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Feasibility Study Wad Meskin Irrigation Project

Final Report

ANNEX 10: ENVIRONMENTAL AND SOCIAL IMPACT ASSESSMENT

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ANNEX 10: ENVIRONMENTAL AND SOCIAL IMPACT ASSESSMENT

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1. INTRODUCTION

1.1 THE PROJECT

The proposed Wad Miskeen Irrigation Project is located to the south of the proposed Rahad II Irrigation project, immediately south of the defunct Hawata to Gedaref railway line, and covers about 7,500 ha net, between Hawata town and Wad Miskeen village on the right bank of the seasonal Rahad river. The project proposes a barrage at Wad Miskeen across the Rahad River to regulate the flood flows during the rainy season, and a barrage on the Dinder River on the edge of the Dinder National Park would serve a similar purpose, whilst a 54 km long link canal would take water from the Dinder, across the Khor el Atshan, to the Rahad River Wad Miskeen and into the Project area.

Wad Miskeen lies some of 70 km south of Al Hawata village. Several tracks connect Hawata and Wad Miskeen: these are unpaved and largely impassable during the rainy season being on heavy clays. The proposed irrigation area of Wad Miskeen lies on deep clay plains that slope upwards to the north east towards the Atbara basin watershed at Gedaref.

The clay soils of the study area are heavily utilised for rain fed cultivation under a rotation system whereby, ideally, land is left fallow for a number of years to allow bush and woodland (Acacia spp.) to regenerate and restore some level of fertility. In the 2009 cropping season there has been widespread crop failure due to a shortage of rainfall. Forest Reserves occur on the margins of the proposed area and come under the control of the Forests Management Corporation (FNC). Along the Rahad and Khor Atshan there are dense Acacia nilotica woodlands. The Dinder barrage site lies in the Dinder National Park where there is mixed savanna woodland of Acacia seyal and other species.

The area was covered by soil surveys during the Roseires Soil Survey (HTS, 1966) and later by LWRC (1994). Additional baseline date collection was made by site investigations were carried out during the 2008-09 dry season to locate 7,500 hectares net of land and included semi-detailed soil survey and land suitability evaluation of 7,500 hectares (net) of irrigable land; detailed topographic surveys and map preparation of the barrages, link canal and irrigation scheme; and detailed geotechnical investigations on diversion sites, pump sites, major structures, and along canal routes of the selected areas.

The location of the irrigation project is shown in **Figure 1** and **2**. This shows the canals and irrigation layout, as well as existing villages, and forested areas. **Figure 3** shows the locations of the weirs, link canal and irrigation project.

Figure 1. Project Area Design - North

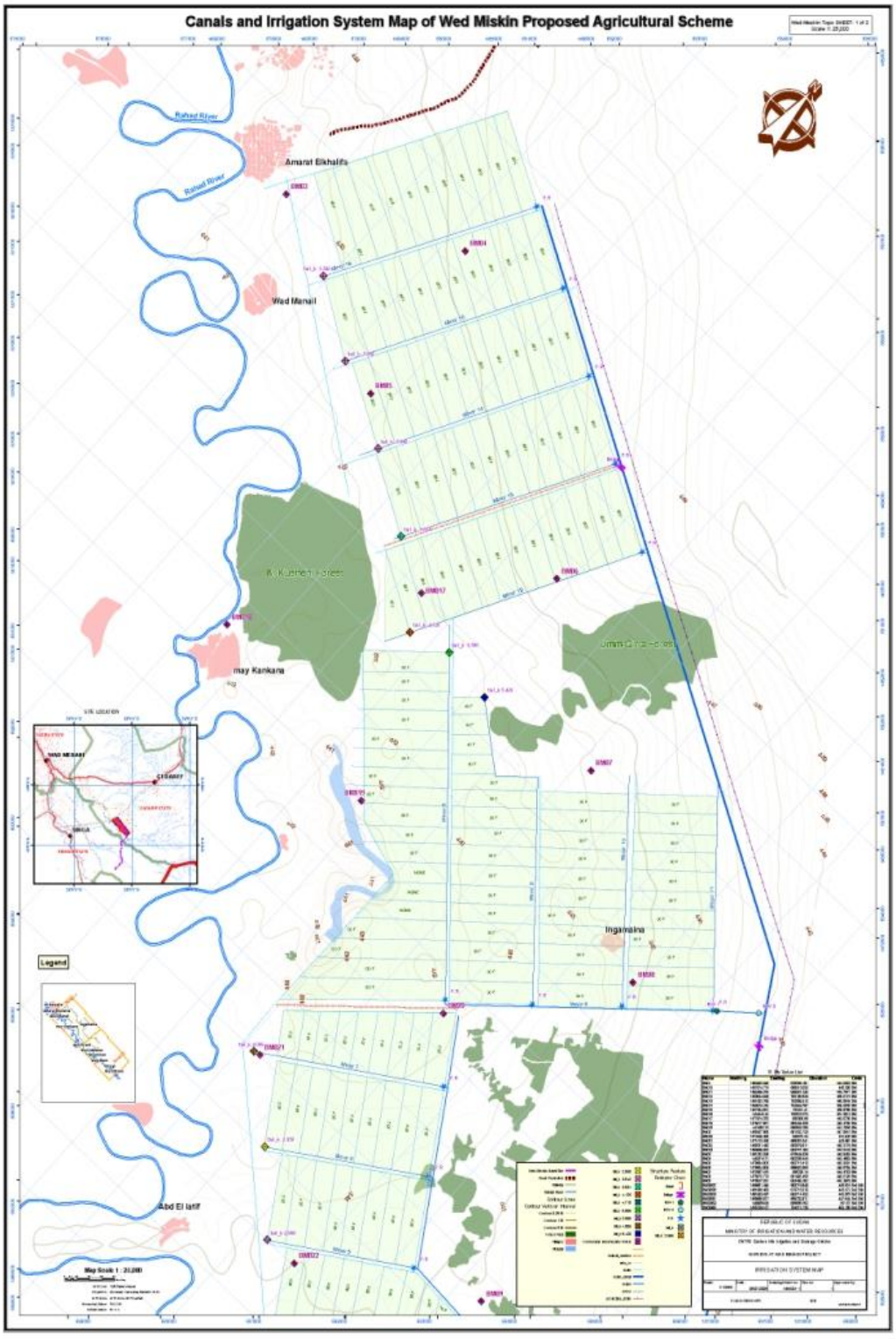


Figure 2. Project Area Design - South

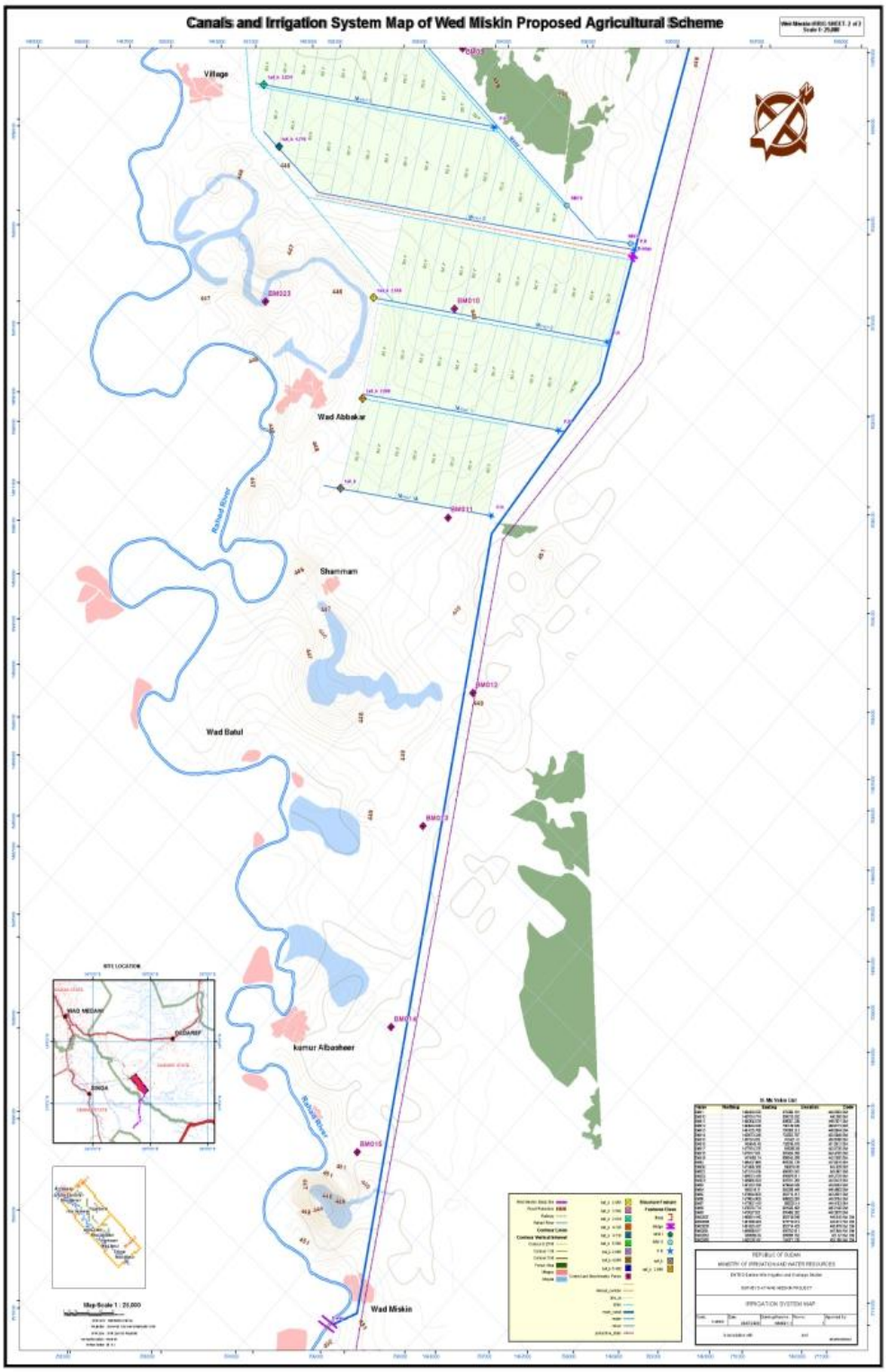
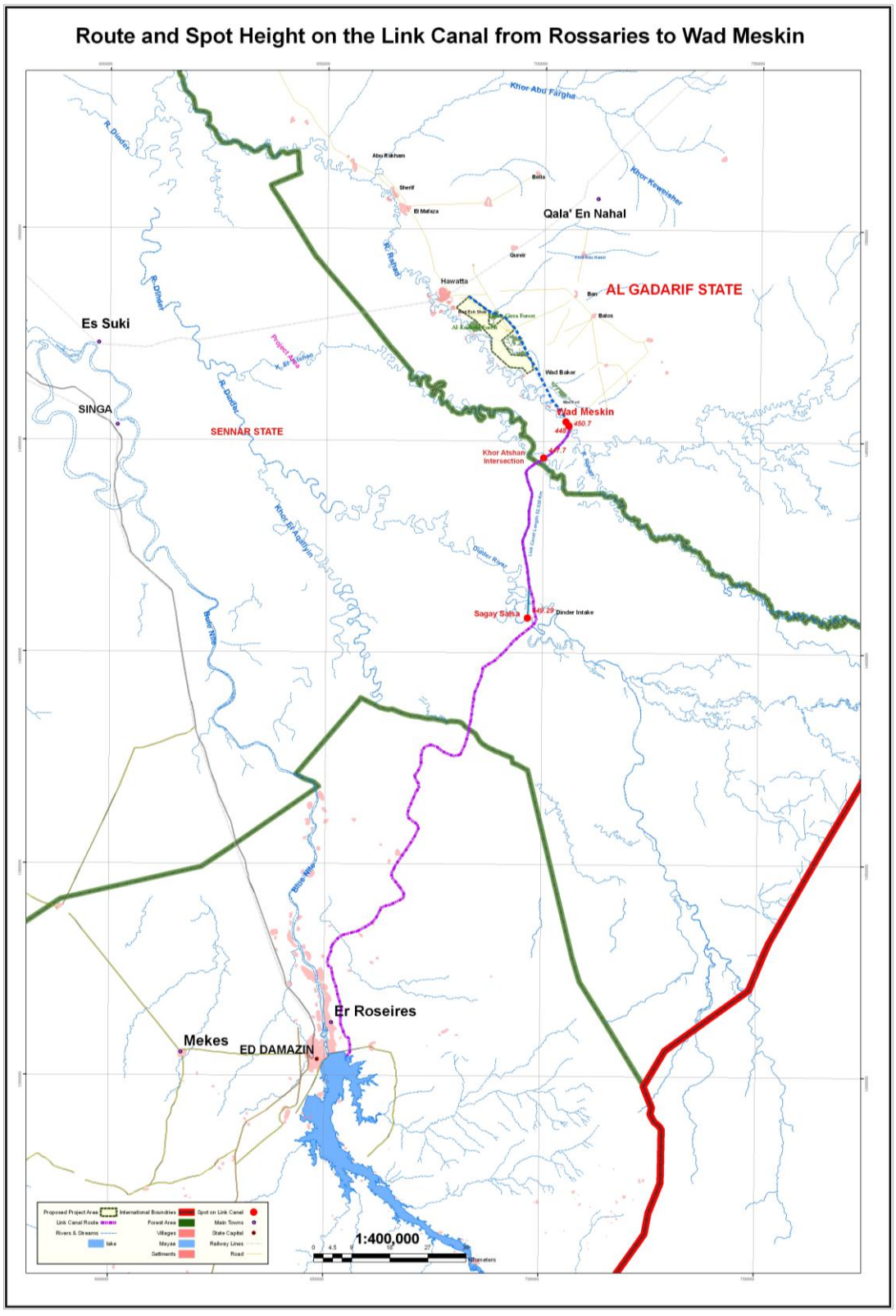


Figure 3: Location of Barrage Sites and Project Area



Barrages: The Wad Miskeen barrage across the Rahad River has been planned as part of a large development plan that would regulate the flood flow of Rahad and Dinder during the wet season. These are intended to be linked to other work in progress by the Dams Implementation Unit (DIU) that is being planned in relation by the GoS heightening of the Roseires Dam. The barrage site on Rahad River is located upstream Wad Meskin village. At the barrage site, the river reach is narrow and straight. There are gardens on both banks of the river there. The barrage is designed to pass safely a flood discharge of 220m^3/s with a 100-year return period. The retention level is at RL 448.5, while the riverbed level there is at RL 445.0.
In the Wad Miskeen Project, the site for a proposed barrage across Dinder River has been selected on the edge of Dinder National Park (Salsal). This supersedes an earlier plan for a siphon that would pass the Roseires canal under Dinder River (Coyne et Belier, 1979).
According to the Ministry of Irrigation and Water Resources these irrigation structures - *the Rahad and Dinder barrages, link canal and the main canal*- that would be built as a supplementary irrigation phase are part of the requirements of the irrigation system needed after heightening Roseires dam, when some 185,000 ha would be implemented. The design procedure is very similar to that over the Rahad, but it is larger and flows longer than Rahad and is designed to pond and maintains water levels at RL 454.0m and to pass a flood discharge with a 100-year return period of 1,000 m^3/s with an upstream afflux not exceeding 0.30m.

Link Canal: This is proposed to be an open earth canal linking the two barrages at Salsal and Wad Meskin on Dinder and Rahad rivers respectively. Its function would be to convey part of Dinder waters to Rahad. The design flow of the link canal is 100m^3/s and it is 53.8 km long. The link canal route follows the original alignment (that of Sir M. MacDonald & Partners: reported in Coyne et Belier, 1979) except in the first 9 km of its length. The canal crosses a number of khors, notable among them is Al Atshan. The natural ground slope along the canal route is about 0.10m/km. The link canal would supply water for supplementary irrigation in an area much larger than Wad Meskin, and is expected to operate intermittently during the rainy season.
Accordingly, heavy siltation is anticipated. In order to get rid of the fine suspended sediment that manages to enter the head works, and makes it to deposit at some specified places, provision of a settling basin in the head reach of the link canal is necessary. A settling basin there is important in reducing future maintenance costs: firstly by confining sediment clearance works at the head reach only instead of all along the canal length; secondly the maintenance of El Atshan siphon, with reduced suspended sediment load in the flow will be much easier and less costly. The project has designed a wide and long settling basin to settle suspended sediment in the range of very fine sand or smaller and the longitudinal bed slope of the link canal has been designed to be flat with a slope of 4cm/km, and a wide bed width in order to settle a significant part of the suspended wash load. Engineering calculations indicate that a basin having a bed width of 40m and a length of about 26.5km and a flow depth of 3.83m with side slope 2H: 1V is needed in order to settle down suspended sediment down to the size of coarse silt. After the settling basin, between km 26.623 and 38.296, the link canal will have a longitudinal bed slope of 8.6cm/km and a trapezoidal cross section with bed width of 30m, normal flow depth of 3.58m and side slope of 2H: 1V. This particular longitudinal slope was determined so that the resulting mean velocity (0.75m/s) will be the maximum allowed for the type of soil i.e. black cotton soil. At station 38.296km, the link canal crosses underneath khor El Atshan by a siphon. Thereafter, the same canal cross section is maintained up to the canal outfall at km 50.0. The outfall is a gated structure in every aspect very similar to the canal head works at Salsal. The outfall structure serves two purposes: to control the flow into Wad Meskin barrage pond, and to prevent the ponded water from getting into the link canal when the latter is dry.

Main Canal: The main canal is designed according to the Ministry of Irrigation standards which is now operating in the Gazira scheme with an area of one million ha (about 2.2 million feddans) and working with high efficiency for about 80 years. Also Rahad phase I with an area of 126,000 hectares (300,000 Feddans) and working for 30 years. The main canal is designed with capacity of 10m3/s, taking water from Wad Meskin proposed barrage and extending to Sudan railway line in Hawata town. The main canal length is 37.5 km irrigating an area of 7,743 ha; the bed width is 6.00 m with a side slope 2:1. The total excavation of earthworks is 312,173 m^3. The main canal has two major canals branching from it. There will be a regional road 6.00 m wide parallel to the main canal with a gravel layer of 0.2 m.
Cost estimates and feasibility calculations were made for the following development scenario:

1) Phase 1 would comprise the implementation of the 7,500 ha net Wad Miskeen project, the Rahad Barrage and a 10 m3/s feeder canal. These developments are only intended to improve rainfed agriculture.
2) Phase 2 would comprise the implementation of 100,000 ha with water from Rahad River and Dinder River, diverting water via a 100 m3/s link canal. The Wad Miskeen feeder and main canal would be enlarged and extended.

3) Phase 3 would comprise the construction of the Roseires Canal either up to the Dinder Barrage, where it would be linked to the Phase 2 conveyance system, or to the extended main canal if the Roseires Canal has to follow an alignment that would cross the Dinder downstream of the Salsal Barrage.

1.2 TERMS OF REFERENCE

The Terms of Reference for the Environmental and Social Impact Assessment of the Wad Miskeen Study were given in the ENIDS contract between BRL and ENTRO, and stated that:

"Irrigation and drainage schemes, whether large or small-scale, are likely to generate impacts that can have significant effects on the immediate and off-site environments, and these may range from soil erosion and sedimentation, to an increase in the prevalence of vector-borne diseases, especially malaria, guinea worm. The Consultant will undertake an environmental impact assessment, in line with African Development Bank guidelines.
These will include assessments of the institutions responsible for the resettlement of affected population and make recommendations for their improvement. The study also, will include collection and analysis of environmental baseline data, identification of impacts (both positive and negative) and their evaluation, design of mitigating measures, and an environmental management and monitoring plan. The particular issues that are to be addressed will include but not be limited to:

- Soil erosion and sedimentation in the catchment area of the project;
- Flooding and water-logging;
- Water-borne diseases (malaria, schistosomiasis, bilharzia and others);
- Fertilizer and pesticide application;
- Effects on quality of water in downstream receptors;
- Re-settlement of affected population;
- Transboundary impacts.

"The Environmental Impact Assessment studies would cover the downstream countries as well as the project areas. The Social value of irrigation development in terms of mitigating the negative effects of drought such as loss of human and animal life would be discussed, and the Consultant will provide a methodology on how to quantify in monitoring terms the social benefits that can be accrued from irrigation development like curtailing movement of refugees around the border areas. The study will identify the relevant natural resources, the eco-system and the population likely to be affected. Direct and indirect impacts will be identified and any particularly vulnerable groups or species highlighted. In some instances views will be subjective and the Consultant will give an indication of the degree of risk or confidence and the assumptions on which conclusions have been drawn.
"The output required will be a report examining the existing environment, the impacts of the proposed project on the environment and the affects of the environment on the project, both positive and negative, the mitigating measures to be taken and any actions needed. Interim reports, for example of baseline studies, will be phased to be of maximum value to parallel technical and economic studies.
"Baseline data collection, if needed, can be time consuming and will have a major impact on the cost and time needed for the study. If considerable data exists, for example a good record of water quality information and hydrological statistics, the EIA may be possible without further primary data collection. If data are scarce, time must be allowed for field measurement and analysis. In any event, reference would be made to publications such as the ADB guidelines (available at the Bank website) and World Bank Operational Directive 4.01 (1991). The format will be designed to suit the national and transboundary aspects. The Consultant will focus on the major issues and the most serious likely impacts, opportunities for enhancing any positive benefits from the project should also be highlighted."

1.3 COMMENTS ON THE TOR

1.3.1 Downstream Countries

The Wad Miskeen study area lies along the Rahad River and would receive water from that and the Dinder River. Both these are important ephemeral tributaries of the Blue Nile. Egypt, the downstream country lies 1,080 km to the north where the Main Nile enters Lake Nuba. The environmental team has not made a special visit to Egypt for ENIDS but is familiar with the Blue and Main Nile throughout its length in Sudan and Egypt. This assessment has considered the impact of the project on the flow into Lake Nuba (Aswan) and upstream reservoirs.

1.3.2 Field Measurement and Analysis

The environmental studies, which have involved two environmental specialists - one Sudanese for 1 mm, and one international for three weeks, have utilised the baseline surveys made for soils, social studies, topography, agriculture, livestock, and geotechnical works. It was not possible to commission any further studies, since there was no provision in the project costs for additional staff and time. The study area was visited during the dry and wet seasons of 2008-2009, pre- and post-harvest, to gauge the status of the natural vegetation, land use practices and assess the crop calendar.
Where it is not clear that we have the data to close on a particular issue we say so. This is usually because we did not have the personnel or time resources to make detailed assessments of, for example, faunal and floral ecology including *maya* lakes, archaeology, and nomadic movements. These need to be included in a detailed programme of assessment at the time of detailed design. All these types of surveys would each take several months work by various specialists. Both dry and wet season surveys are needed, and for fauna night-time surveys are important as much of the smaller mammals are nocturnal. The FS had no budget or time allocation for such surveys, interesting and essential as they might be, and we have made the best of the available data and our own extensive field surveys.

1.4 METHODS

1.4.1 General

The methods used in the environmental impact assessment (EIA) of the Wad Miskeen project follow the procedure given in the ToR, with reference to EIA guidelines of the AfDB, the World Bank Operational Directive 4.01 (1991), and Sudan Environment Protection Act. The environmental work has made full use of other annexes in the project, and examined numerous research papers, documents and reports on the area. It has not though had official access to a parallel study being made for the Kenana-Rahad Irrigation Projects by the Dams Implementation Unit (DIU).
The EIA describes the biophysical and social environments of the study are, and relates identified environmental impacts with proposed mitigation measures, where these are necessary, so as to ensure that the project proposals and design plans are compliant, and in accord, with the AfDB and Sudanese environmental assessment procedures and requirements.
The principal purpose of an irrigation project is to increase agricultural food production, usually in an area where rainfed cropping is difficult or impossible as rainfall is deficient, insufficient or irregular, and there is a high risk of crop failure: in 2009 in the Wad Miskeen and adjacent lands, very large areas of rainfed sorghum have totally withered as the rains started and then stopped. In this case irrigation water could have supplemented the rainfall and allowed a harvest. The potential of the proposed project therefore for food security amongst the local population and region is strong.
Other positive environmental and social impacts resulting from irrigation development include higher crop yields; and higher cropping intensities with multiple cropping; poverty reduction and reduction in malnutrition; the elevation of farm outputs and higher farm incomes; creation of employment possibilities on the farm and other infrastructural activities.
Land use changes effected by irrigation development will also impact on the bio-physical environments, and all or part of forests and woodland, rangeland and pasture, flora and fauna can be lost. The social impact from the forced displacement of, for example, farmers and nomads already in an area is one such issue that requires careful assessment of existing land use practices. The land tenure studies of the FS examine the existing land use patterns and rights, so that all potentially project-affected populations are indentified.
Water abstraction from rivers and agrochemical or industrial waste laden polluted return flows can cause further impacts on water users, biota and habitats, and there are threats also to near surface or deep aquifers, who may be extracted at locations remote from the project. Disease vectors can be enhanced by irrigation infrastructure, but the delivery of water to lands previously water-short areas, that improves human settlement and livestock are positive impacts. A recent study on pollutants in the Nile by Mostafa El-Sheekh (2009) noted that few studies have been made in Sudan.
Negative impacts of the bio-physical environments though can be common, and have the capability to wreck a project before it is off the ground. Sufficient care must be taken to plan a project, and a successful project plan will need to make a balance of the contrasting impacts: the ICID checklist, with its supporting guidelines, ensures that these issues are thoroughly examined in a step-by-step procedure.

The key tasks of the environmental impact assessment studies are to assess any potential positive and negative impacts that may arise from the implementation of the Project in a manner that facilitates the comparison between available project alternatives. These involve screening and scoping of impacts, the identification of mitigation measures, and proposals for environmental management.

1.4.2 Screening

The EIA has been initiated with the collection of all known previous baseline studies in the area, and the database assembled in the screening has included previous works and assessments made as part of the study: soils, topography, geotechnical studies, hydrology and hydrogeology, land use and land cover, fauna and flora, socio-economic and livelihoods. The initial screening also is central to categorising the project in terms of the level of environmental assessment required (see 1.5).
A full list of sources is given in the references at the end of this Annex. A key part of the screening, scoping and impact assessments of the EIA for this project has been the use of the guidelines and checklist prepared by the International Commission for Irrigation and Drainage (ICID). The ICID checklist (Mock and Bolton, 1993; Doughtery and Wall, 1995) provides a very useful template with six categories for classification of impacts:

- A Positive impact very likely
- B Positive impact possible
- C No impact likely
- D Negative impact possible
- E Negative impact very likely
- F No judgement possible at present

The ICID checklist (**Table 1)** system assists project planners and higher-level decision-makers in trading-off between the different alternatives for an irrigation project. The criteria used for comparing project alternatives are not limited to the impacts of the project on the physical environment - such as natural resources and biological life - but also include the impacts on socio-economics, as well as economics. The ICID checklist is useful for making systematic basic or in-depth assessments of possible impact issues related to a Project.
When applied to screening process it also enables to provide indications of impacts that are clearly not relevant to the project: for example, estuary erosion and saline intrusion, and these have been eliminated from the impacts requiring further consideration.
The environmental assessment at the screening stage identified impacts that required further evaluation and where possible these have been covered by other specialists in the feasibility team, such as impact of diseases on animal production, suitability of the proposed crops, state of wildlife flora and fauna in the vicinity of Dinder National Park, engineering impacts on hydrology and erosion, and public health considerations resulting from increased irrigation.
At screening and scoping levels, a score indicates the likelihood of an impact, but does not make a conclusion on the significance of the impact. For example a predominant listing in category E might indicate a very likely negative impact for a project, but this may not give an accurate picture as individual impacts cannot readily be compared against each other without making very detailed assessment in an impact analysis. For this reason it is not advisable to list the sum of scores for each level of impact.

1.4.3 Scoping

Whilst screening leads to a narrowing down of the key issues, and elimination or marginalising of possible impacts which are found to be of minimal concern or not relevant to the area, the scoping part of this EIA provides a more detailed assessment. Within the context of the Wad Miskeen Feasibility Study, made over a few months, a practical approach has to be adopted. This has utilised existing baseline knowledge from older surveys and new data gained during the study, to elaborate on the likely environmental impacts relating to the project, and how mitigation measures could be implemented. The scoping defines the scope of the work that is needed to define, in as precisely as possible, the biophysical and social environmental impacts, and the options for mitigation measures, monitoring as part of an environmental management plan, and the necessary institutional matters.

Table 1: ICID Checklist for Environmental Impacts

For each environmental effect a cross (x) is placed in one or more of the columns		Positive impact very likely	Positive impact possible	No impact likely	negative impact possible	Negative impact very likely	No judgment possible at present
Report section	**Impact Category:**	**A**	**B**	**C**	**D**	**E**	**F**
4.1 Hydrology	**Low flow regime**						
	Flood regime						
	Operation of dams						
	Fall of water table						
	Rise of water table						
4.2 Organic & Inorganic Pollution	**Solute dispersion**						
	Toxic substances						
	Organic pollution						
	Anaerobic effects						
	Gas emissions						
4.3 Soils and Salinity	**Soil salinity**						
	Soil properties						
	Saline groundwater						
	Saline drainage						
	Saline intrusion						
4.4 Erosion and Sedimentation	**Local erosion**						
	Hinterland effect						
	River morphology						
	Channel structures						
	Sedimentation						
	Estuary erosion						
4.5 Biological & Ecological Change	**Project lands -a-Land take:**						
	-b-Provision of irrigation						
	-c- Settlement development						
	Water bodies						
	Surrounding area						
	Rivers & riverine habitats						
	Rare species						
	Animal migration						
	Natural industry						
4.6 Socio-economics	**Population change**						
	Income & amenity						
	Human migration						
	Resettlement						
	Women's role						
	Minority groups						
	Sites of value						
	Regional effects						
	User involvement						
	Recreation						
4.7 Health	**Water & sanitation**						
	Habitation						
	Health services						
	Nutrition						
	Relocation effect						
	Disease ecology						
	Disease hosts						
	Disease control						
	Other hazards						
4.8 Ecological Imbalances	**Pests & weeds**						
	Animal diseases						
	Aquatic weeds						
	Structural damage						
	Animal imbalances						

Source: ICID Checklist by Mock and Bolton, 1993.

Consultation with stakeholders on the project proposal and to obtain data is an important part of the EIA, and in this study these have ranged from farmers and nomads through to representatives of government agencies. Potential stakeholders are identified in the initial screening for the project. A list of organisation and people met and a summary of discussions are given in Appendix A.

The environmental assessment for the Wad Miskeen area was made during 2008-2009 by two natural resources and environmental specialists, Sudanese and International, experienced in the practical aspects of rural development planning and environmental assessment.

Activities included: review of existing planning documents of the project; review of reports and studies of other irrigation projects in the study area; field trips to the study area before and after the wet season; and evaluation of the obtained information, discussion with other experts of feasibility study team.
The evaluation of the information obtained is aimed at screening out or highlighting those issues of high significance under particular conditions of the project and the local environment. To do this use has been made of the information and analyses undertaken by the technical, social and economic study teams.

1.4.4 Mitigation Measures

The scoping studies identify the key impacts that will require mitigation measures on the project. These measures are defined in terms of what they are, how serious the issues are; who or what institutions will be responsible for implementing mitigation; how will these be accomplished, in what time frame, and at what cost.

1.4.5 Environmental and Social Impact Management Plan

The last section of this EA is to present an Environmental Management Plan for the proposed project. This provides an implementation plan for the mitigation measures that aim to minimise or eliminate any negative impacts. It will also suggest the proposed indicators for biophysical and socio-economic monitoring on the project, and will review any negative impacts, how they can be mitigated, and lay out the likely institutional arrangements regarding which institutions will implement mitigation monitoring, within a certain time frame and with indicative costs.
The time allowed for the environmental studies has been short and some more comprehensive investigations are recommended to be made during the follow-up detailed design stage to assess, amongst other topics, wildlife biological aspects, and village planning.

1.4.6 Environmental and Social Impacts in the Context of Irrigation Projects

The function of environmental studies during project preparation is to analyse all these issues, to identify the associated risks and opportunities, and to point out ways in which negative impacts can be avoided or mitigated, and positive ones can be enhanced.

1.5 Environmental Categorisation of the Project

The Wad Miskeen Project would involve large-scale engineering works on the Dinder and Rahad Rivers with a link canal crossing the Khor al Atshan. The proposed Dinder barrage lies on the border the Dinder National Park and seasonal movements of wildlife out of the Park could be disrupted by canals acting as barriers.

The presence of a water barrage close to a national park could also lead to pastoralists moving into the park. In the irrigation area and link canal line, canal lines also could cut through riverine forest and farmlands, and nomad pastoralist's stock routes would be displaced. Whilst positive impacts are indeed likely from the project, it is also probable that negative impacts will occur to the ecology and biodiversity of these ecosystems and to the livelihoods of existing inhabitants; mitigation to minimise such disruptions would need to be put in place.
The African Development Bank (ADB) has four categories of environmental assessment (ADB, 2004):

- Category 1 projects will require a full Environmental and Social Impact Assessment (ESIA), including the preparation of an Environmental and Social Management Plan (ESMP). These projects are likely to induce important adverse environmental and/or social impacts that are irreversible, or to significantly affect environmental or social components considered sensitive by the Bank or the borrowing country. The ESIA examines the project's potential beneficial and adverse impacts, compares them with those of feasible alternatives (including the "without project" scenario), and recommends any measures needed to prevent, minimise, mitigate or compensate for adverse impacts and to enhance environmental and social project benefits.
- Category 2 projects require the development of an Environmental and Social Management Plan (ESMP). These projects are likely to have detrimental and site-specific environmental

and/or social impacts that are less adverse than those of Category 1 projects and that can be minimized by the application of mitigation measures or the incorporation of internationally recognised design criteria and standards.

- Category 3 projects require no impact assessment. These projects shall involve no adverse physical intervention in the environment and induce no adverse environmental or social impact. Beyond categorisation, no further ESA action is required for this category of project.
- Category 4 projects involve investment of Bank's funds through Financial Intermediaries (FIs) in subprojects that may result in adverse environmental and/or social impacts. FIs include among others banks, insurance and leasing companies, and investment funds that on-lend Bank's funds to small and medium size enterprises.

These considerations made the Consultants conclude that the proposed project should be deemed as a Category 2 Project in the African Development Bank environmental assessment procedures for which an environmental and social assessment is required. In this category, there would be impacts but they would be less diverse than Category I. Despite this limited time has been allowed for this study (a total of 1.6 mm) and this has meant that detailed surveys and assessments were not possible: baseline studies made by the project have been used to make the environmental and social assessment. Much more could have been possible if resources had been included in the staffing times allocated by ENTRO with surveys over the seasons.

2. LEGISLATIVE AND INSTITUTIONAL FRAMEWORK

2.1 LEGISLATION

There are three types of laws in the Sudan: Islamic Law, Customary Law and Statutory Law. The 1998 Constitution recognizes Islamic Law and Customary Law as the two main sources of legislation in the Sudan. A third set of laws is included in the Statutory Law. The majority of enacted environmental and natural resources law, such as those relating to fisheries, game and wildlife, forestry legislation, etc. fall under Statuary Law. Customary law encompasses those indigenous rules, which govern the rights and duties of indigenous peoples in their relationship and transactions and in their use of natural resources, especially land and water. Hence, customary laws are as numerous as the tribes in the project area. Islamic Law is more homogenous and covers those rules governing personal relationship and transactions, land ownership and land use, which are administered by the Sharia Court (Court based on Islamic law).

Attitude to the three types of law vary. Although customary law usually has less sophisticated means of implementation and/or enforcement, as compared with statutory law provision such as regulations, licenses fines, etc., it has a higher rate of compliance than statutory law. Some of the statutory laws are outdated and out of step with economic, social, political and environmental developments. Although statutory law covers by far the bulk of environmental and natural resources, both the content and the inadequacies in the machinery for enforcement render it the least effectual of the three.
The Sudan Comprehensive Peace Agreement (CPA) and the Sudan Interim Constitution and their various provisions an important opportunity and an enabling environment for Government of National Unity to undertake the required restructuring and reform the bulk of environmental and natural resources legislation. In the absence of a comprehensive environmental and natural resources legislation, regulatory measures for environmental management have been affected on a piecemeal, sectoral basis. There are over 150 natural resources laws and sectoral regulations dealing with health, water supply, land tenure, game, protected areas, fisheries and marine resources and other sectors of natural resources. An important step was taken towards a better Co-ordination with the more recent establishment of an environmental and natural resources law. The Environmental Protection Act (EPA) of June 2001 is a framework law to policies, legislations and executive actions of federal state organs.

2.2 SUDANESE ENVIRONMENTAL INSTITUTIONS

Early work on environmental issues in Sudan were made by the Hydrobiological Research Unit, University of Khartoum (founded in 1953), the Institute of Environmental Studies (IES), founded in 1979 also of University of Khartoum, and the Sudanese Environment Conservation Society (SECS) founded in 1975. IES and SECS remain active and these institutions continue to collect and analyse data and make urban and rural peoples aware of environmental issues.

Concern amongst leading scientists in Sudan of the deterioration of parts of Sudan's environment led, in 1992, to the formation of the Higher Council for Environment and Natural Resources (HCENR), which was established earlier in 1992. In 2001, the HCENR became part of Ministry for Environment and Physical Development (MEPD. The HCENR is responsible for overseeing, co-coordinating and biasing on environmental issues at the national level.
Within the federal system of governance, responsibilities for environmental management are divided between the Federal and State governments. The Federal Government has exclusive jurisdiction over matters relating to natural resources, minerals (surface and underground) and transboundary waters. Detailed regulations on lands, state forests, agriculture, livestock and wildlife are state responsibilities, but are subject to Federal Planning and Coordination.

Accordingly, in addition to the HCENR, there are state Council Comprise representatives of governmental and non-governmental organizations that have connection with environmental matters, including state ministry and federal ministries (e.g. Agriculture, Social and Cultural Affairs, Health), Forestry Administration, Farmers Union, Women's Union, Student's Union and many others. Originally, it was expected that the HCENR would have some Co-coordinating function over the state councils, but with the introduction of the Federal Government Law, in practice they are now acting largely independently of the National Council.

2.3 EIA LEGISLATION IN SUDAN

In the past many rural development projects in Sudan were concerned with sustainable development and environmental impacts, whether negative or positive, were carefully assessed and mitigations built into the project implementation phases. In recent decades, and in response to cases of poorly planned development in many countries elsewhere, the donors began to develop their own sets of environmental guidelines. The World Bank was the first and the African Bank is modelled on this. In Sudan there was no strong concern at Government level to establish EIA legislation.

On the NGO front though there was very active interest in environmental issues from the early seventies, and the Sudanese Environmental Conservation Society (SECS) helped raise awareness of the environment throughout the country. More recently Sudan though has started to make steps towards a comprehensive environmental legislation, the Environmental Protection Act (EPA) of 2001, is awaiting Presidential approval before being implemented. This states that 'any large developmental project, which construction might negatively impact the quality of the environment should undergo an Environment Feasibility Study (EFS)'. Under chapter III, number 17 (1) of the EPA an environmental study should be carried out for all projects that may have adverse effects on the environmental and natural resources. The study must be presented to and signed by a committee constituted by the Higher Council for Environment and Natural Resources (HCENR). Provision number 17 (2) defines what this feasibility study must cover. It includes:

- Expected impact of the proposed project on the environment;
- Negative impacts that can be avoided upon project implementation;
- Available alternatives;
- Sufficient explanation that the short term exploitation of the natural resources and the environment will not affect the productivity of those resources in the long term;
- For a project that will exploit non-renewable natural resources, the feasibility study should include emphasis on national exploitation of such resources; and precaution measures to mitigate negative effects of the project.

How long it will take until the EPA is finalized and made into Law cannot be foreseen, though it is said from informed sources that a final draft is almost ready. According to Marghani (2003) it should provide guidelines that advise who will implement the findings of an EIA, who will supervise the implementation, and who will supervise the implementation.

2.4 NATIONAL POLICIES AND INTERNATIONAL CONVENTIONS

While for a long time the environmental issues were only dealt with by the Ministries that

involved utilization of natural resources (such as Agriculture, Irrigation), the environment was recognized as having a committee of its own within the National Strategy for Comprehensive Development (1992 to 2002).

The Quarter Century National Comprehensive Strategy (2002 to 2007) was prepared. The strategy has highlighted fifteen goals as the most "National Challenges" to be addressed. Three of these are of significance: Achieving integrated human resources development ; The conservation of natural resources and the striking of a balance in their exploitation between the present needs and the rights of the coming generations; preserving the sustainable environmental purity of the natural resources ; emphasizing and achieving rural development.

Sudan was a participant in the UNCED, and it signed and ratified all the related conventions. Since 1992, the Sudan has put in place several strategies, policies and programmes aimed at sustainable development. These include: Capacity 21 – Sudan; National Biodiversity strategy (2001); National Action Plan to Combat Desertification (2002); and the Climate change Enabling Project (2002). Further (proposed as draft) policies include: a water policy; a forest outlook; and Document on Sudan's Commitment to Social Development and Population Policy.

2.5 AFRICAN DEVELOPMENT BANK ENVIRONMENTAL ASSESSMENT PROCEDURES

The ADB produced Integrated Environmental and Social Impact Assessment (IESIA) Guidelines (ADB, 2003) that merge previous environmental and social guidelines into one set of procedures. Appendix 1 of these guidelines deals with irrigation and states that the major issues that can arise relate to specific problems with the crosscutting of poverty, environment, population, health outcomes, gender and participation. The issues to be examined are defined in a series of components, as follows:

- Poverty issues: assessment of economic activity, employment, incomes, compensation for losses, access to benefits, skills and infrastructure.
- Environment: watershed management, water quality, drainage and sedimentation, water use, soil characteristics, natural heritage, and the protection of vegetation, habitats and specific ecosystems.
- Population: involuntary resettlement and migration, population characteristics and dynamics, land uses, water uses and rights, natural resource management, agricultural practiced and local customs, and quality of life.
- Health Outcomes: vector-borne and water borne diseases, sexually transmitted diseases, food supply and drinking water, accidents and injuries, sanitation and hygiene.
- Gender: women's workload, control over land and land proceeds, income generating activities, access to facilities and services, women's involvement in decision-making processes.
- Participation: participation of affected groups in consultations, organisation of irrigation water management.

The guidelines also specify the potential benefits and adverse impacts that may arise, and provides a list of appropriate enhancement and mitigation measures in relation to each component.

Taking wildlife fauna as an example, a positive impact could be water retention; negative impacts include fragmentation of habitats, creation of habitats suitable for disease vectors, and increase in poaching. The mitigation measures include keeping clear of the area during reproductive periods, preservation of wildlife corridors, and control of hunting, appropriate control of disease vectors.

The ADB Guidelines also suggest the types of indicators for environmental and social monitoring that would be included in an environmental management plan. These cover poverty, environment, population, health outcomes, gender and participation. They are discussed later in this report.

3. BASELINE DATA

3.1 LAND RESOURCES

The lands of the Wad Miskeen area lie on the eastern part of the Central Clay plain of Sudan (Blokhuis, 1993; FAO, 1970), and on the right bank of the Rahad River. In the study area they are predominantly dark brown clayey Vertisols (Soil Survey Staff, 1999; Dudal, 1969; HTS, 1966a; LWRC, 1994, 2009).

The undulating clay plains of the Wad Miskeen area are underlain by granitic rock of the Ban–Balos granite complex (Ruxton and Berry, 1961), that were intruded into schists (Ruxton and Berry, 1978). The granite and schists are part of the Pre-Cambrian Basement Complex (HG&G, 1969; GRAS and Robertson Research, 1988 and 1995). Only one small outcrop occurs within the proposed area but granite and other metamorphic occurs at depth over the command area. Neither soil profile pits, nor sections in river banks, show any other bedrock outcrops. The western limit of the basement outcrop lies within a short distance east of the Rahad River, according to Ruxton (1956) and Ruxton and Berry (1978). To the west of the Rahad River there are undulating clay plains developed on old courses of the Rahad and Dinder Rivers, that overlie sediments of the El Atshan Formation (Ruxton and Berry, 1978), part of the Umm Ruwaba Formation which in turn, at depths of 50 to > 80 m pass into a sedimentary basin, for some time the subject of deep groundwater and petroleum exploration (GRAS & Robertson Research, 1995). The Quaternary history of the region has been discussed in a number of benchmark papers (Williams and Adamson, 1982; Williams and Faure, 1980; Williams and Talbot, 2009; Williams, 2009; Williams *et al*, 2010).

Hunting Technical Services (HTS, 1966a) reported that the clay deposits of the Wad Miskeen area are believed to be a weathering product of the Basement Complex of the higher surrounding areas, and that the alluvial deposits of the Blue Nile and Rahad can hardly be found in areas above 400 m asl contour line: except for limited areas along the Rahad River meander belt, the Wad Miskeen area lies above the 400 m contour line and have been considered as colluvial–alluvial. As most of the area lies above the level of the Rahad River floodplain, or traces of its higher extent seen in old meanders, it is apparent that these soils have in general not formed from Rahad alluvium. Blokhuis (1993) reaffirmed this view and distinguished two types of clay plain: aggradational, where alluvial sediments have been subject to soil formation and these include the central parts of the Kenana-Dinder plains deposited by the Blue Nile, Dinder and Rahad rivers and their former courses; and degradational, where soils have formed from products of weathering of rock formations in areas with more than 300 mm rainfall and form clay-rich soil catenas ranging from reddish brown clays in the upper and better drained parts, to black cracking clays in the lower lying to flat areas.

Along the link canal from the Dinder barrage site to the Rahad the lands are slightly undulating plains clay plains with similar properties. In this area in the late 1960s a soil survey was made by the Soil Survey Division (later the Soil Survey Administration and currently LWRC) and FAO, as part of a technical assistance programme to strengthen soil survey procedures (FAO, 1970). These lands are under rainfed cropping but many parts are fallow under grassland or as regenerating woodland.

The soils of the area have been investigated at several times: firstly as part of the Roseires Soil Survey (HTS, 1966a). The area was reviewed by Coyne et Belier, HTS et al. (1978) who agreed that the soils were very uniform, almost everywhere deep Vertisols with about 70% clay content and low land levelling requirements.

The effect of this re-examination of the 1965 field data (*HTS, 1966*) was that much of the land was upgraded from class 3 to 2. In the Rahad II area that extends over Wad Miskeen, the *Blue Nile Waters Study* found that Class 2 land covered over 98% of the area that is determined by soils having a surface ESP (exchangeable sodium percentage) of 10-19 and <35 in the top 0.9 m and a low electrical conductivity.

Sodicity was found to be noticeably higher north of the Jebel Faw, far from the Wad Miskeen area, probably a result of lower rainfall and less leaching by rainfall or due to differences in parent material. It is also known that a number of soil profiles were analysed by the joint FAO-Soil Survey Administration studies in the late 1960s (FAO, 1970) in the wad Miskeen area, but the locations of the sites are at present not known.

Later, semi-detailed soil surveys were made by the Soil Survey Administration (now LWRC) (SSA, 1994). These surveys mapped soils based on the Sudanese soils series classification, and the datasets are available in the reports. The surveys compared data to the HTS (1966) surveys but not to the 1987 Blue Nile Water Study. Fertility was generally low in all soils, particularly nitrogen, and available phosphorous.

The Rahad River originates in the uplands of Ethiopia, west of Lake Tana and has cut meandering channels into clayey coverplains derived from their own overbank deposits and adjacent alluvial – colluvial plains. East of the Rahad River, in the proposed Wad Miskeen irrigation area, these clay alluvial-colluvial coverplains rise gently to the north-east and comprise some 3 – 4 m of dark vertisol clays, but at greater depths the soil substrate is variable, with clayey to sandy alluvium and gravelly and concretionary layers. Elsewhere on these non-alluvial upland plains, the subsoil includes colluvium, weathered Nubian Sandstone and weathered Basement Complex metamorphic rocks but these are not seen in the Wad Miskeen area. There are a few small outcrops of Basement metasediments in the area and the clay deposits come up almost to the rocky slopes.

Under the present project a soil survey has been made of the Wad Miskeen irrigation area in 2009, and has reviewed two soil surveys made over the same area in the past by HTS (1966) and SSA (1993). Within the region a number of key research studies have been made whose findings are of relevance to soil management and conditions on the Vertisols, in particular an analysis of soil conditions made of the Fung at the abandoned Tozi Research Farm, west of Abu en Nail (Bunting and Lea, 1962). The soils on the Wad Miskeen plains are similar, in being very uniform dark coloured smectitic, probably montmorillonite, clays, classed as Vertisols. Salinity and alkalinity (sodicity levels) were found to be generally low, and almost all the flat lands were classed as irrigable classes 2 and 3 (FAO land suitability system). Major limitations are the very heavy clay contents of the soils that in the wet season reduce the period for tillage and access.

From observations in the field and from a study of the contours it is apparent that Vertisol formation has occurred thus on a series of old alluvial and colluvial fan parent materials that have been washed, or flowed, down from the higher elevations to the east, from the most northern parts of the Ethiopian Plateau, and along the volcanic outlier of the Gedaref-Galabat Ridge - the watershed between the Rahad and the Atbara rivers. The topographic surveys of the area made for ENIDS show a steady rise to the east-north-east: on the Rahad River the elevation at Wad Miskeen is 450 m asl, and at Hawata it is 440 m asl, whilst the eastern boundary of the area is around 449 m asl.

In general the soils are deep cracking clays with very dark greyish brown (10YR3/2) moist colour throughout the profiles. The topsoil structure forms a granular mulch over much of the area, though this may be blocky in depressional areas. Below it passes down into a coarse prismatic breaking into coarse and medium sub-angular blocky structure with platy components. The subsoil structure, below 60 cm is medium sub-angular blocky with wedge shaped aggregates, becoming massive at lower depths. Pressure faces are conspicuous within the soil profile control section (25-100 cm deep).

The soils range from moderately well drained on convex sites (Chromic Vertisols) over about 3% of the area, to impermeable clays (Typic Vertisols) in the flatter and lower lying areas when they flood during the rains.

The chemistry of the soils, as indicated by the 2009 soil survey shows that the Typic Vertisols have high clay contents (72-78%), and require careful management, especially if heavy machinery is used under moist conditions. These soils also have a high cation exchange capacity (CEC), low levels of nitrogen and available phosphorous; low salinity from electrical conductivity of the saturation extract (ECe): up to 0.7 dS/cm salinity; and low exchangeable sodium percentage (ESP) up 7. The Chromic Vertisols are similar to the Typic Vertisols above in their chemical properties having high clay content (76-81%), high CEC, low nitrogen content, low available phosphorous, and low ECe (up to 0.4) and low ESP (up to 4). Both ECe and ESP increase slightly in the sub-soils as might be expected in this area of generally moderate rainfall.

A major problem with the Vertisols is the disposal of surface water. This was discussed at Tozi on the left bank of the Blue Nile by Bunting and Lea (1962), but the results are applicable at Wad Miskeen. They noted that land clearing of the savanna woodland for mechanised rainfed farming operations accentuated the drainage problem with standing water forming large pools in some areas. Another important observation made by Harrison and Jackson (1958) and confirmed by HTS (1966a), is that the clay plain soils can only absorb some 700 mm of rainfall and once that threshold is reached water then either ponds (in depressions) or runs off (sloping ground) and can cause gullying on the margins of the clay plains.

Summaries of soil mapping units and their chemical and physical conditions areas given in **Table 2, 3** and **4** respectively, with land suitability classes in **Table 5**.

Table 2: Soil mapping units

Mapping unit symbol	Classification USDA (1999)	Description	Area (ha)	%
VT	Typic Haplustert	Deep, very dark greyish brown (10YR3/2) moist, moderately well drained, non- saline, non-sodic cracking clay occupying flat sites on the clay plain.	6,624	69.0
VC	Chromic Haplustert	Deep, dark greyish brown (2.5Y4/2) moist, moderate to poorly drained cracking soils occupying receiving sites on the clay plain.	288	3.0
VTd	Typic Haplustert	Deep very dark greyish brown (10YR3/2) moist, moderately well drained non-saline, non-sodic cracking clay occupying seasonally flooded or receiving sites on the clay plain.	2,315	24.1
VTg	Typic Haplustert	Deep, very dark greyish brown (10YR3/2) moist; moderately well drained non-saline, non-sodic soils occupying gently undulating sites on the clay plain.	288	3.0
D	Miscellaneous land type (maya)	Low lying sites used as water reservoirs during the dry season for human and animal use.	85	0.9

Table 3: Summary of Soil Chemistry of Typic Vertisols

	Cm	VT Soil Unit 0 – 30	VT Soil Unit 30 – 90	VTd Soil Unit 0 – 30	VTd Soil Unit 30 – 90
Clay	*Average*	75	74	74	73
%	*Range*	70-78	70-78	73-75	73-74
pH	*Average*	7.7	7.8	7.5	7.9
paste	*Range*	7.6-7.7	7.8-7.9	7.3-7.8	7.7-8.1
CEC	*Average*	73	78	81	81
cmol(+) kg-1	*Range*	64-86	73-87	75-87	81-82
Ex. Ca	*Average*	45	46.5	48	49.5
cmol(+) kg-1	*Range*	37-55	38.0-56.0	42-53	49.2-49.8
Ex. Mg	*Average*	22.7	25.1	26.7	26.3
cmol(+) kg-1	*Range*	19.2-26	23.1-26.9	25.6-27.9	25.2-27.4
Ex. Na	*Average*	1.74	2.15	2.21	3.72
cmol(+) kg-1	*Range*	1.43-2.30	1.75-2.58	1.99-2.43	2.87-4.58
Ex. K	*Average*	0.31	0.30	0.18	0.12
cmol(+) kg-1	*Range*	0.17-0.40	0.12-0.45	0.17-0.19	0.12
Ca : Mg	*Average*	2	2	2	2
	Range	2	1-2	2	2
Total N	*Average*	0.051	0.055	0.058	0.055
%	*Range*	0.042-0.065	0.042-0.071	0.047-0.070	0.043-0.067
Org. C	*Average*	0.575	0.515	0.681	0.687
%	*Range*	0.560-0.58	0.499-0.567	0.552-0.810	0.516-0.858
C:N	*Average*	12	10	12	12
	Range	9-14	8-14	11-13	12-13
$CaCO_3$	*Average*	5.1	5.8	6	5
%	*Range*	4.6-5.7	4.8-7.3	6-7	5-6
Avail. P	*Average*	10.9	10.2	22.9	12.8
Ppm	*Range*	9.5-13.1	9.0-11.8	9.5-36.3	12.0-13.7
ECe	*Average*	0.2	0.2	0.3	0.5
dS/m	*Range*	0.2-0.2	0.2-0.3	0.3-0.4	0.3-0.7
ESP	*Average*	2	3	3	5
	Range	2-3	2-4	3	3-6

Source:LWRC,Miskin Soil Survey 2009

Table 4: Summary of Soil Chemistry for Chromic Vertisols

		VCd 0 – 30	VCd 30 – 90
Clay %	*average*	80	77
	Range	80	77
pH paste	*average*	7.8	7.9
	Range	7.8	7.9
CEC cmol(+) kg-1	*average*	88	87
	Range	88	87
Ex. Ca cmol(+) kg-1	*average*	55	53.6
	Range	55	53.6
Ex. Mg cmol(+) kg-1	*average*	25.5	27.9
	Range	25.5	27.9
Ex. Na cmol(+) kg-1	*average*	1.8	3.1
	Range	1.8	3.1
Ex. K cmol(+) kg-1	*average*	0.25	0.14
	Range	0.25	0.14
Ca : Mg	*average*	2.5	2
	Range	2.5	2
Total N %	*average*	0.05	0.04
	Range	0.05	0.04
Org. C %	*average*	0.6	0.5
	Range	0.6	0.5
C:N	*average*	13	13
	Range	13	13
$CaCO_3$ %	*average*	7.8	5.7
	Range	7.8	5.7
Avail. P Ppm	*average*	23	17.3
	Range	23	17.3
ECe dS/m	*average*	0.23	0.4
	range	0.23	0.4
ESP	*average*	2	4
	range	2	4

Source:LWRC,Miskin Soil Survey 2009

Table 5: Summary of Land Suitability Classes

Map unit	Current land suitability classes and subclasses	Potential land suitability classes and subclasses	Area (ha)	% of total area	Recommendations for development based on land suitability classification
VT 10	S2 vf	S2 v	6,624	69	Recommended
VC 20	S2 vf	S2 v	288	3	Recommended
VTd 30	S3 wvf	S3 v	2,315	24.1	Recommended for paddy rice production
VTg 40	S3 tvf	S3 v	288	3	Recommended
D 50	N2	-	86	0.9	Not recommended
Total			9,600	100.0	

3.2 Climate and Water Resources

3.2.1 Climate

The climate of the Wad Miskeen area is tropical sub-humid with annual rainfall between 500-800 mm and 2-3.9 humid months (Walsh, 1991). This climatic zone is suited for a dryland farming system and lies within the major zone for mechanized agriculture (HTSPE-Newtech, 2009). According to van der Kevie (1976) the area lies within the semi-arid climatic zone. The climate of the project area is characterized by two seasons: the hot and humid rainy season (June – October) and cool and dry season (November – May). Bunting and Lea (1962) associated the rainfall of the central Sudan with that of the West African monsoon system, which is derived from South Atlantic and Congo air masses, with little or no Indian Ocean influence.

The isohyets run from west to east and southeast, and are diverted around the Ethiopian highlands. The project area therefore lies in the zone of north-easterly winds, in which rainfall decreases to the north-east. Consequently, the decrease in the mean annual total is of the order 30 mm for every 20 km and this decrease in rainfall is the mean reason for the marked zonation of the natural vegetation in the area. Based on the rainfall of the nearest active meteorological stations in Damazin, and Gedaref average rainfall for the study area is around 600 mm. Historical rainfall data though is available from Hawata (420 months from 1950-1988) (**Table 6**), but no data appears to be collected at Hawata now. This gives the mean annual rainfall at Hawata as 568 mm. In a report on the west bank of the Rahad area (HTS, 1966b) rainfall for Hawata was stated to be 600 mm. There is no other climatic station in the vicinity and for evapotranspiration data one has to refer to Singa, some 80 km to the west south west, where the calculated ETo is 2,266 mm / year.

Table 6: Rainfall at Hawata (1950-1988)

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
0	0	0	1.2	15.1	99.5	154.1	201.7	79.5	15.8	0.6	0	568

Source: worldclimate.com from Sudan Meteorological Department

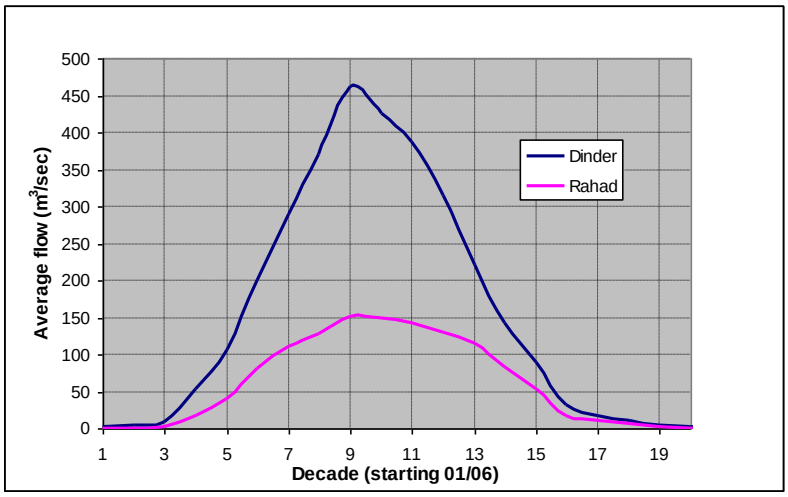
3.2.2 Rahad and Dinder Rivers

Both of these rise in Ethiopia on the westerly draining upland slopes on the watershed west of Lake Tana, and between the Beles and Atbara drainage basins. Barbour (1961) noted that "in summer they rise rapidly, and in September the larger of the two, the Dinder, actually produces almost as much water as the White Nile, including the Sobat, while the Rahad produces about one-third as much".

Discharge data is available for both rivers from 1912 up to the present and was originally tabulated by Merz and McLellan (1997) and more recently by the MoI. Data shows that for this period 1912-2003 the Dinder had a max annual flow of 5,637 Mm^3 (1916) and a minimum of 308.2 Mm^3 (1984), with an average discharge of 2,714 Mm^3. For the same period the Rahad had a maximum discharge of 2,485.38 Mm^3 (1988), a minimum of 338.7 Mm^3 (1984), and a mean of 1069.11 Mm^3. By comparison, the discharges in 2009 were reported to be 80.43 Mm^3 for the Rahad, and 76.31 Mm^3 for the Dinder, which if confirmed are the lowest recorded on both rivers. A full analysis is given elsewhere in this Feasibility Study.

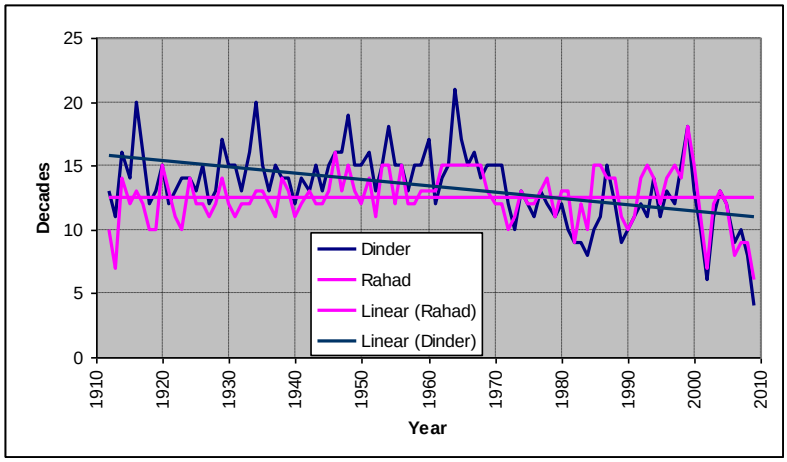
The FS has studied the proposal that the project would take water from both rivers for the irrigation. The hydrological studies analysed data by comparing flows in the two rivers year by year to examine the total period that water is available for irrigation. For this analysis, the flow per decade that was assumed to be sufficient to provide an irrigation of the whole Wad Miskeen area was taken as 7.5 MCM/decade (equivalent to an average flow of 8.7 m3/s). The number of decades during which the flow in the rivers equalled or exceeded this figure is shown in **Figure 4**. The mean floods of the Dinder and Rahad are illustrated in **Figure 5**.

Figure 4: Decades during which flow equals or exceeds 7.5 x 10^6 m^3



The floods in both rivers occur over the same period (Figure 5).

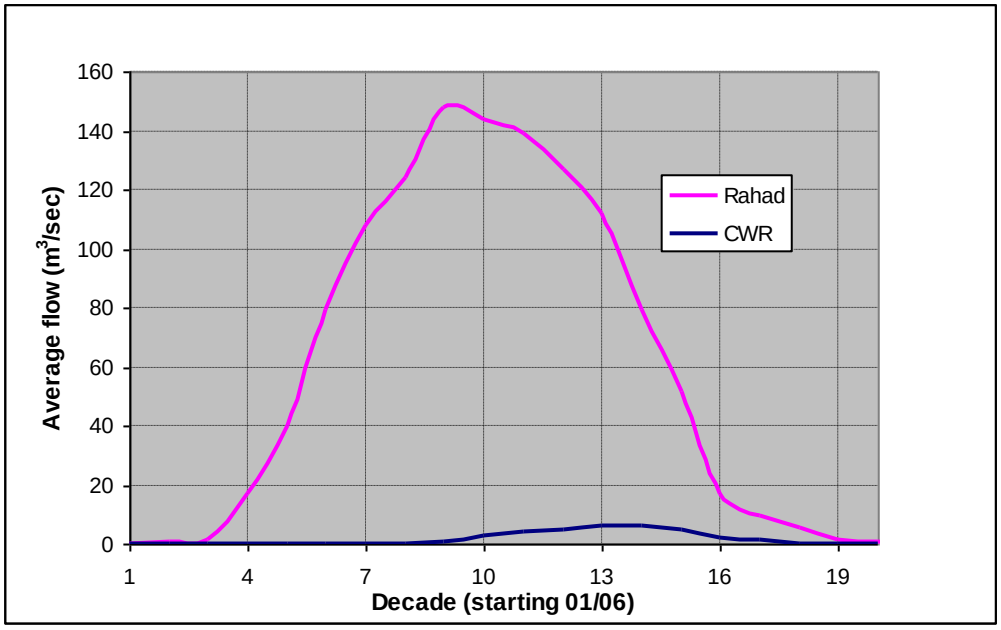
Figure 5: Mean Floods of Dinder and Rahad Rivers



Source: Ministry of Irrigation and Water Resources

On the Wad Miskeen project the peak water requirements are calculated as 6.0 m^3/s, but the canal system is designed for a maximum flow of 10 m^3/s for two reasons, firstly since the flow in the Rahad may be irregular it is desirable to be able to carry out an irrigation quickly when there is water available in the river and secondly, if it is found that the Conveyor Canal to the Rahad II and Rahad North irrigation areas passes by the Wad Miskeen irrigation area, it will be possible to supply the Wad Miskeen area with irrigation water from the Conveyor Canal during the dry season, in which case the full capacity of the canals will be utilised. At the time of preparation of this report it has not been possible to ascertain the exact route of the Conveyor Canal, the detailed design of which is being prepared by the Dams Implementation Unit. From **Figure 6** it can be seen that the overall CWRs' of the project would be a small fraction (<10%) of the total flow in the Rahad.

Figure 6: Comparison of Crop Water Requirements (CWR) and Rahad mean flow.



3.2.3 Runoff from the Plains

A number of *khors* are incised into the clay plains north and south of Hawata. Within the Wad Miskeen area one such feature traverses the plains immediately to the east of the Umm Jirrer Reserve Forest and on the ground is seen as a slightly sinuous channel within mixed *Acacia seyal-Acacia senegal* woodland that originates in the Jebel Ban area. Another channel lies further east and is directed in a *hafir* upslope of the command level. Another feature of the Sudanese central clay plains is that the runoff time after storms appears quite slow and rather than a flood moving along a particular channel, there is more a slow overland flow over the entire plain, that may take several days to reach the lower points, in this case the Rahad River.
The catchment upslope of the Wad Miskeen area extends for some 30 km to the north-east up on the jebels around Ban and Qala en Nahal, and the main runoff from these areas appears to be top the north and then north west through *khors* that reach the Rahad between Hawata and Abu Rakham. Around Hawata flood protection bunds have been installed to reduce the risk in the town from flooding due to this overland flow. Similar features would be needed upslope of the line of the proposed main canal, and could be used to channel waters into a series of *hafir* above the command level.

3.2.4 Groundwater

Apart from a limited supply along the bed of the Rahad and adjacent meander belt, there is no significant groundwater resources at Hawata down to Wad Miskeen, since Basement Complex granite and schists lie at a shallow depth (Ruxton, 1956; Senden 1989. Other regional studies that lie more to the east of the study area were made by Van Enk (1984), Suleiman (1968), Kheir (1980). The assessment by GWE (1985) covers the Hawata-Khor el 'Atshan area.
Some hand-pumps supply villages along the Rahad and lying within the Rahad meander belt are recharged from the Rahad. Most villages on the clay plains rely on storage in *hafirs*, notably at J. Serag and J. Masama, some 25 km south-east of Hawata and just above the command level for the ENIDS project. In November 2009 these *hafir* were all but dry.
The groundwater of the area, and in particular the Atshan Aquifer, has been discussed in several University of Khartoum theses, including Fadlalla (2003) on the groundwater resources of the Blue Nile basin; Mohd'Ali (1976) on the hydrogeology of the Blue Nile and its tributaries; Salih (1989) on the sedimentology of Atshan Formation; Kheir (1972) on the Hawata water supply; Abdel Salam (1982) on geology of the Blue Nile sedimentary basin in Sudan; and El Madeni (1997) on the groundwater geology of the lower Dinder area. The hydrocarbon possibilities of the 4,000m deep Blue Nile basin area, a graben in which drilling is ongoing, are largely confidential but several papers have been produced by Schull (1988) and Salama (1985, 1987, 1999).
At the old railway station of Khor el Atshan, 37 km west by south west of Hawata, eleven deep bores were put down over 50 years ago in the Sennar-Singa area (Ruxton, 1956; Barbour, 1961). One was at the Khor el Atshan station, and showed layers of volcanic gravels, pumice and calcrete: it is not known if the well is still functioning.
A fairly bountiful supply of fresh groundwater though is gained from the well-field at Wad el 'Ageili, some 30 km to the west of Hawata and between 9.5 and 14 km south east of Khor el 'Atshan station. Here, a new development, initiated in 1983, involved drilling of nine deep wells, which provide domestic water to 48 settlements, including villages along Khor el 'Atshan upstream of Wad el 'Ageili, Dinder, Hawata, Mufaza, Ban, Qala en Nahal and others (GWE, 1985). East of Hawata water is pumped up 167m to J. Ban, and then gravity fed to numerous villages. This functioning operation is managed by the Hawata Wad el Ageil Water Supply Corporation, and its operation and maintenance is self-funding from water charges. Water quality testing is made on a routine basis, and a typical analysis, dated 30 August 2009 showed the following: electrical conductivity (EC) ranging from 263-396 /cm; TDS from 381-602 ppm, and pH from 6.96 – 8.02. A number of specialised water quality tests are also made on certain ions (K^+, P, PO_4^{-3}, I^2, F, SO_4^{-2}, Al_2O_3, CN, and others) and these indicate low levels at present, suggesting there is no contamination of the aquifer. These data and others are discussed in Annex 1 Climatology and Water Resources.

Fadlalla (2003) states that the 'Atshan Formation is 25 – 250 m thick and lies over a great thickness of the Damazin Formation (sandstone and mudstones) and Dinder Formation (shale and mudstones) both a part of the Nubian Sandstone group (Cretaceous), that pass down into the Lower Jurassic Blue Nile Formation (halites). Total thickness of the basin is said to be in excess of 4,000m. The 'Atshan water is found at about 25 m. In comparison water is at 7 m near the rivers. The 'Atshan aquifer is mainly a $NaHCO_3$, with some $MgCO_3$ water. The underlying Nubian aquifer is by comparison a $CaHCO_3$ water. Hypersaline water occurs at the basal halite beds above the basement with ECs over 15,000 mg/l salts. For the most the 'Atshan aquifer though is classified as low to moderate salinity + low sodic (C1-S1 and C2-S1) water with EC ranges of up to 750 $\mu S/cm^{-1}$. Trace elements for Boron, Barium, Fluorite are low.
The Khor el 'Atshan, has long been considered to be an earlier course of the Rahad that occasionally receives overflow from the Rahad into the Dinder (Barbour, 1961; HTS, 1966b). Information provided by the Ministry of Irrigation has stated that connections with the Rahad occur at 20 km (South Maitt forest area) and 70 km (South Gordora) upstream of Hawata, where old channels of Khor el 'Atshan come close to the Rahad. The Khor Atshan merges with the Rahad some 56 km above Wad Miskeen village though the actual point of divergence is closed now. It also has significant subsurface groundwater flow, considered to come from the Rahad (Ruxton, 1956). These groundwater flows lie within the El Atshan Formation (Ruxton, 1956; Whiteman, 1971), a local facies of the late Cainozoic Umm Ruwaba Formation.
Surface flow in the Khor Atshan is mainly from runoff from the adjacent plains and when the Rahad has an excessive flood: nomads spoken to in November 2009 stated that most is as a result of runoff from the adjacent plains, and that there has been no significant flow for two years. In 2009, a year without significant rains and a very low flow record for the Rahad, there have been no flows from either source and all surface pools in the Khor Atshan had dried up by November. However, various nomadic groups dig wells down to 10m in the floor of the Khor Atshan to intercept subsurface flow in gritty sand layers, and this flow, coming in from subsurface connections with the Rahad to the south east, is said to remain viable for the entire part of the dry season.
The nomads that pass through the area and the inhabitants of villages in the study area and the link canal rely on the residual flooded areas and groundwater resources that are found along the Dinder, Khor Al Atshan and Rahad Rivers, and the *maya (*old meanders). Some of these remain flooded throughout the year. Along the Dinder residual pools of flood waters are found downstream of the DNP boundary and can remain flooded right through the year until replenished by the seasonal floods: as such they are essential for maintaining livestock at the end of the dry season.

3.3 Settlements and Nomads

Settled populations occur along the Rahad River, Dinder and Khor el 'Atshan. The farming communities are, for the most, found in a number of nucleated settlements along the banks of the Rahad where the lands are slightly more elevated and less clayey than the clay plains. The clay plains become plastic with parts flooded during the rainy season. The composition of the human communities is varied with many long-term immigrant communities that have come from western Africa and include Hausa groups from Nigeria, settled farming Many of these are non-Arab and originated, within the past hundred years from western Sudan, and lands to the west of that – Chad, Nigeria, French Equatorial Africa. Some stopped off on the way back from the Hajj, others fled from unrest elsewhere in Sudan (Barbour, 1961).

There is some small scale irrigation for vegetables and limited patches of sorghum on the Rahad currently. The residual pools in the Rahad are useful for livestock and villages and wholescale use for irrigation is believed to be discouraged. Extensive groves of mango are found between Wad Miskeen and Hawata, and there are also joint FNC and community managed *Acacia nilotica* forests in backswamp areas of meander loops along the Rahad.
People in the project area and its adjacent lands include farmers living in a number of villages, mostly along the Rahad River but also around a series of jebels upslope of the command area, and nomads moving with their livestock through the area using the fallow grasslands and forest areas for grazing areas and drinking water for themselves and their animals.

Most of the farmers are involved in rainfed agriculture, however, some are involved in irrigated agriculture on the banks of Rahad and Dinder rivers, and there is some fishing in flooded depressions of old meanders (maya). The main crops grown in the rainfed agriculture are sorghum, millet, and sesame. The irrigated agriculture comprises a series of small farms around the banks of the rivers where smallholdings have a variety of fruit trees and some vegetables, which are locally marketed. The seasonality of the two rivers flows makes it difficult to cultivate large areas without any water storage facilities. The remains of a small pump scheme are seen at Wad Miskeen village, but have long been defunct. Forest products are important to small scale industries: honey, basket and mat work from tall perennial grasses, furniture.

Historically, for centuries the plains of the Wad Miskeen area have been, and continue to be, utilised by nomadic groups: they play a vital role in maintaining the animal wealth of the region and the preservation of natural forests. Their presence on the land is often disputed by farmers but beneficial impacts livestock movement include, consumption of crop residues, weeds and grasslands; and animal manure, with crop residues, that falls into cracks and is trampled into the topsoil of the Vertisols and is an important, though largely unheralded, part of the nutrient recycling process. The nomad groups include pure nomads, and semi-settled nomad groups from Sudan where part of the family is engaged in nomadic movement with livestock. Nomads in the area belong to various groups of which the most prominent are:

- Rufā'a esh Sharq (also termed al Sheriq), a Fung (Funj) tribe, who are camel nomads with some cattle and sheep who move north-south from the Mufaza area and the Butana across the Rahad River to the edge of DNP. They utilise the residual pools on the Dinder-Rahad Gezira.
- Lahawin', camel nomads with sheep, goats and cattle, whose movements are north-south in the Butana and who comes as far as DNP on east side of Rahad;
- Shukriya, also camel nomads with sheep, goats and cattle, who move north–south from the Butana to the Rahad area.
- Kenana, cattle and sheep nomads who move from NW to SE, from Jebel Moya area across the Blue Nile up to edge of Rahad and DNP areas;

These various groups are present in the area during the dry season but move north-westwards towards Jebel Moya or northwards into the Butana grazing area during the rains when the clay soils become plastic and impassable. In 2009, due to the failure of the rains, many have stayed in the region. The income for both farmers and nomads is low because of the limited production in agricultural crops and livestock products.

In a survey of the Wad Miskeen areas reported in Annex 4, farmers were stated to have complained, as they do in many parts of the Central Clay Plains, that livestock from nomad groups damage the soils and land. This is considered an exaggeration, as discussed elsewhere in this report and Annex 6: livestock contribute manure to soils which helps restore fertility, whereas farmers add almost nothing to the soils; whilst livestock may trample the topsoil to a powder and this could be blown away, the loss of it would seem to be minimal in terms of loss of topsoil fertility, and the soft mulch they help prepare is useful to the farmer as a seed bed; and the browsing of weedy growth in fallow field takes away in part the laborious tasks of land clearing that a farmer may be neglecting.

Thus there is a symbiosis in action here, between farmer and the pastoralist, that needs to be remembered, given out by extension people and accommodated into the future scheme: it should be noted as a comment of relevance to this argument, that pastoral groups coming off the Butana lands successfully interact with sharecroppers on the harvested fields of the Gezira Extension scheme (located on right bank of Blue Nile north of Tamboul), and the same has been observed in parts of the extension to the Rahad I scheme : in both cases extensive herds of livestock use the canal waters and graze on the stubble. In dry periods, such as in 2009 this interaction is all the more essential to maintain and strengthen if animal herds are to be preserved.

It should not be forgotten that the desire for meat is very strong in the Sudanese economy, and almost all is home grown, whether from sheep, goat, camel or beef. The contribution of the pastoral groups to the economy is considerable: some 20% of GDP, 40% of the population are in livestock, and 80% of the animal wealth is owned by nomads and transhumant pastoralists (refer to Annex 6).

3.4 Ecology and Land Use

The project area falls in what was termed the low rainfall woodland savannah on clay with *Acacia seyal-Balanites aegyptiaca* alternating with grasslands (Harrison and Jackson, 1958). They noted that the grassland occurs in patches often of one species, including *Sorghum purpureo-sericieum* and *Hyparrhenia pseudocymbaria*.

In terms of ecological habitats the following distinctions can be made: the Dinder National Park; the courses of the Dinder, Khor Atshan, and Rahad; the clay plains of the inter-riverine plains between the Rahad and the Dinder; and the clay plains between Wad Miskeen and Hawata with some granite jebels.

The Dinder barrage site lays just inside (less than one km) the Dinder National Park (DNP), which has been listed as a Ramsar site (Ramsar Convention Secretariat, 2005). The natural vegetation of DNP is dense mixed woodland of *Balanites aegyptiaca - Acacia seyal - Combretum glutinosum* and other species (HCENR-WCGA, 2004).

The DNP is marked on the ground by a sharp boundary between, on the north side, rainfed agriculture set amongst scattered *Balanites* parkland, and, to the south, dense mature mixed forest of the Dinder National Park. This would appear to be one of the most visual boundaries of its type in Africa (**Figure7**). In the vicinity of the proposed barrage site there is cutting of *Acacia seyal* dominant woodland for charcoal: as this appears to lie inside the DNP it is not clear why these areas are being allowed to be cleared.

As part of the Supplementary Surveys for the Wad Miskeen Feasibility Study, the DNP authorities were pleased to give permission for a series of geotechnical investigations and topographic surveys to be made just inside the park, as long as remedial works left the site clean

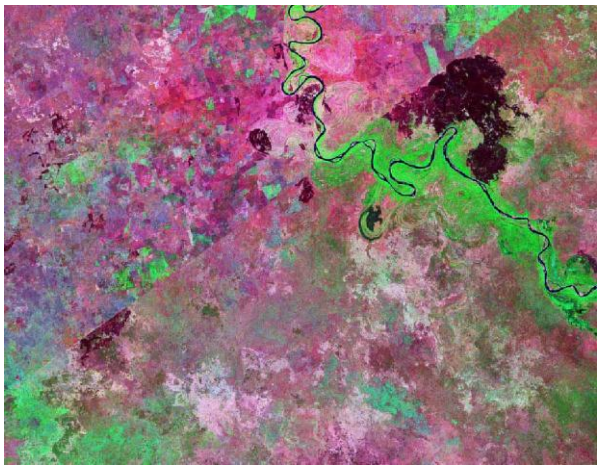
Along the proposed link canal between the Dinder River and Rahad River, there is an open savanna parkland dominated by *Balanites aegyptiaca* (*heglig*) set amongst rainfed cultivated areas for sorghum and sesame. Fallow areas are often under tall grassland where there has been good rainfall, and such lands have long been burnt off at end of dry season. Uncontrolled burning can lead to fires spreading into the Dinder Park and a fire line exists along the edge of DNP There are also patches of regenerating *Acacia seyal* that appear in part to be community woodlands, as they are not cut for poles or being cleared. Elsewhere, are patches of invasive *Zizyphus spina-christi* (*sidr*): this is regenerating naturally

The course of the Rahad River is incised some 7m into the clay plans and has a meandering course. Old backswamps and meander loops (*maya*) are flooded in the wet season. The maya support aquatic grasses and lilies. There are also dense stands of *Acacia nilotica* on the Rahad itself which are community forests managed by the FNC.

Dense stands of *Acacia nilotica* forest occur also along the Khor al Atshan. At the proposed crossing point on the Khor Atshan, the slightly higher lands include *Acacia seyal, Zizyphus spina-christi*, and some *Balanites aegyptiaca*.

Figure 7 shows a 2000 Landsat image of the abrupt and remarkable land cover change along the boundary between Dinder National Park (lower part of image) and semi-mechanised rainfed farming areas to the north. The Dinder River is marked by the green meandering flood plain, and the proposed barrage site lies just inside the DNP boundary. The black areas are lands inside and outside DNP that have been burnt to encourage new grass growth and are contained by a track / fire line on the margin of the park. A narrow buffer zone lies just to the south of this line before the wooded part of the park is entered. It is not clear if this fireline is the actual park boundary, with encroachment occurring beyond it, or if it is a deliberate buffer zone. The burning of grassland inside the DNP appears to indicate activity by nomadic pastoralists during the dry season. This Landsat image was taken in 2000.

Figure 7: North Western Edge of Dinder National Park



Within the Wad Miskeen area the ecological zones reflect long-term effects of rainfed agriculture land use. It is clear from older studies made in the Rahad I area (Adams, 1967) that there used to be a rich arboreal community comprising *Balanites aegyptiaca, Acacia seyal, Acacia senegal* (Gum Arabic), *Acacia mellifera* and some *Acacia nilotica* in the area.
This is largely destroyed now in the proposed irrigation area, though the Reserve Forests of Umm Jirrer and Umm Burush (**Table 7**) still contain elements of this variable forest cover and are under protection by FNC and communities. These two forests were originally designated as reserves to encourage certain species. Some parts of the Umm Jirrer reserve comprise very dense pure stands of *Acacia seyal* and appear to have been planted, but there appears to be little attempt at management and thinning the tree cover.
It is understood that forested parts of the Reserve Forest areas have not been included in the proposed new irrigation area, but the FNC in Hawata stated to us that irrigation in non-forested parts of forest reserve areas would be welcome as this would enhance the meagre growth that is currently the situation. Parts of the Umm Jirrer area are under cultivation for rainfed crops. Elsewhere, where land is under rainfed cultivation, fallow periods are marked by invasive weedy shrubs (*Acacia nubica, Acacia mellifera*) that are interspersed with areas of annual grasslands.

Table 7: Forest Reserves within the Wad Miskeen Region

Forest name	Area - feddan	Locality	State
Umm Jirrer	11,600	Hawata	Gedaref
Umm Burush	15,300	Hawata	Gedaref
Grand-total	26,900		

Source: FNC, Hawata
Note: the areas are based on FNC records. The boundaries are shown on the old rainland series maps (1:100,000 scale). By using GIS the extent of the forest can differ.

3.5 WILDLIFE FAUNA

On the plains of the study area there is a variety of nocturnal wildlife that remains in the area. These include Crawshay's Hare (*Lepus crawshayi*), Ground Squirrel (*Xerus sp*), and civet *(Vivera civetta).* On jebels the dropping heaps of Civet and Rock Dassie (*Procavia capensis*) are seen. The bird life is quite rich in the DNP area with many groups represented (HCENR-WCGA, 2004) and this extends down along the forested parts of the Dinder, Rahad and Khor Atshan.

Common mammal species seen close to El Seneit, the gate to the DNP and a few km from the proposed barrage site include: Reedbuck, Oribi, Warthog, Ostrich, Waterbuck, Singa Gazelle, Patas monkey, Green Monkey, Anubis Baboon, Bushbuck, Mongoose. On the clay plains buzzards, kites, falcons, and eagles frequent the cropped areas in search of small mammals. In villages resident colonies of Cattle Egrets and Open Bill Storks (*Anastomosus lamelligerus*) and Black Stork (*Coconia nigra*), amongst others, roost without harm in *heglig* or *tebelde* trees, inside and outside the DNP. In the *maya* pools along the Rahad numerous species of waders were seen in November 2009, and on the jebels close to the project area Eagle Owls (*Bubo lactea*) are seen.
The status of fish (**Figure 8**) is not well understood despite several studies (Rzóska, 1976; Bailey, 1993; Abu Gideiri, 1984; Sandon, 1950) though it is clear fish migrate up many seasonal rivers in Sudan during the flood flows. The situation regarding fish in the Dinder and Rahad is not discussed in a recent biological study of the Nile (Dumont, 2009).

Figure 8: Fishing at Umm Baggara, Dinder River. Photo R.N.Munro, 19 February 2009

Larger mammals, such as ostrich, gazelle, and even lion are also reported by villagers at Umm Baggara and elsewhere, to venture out of the Park for up to 40 km during the wet season when tall grass covers the park and soils are too wet. As soils are also wet and plastic outside the park this argument is not conclusive and also difficult to verify as it is extremely difficult to access this area in the wet season. It is more likely that larger mammals leave the park in search of water when the *maya* and other pools in DNP dry up.

3.6 Socio-Economic Environment

The rural economy of the Wad Miskeen area at present is based on a mix of sedentary farmers and nomadic groups. The farming groups live in some ten villages along the Rahad from Wad Miskeen to Hawata. One village, Ingamaina, that lies at the south-east edge of the Umm Jirrer Forest Reserve, lies within the proposed scheme. The population of these villages amounts to 18,000-20,000 or about 3,300 households. Characteristics of the villages, taken from the Wad Miskeen socio-economic baseline survey, are given in **Tables 8, 9**, and **10**.

Table 8: Village characteristics

Village	Establishment (approximately	Total population	Main tribe	Other tribes
Bazora Kahlifa	1942	4,000-5,000	Hawsa	Fulani
Hilat Khalifa	1885	5,000-6,000	Rufa'a	Galeen, Barno, Fulani, Abdalab
Ingamaina	1970	400	Masaleet	Tayasha, Bargo, Fur
Kumor Basheer	1950	1,400	Hawsa	Awlaad Saeed
Wad Batool Mokharim	1945	400-500	Habaneya/For	Hawsa
Wad Batool Hilat Bakheet	1930	200-300	Hamada	Gawasma, Marareet, Bargo, Maseerya, Tama, Masaleet
Shamam	1950	600	Barno	Awlad Rashid
Wad Abakar	1831	1,500-2,000	Hawsa	Tama, Fur, Salaamat, Zagawa, Bani Halba, Dago, Abyadaab
Abdel Lateef	1940	1,500	Bargo	Bagara tribes, Masaleet, Dago, Barno, Fur, Folani, Hawsa
Maykankana	1930	1,700	Hawsa	No other tribes

Source: Field Survey July 2009

Table 9: Organization in the village

Village	Traditional organization				Modern organization			
	Sheikh	Omda	Nazir	Showra	People's committee	Youth	Women	NGOS
Bazora Kahlifa	√	X	X	√	√	X	X	X
Hilat Khalifa	√	X	X	X	√	X	X	X
Ingamaina	√	X	X	X	√	X	X	X
Kumor Basheer	√	X	X	X	√	X	X	Child friendly village
Wad Batool Mokharim	√	X	X	X	X	X	X	X
Wad Batool Hilat Bakheet	√	X	X	X	X	X	X	X
Shamam	√	X	X	X	X	X	X	UNICEF
Wad Abakar	√	X	X	X	√	X	X	UNICEF
Abdel Lateef	√	X	X	X	X	√	X	X
Maykankana	√	X	X	X	√	X	X	X

Source: Field Survey July 2009
Note: √ = Available X= Not available

Table 10: Social services

Village	Education		Health	Water							
	Khalwa	Basic	Secondary	Basic	Dispensary	Hospital	H. pump	W. yard	Kishok	River	Vet. Services
Bazora Kahlifa	√	√ shared	X	√ shared	X	X	X	X	√	X	X
Hilat Khalifa	X	√ shared	X	√ shared	X	X	X	X	√	X	X
Ingamaina	X	X	X	X	X	X	X	X	X	√	X
Kumor Basheer	√	√	X	X	√	X	√	X	X	√	X
Wad Batool Mokharim	X	X	X	X	X	X	X	X	X	√	X
Wad Batool Hilat Bakheet	X	X	X	X	X	X	X	X	X	√	X
Shamam	X	√	X	X	X	X	√	X	X	√	X
Wad Abakar	√	X	X	√	X	X	√	X	X	√	X
Abdel Lateef	X	√	X	X	X	X	X	X	X	√	X
Maykankana	√	X	X	X	X	X	X	X	X	√	X

Source: Field Survey July 2009

There are few services in these villages other than simple shops. Most people will travel to the markets in Hawata by truck, and secondary education and health serivces are also centralised in Hawata. Small schools exist in the villages. A certain proportion of the communities in these villages also, appear to work in Hawata as traders, and in the 2009 dry year when rainfed crops have failed people may have been seeking work further afield.

As noted in Annex 6 mobile veterinary clinics tour the area. In the three months of the wet season (June-July-August) all vehicle movement is difficult, even to Hawata, as the tracks are not all-weather.

However, a network of mobile phone masts is now being placed along the Rahad River to the south, so that the communities there are in contact with the outside world at least in this way.

The farming population come from these villages and also from Hawata, where land has been inherited but the 'owner' now lives in the town. It is likely also that some rainfed farmland is also used by people who live further to the east in the villages around Jebel Marafa and Jebel Serag, where there are large *hafir.* In November 2009 these *hafir* were almost dry due to the drought situation and the communities stated they would have to take water from residual pools on the Rahad some 4 km distant. None of these villages around the jebels, nor those in the proposed Wad Miskeen scheme are connected to the freshwater network provided by the Hawata-Wad el 'Ageili Water Corporation from the Wad el 'Ageili well field.

The land tenure issues (see Annex 4 of the FS) show that there is a complex system of land use. People who farm or have control of the lands abide by one or more systems that include: leasehold, usufruct or easement. There is no freehold land.

- **Leasehold** refers to large plots of land that have been given over to semi-mechanised rainfed farmland (SMRF), which corresponds to the semi-traditional landholding reported by the South Kassala Agricultural development Project (SKAP, 1992). Use of this land is for sorghum and sesame, with a certain proportion given over to fallow. The fallow land may have a grass cover that is of poor quality for livestock (see Annex 6) but has uses for other purposes such thatch, fences etc.
  The land tenure studies (Annex 4) note that use of the larger rainfed lands (100-1000 feddans) is 'fraught with legal intricacies' : a farmer may have a title to the land, but since ultimately all land belongs to the State this may not have any legal validity.
- **Usufruct** lands are where villagers have local or traditional rights along the river and are growing mango trees and other fruit trees that receive some supplementary irrigation from small pumps along the residual pools in the Rahad. Some of these people now live in Hawata and travel out. The villages are well established and old, are based on different ethnic groups from Sudan and west Africa, but have few public services: most services are in Hawata. SKAP (1992) referred to these lands as Traditional Landholdings.
- **Easement** lands are those areas where the nomadic groups have historical rights to grazing, water and access through the area.

Amongst the farming community holding size in these areas was found in a survey made for the present study to range from 5 feddans along the Rahad, and up to 1,000 feddans away from the river on the rainfed lands. Most of these holdings were said to be inherited with a few bought and few given by the sheikhs. The survey reported that there was at present no conflict between farmers and pastoralists in any area, though the width of the livestock stock routes was reported to have been cut from 150m to 50m as rainfed farmers have encroached on the routes. This in itself is not a great problem as livestock are as a rule kept out of croplands during the growing season, and many pastoral groups will normally be much further north, out in the Butana, during the wet periods when the land is plastic and biting flies are a major irritance and likely cause of disease transmission (see Annex 6 of this FS).

Table 11 reveals the land tenure status of the respondents to the socio-economic baseline survey. Most admitted that the land owned is inherited from their predecessors. Other land appears to be bought or given by the Sheikh. The range of the holding size is substantially diverse, ranging from five to thousand feddan. However, the larger holdings are owned by few individual. Customary tenure is prevailing but some original inhabitants own large plots while recent migrants rent land for cultivation

Table 11: Land tenure and range of holding size

Village	Agricultural land			Hired	Range of holding size (feddan)
	Inherited	Bought	Given by Sheikh		
Bazora Kahlifa	√	√	X	√	5 – 15
Hilat Khalifa	√	√	X	X	25 – 500
Ingamaina	X	X	√	X	5 – 50
Kumor Basheer	√	√	X	X	10 – 15
Wad Batool Mokharim	√	X	X	X	20 – 1000
Wad Batool Hilat Bakheet	√	X	X	X	Not indicated
Shamam	√	X	X	X	15 – 500
Wad Abakar	√	√	√	X	10 – 1000
Abdel Lateef	X	X	√	X	Not indicated
Maykankana	√	√	√	X	5 – 10

Source: Field Survey July 2009

Table 12, shows that livestock tending is a village-based activity practiced by sedentary population in which cows, sheep, goats are the main livestock raised. Another form of livestock husbandry is the activity undertaken by the itinerant tribes of nomadic pastoralists living around the study area when crop residues are available and moves during the rainy season to the Butana area.

Table 12: Livestock

Village	Livestock				
	Cattle Av. No.	Sheep Av. No.	Goats Av. No.	Camels Av. No.	Others
Bazora Kahlifa	100	300	80	Not available	Not available
Hilat Khalifa	300	500	200	"	"
Ingamaina			20	"	"
Kumor Basheer	15	150	70	"	"
Wad Batool Mokharim		80	20	"	"
Wad Batool Hilat Bakheet			10	"	"
Shamam		200	200	"	"
Wad Abakar	150	400	600	"	"
Abdel Lateef	10	200	150	"	"
Maykankana	75	300	100	"	"

Source: Field Survey July 2009

4. POTENTIAL IMPACTS

The following sections, based on the groups given in the checklist of **Table 1**, examine the environmental impacts that may arise from development of the Wad Miskeen project. Some impacts may be positive, others negative. Within each category there may be a range of possible impacts. Each of these is based on the best available opinion at the present. As more data becomes available, during the detailed design for example, then views may be revised, up or down. The overall assessment is based on the best information available at present. It is shown in tabular form in **Table 13** at the end of this chapter. As noted earlier individual impacts should not be compared against each other without making very detailed assessment in an impact analysis, and for this reason it is not advisable to list the sum of scores for each level of impact.

4.1 4.1 HYDROLOGICAL CHANGES

4.1.1 Low Flow regimes

If significant amounts of the Dinder flow were to be diverted into a canal a number of environmental concerns need to be considered. First of these is that if changes to the low flow regime of a river can have impacts on erosion and sedimentation, wildlife habitats and disease ecology, and on the downstream users who may be using the water for irrigation supply, transportation, hydropower, or drinking water. In the context of the proposed Wad Miskeen project the EIA assesses if such impacts could arise if the project were to cause reduced flows in the Rahad and Dinder Rivers, and these in turn impacted on the flow of the Blue Nile. The project proposes to extract water from the Dinder and Rahad rivers following the peak, silt- and debris-laden, part of the flood has passed. The extraction from the rivers will have some but limited impact on the flow into the Nile above Merowe reservoir. As the Rahad and Dinder are seasonally and have no perennial surface low flow, by the time of low flow period on the Nile (April-May) the Dinder and Rahad will have dried up except for occasional pools and the project will no longer be taking water from these sources.
Assessment of Impact Category: More information is needed on the flow of the Rahad and Dinder and its relation to the Nile [F].

4.1.2 Flood Regimes

This concerns the flood regimes of Blue Nile, Dinder and Rahad Rivers and impact on *hafir, maya* and drainage courses. Changes in abstraction and retention storage caused by a project can lead to changes in the flood regimes of rivers, such as the amount and duration of the peak discharge and flood waves and downstream inundations. Diversion of water would lower the peak flows of the Rahad and Dinder Rivers and reduce the extent and duration of floodplain inundation downstream of such diversion. On the Rahad this would not have an impact because these areas already back up above Abu Rakham barrage (to at least Wad Miskeen in November 2009) and any impact on ecosystems downstream are mitigated by the substantial flow that is released down the Rahad from Abu Rakham. On the Dinder, if flood flows were abstracted into a canal to Wad Miskeen then there could be a significant impact if the abstraction meant that the seasonal pools were not sufficiently fool at the end of the flow period. In drier years such as 2009, the choice might be between supplying the project and losing the downstream pools, and there could also be lack of contribution to groundwater reserves.
The Dinder structure would be a weir that takes part of the flood after the main peak has passed. Its location at present would place it inside the park. There is no long term storage involved but short term backwater effect above the weir could lead to overflow of water into maya in the park which could help to alleviate dry conditions there.

Wildlife Administration staff advised us in 2008 that whilst a large storage reservoir would not be advisable nor welcome within any part of the boundaries of the DNP, the prospect of having some additional water to recharge drying up maya would be welcome. It is known that in the past engineering works have helped to increase flows into some *maya*, and helped provide a perennial water source for wildlife. Inside the DNP the diversion structures have collapsed or are now bypassed by the Dinder, a vigorous river. They are now all inoperable and there are no funds to rehabilitate them. It is reported locally that in the late dry season various large mammals including Lion emerge from DNP to seek water elsewhere along the remaining water pools in the Dinder, and are subsequently at risk from opportunistic hunters.

However the silting up of the DNP and other *maya* on Rahad and Dinder and the inter-riverine plains are part of the natural progression in river systems such as this where old meanders and channels are infilled, and it may not be feasible to rejuvenate these diversions without dredging the maya, or making specific new *hafir*-type depressions.

The suspended load of the Dinder River is not known at this time, but the Dinder River, unlike the Rahad River, carries a substantial bedload of coarse sand/fine gravel that needs to be considered when assessing siltation at the weir.

Depending on the locations, the land take could affect existing settlements outside the Park, reserve forests along the existing buffer zone, forests within the Dinder National Park itself, and nomad routes along the edge of the DNP: the proposed weir site would allow easy movement of stock along the edge of the park. For without it the risk is that livestock would go further upstream and into the park.

Maya are depressions that are mostly meander loops or depressions on the clay plains. In relation to the Wad Miskeen project they occur on both banks of the Dinder River, Khor Atshan and Rahad River. Maya are recharged when the rivers are in flood. They also receive runoff from the adjacent clay plains through drainage lines that cut back in the break of slope (the *kerrib* badlands where eroded) between the rivers and the clay plains, for drainage networks extend throughout the slightly convex clay plains.

The plains are not recent flat to sloping features but mature slightly undulating landforms on which a drainage network has evolved over the thick (>4m) clay mantle. The drainage lines are often not too apparent on the ground, but the locals know where they are. In the Wad Miskeen area these drainage lines are shallow linear depressions and are utilised to create *hafir,* artificial storage reservoirs, both now and in the past. A typical modern *hafir* can store about 80,000 m^3 of flood waters that is used for livestock of nomads and rainfed farmers.

The *maya* alongside the rivers are largely seasonal areas of water and are important to local communities and ecosystems, since they provide a source of water for villages and nomadic groups for much of the year, and are perfect habitats for growth of *Acacia nilotica in the* poorly drained areas and *Acacia seyal, Balanites aegyptiaca* on slopes. Other maya flanks have dense groves of mango. Some of these natural forests are community owned and are managed by local communities (under the supervision of the Forests National Corporation FNC) with controls on tree-felling, management of spontaneous regeneration of cleared areas, use of forest products (such as honey production, supply of seed pods to the tanning industry and poles to building industry, furniture production, some charcoal, and lopping of foliage for forage): Hawata is a major centre for these products. In addition, *maya* are important wetlands for resident and migrating bird populations.

Summing up, negative impacts are possible if there is reduced flooding near to settled areas, and some reduction of productivity of the floodplain ecosystems and production lands, and impacts on plants and animal populations; changes to the flood regime of the Dinder through over extraction could mean the pools dry up faster than normal and impact on populations far downstream; and surplus irrigation water, if disposed into depressions, could have serious negative impacts if it is polluted in any way and could renders the surface and even groundwater flows in these river channels unsuitable for domestic and livestock use.

The potential for blocking the Khor el Atshan by a siphon (which could cut the important subsurface flows) is mitigated in the design now by an embankment that will be designed to have suitable culverts, although it should be noted the hydrology of these plains and the K. Atshan is poorly understood; the link canal can impact on the drainage lines on the clay plain and cross-drainage structures will need to be carefully sited. The positive impacts will be very important in that the main irrigation flow can recharge depressions – *hafir* and *maya*- and can be used also to flood irrigate the reserve forests and give these an aqueous boost. If drainage returns are of good quality these too can be used for this, but monitoring will be essential.

Assessment of Impact Category: More detailed information on the actual impacts is needed [F]. Overall negative impacts are very likely (E), but positive impacts are also possible [B].

4.1.3 Surface Waters

Examining the impact of surface runoff from the clay plains on the project, the embankments of the supply link and main canals may alter the surface drainage pattern by blocking surface water flows. As a result cross-drainage structures are being included in the canal designs. Few details are known about the surface water hydrology of the clay plains and the extent and location of changes to be caused by the new structures. In addition there is little information on the patterns of flooding and the sensitivity of the riverine and floodplain ecosystems of the Rahad and Dinder rivers, and the westwards-flowing khors in the Wad Miskeen area. However, evidence from 2000 Landsat imagery and field visits elsewhere help to guage likely trends: a wetland area with dense *Acacia nilotica* woodland has developed upstream of the Rahad link canal (built to provide Blue Nile water to the Rahad I scheme), due to flooding back along the Rahad, and is being designated as a protected forest. Research by Bunting and Lea (1962) remains valid: land cleared for agriculture accentuated the drainage problem with standing water forming large pools in some areas.
HTS (1966) noted that the clay plain soils can only absorb some 700 mm of rainfall and once that threshold is reached water then either ponds (in depressions) or runs off (sloping ground). Important also is the state of the ground prior to rainfall. If land upslope of the supply canal lines are ploughed they will receive far more water from runoff than an unploughed field where the surface may be flattened and cracks obscured by the thick surface mulch.
Assessment of Impact Category: More information is needed on the current surface drainage situation [F]. Negative impacts are possible locally [D], but where current drainage problems would be solved by the drainage infrastructure introduced by the project, such as *maya* remaining full, and flooded areas create ecologically valuable and sensitive habitats, then these represent possible positive impacts [B].

4.1.4 Operation of Dams and Weirs

No major dams are involved in the project and therefore there will be no impacts associated with flow regime changes, but weirs / barrages being designed for a project can be considered to fall within this category and should be considered. The effect of dams is to disrupt the flow regime, lead to bank erosion, sedimentation, cause health and disease hazards, increase weeds in new reservoir area.

a) Salsa Diversion Structure on the Dinder
The barrage is located on Dinder river just on the border of the DNP. The function of the barrage is to control the flow and water levels to enable water to be diverted through the link canal head works. The barrage is designed to pond and maintain water levels at RL 454.0m and to pass a flood discharge with a 100-year return period of 1,000 m^3/s with an upstream afflux not exceeding 0.30m. The barrage would be of reinforced cement concrete, with 22 bays, 4m wide each equipped with roller sluice gates to control water levels and discharges. A sediment sluicing facility would be provided to sluice bed-load sediments (high in sand on the Dinder) in front of the link canal head works. A divide wall would separate the sluiceway from the main body of the barrage.
Although geotechnical investigations revealed that seepage underneath the structure is expected to be low, sheet piles would be installed along the bottom of the upstream cut-off wall running the full width of the barrage as a further safety measure. Also heavy riprap gabions are provided at the location of seepage exit. A 4m wide heavy road bridge is also provided to allow access for livestock and people moving along the edge of the Park.

Impacts: The risk of the barrage being abandoned if the Dinder were to cut a new channel round its edge is a possibility on flood plains such as this, and the design has been made so that the structure is well bedded onto the edges of the flood plain. This needs more careful study at detailed design as the flood plain consists of two levels and the barrage appears to cover the lowest. The concentration of flow into the barrage may increase bank erosion upstream.

A certain amount of water will back up the Dinder during the flood period and this could enter into depressions and *maya* upstream of the barrage. The DNP management has said that this would be a useful and welcome bonus to the project as the *maya* used to receive floodwater by way of cut channels and overflow but this has largely stopped in recent years. It is clear that any operations at the edge of the DNP would need much more detailed planning and consultation with the DNP management.

Assessment of Impact Category: More information is needed on the proposed system and how it would affect the DNP [F]. Negative impacts are possible [D], but also positive impacts are possible [B].

b) Wad Miskeen Barrage on Rahad.
The barrage site on Rahad River is located upstream Wad Meskin village. At the barrage site, the river reach is narrow and straight. There are gardens on both banks of the river there. The barrage is designed to pass safely a flood discharge of 220m^3/s with a 100-year return period. The retention level is at RL 448.5, while the riverbed level there is at RL 445.0. The adopted command level for Wad Meskin irrigation project is at RL 447.5. In its layout, this barrage is very similar to the already existing one at Abu Rakham. The barrage is designed as a reinforced cement concrete (RCC) structure with 9-gated openings, 4 m wide each in addition to a sluice way with two bays also 4 m wide each. The crest of the barrage is set at RL 446.0. The barrage is thus capable of passing the design flood discharge with an afflux of 0.30m in order to protect villages upstream the barrage from high backwater effects. Energy dissipation downstream the barrage is by a USBR type III stilling basin. Water will be diverted to the irrigation project through head works located on the right bank of the barrage. The head works have a design discharge of 10m^3/s. The full supply level of the project's main canal just downstream the head works will be set at RL 447.5. A heavy traffic road bridge will be provided to pass over the barrage and the head works. Bunds will appropriately be provided to contain floods upstream the barrage and to protect Wad Meskin village.
Impacts: The Rahad is a markedly different river from the Dinder. It has a narrow channel incised into the clay plain with moderate flood plain development, and carries a more clayey bed load than the Dinder. In comparison with the barrage at Abu Rakham it can be seen that there is little erosion at the latter. Protection of farmlands and economically important mango groves along the river upstream of the barrage will be needed.
Assessment of Impact Category: Both Negative and Positive impacts are possible [B] [D].

4.1.5 Fall in Water Table

A fall in the water table below an irrigation scheme can have both positive and negative impacts. If abstraction, by tubewell, exceeds the capacity of the aquifer to recharge the impact is negative. Irreversible and damaging acid-sulphate producing changes to soils resulting from drainage of swamps are a problem in the humid tropics, but such features do not occur in the DNP area.
Tubewell abstraction may also cause subsurface waters to be reduced but at present these waters lie far from the project area and in any case the Project will not abstract groundwater for irrigation purposes. Positive impacts can occur however where abstraction, or installation of a drainage network, results in reclamation of waterlogged land.
Miskeen area: in the Miskeen area such lands are limited to *maya* and these will be left unchanged. In the Wad Miskeen area there is no groundwater within the proposed irrigated area. A shallow water table exists adjacent to the *maya* found along the Rahad, and there is deeper water along the Khor el 'Atshan at depths of over 40m. From wells along the Dinder, it is apparent that the Atshan Formation underlies the alluvium and must receive recharge from floods in the Dinder. At the DNP ranger station of Ras el Fiel that lies on the Park boundary and is on the River Dinder close to the barrage site, the water is found at 48 m and is potable. The smectitic clay soils become plastic and impermeable during the wet season and any project-introduced surface drainage is unlikely to lead to changes in groundwater water table, or recharge. An examination of these factors concludes the project would not cause a lowering of water tables.
Link Canal: there are no water tables along most of the route.

Khor Atshan Siphon: this is the biggest crossing in the route of the link canal. El Atshan is a very meandering ephemeral stream. Its watershed is un-gauged but it flows when water runs off the surrounding plains, and also rarer it appears from locals, when there is an overflow event from the Rahad (one should note that the Khor Atshan is an old Rahad course). Because of the uncertain estimate of the khor's peak runoff, the project has decided to pass the link canal underneath the khor by a siphon. The siphon will be a reinforced concrete multi-cell barrel structure. There will be three square barrels, each 3.4x3.4m very similar to the existing Dinder siphon for Rahad I project. At the inlet, gates will be provided to control the flow into the siphon. At the downstream side, appropriate scour protection by pitching will be provided. At the crossing, Atshan Khor is about 70m wide, while the length of the siphon is about 100-110m. The head loss across the siphon is close to 1.0m. The purpose of the siphon is stated by the project so as to avoid any risk to the canal if it is allowed to pass over the khor, and considers that it is better to avoid interrupting the course of a natural stream because the impact of doing so cannot adequately be quantified. The Khor Atshan has a significant subsurface flow at several metres depth that a), is used by nomads in dry season, and b) more importantly may contribute to the Wad Ageili well field and Atshan Aquifer. The siphon will take into account of this flow and be designed so that subsurface flow down the Atshan is not cut off.
Assessment of Impact Category: Negative Impacts are likely on the Khor Atshan siphon [D] but can be mitigated by careful planning of the problem. On the other rivers no impact is likely. [C].

4.1.6 Rise of Water Table

A serious and common cause of failure in an irrigation project is rise of water table causing waterlogging to the root zone and capillary rise to the surface of salts. In semi arid areas, a water table should be maintained by a drainage network to at least 1.5 to 2.0 m below the surface. But overall, good irrigation planning and management, that mitigate against such potentially hazardous soil and water conditions, are essential.
The Wad Miskeen area, lies on slightly undulating clay plains that lie over impermeable Basement rocks, but the soil cover is almost entirely well over 2 m thick, the clays seal up rapidly when irrigated, and excessive irrigation during implementation is not expected to lead to formation of a water table: on similar soils in the Rahad Scheme there is no evidence of this occurring. Irrigation of the clay soils will close cracks and any surplus irrigation water will run-off into the drains or *khor*s, as noted by Bunting and Lea (1962). Where fields are insufficiently levelled, surface ponding is likely and soils may become waterlogged. However, a rise of groundwater tables caused by irrigation is not to be expected on the Vertisols with their very low permeability.
It should be noted continuous farming on Vertisols, such as in past at Kenana Sugar Estate, waterlogging in the soils was a long-term problem and was recognised to be due to inadequate aeration in continuously irrigated sugarcane and, to a possibly lesser extent, compaction from farm machinery. In Vertisol clays, cracking and development of surface mulches is a natural process that aerates the soil. Whilst continuous irrigation will severely impede this, a system of fallowing and rotation will mitigate the problem. But these signs of waterlogging cannot be equated to a rise in the water table.
Assessment of Impact Category: No Impact is though likely.

4.2 Organic and Inorganic Pollution

Irrigated farming depends on the provision of good quality irrigation water. The water should be, as far as possible, free from harmful levels of soluble salts, introduced toxic substances or pollutants. Generally polluted sources will result from poor management by upstream users. At the same time where project drainage waters will be passed back into the river system (in this case the Rahad River) or into the groundwater there is a risk that project generated pollutants will affect downstream users. In the proposed Project pollution control and disposal of effluents will be a crucial part of operation and management, since it is likely that a range of organic and inorganic substances and materials will be used and produced in the scheme. These need careful disposal. Key issues are solute dispersion, toxic substances, anaerobic effects and gas emissions.

4.2.1 Solute Dispersion

Concentrations of organic or inorganic solutes that occur in drainage water from irrigation schemes can pollute river waters. On the Blue Nile for example (Nile Basin Initiative, 2005, the Blue Nile River at Soba, near Khartoum, is not chemically polluted, but an increase of electrical conductivity, chloride concentrations and ammonia values were observed during the years 2001 to 2003 and has been attributed to irrigation return flows. At present there is no data for the study area.

Assessment of Impact Category: The capacity of the Rahad River to assimilate solute pollutants will require careful study by modelling of the Project and the river with monitoring during implementation. No judgement is possible at present [F].

4.2.2 Toxic Substances

Negative impact will occur where irrigation waters and clay rich sediments contain harmful levels of dissolved salts, often the product of pesticide or herbicide applications far upstream. Also, discharges from industry can raise the levels of heavy metals and other toxic pollutants. In the Blue Nile (Nile Initiative, 2005) and the tributaries of the Rahad and Dinder, this type of pollution is not present, but there is no regular monitoring. If soils contain toxic substances these too, can be mobilised into waters. There does not appear to be any use of herbicides and pesticides in the area so far but this can change when the project starts. The risk is that surface run-off will contain residues of applied chemicals and these will reach the Rahad, downstream irrigated area and ultimately the Blue Nile. Chemical analyses carried out during the recent soil surveys did not show any toxic levels of sodium salts.

Tests for residues of herbicides and pesticides were not included in these analyses. According to Nile Basin Initiative (2005) irrigation canals of Gezira scheme have been polluted by agrochemicals, and that this pollution extends to food and people as well. According to UNEP (2007) many irrigation schemes in Sudan, including the Gezira and Rahad I, have a legacy of obsolete and now internationally banned pesticide stocks, and these are poorly stored and have leaked into the ground close to settlements. On the project any industrial development, such as tanning and leather finishing, will contain a risk that polluting and toxic substances could enter the environment (World Bank, 1998), and it will be essential that any food processing and other production plants have proper treatment plants from the start. At present there is no data.

Assessment of Impact Category: Negative impacts are possible [D].

4.2.3 Organic Pollution / Fertilisers

In aquatic ecosystems, such as *maya* or standing water pools in the rivers, could be seriously negatively impacted from the influx of chemical fertilisers or organic matter. Animal dung or sewage from settlements can cause also organic pollution of water bodies, and contain pathogens. In such situations weed growth can be increased and this assists in the spread of disease vectors. In the Wad Miskeen Area it is known that increasing nitrate and ammonia values have been recorded in the Blue Nile in the past years, but the data from the Wad Ageili scheme shows that the waters here are not contaminated. The operation of an irrigation scheme at Wad Miskeen though could lead to drainage waters containing nutrients and other pollutants from irrigation areas being discharged into *maya* and the Rahad and through surface and subsurface connections to reach the Khor el 'Atshan, Dinder and ultimately Blue Nile.

A water quality study (Nile Initiative, 2005) highlighted the fact that the disposal of "highly enriched organic waste" from sugar processing industries into the Nile in Sudan was the principal cause of organic pollution in both the White and Blue Niles: at Wad Miskeen though, no sugar processing is planned. The irrigated lands may be used for fodder production with livestock being stall-fed. But since farmers, and semi-nomads, enjoy the agro-pastoralist lifestyle, it can be expected that animals will be kept not only on the specialised livestock farms but wherever possible. Careful planning will therefore be required for the disposal of residues and leachates. At present there is no data.

Assessment of Impact Category: Negative impacts on watercourses from organic pollution and fertilisers are possible [D]

4.2.4 Anaerobic Effects

The project is not planning to make any large storage reservoirs. The evidence from existing *maya* depressions, some which remain flooded throughout the year, appears to be that this whilst anaerobic effect may well occur in deeper parts of maya, such as the large *maya Er Rekuba* near Wad Meskin, the operation of the Project would not change the present situation in terms of organic material. In the Wad Miskeen area and along the Dinder River there are meander loops and some backswamp areas of the Khor El Atshan that remain flooded all year. These are important for local water supply of villages and nomads, and migrating birds. These areas may also receive runoff from some distance away due to the development of natural drainage networks and these drainage flow lines should become apparent on receipt of the orthophoto mapping.
The project will provide a system of surface drains to remove surface run-off from the irrigation area. These discharge into natural watercourses, or collector drains. The clay soils, once wet and plastic, and cracks are sealed, have very low rates from surface infiltration and subsurface permeability. Thus, any chemical fertilizer and organic waste effluents would be concentrated into a nutrient-laden surface runoff. This situation could lead to a build up of anaerobic conditions in drainage channels and the receiving water bodies. No details are as yet known about the amounts of return flows to be expected in the drainage system. At present there is no data.
Assessment of Impact Category: Negative impacts are possible [D].

4.2.5 Gas Emissions

Gaseous emissions from industrial plants that become established in, either directly or by association with, an irrigation project can seriously pollute the atmosphere, if not properly controlled, and there is a high risk that emissions, such as SO_3, NO_x and other more toxic elements, could contaminate the soils, vegetation and waters of the Project, its hinterland and locations further away. Any initiation of agro-industry to process different types of foods will generate, as noted above, solid wastes and polluted effluents but for air emissions, odour may often be of concern. An increase in gaseous emissions from livestock was mentioned in the draft report review and that this should be monitored. While this is thought likely to be of minor concern monitoring of livestock numbers will be required. Other gaseous emissions result from fuel combustions to cover the energy needs. Certain production processes may require considerable energy inputs and flue gases may also contain dust emissions. Agro-industry associated with or induced by the development of the scheme, will contribute to air pollution. Emission control technology, if properly applied, can minimise these impacts. At present there is no data.
Assessment of Impact Category: Negative impacts are possible [D].

4.3 Soils and Salinity

4.3.1 Soil Salinity

The build up of salts in soils under irrigation is a common process where the water quality is poor, or the soils too shallow to allow adequate leaching, and land management inadequate.
Early work on water quality by Talling (1963) on the Blue and White Nile Rivers has been partly updated in the *National Nile Basin Water Quality Monitoring Baseline Report for Sudan* (Nile Initiative, 2005) which indicates a low salt content of the Blue Nile water. Values given for the Blue Nile at Sobat for electrical conductivity are 194 to 295 µS/cm (min/max) and total dissolved solids (TDS) of 126 to 189 mg/l (min/max).
These can be compared favourably with data presented in Coyne et Bellier et al. (1979) that gave the following undated values: Blue Nile Water, Khartoum. Sodium Absorption Ratio (SAR) ranges from 0.2 to 1.6, indicating low sodium hazard; Electrical conductivity (EC) ranges from 120 to 430 µS/cm, indicating moderate salinity increases at times; and TDS ranging from 100 to 220 mg/l.

The conclusion is that any build-up of salinity in the Wad Miskeen soils due to effects of irrigation water would therefore be very slight and slow. Analyses for water quality along the Dinder River and Rahad Rivers are wanting. Some recent water analyses are available for wells along these rivers. A sample taken at Ras En Fil, at 48m in a well close to the Dinder River on DNP boundary, shows an EC of 760 µS/cm and an SAR of 0.5, making this C3-S1 water. Samples from a hand pump close to the Rahad River within the study area, taken in November 2009 were declared to be potable by villagers. At present no data can be located for the Rahad and Dinder rivers whilst in flood but there are no reports of it being anything but of low salinity.
Assessment of Impact Category: Negative impacts are possible [D].

4.3.2 Soil Properties

Previous and recent soil studies (see Baseline chapter) indicate that land suitability limitations are related to the Vertisolic characteristics of the soil with their wetness and plastic properties. There is also a low level of soil fertility, and while some soils are in an exhausted state resulting from a lack of fertilisers and negligible accumulation of organic matter (HTSPE, 2008; Mahmoud, 1988), nutrients are present in the subsoil and used by arboreal vegetation but these are unavailable to shallow-rooted field crops. While the high clay content of Vertisols cannot be altered, other wetness and flooding limitations can be managed by better drainage and protection from flooding. Topsoil fertility will be ameliorated by fertiliser application. Generally, wetness and inundation problems could further deteriorate as a consequence of poor irrigation management. However, with appropriate land and water management practices, soil suitability can also be improved under irrigation.
Assessment of Impact Category: Both positive and negative impacts are possible. [B], [D]

4.3.3 Saline Groundwater

It is thought unlikely that leaching down of any moderately saline drainage-water would percolate through the Vertisols, which have very low permeability, down to the interface between soil and bedrock. Excess irrigation water would flow back into the Rahad River and thence towards the Blue Nile. There is a risk however, that if the quality of the Rahad is changed thus then these could impact on the groundwater quality near to the rivers and of more concern in the Atshan aquifer.
Assessment of Impact Category: Negative impact possible. [D]

4.3.4 Saline Drainage

It is normal that irrigation return flows from the drainage networks and subsurface seepage are more saline than the irrigation water. In the Wad Miskeen area saline conditions are rare and that soluble salts are at low levels in soil profiles. Being a rainfed cropped area and with rainfall increasing from north to south, the field evidence is that leaching of salts also increases towards the south. Salts though are added to the soil profile from both airborne dust sources coming from Northern Sudan or beyond, and from the irrigation water. The very low infiltration and permeability rates of the clay soils leads to a slow build up of salts in the deep profile. With the project area some salts could build up at soil-rock interface. Some movement of soluble salts deeper into groundwater would be minimal as, west of the Rahad, it lies at a considerable depth.
Assessment of Impact Category: Negative impacts are possible. [D]

4.3.5 Saline Intrusion

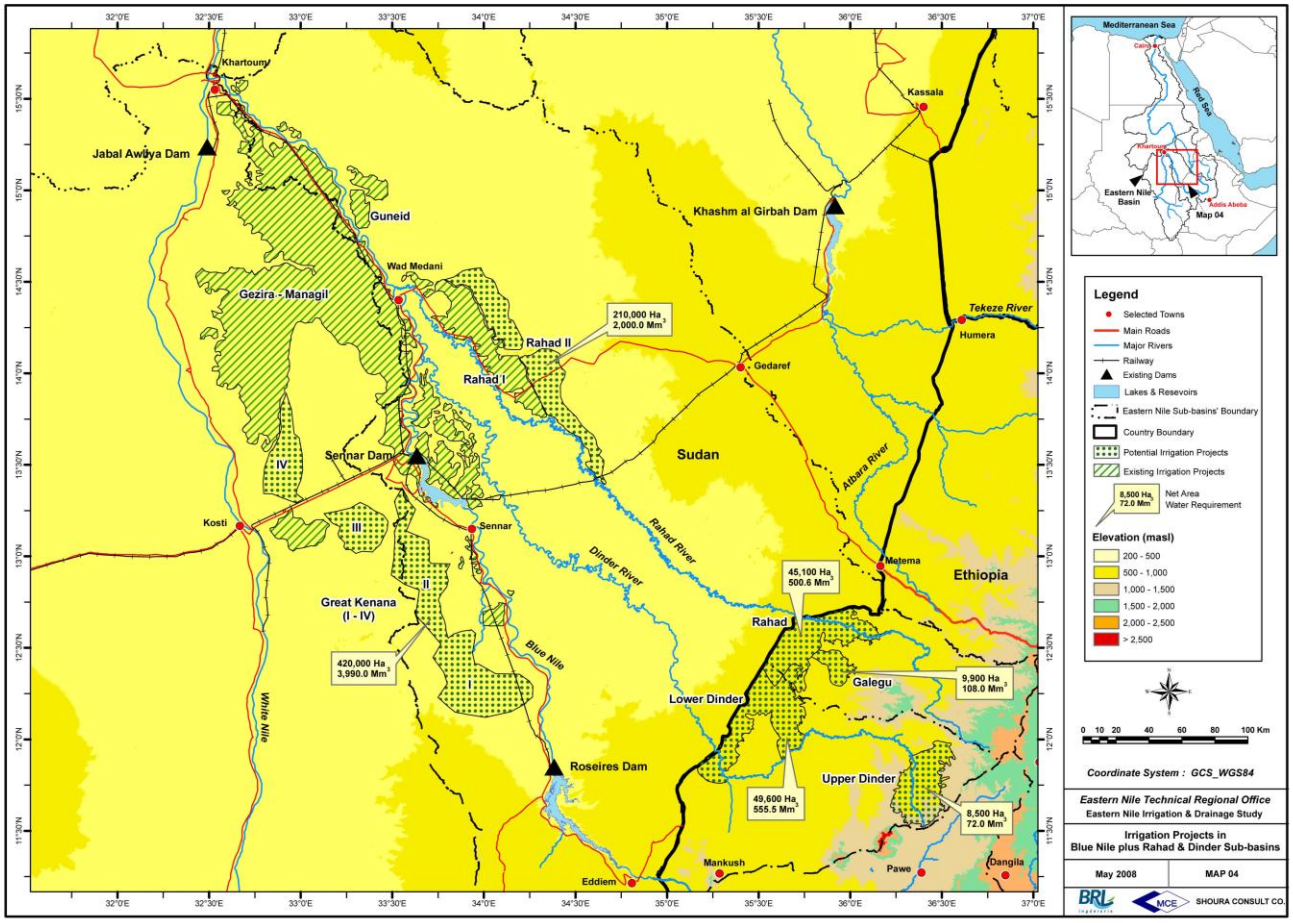
The issue of saline intrusion is primarily a risk in coastal areas, but also elsewhere where a saline groundwater aquifer might intrude into the upper and surface fresh water layers. Hypersaline water occurs at depths of hundreds of metres below the Khor el 'Atshan and Dinder River but this is remote from the irrigation area, and the project will not abstract groundwater for irrigation (see discussion in Chapter 3.2). Thus there is no evidence that any saline intrusion might take place as a result of the project.
Assessment of Impact Category: No impact likely. [C]

4.4 EROSION AND SEDIMENTATION

A number of environmental impacts relate to erosion and sedimentation in the rivers, canals and soils, with degradation of lands and riverbanks. A heavy load of silt and clay in a canal during the flood season will lead to canals siltation.

Annual sediment loads in the Blue Nile have been estimated at between 50-100 Mt and are the result of erosion of soils in the Blue Nile catchment on Ethiopia (Williams and Faure, 1980). At Roseires dam, from the amount of fine sediment and vegetative matter deposited in the lowest parts of the reservoir, it is evident that despite conservation efforts loss of soil and vegetation remains an issue in the upper catchment. Some hydrological data is available for the Dinder and Rahad rivers in Ethiopia, and these were collected for early studies of reservoirs and irrigation schemes (USBR, 1964), but there are no sediment data (BCEOM, 1998; BRL, 2008). The location of the early studies on the Rahad and Dinder Rivers in Ethiopia are shown on **Figure 9.**

Figure 9: Rahad and Dinder in Ethiopia and Sudan



4.4.1 Local Erosion

Rainfall in the Wad Miskeen area usually occurs as short-lived high intensity rainfall events, and soil erosion by water occurs on the plains (the *dahara*) since the dry clay soils flake immediately on contact with water. Once they are wetted up and expanded this form of erosion diminishes on the Vertisols clays but on the steeper slopes beside khors and maya gullies may develop. On a new irrigation project water erosion will occur locally on canal embankments or other structures and where vegetation is removed. Wind erosion is a significant process on the clay plains, in the dry season, when large amounts of clayey soil can be lifted up by a range of features such as: livestock routes, vehicles, mechanised farming operations, short lived and localised dust devils, or occasional longer-lived and larger dust storms. Into the rainy season an approaching storm front will raises considerable dust in front of the rain as strong winds surge in.
Negative impacts are possible. [D]

4.4.2 Hinterland Effect

The hinterland effect is where a new scheme attracts more people into the fringing parts of an area and these can unbalance the existing and long sustained land use practices, causing land degradation, erosion, and conflict. The project could attract establishment of more settlers on the land lying upslope of the command where there are few village sat present but extensive areas of rainfed farming. Land use planning though needs to examine all lands within and adjacent to an irrigation scheme. At present, a significant population based along the Rahad River, for the most in small nucleus settlements but also in the major market centre of Hawata, farm the rainfed areas.
Additional influxes of people into the surrounding areas are possible and an increase in the population density of the Wad Miskeen Project, may result in negative impacts over a wider area. The settlements along the Rahad River lie outside the irrigated area and can be said to be in the hinterland. These people, from mixed ethnic groups have long been settled there, utilising the rainfed areas and growing crops along the meander belt, where there are extensive groves of mangos, and fish in the *maya*. It is clear they will expect to continue to use these lands, albeit with assistance from irrigation. The proportion of land that is actually used for rainfed farming varies from year to year depending on the rainfall and state of the fallow period.
Clearly, not all land is used in any one year. Some are Forest Reserves, though parts of these may be rainfed farmed. In 2009, when the rains failed throughout the Wad Miskeen area almost no grain was recovered from field crops.
Under irrigation the land could be much more intensively utilised and in such cases there is always a risk, which the residents are aware of, that they could become marginalised in this respect if additional settlers were brought in. The project must aim to accommodate all existing residents and land users, including the sedentary farmers and nomads.
The project should aim to ensure that none will be excluded and none forced to leave, and that the traditional rights of the various nomadic groups will be honoured. The Project design will allow for nomadic routes to be maintained. If at this stage there is capacity for additional people to be moved to the area then careful planning will be required to ensure that they understand and completely agree with these principles and respect the traditional rights of customary law. Without such agreements then conflict is very likely. Therefore it is seen that any increase in the population density of the Wad Miskeen area as an irrigation project, may result in negative impacts over a wider area.
Assessment of Impact Category: Negative impact possible. [D].

4.4.3 River Morphology

The impact of weirs on the Rahad and Dinder Rivers will be to change, to a certain extent, the sediment regime of these rivers and this could lead to changes in river morphology and downstream impacts on ecosystems.

It is proposed that the initial flood and peak flows will be allowed to pass the weirs. This will ensure that a substantial proportion of the suspended and bed load will pass downstream, and the existing pattern of erosion of banks and formation of channel bars and islands will be maintained: the 'clear water effect' when waters slow in sediment - such that would come out of dam reservoir- results in greater erosion downstream.
On the Dinder a degree of flooding upstream into the DNP is possible and these could flood *maya* that at present dry out at times. A subsequent low flow in the Dinder could lead to draining of the *maya* and erosion (flushing) of sediments within them. This can be interpreted as being good for long term survival for *maya (*the DNP authorities in the park have tried to achieve this infilling anyway and these maya have to an extent that is not quantified, a man-made ecosystem), but this will be bad for these habitats in the short term. Clearly, on the Dinder, this requires much more study of these ecosystems and the impact of a weir.
Assessment of Impact Category: Both Positive [B] and Negative [D] impacts possible.

4.4.4 River Channel Structures

The Dinder and Rahad are quite different rivers. The Rahad has a narrow channel whose banks appear stable, but it shows a recent meandering course with numerous cut-off meanders (*maya*). However it appears well incised into the plains. The Dinder illustrates a channel that is quite vigorously eroding its bank whether in the DNP or in lands well downstream of this. The Rahad has apparently a clayey floor whereas the Dinder supports a moving bed-load of coarse sand to fine gravel. The baseline study on these rivers (Gibb, 1954) advised against building any structures upstream of their confluence with the Blue Nile until rock is reached. Appendix C of the Gibb (1954) report examined development possibilities on the Rahad and Dinder and recommended that any structure should rest on rock foundations: these occur what is now well within the DNP within 20 and 40 km downstream of the Ethiopian border respectively. Since then engineering procedures have and practices have improved and construction on non-rock foundations are standard: the Abu Rakham barrage for example lies on alluvium.
Care though should be taken when making the detailed designs at both proposed weir sites to avoid any erosion of structures as the rivers attempt to modify their course Assessment of Impact Category: Negative impacts are possible [D].

4.4.5 Sedimentation

Sedimentation in canals will be an issue on the project, which will take flood waters laden with silts from the Rahad and Dinder. The silt content of these rivers is not known: we could find no records and it was not possible to sample during the flood season due to access problems. Dry season observations though showed that the bed load of the Dinder is coarse sand and fine gravel (as in **Figure 10** below), whereas in the Rahad there appears to be very little sandy bed load. Along the Dinder River close to the weir site in DNP, there is heavy coarse sand bed-load and bank erosion is significant (fig. 9). On the one hand sand and silt would clog up the canal system, but on the other clay particles would settle on fields and impart a degree of fertility to the soils.
Assessment of Impact Category: Both positive and negative impacts are likely [B] and [E].

Figure 10: Bank Erosion, Dinder River

View upstream of bank erosion and spreading lobe of channel sands. Location just inside Dinder National Park, April 2008. Photo: R.N.Munro

4.4.6 Estuary Erosion

In the Wad Miskeen area changes to the hydrology or sediment regime of the rivers affecting delta formation or estuary and coastal erosion are not considered relevant.
Assessment of Impact Category: No impacts likely [C].

4.5 BIOLOGICAL AND ECOLOGICAL CHANGES

4.5.1 Project Lands

To assess if an irrigation project will cause positive or negative changes to the environment requires a baseline assessment of ecosystems to gauge any such change on. In the Wad Miskeen area much of the baseline data relating to ecology is rather dated (Worrall, 1960; Joyce, 1952) but remains of value and has been useful to assess the present situation. On desertification in the adjacent Butana region there is much of interest: the Southern Kassala Agricultural Development Project (SKAP) study made by Masdar (1992) and El Hag, 2006). A very useful and recent study is the Management Plan for Dinder National Park (HCENR, 2004).
Nomads. The nomads here are mobile groups who, in the Dinder to Wad Miskeen area, move along well-marked traditional routes. One route is along the railway line from Hawata north-eastwards towards Qala en Nahl and Al Matna and on into the Butana: this is the 'Black Route'. Another is along the right bank of the Rahad northwards towards Hawata and then north of the Wad Miskeen area at Qala al Baggara, past Umm Burush Reserve Forest, and thence to the railway line east of Hawata. A third is along the northern fringe of the DNP, with watering place on the Dinder at Umm Baggara and thence northwards to the railway at Hawata, or beyond, to Abu Rakham on the Rahad supply canal. The routes can be quite broad, up to 2km wide in places, and usually are not exact straight tracks across the savanna. In the more intensive rainfed areas the routes can be found to be reduced in width to a few hundred metres.
There are three issues at stake: land take, provision of irrigation and settlement development.

Farming. The Wad Miskeen area is a mix of rainfed farming, with fallow lands reverting to tall grasslands and *Acacia mellifera* bushland. Until the 1940s the main rainfed farming system was that of a sustainable smallholder farming system set amongst savanna woodland. Since then large scale mechanised rainfed farming expanded and the previous vegetation cover has been largely destroyed. The Wad Miskeen is typical of this. Much of the area is under rainfed farming for numerous sorghum varieties and sesame. These lands have been developed as part of the mechanised farming system but harvesting is often done by hand, since combine machinery cannot handle crops of variable height. Land that is fallow reverts to *Acacia mellifera* bushland and / or tall grassland. *Balanites aegyptiaca* (Heglig) is protected and the result is that parts of the area remain as open savanna parkland.

Forest Reserves. In Sudan a 'Forest' is an area where trees have $7m^3$/ha biomass. These are registered in the Sudan Gazette in the name of the Government and are managed by the Forest National Corporation.

Several areas of Forest Reserves occur close to the Wad Miskeen area and there is a risk they could be destroyed during irrigation development. These are remnants of the great swaths of *Acacia spp / Balanites* woodland that once covered the rainlands. Significant areas remained in the 1960s when the Rahad area was cleared mechanically (Adams, 1967). The Umm Jirrer and the Umm Burush areas lie adjacent to the Wad Miskeen project lands. The Umm Jirrer and Umm Burush woodlands are of *Acacia mellifera, A. Seyal, A. Senegal, Balanites aegyptiaca*. Much of this woodland appears recent and secondary growth, but is has various functions, particularly for nomads and charcoal makers. Other, more recent, community Forest Reserves occur along the Rahad backswamps (*maya*) and are dominated by *Acacia nilotica* (Sunt) forest.

Dinder Park. The Dinder National Park remains an area which has retained, it appears, elements of its natural flora and fauna. The DNP management plan, though, requires a very considerable update using modern techniques to assess the status of its varied ecosystems. In Sudan woodland is based on the FAO classification system where the canopy covers 10% of the land. Where such lands lies outside Forest Reserves, and has less than 10% cover then it is called 'trees outside forest'. Individual trees may have protected status, such as *Balanites aegyptiaca* which is present in the area and has been protected since 1901 on account of its usefulness a fruit tree. In a fringe around the DNP, where *Acacia senegal* (Gum Arabic) and *Combretum sp* occur, and at the proposed weir site these, and other *Acacia* are being cut down for fuel wood and charcoal. Elsewhere branches of all species are lopped, often quite excessively, by nomads seeking end of dry season forage. There is little if no control over lopping, and the apparent clearing of forest inside the DNP is a matter of concern.

4.5.2 Land Take

The concept of 'Land Take' is where land is appropriated by the project infrastructure within a future scheme area, either permanently (as structures, canals, buildings, roads, settlements) or temporary during the period of construction. These changes can adversely affect current land use and permanently impact on livelihoods, ecosystems and habitats, as well as, for example, wildlife movements.

It should be noted that the project will not take lands from existing forest reserves, and in fact the FNC has welcomed the idea that these lands could in part be irrigated. The loss of woodland around the barrage site in Dinder National Park is a more serious issue and one that would demand a much fuller assessment than possible here.

The project proposes to make a weir just inside the DNP, and a link canal that would snake away from it to Wad Miskeen. There are positive and negative arguments for this plan. When an environmental assessment is made within an engineering design the environmental studies can make arguments and hope that they are taken into account. The final say though, in whether a weir and link canal is built at the edge of DNP will be decided during the Detailed and Tender Design stages. At that point the Government must decide and work out the best deal on this whole issue: whether this particular element (weir and link canal) should either, go ahead because of an over-riding National food security interest of Sudan, or be cut out completely as it touches the DNP which is held to be a sanctuary not to be touched in any way, or some compromise is reached.

It is clear though, that from the outset of contacts made with the DNP people, in Khartoum (since 2007), that they have been very much in favour of gaining some spin-off from this proposed project, and also we understand the ongoing DIU Kenana-Rahad Irrigation Project that is located in the same area, so that somehow their increasingly dire water shortage situation in the park at the end of the dry season can be resolved. That is why we do believe that this particular element could have a direct possible strong impact to the DNP and save the *maya* wetlands, previously artificially replenished by cuts and canals for many years from the Dinder but now silting up rapidly.
Indeed the DNP Management Plan discusses these every issues. Implementation of this element though would require much dialogue between the DNP management than was possible in the short time allocated for the environmental issues. As noted elsewhere the irrigated agricultural project lies in areas to the north and north east of, and quite remote from, DNP, and also on the eastern bank of the Rahad River. Villages on the left bank of the Rahad along the North Eastern edge of the DNP are technically within the park already, as the boundary lies along the Rahad River. These villages though are many km from Wad Meskin and the proposed irrigation area. Access into the rest of the park by villagers there for grazing and illegal charcoal cutting may take place. Certainly charcoal making is taking place in the area around the park boundary where the proposed weir would be. There was, it appeared to us, confusion amongst DNP rangers here as to where the boundary actually was. We considered this was within the DNP area, the rangers said it was outside.
The villages to benefit from the irrigation project it is intended provide a buffer zone that will keep livestock and possible migrants away from DNP. If the Dinder weir and link are not made then the DNP is in any case far from the Project area: the area lies between 45 and 75 km from the proposed weir site at Salsa. The DNP management plan (2005) suggested establishment of such buffer areas to keep nomads and wood and charcoal makers away from DNP. The plan has not been implemented yet. If a settlement were to be established at the Dinder weir site, then the irrigated project could provide such a buffer benefiting DNP.
The irrigation planning has taken into account the nomadic routes that traverse the area radiating out from the Rahad River towards the Butana and Gedaref Ridge and provided for corridors to be maintained. Project construction will lead to both permanent and temporary land-take and for this compensation will be due to the existing land users. The exact degree of such compensation will be worked out during tender design when the final project layout is finalised.
The impacts of the link canal would likely include disruption of nomadic and wildlife trails. The impact of the siphon on the groundwater flow of the Khor Atshan, and other khors, is discussed elsewhere. A negative impact of the link canal would be wild animals from the Park falling in to the link canal. Such animals would have come out of the park and while there is some evidence of this from local farmers it is minor in case of large mammals. Small mammals, which exist both inside and outside the DNP, could suffer. This must be the case already in the rainy season. The detailed design would need to examine the latest measures considered appropriate to minimize such loss; the same would apply for livestock and humans of course. People would need access steps down to the water. Low bridges over the canal could allow wandering animals to cross the canal, even if it operates for only a short time each year.
Assessment of Impact Category: Without planning and effective mitigation measures, project land take could cause negative to very negative impacts [E]. But, with carefully planned and implemented mitigation measures, the Wad Miskeen Project could actually improve current land use practices that would benefit the pastoralists in particular [B].

4.5.3 Provision of Irrigation

The conversion of a rainfed farming system to an irrigated one is not new in Sudan and is usually embraced by the farmers, and even nomads. In the Wad Miskeen area, whether this will lead to an increase or decrease of the existing state of biodiversity (albeit that it is one of a variable and often regarded as being of a degraded status) will depend on the adopted cropping patterns and methods and levels of plant protection. Wad Miskeen will raise cropping intensities, introduce crop rotation, provide at least 5% of irrigated forestry, and provide for animal production and horticultural crops.
At present, the nomad and agro-pastoralists groups use the fallow lands, failed crops lands and crop residues. They could lose these resources in an intensive irrigation system, as could those who depend on collection of grasses for thatching, mats and fences, all products of the local biodiversity.

Special provision must be made for maintaining these traditional and valuable rural industries. Any future development should include plans to accommodate the traditional livelihoods. It will not be difficult to plan for an integrated system whereby the rights and livelihoods of peoples are respected, whilst at the same time the new project will lead to an enhancement of crop production. Lack of attention to these details will lead to disappointment and even conflict and failure of the scheme. Initial discussions with stakeholders on participation are positive but must be strengthened at an early stage of detailed project planning.
Assessment of Impact Category: Both positive and negative impacts are possible [B], [D].

4.5.4 Settlement Development

Settlement planning will be finalised during the detailed design of the project, and could certainly affect the environment: the development of settlements in the nearby Rahad I scheme provides a guideline of the problems that will need to be examined to reduce negative impacts. Problems in the past have included: the expansion of villages far beyond their original design; growth of unplanned villages without any infrastructure or services; decline of or just lack of health and sanitation facilities; inadequate water supply with canals being used for domestic water supply; lack of electricity; depletion of natural and planted vegetation for fuel wood; and inadequate attention to drainage and flood protection. The Wad Miskeen project should address all these issues in its final design. In particular the villages could be linked to the Hawata water supply network from the wad Ageili well field. Villages in the study areas at present are from various long-established ethnic groups and undue alteration of these societies is not recommended, without at least an in-depth consultation to appreciate their needs.
Assessment of Impact Category: it is possible that the creation of settlements may lead to negative impacts [D].

4.5.5 Water Bodies

The project will create a landscape of new canals, drains and wetlands with habitats for plants, animals, aquatic birds and livestock. The primary function of such a wetland is as part irrigation infrastructure, and habitats will be disturbed by flow variation or cessation, and weeding and de-silting will disturb habitats, whilst drainage effluents may cause harm to species. New water bodies may enhance water- and vector-borne diseases, and the spread of aquatic weeds. People and animals can drown in canals unless appropriate access steps are made at regular intervals. Proposals for a water reservoir in, or immediately adjacent to, the Dinder National Park will require special study to assess the impact of such a feature on vegetation and wildlife.
Assessment of Impact Category: Both positive and negative impacts are possible [B], [D].

4.5.6 Surrounding Area

The project area and its surroundings consists of a mosaic of semi-mechanised rainfed agriculture, traditional agriculture close to the river Rahad, livestock grazing on fallow and harvested lands, and reserve forest lands utilised by nomads for their settlements and grazing. If the current land users were to become beneficiaries of the new scheme, as seems likely, they would not have to look for compensation and land outside of the scheme boundaries, where available land is likely to be lacking. The existing land users should have priority over any new immigrants attracted to the scheme. The future role of nomads in the area requires careful analysis to avoid conflict with irrigation farmers. There is good evidence from discussions there, and history elsewhere in Sudan, that the nomadic populations would entertain having adequate forage supplies from irrigation. A risk could if displaced populations moved into Dinder National Park, but this is - as noted elsewhere - fairly remote from the irrigation area.
Assessment of Impact Category: No details are yet known about the future mechanisms for allocating land in the new scheme [F]. Both positive and negative impacts are possible [B], [D].

4.5.7 Rivers and Riverine Habitats

There is a risk that the Wad Miskeen area would impact on the riverine habitats of the Rahad and Dinder rivers, from discharge of any polluted irrigation return flows, and changed river flood regimes. The riverine environments support a considerable human population downstream of weir sites, with riparian forests, and surface / groundwater supplies for villages, livestock and traditional agriculture. The Rahad and Dinder *maya* support riparian vegetation, and flood basin forests with *Acacia nilotica* occur downstream on the Rahad. The Khor el 'Atshan plays an important role, it appears, in groundwater supplies for Hawata and sustaining nomadic populations in the dry season, but the groundwater sources appear to lie well upstream of the Wad Miskeen weir site. There is fishing on the Dinder and Rahad rivers and *maya*, with the residual pools being utilised for these, but there is no data on the ecology, stocks, and management of this resource. In all the data is too limited to provide an assessment of the sensitivity to these riparian habitats. It is true too of the m*aya,* which depend on threshold flood levels that feed water and nutrients from the rivers into them. Whilst changes occur naturally according to state of low flows, negative impacts will occur if flood levels are reduced due to abstraction or if the *maya* will receive polluted drainage.
Assessment of Impact Category: A lack of data means that further studies will be needed [F] but negative impacts are possible [D].

4.5.8 Rare Species

The nearest protected area where rare species are found is Dinder National Park (DNP) (HCENR, 2004). Outside of the DNP, deforestation and mechanised farming have destroyed most of the natural habitats and larger wildlife is practically absent. Within the Wad Miskeen area birds of prey, that may be considered rare elsewhere (including owls, eagles, buzzards and smaller raptors), are remarkably common and collectively perform a useful service in reducing rodent populations. No assessment of their rarity or of present populations has been made.
Assessment of Impact Category: Further study needed [F]. Both positive and negative impacts are possible [B], [D].

4.5.9 Animal Migration

No recent information is available on terrestrial migration of wild animals in the Wad Miskeen area. For many years though no larger mammals, such as the gazelle seen by HTS (1966) in the Rahad I area, have been seen in the area. Any movement by large mammals are those of solitary animals wandering out of the DNP. Movements of smaller mammals – foxes, rabbits, rock hyrax, and others - are localised and not linked to any large scale migration pattern, though conveyors could obstruct local routes and territories. The availability of water from the canals would however enhance the habitat value. The likely improvement to water supply in *maya*, irrigated fields could have a positive impact on migratory birds, as they would provide feeding and resting sites.
Assessment of Impact Category: Both positive and negative impacts are possible [B], [D].

4.5.10 Natural Industry

Unplanned changes to commercial or subsistence activities which depend on the natural terrestrial and aquatic environment of the existing project area can lead to negative impacts.

Woodlands

In the Wad Miskeen area the loss of natural vegetation at barrage sites and along the link canal and main canals by project land take will affect nomadic groups and other periodic users of the woodlands. Whilst significant parts of the proposed irrigation area, are at present under regenerating *Acacia mellifera* bushland fallow state, this is for the most secondary, and almost a weedy, growth. Nevertheless it is widely used by the pastoralists for grazing by camels.

Any loss of the more natural woodlands, along and outside the forest reserve, will have an impact on those that use these resources such as for grazing, browsing, furniture making, gum Arabic collection, fuel wood collection, grasses for thatching and mats. Mitigation measures will have to be developed for nomadic groups and other users. As a start the project does not plan to include any of the existing forested areas in the irrigation layout. This positive step, made possible by use of up to date Quick bird imagery for defining forested areas, will ensure they should remain protected. Canals may by necessity have to pass through these areas and compensation will be due, but it is also likely that irrigation water can be used to enhance the forests. A final point is that the *A. mellifera* bushland is also widely used by locusts and grasshoppers when they are on the move and clearance of woodland would mean other food sources would be sought.

Assessment of Impact Category: it is clear that both negative and positive impacts are possible [B], [D]. The actual extent and significance will be defined during the detailed planning [F].

Fisheries

Fishing is quite important along the rivers. Traditional nets are used. Pisciverous bird life is seen all along the rivers until the pools dry up. Some pools on the Dinder are fed by subsurface flow that occasionally comes to the surface, and small fish will exist in these, all the year. There are numerous freshwater shell crustacea in the Rahad. However, there is insufficient information available to be able to assess the likely impacts on aquatic ecosystems – *maya (***Figure 11)**, residual pools in the rivers, and fishing from these. We have been unable at this stage to obtain any relevant research data on fish movements or their ecology in the Rahad and Dinder rivers. There is no mention of the fish resources of the Dinder or Rahad Rivers in the recent biological monograph on the Nile by Dumont (2009). The alteration of flood flows in the rivers could impact adversely on the resources: certainly all barrages and weirs should be designed so that they do not block the migration of fish up and down the rivers when they are in flood and at low stages. A series of side rapids would appear to be the most appropriate system.

Assessment of Impact Category: There is a data gap on fisheries and aquatic ecosystems [F] and both negative and positive impacts are possible [D], [B].

Figure 11. Maya wetland in Wad Miskeen Area

4.6 SOCIO-ECONOMIC IMPACTS

4.6.1 Population Change

The lessons from another adjacent project, at Rahad 1, are pertinent. Before the scheme was established the land was occupied by sedentary rainfed farmers and nomads, and there were areas of thick woodland (Adams, 1967). In the distribution of tenancies in Rahad I priority was given to people who had either owned land in the area, had registered rights to the land inside the project area, or who lived permanently inside the project area.

Subsequently, people were drawn from villages along the Rahad and Dinder rivers, and adjacent areas, and hired labour from further afield settled including refugees from Eritrea and Ethiopia. Tribal, but not so many nomadic, groups stayed together so that the new villages continued to have tribal identities. In general in the Rahad 1 scheme, there was a rise from 72,500 people in 1975, to about 200,000 in 1985, and at present the estimate may be around 800,000. Elsewhere in Gedaref state, the SKAP study (1992) found that pastoralists had been put under considerable pressure due to the introduction of mechanised farms, and key issues included: former common grazing resources were now allocated to individual owners of the mechanised farmers who now sold residues to pastoralists; there was increasing conflict between pastoralists and farmers; due to lack of feed and water some nomads had been forced to reduce stocks, and some became herdsmen, shepherds or even labourers. The present population of the study area, is estimated 18,000 to 20,000. This includes sedentary rainfed farmers based either in diverse ethnic groups in numerous villages along the Rahad River and within the proposed scheme, or in Hawata. There are also nomadic groups who have semi-permanent camps in the woodlands within the area: in 2009 these have not moved as far afield as normal due to the poor rains. At present there are said to be slight conflicts between the settlers and nomads, but in a year of low rainfall the pressures on all land users will be strong to survive.

In the future project it is essential that the present occupiers and land users be accommodated first and that their traditional rights are respected. Any outside pressure or suggestions to establish new settlements in the area, which may be seen as some as being empty, should be the subject of extremely careful planning and consultation, and examine especially the capacity of the project to accommodate new populations above of those who already live in and use the area. The project will also draw in hired workers and sharecroppers, as well as small businesses and traders. The irrigation area will extend right up to Hawata, already a major market and commercial centre, and it is expected that it would absorb much of this increase, especially agro-industries. But, social-enhancing developments should and must also be made in the villages, where existing infrastructure and public services are poor.

Assessment of Impact Category: It is possible that negative impacts to the social harmony will occur [D]. If allocation of irrigated land can be achieved in an amicable way then positive impacts are possible [B].

4.6.2 Income and Amenity

Over several decades, agricultural income in the area from the semi-mechanised rainfed farming sector has seen a general decline in yields. Whilst variable rainfall (such as in 2009) plays a role, other issues are important: sorghum monoculture and associated crop weed infestation; lack of appropriate machinery; decline in topsoil fertility due to a lack of inputs; and invasion of bushland as land is rested or abandoned. The Wad Miskeen irrigated schemes offers a chance for the resident farmers, and others, to break out of this cycle of degradation.

Assessment of Impact Category: If the opportunity to increase production by irrigated agriculture is successfully used, and if the scheme succeeds in operating sustainable in the long term, then positive impacts are very likely [A]. If the rights of stakeholders who currently use the area are not accommodated then negative impacts are possible [D].

4.6.3 Human Migration

The Wad Miskeen scheme is likely to attract additional populations migrating into the area. Settlement development must be planned in an expert way and spontaneous settlement without public infrastructure and social services be avoided. All these issues must be addressed as a central part of the tender designs, and will include provisions for water supply, schools, health services, markets, public transport.
Assessment of Impact Category: If adequate provisions are made for the entire population that may be attracted to the scheme area, positive impacts are very likely [A]. If provisions are insufficient, negative impacts are very likely [E]. Appropriate study and planning is needed for a more detailed assessment of this issue [F].

4.6.4 Resettlement

In any irrigation development, where existing populations are present, it is important to minimise or avoid any physical displacement of such peoples in the new irrigation area. Some movement may well be necessary, where structures and canals are built over rights of way or cultivated lands, for example, and the impacts on livelihoods. Disruption can be minimised if those who live in the area become beneficiaries of the Project, and a participatory approach used to find solutions. Procedures for land acquisition will be made according to Sudanese legislation and good practices following the guidelines of the ADB. During tender design a detailed assessment will be made of possible land acquisition impacts, and this will involve consultation with impacted peoples on procedures and provisions for land acquisition and compensation, and also establish procedures for settling disputes.
As yet no settlement planning has been made for the study. Within the Wad Meskin irrigation area, it is not known whether the existing farmers will be included as stakeholders: this is hoped to be the case. These existing stakeholders have lived in the numerous villages along the Rahad for a hundred years or more. Farmers in the area travel out from Hawata or the villages along the Rahad. We recommend that these same people will be the key workers on the project. Indeed, this is what they are expecting. Any other planning could lead to civil strife. There will however, be no planned settlements along the link canal.
The sensitivity of the area would refer only to a weir and link canal development on the Dinder at the edge of the National Park. (This option is, in any case thought unnecessary at this stage as the Wad Miskeen area can be successful based only on use of the Rahad River alone). If a weir is made at the DNP edge however, and as noted the park management people are keen to see some cooperative work in making more water available in the park during the dry season, then there would be some development but the only nearby existing village is at Umm Baggara (a small and thriving market village with new mobile tower communications that is located about 15 minutes drive from the DNP edge). This would need to be encouraged to take be expanded for construction workers and maintenance work later on. There are already good relations between nomadic peoples and sedentary farmers in these areas. There are small settlements along the Dinder River up towards the DNP where people are engaged in herding, fishing, and small scale irrigation. The traditions and inherited rights of the long settled peoples should be respected.
Assessment of Impact Category: If adequate provisions are not established and/or implemented, negative impacts are very likely [E]. If planned and implemented properly, resettlement can under certain conditions however also improve the livelihoods of affected people [B]. The adequacy of the provisions to be developed and implemented cannot currently be assessed [F].

4.6.5 Women's Roles

The sociological studies (Annex 4) reported from their baseline survey that women occupy a very low status in the local society. It found they are totally excluded from domestic services and agriculture, and their needs are not considered by the village community. Very limited education facilities are available to women. In village, Makankana, inhabited by Hausa people (West African origin), no single girl attended school. In other villages, girl's education does not go beyond basic level education. Women after marriage are totally under the control of the husband. The husband takes all decisions regarding the household. Women's participation in village decision making is not allowed, because this is the man's domain. Owning land is also men's domain despite their participation in farming activities. These findings are extremely disappointing, and thus, there is much that can be improved in this respect.
Will the project bring positive benefits to women and their role in society and rural economy? At present it would seem not, but in other irrigation schemes, such as New Halfa and Rahad I women do play a considerable role in weeding and harvesting, and if family groups wish to make the most of their lands under irrigation, and save on hired labour, then it will be appropriate that all the family are involved. Social change will be needed for this to happen and education for all in this respect will be necessary. Given that the local peoples are approving of the project this is a good sign.
Assessment of Impact Category: Both positive [B] and negative [D] impacts are likely. Further assessment is required [F] but could be negative if planning does not consider these issues.

4.6.6 Minority Groups

There are a number of ethnic groups in villages along the Rahad. These are small communities, proud of their origins in other parts of Sudan or West Africa and anxious to maintain their traditions and role in the community as a whole. They are Sudanese though and not regarded as an Minority Group as such, but their traditions are important as they play key roles in the markets and industrial businesses in Hawata. There is insufficient data to assess whether the Wad Miskeen Project would change their status.
Assessment of Impact Category: further assessment required [F] but could be negative if planning does not consider these issues [D].

4.6.7 Sites of Value and Cultural Heritage

The Wad Miskeen area has not been assessed for sites of national archaeological heritage value: this was outside the scope of the present short-term study. However, it should be noted that at one small rock outcrop in the proposed irrigation area some traces of cultural deposits of various ages were noted. Since this lies along an established, probably ancient, nomad route there are likely to be significant remains that could yield valuable information on the cultural history of this area.
Traces of early man were found at Singa on the Blue Nile, many years ago before the Sennar Dam was constructed, and it is entirely possible that similar remains could exist on the Rahad and Dinder rivers in the alluvium. Any proposed works along present and old river course should involve the full-time presence of an archaeologist to assess find on the spot.
Significant and famous palaeontological remains have been found at Singa, slightly to the east of Kenana II, where an Upper Pleistocene (so-called 'bushmanoid') skull and other fossil remains were found in the late 1930s and described by Woodward (1938), Arkell (1949) and Whiteman (1971). The site remains undated and has considerable interest (Schepartz,1988) and, although that particular location now lies under the Sennar Reservoir, others could exist within the complex of old Nile channels that lies west of the Blue Nile between Abu Hagar and Sennar and within the Kenana II area.

Clearly, construction of irrigation canals and other infrastructural features should avoid areas with suspected heritage value until further surveys are made to avoid any unnecessary destruction of remains. There are no economic mineral resources in the immediate vicinity of the project area (Ruxton, 1956; HG&G, 1969; Whiteman, 1971) and bedrock exposures, suitable for quarries required in construction, lie well outside the study area. The heritage value of the Dinder National Park, which lies immediately south of the Dinder barrage, and is regarded as an important biodiversity reserve for Sudan and sub-Saharan Africa, is discussed elsewhere in this Annex.

The Dinder National Park Management Plan (2004) reported on investigations (1997 and 2002) along Dinder and Rahad Rivers and had revealed some areas of archaeological sites. These are mainly situated inside the DNP and closely associated with Mayas such as Abdel Ghani, Ras Amir, Gererrisa and Farsh El Naam. These sites are dated to late Meroitic period. Near Jebel Abu Sabika, rock paintings and engravings were also found (Management Plan for DNP 2005). In the area under study, particularly in the agricultural project area, no such discoveries were found. However, and according to Sudanese laws (antiquities Act 1951) that during construction or digging for canals, that the contractor came across any remains that may be considered of archaeological significance, construction should stop and notify the Antiquities Department to investigate the matter. A proper survey should be part of the Tender Design work for this area, and whether this includes the Dinder weir and link canal, or just the Rahad weir and works inside the irrigation area, will affect the overall cost of such a survey.
At Wad Miskeen, there are the remains of the pump house and plastered settling pools for the small irrigation scheme that once existed there in the 1950-1960s'. It is clear that river-bank erosion repeatedly damaged the brick works and several generations of repairs are visible. This is an interesting item of industrial archaeology.

There appear to be no economic mineral resources in the project area (HGG, 1969 ; Whiteman, 1971), but the Basement rocks have considerable value in quarries for hard rocks of the type required in construction, but use of these resources could be at the expense of what little scenic value exists, and any cultural heritage on them. A particular hill maya need to be avoided as it has a deep spiritual value, or contain graves, or wildlife refuge (owls, raptors that have useful purposes for pest control), and etc. Alternative hard rock sites (such as deep quarries rather than excavation of the Jebels) could be a solution. Identification of quarry sites should be made with all these points in mind and not just because the rock is suitable.
Assessment of Impact Category: Given that at least one area within the irrigation area could have heritage value, negative impacts are possible [D]. These can however be avoided or at least minimised, if appropriate mitigation measures are taken. Sites with likely presence of significant archaeological remains or other heritage values should best be excluded from the project lands. Should this not be entirely possible, then mitigation measures such as investigation, excavation, documentation and/or removal of the relicts must be planned and initiated before start of construction.

4.6.8 Regional Effects

The Wad Miskeen project will introduce a range of economic, infrastructural, social and demographic changes and these could induce regional development effects.
Assessment of Impact Category: Positive impacts are possible [B], but at present the extent of change cannot be quantified [F].

4.6.9 User Environment

The participation of farmers is needed to ensure that existing land use and land tenure systems are integrated into the future Project. A programme of information distribution and collection of opinions is strongly recommended.
Assessment of Impact Category: Both positive and negative impacts are possible, depending on the level of future participatory efforts [B], [D]. Outcome and integration thereof into the Project planning cannot be assessed currently [F].

4.6.10 Recreation

There are no recreational facilities in the Project area, or in Hawata, at present. Dinder National Park lies at a moderate distance from Wad Miskeen, but the main gate and park headquarters is remote, on the Dinder river. Local visitors are limited.
Assessment of Impact Category: It is likely that the project will generate positive impacts [B] as facilities are improved around villages and these will have recreational offsets.

4.7 HUMAN HEALTH

4.7.1 Water and Sanitation

Settlement planning and the related water, sanitation and waste collection services will be included in the scope of the Tender Design for the Project. Appropriate provisions will, therefore, have to be planned and implemented for the settlements of the future scheme in order to establish hygienic conditions and to control the pollution of water and the spread of diseases. Surface water sources (*hafirs* - artificial ponds - and irrigation canals) for domestic water supplies have to be protected against pollution (faecal pollution from settlements and livestock, and polluted surface runoff from irrigation areas). Ideally, treatment of the surface waters in *hafirs* is required before using it for domestic purposes. In practice this does not happen and will be very difficult to achieve at the source and some other form of treatment or supply will be necessary. Some near surface water is found at villages along the Rahad but there is no groundwater inside the area. It is better thus if piped water is supplied from the Hawata –Wad Ageili network. Provision of pit latrines for all households is a necessity but due to the difficulty of digging into the clay soils this requires some effort and currently is often avoided. Provision of waste collection services in the local villages is required. Currently both these aspects are very poor or absent.

Assessment of Impact Category: If adequate provisions are made for the entire population that may be attracted to the scheme area, positive impacts are very likely [A]. Negative impacts are possible, if provisions are insufficient [D]. Appropriate study and planning is needed for a more detailed assessment of this issue [F].

4.7.2 Habitation

The physical planning for settlements and associated infrastructure should be made at same time and coordinated with the planning for the irrigation infrastructure. There is a risk that physical planning for settlements would be inadequate and not implemented according to the most appropriate design.

Assessment of Impact Category: Positive impacts are very likely [A], but negative impacts are also very likely if provisions are insufficient [E]. Appropriate study and planning is needed for a more detailed assessment of this issue [F] at tender design stage.

4.7.3 Health Services

In the Gezira-Managil scheme health problems (bilharzia, malaria and diarrheal diseases) increased as a result of intensive irrigated agriculture in the 1970s', and in response to this the Blue Nile Health Project (BNHP) ran successful health programmes. However, after donor funding was terminated in early 1990s many services ceased operation, and since then local government has been unable to continue programmes at an adequate level, and incidence of diseases have increased. In the Wad Miskeen area, with its proximity to Hawata where there are health services, it should be possible to reduce the impact of these diseases. If adequate and sustainable provisions are made for the entire population that may be attracted to the new scheme area, health problems associated with intensive irrigated agriculture can be controlled. However, failure to address the increased health risks would produce negative results.

Assessment of Impact Category: Therefore, both positive and negative impacts are possible [B], [D].

4.7.4 Nutrition

Irrigation projects have the potential to increase agricultural productivity, incomes and the indirect effects of a reduction of poverty-related malnutrition.

Assessment of Impact Category: Positive impacts are possible [B], as are negative impacts if some population groups were to suffer losses without being adequately compensated or if new introduced livelihood schemes turned out to be unsustainable [D]. More information is needed on the current social situation [F].

4.7.5 Relocation Effect

Final details for the size and origins of the population on the Wad Miskeen scheme cannot be judged at this time, and it is not known if project-induced population movements would trigger health issues.
Assessment of Impact Category: [F]. More information is needed.

4.7.6 Disease Ecology

The Wad Miskeen area, the weir sites and the link canal cover a various habitats that harbour numerous pests and diseases and affect plants/crops, animals and humans. The main human health risks are from bilharzia, malaria, and Rift Valley Fever. The creation of a new irrigation and drainage infrastructure will introduce wetlands to the landscape, which will increase the available habitat area for disease vectors. A significant change in the transmission risk of water related diseases is very likely as the population rises.
Assessment of Impact Category: Negative impact very likely [E].

4.7.7 Disease Hosts

It is certain that when crop production is increased and becomes more variable in the proposed Wad Miskeen scheme there will be a concomitant increase in disease host populations of rats and birds. Livestock already are of considerable importance in the study area and numbers can be expected to increase with the project, and also lead to more interaction with disease vectors.
Assessment of Impact Category: Negative impact very likely [E].

4.7.8 Disease Control

Disease control measures have been successfully applied for many decades in the major irrigation projects in Sudan. Control measures however have required considerable application of chemicals for disease vector control and provision of drugs for treatment of people. When, after 10 years the donor funding ended, for example the BNHP, these control measures also stopped.
Assessment of Impact Category: Negative impacts are very likely [E] and appropriate expert study and planning is needed for a more detailed assessment of this issue [F].

4.7.9 Other Hazards-1.Toxic Chemicals and Pathogens

It is possible that other health risks for the population will increase, for example, pathogens and toxic chemicals present in irrigation water, flooding of existing dwellings due to changes in surface hydrology.
Assessment of Impact Category: Negative impacts are possible [D].

4.7.10 Other Hazards-2. Land Mines

According to a map released by United Nations Mine Action Office for Sudan at beginning of 2007, the Wad Miskeen project and its proposed sites lies outside known dangerous areas (UNMAS, 2007). Assessment of Impact Category: No impact likely [C].

4.8 Ecological Imbalances

4.8.1 Pests and Weeds

In the study area crops are affected by a variety of pests and diseases that launch attacks during all stages of the cropping cycle. A number of studies made in the past covered various aspects of ecology and agriculture of eastern Sudan and remain relevant: Joyce, 1952; Worrall, 1960; Bunting and Lea, 1962; Adams, 1967. A detailed assessment of the wildlife ecology is given for the Dinder Park (HCENR, 2004). More recently ACSAD (2008) has prepared an assessment of land use in eastern region, which includes the wad Miskeen area.

The semi-detailed soil survey of the Wad Miskeen area (LWRC, 209) has given point data on land use and land cover. Collectively, these studies and the field visits made by the environmental team, indicate that most of the proposed agricultural lands have long been cropped and have a low biodiversity such that in parts poor soil management practices have allowed weeds, such as the sorghum root parasite weed *Striga* to flourish, and a lack of soil inputs to boost fertility, and appear to confirm long-held views (Tothill, 1948; Mahmoud, 1988). Where land is fallow *Acacia mellifera* and *Acacia nubica* spread into farmlands and develop a bushy habit. These plants, more typical of the zones of more arid lands and degraded kerrib soils to the north, are difficult to clear.

Biodiversity is maintained in the Wad Miskeen area within the reserve forests with mixed *Acacia* woodland, and the *maya* with aquatic plants, and such areas of biodiversity should be protected but will be at risk. Within the Wad Miskeen project a supply of irrigation water, will lead to crop diversification, use of fertilisers, enhancement of biological activity in soils, and parallel spread of weeds and diseases. Other inputs such as pesticides and herbicides are likely to be needed.

Careful management in the future scheme will be essential to avoid imbalances dominating. The crop production will also attract and could lead to a vulnerability to attack by crop pest populations such as rats, qualea, Wad Abrag (sparrow) and insects.

The existing relict woodlands and project driven shelterbelts will offer suitable sites for bird breeding and roosting. Field rats may become a problem, and experience from Rahad, Gezira and other irrigated schemes has shown that rats in general, and the Nile Rat (*Arvicanthus niloticus*) in particular, can establish themselves very quickly as a serious crop pest wherever food, water and shelter would be readily available throughout the year.

The role of raptors in pest control is important throughout the rainlands belt where a wide range of Eagles and Buzzards appear to have territorial blocks of lands that they roam over reducing the small mammal harvest pests.

Assessment of Impact Category: It would appear that both positive and negative impacts are possible [B], [D].

4.8.2 Animal Diseases

During the rains nomads move out of wet areas that are also infested with biting flies. Other diseases that are common include rinderpest, anthrax, bovine trypanosomiasis, contagious bovine pleuropneumonia and tick-borne diseases (see Livestock Annex; Gaafar Karrar & Partners, 1994). An increase in local production of fodder in the project could result in more livestock being maintained in the area throughout the year in villages. There is also an increased risk of livestock contracting water related diseases.

Increases in numbers need to be matched by improved veterinary services. If a barrage is built across the Dinder River, and that being proposed is just within the park, then it is important that provision is made for nomad animal populations to be able to use the barrage as a crossing on their stock routes that currently take them along the edge of the park. The reason is that if traditional routes are blocked, then there will be increases of incursions into the DNP by nomadic pastoralists during parts of the year when water and forage resources may be deficient elsewhere, and when grassland areas within the DNP are illicitly burnt to provide new grass growth. Park officials have acknowledged to the study team though that they are concerned that the entry of livestock to DNP where lands have been burnt.

Park officials stated that this happens but they cannot completely police without risk to their small ranger force. These incursions though are felt to be leading to the spread of diseases within both the livestock and wildlife populations. The barrage crossing will necessarily be narrow but will ensure that livestock can move over the Dinder, and same is true of Rahad, during the flood season. On each side of the crossing there must be physical space to allow herds coming say in different directions to rest as not all can be accommodated on the barrage at once.

Assessment of Impact Category: Both positive and negative impacts possible [B], [D].

4.8.3 Aquatic Weeds

The principal problem concerning aquatic weeds, is that they increase water loss by evapotranspiration, lead to introduction of exotic species, reduce the storage and conveyance capacities of canals and drains, and can provide favourable habitats for disease vectors.

Vegetation growth in irrigation canals is influenced by sediment and turbidity, current, water level fluctuation, de-silting and de-weeding activities. A range of aquatic plants are found in *maya* along the Rahad River north of the area. The irrigation canals of Rahad I, supplied from Roseires, are infested with different aquatic macrophytic weeds. It should be noted that the project area is thought to lie within the command of a proposed conveyor being designed by the Dams Implementation Unit, to carry water from Roseires to Rahad II area. This conveyor, if constructed, would require an assessment so that the biota of the *maya*, and perhaps those in DNP that are more sensitive (HCENR, 2004), would not disturbed by an invasion of Nile weeds.
Attention to aquatic plants in Sudan was initiated by the appearance of aquatic weeds in the Gezira Irrigation Scheme in 1929, only four years after gravity irrigation started to operate (Andrews, 1945). The problem was not at first an issue in the main canals due to their particular shape, depth, size and water velocity. The canals also were not suitable for the vectors of malaria and bilharzia. Irrigation canals with weed problems were and are, the minor canals, and now to some extent the major canals.
When the policy of intensification and diversification of cropping was accepted in the 1960's, this was reflected in continuous flow, resulting in loss of head and corresponding decrease in velocity. Aquatic plants then became a serious problem (Hamdoun and Desougi, 1979). The minor canals receive water continuously, filling up in the night and feeding smaller field channels (Abu XX and Abu XI) during the day. This night storage design system for minor canal is advantageous for weed growth, of which *Potamogeton spp*. and *Echinochloa stagnina* are the most common species.
Data on the aquatic plants in irrigation canals are found in the works of Nouman (1983), Ahmed (1984), and Hamdoun and Desougi, (1985). But studies on role of aquatic plants in enhancing sedimentation processes and providing suitable habitats for snails are almost lacking in the Sudan. The schistosomiasis vector snails *Biomphalaria pfeifferi* and *Bulinus truncatus* were found in conjunction with aquatic weeds in Gezira irrigation canals and *B. pfeifferi* in particular increased in numbers as weed density increases. Aquatic weeds also are associated with Malaria, *Anopheles gambia*, the principal vector of malaria in northern Sudan, is found in heavy densities in Abu XXs, where the water stagnates as a result of dense vegetation.
A range of aquatic plants are found in *maya* along the Rahad River. North of the area, irrigation canals of Rahad I, supplied from Roseires, are infested with different aquatic macrophytic weeds. It should be noted that the project area is thought to lie within the command of a proposed conveyor being designed by the Dams Implementation Unit, to carry water from Roseires to Rahad II area. This conveyor, if constructed, would require an assessment so that the biota of the *maya*, and perhaps those in DNP that are more sensitive (HCENR, 2004), were not disturbed by an invasion of Nile weeds.
Four methods have been applied to control aquatic weeds in the unlined irrigation canals of agricultural schemes: manual, mechanical, chemical, and biological. Manual control used to be the dominant method of control including pulling, cutting, raking and by pulling chain – like saws across the canals. Manual control proved very successful in the past mainly because of the availability of labour at cheap prices. With development of additional irrigated land, escalating labour casts, and health hazards, this method is no longer appropriate in terms of economics, effectiveness and feasibility. Mechanical control is affected by draglines operated wherever it is necessary to desilt a canal.
Chemical weed control has not been considered seriously because humans as well as animals use minor canals to swim, wash and sometimes for drinking water. Some herbicides such as Dalapon, paraquat and Glyphosate were applied in dried out Abu XXs. Biological control of aquatic weeds have been tried in the Gezira Scheme when a limited number of the Chinese grass carp (Ctenopharyngodon idella) was introduced in 1976 into an enclosed section of a minor canal that had been heavily infested by potamogeton Spp. And Najas pectinata. Within a few months all the submerged vegetation was eaten, and the fish were supplied with potamogeton spp. From nearby infested canals. Another effective biological approach is the use of competitive plants to displace the noxious species. Pigeon pea (Cajanus cajan) and Lupia (Dolichos lablab) are along the banks of Abu XXS and Abu VIS to reduce weed infestation by ditch bank grasses.
Assessment of Impact Category: Negative impacts are likely [E], but can be minimised if technical design and scheme organisation are appropriate and financing and managing of on-going maintenance is accomplished.

4.8.4 Structural Damage

It would appear to be unlikely that there is any risk of significant damage to irrigation infrastructure by burrowing activities of plants or animals, and there is no evidence of this occurring at other irrigation projects in Sudan.
Current Assessment of Impact Category: None [C].

4.8.5 Animal Imbalances

The new scheme will lead to habitat modification in the Project area, such as improved irrigation in reserve forests. It is expected that biological activity will increase in the area, in terms of fauna and flora. It is speculative at this stage to assess whether this may lead to zoological imbalances, but they are not known to have occurred on other irrigation projects on the Nile in Sudan.
Current Assessment of Impact Category: no decision possible [F].

4.9 TRANSBOUNDARY IMPACTS

The impact of a project across a border on another country can have deleterious effects if possible impacts are not examined during project planning. A study on transboundary environmental analysis by NBI et al (2001) identified several issues that relate to the Nile basin:

- Physical or chemical impacts that can cross national boundaries downstream;
- Loss of degradation of wetlands and lakes;
- Need for transboundary cooperation to protect key habitats;
- Lack of early warning systems;
- Spread of exotic and invasive water weeds;
- Waterborne diseases (malaria, diarrhoea, bilharzia).

The report noted that a protected area of 500,000 ha lies between the Dinder and Rahad Rivers on meandering floodplains and is important for wildlife grazing and migratory birds but is affected by poaching, firewood collection, illegal grazing. This area, termed a Significant Wetland, is actually the more undulating lands of the Dinder National Park, and the subject of a GEF/UNDP funded management plan in 2004.
The DNP might be affected by any future water resource developments in the catchment of the Dinder, within Ethiopia. The Blue Nile Basin studies in the 1960s proposed an irrigation project in Ethiopia along the border with Sudan but no further surveys were made and it appears to have been a somewhat speculative assessment. At present nothing is planned and further into Ethiopia the upper waters are remote with poor access and steep slopes unsuitable for agricultural development.
The Wad Miskeen area lies well within Sudan and is some 150 km, and at a much lower elevation from the Ethiopian border. It is remote from the Egyptian border far to the north.
The WAD MISKEEN Project (Phase I) will take 10 % off the peak flow from the Rahad River, and 0 % from the Dinder. The impact of this reduced flow into the Nile is considered by the project to be minimal. In the second phase of the project, that would be for 100,000 ha of supplementary irrigation in the Rahad II area, 10% would be taken from the Rahad peak flow and max 80% of the Dinder peak flow. The downtream impacts of this on the fishing, water supply for livestock and villages, small scale irrigation, and other livelihoods along the Dinder River are likely to be significant.
Transboundary impacts are, therefore, not considered relevant in this context at this time, but any future development in Ethiopia should be carefully monitored. Regulation of the Dinder River by a dam in the upper catchment could actually improve the seasonality of water supply and flow downstream, but no studies have been made to see if such an undertaking is feasible.

Table 13: Results of Impact Assessment – Wad Miskeen

For each environmental effect a cross (x) is placed in one or more of the columns:		**Positive impact very likely**	**Positive impact possible**	**No impact likely**	**negative impact possible**	**Negative impact very likely**	**No judgment possible at present**
Report section	Impact Category:	A	B	C	D	E	F
4.1 Hydrology	Low flow regime						X
	Flood regime		X		X	X	
	Operation of dams		X		X		
	Fall of water table			X	X		
	Rise of water table			X			
4.2 Organic & Inorganic Pollution	Solute dispersion						X
	Toxic substances				X		
	Organic pollution				X		
	Anaerobic effects				X		
	Gas emissions				X		
4.3 Soils and Salinity	Soil salinity				X		
	Soil properties		X		X		
	Saline groundwater				X		
	Saline drainage				X		
	Saline intrusion			X			
4.4 Erosion and Sedimentation	Local erosion				X		
	Hinterland effect				X		
	River morphology		X		X		
	Channel structures				X		
	Sedimentation		X			X	
	Estuary erosion			X			
4.5 Biological & Ecological Change	Project lands -a-Land take:		X			X	
	-b-Provision of irrigation		X		X		
	-c- Settlement development				X		
	Water bodies		X		X		
	Surrounding area		X		X		X
	Rivers & riverine habitats				X		X
	Rare species		X		X		X
	Animal migration		X		X		
	Natural industry		X		X		X
4.6 Socio-economics	Population change		X		X		X
	Income & amenity	X			X		X
	Human migration	X			X		X
	Resettlement		X		X		X
	Women's role		X		X		X
	Minority groups				X		X
	Sites of value						X
	Regional effects				X		X
	User involvement		X		X		X
	Recreation		X		X		X
4.7 Health	Water & sanitation	X			X		X
	Habitation	X				X	X
	Health services		X		X		X
	Nutrition		X		X		X
	Relocation effect						X
	Disease ecology					X	
	Disease hosts					X	
	Disease control					X	X
	Other hazards				X		
4.8 Ecological Imbalances	Pests & weeds		X		X		
	Animal diseases		X		X		
	Aquatic weeds					X	
	Structural damage			X			
	Animal imbalances						X

Source: Field assessments by BRLi, 2008-2009

5. Mitigation Measures

5.1 Introduction

The assessment of impacts made in the previous chapter has shown that both positive and negative impacts could be likely as a result of project implementation. For some impact categories it is not possible to determine at this stage what the outcome would be. Also, the scale of the negative impacts cannot be defined exactly at this time in a feasibility study, as these will depend on the proposals for a final detailed design for the project. During detailed design the ESIA impacts, proposed mitigation measures and the EMP should be reviewed, brought up to date and costed. These measures would then be incorporated into the final engineering designs, the tenders, the client's and consulting engineer's tender supervision, and made available too to other agencies concerned with implementation.

5.2 Summary of Major Impacts

The major changes caused by the project will be a change of landuse, due to the creation of new agro-ecosystems and changes to existing ones. Land take will be necessary where project constructions of canals, weirs, barrages, and various other constructions for maintenance, fuel storage, settlements and administration. New water bodies may form and the ecology of existing ones (*maya* and river courses) could be affected adversely by agrochemicals. All these have the possibility to cause negative physical and social impacts if not the subject of careful project planning and implementation.

The creation of irrigated farming areas will greatly increase the biological activity and production, and biodiversity will be increased in the irrigated areas, with likely creation of new habitats that could impact on existing ecosystems, such as rats. Mitigation will be in the form of an Integrated Pest Management (IPM) programme that the project will need to establish in collaboration with the Ministry of Agriculture (Gedaref State) and with the technical advice given out by the Agricultural Research Corporation (ARC).

The proximity of proposed project works to the Dinder National Park poses serious questions on impact to DNP fauna and flora wildlife. There is a limited knowledge on movements of wildlife outside the park and conflicts with pastoralists gained from interviews with park officials and local communities. The project could lead to both positive and negative impacts on wildlife. The canal and weir located just within the DNP could obstruct the passage of wild animals, but it is technically possible to incorporate access structures into the design of the canals that provide access for wild animals to the water surface in the canal. The usefulness of such structures depends on appropriate siting also, and these would need to be established during the next phase of detailed design, when a more detailed assessment of wildlife movements may be needed, probably over a whole year. At that time additional consultations with local people will help identify wildlife movements in the area, and ensure that locations of structures would be such that they do not impede wildlife from access to traditional water sites.

The main sensitive areas where barrage implementation would impact on natural or semi-natural habitats are along the two river banks of the Dinder and Rahad. The tender design is expected to minimize the local impacts by possibly avoiding the loss of valuable bank vegetation, in particular larger trees and shrubs, and especially where those have a stabilizing function for erodible banks. Unavoidable losses can be compensated by replanting of trees and shrubs after the construction phase. The EMP, utilising the experience of the FNC in Hawata will specify where these should be and the appropriate species to be adopted: these should be indigenous species in any case.

Within the irrigation scheme, access to the canals may also be required for domestic purposes, and it will be necessary to specify the access locations (steps and / or ramps) in the tender design phase. This should be based on consultations with nearby communities, and on planning for any new settlements (as yet not identified in the planning process).

The occurrence of aquatic weed problems cannot be ruled out in any part of the project. Further areas of concern, as experienced elsewhere, would be the areas at the tail ends of gravity irrigation schemes, where frequent over – irrigation could lead to stagnant water in field canals and drains. The drains, increased nutrient content of the water due to fertilizer application can enhance the weed growth. In a small scheme such as Wad Miskeen these issues should be controllable by the project management.
The project is likely to impact on the passage and traditional grazing habits of nomadic groups. The latter with their extensive livestock herds already play a vital part of the local rural economy of Hawata and Mufaza and their hinterlands, as well as the Sudan meat economy (see Annex 6 of this FS). The project must ensure that traditional rights of way are not impeded, and that provision of grazing lands and forage production are accommodated in the project development plan. The irrigation design has provided for various stock routes that lead from the Rahad River, the water source, out to the plains, the grazing source. But these routes need to be finalised in consultation with, and participation of, all stakeholders. The project can also develop irrigated fodder resources that pastoralists can buy, as in other areas.

5.3 DISCUSSION ON 'WITHOUT THE PROJECT' IMPACT

Economic analysis for a project traditionally looks at the 'without project' or 'no project' scenario where conditions in the project area are assessed assuming, as in this case, no irrigation development will take place. This sections looks at what would be the likely impacts to occur in the Wad Miskeen area if an irrigation supply was not taken from the Rahad (and conceivably the Dinder).

To gauge the likely trends that would take place in the rural economy without irrigation it is necessary to have a baseline on which to measure subsequent change.
In the Wad Miskeen area, both for the proposed irrigation area, the structures on the Rahad and Dinder, and canals there is considerable information from the soils, agriculture, livestock, land-tenure and socio-economic studies made for the Feasibility Study. These baseline data have been obtained in the project area during 2008-2009.
The rural economy of the wad Miskeen area is one dominated by rainfed agriculture for cereals, mainly sorghum. There are some fruit trees – mangos principally - along the Rahad. These are fed by groundwater and supplemented with irrigation from pools during the dry season. These areas, though, lie outside the proposed irrigation area. Similarly, and on the edge of the proposed irrigation area, there are flooded old river channel depressions (*maya)* that have fishing possibilities that can be sustained throughout the year.
Within the proposed irrigation belt the lands are under a system of long rotation for cereal cropping with certain parts always under bushland. This rainfed belt extends far to the east of the project boundary but within ten kilometres there are numerous villages and hafir. In the cropping year 2009-2010 there was almost complete crop failure in the proposed irrigation area due to a number of reasons. This was a complete disaster for farmers and many are said to selling livestock to make ends meet. It appears that farmers were encouraged to plant widely this past year as 2009 was going to be an exceptional year for rainfall and bumper harvest. This was unfortunate if true, as nobody can forecast the rainfall pattern. As it happened, the rain started early and with some intensity that gave farmers great hope, so most planted: the rains then stopped over a huge area between Singa and Gedaref, and did not return. The result was that crops used up the soil moisture that was accumulated form this first rainfall phase and then withered.
This is the pattern of rainfed cropping in the area, which would be the 'without project' situation in several years in a decade perhaps: an analysis of rainfall and crop harvests could provide a better indication of the risk a farmer faces.
An alternative tactic in this area would be to make more use of the *teras* system of water harvesting capturing runoff into field and then passing it onto the next field downslope. There is at present little field evidence that this method, common in other parts of the Butana, is adopted. In any case the land is quite flat and the scope for *teras* improvement here is low, as it depends often on runoff water moving from a moderate to long distance upslope.

Whilst the *teras* system could alleviate water shortage in small areas, it cannot flood the entire area. Based on the 2009-2010 experience the 'without project' situation is clearly outshone by the proposed project that would, using a small portion of the Rahad flood, have the potential to provide food security in this region. Thus, the impact of the 'no project' situation would mean that farming would continue to be a very risky business. As it exists now, farmers are reluctant to put more inputs into the soil and adopt better varieties, and improved land husbandry and management, as they stand to lose all their investment if there is low rainfall and crop failure. The irrigation project, by contrast, appears to offer, at least for this small area, a chance for better food security.

5.4 CONCLUSION

The mitigation measures that are recommended to be taken further during detailed project planning, and then in implementation, are shown in **Table 14,** below. These are recommended in order to ensure that the environmental and social risks identified in the environmental impact assessment are properly addressed. If they are not then the project will fail in its duty to protect and sustain the environment.

Because the project is command area is in a fixed area the location of weir sites on the Rahad is also determined by this. There are thus no alternatives that can be offered to the area. The without or no project situation would mean that the area remains under rainfed agriculture with its persistent risk of reduced rainfall and crop failure.

Table 14 Mitigation Measures

Technical Field	**Impact**	**Mitigation Measures**	**Institutional Bodies Responsible**
Water	Water losses	Downstream controlled water distribution systems.	Ministry of Irrigation and Water Resources
	Risks of spillage and flooding	To minimize the risks from uncontrolled spillage and subsequent flooding, the design will include escape to evacuate such excess water safely.	Min. Irrigation and Water Resources (MIWR)
	Waste water from all construction sites should not be allowed to be discharged uncontrolled over land on into surface water drains or rivers	Routing waste water through settling ponds, and control of pH.	MIWR / contractor and Monitoring team
	Water pollution from drainage water of the project, after construction	The operation phase needs a regular monitoring programme for canal and drainage water quality with testing for EC, pH, TDS, residues etc.	MIWR and Monitoring team
	Downstream effects Sudan and beyond: erosion, lack of water affecting livelihoods.	National policy not to overuse the resource	MIWR
Engineering Impacts	Erosion, deforestation at Dinder weir site; impact on wildlife in DNP.	Careful construction to minimise damage. Replanting.	WIWR and DNP management / FNC
	Erosion, deforestation, disruption of nomad routes along link canal	Careful construction to minimise damage. Replanting	MoA; FNC
	Erosion and deforestation at Rahad weir site.	Careful construction to minimise damage. Replanting	MIWR ; FNC
	Erosion and disruption of farms, nomadic routes along Wad Miskeen main canal.	Careful construction to minimise damage. Replanting	MIWR; FNC

Table 14 Mitigation Measures (cont.

Technical Field	Impact	Mitigation Measures	Institutional Bodies Responsible
Soil	Soil erosion by wind or water	Shelter belt (5% from total irrigated area in the project) plantation. Incentive for a farmer to invest in long term soil conservation measures.	Forests National Corporation, and Monitoring team
	Soil surface disturbed during construction work	Construction traffic should not be allowed to spread over large areas, and trigger unnecessary erosion, if necessary gravel roads should be established for construction traffic.	Contractor responsibility supervised by MIWR, and Monitoring team
	Continued decline in soil fertility	Adoption of improved soil management techniques and agricultural inputs	Ministry of Agriculture and ARC, and Monitoring team
Socio-Economic	Loss of traditional grazing and access rights of pastoralists	Maintenance of stock routes and irrigated grazing production areas for nomads	Gedaref State Ministry of Animal and Fish Resources, and Monitoring team
	Decline of health and public services	Integrated project planning to include provision of adequate health, water, sanitation.	Ministry of Health and other State agencies, and Monitoring team
	Impact of temporary labour on local economy	Ensure that local existing populations in villages are given and take full opportunity for work	Locality and State education amongst population
Biology and Ecology	Effects on passage of wild animals in the canals	Incorporate structures in the design of the canals that would be provide access for wild animals to the water surface in the canal ; and ensure that fish are able to pass through weir sites via special rapids	MIWR and Wildlife Administration, and Monitoring team
	The loss of valuable riverine forest and or fruit trees during construction work, especially where those have stabilizing function for erodible banks.	Compensated by replanting of trees and shrubs after construction phase.	Forests National Corporation ; Ministry of Agriculture, and Monitoring team
	Increase of malaria in artificially created irrigated project	Prevention and control of transmission through indoor residual spraying and impregnation of bed net.	MIWR and Ministry of Health
	Aquatic weeds in the irrigation canals. The waters of the Wad Miskeen irrigation project as designed should be free of the type of aquatic weeds that affect the Nile system.	IPM, with use of competitive plants to displace the noxious species (biological approach). Regular de weeding activities.	MIWR and Ministry of Agriculture, and Monitoring tea

Table 14 Mitigation Measures (cont.

Technical Field	**Impact**	**Mitigation Measures**	**Institutional Bodies Responsible**
Biology and Ecology (cont.	Increase in rats, birds and other agricultural pests	Appropriate IPM.	MIWR and Ministry of Agriculture (MoA) , Extension Administration; and Monitoring team
	Degradation of Forest Reserves	Careful construction to minimise damage. Replanting	MIWR ; FNC
Transboundary affects	Use of irrigation water upstream in Ethiopia	Nothing planned at moment but part of old designs (?)	MIWR, NBI, Government liaison

Source: BRLi field assessments, 2008-2009

6. Environmental Management Plan

6.1 Introduction

This section outlines mitigation, monitoring and institutional measure to be taken during further project planning and implementation, in order to ensure that the environmental and social risks identified in the environmental assessment during Feasibility Study are properly addressed, resolved and mitigated in the subsequent project phases as part of an Environmental Management Plan (EMP).

Guidelines for the implementation of an EMP vary from country to country. For many decades in Sudan, as in most developing countries, there was no regulatory framework that laid down the conditions under which development should proceed. Agricultural development for new irrigation schemes, for example on the Roseires Project in the 1960s, used the framework for irrigated land use of the Reclamation Manual of the United States Bureau of Reclamation (USDI, 1953) which laid out the best practices for irrigation planning and development, from the soil conditions through the engineering ones.
Later, guidelines were developed by the FAO (FAO, 1976, 1979, 1989) for land resources evaluation of rainfed or irrigation development. These were all based on best practice for an area and encouraged the users to take into account both the bio-physical and social environments. All these had originated in good practices that used to be the norm in development, but had somehow become weakened. Throughout Sudan from the 1960s to the new millennium, development projects that were externally funded used, as a rule, such guidelines, EMPs' in their own way and followed what was and is known as the project cycle. From the early 1980s', due to increasing experience from undisciplined development and project failure, the project planning cycle procedures became more formalised with environmental and social impact assessment guidelines built into development planning, initially by the World Bank and followed soon after by other lending banks and international development agencies including the ADB.
The basic principles of an environmental management plan are numerous They include that there is an informed decision-making process, and that there is accountability of data and when decisions and the approach is participatory and consultative with public awareness of the development plan. The plan should have considered other alternatives and will aim to mitigate the negative impacts, and enhance the positive ones. At all stages of planning and implementation it will comply with national guidelines and regulatory procedures.

6.2 Proposals for Wad Miskeen

The depth of planning that could be reached in this present study for the assessment of environmental and social issues, was limited by the time available. It was nevertheless aimed to screen all potentially relevant issues using the ICID method, and the scoping then was able to recommend how to proceed further, and make the assessment as inclusive as possible.

However, due to the given limitations this study does not reach the detailed level of an Environmental Management and Monitoring Plan, which should specify and all necessary measures by type, defined locations, quantities, duration and frequency. For a number of issues, the specification of measures will be possible only during the tender design phase when final areas and affected villages are indicated. For all measures the timing, frequency and duration will have to be specified in an implementation schedule, which must be linked to the overall project implementation schedule. For many important issues, the current recommendations consist of implementing an organizational mechanism that will serve to initiate the more in – depth study and planning of the actual safeguarding activities.
These concerns e.g. a number of more detailed plans for the construction phase, the conducting of which would be the responsibility of the construction contractor, but also important issues in fields such as public health.

The first and foremost recommendation in this context would be for the project proponent to implement an Environmental and Social Management Unit, which would specify and approve implementation plans, monitor implementation, identify areas of non-compliance and instruct corrective measures (if necessary in conjunction with local authorities). The implementation and operation of this E & S Management Unit would be the main mechanism to ensure that the environmental and social safeguarding measures identified in this report and to be further specified during the tender design phase and during implementation, would actually be carried out.

6.3 MONITORING

A central part of the EMP is monitoring of the project so that predicted and actual impacts can be compared. On the Wad Miskeen project the key monitoring issues will be made during both construction and implementation. They are recommended to address the following as essential components: monitoring any changes in water quality, changes in soil fertility, status of aquatic ecosystems and biodiversity, changes in water related health issues, impacts on pastoralist routes, changes to traditional livelihoods, demographic trends, changes to crop production and markets.

The African Development Bank (AfDB, 2003) provided a detailed list of monitoring indicators on irrigation projects, under the general headings of poverty, environment, population, health outcomes, gender and participation.
The management of future Wad Miskeen project would follow these guidelines on a regular basis. Technical and non-technical issues would be the responsibility of the relevant department of the project (administration, engineering, water supply, health and safety, agriculture ; transport; settlements etc). Other data is already collected in the area by the Locality departments in Hawata and the projects would need to come to data-sharing agreements with these organisations.
We have added suggested estimates of the frequency of monitoring activities within each section, as follows:

Poverty Indicators - Economy

- Number of jobs created (directly and indirectly) and occupied by men and women; *Frequency: monthly.*
- Level of satisfaction of adversely affected men and women toward compensations and offered alternatives (survey). *Frequency: annual*

Information, Education and Communication

- Acquired irrigation systems management skills by trained men & women. *Frequency: annual*

Access to Infrastructures and services

- volume of sedimentation in irrigation canals to evaluate soil degradation; *Frequency: monthly*
- maintenance expenses on irrigation canals; *Frequency: monthly*
- number of breakdowns of the irrigation systems; *Frequency: daily in the flood season*
- number of water points as a function of the population; *Frequency: monthly*
- number of domestic water supply breakdowns. *Frequency: daily reporting*

Environment – Water

- Groundwater static level and refilling capacity. *Frequency: weekly at key sites*
- Parameters of *WHO Guidelines for Drinking-water Quality* for evaluating the physico-chemical characteristics of underground and surface water quality (upstream, on the site and downstream). *Frequency:weekly to monthly (liaise with Wad Ageili company).*
- Coliforms and viable intestinal nematode eggs per litre for evaluating wastewater quality for irrigation purposes (*WHO Guidelines for the Safe Use of Wastewater and Excreta in Agriculture and Aquaculture*). *Frequency: weekly to monthly (liaise with Wad Ageili company).*
- Quantity of water used compared to initial estimates. *Frequency: weekly.*

Environment – Soils

- Volume of sedimentation downstream of irrigated area. *Frequency: weekly in flood season*
- Changes in soil physical and chemical parameters (e.g.: pH, salinity, water retention, etc.). *Frequency: weekly to monthly, with annual checks at bench mark sites*

Environment –Ecosystems

- Surface of sensitive areas affected by the irrigation project. *Frequency: monthly.*

Environment – Flora:

- Area covered by aquatic plants in canals. *Frequency: monthly.*
- Biomass per inhabitant nearby the project area. *Frequency: annual.*

Environment -Natural and cultural heritage:

- Natural and cultural sites affected by the project. *Frequency: daily checks during construction.*

Population - Demographic trends

- Population growth and ethnic composition. *Frequency: annual*

Population - Migration and Resettlement

- Type of house and accessible services to displaced men and women before and after project implementation. *Frequency: monthly.*
- Integration level of migrants in host communities (survey). *Frequency: monthly consultations to annual.*
- Number of informal settlements built by migrants. *Frequency: monthly.*

Natural Resources and Land Management

- Subsistence production in calories per inhabitant. *Frequency: annual.*
- Presence of a water user organisation, including men and women. *Frequency: monthly checks on status, higher in flood season.*
- Revenues from irrigation water fee collection and allocation. *Frequency: monthly.*

Quality of life

- Level of satisfaction of displaced men and women (survey). *Frequency: annual.*

Health Outcomes - Communicable Diseases

- Prevalence rates of diseases such as malaria, schistosomiasis, diarrhoea and HIV. *Frequency: monthly liaison with health centres.*
- Number of vector breeding sites and vector density. *Frequency: annual surveys.*
- Availability of condoms, impregnated bed nets, mosquito repellents. *Frequency: weekly status.*
- Outpatient attendance records. *Frequency: monthly.*
- Quantities of drug supplied/used from health services & local shops. *Frequency: monthly*

Health Outcomes - Non-Communicable Diseases

- Inventory of exposure sites including wastewater drainage. *Frequency: monthly.*
- Water quality analysis results. *Frequency: monthly to bi-weekly.*

Health Outcomes - Malnutrition

- Number of people affected by seasonal hunger (evolution over time). *Frequency: annual.*
- Height/weight monitoring of children. *Frequency: annual.*

Health Outcomes - Injuries

- Number of violent events reported by the police & social services. *Frequency: annual.*
- Construction site occupational health and safety records. *Frequency: daily checks.*

Gender - Division of labour

- Time allocation of women before and after the irrigation project. *Frequency: annual*
- School attendance of girls / boys before & after the irrigation project. *Frequency: monthly.*
- Number of children working on a regular basis in irrigated schemes. *Frequency: monthly.*

Gender - Income-Generating Activities

- Proportion of family income received and managed by men and women before and after the project. *Frequency: monthly.*

Gender - Access to and Control over Productive Factors

- Proportion of men and women being owners or tenants of irrigated schemes. *Frequency: annual.*
- Level of satisfaction of women toward project investment decisions & management methods (survey). *Frequency: annual.*

Gender - Involvement in Societal Organisations

- Number of women and men involved in user organisations. *Frequency: annual.*

Participation - Civil Society Strengthening

- Level of participation of user organisations in the water management decision-making processes. *Frequency: monthly.*

All these have to be judged in relation to a baseline established before the project starts. It is known there are gaps in the baseline data and the sections below suggest how these might be filled. As such the first task of the EMP, in the run up to the start of construction, and probably best initiated at the start of the Tender Design stage, will be to:

- Provide an update to the local population and other stakeholders in the area of the final project plan- what impacts it might have that effect their environments and their livelihoods, and what mitigations are necessary if these are negative. The positive aspects too will be discussed and the economic advantages as such outlined. It will be essential to enlist their support in all these issues. This will be made by the ESMU and MIWR project staff in cooperation with staff from other agencies in Hawata or Gedaref.
- Limitations of the exiting agencies, for example for livestock management given Annex 6 will require serious decisions to ensure that they modernise and improve. It will be necessary to provide some form of budgetary upgrade to these agencies first, so their participation in the project and to others will be useful.
- Bring up to date any and all existing environmental, agricultural cropping and livestock, forestry, and social datasets, from sources in Hawata, the locality town. If none then such data collection must be initiated by special surveys, such as for fisheries and aquatic ecosystems.
- It will be very advantageous to establish a full automatic climate station in Hawata, ideally at the same location where rainfall used to be collected. This should be achieved at an early stage, preferably during the detailed design stage, and will involve establishing modern climate station at site of old defunct station. This will take digital data readings every hour of a wide range of parameters including: rainfall, rainfall intensity, maximum and minimum temperatures, dry and wet bulb temperatures, soil temperatures, wind speed and direction, sunshine hours, solar radiation, evaporation, soil moisture.
- Initiate regular testing of waters in the principal sources (the Hawata – Wad el 'Ageili sources are already tested on a regular basis at the Hawata compound). The Ministry of Irrigation (Hawata station) will be responsible for this. Any shortfall in equipment and staff capability will be identified during the initial stage of Tender Design. A budget for this section will be required. The testing could be made at the Hawata water supply compound or elsewhere.
- Ensure that hydrologic flows in the Rahad and Dinder are measured at all times in the flood season; and make a detailed examination of the influence of the connection between these rivers by the Khor el'Atshan channel link. The Ministry of Irrigation (Hawata station) will be responsible for this, as noted above.

- Make a series of sediment measurements in the Rahad and Dinder Rivers during the floods and at low water flows.
- Make a survey of fish in the Dinder and Rahad and maya, and examine the role of fish migrating up these rivers into the catchments during the floods.
- Gaseous emissions from livestock. The review of the draft report mentioned this as a possible impact in the area, presumably, though not stated, from increased methane production. The project does not see a substantial increase in livestock in the area and this is not seen as serious negative possibility. Some air quality monitoring should be included, but there is no baseline on this.
- Soil Fertility. The steady decline in yields is seen due to a loss of fertility in the soils by many. But it is a complicated issue and a key element is livestock manure. Livestock manure has an important role in the rural economy as components of brick making, as fuel for domestic fires, and as fertilizer incorporated into the soil, though not usually deliberately. In fact, animal manure and crop residues are the only inputs into the soil, usually by falling down cracks of the Vertisols where the recycling of nutrients is a key and generally completely unheralded part of the long term fallow cycle in the rainland soils, whereby soils recover some level of fertility. Because the additions fall down to 1m or so in the soil they are utilised by arboreal vegetation rather than shallow rooting cereals. Thus the tree vegetation recovers but not the topsoil. Studies in the past on the rainlands (Buraymah, 1977) concluded that under continuous monoculture of sorghum (even on the areas scheduled for rotation) and with shallow ploughing some form of poorly structured and compacted layer had formed. This was not a hard pan as believed by some. This could be broken by deep ploughing but this advice was not generally followed. In the proposed irrigation area of Wad Miskeen soils will be wetted more than under rainfed conditions and this phenomenon should not occur. But, the whole issue demands a monitoring programme to assess changes and progress. Project machinery could be hired out to deep rip rainfed soils in other areas during the dry season.
- The project could and should play a very useful role here with routine monitoring of bench mark soils, where there is now up-to-date analysis including trace elements from several soil profiles whose location is known exactly (unlike older datasets). Re-sampling should be made every few years. At the same time sites should be sampled for soil moisture measurements at depth down profiles throughout the year. Associated monitoring would include climate, farming practices and agricultural inputs.
- Pests. Traditionally, and we support this, the local (State) offices of Ministry of Agriculture, in Hawata for Wad Meskin area (Gedaref State) and in Quweisi (Dinder for Sennar State) for the Dinder river areas, are supposed to provide, in coordination with the Federal Ministry of Agriculture and Forests, Plant Protection services, regarding pan territorial pests such as rats, locusts and *quelea*, to farmers. Their capacity to do this is weak, and according to the recent World Bank funded semi-mechanized rain-fed farming study (Newtech-HTSPE, 2009) any services that are applied are too late and are of inadequate coverage. Technical innovations that should come from the Agricultural Research Corporation (ARC) are hampered by the fact that the ARC is no longer part of the Ministry of Agriculture but lies now within the Ministry of Science and Technology, and there are no formal links between the ARC and the State Ministries of Agriculture (Newtech-HTSPE, 2009). Currently, according to Newtech-HTSPE (2009), the State Governments are now responsible for Extension Services, but lack the capacity to do so. As this seems to be because of lack of funds, then the project could help to strengthen their ability to do this. These organizations must be improved and links to research forged.

To summarise on the key issues where monitoring needs to be started soon, and this should in reality be not just for the proposed project but for the region as a whole. In any case the key issue will incorporate some of the proposal above and make provisions for, and commence funding of, programmes to fill the gaps in the baseline data situation. We have identified that information is needed on: *maya* ecology, fishing, fauna and flora, climate data, decline in soil fertility, hydrologic flows on rivers, sediment loads on the rivers, and water quality testing. Some of these are made at Hawata but need upgrading.

6.4 Environmental and Social Management Unit (ESMU) Costs

An Environmental and Social Management Unit (ESMU) would be established as part of the project's construction supervision office / Project Management Unit.

It is recommended that there should be three staff: one land and vegetation specialist; one aquatic biologist; and one social environmentalist professional working in this unit, with individual staff cost of SDG 15,000 /month. Additional specialists might have to be called in, for example, pesticide management, range management and livestock husbandry: these should be available in line agencies in Gedaref State.
The permanent staff should be recent graduates, but with MSc in these fields, and good experienced in environmental impact assessment and mitigation. They should be willing to devote several years to this project. The ADB could provide additional advanced specialised training and / or short courses in Sudan or overseas, for the selected staff.
Staff could use the same office locality as the project implementation supervision staff, but must be seen also to be independent and supporting the overall aims of the project to assist the local peoples. They will though have direct link to the resident engineer and will be key participants in all decisions on the construction where mitigation is involved.
Realistic costs estimates for the identified mitigation measures are difficult to give at the current stage of planning. This is due to a limited degree of overall project planning, at which the detailed scopes and quantities for mitigation measures have not been identified yet. For these issues, we recommend that the cost estimates can be updated on a more profound basis during the detailed/tender design phase.

Recurrent costs/environmental monitoring during construction and first five years of implementation:

- 40,000 SDG / year for bio-physical (soil, vegetation ecosystem) environmental monitoring at weir sites, along the canals and in *maya* wetlands. In addition we would cost for a set of monitoring meters (1: Electrical Conductivity + pH + TDS) for setting up in a small laboratory equipped with bench. Ideally samples are collected din the field and brought to the laboratory. Cost allows €1000 for robust instrument and associated glassware equipment; (2: A 50m dipmeter for measuring water table depth is useful. Cost €300 euro; (3. Furniture and start up consumables for the laboratory. Cost €1000 euro; (4. Annual consumable costs of €500, including purchase of distilled water from LWRC laboratory in Wad Medani, buffers and replacement glassware etc.
- 40,000 SDG / year (settlements, health, water) year for monitoring of social issues. These includes transport into the site, laboratory testing for water related diseases in the Rahad, *maya* and hand pumps. No analysis of water for biological test would be made on site, but arrangements to take these to reputable laboratory in Sennar or Gedaref within normal time-frame allowed between sampling and analysis, needs to resolved during detailed design. Use of testing facilities at Hawata / Wad Ageili water company might be possible. Allow a further €2000 / year for this. Water quality testing once a month from about 5 selected locations
- 20,000 SDG / year for public information and meetings in Hawata and villages. A permanent display should be set up in Hawata to advertise the progress of the project. This would cover costs of printing and distribution.
- Annual auditing of the ESMU and its output will be essential to demonstrate that the EMP is proceeding as desired. This audit should be made by an independent body selected by the HCENR. In turn the ESMU will report regularly to the MIWR and HCENR on progress in its work so that any shortcomings in the design and problems with stakeholders can be identified at an early stage and attempts made to resolve issues.

7. Conclusions

As has been emphasized throughout all Feasibility Study reports and annexes of the Wad Meskin Agricultural Development Project (WADP), this development of the project would be a major undertaking in the region, which cannot be limited to constructing the irrigation infrastructure, without also considering the necessary social, economical, institutional and policy framework. In any irrigation development project the technical and social planning are both important (ICID & WB, 1998).
By paying close attention to the social and environmental conditions alongside the technical engineering can not only greatly enhance the benefits of the project for the population, but is actually crucial for its success.
The initial contacts made to some important stakeholders during the environmental study preparations, as well as interviews held with farmers, have shown that officials and the people in the project area are largely supportive of the project. The failure of the rains in the Hawata area in 2009 with widespread crop failure, and the apparent record low flow record of the Rahad River, have alerted all to the fragility of their livelihoods. The advantages of a scheme that would take a small proportion of the Rahad flood flow and transform it is hoped a predominantly subsistence rainfed area into a more stable one will be welcomed in the area.
To make the Wad Miskeen project a success, it will be necessary that all available institutional capacity is utilized in a concerted action, and to help develop the social and economical conditions that will enable the population to seize those opportunities that the project can offer. A central recommendation is therefore to establish a stakeholder participation, and a public information campaign in the project area. This would be coordinated by an environmental and social assessment unit established within the project management unit. This unit would be the main mechanism to ensure that the environmental and social safeguarding measures identified in this report, and those further specified during the future tender design phase, and also of course during implementation, will actually be carried out.

Monitoring of possible impacts is essential, as there are substantial risks to land, water and vegetation if extreme care is not taken during constriction and implementation. Some key monitoring issues will include:

- to avoid negative impacts of polluted drainage water on natural water bodies or on water uses for domestic purposes, canal and drainage water by regular assessment of water quality.
- To avoid any groundwater pollution of the 'Atshan aquifer, from intrusion of agrochemicals into the shallow groundwater aquifers. These are used for drinking water supply in many locations. It is necessary to monitor regularly the groundwater quality in order to detect any such impacts. Parameter should include pH, TDS, Nitrate, P04, BoD, coliform bacteria, and pesticide residues. The testing at Hawata by the water corporation should be stepped up and the ADB could help finance this upgrading so that it becomes part of the project monitoring and testing capability

Based on the final design, further areas where protection or compensation measures are to be established have to be specified. This will include:-

- Areas disturbed during construction that need to be re-planted with trees and shrubs to protect river bank from erosion. Safety provision at canal crossings at places where canals are used for domestic and wildlife purposes, and in regular intervals along the canals. Safe design for structures and equipment for storage and handling of water-endangering and hazardous substance (e.g. fuel storage, fertilizer and pesticide storages). Wastewater from all construction sites shall not be allowed to be discharged uncontrolled over land on into surface water drains or rivers. To control aquatic weeds in the irrigation canals biological control (IPM) is recommended.

APPENDICES

APPENDIX A: References

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APPENDIX B: List of contacts and summary of discussion

A.1 Stakeholders Met

The Socio Economic Baseline Study. This was made in the villages located close to Rahad River, different methods of data collection were followed, and it included two types of questionnaires, observations and group discussion. In all, 10 villages were investigated. For each village a survey was conducted to collect information on total population, village ecology, services available, village institutions, main economic activities and main ethnic groups. Also in each village limited numbers of persons were interviewed through a prepared household baseline survey. This survey provides information or personnel characteristics, main occupation, agricultural services available and methods of farming and perception of the proposed project. Group discussions were conducted with group of villagers to get their perception of the proposed project and willingness to participate. Results are given in Annex 4, and summary tables in this Annex. The names of those who participated was agreed to be kept confidential. The records are kept with Shouraconsult.

Environmental Assessment studies 2008-2009.

- Forests National Corporation (FNC) Staff in Hawata;
- Staff of the Wad Egeili Water Company, in Hawata & Wad Egeili ;
- Nomads and met at a maya in proposed irrigation area;
- Farmers in field after failure of crops;
- Park Ranger staff in Dinder National Park at Ras el Fil station and Seneit;
- Fisherman at Umm Baggara;
- Village elders at Umm Baggara;
- Nomads taking water in Khor el Atshan from well;
- Wildlife Administration staff in Khartoum;
- Ministry of Agriculture & Forests staff, Hawata and Gedaref;
- Buyers and sellers at livestock market in Hawata;
- Honey trader in Hawata;
- Villagers in Wad Meskin;
- Ministry of Irrigation water laboratory in Sennar.

A.2 Summary of Discussions with Stakeholders and the Environmental, Land Tenure, Livestock and Social Specialists.

The initial contacts made to date during the environmental study preparations, include discussions with key stakeholders, as well as interviews held with farmers. These have shown that officials and the people in the project area are largely supportive of the project.

During the feasibility study a number of useful discussions have been made with stakeholders by numerous specialists involved in the study. The results of these have been very favourable and the sedentary rainfed farming communities in particular look forward to this project being implemented, particularly those owning small plots. The social studies found that inhabitants agree on the project and are expecting benefits by owing irrigated farms and good agricultural services.

The final design though is not yet established and if the project goes to Tender Design then the process of participation and involvement with the stakeholders at all levels will be developed more strongly and positively. A key issue will be to allay any fears amongst the nomadic groups that they will somehow be pushed out of the area. The traditional rights of the pastoral groups are as strong and worthy as the cereal farming groups, and their contribution to the livestock economy of this part of Sudan must not be allowed to be degraded.

Despite the heterogeneous tribal mix, social interaction and peaceful coexistence is apparent in all villages. The project is expected by all to bring improvement to the way of life, particularly provision of services and improved infrastructure. The inhabitants perceive that the project will bring with it more services to the area. They complain about the spread of malaria and no medical facilities to contain it. They also complain about lack of clean drinking water and other services. They also feel that the project may contain Rahad River to its banks and reduce overflow on villages and floods that destroy houses and buildings.

The project is expected to provide capacity building at village level to maximize the willingness to participate in the project. Such institution building may be through formation of farmers unions to enable farmers participate effectively and to help solving problems of land tenure and to organize the presence of nomads during the dry season. Capacity building may also extend to formation of village development communities to take care of village development needs and to be the link between the villagers, project management and the locality. It is expected that in the project management there must be a social mobilize to take care of these issue. Capacity building may extend to the formation of water users associations (WUA) to help in organizing irrigation of different fields.

APPENDIX C: Additional comments on potential impacts

This appendix provides additional detailed comments and discussions on possible impacts and should be read in relation to sections under the same headings in Chapter 4 of Annex 10.

Hydrological Changes

Flood regime

The Dinder structure would be a weir that takes part of the flood after the main peak has passed. Its location at present would place it inside the park. There is no long term storage involved but short term backwater effect above the weir could lead to overflow of water into maya in the park which could help to alleviate dry conditions there.

Wildlife Administration staff advised in 2008 that whilst a large storage reservoir would not be advisable nor welcome within any part of the boundaries of the DNP, the prospect of having some additional water to recharge drying up maya would be welcome. It is known that in the past engineering works have helped to increase flows into some *maya*s, and helped provide a perennial water source for wildlife. Inside the DNP the diversion structures have collapsed or are now bypassed by the Dinder, a vigorous river. They are now all inoperable and there are no funds to rehabilitate them. It is reported locally that in the late dry season various large mammals including Lion emerge from DNP to seek water elsewhere along the remaining water pools in the Dinder, and are subsequently at risk from opportunistic hunters.

However the silting up of the DNP and other *maya* on Rahad and Dinder and the inter-riverine plains are part of the natural progression in river systems such as this where old meanders and channels are infilled, and it may not be feasible to rejuvenate these diversions without dredging the maya, or making specific new *hafir*-type depressions.

The suspended load of the Dinder River is not known at this time, but the Dinder River, unlike the Rahad River, carries a substantial bedload of coarse sand / fine gravel that needs to be considered when assessing siltation at the weir.

Depending on the locations, the land take could affect existing settlements outside the Park, reserve forests along the existing buffer zone, forests within the Dinder National Park itself, and nomad routes along the edge of the DNP: the proposed weir site would allow easy movement of stock along the edge of the park. For without it the risk is that livestock would go further upstream and into the park.

Maya are depressions that are mostly meander loops or depressions on the clay plains. In relation to the Wad Miskeen project they occur on both banks of the Dinder River, Khor Atshan and Rahad River. Maya are recharged when the rivers are in flood. They also receive runoff from the adjacent clay plains through drainage lines that cut back in the break of slope (the *kerrib* badlands where eroded) between the rivers and the clay plains, for drainage networks extend throughout the slightly convex clay plains.

The plains are not recent flat to sloping features but mature slightly undulating landforms on which a drainage network has evolved over the thick (>4m) clay mantle. The drainage lines are often not too apparent on the ground, but the locals know where they are. In the Wad Miskeen area these drainage lines are shallow linear depressions and are utilised to create *hafir,* artificial storage reservoirs, both now and in the past. A typical modern *hafir* can store about 80,000 m^3 of flood waters that is used for livestock of nomads and rainfed farmers.

The *maya* alongside the rivers are largely seasonal areas of water and are important to local communities and ecosystems, since they provide a source of water for villages and nomadic groups for much of the year, and are perfect habitats for growth of *Acacia nilotica in the* poorly drained areas and *Acacia seyal, Balanites aegyptiaca* on slopes. Other maya flanks have dense groves of mango. Some of these natural forests are community owned and are managed by local communities (under the supervision of the Forests National Corporation - FNC) with controls on tree-felling, management of spontaneous regeneration of cleared areas, use of forest products (such as honey production, supply of seed pods to the tanning industry and poles to building industry, furniture production, some charcoal, and lopping of foliage for forage): Hawata is a major centre for these products. In addition, *maya* are important wetlands for resident and migrating bird populations.

Summing up, negative impacts are possible if there is reduced flooding near to settled areas, and some reduction of productivity of the floodplain ecosystems and production lands, and impacts on plants and animal populations; changes to the flood regime of the Dinder through over extraction could mean the pools dry up faster than normal and impact on populations far downstream; and surplus irrigation water, if disposed into depressions, could have serious negative impacts if it is polluted in any way and could renders the surface and even groundwater flows in these river channels unsuitable for domestic and livestock use. The potential for blocking the Khor el Atshan by a siphon (which could cut the important subsurface flows) is mitigated in the design now by an embankment that will be designed to have suitable culverts, although it should be noted the hydrology of these plains and the K. Atshan is poorly understood; the link canal can impact on the drainage lines on the clay plain and cross-drainage structures will need to be carefully sited. The positive impacts will be very important in that the main irrigation flow can recharge depressions – *hafir* and *maya*- and can be used also to flood irrigate the reserve forests and give these an aqueous boost. If drainage returns are of good quality these too can be used for this, but monitoring will be essential.

Surface Waters

HTS (1966) noted that the clay plain soils can only absorb some 700 mm of rainfall and once that threshold is reached water then either ponds (in depressions) or runs off (sloping ground). Important also is the state of the ground prior to rainfall. If land upslope of the supply canal lines are ploughed they will receive far more water from runoff than an unploughed field where the surface may be flattened and cracks obscured by the thick surface mulch.

Fall of Water Table

In the Miskeen area such lands are limited to *maya* and these will be left unchanged. In the Wad Miskeen area there is no groundwater within the proposed irrigated area. A shallow water table exists adjacent to the *maya* found along the Rahad, and there is deeper water along the Khor el 'Atshan at depths of over 40m. From wells along the Dinder, it is apparent that the Atshan Formation underlies the alluvium and must receive recharge from floods in the Dinder. At the DNP ranger station of Ras el Fiel that lies on the Park boundary and is on the River Dinder close to the barrage site, the water is found at 48 m and is potable. The smectitic clay soils become plastic and impermeable during the wet season and any project-introduced surface drainage is unlikely to lead to changes in groundwater water table, or recharge. An examination of these factors concludes the project would not cause a lowering of water tables.

Rise of Water Table

The Wad Miskeen area, lies on slightly undulating clay plains that lie nover impermeable Basement rocks, but the soil cover is almost entirely well over 2 m thick, the clays seal up rapidly when irrigated, and excessive irrigation during implementation is not expected to lead to formation of a water table: on similar soils in the Rahad Scheme there is no evidence of this occurring. Irrigation of the clay soils will close cracks and any surplus irrigation water will run-off into the drains or *khor*s, as noted by Bunting and Lea (1962). Where fields are insufficiently levelled, surface ponding is likely and soils may become waterlogged. However, a rise of groundwater tables caused by irrigation is not to be expected on the Vertisols with their very low permeability. It should be noted continuous farming on Vertisols, such as in past at Kenana Sugar Estate, waterlogging in the soils was a long-term problem and was recognised to be due to inadequate aeration in continuously irrigated sugarcane and, to a possibly lesser extent, compaction from farm machinery. In Vertisol clays, cracking and development of surface mulches is a natural process that aerates the soil. Whilst continuous irrigation will severely impede this, a system of fallowing and rotation will mitigate the problem. But these signs of waterlogging cannot be equated to a rise in the water table.

Organic and Inorganic Pollution

Toxic Substances

In the Blue Nile (Nile Initiative, 2005) and the tributaries of the Rahad and Dinder, this type of pollution is not present, but there is no regular monitoring. If soils contain toxic substances these too, can be mobilised into waters. There does not appear to be any use of herbicides and pesticides in the area so far but this can change when the project starts. The risk is that surface run-off will contain residues of applied chemicals and these will reach the Rahad, downstream irrigated area and ultimately the Blue Nile. Chemical analyses carried out during the recent soil surveys did not show any toxic levels of sodium salts. Tests for residues of herbicides and pesticides were not included in these analyses. According to Nile Basin Initiative (2005) irrigation canals of Gezira scheme have been polluted by agrochemicals, and that this pollution extends to food and people as well. According to UNEP (2007) many irrigation schemes in Sudan, including the Gezira and Rahad I, have a legacy of obsolete and now internationally banned pesticide stocks, and these are poorly stored and have leaked into the ground close to settlements. On the project any industrial development, such as tanning and leather finishing, will contain a risk that polluting and toxic substances could enter the environment (World Bank, 1998), and it will be essential that any food processing and other production plants have proper treatment plants from the start.

Organic Pollution/Chemical Fertilisers

In the Wad Miskeen Area it is known that increasing nitrate and ammonia values have been recorded in the Blue Nile in the past years, but the data from the Wad Ageili scheme shows that the waters here are not contaminated. The operation of an irrigation scheme at Wad Miskeen though could lead to drainage waters containing nutrients and other pollutants from irrigation areas being discharged into *maya* and the Rahad and through surface and subsurface connections to reach the Khor el 'Atshan, Dinder and ultimately Blue Nile.

A water quality study (Nile Initiative, 2005) highlighted the fact that the disposal of "highly enriched organic waste" from sugar processing industries into the Nile in Sudan was the principal cause of organic pollution in both the White and Blue Niles. Thus, any sugar processing therefore planned for the Wad Miskeen area should ensure that that organic waste is treated on site. The irrigated lands may be used for fodder production with livestock being stall-fed. But since farmers, and semi-nomads, enjoy the agro-pastoralist lifestyle, it can be expected that animals will be kept not only on the specialised livestock farms but wherever possible. Careful planning will therefore be required for the disposal of residues and leachates.

Anaerobic Effects

In the Wad Misken area and along the Dinder River there are meander loops and some backswamp areas of the Khor El Atshan that remain flooded all year. These are important for local water supply of villages and nomads, and migrating birds. These areas may also receive runoff from some distance away due to the development of natural drainage networks and these drainage flow lines should become apparent on receipt of the orthophoto mapping. The project will provide a system of surface drains to remove surface run-off from the irrigation area. These discharge into natural watercourses, or collector drains. The clay soils, once wet and plastic, and cracks are sealed, have very low rates from surface infiltration and subsurface permeability. Thus, any chemical fertilizer and organic waste effluents would be concentrated into a nutrient-laden surface runoff. This situation could lead to a build up of anaerobic conditions in drainage channels and the receiving water bodies. No details are as yet known about the amounts of return flows to be expected in the drainage system.

Gas Emissions

Other gaseous emissions result from fuel combustions to cover the energy needs. Certain production processes may require considerable energy inputs (e.g. sugar manufacturing). Flue gases may also contain dust emissions (e.g. the combustion of the sugarcane waste biomass bagasse to power the sugar refinery generates large amounts of fly ash) as well as considerable levels of sulphur dioxide and nitrogen concentrations (World Bank, 1998). Agro-industry associated with or induced by the development of the scheme, will contribute to air pollution. Emission control technology, if properly applied, can minimise these impacts.

Soil and Salts

Soil Salinity

Analyses for water quality along the Dinder River and Rahad Rivers are wanting. Some recent water analyses are available for wells along these rivers. A sample taken at Ras En Fil, at 48m in a well close to the Dinder River on DNP boundary, shows an EC of 760 µS/cm and an SAR of 0.5, making this C3-S1 water. Samples from a hand pump close to the Rahad River within the study area, taken in November 2009 were declarted to be potable by villagers. At present no data can be located for the Rahad and Dinder rivers whilst in flood but there are no reports of it being anything but of low salinity.

Erosion and Sedimentation

Hinterland Effect

The settlements along the Rahad River lie outside the irrigated area and can be said to be in the hinterland. These people, from mixed ethnic groups have long been settled there, utilising the rainfed areas and growing crops along the meander belt, where there are extensive groves of mangos, and fish in the *maya*. It is clear they will expect to continue to use these lands, albeit with assistance from irrigation. The proportion of land that is actually used for rainfed farming varies from year to year depending on the rainfall and state of the fallow period.

Clearly, not all land is used in any one year. Some are Forest Reserves, though parts of these may be rainfed farmed. In 2009, when the rains failed throughout the Wad Miskeen area almost no grain was recovered from field crops.

Under irrigation the land could be much more intensively utilised and in such cases there is always a risk, which the residents are aware of, that they could become marginalised in this respect if additional settlers were brought in. The project must aim to accommodate all existing residents and land users – including the sedentary farmers and nomads. The project should aim to ensure that none will excluded, none forced to leave, and that the traditional rights of the various nomadic groups will be honoured. The project design will allow for nomadic routes to be maintained. If at this stage there is capacity for additional people to be moved to the area then careful planning will be required to ensure that they understand and completely agree with these principles and respect the traditional rights of customary law. Without such agreements then conflict is very likely. Therefore it is seen that any increase in the population density of the Wad Miskeen area as an irrigation project, may result in negative impacts over a wider area.

River Morphology

On the Dinder a degree of flooding upstream into the DNP is possible and these could flood *mayas* that at present dry out at times. A subsequent low flow in the Dinder could lead to draining of the *maya* and erosion (flushing) of sediments within them. This can be interpreted as being good for long term survival for *maya (*the DNP authorities in the park have tried to achieve this infilling anyway and these maya have to an extent that is not quantified, a man-made ecosystem), but this will be bad for these habitats in the short term. Clearly, on the Dinder, this requires much more study of these ecosystems and the impact of a weir.

River Channel Structures

Appendix C of the Gibb (1954) report examined development possibilities on the Rahad and Dinder and recommended that any structure should rest on rock foundations: these occur what is now well within the DNP within 20 and 40 km downstream of the Ethiopian border respectively: far away from the proposed sites. On both proposed weir sites, and especially the Dinder, the dynamic state of the rivers is such that changes to river bed and bank morphology, will require very careful planning to avoid structures being eroded or abandoned as course are modified.

Biological and Ecological Changes

Project Lands

The Wad Miskeen area is a mix of rainfed farming, with fallow lands reverting to tall grasslands and *Acacia mellifera* bushland. Until the 1940s the main rainfed farming system was that of a sustainable smallholder farming system set amongst savanna woodland. Since then large scale mechanised rainfed farming expanded and the previous vegetation cover has been largely destroyed. The Wad Miskeen is typical of this. Much of the area is under rainfed farming for numerous sorghum varieties and sesame. These lands have been developed as part of the mechanised farming system but harvesting is often done by hand, since combine machinery cannot handle crops of variable height. Land that is fallow reverts to *Acacia mellifera* bushland and / or tall grassland. *Balanites aegyptiaca* (Heglig) is protected and the result is that parts of the area remain as open savanna parkland.

Several areas of Reserve Forest occur: the Umm Jirrer and the Umm Burush areas. In Sudan a 'Forest' is an area where trees have 7 m^3/ha biomass.These are registered in the Sudan Gazette in the name of the Government and are managed by the Forest National Corporation. The woodlands are of *Acacia mellifera, A. Seyal, A. Senegal, Balanites aegyptiaca*. Much of this woodland appears recent and secondary growth, but is has various functions, particularly for nomads and charcoal makers. Other, more recent, community Forest Reserves occur along the Rahad backswamps (*maya*) and are dominated by *Acacia nilotica* (Sunt) forest.

The Dinder National Park remains an area which has retained, it appears, elements of its natural flora and fauna. The DNP man management plan, though, requires a very considerable update using modern techniques to assess the status of its varied ecosystems. In Sudan woodland is based on the FAO classification system where the canopy covers 10% of the land. Where such lands lies outside Forest Reserves, and has less than 10% cover then it is called 'trees outside forest'. Individual trees may have protected status, such as *Balanites aegyptiaca* which is present in the area and has been protected since 1901 on account of its usefulness a fruit tree. In a fringe around the DNP, where *Acacia senegal* (Gum Arabic) and *Combretum sp* occur, and at the proposed weir site these, and other *Acacia* are being cut down for fuel wood and charcoal. Elsewhere branches of all species are lopped, often quiet excessively, by nomads seeking end of dry season forage.

Ecological Imbalances

Pests and Diseases

The crop production will also attract and could lead to a vulnerability to attack by crop pest populations such as rats, qualea, Wad Abrag (sparrow) and insects. The existing relict woodlands and project driven shelterbelts will offer suitable sites for bird breeding and roosting. Field rats may become a problem, and experience from Rahad, Gezira and other irrigated schemes has shown that rats in general, and the Nile Rat (*Arvicanthus niloticus*) in particular, can establish themselves very quickly as a serious crop pest wherever food, water and shelter would be readily available throughout the year.

Aquatic Weeds

Attention to aquatic plants in Sudan was initiated by the appearance of aquatic weeds in the Gezira Irrigation Scheme in 1929, only four years after gravity irrigation started to operate (Andrews, 1945). The problem was not at first an issue in the main canals due to their particular shape, depth, size and water velocity. The canals also were not suitable for the vectors of malaria and bilharzia. Irrigation canals with weed problems were and are, the minor canals, and now to some extent the major canals.

When the policy of intensification and diversification of cropping was a accepted in the 1960's, this was reflected in continuous flow, resulting in loss of head and corresponding decrease in velocity. Aquatic plants then became a serious problem (Hamdoun and Desougi, 1979). The minor canals receive water continuously, filling up in the night and feeding smaller field channels (Abu XX and Abu XI) during the day. This night storage design system for minor canal is advantageous for weed growth, of which *Potamogeton spp*. and *Echinochloa stagnina* are the most common species.

Data on the aquatic plants in irrigation canals are found in the works of Nouman (1983), Ahmed (1984), and Hamdoun and Desougi, (1985). But studies on role of aquatic plants in enhancing sedimentation processes and providing suitable habitats for snails are almost lacking in the Sudan. The schistosomiasis vector snails *Biomphalaria pfeifferi* and *Bulinus truncatus* were found in conjunction with aquatic weeds in Gezira irrigation canals and *B. pfeifferi* in particular increased in numbers as weed density increases. Aquatic weeds also are associated with Malaria, *Anopheles gambia*, the principal vector of malaria in northern Sudan, is found in heavy densities in Abu XXs, where the water stagnates as a result of dense vegetation.

A range of aquatic plants are found in *maya* along the Rahad River. North of the area, irrigation canals of Rahad I, supplied from Roseires, are infested with different aquatic macrophytic weeds. It should be noted that the project area is thought to lie within the command of a proposed conveyor being designed by the Dams Implementation Unit, to carry water from Roseires to Rahad II area. This conveyor, if constructed, would require an assessment so that the biota of the *maya*, and perhaps those in DNP that are more sensitive (HCENR, 2004), were not disturbed by an invasion of Nile weeds.

Four methods have been applied to control aquatic weeds in the unlined irrigation canals of agricultural schemes: manual, mechanical, chemical, and biological. Manual control used to be the dominant method of control including pulling, cutting, raking and by pulling chain – like saws across the canals. Manual control proved very successful in the past mainly because of the availability of labour at cheap prices. With development of additional irrigated land, escalating labour casts, and health hazards, this method is no longer appropriate in terms of economics, effectiveness and feasibility. Mechanical control is affected by draglines operated wherever it is necessary to desilt a canal.

Chemical weed control has not been considered seriously because humans as well as animals use minor canals to swim, wash and sometimes for drinking water. Some herbicides such as Dalapon, paraquat and Glyphosate were applied in dried out Abu XXs.

Biological control of aquatic weeds have been tried in the Gezira Scheme when a limited number of the Chinese grass carp (Ctenopharyngodon idella) was introduced in 1976 into an enclosed section of a minor canal that had been heavily infested by potamogeton Spp. And Najas pectinata. Within a few months all the submerged vegetation was eaten, and the fish were supplied with potamogeton spp. From nearby infested canals. Another effective biological approach is the use of competitive plants to displace the noxious species. Pigeon pea (Cajanus cajan) and Lupia (Dolichos lablab) are along the banks of Abu XXS and Abu VIS to reduce weed infestation by ditch bank grasses.