occurring as well as the largest area of wetlands (excluding dams) are drainage lines with riparian zones. Other major wetlands types present in the area include foot- and midslope seepage wetlands, seasonally inundated channelled valley bottom floodplain wetlands with footslope seepage wetlands, and permanently wet pans. These are discussed in more detail below.

5.3.1 Riparian Wetlands

The most extensive wetland units (accounting for 22% of the total wetland area) are the riparian zones associated with drainage lines. It is the cumulative area of the 710 of these that accounts for their large total area of these.

5.3.2 Non-riparian Wetlands

The largest individual wetland units were the seasonally inundated channelled valley bottom floodplains with footslope seepage wetlands with only 26 accounting for almost 18% of the total wetland area.

Footslope and midslope seepage wetlands had the next largest area accounting for 13% and 12% of the total wetland area respectively. As has already been discussed in section 4.2.1, the estimated area of the midslope and valleyhead seepage wetlands is likely to be considerably higher than the value reported. This is because many of these are likely to have been missed during the mapping due to masking of the boundaries as a result of the cultivation of many of these systems. Even among those more undisturbed systems delineated, the hydric boundaries extended into cultivated fields and these boundaries could therefore not be accurately determined. The extent given for those delineated is therefore also likely to be a conservative estimate of the actual extent.

5.3.3 Pans

A total of 149 permanently wet pans occur in the area accounting for just over 5% of the total wetland area. Despite the greater number (498), non-permanently wet pans account for just less than 4% of the total wetland area. The average size of the permanently wet pans is therefore larger than that of non-permanently wet pans. A further 65 pans associated with seepage areas occur accounting for 2% of the total wetland area. In total therefore, all the pan types and their associated seepage areas account for about 11% of the total wetland area and represent the most number of wetlands (712) in the study area.

5.3.4 Artificial Wetlands

Dams and weirs are the most common type of wetland in the study area, accounting for 50% of the total number of wetland units recorded. The total number of dams and weirs recorded in the UORC is 2 237, and these account for almost 11% of the total wetland area.

5.4 Summary

Wetlands in the study area were classified into 17 different hydro-geomorphic units. These covered a total area of 64 813ha, representing 9,9% of the total area of the UORC. Of the total wetland area, 47,5% comprised natural riparian wetlands, 41,1% comprised natural non-riparian wetlands, and 11,4% comprised artificial wetlands.

6. INFLUENCE OF GEOLOGY, SOILS AND PHYSIOREGION

P.-L. Grundling, G. Marneweck & J. Muller

6.1 Geology

The geology of the UORC is dominated by Permian age sediments of the Karoo Supergroup. The landscape is dominated by shale, shaly sandstone, grit, sandstone, conglomerate and coal beds in places.

The northern portion (downstream section of the UORC) immediately south of the town of Witbank and to the south and east of Middelburg is dominated by localised volcanic rock outcrops of the Selons River Formation. Immediately north of the above-mentioned towns, sediments and volcanic rocks of the Loskop Formation occur. The most northern portion of the UORC, between the confluence of the Olifants and Klein-Olifants is dominated by sandstones of the Waterberg Group, tillite and shales of the Dwyka Formation and the sediments of the Vryheid Formation.

The catchment watershed is defined by dolerite sills and dykes in the southern and central portions of the UORC. Contacts between various other lithologies define the watershed in the north west: mainly between sediments of the Waterberg Group, Dwyka sediments of the Vryheid Formations, as well as contacts in the north east between the Vryheid Formation and various igneous rocks associated with the Bushveld Complex.

6.1.1 Karoo Supergroup

The geology of the Karoo Supergroup is discussed briefly as it forms the template of the current landscape of the UORC and as it closely controls the distribution of the region's coal resources. It is the economic exploitation of these coal resources that is currently posing one of the largest threats to wetlands in this region. The cool to cold climate peat wetlands that would have occurred in the area about 260 million years ago and which formed the basis of the coal deposits of today would have looked different from the more temperate palustrine wetlands of today.

The Karoo Supergroup is located in various basins across southern Africa and covers about two-thirds of South Africa. The UORC is located in the Main Karoo Basin. The deposition of the Karoo Supergroup took place across the ancient super continent of Gondwanaland. Migration of the super continent across and away from the South Pole resulted in the differing depositional environments represented in the Karoo Supergroup. The supergroup was formed between 300 and 200 million years ago (Carboniferous to Jurassic period) and the sediments reached a thickness of 7 000 m in the main basin.

The depositional sequences of the Karoo Supergroup are characterised by changing environments, starting with an arctic glacial landscape and ending with a dry arid dessert. These changes can be summarised as follows:

The Dwyka Formation consists of tillites and fine to coarse clastic sediments (including some coal) that were deposited in a period of glaciation. This was followed by the Ecca Group shales, sandstone and coal deposited by basinal muds and deltaic sands. Extensive peat accumulating wetlands associated with fluvial floodplains and alluvial deltas occurred in the northern parts of the basin. An interesting feature of the landscape at that time was that rivers were flowing mainly in a southerly direction as was pre-determined by elongated valleys scoured into the pre-Karoo basement by Dwyka glaciers and continental ice sheets (Snyman, 1998).

These glacial valleys were dammed by terminal moraines with the northward retreat of the ice sheets. Shallow proglacial lakes were formed when the dammed glacial valleys were infilled by fluvioglacial sediments. These lakes were transformed into peat wetlands and resulted in the formation of the lower coal seam of the Witbank and other coal fields (Snyman, 1998). Within the main basin the number of coal seams in the Vryheid Formation varies from one coal field to another (Snyman, 1998), reflecting the dynamic nature of the environment over time, including that of the peat wetlands associated with the coals seams.

The Witbank Coal Field (north of Kriel) was exploited by 37 collieries in 1995 and has developed, since mining commenced in 1895, as the most important coal field in South Africa. About 100 million tons of saleable coal were produced in 1995 in this coal field (Snyman, 1998). The area between Kriel and Trichardt falls within the Highveld Coal Field. Only three of the Highveld Coal Field mines fall within the UORC.

The Ecca Group is dominated by plant fossils (forming the economic coal deposits of South Africa) of the *Glossopteris* flora. It also contains some fossils of water dependent reptiles such as *Mesosaurus*.

The following lithologies (except for the Drakensberg lavas) are not important in terms of their abundance in UORC, but are included for the sake of a complete geological setting of the catchment. The sandstones and shales of the Beaufort Group were deposited in lacustrine, fluvial floodplain and channel environments. This group has a very rich fossil content and the sandstone contains some uranium and molybdenum deposits.

The sandstones of the Molteno Formation were deposited by meandering fluvial systems associated with alluvial fans. The Molteno Formation contains less extensive coal deposits. Sandstones of the Elliot Formation were deposited as loess (wind blown deposits) and by some fluvial systems. The Clarens Formation contains sandstones representing a general desert environment with alluvial fans, channels, playa lakes and sand dunes.

The Drakensberg Formation caps the Karoo Supergroup and signals the break-up of Gondwanaland. This formation consists of extensive basic (basalts) and acid (rhyolite) lavas with localised pyroclastic rocks. Dolerite dykes and sills may represent the feeder conduits for the Drakensberg lavas.

Dolerite dykes and sills play an important role in defining the watershed boundaries of the UORC and wetland distribution. Dolerite intrusions could also have replaced coal deposits. Areas associated with high concentrations of dolerite intrusions may therefore be less targeted for coal mining operations, also as a result of unstable mining conditions associated with dolerite intrusions. However, the intrusion of dolerite may, due to an increase in temperature, lead to an increase in the rank of coal (a higher rank means a better quality of coal, such as anthrasite). Such areas may be selectively mining.

Areas of high potential mining occur in two convex zones between Ogies and towards the Greenside Colliery and Witbank, and from 10 km north of Kriel, towards Blinkpan and the Mavela Colliery south of Witbank.

6.1.2 Wetland Distribution in Relation to Geology

The control of wetlands by geological factors in southern Africa is acknowledged by various authors (Breen et al., 1994; Grundling, Baartman & Mazus, 1998; Grundling & Marneweck, 1999; Marneweck, Grundling & Muller, 2001). Underlying geology influences the local landform, soil type, surface water movement, recharge of the aquifer and base flow maintenance of the aquifer, effective rainfall (Vegter, 1995), and even erosional processes and vegetation cover. The UORC is no exception and there is evidence of a correlation between geology and wetland distribution, type and size.

More than 90% of the wetlands occur on the sediments of the Vryheid Formation in the southern and central portions of the UORC. Between 6 - 8% occur on the sandstones, shales and tillites of the Waterberg Group and Dwyka Formation. Less the 1% occur on the igneous rocks associated with the Rooiberg Group and Bushveld Complex.

The highest concentrations of wetlands are associated with the distribution of dolerite intrusions within the Vryheid sediments in the southern section of the UORC. The structural control of the geological lithologies (contacts between sandstones, shales, dolerites and faults) in terms of landform and wetland keypoints and the hydrological control as a result of these probably contribute to the high concentration of wetlands in this portion of the catchment.

6.1.3 Wetland Types in Relation to Geology

The distribution of wetland types once again appears to be associated with the underlying geological lithologies. The drainage line wetlands with riparian zones drain the southern dolerite defined watershed (and to a lesser extent the central, western and eastern watersheds). One of the most biologically diverse and geomorphologically interesting wetland types in the UORC is the seasonally inundated channelled valley bottom floodplains with footslope seepage wetlands. The majority (92%) of these are associated with the above-mentioned drainage line wetlands draining the dolerite-dominated watershed. Two exceptions to this are located in the north-eastern portion of the catchment, where they are closely related to the rhyolite (an igneous rock, as is dolerite) of the Rooiberg Group.

The structural controls as a result of the valleybottom settings of the floodplain wetlands in general (seasonally inundated un- and channelled valley bottom floodplains with/without footslope seepage wetlands) are most probably defined by the weathering and erosional properties of the shales and sandstone of the Vryheid Formation, as well as linear features associated with contacts between various lithologies and faults. Keypoints reflecting the above-mentioned factors are evident in all of the above-mentioned wetlands.

Hydrology and the nature of lithological units (e.g. permeable sandstones underlain by impermeable dolerite sills) as well as contacts between these units and faults, largely controls the distribution and process underlying the formation of the various types of seepage wetlands.

Although pans occur throughout the catchment, most (more than 95%) are restricted to the sediments of the Vryheid Formation. The distribution of the pans may be closely related to the outcrop and sub-outcrops of the shales of the Vryheid Formation (Crail, *pers. comm.*, 1997).

6.1.4 Wetland Size in Relation to Geology

Wetland size varies significantly from the upstream watershed areas in the south and east of the catchment to the central and northern portions. The majority of the larger wetlands (mostly referring to the seasonally inundated un- and channelled valley bottom floodplains with/without footslope seepage wetlands) occur in the upper catchment areas and appear to be strongly associated with the dolerite intrusions within the Vryheid sediments. These features strongly influence groundwater movement and contact with the surface thus also influencing the formation of seepage type wetlands.

There is an obvious absence of the larger wetlands from the Waterberg Group and Dwyka Formation sediments and the igneous rocks associated with the Rooiberg Group and Bushveld Complex.

6.2 Soils

The wetlands in the UORC are associated with many soil forms, including Avalon, Katspruit, Kroonstad, Pinedene, Rensburg, Sepane, Glencoe, Dresden and Westleigh. All these forms apart from Kroonstad, are either always or sometimes associated with wetlands (Table 6.1). In general, the Kroonstad, Katspruit and Rensburg soil forms were commonly associated with the drainage lines, floodplains and pans whereas the Avalon, Pinedene, Sepane, Dresden and Westleigh forms were commonly associated with the seepage wetlands and associated moist grasslands and some of the pans.

Table 6.1.Soil forms associated with wetlands (from Kotze, Hughes, Breen & Klugg, 1994).

Soil forms always associated with wetlands				
Champagne	Katspruit	Willowbrook	Rensburg	
Soil forms sometimes associated with wetlands				
Inhoek	Longlands	Wasbank	Lamotte	Estcourt
Klapmuts	Tukulu	Cartref	Fernwood	Westleigh
Dresden	Avalon	Pinedene	Glencoe	Bainsvlei
Bloemdal	Witfontein	Sterkspruit	Sepane	Valsrivier
Dundee				

6.2.1 Floodplain Soil Forms

i) Kroonstad

In areas where the Kroonstad soil form occurs in wetlands, it has a typical E horizon with a grey matrix which in places is shallower than 50 cm. Below this a typically gleyed B horizon occurs. In the floodplain of the Steenkoolspruit for example, the orthic A horizon had a very high organic content up to a depth of 20 cm and was colonised by extensive stands of the hydrophytic grass (*Leersia hexandra*). The orthic A horizon can also range from damp in some floodplains to dry in others. In some areas, these soils are cultivated.

ii) Katspruit

In the Katspruit soil form an orthic A horizon overlies a G horizon which is typical moist with grey matrix colours. Mottling may or may not occur down to a depth of 50 cm. Many of the Katspruit soils associated with the floodplains in the area are not characteristically saturated at depth. This is largely the result of incision of the stream channel which serves to drain these areas and also reduces the likelihood of overbank topping during flooding rainfall and thus reduces the frequency of flooding. The soil profile thus dries out. These soils are generally not cultivated.

iii) Rensburg

The vertic A horizon of the Rensburg form has clearly visible slickensides in the transition to the lower layers and is characteristically cracked when dry. The vertic A horizon ranges from moist to dry depending on the frequency and duration of wetting when the soils are flooded. The underlying G horizon is often saturated unless the system has been drained and has typical grey matrix colours often with blue or green tint with or without mottling. These soils are generally not cultivated.

6.2.2 Seepage Wetland Soil Forms

i) Avalon

This soil form was commonly associated with the seepage areas and moist grasslands in the area. These soils were characterised by an orthic A horizon overlying a yellow-brown apedal B above a soft plinthic B horizon. The orthic A horizon is usually sandy, but saturated to inundated in places depending on the extent and origin of the subsurface seepage as well as whether or not the wetland is drained. The yellow-brown apedal B horizon often contained high chroma mottles which increase in density towards the underlying soft plinthic B which in turn has a characteristic grey colour associated with gleying. These soils are extensively drained and utilised for cultivation.

ii) Pinedene

This soil form is commonly associated with the seepage areas and moist grasslands in the area. These soils are characterised by an orthic A horizon overlying a yellow-brown apedal B above a gleycutanic B horizon. The gleycutanic B horizon is characterised by variation in dark, grey and high chroma colours (associated with mottling). Diffuse mottling and streaking by high chroma yellows and reds is common in the seepage wetlands with these soils. These soils are extensively drained and utilised for cultivation.

iii) Westleigh

This soil form is commonly associated with the seepage wetlands and moist grasslands in the area. These soils are characterised by an orthic A horizon overlying a soft plinthic B horizon. The orthic A horizon is usually sandy, but saturated to inundated in places depending on the extent and origin of the subsurface seepage as well as whether or not the wetland is drained. The soft plinthic B often has a characteristic grey colour associated with gleying. These soils are extensively drained and utilised for cultivation.

iv) <u>Sepane</u>

This soil form may be associated with many wetland types in the area. These soils are characterised by an orthic A horizon overlying a pedocutanic B horizon overlying unconsolidated material with signs of wetness.

v) <u>Dresden</u>

This soil form was commonly associated with the seepage areas and moist grasslands in the area. These soils are characterised by an orthic A horizon overlying a hard plinthic B horizon. The orthic A horizon may be sandy and saturated to inundated in places depending on the extent and origin of the subsurface seepage as well as whether or not the wetland is drained.

vi) <u>Glencoe</u>

This soil form is also commonly associated with hillslope seepage wetlands on perched water tables in the area. These soils are characterised by an orthic A horizon overlying a yellow-brown apedal B above a hard plinthic B horizon The hard plinthic B horizon provides the impervious base which allows the shallow ground water to surface. In gradual slope areas, surface water may collect in some of these systems.

6.3 Physioregions

6.3.1 Identification of Physioregions

Of the fifteen variables analysed, eight (baseflow, elevation, soil fertility, growth days, geology, groundwater recharge, slope, and topographic index) were chosen as explanatory variables or essential components in defining the landscape. After re-analysis of the variables with loading factors of greater than 0,6, six variables were finally delineated as being defining components of the landscape: baseflow, elevation, soil fertility, growth days, geology, and groundwater recharge (Figure 6.1). These six variables explained 82% of the variation in the landscape (Table 6.2).

Table 6.2. Factor weights, eigenvalues, and total variance explained derived from the Principal Component Analysis on chosen explanatory variables[a].

Variables[b]	Axis 1	Axis 2	Axis 3
BASEFLOWN	**0,772**[a]	-0,170	0,159
DEMN	**-0,820**	0,429	-0,060
FERTN	-0,018	-0,145	**0,917**
GDN	-0,098	**0,959**	-0,026
GEOLN	0,382	0,160	**0,763**
RECHARGEN	**0,845**	0,363	0,140
Eigenvalues	2,139	1,311	1,472
Total variance explained (%)	35,647	21,853	24,538

[a] values in bold denote the significant variables identified for each axis

[b] variable names: baseflown = baseflow; demn = elevation; fertn = soil fertility; gdn = growth days; geoln = geology; rechargen = ground water recharge.

A maximum likelihood classification created the final groupings or clusters that divided the landscape into three physioregions (Figure 6.1):

- **Region A** depicts: low elevation and growth days (i.e. high evaporation with low rainfall); variable geology and soil fertility; high hydrology components (i.e. recharge and baseflow)
- **Region B** depicts: medium elevation and growth days; uniform geology and soil fertility; and low hydrology components
- **Region C** depicts: high elevation and growth days; variable geology and soil fertility; and low hydrology components.

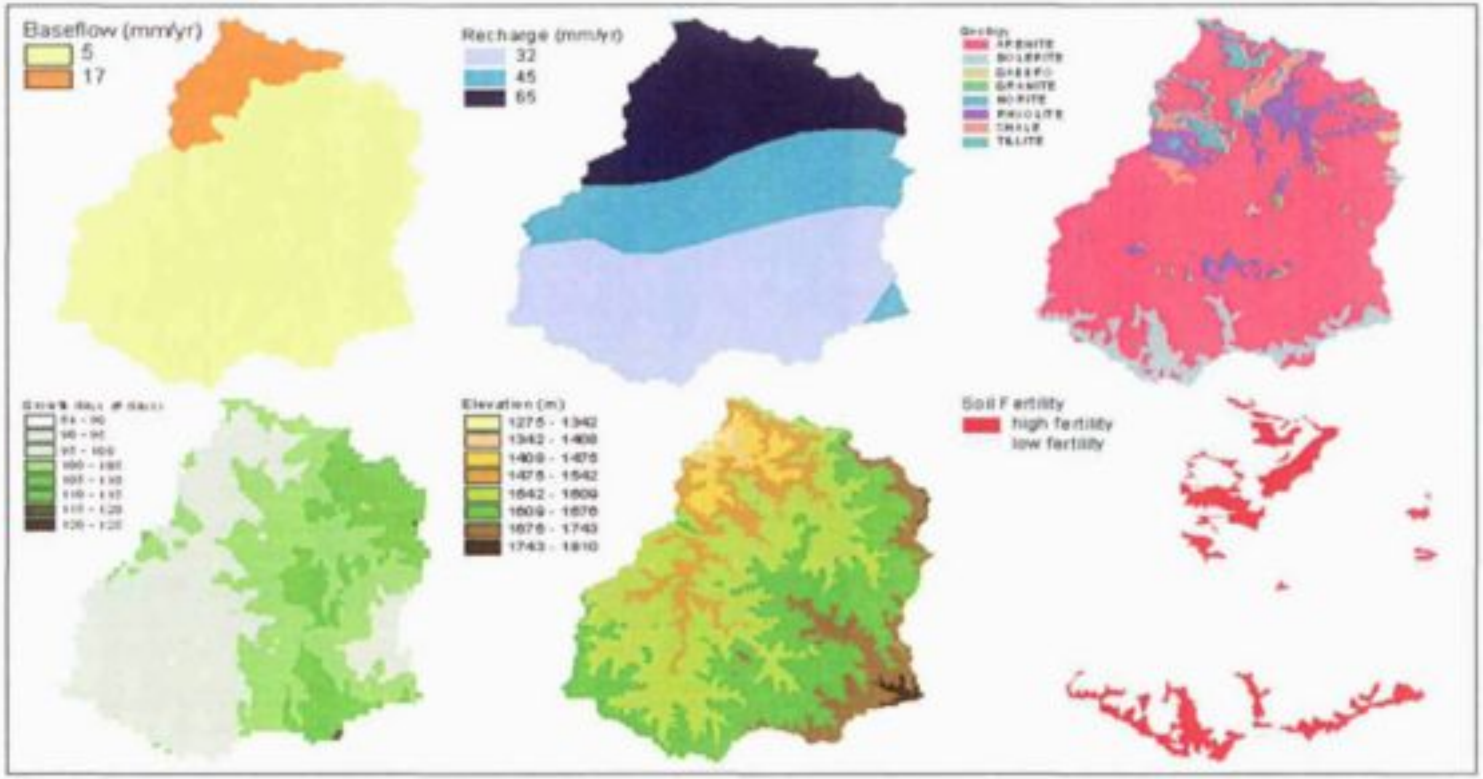


Figure 6.1. Landscape explanatory variables according to principal component analysis.

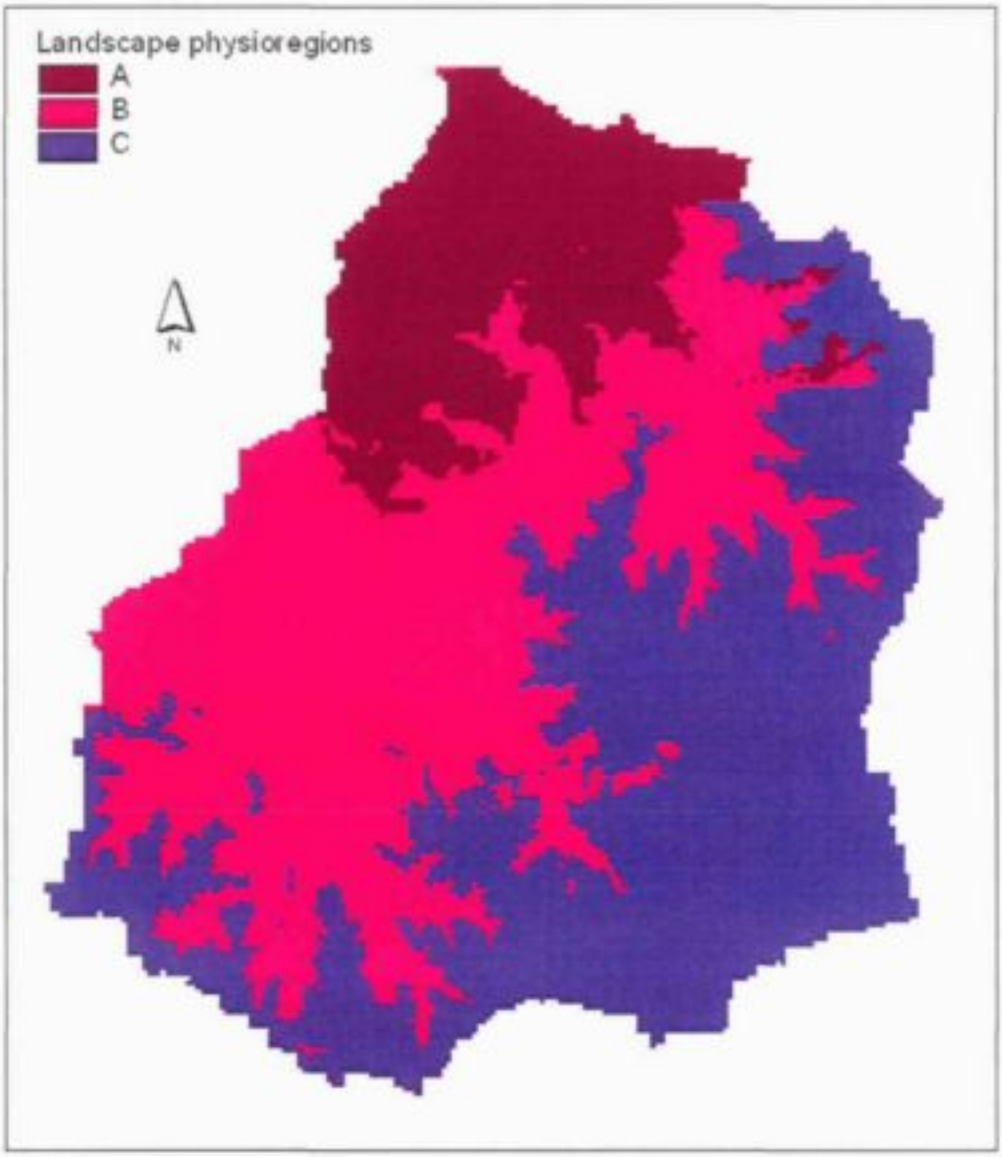


Figure 6.2. Physioregions defined from maximum likelihood classification.

A Discriminant Analysis was performed to validate the physioregion groupings delineated by the cluster analysis (Figure 6.2). Discriminant analysis can be used to test multivariate difference among groups (in this case the pre-delineated physioregions) and determine if cases have been separated into the correct groupings. Using the jackknifed classification matrix, an average of 94% of the variables are classified correctly (Table 6.3). For physioregion A 702 cases are classified correctly and 40 are misclassified (39 in physioregion B and 1 in physioregion C). This analysis would seem to suggest that a good "fit" of the physioregion model has been achieved based on the parameters that defined it (baseflow, elevation, soil fertility, growth days, geology, and recharge to ground water).

Table 6.3. Discriminant Analysis Jackknifed classification matrix for environment variables classification.

	Physioregion A	Physioregion B	Physioregion C	% correct
1	702	39	1	95
2	58	1 839	54	94
3	0	122	1 782	94
Total	760	2 000	1 837	94

6.3.2 Application of Physioregions to Wetland Classification

The applicability of the physioregions to the wetland classification was then tested. Again a discriminate analysis was performed but this time using the wetlands as the case study. In physioregion C, 84% of the wetlands were classified correctly, however in physioregions A and B, only 41 and 14% of the wetlands respectively were classified correctly (Table 6.4). Overall, 44% of wetlands were classified correctly.

Table 6.4. Discriminant Analysis Jackknifed classification matrix for wetland classification.

	Physioregion A	Physioregion B	Physioregion C	%correct
1	85	15	108	41
2	95	169	974	14
3	40	118	802	84
Total	220	302	1 884	44

Frequency analyses were then performed on wetland types for each physioregion and compared to a frequency analysis of all wetland types for the whole study area (Figure 6.3). In Figure 6.3 wetland types are represented along the X-axis and the frequency of occurrence of each wetland type along the Y-axis. The secondary Y-axis represents the percentage of occurrence of each wetland type. This analysis indicates that wetland types are well represented across all physioregions. In other words, there is no real differentiation in the types of wetlands represented in different physioregions. The frequency analysis therefore corroborates the findings of the discriminant analysis.

From the above two analyses, discriminant and frequency analyses, it would seem that the generated physioregions are not the best framework for analysing the diversity of wetlands in the UORC. There could be many reasons for this, one of them being that the key environmental variables (baseflow, elevation, soil fertility, growth days, geology, and recharge to ground water) used to generate the physioregions are not the correct drivers for wetland type occurrence. They could still be the correct drivers for wetland occurrence (not wetland type), but this was not tested, as the objective of the physioregion study was to determine management regions based on wetland diversity.

Another possible reason for this could be the coarseness of the key environment variables, particularly the hydrological and geological variables which were captured at a 1: 1 000 000 scale. These variables are particularly important drivers in the model as the wetland classification for this study is based on hydro-geomorphic parameters. At the scale at which the analyses were undertaken, the finer discrepancies in geology, slope, and groundwater occurrence would not have been depicted. A comparison of this scale of information with the detailed wetland classification map, which was captured at a 1: 50 000 scale does not yield accurate results. Preferably, finer resolution data should have been used to generate the physioregion surface, however this level of information is often not available or is very costly to acquire.

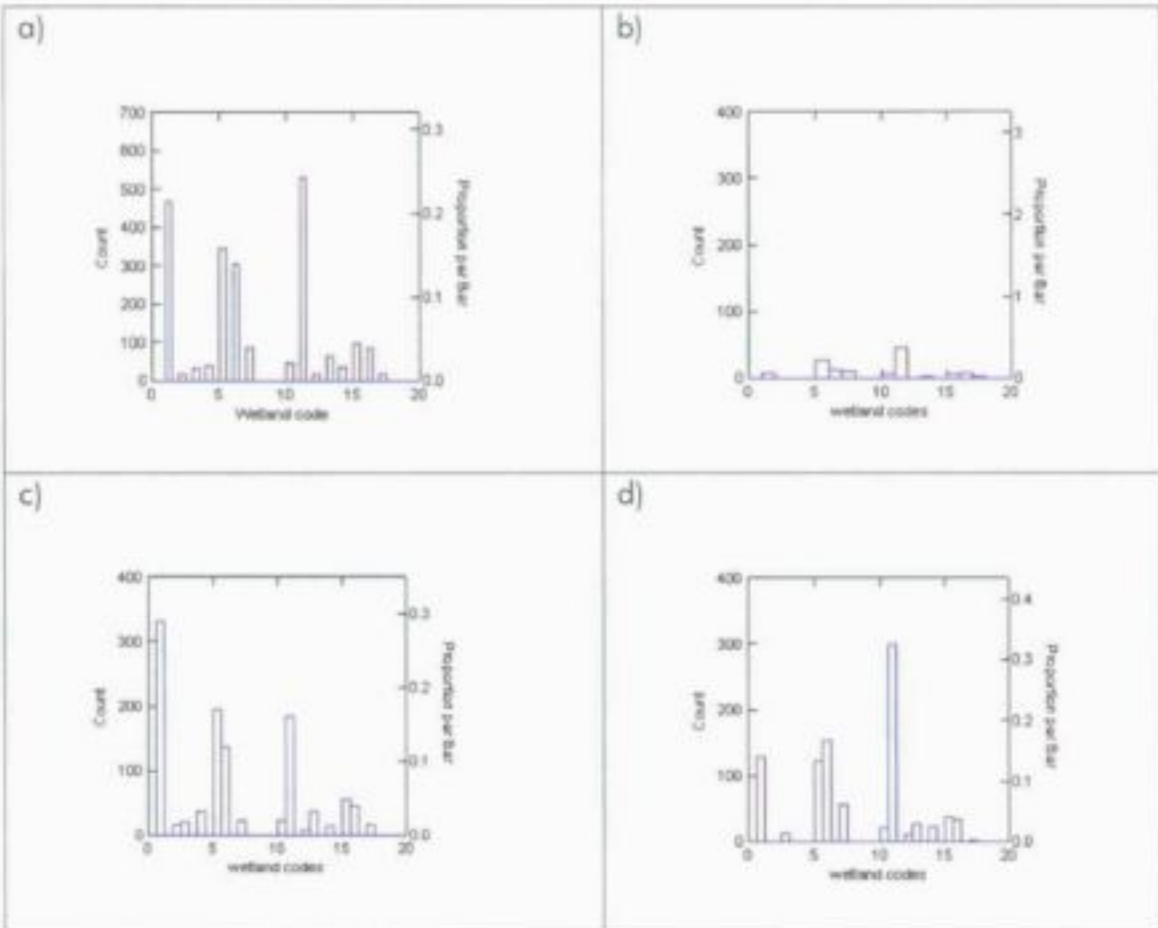


Figure 6.3. Wetland type frequencies for a) the whole study area b) physioregion A c) physioregion B and d) physioregion C.

6.4 Summary

Geology

The geology of the UORC appears to plays an important role in distribution and extent of the wetlands in the catchment, not only in terms of the origin, maintenance and underlying processes in these systems, but also in terms of the land use and economic development of the region. The highest concentrations of wetlands are associated with the distribution of dolerite intrusions within the Vryheid sediments in the southern section of the UORC. The structural control of the geological lithologies in terms of landform and wetland keypoints contributed to the high concentration of wetlands in these areas. The smaller non-pan wetlands occur in the southern, central and northwestern portions of the catchment. The absence of the larger wetlands from the Waterberg Group and Dwyka Formation sediments and the igneous rocks associated with the Rooiberg Group and Bushveld Complex are quite evident.

Soils

Katspruit and Rensberg soil forms associated with the floodplains are usually not used for cultivation. Instead these areas are used predominantly for livestock grazing and some areas are mowed and baled. By contrast, most of the more sandy soils and soil forms associated with the seepage wetlands (particularly the Avalon, Pinedene and Westleigh soil forms) are extensively cultivated. Cultivation is preferred where saturation is not extensive or where hydric conditions are not well expressed such as in the more intermittently saturated part of these seepage systems. As a result of the agricultural value of the soils associated with these systems, many of the seepage wetlands have been heavily impacted by cultivation.

Physioregions

Physioregions do not provide the best framework for analysing the diversity of wetlands in the UORC. This may reflect the finer scale variations in geology, slope, and groundwater occurrence that were not detected by the analyses. The relationships among geology, soil types, hydrology, geomorpholgy and topography with respect to wetland distribution, types and extent in the catchment is complex and dependent on the combination of these various determinants. We have provided a simplified representation of this variability.

7. ECOSYSTEM SERVICES OF THE UORC WETLANDS

A. L. Batchelor, G. Matthews & T. Coleman

7.1 Water Balance

A water balance was done on the ACRU outputs for the wetland and non-wetland scenarios. The variables that were considered were the mean annual values for rainfall, total evapotranspiration, baseflow and surface runoff. Figure 7.1 shows the results of this analysis. The results of the water balance are summarised in Table 7.1 The deficit values of 28.31 $m^3 \times 10^6$ (Wetland scenario) and 35.22 $m^3 \times 10^6$ (Non-wetland scenario) in the water balance can be accounted for by groundwater store.

Table 7.1 Water balance of the ACRU modelling for the Wetland and Non-wetland Scenarios ($m^3 \times 10^6$).

	Rainfall	Evap	Baseflow	Runoff	Store	MAR
Wetland Scenario						
Wetland ($53km^2$)	33.72	29.31	3.38	3.11	28.31	**31.93**
Contributing Area ($333km^2$)	211.86	156.03	0.30	25.14		
Total Catchment ($386km^2$)	245.58	185.34	3.68	28.25		
Non- Wetland Scenario						
Total Catchment ($386km^2$)	245.58	180.87	0.34	29.15	35.22	**29.41**

A review of models for investigating the influence of wetlands on flooding is presented by Melanie Bengston and G Padmanabhan, North Dakota State University and "A hydrologic model for assessing the influence of wetlands on flood hydrographs in the Red River Basin" by the same authors. They conclude that if all the wetlands were restored (0,24% of the watershed) they would lower the flood stage for a 1:100 year event by less than 0,4%, even if the wetlands were "empty" before the event. Increasing the percentage of restored wetlands to 1% of watershed area (4 times the present area) reduced the 100 year flood stage by 0,9%.

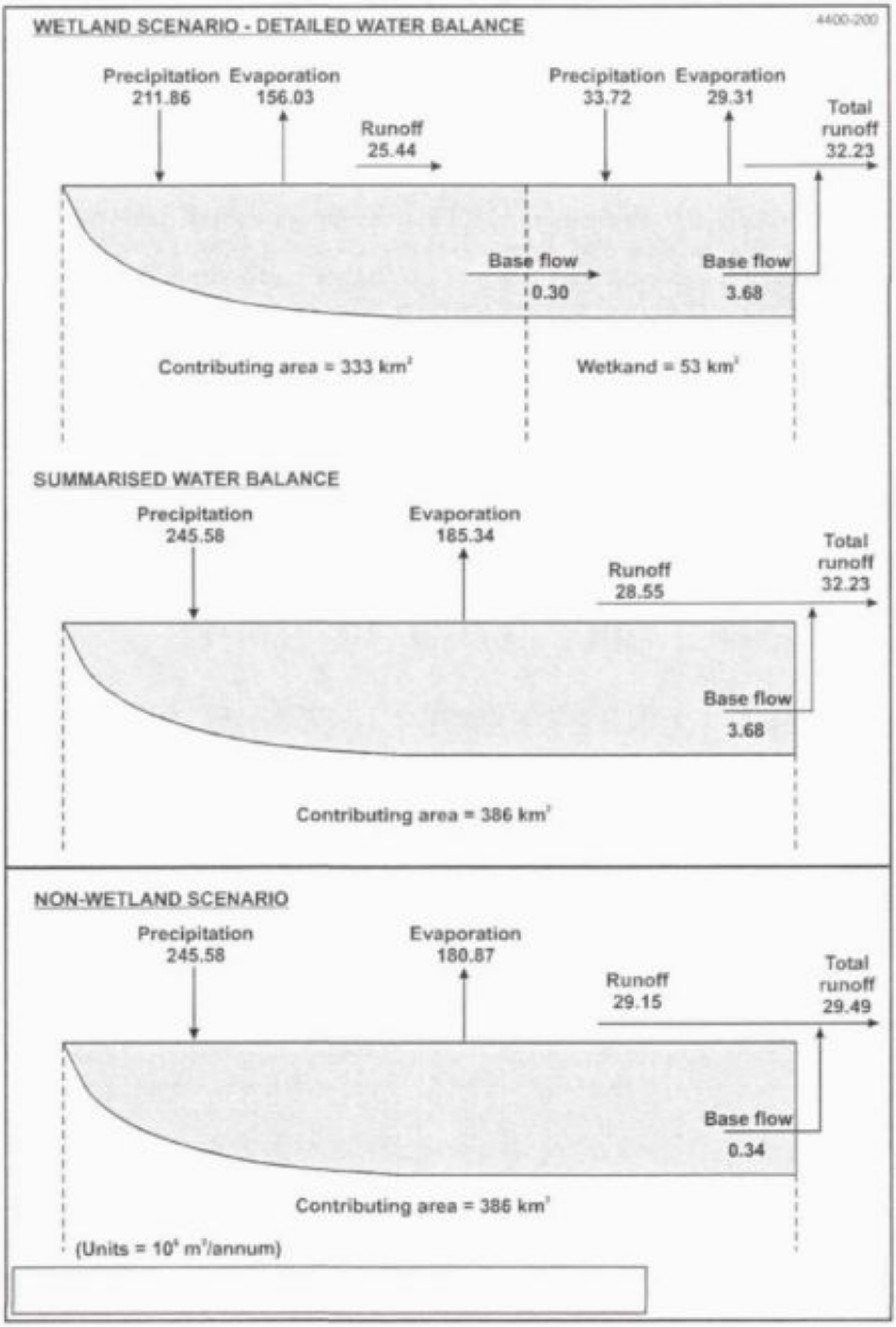


Figure 7.1. Water balance for the wetland and non-wetland scenarios.

An extreme value distribution analysis was done on the ACRU outputs of the two scenarios. The variables that were assessed were the extreme values for evapotranspiration, runoff, and baseflow from the B11C quaternary catchment. For the Wetland scenario, the modelled values of both the "wetland" and "contributing" areas were areally distributed over the entire catchment so a direct comparison of absolute values of the two scenarios could be performed.

Figure 7.2 and Table 7.2 illustrate the percentage difference of the ACRU outputs of Evapotranspiration, Runoff and Baseflow for the Wetland and Non-wetland Scenarios for various return periods. The percentage difference is defined by:

$$\frac{(x_w - x_{nw})}{x_w}.100$$

where:

x_w = ACRU Wetland Scenario result.

x_{nw} = ACRU Non-wetland Scenario result.

It is important to note that the percentage difference of the ACRU results is a function of the relative area of the wetlands present in the catchment.

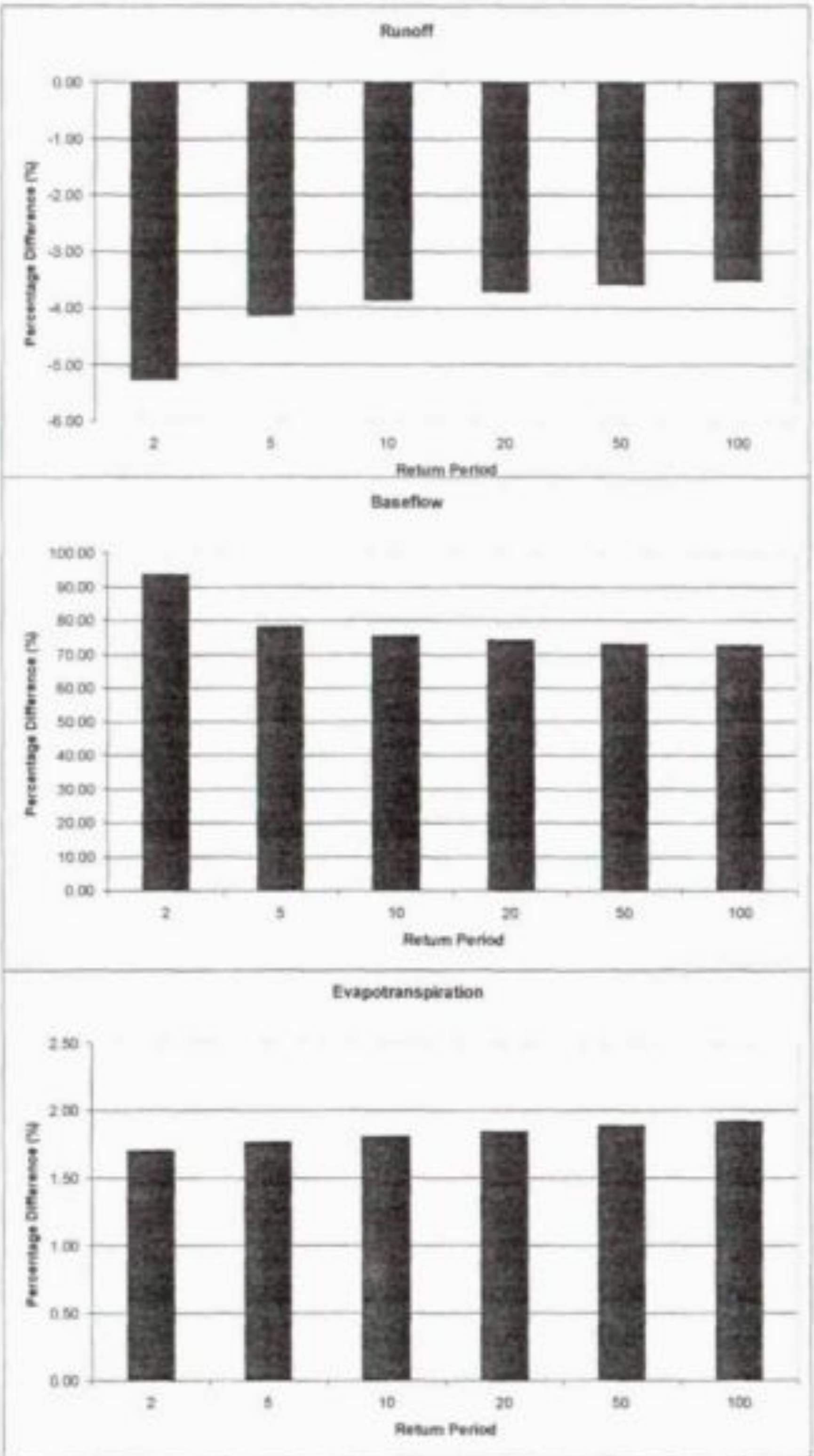


Figure 7.2 Percentage difference between Wetland and Non-wetland ACRU scenarios for runoff, baseflows and evapotransipration.

Table 7.2. Percentage difference in flows and evaporation between wetland and non-wetland scenarios in catchment B11C.

Return Period (years)	Runoff (mm)	Evaporation (mm)	Baseflow (mm)	Baseflow Store (mm)
95 Percentile				
2	2,87	11,46	97,77	96,46
5	31,46	11,77	95,89	92,11
10	30,53	11,92	95,45	90,73
20	29,51	12,05	95,20	89,87
50	29,91	12,21	94,99	89,12
100	31,05	12,32	94,89	88,73
5 Percentile				
2	48,85	11,18	98,04	100,00
5	79,18	11,54	97,13	95,19
10	76,81	11,68	96,33	93,30
20	74,77	11,75	95,89	92,11
50	73,73	11,79	95,55	91,06
100	73,84	11,80	95,37	90,47

The following hydrological trends resulting from the action of the wetland on the hydrology of the catchment could be established.

7.1.1 Runoff

- The non-wetland scenario produces on average 8.5% less runoff per annum than the wetland scenario. This would be as a result of the wetlands within the catchment augmenting surface flows during low flow periods by addition of baseflows to the total annual water budget.

- The runoff results from the two scenarios showed that runoff from the wetland scenario would be less than that for the non-wetland scenario (ie. negative results).

- The difference in runoff between the two scenarios would be more marked in dryer conditions as a result of the wetland retaining the lateral inflow to the channel.

7.1.2 Baseflow

- Baseflow percentage differences were the most marked for all the variables considered for the two scenarios.

- The Wetland scenario produces significantly more than the Non-wetland scenario.

- The decreasing trend from dryer to wetter conditions indicated that baseflow has a more marked effect during dryer conditions on the amount of streamflow (ie. streamflow regulation).

- Wetlands have the capacity to regulate streamflow from water stored within them.

7.1.3 Evaporation

- The average annual value for evapotranspiration for the wetland scenario is higher than those for the non-wetland scenario. This would be as a result of the soil moisture in the wetland being very high and for this reason the sedge meadows found in the wetland would be evapotranspiring at a rate close to the potential evaporation value.

- The reductions in evapotranspiration as a result of removing the wetland were 2.4% for the entire catchment area (386 km^2), and 15.3% for the equivalent wetland area (53 km^2) under natural veld conditions.

- The extreme value for evapotranspiration for the Wetland scenario is higher than those of the Non-wetland scenario for all return periods. This is as a result of the near to potential evaporation rates occurring within the area under wetland conditions.

- The positive slope of the absolute percentage difference curve for evapotranspiration is indicative of the more water available for evaporation for the larger return periods.

- Evapotranspiration for the Wetland scenario is higher than for the Non-wetland scenario as evaporation rates are close to potential evaporation owing to the high water content present.

- For wetter periods the transpiration rate would increase with more water being available, thus the general increasing trend from the 2 to the 100 year return period results.

7.2 Water Purification

A number of processes occur in wetlands that facilitate the removal and/or transformation of "contaminants". The use of the word contaminants is used with circumspection as, depending on the particular substance and its concentration, many may be a source of energy to the biota occupying niches within wetlands. As most of the land use in the UORC involves agricultural and mining related activities, the following section focuses on the principle mechanisms associated with the transformation of some of the more important "contaminants" arising from these activities in wetlands in general. This section is followed by a discussion of the removal/transformation processes in specific wetland types. The types selected include pans (chapter 7.2.6), floodplains (7.2.7) and seepage wetlands (7.2.7).

7.2.1 Nitrogen Removal/Transformation

Nitrogen may enter a wetland system from a number of sources. Some of these include:

- Livestock dung (historically game),
- Birds which use the pans and wetlands as a roost and or feeding areas,
- Runoff from anthropogenic activities, such as farming
- Runoff from the landscape
- Rainfall (dissolved or adsorbed to particulates associated with rainfall).
- Wind inputs associated with rain and dust can be significant particularly near industrial areas (Archibald & Muller, 1982).
- Nitrogen fixation
- Decomposition of plant material
- Direct fixation
- Diffusion

There are no easy ways of estimating the mass of nitrogen that enters a wetland from any of these possible sources, except through direct measurement. Without this information it is impossible to quantify mass transformation/removal. However, various conceptual models of the fate of nitrogen in wetland ecosystems have been developed, and these provide a general understanding of some of the important pathways (Gambrell and Patrick, 1978; Twinch and Ashton, 1983).

Nitrogen may enter a wetland system as inorganic and organic nitrogen with the former as reduced (NH_4^+) and/or oxidised N (NO_3^-), and the latter as particulate and/or soluble organic N. The interaction between the different forms is conceptualised in Figure 7.3. The transformation processes indicated in Figure 7.3 depend on the appropriate conditions being met. For example denitrification, the process of reducing NO_3^- to N_2 (g), requires a low level of dissolved oxygen as well as a source of dissolved organic carbon. Other conditions that need be met include a roughly neutral pH and a temperature of about 15° C, as well sufficient time for the necessary microbes, ultimately responsible for the conversion, to perform the task. The reaction rate is also a function of the initial concentrations of the reactants and the numbers of bacteria present. Denitrification is thus more likely to occur in organically rich areas in the wetland, for example in detritus and in the sediment.

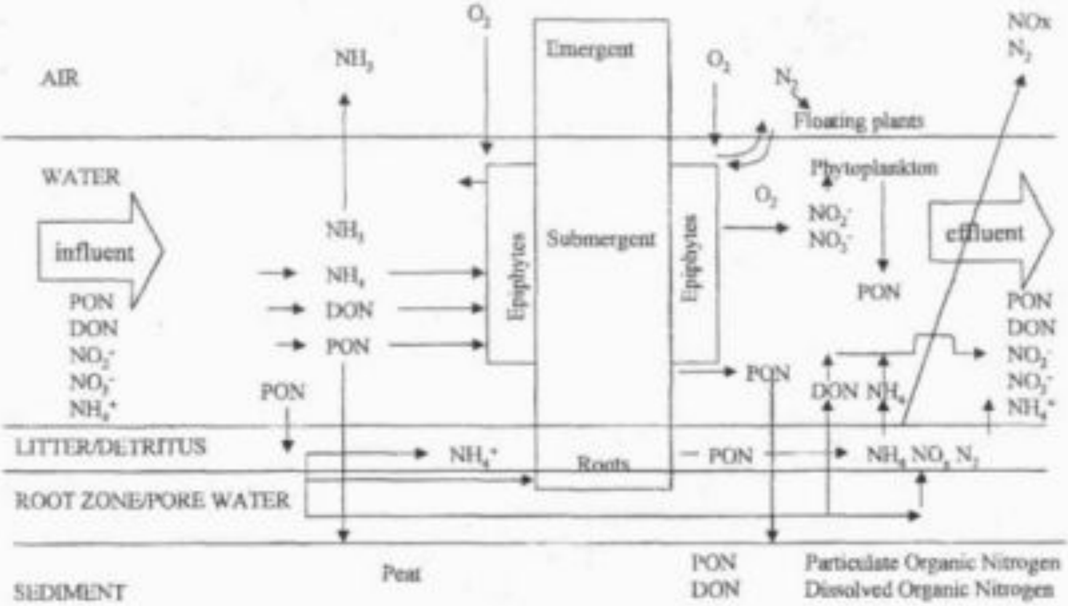


Figure 7.3. Conceptual nitrogen model in a hypothetical wetland.

Nitrogen in the groundwater, if present, will largely be in the form of nitrates due to nitrification processes that would be expected in the unsaturated soil mass. If both ammonia as well as nitrate nitrogen are applied in the landscape, ammonia is likely to be oxidised and or bound to clay minerals which will be present in the soils, hence it's concentration in groundwater is likely to be low. Nitrate concentrations could be high as ammonia nitrogen is oxidised. Livestock and/or birds could contribute significant nutrient loads directly into a pan. Dissolved nitrogen compounds in a pan system are likely to be transformed via three processes, *viz*: (1) Plant uptake, (2) Nitrification and (3) Denitrification.

Plant uptake

Plant uptake forms a temporary storage compartment for nitrogen. Plants require nitrogen for cell synthesis, but on senescence this nitrogen (organic nitrogen) is released into the water column, as organic nitrogen. This may be hydrolysed to ammonia nitrogen.

Nitrification/Denitrification

An important mechanism for nitrogen loss from wetland systems is via the process of nitrification followed by denitrification.

Nitrification depends on the presence of appropriate bacteria, a pH between 7,5 to 8,6, alkalinity, temperatures above 10 °C are generally recommended and an aerobic environment. The reactions are described below:

$$NH_4 + 3/2\ O_2 \text{ Nitrosomanas - } NO_2^- + 2H^+ + H_2O$$
$$NO_2^- + 1/2\ O_2 \text{ Nitrobacter } NO_3^-$$

Dentrification

Denitrification takes place in an anoxic environment and is dependent on a source of carbon and circum neutral pH and bacteria. In the process alkalinity is generated. Denitrification also requires temperatures above 10 °C. During the process nitrates are reduced to nitrites and finally nitrogen gas. These reactions are biological, the rate at which they occur is governed by some of the following factors:

- numbers of active organisms,
- contact time,
- concentration of substrate and
- the presence of appropriate conditions.

In terms of denitrification, one of the more "important" constraints is the availability of carbon, and anaerobic/anoxic conditions. These conditions are generally confined to well vegetated areas and or in organic rich sediments. The fact that denitrification occurs in well defined and restricted zones may act as a limiting factor as movement into these sites is likely to take place via diffusion.

7.2.2 Phosphate Removal/Transformation

Phosphates enter wetlands via runoff and stream flow containing organic and inorganic forms and in both soluble and particulate forms. Sources of phosphate include:

- Livestock (historically game),
- Birds which use the pans as a roost and or feeding area,
- Surface runoff from anthropogenic activities, such as farming and mining,
- Runoff from the landscapes,
- Rainfall (dissolved or adsorbed to particulates associated with rainfall),
- Wind inputs associated with rain and dust can be significant particularly near industrial areas (Archibald & Muller, 1982),

It is clear from this that the source of water is likely to play an important contribution to the mass loadings. For example groundwater (interflow) is unlikely to contribute significantly to soluble reactive phosphate loading as most will be retained within the soil matrix bound to either/both iron and aluminium. This could change if the pH of the groundwater were to change as a result of acid rain, once the natural buffering capacity of the soils had been eliminated.

The Australian National Eutrophication Management Programme has published a statement representing the agreed scientific consensus on sources and transport of phosphorus to inland surface waters. They have suggested that only in certain circumstances (intensive agriculture, urban areas and poorly absorbing sands) that most phosphorus derives from soil erosion, in particular caused by water (Scope Newsletter, 33, September, 1999). In wetland situations direct input may also be important, e.g. from birds and grazing ungulates.

Unlike microbially mediated nitrogen transformation reactions, primarily physico chemical processes affect the removal of phosphates. Particulate phosphate may settle out in wetlands or be entrapped within the plant stem matrix and attached on biofilms. Soluble phosphate may be sorbed onto plant biofilms in the water column, onto biofilms in the floating plant litter, or onto the wetland sediments. Again, there are no easy ways of estimating the mass of phosphate that enter a wetland, except through direct measurement.

A conceptual phosphorus model in a hypothetical wetland is presented in Figure 7.4.

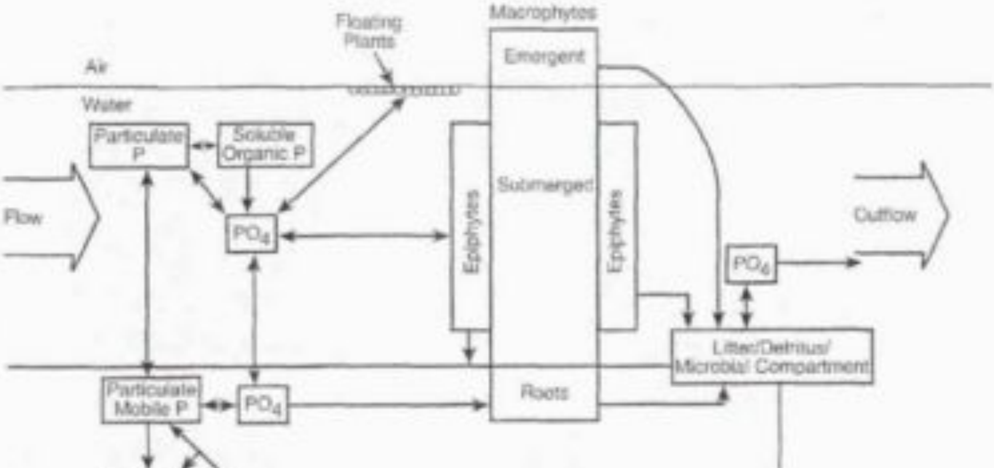


Figure 7.4. Conceptual phosphorus model in a hypothetical wetland.

The exchange of soluble phosphate between sediment pore water and the overlying water column via diffusion and sorption/desorption processes is a major pathway for soluble phosphates in wetlands (USEPA,1999). In the sediment, phosphates may be precipitated as insoluble ferric, calcium and aluminium phosphates or be adsorbed onto clay particles, organic peat and ferric and aluminium oxides and hydroxides. Precipitation as calcium phosphate occurs at pH >7, and may occur throughout the wetland. The sorption of phosphates on clays involves both chemical bonding of the negatively charged phosphates with positively charged clay particles and the substitution of phosphates for silicates in the clay matrix (Stumm & Morgan, 1970).

Under anaerobic and reducing conditions previously adsorbed phosphates can be released as ferric iron is reduced to the more soluble ferrous form and also by hydrolysis. Phosphates sorbed onto clays may be resolubilised through the exchange of anions. Phosphates may also be released if there is a decrease in pH as a result of the biological formation of organic acids, nitrates or sulphates.

Phosphates may be removed from the aqueous environment by plants, via uptake through their root systems. This is generally a short term, rapid cycling mechanism for both the soluble and insoluble forms. The net annual uptake of by emergent macrophytes varies from 1,8 to 18 g P per m^2.year (Burgoon et al., 1991).

7.2.3 Sulphate Reduction/Transformation

Sulphate reduction is an important process in wetland biogeochemistry, and may account for more than 50% of the respiration rates in salt marshes (Table 7.3). Sources of sulphate include rainfall, groundwater from pedogenic dissolution as a result of rainfall with low pH, surface runoff particularly from mining areas, and aeolian deposition directly into pan or wetland.

Table 7.3. Respiration rates in two salt marshes (g C m^{-2} yr^{-1}), from Westermann, 1993. (These estimates assumed that 50% of the oxygen consumption by the sediment represented aerobic respiration, excluding oxygen transport down arenchymal spaces.)

	Sapelo Island Ga	Sippewissett Ma
Aerobic respiration	390	390
Denitrification	10	3
Mn and Fe reduction	Negligible	Negligible
Sulphate reduction	850	1 800
Methanogenesis	40	1-8

The generalised reaction for sulphate reduction is presented in the following equation:

$$2C + SO_4^{2-} + 2H_2O \xrightarrow{\text{Sulphate Reducing Bacteria}} H_2S + 2HCO_3^-$$

Typically sulphate reduction occurs in an environment characterised by a low oxidation potential, -120 mV.

In wetland systems the energy source is derived from plants, including algae. Oxidation potentials approaching those required to support sulphate reducing bacteria occur in the sediment and also in microzones in the plant litter (detritus) which occur at the sediment water interface.

Despite the apparent importance of sulphate reduction as an electron acceptor, there is an increasing body of evidence that suggests that the allochthonous production of energy may be rate limiting in terms of significant sulphate reduction.

An important factor affecting the rate of SO_4^{2-} decomposition is the amount of organic matter available to the micro-organisms (Nedwell, et al.,1979; Crawford, et al., 1977). For example in marine sediments, organic carbon becomes limiting when the sulphate concentration exceeds 5 mmol per l (Westrich & Berner, 1984). However the reactivity of the organic matter may be even more important as a rate controlling factor (Westrich & Berner, 1984). Natural organic polymers have vastly different susceptibilities to bacterial attack (enzymatic hydrolysis), and this variation can express itself in terms of different rates of sulphate reduction Crawford et al. (1977). For example, Crawford et al. (1977) showed that lignin degrades 4 to 10 times slower than cellulose when differentially ^{14}C - labelled lignocellulose was decomposed.

The rate at which sulphate is reduced, together with the fact that much of the carbon released into a wetland is likely to be oxidised in the surficial layers in the presence of other electron acceptors, imposes constraints on the ability of wetlands to significantly reduce high sulphate loads. It is likely that this same constraint will apply to denitrification, but to a lesser extent, as the redox potential at which denitrification takes place is higher than for sulphate reduction. Hence there will be competition for carbon.

Other processes are required to ensure the immobilisation or removal of the reduced sulphur compounds from wetland systems. These include:

- The formation of metal sulphide compounds
- The oxidation of the sulphur compounds to form elemental sulphur
- The diffusion of reduced sulphur compounds into the atmosphere.

In inundated systems, where the capacity of metals to bind with the reduced sulphur compounds is limited, it is likely that most of the reduced sulphur compounds will be oxidised completely to form sulphates, but under certain conditions reduced sulphides can be oxidised to form elemental sulphur. These areas include the interface of reduced sediments and surface water where photo oxidation can occur, or within the sediment in the rhizosphere.

Despite the apparent limitations of wetlands' ability to reduce sulphates, wetlands support a number of processes that make them suitable for ameliorating mine drainage. These include providing an environment favouring the precipitation of metals as oxides and oxyhydroxides when the pH of the influent stream is >4. When the pH is < 4 similar metal precipitation processes can occur, where localised conditions favouring sulphate reduction and with a corresponding increase in pH are present. Whether considered significant or not, sulphate reduction remains an important process as a means of recycling carbon and other nutrients.

In contrast to the increase in oxidation potential attributed to the presence of plants, the opposite is also true, with decomposing plant material and leakage of organic material from the roots and rhizomes contributing to a reduction in the redox state. If the oxygen consumption rate of easily degradable organics exceeds the diffusion rate, anaerobic conditions may develop, resulting in a reduction of the oxidation potential. Under these conditions the end products of organic mineralisation are CH_4, N_2, H_2S, depending on the relative availability of inorganic electron acceptors, with consumption proceeding in the order $O_2 > NO_3 > Mn^{4+} > Fe^{3+} > SO_4^{2-}$ (Nedwell et al., 1979).

In mine drainage, with moderate to high sulphate concentrations, it is likely that the key electron acceptor is likely to be, the same as the above, with SO_4^{2-} potentially being the dominant acceptor.

7.2.4 Metal Removal

Metals can enter wetland systems in either the dissolved state (generally associated with low pH) or in the particulate form associated with soils. The removal of metals can take place through various pathways that may include precipitation, adsorption and plant uptake.

Metal Precipitation

The precipitation behaviour of some of the metals associated with mine waters can be predicted using Pourbaix diagrams. A typical diagram describing the behaviour of iron is presented in Figure 7.5.

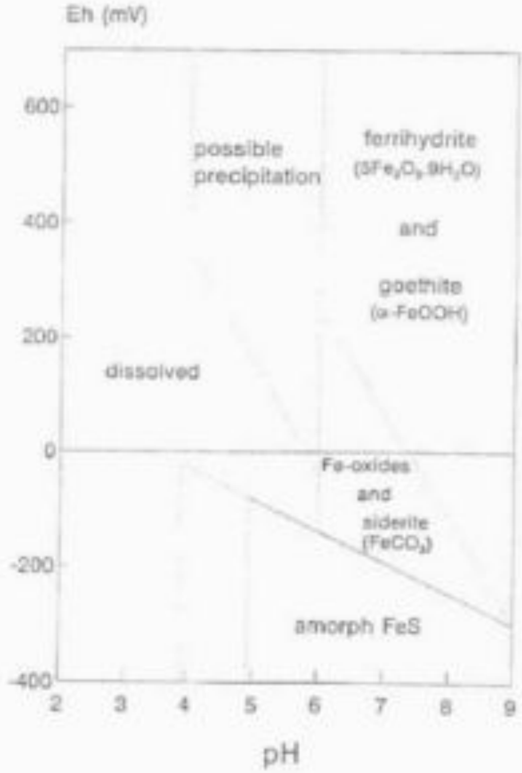


Figure 7.5 Pourbaix diagram depicting the oxidation state and form of iron as influenced by pH and redox potential.

It is evident from this diagram that environments and processes which tend to shift the pH above 6 with oxidation potentials greater than -100 mV would favour the precipitation of iron oxides, whereas in a similar pH range at low oxidation potentials (< -100 mV), metal sulphides would likely form.

Both pH and oxidation potentials vary within wetlands. This variation is best illustrated by comparing the oxidation potential profile in an unvegetated sediment and a vegetated one (Figure 7.6). The reason suggested for the observed increase in the oxidation potential is due to the capability of some wetland plants being able to aerate the sediments by releasing oxygen from their roots (Armstrong, 1978).

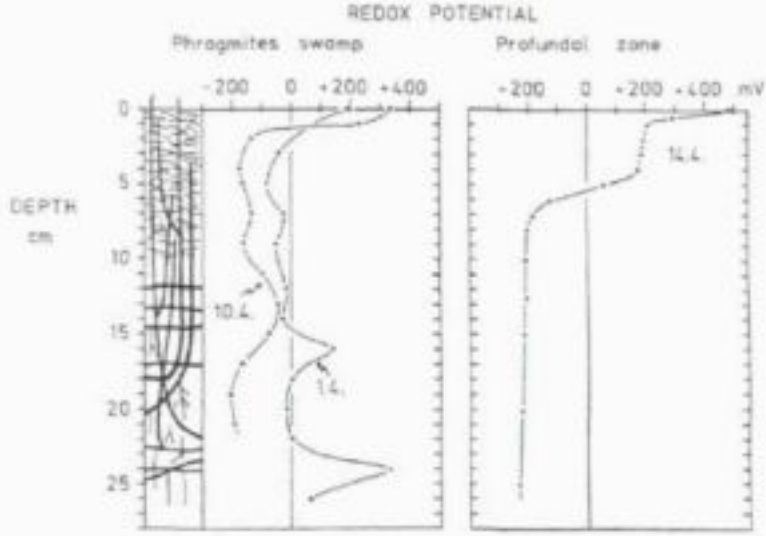


Figure 7.6. Vertical profiles of redox potential in vegetated and unvegetated sediment, with the outer left column showing the roots and rhizomes. (Source: Hansen & Andersen, 1995.)

Using this information, and assuming the water entering the system has a pH above 5, it is possible to theoretically predict the fate of iron.

Field results obtained from a local wetland, the Landau wetland receiving mine drainage, identified the precipitation process as an important process in wetlands (Batchelor, 1993). Most iron in this wetland was located in the top 10 cm. An analysis of the metal fractions indicated that much of the iron in the wetland was present in the residual (15 to 73%), crystalline (8 to 51%) and amorphous oxide (4 to 34%) fractions, with an organically bound fraction accounting for up to 28% in some samples (Batchelor, 1993). Similar results were recorded by Faulkner and Richardson (1990), who found 70,4 to 80,4% of the iron in an oxide form, with the next largest fraction being amorphous iron oxide accounting for 17,2 to 22,9% of the total iron.

An interesting observation was that less than 4% of the metal fraction recorded in the Landau wetland was in the acid soluble form. This fraction includes iron bound to sulphide. This was contrary to expectation given that the surficial waters were high in sulphate and the expectation was that iron sulphides would form the dominant sink. This suggests that either the oxides are thermodynamically stable in the sediments or alternatively that the oxides form first and are kinetically stable in the sediments.

Metal Adsorption

The metals that accumulate in plants may form part of the organic fractions which accounted for about 28% of the iron and 7% of the manganese reflected as organically bound metals recorded in a local wetlands sediment (Batchelor, 1993). This hypothesis was tested by comparing the ratio of organically bound iron and manganese in plants with that in the sediments. In the plants the ratio was $0.1 < R < 20$ whereas in sediments $30 < R < 10\ 000$. This was then compared with a theoretical ratio calculated in a pure Fe-Mn Citrate solution where citrate was used to represent a model of a moderately strongly binding organic ligand. The ratio calculated was $3 < R < 10\ 000$ which suggests that when the ratio of Fe to Mn is low, that the metals may be bound to plant material, and when high, to extracellular organics (Murray & Jooste, 1994).

Metal Uptake by Plants

Many of the wetlands receiving mine drainage in the UORC are dominated by two reed types, *Typha* and *Phragmites*. Both are known to accumulate metals (Batchelor, 1993). Rooted macrophytes such as *Typha* and *Phragmites* are much more tolerant of mine drainage than *Sphagnum*, probably because they do not accumulate metals to high, toxic concentrations (Sencindiver and Bhumbla, 1988). Although *Typha* probably accounts for most of the productivity and living biomass in both created and natural wetlands, it's role as a metal sink in those systems receiving mine drainage, is negligible. At one *Typha* dominated site that received low level acid rock drainage (10 mg per l Fe), bioaccumulation of iron and manganese in the plants (Table 7.4) only accounted for 0.2% of the annual influent load, the remainder being either exported or associated with the sediment (Sencindiver and Bhumbla, 1988).

Table 7.4Range of concentrations of iron and manganese in cattails sampled from wetlands receiving mine drainage (modified from Sencindiver and Bhumbla, 1988).

Plant Parts	Season	Sediment Concentration Range (mg per kg)	Monongalia Co.	Preston Co.
<u>Manganese</u>[1] Rhizomes (mg per kg)	 Spring Fall	 430 – 2 216 422 – 2 617	 625 - 705 567 - 972	 498 –1 278 394 –1 119
Leaves + Stems (mg per kg)	Spring Fall		702 - 1 824 586 - 2 912	1 879 – 4 071 2 653 –3 970
<u>Iron</u>[1] Rhizomes (mg per kg)	 Spring Fall	 1 992 – 10 154 2 436 – 13 550	 1 000-10 818	 9 648 – 1 9506 8 036 – 1 4650
Leaves + Stems (mg per kg)	Spring Fall		109 - 1 539 409 – 7 352	213 – 5 369 88 - 344

[1] 0.1 N HCl extractable iron and manganese (mg per kg)

Attention has been given to algae, because of observations that algal blooms are associated with decreased dissolved manganese concentrations and other metals (Jennett et al., 1977; Brierley et al., 1985; Gale et al., 1979). Both *Oscillatoria* (Kepler, 1988), and *Microspora* (Hedin and Nairn, 1990) have been collected from constructed wetlands receiving acid rock drainage where the manganese concentrations were being lowered. These algae had concentrations of manganese of 56 000 mg per kg (dry weight) and up to 85 000 mg per kg respectively. In addition to this direct uptake numerous samples of both *Microspora* and *Oedogonium* had encrustations of manganese (Stevens et al., 1989). These observations have lead to the development of artificial meander systems in which algae are encouraged to grow and when washed out of the system are retained in a sedimentation pond (Jennett et al.,1977; Brierley et al., 1985). Metal uptake by algae appears to be controlled by two processes, namely bioaccumulation through absorption onto the cell surfaces and uptake for cellular processes as a trace element, and physical-chemical factors such as an affinity for carbon and adsorption onto negatively charged algal cell surfaces. The relative importance of these two processes appears to be both metal and algal species dependent.

However, total algal biomass in a wetland is very limited, so that its contribution to metal removal is rarely significant. Calculations show that very productive algal systems accumulating manganese at 50 000 mg per kg of algae would still only remove 4 mg per l of manganese from mine drainage, assuming currently sized wetland systems (Hedin, 1989).

In some instances attempts have been made to enhance algal production with periodic fertilisation and by creating open water areas in constructed wetlands. At present the association between fertiliser stimulated algal blooms and manganese removal is confounded with abiotic metal removal reactions that occur when phosphate is added to mine drainage (Hedin and Nairn, 1990). This can result in the direct precipitation of an insoluble metal phosphate salt. It is thought that, as in the case of metal removal by *Typha*, metal removal by algae will probably only account for a minor fraction of the metal entering the system (Hedin et al., 1989).

Besides the role plants play in reducing the level of contaminants via accumulation pathways, a more important role of both higher plants and algae in wetlands is the effect that they have in their immediate environments. Reference has already been made to the influence of plants on the oxidation potential in sediments. A similar effect results from the presence of algae. Oxygen generated and carbon dioxide consumed during photosynthesis results in an increase in the oxidation potential as well as pH due to the utilisation of carbon dioxide. These conditions favour the formation of oxyhydroxides as has been suggested to be occurring in the root zone. (Taylor et al., 1984; Westermann, 1993). The orange colour associated with algal mats in a local wetland (Figure 7.7), bear testimony to the effectiveness of this process.

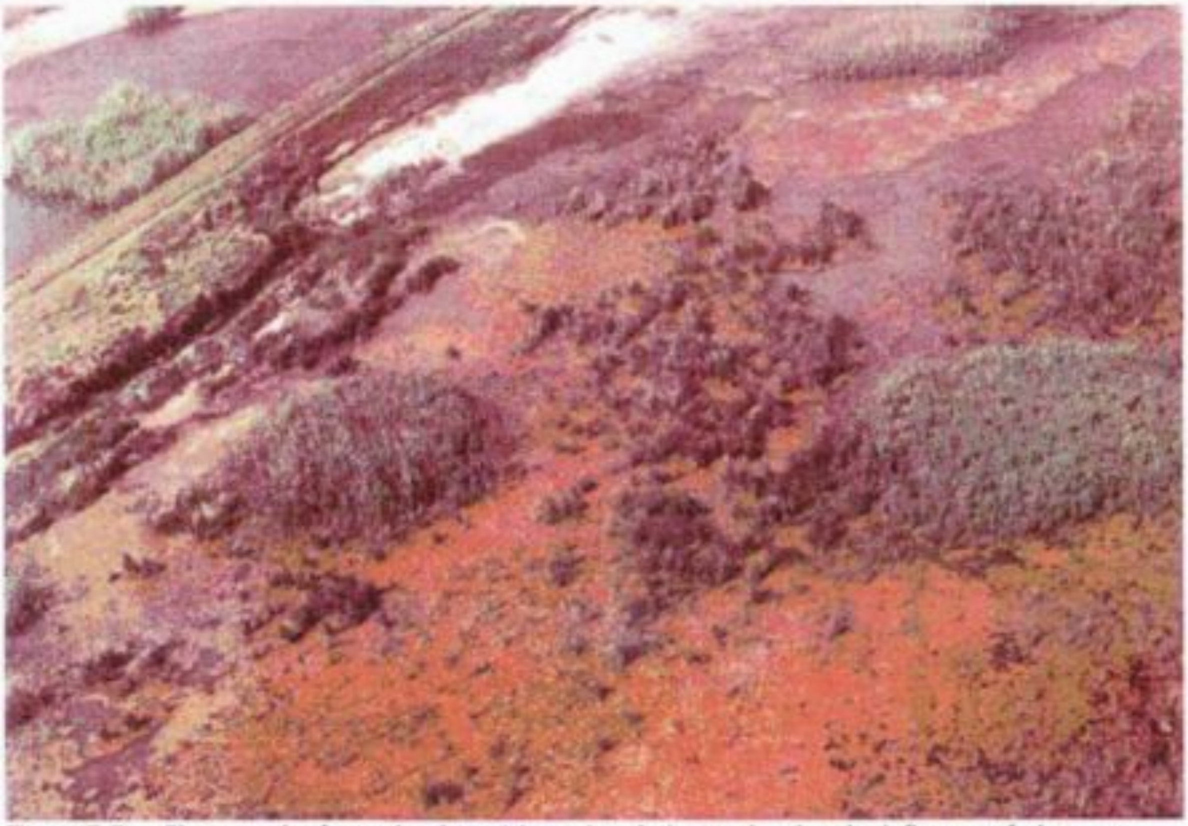


Figure 7.7 Photograph of a wetland receiving mine drainage showing the influence of algae on iron precipitation (Photo A. L. Batchelor).

7.2.5 Pans

Pans are closed systems with inputs from surface runoff, interflow through groundwater, and direct contribution from rainfall. Water loss is through evapotranspiration and seepage. A typical water balance could be expressed by the following equation:

$$\Delta V = V_i + V_p + V_r + V_e$$

V_i = contribution from perched groundwater
V_p = direct precipitation on the lake surface
V_r = surface runoff
V_e = all evaporative losses

In an arid to semi arid environment, with seasonal rainfall patterns it would be expected that there would be a negative ΔV in winter and a positive ΔV in summer, assuming a summer rainfall area, and conversely for a winter rainfall area. In areas where the evaporative and seepage losses exceed nett inflow from all sources the pan would be expected to dry out. The local conditions would thus be expected to have a marked effect on the concentration of solutes in the

water body at any given time. For example in a study on salt pan near Pretoria it was found that extensive evaporite deposits formed at the lake edge during the drying out phase, with the deposits consisting of $NaHCO_3ANa_2CO_3A2H_2O$ and Halite NaCl (Ashton and Schoeman, 1983). These deposits reflected the composition of the water and were predictable given that the water in the salt pan was classified as an $Na\text{-}Cl\text{-}CO_3$ system, following the classification system of Eugster and Hardie (1978).

Changes in water chemistry as a result of the concentrating and precipitation of elements due to evaporative concentration would thus be expected to have a marked influence on the composition of the solution as a whole, and would also exert an influence on the faunal and floristic components of a system.

Limited published information exists on the water quality or other aspects of pans in the UORC, even though pans occupy almost 8% of the total area occupied by wetlands. Water quality data presented in Hutchinson et al. (1932) indicate that many of the larger and "presumably" more older pans are saline, with salts derived from the Ecca and Dwyka shales, characterised by high concentrations of sodium sulphate. Seaman et al. (1991) found that sodium, calcium magnesium and potassium are the dominant cations (in this order of dominance), whereas chlorides, sulphates bicarbonates and carbonates represent the dominant cations in 55 saline pans in southern Africa.

It is obvious from the above that the water quality in pans is influenced by the pedology, geology, and local climate. This in turn is likely to have a marked influence of the response of these systems to nutrient inputs.

Where systems dry out completely some of the accumulated salts and nutrients such as organic nitrogen, various phosphate and sulphate salts might be transported out of system by wind and be deposited on the surrounding slopes. Furthermore there is evidence from other parts of the world that suggests that pans contribute to groundwater recharge. Outward seepage from marshy prairie ponds investigated by Eisenlohr (1975) acted as a source of recharge to groundwater mounds. The majority of water flowing radially outwards from the pond was used locally by plants rooting into the water table, but outward seepage was good for the pond, as it helped to regulate the build-up of dissolved solids, mainly sodium sulphate. A more detailed and extensive study by La Baugh et al. (1987) presented a picture of ponds in the same general area acting as sources, conduits and sinks of groundwater.

Where deposited materials are not transported out of the system they may redissolve when waters enter the system after rainfall events. Repetitions of this filling and drying process over decades to thousands of years could account for the saline nature of some of these pans.

Of the phosphate load entering a pan, some may enter absorbed to particulates including the soil, and the other fraction as soluble reactive phosphate. It is likely that there will be transfer between these forms. When on the one hand pans fill, anaerobic/anoxic conditions will develop, leading to the solubilisation of a fraction of the sediment bound P component. When the pans dry out, conditions favouring the precipitation of P bound to iron and aluminium and/or as calcium phosphate will result followed by diagenesis.

Another possible sink for phosphates are plants that occur in the pans, either as terrestrial plants when the pan is empty or as aquatic plants when flooded. Some of the phosphates will be taken up by macrophytes present within the system, but unless these are removed, either by grazing and or harvesting, they will not in the long term contribute to P removal, but will be part of an internal recycling system.

7.2.6 Floodplains

The processes operating on floodplains are, like the pans dominated by hydrological forces. Unlike pans that are essentially sinks, the water mass balance on floodplains includes an outflow. A typical water balance equation for a wetland system other than an endorheic pan is described below (Gilman, 1994)

$$P + G_{in} + Q_{in} = E + G_{out} + Q_{out} + \Delta s$$

Where P is precipitation

G_{in} is the groundwater inflow
Q_{in} the surface inflow
E is actual evaporation from the wetland
G_{out} is the groundwater outflow
Q_{out} is the surface outflow

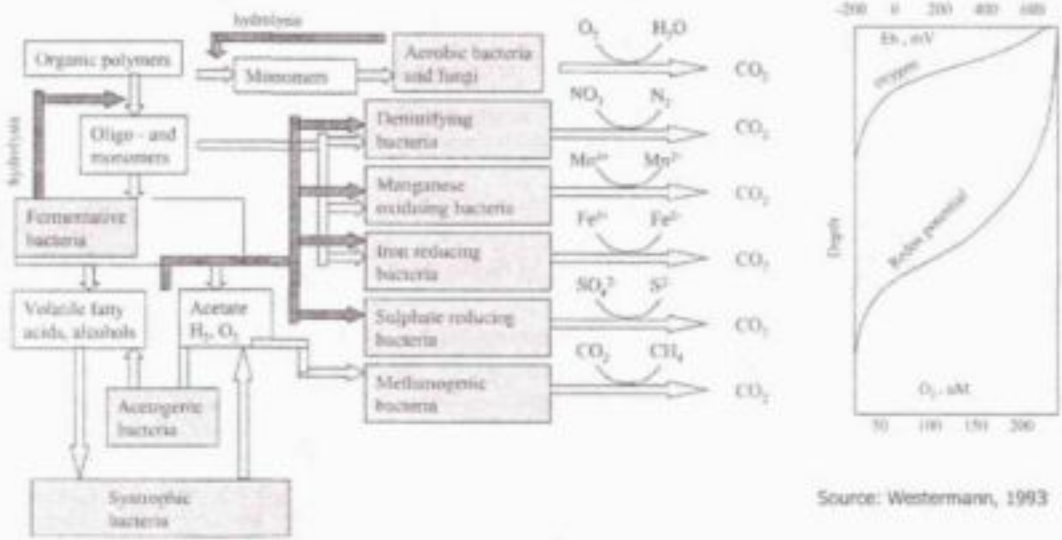
And Δs is the change in water storage, usually seen as a change in water level or the water table.

This can be further broken down into flows between compartments in the wetland itself. For example the storage of water in a wetland may take place in permanent open water bodies or as temporary flooding, in the unsaturated zone of the soil (many wetlands, e.g. meadows and grazing marshes, have soils that are merely moist) and in the saturated zone. The wetland groundwater body may be isolated from the regional groundwater body by impeding or confining layers. The flows between these various storages are of vital importance in the water quality functions of wetlands (Patten & Matis, 1984).

Floodplains, as their name implies, receive water during periods of high rainfall, where the volume of water flowing down a water course exceeds the capacity of the channel, and spills out onto marginal areas. After wetting, which takes place progressively and vertically, either downwards (sediments with low permeability), or upwards (sediments with high permeability and porosity), floodwaters flow horizontally over the surface. Additional flows may occur along the lateral edges of floodplains as groundwater seeps. (These seepage wetlands will be dealt with separately.)

During the initial wetting phase previously deposited salts and nutrients may be dissolved and leached from the sediments into the water column, and by the same token mineral exchange may occur between the flood waters and the sediment, a function of the exchange capacity of the sediments. Typically in mineral soils the cation exchange capacity is saturated with metal cations, whereas with soils with a high organic content, the cation exchange capacity is dominated by hydrogen ions (Gorham, 1967, in Faulkner and Richardson undated).

Another effect that flooding has on sediments is a change in the redox potential. Typically the redox potential would decrease as a function of time after flooding. Oxygen concentrations in the pore spaces decrease to almost zero after a day, in organically rich soils, due to low diffusion rates (1 000 times less in aqueous solution than in porous medium such as well drained soil; Greenwood, 1961). The change in redox increases the solubility of a number metals such as manganese and iron and can result in the release of these and previously bound phosphates. The converse also holds when the floodplain systems drain and the sediments become re aerated. In areas of permanent wetness anaerobic conditions with low redox potential remain. This has implications for the removal; and/or transformation a number of elements. Some of these are depicted in Figure 7.8.



Source: Westermann, 1993

Figure 7.8. Redox potential of wetlands.

The dominant source of water on floodplain wetlands is however likely to be the volume of water flowing over the surface of the floodplain area. Under these conditions concentrations of nutrients are generally low due to the dilution effects, with the possible exception of suspended solids that might be high. The latter can be attributed to the velocity of floodwaters which permits them to transport higher suspended loads. Once flows overtop riverbanks, the velocity of the floodwaters reduces and permits the selective deposition of particles, with fine particles associated with slow flows and coarser sediments progressively higher flows. Floodplain wetlands develop as a result of the depositional history and the associated topography. Some nutrient removal, for example phosphates and ammonia bound to clay minerals and soil particles, is likely to occur coincidentally with the deposition of sediments.

Sedimentation in floodplain wetland systems will thus tend to reduce phosphate loads in the short term. This is likely to be recycled through plant and animal uptake and possibly re released into the system. Re-release may also occur if the sediments are submerged for periods long enough to result in the formation of anaerobic conditions, such as would occur in pans or saturated depressions.

During the drying out phase of floodplains similar processes to those documented in endorheic pans can be expected, with progressive drying out, concentrating solutes until their solubility products are exceeded. The actual mass of these precipitates is unlikely to represent a significant proportion of the mass of elements transported during the flood event. The fate of the deposited material will be similar to that suggested in the section on pans.

7.2.7 Seepage Wetlands

Seepage wetlands develop where groundwaters emerge. Plants adapted to these local conditions colonise these areas which generally show saturated soil conditions to form wetlands. Seepage wetlands take on many different forms, from peat wetlands to bryophyte mires and at the other extreme seasonal footslope seeps along floodplain margins. These systems probably represent the most difficult systems to quantify nutrient removal, because of their diversity and practical difficulty in measuring groundwater flows. Quantification is further complicated by a lack of information on evapotranspirative losses and because they may also receive contaminated surface runoff. Hence the apportionment of load between these two sources is not easily achieved.

Seeps and springs may be defined as the set of surficial and shallow subsurficial materials and phenomena associated with an outcrop of groundwater, characterised by definite hydrologic, geomorphic, geochemical and sedimentologic systems separating it from the context in which it occurs. Wetlands are typical expressions of these systems. Springs/seeps may be seasonal, permanent, diffuse or point source, and may be classified into two broad groups, confined or unconfined seeps/springs:

i) Unconfined springs are defined as those seeps in which the hydraulic conduit is an unconfined near-surface aquifer. They can be further sub divided into slope, karst and unconfined stratigraphic springs. Karst springs are not found in the area.

ii) Confined springs on the other hand are defined as those springs in which hydraulic conduits are confined by relatively impermeable media, and are, by nature, typically under some pressure. Source waters may tap near surface, formation, or deep groundwater sources. They may be further sub divided into the following classes: fault springs, confined stratigraphic springs, contact springs and fracture springs.

(Deocampo, 1997)

The dominant controls and feedbacks on springs/seeps are depicted in Figure 7.9. The primary processes which lead to the sedimentary record are 1) Aeolian and subaqueous deposition, 2) mineralogic neoformation and diagenesis, 3) bioturbation and fossilisation and peat formation and vegetation and sediment trapping. These are in turn controlled by source lithology, aqueous geochemistry, faunal distribution and vegetation distribution respectively. Tectonism, volcanism and climate all have impacts on these controls.

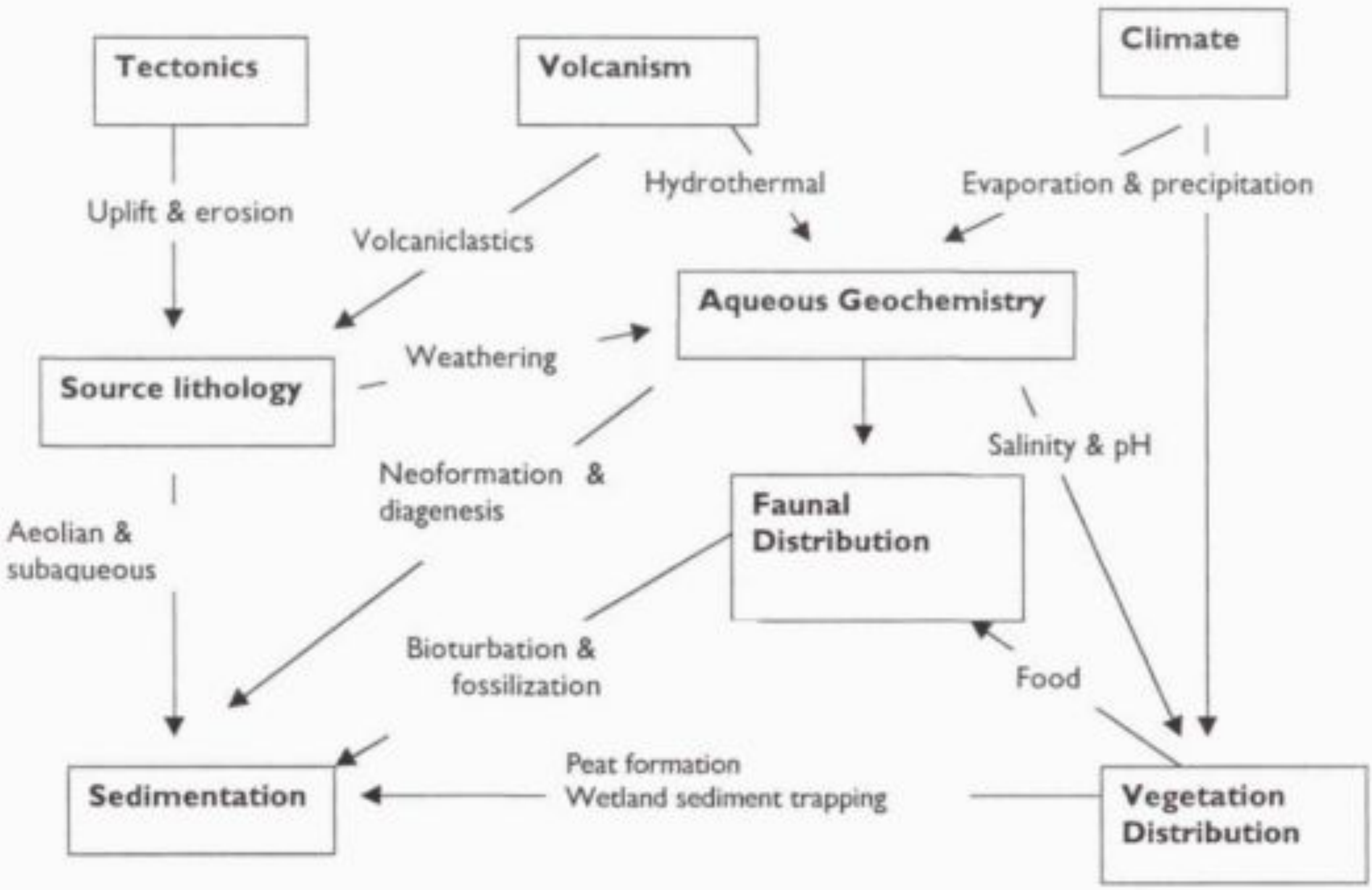


Figure 7.9 Primary controls and feedbacks in spring/seep environments.

In the study area typical wetland types associated with springs and seeps are mid, foot slope and valley head seeps. Usually these are unconfined springs and are generally seasonal. Where springs are confined they are either seasonal or permanent. Where groundwater flows are permanent and relatively constant, organic deposits may accumulate and may result in organically rich sediments.

The aerial extent of wetlands associated with groundwater emergence is largely regulated by the landform setting in which they occur and the volume of water discharged. Direction of flow in these systems may consist of both vertical and horizontal flow elements, with vertical up flow more likely to be significant in the case of confined springs. In unconfined springs, save for the immediate zone of emergence, once soil saturation has occurred, flows are more likely to be horizontal and over the surface due to the lower resistance offered by plants to the movement of water than the substrate.

Nutrient transformations that could be expected in permanently wet seeps include nitrate and sulphate reduction as well as the reduction of iron and manganese. These transformation processes will occur as water passes through low redox zones with the extent of transformation governed by the, contact time and in the case of sulphate and nitrate reduction the bioavailability of dissolved organic compounds. Where both nitrates and sulphates occur in the groundwater feed to the system competition will exist for the available carbon between facultative anaerobes, sulphate reducing and denitrifying bacteria. Of these transformation processes, those involving the oxidation of carbon using available compounds yielding CO_2 and the denitrification process, are the two process that will result in actual losses from the aqueous to gaseous phase. Reduced sulphur compounds are likely to re oxidised in the free water film in the presence of sulphur oxidising bacteria and light energy. If the nitrogen present in the groundwater is in the reduced form it is unlikely that much removal will occur, unless the wetland contains sufficient areas with a high dissolved oxygen content to permit it's oxidation. The release of plant derived organic carbon and its subsequent oxidation and release of organic nitrogen negatively influence nitrification in permanently inundated systems.

Similar nutrient transformation processes could be expected in seasonal seeps, with the exception that during the period leading up to saturation, leaching of previously immobilised substances is likely to occur. This will happen in response to changes in the redox and pH, following saturation and subsequent flooding. Organic material that may accumulate during the flooded period is likely to be lost when water levels recede.

7.2.8 Case Study

The characteristics of the two catchments selected for the paired catchment comparison are presented in Table 7.5. The rationale for selecting these particular catchments was based on their similar landscape positions, draining the higher dolerite areas, similar catchment area and the availability of both hydrological and water quality records, as having both flow and water quality data permitted the calculation of loads. The two stations that represent the catchments were 21Q01, the upper Steenkoolspruit catchment and 18Q01, the upper Viskuile catchment. The Steenkoolspruit has lost some wetlands above the gauging station to mining activities, and is referred to as the disturbed catchment.

Table 7.5. Comparative catchment statistics.

		B1H021Q		B1H018Q	
	Wetland Classes	**Area in ha**	**%**	**Area in ha**	**%**
1	Artificial wetlands	97,67	0,07	0,00	0,00
2	Channeled riparian wetlands	236,48	0,17	88,87	0,09
3	Dams	1 587,43	1,17	550,87	0,57
4	Drainage lines with riparian zone	5 033,52	3,72	2 737,25	2,86
5	Footslope seepage wetlands	888,83	0,66	1 439,92	1,50
6	Midslope seepage wetlands	2 130,76	1,58	1 754,88	1,83
7	Non-channelled riparian wetlands	180,00	0,13	175,51	0,18
8	Non-permanently wet pans	364,48	0,27	174,84	0,18
9	Permanently wet pans	215,82	0,16	274,71	0,29
10	Seasonally inundated non-channelled valley bottom floodplain	454,29	0,34	579,27	0,60
11	Seasonally inundated channelled valley bottom floodplain wetlands with footslope seepage wetlands	6 989,99	5,17	3 274,75	3,42
12	Seepage wetlands associated with pans	64,38	0,05	111,06	0,12
13	Temporarily to seasonally inundated channelled valley bottom foodplain	380,23	0,28	284,38	0,30
14	Valleyhead seepage wetlands	172,35	0,13	697,08	0,73
15	Wet grasslands	357,68	0,26	0.00	0,00
	Total	19 153,91	14,17	12 143,39	12,67
	National Land Cover Classes	**Area ha**	**%**	**Area ha**	**%**
1	Cultivated: temporary – commercial dryland	51 171,23	37,85	39 103,91	40,81
2	Cultivated: temporary – commercial irrigated	292,23	0,22	211,70	0,22
3	Forest plantations	388,96	0,29	448,47	0,47
4	Improved grassland	353,75	0,26	0,00	0,00
5	Mines & quarries	3 927,03	2,90	0,00	0,00
6	Thicket & bushland (etc)			29,17	0,03
7	Unimproved grassland	58 252,83	43,09	43 673,03	45,58
8	Urban / built-up land: industrial / transport	150,88	0,11	0,28	0,00
9	Urban / built-up land: residential	1 101,76	0,81	65,31	0,07
10	Waterbodies	271,06	0,20	95,92	0,10
11	Wetlands	132,34	0,10	39,50	0,04
	Total	116 042,07	85,83	83 667,29	87,33

An analysis of the National Land Use Classes (NLC) suggests that the principle differences between the catchments is the presence of mines and quarries in the Steenkoolspruit catchment, about 2.9% of the catchment. The areas occupied by wetlands represent 14 and 12% of the respective catchments, although the NLC classification records only 0.1 and 0.04% wetland area for the same catchments. Some of the mining activity in the Steenkoolspruit catchment has occurred in the watercourse itself resulting in the loss of wetlands. Further loss of wetlands has in both catchments can be attributed to agricultural practices, but the extent is not known.

Water quality and flow data were obtained from the Department of Water Affairs and Forestry database.

The period for which data were available for comparison was restricted to a very limited period, the 90/91 to the 95/96 hydrological periods. A plot of the respective catchment yields is presented in Figure 7.10. As the respective catchment areas are similar, total annual yields are similar, with differences in yields between years being influenced by local rainfall patterns.

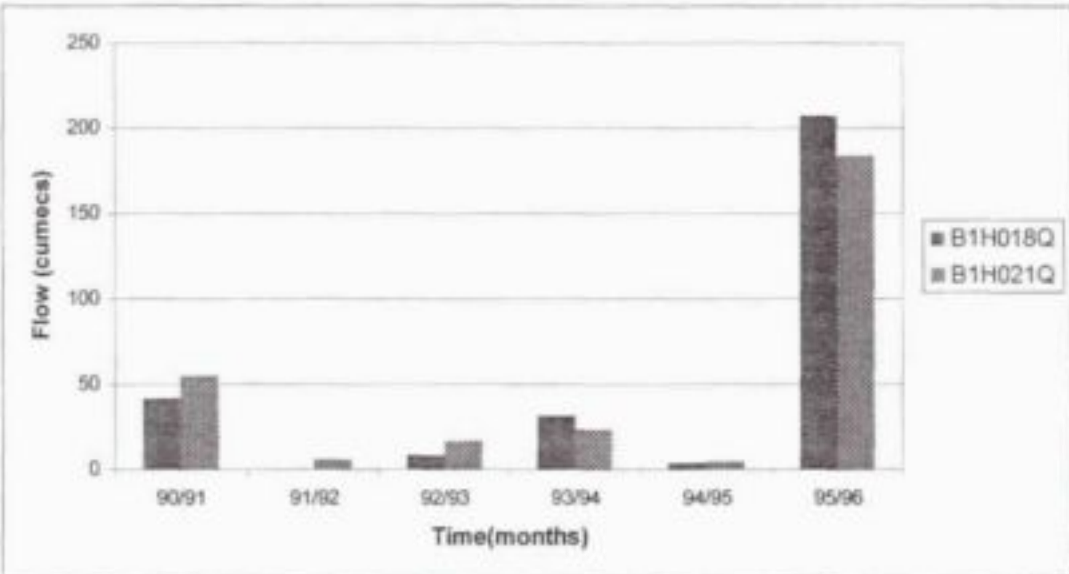


Figure 7.10 A plot of the comparative annual flows for the two catchments. Data for the 91/92 hydrological year for 18Q were incomplete.

Mean water quality data for the respective catchments for some selected water quality variables are presented in Table 7.6.

Table 7.6. Summarised water quality data variables for some selected determinants recorded at the two gauging stations.

Determinant	18Q		21Q	
	Mean	Std. Dev.	Mean	Std. Dev
Ca	20,4	7,05	36,1	28,72
Mg	13,5	5,3	23,5	19,36
K	5,3	1,18	6,1	1,45
Na	28,3	16,97	40,2	22,13
NH_4	0,04	0,07	0,08	0,21
NO_3	0,13	0,76	0,56	0,83
SO_4	29,8	22,1	115,3	140,64

Evident from these results are the increases in concentration of sulphates, nitrates as well as calcium an magnesium in the water samples collected at the gauging in the catchment associated with the mining activities. The sulphates, sodium, magnesium and calcium can probably be attributed to the weathering of pyritic material associated with coal, whereas the elevated nitrates possibly reflect blasting residues. The concentrations of potassium at both sites are similar. A comparison of these results with those of perched groundwater samples (Table 7.7), suggest this groundwater will tend to alter the concentration of the surface waters through dilution. This is likely to occur as the groundwater emerges along seeplines. For this reason, any attempt to ascribe changes in nutrients through wetlands must be based on load differences before and after the wetland.

Table 7.7 Average water quality data for selected determinants from the perched groundwater aquifer (modified from Hodgson and Krantz, 1998).

Statistics	PH	Mg	Na	Ca	SO4c	Ec
Mean	6,23	3,1	10,7	12,3	1,8	13
Std Deviation	1,23	1,9	6,2	8,9	1,4	6,2
Min	5,02	0	3.0	1,0	0	3,7
Max	6,98	8	33	35	6	25

Differences in flow and nutrient loads for the annual periods for which data were compatible are presented in Table 7.8. A more refined assessment, based on monthly differences could not be undertaken because of lack of continuity of data in one or other of the stations.

Table 7.8 Comparative annual loads, in metric tons of selected water quality variables exported from a relatively undisturbed catchment (18Q) and from a catchment which has been modified predominantly through mining and lost wetlands (21Q).

	Undisturbed Catchment 18Q (Water yield 24.8 x 10^6 m^3)					Disturbed Catchment 21Q (Water yield 23.5 x 10^6 m^3)				
	91/92	92/93	93/94	94/95	95/96	91/92	92/93	93/94	94/95	95/96
TDS	5.53	196,7	553,9	62,2	4 120,3	145,4	466,2	754,0	101,4	6437,2
CA	0,40	12,71	44,86	4,85	331,12	14,41	42,08	64,23	8,74	565,76
MG	0,29	9,31	29,43	3,10	215,98	8,25	25,07	43,79	5,18	411,39
K	0,07	4,22	14,53	1,76	104,76	2,56	8,37	12,64	2,28	96,73
NA	0,69	26,69	52,07	5,87	412,92	13,07	48,30	76,10	9,75	579,23
TAL	2,57	74,34	255,55	28,19	1 846,9	51,91	156,68	270,13	39,37	2 054,02
Cl	0,48	20,63	33,73	3,94	352,90	8,08	24,40	42,85	6,70	320,09
F	0,01	0,46	1,22	0,15	5,85	0,20	0,63	0,96	0,17	5,99
SI	0,03	3,20	11,30	1,14	78,90	0,92	3,71	6,18	0,95	46,71
SO_4	0,45	29,08	65,45	8,07	429,20	35,35	123,68	179,38	19,12	1 881,18
NH_4	0,00	0,08	0,08	0,01	0,25	0,03	0,12	0,11	0,06	1,71
NO_2_NO_3	0,00	0,62	0,20	0,02	1,31	0,03	0,46	0,82	0,27	14,93
PO_4	0,00	0,03	0,07	0,01	0,39	0,01	0,12	0,30	0,06	1,27

In general the catchment in which mining has taken place exports higher loads of all the determinants that were measured with the exception of fluoride and silica. This is despite that flows from 18Q, the undisturbed catchment, were 5% higher than the comparative catchment. It would be tempting to attribute the change in water quality, as reflected by the loads, to a loss of wetlands. However wetlands do not generally support processes that remove salts such as calcium, sodium and magnesium except indirectly for example where calcium/magnesium and sulphates might reach super saturation through evapotranspiration, resulting in the precipitation of gypsum.

It is far more likely that the observed changes in the loads reflects the small change in land use from predominantly agriculture to mining, as it is well known that one of the consequences of mining and mining rehabilitation is a deterioration of water quality (Hodgson and Krantz, 1998).

Given the positions of the current gauging stations and the data associated with each of the gauging stations, as well as a general lack of understanding of the relationship between stream flow, deep and perched groundwater, it is not possible to establish a quantifiable relationship between the type and extent of wetlands and their influence on water quality.

7.3 Sediment Trapping

Sediment yield in the catchment is moderate to high, with average soil losses ranging between 44 and 47 tons per km^2 per annum (Midgley et al. 1994). The total annual sediment yield for the catchment is estimated to be 294 000 tons per annum (Appendix A). Quantifying the extent to which wetlands contribute to sediment trapping in the UORC fell beyond the scope of this study. However, it is likely that the capacity of wetlands to trap sediments in the UORC has been reduced significantly because of the channalisation and unattural incision of the riparian wetlands.

7.4 Summary

Evapotranspiration
The results of this study confirm that more water is lost to evaporation and evapotransipration in wetlands than in areas that have no wetlands.

Baseflow
Baseflows produced by wetlands are higher than those produced by non-wetlands. This results in an augmentary and regulatory effect on flow conditions during dry periods.

Runoff
The Mean Annual Runoff from wetlands is higher than for non-wetland scenarios, as the dry flows are regulated by baseflows occurring as a result of wetlands. For extreme values wetlands have the capacity to reduce the streamflows occurring from an event.

Water Purification
It is concluded that the wetland systems in the UORC are complex, with the complexity compounded by differences in position in the landscape, water quality, hydraulics, hydrology and landuse. An understanding of the water balance and nutrient mass balance is critical in attributing a water quality improvement capacity to wetlands. There are no data on any of the systems individually, or even collectively, to provide an indication of the role besides anecdotal, that the systems are playing with respect to nutrient removal.

Until such time as we are able to construct water and mass balances on wetlands, we are unable to attribute water quality changes to nutrient removal and or transformation with any degree of confidence, as the observed changes may simply be a reflection of dilution. This is especially true in areas where high quality perched groundwater, probably contribute to valley bottom, mid slope and valley head seeps as well as pans and ultimately to flows in the rivers.

Floodplains

Floodplain wetlands are unlikely to markedly reduce the concentrations of soluble nutrients as the contact period between wetland biota and water/substrate is short during flood periods. If floodwaters are retained in floodplain wetlands, typically in depressions, the total volume and hence mass of nutrients that are retained is likely to represent only a small fraction of the nutrients exported during any one flood event. The behaviour of nutrients in these pans, once water levels have receded, would be similar to those recorded for pans. If the dominant source of phosphates in the UORC is associated with sediment, then sedimentation is likely to be an important process for nutrient removal in floodplain systems.

Pans

Nutrient cycling removal within a pan environment is likely to be the dominant process, rather than nutrient loss. With respect to nitrogen, a portion will be lost through volatilisation if the pH exceeds 8, and some will be lost to the atmosphere via nitrification/denitrification. Plants will take up some, but this is likely to be short-term removal unless the plants are harvested and removed from the system. If grazed, some of the nitrogen will be returned in the waste of the grazer. It is likely that as the solutes in the pans concentrate through evaporative losses that the relative importance of each one of the processes is likely to change, for example as the pH and salinity increase, ammonia volatilisation could replace nitrification/denitrification as the dominant process. Phosphates precipitation is likely to be the dominant removal process as calcium/phosphate type complexes form, particularly at higher pH's. The concentration in pan waters is likely to reflect some form of equilibrium between precipitated phosphates and release of phosphates from the predominantly anaerobic sediments. Unless pans are leaky, nutrients will accrete in pan systems with loss being dependent on the rate of diagenesis within the pan sediments.

Seepage Wetlands

Seepage wetlands offer the potential to remove oxidised substances as flows typically move through reducing areas before emerging into areas with a higher redox. Flow direction through seepage systems will have an influence on the transformation processes, with a higher removal propensity in those systems with a vertical flow component. When permanently flooded, seepage wetlands would perform typical functions documented for constructed free water surface wetlands, such as organic transformation, suspended solids removal, limited ammonia removal, limited sulphate removal and metals removal.

8. BIODIVERSITY OF THE UORC WETLANDS

G. C. Marneweck, R. W. Palmer, J. Engelbrecht, N. H. G. Jacobsen & J Turpie

The major components of biodiversity of the UORC wetlands are described below on the basis of desktop studies. Species lists, given by wetland type, are provided in the Appendices.

8.1 Plants

A total of 354 indigenous species of plant, and a further 59 exotic species, has been recorded in or are associated with the wetlands in the UORC (Appendix H). The plant species lists provides a preliminary database only of plant species occurring in the wetlands of the UORC, and should not be considered as complete or fully representative of each of the main wetland types. Many more species, as well as similarities and differences in species composition between the wetland types, may be expected as more data become available. Known uses of plant species found in wetlands in the UORC are described in Appendix I.

8.1.1 Non-floodplain Wetlands

Groundwater within the riparian zone as well as the hydrological regime of associated streams or rivers are expected to be key determinants of the biotic species composition and distribution in these systems. These systems comprise predominantly mixed grass/sedge meadows with interspersed patches of sedges and sedge meadows. Based on the information currently available, these systems provide habitat for at least four species listed in the Red Data Book of plants *viz.* the bulbs *Nerine gracilis* (considered rare) and *Eucomis autumnalis* ssp. *clavata* (considered non-threatened), as well as the Snapdragon *Nemesia fruticans* (considered non-threatened) and the Red-hot Poker *Kniphofia typhoides* described as "insufficiently known".

8.1.2 Floodplain Wetlands

The hydrological regime resulting from flooding is a key determinant of the biotic species composition and distribution in all the floodplain systems. However there are differences among the four hydro-geomorphic floodplain types in terms of both plant species composition and richness. The seasonally inundated unchannelled and channelled systems with footslope seepage wetlands have by far the highest plant species richness. In contrast, the temporarily to seasonally inundated systems without footslope seepage have the lowest plant species richness.

Comparisons of the Steenkoolspruit and Rietspruit floodplains (both seasonally inundated channelled systems with footslope seepage wetlands) with five other systems that were classified as seasonally inundated channelled systems without footslope seepage wetlands (Marneweck, 2001), showed that the former two systems had considerably higher species richness (more than 60% more plant species) than the latter.

In the former, the hydrological regime resulting from flooding is a key determinant of the species composition and distribution in these systems, although other factors also appear to contribute to the high plant species richness in these systems. Lateral seepage from the footslope seepage wetlands associated with these systems together with spillage from small tributaries that enter these systems and backflooding all contribute to keeping sections of these floodplains wet throughout the summer months, even well after flooding occurs. This also serves to increase the habitat diversity in these floodplains. This facilitates the establishment of relatively extensive mixed grass/sedge and sedge meadows in sections of these systems. These areas are colonised by many hydrophytic plant species. The systems therefore comprise a diversity of habitats including meadows, oxbows, depressions and levees, all with different wetting regimes and often differences in plant species richness and composition. During the summer months therefore, these systems comprise a mixture of upland, semi-hydrophytic and hydrophytic plant species.

Even among the same types of floodplain systems, there appears to be a considerable degree of both local and regional variability in plant species composition. For example, a plant species composition comparison of the Steenkoolspruit and Rietvlei floodplains (both seasonally inundated channeled valley bottom systems with footslope seepage wetlands) showed that less than 50% of the indigenous plant species recorded were common to both systems despite them having similar numbers of total species (Marneweck, 2001).

Based on the information currently available, floodplain wetlands provide habitats for four species listed in the Red Data Book of plants viz. the bulbs *Nerine gracilis* - considered rare, and *Eucomis autumnalis* ssp. *clavata* (considered non-threatened), the Snapdragon *Nemesia fruticans* (considered non- threatened) and the Red-hot Poker *Kniphofia typhoides* (described as "insufficiently known"). In addition, floodplain areas also provide habitat for various species of lily, including the Orange River Lily, *Crinum bulbispermum*. Extensive stands of flowering Orange River Lily's can be seen in early summer in many of these systems. At times the flowering lily's of numerous species attract an abundance of insects to the floodplains including large numbers of beetles and butterflies during early summer.

Red Data Book plant species have also been recorded in the riparian zones associated with the floodplains as well as the drainage lines and these areas also include some woody riparian species (indigenous shrubs and exotic trees such as Willows *Salix babylonica*) in places. Species of the hemi-parasite *Harveya* have also been found in the riparian zones in the UORC.

Probably the most common grass species occurring in all the floodplain types is *Eragrostis plana*, which together with *Eragrostis curvula* in the drier systems, dominates extensive areas.

Development of the catchment, overgrazing, localised modification of run-off patterns, the construction of roads and so on have all had impacts on the wetlands of the UORC. With respect to the floodplain wetlands, road bridges in particular have constrained surface flows in many of the systems resulting in backflooding behind the bridges and increased constricted flows below the bridges. This has resulted in the development of erosion fronts below the bridges that, in many cases, have developed into extensive networks of headward cutting erosion gullies. This together with other factors related to catchment development and modification appears to have contributed to the large-scale channel incision that is evident in the floodplain systems throughout the catchment. Deepened and widened channels in turn reduce the frequency of overbank topping during flooding.

Channel incision has reduced the flooding frequency in some systems from seasonal to more temporary and this has caused many of these systems to start showing signs of extended drying. The resulting plant species composition in many of these systems therefore no longer represent what is termed reference conditions (i.e. a representative example of what a system would have looked like under unimpacted or natural conditions).

Based on evidence currently available, only four of the main floodplain systems in the catchment still to some extent represent what could be referred to as reference conditions. These are the floodplains of the Rietspruit, Steenkoolspruit and De Beerspruit (all seasonally inundated channelled valley bottom systems with footslope seepage wetlands) and the floodplain of the Viskuile (seasonally inundated unchannelled valley bottom system).

With the introduction of commercial livestock farming came the introduction of many livestock related exotic and alien invasive plants including, among others the Scottish thistle *Cirsium vulgare*. In most of the heavily grazed floodplain systems as well as other wetland types exposed to intensive livestock grazing there is an abundance of exotic invasive species of plants, particularly forbs.

In summary, our understanding of these systems is limited and based on only a few detailed investigations. It is expected that as more information is collected on these systems, we will get a better understanding about what key factors influence or account for the apparent local and regional plant species variability observed to date.

8.1.3 Hillslope Seepage Wetlands

Little information is available on the plants occurring in hillslope seepage wetlands. These systems have largely been overlooked as a wetland type and in many cases, at best, have only been considered as moist grasslands. Most of the information on these systems in this report comes from work undertaken by G. Marneweck and this is only based on plant surveys at a few sites. Nevertheless, some generalisations can be made about the plant species occurring in these systems.

Although hillslope seepage wetlands are maintained by subsurface seepage, there appears to be a considerable degree of both local and regional variability in plant species composition among and within these systems. We speculate that this variability may be influenced by a number of factors ranging from the more obvious ones such as hydrological characteristics, to the more obscure factors such as subtle water quality differences in perched groundwater. Clearly more work is needed in this regard. Generally these systems have a high species richness and these areas are characterised by the presence of orchids, particularly ground orchids.

Many of these systems may remain saturated for extensive periods throughout the year but, most are characterised by a fluctuating water table, and are wettest during summer months. The natural wetland vegetation therefore comprises a mixture of both semi- and hydrophytic plants. The drier periphery of many of these systems form moist grasslands.

Based on the information currently available, hillslope seepage wetlands provide habitats for at least two species listed in the Red Data Book of plants *viz.* the bulb *Nerine gracilis* (considered rare) and the Snapdragon *Nemesia fruticans* (considered non-threatened). These wetlands also provide habitat for the bulb *Haemanthus montanus*, many species of sedge, as well as ground orchids including *Eulophia* and *Habenaria* species. Moss mats are found in some of the wetter systems. It is expected that as more information is collected on these systems, many more special plants, including Red Data species, may be found.

Very few unimpacted hillslope seepage wetlands remain in the UORC due to the use of many of these systems for agricultural purposes, particularly for cultivation and planted pastures. As a result it is seldom that the plant species found on these systems reflect a totally natural state, or are representative of what would naturally have occurred in the system. As a result it is likely that a large portion of the plant species diversity that was naturally associated with these systems has been lost. In addition, in many of the heavily grazed or modified hillslope seepage systems, there is an abundance of exotic invasive species of plants that also do not reflect natural reference conditions.

8.1.4 Wet Grasslands

Wet grasslands represent what are commonly referred to as hydromorphic grasslands. These are probably a lot more common in the UORC than this report reflects. Because they are waterlogged for short periods only following rainfall, the plant species comprise predominantly grass meadows with some sedges and very few other hydrophytic species. Similar systems occur on the edges of the hillslope seepage wetlands but these could not be separated out at the scale the wetlands were mapped for this project. Many are also often linked to pans but these are also not shown on the map for the same reason.

Because there is very little information available on this wetland type in the catchment, all that can be said at this stage is that there are no known species of endangered plant associated with wet grasslands in the UORC. However, these areas are expected to provide habitats for various species of ground orchids, including *Eulophia* and *Habenaria* species and the occurrence of Red Data species in these systems cannot be ruled out.

8.1.5 Pans

Although most pans in the UORC show distinct zonation of vegetation at any one time, these zones and the plant species that occupy them vary in response to fluctuating water levels. These zones often relate to the topography of the pan which in turn defines the extent of open water, the depth of water, and the steepness of transition and boundary gradients and so on. This all influences what plant species may be more commonly associated with for example, the floor, as opposed to the margins and areas upslope of this. Even within these zones there may be patch mozaics of plant communities or stands of vegetation that too can vary with time.

The dynamic nature of most of the pans also allows the colonisation of areas by opportunistic plant species such as annual grasses and certain sedges which can take advantage of the favourable conditions while they last. As a result, there appears to be a considerable degree of variability in plant species composition and richness between pans, both at a local as well as regional scale within the UORC.

Although plant species lists are available for a number of pans in the catchment and surrounding catchments based on once-off surveys, there is very little information on how the plant species richness and composition change in relation to the natural hydrological and water quality dynamics of the pans concerned. More work is needed in this regard. Nevertheless, based on the information available, it is apparent that there are no known species of endangered plant associated with pans in the UORC. However considering the variety of pan habitats as well as the dynamic nature of these systems, the presence of endangered species occurring certain times and under certain conditions cannot be ruled out.

Seepage wetlands associated with some of the pans are likely to provide suitable habitat for species of conservation importance, such as the Snapdragon *Nemesia fruticans* (considered non- threatened), and the bulb *Nerine gracilis* (considered rare). These associated seepage systems may also include ground orchids such as *Eulophia* and *Habenaria*.

8.2 Aquatic Invertebrates

Aquatic invertebrates associated or expected to be associated with the various wetland types in the UORC are listed in Appendix J. Available information on the aquatic invertebrates in the UORC is largely limited to invertebrates found in pans and rivers. Information available on invertebrates inhabiting other wetland types is largely anecdotal. However, many taxa found in slow-flowing sections of river, particularly the marginal vegetation out-of-current, may be expected in adjacent wetland types, particularly floodplain wetlands. All aquatic invertebrate taxa recorded in the area, or likely to occur in the area, were therefore included in a list of invertebrates from the area, but it was not possible to associate all these taxa with the different wetland types.

It is likely that the distribution, composition and abundance of aquatic invertebrates has changed considerably over the years. For example, an estimated 2 476 dams, weirs and other artificial wetlands have been built throughout the catchment, equivalent to one every 2,8 km^2. This is likely to have had a highly significant impact on the distribution and species composition of aquatic invertebrates.

Mining is also likely to have impacted on invertebrate diversity, as suggested by a 1956 study that compared aquatic invertebrates in an unpolluted stream near Witbank, the Sadelboom Stream (adjacent to the current study area), with the Klipspruit, a nearby stream polluted by acid mine drainage (Harrison, 1958, 1965).

The polluted Klipspruit had a pH of 2,9, attributed to drainage from coal mines. The river was overgrown with reeds, the water was very clear, and the flow was impeded by masses of partially decayed or undecayed vegetable matter covered with a jelly like growth of the alga *Frustulia rhomoides*. Deeper pools were floored with a thick growth of the moss *Sphagnum truncatum*. The fauna was limited, and dominated Chironomidae (mostly *Pentapedilum anale*) and water mites (*Hydrozetes* sp. and others). A caddisfly species (*Athripsodes harrisoni*), known from the naturally acidic waters in the south western Cape, was also found. Mayflies, aquatic beetles, blackflies and Orthoclad midges were not found.

8.2.1 Wet Grasslands

Very little is know about the aquatic fauna inhabiting wet grasslands, but it is certain that they provide provide ideal breeding ground for *Culiciodes* midges. Waterlooged sandy to silty soils with a high organic content and a cover of short grass provide ideal habitats for the larvae of the biting midge *Culicoides magnus* (Meiswinkel, pers. comm., 2000). During this study the adults of this species were recorded biting humans in a riparian zone of at dusk (17h00) in August 2000. There are no previous records of this species feeding on humans (Meiswinkel, pers. comm., 2000). This is species is found in cooler parts of southern Africa, and its highest numbers (in the thousands) have been recorded in the vicinity of Middelburg, in the UORC (Meiswinkel, pers. comm., 2000). The available data suggest that this species could be univoltine, hence its appearance early in the season.

8.2.2 Pans

Aquatic invertebrates inhabiting pans in the UORC appear to be characterised by high numbers and low diversity. The majority of species have life histories adapted to seasonal drying. This usually means that at least one stage of their life cycle is capable of tolerating high temperatures and complete descication. Furthermore, such taxa are often capable of fast growth and reproduction.

An interesting observation is that the composition and abundance of invertebrates inhabiting a specific pan often bears little resemblance to that in adjacent pans. In other words, each pan has an invertebrate fauna that reflects the specific conditions in that pan at the time. Factors that are likely to be responsible for these differences include the length of time that the pan has been inundated, the size and depth of the pan, adjacent landuse, the water quality and soil type, and types and age of the aquatic plant growth, and other biotic interactions, such as the presence or absence of fish. These differences are supported by the available data on water quality, which shows significant differences between pans, even between pans that are situated close to each other.

Many pans in the UORC are highly eutrophic, and support seasonal blooms of aglae, such as *Microcystis* sp. Oxygen levels in such pans are likely to drop significantly at night. It is therefore not suprising that many of the macroinvertebrates found in these pans are air-breathers and highly tolerant of low oxygen levels (e.g. Culicidae, Nepidae, Physidae, Naucoridae, Corixidae, Gerridae and adult Dytiscidae).

A survey of caddisfly inhabiting nearby Lake Chrissie recorded only two species:

Ecnomuc oppidanus from the bottom mud, and *Athripsodes ?harrisoni* from marginal vegetation (Scott, 1970). Both species tolerate wide ranges in pH (3,7-9,2).

Most pans in the area support populations of snails. Between 1957 and 1978, a detailed study of the distribution of aquatic snails in the UORC was undertaken by the University of Potchefstroom (Pretorius et al., 1980). The study recorded 16 species of snails, including one of the intermediate hosts for bilharzia, *Bulinus (Physopsis) sp*. The alien invasive pouched snail, *Physa acuta*, was not recorded at the time, but today this species is widespread in the catchment. The alien invasive *Lymnaea columella* was recorded in low numbers mostly in the vicinity of Witbank Dam, and today this species is widespread within the catchment.

8.3 Fish

Based on present and historical records as well as the presence of several species in smaller tributaries, such as the Rietspruit, it is most likely that the UORC historically contained about 11 indigenous species of fish. Presently nine indigenous, five exotic species and four translocated indigenous species still occur in the UORC (Appendix K). The habitat requirements of these species are described in Appendix L.

Two of the expected species, the mountain catfish (*Amphilius uranoscopus*) and the shortfin rock catlet (*Chiloglanis pretoriae*), have recently been collected downstream of Witbank and Middelburg Dams, and are restricted to clear fast flowing, well-oxygenated water in rocky rapid and riffle areas. Because the latter habitat is not abundant within the UORC, their presence may have been highly restricted even under natural conditions. The former species have also been noted to be very susceptible to poor water quality, and especially metals such as copper.

Many of the wetlands in the UORC have been extensively canalised, and much of the former fish habitats have been destroyed. Poor water quality and several major impoundments that effectively isolate this area from possible refuge areas and any potential for re-colonisation, have also exacerbated this condition.

The small minnows recorded for this area such as the straightfin barb (*Barbus paludinosus*) and the threespot barb (*Barbus trimaculatus*) are presently known only from a few localities in the UORC. These species were probably common and more widely distributed in these wetlands under natural conditions. Some of the remaining localities where these species still occur are presently under severe threat due to mining activities in wetlands, in particular the Rietspruit.

Larger species recorded in the UORC, such as the small-scale yellowfish (*Barbus polylepis*) have specific requirements for breeding and nursery areas. Although this species is does not depend on permanent flow during all life stages, the juveniles of this fish is commonly found in clear fast flowing, well-oxygenated water in rocky rapid and riffle areas, whereas the adults prefer deeper pools. This species also needs a cobble bed, underlain by gravel in fast flowing water, and a water temperature of 22°C during early summer to trigger spawning. The presence of several large impoundments in the area, which restricts their movement, may therefore limit the available habitat and numbers of this species. Where suitable habitat is still available, e.g. pools in the lower Viskuile Spruit, large numbers of this species are still present.

Three exotic species (mosquitofish, *Gambusia affinis;* common Carp, *Cyprinus carpio* and Largemouth bass, *Micropterus salmoides)* as well as three translocated species (moggel, *Labeo umbratus;*, silver labeo, *L. capensis* and rock catfish, *Austroglanis sclateri*) have become well established in the UORC.

8.4 Amphibians

The use of wetlands in the UORC by amphibians is mostly unknown, and little has been documented of the habitat requirements of most species except anecdotally and repeated in most field guides and checklists. Most of the species within the UORC are common and widespread, with only a few sparsely distributed and of low abundance. A total of 15 species of ampibians has been recorded in the UORC (Appendix M). None is listed in the Red Data Books, although one species, the Giant Bullfrog, is near threatened according to IUCN criteria (Harrison et al., 2001).

All the wetland types, perhaps with the exception of wet grasslands, are important to the amphibians in the study area. Most species need shallow water of sufficient permanence for egg and larval development to take place, together with sufficient cover against predation. Most species are therefore found in the vicinity of more permanent wetland types, particularly floodplain wetlands, pans and artificial wetlands (Appendix M). Amphibians have therefore adapted to man-made conditions where sufficient water of the right depth and quality are available.

What each species' preferred habitat may be is not known, although some predictions are possible. Many factors influence the suitability of a specific wetland to a specific species. Some taxa, such as *Bufo gutteralis, Cacosternum boettgeri, Phrynobatrachus natalensis, Kassina senegalensis* and *Xenopus laevis* are eurytopic, inhabiting a wide range of wetland habitats, typified by the permanent availability of water.

Other species such as *Afrana angolensis, A. fuscigula, Ptychadena porosissima* and *Strongylopus fasciatus* may be considered stenotopic, mostly requiring specific habitats such as streams, rivers or seeps. Shallow grassy pans are very important to the threatened Giant Bullfrog *Pyxicephalus adspersus*. It is estimated that 40% of pans on the Witwatersrand have been affected by development (Allan et al. 1995), including pans which probably hosted the largest concentrations of the Giant Bullfrog in southern Africa.

Most amphibian species in the study area (11) are seasonally associated with wetlands, many overlapping in habitat requirements. Many amphibians use seasonal shallow depressions to reproduce in, provided sufficient water and cover is available. Toads and most frog species move away from water towards the end of summer, seeking refuges where they are safe and can minimise water loss during winter. Distances from the water body may be quite extensive, and in excess of a kilometre. The autumn and winter is therefore spent away from water, in burrows of other animals, cracks in the ground or buried in the soil, sometimes encased in a cocoon to reduce water loss (Loveridge & Craye, 1979). In these species, adult association with water is mostly related to reproduction and rehydration.

During spring and summer, adults must find water of sufficient permanence for the egg and larval stages to be completed before the water body dries up. Many species meet and mate at established water bodies. This is especially true of bufonids. Others rely on seasonal and ephemeral water bodies where they adopt a hit and miss approach to reproductive success. Van Dijk (1972, Figure 3a & b) depicts the relationship between genera and habitat in this regard.

Survival of tadpoles is largely governed by the type of water body where the eggs are deposited. Most of the taxa in the study area require shallow, standing or slow moving water for the larval stages to reach maturity (van Dijk, 1971). Parental care is absent, except among Giant Bullfrog, *Pyxicephalus adspersus*.

According to Channing and Van Dijk (1995) and De Villiers (1999) both adult and larval anurans are sensitive to chemicals such as herbicides and pesticides and that even low concentrations of chemicals from fertilisers may be dangerous to many amphibian species. The relatively high water temperatures found in South African wetlands may enhance this effect. Some of the more common species such as the Common clawed frog may have higher tolerance levels mostly in relation to acidity levels.

It is not possible to rank the wetland types in order of importance to the amphibian fauna because of the complexities of the interactions between the animals and the wetlands. The most important aspects to amphibians are permanent and seasonal shallow water, and cover from predation of the adults, eggs and larval stages.

Most species of amphibians are associated with floodplain riparian wetlands, permanently wet pans, shallow depressions that fill with rainwater and artificial wetlands (Appendix M), but this is not a reflection of their importance. Two of the rarer amphibians *Strongylopus fasciatus* and *Ptychadena porosissima* are mostly restricted to seeps along hillsides which are therefore very important.

Throughout the world, declining amphibian populations are cause for concern. This decline is not only related to countries which harvest large numbers for food but includes most developed countries as well as South Africa (Channing & Van Dijk 1995; De Villiers, 1999). This has led to the formation of amphibian awareness groups such as the World Conservation Union's Declining Amphibian Populations Task Force and locally the Southern African Frog Atlas Project (Harrison & Burger, 1999). Identified threats to amphibians and other wetland vertebrates include degradation of wetlands, destruction of water bodies, chemical pollution, encroachment by alien vegetation, public apathy and inadequate legislation.

8.5 Reptiles

As with amphibians, the use of wetlands in the UORC by reptiles is mostly unknown, and little has been documented of the habitat requirements of most species except anecdotally and repeated in most field guides and checklists. Most species found within the UORC tend to be relatively eurytopic occurring in a range of wetland types. Few species can be considered stenotopic, exhibiting preferences for specific wetlands. Most of the species within the UORC are common and widespread, with only a few sparsely distributed and of low abundance. Only eight species of reptiles associated with wetlands have been recorded in the UORC (Appendix N). None is listed in the Red Data Books.

Few reptiles are associated with wetlands in South Africa (Jacobsen, 1995). In the UORC only the Water Monitor (*Varanus niloticus*), Cape Terrapin (*Pelomedusa subrufa*), the Brown Water Snake (*Lycodonomorphus rufulus*), and the Green Water Snake (*Philothamnus hoplogaster*) are aquatic or partially aquatic, although the terrapin also lives around seasonal and even ephemeral water bodies. Other species such as the Aurora House Snake *Lamprophis aurora*, Spotted Skaapsteker *Psammophylax rhombeatus* and Rinkhals *Hemachatus haemachatus* partly occur in moist areas because of the availability of prey such as rodent and amphibians. All species, with the exception of the Rinkhals which is live-bearing, lay eggs away from the water to avoid waterlogging and fungal attack, but moist enough to prevent dehydration. The Slender-tailed Legless Skink *Acontias gracilicauda* is usually found in moist soils under rocks or other refuge along or close to drainage lines.

It is not possible to rank the wetland types in order of importance to the reptiles because of the complexities of the interactions between the animals and the wetlands. The lack of more detailed knowledge of the use of the various wetland types by the herpetofauna precludes this. The most important aspects to reptiles are cover and food availability. Most species of reptiles are associated with wetlands drainage lines and floodplain type wetlands (Appendix N), but this is not a reflection of the importance of this wetland type. A ranking of wetlands based on this was attempted but does little except to highlight the number of species expected in each wetland type.

8.6 Mammals

There are a limited variety of aquatic habitats for mammals in the UORC. Consequently, the diversity of mammals associated with wetlands is low. Only seven mammal species associated with wetlands have been recorded in the UORC (Appendix P). Most of these species inhabit dense vegetation around the perimeter of waterbodies, particularly along rivers and streams. These include the Black Musk Shrew *Crocidura mariquensis*, Greater Canerat *Thryonomys swinderianus*, Vlei Rat *Otomys irroratus* and Swamp Rat *Dasymys incomtus* as well as the Water Mongoose *Atilax paludinosus* and the two Otter species *Lutra maculicollis* and *Aonyx capensis*.

A single waterbuck (*Kobus ellipsiprymnus*) was recently reported from the UORC, but it most probably escaped from a game farm in the area, as they do not occur naturally in the UORC.

The Canerat has been mostly overlooked on the Highveld in the past, but appears to occur widely within the UORC and more recently even in the Vaal River Catchment.

It appears to be comprised of small disjunct populations occurring in suitable habitat along some drainage lines. No information on abundance is available.

Similarly the Swamp Rat, *Dasymys incomtus*, listed in the Red Data Book (Smithers, 1986) as Indeterminate, is widely but sparsely distributed with little information on abundance. It is uncertain whether it occurs within the catchment although habitat is available.

Although currently not listed in the outdated Red Data Book on terrestrial mammals (Smithers, 1986), some taxa such as the Spotted-neck and Clawless Otters should be incorporated in future revisions. The former tends to prefer rivers while the latter is more eurytopic, occurring along slow flowing and standing water bodies, but also visiting ephemeral and seasonal water bodies. Both appear to be rare in the UORC, although distribution and abundance are unknown.

It is not possible to rank the wetland types in order of importance to the mammals because of the complexities of the interactions between the animals and the wetlands. The lack of more detailed knowledge of the uses of the various wetland types by the mammals precludes this. The most important habitat components to most terrestrial mammals are cover and food availability.

Most species of indigenous wetland mammals in the UORC are found along drainage line wetlands, riparian wetlands, floodplain wetlands, dams and weirs (Appendix P). However, this does not reflect the importance of these wetlands types.

The reduction in the number of freshwater crabs *Potamonautes* spp., resulting from chemical pollution of water, will affect the survival of wetland associated mammals such as Water mongoose, Spotted-neck and Clawless Otters, all of which prey heavily on these invertebrates. The reduction in fish species and frogs by chemical pollutants also leads to a reduction in the Spotted-neck Otter, Water Mongoose and others fauna dependent on these for food. Pollution may affect the growth of vegetation around wetlands reducing habitat for small mammals such as the Black Musk Shrew, Vlei Rat, Canerats and Water Rats.

8.7 Birds

A total of 142 bird species has been recorded as associated with or likely to occur in the wetlands in the UORC (Appendix O). Of these about 90 are waterbirds – birds that are at least partially dependent on aquatic habitats, which is roughly the total number of waterbird species expected to be found in the highveld region. This is slightly higher than the estimate made for a large area of pans in the vicinity of Lake Chrissie (73 waterbird species - Allan & Brown, 1991; Allan et al., 1995), but the latter study was confined to pans.

Four species are listed as Red Data species – Greater and Lesser Flamingo, Painted Snipe and Half-collared Kingfisher (all near-threatened – Barnes, 1998), although the latest South African Red Data species list (Barnes, 1998) is different from the previous listing (Brooke, 1984), which included Grass Owl and Little Bittern. Brooke (1984) estimated that there were less than 100 breeding pairs of Little

Bittern in South Africa, but more recent experience indicates that this species is not as rare as this.

Without fieldwork, it was not possible to estimate the numbers of the Red Data species occurring in the study area, or the size of their populations relative to their South African populations. Anecdotal evidence suggests that the area may support significant numbers of flamingos, although this is likely to vary interannually as well as seasonally. The highveld grassland areas of the eastern Free State and Mpumalanga are an important centre of the Greater and Lesser Flamingo populations in South Africa (Harrison et al. 1997). There are several hundred thousand Greater Flamingos and about 60 000 Lesser Flamingos in southern Africa (Harrison et al. 1997). In the study area, bird numbers probably remain fairly high for most of the year, but dipping around March to May. Greater Flamingos favour open shallow eutrophic wetlands from which they filter small invertebrates such as crustaceans and dipterid larvae. Lesser Flamingos tend to occur in slightly more saline and more alkaline wetlands, because they feed on microscopic blue-green algae that bloom under these conditions. Neither species is thought to breed in the study area, but their movements mean that nonbreeding habitats are also critical to the survival of the species. Both species of flamingos are highly vulnerable to human disturbance.

It is unlikely that the UORC wetlands provide a stronghold for the South African population of Halfcollared Kingfisher, another Red Data species that has been recorded in the area.

Significant numbers of Grass Owl *Tyto capensis*, which tend to be associated with marshy habitats, probably occur in the study area. The South African population of Grass Owls is thought to be less than 5 000 breeding birds (Brooke, 1984). Numbers of Grass Owl are thought to be diminishing in South Africa as a result of habitat loss and degradation. Confined to grassland areas of the country, although also extending northwards beyond the equator, this species is highly vulnerable to disturbance, having already lost its Lesotho breeding population and most of its Cape province breeding population. It prefers moist to sodden grassland of about 1 m height, a habitat which is common in the UORC area. Drainage, burning and overgrazing of these habitats are serious threats to the Grass Owl population.

Also of interest is that numbers of Marsh Owl *Asio capensis* are thought to be very high in the study area. Mpumalanga is the main centre of the southern African population of this species. However, the Marsh Owl is a far more common species than the Grass Owl, being widespread in Africa, and having a slightly wider range of suitable habitats, being common in drier open grasslands as well as marshy habitats. Nevertheless, its frequent use of marshy habitats means that it is subject to similar threats to the Grass Owl in the UORC area.

8.7.1 Non-floodplain Riparian Wetlands

Non-floodplain riparian wetlands tend to be narrow and structurally fairly simple. Reedbeds or bulrushes are likely to provide the predominant bird habitat. These are frequented by numerous passerine species such as bishops and warblers. River banks, emergent vegetation and trees are also likely to attract species such as Reed Cormorants, egrets, Hamerkops, and Egyptian Geese. The diversity of birds

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8.7.2 Floodplain Riparian Wetlands

Floodplain wetlands offer a more extensive habitat than the above, and potentially support a high variety of species, with over 80 species likely to occur in these habitats. The numbers and diversity of birds in these wetlands depends on the presence of open water and variety of vegetative habitats within the floodplain wetlands, but they are often fairly diverse (see description of habitat use under pans). These wetlands attract large numbers of waterfowl.

8.7.3 Seepage Wetlands

Seepage wetlands are the least structurally diverse in terms of habitat for birds, being dominated by a rank grass layer, and sometimes a sedge-marsh vegetation, which is structurally similar. There is little open water, and thus waterfowl are uncommon in these types of wetlands. The dominant avifauna are secretive species such as Purple Heron, Ethiopian Snipe, Marsh Owl and Purple Gallinule. Passerines will also abound in these habitats, including species such as Fantailed Cisticola, Longtailed Widow and Pintailed Whydah. The most important feature of these wetlands in terms of birds is that they apparently support a high number of Marsh Owls, with numerous owls having been flushed in these habitats by members of this study team.

8.7.4 Pans

Pans are probably the most important habitat for birds in the UORC wetland system. This is because they usually provide shallow-water and shoreline habitats which are rare in the other types of wetlands. Pan systems are the most important in terms of providing habitat for Red Data species such as Greater and Lesser Flamingos and Painted Snipe. They are also an important habitat for owls.

The seasonal changes in water levels, even in perennial pans, exposes a gently sloping open shoreline which is often rich in invertebrate pickings, especially in recently exposed areas. Exposed shorelines provide a loafing habitat for waterfowl such as Yellowbilled Ducks and Egyptian Geese. The shoreline immediately around the water's edge provides a foraging habitat for waders such as Little Stint, Threebanded and Kittlitz's Plovers, and shallow water areas are frequented by species such as Wood Sandpipers, Ruff and Avocet. Slightly deeper water provides a niche for wading birds such as herons and egrets. Large shallow pans, especially the relatively saline pans, are likely to provide suitable habitat for Greater or Lesser Flamingos, which, when they do occur, often do so in substantial numbers. Large freshwater pans which include a deeper open water area may also provide suitable habitat for several waterfowl species. Emergent vegetation such as reeds and bulrushes attract a number of passerine species such as Red Bishops and warblers, while fringing sedge marshes and rank grasses attract species such as Ethiopian and Painted Snipes and Marsh and Grass Owls.

The numbers and diversity of birds is likely to vary substantially from pan to pan depending on habitat characteristics, with increasing diversity and numbers being associated with larger pans and those offering a greater habitat diversity. Similarly, the dominant avifaunal elements will range widely, and could be waders for receding and dry pans, wading birds for shallow, water-dominated pans, waterfowl for deeper, water-dominated pans or those with suitable shoreline, and even passerines in the case of a pan dominated by emergent vegetation. In addition, there will be substantial seasonal variation in the use of pans, particularly in the case of ephemerally inundated pans. Although temporarily abandoned by most waterbirds, dry pans do provide habitat for some species, such as Kittlitz's Plover.

The substantial difference in avifauna than can occur among pans is illustrated by a study of pans in the Lake Chrissie area. Allan et al. (1995) compared the avifauna of three different types of pans – reed pans, sedge pans and open pans. Reed pans had the highest diversity of waterbird species (57), followed by sedge pans (55) and open pans (43). Nine species were found only in reed pans (including Baillon's Crake, a Red Data species), and four each to sedge (e.g. Crowned Crane) and open pans (e.g. Knobbilled Duck). Baillon's Crake is not known from the UORC area, however.

8.7.5 Artificial Wetlands

Artificial wetlands in the study are highly variable as a habitat for birds. They range from small farm dams to storage dams for mines and large dams such as Witbank Dam. Their vegetation ranges from bare shorelines to complex and diversely vegetated areas. The avifauna of artificial wetlands is likely to bear most resemblance to that of perennial pans, but because of the variety of habitats and sizes of these wetlands, they potentially support the highest diversity of species, in aggregate, with about 115 species being likely to frequent these habitats. The only quantitative information on the birds of artificial wetlands are the co-ordinated waterbird counts from Witbank Dam, which is much larger than the farm dams that make up most of this habitat. A total of 62 bird species have been recorded on Witbank Dam (Taylor et al. 1999). Mean winter numbers are 1 717 birds, reaching up to 3 769, and mean numbers in summer are 2 174, with a maximum of 2 885 birds. Waterfowl numbers peak in winter, while numbers of cormorants, herons, egrets, Blacksmith Plovers and terns peak in summer. Bird numbers are dominated by Redknobbed Coot, making up a third to a half of waterbird numbers, and by Whitebreasted and Reed Cormorants, Darters, Egyptian Geese, Yellowbilled Duck, Blacksmith, Threebanded and Ktillitz's Plovers, and Greyheaded Gulls, and in summer, Whiskered and Whitewinged Terns. The remaining species are usually present in numbers of below 50 birds.

8.8 Summary

Plants

The available information indicates that plants species diversity in the wetlands of the UORC is exceptionally high. A total of 354 indigenous plant species, and a further 59 exotic species, has been reported in these wetlands. The Nyslvlei wetland, by comparison, supports about 60 species of plant in total. There also appears to be considerable local and regional variability in plant species composition and richness among and within the different wetland types. We speculate that this variability may be influenced by a number of factors ranging from the more obvious ones such as hydrological characteristics, to subtle water quality differences in perched groundwater. Clearly more work is needed in this regard.

Hillslope seepage wetlands are the most impacted of all wetland types in the area, and very few unimpacted hillslope seepage wetlands remain due to cultivation and planted pastures. As a result it is seldom the case that the plant species found on these systems reflect a natural state, or are representative of what would naturally have occurred in the system. It is likely that a large portion of the plant species diversity that was naturally associated with these systems has been lost.

With respect to the pans, there is very little information on how the plant species richness and composition change in relation to the natural hydrological and water quality dynamics of these systems.

Although Red Data Book listed plant species do occur in the systems, only a few were recorded. Considering the diversity of habitats among all the systems, the likelihood of the occurrence of others cannot however be ruled out. It can be concluded that the different wetland types as well as the high degree of variability in plant species composition and richness among and within these adds to the biodiversity of the UORC.

Aquatic Invertebrates

Available data on the aquatic invertebrates in the UORC indicates that the fauna comprises mostly widespread, common and hardy taxa. However, their abundance and high productivity are important in maintaining populations of higher trophic levels, particularly birds. Local variation in species composition is high.

Most insect species have good dispersal abilities, and are capable of rapid recolonisation. However, their ability to recolonise disturbed areas depends on the presence of undisturbed refugia. This highlights the need to designate wetland areas worthy of special protection.

Most of the crustacea and common snail species are adapted to temporary drying. Permanently inundated conditions, such as found in dams and weirs, leads to a drop in the diversity of such species, and replacement by species that are sensitive to drying. This highlights the importance of maintaining a mosaic of intermittent, seasonal and permananet systems.

There is no standard method for assessing the health of wetland systems in Southern Africa. Given the large extent of wetlands in the UORC, their importance as nodes of biological diversity, and the rapid rate at which they are disappearing or being altered, a rapid bio-assessment method similar to the SASS sampling technique, would provide a useful tool for managing and monitoring wetlands in the catchment.

Fish

The wetlands of the UORC are characterised by a low diversity of fish fauna, historically with 11 indigenous species, but presently with eight indigenous, three exotic species and three translocated indigenous species. The presence of several large impoundments in the area, which restricts the movement of fish, may limit the available habitat and numbers of fish and fish species in the area. Where suitable habitat is still available, e.g. pools in the lower Viskuile Spruit, large numbers of small-scale yellowfish (*Barbus polylepis*) are still present.

Amphibians, Reptiles & Mammals

The wetlands of the UORC are characterised by a low diversity of herpetofauna and mammal fauna, with few rare or endangered species. The naturally low diversity has been aggravated by large-scale habitat degradation, coupled with the use of pesticides, particularly treated seeds, reducing the amount of available prey. An important attribute of these wetlands is that they provide pathways of genetic interchange, linking populations of amphibians and aquatic reptiles and mammals.

Birds

Birds are the most conspicuous faunal element of the UORC wetlands. The variety of habitats offered by the different types of wetlands results in a large diversity of birds using the area, and their large aggregate area probably means that many of the waterbird populations are significant in terms of their overall South African numbers. These include the populations of Red Data species such as Greater and Lesser Flamingo, as well as of a former Red Data species, the Grass Owl. These three species are all highly sensitive to disturbance. Although all of the major wetland types provide complementary habitats for birds, pans probably constitute the most important wetland type in the area. Because most waterbird species are so opportunistic, the diversity and numbers of birds using artificial wetlands is also high, and the construction of dams in the area thus adds to waterbird numbers in the area. It does not contribute to the conservation of rare species, however.

9. LAND USE, WETLAND USERS & THREATS TO WETLANDS

J. Muller, D. Vink and R. Palmer

9.1 Land Use Pattern

The total study area comprises over 64 800 ha, with twelve land use classes ranging from natural vegetation (grassland) to dryland farming, residential, and industrial urban land use (Figure 9.1) being depicted by the 1996 National Landcover database. Just over 50% of the land in the UORC remains in its natural state (unimproved grassland, wetlands, and thicket and bushland) (Appendix B).

By far the largest land use in the area is dryland commercial agriculture (mainly maize farming) at 37%, followed by mining and quarrying, forest plantations and urban residential land use at 5%, 2%, and 1% respectively. The number of polygons per land use category provides some insight into the impact of human settlement in the area. The landscape would appear to be highly fragmented by human land use activities (agriculture, mining, and housing) impacting on the natural environment quite significantly.

9.2 Land Ownership

Land ownership is central to understanding who is entitled to use the resources associated with wetlands in the area, although there may be many more informal users who gain access to these resources. Most of the wetlands in the UORC are situated on privately owned farms. The average size of these farms has increased significantly in recent years, as larger-scale farmers and companies have bought out small-scale farmers. Farming operations have changed accordingly, and have generally become less diverse, with owners not necessarily living on the land.

The surface and mineral rights to many of these farms are owned by coal mining companies, although in most cases the land is rented to farmers until such a time that it is needed for mining. The renters control access to the farms, and usually this is limited to farm labourers.

An initial meeting with stakeholders, held in Witbank, concluded that the main users of wetlands in the area are Agriculture and Mines. The uses of wetlands by these sectors were therefore investigated detail in this study. Other users of wetlands were identified and considered, but not to the same level of detail.

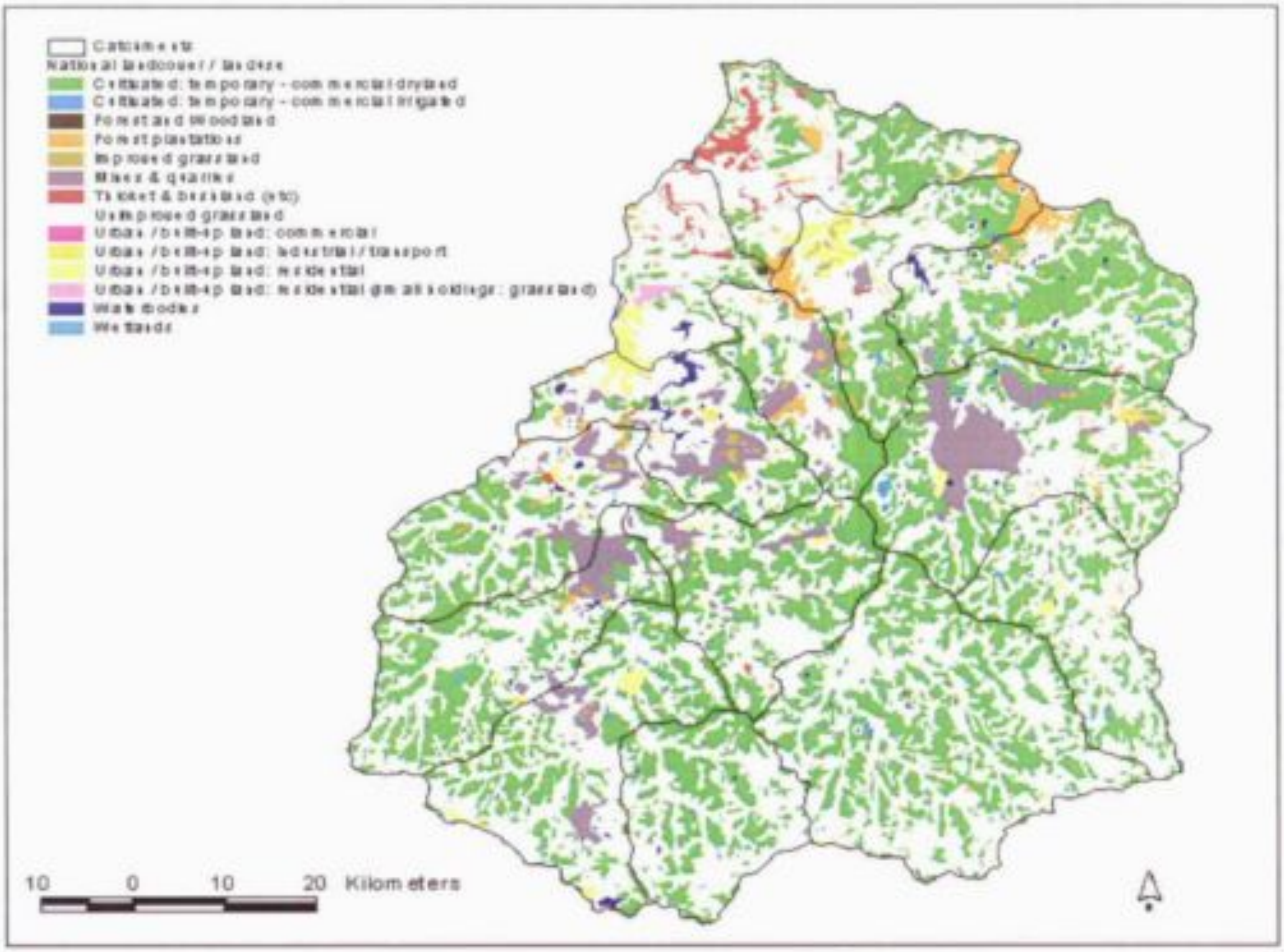

Figure 9.1. 1996 National Land-cover/land use for the Upper Olifants River Catchment (UORC). This map underestimates the occurrence of wetlands in the UORC by 97%.

Mines, industry and power were considered as one user group, as their interests in wetlands are similar. This sector uses wetlands mainly for water supply and storage, including storage of polluted water during low flow periods. Key issues regarding wetlands raised by this sector were the sterilisation of coal resources by wetlands, and the costs of rehabilitation.

9.3 Threats to Wetlands in the UORC

Threats to the wetlands in the UORC arise both out of some of the land uses described above, and out of demand for water from the catchment by users further afield. Developments in the UORC have been characterised by little or no strategic environmental planning, and this has lead to serious, and in some cases irreversible, degradation of ecosystems, particularly wetlands. Major threats to the wetlands in the area include total destruction due to coal mining or agriculture, and changes in hydrology and water quality due to abstraction, farm dams and weirs, and effluent from agriculture, mines, power stations, industry and urban environments, and increasing demands for water.

9.3.1 Cultivation

Commercial dryland agriculture is one of the largest threats to wetlands based on the area abutting or adjacent to wetlands (Appendix C). Approximately 35% of land adjacent to wetlands is taken up by agriculture. Other land use threats include mining and quarrying (3,8%), forest plantations (1,3%), creation of dams and therefore flooding of an area (1,3%), and urban residential growth (0,8%).

Land use encroachment on individual wetland types (e.g. channeled riparian, midslope seepage etc) shows a similar picture to the overall study area. All wetland types except artificial wetlands and wet grasslands are most threatened by commercial dryland agriculture.

One of the most widespread threats to wetlands in the UORC is that caused by cultivation, particularly dryland maize. Much of this is situated on midslope seepage areas which have been drained to allow cultivation. Other crops in the area include potatoes, beans, lucerne and soyabeans. Pesticides and herbicides applied to these crops have presumably had a negative impact on local flora and fauna.

Grasses growing in many of the wetlands are harvested for winter fodder, and some are cultivated with pasture grasses, mainly Weeping Love Grass (*Eragrostis curvula*), Tef *(E. tef)*.

9.3.2 Livestock

Another threat to the wetlands in the UORC is grazing and trampling by livestock (mainly cattle), and associated fencing.

9.3.3 Burning

Many of the wetlands are burnt annually, either intentionally to promote grazing for livestock, or by accidental fires. Frequent burning leads to significant loss of organic material, and consequent deterioration of soil properties. Burning also leads to significant loss of wildlife, particularly birds eggs.

9.3.4 Dams and Weirs

Associated with agricultural development is the construction of dams and weirs, used mainly for irrigation water and stock watering. There are at least 2 237 of these in the UORC. These structures are often situated immediately downstream of a wetland, and so filling of the impoundment leads to inundation of the upstream wetland. In many cases the dam outlets are too small to accommodate floodwaters, and so the dams have burst and this has caused erosion gullies to form. The cumulative impacts that small dams have had on the hydrological characteristics of the UORC, particularly during low-flow periods, cannot be overestimated.

9.3.5 Removal of Key Points

Many of the floodplain type wetlands are situated upstream of dykes, which act as hydraulic control or key points. Removal of the key point, for whatever reason, leads to rejuvenation of the main channel, and consequent erosion and drying of the floodplain wetlands.

9.3.6 Harvesting of Wetland Resources

Various resources are harvested from wetlands in the UORC, such as building sand, fish and medicinal plants. These activities are generally uncontrolled and uncontrollable, and have led to significant deterioration in some cases. Wetlands in the UORC are an important source of building sand. In many cases the sand has been excavated and left without rehabilitation. This has caused degradation of vegetation and habitats, and encouraged pioneer plants, particularly alien plants, to establish.

9.3.7 Roads, Bridges and Railway Lines

The UORC has a well-developed network of roads and railway lines, with associated bridges, culverts and other forms of river crossings. These have changed surface drainage patterns significantly, and as a result, many wetlands downstream of these sites have been cut off from their normal water supply, while new wetlands have formed in areas upstream of the crossings. Roads also interfere with the movement and migration of animals. This can results in large-scale mortalities, particularly for frogs.

An important impact of road and rail networks is that they constrain surface flows in many of the floodplain wetland systems, resulting in backflooding upstream of the bridges, and constricted flows downstream of the bridges. This has resulted in the development of erosion fronts downstream of bridges that, in many cases, have developed into extensive networks of headward cutting erosion gullies. This effect has probably contributed to the large-scale channel incision that is evident in the floodplain systems throughout the catchment. Deepened and widened channels in turn reduce the frequency of overbank topping during flooding. Channel incision has reduced the flooding frequency in some systems from seasonal to more temporary, and this has caused many of these systems to start showing signs of extended drying.

9.3.8 Alien Plants

Disturbances to vegetation caused by construction activities, particularly roads, create ideal opportunities for the spread of alien vegetation. With the introduction of commercial livestock farming came the introduction of many livestock related exotic and alien invasive plants including, among others the Scottish thistle *Cirsium vulgare*. In most of the heavily grazed floodplain systems as well as other wetland types exposed to intensive livestock grazing there is an abundance of exotic invasive species of forbs in particular. The most common aliens plants found in the riparian zones of the UORC include wattle and *Sesbania*.

9.3.9 Alien Animals

The UORC has been inundated by a number of alien fish and invertebrate species. These species tend to have a negative impact on indigenous species.

9.3.10 Forestry

Forestry in the UORC is limited to a few areas, mainly in the Klein Olifants Catchment. The most common trees planted in wetland areas are Poplars (*Populus* spp.) and Eucalyptus (*Eucalyptus* spp.). These drain wetlands and almost totally destroy the indigenous vegetation, reducing cover, rendering it poor quality habitat for wetland fauna.

9.3.11 Mining and Quarrying

Perhaps the most significant threat to wetlands in the UORC is that many of the larger wetlands are underlain by large reserves of coal. In 1997 an estimated 180 million tons of coal were mined from this area alone (the Mpumalanga highveld), of which about 70% was used locally for thermal power generation, and the remainder was exported (Prevost, 1998). Wetland areas are often targeted for surface coal mining, simply because wetlands are usually situated in the low-lying areas where the distance to the coal seams is less than elsewhere, and so the costs of mining are lower than elsewhere.

Surface mining leads to irreversible destruction of wetlands, while underground mining can have significant impacts on water quality and quantity, particularly in cases where the underground mines are near the surface. During underground mining operations, draw-down of the groundwater level may cause wetlands to dry up. After the mining operation, water decanting from the mine can be highly polluted, and can remain so for decades. The long-term environmental impacts of such mining activities is unknown (Wates, 1997).

Subsidence of underground mines has also lead to the formation of new wetlands (although their soil profiles and associated flora and fauna cannot be compared to that of a natural wetland), and the alteration of the hydrological regime or surface profiles of existing wetlands.

All wetland types, including artificial wetlands and wet grasslands, are threatened by mining and quarrying in the UORC. Artificial wetlands are often created around mines as a result of excess water being pumped from the mine, so this finding is not that surprising. Certain wetland types are more threatened than others, for instance classes: drainage lines with riparian zones; midslope seepage wetlands; non-permanently wetpans; and seasonally inundated valley bottom floodplain without footslope seepage wetlands all have greater than 20% of the surrounding landscape altered from natural (Appendix D). Sections of the remaining seasonally inundated valley bottom floodplains with footslope seepage wetlands are also under threat from mining. A section of the Rietspruit floodplain system is currently being mined and a section of the Steenkoolspruit floodplain is proposed to be mined in the near future.

9.3.12 Water Demand

The UORC faces a number of urgent water related issues. Demands for water currently exceed supplies, so much so that water is imported from the Usutu, Vaal and Komati River basins. Furthermore, the quality of surface and ground water in many parts of the catchment fails to achieve the guideline values for aquatic ecosystems set by the Department of Water Affairs and Forestry (DWAF). A significant number of South Africa's water-cooled power stations are situated within the UORC. A breakdown of the various amounts of water used for each water user within the UORC is given in Table 9.1.

Table 9.1: Water requirements per annum for water user for the Olifants and Klein Olifants catchments (upstream of their confluence). [Data from Coleman et al. (2001).]

Water User	Water Requirements (Million m^3/annum)
Power Stations	160,31
Urban (1995)	36,59
Mining (1995)	25,82
Industrial (1995)	9,07
Irrigation	8,80
Stock	5,78
Afforestation	1,09
Total	**210,87**

Although the Komati, Usutu and Vaal River systems supply water for power stations in the UORC, most of this water is lost to evaporation in the cooling towers. However, some of this transferred water is released into the UORC in the form of effluent from sewage treatment plants.

10. DIRECT USE VALUES OF WETLANDS

J. Turpie & H. van Zyl

The direct use values of the UORC wetlands arise from their consumptive use, or harvesting of goods such as plants or sand, and from recreational use, such as for fishing, birdwatching or hunting. Estimation of direct use values usually requires quantification of the use, such as numbers of users, frequency of use, and quantities of resources harvested. Since this is a desktop study, and the first study of this nature for the study area, such quantitative data were not available. However, very rough estimates were made on the basis of key-informant interviews and a small questionnaire survey of 22 farmers in the area, which was conducted opportunistically during the course of the study (see example of questionnaire in Appendix F). Note that such a small sample could not provide statistically-robust estimates, but formed the basis of assumptions made in our calculations. The direct uses of the wetlands and their values are described below.

10.1 Harvesting Food, Medicinal and Building Materials

Harvesting of food and medicinal plants, and construction materials such as reeds and sand, is common practice in wetlands throughout the world. It is particularly prevalent in communal lands of developing countries, but often also occurs on private lands. The amount of harvesting of wetland resources in the study area is unknown, but some idea was gleaned from interviews during this study. Food and medicinal plants are generally accessed by farm labourers and traditional healers from nearby towns, rather than by the landowners themselves. Both landowners and labourers do, however, harvest materials used in construction, such as sand, and most also partake in the recreational activities described separately below.

The use of the wetlands for harvesting food and medicinal plants was difficult to quantify. Over 50 of the species of plants recorded from the UORC are known to be used for various purposes, ranging from staple food sources to treating a wide range of ailments (Appendix F), although which of these plants are used within the UORC is not known. An attempted survey of farm labourers was unsuccessful due to enumerator difficulties. About half the farmers interviewed claimed that their labourers did harvest resources from the wetlands. Of these, a third supposedly did so without the farmers' consent. On the whole, farmers did not believe many outsiders accessed wetland resources on their farms, except for one who had a problem with squatters, and another that claimed people harvested grass along the roadside.

Farmers that were aware of their labourers using wetland resources named mammals most frequently, followed by grass and medicinal plants (Table 10.1). Small mammals are hunted with dogs or traps. Grass is presumably used for thatching, unless hay is sold or labourers keep livestock. Farmers knew little about medicinal plant use.

Table 10.1. Harvesting of resources by labourers as described by farm managers or owners in structured interviews.

Resources harvested	% farms	Comments
Mammals	26%	e.g. Steenbok, porcupine; often using dogs, traps
Grass	17%	Up to 130 tons hay on a farm
Medicinal plants	17%	Much uncertainty; e.g. bulbs
Clay	9%	Used for pots, etc
Reed	9%	Used to make mats
Fish	9%	Barbel, carp, bass, tilapia
Birds	4%	Farmers uncertain
Crabs	4%	

In addition, clay, reeds, fish, birds and crabs are also harvested from the wetlands on a few farms. In general, the harvesting activities are probably understated by farmers, who may well be unaware of all the activities of their labourers. No satisfactory estimates of quantities harvested could be obtained. However, since the labourers have cash-based and somewhat westernised, rather than subsistence-based or highly traditional livelihoods, it is unlikely that any households are highly reliant on harvesting wetland resources. Resource harvesting may make a significant contribution to household income, or significant cost savings in terms of food, medicines and building materials, but is unlikely to make a major contribution to local livelihoods.

None of the farmers interviewed claimed that they or their families harvested plants of any kind from wetlands. However, 30% of farmers claimed to harvest sand, some claiming to harvest now and again when building, and others claiming to have harvested commercial-scale quantities of 100 tons or even 500 tons in the last year. One farmer claimed that the previous owner had mined all the available sand already. Insufficient quantitative data were provided to estimate a mean harvest. Follow-up research on this issue with mining and sand-mining companies did not yield any usable estimates.

Based on quantitative studies of the consumptive use values of wetlands elsewhere, and adjusting for the different socio-economic environment of the study area, we estimate that the wetlands are currently worth in the order of R10 - R100 per ha per year in terms of resource harvesting.

10.2 Fishing

Fishing is one of the largest recreational activities in the UORC, and at least 18 angling clubs can be found in the towns within the catchment. Although these clubs fish mainly in the UORC, their activities are not limited to the area. Most of the towns in the catchment have at least one shop dealing in fishing gear, and larger towns such as Witbank have as many as four. Venues with the greatest importance for angling include larger dams such as Witbank, Middelburg and Trichardsfontein Dams. Dams such as Middelburg and Witbank Dam generate in excess of R15 000 monthly from gate fees alone. However, it seems that smaller private farm dams and river pools are also of significance to this recreational activity.

To attach a value to the fishing associated with wetlands, estimates of the total annual fishing-related expenditure by fishers were made. These expenditures were then roughly apportioned to wetlands. Total expenditure was divided into expenditure on (1) fishing gear, (2) licences and (3) other fishing trip related costs.

Expenditure on fishing gear was estimated based on the turnover of fishing shops in the study area. A total of 13 angling shops were contacted. The estimated turnover of a single shop in some of the smaller towns was found to be between R20 000 and R30 000 per month. In larger towns, such as Witbank, the turnover was as high as R100 000 per month. In total, the turnover of angling shops in the UORC should be in excess of R500 000 per month or R6 million per annum. Note that this figure excludes purchases of equipment outside of the study area used for fishing in the study area making it a conservative estimate of the total amount spent. Not all the equipment is bought exclusively for use in the study area. However, it seemed reasonable to assume that 70% of the use derived from the equipment occurs in the study area (own estimate and pers. comm., Frans van Zyl, Rod 'n Reel). Thus an annual equipment expenditure value of R4,2 million can be assigned to the area.

Discussions with Blackie Swart of the Mpumalanga Parks Board (MPB) revealed that approximately 5 400 fishing licences were issued in the study area during the last year. At a cost of R20 each, they generated annual revenues of R108 000. The number of licences sold does not, however, correspond to the number of fishers in the area as licences are not required for fishing on one's own property and some illegally fishing without a licence does occur. In order to take this into account, licenses sold were increased by 30% to generate a more accurate value of approximately 7 020 fishers. It was more difficult to estimate the number of fishing trips undertaken annually per fisher, but an average of 12 (i.e. one per month) was agreed on as a reasonable estimate.[2] This implies that approximately 84 240 fishing trips are undertaken annually in the study area. Using these values and the abovementioned estimate of equipment expenditure, we estimate that the average fisher spends R600 per year on equipment, which translates to an average of R50 per fishing day. The average daily travel and subsistence expenditure on a fishing trip was assumed to be similar to that of a birding trip (Turpie & Ryan, 1999), which in 2001 Rands, equates to R145 per person per day. All of this expenditure adds up to a total of R16,5 million per year in the study area.

This value represents the value of fishing at all venues in the study area. Discussions with the MPB revealed that of all fishing in the area, 70% takes place at dams, 20% in rivers and 10% in pans. Thus dams (6 840 ha) were estimated to be worth R1 690 per ha per year, and pans (5 975 ha) are worth R276 per ha per year.

10.3 Bird Watching

To attach a value to the bird watching associated with wetlands, estimates of the total annual birding-related expenditure by birders were made. These expenditures were then roughly apportioned to wetlands. Total expenditure was divided into

[2] Average number of trips per year as well as percentage of non-license fishing were both estimated with the assistance of Blackie Swart, Mpumalanga Parks Board.

expenditure on (1) birding gear, and (2) other birding trip related costs.

Discussions with the chairmen of the Middelburg and Witbank Bird Clubs (Ken Hattingh and Gert Opperman) revealed that there are approximately 150 people in the area that belong to bird clubs. This number does not, however, correspond to the number of birders as some birders are not members of clubs. Non-members were assumed to also number roughly 150 people implying that there are a total of roughly 300 birders in the area. The average South African birder birds for about 46 days per year. About 62% of birding days are at sites within 200 km of home base (Turpie & Ryan, 1999) and thus it was estimated that the local birders may bird in the region of the study area on an average of 28 days per birder per year. Thus we estimate a total of 8 526 birding days in the study area per year. The average expenditure on a birding trip is about R145 per person per day in 2001 rands (Turpie & Ryan, 1999). In addition, the average birder spends some R2 658 per year on equipment. Thus the total expenditure on birding ascribed to the study area was R1 855 440 per year.

This quantity represents the value of birding at all sites in the study area. Discussions with the bird club chairmen suggested that of all birding in the area, roughly 40% takes place at dry land sites, 20% at rivers, 20% at dams and 20% at wetlands. Furthermore, it is estimated that 15% of wetland birding takes place at pans. Thus , based on the above estimates, dams are worth about R54 per ha per year, pans are worth R47 per ha and all other natural wetlands are worth R2 per ha in terms of birding. Of course these averages would only apply to particular wetlands if the value were evenly spread across all wetlands. In reality, it is to be expected that the value is patchily distributed and strongly influenced by particular site attributes such as size and habitat diversity.

10.4 Waterfowl Hunting

Discussions with the MPB revealed that a closed season has been declared on waterfowl hunting in the study area for the last ten seasons. The only value that could be derived from hunting would thus be illegal. For obvious reasons it is not possible to estimate this, but it is not considered significant according to the MPB as compliance is generally satisfactory. Given this and the uncertainty over whether another open season will occur, no values were estimated for waterfowl hunting.

10.5 Water for Livestock

In terms of agricultural use, wetlands have the potential to obviate the construction of boreholes or the expansion of the network used to distribute water to farm camps. They do not have the potential to replace storage dams as these are fairly scarce in the area. The Department of Agriculture does not recommend their construction in the study area and farmers generally favour boreholes as they are usually cheaper to construct and offer the further advantages of permanent and clean water.

The likelihood that a wetland can replace a borehole as a source of water on a farm depends on the position, permanency and amount of water that the wetland can hold. Positioning of boreholes is one of the key determinants of the overall costs of a water provision system. This is because delivering water from a borehole to the camps on a farm is the major cost in a water provision system (pers. comm., Gert Pool, Department of Agriculture). So positions with higher elevations that allow for the use of gravity offer substantial savings in pumping/distribution costs. As a rule, wetlands are in low-lying areas making their positions unfavourable for the establishment of boreholes. In addition, boreholes generally offer permanent and plentiful water. Some wetlands such as larger pans will also offer this, but they are not commonplace and even so, are unlikely to offer a good position as well.

Although it is fairly unlikely that wetlands can replace boreholes for the reasons given above, they do have greater potential when it comes to acting as replacements for watering points that are fed by boreholes. In other words, they can save a farmer from having to distribute water to the camps where they are located provided that they offer permanent and adequate source of water.

Discussions with the Department of Agriculture revealed that an average perennial pan would save: 500 m of piping at a cost of R7 per m, a reservoir at an average cost of R8 000 and a trough at an average cost of R750. The total capital cost saved by the average pan would thus come to R12 250. Seeing that there are 149 permanently wet pans in the UORC, their combined maximum value is R1 825 250 (R12 250 X 149) assuming that they are all used for livestock watering. This translates into a per hectare value of R522 (R1 825 250 / 3496 ha) which can be converted into an annual value of R42 (using an 8% discount rate). When the value of the permanently wet pans is given a per hectare value based on the total area covered by all pans and not just permanently wet pans, the value changes to R249 (R1 825 250 / 7 321 ha) which can be converted into an annual value of R20 (using an 8% discount rate).

10.6 Storage and Evaporation of Mine Water

Mines are interested in wetlands mainly because they offer the opportunity for water storage and evaporation. Although some purification does take place when mine water runs through wetlands, this is seen as a relatively minor extra benefit (pers. comm. Mark Aken, Anglo Coal). To give an indication of the cost of storage through the construction of a conventional dam, Anglo Coal is planning the construction of a storage dam with a 5 million m^3 capacity. The dam is expected to cost R15 million, R3 million of which will be for controlled release equipment. The question now becomes what size of pan would be capable of storing this volume of water? The average pan depth in the area was estimated at approximately 1,5 metres over the whole area of the pan. This means that the average water storage capacity associated with pans is 15 000 m^3 per hectare. Using this value, a pan of 333,3 hectares would be required to store 5 million m^3 of water thereby theoretically saving R12 million. This translates into a R36 000 (R12 million per 333,3 ha) total saving per hectare of pan and a R2 800 annual saving. Note that this is the maximum saving as it assumes that all pans will be used for storage. This value however, is only realised if a wetland is on a mining property and not underlain by coal.

10.7 Grazing for Livestock

The main value of wetlands for livestock grazing in the UORC is a short (6 week) period towards the end of winter, when wetlands provide the only available good grazing. Once the summer rains start, grazing takes place throughout the area, and the wetlands do not have any particular benefits for grazing. Generally seepage wetlands are the wetland types most commonly grazed. The dominant grass type found in the area is *Eragrostis*. *Eragrostis plana* commonly occurs naturally on wetlands while *Eragrostis circula* is common in upland areas. When farmers seed wetlands they often choose Fescue as it is well suited to wet conditions even producing grass in the winter provided that ample moisture is present as in the case of wetlands. In addition to this it produces a high quality grass with a protein content of roughly 12% in comparison to the 6 to 8% protein content of *Eragrostis* used to seed pasture.

Research by the Department of Agriculture over four growing seasons between 1993 and 1997 on a farm south of Middelburg showed that seepage wetlands are roughly twice as productive (+/- 6 tons of grass per ha) as natural veld (+/- 3 – 3.5 tons/ha). This result was further backed up by a comment made by one of the farmers surveyed for this study. Fertilised pasture, on the other hand, was found to produce between 6 and 8 tons of grass per hectare which was roughly the same amount produced by seepage wetlands that have been seeded with grass (pers. comm., Dr. Kevin Kirkman, University of Natal). These estimates are for actual grass consumed by livestock. Seeded seepage wetlands produce more grass than pasture, but they are not really grazed in summer as they are generally too wet for livestock to remain mobile and can pose the risk of disease.

To get a rough indication of the value of the grass produced by wetlands, the cost of buying fodder was estimated. An average price of *Eragrostis* hay of R300 per ton was taken as an acceptable approximation of this cost. Multiplying this cost by the productivity estimates above, translated into a wetland value of between R1 800 per ha for natural seepage wetlands and between R1 800 per ha and R2 400 per ha for seeded seepage wetlands. Note that these are gross values and not net values specifically attributable to the contribution of wetlands in the production process. While this was not the ideal way to determine value, it gave a fair indication of value and was the only method feasible give data and resource constraints. If more resources were available, it should be possible to calculate the value of grazing using the production function approach. This approach would allow for the isolation of the value contributed by grazing by treating it as an input into cattle production.

10.7.1 Livestock Diseases

Following the previous section it is important to note that livestock grazing values may be compromised to some extent by the diseases present in certain wetlands. These costs are implicit in the production capacity of lands containing wetlands, but it was beyond the scope of this study to estimate them explicitly. The following is thus a brief description of livestock diseases associated with wetlands in the UORC, based on research by Dr. Rob Palmer. Information was obtained from various farmers interviewed, as well as discussions with Witbank vetenarian, Dr Rezin. It is clear from these discussions that wetlands in the UORC are directly associated with a number of important diseases of livestock, listed in Table 10.2. The most important of these are nematodes, internal parasites associated with aquatic snails, and arboviruses associated with *Culicoides* midges. Most livestock owners in the UORC vaccinate and dose cattle and sheep regularly against these diseases, particularly in summer. In addition, many farmers indicated that they tend to remove their livestock from wetland areas during summer (February to April) so as to reduce the rates of infection.

Table 10.2. Summary of important livestock diseases associated with wetlands in the Upper Olifants River Catchment.

Disease (&Victim)	Parasite	Vector/host
Worms (Sheep & Cattle)	Nematode (e.g. Wireworm and roundworm)	None
Fluke (Sheep & Cattle)	Sheep Liver Fluke (*Fasciola hepatica*)	*Lymnaea truncatula* *L. columella*
	Giant Liver Fluke (*Fasciola gigantica*)	*Lymnaea natalensis* *L. columella*
Fluke (Cattle)	Conical fluke (*Calicophoron microbothrium*)	*Bulinus tropicus*
Lumpy Skin (Cattle)	Virus	*Culicoides*
Blue tongue (Sheep)	Virus	*Culicoides*
Horse sickness (Horse)	Virus	*Culicoides*
Three day stiff sickness (Cattle)	Virus	*Culicoides*

Nematodes

There are numerous species of nematodes associated with wetlands that can cause problems to livestock, but Wireworm (*Haemonchus contortus*) is considered to be one the biggest veterinary problems in the UORC, causing major fatalities among sheep and cattle (Dr Rezin, pers. comm., 2001). The eggs hatch in moist soil or water and develop directly to third stage infective juveniles, and enormous numbers may accumulate on heavily grazed pastures. If they are swallowed by livestock, they spend the rest of their life in the small intestine. During summer months sheep need to be dosed monthly at a cost of R4 per head per dose. Cattle are usually dosed twice a year, depending on the rainfall, at a cost of R10-15 per head per dose. The costs are variable, as numerous products are available. Some of the more expensive products are also affective against external parasites, such as ticks and lice.

Flukes
In the case of flukes, most farmers indicated that they dose two to three times per year, depending on the rainfall. The costs of doing so for cattle ranges between R 40 and R60 per head per year, while for sheep the costs amount to about R10 to R15 per head per year.

Lumpy Skin Disease
Lumpy Skin Disease is a debilitating viral disease of cattle, transmitted either mechanically or more commonly by *Culicoides* midges. About 20% of the cattle on every cattle farm in the UORC contracted the disease following heavy rains in 2000. At the time vaccine was not available, and the economic consequences were enormomous (Dr Rezin pers. comm., 2001). In 2001 sufficient vaccine was available, and most farmers vaccinated their cattle at a cost of R3 per head.

Three Day Stiff Sickness
Three Day Stiff Sickness is also a viral disease of cattle, transmitted either mechanically or more commonly by *Culicoides* midges. Most farmers vaccinate their cattle annually against this disease at a cost of R3 per head.

Blue Tongue
Blue Tongue is a debilitating and often fatal viral disease of sheep, transmitted by *Culicoides* midges. The disease is considered a moderate problem in the UORC. Although the vaccine is cheap (about R3 per sheep), it has to be administered three times to be effective (an initial vaccination and two boosters), and this makes it relatively expensive and labour-intensive.

Horse Sickness
Horse Sickness is a fatal viral disease of horses, transmitted by *Culicoides* midges. Most horse owners in the UORC take the disease very seriously, and vaccinate annually. Some owners also use insecticeds in an attempt to prevent infection. The vaccine costs R42 for three administrations (an initial vaccination and two boosters).

10.8 Crop Production

The Agricultural Resources Act (Nr. 43 of 1983) stipulates that crop production is not allowed on wetlands. In section 7 on the use and protection of vlei, marshes, water sponges and water courses, the Act stipulates that:

> Except on authority of a written permission by the executive officer, no land user shall-
> (a) drain or cultivate any vlei, marsh or water sponge or a portion thereof on his farm unit; or
> (b) cultivate any land on his farm unit within the flood area of a water course or within 10 m horizontally outside the flood area of a water course.

This prohibition shall not apply in respect of-

(a) a vlei, marsh or water sponge or a portion thereof that has already been drained or is under cultivation on the date of commencement of these regulations provided it is not done at the expense of the conservation of the natural agricultural resources; and

(b) Land within the flood area of a water course or within 10 m horizontally outside the flood area of a water course that is under cultivation on the date of commencement of these regulations, provided it is already protected effectively in terms of regulation 4 against excessive soil loss due to erosion through the action of water.

In addition, agricultural extension officers encourage farmers to only farm above the 100 year flood line surrounding wetlands. Given this one would hope that the conversion of wetlands that has occurred took place prior to the Act has ceased. Agricultural extension officers and National Department of Agriculture representatives believe that no, or highly limited, conversion still takes place (pers. comm., Gert Pool & David Kleyn). They believe that farmers comply with the Act and that it is adequately enforced. Furthermore, they point out that conversion was a significantly more attractive proposition when maize prices were far higher than their current levels. Given current prices and high input costs, farmers are generally only willing to cultivate the high potential soils not commonly found in wetlands. Nevertheless, whether farmers, and even extension officers, recognise some types of wetlands such as hillslope seepage wetlands as being wetlands is another matter, and we feel that it is highly likely that much of this habitat has been lost to agricultural conversion. Given that conversion is illegal, it was not possible to confirm the extent to which it has occurred through interviewing farmers.

10.9 Summary

The direct use values estimated above are summarised in Table 10.3 below. It appears that pans are the most valuable wetlands in terms of direct use value, followed by seepage wetlands and artificial wetlands. Riparian wetlands provide considerably less use value. The total value of the wetlands is estimated to be as much as R70 to 86 million per year.

Table 10.3. Estimated direct values of different types of wetlands to different user groups, given as Rands per ha per year.

Direct uses of different wetland types		Recreation & Tourism	Households, Traditional healers	Mines, Industry & power	Agriculture	TOTAL
Resource harvesting	Riparian floodplain		10-100			
	Riparian non-floodplain		10-100			
	Seepage		10-100			
	Pan		10-100			
	Artificial wetland		10-100			
Fishing	Riparian floodplain					
	Riparian non-floodplain					
	Seepage					
	Pan	276				
	Artificial wetland	1 690				
Bird-watching	Riparian floodplain	2				
	Riparian non-floodplain	2				
	Seepage	2				
	Pan	47				
	Artificial wetland	54				
Water for cattle	Riparian floodplain					
	Riparian non-floodplain					
	Seepage					
	Pan				20	
	Artificial wetland					
Grazing	Riparian floodplain					
	Riparian non-floodplain					
	Seepage				1800-2400	
	Pan					
	Artificial wetland					
Water storage	Riparian floodplain					
	Riparian non-floodplain					
	Seepage					
	Pan			2800		
	Artificial wetland					
Total	Riparian floodplain	2	10-100			10 – 100
	Riparian non-floodplain	2	10-100			10 - 100
	Seepage	2	10-100		1800-2400	1 800 – 2 500
	Pan	323	10-100	2800	20	3 100 – 3 200
	Artificial wetland	1 744	10-100			1 700 – 1 900

11. INDIRECT USE VALUES OF THE UORC WETLANDS

J. Turpie

The studies on wetland functioning were unable to provide quantitative estimates that could be used in a valuation study. This is largely because the study relied on desktop review and modelling rather than on measured values. The latter were not feasible due to the vast geographic area of the study. The main lesson learned here is that the valuation of ecosystem functions is complex and needs to be carried out on a smaller area such that appropriate fieldwork can be done. However, the preliminary findings of this study also indicate that the increasing tendency to accept some of the known values of wetlands as generally applicable needs to be challenged.

11.1 Water Purification

Wetlands are commonly considered to be highly valuable in that they perform a function of removing excess nutrients and inorganic pollutants produced by agriculture, industry and domestic waste (Rogers et al.,1985; Gren, 1995; Ewel, 1997; Postel & Carpenter, 1997). In so doing they perform a purification service that saves on purification costs of downstream water supplies, and prevent damage caused by polluted water. Despite this widely-held notion, extensive literature searches reveal that very few practitioners have actually quantified the purification capacity of wetlands. Moreover, it appears that this function is highly variable depending on the characteristics of the wetland. In this study, it was not possible to perform a nutrient balance study on any wetlands in the study area due to the complexity of the task, but considerable attention was paid to investigating the possible water purification function of the UORC wetlands. The preliminary conclusions reached were as follows:

- Artificial wetlands and pans do not remove nutrients – they are already nutrient rich systems in which nutrients are cycled and enter and leave the system, but in which there is unlikely to be a net change with the addition of surplus nutrients.
- Riparian systems and floodplains are not very efficient in nutrient removal because most water entering these systems has a short contact time with the vegetation, and most phosphates entering rivers is attached to the iron in soils.
- A small amount of nutrients may be removed in floodplain systems during high flow periods in summer.
- Seepage wetlands are the only types of wetlands in the UORC which are likely to remove significant quantities of excess nutrients, although this quantity is not expected to be particularly high.
- Although it appears that the water purification value of the wetlands may be low, the results of this largely desktop study were inadequate to draw conclusions about the actual value of this function.

11.2 Flow Regulation

Wetlands can play an important role in replenishing or recharging groundwater supplies (e.g. Thompson & Goes, 1997). This occurs when water percolates through the topsoil to the underlying aquifer. Alternatively, a wetland may act as a conduit for groundwater discharge, when water that has been stored underground comes up into a wetland and becomes surface water. This process is particularly common when wetlands are located at low points in the landscape. In high altitude catchment areas, wetlands are generally considered to collect precipitation, thereby preventing excessive downstream runoff in the rainy season and recharging groundwater supplies. Groundwater is then released into the catchment streams more gradually, and continues into the dry season. This serves to augment river flow during the period when streams may otherwise have dried up.

In this study, the presence of the wetlands was found to be inextricably linked to the groundwater of the UORC, but not exactly in the way described above. Although the exact relationship between them was difficult to determine, the implication is that the water is supplied to seeps and other types of wetlands from groundwater. This is analogous to the function described above as groundwater discharge, but we argue that the wetlands occur because of this and not *vice versa*. Our argument rests on the belief that the wetlands are often present because of a dyke formation, which intercepts groundwater flow and moves it to the surface. In this sort of situation, if the dyke was not present, the wetland would not exist, but the groundwater would continue to move gradually towards streams in any case. Thus the hydrology study concluded that the removal of wetlands from the study areas would probably not affect the hydrology to the extent that streamflow would be significantly affected. Undoubtedly some change in water flow patterns might occur, but it was impossible to model this within the scope of this study, due to a lack of understanding of the relevant hydrological movements.

11.3 Flood Attenuation

Natural wetlands are often cited as having a very important role in reducing damages from floods (e.g. Farber & Costanza, 1987; Gren, et al. 1994; Barbier et al., 1997). This is because wetlands store potential floodwaters, at least temporarily, and then release run-off more evenly, and wetlands in the upper catchment reduce floodwater peaks by ensuring that floodwaters from tributaries do not all reach the main river at the same time. Similarly, large floodplain wetlands may absorb a lot of the potential impact of floods by reducing the speed of flow and attenuating some of the peak flood.

This study made the preliminary conclusion that the wetlands in the UORC do not provide a flood attenuation function, but that they reduce flows slightly during low flow periods. The reason for this because wetlands largely exist due to the topography of the landscape and its underlying geology. Most of the seepage wetlands are points of water discharge rather than recharge. The drainage line wetlands are mostly very narrow and are thought not to have much attenuating capacity. The pans are not connected to streamflow. Thus in general, if the wetlands of the UORC were removed, e.g. replaced by maize fields or storage dams, it is estimated that there would be no change in the flooding of rivers within the study area or downstream.

It should be stressed that the modelling exercise did not consider other factors, such as the soil binding properties of floodplain vegetation (many being clonal with extensive rhizome systems), is important for protecting the floodplain soils and even the channel banks from erosion during flooding.

11.4 Sediment Trapping

Sediment trapping does occur in wetlands in the study area, but no information was available on silt loads, apart from the amount of sediment entering Witbank Dam. Without this information, it was impossible to model the loads of sediment that would be carried downstream into the dam if the wetlands did not exist in the catchment. Nevertheless, it was felt that due to the nature of the wetlands and the topography of the landscape, the wetlands probably do not play a major role in this regard.

11.5 Summary and Conclusions

The preliminary findings of this study provide a major deviation from general beliefs about the economic services provided by wetlands (e.g. Costanza et al., 1997; Ewell, 1997; Barbier, 1989) and illustrate the potential danger of transferring the benefits of one wetland system to another on the assumption that all wetlands provide similar goods and services (see Bergland et al., 1999).

The classification exercise in this study alone has demonstrated the wide variety of functional types of wetlands that occur in the UORC, and these are undoubtedly vastly different in function from many of the wetlands for which more accurate measures of functional value have been made. Almost without exception, existing studies on the indirect use values of wetlands concern very large systems such as the Hadejia-Nguru wetlands in Nigeria and Chesapeake Bay in the USA (Farber & Costanza, 1987; Hollis et al., 1993; Emerton, 1994; Barbier et al., 1997; Turpie et al., 1999).

Hydrology

Based on limited modelling and available data, it appears that the wetlands of the UORC have little impact on flow regulation or flood attenuation. Instead, it appears that *hydrological characteristics have a major impact on the wetlands*. It should be stressed that the modelling exercise did not consider other factors, such as the soil binding properties of floodplain vegetation (many being clonal with extensive rhizome systems), which is important for protecting the floodplain soils and even the channel banks from erosion during flooding.

Water Quality

The water purification functions of the wetlands in the UORC are considered to be limited to a small amount of removal of certain contaminants by seepage wetlands only, and their sediment retention function is unknown, but thought to be negligible. There is danger in citing these preliminary findings, as detailed data collection and modelling may still prove otherwise. Moreover, we have not investigated all possible values, such as carbon sequestration.

12. SYNTHESIS

J. Turpie & H. van Zyl

In this chapter we review the findings of this study regarding the importance of the UORC wetlands in terms of their biodiversity and their economic values. Conservation strategies have traditionally been based on biodiversity importance alone, but if these strategies are to be effective, then they need to be economically defendable and they need to address the ultimate as well as proximate threats to wetlands. We thus also consider the economic forces that threaten the wetlands, and compare the benefits of wetlands in their current state with the opportunity costs of their conservation. Finally, we discuss the implications of these findings for future conservation strategies for these wetlands.

12.1 Biodiversity Value of Wetlands

12.1.1 What is Biodiversity?

The Convention on Biodiversity defines biodiversity as *"the variability among living organisms from all sources including* inter alia, *terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are part; this includes diversity within species, between species and of ecosystems"*.

This is a rather narrow, almost species-based, structural, view of biodiversity. The term is now often used much more broadly to include functional diversity as well as structural diversity. For the purpose of this study, we stick to the above definition, but recognising that functionality arises out of this biodiversity. Indeed, although some of the benefits of wetlands to human societies are directly attributable to their biodiversity (in the sense of the above definition), in most cases, their value is attributed to their high productivity or the functioning of these ecosystems. However, both productivity and functioning of wetland ecosystems hinge upon their biodiversity.

12.1.2 Measurement of Wetland Biodiversity

Wetland inventories and databases are seen as a potentially important tool for determining priorities for conservation as well as evaluating the success of conservation actions (Frazier, 1997). Such inventories include measures of biodiversity. The measurement of biodiversity is a widely debated topic. It does not only include species lists as we have provided in this study, but should also consider species assemblages and abundance. However, the latter could only have been achieved with field studies, which fell beyond the scope of this study.

12.1.3 Biodiversity Values of the UORC Wetlands

Being a desktop study, this study was not able to make definitive statements about the biodiversity value of each wetland type, especially because little information exists in a form that could be generalised for the study area as a whole. The biodiversity associated with wetlands usually comprises common and widespread taxa. This is true for plants through to birds and mammals, and was reiterated by the findings of this study. It is therefore not expected that the wetlands of the study area harbour important populations of any particularly rare species, although several Red Data species do occur in the area. Nevertheless, wetlands, and the UORC wetlands are no exception, support a relatively high diversity of species, and being highly productive systems, are also capable of supporting large populations of these species.

The main biodiversity value of the UORC wetlands lies in the sheer abundance of wetland habitat in the region. In aggregate, the abundance of many taxa is likely to be very high, and since South Africa as a whole is a relatively arid country which is depauperate in wetlands, the wetlands of the highveld grassland areas of which the UORC forms a part, are likely to support a significant proportion of the national populations of many wetland associated species.

Taken alone, on the other hand, most of the wetlands are small and make a very small contribution to the whole. This is probably the single most important ecological factor that has promoted the degradation of the wetlands, which prove insignificant in environmental impact assessment studies. The UORC contains nearly 4 500 small wetlands (mostly under 10 ha) which form part of a larger ecological system. Indeed, at a larger scale, the study area forms part of an even more widespread system of pans, which spans the eastern Free State and Gauteng into Mpumalanga. Within this region, the UORC is one of the areas with the highest densities of pans. Single wetlands in this system cannot be said to house isolated populations for most taxa, and individuals within wetlands undoubtedly form part of a regional metapopulation. This is especially true for more mobile taxa such as birds. The total area of wetlands in the study area is some 65 000 ha. Compare this to conserved wetlands such as Lake Chrissie and Barberspan, both in the region of 1 050 ha (Allan & Brown, 1991; Allan et al., 1995). Thus if the wetlands of the study area were seen as a single system, they may be treated differently in terms of a conservation strategy.

Another factor that adds to the aggregate biodiversity value of the wetlands is their diversity of types, providing a high variety of wetland habitats. The fact that no less than 17 wetland types could be distinguished in the study area is of conservation significance alone. The relative value of the different broad categories of wetland types was roughly assessed in terms of different taxa. In general, pans are the most important type of wetlands, largely due to their seasonality in water level and variety of habitats. Riparian wetlands are the next most important category, followed by seepage wetlands. Artificial wetlands also support a relatively high diversity of taxa, but are not particularly important in terms of rare taxa.

12.1.4 Using Biodiversity Measures to Determine Conservation Priorities

There is much debate on setting priorities for biodiversity conservation. Some practitioners concentrate on identifying the species most at risk and ensure their protection, and this sort of approach has lent great importance to the naming of Red Data species. It is also argued that the protection of these species will ensure habitat and ecoystem protection; and the idea of protecting endangered species appeals to the general public. Other practitioners promote an ecosystem approach to conservation. Assemblages of species and changes in communities indicate stresses, and thus conservation strategies should target species assemblages as well as 'flagship' species.

Much progress has been made in the last decade with respect to this type of priority setting, with a general move away from excessive reliance on the hotspot approach, in which sites are rated according to the biodiversity, taking factors such as rare species into account, to a more sophisticated approach which takes irreplaceability, complementarity and connectivity into account. The latter approach achieves greater representation of biodiversity as well as improved viability. Used together, these approaches make powerful conservation planning tools. Ideally they require a greater understanding of biodiversity at the site level than this study has produced. A similar, but less efficient, result could be achieved by conserving a number of sizeable examples of each wetland types.

Wetland size is important as species need to be represented in sufficient quantities that their populations are viable for the next 500 years or so (there is an extensive literature on minimum viable populations). At this stage, however, we are not able to estimate how much of the wetland area should be conserved in order to maintain viable populations of the desired species. This is made all the more complicated because any species, and birds in particular, may depend on a whole suite of sites which are suitable for different functions or at different times of year. We are thus forced to adopt the precautionary principle, which is to conserve as much of the wetland area as possible until we have a better idea of how these systems work.

Finally, if it is accepted that the ecosystem is the basic unit for biodiversity conservation, then mention of the process and dynamics of ecosystems is perhaps unnecessary. However, it should be noted that, although we accept that functional aspects of wetlands are intricately linked to their biodiversity, inventories of wetland biota do not provide any information about their functional importance. This study therefore placed considerable emphasis on determining the latter.

12.2 Threats to the Wetlands: an Economic Perspective

12.2.1 Proximate versus Ultimate Threats

Despite increasing understanding of the biodiversity value of wetlands, many decision makers continue to think of wetlands as wastelands. Wetlands thus continue to be depleted at an alarming rate through conversion to what are considered as better alternate uses. Already, the global wetland estate has been reduced by half. A comparable proportion of the wetland area of the UORC is thought to be degraded or lost. Efforts to conserve wetlands require the type of information, understanding and prioritisation approaches described above. However, they should also address the fundamental forces that lead to the degradation and loss of wetlands if they are to be successful (Fillion, 1997).

This study identified numerous threats to the biodiversity of the UORC wetlands and to the wetland habitats themselves. These included the degradation of wetlands due to harvesting of resources, overgrazing, invasion by alien plants and animals, and the loss of wetlands due to cultivation, mining, quarrying and construction of dams and other infrastructure.

All of these threats are what we might call the proximate threats to wetlands. Conservation strategies have, in the past, mainly been concerned with such proximate threats. These have been addressed mainly through laws that protect the environment, such as provision of environmental flows and the requirement for environmental impact assessments before development. Wetlands continue to be degraded not because these laws are inadequate, but because conservation strategies have failed to identify and address the ultimate or underlying causes of wetland degradation and loss.

The underlying causes of these problems are mostly economic in nature. In simple terms, the actions associated with the proximate threats described above take place because the benefits realised by the actors are greater than the costs. The potential benefits of conversion are the opportunity costs of conservation, and the higher they are, the more rapidly a wetland is likely to be converted to its best alternative use. In following an economically rational approach, the actors may not, however, be acting in the interests of society as a whole, and this is very often the case. Thus, the underlying causes of wetland degradation include factors such as price distortions (subsidies and taxes, such as under-pricing of water for irrigation), income distribution inequalities, absence of full cost accounting, policy failures (such as policies promoting agriculture at the expense of conservation), market failures in that there are no facts on the value of wetlands, and lack of property rights. Any of these factors may make conversion of wetlands more attractive than conservation due to the apparent benefits of conversion being higher.

Conservation of wetlands has not been a priority in the UORC up until now due to some of the economic factors described below. We concentrate on agriculture and coal mining as the main threats to wetlands.

12.2.2 Agricultural Opportunity Costs

The presence of a wetland may preclude the use of the land for agricultural purposes. This represents an opportunity cost valued as the lost income that could have been generated by agriculture. The total value of this lost income can be estimated by calculating foregone yearly income for the long-term and generating a discounted present value of this income. There is, however, an easier way whereby land prices are simply used. This is possible as land prices generally reflect the expected future income streams from land in a well-functioning market. The following ranges of land prices for grazing and cultivated land give an indication of opportunity costs:

Poor quality grazing land:	R500 – R750 per ha
Good quality grazing land:	R750 – R1 000 per ha
Poor quality cultivated land:	R1 000 – R2 000 per ha
Good quality cultivated land:	R2 000 – R3 000 per ha

Given these ranges it seems sensible to assume that the average opportunity cost for wetlands that can be drained would be in the middle of the range of values for grazing land (i.e. R725 per ha) and the lower end of the range for cultivated land (R1 500 per ha).

12.2.3 Opportunity Costs Associated with Mining

Where coal mining is the next best use of a wetland area, property prices are an inadequate reflection of opportunity costs. This is because property prices only capture the value of the top layer of ground. For a true reflection one has to add the value of underground minerals reflected in the value of mineral rights. Note that using the gross income from coal would be an incorrect reflection of the true value of the resource as it would also capture the return to capital and labour required to extract and process the coal. The value of mineral rights is thus theoretically the best reflection of the returns from the resource itself.

In order to determine this, a value of mineral rights per hectare needs to be established and then multiplied by the number of hectares that are not mined due to the presence of a wetland. The value of mineral rights per hectare is highly variable because of the varying size, quality and ease of extraction of the deposits below each hectare of surface land. In addition, values can vary depending on the coal price and state of the coal market. Values can range from as low as 30c per ton of coal up to approximately R4 per ton representing a difference factor of 13. For the purposes of this study, R1 per ton was agreed upon as an acceptable average in consultation with Anglo Coal (pers. Comm., Johan Bloemsma, Anglo Coal). It was also agreed that each hectare in the study area would yield between 15 000 and 75 000 tons of coal with an average of approximately 45 000 tons of coal. This implies that the average hectare of wetland underlain by coal deposits has an opportunity cost of R45 000 (R1 per ton X 45 000 tons per ha) plus the agricultural value of surface land. To illustrate the substantial difference between using mineral rights values and gross income for coal to estimate values, the gross income of a hectare of coal was estimated by Anglo Coal to be between R4 million and R9 million.

It needs to borne in mind that these values are based on current and historical averages paid for mineral rights that are not likely to be accurate indicators of future values. In the past, private landowners (mostly farmers) sold their mineral rights directly to mining companies. In many cases they were in a weak bargaining position given their limited knowledge of the market for mineral rights compared to the knowledge of the mining companies. However, this is about to change as the Minerals Bill of South Africa that governs the sale of rights in being revised. Indications are that the new Bill will make the state the sole owner (and thus seller) of mineral rights. If anything, rights are likely to become more expensive when this happens as the state should be in a better position to negotiate better prices for mineral rights (pers comm., Xavier Prevost; Department of Minerals and Energy Affairs). This means that the estimates used here should increase in the future. Unfortunately, it was not possible to predict the magnitude of possible increases at this stage.

12.2.4 Wetlands are Cheaper to Mine

The costs associated with mining wetland areas are generally lower than the average for all land types. This is because wetlands are commonly found in low-lying areas where coal seams are closer to the surface and thus easier and cheaper to mine. The shallow seams associated with wetland areas means that the majority of mining in wetland areas is strip mining as this is the most economical way to mine shallower deposits. In the case of drainage costs, it may make intuitive sense that the presence of wetlands should drive them up and that they may offset extraction cost savings. However, this is not generally the case as drainage is needed for mines even in areas where there are no wetlands and even if drainage costs are higher they are seldom high enough to offset decreased extraction costs.

Lower average mining costs make wetland areas more sought after when considering what parts of a coal deposit to mine. This makes the likelihood of wetlands being mined around and conserved when underlain by coal low. In fact, if a wetland is mined around, a block of coal could become too expensive to mine on average, as the main reason for keeping overall costs low (i.e. the presence of a wetland) would be gone.

12.3 Economic Values of the UORC Wetlands

12.3.1 Rationale for Valuation

This study has concentrated on one of the many underlying causes of wetland degradation and loss in the UORC - the lack of understanding of full value of wetlands – which is in many ways, precipitates several of the other underlying problems, such as policy failure. Economic valuation of the unmeasured wealth of goods and services that wetlands provide to people is considered to be an essential instrument in countering the forces leading to degradation and loss (Fillion, 1997). Valuation can be used to set new priorities, rationalise new investments in wetland conservation, remove perverse incentives, internalise the costs of wetland losses, for justifying regulations, setting appropriate fines and revising policies which lead to overuse, land conversion and pollution (Fillion, 1997).

12.3.2 Values of the UORC Wetlands

This study provides a preliminary assessment of the current direct use value of the UORC wetlands. The wetlands are known to be used for harvesting of natural resources such as medicinal plants and sand, for recreational activities such as birdwatching and fishing, they provide water and fodder for cattle, and they provide a water storage facility for mines. Our estimates of these values are rough, but preliminary estimates indicate values of up to R2 500 per ha for Seepage wetlands, and up to R3 250 per ha for pans. Riparian wetlands are probably worth much less than this, but artificial wetlands are relatively valuable, especially for recreational fishing, with estimated values of up to R1 850 per ha. In present value terms (calculated at an 8% discount rate), the land value of wetlands (using upper bound estimates) is thus approximately R1 000 per ha for riparian wetlands, R25 000 per ha for Seepage wetlands, R32 000 per ha for pans, and R18 200 per ha for artificial wetlands. Based on our rough estimates, the wetlands of the UORC could generate as much as R70 to 86 million per year in terms of direct use value.

The indirect use value of the wetlands could not be estimated in monetary terms due to the desktop nature of this study and required complexity involved in making such estimates. The UORC wetlands may be of considerable value to downstream users. Dams in the middle and lower catchments are dependent on run-off from the UORC, which is augmented in part by the wetlands. Similarly purification of these water supplies may be obviated to some extent by the presence of these wetlands. Thus while the value to users within the catchment may be estimated to some extent, the value on a broader scale is still unknown and may be far greater.

This study did not attempt to estimate the existence value of the UORC wetlands due to the extensive resources required for a Contingent Valuation or similar stated-preference valuation study. However some general comments can be made on the likely magnitude of this value. The existence value of wetlands or any such amenity is strongly linked to the awareness of their existence as well as to the amount of knowledge about them (e.g. Turpie, 1996). Few people are probably aware of the existence of the UORC wetlands, and these are probably largely restricted to the population of the immediate area. Indeed, it is likely that several inhabitants of this area may not have noticed the wetlands. Environmental awareness is generally low among South Africans, and even among those that know of the wetlands, it is likely that very few people actually know anything about them, such as their ecological function within the landscape or the biodiversity that they contain. It is probable that the existence value is therefore low. Moreover, because the wetlands are so numerous, the existence value of any particular wetlands is likely to be very low. It is probable that pans have a greater existence value than other types of wetlands as they are most noticeable, as is their biodiversity, notably birdlife.

12.4 Implications for Wetland Conservation

12.4.1 The Value of Conservation versus Conversion of Wetlands

Because wetlands make a contribution to society, their values need to be accounted for in development processes. The most effective approach in a world driven by economic growth is to demonstrate the economic values of wetlands, and to build these values into the planning process so that they receive due consideration. However, certain values are intangible – that is a monetary value cannot be assigned to them, and there are other issues that make it difficult to estimate values in monetary terms.

The comparison of valuation and opportunity cost results in a cost-benefit framework that can provide valuable guidance for land use decisions. If the value of conserving wetlands is higher than the opportunity cost of developing them, then conversion to other land uses is not advisable. If, however, the value of conserving wetlands is lower than the opportunity cost, then conversion should be considered further. The results of this partial valuation study suggest that, although conservation of wetlands is generally more valuable that conversion to agricultural use, conversion to mining may often be the most beneficial course of action for most wetlands.

However, it would be incorrect to base decisions solely on a comparison of incomplete total values with opportunity costs. It is also important to compare the correct types of values. For instance, the water storage value of wetlands cannot be considered to be included in the value of conservation since this service only accrues to the mining industry. In other words, the value is only realised when the conversion to mining option is taken so it cannot be used to argue that conservation is preferable to conversion to mining.

This and numerous other valuation studies show that attaching a value to conserved areas is more complex and difficult than calculating opportunity costs. In addition to clarity on whether valuation results are reasonably accurate reflections of total value, the strategic land use planning objectives of an area need to be considered in any decision involving possible conversion of wetlands. The results of valuation exercises are not intended to replace these objectives in the decision making process, but rather to provide decision makers with additional information to aid decision making. Bearing in mind the probable under valuation of wetlands in this study, it is best to adopt the precautionary principle as far as conversion of wetlands is concerned.

12.4.2 The Optimal Amount to Conserve

Most of the values presented above are average values. Similarly, the biodiversity values discussed in this study are generalised for each wetland type. Average values such as those presented in this study cannot be used to make conservation planning decisions for the study area. Decisions must be based on marginal costs and benefits, rather than averages. In reality, both the biodiversity values and economic values of wetland differ from wetland to wetland, and the aggregate value will depend on the state of the wetland system as a whole. These differences in value should be taken into account when making decisions about individual wetlands, and in devising a strategy for conservation of the wetlands in the whole study area. Thus the costs and benefits of conserving each additional hectare of wetland will differ depending on how much has been conserved already. A point may be reached where the opportunity costs of conservation start to outweigh the benefits, and conversion is acceptable. This is the point at which the optimal amount of wetland will have been conserved.

Recognising that the opportunity costs also differ from wetland to wetland, it makes sense to allow conversion of those wetlands for which the opportunity costs of conservation are high and the (non-monetised or monetised) biodiversity value is low, and to promote conservation where the opposite is true. Where the conservation value of the wetlands is relatively low in monetary terms, as seems to be the case in the UORC, there could be excessive pressure for conversion if this is the only criterion for decision- making. Following the precautionary principle, it is still necessary to conserve a large enough area of wetlands to maintain the integrity of the system and the viability of its populations.

12.5 Rehabilitation

The conversion of a wetland to mining does not necessary lead to the total loss of the wetland in perpetuity. Rehabilitation is possible, although usually to a poorer quality wetland than existed previously. If a certain proportion of the ecosystem function of the rehabilitated wetland can be restored then the losses in value associated with this proportion should only be regarded as a loss for the period during which they remain un-rehabilitated.

As a condition of closure, mines are required by law to rehabilitate mined land back to its previous potential when mining ceases (The Mines Act of 1991). Agricultural and other land capability is determined before mining starts and rehabilitation is designed to recreate the same proportion of land capability classes after mining. This is a relatively easy task in the case of rehabilitation to a relatively 'simple' state such as poor quality grazing land. It is, however, seldom possible in the case of better quality agricultural land and some loss in agricultural potential is usually accepted (e.g. arable land becomes grazing land). Post rehabilitation soil potential can still be affected through changes in soil structure, soil compaction, water holding capacity, acidity levels, salinity levels, lower carbon (organic) content and other changes in soil chemistry.

The Agricultural Research Commission (ARC) is currently conducting trials investigating the viability of growing maize on rehabilitated coal mine soils at three mines in Mpumalanga. Preliminary results indicate that maize could hardly be produced economically with long-term average rainfall and only in special cases could half of previous yields be achieved (Prinsloo & Erasmus, 1998; Jan Schoeman, Agricultural Research Commission, 1999 pers. comm. in Van Zyl et al. 1999).

Previous research funded by the Water Research Commission (Nell & Steenkamp, 1998) found that soil compaction or high bulk density was a problem in the majority of rehabilitated soils adversely affecting root development and plant growth. As in the case of the loss of agricultural potential, the rehabilitation of wetlands seldom results in wetlands that are as rich in biodiversity, or reflect the same or similar biodiversity, when compared to their pre-mining condition.

Rehabilitation costs per hectare are highly variable and depend on the degree of rehabilitation required, topography and the current state of the land cover. They generally range between R100 000 and R200 000 per hectare. The highest costs at a maximum of R200 000 per ha are generally associated with rehabilitation to arable land where a topsoil of at least 700 mm is required. Rehabilitation to grazing land requires a topsoil of between 300 and 600 mm and generally entails maximum costs of R175 000 per ha. The costs associated with rehabilitation back to wetlands tend to fall between those associated with rehabilitation to arable land and grazing land (pers. comm., Biellie van Zyl, Anglo Coal). However, these are not the costs associated with rehabilitation to a pristine state with original level of species diversity. These costs are likely to be higher, but are difficult to estimate given that rehabilitation to this state is not generally required.

Mines are required to rehabilitate land beyond the point where externalities no longer occur. However, rehabilitation beyond this point cannot be justified from a purely economic cost-benefit perspective if its costs cannot be covered by the use or sale of rehabilitated land. When comparing the current average rehabilitation cost of between R100 000 and R200 000 per ha to the average price of agricultural land in the mining areas of R500 to R3 000 per ha it becomes obvious that the extra money mining companies are spending on complete rehabilitation is likely to far outstrip the future productive value of the land. Thus although the strategic decision by the Department of Agriculture to maintain as much land as possible for agriculture is understandable from a purely agricultural perspective, the high costs it imposes may not be leading to optimal overall environmental benefits.

It could be argued that a system that achieved greater overall environmental improvement for South Africa for each Rand spent would be worth considering. This system could require the same financial commitments from mining companies as they make currently for full rehabilitation, but then only require them to rehabilitate areas enough to ensure no externalities occur while maintaining aesthetic standards. The remaining funds could be used for other environmental improvements where the money would be used more cost effectively (i.e. more environmental bang for your buck). These could include a variety of improvement such as wetland rehabilitation or environmental clean-ups that are more urgently needed than, for example, re-establishing the agricultural potential of land (something which has not been successful in the case of arable land anyway). In this way the benefits from the 'debt to society' owed by coal mining companies in the form of rehabilitation expenditure could be optimised.

12.6 Summary and Conclusions

The biodiversity value of the UORC wetlands lies in its diversity and the abundance of different species in the system. The diversity and abundance stems from the wide variety of types of wetlands in the area as well as the large overall size of the wetlands. Most of the 4 500 wetlands are very small, and taken alone might be considered insignificant. However, the wetlands and their populations are very much part of a larger functioning ecosystem, which extends beyond the borders of the study area. The wetland area totals 65 000 ha, a considerable area of wetlands which deserves conservation attention. Conservation planning needs to take irreplaceablity, complementarity and connectivity of the wetlands into account. Thus, ideally, more detailed data on individual wetlands is required in order to set conservation priorities in an efficient manner. An ecosystem approach is needed so that functional processes as well as structural diversity are taken into account.

Conservation strategies also have to address threats. The wetlands and their biodiversity are threatened by numerous activities, the most important of which are mining and agriculture conversion. These are proximate threats to wetlands, and are addressed in various ways, particularly through legal protection. However, the ultimate threats must be recognised and addressed, and these are largely economic issues which distort the perceived benefit of conversion or degradation of wetlands relative to the cost. In this study we only address one of these, which is the understanding of the full economic value of wetlands.

Wetland conservation currently carries one of two alternative opportunity costs, depending on the location of the wetland. In agricultural areas, wetlands conversion is worth between R725 and R1 500 per ha. In areas underlain by coal deposits, the opportunity cost of conservation is at least R45 000 per ha using conservative estimates. These benefits, together with the fact that it is cheaper to mine in wetlands than in other land types, all fuel the loss of wetlands in the UORC.

A crude estimate was made of wetland values in this study, but the estimates suggest that, despite the wetlands having little or no indirect use value, their direct use values are not insubstantial. Excluding the potential for water storage, the average direct use value of wetlands is estimated to be R1000 to R25 000 per ha in present terms. This suggests that conservation is often more beneficial than agricultural conversion, but that where wetlands are underlain by coal, mining is more beneficial. However, since this is only a partial valuation it is not possible to draw any firm conclusions.

The optimal amount to conserve and the decision of which wetlands to conserve will need to be decided on the basis of individual values rather than average values, as considerable variation is to be expected between wetlands. Because of the difficulties in monetising all value, the precautionary principle should also still apply, in that enough wetland area should be conserved to maintain ecosystem integrity and viable populations. Planning decisions should also take into account the fact that wetlands can be rehabilitated after mining, albeit to a poorer than initial state. However, the costs of this rehabilitation are difficult to justify in terms of the values estimated in this study.

13. CAPACITY BUILDING

P-L. Grundling, & A. L. Grundling

13.1 Secondary Schools

13.1.1 Phase 1: The Teachers

The first phase of the secondary schools capacity building programme for this project involved introducing the project to both the principal of Elukhanyisweni Secondary School in Witbank, Mrs Buyi Nkosi, and C R Swart Mosstrosity Environmental Enviro Club in Pretoria. This took place during two meetings held in March 2001. Both parties welcomed the interaction and pledged their full support to the project.

This was followed by a one-day Teachers Symposium at Colbyn Valley Wetland. The symposium was arranged for teachers of the Elukhanyisweni Secondary School at the Colbyn Valley Wetland. The teacher's backgrounds included Geography, Biology and Life Skills. The purpose of this symposium was to:

- introduce the teachers to the Mosstrosities Wetland Project;
- to install an understanding and appreciation for wetlands among teachers; and
- to assist teachers in identifying and supporting interested learners.

The symposium took place on the 12 April 2001 in the Scout Hall next to the Colbyn Valley Wetland. The following parties attended:

8 Teachers	- Elukhanyisweni Secondary School
11 Learners	- Mosstrosity Environmental Impact Study Group
Anette van Heerden	- Friends of Colbyn
Mr Cain Chunda	- DWAF (Part of the lecture team
Mr Calvin Chirwa	- Afridev (Part of the lecture team)
Mr Mpho Nanngambi	- WFW (Guide)
Mr Eric Munzhedzi	- WFW (Guide)
Mr Piet-Louis Grundling	- Ihlaphosi Enviro Services (Lecture team)
Mrs Althea Grundling	- Ihlaphosi Enviro Services (Lecture team)

The one-day Symposium was very successful and both the Mosstrosities and teachers benefited from the event. The Mosstrosities were excited to visit the Elukhanyisweni Secondary School and the teachers decided to give them their whole-hearted support in creating a Wetland Awareness Programme at their school. The outing into this wetland was definitely a highlight (Figure 14.1). Remarks from the teachers varied from "informative and inspiring" to "empowering and challenging".

13.1.2 Phase 2: The Learners

The second phase of the capacity building concentrated on creating awareness amongst the learners of the Elukhanyisweni Secondary School in Witbank and a field visit to wetlands in the catchment. Learners of the two schools were introduced to each other on the first day of this exercise on 15 August, 2001 (Figure 14.1).

Figure 14.1: Learners of the Elukhanyisweni Secondary School and learners of Mosstrosity Environmental Group at the Elukhanyisweni Secondary School.(Photo by P.L. Grundling.)

Mirelle van Heerden of the Mosstrosity Environmental Impact Study Group (C.R. Swart High School) shared their experiences at the Colbyn Valley Wetland. Learners of both schools divided into two mixed groups to visit the local wetland after a wetland information section in the form of a slide show and practical demonstrations.

The field visit to the local Lynnville wetland and the Kaal Spruit wetland, a *Phragmites* dominated wetland, took the shape of an outcome based practical assignment. Each learner had to complete an activity sheet on the day's activities at the wetland (Figure 14.2). The learners had to define the wetland and catchment boundaries, and described wetland vegetation, uses and threats.

Figure 14.2. A combined group of Elukhanyisweni Secondary School and of the Mosstrosity Environmental Group filling in activity sheets. (Photo by P.L. Grundling.)

The second day of the Witbank visit (16 August 2001) was spent in the upper Olifants River Catchment. The purpose of this catchment visit was to introduce the learners to the different types of wetlands and land uses in the UORC.

Forty learners from both schools, as well as 4 teachers from Elukhanyisweni Secondary School amongst other, the principal, Mrs Buyi Nkosi attended the catchment field trip. The route took the group from Witbank towards Van Dyks Drift, Greenside and via Phoenix back to Witbank. Various types of wetlands were visited and discussed, including a shallow burnt valley bottom peatland, a pan and the Witbank Dam.

The day was a big success and was ended off with a light lunch in Witbank. However, the best reflection of the success of this awareness and capacity campaign was the rewarding contributions that the learners of the Elukhanyisweni Secondary School made in the week following the visit. These included amongst others:

- A scale model of a traditional hut built with "pseudo-wetland" vegetation, and its own wetland.
- Various wetland related posters, hand painted and drawn by the learners. These posters reflect channelled and urban wetlands and the Olifants River in a multi-landuse setting.
- Various essays on wetlands, the Upper Olifants River project and expressions of gratitude from the projects contribution to the enrichment of their life experiences and wishes for the project to continue at their school. This is a sentiment that is strongly

echoed by the principal and all of us from the project that were involved in the awareness and capacity building exercises.

13.2 Tertiary Level Students

Tertiary level students who participated in the project included the following:

- Mr Chirwa attended the initial field visit and meeting of specialists, and assisted with the stakeholder meeting. He also spent one week at the CSIR assisting with the digitising and preparation of the maps, and learning about GIS modelling. He prepared a hand-written report on what he had learnt about wetlands during this time. Mr Chirwa's appointment to this project, as with all other team members, was on a part-time basis only. However, in August 2001 he indicated that he had found alternative employment, and was no longer available to assist with the wetlands project.
- Two students from the University of Venda participating in the Wetland Rehabilitation projects of Working for Water Programme, Mr Eric Munzhedzi and Mr Mpho Nanngambi, participated as field guides during the excursion of the Colbyn Wetland.
- Mr Cain Chunda of Department of Water Affairs and Forestry (DWAF), Nelspruit, was invited and participated in the first Wetland Awareness Meeting between the Teachers of the Elukhanyisweni Secondary School (Witbank) and the Learners from C R Swart High School (Colbyn Valley Wetland). Mr Chunda intends to use the wetlands in the UORC as the focus of his Masters thesis in Water Management with University of Pretoria.

13.3 Technology Transfer

Members of the study team attended and introduced this project to the following meetings and organisations during the course of the project:

- International Association of Impact Assessors (Witbank, May 2000)
- Controlled Release Scheme (SACE Recreation Club, May 2000)
- Banke Farmers Union Meeting (Middelburg, September 2001)
- Matla Coal Environmental Forum (Matla Mine, December 2001)

14. RECOMMENDATIONS

14.1 Recommendations for Management and Policy Formulation

14.1.1 Strategic Environmental Management Plan

It is recommended that a Strategic Environmental Management Plan should be developed for the UORC. The central component to such a plan would be active involvement of key Stakeholders in setting environmental objectives and priorities, and addressing environmental policy and regulatory failure. A key component to such a plan would be the development of a conservation plan specifically for wetlands, in which wetlands would be zoned in terms of their ecological importance, future uses and threats. The plan should be based on an ecosystem approach to conservation, in which irreplaceablity, complementarity and connectivity of the wetlands are taken into account.

The present study has provided a basic framework for such a plan, but more detailed studies are needed to evaluate and categorise the different wetland types according to their current status, ecological and economic values, key threats and management needs. This will require more detailed understanding of the key drivers, functions, biodiversity values and uses of each wetland type.

14.1.2 Monitoring

It is strongly recommended that appropriate environmental and social indicators should be developed to monitor conditions in the catchment. In particular, indicators designed specifically for the wetlands of the UORC should be developed, and a monitoring plan that details the aims, frequency and distribution of monitoring should be developed and implemented as part of the Environmental Management Plan.

14.2 Rehabilitation

We suggest that some of the money that is spent on rehabilitation of mining areas in the UORC could be used more effectively for other more critical environmental improvements that are urgently needed in the catchment, such as wetland and river rehabilitation. This means that the standards that are set for rehabilitation could be relaxed, but in doing so, the 'debt to society' owed by coal mining companies in the form of rehabilitation expenditure could be optimised.

14.3 Recommendations for Future Research

14.3.1 Biodiversity

We recommend further studies should investigate the processes underlying the formation, maintenance and dynamics of plant species diversity of wetlands in the UORC, particularly in relation to groundwater and the variability in surface water supply and quality in pans. Attention should also focus on the reasons for the considerable degree of local and regional variability in plant species composition among and within the different wetland types. Understanding the processes underlying this will assist in the development of rehabilitation methods, assist in ecological Reserve determinations for these systems, and help in predicting and mitigating the impacts of water abstraction or storage by mines.

14.3.2 Mass Balance

We recommend that a mass balance approach should be used to understand the water quality dynamics in wetland systems. Particular attention should focus on the water quality dynamics of pans in the UORC, the extent to which they leak, and the ecological implications of using them to store mine water.

14.4 Further Inventories

The present study has provided valuable insights into the functions and values of wetlands in the UORC. It is recommended that similar inventories of wetlands are undertaken in other priority catchments that are under threat as a result of water resource or other developments or activities (e.g. the wetlands in the adjacent Wilge River Catchment).

14.5 Recommendations for Capacity Building

The present study generated considerable interest among teachers and children living within the catchment. It is recommended that this interest and enthusiasm should be encouraged by the following activities:

- Assisting the Elukhanyisweni Secondary School in the establishment, management and expansion of their own Environmental Group;
- Assisting with the development of an environmental library/centre at the school and to forward any information on wetland and environmental related subjects;
- Surveying the Lynnville Wetland in the Kaal Spruit, near the school, for rehabilitation and job creation purposes in the community around the Elukhanyisweni Secondary School;
- Expanding the awareness and capacity building exercises to other schools in the UORC;
- Awarding prizes to the best posters/essays or models that have been produced and/or written by the learners after the wetland programme; and
- Monitoring the success of the programme over a limited period of time to ensure their self-confidence and own growth.

Furthermore, we recommend that future emphasis should be placed on building capacity within relevant regulatory institutions and other organisations, and in doing so, narrow the gap between environmental policy and its implementation.

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16. APPENDICES

Appendix A. Details of quaternary sub-catchments in the UORC

The table below lists the quaternary subcatchments in the UORC, their respective sizes, Mean Annual Precipitation (MAP), Mean Annual Evaporation (MAE), and naturalised (virgin) Mean Annual Runoff (MAR), and the average annual sediment yeild per catchment. [Data from Midgley *et. al.* (1994).]

Quaternary sub-catchment		Area (km^2)	MAP (mm)	MAE (mm)	Gross MAR ($x10^6$ m^3 / annum)	Sediment Yield (1000 t/a)
B11	**Olifants**					
B11A	Olifants: Headwater	945	699	1 550	36,8	43
B11B	Olifants: Middelkraal	435	687	1 550	15,7	20
B11C	Steenskoolspruit: headwater	385	673	1 550	12,8	18
B11D	Trichardspruit: headwater	551	671	1 600	16,6	25
B11E	Rietspruit: headwater	467	682	1 600	15,1	21
B11F	Tweefonteinspruit	428	692	1 600	14,7	19
B11G	Olifants: Witbank Dam	368	693	1 600	13,2	17
B11H	Spookspruit	246	695	1 600	8,9	11
B11J	Olifants: Aasvoelkrans	269	682	1 650	13,1	12
B12	**Klein Olifants**					
B12A	Klein Olifants: Headwater	405	672	1 500	10,6	18
B12B	Klein Olifants: Arnot	659	697	1 550	18,5	30
B12C	Klein Olifants: Middelburg Dam	529	707	1 550	15,8	24
B12D	Klein Olifants: Middelburg	362	703	1 600	13,8	16
B12E	Klein Olifants: Lower	436	697	1 650	22,9	20
	TOTAL	**6 485**			**228,5**	**294**

Appendix B. 1996 National Land-cover / Land use in the UORC.

Land-cover / Land use type	Number of occurrences	Area (ha)	% of Area
Cultivated: temporary - commercial dryland	511	238 797	36,8
Cultivated: temporary - commercial irrigated	45	1 957	0,3
Forest and Woodland	1	140	0,02
Forest plantations	413	15 487	2,4
Improved grassland	23	1 952	0,3
Mines & quarries	81	33 205	5,1
Thicket & bushland (etc)	33	5 732	0,9
Unimproved grassland	94	333 429	51,4
Urban / built-up land: commercial	1	49	0,01
Urban / built-up land: industrial / transport	11	1 198	0,2
Urban / built-up land: residential	36	8 501	1,3
Urban / built-up land: residential (small holdings: grassland)	1	758	0,12
Waterbodies	352	5 772	0,9
Wetlands	76	1 635	0,25
TOTAL	**1 678**	**648 613**	**100,0**

Appendix C. Land use encroachment on wetlands in the UORC.

J. Muller

Land-cover / land use type	Number of Occurrences	Area (ha)	% Area
Cultivated: temporary – commercial dryland	1 228	149 514	34,9
Cultivated: temporary – commercial irrigated	45	1 070	0,2
Forest and Woodland	1	140	0,0
Forest plantations	375	5 617	1,3
Improved grassland	26	1 163	0,3
Mines & quarries	155	16 190	3,8
Thicket & bushland (etc)	44	2 177	0,5
Unimproved grassland	529	241 183	56,3
Urban / built-up land: industrial / transport	13	465	0,1
Urban / built-up land: residential	54	3 331	0,8
Urban / built-up land: residential (small holdings: grassland)	1	621	0,1
Waterbodies	340	5 548	1,3
Wetlands	72	1 527	0,4
TOTAL	**2 883**	**428 547**	**100**

Appendix D. Land use encroachment per wetland type in the UORC.

J. Muller

Land-cover	Wetland Type											
	Artificial			Channelled Riparian Wetlands			Crest Seepage Wetlands			Drainage lines with riparian zones		
	# Poly	Area (ha)	% Area	# Poly	Area(ha)	% Area	# Poly	Area(ha)	% Area	# Poly	Area(ha)	% Area
Cultivated:Temporarily-commercial dryland	6	1901.00	1.1	24	8260	**5.1**	1	41	**0.03**	280	96730	**29.31**
Cultivated:Temporarily-commercial irrigated	1	31.00	0.0	0	0	0.0	0	0	0.00	3	146	0.04
Forest & Woodland	0	0.00	0.0	0	0	0.0	0	0	0.00	0	0	0.00
Forest Plantation	2	16.00	0.0	0	0	0.0	0	0	0.00	49	1446	0.44
Improved Grassland	5	354.00	0.2	0	0	0.0	0	0	0.00	3	271	0.08
Mines & Quarries	8	5067.00	**3.1**	5	1706	1.0	0	0	0.00	28	8388	2.54
Thicket & Bushland	3	318.00	0.2	1	39	0.0	0	0	0.00	8	1131	0.34
Unimproved Grassland	16	158115.00	95.2	9	152315	93.5	2	142250	99.97	112	218620	66.25
Urban/Built-Up Land: commercial	0	0.00	0.0	0	0	0.0	0	0	0.00	0	0	0.00
Urban/ Built-Up Land: residential	2	262.00	0.2	4	471	0.3	0	0	0.00	6	1316	0.40
Urban/built-up: residential(small holdings:grassland)	0	0.00	0.0	0	0	0.0	0	0	0.00	1	621	0.19
Urban/Built-Up Land: industrial/transport	0	0.00	0.0	0	0	0.0	0	0	0.00	2	187	0.06
Waterbodies	6	64.00	0.0	9	71	0.0	0	0	0.00	90	1154	0.35
Wetlands	0	0.00	0.0	0	0	0.0	0	0	0.00	0	0	0.00
TOTAL	**49**	**166128**	**100.0**	**52**	**162862**	**100.0**	**3**	**142291**	**100.00**	**582**	**330011**	**100**

Appendix D continued…

Footslope seepage wetlands			Midslope seepage wetlands			Valleyhead seepage wetlands			Seepage wetlands associated with pans			Seasonally inundated non-channelled valley bottom floodplain			Permanently wetpans		
# Poly	Area(ha)	% Area	# Poly	Area(ha)	% Area	# Poly	Area(ha)	% Area	# Poly	Area(ha)	% Area	# Poly	Area(ha)	% Area	# Poly	Area(ha)	% Area
104	47860	**19.30**	135	73751	**25.79**	50	29090	**14.24**	21	18235	**9.77**	4	4499	**3.07**	37	29650	**14.88**
3	81	0.03	1	44	0.02	0	0	0.00	0	0	0.00	0	0	0.00	0	0	0.00
0	0	0.00		0	0.00	0	0	0.00	1	140	0.08	0	0	0.00	0	0	0.00
8	191	0.08	9	309	0.11	7	137	0.07	2	186	0.10	0	0	0.00	4	101	0.05
2	158	0.06		0	0.00	0	0	0.00	0	0	0.00	0	0	0.00	0	0	0.00
12	3573	1.44	7	3038	1.06	0	0	0.00	4	577	0.31	0	0	0.00	7	1237	0.62
6	471	0.19	1	153	0.05	1	66	0.03	0	0	0.00	0	0	0.00	0	0	0.00
43	193322	77.95	74	207887	72.69	31	174980	85.65	23	167037	89.51	1	141971	96.93	32	166590	83.62
0	0	0.00		0	0.00	0	0	0.00	0	0	0.00	0	0	0.00	0	0	0.00
2	115	0.05	1	42	0.01	0	0	0.00	0	0	0.00	0	0	0.00	0	0	0.00
1	621	0.25	1	621	0.22	0	0	0.00	0	0	0.00	0	0	0.00	0	0	0.00
1	121	0.05		0	0.00	0	0	0.00	0	0	0.00	0	0	0.00	0	0	0.00
32	1470	0.59	13	90	0.03	3	7	0.00	16	242	0.13	0	0	0.00	57	1103	0.55
1	36	0.01	1	45	0.02	1	19	0.01	11	199	0.11	0	0	0.00	29	541	0.27
215	**248019**	**100**	**243**	**285981**	**100**	**93**	**204299**	**100**	**78**	**186616**	**100**	**5**	**146470**	**100**	**166**	**199222**	**100**

Appendix D continued…

Non-channelled riparian wetlands wetlands			Wet Grasslands			Temporarily to seasonally inundated channelled valley bottom floodplain			Seasonally inundated valley bottom floodplain without footslope seepage wetlands			Seasonally inundated channelled valley bottom floodplain wetlands with footslope seepage wetlands			Non-permanent wetpans		
# Poly	Area(ha)	% Area	# Poly	Area(ha)	% Area	# Poly	Area(ha)	% Area	# Poly	Area(ha)	% Area	# Poly	Area(ha)	% Area	# Poly	Area(ha)	% Area
4	3228	**2.22**	4	362	0.24	5	2473	**1.69**	3	3208	**55.60**	80	35602	**18.71**	146	78112	**27.96**
0	0	0.00	0	0	0.00	1	51	0.03	0	0	0.00	2	76	0.04	1	52	0.02
0	0	0.00	0	0	0.00	0	0	0.00	0	0	0.00		0	0.00		0	0.00
0	0	0.00	0	0	0.00	1	22	0.02	1	26	0.45	6	120	0.06	16	978	0.35
0	0	0.00	0	0	0.00	0	0	0.00	0	0	0.00		0	0.00	1	62	0.02
0	0	0.00	1	2281	**1.54**	2	385	0.26	1	646	11.20	1	41	0.02	6	3155	1.13
0	0	0.00	0	0	0.00	0	0	0.00	0	0	0.00		0	0.00	1	25	0.01
2	142139	97.78	2	145266	98.21	2	143428	98.00	2	1873	32.46	3	153897	80.90	79	194915	69.77
0	0	0.00	0	0	0.00	0	0	0.00	0	0	0.00		0	0.00		0	0.00
0	0	0.00	0	0	0.00	0	0	0.00	1	17	0.29	2	217	0.11	1	112	0.04
0	0	0.00	0	0	0.00	0	0	0.00	0	0	0.00		0	0.00	1	621	0.22
0	0	0.00	0	0	0.00	0	0	0.00	0	0	0.00		0	0.00		0	0.00
0	0	0.00	0	0	0.00	0	0	0.00	0	0	0.00	21	289	0.15	36	373	0.13
0	0	0.00	0	0	0.00	0	0	0.00	0	0	0.00	0	0	0.00	37	954	0.34
6	**145367**	**100**	**7**	**147909**	**100**	**11**	**146359**	**100**	**8**	**5770**	**100**	**115**	**190242**	**100**	**325**	**279358**	**100**

Appendix E. List of aerial photographs used for wetland mapping

The year, job and print numbers of the black and white aerial photograph prints used in the wetland survey of the upper catchment area of the Olifants and Klein Olifants Rivers. The scale of the photography and prints was 1:50 000.

Year	Job	Strip	Prints
1991	951	7	6056, 6058, 6060, 6062, 6064, 6066, 6067, 6069, 6071, 6072, 6074, 6676
		8	5063, 5065, 5067, 5069, 5071, 5073, 5075, 5077, 5079, 5081, 5083, 5085
		9	2049, 2051, 2053, 2055, 2057, 2059, 2060, 2062, 2064, 2065, 2067, 2069, 2071
		10	1216, 1218, 1220, 1222, 1224, 1226, 1228, 1230, 1232, 1234, 1236
		11	7031, 7030, 7032, 7033, 7034, 7035, 7036, 7037, 7038, 7039, 7040, 7041, 7042, 7044, 7046, 7047, 7048, 7049, 7050, 7051, 7052
		12	5027, 5029, 5031, 5033, 5035, 5037, 5039, 5041, 5043, 5045, 5047
		13	110, 112, 114, 116, 118, 120, 122, 124, 126, 128, 130, 132
		14	2080, 2082, 2084, 2086, 2088, 2090, 2092, 2094, 2096, 2098, 2100, 2102, 2104
1991	952	1	4204, 4206, 4208, 4210, 4212, 4214, 4216, 4218, 4220, 4222, 4224, 4226
		2	4044, 4045, 4047, 4049, 4051, 4053, 4055, 4057, 4059, 4061, 4063, 4065
		3	4076, 4078, 4080, 4082, 4084, 4086, 4088, 4090, 4092, 4094, 4096, 4097
		4	5057, 5058, 5060, 5062, 5064, 5066, 5068, 5070, 5072, 5074, 5076, 5078, 5080
		5	0051, 0052, 0054, 0056, 0058, 0060, 0062, 0064, 0066, 0068, 0070, 0072, 0074
		6	0085, 0087, 0089, 0091, 0093, 0095, 0097, 0099, 0101, 0103, 0105, 0107, 0108
		7	5094, 5096, 5098, 5100, 5102, 5104, 5106, 5107, 5108, 5110, 5112, 5114, 5116
		8	3053, 3055, 3057, 3059, 3061, 3063, 3065
		9	3113
		10	1048

Appendix F. Natural resource use questionnaire to farmers

J. Turpie

Interviewer:________ Farm No:_____
Farm name:_________________ Date:______ GPS position__________

Hello, my name is _________ and this is my student ____________. We are doing a study on the wetlands in this area, looking at their conservation value and the various uses that they are put to, and part of our study is to try and estimate the value of these wetlands to farmers like you, as well as to other members of society. We ultimately hope to make recommendations about which wetlands or types of wetlands should be conserved, and which would be better put to alternative uses. Would you mind if we ask you a few questions about how you and others use the wetlands on your property? – it shouldn't take very long.

1. Perhaps we could start by asking you to show us the extent of your farm(s) on this map. Please draw in the farm boundaries (*remember to mark farm name and number on mapped area*)
2. What is the total area of your farm?____________ha
3. Roughly how much do you have in the way of wetland areas (anything from seep areas to large pans)________ha
4. How much of your farm is under the following (in ha):
   a. Crops (name and ha): 1. _______ - ___ha. 2. _________ - ___ha 3._________ - _____ha
   b. Planted pastures (name and ha) 1. __________ - __ha 2. _________ - _____ha
   c. Fallow fields _________ha
   d. Natural pastures______________.ha
5. What yields do you get per ha (in a normal year) for the main crops? ______________, ______________
6. If you plant in wetland/marshy/boggy areas, what sort of yields do you get as compared with normal yields on drylands?_______________________
7. What percentage of your crop area and pasture area is in wetland areas? Crop:_________ Pasture________
8. What livestock do you have (numbers)?____
9. What percentage of time do your cattle spend grazing in wetland areas?_____________
10. What percentage of livestock watering takes place at boreholes:_____dams:___natural pans:_____other:___
11. What proportion of your hay comes from natural wetlands:_____ planted wetlands:_____ irrigated pastures:_______other(explain):________________

12. Does anyone use the wetlands for fishing, birdwatching or hunting? Y / N (*If yes*): please give details:

Fishing on the farm wetlands and rivers

13. Number of fishing days per year by farmer and his family and friends___________ (*add up people x days fished*)
14. Number of fishing days per year by others: _______________________ (*rough estimate is OK*)
15. Where do the latter fishers come from?______________________________
16. Payments made by outsiders?______________________
17. What fish are targeted? ___________________________________
18. Any details on where fishing is best, relative amounts of time spent fishing in different localities/types of wetlands?____

Birdwatching on farm wetlands

19. Number of birdwatching days per year by farmer and his family and friends___________
20. Number of birdwatching days per year by others: _______________________ (*rough estimate is OK*)
21. Where do the latter birders come from?_____________________________
22. Payments made by outsiders?______________________
23. Are any bird species sought in particular? __________________________________
24. Any details on where birding is best, relative amounts of time spent birding in different localities/types of wetlands?____

Bird hunting on farm wetlands

25. Number of bird hunting days per year by farmer and his family and friends___________
26. Number of bird hunting days per year by others: _______________________ (*rough estimate is OK*)
27. Where do the latter hunters come from?_____________________________
28. Payments made by outsiders?______________________
29. Which species are targetted? ______________________________
30. Any details on where hunting is best, relative amounts of time spent hunting in different localities/types of wetlands?____

(*If outsiders do use the farm for any of the above*)

31. Do you have paying guesthouse accommodation for outsiders?_Y / N

(*If yes*):

32. What is your annual occupancy (total bed nights/y) __________ and price R______pppn.
33. Roughly what percentage of bednights are for fishers____birders_____hunters______other______

The next set of questions is about harvesting of wetland resources such as plants by your family, the farm labourers and others.

<u>34.</u> Do you/your family/friends harvest any other resources from the wetlands such as reeds, sand or such like? <u>Y/N</u>

(If yes) Please give details on what you have harvested and rough quantities harvested over the last year.

Resource	Unit (*e.g. kg, 50cm bundles*)	Units harvested	Time taken per unit	Price per unit	Purpose
Reeds					
Grass (/hay)					
Sand					
Clay					
Food plants					

35. Do the labourers harvest resources from the wetlands for their own use, such as reeds, fish, medicinal plants? Y / N
36. Do you think you could give a rough estimate of what and how much is harvested? (*fill in table*)

Resource	Unit	Units harvested	Time taken per unit	Price per unit	Purpose
Reeds					
Grass					
Sand					
Clay					
Food plants					
Medicinal plants					
Mammals					
Birds					

37. Are these activities carried out with your permission/blessing? ____________
38. Would it be alright if we also verify this estimate by interviewing some labourers? ___(*If Y, follow up after*)
39. How many labourers are there on the farm?_________How many families_________ Total people____

40. Do outsiders come onto the property to harvest any resources from the wetlands? Y / N
41. (If yes) Please could you estimate roughly what and how much you think was harvested over the last year.

Resource	Unit	Units harvested	Time taken per unit	Price per unit	Purpose
Reeds					
Grass					
Sand					
Clay					
Food plants					
Medicinal plants					
Mammals					
Birds					

42. How much were you remunerated for the above harvests?_______________

That's all! Thanks very much for your time.

Appendix G. Contact details of Study Team and Stakeholders, including meeting attendees and people and groups that were interviewed, grouped according to main interests.

	Organisation	Name		Tel.	Cell.	Fax.	Address			e-Mail	Notes
	STUDY TEAM										
1	AfriDev Consultants	Palmer	RW	013 7511533	0825744486	013 751 1533	PO Box 4349	White River	1240	Afridevr@iafrica.com	Project Leader and aquatic invertebrates
2	Wetland Construction Services	Batchelor	AL	012 349 2437	082 789 0718		PO Box 72295	Pretria	0001	En.eng@smartnet.co.za	Water Quality
3	CSIR	Muller	J	012-841 3992		012 841 2028	Po Box 395	Pretoria	0001	jmuller@csir.co.za	GIS
4	CSIR	Vink	D	012-841 3992		012 841 2028	Po Box 395	Pretoria	0001	dvink@csir.co.za	GIS
5	Freelance Consultant	Jacobsen	NHG	0448 770309			PO Box 671	Wilderness	6560	jvl@lantic.net	Amphibians, reptiles & mammals
6	Freelance Consultant	Turpie	J	021-650 3302	082 459 5960	021-650 3295	Fitzpatrick Institute UCT	Rondebosch	7701	jturpie@botzoo.uct.ac.za	Resource Economics & birds
7	Ihlaphosi Enviro Services	Grundling	P-L	012 253 1787		083 231 3489	P.O. Box 912 924	Silverton	0127	peatland@mweb.co.za	Capacity Building
8	Ihlaphosi Enviro Services	Grundling	A	As above			As above			As above	Capacity Building & Surveys
9	Independent Economics Researchers	Van Zyl	H	021-423 0633	082 5784148		PO Box 1015	Green Point	8015	hugovz@mweb.co.za	Economics
10	Mpumalanga Parks Board	Engelbrecht	J	013-235 1673	083-6266303	013-235 1674	P Bag X 1088	Lydenburg	1120	jseng@cis.co.za	Fish
11	Wates, Meiring & Barnard	Coleman	T	011 254 4882	083 447 2003	011 315 0317	PO Box 6014	Halfway House	1685	trevorc@sanda.co.za	Hydrology
12	Wates, Meiring & Barnard	Matthews	G	011 254 4882		011 315 0317	PO Box 6014	Halfway House	1685		Hydrology
13	Wetland Consulting Services	Marneweck	GC	012 349 2699	083 287 4082	(012) 349 2993	PO box 72295	Lynwood Ridge	0040	wetlandgm@smartnet.co.za	Wetland inventory & classification

	AGRICULTURE										
1	Agriculture: Witbank	Bosch	GJ				POSBUS 340	WITBAN K	1035		
2	Agriculture: Witbank	Botha	JH				POSBUS 525	OGIES	2230		
3	Agriculture: Witbank	Brugman	N				POSBUS 1130	WITBAN K	1035		
4	Agriculture: Witbank	Cronje	AJ				POSBUS 241	OGIES	2230		
5	Agriculture: Witbank	De Burto	PJ				POSBUS 414	OGIES	2230		
6	Agriculture: Witbank	De Lange	AHJ				POSBUS 2274	WITBANK	1035		
7	Agriculture: Witbank: Rand Sent Boedery	De Villiers	EKW		082 757 5384	013 656 9414	POSBUS 13	BLACKHILL	1032		Attended second meeting
8	Agriculture: Witbank	De Villiers	F				POSBUS 13	BLACKHILL	1032		
9	Agriculture: Witbank	De Villiers	HJB				POSBUS 963	WITBANK	1035		
10	Agriculture: Witbank	Du Preez	JT				POSBUS 2	BLACKHILL	1032		
11	Agriculture: Witbank	Ehler	JG				POSBUS 1401	WITBAN K	1035		
12	Agriculture: Witbank	Enslin	I				POSBUS 166	OGIES	2230		
13	Agriculture: Witbank	Enslin	RP				POSBUS 166	OGIES	2230		
14	Agriculture: Witbank	Erasmus	AS				POSBUS 443	OGIES	2230		
16	Agriculture: Witbank	Erasmus	P				POSBUS 128	OGIES	2230		
17	Agriculture: Witbank	Farrel	JFJ				POSBUS 12	OGIES	2230		
18	Agriculture: Witbank	Gerber	CG				POSBUS 595	WITBANK	1035		
19	Agriculture: Witbank	Grobler	JM				POSBUS 94	KEN DAL	2225		
20	Agriculture: Witbank	Hanekom Broers					PQSBUS 222	OGIES	2230		
21	Agriculture: Witbank	Hertzog	JBM				POSBUS2	BALMORAL	1037		
22	Agriculture: Witbank	Keet	DL				POSBUS 968	WITBANK	1035		
23	Agriculture: Witbank	Krige	WA				POSBUS 1528	WITBANK	1035		
24	Agriculture: Witbank	Ludik	WJ				POSBUS 14072	LERAATSFONTEIN	1038		
25	Agriculture: Witbank	Naue	JS				POSBUS 36	BALMORAL	1037		
26	Agriculture: Witbank	Prinsloo	GDF				POBUS 355	DELMAS	2210		
27	Agriculture: Witbank	Prinsloo	MJ				POSBUS 45	KENDAL	2225		
28	Agriculture: Witbank	Prinsloo	PJ				PoSBUS 225	OGIES	2230		
29	Agriculture: Witbank	Prinsloo	ST				POSBUS 152	OGIES	2230		
30	Agriculture: Witbank	Rademan	JJ				POSBUS 3039	WITBANK	1035		
31	Agriculture: Witbank	Res	BG				POSBUS 150	KENDAL	2225		
32	Agriculture: Witbank	Roets	WSJ				POSBUS 156	OGIES	2230		
33	Agriculture: Witbank	Scheffer	HJ				POSBUS 245	WITBANK	1035		
34	Agriculture: Witbank	Smith	E				POSBUS 113	OGIES	2230		
36	Agriculture: Witbank	Steenkamp	EKW				ROSBUS 2360	WITBANK	1035		
37	Agriculture: Witbank	Stoltz	JGG				POSBUS 170	OGIES	2230		
39	Agriculture: Witbank	Truter	CH				Posbus 505	OGIES	2230		

40	Agriculture: Witbank	Truter	JE				POSBUS 21	OGIES	2230		
41	Agriculture: Witbank	Van Aardt	JDV				GOEDVERIROUD	BALMORAL	1037		
42	Agriculture: Witbank	Van der Merwe	J				POSBUS 3178	WITBANK	1035		
43	Agriculture: Witbank	Van Eeden	CJJ				POSBUS 10	VOLTARGO	2226		
44	Agriculture: Witbank	Van Jaarsveld	SVJ	013-686 9524		013 686 9524	POSBUS 21	COALVI LLE	1033	friends@fast.co.za	Attended first meeting
45	Agriculture: Witbank	Van Rooyen	AM				POSBUS 1545	WITBANK	1035		
46	Agriculture: Witbank	Velthuys	A				POSBUS 341	WITBANK	1035		
47	Agri-SA	Smith	Gert	013-690 1130	082 891 3176		PO Box 677	WITBANK	1035		Interviewed
48	Bombardie Boedery	Sullwald	Werner	013 643 2503	082 331 0823	013 643 2000	P Box 187	Ogies	2230	Sullwald@mweb.co.za	Interviewed and attended second meeting
49	Dept. Agriculture, Middelburg	Pool	Gert	013-282 4826							
50	Dept. Agriculture, Pretoria	Lindeque	Lehman	012-319-6000		012-329 5938	P Bag X120	Pretoria	1000		
51	Dept. Agriculture, Pretoria	Bagoga	Lydia (Mrs)	012-319-7634		012-329 5938	P Bag X120	Pretoria	1000	Ldiab@nda.agric.za	Attended second meeting
52	Middelburg District Agricultural Union:	Erichsen	Vilhelm	013-2456 1753	083 229 1315		PO Box 2609	Middelburg	1050		
53	Middelburg District Agricultural Union: Banke	?					PO Box 660	Middelburg	1050		Interviewed
54	Middelburg District Agricultural Union: Banke	Cloete	PG	013 243 8122			Leeupoortjie				Interviewed
55	Middelburg District Agricultural Union: Banke	Grobler	Hennie	013-245 9303			PO Box 717	Middelburg	1050		
56	Middelburg District Agricultural Union: Banke	van Rensburg	Johan		083 229 8844			Lammerkop			Interviewed
57	Middelburg District Agricultural Union: Broodsnyersplaas	Schoeman	Jannie	013-291 5501	083 2513 42		PO Box 345	Middelburg	1050		
58	Middelburg District Agricultural Union: Hendrina	Scheepers	Hannes				PO Box 49	Hendrina	1095		
59	Middelburg District Agricultural Union: Hendrina	van Wyk	Christi	013-296 1922			PO Box 137	Hendrina	1095		
60	Middelburg District Agricultural Union: Mpumalanga Agricultrual Union	Erichsen	Kallie	013-243-4794	082 388 3550	013 282 6381	PO Box 1012	Middelburg	1.050		Interviewed
61	Middelburg District Agricultural Union: Selonsrivier	Heyl	Johan	013-282 6531			PO Box 4013	Middelburg	1050		

62	Middelburg District Agricultural Union: Selonsrivier	Nell	Kosie	013-245 4103			PO Box 1643	Middelburg	1050		
63	Middelburg District Agricultural Union: Stoffberg	Botha	Marius	013-2712-2111			PO Box 10	Stoffberg	1056		
64	Middelburg District Agricultural Union: Stoffberg	Roux	Danie	013 2712 2602			PO Box 15	Stofberg	1056		
65	Middelburg District Agricultural Union: Transvaal Agricultural Union	van Heerden	Susan	013-243 1460		013-243 1461	PO Box 2010	Middelburg	1050		
66	Middelburg District Agricultural Union: Transvaal Agricultural Union	Van Zyl	JJ (Koos)			013-243 8767	PO Box 3688	Middelburg	1050		
67	National Department of Agriculture	Kleyn	David	012-319-7560	082 329 5938	012-329 5938	P Bag X120	Pretoria	1000	davidkl@nda.agric.za	Attended first meeting
68	National Department of Agriculture	Swemmer	PR	012-319 7554		012-3295 938	P Bag X120	Pretoria	1000	philips@nda.agric.za	Attended first meeting
69		Bosman	Adolf		083 484 6802		PO Box 1271	Bethal			Interviewed
70		de Lange	Botha				PO Box 167	Hendrina	1095		Interviewed
71		Kadish	Max								Interviewed
72		Nell	Dries					Rietvlei			Interviewed
73		Vollmer	AAC	013 246 7025							Interviewed
74	Beestepan Boerdery	Kane-Berman	Peter	013 297 1670	082 801 7792	013 297 1670	P Bag X 251836	Middelburg	1050		Interviewed
75	Cosmos Place Farm Guesthouse										Interviewed
COMMUNITY											
76	?Bacodi	Mathebe	Ace (MJ)	013-934 4449	083 477 6552		PO Box 933	Dennilton	1030		Attended first meeting
77	Group for Environmental Monitoring	Hlabane	M	013-656 0502						envmongr@wn.apc.org	
INDUSTRY											
78	Columbus	Scurr	Peter	013 247 2357		013 247 3377	PO Box 133	Middelburg	1050	Scurr.peter@columbus.co.za	

ENVIRONMENT											
79	Clean Stream Environmental Services	Erasmus	Mrs A	013-697 5021		013-697 5021	PO Box 647	WITBANK	1035	daines@mweb.co.za	Attended first and second meeting
80	Clean Stream Environmental Services	Scheepers	N	012-993 1863		012-993 1863	Durr Straat 433	Waterglen		Attended second meeting	
81	DACE, Nelspruit	Batchelor	Garth	013-759 4112			P Bag X11233	Nelspruit	1200	keyart@global.co.za	
82	DACE, Nelspruit	de Beer		013-759 4087	083 275 0521	013-759 4015	P Bag X11233	Nelspruit	1200	bdbeer@nel.mpu.gov.za	Attended first meeting
83	DEAT	Cowan	Geoff							nat_geof@ozone.pwv.gov.za	
84	DEAT - Wetland Conservation Programme	Moloto	Mmakoma	(012) 310 3495		(012) 320 7026	P Bag X447	Pretoria	0001	Mmoloto@ozone.pwv.gov.za	
85	DEAT - Wetlands Conservation Programme	Dini	John	012-310 3789		012-320 7026	P Bag X447	Pretoria	0001	jdini@ozone.pwv.gov.za	Attended first meeting
86	DWAF - IWQS	Kleynhans	Neels							nels@xsinet.co.za	
87	ECO SUN	Rall	J&V	(011) 315 8064		(011) 672 0666				rall@global.co.za	
88	Highlands Crane Group	Catterall	Shawn							crane@ewt.org.za	
89	Highlands Crane Group	Morrison	Kerryn	082 877 5126						kerryn@ewt.org.za	
90	Mpumalanga Parks Board	Linstrom	Anton	013-2352 395/7			PO Box 4442	Lydenberg	1120	cyperus@xsinet.co.za	
91	Wildlife & Environment	Lindley	David	(011) 486 3294			31 Oxford St	Linden	2104	wetfix@icon.co.za	
92	Witbank Fishing Club	Bresler	JR								Interviewed
93	Letaba Tourism	Prinsloo	Nico							tourist@tzaneen.co.za	Would like to be kept informed
MINING											
94	Kleinkopje Colliery	Joubert	A C	(013)693 0113		(013) 691 9415; PO Box 2851		Witbank	1035	cljoubert@coal.anglo.co.za; Attended Second Meeting	
95	Anglo Coal	Bloemsma	JP	011 6385291		011 638 4044	PO Box 61587	Marshaltown		Jbloemsma@angloamerican.co.za	Attended second meeting
96	Anglo Coal	Aken	Mark	(013)691 9006	083 2296 840	(013)691 9139	P. Bag X9	LERAATSFONTEIN	1038	maken@coal.anglo.co.za	Attended first meeting
97	Anglo Coal	de Jager	Kirsten	013-693-0156		013-691-9415				kdejager@coal.anglo.co.za	
98	Anglo Coal	Ritchie	DC	013 691 5173		013 691 9200; P Bag 9		Leraatsfontein	1038	Critchie@coal.anglo.co.za; Attended second meeting	
99	Anglo Coal	Lodewijks	Henk	(011) 638 3168		(011)6382645; PO Box 61587		Marshalltown	2107	hlodewijks@angloamerican.co.za; Attended second meeting	
100	Anglo Coal	Salmon	Dave	(013)691 9006		(013)691 9139		P Box 9 Leraatsfontein	1048	dasalmon@coal.anglo.co.za; Attended second meeting	

101	Anglo Coal	Tanner	Phil	(013) 691 9006		(013)691 9139				pdtanner@coal.anglo.co.za	
102	Anglo Coal	van Zyl	H C	(011)638 3630		(011)638 2901				bvanzyl@anglo.co.za; Attended second meeting	
103	Anglo Coal	Wakerman	W			(031)654 4064					
104	Arnot	Amos	G	(013)297 8021		(013)297 8029				gamos@coal.anglo.co.za	
105	Arnot	Hartzenberg	R	(013)297 8201		(013)297 8264				r.hartzenberg@coal.anglo.co.za	
106	Arnot	Schoeman	Lourens	(013)297 9084		(013)297 9142				schoem.lb@eskom.co.za	
107	Delmas	Mostert	E	082 651 2439		(012)667 2545				Omostert@pixie.co.za	
108	Department of Minerals & Energy	Webb	Elmien	(013) 656 1448		(013) 690 3288					
109	Dorstfontein Coal Mine	Spendler	Mike	(011) 472 0686		(011) 472 0700					
110	Duhva	Meintjies	P	(013)690 0200		(013)690 0168				Petrus.meintjies@eskom.co.za	
111	Duiker	Bartholomew	Graham	011-644 7000		011-484 2882	PO Box 1146	JHB	2000	graham.bart@jhb.duiker.co.za	
112	Goedehoop Colliery	Donaldson	K	013 691 5172		(013)687 5426		P Bog X9, Leraatsfontein	1038	kdonaldson@coal.anglo.co.za	
113	Kriel	Mokgwajana	BM	017 617 1123				PO Box 3310 Kriel		B.Mokgwajana@coal.anglo.co.za	Attended second meeting
114	Goedehoop Colliery	Garner	R	(013)687 5329	082 922 6350	(013) 687 5426				rgarner@coal.anglo.co.za	Interviewed
115	Goedehoop Colliery	Lake	James	(0135)687 5329		(0135)687 5426				Jlake@coal.agnlo.co.za	
116	Greenside Colliery	Hurburn	Vassi								Interviewed
117	Hendrina PS	Klopper	Jana	(013)296 3578		(013)296 3688				Janaklopper@eskom.co.za	
118	Impunzi Colliery	Wessels	Piet	(013)690 5081		(013)690 5062					Interviewed
119	Ingwe	Dippernaar	Kobus								Interviewed
120	Ingwe	Henderson	Piet	(011)376 2297		(011)834 2017				PietH@ingwe.co.za	
121	Ingwe	Naudé	Chris	082 902 0602 / 013 6833165		(013)683 3156				ChrisN@ingwe.co.za	
122	Ingwe	van Zyl	Morné	(013)683 3148		(013)683 3156				mornévz@ingwe.co.za	
123	Ingwe	Viljoen	Jaap	(011)376 2195		(011)824 3299				jaapv@ingwe.co.za	
124	Ingwe (Douglas Colliery)	Bloy	SD	013-687 5162		013-687 1028	Douglas Colliery	Vandyksdrift	2245	stevenbl@ingwe.co.za	Attended first meeting
125	Ingwe (Douglas Colliery)	Kleynhans	Jaco	(013)687 5162		(013)687 1028				JacoK@ingwe.co.za	
126	Ingwe (Douglas Colliery)	Eksteen	Ms							Marietjie.eksteen@bhpbilliton.com	
127	Ingwe (Matla Coal)	Ferraira	A	(017) 616 2233		(017) 616 2620					
128	Ingwe (Matla Coal)	Nengovhela	L M	(017)616 2233		(017)616 2605	PO Box X5006	Kriel	2271	LucasN@ingwe.co.za	Attended meetinmg and Interviewed

129	INGWE Rietspruit Mine	Ryciak	R	(013)688 6241		(013)688 6480					
130	Khutala	Hodge	K	(013)648 5009		(013)648 1423				kenh@ingwe.co.za	
131	Kleinkopje	Christie	Angus	(013)693 0135 / 082 331 0460		(013)691 9426				achristie@coal.anglo.co.za	
132	Kleinkopje	Ncina	Jerome	(0135)913 3137		(0136)91 9415				WarrenV@coal.anglo.co.za	
133	Kleinkopje/Greenside	Lambert	Warren	(013)693 0116		(013)691 9415				WVlambert@coal.anglo.co.za	
134	Koornfontein	Busby	Clive	(0132)95 5008		(0132)95 3185				Clive82@ingwe.co.za	
135	Kriel Colliery	McMillan	David.	017 617 1118		017 648 3910				DMcmillan@coal.anglo.co.za	
136	Kriel	Lamb	AJ	(017) 617 01241		(017) 648 3910				alamb@coal.anglo.co.za	
137	Kriel	Leibrandt	P	(017)615 2947		(017)615 2973				Pierre.leibrandt@eskom.co.za	
138	Kriel	Prinsloo	Erika	(017) 615 2369		(017)615 2326				ErikaPrinsloo@eskom.co.za	Interviewed
139	Middelburg	Cronjé	Jannie	(013)249 3271		(013)243 1352				JannieC2@ingwe.co.za	
140	Middelburg Mine Serv.	Dooge	N	(013) 249 3313		(013)243 1352	PO Box 1672	Middelburg	1050	nicodo@ingwe.co.za	Attended first meeting
141	Optimum	Cogho	Vik	(013)296 5030		(013)296 5108				Vikc@ingwe.co.za	
142	Rietspruit	van Vuuren	GJ	(013)688 6241		(013)688 6584				GerhardJV@ingwe.co.za	
143	SASOL	van Tonder	DJJ		082 497 4423					dean.vantonder@sasol.com	Attended first meeting
144	Syferfontein	Botha	Bertie	(017)614 5539		(017)614 5769		P Bag X1015 Secunda		Bertie.botha@sasol.com	Attended first and second meeting
145	Tweefontein Colliery	Swanepoel	Jan	(013)686 3541		(013)686 9592					
146	WMB	Fraser	Max	(011)442 4888		(011) 4448206				marynaf@barlows.com	
147	SASOL	Smith	Carol	017 613 2043		P Bag X 506		Trichardt		Carol.smith@sasol.com	Attended second meeting
148	Woestalleen	Jones	R	(013)246 6809		(013)246 6808					

POWER

149	Arnot P/S	Schoeman	Lourens	013 297 9084	082 686 0059		Arnot				Interviewed
150	Eskom	Netch	A	011 800 6140		011 800 5555	PO Box 1091	JHB	2000	Alfred,netch@eskom.co.za	Attended second meeting
151	Eskom	Bothma	Riana	(011) 800 4622		(011)800 4622	PO Box 1091	JHB	2000	riana.bothma@eskom.co.za	Attended first and second meeting
152	Eskom	Conlin	B	(011)629 5430		(011)629 5528				Barry.conlin@eksom.co.za	
153	Eskom	Courtney	Trevor			(011)800 4522				trevor.courtney@eskom.co.za	
154	Eskom	du Plooy	AD (Dani	011-800-5554		011-800 5559	PO Box 1091,	JHB	2000	danie.duplooy@eskom.co.za	Attended first meeting

			e)								
155	Eskom	Naidoo	S iven	(011)629 5414		(011)629 5291				Siven.niadoo@eskom.co.za+K69	
156	Eskom	Nieman	J	017-612 9270			Matla Power Station				Attended first meeting
157	Eskom	Pather	V	(011) 800 4897		(011) 800 4522				vasanie.pather@eskom.co.za	
158	Eskom	Ramokolo	John							John.Ramokolo@eskom.co.za	
159	Eskom	Steeneveldt	Deirdre	(011) 800 4788		(011)800 4522				deirdre.steeneveldt@eskom.co.za	
160	Eskom (Duvha)	Govindasamy	Verny	013 690 0320							Interviewed
161	Eskom (Duvha)	Thomson	Vivienne	(013)690 0320		(013)690 0168	PO Box 2199	WITBANK	1035	vivienne.thomson@eskom.co.za	Attended first meeting
162	Eskom (Kriel)	Nolan	E	(017)615 2369		(017)615 2326				elmien.nolan@eskom.co.za	
163	Eskom (Megawatt Park)	Hoffman	H	(011) 800 3713		(011) 800 4522				heine.hoffman@eskom.co.za	
164	Eskom (Hydro & Water)	Hanekom	D	011 800 4482		011 800 4522, PO Box 1091		JHB	2000	Derik.hanekom@eskom.co.za	Attended second meeting
165	Ingwe (Matla)	Dalton	M elanie	(017)612 6307		(017)612 6651				melane.dalton@eskom.co.za	Interviewed
TEACHING											
166	Elukhanyisweni Secondary School	Buthelezi	Busisiwe	013 699 1207							
167	Beestepan High School	Jackson	Owen	013 297 1697							Interviewed
168	Elukhanyisweni Secondary School	Mabele	Angel	082 682 2265							
169	Elukhanyisweni Secondary School	Mabimela	Lala	082 730 3342							
170	Elukhanyisweni Secondary School	Makuse	Dimakatso	082 7408101							
171	Elukhanyisweni Secondary School	Maphosa	Levy	082 295 0992							
172	Elukhanyisweni Secondary School	Ntobizethu	Masina	082 226 17455							
173	Elukhanyisweni Secondary School	Ranape	Masina	083 7655 409							
174	Elukhanyisweni Secondary School	Twane	Simon	082 5194298							

WATER

175	DWAF	de Jager	Morné	(012)672 2995		(012)672 2936				Vco@dwaf-nuc.pwv.gov.za	
176	DWAF	Havenga	Beyers	012 336 8594		012 336 8295	P Bag X 313	Pretoria	0001	havenga@ibm.net or havenga@dwaf.gov.za;	Attended second meeting
177	DWAF	de Plessis	Ms V							dei@dwaf.pwv.gov.za	
178	DWAF	Maré	Johan	(012)672 2948		(012)672 2936				vcg@dwaf-nuc.pwv.gov.za	
179	DWAF	Schwab	Rod	(012)338 7512		(012)323 0321				tce@dwaf.pwv.gov.za	
180	DWAF	Viljoen	P	(012)338 7514		(012)323 0321					
181	DWAF	Weston	Barbara							ded@dwaf.pwv.gov.za	
182	DWAF: IWQS	Thirion	Christa	012 808 0374		012 8080338	P Bag X313	Pretoria	0001	eec@dwaf-hri.pwv.gov.za	Attended first meeting
183	DWAF: Nelspruit	Colyn	Alta	(013)752 4183		(013)755 1678	P Bag X11259	Nelspruit	1200	colyna@dwaf.mpu.gov.za	Attended first meeting
184	DWAF: Nelspruit	Ligthelm	Magda	(013)752 4183 / 082 806 0699		(013)755 1678	P Bag X11259	Nelspruit	1200	ligthelmm@dwaf.mpu.gov.za	
185	DWAF: Chief Engineer, Gauteng	Botha	Rens	012-672 2961	082 808 9560	012-672 2987	P Bag X8007	Centurion	0046	vbc@dwaf-nuc.pwv.gov.za	
186	DWAF: D: SES	du Plessis	Valerie							dei@dwaf.pwv.gov.za	Would like to be kept informed
187	DWAF: D: SES	Geraldine	Munro								Would like to be kept informed
188	DWAF: Nelspruit	Dowling	Anthea	(013)752 4183		(013)755 1678	P Bag X11259	Nelspruit	1200	dowlinga@dwaf.mpu.gov.za	Attended first meeting
189	DWAF: Nelspruit	Fourie	Naomi (JC)	013 759 7417		013 752 5270	P Bag X11257	Nelspruit	1200	FourieN@dwaf.mpu.gov.za	Attended second meeting
190	DWAF: Nelspruit	Lizamore	Morné				P Bag X11259	Nelspruit	1200	LizamoreM@dwaf.mpu.gov.za	Attended second meeting
191	DWAF: Water Quality Management: Mines	Postma	Blanche	(012)338 7511			P Bag X313	Pretoria	0001	tcf@dwaf.pwv.gov.za	Would like to be kept informed
192	DWAF: Water Resources Planning	Jezewski	W A	(012)338 8605		(012)338 8295	P Bag X313	Pretoria		lgf@dwaf.pwv.gov.za	Attended first meeting
193	DWAF: Working for Water Programme	Poulter	Tony		0832 573 9870		PO Box 4341	White River	1240	Water@soft.co.za	
194	Ikangala Water	Mtsweni	PE	013-933 3763			P Bag X10576	Bronkhorstspruit	1020	ikangala@netactive.co.za	

Appendix H. List of plant species

G. C. Marneweck

The table lists indigenous and exotic plant species that have been reported in each of the major wetland types in the UORC. This list is based mainly on species lists from various studies and reports listed in the appendix, and is not comprehensive.

Species	Non-floodplain riparian	Floodplain Riparian	Seepage wetlands	Pans	Artificial wetlands
Pteridophyta					
Azolla filiculoides				X	
Typhaceae					
Typha capensis	X	X		X	X
Poaceae					
Agrostis continuata				X	
Agrostis eriantha	X		X	X	
Agrostis eriantha var. eriantha	X	X		X	
Agrostis lachnantha var. lachnantha	X	X	X	X	X
Alloteropsis semialata				X	
Andropogon appendiculatus		X			
Andropogon eucomis	X			X	
Andropogon huillensis	X			X	
Andropogon schirensis				X	
Aristida congesta				X	
Aristida congesta subsp. barbicollis				X	
Aristida congesta subsp. congesta				X	
Aristida diffusa subsp. burkei				X	
Aristida junciformis subsp. junciformis	X	X	X	X	
Aristida transvaalensis				X	
Arundinella nepalensis	X	X		X	
Bothriochloa bladhii	X				
Brachiaria serrata		X		X	
Calamagrostis epigeios var. capensis				X	
Chloris gayana					X
Chloris pycnothrix				X	
Ctenium concinnum				X	
Cymbopogon excavatus				X	
Cymbopogon plurinoides		X		X	
Cymbopogon validus	X	X		X	
Cynodon dactylon	X	X	X	X	X
Cynodon transvaalensis				X	
Dactyloctenium aegyptium			X		
Digitaria eriantha		X		X	X
Digitaria tricholaenoides				X	
Diheteropogon amplectens				X	
Echinochloa crus-pavonis					X
Echinochloa jubata				X	X
Eleusine coracana subsp. africana				X	X

Species	**Non-floodplain riparian**	**Floodplain Riparian**	**Seepage wetlands**	**Pans**	**Artificial wetlands**
Elionurus muticus		X	X	X	
Eragrostis capensis	X	X	X	X	
Eragrostis chloromelas	X	X		X	
Eragrostis curvula	X	X	X	X	X
Eragrostis gummiflua	X	X	X	X	
Eragrostis heteromera	X	X			
Eragrostis inamoena				X	
Eragrostis lappula				X	
Eragrostis nindensis				X	
Eragrostis plana	X	X	X	X	
Eragrostis planiculmis				X	
Eragrostis racemosa	X	X	X	X	
Eragrostis rotifer				X	
Harpochloa falx	X	X		X	
Helictotrichon caespititium		X			
Helictotrichon turgidulum		X	X	X	
Hemarthria altissima	X	X		X	
Heteropogon contortus	X	X		X	
Hyparrhenia dregeana				X	
Hyparrhenia filipendula				X	X
Hyparrhenia hirta	X	X	X	X	
Hyparrhenia rufa				X	
Imperata cylindrica	X	X	X	X	
Ischaemum fasciculatum	X	X	X		
Leersia hexandra	X	X	X	X	X
Melinis nerviglumis				X	
Melinis repens	X			X	
Microchloa caffra				X	
Miscanthus junceus	X	X			
Monocymbium ceresiiforme				X	
Oropetium capense				X	
Panicum coloratum		X			
Panicum dregeanum	X				
Panicum natalense				X	
Panicum repens				X	
Panicum repentellum				X	
Panicum schinzii				X	
Paspalum distichum				X	X
Paspalum scrobiculatum				X	
Pennisetum sphacelatum				X	
Perotis patens				X	
Phragmites australis	X	X		X	X
Pogonarthria squarrosa				X	
Schizachyrium jeffreysii				X	
Schizachyrium sanguineum	X				
Setaria incrassata		X		X	
Setaria nigrirostris	X	X	X	X	
Setaria pallide-fusca		X		X	X
Setaria sphacelata				X	
Setaria sphacelata var. sericea	X	X	X	X	
Setaria sphacelata var. sphacelata		X		X	

Species	Non-floodplain riparian	Floodplain Riparian	Seepage wetlands	Pans	Artificial wetlands
Setaria verticillata				X	
Sporobolus pyramidalis				X	
Stirburus alopecuroides		X		X	
Themeda triandra	X	X	X	X	
Trachypogon spicatus				X	
Trichoneura grandiglumis				X	
Triraphis andropogonoides				X	
Tristachya leucothrix				X	
Urelytrum agropyroides		X		X	
Urochloa panicoides				X	
Cyperaceae and Juncaceae					
Bulbostylis burchellii				X	
Bulbostylis humilis				X	
Carex cf. austro-africana		X			
Carex glomerabilis		X	X		
Coleochloa setifera		X			
Cyperus denudatus		X		X	
Cyperus distans		X			
Cyperus fastigiatus	X	X			
Cyperus longus	X			X	
Cyperus longus var. longus		X			
Cyperus longus var. tenuiflorus		X			
Cyperus maculatus		X			
Cyperus marginatus		X			
Cyperus obtusiflorus		X			
Cyperus rupestris		X			
Cyperus sphaerospermus			X		
Eleocharis dregeana		X	X		
Eleocharis palustris				X	
Fimbristylis complanata			X	X	
Fuirena coerulescens		X	X		
Fuirena pubescens	X	X		X	
Fuirena pubescens var. pubescens.			X		
Isolepis cernua	X	X			
Isolepis costata		X		X	
Isolepis costata var. costata			X		
Isolepis setacea		X	X		
Kyllinga alba	X	X			
Kyllinga erecta		X	X	X	
Kyllinga intricata				X	
Mariscus congestus	X	X		X	
Pycreus macranthus		X	X		
Schoenoplectus brachyceral			X	X	
Schoenoplectus corymbosus		X		X	
Schoenoplectus decipiens	X	X	X		
Schoenoplectus muriculatus		X	X		
Schoenoplectus tabernaemontani				X	
Scirpus burkei		X	X		
Scleria woodii			X		
Juncus dregeanus	X	X	X		

Species	Non-floodplain riparian	Floodplain Riparian	Seepage wetlands	Pans	Artificial wetlands
Juncus effusus			X		
Juncus lomatophyllus		X	X	X	
Juncus oxycarpus	X	X	X	X	
Juncus punctorius		X	X		
Other Monocotyledons					
Aloe ecklonis				X	
Anthericum fasciculatum				X	
Boophane disticha				X	
Commelina africana		X	X	X	
Commelina subulata				X	
Crinum bulbispermum		X			
Cyanotis speciosa		X			
Cyrtanthus tuckii		X			
Dipcadi ciliare		X			
Disa woodii		X			
Eucomis autumnalis				X	
Eulophia welwitschii			X		
Gladiolus elliotii	X				
Gladiolus papilio		X			
Habenaria filicornis			X		
Haemanthus montanus		X	X		
Homeria pallida	X	X		X	
Hypoxis acuminata	X	X	X	X	
Hypoxis filiformis		X	X		
Hypoxis hemerocallidea		X	X	X	
Hypoxis rigidula	X	X			
Lagarosiphon major		X	X		
Lagarosiphon muscoides				X	
Ledebouria cooperi		X			
Ledebouria marginatus				X	
Ledebouria ovatifolia		X	X		
Lemna minor				X	
Moraea elliotii	X	X			
Moraea stricta				X	
Potamogeton pectinatus				X	X
Potamogeton schweinfurthii	X				
Potamogeton thunbergii				X	
Trachyandra asperata		X			
Trachyandra asperata var. nataglencoensis			X		
Trachyandra saltii		X		X	
Tulbaghia acutiloba		X			
Typha capensis	X	X	X	X	
Xyris capensis		X			
Dicotyledons					
Acalypha angustata		X		X	
Acalypha caperonioides				X	
Acalypha punctata				X	
Acrotome hispida				X	
Ajuga ophrydis		X			
Amaranthus viridis		X			

Species	Non-floodplain riparian	Floodplain Riparian	Seepage wetlands	Pans	Artificial wetlands
Anagallis huttonii				X	
Anthospermum hispidulum		X		X	
Anthospermum rigidum				X	
Arctotis arctotoides		X			
Asclepias burchellii		X			
Asclepias fruticosa			X	X	X
Asclepias gibba var. gibba	X	X	X		
Asclepias multicaulis		X			
Asclepias stellifera		X			
Aster harveyanus				X	
Becium obovatum		X		X	
Berkheya insignis				X	
Berkheya radula	X	X	X		
Berkheya seminivea				X	
Berkheya setifera				X	
Berkheya speciosa				X	
Berula erecta		X			
Blumea mollis		X			
C.f. Laurembergia repens		X			
C.f. Laurembergia repens subsp. brachypoda			X		
Callilepis leptophylla				X	
Cephalaria zeyheriana		X			
Chaetacanthus costatus		X			
Chaetacanthus setiger		X			
Chamaecrista biensis				X	
Chameachrista mimosoides				X	
Chenopodium album				X	X
Chenopodium glaucum		X		X	
Chenopodium schraderianum					X
Chironia palustris	X	X			
Chironia purpurascens				X	
Cineraria lyrata		X		X	
Cleome monophylla	X				
Cleome rubella				X	
Conium chaerophylloides	X	X			
Convolvulus sagittatus				X	
Conyza podocephala				X	
Cordylogyne globosa		X	X		
Cotula anthemoides		X			
Crabbea acaulis				X	
Crepis hypochoeridea				X	
Cucumis myriocarpus				X	
Cycnium tubulosum		X			
Denekia capensis		X	X		
Dicoma anomala				X	
Dicoma zeyheri				X	
Diospyros lycioides	X				
Dissotis canescens				X	
Epilobium hirsutum		X			
Eriosema cordatum				X	
Erythrina zeyheri		X		X	

Species	Non-floodplain riparian	Floodplain Riparian	Seepage wetlands	Pans	Artificial wetlands
Euphorbia clavaroides		X			
Euphorbia striata var. striata		X	X	X	
Falkia oblonga		X		X	X
Felicia muricata				X	
Galium capense	X	X			
Gamochaeta coarctata		X	X		
Gazania krebsiana		X		X	
Geigeria burkei		X			
Gerbera piloselloides		X		X	
Gerbera viridifolia		X		X	
Gnidia capitata		X		X	
Gomphostigma virgatum	X	X			
Gomphocarpus fruticosus				X	
Haplocarpha lyrata	X	X	X		
Haplocarpha scaposa		X	X	X	
Harveya randii	X	X			
Helichrysum aureonitens	X	X	X	X	
Helichrysum caespititium				X	
Helichrysum callicomum				X	
Helichrysum coriaceum		X		X	
Helichrysum nudifolium	X	X		X	
Helichrysum oreophilum				X	
Helichrysum pilosellum		X			
Helichrysum rugulosum	X	X		X	
Hermannia depressa				X	
Hermannia transvaalensis				X	
Hibiscus aethiopicus				X	
Hibiscus microcarpus				X	
Hibiscus pusillus				X	
Hypericum aethiopicum				X	
Hypericum lalandei				X	
Indigofera daleoides				X	
Indigofera dimidiata		X	X		
Indigofera evansiana	X	X			
Indigofera filipes				X	
Ipomoea bathycolpos		X		X	
Justicia anagalloides				X	
Kohautia amatymbica		X		X	
Lactuca inermis		X		X	
Lightfootia denticulata				X	
Limosella longiflora				X	
Lippia javanica				X	
Lobelia erinus		X		X	
Lobelia flaccida		X			
Lobelia flaccida subsp. flaccida			X		
Lotononis laxa				X	
Melolobium wilmsii				X	
Mentha aquatica	X	X			
Mimulus gracilis		X	X		
Monopsis decipiens	X	X	X	X	
Monsonia angustifolia				X	

Species	Non-floodplain riparian	Floodplain Riparian	Seepage wetlands	Pans	Artificial wetlands
Nemesia fruticans		X		X	
Nidorella anomala	X				
Oldenlandia herbacea				X	
Osteospermum jucundum				X	
Osteospermum scariosum		X			
Oxalis obliquifolia	X	X	X	X	
Pelargonium luridum	X	X	X	X	
Pentanisia angustifolia	X	X		X	
Persicaria salicifolium	X	X	X	X	X
Peucedanum magalismontanum				X	
Plantago longissima		X			
Pollichia campestris				X	
Pygmaeothamnus pygmaeum				X	
Pygmaeothamnus zeyheri				X	
Ranunculus meyeri		X		X	
Ranunculus multifidus	X	X	X	X	
Rhus dentata	X				
Rhus rigida	X				
Rhynchosia caribaea	X				
Rhynchosia minima				X	
Riocreuxia picta	X				
Rorippa nudiuscula		X	X		
Rumex acetosella subsp. angiocarpus		X	X		
Rumex lanceolatus	X	X	X		
Salsola kali					X
Scabiosa columbaria		X		X	
Schistostephium crataegifolium				X	
Sebaea grandis		X		X	
Sebeae leiostyla			X		
Seddera capensis				X	
Senecio apiifolius				X	X
Senecio coronatus				X	
Senecio erubescens var. crepidifolius			X		
Senecio inaequidens		X	X	X	X
Senecio inornatus	X	X		X	
Senecio othonniflorus				X	
Senecio polyodon var. polyodon		X	X		
Senecio venosus		X			
Senecio vimineus				X	
Silene bellidiodes		X			
Sisymbrium thellungii				X	
Sium repandum	X				
Solanum incanum				X	
Solanum panduriforme				X	
Sonchus asper				X	
Sonchus wilmsii		X			
Spergularia media				X	
Stachys hyssopoides		X			
Stoebe vulgaris	X		X	X	
Striga asiatica				X	
Tephrosia capensis		X		X	

Species	Non-floodplain riparian	Floodplain Riparian	Seepage wetlands	Pans	Artificial wetlands
Tephrosia longipes		X			
Tephrosia lupinifolia				X	
Tephrosia multijuga				X	
Tephrosia purpurea				X	
Turbina oblongata				X	
Utricularia gibba			X		
Vernonia galpinii				X	
Vernonia oligocephala		X	X	X	
Vernonia poskeana				X	
Veronica anagallis-aquatica		X	X		
Vigna vexillata				X	
Wahlenbergia caledonica	X				
Wahlenbergia undulata		X		X	X
Walafrida densiflora	X	X		X	
Xysmalobium undulatum				X	
Ziziphus zeyherana				X	
Zornia capensis				X	
TOTAL: (354 species)	**81**	**174**	**80**	**232**	**24**
Number of spp. unique to each wetland type	**14**	**54**	**19**	**138**	**6**

Exotic plant species

Species	Non-floodplain riparian	Floodplain Riparian	Seepage wetlands	Pans	Artificial wetlands
Acacia mearnsii	X			X	
Acanthospermum australe				X	
Amaranthus hybridus				X	
Argemone subfusiformis	X	X			
Aster squamatus				X	X
Bidens bipinnata				X	
Bidens biternata				X	
Bidens formosa		X		X	X
Bidens pilosa		X		X	
Bromus catharticus	X	X			
Centella asiatica	X	X	X	X	
Ciclospermum leptophyllum		X	X	X	
Cirsium vulgare		X	X	X	X
Conyza albida				X	
Conyza bonriensis		X			
Conyza chilensis				X	
Conyza floribunda				X	X
Cynodon hirsutus		X		X	X
Cyperus difformis				X	
Cyperus esculentus		X		X	X
Datura stramonium				X	X
Gomphrena celosioides	X			X	
Hibiscus trionum					X
Hypochaeris radicata	X	X	X	X	
Lepidium bonariense		X			
Medicago sativa					X
Oenothera indecora		X		X	
Oenothera parodiana subsp. parodiana		X	X		
Oenothera rosea	X	X	X	X	X
Oenothera tetraptera		X	X		X
Oxalis corniculata				X	
Paspalum dilatatum	X	X		X	X
Paspalum notatum				X	
Paspalum urvillei			X	X	
Pennisetum clandestinum				X	X
Persicaria lapathifolium	X	X	X	X	X
Plantago lanceolata	X	X	X		X
Plantago virginica					
Portulaca oleracea					X
Pseudognaphalium luteo-album		X	X	X	X
Pseudognaphalium undulatum				X	X
Richardia brasiliensis				X	
Richardia humistrata				X	
Rorippa nasturtium-aquaticum		X			
Rumex crispus	X	X	X		X
Salix babylonica	X	X		X	X
Schkuhria pinnata		X		X	X
Silybum marianum					X
Solanum eleagnifolium				X	
Solanum nigrum				X	

Species	**Non-floodplain riparian**	**Floodplain Riparian**	**Seepage wetlands**	**Pans**	**Artificial wetlands**
Solanum sisymbrifolium				X	
Tagetes minuta	X	X	X	X	X
Tragopogon dubius		X			
Trifolium repens		X			
Trifolium pratense		X			
Verbena bonariensis		X	X	X	X
Verbena brasiliensis		X		X	X
Xanthium strumarium				X	X
Xanthium spinosum				X	X
TOTAL: (59 species)	**13**	**30**	**14**	**42**	**27**

Appendix I. List of known uses of plant species

G. C. Marneweck

The following list of plants is based on the results of a desktop investigation of the uses of the plants found in the UORC. The analysis was based mainly on reference books by Fox and Norwood Young (1988), van Wyk, et al., (1997) and Venter and Venter (1996). Species marked with an asterisk are alien.

Grasses (Poaceae)

Eleusine coracana subsp. *africana:* Mainly cultivated for its grain and used to make porridge. It was also used by many cultures for the brewing of beer.

Eragrostis spp.: Many species are used for flour and beer.

Imperata cylindrica: Herd boys in Lesotho are said to eat the raw roots.

Hemarthria altissima: The rhizome base of is eaten raw in Lesotho.

Phragmites australis: The rootstock is said to be edible.

Setaria sphacelata var. *sericea* and var. *sphacelata:* The seeds of this species are boiled before grinding in into meal to remove the supposed toxic properties.

Sedges

Cyperus esculentus: The tuber is used as a vegetable as it has a sweet, nutty taste.

Mariscus congestus: The bulbs are edible, with a sweet taste, and are an important source of food for the !Kung Bushmen in Namibia.

Other

Albuca sp.: *Albuca canadensis* is edible and the mucilaginous stems are chewed by Hottentots as a thirst-quencher.

Asclepias fruticosa: The dried leaves are used for the treatment of headaches, tuberculosis and an emetic to strengthen the body. The leaves are dried, powdered and snuffed. The roots are used to relieve stomach pain and general body ache.

Asclepias gibba var. gibba: This species is eaten raw or cooked by Zulus, while the roots provide them with famine food.

Asclepias multicaulis: The young leaves, stems, flowers and pod are eaten raw of cooked. In the Transkei, the leaves are boiled and added to other food.

Bidens bipinnata: Young plants have a high food value although the leaf has an astringent taste. The fresh shoots are used, but are also dried for later use.

**Centella asiatica:* This plant has been used to treat leprosy, wounds and cancer in South Africa. It is also widely used for treatment of wounds, fever and syphilis, and as a diuretic and purgative. It is taken orally to relieve the symptoms of lymphatic and venous vessel insufficiency and is a popular constituent of homeopathic remedies claimed to be useful in treating acne and allergies. Extracts and tinctures of the plant material are used and the active components may be extracted and used. The leaves of this plant are used and cooked like spinach. They may also be added to porridge. Occasionally, the leaves are dried and used in seasons of scarcity.

Cleome monophylla: The seeds are used like mustard. Blades of older leaves are cooked together with pounded, ground nuts and tomatoes as a side dish.

Conyza bonariensis: This plant is said to be eaten in the Transkei.

Cotula anthemoides: This herb is said to be eaten in the Transkei.

Crabbea nana: This plant is said to be eaten in the Transkei.

Cyanotis speciosa: The Zulus are reported to eat this plant, raw or cooked.

**Datura stramonium*: This plant is widely used in tradition medicines, relieving asthma and reducing pain. Weak infusions are used by the elderly as hypnotics and by the adults as aphrodisiacs. A poultice of fresh, warmed leaves is used to relieve the pain of rheumatism, gout, boils, abscesses and wounds. Toothache, sore throats and tonsillitis can be relieved by locally applying the fresh, green fruit. Interestingly, the leaf is rolled and smoked to relieve asthma and bronchitis. The two major alkaloids are used commercially: atropine is used in eyedrops and hyoscine is used to treat motion sickness and as an injection to treat Parkinsonism and painful visceral spasms.

Dicoma anomala: The leaves of this plant are used to make "wild tea".

Diospyros lyciodes: The ripe fruits are eaten by people in Zimbabwe, but are regarded with some suspicion by certain tribes on superstitious grounds.

Dissotis canescens: This species is said to be eaten in times of famine in KwaZulu-Natal.

Epilobium hirsutum: The leaves of this species have a pleasant taste, but are only licked; they are not eaten, chewed or swallowed. The leaves are sucked in Lesotho for their salty taste.

Eriosema cordatum: The tubers of this species are eaten occasionally by Bushmen.

Eulophia sp.: Bushmen eat the tuberous stems after baking them in hot ashes.

Euphorbia clavaroides: The dried latex is used as a chewing gum in Lesotho.

Euphorbia striata: This plant is added to sour milk to give it a pleasant taste.

Helichrysum species: Coughs and colds are treated with a tea made from the leaves or the leaves are boiled in milk. Pain is relieved by inhaling the smoke from burning leaves. Infection of wounds is prevented by application of the leaves.

Hypoxis filiformis and Hypoxis rigidula: The bulbs or corms are edible and used by Zulus.

Hypoxis hemerocallidea: Infusions of the corm are used as emetics to treat dizziness, bladder disorders and insanity. Decoctions are given to weak children as a tonic and the juice is applied to burns. The stems and leaves are used in a mixture with other ingredients to treat prostate problems. Testicular tumours, prostate hypertrophy and urinary infections are also treated using this plant.

Lactuca capensis (=L inermis): The leaves are eaten by the Zulus as a vegetable.

Medicago sativa: This is a fodder plant known as lucerne, and used by Zulus as a vegetable at times of famine.

Mentha aquatica: The leaves are used to prepare a tea.

Nemesia fruticans: The leaves are boiled as a spinach to add to porridge. Both the leaves and stems are used as foodstuffs.

Pelargonium luridum: Diarrhoea and dysentery and treated using an infusion of the tubers. The Zulus eat this plant raw as a vegetable.

Pellaea calomelanos: The leaves are smoked or smoke from burning leaves in inhaled to relieve chest colds, head colds and asthma. Decoctions of the rhizomes are traditionally used to treat boils, abscesses and internal parasites, either applied externally or taken.

**Plantago lanceolata:* The seeds are rich in starch and the leaves and roots are eaten.

Pollichia campestris: The fruits are fleshy and readily eaten. Bushmen eat the fleshy parts of the flowers, which have a sweet, earthy flavour.

Rhus dentata: The raw fruits are eaten, although they may have an astringent taste

Rhus leptodictya: An intoxicating drink is made from the fruit

Riocreuxia picta: The leaves are cooked as a spinach.

**Rorippa nasturtium – aquaticum:* The leaves are used in salads and the juice and seeds are used as a mustard. All parts are eaten as a vegetable.

Rumex crispus: The young leaves are eaten as a spinach, although they should be boiled to remove the slightly bitter taste.

Rumex lanceolatus: This plant is used as remedy for internal parasites, vascular diseases and internal bleeding by taking an infusion of leaves or roots boiled in water or milk. It is used externally to treat abscesses, boils and tumours, by applying a hot poultice made from pounded roots and leaves. The leaves are only eaten, chopped, boiled and mixed with porridge.

Scabiosa columbaria: The plant is used as a remedy for colic and heartburn. Dried, roasted roots are made into a wound-healing ointment and the powdered roots are used a a pleasant-smelling baby powder. The roots and leaves are either chewed fresh or taken in dried and powdered form, either directly or as a decoction.

Schkuhria pinnata: This plant is edible in the Transkei.

Senecio burchellii, Senecio erubescens and Senecio inaequidens: The leaves are used as a spinach.

Trifolium africanum: Folklore states that this plant is only eaten by women. Children in Lesotho eat the inflorescence.

Tulbaghia acutiloba: Young plants are eaten as a cooked vegetable by the Sotho.

Vernonia oligocephala: Abdominal pain and colic are treated with an infusion. Rheumatism, dysentery and diabetes are also treated with this plant and the roots are used to treat ulcerative colitis.

Vigna vexillata: The roots of this creeper are eaten as a staple diet in Swaziland; the outer bark is removed and the inner part is chewed.

Wahlenbergia undulata: The plant is used as a spinach.

Appendix J. List of aquatic invertebrates

R W Palmer

Group/Species	1. Drainage lines with riparian zones	2 Channelled riparian wetlands	3 Non-channelled riparian wetlands	4. channelled valley bottom floodplains with footslope seepage	5. valley bottom floodplains without footslope seepage	6. non-channelled valley bottom floodplains	7. Temporarily to seasonally inundated channelled valley bottom	8. Footslope seepage wetlands	9. Midslope seepage wetlands	10. Valleyhead seepage wetlands	11. Crest seepage wetlands	12. Permanently wet pans	13 Non-permanently wet pans	14 Seepage wetlands associated with pans	15. Wet grasslands	16. Dams and weirs	17. Other artificial	Total
	NON-FLOODPLAIN RIPARIAN			FLOODPLAIN RIPARIAN				HILLSLOPE SEEPAGE				PANS			OTHER NON-	ARTIFICIAL		
Nematodes (Roundworms) *Actinolaimus hutchinsoni* *Haemonchus contortus*	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	
Porifera (Sponges)	-	-	-	?	-	-	?	-	-	-	-	?	?	-	-	?	-	
Ectoprocta/Bryozoa (Moss animalcules) *Plumatella sp.* *Lophopodella capensis*	-	?	?	X	X	X	X	?	?	?	?	X	X	X	-	X	X	
Coelenterata (Cnidaria) *Hydra sp.*	-	?	?	X	X	X	X	?	?	?		X	X	X	-	X	X	
Platyhelminthes (Flatworms) *Turbellaria*	?	?	?	X	X	X	X	?	?	?	?	X	X	X	-	X	X	
Oligochaeta (Earthworms) *Tubificidae* *Branchiura sowerbyi*	X	X	X	X	X	X	X	X	X	X	X	X	X	X	?	X	X	
Hirudinea (Leeches)	-	-	-	?	?	?	?	-	-	-	-	X	X	X	-	X	X	
CRUSTACEA																		
Anostraca (Fairy shrimps) *Streptocephalus cafer* *Streptocephalus indistinctus*	-	-	-	-	-	-	-	-	-	-	-	-	X	-	-	-	?	
Conchostraca(Clam shrimps) *Cyzicus australis*	-	-	-	-	-	-	-	-	-	-	-	-	X	-	-	-	?	

Group/Species	NON-FLOODPLAIN RIPARIAN			FLOODPLAIN RIPARIAN				HILLSLOPE SEEPAGE				PANS			OTHER NON-	ARTIFICIAL		Total
	1. Drainage lines with riparian zones	2 Channelled riparian wetlands	3 Non-channelled riparian wetlands	4. channelled valley bottom floodplains with footslope seepage	5. valley bottom floodplains without footslope seepage	6. non-channelled valley bottom floodplains	7.Temporarily to seasonally inundated channelled valley bottom	8.Footslope seepage wetlands	9.Midslope seepage wetlands	10.Valleyhead seepage wetlands	11.Crest seepage wetlands	12.Permanently wet pans	13Non-permanently wet pans	14.Seepage wetlands associated with pans	15.Wet grasslands	16.Dams and weirs	17.Other artificial	Total
Ostracoda (Seed Shrimps)	X	X	X	X	X	X	X	X	X	X	X	X	X	X	-	X	X	
Actocypris obtusa																		
Chrissia levetzoti																		
Cypria capensis																		
Cyprinotus congener																		
Cyprodopsis mastigophora																		
Heterocypris gunningi																		
Limnocythere aethiopica																		
Plesiocypridopsis chrissiensis																		
Plesiocypridopsis inaequivalva																		
Pseudocypris expansa																		
Pseudocypris spinosa																		
Sclerocypris tuberculata																		
Stenocypris pectinata																		
Tanycypris obtusa																		
Copepoda	-	-	-	?	?	?	?	-	-	-	-	X	X	X	-	X	X	
Cyclops varicans																		
Diaptomus spectabilis																		
Eucyclops prasinus																		
Eucyclops serrulatus																		
Lovenula sp.																		
Lovenula excellens																		
Lovenula falcifera																		
Macrocyclops albidus																		
Mesocyclops leuckarti																		
Mesocyclops macrocanthus																		
Metadiaptomus transvaalensis																		
Thermodiaptomus mixtus																		

	NON-FLOODPLAIN RIPARIAN			FLOODPLAIN RIPARIAN				HILLSLOPE SEEPAGE				PANS			OTHER NON-	ARTIFICIAL		
Group/Species	1. Drainage lines with riparian zones	2 Channelled riparian wetlands	3 Non-channelled riparian wetlands	4. channelled valley bottom floodplains with footslope seepage	5. valley bottom floodplains without footslope seepage	6. non-channelled valley bottom floodplains	7. Temporarily to seasonally inundated channelled valley bottom	8. Footslope seepage wetlands	9. Midslope seepage wetlands	10. Valleyhead seepage wetlands	11. Crest seepage wetlands	12. Permanently wet pans	13 Non-permanently wet pans	14. Seepage wetlands associated with pans	15. Wet grasslands	16. Dams and weirs	17. Other artificial	**Total**
Cladocera (Water fleas)	-	-	-	?	?	?	?	-	-	-	-	X	X	X	-	X	X	
Chyodoridae																		
Alona sp.																		
Alona guttata																		
Alona intermedia																		
Chydorus carolinae																		
Chydorus gibsoni																		
Chydorus sphaericus																		
Graptoleberis testudinaria																		
Leydigia propingua																		
Leydigia trispinosa																		
Macrothricidae																		
Macrothrix laticornis																		
Moinidae																		
Moina dubia																		
Daphniidae																		
Ceriodaphnia quadrangular																		
Ceriodaphnia rigaudi																		
Daphnia sp.																		
Daphnia gibba																		
Daphnia pulex																		
Simocephalus capensis																		
Simocephalus corniger																		
Simocephalus vetulus																		
Simocephalus vetuloides																		
Potamonidae (Crabs)	X	X	X	X	X	X	X	?	?	?	?	X	X	X	-	X	X	
Potamonautes sidneyi (Natal River Crab)																		
Potamonautes unispinus (Single spined river crab)																		
Atyidae(Freshwater shrimps)	-	X	-	?	?	?	?	-	-	-	-	-	-	-	-	?	-	
Caridina nilotica																		
Hydrachnellidae (Water mites)	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	
Hydrozetes sp.																		
Limnesia africana																		
Neumania dura																		
Piona coccinea																		

	NON-FLOODPLAIN RIPARIAN			FLOODPLAIN RIPARIAN				HILLSLOPE SEEPAGE				PANS			OTHER NON-	ARTIFICIAL		
Group/Species	1. Drainage lines with riparian zones	2 Channelled riparian wetlands	3 Non-channelled riparian wetlands	4. channelled valley bottom floodplains with footslope seepage	5. valley bottom floodplains without footslope seepage	6. non-channelled valley bottom floodplains	7.Temporarily to seasonally inundated channelled valley bottom	8.Footslope seepage wetlands	9.Midslope seepage wetlands	10.Valleyhead seepage wetlands	11.Crest seepage wetlands	12.Permanently wet pans	13Non-permanently wet pans	14.Seepage wetlands associated with pans	15.Wet grasslands	16.Dams and weirs	17.Other artificial	**Total**
Collembola (Springtails)	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	
Plecoptera (Stoneflies) *Neoperla spio complex*	-	-	-	?	-	-	?	-	-	-	-	-	-	-	-	-	-	
Sisyridae (Sponge flies) *Sisyra producta*	-	-	-	?	-	-	?	-	-	-	-	-	-	-	-	-	-	
Ephemeroptera (Mayflies)																		
Leptophlebiidae (Prongills) *Choroterpes nigrescens* *Euthraulus sp.* *Euthraulus elegans*	-	-	-	?	-	-	?	-	-	-	-	-	-	-	-	-	-	
Polymitarcyidae (Pale burrowers) *Povilla ?adusta*	-	-	-	?	-	-	?	-	-	-	-	X	?	-	-	X	-	
Caenidae (Squaregills)	X	X	X	X	X	X	X	?	?	?	?	X	X	X	-	X	X	
Tricorythidae (Stout crawlers) *Dicercomyzon costale* *Tricorythus spp. Tricorythus discolor*	-	-	-	?	-	-	?	-	-	-	-	-	-	-	-	-	-	
Prosopistomatidae (Water specs) *Prosopistoma sp.*	-	-	-	?	-	-	?	-	-	-	-	-	-	-	-	-	-	
Oligoneuriidae (Brushlegged mayflies) *Elassoneuria sp.*	-																	
Heptageniidae (Flathead mayflies) *Afronurus sp.* *Compsoneuria njalensis*	-																	

	NON-FLOODPLAIN RIPARIAN			FLOODPLAIN RIPARIAN				HILLSLOPE SEEPAGE				PANS			OTHER NON-	ARTIFICIAL		
Group/Species	1. Drainage lines with riparian zones	2 Channelled riparian wetlands	3 Non-channelled riparian wetlands	4. channelled valley bottom floodplains with footslope seepage	5. valley bottom floodplains without footslope seepage	6. non-channelled valley bottom floodplains	7.Temporarily to seasonally inundated channelled valley bottom	8.Footslope seepage wetlands	9.Midslope seepage wetlands	10.Valleyhead seepage wetlands	11.Crest seepage wetlands	12.Permanently wet pans	13Non-permanently wet pans	14.Seepage wetlands associated with pans	15.Wet grasslands	16.Dams and weirs	17.Other artificial	Total
Baetidae (Small minnow mayflies) *Baetis harrisoni* *Centroptiloides bifasciata* *Cheleocloeon (Afroptilum) excisum* *Cloeon spp.* *Cloeon virgillae* *Demoulinia crassi (Centroptilum pulchrum)* *Potamocloeon macafertiorum* *Pseudocloeon gluacum (Baetis glaucus)* *Psuedopannata maculosa*	-	X												X				
Zygoptera (Damselflies)																		
Chlorestidae (Synlestidae) *Chlorolestes fasciata* *Chlorestes tessellata*	-	-	-	X	?	?	X	-	-	-	-	-	-	-	-	-	-	
Lestidae *Lestes pallida* *Lestes plagiata* *Lestes virgata*	?	?	?	X	?	?	X	?	?	?	-	?	?	?	-	X	?	
Protoneuridae *Elattoneura glauca*	?	?	?	X	X	X	X	?	?	?	?	?	?	?	-	?	?	
Platycnemididae	-	-	-	?	-	-	?	-	-	-	-	-	-	-	-	-	-	
Coenagrionidae *Ceriagrion glabrum* *Enallagma glaucum* *Ischnura senegalensis* *Pseudagrion sp.* *Pseudagrion assegaii* *Pseudagrion kersteni* *Pseudagrion newtoni* *Pseudagrion salisburyense* *Pseudagrion vaalense*	X	X	X	X	X	X	X	X	X	X	X	X	X	X	-	X	X	
Calopterygidae /Agriidae	?	?	?	?	?	?	?	-	-	-	-	-	-	-	-	-	-	
Chlorocyphidae *Platycypha caligata*	-	-	-	?	?	?	?	-	-	-	-	-	-	-	-	-	-	
Anispotera (Dragonflies)																		

Group/*Species*	NON-FLOODPLAIN RIPARIAN			FLOODPLAIN RIPARIAN				HILLSLOPE SEEPAGE				PANS			OTHER NON-	ARTIFICIAL		Total
	1. Drainage lines with riparian zones	2 Channelled riparian wetlands	3 Non-channelled riparian wetlands	4. channelled valley bottom floodplains with footslope seepage	5. valley bottom floodplains without footslope seepage	6. non-channelled valley bottom floodplains	7.Temporarily to seasonally inundated channelled valley bottom	8.Footslope seepage wetlands	9.Midslope seepage wetlands	10.Valleyhead seepage wetlands	11.Crest seepage wetlands	12.Permanently wet pans	13Non-permanently wet pans	14.Seepage wetlands associated with pans	15.Wet grasslands	16.Dams and weirs	17.Other artificial	
Aeshnidae	?	X	?	X	X	X	X	?	?	?	?	X	X	X	-	X	X	
Aeshna sp.																		
Anax imperator																		
Anax sp																		
Hemianax ephippiger																		
Corduliidae	-	X	-	?	-	-	?	-	-	-	-	X	?	X	-	X	X	
Gomphidae	-	-	-	X	-	-	X	-	-	-	-	X	?	X	-	X	X	
Ceratogomphus pictus																		
Paragomphus cognatus																		
Libelluliidae	?	X	?	X	X	X	X	?	?	?	?	X	X	X	-	X	X	
Diplacodes lefebvrii																		
Nesciothems farinosa																		
Ortherum machadoi																		
Orthetrum abbotti																		
Orthetrum chrysostigma																		
Orthetrum icteromelas																		
Orthetrum julia falsum																		
Orthetrum trinacria																		
Palpopleura lucia																		
Pantala flavescens																		
Sympetrum fonscolombei																		
Trithemis arteriosa																		
Trithemis dorsalis																		
Trithemis stictica																		
Hemiptera (Bugs)																		
Notonectidae (Back swimmers)	-	X												X			X	
Anisops sp.																		
Anispos aglaia																		
Nychia sp.																		
Pleidae (Pigmy back swimmers)	?	X												X			X	
Plea pullula																		
Naucoridae (Creeping water bugs)	?													X				
Nepidae (Water scorpions)	?													X			X	
Ranatra sp.																		

	NON-FLOODPLAIN RIPARIAN			FLOODPLAIN RIPARIAN				HILLSLOPE SEEPAGE				PANS			OTHER NON-	ARTIFICIAL		
Group/Species	1. Drainage lines with riparian zones	2 Channelled riparian wetlands	3 Non-channelled riparian wetlands	4. channelled valley bottom floodplains with footslope seepage	5. valley bottom floodplains without footslope seepage	6. non-channelled valley bottom floodplains	7. Temporarily to seasonally inundated channelled valley bottom	8 Footslope seepage wetlands	9 Midslope seepage wetlands	10. Valleyhead seepage wetlands	11. Crest seepage wetlands	12. Permanently wet pans	13 Non-permanently wet pans	14. Seepage wetlands associated with pans	15. Wet grasslands	16. Dams and weirs	17. Other artificial	**Total**
Belostomatidae (Giant water bugs) *Sphaerodema sp.*	?																X	
Corixidae (Water boatmen) *Micronecta sp.* *Micronecta piccanin* *Micronecta scutellaris*	X	X												X			X	
Gerridae (Water striders) *Gerris sp.*	-	X															X	
Hydrometridae (Water measurers)	?																	
Veliidae (Broad-shouldered water striders) *Rhagovelia sp.*	?	X																
Trichoptera (Caddisflies)																		
Ecnomidae *Ecnomus sp.* *Ecnopmus oppidanus*	-																	
Hydropsychidae *Aethaloptera maxima* *Cheumatopsyche afra* *Cheumatopsyche thomasseti* *Cheumatopsyche near zuluensis* *Macrostemum sp.* *Macrostemum capense*	-																	
Hydroptilidae *Hydroptila sp.* *Hydroptila capensis* *Oxyethira velocipes* *Orthotrichia*	?																	
Leptoceridae *Athripsodes sp.* *Athripsodes harrisoni* *Leptocerus sp.*	-																	
Philopotamidae *Chimarra sp.*	-																	
Psychomyiidae	-																	

Group/Species	NON-FLOODPLAIN RIPARIAN			FLOODPLAIN RIPARIAN				HILLSLOPE SEEPAGE				PANS			OTHER NON-ARTIFICIAL			
	1. Drainage lines with riparian zones	2 Channelled riparian wetlands	3 Non-channelled riparian wetlands	4. channelled valley bottom floodplains with footslope seepage	5. valley bottom floodplains without footslope seepage	6. non-channelled valley bottom floodplains	7.Temporarily to seasonally inundated channelled valley bottom	8.Footslope seepage wetlands	9.Midslope seepage wetlands	10.Valleyhead seepage wetlands	11.Crest seepage wetlands	12.Permanently wet pans	13Non-permanently wet pans	14.Seepage wetlands associated with pans	15.Wet grasslands	16.Dams and weirs	17.Other artificial	Total
Lepidoptera (Moths) *Nymphulidae/Pyralidae*	?																	
Coleoptera (Beetles)																		
Dytiscidae (Diving beetles) *Laccophilus sp.*	-																X	
Elmidae/Dryopidae (Riffle beetles) *Stenelmis thusa*	-																	
Gyrinidae (Whirligig beetles) *Aulonogyrus sp.*	-													X				
Haliplidae (Crawling Water beetles)	X																	
Noteridae	X																	
Helodidae (Marsh beetles)	X																	
Hydraenidae (Minute moss beetles)	X																	
Hydrophilidae (Water scavenger beetles) *Berosus sp.*	X													X				
Psephenidae (Water pennies)	-																	
Diptera (Flies)																		
Tipulidae (Crane flies)	?																	
Dixidae (Dixid midges) *Dixa sp.*	?																	
Chaoboridae *Chaoborus sp.*																	X	
Culicidae (Mosquitoes) *Culicinae* *Anopheles sp.*	X	X												X			X	
Ceratopogonidae (Biting midges) *Bezzia sp.* *Culicoides magna* *Dasyhelea sp.*	X																	
Chironomidae (Midges)	X	X												X			X	

	NON-FLOODPLAIN RIPARIAN			FLOODPLAIN RIPARIAN				HILLSLOPE SEEPAGE				PANS			OTHER NON-	ARTIFICIAL		
Group/Species	1. Drainage lines with riparian zones	2 Channelled riparian wetlands	3 Non-channelled riparian wetlands	4. channelled valley bottom floodplains with footslope seepage	5. valley bottom floodplains without footslope seepage	6. non-channelled valley bottom floodplains	7.Temporarily to seasonally inundated channelled valley bottom	8.Footslope seepage wetlands	9.Midslope seepage wetlands	10.Valleyhead seepage wetlands	11.Crest seepage wetlands	12.Permanently wet pans	13Non-permanently wet pans	14.Seepage wetlands associated with pans	15.Wet grasslands	16.Dams and weirs	17.Other artificial	**Total**
Tanypodinae																		
Pentaneura sp.																		
Pentaneura dusoleili																		
Orthocladiinae																		
Corynoneura scotti																		
Corynoneura sp.																		
Cricotopus harrisoni																		
Cricotopus obscurus																		
Cricotopus sp.																		
Limnophyes spinosa																		
Metriocnemus																		
Nanocladius calviger																		
Orthocladius scotti																		
Smittia conigera																		
Thienemanniella lineola																		
Trichocladius capensis																		
Chironominae																		
Chironomus linearis																		
Chironomus peringueyi																		
Chironomus pulcher																		
Chironomus sp.																		
Cricotopus sp.																		
Cryptochironomus sp.																		
Endochironomus disparilis																		
Microtendipes																		
Pentaneura sp.																		
Pentapedilum anale																		
Rheotanytarsus sp.																		
Tanytarsini																		
Tanytarsus pallidus																		
Xenochironomus ugandae																		

	NON-FLOODPLAIN RIPARIAN			FLOODPLAIN RIPARIAN				HILLSLOPE SEEPAGE				PANS			OTHER NON-	ARTIFICIAL		
Group/*Species*	1. Drainage lines with riparian zones	2 Channelled riparian wetlands	3 Non-channelled riparian wetlands	4. channelled valley bottom floodplains with footslope seepage	5. valley bottom floodplains without footslope seepage	6. non-channelled valley bottom floodplains	7.Temporarily to seasonally inundated channelled valley bottom	8.Footslope seepage wetlands	9.Midslope seepage wetlands	10.Valleyhead seepage wetlands	11.Crest seepage wetlands	12.Permanently wet pans	13Non-permanently wet pans	14.Seepage wetlands associated with pans	15.Wet grasslands	16.Dams and weirs	17.Other artificial	**Total**
Simuliidae (Blackflies)	-	X																
Simulium adersi																		
Simulium ?bequaerti																		
Simulium damnosum																		
Simulium dentulosum																		
Simulium hargreavesi																		
Simulium impukane																		
Simulium mcmahoni																		
Simulium nigritarse																		
Simulium ruficorne																		
Tabanidae (Horse Flies)	?	X																
Tabanus sp.																		
Athericidae/Rhagionidae	?																	
Empididae (Dance Flies)	?																	
Ephydridae (Shore Flies)	?																	
Muscidae	X																	
MOLLUSCA																		
Thiaridae /Melanidae	-																	
Melanoides sp.																		
Lymnaeidae	?																	
Lymnaea columella																		
Lymnaea natalensis																		
Lymnaea truncatula																		
Ancylidae	-																	
Burnupia sp.																		
Ferrissia sp.																		
Planorbidae	?	X																
Biomphalaria pfeifferi																		
Bulinis reticulatus																		
Bulinis tropicus																		
Bulinus depressus																		
Bulinus forskalii																		
Bulinus spp.																		
Ceratophallus natalensis																		
Gyraulus connollyi																		
Gyraulus costulatus																		
Physidae (Pouch snails)	?													X				
Physa acuta																		

	NON-FLOODPLAIN RIPARIAN			FLOODPLAIN RIPARIAN				HILLSLOPE SEEPAGE				PANS			OTHER NON-	ARTIFICIAL		
Group/Species	1. Drainage lines with riparian zones	2 Channelled riparian wetlands	3 Non-channelled riparian wetlands	4. channelled valley bottom floodplains with footslope seepage	5. valley bottom floodplains without footslope seepage	6. non-channelled valley bottom floodplains	7.Temporarily to seasonally inundated channelled valley bottom	8.Footslope seepage wetlands	9.Midslope seepage wetlands	10.Valleyhead seepage wetlands	11.Crest seepage wetlands	12.Permanently wet pans	13Non-permanently wet pans	14.Seepage wetlands associated with pans	15.Wet grasslands	16.Dams and weirs	17.Other artificial	**Total**
Unionidae *Unio caffer* *Unio framesi*	-																	
Corbiculidae *Corbicula sp.* *Corbicula astartina*	-																	
Sphaeriidae *Pisidium spp.* *Sphaerium capense*	?																	
Total	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	

Appendix K. List of fish species

J Engelbrecht

Fish Species	NON-FLOODPLAIN RIPARIAN			FLOODPLAIN RIPARIAN				HILLSLOPE SEEPAGE				PANS			OTHER	ARTIFICIAL		Total
	1. Drainage lines with riparian zones	2 Channelled riparian wetlands	3 Non-channelled riparian wetlands	4. channelled valley bottom floodplains with footslope seepage	5. valley bottom floodplains without footslope seepage	6. non-channelled valley bottom floodplains	7.Temporarily to seasonally inundated channelled valley bottom	8.Footslope seepage wetlands	9.Midslope seepage wetlands	10.Valleyhead seepage wetlands	11.Crest seepage wetlands	12.Permanently wet pans	13Non-permanently wet pans	14.Seepage wetlands associated with pans	15.Wet grasslands	16.Dams and weirs	17.Other artificial	
Indigenous species																		
Anguilla mossambica	?															?		?
Barbus anoplus	X			X	X			X								X		5
Barbus neefi	X			X	X			X								X		5
Barbus paludinosus	X			X	X			X								X		5
Barbus polylepis	X			X												X		3
Barbus trimaculatus	X			X												X		3
Clarias gariepinus	X			X												X		3
Pseudocrenilabrus philander	X			X	X			X								X		5
Tilapia sparrmanii	X			X	X			X				X				X		6
Exotic species																		
Ctenopharyngodon idella																X		1
Cyprinus carpio	X			X								X				X		4
Gambusia affinis				X												X		2
Micropterus salmoides	X			X								X				X		4
Onchorhynchus mykiss																X		1
Translocated indigenous																		
Austroglanis sclateri				X												X		2
Barbus aeneus	X			X												X		3
Labeo capensis	X			X												X		3
Labeo umbratus	X			X												X		3
Total: (18 species)	14			15	5			5				3				18		
Ranking	3			2	4			4				5				1		

Appendix L. Fish species and their habitat requirements

J Engelbrecht

Anguilla mossambica **Longfin eel**

This species is a widespread species in east flowing rivers and has been recorded historically above Witbank Dam. However, its numbers have most probably been drastically reduced in the Upper Olifants River due to obstruction to their migration patterns by major dams. This fish has been recorded in a wide range of habitats, but seems to favour strong, deep flowing waters or pools This species probably does not depend on permanent flow. Mature eels migrate down to the sea to spawn and larvae are carried from their spawning grounds in the Indian Ocean southwards via the Mozambique and Agulhas currents past the coast of southern Africa from where the glass eels enter our rivers during January and February each year. Juveniles migrate towards their freshwater feeding and maturation areas in east flowing rivers. It feeds on fish, amphibians and invertebrates associated with its habitat.

Clarias gariepinus **Sharptooth catfish**

The most widely distributed fish in southern Africa. Was collected from the upper Olifants River and is common in all the dams. Occurs in almost any aquatic habitat and breeds in marginal vegetation. It feeds virtually on any available food source including invertebrates, mussels, fish, amphibians, birds, reptiles snails, fruit and small mammals. This species is extremely tolerant and not sensitive to water quality changes.

Austroglanis sclateri **Rock catfish**

Probably translocated from the Vaal River via the Tricardtsfontein Dam water transfer scheme. This species prefer rocky habitats in flowing water and are often found in rapids. Feeds on invertebrates taken from the rock surface. Larger specimens may feed on fish.

Barbus aeneus **Smallmouth yellowfish**

Translocated from the Vaal River and stocked into the Middelburg and Witbank Dams for angling purposes. Prefer clear flowing waters of larger tributaries and rivers. Broadly omnivorous, feeding on bivalve molluscs, vegetation, algae and detritus.

Barbus anoplus **Chubbyhead barb**

This species is one of the most widely distributed species in South Africa. However, studies suggest that it probably represents a complex of several species (Engelbrecht and van Der Bank, 1996). This species is common in the Highveld and has been recorded in a wide range of habitats, but seems to favour areas with slow-flowing water and sufficient cover such as marginal vegetation. This species is not dependent on permanent flow. It needs inundated marginal vegetation to spawn and shallow, slow flowing, vegetated backwaters as nursery areas. It feeds on invertebrates and plant matter associated with is habitat. This species was found in abundance in wetlands associated with the Koringspruit, and lower Vaalbankspruit, suggesting that it may be quite tolerant of the highly modified salinity in these streams.

Barbus neefi **Sidespot barb**

In South Africa, this species occur in the Blyde, Steelpoort and Vaal Rivers. It has been recorded in the Rietspruit and several other tributaries, which suggest that it also occurred in the rest of the upper Olifants River. This fish has been recorded in a wide range of habitats, but it seems to favour areas with slow-flowing water and sufficient cover such as marginal vegetation. This species is not dependent on permanent flow. It needs inundated marginal vegetation to spawn and shallow, slow flowing, vegetated backwaters as nursery areas. It feeds on invertebrates and plant matter associated with is habitat.

Barbus paludinosus **Straightfin barb**

This species occurs from the Cunuene and Zambezi Rivers in the north to the Orange River. It has been recorded only at a few localities in the Upper Olifants River. This fish is tolerant of a wide range of habitats and prefers quiet or standing waters with vegetation, swamps and marshes. It feeds on aquatic insects, invertebrates, algae and diatoms. It needs inundated marginal vegetation to spawn and shallow, slow-flowing or standing vegetated backwaters as nursery areas. This species is not dependent on permanent flow and is probably not very sensitive to water quality changes.

Barbus polylepis **Small-scale yellowfish**

This species is restricted to the upper reaches of the Olifants, Incomati and Pongolo Rivers and is present in relative low numbers in the Upper Olifants River. The juveniles of this fish is commonly found in fast flowing, well-oxygenated water in rocky rapid and riffle areas, whilst the adults prefer deeper pools. This species is not dependent on permanent flow during all life stages. This species migrates during floods and needs a cobble bed in fast flowing water and a water temperature of about 22°C during early summer to trigger spawning. Shallow, warm backwaters are important as nursery areas. Feed on wide variety of items such as invertebrates, mussels, fish, algae and snails. This species is probably not very sensitive to water quality changes but may be drastically effected by habitat modifications.

Barbus trimaculatus **Threespot barb**

This species occurs from the Zambezi River in the north to the Orange River. It has been recorded in the Rietspruit and Vaalbankspruit, which suggest that it also occurred in the rest of the upper Olifants River. This fish is tolerant of a wide range of habitats and prefers quiet or standing waters with vegetation, swamps and marshes. It feeds on aquatic insects, and other invertebrates. It needs inundated marginal vegetation to spawn and shallow, slow -flowing or standing vegetated backwaters as nursery areas. This species is not dependent on permanent flow and is probably not very sensitive to water quality changes.

Ctenopharyngodon idella **Grass carp**

This species is native to China and was introduced into South Africa from Malaysia for the control of aquatic weeds. Presently triploid stock is introduced for stocking in other areas to control aquatic weeds.

Cyprinus carpio **Carp**

Introduced during the 1700 and 1800. This species is hardy and tolerant of a wide variety of conditions. Favours deeper, slow-flowing habitats with soft bottom sediments such as dams. This species is omnivorous and feeds on a wide variety of plant and animal matter by grubbing in the sediments. This manner of feeding often results in increased turbidity.

Gambusia affinis **Mosquitofish**

Introduced from North America before 1936 and distributed as a mosquito control agent and as forage for bass. Proven to an aggressive invader species capable of restricting other fish populations by preying on fish larvae. Prefers standing waters with vegetation and is tolerant of a wide range of water temperatures (4 - 38 C) as well as salinity.

Labeo capensis **Orange River labeo**

Probably translocated from the Vaal River via the Tricardtsfontein Dam water transfer scheme. Prefers larger rivers and deeper habitats. Feeds by scraping matter from firm surfaces of rocks and plants.

Labeo umbratus **Moggel**

Translocted from the Vaal River. Prefers standing waters and thrives in shallow impoundments. Feeds on soft sediments and detritus.

Micropterus salmoides **Largemouth bass**

Introduced from North America as an angling species. Prefers clear standing or slow-flowing water with submerged vegetation. This species is fairly tolerant of temperatures (10 - 32 C). Feeds mainly on fish, but crabs, frogs, reptiles and even small mammals are taken.

Onchorhynchus mykiss **Rainbow trout**

Introduced from North America into temperate regions of southern Africa. This species prefer well-aerated cool waters and prey on a wide range of aquatic vertebrates and invertebrates.

Pseudocrenilabrus philander **Southern mouthbrooder**

This species occurs from the Cunuene and Zambezi Rivers in the north to the Orange River. It has been recorded widely in the upper Olifants River. This fish is tolerant of a wide range of habitats and prefers quiet or standing waters with vegetation. It feeds on aquatic insects and small fish. This species is not dependent on permanent flow and is not sensitive to water quality changes.

Tilapia sparrmanii **Banded tilapia**

In South Africa, this species occurs from the Limpopo to the Orange River. It has been recorded widely in the upper Olifants River. This fish is tolerant of a wide range of habitats and prefers quiet or standing waters with submerged or emergent vegetation. It is omnivorous and feeds on all available food including algae, plant matter, insects and invertebrates. This species is not dependent on permanent flow and is tolerant to water quality changes

Appendix M. List of frog species

N. H. G Jacobsen

Family & species	NON-FLOODPLAIN RIPARIAN			FLOODPLAIN RIPARIAN				HILLSLOPE SEEPAGE				PANS			OTHER NON-	ARTIFICIAL		Total
	1. Drainage lines with riparian zones	2 Channelled riparian wetlands	3 Non-channelled riparian wetlands	4. channelled valley bottom floodplains with footslope seepage	5. valley bottom floodplains without footslope seepage	6. non-channelled valley bottom floodplains	7. Temporarily to seasonally inundated channelled valley bottom	8. Footslope seepage wetlands	9. Midslope seepage wetlands	10. Valleyhead seepage wetlands	11. Crest seepage wetlands	12. Permanently wet pans	13 Non-permanently wet pans	14. Seepage wetlands associated with pans	15. Wet grasslands	16. Dams and weirs	17. Other artificial	
Pipidae																		
Xenopus l. laevis Common clawed frog	X	X		X	X	X	X					X				X	X	9
Bufonidae																		
Bufo gutturalis Gutteral toad				X	X	X	X					X	X	X		X	X	9
Bufo maculatus Flat-backed toad				X	X	X	X											4
Bufo rangeri Raucous toad				X	X	X	X									X	X	6
Schismaderma carens Red toad				X	X	X	X									X	X	6
Ranidae																		
Pyxicephalus a. adspersus Highveld bullfrog				X	X	X	X					X	X	X		X	X	9
Tomopterna cryptotis Tremolo sand frog				X	X	X	X					X	X	X		X	X	9
Afrana angolensis Common river frog	X	X		X	X											X	X	6
Afrana fuscigula Cape river frog	X	X		X	X												X	5
Strongylopus f. fasciatus Striped stream frog				X	X	X	X	X	X	X	X	X				X	X	11
Ptychadena porosissima Striped grass frog								X	X	X	X	X						5
Phrynobatrachus natalensis Common puddle frog				X	X	X	X					X	X	X		X	X	9
Cacosternum boettgeri Common caco			X	X	X	X	X	X	X	X	X	X	X	X		X	X	14
Kassina senegalensis Bubbling kassina				X	X	X	X					X	X	X		X	X	9
Kassina (Semnodactylus) wealii Rattling kassina				X	X	X	X					X	X	X		X	X	9
Total: (15 species)	3	3	1	1	1	1	1	3	3	3	3	1	7	7	0	1	1	
Ranking	6	6	7	1	1	3	3	6	6	6	6	4	5	5	1	3	2	

Appendix N. List of reptile species

N. H. G. Jacobsen

	NON-FLOODPLAIN RIPARIAN			FLOODPLAIN RIPARIAN				HILLSLOPE SEEPAGE				PANS			OTHER NON-RIPARIAN	ARTIFICIAL		
Species	1. Drainage lines with riparian zones	2 Channelled riparian wetlands	3 Non-channelled riparian wetlands	4. channelled valley bottom floodplains with footslope seepage	5. valley bottom floodplains without footslope seepage	6. non-channelled valley bottom floodplains	7.Temporarily to seasonally inundated channelled valley bottom	8.Footslope seepage wetlands	9.Midslope seepage wetlands	10.Valleyhead seepage wetlands	11.Crest seepage wetlands	12.Permanently wet pans	13Non-permanently wet pans	14.Seepage wetlands associated with pans	15.Wet grasslands	16.Dams and weirs	17.Other artificial	**Total**
Sauria																		
Acontias g. gracilicauda Slender-tailed legless skink	X	X		X	X		X								X			**6**
Varanus niloticus Water monitor	X	X		X	X											X		**5**
Serpentes																		
Colubridae																		
Lycodonomorphus rufulus Brown water snake	X	X	X	X	X		X					X				X	X	**9**
Lamprophis aurora Aurora house snake	X	X		X	X												X	**5**
Psammophylax r. rhombeatus Spotted skaapsteker	X	X		X	X	X	X					X	X	X	X	X	X	**12**
Philothamnus hoplogaster Green Water Snake	X	X	X	X	X		X									X	X	**8**
Elapidae																		
Hemachatus haemachatus Rinkhals	X	X		X	X	X	X					X	X	X	X	X		**11**
Pelomedusidae																		
Pelomedusa subrufa Cape terrapin	X	X		X	X	X	X					X	X	X		X	X	**11**
Total: (8 species)	**8**	**8**	**2**	**8**	**8**	**3**	**6**	**0**	**0**	**0**	**0**	**4**	**3**	**3**	**3**	**6**	**5**	
Ranking	**1**	**1**	**6**	**1**	**1**	**5**	**2**	**17**	**17**	**17**	**17**	**4**	**5**	**5**	**5**	**2**	**3**	

Appendix O. List of bird species

J Turpie

The table lists indigenous bird species that have been recorded (X) or are likely to occur (x) in each of the major wetland types in the UORC. Reporting rate score is the mean score of selected species for 12 quarter-degree squares in the study area where each species is scored within each square as 0 – not reported or 1 – 4, with 4 the highest category of reporting rate for that species (SABAP data). An asterisk following a name represents a Red Data species. Please note that this list is not necessarily comprehensive since it is based mainly on species lists from various studies and reports (see text).

Species	Common name	Reporting rate score	Non-floodplain riparian	Floodplain Riparian	Seepage wetlands	Pans	Artificial wetlands
Tachybaptus ruficollis	Dabchick	3.8		X		X	X
Podiceps cristatus	Great Crested Grebe	2.3					X
Podiceps nigricollis	Blacknecked Grebe	0.6					
Phalacrocorax carbo	Whitebreasted Cormorant	3.7		X		X	X
Phalacrocorax africanus	Reed Cormorant	3.9	X	X		X	X
Anhinga melanogaster	Darter	3.0		X		X	X
Ardea cinerea	Grey Heron	3.6		X		X	X
Ardea melanocephala	Blackheaded Heron	3.9		X		X	X
Ardea goliath	Goliath Heron	1.3					X
Ardea purpurea	Purple Heron	2.8		X	X	X	X
Casmerodius albus	Great White Heron	3.3		X			X
Egretta intermedia	Yellowbilled Egret	3.7	X	X		X	X
Egretta garzetta	Little Egret	3.5	X	X			X
Egretta ardesiaca	Black Egret	0.8					X
Bubulcus ibis	Cattle Egret	3.9	X	X		X	X
Ardeola ralloides	Squacco Heron	2.2					X
Nycticorax nycticorax	Blackcrowned Night Heron	2.3		X		X	X
Butorides striatus	Greenbacked Heron	0.8					
Ixobrychus minutus	Little Bittern	0.4		X		X	x
Scopus umbretta	Hamerkop	2.8	X	X		X	x
Ciconia ciconia	White Stork	2.4				X	x
Ciconia abdimii	Abdim's Stork	1.2					
Ciconia nigra	Black Stork	0.8					
Mycteria ibis	Yellowbilled Stork	0.9					X
Threskiornis aethiopicus	Sacred Ibis	3.8		X		X	X
Geronticus calvus	Bald Ibis	1.9					
Plegadis falcinellus	Glossy Ibis	3.8				X	X
Bostrychia hagedash	Hadeda Ibis	3.7	X	X		X	X
Platalea alba	African Spoonbill	3.7		X		X	X
* *Phoenicopterus ruber*	Greater Flamingo	3.2				X	X
* *Phoeniconaias minor*	Lesser Flamingo	2.3				X	
Dendrocygna viduata	Whitefaced Duck	2.5					X
Dendrocygna bicolor	Fulvous Duck	1.2				X	x
Thalassornis leuconotus	Whitebacked Duck	2.3					
Alopochen aegyptiacus	Egyptian Goose	3.8	X	X		X	X

Species	Common name	Reporting rate score	Non-floodplain riparian	Floodplain Riparian	Seepage wetlands	Pans	Artificial wetlands
Tadorna cana	South African Shelduck	0.8					
Anas undulata	Yellowbilled Duck	3.8	X	X		X	X
Anas sparsa	African Black Duck	2.3					X
Anas capensis	Cape Teal	1.1		X		X	X
Anas Hottnetota	Hottentot Teal	1.8		X		X	x
Anas erythrorhyncha	Redbilled Teal	3.8		X		X	X
Anas smithii	Cape Shoveller	3.5		X		X	X
Netta erythrophthalma	Southern Pochard	3.4		X		X	X
Sarkidiornis melanotos	Knobbilled Duck	0.8					X
Plectropterus gambensis	Spurwinged Goose	3.4	X	X		X	X
Oxyura maccoa	Maccoa Duck	2.2					
Elanus caeruleus	Blackshouldered Kite		X	X		X	x
Haliaeetus vocifer	African Fish Eagle	0.7					X
Pandion halieatus	Osprey						X
Circus ranivorus	African Marsh Harrier	0.5		X			
Francolinus swainsonii	Swainson's Francolin			X		X	x
Numida meleagris	Helmeted Guineafowl		X	X	X	X	x
Bugeranus carunculatus	Wattled Crane	0.2					
Balearica regulorum	Crowned Crane	0.4					
Rallus caerulescens	African Rail	0.3		X		X	x
Amaurornis flavirostis	Black Crake	1.5		X		X	X
Sarothrura rufa	Redchested Flufftail	0.2					
Porphyrio porphyrio	Purple Gallinule	3.2		X	X	X	X
Gallinula chloropus	Moorhen	3.8		X		X	X
Fulica cristata	Redknobbed Coot	3.9	X	X		X	X
Podica senegalensis	African Finfoot	0.2					
Actophilornis africanus	African Jacana	0.5					X
* *Rostratula benghalensis*	Painted Snipe	0.2					
Charadrius hiaticula	Ringed Plover	0.3					
Charadrius pecuarius	Kittlitz's Plover	2.3				X	X
C. tricollaris	Threebanded Plover	3.1		X		X	X
Vanellus coronatus	Crowned Plover	3.8		X		X	x
Vanellus armatus	Blacksmith Plover	4.0	X	X		X	X
V. senegallus	Wattled Plover	3.2		X	X	X	X
Actitis hypoleucos	Common Sandpiper	2.9	X				X
Tringa glareola	Wood Sandpiper	3.0				X	X
T. stagnatilis	Marsh Sandpiper	3.1					X
T. nebularia	Greenshank	2.4					X
Calidris ferruginea	Curlew Sandpiper	2.3					X
C. minuta	Little Stinit	2.8				X	X
Philomachus pugnax	Ruff	2.8				X	X
Gallinago nigripennis	Ethiopian Snipe	3.7		X	X	X	X
Recurvirostra avosetta	Avocet	2.4				X	X
Himantopus himantopus	Blackwinged Stilt	3.3				X	X
Burhinus capensis	Spotted Dikkop	2.9		X			
Larus cirrocephalus	Greyheaded Gull	3.3		X		X	X
Hydroprogne caspia	Caspian Tern	0.4		X			X
Chlidonias leucopterus	Whitewinged Tern	3.5					X
C. hybrida	Whiskered Tern	2.8				X	x
Columbus arquatrix	Rock Pigeon			X		X	x

Species	Common name	Reporting rate score	Non-floodplain riparian	Floodplain Riparian	Seepage wetlands	Pans	Artificial wetlands
Streptopelia semitorquata	Redeyed Dove		X	X		X	x
Streptopelia capicola	Cape Turtle Dove			X		X	x
Streptopelia senegalensis	Laughing dove		X	X		X	x
Oena capensis	Namaqua Dove		X	X			
Tyto capensis	Grass Owl					X	
Asio capensis	Marsh Owl	3.7		X	x	X	X
Apus caffer	Whiterumped Swift		X	X		X	x
Colius indicus	Redfaced Mousebird			X		X	x
Ceryle rudis	Pied Kingfisher	2.5	X	X		X	X
C. maxima	Giant Kingfisher	1.6	x	X		x	X
* *Alcedo semitorquata*	Halfcollared Kingfisher	0.4	x				
A. cristata	Malachite Kingfisher	1.8	x	X			X
Ispidina picta	Pygmy Kingfisher		X				
Phoeniculus purpureus	Redbilled Woodhoopoe			X		X	x
Mirafra sobota	Sabota lark					X	x
Hirundo rustica	European swallow		X	X		X	x
Hirundo albigularis	Whitethroated Swallow		X	X		X	x
Hirundo cucullata	Greater Striped Swallow		X	X		X	x
Hirundo dimidiata	Pearl Breasted Swallow		X				
Hirundo fuligula	Rock Martin			X		X	x
Riparia paludicola	Brown Throated Martin		X	X		X	x
R. cincta	Banded Martin			X		X	x
Pycnonotus barbatus	Blackeyed bulbul			X		X	x
Myrmecocichla formicivora	Anteating chat			X		X	x
Saxicola torquata	Stone Chat		X	X		X	x
Acrocephalus arundinaceus	Great Reed Warbler	0.7	x			x	x
A. gracilirostris	Cape Reed Warbler	2.4		X		X	x
A. baeticatus	African Marsh Warbler	1.1	X			X	x
A. Palustris	European Marsh Warbler	0.3	x			x	
A. schoenobaeus	European Sedge Warbler	0.6	x			x	
Bradypterus baboecala	African Sedge Warbler	1.0	x			x	x
Cisticola juncidis	Fantained cisticola		x	X	x	X	x
Cisticola aridula	Desert cisticola					X	x
Cisticola ayresii	Ayres' cisticola		X			X	x
Cisticola lais	Wailing cisticola		X	X			
Cisticola tinniens	Levaillant's Cisticola	3.7		X		X	x
Cisticola fulvicapilla	Neddicky			X		X	x
Sigelus silens	Fiscal Flycatcher			X		X	x
Motacilla capensis	Cape Wagtail	3.6	X	X		X	X
Motacilla flava	Yellow Wagtail					X	x
Macronyx capensis	Orangethroated Longclaw			X		X	x
Lanius collaris	Fiscal Shrike		X	X		X	x
Lanius collurio	Redbacked Shrike			X		X	x
Spreo bicolour	Pied Starling			X		X	x
Tchagra senegala	Blackcrowned Tchagra					X	x
Telephorus zeylonus	Bokmakierie			X		X	x
Passer domesticus	House Sparrow			X			
Passer melanurus	Cape Sparrow			X		X	x

Species	Common name	Reporting rate score	Non-floodplain riparian	Floodplain Riparian	Seepage wetlands	Pans	Artificial wetlands
Ploceus velatus	Masked Weaver	3.9	X	X		X	x
Euplectes orix	Red Bishop	3.9	X	X		X	x
Euplectes afer	Golden Bishop		X	X			
Euplectes progne	Longtailed widow		X	X	X	X	x
Uraeginthus angolensis	Blue Waxbill			X		X	x
Esrilda astrild	Common Waxbill	2.4	X	X		X	x
Ortygospiza atricollis	Quail Finch			X		X	x
Sporeaginthus subflavus	Orangebreasted waxbill		X	X		X	x
Vidua macroura	Pintailed Whydah	3.9	X	X	X	X	x
Serinus atrogularis	Blackthroated Canary					X	x
	TOTAL: (143 species)		45	85	8	99	115

Appendix P. List of aquatic mammals

N. H. G. Jacobsen

	NON-FLOODPLAIN RIPARIAN			FLOODPLAIN RIPARIAN				HILLSLOPE SEEPAGE				PANS			OTHER NON-RIPARIAN	ARTIFICIAL		
Species	1. Drainage lines with riparian zones	2 Channelled riparian wetlands	3 Non-channelled riparian wetlands	4. channelled valley bottom floodplains with footslope	5. valley bottom floodplains without footslope seepage	6. non-channelled valley bottom floodplains	7.Temporarily to seasonally inundated channelled valley	8.Footslope seepage wetlands	9.Midslope seepage wetlands	10.Valleyhead seepage wetlands	11.Crest seepage wetlands	12.Permanently wet pans	13Non-permanently wet pans	14.Seepage wetlands associated with pans	15.Wet grasslands	16.Dams and weirs	17.Other artificial	**Total**
Soricidae																		
Crocidura mariquensis Black or Swamp musk shrew	X	X	X	X	X	X	X	?	?	?	?	X		?		X		8
Rodentia																		
Thryonomys swinderianus Greater canerat	X	X		X	X													4
Otomys irroratus Vlei rat	X	X	X	X	X	X						X				X		8
Dasymys incomtus Swamp rat	X	X	X	X	X											X		6
Carnivora																		
Viverridae																		
Atilax paludinosus Water mongoose	X	X	X	X	X	X	X					X	X	X		X	X	12
Mustelidae																		
Lutra maculicollis Spotted neck otter	X	X														X		3
Aonyx capensis Clawless otter	X	X										X	X			X	X	6
Total: (7 species)	7	7	4	5	5	3	2	?	?	?	?	4	2	1	?	6	2	7
Ranking	1	1	4	3	3	5	6	-	-	-	-	4	6	-	-	2	6	

Appendix Q. Attributes of wetland types

C. C. Marneweck

Table 5-5. Attribute table for drainage lines with riparian zones.

ATTRIBUTE	DESCRIPTION	
Wetland unit type	Drainage lines with riparian zones	
Topographic setting	Valley bottom	
Slope	10 - 30%	
Vegetation cover types	Grass riparian fringes and occasionally exotic trees along the channel banks	
Dominant vegetation	Grasses	
Estimates of plant species diversity	Relatively low with approximately 30 - 40 species	
Wetting regime	Seasonally wet	
Hydrological drivers	Overland flow from catchment runoff, channel flow and lateral seepage.	
Keypoints or substrate	Varied substrate and no real keypoints	
Soil forms	Varied	
Special habitats	Riparian fringe	
Red Data Species which may occur	<u>Flora</u> *Nemesia fruticans* - considered non-threatened. *Kniphofia typhoides* - insufficiently known	<u>Fauna</u> Swamp rat *Dasymus incomtus* - indeterminate
Other special flora and fauna	<u>Flora</u> *Harveya* species have been recorded	<u>Fauna</u> Slender-tailed legless skink *Acontias gracilicauda* Brown water snake *Lycodonomorphus rufulus* Aurora house snake *Lamprophis aurora* Spotted skaapsteker *Psammophylax rhombeatus* Rinkhals *Hemachatus haemachatus* Cape terrapin *Pelomedusa subrufa* Common clawed frog *Xenopus laevis* Common river frog *Afrana angolensis* Cape river frog *Afrana fuscigula* Black musk shrew *Crocidura mariquensis* Greater cane rat *Thryonomys swinderianus* Vlei rat *Otomys irroratus* Water mongoose *Atilax paludinosus* Cape Clawless otter *Aonyx capensis* Spotted necked otter *Lutra maculicollis*
Adjacent land-uses	Varied	
Land-use within wetland	Livestock watering and grazing	
Notes on degradation	Areas towards the top end of the catchment with stream channels having steep gradients show signs of erosion and net downcutting of the stream channel. Loss from mining activities. Roads, railways, conveyor belts, pipelines etc.	
Functions the unit is likely to perform	Biodiversity support	

Table 5-6. Attribute table for channelled riparian wetlands.

ATTRIBUTE	DESCRIPTION	
Wetland unit type	Channelled riparian	
Topographic setting	Valley bottom	
Slope	< 15%	
Vegetation cover types	Grass and sedge meadows and riparian fringes along the channel banks	
Dominant vegetation	Grasses and sedges, including tall emergent vegetation in places	
Estimates of plant species diversity	Approximately 50 - 60 species	
Wetting regime	Permanently to seasonally wet	
Hydrological drivers	Stream flow and lateral seepage.	
Keypoints or substrate	Varied substrate, often clay bases and bedrock keypoints	
Soil forms	Varied	
Special habitats	Mixed grass sedge meadows and riparian fringe	
Red Data Species which may occur	Flora *Nemesia fruticans* - considered non-threatened, *Eucomis autumnalis* ssp. *clavata* - considered non threatened, *Kniphofia typhoides* - insufficiently known, and *Nerine gracilis* - considered rare	Fauna Grass Owl *Tyto capensis* - vulnerable Swamp rat *Dasymus incomtus* - indeterminate
Other special flora and fauna	Flora	Fauna Slender-tailed legless skink *Acontias gracilicauda* Brown water snake *Lycodonomorphus rufulus* Aurora house snake *Lamprophis aurora* Spotted skaapsteker *Psammophylax rhombeatus* Rinkhals *Hemachatus haemachatus* Cape terrapin *Pelomedusa subrufa* Common clawed frog *Xenopus laevis* Common river frog *Afrana angolensis* Cape river frog *Afrana fuscigula* Black musk shrew *Crocidura mariquensis* Greater cane rat *Thryonomys swinderianus* Vlei rat *Otomys irroratus* Water mongoose *Atilax paludinosus* Cape Clawless otter *Aonyx capensis* Spotted necked otter *Lutra maculicollis*
Adjacent land-uses	Varied, often cultivated for maize	
Land-use within wetland	Livestock watering and grazing	
Notes on degradation	Signs of erosion and net downcutting of the stream channel throughout, draining, trampling and drying	
Functions the unit is likely to perform	Biodiversity support	

Table 5-7. Attribute table for non-channelled riparian wetlands.

ATTRIBUTE	DESCRIPTION	
Wetland unit type	Non-channelled riparian	
Topographic setting	Valley bottom	
Slope	< 5%	
Vegetation cover types	Grass and sedge meadows	
Dominant vegetation	Grasses and sedges, including tall emergent vegetation in places	
Estimates of plant species diversity	Approximately 40 - 50 species	
Wetting regime	Permanently to seasonally wet	
Hydrological drivers	Diffuse flow from upstream channel flow and seepage	
Keypoints or substrate	Varied substrate, often clay bases and bedrock keypoints	
Soil forms	Varied	
Special habitats	Mixed grass sedge meadows	
Red Data Species which may occur	Flora *Nemesia fruticans* - considered non-threatened, *Eucomis autumnalis* ssp. *clavata* - considered non threatened, *Kniphofia typhoides* - insufficiently known, and *Nerine gracilis* - considered rare	Fauna Grass Owl *Tyto capensis* - vulnerable Swamp rat *Dasymus incomtus* - indeterminate
Other special flora and fauna	Flora	Fauna Brown water snake *Lycodonomorphus rufulus* Common caco *Cacosternum boettgeri* Black musk shrew *Crocidura mariquensis* Vlei rat *Otomys irroratus* Water mongoose *Atilax paludinosus* Cape Clawless otter *Aonyx capensis* Spotted necked otter *Lutra maculicollis*
Adjacent land-uses	Varied often cultivated for maize	
Land-use within wetland	Livestock watering and grazing	
Notes on degradation	Signs of erosion with nick points, trampling, draining and drying	
Functions the unit is likely to perform	Biodiversity support and water quality enhancement	

Table 5-8. Attribute table for seasonally inundated channelled valley bottom floodplains with footslope seepage wetlands

ATTRIBUTE	DESCRIPTION	
Wetland unit type	Seasonally inundated channelled valley bottom floodplains with footslope seepage wetlands	
Topographic setting	Valley bottom	
Slope	< 5%	
Vegetation cover types	Grass and sedge meadows	
Dominant vegetation	Grasses and sedges	
Estimates of plant species diversity	High with up to 130 species having been recorded	
Wetting regime	Semi-permanently to seasonally wet	
Hydrological drivers	Channel overspill during flooding and flow from adjacent slopes and from footslope seepage wetlands[1]	
Keypoints or substrate	Varied substrate, but most often clay base and bedrock keypoints	
Soil forms	Predominantly Kroonstad, Katspruit and Rensburg as well as alluvium	
Special habitats	Mixed grass/sedge meadows, open water in oxbows and depressions and in the areas where seepage accumulates, tall emergent sedge meadows and short sedge meadows, grass meadows on the levee and in the riparian zone	
Red Data Species which may occur	Flora *Nemesia fruticans* - considered non-threatened. *Eucomis autumnalis* ssp. *clavata* - considered non threatened, *Kniphofia typhoides* - insufficiently known, and *Nerine gracilis* - considered rare	Fauna Grass Owl *Tyto capensis* - vulnerable Giant Bullfrog *Pyxicephalus adspersus* Swamp rat *Dasymus incomtus* - indeterminate
Other special flora and fauna	Flora Orange River Lily *Crinum bulbispermum* occur in large stands and many other lily's also occur. *Harveya* species have been recorded on the levees.	Fauna Slender-tailed legless skink *Acontias gracilicauda* Brown water snake *Lycodonomorphus rufulus* Aurora house snake *Lamprophis aurora* Spotted skaapsteker *Psammophylax rhombeatus* Rinkhals *Hemachatus haemachatus* Cape terrapin *Pelomedusa subrufa* Common clawed frog *Xenopus laevis* Gutteral toad *Bufo gutturalis* Flat-backed toad *Bufo maculatus* Raucous toad *Bufo rangeri* Red toad *Schismaderma carens* Tremelo sand frog *Tomopterna cryptotis* Common river frog *Afrana angolensis* Cape river frog *Afrana fuscigula* Striped stream frog *Strongylopus fasciatus* Common puddle frog *Phrynobatrachus natalensis* Common caco *Cacosternum boettgeri* Bubbling kassina *Kassina senegalensis* Rattling kassina *Kassina wealii* Black musk shrew *Crocidura mariquensis* Greater cane rat *Thryonomys swinderianus* Vlei rat *Otomys irroratus* Water mongoose *Atilax paludinosus* Cape Clawless otter *Aonyx capensis* Spotted necked otter *Lutra maculicollis* Ethiopian snipes *Gallinago nigripennis* were seen breeding in tsome of these wetlands. High diversity of butterflies and amphibians.
Adjacent land-uses	Cultivated lands for maize, natural pastures and coal mining	
Land-use within wetland	Livestock watering and grazing, hay bales, coal mining, sand mining and possibly even medicinal plant collection. Dry mass production estimated at approximately 10 - 20 tons per hectare for average rainfall season and at 20 - 40 tons per hectare for the season following flooding.	
Notes on degradation	Drying as a result of cut off of adjacent seepage from mining. Direct loss as a result of mining Trampling and bank erosion by livestock. Roads including main roads as well as haulage and mining access roads concentrating flows. Channel incision and dropping of water tables which together contribute to a reduction in the frequency of flows overtopping the banks	
Functions the unit is likely to perform	Biodiversity support, water quality enhancement and flood attenuation	

Table 5-9. Attribute table for seasonally inundated channelled valley bottom floodplains without footslope seepage wetlands

ATTRIBUTE	DESCRIPTION	
Wetland unit type	Seasonally inundated channelled valley bottom floodplains without footslope seepage wetlands	
Topographic setting	Valley bottom	
Slope	< 5%	
Vegetation cover types	Grass and sedge meadows	
Dominant vegetation	Grasses	
Estimates of plant species diversity	Relatively low between approximately 30 and 50 species	
Wetting regime	Seasonally to intermittently wet	
Hydrological drivers	Channel overspill during flooding	
Keypoints or substrate	Varied substrate, but most often clay base and bedrock keypoints	
Soil forms	Predominantly Kroonstad, Katspruit and Rensburg as well as alluvium	
Special habitats	Mixed grass/sedge meadows, oxbows and depressions, grass meadows on the levee and in the riparian zone	
Red Data Species which may occur	Flora *Nemesia fruticans* - considered non-threatened, and *Kniphofia typhoides* - insufficiently known,	Fauna Grass Owl *Tyto capensis* - vulnerable Giant Bullfrog *Pyxicephalus adspersus* Swamp rat *Dasymus incomtus* - indeterminate
Other special flora and fauna	Flora	Fauna Slender-tailed legless skink *Acontias gracilicauda* Brown water snake *Lycodonomorphus rufulus* Aurora house snake *Lamprophis aurora* Spotted skaapsteker *Psammophylax rhombeatus* Rinkhals *Hemachatus haemachatus* Cape terrapin *Pelomedusa subrufa* Common clawed frog *Xenopus laevis* Gutteral toad *Bufo gutturalis* Flat-backed toad *Bufo maculatus* Raucous toad *Bufo rangeri* Red toad *Schismoderma carens* Tremelo sand frog *Tomopterna cryptotis* Common river frog *Afrana angolensis* Cape river frog *Afrana fuscigula* Striped stream frog *Strongylopus fasciatus* Common puddle frog *Phrynobatrachus natalensis* Common caco *Cacosternum boettgeri* Bubbling kassina *Kassina senegalensis* Rattling kassina *Kassina wealii* Black musk shrew *Crocidura mariquensis* Greater cane rat *Thryonomys swinderianus* Vlei rat *Otomys irroratus* Water mongoose *Atilax paludinosus* Cape Clawless otter *Aonyx capensis* Spotted necked otter *Lutra maculicollis*
Adjacent land-uses	Cultivated lands for maize, natural pastures and coal mining	
Land-use within wetland	Livestock watering and grazing, hay bales, coal mining and sand mining	
Notes on degradation	Direct loss as a result of mining. Trampling and bank erosion by livestock. Roads including main roads as well as haulage and mining access roads concentrating flows. Channel incision and dropping of water tables which together contribute to a reduction in the frequency of flows overtopping the banks	
Functions the unit is likely to perform	Biodiversity support and flood attenuation	

Table 5-10. Attribute table for seasonally inundated non-channelled valley bottom floodplains

ATTRIBUTE	DESCRIPTION	
Wetland unit type	Seasonally inundated non-channelled valley bottom floodplains	
Topographic setting	Valley bottom	
Slope	< 5%	
Vegetation cover types	Grass and sedge meadows	
Dominant vegetation	Grasses	
Estimates of plant species diversity	High with 100 or more species	
Wetting regime	Seasonally to semi-permanently wet	
Hydrological drivers	Diffuse flow from upstream channel flow, flooding and seepage	
Keypoints or substrate	Varied substrate with bedrock keypoint	
Soil forms	Predominantly Kroonstad, Katspruit and Rensburg as well as alluvium	
Special habitats	Mixed grass/sedge meadows, open water in oxbows and depressions and in the areas where seepage accumulates, tall emergent sedge meadows and short sedge meadows.	
Red Data Species which may occur	Flora *Nemesia fruticans* - considered non-threatened, *Eucomis autumnalis* ssp. *clavata* - considered non threatened, *Kniphofia typhoides* - insufficiently known, and *Nerine gracilis* - considered rare	Fauna Grass Owl *Tyto capensis* - vulnerable Giant Bullfrog *Pyxicephalus adspersus*
Other special flora and fauna	Flora Orange River Lily *Crinum bulbispermum* occur in large stands and many other lily's also occur.	Fauna Spotted skaapsteker *Psammophylax rhombeatus* Rinkhals *Hemachatus haemachatus* Cape terrapin *Pelomedusa subrufa* Common clawed frog *Xenopus laevis* Gutteral toad *Bufo gutturalis* Flat-backed toad *Bufo maculatus* Raucous toad *Bufo rangeri* Red toad *Schismoderma carens* Tremelo sand frog *Tomopterna cryptotis* Striped stream frog *Strongylopus fasciatus* Common puddle frog *Phrynobatrachus natalensis* Common caco *Cacosternum boettgeri* Bubbling kassina *Kassina senegalensis* Rattling kassina *Kassina wealii* Black musk shrew *Crocidura mariquensis* Vlei rat *Otomys irroratus* Water mongoose *Atilax paludinosus* Cape Clawless otter *Aonyx capensis* Spotted necked otter *Lutra maculicollis*
Adjacent land-uses	Cultivated lands for maize and natural pastures	
Land-use within wetland	Livestock watering and grazing, hay bales and sand mining	
Notes on degradation	Direct loss as a result of mining. Trampling and erosion by livestock. Roads including main roads as well as haulage and mining access roads concentrating flows. Draining and dropping of water tables which together contribute to drying of the wetter areas	
Functions the unit is likely to perform	Biodiversity support , water quality enhancement and flood attenuation	

Table 5-11. Attribute table for temporarily inundated channelled valley bottom floodplains

ATTRIBUTE	DESCRIPTION	
Wetland unit type	Temporarily inundated channelled valley bottom floodplains	
Topographic setting	Valley bottom	
Slope	< 5%	
Vegetation cover types	Grass and sedge meadows	
Dominant vegetation	Grasses	
Estimates of plant species diversity	Relatively low with 50 species or less	
Wetting regime	Temporarily inundated and seasonally wet in places	
Hydrological drivers	Channel overspill during flooding, and lateral surface flow from adjacent slopes and lateral sub-surface flow adjacent seepage areas	
Keypoints or substrate	Varied substrate with bedrock varied keypoints	
Soil forms	Predominantly Kroonstad, Katspruit and Rensburg as well as alluvium	
Special habitats	Mainly extensive grass meadows	
Red Data Species which may occur	Flora None expected to occur	Fauna Grass Owl *Tyto capensis* - vulnerable Giant Bullfrog *Pyxicephalus adspersus*
Other special flora and fauna	Flora Some Orange River Lily *Crinum bulbispermum*	Fauna Slender-tailed legless skink *Acontias gracilicauda* Brown water snake *Lycodonomorphus rufulus* Spotted skaapsteker *Psammophylax rhombeatus* Rinkhals *Hemachatus haemachatus* Cape terrapin *Pelomedusa subrufa* Common clawed frog *Xenopus laevis* Gutteral toad *Bufo gutturalis* Flat-backed toad *Bufo maculatus* Raucous toad *Bufo rangeri* Red toad *Schismaderma carens* Tremelo sand frog *Tomopterna cryptotis* Striped stream frog *Strongylopus fasciatus* Common puddle frog *Phrynobatrachus natalensis* Common caco *Cacosternum boettgeri* Bubbling kassina *Kassina senegalensis* Rattling kassina *Kassina wealii* Black musk shrew *Crocidura mariquensis* Water mongoose *Atilax paludinosus* Cape Clawless otter *Aonyx capensis* Spotted necked otter *Lutra maculicollis*
Adjacent land-uses	Cultivated lands for maize and natural pastures	
Land-use within wetland	Livestock watering and grazing, hay bales and sand mining	
Notes on degradation	Direct loss as a result of mining. Trampling and erosion by livestock. Roads including main roads as well as haulage and mining access roads concentrating flows. Channel incision resulting in dropping of water tables which together contribute to drying of the systems and a reduced frequency of bank overflow during flooding	
Functions the unit is likely to perform	Biodiversity support and some flood attenuation	

Table 5-12. Attribute table for footslope seepage wetlands.

ATTRIBUTE	DESCRIPTION	
Wetland unit type	Footslope seepage wetlands	
Topographic setting	Bottom of hillslopes towards the channels	
Slope	5 - 30%	
Vegetation cover types	Grass and sedge meadows	
Dominant vegetation	Mixed grass/sedge meadows	
Estimates of plant species diversity	Relatively high with 50 species or more	
Wetting regime	Semi-permanently to seasonally wet	
Hydrological drivers	Predominantly groundwater and interflow	
Keypoints or substrate	Soft or hard plinthic B horizons and clays	
Soil forms	Varied and often associated with a number of soil forms, particularly Avalon, Pinedene, Sepane, Dresden and Westleigh soil forms	
Special habitats	Mixed grass/sedge meadows	
Red Data Species which may occur	Flora *Nemesia fruticans* - considered non-threatened	Fauna Grass Owl *Tyto capensis* - vulnerable
Other special flora and fauna	Flora Stands of *Haemanthus montanus*	Fauna Striped stream frog *Strongylopus fasciatus* Striped grass frog *Ptychadena porosissima* Common caco *Cacosternum boettgeri*
Adjacent land-uses	Cultivated lands for maize and natural pastures	
Land-use within wetland	Livestock grazing and hay bales	
Notes on degradation	Direct loss as a result of mining. Trampling and erosion by livestock.	
Functions the unit is likely to perform	Biodiversity support, some water quality enhancement and stream baseflow augmentation	

Table 5-13. Attribute table for midslope seepage wetlands.

ATTRIBUTE	DESCRIPTION	
Wetland unit type	Midslope seepage wetlands	
Topographic setting	Hillslopes towards the middle of the slopes	
Slope	5 - 30%	
Vegetation cover types	Grass and sedge meadows	
Dominant vegetation	Mixed grass/sedge meadows	
Estimates of plant species diversity	Relatively high with 50 species or more	
Wetting regime	Semi-permanently to seasonally wet	
Hydrological drivers	Predominantly groundwater and interflow	
Keypoints or substrate	Soft or hard plinthic B horizons and clays	
Soil forms	Most often associated with Avalon, Pinedene and Westleigh soil forms	
Special habitats	Mixed grass/sedge meadows	
Red Data Species which may occur	<u>Flora</u> *Nemesia fruticans* - considered non-threatened and *Nerine gracilis* - considered rare	<u>Fauna</u> Grass Owl *Tyto capensis* - vulnerable
Other special flora and fauna	<u>Flora</u> Many sedge species as well as ground orchids including *Eulophia* and *Habenaria* species	<u>Fauna</u> Striped stream frog *Strongylopus fasciatus* Striped grass frog *Ptychadena porosissima* Common caco *Cacosternum boettgeri*
Adjacent land-uses	Cultivated lands for maize and natural pastures	
Land-use within wetland	Livestock grazing and hay bales, cultivation - Probably close to 90% of these systems are influenced by direct cultivation to some extent or another	
Notes on degradation	Direct loss as a result of mining, cultivation and draining. Trampling and erosion by livestock.	
Functions the unit is likely to perform	Biodiversity support, water quality enhancement and stream baseflow augmentation	

Table 5-14. Attribute table for valleyhead seepage wetlands.

ATTRIBUTE	DESCRIPTION	
Wetland unit type	Valleyhead seepage wetlands	
Topographic setting	Head of valleys towards the top of the slopes	
Slope	10 - 40%	
Vegetation cover types	Grass and sedge meadows	
Dominant vegetation	Mixed grass/sedge meadows	
Estimates of plant species diversity	Low to relatively high with 30 - 50 species or more	
Wetting regime	Semi-permanently to seasonally wet	
Hydrological drivers	Predominantly groundwater and interflow with some surface runoff from the top of the catchment	
Keypoints or substrate	Variable	
Soil forms	Variable	
Special habitats	Mixed grass/sedge meadows	
Red Data Species which may occur	Flora *Nemesia fruticans* - considered non-threatened and *Nerine gracilis* - considered rare	Fauna Grass Owl *Tyto capensis* - vulnerable
Other special flora and fauna	Flora Ground orchids including *Eulophia* and *Habenaria* species may occur	Fauna Striped stream frog *Strongylopus fasciatus* Striped grass frog *Ptychadena porosissima* Common caco *Cacosternum boettgeri*
Adjacent land-uses	Cultivated lands for maize and natural pastures	
Land-use within wetland	Livestock grazing and hay bales, cultivation - Some of these systems are influenced by direct cultivation to some extent or another	
Notes on degradation	Direct loss as a result of mining, cultivation and draining. Trampling and erosion by livestock.	
Functions the unit is likely to perform	Biodiversity support and stream baseflow flow augmentation	

Table 5-15. Attribute table for crest seepage wetlands.

ATTRIBUTE	DESCRIPTION	
Wetland unit type	Crest seepage wetlands	
Topographic setting	Hillslopes normally above rocky outcrops at the crest of the hills where the soils are shallow.	
Slope	5 - 15%	
Vegetation cover types	Mosses and open water	
Dominant vegetation	Grasses, small sedges and mosses	
Estimates of plant species diversity	Relatively low with 20 - 30 species occurring	
Wetting regime	Seasonally to temporarily wet	
Hydrological drivers	Predominantly shallow sub-surface water seepage on bedrock	
Keypoints or substrate	Bedrock	
Soil forms	Shallow soil and bedrock	
Special habitats	None	
Red Data Species which may occur	Flora	Fauna
Other special flora and fauna	Flora Mosses	Fauna Striped stream frog *Strongylopus fasciatus* Striped grass frog *Ptychadena porosissima* Common caco *Cacosternum boettgeri*
Adjacent land-uses	Varied	
Land-use within wetland	Livestock grazing	
Notes on degradation	Livestock grazing and trampling	
Functions the unit is likely to perform	Biodiversity support	

Table 5-16. Attribute table for permanently wet pans.

ATTRIBUTE	DESCRIPTION	
Wetland unit type	Permanently wet pans	
Topographic setting	Mainly on the top of drainage divides	
Slope	Depression	
Vegetation cover types	Fringe communities and tall emergents	
Dominant vegetation	Sedges and grasses	
Estimates of plant species diversity	Relatively high in fringe communities with up to 70 species occurring	
Wetting regime	Permanently wet	
Hydrological drivers	Runoff from adjacent slopes	
Keypoints or substrate	Commonly a clay base	
Soil forms	Varied	
Special habitats	Open water and fringe communities	
Red Data Species which may occur	Flora ?	Fauna Giant Bullfrog *Pyxicephalus adspersus*
Other special flora and fauna	Flora	Fauna Brown water snake *Lycodonomorphus rufulus* Spotted skaapsteker *Psammophylax rhombeatus* Rinkhals *Hemachatus haemachatus* Cape terrapin *Pelomedusa subrufa* Common clawed frog *Xenopus laevis* Gutteral toad *Bufo gutturalis* Tremelo sand frog *Tomopterna cryptotis* Striped stream frog *Strongylopus fasciatus* Striped grass frog *Ptychadena porosissima* Common puddle frog *Phrynobatrachus natalensis* Common caco *Cacosternum boettgeri* Bubbling kassina *Kassina senegalensis* Rattling kassina *Kassina wealii* Vlei rat *Otomys irroratus* Water mongoose *Atilax paludinosus* Cape clawless otter *Aonyx capensis* A high diversity of birds utilise these systems
Adjacent land-uses	Varied	
Land-use within wetland	Livestock watering and grazing of fringe communities, storage of mine and other industrial waste water and recreation - birding and duck hunting	
Notes on degradation	Livestock grazing and trampling of fringe communities Water quality degradation as a result of waste water inputs	
Functions the unit is likely to perform	Biodiversity support	

Table 5-17. Attribute table for non-permanently wet pans.

ATTRIBUTE	DESCRIPTION	
Wetland unit type	Non-permanently wet pans	
Topographic setting	Mainly on the top of drainage divides	
Slope	Depression	
Vegetation cover types	Mixed grass/sedge meadows, sedge meadows and tall emergents	
Dominant vegetation	Sedges and grasses	
Estimates of plant species diversity	Relatively high with up to 70 species occurring	
Wetting regime	Seasonally to temporarily wet	
Hydrological drivers	Runoff from adjacent slopes	
Keypoints or substrate	Commonly a clay base	
Soil forms	Varied	
Special habitats	Mixed gras/sedge communities and shallow water sedge and grass communities	
Red Data Species which may occur	Flora *Calamagrostis epigeios*	Fauna Giant Bullfrog *Pyxicephalus adspersus*
Other special flora and fauna	Flora	Fauna Spotted skaapsteker *Psammophylax rhombeatus* Rinkhals *Hemachatus haemachatus* Cape terrapin *Pelomedusa subrufa* Gutteral toad *Bufo gutturalis* Tremelo sand frog *Tomopterna cryptotis* Common puddle frog *Phrynobatrachus natalensis* Common caco *Cacosternum boettgeri* Bubbling kassina *Kassina senegalensis* Rattling kassina *Kassina wealii* Water mongoose *Atilax paludinosus* Cape clawless otter *Aonyx capensis* A high diversity of birds utilise these systems
Adjacent land-uses	Varied	
Land-use within wetland	Livestock watering and grazing, storage of mine and other industrial waste water	
Notes on degradation	Livestock grazing and trampling, water quality degradation as a result of waste water inputs, cultivation and impacts due to main roads, railways, conveyor belts, mine haul roads and farm roads that bisect and /or cross many of the systems	
Functions the unit is likely to perform	Biodiversity support	

Table 5-18. Attribute table for pans associated with seepage wetlands.

ATTRIBUTE	DESCRIPTION	
Wetland unit type	Pans associated with seepage wetlands	
Topographic setting	Mainly on the hillslopes but also on drainage divides	
Slope	Depression plus outlet	
Vegetation cover types	Mixed grass/sedge meadows and sedge meadows	
Dominant vegetation	Sedges and grasses	
Estimates of plant species diversity	Relatively high with up to 70 species occurring	
Wetting regime	Semi-permanently to seasonally and temporarily wet	
Hydrological drivers	Runoff from adjacent slopes and seepage from adjacent seepage wetlands	
Keypoints or substrate	Commonly a clay base surrounded by sandy soils of the seepage areas	
Soil forms	Often associated with Avalon, Pinedene and Westleigh soil forms	
Special habitats	Mixed gras/sedge communities and shallow water sedge and grass communities	
Red Data Species which may occur	Flora *Nemesia fruticans* - considered non-threatened and *Nerine gracilis* - considered rare	Fauna Grass Owl *Tyto capensis* - vulnerable Giant Bullfrog *Pyxicephalus adspersus*
Other special flora and fauna	Flora Many sedge species as well as ground orchids including *Eulophia* and *Habenaria* species in surrounding seepage areas	Fauna Spotted skaapsteker *Psammophylax rhombeatus* Rinkhals *Hemachatus haemachatus* Cape terrapin *Pelomedusa subrufa* Gutteral toad *Bufo gutturalis* Tremelo sand frog *Tomopterna cryptotis* Common puddle frog *Phrynobatrachus natalensis* Common caco *Cacosternum boettgeri* Bubbling kassina *Kassina senegalensis* Rattling kassina *Kassina wealii* Water mongoose *Atilax paludinosus*
Adjacent land-uses	Varied	
Land-use within wetland	Livestock watering and grazing, storage of mine and other industrial waste water and recreation and cultivated for crops	
Notes on degradation	Livestock grazing and trampling, water quality degradation as a result of waste water inputs, cultivation and impacts due to main roads, railways, conveyor belts, mine haul roads and farm roads that bisect and /or cross many of the systems	
Functions the unit is likely to perform	Biodiversity support and streamflow augmentation as well as possible water quality enhancement functions	

Table 5-19. Attribute table for wet grasslands.

ATTRIBUTE	DESCRIPTION	
Wetland unit type	Wet grasslands	
Topographic setting	Hillslopes	
Slope	0-25%	
Vegetation cover types	Grass meadows	
Dominant vegetation	Grasses	
Estimates of plant species diversity	Relatively high with 60 species or more	
Wetting regime	Temporarily wet	
Hydrological drivers	Variable but may include seepage and rainfall	
Keypoints or substrate	Varied	
Soil forms	Varied	
Special habitats	Damp grasslands	
Red Data Species which may occur	Flora	Fauna Grass Owl *Tyto capensis* - vulnerable
Other special flora and fauna	Flora Ground orchids including *Eulophia* and *Habenaria* species may occur	Fauna Slender-tailed legless skink *Acontias gracilicauda* Spotted skaapsteker *Psammophylax rhombeatus* Rinkhals *Hemachatus haemachatus*
Adjacent land-uses	Varied	
Land-use within wetland	Livestock grazing and cultivation	
Notes on degradation	Livestock grazing and trampling, cultivation and impacts due to main roads, railways, conveyor belts, mine haul roads and farm roads that bisect and /or cross these systems	
Functions the unit is likely to perform	Biodiversity support	

Table 5-20. Attribute table for dams and weirs.

ATTRIBUTE	DESCRIPTION	
Wetland unit type	Dams	
Topographic setting	Valley bottom	
Slope	0%	
Vegetation cover types	Tall emergent and mixed grass/sedge meadows	
Dominant vegetation	Sedges and grasses	
Estimates of plant species diversity	Relatively low with < 30 species occurring	
Wetting regime	Permanently to seasonally wet	
Hydrological drivers	Channel flow	
Keypoints or substrate	Artificial walls	
Soil forms	Varied	
Special habitats	Open water and tall emergents	
Red Data Species which may occur	Flora	Fauna Grass Owl *Tyto capensis* - vulnerable Giant Bullfrog *Pyxicephalus adspersus* Swamp rat *Dasymus incomtus* - indeterminate
Other special flora and fauna	Flora	Fauna Brown water snake *Lycodonomorphus rufulus* Spotted skaapsteker *Psammophylax rhombeatus* Rinkhals *Hemachatus haemachatus* Cape terrapin *Pelomedusa subrufa* Common clawed frog *Xenopus laevis* Gutteral toad *Bufo gutturalis* Raucous toad *Bufo rangeri* Red toad *Schismoderma carens* Tremelo sand frog *Tomopterna cryptotis* Common river frog *Afrana angolensis* Striped stream frog *Strongylopus fasciatus* Common puddle frog *Phrynobatrachus natalensis* Common caco *Cacosternum boettgeri* Bubbling kassina *Kassina senegalensis* Rattling kassina *Kassina wealii* Black musk shrew *Crocidura mariquensis* Vlei rat *Otomys irroratus* Water mongoose *Atilax paludinosus* Cape Clawless otter *Aonyx capensis* Spotted necked otter *Lutra maculicollis*
Adjacent land-uses	Varied	
Land-use within wetland	Livestock watering, crop irrigation , birding and fishing	
Notes on degradation	N/A	
Functions the unit is likely to perform	Water storage	