Overseas Development Administration

REPORT ON A VISIT TO KENYA, 19 JULY-11 AUGUST 1984

TECHNICAL ANNEX

An Outline Proposal to Test some Low Cost, Small Scale Irrigation Techniques

G L SILVA

Miscellaneous Report 305

Land Resources Development Centre,
Tolworth Tower, Surbiton, Surrey,
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1. INTRODUCTION

Miscellaneous Report 305 defined the possibilities and estimated the approximate scale of costs involved in setting up a pilot project to test three small scale irrigation techniques at different sites in Embu and Meru Districts. This report discusses these techniques in more detail and serves as a technical supplement to Miscellaneous Report 305. It includes a cost breakdown of sub-projects based on each technique and a bar chart of activities on the proposed pilot project.

Potential exists to develop small scale irrigation in the lower parts of Embu and Meru Districts. Irrigated agriculture is not common in the area but rainfed subsistence farming is widespread. Some opportunities exist for farmers to practice cash crop production but the unreliable rainfall pattern is a major impediment. Compelled by the prevailing drought situation, GOK give high priority to irrigation development. Land pressure, caused by the rapidly increasing population, is beginning to bite in Kenya and efficient agriculture based on multiple cropping is becoming a necessity. In parallel to the large scale irrigation development projects (e.g. Tana river projects), the government is keen to develop small scale irrigation. Enlightened by the experience related to large scale projects as to why they do not yield envisaged benefits, the government feels that the associated problems could be mitigated and/or handled more efficiently under small scale projects. Development funds are limited, so the government is obliged to adopt a low cost approach.

With due consideration to government's overall objectives, the farmer's desires and capabilities, and the available physical resources, three small scale appropriate techniques were identified. It is proposed that these are introduced to the Embu and Meru districts as pilot projects, with a view to testing their technical, economic and social viability within the broad context of irrigated agriculture.

Based on the experience gained through planning, design, implementation and operation of the projects, guidelines would be set up for those who undertake similar ventures in the future. The proposed pilot project would also provide on the job training for the local counterpart officials both in their own and in other disciplines.

Exact sites where the proposed projects could be launched have not yet been identified and therefore the technical issues are discussed in relation only to the limited number of sites inspected during the visit to the Embu and Meru districts. The three techniques are discussed in the next three Sections.

2. MINI-HYDRO-LIFT (MHL) TECHNIQUE

MHL technique may be employed to lift small quantities of water, up to about 100 litres per second, from the deeply incised rivers in the EMI area using the energy of the river itself. The application of the technique, however, is limited to those river reaches where the required energy can be harnessed at an appropriate rate from the flowing water. Waterfalls provide ideal sites. Essentially the technique involves the use of a turbine-cum-pump combination to lift the water. The arrangement * is shown in Figure 1.

A water turbine, mechanically coupled to a centrifugal pump, is located downstream of the waterfall, at an elevation between the river levels below and above the fall. The open ends of the inlet pipes of the turbine and of the pump are connected to an intake chamber located nearer the upper end of the waterfall. Water enters the turbine through the penstock, imparts its hydraulic energy to the impeller of the turbine, and re-enters the river below the waterfall via the turbine outlet. The mechanical coupling enables the turbine to transfer the acquired energy to the pump.

A separate quantity of water enters the pump through the inlet (suction) pipe. The energised pump increases the hydraulic head of this water and thus makes it possible to deliver it to land above the waterfall.

A heavy duty, low lift pump may be used instead of a turbine, provided that the inlet and outlet function in the reverse order. Thus the open end of the delivery pipe of this pump is connected to the intake chambers and the open end of the suction pipe is directed towards the

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*This arrangement may be compared with a combination of the following two systems. (a) a conventional mini hydropower generating system which uses a generator coupled to a water turbine to produce electricity and (b) a water pump driven by either a fossil fuel powered engine or an electric motor. The proposed arrangement is an amalgamation of the above two, but with the exclusion of the electricity generator and the fossil fuel powered engine or the electric motor, thereby eliminating the need for costly machinery and scarce fossil fuel to pump the water.

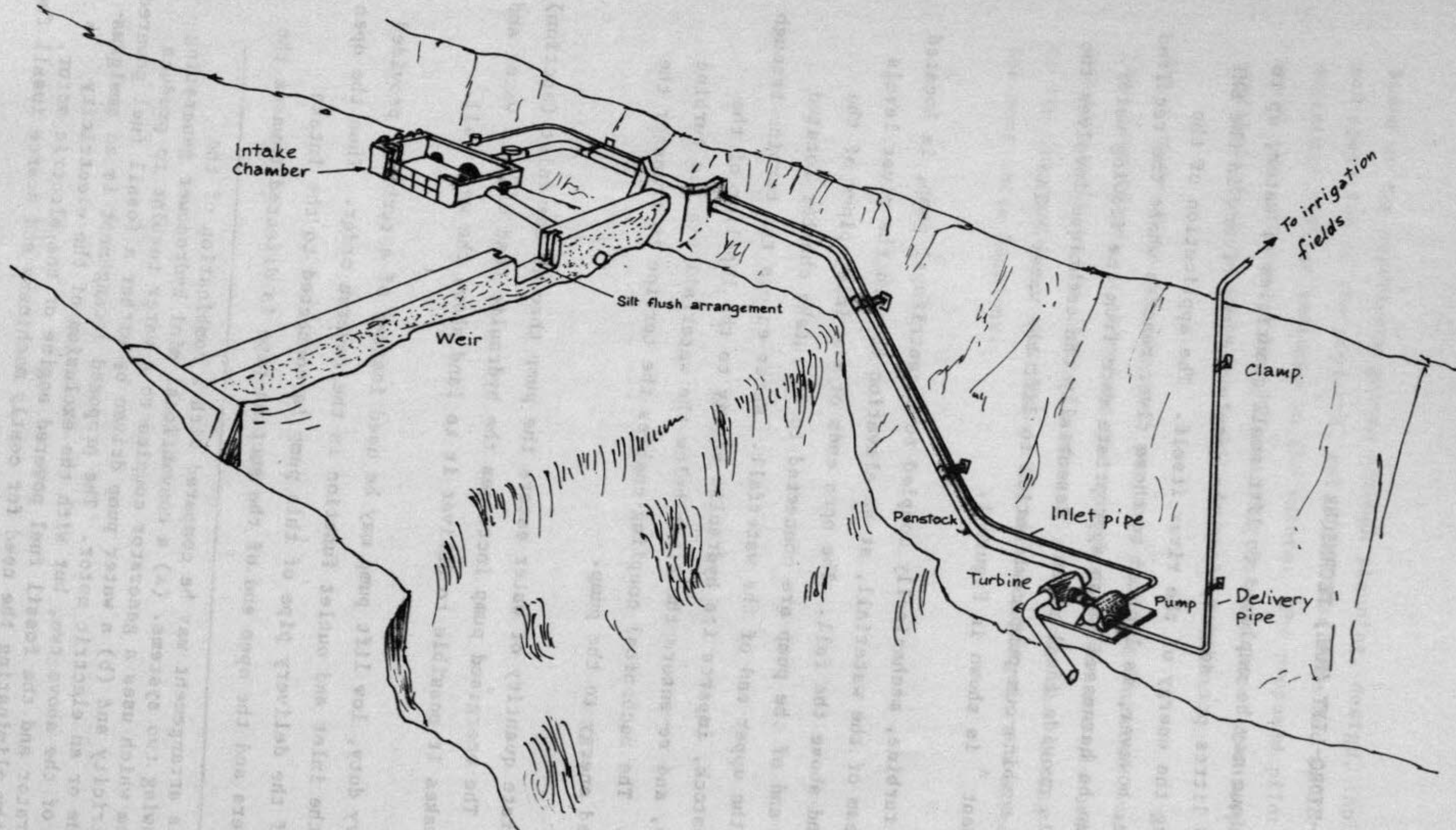

FIGURE 1 Sketch of mini-hydro-lift system

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river, downstream of the waterfall. The hydraulic efficiency of such an arrangement is far below that of a turbine designed to produce the same power output, but the financial cost is also considerably lower. The opportunity cost of the energy of the water at the waterfall is zero, and on balance it is advantageous to use a reverse pump in the proposed projects.

The water level in the river above the waterfall is controlled by a small weir designed to operate as a submerged (drowned) weir during flood conditions. The intake chamber is protected with trash racks and screens to prevent debris and other floating material entering the pumps (see Figure 2). Silt exclusion mechanisms are incorporated into the headworks to desilt the intake chamber and to remove any silt that may accumulate immediately upstream of the weir, especially under low flow conditions. The inlet and the delivery pipes are securely fastened to the soft rock on the river embankment.

The delivery pipe of the conventional pump may either end at the head of the main (primary) irrigation canal or it may function as the primary component of the irrigation distribution system. The advantages of the latter arrangement are: easy control and management of the issue of irrigation water, the possibility of commanding land higher than the river bank near the pump site, and the reduction of water losses through the distribution system, thereby reducing the risk of waterlogging. These advantages would be even greater if used as a sprinkler system, and therefore this arrangement can be viewed as intermediate between the sprinkler and open channel systems. The rationale for suggesting such a system is not so much to conserve water in the streams, but to conserve pumped water at reasonable cost. In other words, given the fixed capacity of the installations (turbine and pump), in order to maximise the crop hectarage commandable under each such unit, it is necessary to minimise the conveyance and field water losses.

Compared to an expensive sprinkler system which is capable of cutting down the water losses to a high degree, the investment needed to provide the extra piping requirement (i.e. to extend the delivery pipe) to

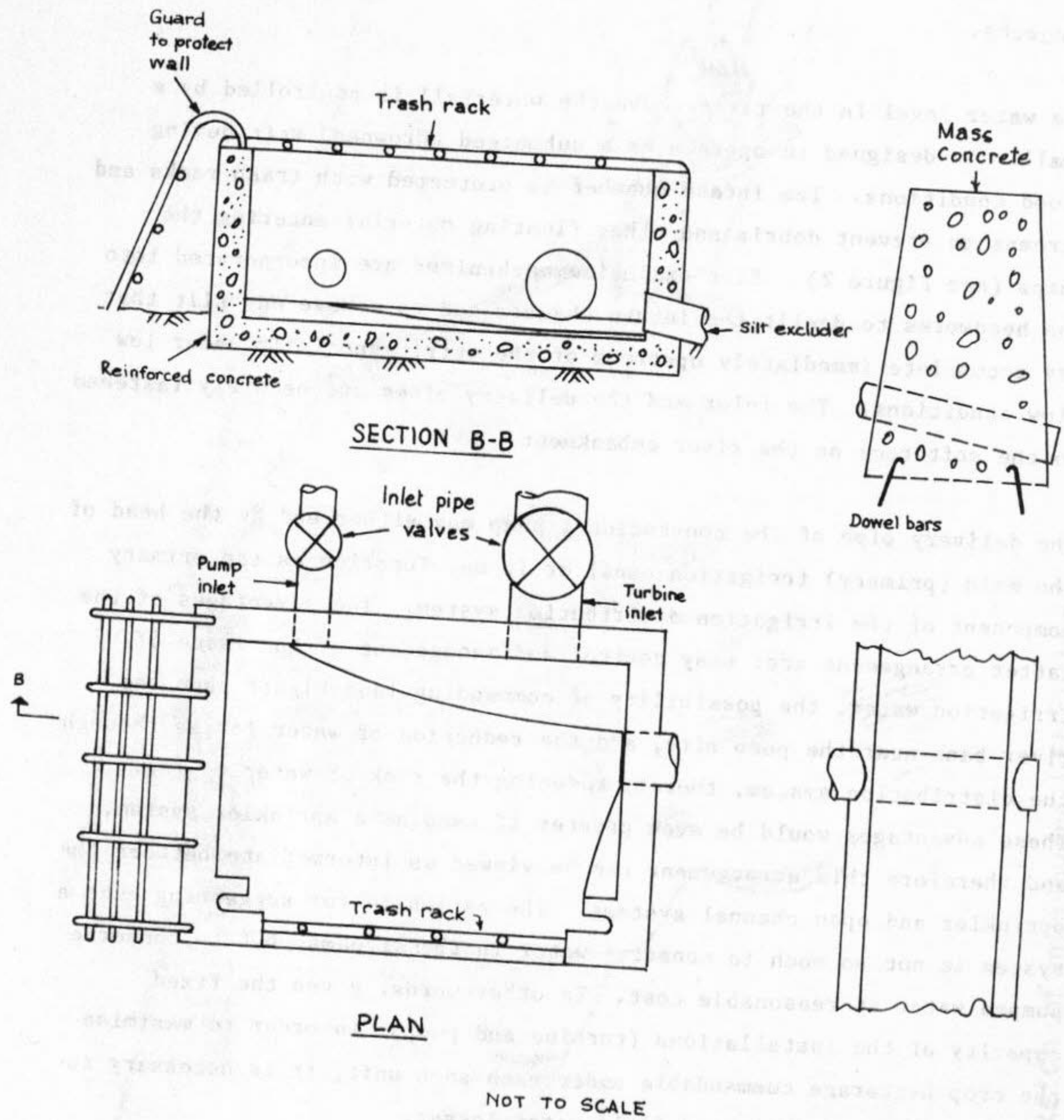

FIGURE 2 Details of intake chamber

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conserve water to a more limited extent is small and hence could be cost effective. The optimum extent to which pipes should replace open canals in the future schemes needs detailed investigation in the pilot project.

In assessing the cost of piping, account should be taken of the cost savings resulting from the reduction in the total length of main canals and the number of associated structures consequent upon the use of pipes. Some savings can also be expected from reduced canal maintenance.

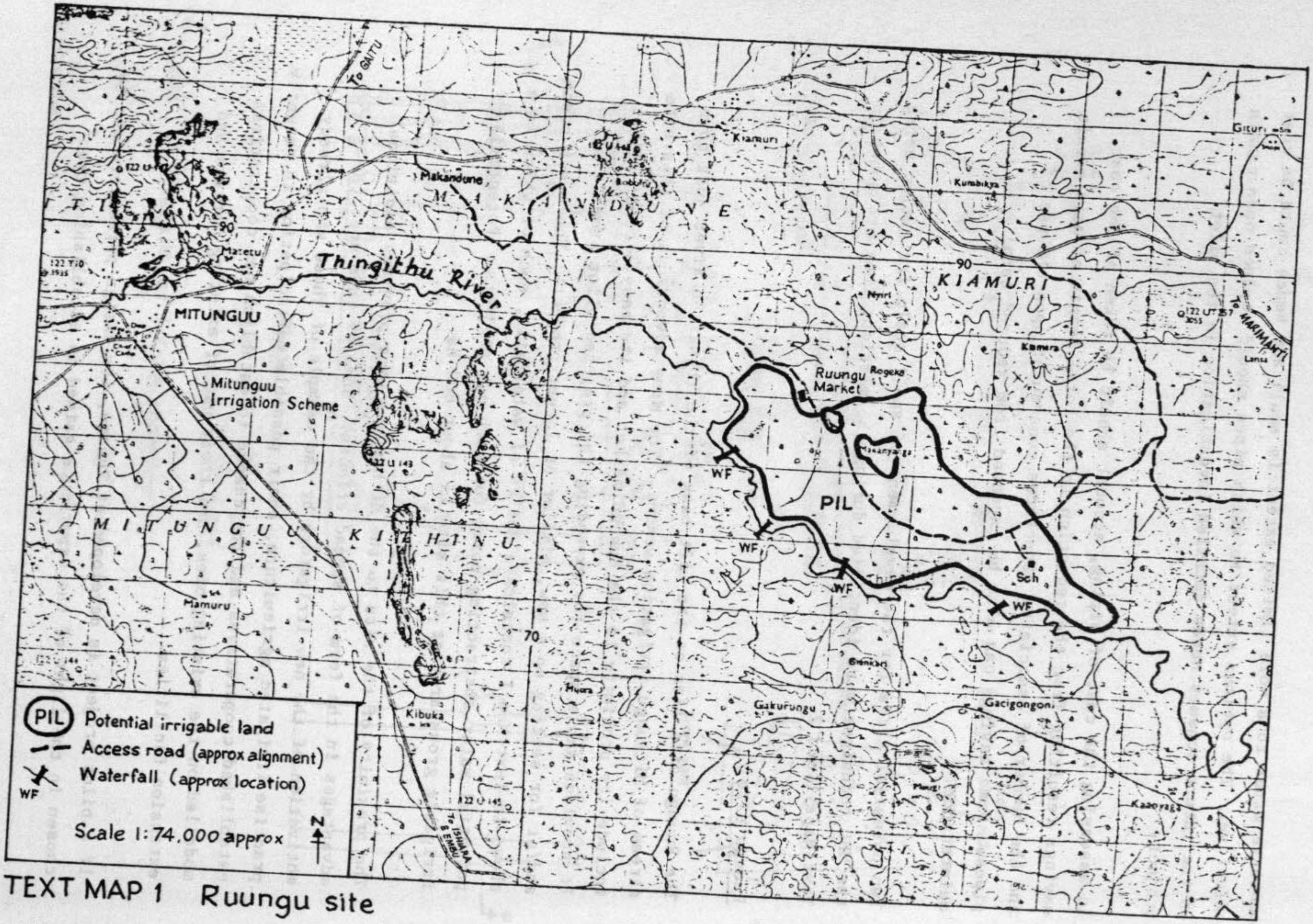
Two potential sites for the development of small scale irrigation using the MHL technique were identified during the mission; they are shown in Text Maps 1 and 2.

Ruungu site

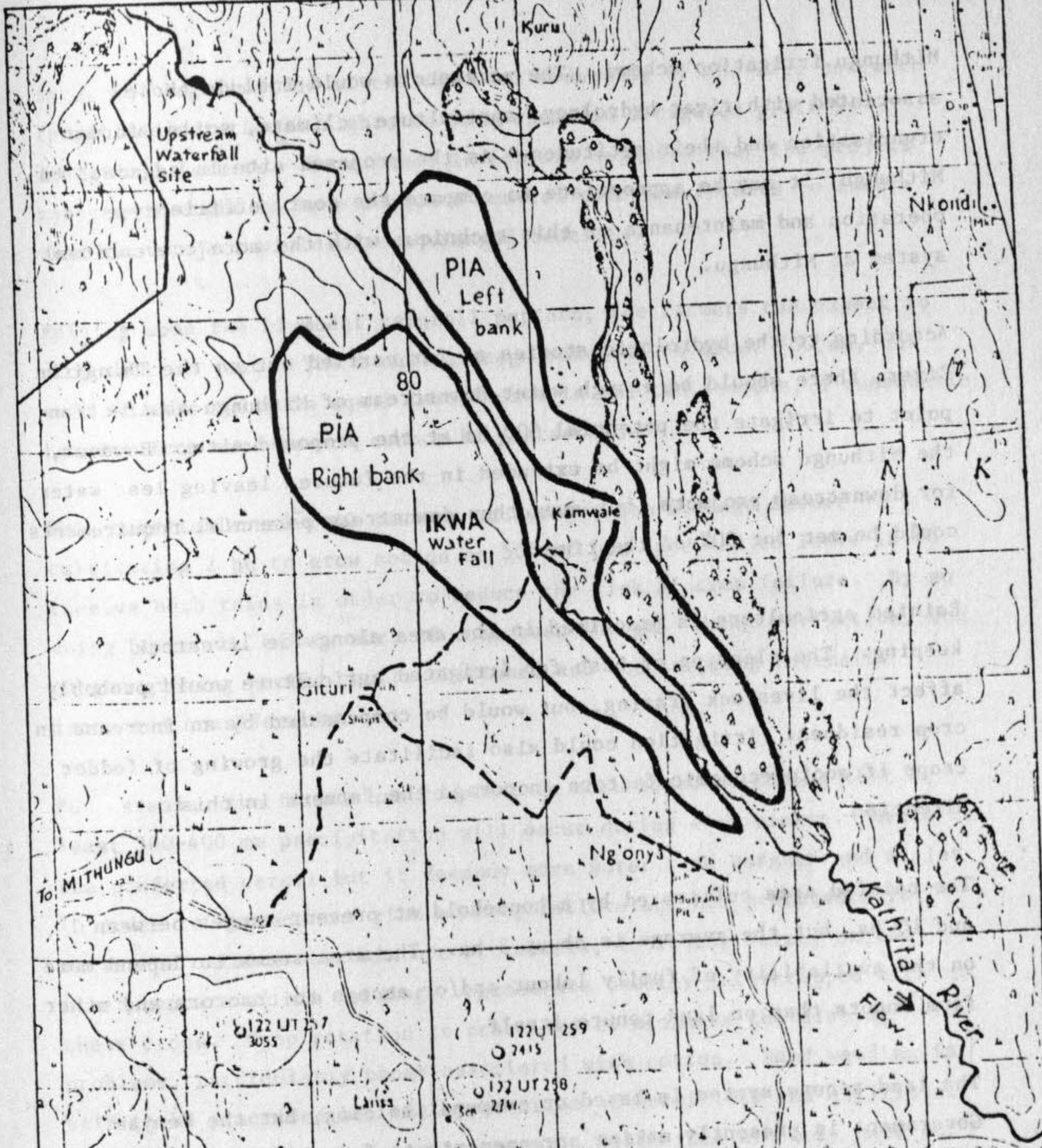
The Ruungu site lies on the left bank of the Thingithu River just down stream of Mithungu irrigation scheme. The many advantages of this site include its proximity to the Ruungu market and its easy accessibility. It provides ample space for expanding the proposed pilot area itself and/or for setting up a new, similar or larger project. The river reach shown in Text Map 1 contains a series of waterfalls, each of which is a potential water abstracting point for such new projects. Potentially irrigable gross area at this site is about 600 ha.

The proximity of the site to the Mithungu scheme provides additional advantages in the form of spread effects. Some of them are: the motivation of the new irrigators by the example of those who already practise irrigated agriculture, their possible participation in recently established cooperatives and the chance to establish new cooperatives modelled on the existing ones, and their use of existing markets and extension facilities.

If a pilot project is developed at Ruungu, its design parameters can be chosen in the light of the experience gained in establishing the



TEXT MAP 1 Ruungu site



TEXT MAP 2 Ikwa site

Mithungu irrigation scheme. The parameters would include those associated with river hydrology, agriculture, climate, soils, farmer organisation and their attitudes. As the proposed site is adjacent to Mithungu, it may be appropriate to compare the cost, efficiency, operation and maintenance of this technique with the more conventioanl system at Mithungu.

According to the hydrologic studies so far carried out on the Thingithu River, there should be enough water downstream of Mithungu abstraction point to irrigate the potential 600 ha at the proposed site. However, the Mithungu scheme might be extended in the future, leaving less water for downstream projects, but even then downstream perennial requirements could be met for 80% of the time.

Rainfed agriculture is practised in the area alongside livestock keeping. The clearing of bush for irrigated agriculture would probably affect the livestock grazing, but would be compensated by an increase in crop residues. Irrigation could also facilitate the growing of fodder crops if socio-economic factors encourage the farmers in this direction.

The rainfed area cultivated by a household at present ranges between 1 and 10 ha, but the average is about 2 ha. The area seems to depend more on the availability of family labour and/or access to tractors and other farm inputs than on land tenure itself.

The land tenure system is based on communal holding, but the Kenyan Government is presently making arrangements to formalise the individual's rights to land. It is unlikely, however, that the adjudication process will be completed at Ruungu before the start of the pilot project.

If the pilot projects are to be implemented in the near future, measures in addition to land adjudication must commence immediately. Measures worthy of consideration include compulsory acquisition of land by the government, with compensation as cash, alternate land or rights to farm, and legalisation of the communal ownership of the site but with formalised rotational rights to farm specific irrigated plots by individual farmers. Experience in Ishiara suggests that the project management ought to have adequate control over the farmers to ensure that the project yields its envisaged benefits.

Relying upon the bi-modal rainfall pattern, the farmers can expect to crop twice a year. The annual average rainfall is about 700 mm, but even if this falls in equal instalments in the two seasons, a reasonable harvest from each season cannot be guaranteed.

This unreliable rainfall pattern encourages the average farmer cultivating 2 ha to grow cotton on 50% of his land and to leave it to receive both rains in order to reduce the risk of crop failure. By so doing he can be fairly sure of some cash income. Under irrigation, the cotton growing period can be shortened and the cropping intensity increased considerably.

For cereals, the farmer has to plant in both seasons, hoping that at least 300-400 mm precipitation will occur during each season. Maize is the preferred cereal but it demands more water than sorghum and millet. In order to balance the risk of crop failure and his preference for maize, he cultivates a mixture of cereals, including maize, on the other hectare of his holding. Legumes are usually intercropped with these crops. Crop rotation is practised to minimise the disease problems, particularly those associated with cotton. Hand weeding is said to be practised but the application of herbicides and artificial fertilisers does not seem to be common. Pesticides are only used on cotton. The farmers sow the cotton seeds provided free by the cotton board, but for other crops they use local varieties.

During the short visit to the EMI project area, only a few farmers could be interviewed, near the Ruungu and Mithungu area, so the practices described above are strictly applicable to these sites only, but it is believed that the situation is similar in the other sites visited.

Ikwa site

Land beside the Ikwa waterfall on the Kazita River can also be irrigated using the MHL technique. Referring to Text Map 2, the potential gross area irrigable on the left and right banks of the river is about 500 and 350 ha respectively. Of this, a total of about 600 ha is located upstream of the waterfall. To command this land, water from the waterfall cannot be conveyed via an open channel and therefore the delivery pipe of the pump needs to be extended appropriately.

During the visit, the mission was informed of another waterfall upstream of Ikwa. The probable location is shown on Text Map 2. It was not possible to establish whether there are any more waterfalls between these two sites. The 600 ha of irrigable land upstream of Ikwa could be gravity fed from the upstream waterfall, but excessively long, lined open channel would be required and the cost would be considerably more than the alternative suggested above.

The drop at the Ikwa fall is about 15 m. Kazita is a major river and its flow is considerably larger than that of River Thingithu (Ruungu site). Since there is a plentiful supply of water available to energise the pump and for extraction, large capacity machinery (turbine and pump) could be installed at this site in order to benefit from the economies of scale. The Ikwa site therefore offers the opportunity to adopt low cost, small scale technology but to irrigate a relatively large extent of land. At the full operational stage, the cost of providing irrigation facilities at this site could be less than £300 per ha.

When this site is considered for a pilot project some awkward decisions need to be made on capital investment. Bearing in mind that there is only one suitable waterfall at the site, and with the intention of developing the entire site in the long term, should large capacity machinery be installed before the viability of the technique is fully established by pilot studies? In the unlikely event that the pilot studies prove unfavourable, should the large cost of installation be written off? Alternatively, should smaller machinery be installed during the pilot phase, recognising that it is likely to be replaced by larger scale machinery at the proto scale development stage?

The cost of the headworks required at this site to command a pilot irrigation scheme would be approximately £25 000. For an extra £20 000, say, headworks to command the entire 850 ha site could be installed. The sum total is much less than the capital required to provide irrigation for a similar extent of land by using conventional technology. The probability of failure of a pilot project at this site is low, and the additional investment even at the pilot stage could therefore be justified.

At the time of the visit, only land on the right bank could be inspected. Much of this land was cleared and showed signs of continuous cultivation. Except for some patches of a withering cotton crop intercropped with pigeon pea there was hardly any other crop surviving the present drought. Dried-up but still standing stalks of maize, sorghum and millet could also been seen. The scene suggested that farming practices are similar to those at Ruungu.

The site has reasonably good access. Land tenure is likely to be similar to Ruungu, but the soils look more variable.

Upstream of the waterfall, the right bank in particular is shallow. This feature provides the opportunity to divert a part of the river flow by gravity using conventional methods. In the upper reaches of such a diversion canal, the subsurface formation is rock and construction could be expensive. Deep canal excavation could be avoided, however, if the water level in the river is raised by heightening the weir, but this will invariably give rise to upstream flooding and hence the need for flood protection works. It should be noted that with gravity methods, only land downstream of the waterfall site can be irrigated. Any attempt to use gravity, however, need not necessarily exclude the simultaneous application of the MHL technique. Indeed an interesting combination worth studying would be the use of both systems, to irrigate the upstream and downstream lands separately using the respective technologies.

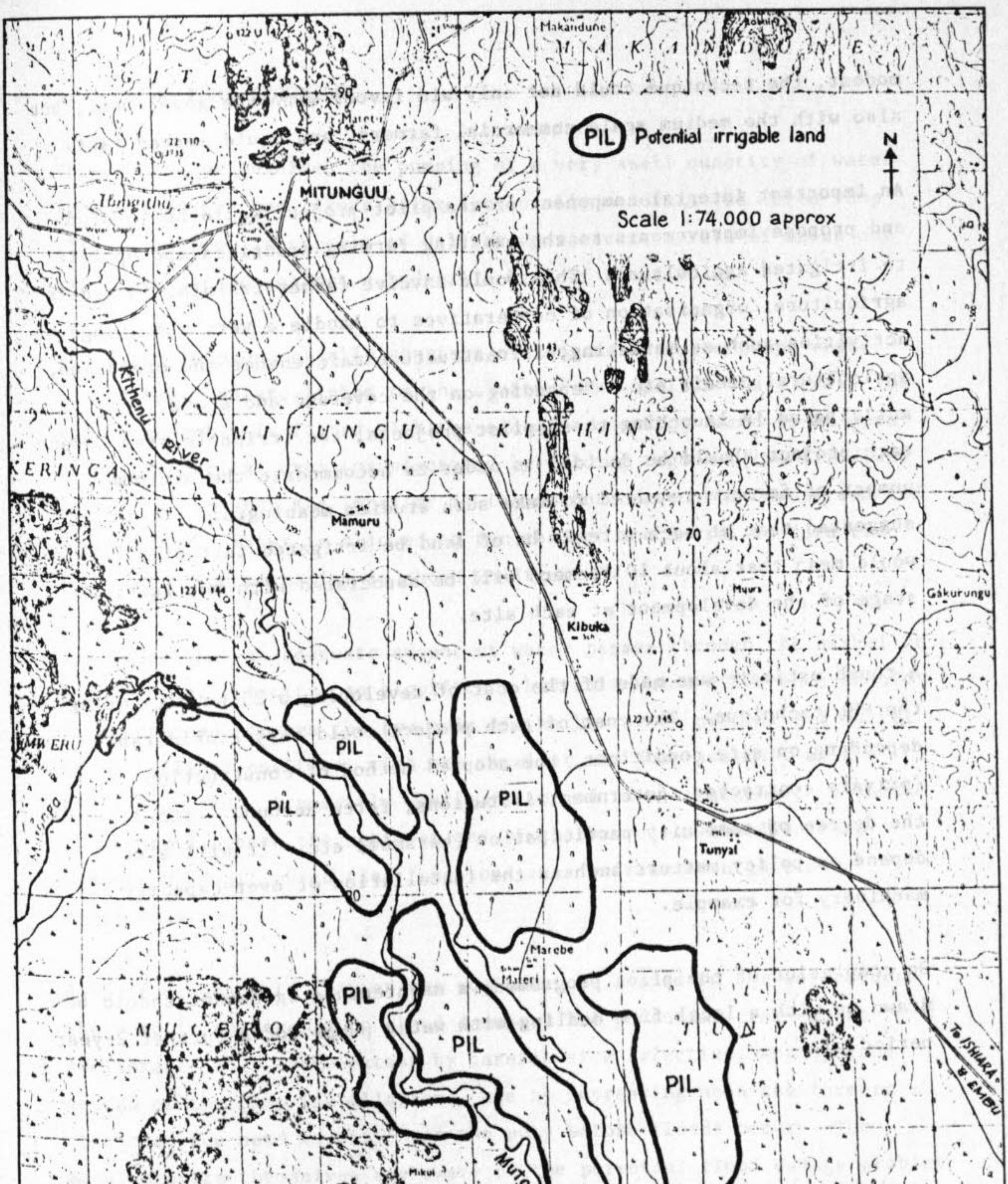
Mutonga-Kithenu and other sites

The banks of the rivers Mutonga and Kithenu (see Text Map 3) show similar characteristics to those at the Ruungu and Ikwa sites. The site is fairly close to the other two, and the geology, river morphology, hydrology etc. are also likely to be similar. The potentially irrigable area at this site could be about 1 500 ha. The profiles of the two river reaches are steep, which implies that there could be several waterfalls within them.

The mission was unable to visit the site, so the relative advantages and disadvantages cannot be discussed here in specific terms. Nevertheless, when the sites are to be selected for development using the MHL technique, this site, together with any others identified through a thorough examination of the EMI project area, needs careful consideration.

General considerations

It is proposed that at least two sites are developed using the MHL technique. They should be developed sequentially so that lessons learnt during the implementation of the first can be incorporated into the second. During the operational stages of the two proposed pilot projects, comparisons can be made of their performances in relation to their varied socio-economic environments. From the staff training point of view, the trainees will have the opportunity to set up the second project on their own, based on the training they received during the setting up of the first, but still under supervision. If the two projects are at sites some distance apart, this will accelerate the geographical spread of the technology. Since the capital outlay is



TEXT MAP 3 Mutonga-Kithenu site

modest, the technique could not only win favour with the government, but also with the medium scale commercial farmers, and could spread fast.

An important integral component of the pilot project would be to study and propose improvements to the existing farming practices appropriate to irrigated agriculture. This would involve farmer training in modern agriculture, organisation of cooperatives to handle a very wide range of activities such as marketing, infrastructure maintenance and operation, agricultural credit etc. Depending on the coverage and scope anticipated in launching these pilot projects, the irrigable area under each project should be decided in order to accommodate the minimum number of farmers required to make such studies meaningful. It is suggested that at each site 25 ha of land be irrigated initially. This would mean that about 10 farmers will be associated with the initial stage of the development at each site.

A rough estimate was made of the cost of developing a 25 ha site using the MHL technique. The cost of each project could vary considerably depending on site conditions, the adopted method of construction (private contractor, government instutions, force account * etc.), the degree of community participation (harambe) etc. It will also depend on policy matters such as the installation of over-capacity machinery for example.

On completion of the pilot programme, a maintenance agreement should be drawn up with a local firm dealing with water pumps for a further 2-year period.

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* Employing direct labour on a casual basis.

3. TURBO-PUMP TECHNIQUE

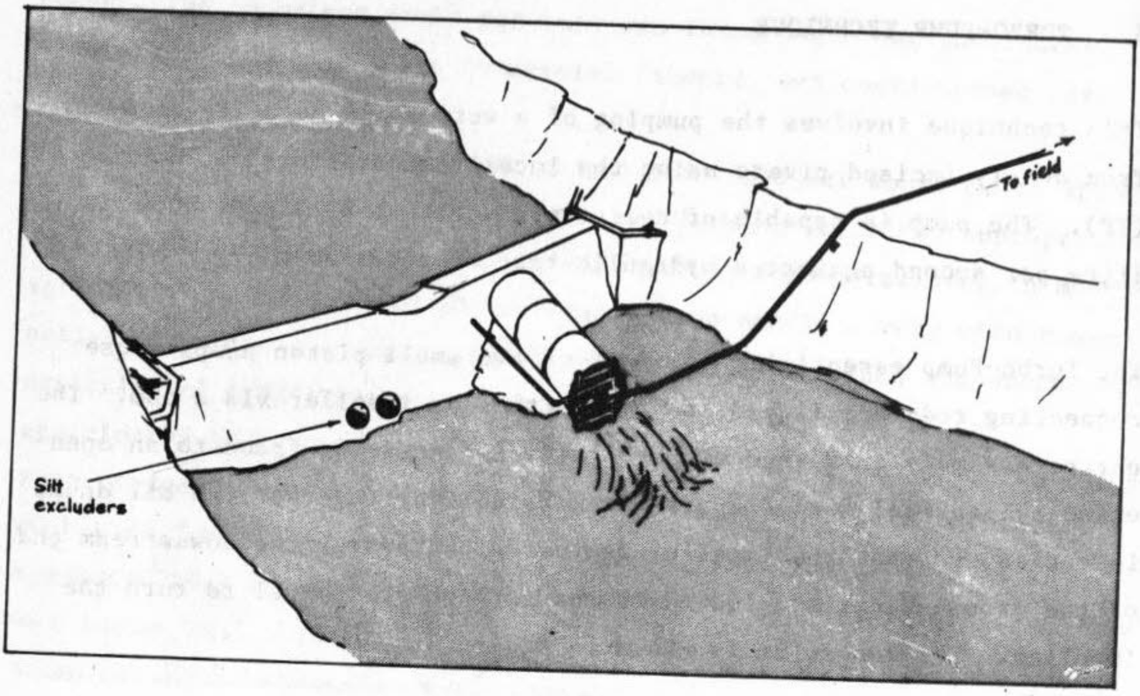
This technique involves the pumping of a very small quantity of water from deeply incised rivers using the locally manufactured Turbo-Pump (TP). The pump is capable of delivering water at a rate of about one litre per second against a hydraulic head of about 20 m.

The Turbo-Pump essentially consists of two small piston pumps whose connecting rods are linked to the shaft of an impeller via a cam. The entire assembly is fitted with the aid of a mounting frame to an open-ended cylindrical drum (manufactured by welding together two oil drums in series) so that the impeller is inside but nearer the downstream end of the drum. Water is allowed to run through the barrel to turn the impeller. The mechanism is shown in Figure 3.

To ensure that an adequate amount of water passes through the barrel at a sufficient velocity, an significant hydraulic head difference should be maintained between the two ends of the barrel by placing the barrel at an inclined position, with the impeller and pump assembly at the downstream end. A possible configuration of this arrangement is shown in Figure 3, where the upstream end of the barrel is embedded in a masonry headwall which also functions as a weir under high flow conditions.

A major drawback is that as the equipment is placed in the watercourse the pump is vulnerable to flood damage. The potential risk can be ameliorated to a large extent by careful site selection, appropriate design of the pump installations, and by impressing upon the farmers concerned the need to dismantle the pump before floods occur. The manufacturers themselves are aware of the potential flood damage problem and are keen to modify the design. Field testing under different site conditions is a prerequisite to design alterations.

One pump unit could deliver water to irrigate about a hectare on a perennial basis or up to about 3 ha on a supplementary basis. The irrigable extent, however, can be significantly increased with night



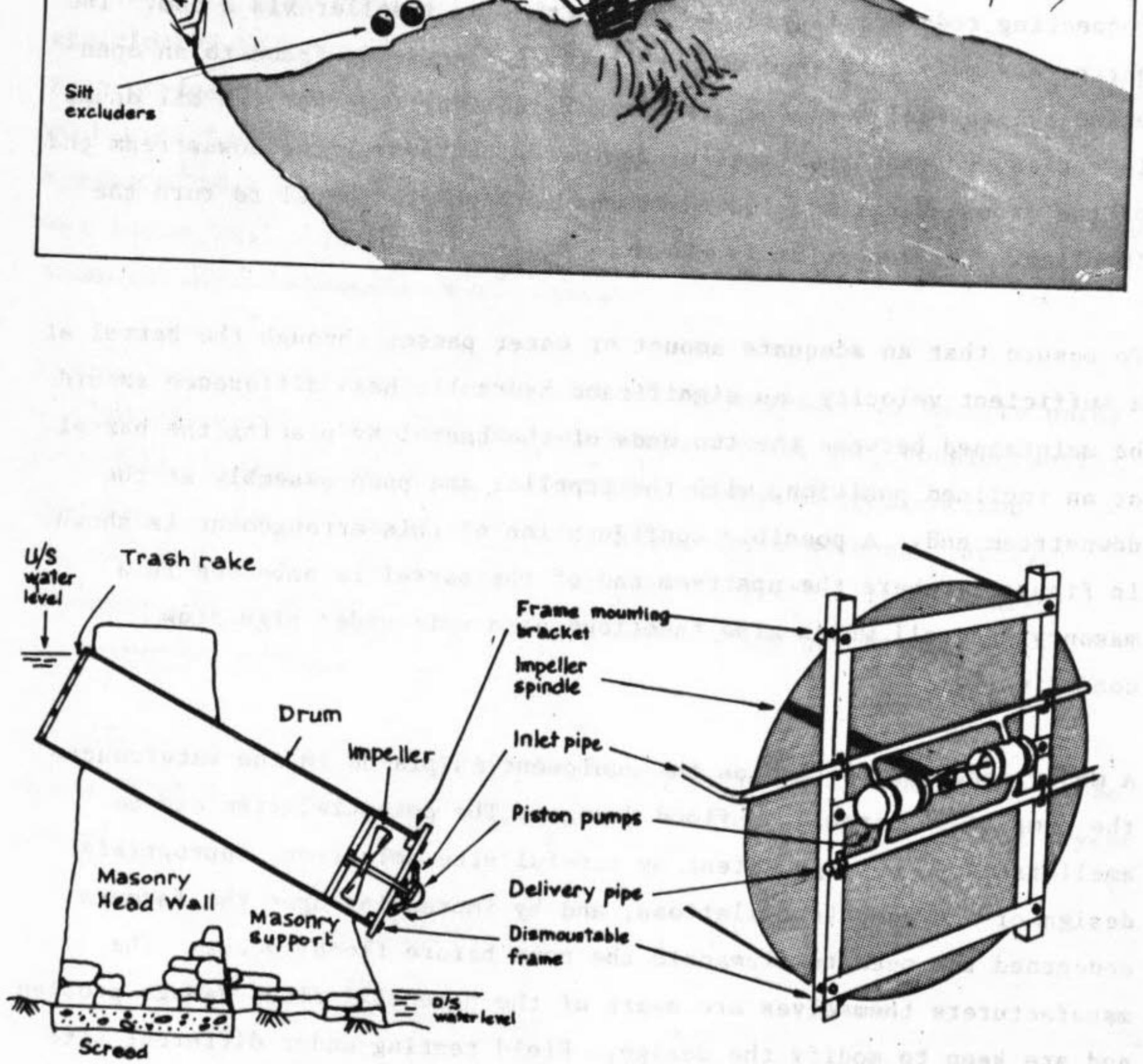


FIGURE 3 Turbo-Pump assembly

irrigation or if a storage tank is incorporated to store the water pumped overnight. A further expansion in the irrigable area can be invisaged by increasing the hydraulic head difference between the two ends of the barrel, thereby allowing more water to be pumped. This can be achieved by raising the spill level of the weir referred to in Figure 3, subject to the performance specifications of the pump.

Given the very small delivery rate of the pump, no conveyance losses can be accommodated. Ideally the entire distribution system should therefore be by pipe. If the tanks provided for night water storage are also designed to provide a degree of primary settlement, sprinkler irrigation could be practised, especially during the dry season when the water is most scarce but is relatively free of suspended material. Incorporation of a sprinkler system considerably increases the capital investment cost and can only be justified if the cultivation of high value crops is feasible and the produce is marketable.

Compared to the cost of the pump, the civil engineering works necessarily for its installation are expensive. This raises the unit cost of water pumped through a single pump. It is therefore worthwhile for several Turbo-pumps to be installed at the same site to reduce the unit cost. On this basis, a single pilot project could accommodate say three pumps at the given site and irrigate up to about 10 ha on a supplementary basis.

No specific sites for the T-P technique are recommended at this stage, although from a technical point of view, there could be many suitable sites. Socio-economic and political considerations are likely to be an important factor in site selection.

The scale of each project (viz the irrigable extent and the number of farmers) needs to be determined precisely, according to the objectives of the proposed pilot scale operations. In order to make the agro-socio-economic studies meaningful, a minimum number of farmers needs to be associated with the project.

In view of the size of the EMI concept and the modest cost of each project, sites may be selected from each of the three districts. While this is likely to win political favour, the scattering of the projects will also help in the fast dissemination of the technique.

It is proposed that at least five sites are developed using the T-P technique but in order to spread the work load of the project staff, that sites should be developed in sequence.

The proposals for developing pilot projects using the MHL technique are equally if not more valid in the case of T-P technique. With T-P, the number of farmers involved will be comparatively small and setbacks caused by farmer default could lead to the collapse of a project. The identification and study of the factors affecting the individual farmer response towards irrigated agriculture is therefore important in order to ensure the success of future T-P projects. Since the nature of these factors is varied and diverse, several pilot studies should be carried out so that they will collectively encompass the full range of variability likely to be associated with projects based on the T-P technique.

The T-P technique has many advantageous features including: small capital outlay and irrigable area, non-dependency on government institutions for planning and implementation, ease of organisation, absolute minimum maintenance cost, virtually zero operating cost, and availability of credit for the capital outlay. These encourage both commercial and subsistance farmers to use this technique. If the proposed pilot projects succeed in demonstrating T-P viability, dissemination of the technology could be rapid.

4. IRRIGATION TANK TECHNIQUE

This technique relies on impounding the rainy season stream runoff in a small storage reservoir and releasing it for irrigation when demanded. The concept and features of projects based on irrigation tanks are similar to those employing large storage reservoirs, except for the scale and that they do not include such other major benefits as hydro-power generation and flood control. The water in the tanks will be used exclusively for irrigation, but modifications could be incorporated to facilitate fish farming and to provide domestic water and recreational needs.

An irrigation tank will comprise essentially an impounding dam built across a valley to a desired height. Often, the dam will be built of earth. A spillway built of non-eroding material will be incorporated in the dam to release the excess floodwater entering the tank. Sluices will be built into the dam to extract irrigation water. The water gushing out through the sluice barrel will flow through a stilling basin before entering an open channel which will convey it to the irrigable land. Figure 4 depicts the features of an irrigation scheme based on tank storage and Figure 5 shows details of some of the associated engineering components.

The tank regulates river flows to meet pre-set demands for irrigation water. The difference between the natural flow in the river and the irrigation demand is absorbed by or released from the reservoir storage (depending on whether the in-flow is greater or less than the demand) or allowed to spill over when the reservoir is full.

Basically reservoir design is the determination of the optimum storage volume. In the process of optimisation, the object is to minimise the cost and maximise irrigation command under the stochastic behaviour of the stream flow regime. This exercise therefore demands a considerable knowledge of the hydrology of the stream concerned.

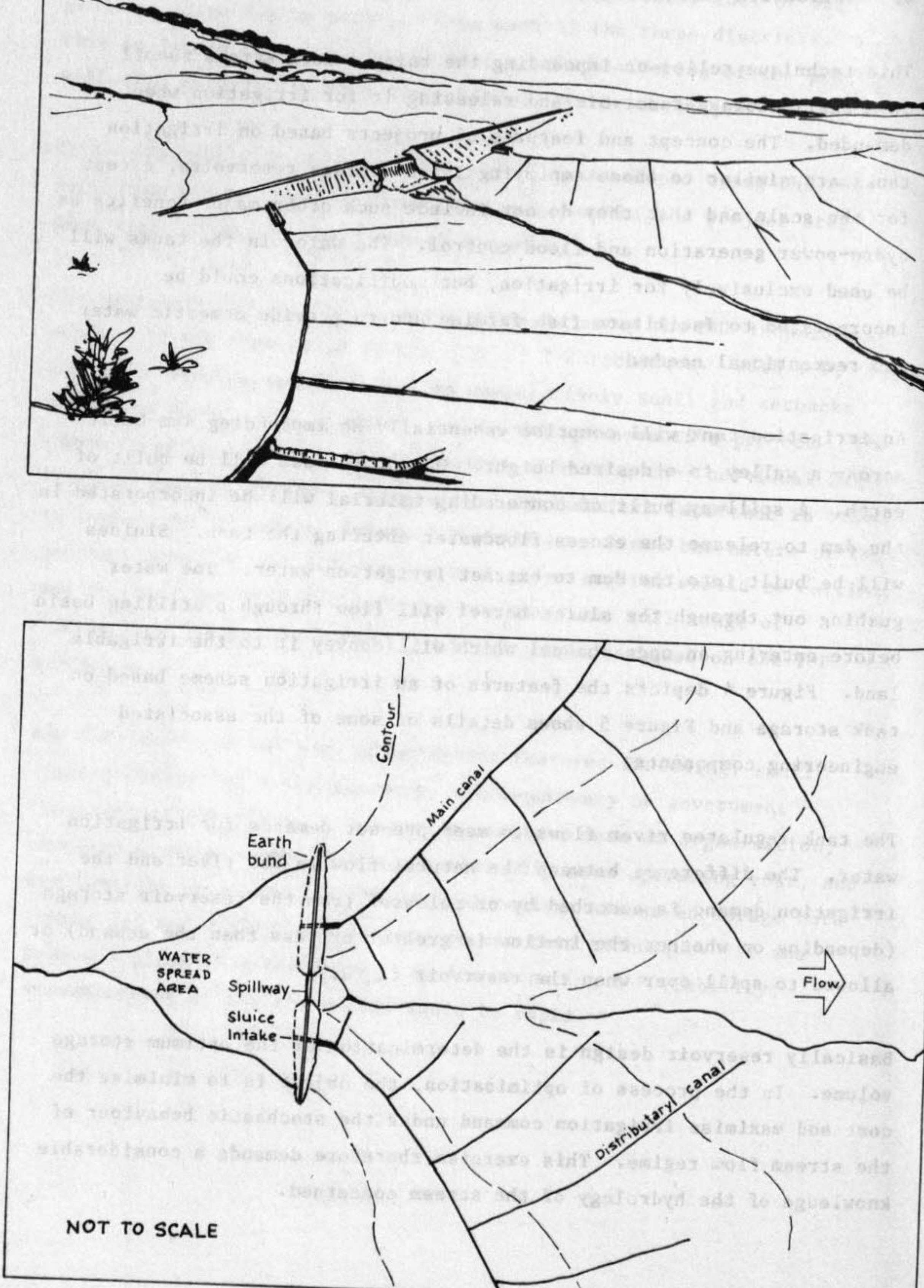


FIGURE 4 Sketch and plan of a tank irrigation system

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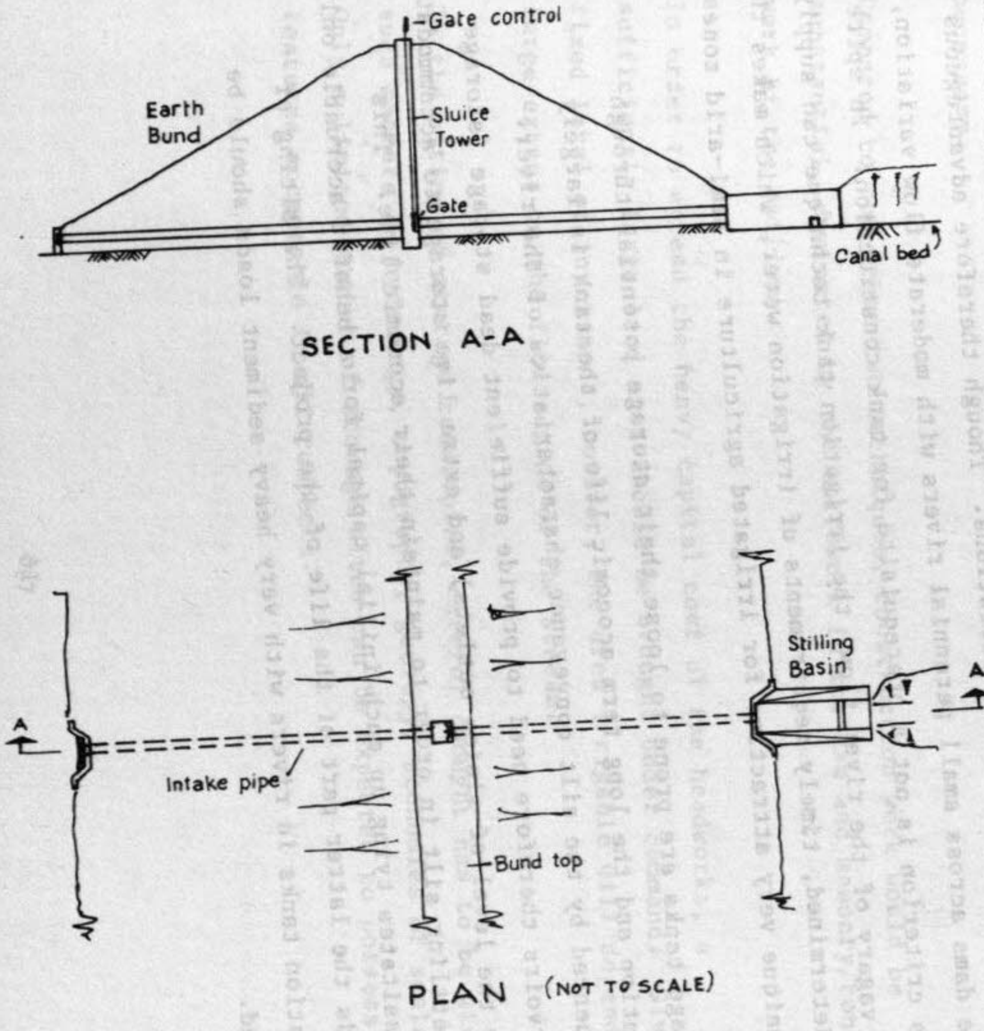


FIGURE 5a Sluice intake

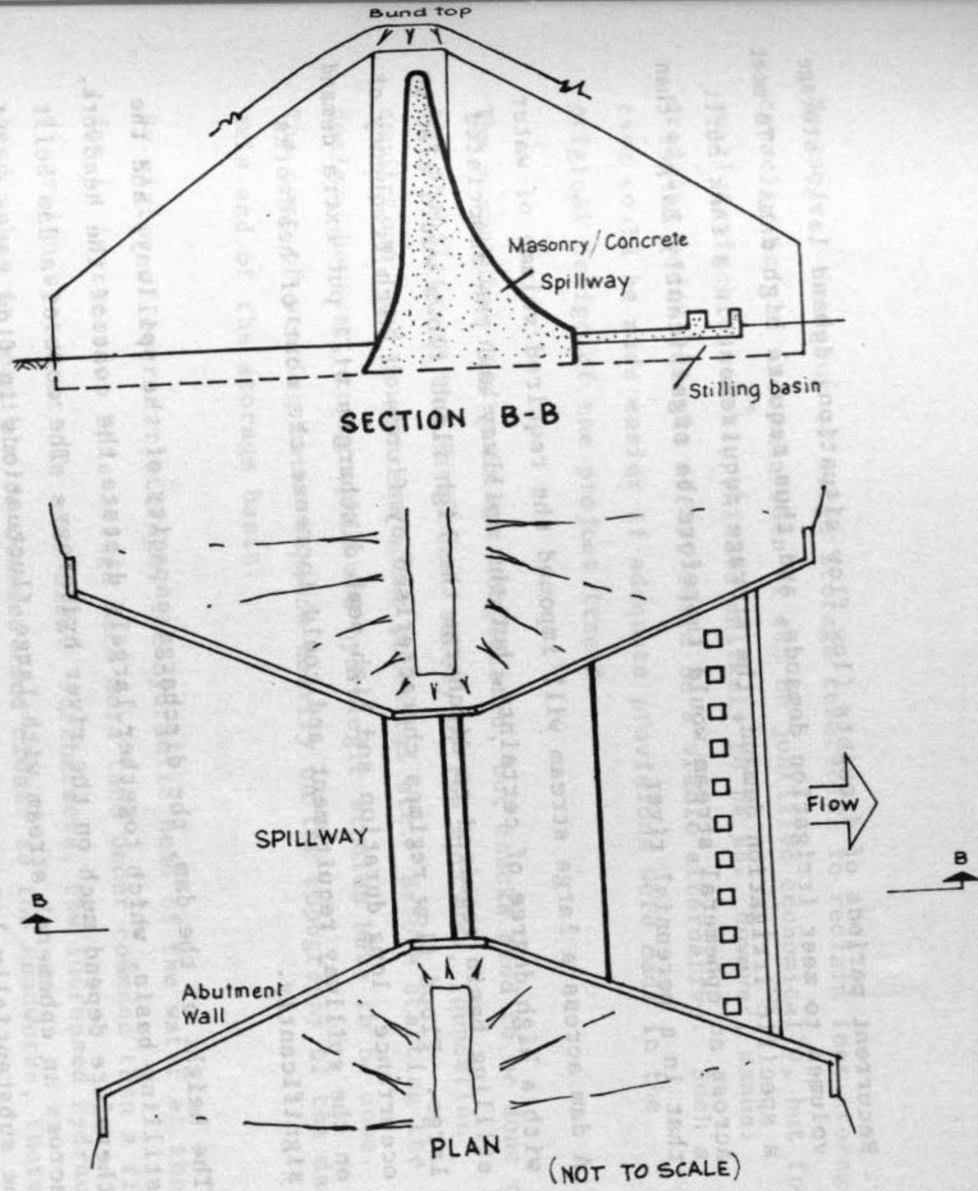


FIGURE 5b Spillway

Recurrent periods of droughts (low flow situation) demand large storage volumes to meet irrigation demands, and thus require high dams. To meet a specific irrigation demand, the storage requirement in a tank built across an ephemeral stream would therefore be significantly larger than that in a perennial river.

A dam across a large stream will impound the required volume of water with a high degree of certainty, but the spillway and the associated stilling basin required to discharge the high flood flows would also be large. Flood flow regimes characterised by floods of high frequency of occurrence, long duration and high peak discharges will put extra demand on the spillway requirement and could increase the cost of headworks significantly.

The height of the dam, the discharge capacity of the spillway, and the stilling basin, which together largely dictate the cost of the headwork, therefore depend much on the river hydrology. The cost of a dam built across an ephemeral stream with large fluctuations in flow rates would be substantially larger than an equivalent dam built across a perennial stream with moderate flow variations. Though therefore advantageous to site dams across small perennial rivers with moderate flow variation, this criterion is not a prerequisite for tank construction. In spite of the vagary of the river flow, the irrigation tank technique can supply predetermined, timely requirements of irrigation water, which makes this technique very attractive for irrigated agriculture in semi-arid zones.

Storage tanks are prone to loose their storage potential through siltation and the long term economic life of the tank is largely influenced by the silt conveyance characteristics of the river. Reservoirs therefore need to provide sufficient dead storage (storage below the level of sluice outlets) and extra live storage to accommodate the settling silt in order to maintain their economic life. This neccessitates tying up much initial capital for a benefit accruable only towards the latter part of the life of the project. The siting of irrigation tanks in rivers with very heavy sediment loads should be avoided.

Mechanical dredging of large storage reservoirs to reclaim lost storage capacity is not uncommon when it can be justified economically, but for small irrigation tanks, this is unlikely to be so. However, manual dredging under harambe effort could be a viable alternative. Such a task could be made easier if adequate provisions were made in the original design of the project itself.

The structural design is not complicated, but checks need to be done on the stability of the earth dam, safety of the spillway, foundation conditions, and downstream scour potential etc. Before starting the design, however, topographic and hydrologic studies have to be done. The cost of storing water depends heavily on the topography of the dam axis and of the storage basin.

By virtue of on-river storage, the hydraulic head of the water at the dam is increased. This brings much more land under command than a flow diversion system at the same site. Furthermore, the increased hydraulic head makes it possible to command land closer to the headworks, thereby reducing the long idle reaches of main canals that would otherwise by necessary.

Compared to the other two techniques, construction work would be substantial, dominated by the earthwork in the dam and masonry/concrete work of the spillway.

In order to spread the heavy capital cost of the headworks, a sufficiently large land area should be brought under command. Given a fixed level of investment, however, the area irrigable will depend to a large extent on the flow regime of the stream.

In the siting of storage reservoirs, careful thought has to be given to such matters as hydrology, topography, geology, economies of scale etc. Only a limited number of storage sites can be expected to possess features acceptable in all respects.

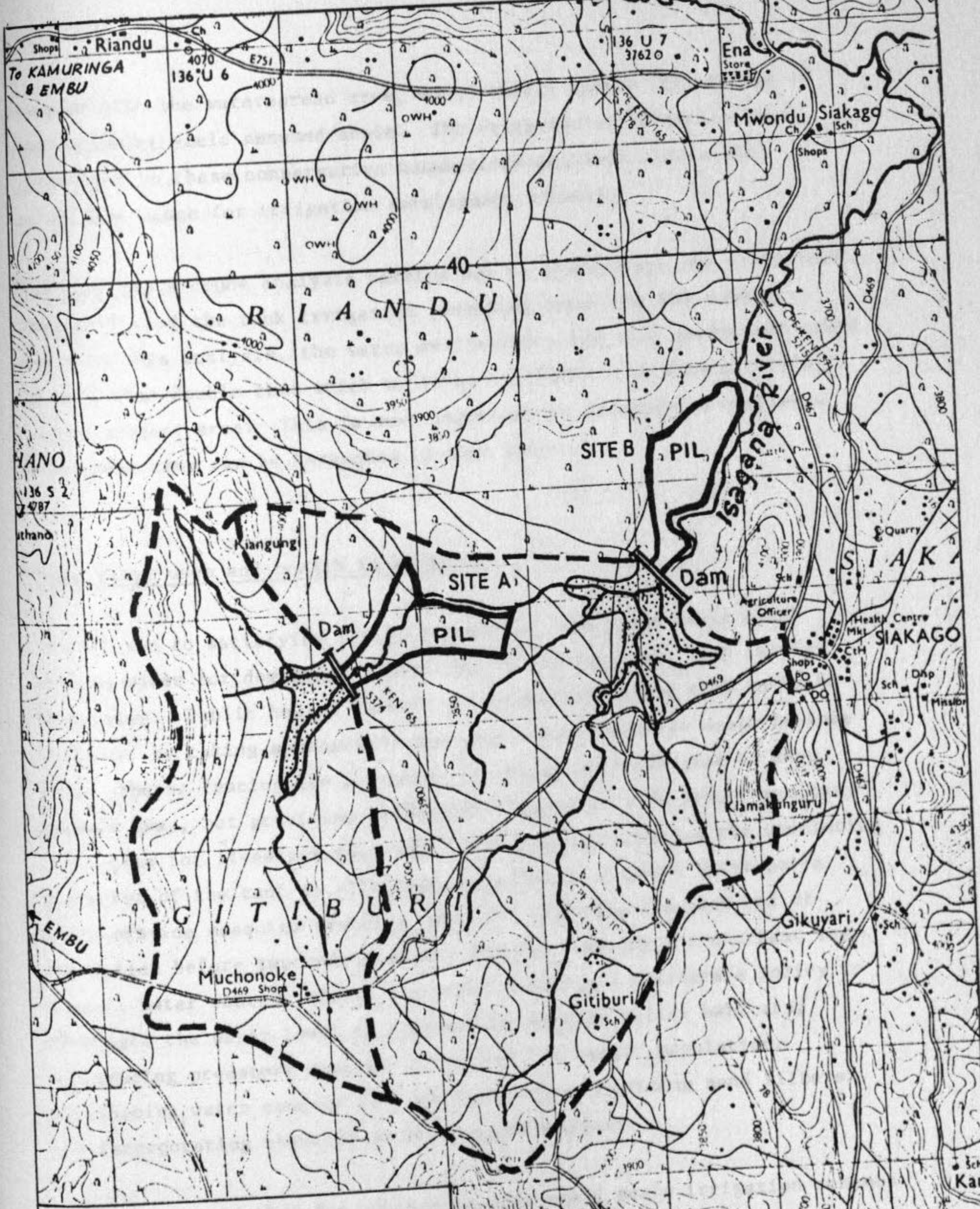
The cost per unit area of the tank technique is greater than of the MHL and T-P techniques, but is still cheapear than existing, conventional smallscale irrigation projects in Kenya and should be tested under Kenyan conditions. In south-east Asia such systems have been in operation for nearly 2 000 years, many in areas receiving less than 750 mm of rain. Using the stored water to supplement rainfall, cropping intensities exceeding 200% can often be achieved. In Tamil Nadu in India, for example, there are some 40 000 tanks irrigating 1 million ha. In EMI, tank irrigation is likely to be a worthwhile proposition, and it should be possible to find a dozen or more sites.

Two possible sites are shown in Text Map 4. They have not been studied to the level required, but are presented to illustrate the scale of operations. Relying only and entirely upon the 50 ft contours in the 1:50 000 topo sheets, two possible dam sites A and B were selected. Waterspread areas resulting from the construction of the dams (maximum height not to exceed about 10 m) and the catchment areas draining into each tank are depicted on the map. In this particular example, A is a subcatchment of B. The hydraulic feasibility of these two sites can be assessed as follows:

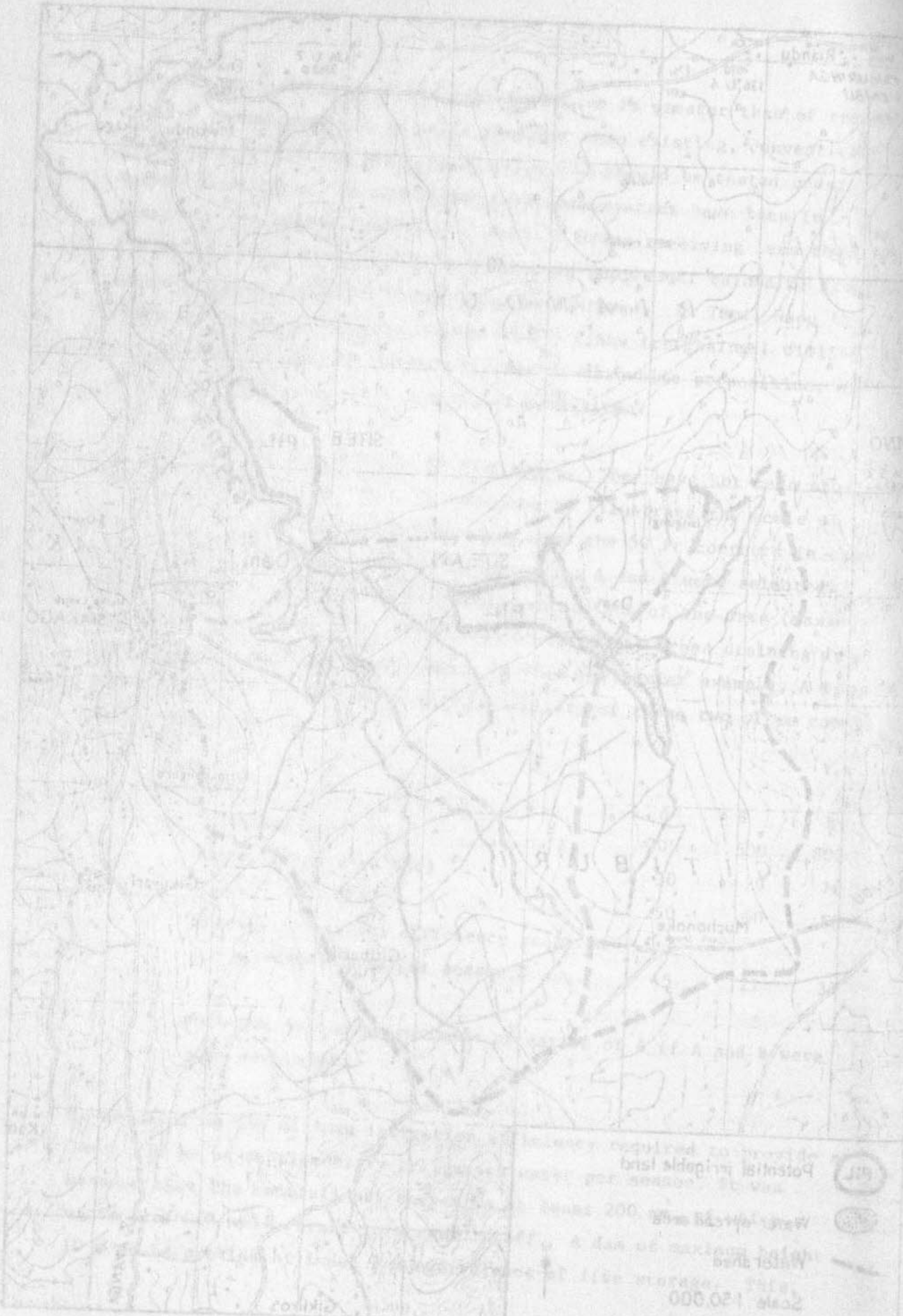
Site	A	B	B*
Catchment area (ha)	700	1 500	800
Water spread area (ha)	30	70	70
Command area (ha)	50	50	50
Minimum irrigation efficiency required to provide 250 mm per season %	45	21	39

B* would be the approximate situation of B if A and B were both developed.

In calculating the minimum irrigation efficiency required to provide at least 250 mm of supplementary irrigation water per season, it was assumed that the rainfall per season is at least 200 mm, of which a minimum of 20% will result in stream runoff. A dam of maximum height 10 m would provide at least 3 m equivalence of live storage. This,



TEXT MAP 4 Two potential irrigation tank sites



TEXT MAP 4   Two potential irrigation tank sites coupled with the waterspread area, would safely ensure the storage of the catchment yield assumed above. The irigation efficiencies thus calculated on these conservative assumptions are well within the acceptable range for irrigation development schemes.

The above is a crude analysis carried out to demonstrate the hydrologic feasibility of the tank irrigation technique under the EMI context. Based on this analysis, the water availability for crop production could be more than double that which would be available from direct rainfall in the project area. This is very important in determining whether a reasonable crop can be harvested in most years.

Other water uses and health implications

In addition to satisfying irrigation demand, the tanks could also provide water for domestic, livestock, recreational and fish farming facilities. Public health hazards are possible but the risk could be minimised by taking appropriate measures. Such measures would include among others: fencing the perimeter of the waterspread area to keep animals away, but providing designated localities with proper sanitary facilities for livestock watering; levelling and draining the undulating perimeter of the tank to eliminate (or reduce) stagnant water holes which provide mosquito breeding habitats; clearing the tank bed of vegetation before impounding water, thereby reducing the nutrient and organic mater content within the tank; adopting a deliberate policy to fluctuate the water level in the tank to destroy vector habitats; introducing predatory species to control the vector population; maintaining water courses free of vegetation; providing sand filters; and incorporating chemical vector control methods.

It is often said that for various reasons small scale irrigation schemes may pose a comparatively greater risk to health than larger projects. Avoidance of health hazards is largely a question of preventive planning, and can be quite inexpensive if properly done from the inception of the project. Most of the above measures can be undertaken by the project beneficiaries by themselves under the communal effort, provided they are sufficiently informed and organised. The alternative is the risk of serious outbreaks of diseases such as malaria, schistosomiasis, gastro-enteritis and other infections transmitted through bad sanitation.

5. COSTS

The proposed pilot project envisages the testing of all three techniques. As indicated in Section 10 of Miscellaneous Report 305, the proposal is to set up two, five and one subproject(s) based on the techniques outlined in 2 (a), 2 (b) and 2 (c) therein respectively. The costs of these sub projects vary considerably according to technique and site conditions.

The volume of civil engineering work associated with the headworks in particular is very much a function of site dimensions, geology, topography and hydrology. As for the irrigation distribution system, the workload is more a function of the extent of irrigation, topography and farm layout.

Unit costs of work items also depend on the site location. Availability and price of labour, accessibility and transportation costs, and proximity to town centres, for example, influence unit prices.

Project costs will also be governed by the choice of the organisation and method of construction. The construction organisations could be private contracting firms, construction units of Government departments, publicly or privately executed force account systems, or community participation schemes, adopted singly or in combination.

Construction costs could vary appreciably according to the construction method and whether capital intensive or labour intensive methods are used.

The pilot projects based on low cost technology are proposed with development in mind. Site selection, organisation and method of construction should therefore be considered in the context of development but bearing in mind the practical limitations.

During the short visit to Kenya, it was not possible to assess with precision the optimum sites to develop and which construction organisation and method to use. An attempt was made nevertheless to estimate the cost of the proposal on a preliminary basis in order to indicate the likely demand for funds should the proposals be implemented.

The cost of a typical project based on each technique was estimated. In doing so, notional site conditions were assumed, based on conditions prevailing at the few sites inspected. Guided by the figures used in the preparation of the Engineer's cost estimates for the Mithungu irrigation project, appropriate unit rates had to be guesstimated. In doing so, some allowance was made for the possibility of adopting labour intensive construction methods based on a government force account system. The effect of inflation was also considered.

A cost breakdown of a typical project under each technique is presented below. The unit rates of work items and the principal dimensions of the work items assumed are indicated whenever possible.

Mini Hydro Lift technique

Item		K.Sh'000
Site clearing and access		10
Temporary river diversions		25
Mass concrete	(40 m^3 @ 1 000)	40
Reinforced concrete	(10 m^3 @ 2 000)	20
Earth excavation	(500 m^3 @ 20)	10
Soft rock excavation	(80 m^3 @ 500)	40
Pipe works		85
Miscellaneous steel works		10
Pumps		125
Pump house		10
Irrigation distribution works	(25 ha @ 5 000)	125
Total		500

Approximately £25 000.

Turbo-Pump technique

Item		K.Sh'000
Site clearing and access		5
Temporary river diversion		10
Excavation		5
Masonry	(50 m^3 @ 300)	15
Pipe works		20
Turbo-pump (3 no)		55
Irrigation distribution works	(10 ha @ 1 000)	10
Total		120

Approximately £6 000.

Irrigation Tank technique

Item		K.Sh'000
Dam site preparation	(7 000 m^2 @ 10)	70
Tank bed clearing	(20 ha @ 500)	10
Compensation for inundated land	(20 ha @ 2 000)	40
Earth work	(35 000 m^3 @ 35)	1 225
Cyclopean concrete	(800 m^3 @ 600)	480
Reinforced concrete	(180 m^3 @ 2 500)	450
Steel works and gates		175
Irrigation distribution works	(50 ha @ 3 000)	150
Total		2 600

Approximately £130 000.

A full schedule of indicative costs for the proposal as a whole is contained in the general report on the visit to Kenya in Miscellaneous Report 305.

6. TIME SCHEDULING OF ACTIVITIES

The time-scheduling of the activities associated with the different subprojects are presented as bar charts in Figures 6-8. In preparing these schedules, notice was taken of the rainy season so the construction work, particularly of the headworks, is minimised during these periods. For convenience, it was assumed that a dry spell of 4 months would be followed by a rainy period of 2 months. It was thus possible to schedule operations with respect to rainy season rather than to a calendar or financial year.

These diagrams attempt to illustrate the nature of activities, their relative duration and their time dependancy on one another. Each subproject is considered in isolation with no reference to other ongoing subprojects but it should be appreciated that when implementing the overall project (i.e. several subprojects using the three techniques in parallel), several of the work items would overlap and the overall project would be far shorter than the sum of the individual subprojects. When planning the entire package, the time sequencing of the activities could differ significantly from that which is indicated in Figures 6-8. In addition to interactions between the subprojects, factors such as inadequacy of counterpart staff, unfavourable weather conditions, labour shortages, work site disputes, non-anticipated construction methodology/ organisational mix and many others could affect the schedules. The schedules presented should therefore be treated only as a preliminary guide.

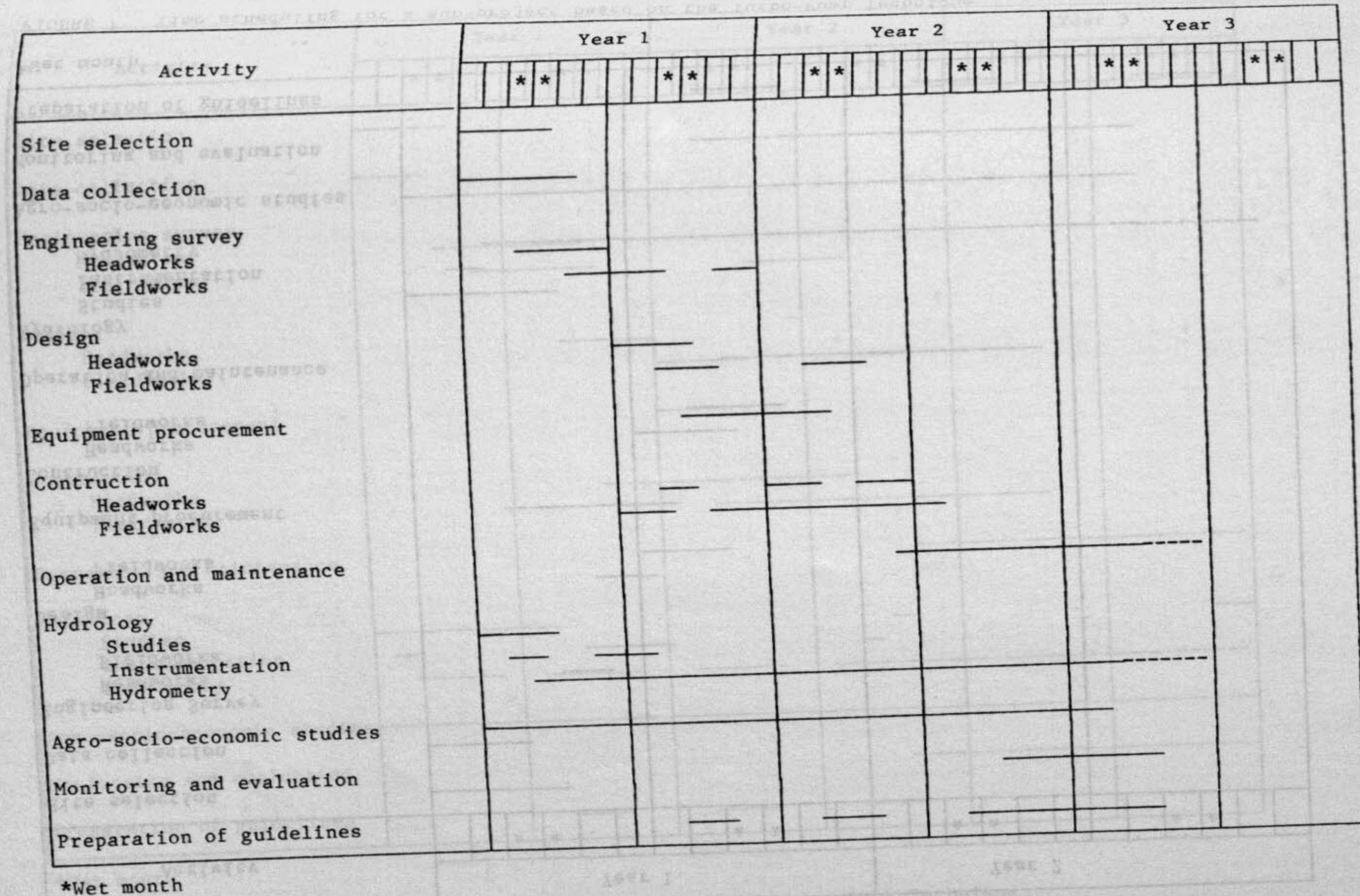
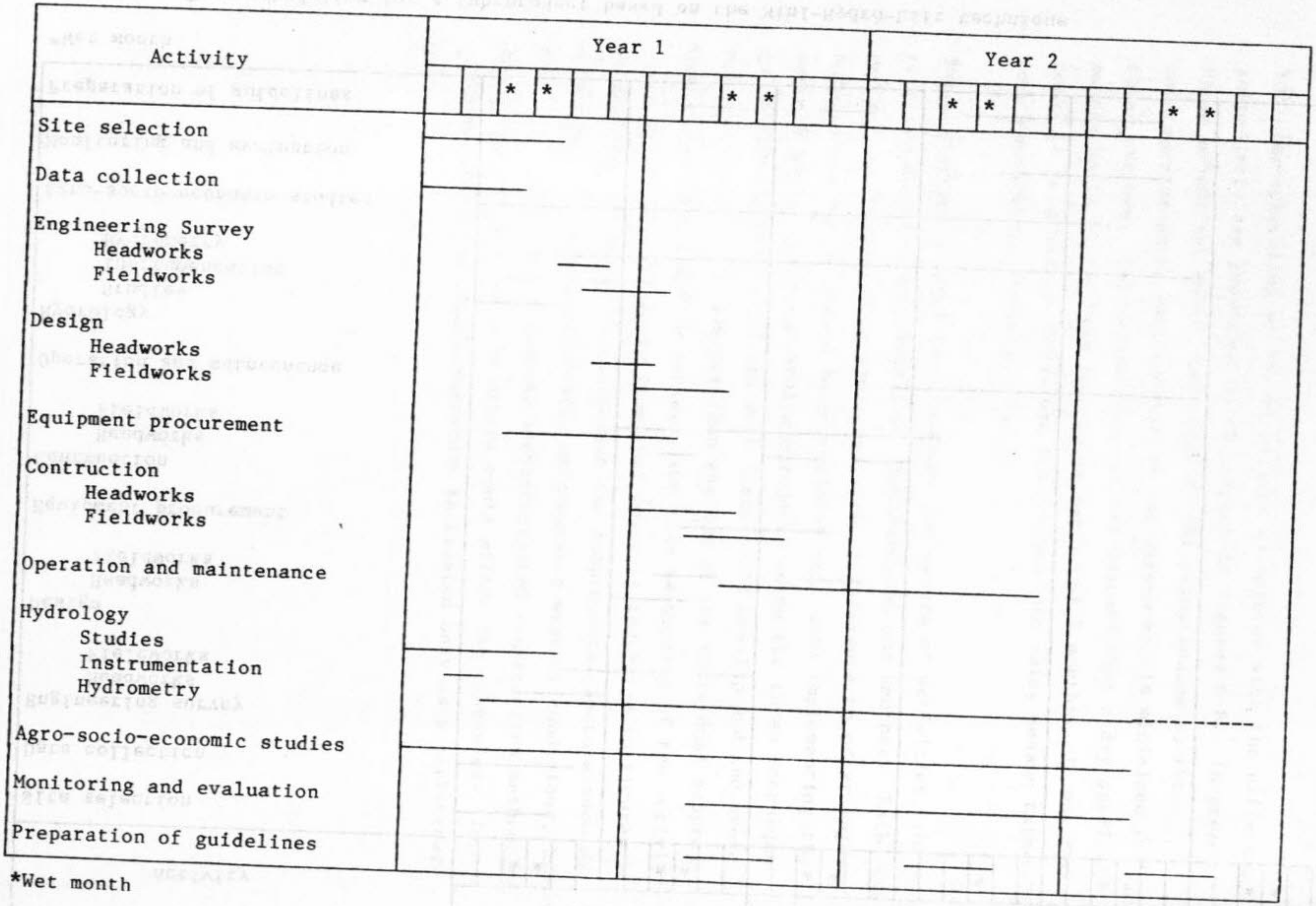
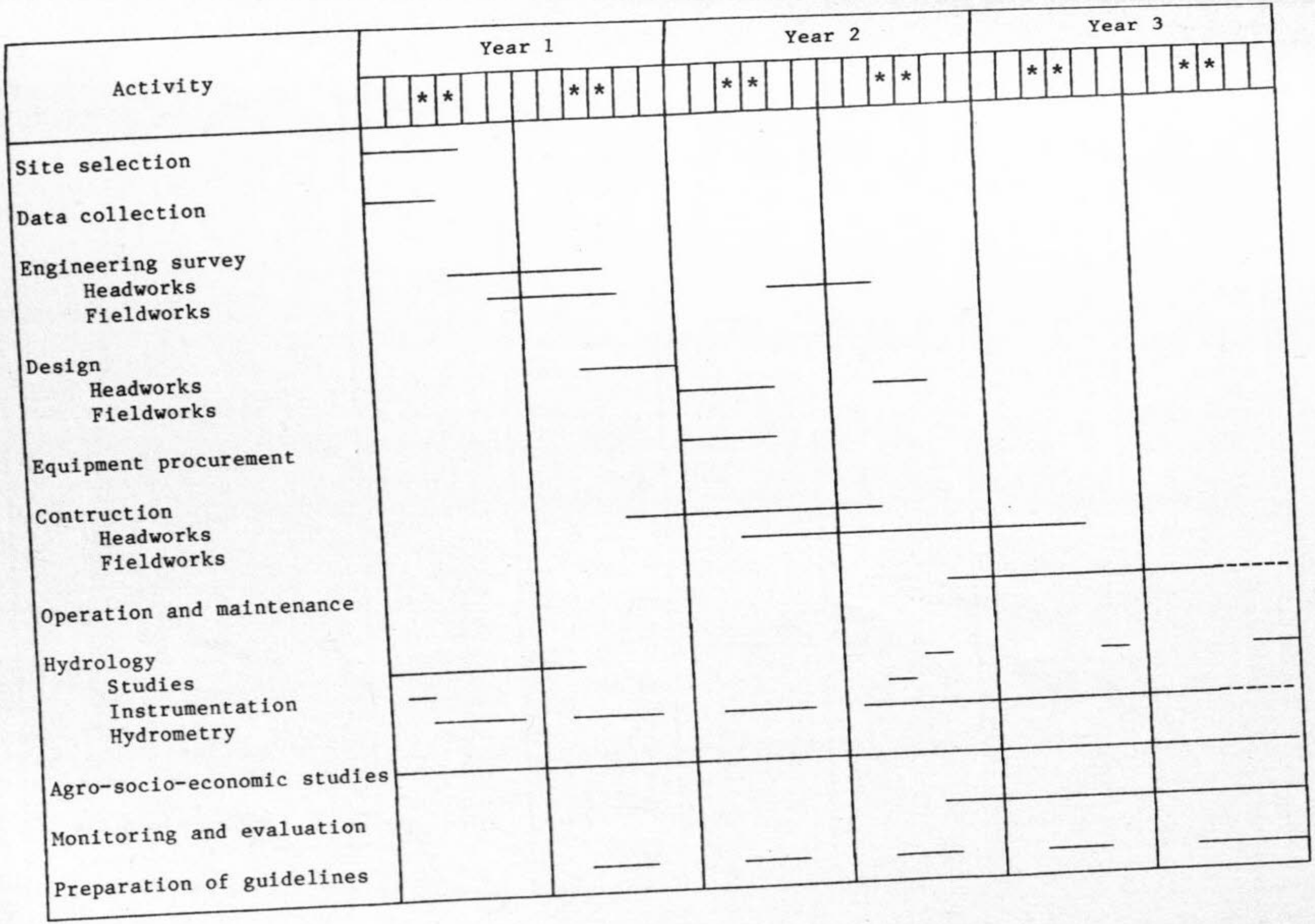


FIGURE 6 Time scheduling for a sub-project based on the Mini-Hydro-Lift technique



*Wet month

FIGURE 7 Time scheduling for a sub-project based on the Turbo-Pump Technique



*Wet month

FIGURE 8 Time scheduling for a sub-project based on Irrigation Tank Technique