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SURVEY AND RECOMMENDATIONS FOR VILLAGE-LEVEL DRAINAGE IMPROVEMENTS, NORTHERN PROGRAM AREA, SUDAN

Since the initial 1988 post-flood assessment, it has been clearly recognized that a very large proportion of the damage occurring during the heavy rainfall in August-September in Sudan resulted from inadequate or impeded drainage, and that drainage problems on both the village and regional levels would have to be addressed in any serious attempt to reduce future losses. This report summarizes a survey of community-level drainage problems, conducted by INTERTECT engineers in November-December 1989 in the Northern Program Area of PLAN/Khartoum, in order to determine the extent of drainage problems and the level of risk for the future. After documenting the problems, possible solutions were examined and are detailed herein.

One of the primary objectives of the study was to establish solutions that are not only realistic but also involve the affected communities at all levels. It would not be realistic to suggest that the village-level activities described in this report would be sufficient to protect the residents from future damage; however, in the absence of regional improvements, these activities can improve a poor situation and can reduce potential losses in future heavy rainfalls. Because of the overriding influence of the regional problems, a decision was made during the on-site survey to collect and analyze regional data as well, and to submit our commentary on the regional issues to PLAN International, although it was beyond the scope of this study as initially conceived.

Involvement of the communities in the resolution of these problems will be more difficult, as many of the solutions and recommendations primarily involve major assistance with governmental agencies and private institutions. Large-scale engineering and construction will need to take place to solve the drainage problems caused by poor engineering and improper construction techniques in the past which have resulted in man-made obstructions and reconfigurations of natural drainage patterns. On the other hand, there are projects that can be accomplished with local work teams without relying on heavy equipment. The various facets of local involvement in community protection projects became clear at the village meetings held during our visit. During these meetings, general drainage design workshops were conducted involving simple techniques such as proper excavation and maintenance of drainage channels, and guidelines for water-resistant construction of individual dwelling units. It was here that the village elders voiced their support of our ideas and issues and assured us that, where self-help solutions were inadequate, they would get the community active in requesting changes by the appropriate authorities.

The report is divided into three sections. The first section describes the use of hydrology and hydraulics to establish the probability of occurrence, acceptable risk, and design criteria for drainage improvements. A section on regional issues lays the groundwork for comprehension of the village problems from the regional perspective, including initial recommendations to address the problems. The third section focuses on identifying the village issues and detailing a range of possible solutions that can be undertaken on various levels. An appendix contains maps, hydrologic and hydraulic data runs, and other technical information.

Throughout the report, costs are quoted in U.S. dollars. A private contractor provided costing for many of the larger projects, generally based on $1.50 per cubic meter for excavation -- an amount that includes any labor and appropriate machinery. When quantifying local labor for a project, an estimate has been made that one person can move 1.5 cubic meters of material per hour, maximum. Due to the uncertainty of labor costs, dollar budgets are not provided for locally-implemented projects; rather, minimum man-hours required to accomplish the task are included, independent of paid labor/volunteer questions.

I. HYDROLOGY AND HYDRAULICS

Hydrology is the study by which the relationship between rainfall and storm runoff is quantified. Various factors considered in the study of hydrology include rainfall intensities, temporal and areal distributions, evaporation, infiltration and geophysical characteristics. Hydraulics is the science of the behavior of fluids in motion; in the case of flood-plains, it provides a means by which stormwater runoff velocities and water surface elevations may be determined.

The August 1988 Flood

The rainstorm that occurred on August 4, 1988, in the Khartoum area produced runoff in proportions previously unseen by most residents. The rain gauge at Shambat recorded 147.5 mm., while the gauge at Khartoum recorded 200.55 mm. These figures represent the largest amount of rainfall recorded for a single event since the government began record-keeping over forty years ago. Although flooding due to the Nile overflowing its banks is relatively common in the area, the villagers spoken with generally agree that this storm was greater than any they could recall. One older resident of El Sayal, who stated that his family and ancestors had been in the area for 130 years, indicated that flood levels produced by this storm exceeded those of any of the stories that had been passed down.

In assessing the need for drainage and flood abatement facilities, an acceptable risk determination must be made. This is necessary since, in all probability, it would be cost-prohibitive to design against the maximum possible flood, to say nothing of the effort required to determine such; nevertheless, a reasonable degree of protection is required.

Storm Frequency

As a means of quantifying the degree of protection available against flooding in a given situation, the storm frequency -- sometimes referred to as the return period -- is invariably discussed. The return period of a particular storm is the average time interval within which that storm will be equalled or exceeded once. The probability of occurrence of a specified storm within any given year is equal to 1 divided by the number of years in the return period. For instance, a five-year storm is that storm which has a .2 probability or 20% chance of being equalled or exceeded in any year. The return period is a probabilistic determination, rather than a prediction, representing the average interval between occurrences over a long period of time.

In order to determine the probability of occurrence of a given storm, the storm must be compared to other storms of similar intensity and duration that have occurred within that same region. The reliability of the probability determination is proportional to the number of years of data collection that has taken place. The Sudan Meteorological Department has been collecting rainfall data in the Khartoum area since 1946, providing a record base of 43 years. The probability that 4 ten-year storms would have occurred in this time frame is .95 or a 95% chance. However, the probability that a one-hundred-year storm would have occurred is only .35. Therefore, the basis for establishing the recurrence interval for small storms is relatively good, while the basis for large storms is very poor.

Given the absence of adequate historical data for statistical analysis, a stochastic method must be employed. A statistical analysis of the collected historical data has been performed in a report by Khalid Tewfig Mohamed and Hassan Babiker Abdul Rahman entitled "Design of Drainage System for Storm Water for Khartoum North". From the analysis of Mr. Tewfig and Mr. Babiker, duration/frequency curves were plotted on probability paper. These curves were compared to those of areas for which a substantial data base has been established in order to extrapolate higher-intensity, longer-duration storms. Areas investigated include desert areas around the world, and areas of the Horn of Africa with similar drought and desertification characteristics. The area chosen for comparison was Yuma, Arizona, because of similarities in annual rainfall, rainfall pattern and average number of days in the year with measurable precipitation, and the size of the data base. Although the curves are not parallel, a pattern is apparent. The return period of the August 1988 storm was extrapolated from the plotted curves and estimated to be in excess of 200 years. [The plotted curves are included in the Appendix of this report.]

Development of design criteria for drainage facilities involves the adoption of a certain risk factor as mentioned earlier. The determination that the 1988 flood was at least a 200-year event was essential to our study, as it forms the basis for understanding what degree of protection to persons and property exists and allows us to quantify the contributions that drainage improvements will make toward reducing flood vulnerability. Also significant is the fact that no known loss of life occurred as a direct result of this 1988 flood. Therefore, recommendations for drainage improvements at all levels can be made on the basis of lowering the vulnerability to personal property damage, while at the same time reducing the risk of loss of life to persons. For example, assume that the existing drainage infrastructure will safely convey a 5-year rainstorm without any damage to property. The same infrastructure will flood villages but might not result in loss of life during the 200-year storm. If improvements are made to the infrastructure to provide protection to homes for a 25-year storm, protection to persons will also increase.

It is possible with current engineering standards to design drainage channels which would convey stormwater that might only occur once in a 2,000-year period. Yet this is unrealistic because of the cost of such improvements which might never be fully utilized. The risk factor used in drainage theory must be developed with realistic goals in mind, such as the prevention of destruction to life or certain infrastructure (i.e. railroad, bridges, roadways, etc.). Risk factor design parameters, therefore, might not provide protection to homes expected to last for 20 years, because the investment might be better spent on items such as health, nutrition or agricultural programs. In the United States, for example, most localized drainage infrastructure is designed for 10- to 50-year return periods, while regional infrastructure such as bridges, highways and railroads are traditionally designed to convey the 100- to 200-year storm.

In determining that the Khartoum flood of 1988 was approximately a 200-year storm, the criterion for selection of a design storm frequency simply becomes the protection of property.

In analyzing the data collected by Khalid Tewfig and Hassan Babiker for the determination of storm frequency curves, it is our evaluation that portions of the existing infrastructure, if maintained at a level consistent with original design, would provide adequate protection from the 10-year storm. Therefore, the recommendations outlined in the following sections of the report focus mainly on reducing damage to property in view of the fact that no life was known to be lost during the 1988 flood (200-year frequency). The recommendations aim to increase protection against the 10-year storm in the PLAN program area by means of maintenance of the existing system, modification of the existing infrastructure, and construction of new drainage facilities.

Hydrology

Having selected a reasonable return frequency, the next step was to quantify the storm runoff corresponding to that frequency. The rate of runoff is a function of numerous factors ranging from atmospheric to hydrogeologic to topographic. Such factors include rainfall rate and duration, evaporation, depression storage, basin area and slope, basin configuration and infiltration (as determined by soil types, moisture condition of soil, and type and degree of ground cover).

To facilitate the determination of expected runoff rates for various storm conditions at selected points throughout the drainage basin, a computer modeling process developed by the U.S. Dept. of Agriculture Soil Conservation Service was employed. More information on the program is included in the Appendix, along with a copy of the computer output and a map showing the overall watershed with drainage divides and watercourses.

Hydraulics

With peak runoff rates estimated at various points in the watershed, the required channel or swale cross-sections could be determined using Manning's equation. A description of this equation, information on the hydraulic computer model used to determine recommended improvements for the railroad bridge and downstream channel, and a copy of the computer printout are included in the Appendix.

II. REGIONAL ISSUES

In the early stages of the site survey, it became apparent that the regional issues would overwhelm most mitigation measures at the lower levels. Certain regional issues, such as drainage design theory and the impact of large infrastructure on village drainage patterns, had to be investigated in order to understand the interrelationships at play on the macro level, and to weave them into village-level solutions. The major issues have been sorted here into three problem areas: institution/agency responsibility; technical data and resources; and standard drainage design theory/policy.

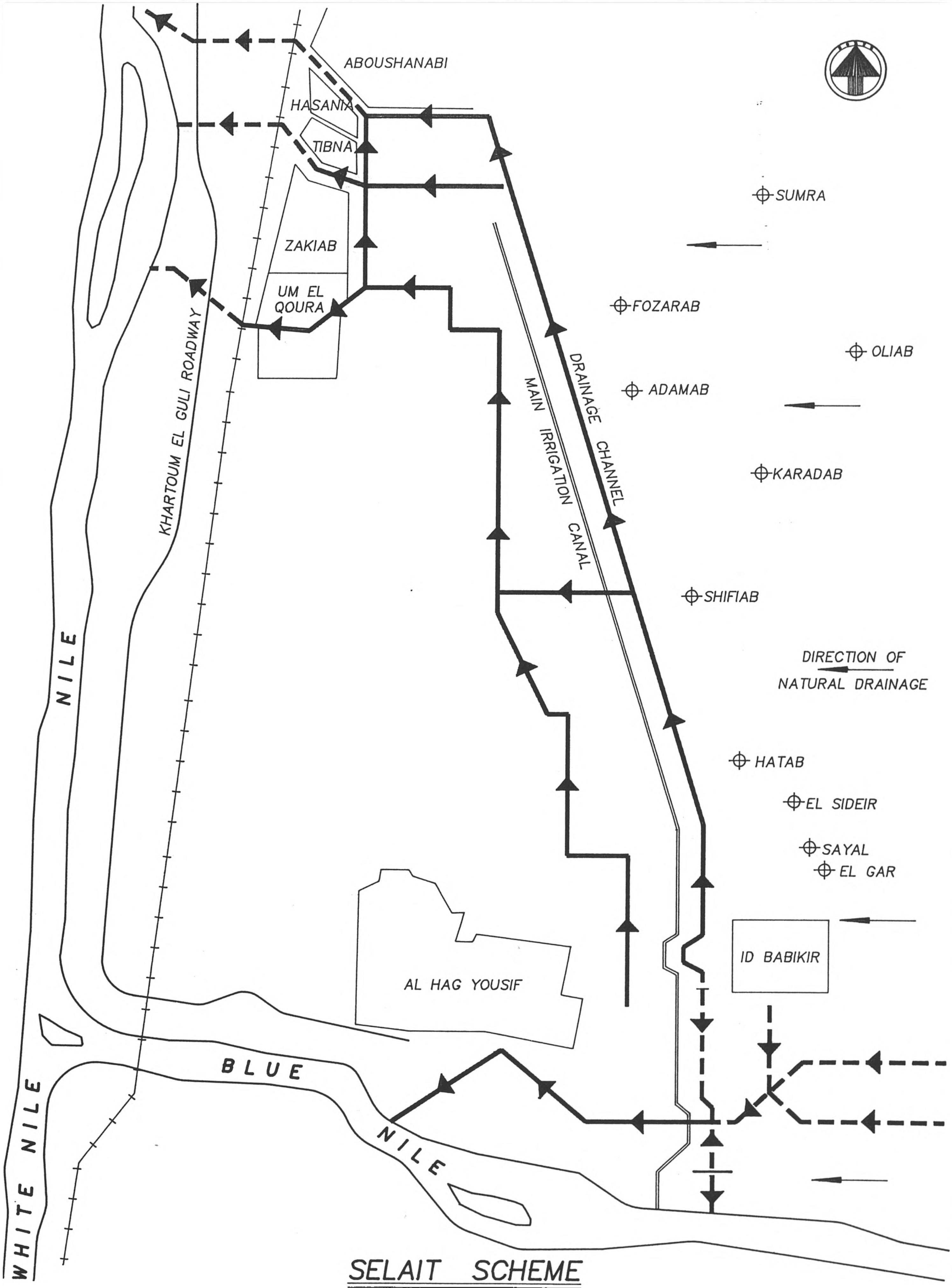
Institution/Agency Responsibility

The flooding vulnerability of most of the villages in the North Khartoum PLAN Housing Reconstruction Project (HRP) area is adversely affected due to the presence and condition of the Selait irrigation scheme, the government-owned railway, and the Khartoum North/El Guli roadway. Without serious attention and participation of the owners of these various entities, little can be done to lower the risk of flooding in the communities.

A. Selait Scheme: The presence of the Selait scheme is a major contributing factor to the flooding of a number of PLAN villages. Meetings with the Selait scheme design engineer revealed that major portions of the original engineering design of the Selait drainage network were never constructed. This supposedly occurred as a result of several factors. First, certain landholders would not give up land for drainage channel easements. Second, the contractor who built the scheme's collection system constructed the channel improperly.

The figure on the following page shows the proposed design of the main irrigation and drainage components of the Selait scheme. Note the portions of the drainage outlets highlighted by dashes. These areas have not been constructed; thus the flows are increased through the other outlet points at Um El Qoura, Zakiab and Aboushanabi. Inability to secure the land for the proposed drainage outlets is a weak excuse. Construction of the drainage channel should not have been allowed to begin until this issue was resolved or an alternative solution found.

The owners of the Selait scheme should be held responsible for completing construction of the proposed drainage channels. To facilitate discussion with the appropriate representatives, a preliminary cost estimate has been prepared for the completion of those Selait drainage components that are critical to flood mitigation in the PLAN villages. These include the continuation of channels at Um El Qoura, Zakiab, Aboushanabi and Id Babikir. The estimated cost is roughly $760,000, based on the assumption that a private contractor would perform the work independent of the Selait corporation. Current equipment rate quotes were obtained from Hussein Musa's Enterprises, a local Sudanese contractor. A detailed estimate is included in the

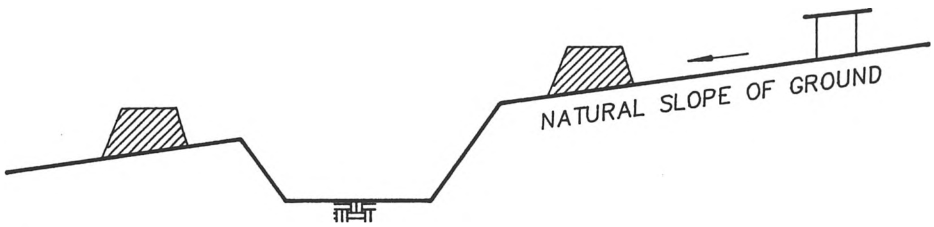


SELAIT SCHEME

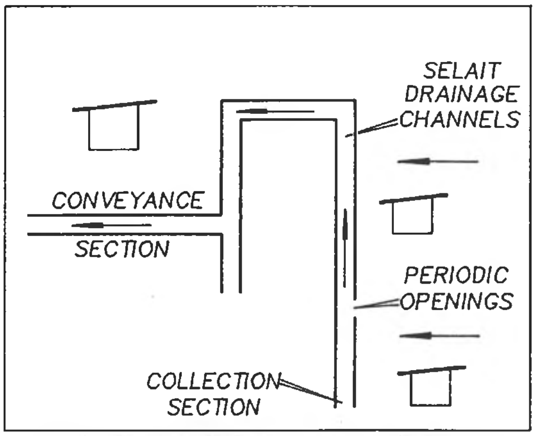
Appendix. The Selait corporation currently owns the equipment necessary to perform the work outlined in the Appendix.

The second aspect of the Selait scheme that resulted in major damage to villages is the method of construction of the drainage channels themselves, which were constructed in a way similar to the main irrigation components. Specifically, the banks of the drainage channel were constructed at elevations above the natural grade.

The figures below illustrate the problem.



EXISTING CROSS SECTION OF SELAIT DRAINAGE CHANNEL



DRAINAGE CONVEYANCE AND COLLECTION BRANCHES OF THE SELAIT