An Innovative Intervention by a Multiplicity of Surface and Underground Interlinked Dams/Weirs, Sand Storages, and Sub-Geological Engineering to Solve Karamoja's Perennial Water Stress

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ABSTRACT

If Karamoja has sufficient water to cause devastating floods that resulted in 50 fatalities and many more homeless in 2007 means that it has the potential to save its situation by turning the disaster around with application of interventions that target self-healing by innovative application of geological science and water engineering at surface and subsurface levels. Karamoja's problems of drought, despite the region being apparently highly "irrigated" with a vast network of (perennial?) rivers/streams, raises a question of what is really wrong? The fact is that most rivers and streams are simply seasonal and a sustainable solution to soil moisture management (retention and strategic utilisation) does not exist.

In this paper, it will be indicated that the water resources of the region are sufficient to sustain a normal non-drought prone lifestyle. The apparent problem is inherently indigenous and hence has more to do with the physical layout of the terrain criss-crossed by numerous stream-mini-valleys that provide quick drainage of any water that would come in contact withit. It is a situation of over drained landscape, which easily explains the devastating floods from rainfall that cannot be described as extreme.

With the intervention suggested, there will be no more devastating floods and instead the potential flood water will be slowed down till it infiltrates thus recharging the surface, underground, and sand storages. These will be a base for building up groundwater reserves that, by capillary action, will raise water even above the stream level thus proving needed soil moisture for normal growth of vegetation.

If these interventions proposed, underground dams, sand storages, and interlinked systems were adopted and executed, they would be engineered locally with minimal external consultation and from three years of the start of the project, visual manifestations of greenery will start occurring.

Keywords: groundwater engineering, floods intervention, subsurface dams, sand storages

1.0 INTRODUCTION

If Karamoja, a north-eastern region of Uganda, could have sufficient water to cause devastating floods that resulted in 50 fatalities and hundreds of homeless, in 2007, then it means that it has the potential to turn around its water stress situation by turning that potentiality into positive reality of applying interventions that target keeping the floods in/on the land to give it time to infiltrate/percolate thus recharging the soil moisture and subsurface storages.

The innovations would be based on geology of the area,engineering and scientific properties of soil, and applied through engineering and hydraulics of sub-surface media for water flow to impede the fast through-flow of gravity waterwhich currently makes it impossible for infiltration to take place. This needs to be planned and executedcorrectlybecause when done, the ease of regular rehabilitation would not be possible.With the known recharge rate at

30mm/annum, 2000mm/a of potential evaporation and 650-1300mm/a rainfall, a less than 3% recharge of unstored groundwater is a situation that cannot build up the necessary groundwater/soilmoisture to sustain apermanent green environment.

Fig. 1: Sand storage dam in Kitui (Source: Borst and de Hass)

If the runoff is significantly slowed down or stoppedto let it sink into the grounditshouldbe tracked down to ensure that it does not massively move away from where it infiltrated.Such a movement would just be like providing an alterna-tive path for it to still move fast downslope without redist-ribution. A way of preventing undesirable underground water movement/lossthroughsub-surface corridors, faults, high porosity zones, or simply by sinkholes. Thisindicates an intervention characterised by surface or subsurface dams, sand-dams (Fig.1), sheet/spotgrouting, and other systems to slow down or impede water flow. With such impervious/semi-pervious confinement, provision of a system toenhance/facilitateinitiation of capillary action to raise/redistribute the water in upper soil structure is a logical follow-up.

Sand dams are actually graded-sand filled reservoirs held behind earth or concrete embankments/dams, whichcan holdwater temporarily as it sinks to lower layers. If the underlying formation is of very pervious material then most of the water would be lost irretrievably. The holding time or slowing down that is provided by the sand dams play an important role of filtering the water and keeping it hidden/away from the sun thus making it possible to be used for longer period. While it is being slowed down then capillary action can proceed and redistribute it in many parts/layers of the catchment that did not have water initially or where water was not staying long enough. With cascaded dams, the effect covers much bigger areas than are covered by the physical structure of the dam (Fig 2).

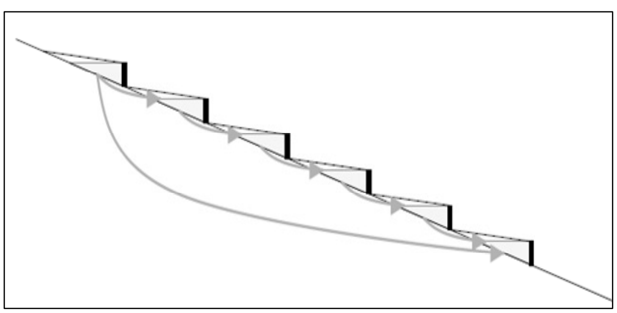

Fig.2: Sketch of Cascaded Dams'Network (Borst & de

Putting the above into practice is preceded by studying the situation/catchment under consideration – its surface topography and geological layout, material composition of these soil structures in terms of soil types and level of consolidation, where interventions have to be located in order to achieve an effective level of connectivity of the impact of the interventions (cascading of reservoirs, see diagram in Fig.2), types of practical structures that have to be constructed, and planning, implementation, and maintenance of the system so setup.

1.1 The Background

Karamoja Basin (Fig.3) is located in north-eastern Uganda along the borders with Sudan and Kenya. The basin is a semi-arid area extending from the Teso region to Karamoja region as shown in Figure 1. With an estimated population of over 1.1 million people, the majority of Karamojong subsist through agro-pastoral or purely pastoral livelihoods. A chronically water/food insecure region, Karamoja is badly affected by severe droughts, a combination of extended dry spells and late rains, placing pressure on water availability in

most parts of the region.

The rivers and streams sources in Karamoja are seasonal and dry up in the dry seasons leading to increased pastoralist mobility, increased conflicts over pastures, and limited access to wetter areas. In this difficult context, water development has logically always been a priority but unfortunately, most,if not all, water development projects undertakenin the past have failed. They were characterised as misguided both for their huge size and for where they were built, but also the ineffective/inadequate technologies employed in their construction.

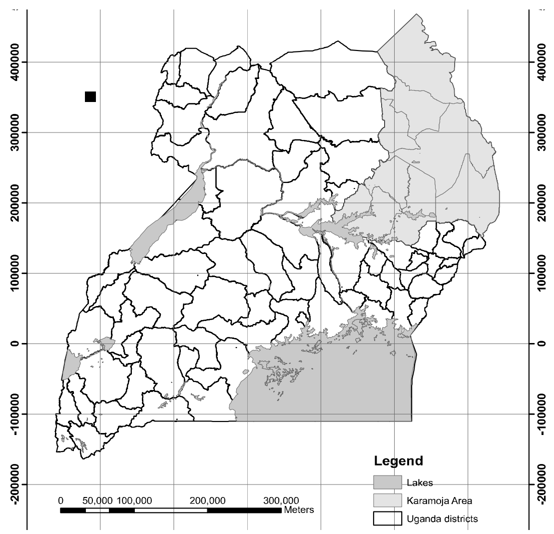

Fig.3: Uganda map showing the Karamoja Region

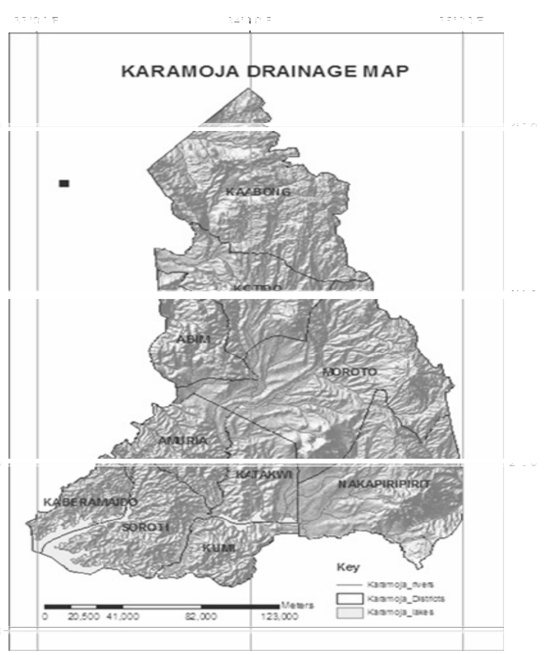

Fig.4: The Karamoja Drainage Map

1.1.1 Climate

The Karamoja Region lies in the sub-tropical semi-arid savannah climatic zone with typical less than 650 mm/a rainfall with very high variability. The average rainfall across the project area decreases from around 1300 mm/a in the southwest to less than 650 mm/a in the north and east. This change from sub-humid to semi-arid conditions is reflected in the transition from the settled agrarian lifestyle of the Iteso to that of semi-pastoralist Karamojong. Rainfall has a bimodal distribution throughout the year with, on average, peaks in May and August and very little rain between December and February. Storms often build up in the afternoon, typical of convective type that is fed by intense evapotranspiration, with velocities of around 13-18km/h and with storm diameters of 32 to 48 km producing highly intense rainfall up to 25 mm/h and more in some instances (UNDP 1968). It remains to anybody's imagination how much water reaches the ground in that hour.

1.1.3 Hydrological

Karamoja plain is generally a semi-arid region as reflected by the semi-pastoralist ways of life of the Karamojong, has an average rainfall below 650 mm/a, and average potential evapo-transpiration of about 2000 mm/a. The drainage in Karamoja region (Fig.4) is dominated by deeply incised, sand filled, ephemeral channels flowing from east to west. These 'sand rivers' such as the Omanimani near Kangole, are a locally important source of water during the dry season when water can be found within a few metres of the surface (Faillace 1973). These channels feed into the southerly flowing Akokorio River via its tributaries, the Okokand Okere Rivers, leading through perennially swampy areas on its lower reaches and eventually draining into Lake Kyoga to the southwest of the project area.

1.1.4 Hydro-geological Setting of Karamoja

The solid geology is predominantly Precambrian African 'Basement' Complex dominated by Undifferentiated Acid and Granitoid Gneisses (Faillace 1973). Much of the study area within Karamoja is mapped showing Pleistocene to recent Alluvium covering the flat valley bottoms, at least 10 to 15 m thick in some areas, and sometimes coalescing across interfluves (Trendall 1965). More recent Alluvium is present along the courses of the main rivers extending into the Teso Region. Fig.5 indicates the flood scenario and redistribution (BC) and dry situation and recharge from sand storage (AD). With more water in the sand storages, there would be adequate soil moisture built-up to negate impact of extended dry seasons.

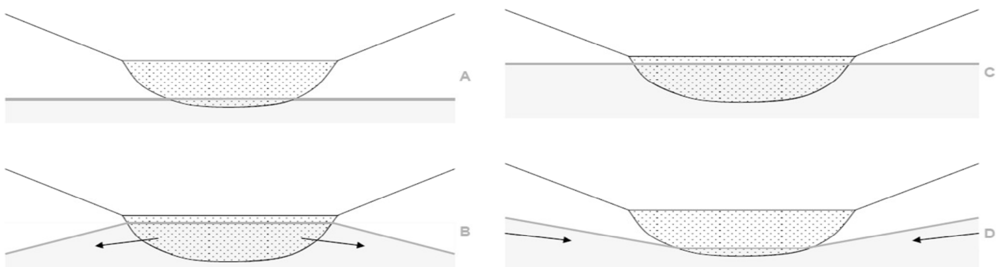

Fig.5: The process that occurs in a sand dam or sand river during flood and normal flow

Based on the available flow data and a UNDP Report (UNDP 1968) the following generalisations about the surface flow regime in the study area may be made as follows:

i) In Karamoja, heavy rainfall causes high surface runoff which may persist for a dayor two after the rainfall has ceased.

ii) In the headwaters, river flows commence soon after rainfall starts with peak flows occurring in the afternoon or evening.

iii) River flows across the plains of Karamoja occur from around April to August with flow in later months being fed by shallow groundwater from adjacent areas.

iv) There is a lag-time of a month for upland flows to reach the dambos downstream of the Teso-Karamoja border which flow from May to October again supported by shallow groundwater flow long after the main rains have passed.

v) The downstream Rivers are then fed for another one or two months after upstream flows have ceased.

vi) Total surface outflow is thought to be approximately 5% of the total catchment rainfall.

1.1.5 Impacts of Climate Change

Due to probable effect of climate change in the northern and eastern parts of Uganda, the region experiences heavy rains in the wet seasons making the area flood prone. A case in point was in 2007 when severe floods swept through Teso, Acholi, Lango, and Karamoja sub-regions while Bugisu and Sebei experienced landslides. These areas are also affected by severe dryness in the extended dry seasons. Studies, followed by action/implementation, to explore more ways to improve sources and management of water resources in the region are necessary to increase availability of water supply for the communities, livestock farming and irrigation for agriculture. Effective action/implementation would be achieved by designing projects that would maximize water storage with minimum evaporation/through-flow while protecting people and property from damage due to climate change impacts such as drought and floods.

1.2 The Problem

The problem in Karamoja is two pronged but related namely:
1) Karamoja is a semi-arid region with seasonal rivers that dry up in the dry seasons leading to pastoralist mobility, increased conflicts over pastures and limited access to wetter areas. There is need to develop the water resources in the region by reviving the seasonal rivers and other water catchment areas into perennial water sources to ensure modification or transformation of the Karamojong pastoralism into semi-permanent pastoralism and eventually to permanent cattle/livestock farmers and settled peasants with agrarian supplemented lifestyle.
2) There is no effective drainage and floodplain management system in place with measures to prevent floods from damaging property nor is there enough information on the drainage characteristics of the areas affected and this makes it harder to identify mitigation measures for damage due to flooding. There is need to establish the necessary information needed for the planners and engineers to intervene timeously in disaster relief operations, evacuation of the affected people, and mitigating the effects of flooding.

1.3 Main Objectives of the Project

The Study would have four main objectives, namely:
→ To identify methods for alleviating Karamoja's perennial water stress problem;
→ To formulate ways of practicalising the identified methods;
→ To suggest ways of implementing these methods; and
→ To formulate an effective conservative floodwater management strategy.

And three Objectives at Implementation Stage

→ To design a network of subsurface and sand storage dams across major rivers in Karamoja.
→ To carry out geophysical studies to identify sites for construction of subsurface and sand storage dams.
→ To investigate presence of fractures and other unfavourable hydro-geological conditions to recommend alternative artificial recharge structures and water conservation measures.

1.3.2 Specific Implementation Objectives

i) To design and construct networks of subsurface and sand storage dams/structures across major seasonal rivers and streams in the Karamoja Plain.
ii) To design and construct valley dams and other point water sources such as hand dug wells, shallow wells, boreholes, protected springs in locations confirmed by feasibility studies.
iii) To carry out geophysical studies to identify sites for construction of subsurface and sand storage dams.
iv) To investigate presence of fractures and other unfavourable hydro-geological conditions in order to recommend alternative artificial recharge structures and water conservation measures.
v) To conduct flood studies along rivers and streams in the Karamoja Basin to help develop a dynamic flood zoning facility in terms of flood maps, zones, and levels thus be able to develop flood interventions and their costed designs. The outcome of this project will also assist planners and engineers in the flooding disaster(s) relief/relocation operations and also in mitigating flood damage.

2.0 LESSONS FROM STUDIES ELSEWHERE

The situation of Karamoja is not unique and can be solved. Other areas in the world that had similar problems have had their situation improved by simply encouraging the water to infiltrate thus recharging soil moisture and letting nature take it from there. Below are some facts that could be adopted from other countries and the Karamoja Plain characteristics that will show how it is suited to the interventions that transformed other areas in Kenya and Brazil.A USA example of flood (non-structural) management is given as Karamoja area is also prone to flooding.

2.1 Groundwater Recharge Mechanisms in the Karamoja Plain

Preliminary groundwater recharge simulations gave estimates for groundwater recharge of less than 30 mm/a in the semi-arid Karamoja plain and strongly suggested that recharge occurs predominantly through indirect or localised mechanisms. The effects of higher temperatures as predicted in underlying studies may be offset by the predicted increase in future precipitation in the region leading to an increase in groundwater resource. Adaptive strategies for the people of NE Uganda may depend on future groundwater use which calls for further research into suitable technologies to sustain or initiate groundwater recharge in the region.

2.2 National Experiences in Brazil and Kenya

Several studies focusing on experiences gained by Universidade Federal de Pernambuco (UFPE) in north-eastern Brazil and Sahelian Solutions Foundation (SASOL) in Kitui Kenya, in using water conservation techniques, have revealed that in areas where the climate is such that the construction of small surface dams to impound runoff will result in very high evaporative losses, underground water dams offer an interesting alternative. Two types of subsurface structures have been used with notable success, namely:(i) the groundwater dams which cut into the alluvial cover to intercept groundwater flow and (ii) sand dams built in streambeds forming local aquifersupstream by sedimentation.

These studies show that for this technique to be successful, unconfined strata should be present within shallow to moderate depth (preferably not more than 10 m), and underlain by a well-defined impermeable layer. Therefore, the use of underground dams would appear applicable to other semi-arid regions with similar soil and climate, and equally unfavourable hydrogeological conditions. In other areas where groundwater flow occurs through fractures in the bedrock, more geophysical studies are recommended so as to determine alternative methods to augment aquifer storage.

Further studies involving use of models to study the behaviour of networks of groundwater dams on regional scale show that a series of sand storage dams built along a particular stream, can act as a connected network of dams, if they are spaced to allow overlapping of influence. In such a situation, the soil moisture can increase in the whole catchment.

2.2.1 Conclusions from a modelling of Sand Storage Dams in Kitui - Kenya

The effect of a sand storage dam was to raise the water levels in the surrounding area as desired and this happened up and downstream of the dam with some variation according to each studied scenario.

It was observed that from the first year after the sand storage dam was built, the gain on water volume (compared with the situation with no dam) increased every year and thus, not only were the dams useful to store water from the wet to the dry season but also to store water between years.For low values of k the inertia of the system was higher, meaning that the system responded slower to changes and lower influences/response rates occurred.For higher k values, the rates increased, including the area of influence.

When the slope in the river length direction was steeper, the wedge of sedimentscarried by the river and deposited behind the dam was smaller, meaning that theartificial aquifer created by the sand storage dam was smaller. Furthermore, theflow downstream was easier. As a result, the distance to which the influence of thedam could be noticed was shorter and the rises in water levels were lower.The optimal location for placing awell (maximum rises caused by the dam) was further upstream and not immediately upstream of thedam, but a few meters further upstream.

When the aquifer was thicker the water volume infiltrated and stored in the aquiferduring the rainy season was higher and the inertia of the system was larger. Theinfluence area of the dam was longer. When the blocked depth of the aquiferextended until the rock bed, the damming effects were much more significant thanfor the shallow system: larger rises caused by the dam and longer influence area.

On the other hand, the higher the sand storage dam is, the larger effects could beexpected. However, when the dam is blocking only the flow in the upperlayers of the aquifer, the effect of the dam is lower due to the groundwater flowbelow the dam. Also, the more impermeable the soil in which the dam base isconstructed, the larger effects of the dam could be expected.

If the distancebetween dams was such that no overlaps of influence areas took place, the damsbehaved as individual structures. On the other hand, when influence areas ofsuccessive dams overlapped, the system behaved as a connected network (cascade effect). Then ageneral rise in the water levels in the area was observed as water flow downstream was obstructed by the next dam.

2.3 U.S.A Experience in Floodplain Management

The cost of providing flood protection in flood-prone areas is likely to be too high far exceeding the benefits. Therefore, a programme focusing more on non-structural measures of flood reduction and mitigation is needed to address frequent flood damage in such flood-prone areas. The traditional flood control and relief programmes, as the flood studies in the U.S.A show, have evolved from a heavy reliance on strictly structural measures like construction of dams and levees, widening of drainage structures, to one using a combination of many tools with a focus on the use of non-structural measures (Kaford,2006). The operational strategy being flood plain zoning.

3.0 PROPOSED STRATEGIES AND IMPLEMENTATION

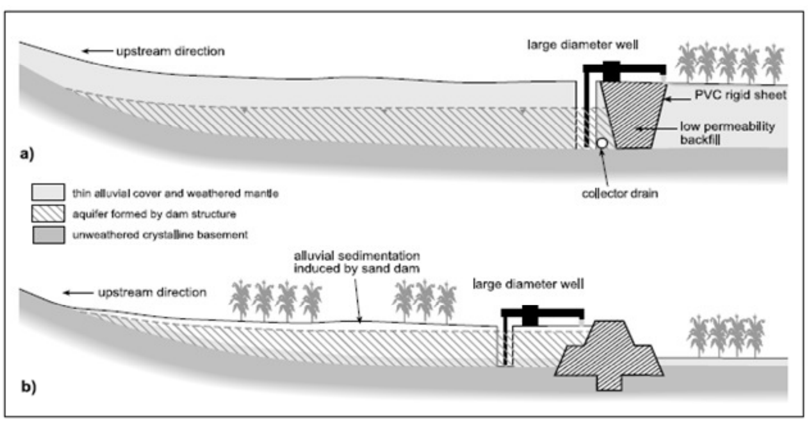

Fig.5: Sand Dams for water supply/irrigation(Foster &Tuinhof)

3.1 Proposed Strategies

The main interv-entions proposed in this Project, after assessing what other countries have been able to do successfully and taking into consi-deration, include but not limited to the following:

i) A network of subsurface and sand storage dams across major seasonal rivers and streams where the physical/geophysical and hydrological-/hydrogeological conditions are favourable.

ii) Construction of valley dams and other point water sources such as hand dug wells, shallow wells, boreholes, protected springs in locations confirmed by feasibility studies.
iii) Further geophysical studies to identify fractures and unfavourable hydrogeological conditions so as to recommend alternative recharge structures/conservation measures.
iv) Conduct flood studies along rivers and streams in the basin to develop a dynamic flood zoning facility to include flood maps/zones/levels thus develop interventions/designs.
v) The outcome would assist planners and engineers in the flooding disaster(s) relief/relocation operations and also in mitigating flood damage.

3.3 Activities and Outputs

The Implementation Scope of the Project as planned by WTI-Uganda (hypothetical entity) shall include but not necessarily be limited to the following (please note that these activities are abbreviated to conserve space – but in reality, they would be more detailed):

Karamoja Water Plan Implementation:01.Review of previous reports, topographical and geological maps, stream flow data and other available data on the project area.02.Conduct field visits and land surveys along major rivers and valleys. 03.Conduct geo-physical surveys to confirm the physical and geological conditions and the mechanisms of groundwater recharge across the Karamoja Plain. 04.Carry out mapping and identification of sites for subsurface and sand storage dams. 05.Selection of the proposed implementation plan of the construction of subsurface and sand storage dams and other point water sources such as hand dug wells, shallow wells, boreholes and protected springs.06.Prepare materials, equipment and human resources requirement lists. 07.Undertake the construction of subsurface, storage dams, valley dams, and other point water sources such as hand-dug wells, shallow wells, boreholes, protected springs as per the developed work plan.09.Supervision and compliance monitoring of implementation of works.09.Mobilisation of beneficiary communities.and10.Tendering of works

Flood Management Implementation:11.To identify peak discharges and levels in all relevant streams and rivers that would be associated with floods of certain specified return periods (2, 5, 10, 20, 30, 50, 100yr) to provide the discharge input for the floodplain hydraulic analysis. 12.To generate digital elevation models (DEMs) and digital terrain models (DTMs) to provide the required geometrical input for the floodplain hydraulic analysis.13.To calculate and map-plot flood elevations using a developed and dedicated computer software to provide the required flood maps, zones, and levels.14.To designate hazard-area zones that will be inundated by a flood having a 1% or greater chance of occurring in any given year.15. To designate the floodway and the necessary information to assist Local and Central Governments, NGO's, and other Organizations involved in flood disaster relief operations, to carry out evacuation of hazard-areas and to locate areas that have the lowest risk from floods. 16.To produce feasibility designs and the associated BOQs for the structural and/or non-structural flood interventions. 17.Social and environmental analysis to investigate and mitigate against negative environmental effects that may accrue from the interventions proposed so as ensure the sustainability of the developments, and 18.Carry out socio-economic surveys concerning stakeholder and community involvement during further planning, implementation and future maintenance of the interventions and to determine possible social economic benefits in relation to improvement of quality of life of the communities through improved agriculture and livestock farming.

3.4 A Typical Specific Project Sub-Areaswith Summary Data

The specific project areas will include Kotido, Moroto, Nakapirpirit, and Katakwi. The specific locations of sites of the proposed interventions will be identified in the course of the feasibility studies. The proposed streambed dams to be constructed will vary in size according to valley dimensions and the dam sizing will take intoaccount the level of peak river flows. The sand storage dams, where appropriate,would be built across major seasonal rivers.These are the functional units of the system – a typical but very abbreviated plan is in the Table below.

4.0 CONCLUSIONS

After assessing what other countries have been able to do and basing on the theories of groundwater recharge and related issues, the following can remedy Karamoja's water problem, if tackled with dedication and patience: i) Construction of a network of subsurface storages and sand filled surface dams across major seasonal rivers and streams where the physical/geophysical and hydrological/hydrogeological conditions are favourable. ii) Construction of valley dams and point water sources such as hand dug wells, shallow wells, boreholes, protected springs in locations confirmed by preliminary studies. iii)Further geophysical studies to identify fractures and other unfavourable hydro-geological conditions in order to recommend alternative artificial recharge structures/conservation measures including grouting. iv) Conduct flood studies along rivers/streams in the basin and develop a dynamic flood zoning facility to include flood maps, zones, and levels thus be able to develop flood interventions and their costed designs. v) The outcome of this project would also assist planners and engineers in the flood disaster(s) relief/relocation operations and also in mitigating flood damage.

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#	District	No	River	Tributary	Description of location	Number dams
1	**Nakapiriprit**	1	Kanyangureg		Kenya Border to Upstream end of river	120
		2	Okutat tributaries	Kamothing	Okutat Junction to upstream end of river	110
				Beletur	Okutat Junction to upstream end of river	100
		3	Muchi-Imakat		Before junction at the swamp	120
		4	Kathiolem		Junction to upstream end	82
		7	Lokalas		portion	100
				Nalakais	From Junction at Lokalas	80
				Kapedo	From Junction at Lokalas	50
				Kapelepelot	From Junction at Lokalas	90
TOTAL NO. OF SAND STORAGE DAMS						**4584**