SMALL - SCALE IRRIGATION DEVELOPMENT

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WMS REPORT 32

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PREFACE

This study was conducted as part of the Water Management Synthesis II Project, a program funded and assisted by the United States Agency for International Development through the Consortium for International Development. Utah State University, Colorado State University and Cornell University serve as co-lead universities for the Project.

The key objective is to provide services in irrigated regions of the world for improving water management practices in the design and operation of existing and future irrigation projects and give guidance to USAID for selecting and implementing development options and investment strategies.

For more information about the Project and any of its services, contact the Water Management Synthesis II Project.

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The cooperation of various Government of Indonesia departmental officials is sincerely appreciated, particularly the Department of Public Works administrators and engineers. These individuls, too numerous to name, were extremely helpful during the Team's visit to potential project sites. Their attention to the Team's comfort is very much appreciated.

Finally, the activity involved substantial coordination by the WMS II Project, including travel arrangements and production typing. All of these details were facilitated efficiently and have made this experience enjoyable and rewarding.

FOREWORD

This report is an intermediate output of a Water Management Synthesis II Project activity in Indonesia directed toward the development of a small-scale irrigation system project. The writers were asked to evaluate alternatives in West Java, Western Nusa Tenggara (NTB) and Eastern Nusa Tenggara (NTT). In doing so, a strategy for implementation emerged which would, if accepted, lead to a new concept for USAID support of small-scale irrigation projects. This strategy is the primary contribution of this report.

Individual projects were identified in all three provinces, but in most cases the Team felt there was a need for more detailed information, and subsequently recommended a series of initialization studies. This recommendation appears to have been accepted by the Mission, and additional WMS II personnel are scheduled to further the Team's initial effort. Although the Team made some analysis with regard to the economic feasibilty of the project, it was felt that an in-depth evaluation would be premature. Consequently, this report omits a discussion of economic factors except in the general sense. Appendix D is, however, included to illustrate the potential benefits of irrigation developments which support rice and polowijo cropping.

This report also defers the formulation of specific operation and maintenance issues and a program of technical assistance and training related to project implementation and management. The future role of WMS II in the Indonesia Small-Scale Irrigation Project is not clearly defined at this intermediate stage, but the Team feels the opportunities would be very interesting and would hope that a linkage could be established.

EXECUTIVE SUMMARY

General Introduction

Background

The objective of the project is to . . . "improve the Government of Indonesia's institutional capability to increase food production by improving the performance of small-scale irrigation systems. . ." Three institutional elements are considered essential to the accomplishment of this objective. The first is to "deconcentrate," to increase the responsibility of province and district irrigation and agricultural agencies. The second is to improve farmer participation in the irrigation project in order to enhance both on-farm water utilization as well as the operation and maintenance of the diversion and delivery system. The third is to diversify irrigation technologies and designs.

There is an important water management problem associated with small-scale irrigation systems that should be outlined at the outset. Irrigation engineering principles are not easily applied at what might be called the "micro" scale of small systems. The flows are small so that channels and related control structures are simple and usually oversized. Fields are small, level and often irregularly shaped. Major hydraulic issues do not often come into play. Management therefore is more of an "art" than a "science" and experience becomes more valuable than expertise. The result is that irrigators may be more adept and efficient than, say, engineers or agronomists in small-scale system operation and management. This is particularly true at or below the tertiary level of the distribution system and, depending on size, may also be true at the secondary level. Usually, good engineering practices emerge in an important role at the diversion works and primary canal.

Proposed Project Strategy

The fundamental conceptual problem of small-scale irrigation systems mentioned earlier lead to three conclusions and observations directly associated with the provinces of West Java, Eastern Nusa Tenggara (NTB) and Western Nusa Tenggara (NTT). Those are:

1. The hydrologic variations in the typical rainfall-runoff processes should be mitigated to reduce the uncertainty of the water supply for irrigation purposes. This introduces the first of three dimensions in the recommended small-scale strategy -- <u>Augmentation</u> of the rainy and dry season water supply;

2. The technical capability of Public Works personnel will in all likelihood be severely overextended if present plans are put in motion for small-scale irrigation systems. If each small

system is considered a discrete project in which responsibiity is assigned for planning, design, construction supervision, operation and maintenance, and this responsibilty extends beyond the diversion works of the irrigation system, the Department of Public Works will require large and probably unreasonable increases in staff and operating funds. It was found in discussions with Public Works personnel and administrators that this would be difficult. This conclusion gives rise to the Team's second proposed dimension of the strategy -- Decoupling of basic water supply functions and irrigation management; and

3. In order for water resources developed to be effectively used for small-scale irrigation, given the limitations on Public Works noted above, substantial technical, institutional and financial assistance is needed at the village level. This conclusion leads to the third dimension of the proposed strategy -- Farmer operated and maintained small-scale irrigation systems.

It is proposed that the Ministry of Public Works, in terms of this project, adopt as a primary objective the stabilization and augmentation of water flows to small irrigation systems. This does not imply that many Public Works run-of-the-river systems already planned or in progress in areas where small systems are located should be abandoned or neglected, but it does suggest that areas with individual functioning irrigation systems should not be complicated by the further addition of facilities which require Public Works involvement.

This strategy has a number of important advantages. These include:

1. A more regional focus on water resource development leading to higher efficiencies and better equity;

2. A more concentrated and effective use of GOI technical and administrative personnel, particularly focusing their expertise where it is needed most and is more effective;

3. A more rapid implementation of irrigation goals such as expansion and intensification because even without secondary and tertiary components, more reliable water supplies would be distributed faster and over larger geographical areas;

4. Better possibilities for maintenance since fewer kilometers of canals would be constructed initially in sucn an augmenting system; and hopefully

5. A more flexible and responsible system of irrigation; and

6. A more effective use of local capacities and an affirmative approval to the role of local organizations in irrigation development.

This strategy also has two unique features. It would not preclude the traditional irrigation development strategy since it produces the same first phase irrigation works. If the village level unit is not effective as put forth, the system need only be expanded to include the primary and secondary conveyance as currently practiced to form the more traditional project. The second unique feature is that this strategy allows medium- and large-scale project resources and expertise to be focused in the small-scale setting. It can implement some medium- and large-scale projects with far less investment and manpower. One may also argue that it simplifies the function of technical project implementation by standardizing planning and implementation procedures.

One observes that most small systems do not irrigate all the potentially commandable lands and certainly the dry season crops are less intensively cultivated than the wet season paddy. If the main waterway is very large it is unlikely that small systems would divert water from it because of the need for large structures. It may, however, be observed that some farmers are pumping irrigation water directly from the river. The important aspect to consider hydrologically is that the tributary streams are very often non-perennial. One option for augmentation for large run-of-the-river diversions on the perennial waterway involves constructing a peripheral canal connection to some of the tributaries. During the dry season or other low flow periods in the tributaries water is diverted into the individual catchments to stabilize the base flows. This type of augmentation system is probably most adaptable in West Java, but it also has occurred in Central Java as part of a World Bank project near Yogyakarta.

Another augmentation strategy, applicable primarily to NTB, is to build small reservoirs, called embungs, in the uplands of a watershed to collect any excess water duing the wet season that would ordinarily drain to the sea. This stored water can then be resupplied to the stream during dry periods to encourage expanded irrigated acreage as well as double or triple cropping, or it may simply be needed to augment rainfall shortage during the first crop of paddy.

Finally, the option of pumping as a means of augmenting water supplies is proposed. The pumps may supply water from perennial streams or from groundwater. They may irrigate new lands as well as supplement supplies on existing lands. Of course, any particular project area may include any number of these options in a mix favorable to the local circumstances.

These options illustrate the augmentation component of the strategy as well as the decoupling, since the small-scale systems remain intact. In support of this configuration, it is also assumed that the individual small-scale systems may need to be improved to use the augmented supplies better. Technical and financial assistance may be required in case the more reliable water supply would necessitate rehabilitation of the village system beyond their temporary means.

Project Objectives

The larger objectives of increased agricultural production and institutional strengthening are discussed above. Objectives of a specific nature are:

1. To improve reliability and duration of the irrigation water supply to as much as 30,000 hectares of new and existing irrigable lands in West Java, NTB and NTT provinces (based on Repelita IV);

2. To improve the capability of village level organization of farmers to operate and maintain small-scale irrigation systems;

3. To introduce and test several new technologies and institutional arrangements that may address particular problems in the three provinces; and

4. To monitor and evaluate the evolution of the small-scale development strategy to establish the effectiveness of water utilization and system maintenance.

Candidate Projects

West Java

Eight subproject sites are recommended for consideration subject to further assessment: Cikaso Hilir and Cikaso Udik on the Cikaso River; Cibuni Hilir, Cibuni Udik, Cikulina and Cijampang Udik on the Cibuni River; and Cisadea Hilir and Cisadea Udik on the Cisadea River. No subprojects on the Cisokan River are specifically recommended at this point. Since the overall concept of these eight subproject irrigation schemes is the same, the Cikaso Udik Project will be described here to illustrate the West Java components.

The proposed layout for the Cikaso Udik subproject is basically that suggested by Snowy Mountain Engineering Corporation with modifications to reflect the proposed augmentation approach. The Cikaso Udik weir will have an offtake on the right bank. This requires a 200 m long aqueduct over the Cikaso about 2.5 km downstream of the weir, but enables irrigation of 350 ha on the right bank of the Cikaso. The weir will have a crest length of about 35 m and height of about 5.5 m. The main canal system would be about 57.3 km long with a design discharge of 4.75 m^3/s. The majority of the 3,510 ha of net irrigated area lies within a small river basin which feeds into the Cibuni River. The proposed main canal will split with one leg following the contour on one side of this watershed and the other leg following the contour on the other side. Both legs will augment the flows in the small natural drainages of the watershed. Village diversion structures will tap the augmented flow of these natural watercourses. Any water not diverted by a village weir plus any return flow will be available for diversion by village systems lower down.

An economic assessment of the Cikaso Udik and Cikaso Hilir projects produced benefit/cost ratios of 1.7 and 1.5, respectively. However, there is serious question regarding the incremental yields assumed to result from irrigation. Rainfall in the region equals or exceeds 200 mm per month for at least eight months per year. Usually this would be sufficient for two paddy crops and possibly a polowijo crop on residual moisture. This issue needs close examination before a final decision on the projects in West Java is made.

NTB - Sumbawa

The irrigation development program in Sumbawa can follow two broad strategies: (1) simple diversion of river runoff by means of weirs; and (2) storage of excess river runoff in the periods of high flow to be used in the periods of low flow. This will require building reservoir capacity in the form of tanks (embungs). Included in both strategies could be the exploitation of groundwater to increase water supply available for irrigation. However, compared to surface water, the contribution of groundwater will be limited since it is available in only one of the following potential irrigation projects.

Four general projects consisting of one or more components are proposed. The first is the Taliwang complex located on the west coast of the Sumbawa Island. Two relatively major river basins in the complex, Taliwang and Kalimontang, are reported to be perennial, and hence the project proposes to construct diversion weirs and necessary conveyance canals to increase water supplies. Taliwang River is the second largest on the island with good average and dependable flow throughout the year. The total area presently under irrigation is about 2,590 ha, mainly in the lower basin adjacent to the Kalimontang River and downstream of Taliwang. Most of this area receives irrigation in the rainy season and only about 170 ha receive irrigation in the dry season. The major irrigation works being proposed by Public Works consist of a weir on the Kalimontang River irrigating about 850 ha, along with two weirs on Seteluk River irrigating about 1,445 ha upstream of Taliwang Lake. The remaining area (301 ha) is irrigated by village irrigation systems on small tributaries of the main river. The project should make it possible to grow two crops on about 2,590 ha, which presently grows only one crop. Some additional new land could also be brought under irrigation. The project also has the potential to stabilize water levels in Taliwang Lake with a surface area of about 860 ha. Two canals of about 16 km would direct water from the weir to the croplands. The left bank main canal, after irrigating some area in its head reaches, would augment water supples in the Kalimontang weir irrigation system. The right bank main canal would supply water to the Taliwang Lake in addition to irrigating agricultural land.

The Design Team has one primary concern related to the Taliwang Project. First, the proposed site for the weir is such that the main canals will traverse a long distance (about 14 km) through a very narrow valley before they get to the main irrigation area. Transit losses of diverted water may be very high. An alternate design could be relocating the weir further downstream where it is near the main irrigated area and still be able to command the Taliwang Lake. The area upstream of the weir can then be irrigated by lifting water out of the river by means of pumps. Farmers' groups are already using small pumps to lift water and irrigate land areas varying in size from 12 to 30 ha.

An economic analysis of this project could not be made because the costs were unobtainable during the Team visit. However, based on expected benefits, it is estimated that up to Rp. 12,500,000,000 could be invested for a benefit/cost ratio of 1.5.

The second regional focus would be in the Tiu Kulit, Empang and Plampang areas. There are four major river systems draining the area including the Empang River in the east, the Empang West River, the Plampang River southwest of Plampang Town and the Marunge River system in the northwest corner of the area. Each of the river systems has its source in the hills at a relatively low elevation around 500 m. Cultivated land in this region covers about 8,000 ha, and over half the cultivated lands are down to paddy with about 27 percent of the total cultivated lands presently under irrigation.

Given the characteristic flash peaks of the rivers, any further development of surface irrigation would necessarily involve creation of storage capacity in the systems. The stored water then can be used to modify the daily and weekly fluctuations of water supply so that a dependable irrigation is possible throughout the rainy season. Further, the storage tanks can be used to carry over water from the wet season for use in the dry season for small areas of irrigated polowijo crops. Storage tanks (embungs) will be particularly critical in the Empang-Plampang area since no potential exists for exploiting groundwater for irrigation. However, construction and management of embungs will not be easy. The provincial Public Works Department has not had substantial, if any, experience in the design, construction and operation of storage reservoirs. Although most of the design and construction work will be done by the Contractors, Public Works engineers will need to be trained for supervising the design and construction. Further, they will need to develop skills in the proper operation and maintenance of the storage reservoirs. There are some reasons for optimism regarding the economic feasibility of these projects, although they were not evaluated independently by the Team. During field visits to the proposed sites for Tiu Kulit and Muir tanks the Team was quite impressed with the locations. The site for Muir tank is perfect if future subsoil investigations indicate good bedrock for dam foundation and no excessive seepage losses from the reservoir.

The third area is the Pelaparado Basin which drains an area of about 400 sq.km. south of Bima Bay with one major river and two minor tributaries, namely the Pelaparado River, the Keli River and the Tonggo River. The Pelaparado River rises at an elevation of about 400 m and runs northward, entering a large plain near Bima Bay. The average flow in the wet season in the Pelaparado River is only about 500 lps, which is insufficient to irrigate the total available land. In the dry season the flow is virtually zero in the river. Presently about 4,225 ha grows one rice crop in the rainy season out of a total cultivated area of about 8,666 ha. Other popular cash crops grown are onions, tomatoes and soybeans. With irrigation farmers can grow one rice crop and three onion crops, or two rice crops and one onion crop in a year. Market for onions and tomatoes is reported to be very good; a substantial part of the produce is being exported to Kalimontang.

The Pelaparado Basin has a very good potential for irrigation development. The area of irrigated land can be doubled if water is made available. Every irrigation system visited is critically short of water, so much so that in many places farmers actually apply water by hand, using specially designed buckets. The water is obtained from shallow, open dug wells. As such, farmers in this area are very conscious of the value of water and reportedly very efficienct and experienced irrigators. Pelaparado Reservoir could be constructed to satisfy irrigation requirements in the wet season. However, this would only solve the problem in the upper part of the plain along the main stem of the river. To solve the problem in the lower part an interbasin diversion from the Mori River to bring the water into the area downstream of Kalate may be necessary. The water shortage in the tributaries to the right hand side of the main stem (Tonggo and Karanun) cannot be solved with Pelaparado Reservoir, and more small embungs will be necessary on those tributaries.

An option for increasing water supply in the Pelaparado Basin is the exploitation of groundwater. There is good groundwater potential in the basin around Bima. A test bore by the Department of Public Works near Bima and other tests indicate a safe groundwater yield of 40 to 60 lps, which is adequate to grow all polowijo crops, and even rice. As mentioned, farmers are already using groundwater by tapping the shallow aquifer. These shallow, open wells dug by farmers are about 6 m deep and each well irrigates about 1/4 ha of onions or a tomato crop. If the wells were a little deeper (10 to 15 m), with water being lifted by surface mounted small pumps, the area irrigated by these shallow wells could be dramatically increased. Further, water loss in the farm distribution system could be completely avoided by the use of PVC pipes. In addition to the open dug wells, tubewells can be successfully used to exploit the deeper aquifers. Application of both shallow and deep tubewells should be investigated. Shallow tubewells might be more desirable as small groups of farmers can purchase and conveniently manage this technology. Deep tubewells will require greater assistance, and even funding, by the Department of Public Works.

This complex of projects would cost between Rp. 1,500,000 and Rp. 2,000,000 per hectare and would, if limited to this range of cost, yield a benefit/cost ratio of about 1.1.

The final proposed projects fall in Sape and Sumi River basins. In the Sape and Sumi basins, land suitable for irrigation is about 4,000 ha, of which about 1,820 ha are presently under irrigation. All of the area under irrigation grows one rice crop in the rainy season and about 500 ha grow another crop during the dry season. The major benefit of the proposed irrigation project will be to increase the amount of cropped area during the wet season to about 2,625 ha, and that during the dry season to about 1,500 ha. Two storage reservoirs, one on e- river, are proposed to regulate river flows in the wet season and provide irrigation water for the dry season.

The Sape Reservoir would lead to an increase of wet season irrigated rice by 500 ha and it would add 600 ha of second crop on land not previously double cropped. The benefit/cost done by FENCO assumes an increase of yield from 4 to 5 tons per ha on irrigated rice and a switch from dryland polowijo to paddy for 500 ha. The yearly increase in net farm income was figured to be Rp. 882,500,000. The present value of such an income stream (ending in 30 years) would be about Rp. 8,295,760,000. The benefit/cost ratio for this project would reach 1.0 only if the project were to be completed within two years. This assumes the value of benefits are valued at Rp. 6,856,000,000. Thus, investment in the Sape Reservoir is not recommended based on the existing data and analysis.

The Sumi Reservoir Project is also designed to move from dryland polowijo to double crop paddy (1,800 ha) along with 700 ha of single crop paddy to double crop paddy. The calculated present value of the incremental net farm income is Rp. 6,978,000,000, as compared with a present value for incremental costs of Rp. 6,481,000,000, for a benefit/cost ratio of 1.08.

NTT - Timor

The guiding principles in outlining proposals for development in Timor have been the extremely limited institutional infrastructure, very limited technical information and a relatively undeveloped farming system. The strategy proposed is one of initiating a series of discrete activities to gain some developmental experience and to build an information base for future development. The proposals seek to build on the strongest elements, both institutional and socio-economic.

The first set of activities is recommended for lift irrigation in the Oesao Plain. The Oesao Plain is situated east of Kupang, skirting the Kupang Bay, and is drained in the Kupang Bay by several rivers, the largest being the Oesao and the Airkom. This area is well connected with Kupang by the Kupang-Atambua Highway. Several fair weather roads provide access to the Plain from the main highway. Lack of irrigation is a limiting factor to agricultural intensification in the Oesao Plain. In the wet season the surface water resources, if tapped properly, are adequate to meet the irrigation requirements. In the dry season, however, surface resources nearly dry up and alternatives must be found to provide irrigation.

Project activities would include installation of several infiltration wells on the banks of the Oesao and Airkom rivers. The wells would be 3 to 5 m in diameter and up to 10 m in depth. The wells would be protected against river flooding, where necessary. An infiltration gallery would be built across the riverbed to draw wet season surface flows and dry season subsurface flows into the well. Each well would be mounted with a portable diesel engine pump, sized to irrigate 25 to 30 ha on the wet season. (Along the Airkom River and its tributaries, where the Crippen Study indicates groundwater is available, 150 mm PVC tubewells might be installed to augment dry season water availability.) The infiltration wells would be located in regions not served by existing weirs during the wet season and where the wells would require least protection against flooding. The wells and pumping systems would be installed by the Public Works and handed over to a village water user association for operation and maintenance following the pattern in Central and East Java.

A second set of activities is suggested in the Pariti Plain at the northern extreme of the Oesao Plain, about 15 km southeast of the Biboko River. The region is recently settled and some settlement activity is still going on along the way to Pariti. Transportation is through a fair weather road which branches off from the Kupang-Atambua Highway. Approximately 600 ha of land capable of intensive agriculture is available in Pariti. The soils are deep alluvial and alluvial marine sediments.

The Crippen Study found no groundwater resources in the area, although they did encounter an unconsolidated dry formation between 7 to 17 m deep. Static water levels in shallow dug wells during field visits were found to be at 4 m. Conventional diversion weirs would in all probability be technically difficult and economically infeasible. In any event, as development would require substantial in-migration, only a phased strategy of development would be advisable. The alternative technologies are most suited to such a strategy, but further investigations are needed to establish the feasibility of these alternatives.

NTT - Flores

This program activity would be for the purpose of assisting the local Public Works Seski office development capacity to systematically assist the many small village systems that exist throughout the district. Funds would be channeled through some mechanisms such as the Bupati or the Bappeda with technical assitance coming from the Public Works Department. A small number of technical staff (perhaps graduates of technical high schools) would be added to the Seksi staff to perform this service role. Work on this topic may be timely given the suggestion that a decree may soon be issued giving Public Works explicit responsibilities to support village irrigation.

The Team was strongly urged to consider supporting a project in the Mautenda River Basin which would eventually command 7,200 ha. This is more than double the present sawah area for all of Kabupaten Ende and nearly eight times the present area being served by Public Works systems. The Team felt that this would be too large of a project at this stage of development in Flores. For this reason, and the fact that the population in the Mautenda area would have to more than double in order for there to be enough farmers, the Team recommends a slower pace of activity in Kabupaten Ende, which would involve the upgrading of existing village irrigation systems through improvements and possible primary canals. The Team believes, given the large land and water resource of the Mautenda River Basin, that actual expansion and intensification will occur with the implementation of the suggested small-scale irrigation improved diversion technologies (improved low cost weir, inverted weirs and pipe system and diesel powered lift system). These technologies would be especially appropriate in the Mautenda area where the course of the rivers can change every year, totally bypassing a diversion structure. A pump system can be moved to the water source. The other two alternatives are inexpensive enough to build to span a wide river.

The overall strategy suggested for NTT is to plan the above activities for the initial three years of the project. Following that period an assessment would be made of accomplishments and new opportunities considered for implementation during the second phase of the project.

Project Implementation

The developmental strategy proposed herein creates a need for a larger scale planning and design process plan than is currently being undertaken. Most of the consultant reports and project plans deal with the main diversion of storage facilities and to a lesser extent, the primary elements of the distribution system. What appears to be lacking is an accurate assessment of the nature and configuration of the existing and potential irrigated systems below. Consequently, the Team proposes a phased project implementation beginning with a more complete detailed design. It is recognized that in each of the proposed project sites the Public Works already may have various elements of the project at the detailed design stage, or even under construction. The Team does not suggest these activities be necessarily ended or delayed, but that a review be made to determine what modifications might be made to more closely conform to the augmentation strategy.

Phase 1 Detailed Design

It is proposed that the Small-Scale Irrigation System Project at all locations initiate, as it were, with a "Year-Zero." Upon executing the loan agreement USAID technical assistance teams should assist the Public Works Department in conducting the following detailed design studies (it should be noted that aspects of the following information will be collected for inclusion in the Project Paper, well in advance of "Year-Zero"):

1. A thorough land use inventory of each watershed where a project might augment the water supply. The land use data should be determined for each existing irrigation system in the area, whether public or private. Potentially irrigable land under each system should also be identified. Aerial photos can serve as the basis of this study;

2. An operation and maintenance needs assessment should be made of each small system diversion and primary distribution channel. This information should be utilized to formulate a plan for rehabilitation requirements at the village level under the project;

3. A baseline study of the project's social characteristics should be made to identify the nature of existing user organizations and land tenure status;

4. An integrated development plan for each watershed under the project should be developed using the results generated in the studies noted above. This plan should show the location and alignment of structures in the entire system and how they will be integrated with the major project improvements. The plan should devise operational rules for augmentation, particularly in view of existing water entitlements, and as a contingency plan for periods of severe flooding or drought; and

5. A more comprehensive economic analysis should be developed which would consider the entire watershed impact including secondary impacts due to enhanced streamflow.

The time required to complete Phase 1 will vary substantially depending upon work already completed under various projects. It will undoubtedly be desirable to accelerate the work on a number of projects so they can move into the construction phase. In fact, the manpower and budgeting constraints on an implementation agency like Public Works are such that many activities must be concurrent. Thus, Phase 1 may be completed within as little as two to three months for projects already being planned and then extended project by project over the following years of the overall project. This will require that Public Works develop a priority for potential projects and formulate a longer term plan for its integrated planning-implementation process.

Phase 2 - Augmentation

Based on the results of Phase 1, construction of the diversion, storage and conveyance structures needed to augment the water supply in the entire project area should be undertaken. Major diversions, tanks and primary conveyance should be constructed and begin operation ahead of any rehabilitation at the small system level. Although the operation and maintenance needs assessment will have identified the individual systems requiring attention, it is suggested that they not be made until after the entire augmentation development is completed except where the augmented flows are high enough to prevent construction of the diversions of the private small systems.

Phase 3 - Small-Scale System Readjustment

It is important to note that the development strategy proposed in this report places substantial responsibility for diversion and use of water on the village level system itself. The long-term success of this strategy requires that the individual system remain intact and therefore organize its own resources to make irrigation viable. Thus, the Team would suggest that some time be allowed for the village system to adjust to the more reliable water supply in order to establish just what they can mobilize to do and just what further support they may require. It is felt strongly that governmental intervention and assistance be limited and based on carefully demonstrated need. This is not to say that Public Works should withhold its technical expertise from the irrigators. On the contrary, it should establish a technical assistance team to offer technical advice and suggest alternative measures to improve the village system.

Phase 4 - Small-Scale System Rehabilitation

Following the adjustment of the village system to the augmentation strategy, funds should be provided for the resolution of critical structural problems at the village level.

Monitoring, Evaluation and Testing

In many cases irrigation development processes end when the systems are constructed. The systems are generally operated and maintained, but they are seldom evaluated to identify the strengths and weaknesses of the planning-implementation process. The following paragraphs in this section will suggest a set of activities for monitoring, evaluating and pilot testing of these systems. The Team recommends that Public Works conduct critical reviews of its small-scale projects to determine how the project implementation functions might be modified and improved. The evaluation of pilot scale tests of alternative technologies might, for example, lead to changes in structural as well as operational design policies.

Preproject Baseline

In addition to the information contained in the Phase 1 task described above, there are a number of hydrologic measurements that need to be made. The magnitude and distribution of local streamflow (hydrographs) should be monitored to determine the existing nature of the water supply. Groundwater resources should be further explored. In sample cases conveyance losses and irrigation efficiencies should be measured. A number of agronomic factors such as soil types, fertility and farming practices should be evaluated. Together with the Phase 1 data, a comprehensive picture of the preproject condition should be made. These data provide the basis for selected simulation which might yield some insights as to how the systems will react to the project.

Monitoring and Evaluation

The Team suggests that sample small systems be monitored throughout the life of the project. Measurements of cropping patterns over time will establish the expansion and intensification produced by the project. The volume of augmentation should be measured at the diversion points and compared to the diversion made at the inlets to individual systems to evaluate the augmentation as a function of its timing and in relation to the small systems' individual characteristics.

Special Studies

Several tests of alternative technologies have been referenced and outlined in the body of the Team report. Replacing masonry open canals with buried PVC, pumping directly from streams, alternative run-of-the-river diversion structures and groundwater development at various scales have been suggested. Others might include automation of the peripheral canals to be self-operating or the introduction of computer assisted management for design and training. Few of these can be formulated precisely until a project begins to emerge and personnel are better trained.

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SECTION I

PROJECT CONCEPT AND SCOPE

General Introduction

Background

Irrigation is a major factor in Indonesian agriculture. The configuration of most projects involves a diversion weir in the river or stream with primary and secondary canals leading diverted flows to croplands along either or both sides of the waterway. The need for irrigation increases from a supplemental nature during the rainy season to a primary source of water afterwards. As with irrigation projects worldwide, system performance often suffers from inadequate attention to operation and maintenance, as well as the difficulty in establishing an effective interface between the government project and the irrigators.

The Government of Indonesia (GOI) recognizes in its irrigation sector goals the need to increase food production by increasing the area of cropped land and the intensity of cropping on existing lands. To accomplish these goals, consideration will be given to irrigation developments in addition to run-of-the-river systems. Two basic options exist. The first is to augment surface water supplies currently being utilized with groundwater development, small storage reservoirs (tanks or embungs) and surface flow lift schemes. The second is to increase the efficiency of irrigation systems through improved on- and off-farm water management practices. Typical efficiency measures include channel lining or piping, greater attention to actual crop water requirements and better matching of field and soil characteristics with the frequency, rate and duration of the irrigation water supply.

The proposed USAID-GOI "Small-Scale Irrigation Systems" project is consistent with the broad agricultural sector goals in Indonesia. "Small-Scale Irrigation Systems" are those typically encompassing less than 1,000 hectares (ha), but most often in the range of 50 to 300 ha. The stated objective of the project is to ". . . improve the GOI's institutional capability to increase food production . . . and implement improvements, including alternate water delivery options. . ." Three institutional elements are considered essential to accomplishing this objective. The first is to "deconcentrate," or to increase the responsibility of province and district irrigation agencies. The second is to improve farmer participation in the irrigation project in order to enhance both on-farm water utilization as well as the operation and maintenance of the diversion and delivery system. The third is to diversify irrigation technologies and designs.

There is a difficult water management problem associated with small-scale irrigation systems that should be outlined at the outset of this report. The problem has two aspects. First, irrigation engineering principles are not easily applied at what might be called the "micro" scale of small systems. The flows are so small that channels and related control structures are simple and usually oversized. Safety and cost considerations are generally minimal so that detailed engineering is not needed. Fields are small, level and often irregularly shaped. Major hydraulic issues do not often come into play. Management, therefore, is more of an "art" than a "science" and experience becomes more valuable than expertise. The result is that irrigators may be more adept and efficient than engineers or agronomists in small-scale system operation and management. This is particularly true at or below the tertiary division of the distribution system, and depending on size, may also be true at the secondary level. Usually, good engineering practices emerge in an important role at the diversion works and primary canal. In small systems the optimal combination may be a good engineering design with operation and management left to the collective judgment of the irrigators.

The second aspect of the small system management problem is that the need for maintenance is less obvious to the irrigator, and therefore almost universally neglected. Further, it is less challenging to the engineer from a technical point of view and certainly not funded adequately by most irrigation agencies. Thus, it is not uncommon to hear project officials express a desire for farmers to assume more of the maintenance role and farmers wishing the project would maintain what they designed and implemented.

The result of these symptoms is that a clear, carefully defined and highly effective transition of water control between the supplier and the user is not easily accomplished. In the cases where it appears to function effectively, one is likely to encounter one or more of the following factors: (1) the users are motivated to act and communicate effectively, often through strong community organizations; (2) the system has been designed and maintained to maximize the flexibility for accommodating variable flow rates, watering frequencies and the time one has access to the supply; (3) water itself is considered a valuable resource in the economic sense, occasionally even marketable; and/or (4) a sense of "property" is felt among the users toward the system as a whole.

These views and assertions will lead in the following sections to a proposed small-scale irrigation system strategy which is admittedly not new. The strategy is based on the somewhat unique conditions in Indonesia, but is considered a viable approach to water resource development for agriculture throughout Asia.

WMS Design Team Scope of Work

The composition of the Team is described on the title page of this report. USAID/Indonesia prepared detailed scopes of work for each of the Team members, a summary of which is attached hereto as Appendix A. It should be noted that as indicated on the title page, the senior irrigation engineer and senior sociologist shared the role and responsibility of team leader.

In less detailed terms, the Team collectively viewed its terms of reference as a task of preparing recommendations for various small-scale irrigation system activities in three provinces: (1) West Java; (2) Eastern Nusa Tenggara (NTB); and (3) Western Nusa Tenggara (NTT) (see Figure 1). This effort was guided by a perception that while the primary institutional linkage would couple USAID and the Ministry of Public Works, the principal institutional strengthening should occur at the provincial and village levels. Further, that innovative technologies should be incorporated and tested as part of the project.

Summary of Effort

In addition to the preparation of this report, the design Team collected and reviewed an extensive body of literature describing proposed developments and developmental policy (including its legal framework). Numerous discussions were held with GOI officials, provincial and district personnel, consultants, university staff and farmers. Site visits were made in each of the three target provinces and a number of individual project sites were examined. Follow-up discussions were held to test the appropriateness of the Team's ideas for the project design as well as the accuracy of its assessments. A detailed itinerary will not be given. Individual trip reports are on file with the WMS II administrators.

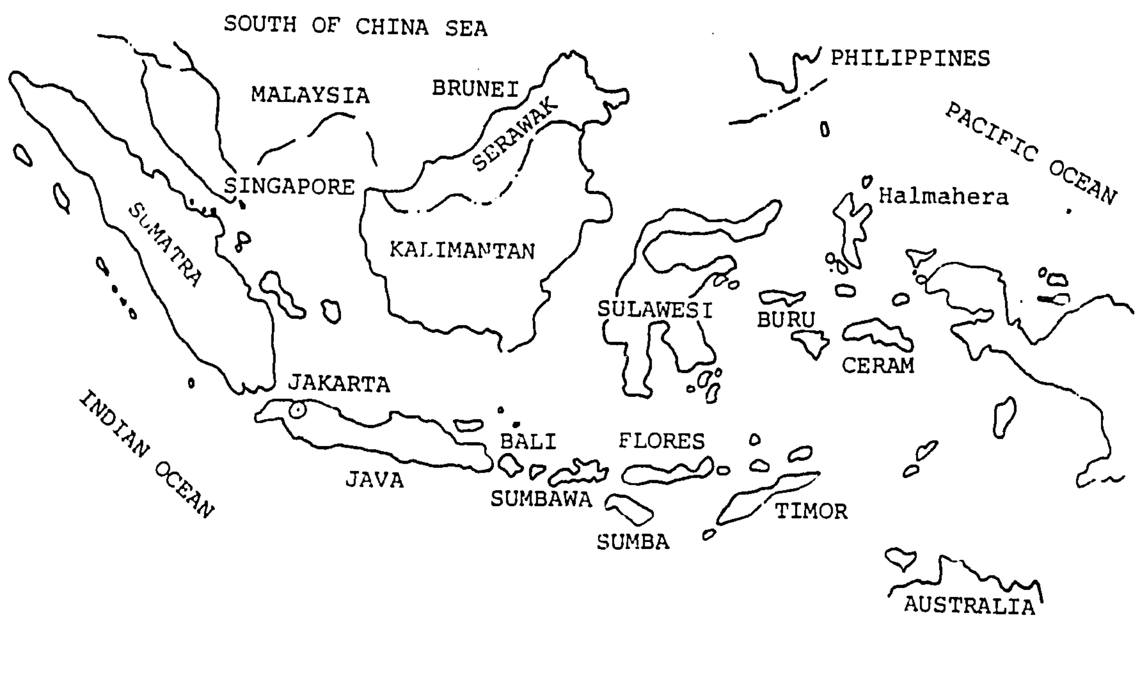

Figure 1. Location and setting of Indonesia.

Proposed Project Strategy

The fundamental conceptual problems with small-scale irrigation systems discussed earlier, as well as the issues and problems observed with regard to present programs of small-scale irrigation development in West Java, NTB and NTT, suggest a program strategy based on the following three components.

The Augmentation Component: There is a need to mitigate the hydrologic variations in the typical rainfall-runoff processes that occur in these three provinces to reduce the uncertainty of the water supply for irrigation purposes in both the "wet" and "dry" seasons. The techniques for augmentation will vary between provinces, and perhaps between subprojects, in a single province. In general, responsibility for planning, executing and managing the augmentation facilities will be with the technical staff of the Department of Public Works, hereinafter referred to as Public Works. USAID project assistance may include financial assistance, technology transfer and staff training, for example, with regard to the operation of the augmentation facilities.

The Decoupling Component: It appears that under the present Public Works policies for small-scale irrigation development a point will soon be reached where the technical staff will be overextended in their mandate to operate and maintain these many small and dispersed schemes. When each small system is considered as a discrete subproject with Public Works responsible for planning, design, construction supervision, operation and maintenance, and this responsibility extends beyond the diversion works into the commands of these small systems, there is a corresponding need for large and probably unreasonable increases in staff and operating funds. In contrast, it is noted that in many of the potential subproject sites there are preexisting local organizations for irrigation management -- some form of village or farmer irrigation institution. When Public Works assumes direct responsibility for actions at and below the small-scale diversions there is a strong tendency for these local organizations to be displaced. The decoupling component of the strategy is intended to develop a clear set of rights and responsibilities for both Public Works and the local irrigation organizations. The Team's recommendation is that Public Works be responsible for the augmentation facilities up to the upstream side of the small-scale diversion works. The small diversion facility and the downstream command area will be the responsibility of the local organization. USAID project assistance may include technical assistance to better define the policies and administrative procedures required to implement this decoupling concept and support needed staff training for concept implementation.

The Capacitation Component: The first two components will operate successfully only if the local irrigation organizations have the capacity to respond and adjust to the new water supplies planned to be more abundant and reliable. There may be need to upgrade physical facilities, modify agricultural patterns or evolve new institutional arrangements as the result of both augmentation and decoupling. Some local organizations will have the capacity to respond to the improved situation and use water at least as efficiently as a system under the management of a public agency. Other local organizations may be able to achieve this performance only with external assistance. The capacitation component of the program is intended to provide local irrigation organizations with the assistance they require to be able to effectively operate in the improved irrigation environment. The Team suggests that this external assistance should include three items: financial aid, technical assistance services and institutional development support. USAID project assistance may include financial support for local level construction, the staffing and training of agency technical service units and support for the establishment of community organizer-like activities.

It is therefore proposed that where possible, under the widely varied hydrologic, agronomic and socio-economic conditions in West Java, NTB and NTT, the Public Works adopt, and USAID provide assistance to, a program of small-scale irrigation development based on the above three program strategies. Under this program Public Works would give major attention to the development of augmentation facilities to improve the amount and reliability of water supplies to small irrigation commands and support local irrigation organizations in remaining or becoming viable and autonomous bodies for using the improved irrigation supply.

Under this program government would have the primary role of insuring the supply of irrigation water to existing and new local groups of irrigators. It would also provide and enforce an equitable access to the water resource among all the interests within a watershed and develop policies for allocating shortages between small-scale systems. Local organizations would be given clear rights and responsibilities for all system facilities at the local level in harmony with a historical principle in Indonesia of local irrigation responsibility.

This strategy may be seen to have the disadvantage that it will require a higher level of operational skill on the part of Public Works staff and, therefore, create the need for specialized training in main system management. Others may worry that the strategy is overly dependent upon local organizations which are certain to be uneven in their capacities and performances. However, neither of these are insurmountable problems and the Team concludes that the proposed strategy enjoys a number of important advantages. These include:

1. A more regional focus on water resource development leading to higher efficiencies and better equity;

2. A more concentrated and effective use of GOI technical and administrative personnel, particularly focusing their expertise where it is needed most and is most effective;

3. A more rapid implementation of irrigation goals such as expansion and intensification because even without secondary and tertiary components, more reliable water supplied would be distributed faster and over larger geographical areas;

4. A more effective use of local capacities and an affirmative approach to the role of local organizations on irrigation development;

5. Better possibilities for maintenance since fewer kilometers of canals would be constructed in augmenting systems; and hopefully at least,

6. A more flexible and responsive agriculture.

This strategy also has two unique features. It would not preclude the traditional irrigation development strategy since it produces the same first phase irrigation works. If more technical manpower is available to Public Works than the Team estimates, or if the village level unit is not effective as put forth, or if any other local condition dictates, the Public Works system need only be extended into the primary and secondary conveyance as currently practiced to form the more traditional project. The second unique feature is that this strategy allows medium- and large-scale project resources and expertise to be focused in the small-scale setting. It can implement some medium- and large-scale projects with far less investment and manpower. One may also argue that it simplifies the function of technical project implementation by standardizing planning and implementation procedures.

It may be helpful to illustrate some examples of this concept. Figure 2 postulates a "typical" watershed in either the southern part of West Java, NTB or NTT. Development of irrigated lands is shown to have evolved from the individual efforts of communities. Also, it may very well be the case that some of these systems have a government initiated origin (Sederhana, for instance). One observes that most small systems do not irrigate all the potentially commandable lands, and certainly the dry season crops are less intensively cultivated than the wet season paddy. If the main waterway is very large, small systems may not divert water from it directly because of the need for large structures. It may, however, be observed that some farmers pump irrigation water directly from the river. The important aspect to consider hydrologically is that the tributary streams are very often non-perennial.

Figure 3 illustrates one option for augmentation involving a large run-of-the-river diversion on the perennial waterway and a peripheral canal connecting it to some of the tributaries. During the dry season or other low flow periods water is diverted into the individual catchments to stabilize the flow. In the three provinces being considered, this type of augmentation system is probably most adaptable in West Java, but it also has been used on a limited scale, for instance, in Central Java.

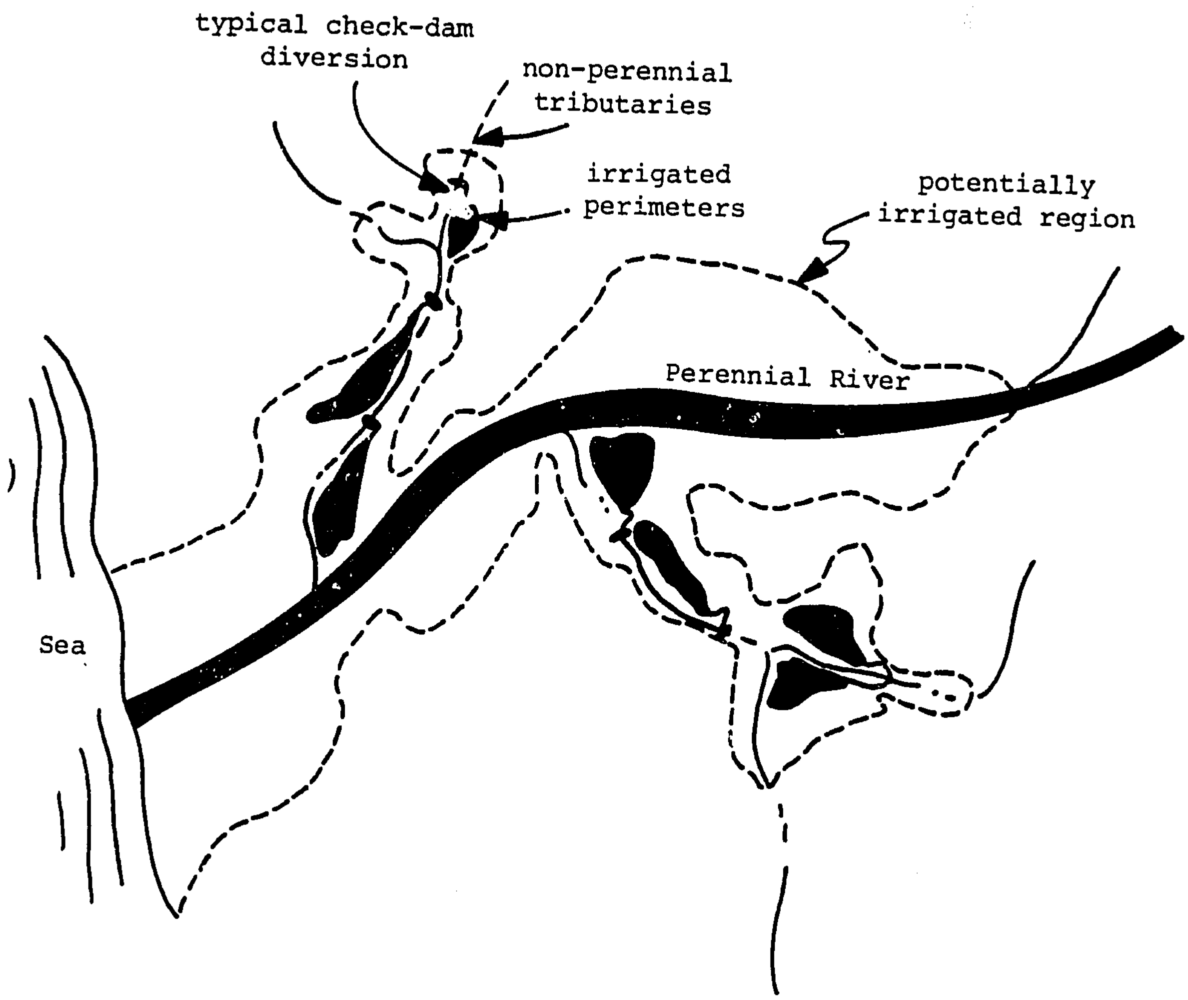

Figure 2. Typical watershed in West Java, NTB or NTT where development has occurred as an aggregation of small-scale irrigation systems.

Figure 4 represents an augmentation strategy applicable primarily to NTB. Small reservoirs called "embungs" are constructed in the uplands of a watershed to collect any access water during the wet season that would ordinarily run into the sea. This stored water can then be resupplied to the stream during dry periods to encourage expanded irrigated acreage as well as double or triple cropping. It may also be needed to augment rainfall shortage during the first crop of paddy.

Finally, Figure 5 is given to illustrate the option of pumping as a means of augmenting water supplies. The pumps may supply water from perennial streams or from groundwater. They may irrigate new lands as well as supplement supplies on existing lands. Any particular project

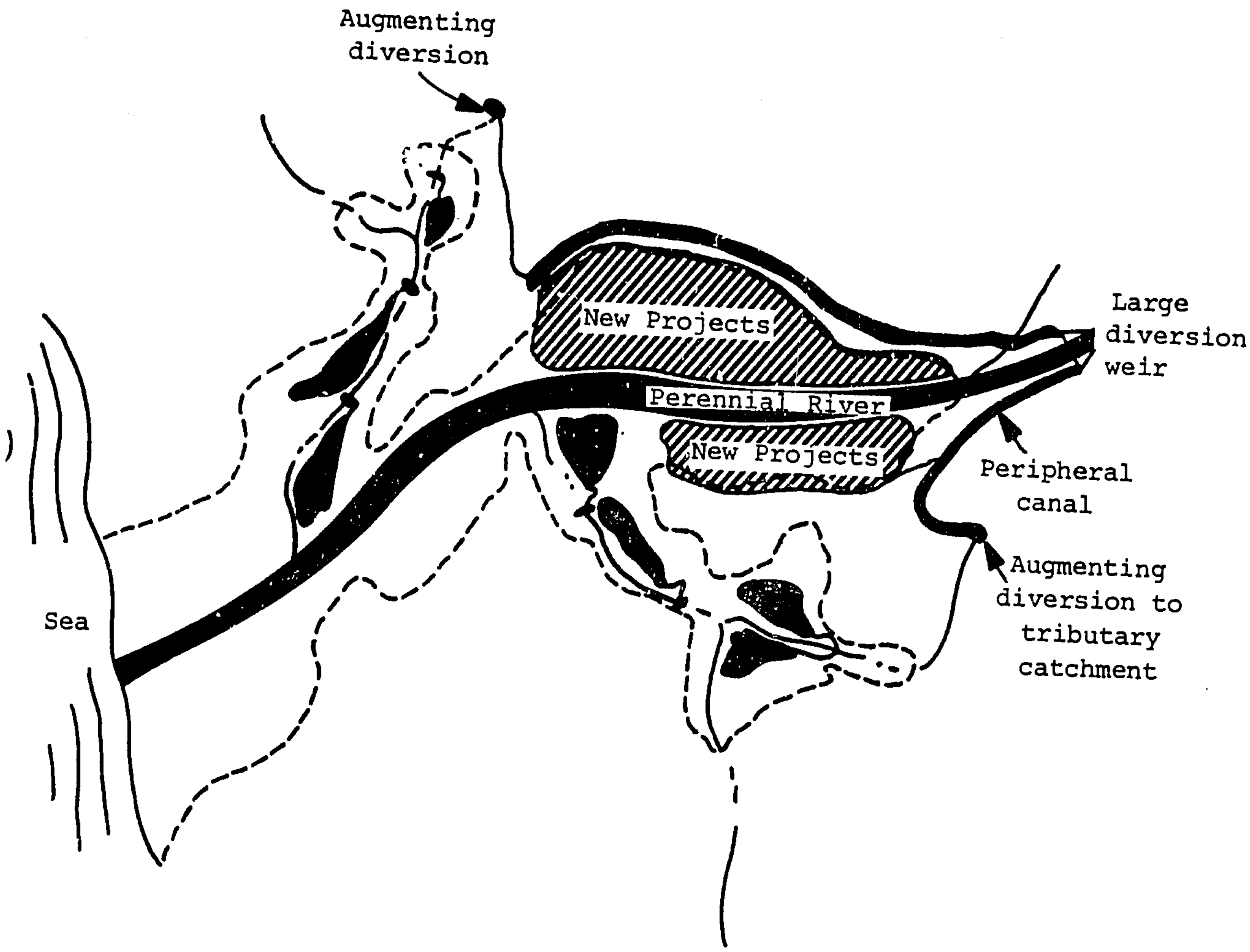

Figure 3. Augmentation of the system using a large diversion weir and peripheral canal, including the development of new irrigated areas.

area may include any number of these options in a mix favorable to the local circumstances. Figures 2 through 5 illustrate the augmentation and decoupling components of the strategy. The small-scale systems remain intact. In support of these configurations, it is also assumed that the individual small-scale systems may be improved to use the augmented supplies better. Technical and financial assistance should be available in case the more reliable water supply requires some rehabilitation of the village system beyond their temporary means, or it causes cropping patterns to shift. Outside assistance may be needed to develop mutually agreeable means for individual small systems to share water along a segment of the waterway.

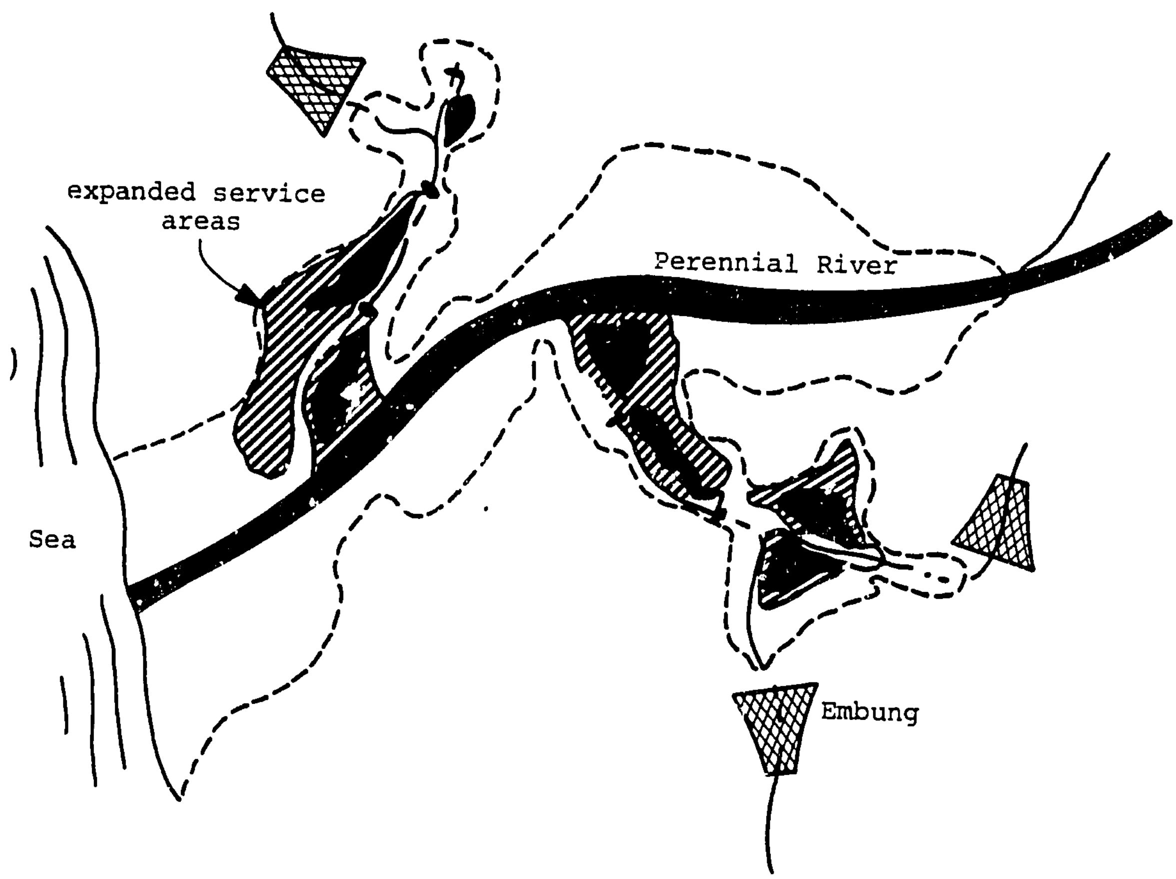

Figure 4. Augmentation using small tanks (embungs) to store rainy season excess runoff for dry season cropping.

Project Objectives

The larger objectives of increased agricultural production and institutional strengthening are outlined above. Objectives of a specific nature are:

1. To improve reliability and duration of the irrigation water supply to approximately 30,000 hectares of new and existing irrigable lands in West Java, NTB and NTT provinces;

2. To improve the capability of village level organizations of farmers to operate and maintain small-scale irrigation systems;

3. To introduce and test several new technologies and institutional arrangements that may address particular problems in the three provinces;

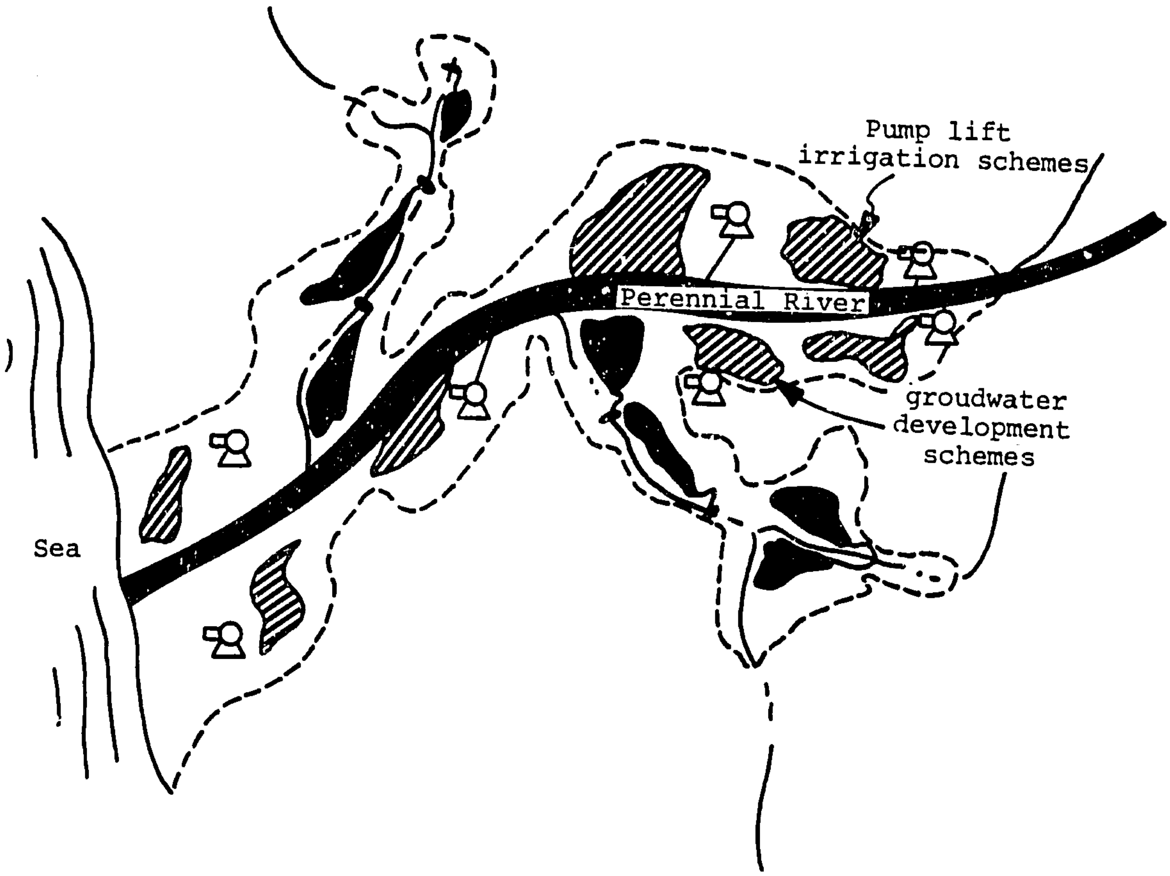

Figure 5. Augmentation using alternative technologies such as lift schemes and groundwater development.

4. To monitor and evaluate the evolution of the small-scale development strategy to establish the effectiveness of water utilization and system maintenance; and

5. To identify the parameters and determine guidelines therefrom for establishing the optimal mix of public and private responsibilities for small-scale irrigation developments.

Scope of Project

As the design of this proposed project emerged, several changes in its original scope were adopted. First, the attention to development in West Java has been limited to the southern half of the province. Groundwater development has not been included in the region, although options may exist for limited development. In NTB, the initial focus of this project has been limited to the island of Sumbawa because it was felt that Lombok was already receiving considerable foreign donor assistance. Again, groundwater development was not found to be a major component except in the Pelaparado complex south of Bima. The scope of groundwater development for NTB is, therefore, reduced to several proposed pilot projects. Added to the scope of NTB investments, however, are the notion of pump lifting directly from the river in the Kalimontang region. For NTT, the scope of the project did not change substantially. The proposals herein are primarily limited to a small effort to develop groundwater.

In the following sections of this report the writers move toward the more specific project components through three general statements. Section II overviews the institutional and social setting of the proposed project. Section III gives a brief technical review of various small system components and the engineering processes that are applied to these projects. Section IV generalizes the agricultural and economic setting with a particularly interesting economic analysis of alternative technologies that are reviewed in Section III. Section V outlines the individual proposed activities for the Small-Scale Irrigation Projects. Section VI briefly summarizes the proposals, their cost and impacts, as well as bringing to the attention of the reader a number of issues and opportunities associated with the project.

SECTION II

THE INSTITUTIONAL AND SOCIAL SETTING

Institutional Setting

Small-Scale Irrigation Facilities

In Indonesia small irrigation facilities are a key component of the total irrigation sector. Even in a province such as West Java, with the numerous large-scale irrigation systems on the north coast, it is reported that approximately 40 percent of the irrigated sawah is served by small village irrigation systems. The institutional setting in which these small systems are created, improved and sustained is complex. It is common in Indonesia to distinguish two broad categories of small irrigation systems: Public Works systems that have been designed, built and are partially operated and maintained by the irrigation section of Public Works; and systems which have been designed, built and are operated by the land owners and water users of the systems. This latter type is variously referred to as non-Public Works, "irigasi desa," or sometimes "irigasi pedesaan." While these local systems are farmer-developed and managed, it does not mean that they have not received public assistance of various kinds.

Most commonly, small systems are thought of as those with command areas of less than 2,000 hectares. However, it is interesting to note that at the present time Public Works typically maintains its irrigation records in three categories -- none of which includes small-scale. The categories that are used to inventory irrigation facilities are: technical, semi-technical and sederhana. Some lists will also contain the category non-Public Works. Small systems, defined as having commands of less than 200 hectares, may be found in any of these four categories. While it appears there has been no national inventory of small systems, partial surveys in scattered locations suggest that many of the small systems are 100 hectares or less in size.

Institutional History of Small Systems

The Indonesian Government has a long history of providing assistance to the small irrigation systems that dot the countryside. During the Soekarno period, for example, there was a separate Ministry of Rural Irrigation ("Irigasi Pedesaan," probably better translated as the Ministry of Village Irrigation). Later, when ministries were consolidated, this became a Directorate and continued until 1969 in the Ministry of Agriculture. The remnant of that involvement in small irrigation systems is seen in the work of the present sub-Directorate for Water Management ("Tata Guna Air"). Over the last decade or more there has been an increase in attention to small irrigation systems in the Ministry of Public Works, Directorate General for Water Resources

Development (DGWRD) and the various provincial public works departments. A major effort has been the Sederhana program funded by USAID, but other activities include the development of small-scale groundwater systems and construction of various small systems in the provinces with the use of provincial or district (kabupaten) Inpres funds.

It is important to note that much of the government's work with small irrigation systems is assistance to existing, farmer-developed facilities. Even the Sederhana program, which in its original conceptualization was aimed at the development of new small-scale commands, has in fact been largely a program of "upgrading," and sometimes expanding, existing facilities. Of course, since Public Works directly administers many small technical, semi-technical and sederhana systems, it also is the case that efforts are directed at small systems which do not fall in the non-Public Works category. Farmer-developed systems may receive assistance from any of several government departments and programs. For example, a village irrigation system might be assisted through Public Works' Sederhana program. Or, it might receive funds from either the "subsidi desa" program or the provincial or district Inpres funds administered through the Department of Home Affairs. Alternately, it might receive assistance by means of the rural infrastructure program of the Department of Labor (the "Padat Karya" program). In a few provinces, such as West Java and North Sumatra, funds might be provided through the Agriculture Department from the Governor's Office. In spite of this diverse set of assistance activities, the actual funding level is modest and Bottrall (1981) concludes: "There is a serious gap, both institutionally and financially, in relation to the provision of support to the very large number of communal desa irrigation systems in Indonesia."

The nature and consequences of these various forms of assistance vary on several important dimensions. First, they vary in what is expected of the local water users. In the typical Sederhana program little is expected of the farmers until after the project is completed, at which time they are expected to assume O&M responsibility for the tertiary level component of the system. The same appears to be true of the Province and District Inpres-funded activities. In the "Padat Karya" program villagers are expected to provide the labor for the construction activities. Limited evidence available (Hafid and Hayami, 1979; Coward, 1982) suggests that when subsidi desa funds are used for irrigation development, these funds are matched with various in-kind or cash contributions by local people. The Agriculture Department's program in West Java, funded by the Governor's Office, does have the explicit policy of funding only about 40 percent of the total project cost, the remainder to be borne by the community. Likewise, the recently developed program "Irigasi Desa Terpadu" (operated by Home Affairs and Agriculture jointly) conceptualizes its assistance funds as a "stimulant" to local mobilization. Second, these various assistance programs differ with regard to the amount of technical assistance that is provided. In nearly all cases, the source of the technical assistance is Public Works, and it is not surprising that its small irrigation systems projects receive the largest amount of this assistance. This includes both work done through the Sederhana program and Public Works activities funded through one of the Inpres sources. In theory, the other programs, such as "subsidi desa" and "Padat Karya," can call on Public Works for technical advice, but the results appear to be uneven. The limited evidence of field visits suggests that the lack of technical backstopping for some of the assistance programs is a serious constraint on their effectiveness. The third area of difference is the impact of the assistance on the governance of the facilities assisted. Here, the significant distinction is between the activities of Public Works and all other programs. With all the assistance programs except Public Works, post-project responsibility for system operation remains fully with the local group. The assisting agency does not assume a continuing responsibility for the operation and maintenance of facilities and does not assign permanent field staff to the project location. However, with Public Works programs, i.e., Sederhana, in the post-project period of assistance to a farmer-developed facility, there is a fundamental shift in governance. The policy is that Public Works will assume responsibility to maintain and to manage the main system facilities and that farmers will use and maintain the tertiary structures. To fulfill its responsibilities, Public Works usually assigns one or more permanent field staff to the location and adds the project to its roll of Public Works systems requiring continuing O&M funding. The result is a de facto shift of these small irrigation works from the private to the public sector. Several observers (Bottrall, 1981; Pasandaran, 1984) have noted that this modification of governance has left the matter of real responsibility confused.

While understanding the range of current assistance programs to small irrigation systems is useful, it seems important to recognize that over the last decade there has been an increasing concentration of agency responsibility for irrigation development in Public Works. It is this agency that has gained wide experience with irrigation development planning and implementation and this agency that has the trained staff and confidence of external donors to implement irrigation projects. Thus, it seems plausible to argue that Public Works will continue to be the major instrument for government assistance to small irrigation systems. Further evidence of this point is the report that the government will soon issue a statement explicitly assigning the DGWRD responsibility to improve village systems. For that reason, attention is given first to a discussion of the institutional arrangements and processes operating in Public Works and then to a closer examination of the local institutions and processes that occur at the local level for irrigation activities.

The Organization of Public Works

As with other technical agencies in Indonesia, there is both a center organization and counterparts of that organization at the provincial level. At the center the Ministry of Public Works is divided into several important units, one of which, DGWRD, includes responsibility for irrigation. The DGWRD is further divided into a number of Directorates.

At the provincial level the Department of Public Works has several units to deal with its major functions -- including an irrigation unit. In addition, the provincial office usually has a number of branch offices throughout the province to supervise irrigation activities in the Public Works systems within the field of that branch office. The most common of these branch offices is called a "Seksi" and is roughly comparable to the territory of an administrative district ("kabupaten"), though the boundaries often do not coincide. In some provinces, such as West Java, several of these Seksi offices will be administered by an intermediate regional office called the "Wilayah." Also, in areas where there is a significant amount of Public Works administered irrigation in the territory of the Seksi, there will be additional field staff responsible for progressively smaller areas. Staff called "pengamats" supervise areas of several thousand hectares and are assisted by staff called "juru," each of whom has responsibility for an area of several hundred hectares. In this way, the total area of the province is divided into progressively smaller zones for irrigation supervision.

As mentioned above, the primary responsibility of the Seksi and the Pengamat Staff is to the Public Works irrigation in their territory. However, they are viewed by local government and local people as the resident irrigation experts, and are called on to provide advice on activities such as improvements in a village system being done with some other agency's funds. Of course, the proposal to have Public Works more explicitly involved in village irrigation could alter the tasks of some of these offices significantly.

Irrigation Institutions at the Local Level

In many regions of Indonesia there exists a long tradition of local responsibilities for irrigation activities and well established rules for system operation and management. The "subaks" of Bali are well known throughout the world as remarkable examples of local initiative and capacity for irrigation activities. In the provinces of Java, where village-level government is well established, there is a long tradition of village government responsibility for local irrigation affairs. Traditionally, these responsibilities have been exercised through the village headman's appointment of village irrigation officials (often called the "ulu-ulu," but with numerous local variants). These village irrigation officials have a number of responsibilities, including the mobilization and supervision of labor and other resources for system construction and repair and the management of water distribution, particularly in the dry season. Where appropriate, the village irrigation officials also have acted as contact persons with other village irrigation officials and with government officials such as Public Works staff. There are other cases in West Java where the village headman works through hamlet-level leaders rather than a village irrigation official for the purpose of managing the village's irrigation infrastructure (Coward, 1982). More recent studies in other parts of Indonesia have further documented the institutional arrangements and capacity of local irrigation groups. For example, research in South Sumatra by a team from Sriwijaya University has provided evidence of remarkable non-village based irrigation groups that have developed small irrigation commands and are completely responsible for their management and upkeep. A useful summary of local irrigation institutions is provided in Asnawi (1984).

The analysis of these local irrigation institutions reveals several important dimensions of their performance which are often unrecognized. One is their ability to persist over long periods of time -- through many changing circumstances in their physical, as well as socio-economic, environments. In fact, it may be that the circumstance to which they are most vulnerable is certain forms of government assistance. A second important feature of these local systems is that they are capable of highly complex water management arrangements, often involving intricate water rotation patterns, using a combination of simple physical structures and sophisticated rules and organization. Visitors to such systems can be misled by the seemingly crude apparatus with which water is divided and channeled. A third key finding is that these local systems are capable of supporting intensive agriculture patterns within the limits of the water supply that they are able to capture.

Obviously, not all local irrigation systems are operating with a high degree of effectiveness and not all local groups have been able to resolve the problems associated with insufficient and erratic water supplies. Nonetheless, this wealth of local experience and capacity represents a very significant resource for any program of small irrigation system development in Indonesia. The Team agrees with Bottrall's (1981) forceful suggestion: ". . . Indonesia's water users . . . themselves represent a local executive capacity which deserves and demands to be used."

The Indonesian Government has recognized the importance of local water associations and has made considerable effort to promote their formation. Known generically as Perkumpulan Petani Pemakai Air (P3A), they have been the subject of attention by both the Ministry of Public Works, the Ministry of Agriculture and the Ministry of Home Affairs. Except in the context of two experimental programs discussed below (the High Performance Sederhana Irrigation Systems [HPSIS] and the Madium program), none of these agencies has attempted to create a cadre of staff with special training in farmer group formation. The common approach has been to add this task to field staff whose basic training is not targeted for these activities and whose burden of responsibilities already is high -- the agricultural extension worker or the irrigation field man.

The Ministry of Agriculture, through its Subdirectorate for Water Management, has drafted a model organizational format for the P3A. In turn many, but not all, provinces have drafted regulations specific to their province to guide P3A formation. This provincial adjustment has worked well where staff were familiar with the actual local scene and could draft appropriate rules and procedures. Many of the provincial regulations are explicit in their recognition of traditional institutions (adat) and advocate their use when possible. However, the level of training and experience of many of the staff forming P3A has resulted in a much more stardard approach with little attention to local variation. Typically, these field staff know very little about existing irrigation institutions and tend to promote new organizations rather than trying to "improve the existing ones." In part, these problems may be ameliorated where strong local institutions exist since local people may essentially place in the "new" organization the experienced and trusted staff of the "old" one. Nonetheless, there may be unnecessary confusion and a period of sorting out roles and responsibilities that probably could be avoided with a more sensitive organizational approach.

The Interaction of Public Works and Local Irrigation Groups

Several key programs of the DGWRD and the provincial irrigation offices require close interaction between the agency's staff and local groups and individuals. This section will review several of those programs and highlight institutional issues that emerge from these past experiences. While not all of the experiences reviewed deal directly with small irrigation systems, they should contribute to our understanding of the basic agency-community interaction.

Public Works and Village Irrigation Systems

As mentioned above, Public Works in recent years has been extending its range of activities to include village irrigation systems and new small irrigation systems. From about the mid-1960s the agency's work was focused on the rehabilitation of the larger public systems in areas such as the north coast of Java and parts of South Sulawesi. The Sederhana program of the last several years has represented an important small irrigation program by Public Works and there is evidence that this trend toward more attention to small systems will continue. Consistent with this point is the statement in a recent World Bank issue paper which suggests the following: "The suggested Repelita IV program emphasizes the continued rehabilitation, upgrading and tertiary construction, moving progressively into small irrigation systems."

A current example of this trend is the recent proposal by the former PROSIDA unit of DGWRD for a program of modernization of small systems in the Sumadang-Majalengka region of West Java. This is a significant proposal because in the past PROSIDA has confined its work exclusively to large-scale system rehabilitation and tertiary development in large systems funded with external loans.

In sum, it seems that one can expect in the years ahead an even greater involvement of Public Works in existing village irrigation systems. Thus, it appears it would be instructive to examine the past experience resulting from such agency-community interactions.

While Public Works sometimes provides technical advice for village irrigation projects funded by some other agency, those activities are not the main point of this discussion. Rather, the discussion here will be on those Public Works activities in which they are the primary agency implementing the project with funds coming through Public Works programs such as Sederhana or the sedang/kecil program, or with support from the Governor's or a Bupati's Inpres funds.

The common approach in these projects has been for Public Works to take charge to plan the changes to be made in the village system, contract with a design firm to prepare the necessary design materials and contract with a construction firm to build the improved facilities. There may be minimal consultation with local water users during the planning and design process so that little attention to either the existing physical apparatus or the institutional and organizational arrangements of the village system may tend to be ignored. There usually is some attempt to organize a water user group to be responsible for O&M at the tertiary level of the system, but this process also tends to ignore local experiences and arrangements. Upon completion of the project, Public Works assigns one or more staff to the system to operate and maintain the main system facilities and to coordinate with the water user group in operating and maintaining the lower level facilities.

Two important institutional consequences are associated with this strategy of assisting village systems, particularly Sederhana systems. Some have immediate impact on the performance of the irrigation systems, while others have longer range implications for system sustainability. First, this lack of local involvement led to poorly planned, designed and constructed facilities that simply fail to improve the irrigation situation. A second institutional issue is that the approach of shifting governance of the main system facilities from the local group to the Public Works results in an increasing staff and financial burden to the agency while both underutilizing local capacity and, in some instances, causing confusion about farmer responsibilities and demobilization of local actions. Public Works staff suggest that it should be the policy to return completed Sederhana projects that serve only a single village to the local group. However, it appears that little of this has actually occurred. It also may reflect an incorrect perception that there is a lack of institutional arrangements at the local level for the inter-desa coordination of irrigation activities. While this issue may not have immediate implications for system performance, it does raise potential problems in the long run. The recurring costs to government implied in this "takeover" approach may prove very burdensome in the future. However, it may also be the case that at that future time it will be difficult to reconstitute the local capacities that previously existed. Public Works is aware of these and other problems that derive from their

Sederhana approach. One attempt to devise alternative ways to implement this program is the HPSIS experiment which is disussed below.

Public Works and Teritiary Development

With assistance from the World Bank, the DGWRD has been involved for the past several years in a major program called Tertiary Development. This activity has been primarily targeted to the larger Public Works systems and has been premised on the need to develop more elaborate and sophisticated tertiary-level facilities to improve water management. While tertiary facility development is supposed to be a farmer responsibility, this program has argued the need for government to become directly involved in the design and construction of these facilities in order to increase the pace and quality of tertiary construction.

As with the Sederhana program, the Tertiary Development program has placed the agency in the position of having to deal directly with local groups since the tertiary facilities are located at the village level. Also, as Sederhana, the program has generally been unsuccessful in incorporating local experience and facilities into the tertiary modifications. Frequently, the result has been facilities that do not operate as intended or layouts that are unacceptable to the water user. Some innovative approaches to deal with this problem are being tested and will be discussed below.

Public Works and Pump Irrigation Groups

Public Works has also been working with small groups of farmers through its various groundwater projects; primarily in East and Central Java. In East Java, for example, these pump groups use groundwater to irrigate commands of approximately 40 hectares. The organizational approach used by Public Works in these projects varies considerably from the approach taken in the Sederhana program and is suggestive of possible models for other small irrigation work by them. The basic principle that distinguishes work with the pump groups is the principle that these irrigation facilities will become the property and responsibility of the local users. With this objective in mind, it appears that Public Works then is able to set in motion a set of activities designed to achieve this end. Farmers are assisted with forming a user group. They are encouraged to establish financial procedures to handle future pump repair and replacement costs and they are provided training in the efficient use of the pump water for agricultural purposes. Unlike other Public Works programs, the assumption is made from the start that farmers will be capable of autonomous operation of the irrigation facilities, and project activities are implemented to achieve this goal. In East Java it is reported that a number of pump facilities have been completely turned over to the user groups for their continued operation. More needs to be known about the advantages and disadvantages of this important variation in Public Works' approach to local groups. For example, it is not clear to what extent local experiences and capacities are utilized in planning the pump project.

Public Works and Program Experiments

Partly in response to perceived problems with both the Sederhana program and the Tertiary Development program, Public Works has begun two interesting experimental efforts to improve the effectiveness of these programs. The HPSIS program is an effort to test a more participatory style of Sederhana program implementation than the conventional approach (Robinson, 1984a). There are 21 sites in this experiment, six of which are being implemented by Public Works. The HPSIS experiment attempts to deal with two of the institutional issues discussed above regarding the Sederhana program -- underutilization of local experience and information and resolving the confusion regarding the matter of post-project governance.

The basic element of the strategy involves the placement of a community organizer (CO) in the locale of a Sederhana subproject to assist the farmers in mobilizing to participate in project planning and implementation and to act as a link between the agency and the community. In this way it is expected that farmer knowledge and experience will become available as inputs into the planning and design processes and that farmers will develop a sense of commitment to the project that will sustain that responsibility in the post-project phase.

This experiment is still in process and there is thus no final set of data to examine and conclusions to be reached. Robinson (1984b) has summarized preliminary data prepared by the Institute for Social and Economic Research, Education and Information. This preliminary data indicates that it is possible to mobilize farmers for greater involvement in the early project steps of planning and system layout. What is not yet documented is the impact of this additional information on the quality of the systems designed. Nor is there clear evidence that this early involvement encourages a sustained post-project involvement.

A similar experiment is being conducted in the Madium area of East Java as part of the Tertiary Development program. As with the HPSIS experiment, COs are assigned to the location where tertiary development programs are to be implemented several months prior to the initiation of surveying and design work. During this period the COs actively work with the involved farmers to carefully map the location and condition of their present tertiary system and to prepare suggestions for the improvements that are required. The process to be followed is that this information will be made available to the staff of the design firm when they enter the field to begin their work and that the preliminary designs prepared by the firm will be reviewed by the farmers for comment and possible modification.

As with HPSIS, this experiment is in process and final evaluations are not now possible. However, in this program there is in place a very well conceived and executed research and monitoring program and strong data should ultimately be available. Preliminary results indicate that as a result of the CO approach, farmers did have much more input into the work of the design team than was previously the case. Since many of the difficulties with the tertiary development program are perceived to derive from the design process, it will be important to determine the effect of farmer input on the final design results.

While neither the HPSIS program nor the Madium project has yielded final data at this time, there are some promising outcomes. Moreover, these experimental activities have attracted the attention of various Public Works staff regarding alternative approaches to village-level irrigation activities and the possible benefits of a new mode of agency-contractor-community interaction. The presence of these experimental institutional efforts within the Public Works system should facilitate the opportunity for continuing institutional testing.

Social Soundness: Response of Impacts of Small-Scale Irrigation Development on Rural People

Past Responses to Small-Scale Irrigation Development

The considerable prior experience in Indonesia with government programs to develop small-scale irrigation provide a good basis for assessing the responses of local people to such programs. In general, given the central importance of irrigation to rice production, local people producing rice, or wishing to do so, have responded very favorably to programs of small-scale irrigation development. This favorable response is measured in terms of their use of the available water for rice and other crop production and the frequent intensification of their general cropping patterns.

The Ministries of Public Works and Agriculture have provided data that indicate positive response of water users to the Sederhana project. Based on the compilation of data from all Sederhana subprojects, the reported increase in area of irrigated rice in the wet season is 56 percent (from 160,220 ha before Sederhana to 250,552 ha after). An enormous increase in dry season irrigation is reported; an increase of 1,455 percent (from 10,475 ha before to 152,413 after).

In addition to the increase in area irrigated, there also is a reported increase in productivity. From numerous studies this increased productivity has occurred because of the increased utilization of various production inputs that typically accompanies better water supplies. It is reported that average yields have increased in the Sederhana project areas by 36 percent in the wet season and 20 percent in the dry season. Studies show a consistently high correlation between regional multiple cropping indices and regional proportion of total cultivated land which is irrigated sawah (Booth, 1977).

It is also useful to note that in general both yields and cropping intensity decrease as the size of holdings increase. Three factors are usually involved: (1) land quality tends to be better in small-holding areas (and more densely populated); (2) small-holders may use inputs more intensively than large-holders; and (3) labor is used more intensively on small-holdings.

In those few cases where there has not been a positive response, a frequent cause has been that the project has been located in an area in which other crops, or economic activities, were more profitable to the farmer, and thus there was little economic incentive to utilize the irrigation facilities. This situation may arise in selected areas in southern West Java in plans for further development of various tree crop plantations and nucleus estates materialize.

Some Sederhana subprojects have experienced difficulty because they are located in areas of relatively low population density and the labor required for conducting wet-rice agriculture simply has not been available. This may be an issue in selected subproject sites in both the Flores and Kupang regions of NTT.

In other cases the expected response has not occurred because technical difficulties of one sort or another have resulted in a less than reliable or adequate water supply for the water user. The combination of augmentation, decoupling and capacitation suggested in this project's strategy should result in fewer problems of this type. Additional constraints may be discovered at proposed project sites.

Past Impacts of Small-Scale Irrigation Development

As mentioned above, a major response of water users to the prior small-scale irrigation programs has been the intensification of their agricutural production activities -- increasing their cropping intensity by extending production into the dry season and in both the wet and dry seasons making more use of production inputs and labor. It is this increase in intensification that has had the greatest socio-economic impact on the rural scene.

To understand these socio-economic impacts one must first begin by disaggregating the rural population into general socio-economic categories; first, to distinguish between farm owners and landless laborers (many of whom are women) and then to decompose farm owners into categories based on size of land ownership and the degree of capacity for self-sufficiency represented by that land size. Since the universal rule in Indonesia is to allocate gravity water supplies in proportion to the amount of land one owns (or operates) in a command area, it is clear that those with the largest amounts of land will be given the greatest potential for improving their situations through the use of the new irrigation supplies.

While it is clearly the case that introducing an improved irrigation system into a rural setting in which land and other assets are unevenly distributed will tend to benefit some more than others, there is also evidence that the introduction of this infrastructure has the potential to improve the conditions of many, if not all. Hayami and Kikuchi (1972) have concluded from intensive field studies in Indonesia that ". . . the real wage (of farm laborers) rose despite rapid increases in both labor force and animal power. The real income of hired laborers increased absolutely even though their relative income share remained constant . . ."

This suggests there is the potential for agricultural laborers to gain in employment opportunities and income because of the more intensive agricultural activities if their labor is not replaced by farm machinery. Thus far, this has not been a large problem in Indonesia since tractorization has been quite limited in extent.

All landowners will have an opportunity to improve their positions because of the improved irrigation, providing that they have relatively equitable access to the water supplies and to the necessary credit for purchase of the yield-increasing production inputs. With regard to the latter, the various BIMAS and INMAS programs appear to have a rather good record of supplying credit and inputs to farmers of a range of sizes. With regard to the former point, the relative small command areas involved in the Sederhana-like projects tend to minimize negative spatial effects of water distribution. However, the positive effects of small size may be outweighed in situations where social power and influence are highly skewed (perhaps directly reflecting a highly skewed pattern of asset control) and allow for a few to enact a pattern of water delivery unfavorable to the many.

What should be clear is that given the existing principles in Indonesia, it is highly unlikely that irrigation development will lead to any fundamental reordering of asset distributions to favor those with fewer assets. On the other hand, by encouraging the intensification of agricultural activities, irrigation development does offer the opportunity for both landless laborers and small-holders to increase their productivity and thereby increase their income streams. Finally, it should be noted that many studies demonstrate that the prevalence of less secure forms of land tenure and smaller harvest shares to tenants are each associated with high population density in rural areas -- that is, under conditions in which the abundance of available farm labor increases the bargaining position of landowners.

The effects of agricultural intensification on women can be negative, as seen in the shift in institutional arrangements for rice harvesting in some regions of Java. New institutional arrangements such as tebasan, harvesting gangs of men moving from village to village, have resulted in fewer opportunities for women in harvesting. Similarly, the increased presence of mechanical rice hullers in rice-abundant areas has reduced employment opportunities in hand milling for some women.

Anticipated Responses to the Augmentation, Decoupling and Capacitation Strategy

The basic objective of the augmentation component of the strategy is to provide each small-scale irrigation system with an enhanced water supply in terms of both quantity and reliability. Assuming that augmentation activities are not implemented in those settings identified above as leading to non-positive response by farmers (areas short of labor, areas involved in other profitable agricultural activities, etc.) there is every reason to believe that water users will respond positively to these improved supplies by increasing agricultural intensity and productivity.

The decoupling component of the strategy will result in a clearer definition of rights and responsibilities between the irrigation agency and the water user community. The suggested pattern is for the irrigation agency to have responsibility for the design, construction, operation and maintenance of the "augmentation structures" -- the facilities at the point of water supply, the supply canals and other control structures required to convey the water from the supply point to the natural waterways from which the small systems divert water. On the other hand, the water user group will have lead responsibility for the construction and operation and maintenance of all facilities starting with their diversion weir and continuing through the actual command areas. In implementing this lead responsibility they may receive assistance from various government agencies as implemented through the capacitation component of the strategy.

Since there is a general lack of experience with an exact case of decoupling as defined in this project strategy, the likely response of local people is somewhat more indeterminate. However, there are several experiences in Indonesia that provide some guidance as to what can be expected. For one, the large number of small-scale non-Public Works systems that exist throughout Indonesia and which operate independently in both securing a water supply and allocating and distributing it to the involved water users suggests the considerable institutional capacity that is possible to achieve. That many such groups have existed for long periods of time and have successfully operated and maintained their social and physical infrastructures is a significant reason to believe that it is reasonable to expect a positive local response to a decoupling approach.

A second example to consider is the subaks of Bali, nearly half of which are now served by main diversion structures and main canals built and operated by the government. There has been a conscious policy to bring the water to the subak command, but to allow the subaks to retain their autonomy in operating and maintaining those commands. Recent research completed at Udayana University suggests that subaks have remained viable local organizations under this arrangement.

The capacitation component of the strategy has as its objective ensuring that the independent small systems have the engineering apparatus, technical assistance and organizational capacity to effectively utilize the augmented water supply and meet the commitments assigned to them as part of the decoupling. Again, while a definitive answer regarding farmer response to this component of the strategy is difficult to formulate, there is some evidence to suggest that a positive response is a plausible expectation. The HPSIS experiment discussed earlier is providing evidence that increasing local capacity through strengthening the organizational arrangements of the local water users is both possible and has positive impacts on aspects of the irrigation development process. HPSIS is showing how more productive interactions between the irrigation agency and the water user community can be structured -- a capacity that will be crucial to the success of the decoupling component. Likewise, limited evidence investigating the use of subsidi desa funds for improving community systems suggests that when external funds are provided to the community along with technical assistance, water user groups are able to apply those resources, often complemented with resources of their own, to make useful improvements in their irrigation facilities.

Finally, the capacitation component as suggested will leave ownership of the local level irrigation facilities with the user group. This arrangement is consistent with the principle suggested by Coward (1983) that in successful small-scale irrigation systems in Asia (and elsewhere) there is a high correspondence between local ownership of facilities and local responsibility for operation and maintenance.

Anticipated Impacts of the Augmentation, Decoupling and Capacitation Strategy

The most significant impact of the improved water supply achieved through the strategy of augmentation will be to prompt farmers to agricultural intensification. Since the augmentation approach is expected to provide a much improved water supply, one can expect that expansion of dry season production will be an especially significant outcome. The socio-economic impacts of this intensification are likely to follow the same pattern as that experienced in Sederhana projects where intensification occurred -- an expansion of employment opportunities for agricultural laborers, increased production and productivity for land owners and farm operators. Where production inputs are made widely available one can expect a general rise in the socio-economic conditions of all those participating, but no fundamental rearrangement in the pattern of asset distribution between landed and landless or between those with different size land holdings.

An explicit policy of decoupling agency and community rights and responsibilities will decrease the negative impact on control and governance of the small irrigation command by the local water users. By terminating direct agency involvement (though not assistance) above the small system's diversion structure, it should be clear to both parties that responsibility for and control over the utilization of water within the small system's command area belongs to the water users of that command to be exercised through their own organizational and institutional arrangements.

SECTION III

TECHNICAL ANALYSIS

Irrigation in Indonesia

Irrigation systems in Indonesia are designed primarily to support paddy production with an increasing secondary interest in dry season crops such as corn, soybeans, vegetables, etc. Most irrigation supplies reach the small land holdings via direct diversion from a local river or stream. Groundwater development and direct pumping from a waterway is present but not common. The most critical problem appears to be one of stabilizing and extending the seasonal runoff pattern. At the farm level, irrigation methods are primarily basin irrigation, furrow irrigation and hand watering. There is practically no use of pressurized systems such as sprinkle or trickle irrigation.

This section contains a technical review of irrigation technology in the Indonesian setting and explores an array of technological options applicable in the country, most of which have been well established elsewhere. Groundwater presents one of the most interesting alternatives to direct stream diversions, as do lift schemes which pump directly from the stream. Alternative components of irrigation systems also appear to be feasible, such as substituting buried PVC pipe for the traditional masonry or earthen open channels.

This section is written in the general, but because the Team's focus was toward West Java, NTB and NTT, the generality is more directed to those regions.

Run-of-the-River Systems

Description and Configurations

The bulk of irrigation in Indonesia is comprised of run-of-the-river systems. Typically, these systems take water from a stream by means of some sort of diversion weir and distribute it throughout the command area by a series of canals and ditches.

The DGWRD within the Ministry of Public Works (Public Works) has classified run-of-the-river systems into four categories: technical, semitechnical, nontechnical and non-Public Works irrigation systems. The primary distinguishing factor between these systems is whether or not any of the canals serve a dual purpose of water distribution as well as drainage. Technical systems have distinctly different distribution and drainage channels and are also typified as having masonry or concrete weirs and flow measurement devices at the headworks and at flow diversion points along the distribution system. In nontechnical (Sederhana) systems a channel may be used both for water distribution as well as drainage. Nontechnical systems have free intakes from the river or simple gabion weirs and lack any measuring devices. Semitechnical systems lie somewhere in between technical and nontechnical. These systems generally have some channels in their tail reaches which serve both as part of the distribution network and as part of the systems' drainage. Such systems usually have masonry weirs and a flow measurement device at the headworks. Non-Public Works systems are typically village irrigation systems, some of which have been in existence for hundreds of years.

This system of classification has led to an inferior design in some cases. The distinction between technical and nontechnical systems implies a difference in the level of sophistication. Yet a so-called non-technical, village irrigation system in which the channels serve both as a collection system and distribution system may reflect a degree of sophistication greater than that of a technical system.

Diversion Structures

There are three types of river diversion structures used in Indonesia: free intakes, gabion weirs and masonry weirs. Free intakes accomplish river diversions without the aid of diversion weirs or other structures to raise the natural water surface of the river. Because the river is uncontrolled, the natural river depth, discharge and sediment transport must approximate the conditions achievable with a diversion weir. Unfortunately, few sites have appropriate or near appropriate natural conditions. Where these conditions are met, however, a free intake diversion may be by far the best choice. Figures 6a and 6b show two typical diversion structures.

Gabion weirs are appropriate in wide shallow streams where the weir length is controlled by the site topography and not by the limitations of the gabion structure (i.e., maximum unit discharge of 4 $m^3/s/m$ of weir crest, maximum weir height of 2.5 meters). In order for a gabion weir to be effective there must be sufficient water available to meet the irrigation diversion requirement and the leakage through an unsealed gabion. (Leakage through an unsealed gabion of the maximum height is about 400 to 600 l/s/m.) Gabion weirs require impervious foundations or high silt and clay sediment stream loads. Stones suitable for gabion construction must also be available near the weir site.

Masonry weirs are used where neither free intakes nor gabion weirs are appropriate. Masonry weirs have the advantages of watertightness and of greater resistance to static and dynamic hydraulic forces, but may or may not be more expensive than gabion weirs. The major disadvantage of masonry weirs is that proper design and construction is usually beyond village capabilities.

Village diversion structures in Indonesia are typically often simple rock and debris checks, as shown in Figure 7, with free intakes, although

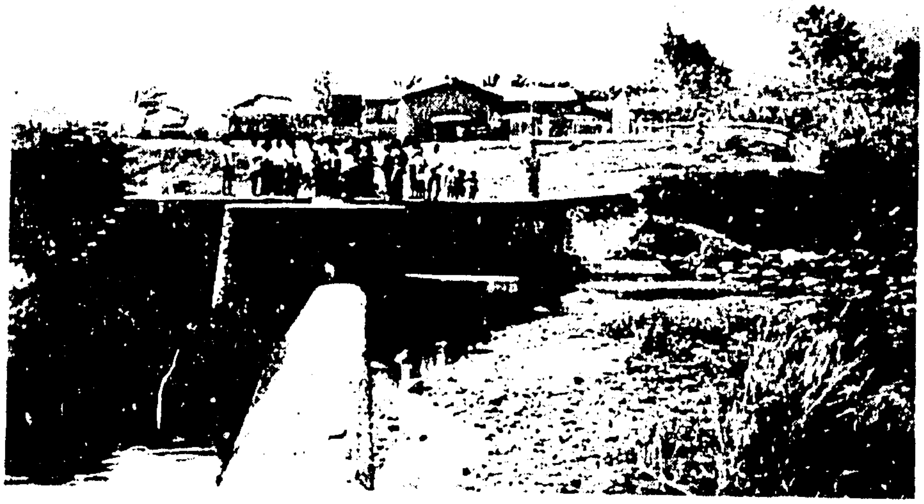

Figure 6a. Typical river diversion structure in Indonesia.

Figure 6b. Typical river diversion structure in Indonesia.

some villages have constructed masonry structures. During periods of low streamflow, simple gabions or dikes of mud, sticks and stones are constructed, extending from the downstream side of the free intakes across the river channel. During high flow periods these dikes are either washed out completely or severely damaged, but because of the increased stream depth, the free intakes are able to divert water from the river until the stream drops to the point where the simple gabions or dikes can be reconstructed or repaired. This is a labor intensive means of diversion that also has the disadvantage of being inefficient in terms of the divertable flow. In an effort to increase the diversion efficiency as well as the life of these typical village diversion structures, some have been plastered over and sealed with cement. Where the dikes are on previous foundations this has had the opposite effect of decreasing the efficiency and life of the structure through accelerated piping beneath the dikes.

Some of the proposed subprojects call for the augmentation of the water supply in natural channels which are already being tapped by village built weirs of the type described. This augmented water supply will come from either diversion dams on nearby larger rivers too big for village systems, or from tanks upstream of the village weirs. In order to realize the potential benefits of such flow augmentation projects, changes to increase the diversion efficiency of existing village weirs

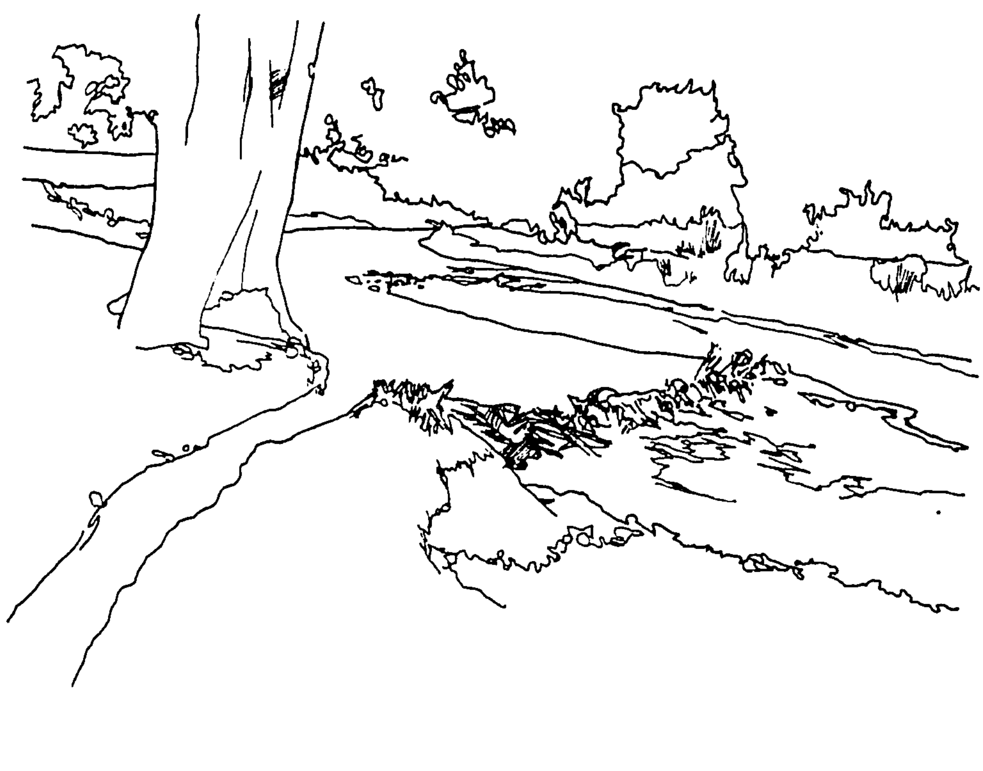

Figure 7. A typical village stream diversion.

may be required. Suggested improvements for existing diversion structures, as well as alternatives to diversion weirs, are presented later in this section.

Conveyance Structures

Canal control structures commonly used in small irrigation systems in Indonesia include drop structures, chutes, division boxes and wasteways. These structures are normally of masonry construction; however, where stones, cement and/or sand are not locally available, timber or bamboo structures are found. Separate check structures to maintain sufficient water levels during low flow periods are not used and are generally not required. Checks below temporary and permanent canal off-takes are common, however.

Both lined (masonry and concrete) and unlined canals are used. Lining is particularly common where canals pass through settlements and where special canal structures exist to allow access for washing and bathing. Bench flumes are widely used where unstable soil conditions exist or severe space restrictions preclude the use of ordinary unlined canals. Closed conduits (i.e., pipes for water conveyance, inverted siphons and elevated flumes) are rarely used in small irrigation systems. The reason for this is unknown.

Water conveyance structures in village irrigation systems are often different from those that would perhaps be designed by public agencies. Modern engineering and technical innovations are needed to enhance many village irrigation systems. Perhaps the most important of these is the design and implementation of diversion structures or methods which are less labor intensive to maintain and more efficient in diverting water than traditional village diversion structures. Technical assistance is needed in village irrigation systems for flood control and protection structures such as cross-drainages and wasteways. Another major benefit from technical assistance could be the expansion of commandable areas through the use of pipes and elevated flumes to deliver water to land otherwise beyond the reach of canals.

Planning, Design, Operation and Maintenance

A flow chart is shown in Figure 8 on the planning and design process used by the Public Works Department was provided by the Subdirectorate of Planning and Design in Bandung. The theoretical criteria used for project selection are:

1. The availability of water in sufficient quantity and acceptable quality to meet crop irrigation requirements;

2. The suitability of soils for the proposed crops;

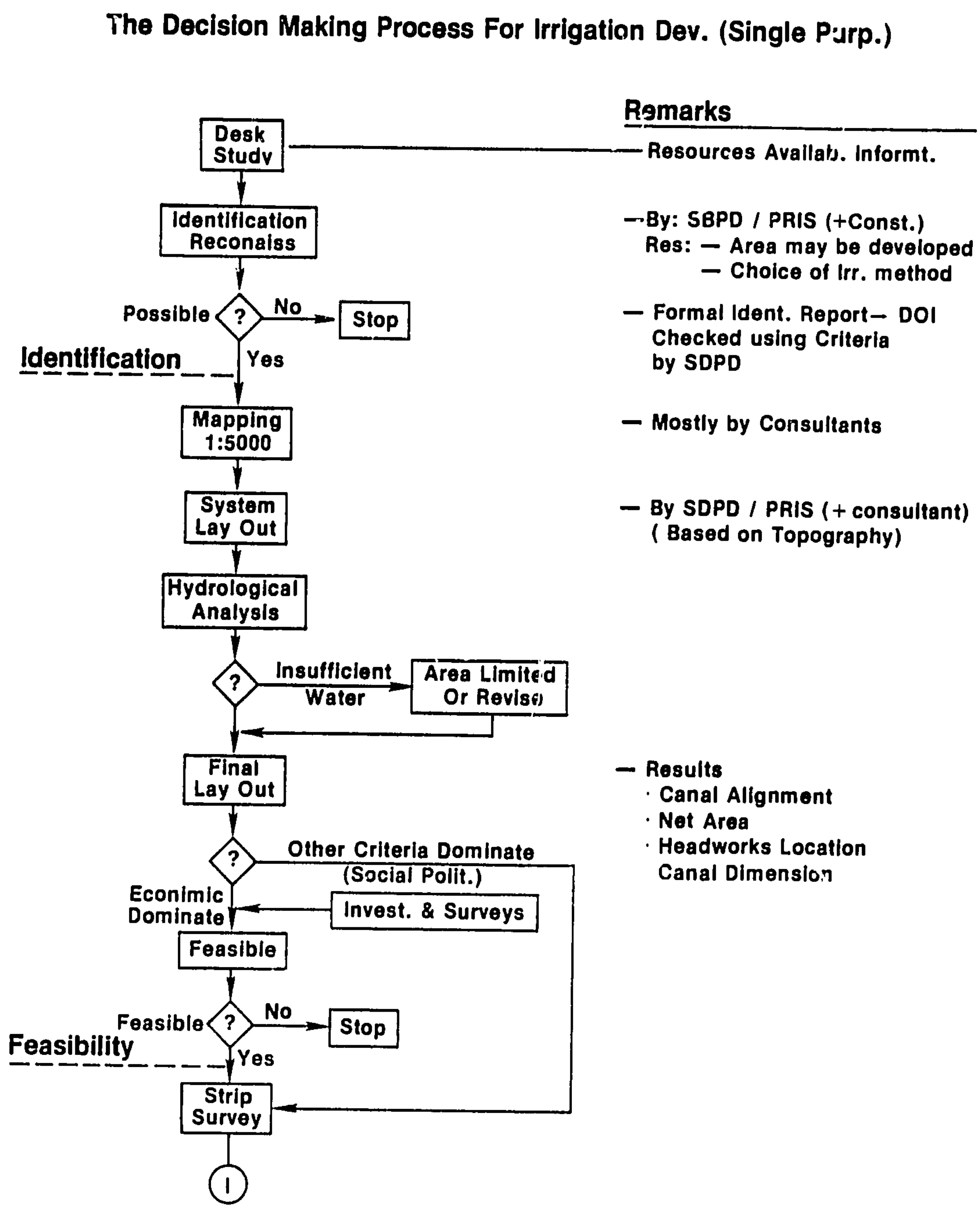

Figure 8. The Public Works planning and design process.

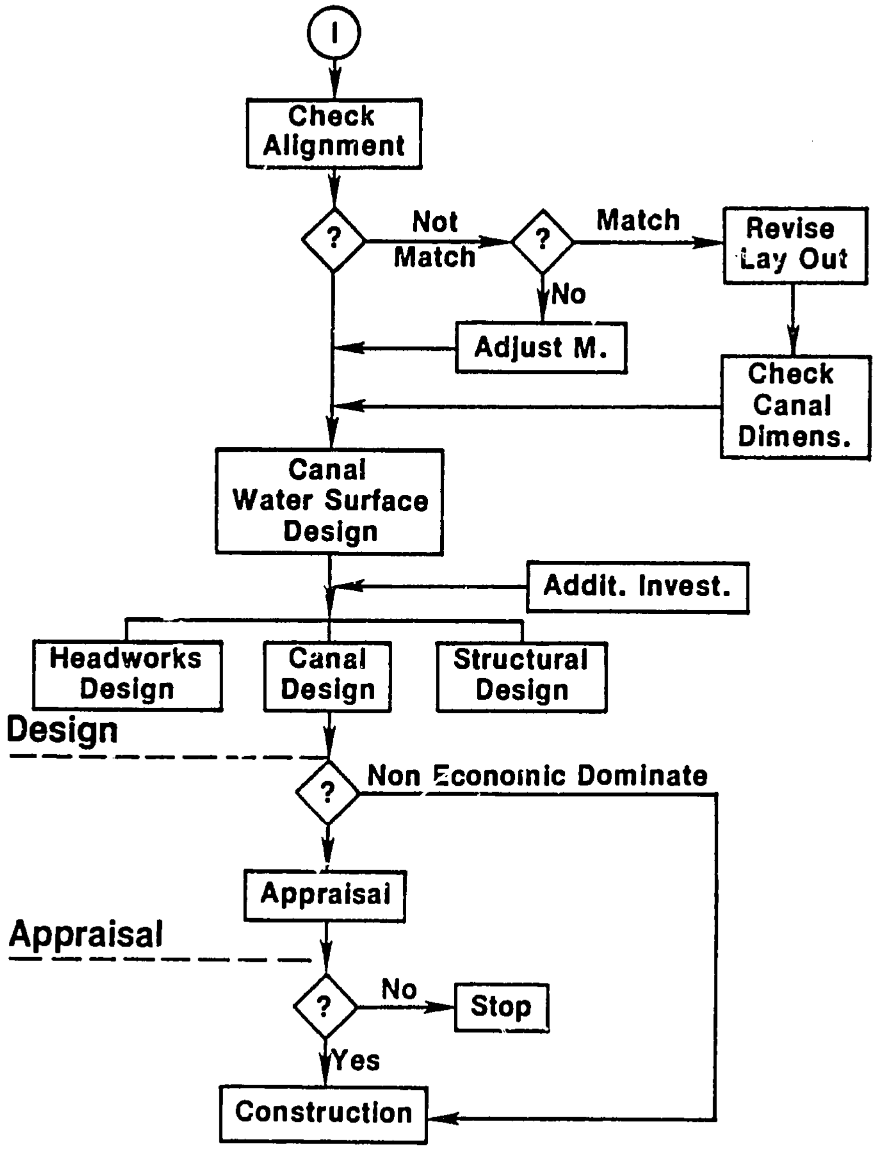

Figure 8. (Continued)

3. Lack of problems with land status;

4. The availability of farmers and manpower;

5. The willingness and support of farmers for the project;

6. Accessibility to the project site;

7. The significance of flood potential;

8. The availability of transportation in the project area; and

9. The priority for development within the region.

The relative degree of importance placed on these criteria individually is not known. Failure to adequately consider some of these criteria has been observed on field visits. The first two criteria are the most important for appropriate project selection and design from a technical standpoint, yet sufficient streamflow data and soils data are seldom available.

An area that seems to be given minimal attention in project planning and design is the inventory of existing irrigation, both within the project design area as well as within the river system being developed. An inventory of existing irrigation systems within the project area is important to determine the local diversion requirements as well as to take advantage of the already existing irrigation infrastructure. An inventory within the river basin of the project is necessary to determine the impact of the project on irrigation systems downstream. The nature of all run-of-the-river systems (except those with transbasin diversions) is such that the only water lost from the basin is that which has been transpired or evaporated. Therefore, a project which increases diversion and conveyance efficiencies in a given system will only effect downstream systems if the project is larger than before. The general assumption has been that water, not land, is the limiting factor to expand production. This may well be the case; but in planning and designing run-of-the-river systems the return flow from existing irrigation as well as the flow at the mouth of the river basin should be investigated. If there is sufficient quantity of unused water of acceptable quality, and if irrigable land is available within the project area, then the command area can be expanded.

Design Standards

There are at present no official design standards for small run-of-the-river irrigation systems in Indonesia. This situation is complicated by the fact that for the last 14 years (since the beginning of the first five-year development plan) irrigation development has been carried out at a very rapid pace. Many international consultants have been retained for their services and each has used its own design criteria. Now concern exists over what criteria should be adopted. The government, in recognition of this problem and the need for official design standards, has contracted with a Dutch firm, Netico, to develop a set of hydraulic design standards appropriate for Indonesia. This is a two-year contract which has not yet begun. Official design standards are not expected before 1987.

As part of the USAID-funded Sederhana Project, the San Francisco based International Engineering Company, IECO, developed a set of design guidelines, standardized drawings and technical papers for small irrigation projects in Indonesia. The original design guidelines prepared by IECO in 1978 were unacceptable to the government because they were developed without consultation with the Subdirectorate for Planning and Design (SDPD) and because they were too theoretical. For the next two years IECO, working with SDPD, developed new design guidelines of a more procedural nature. These guidelines were available late in 1980 and further revised by the middle of 1981. While the new guidelines were acceptable, they were not officially adopted and their status remains as "consultant's recommendations."

The revised design guidelines and materials prepared by IECO have been reviewed and are considered satisfactory for appropriate planning and design of small run-of-the-river systems. It is recommended that these guidelines be adopted as the design standards for the Small-Scale Irrigation Project until the official hydraulic design standards for Indonesia being developed by Netico are available. A listing of the IECO design materials is provided in Appendix B.

Problems with Present Design Practices

There appears to be a tendency toward standardization of design in Indonesia. This is generally desirable in the design of canal structures since the function, hydraulic characteristics and structural requirements remain very nearly the same from location to location. However, the selection and proper location of appropriate structures does vary from site to site, and thus the tendency towards a standardized layout should be avoided. Unnecessary or poorly located structures (i.e., unused division boxes and improperly spaced drop structures) are frequently seen in small irrigation systems. This may be due to the tendency towards a standardized layout, or possibly by designers not visiting the project site, i.e., inadequate consideration may be given to existing structures.

Another limitation of present design practices which might also be due to the tendency towards a standardized run-of-the-river system is lack of innovations in design. Often more ingenuity has been observed in village irrigation systems where farmers have had to rely on indigenous materials such as bamboo for pipes.

The greatest observed weakness in present design practices may be that of masonry weirs. Two major design flaws were consistently observed on field visits: (1) design of the stilling basins; and (2) design of sluiceways. One of the most effective means of dissipating the energy of water discharging over a weir is by means of a hydraulic pump on a concrete apron. The stilling basin should not be omitted from masonry weirs unless a hard rock foundation exists or numerous large boulders passing over the spillway during floods would cause extensive damage to the apron. Stilling basins that have been observed are usually too high in relation to the streambed, too short in length and do not have an adequate downstream baffle. The result is that the energy of the flood waters passing over the spillway is not dissipated within the structure itself, but rather in the soft bed materials below. This causes damage to the toe of the weir and the downstream wingwalls (which also tends to be too short in length). These design flaws in stilling basins may be due to attempts to reduce initial cost, but they can also result in significantly shorter life of the structure, and hence greater cost in the long run.

Sluiceways are required in the majority of diversion structures to reduce the amount of stream bedload entering the headworks and to assist in maintaining a channel to the headworks. The sill of the sluiceway should be placed approximately at the level of the bed of the river and should be at least 30 cm below the sill of the headworks. Some of the sills of the sluiceways observed were generally at the same elevation as the sill of the headworks, thus totally eliminating the effectiveness of the sluiceway. Some sills were located below that of the headworks, but also tended to be below the level of the streambed. Under such conditions the sluiceway has to be kept closed at all times in order to divert water to the headworks. Under normal operation the sluiceway alone is discharging, i.e., no water is flowing over the spillway crest, and the tailwater is at a comparatively low elevation. For these reasons, the sluiceway stilling pool should be placed at a lower elevation than the stilling pool for the spillway. None of the weirs observed have met this criteria. In fact, most have walls separating the sluiceway from the spillway which are too short to separate the stilling pools.

Operation and Maintenance

In village irrigation systems the responsibility for operation and maintenance clearly falls on the users. In systems built or upgraded by Public Works, however, the division of responsibility for operation and maintenance is not so obvious, and as a result, is often not properly carried out. Problems of poor maintenance and operation are further augmented when the design for the system has failed to adequately consider and incorporate the preexisting irrigation infrastructure. For these reasons, it is believed that more clearly defined roles, and hence better operation and maintenance, will occur if the village irrigation systems are decoupled from the systems design, constructed, operated and maintained by Public Works. The suggested point of decoupling is at the point of diversion. Some diversion structures, such as masonry weirs, are beyond the typical resource capabilities of a village and should become the responsibility of Public Works. Other diversion structures, however, such as alternatives to weirs can be constructed, operated and maintained by the village and should thus remain the responsibility of the village. Other recommended technical interventions include flood control structures (i.e., wasteways and cross drainages) and command area expansion facilities (i.e., pipelines, elevated flumes and inverted siphons). While these may require Public Works assistance for design and construction, they could be operated and maintained by the village.

Technical Challenges and Innovative Solutions

Innovative solutions to technical challenges in run-of-the-river systems can be divided into two categories: alternative methods of river diversion and alternatives in water conveyance and control. Alternative methods for diverting water from the river are needed which are less labor intensive to maintain; can be constructed, operated and maintained with typical village resources; are more efficient at diverting low river flows; and/or are more economical than the usually practiced means of river diversion. Alternatives in water conveyance and control are needed which can convey water to land beyond the reach of canals; enhance water management and control; and/or be more efficient, and hence more economical than usual practices.

In Indonesia, practically all diversions of river flows are made by means of a gabion or masonry weir which create a certain amount of head by damming up the stream and diverting it into the canal headworks. Three alternatives to gabion and masonry weirs are suggested for consideration and application in Indonesia. The first suggestion is for a simple check-dam. This would be nothing more than the stabilization of the typical village rock, stick and mud dikes that periodically wash out, and is illustrated in Figure 9. As was mentioned earlier, the plastering over of such dikes generally does not work, as piping below the dikes is accelerated. A solution to this problem of piping would be to place a cutoff wall below the dike extending below the river bed to a depth equal to the water head created by the dike plus the hydraulic gradient head of the river foundation material. Where the conductivity of the river bed material is unknown, 1.5 times the head created by the dike could be used. The dike itself would then be actually an extension of the cutoff wall above the surface. The height of the dike should be no higher than the maximum head required for the canal. Ideally, the dike should be placed in a subcritical flow section of the river and should be placed as far upstream from the point of need as practically possible to minimize the required height of the dike.

A second alternative would be to divert and convey the water to the croplands using a buried pipe system. This structure would be essentially the same as the one shown in Figure 9. Immediately upstream of the check structure the gravel and rock in the streambed is removed for a distance of a few meters. A slotted pipe is then located at the

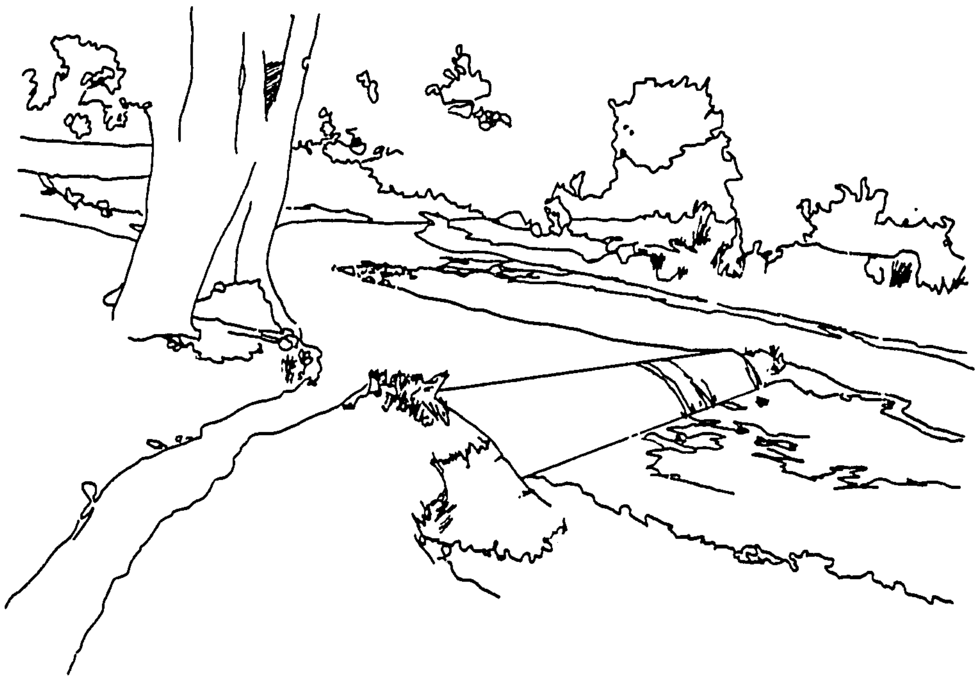

Figure 9. Simple river or stream check-dam.

bottom of the excavation and extending across the stream. The excavated area is then backfilled with a graded rock and gravel pack to provide the pipe with an even flow of water and a filter for sediment and debris. This graded gravel pack should be designed in the same way the gravel pack for a well is designed to increase flow surface area and reduce movement of fine sediments. The slotted pipe should be of a diameter required to carry the design flow and placed in the center of the gravel pack. The water collected in this pipe is then conveyed by pipe to the point of need. The pipe diversion would have to be placed at a point far enough upstream from the point of demand to create enough head to overcome the friction loss in the pipe as well as the head required to lift the water to the elevation of the fields. If this results in a pipe of uneconomical length, the water collected can be pumped. An attractive advantage of this diversion, besides its low cost, is that it can divert some of the subsurface base flow otherwise unavailable to a traditional weir. Since no portion of the in ted weir extends above the river bed, there is no danger of damage to structure during flood flow periods. A brief economic comparison of this alternative is given in Appendix C.

The third suggested alternative to traditional weirs is lift irrigation (Figure 10). A diesel powered pumping plant lifting water 3.5 m above the river to serve 30 ha of land would require a 5 hp engine.

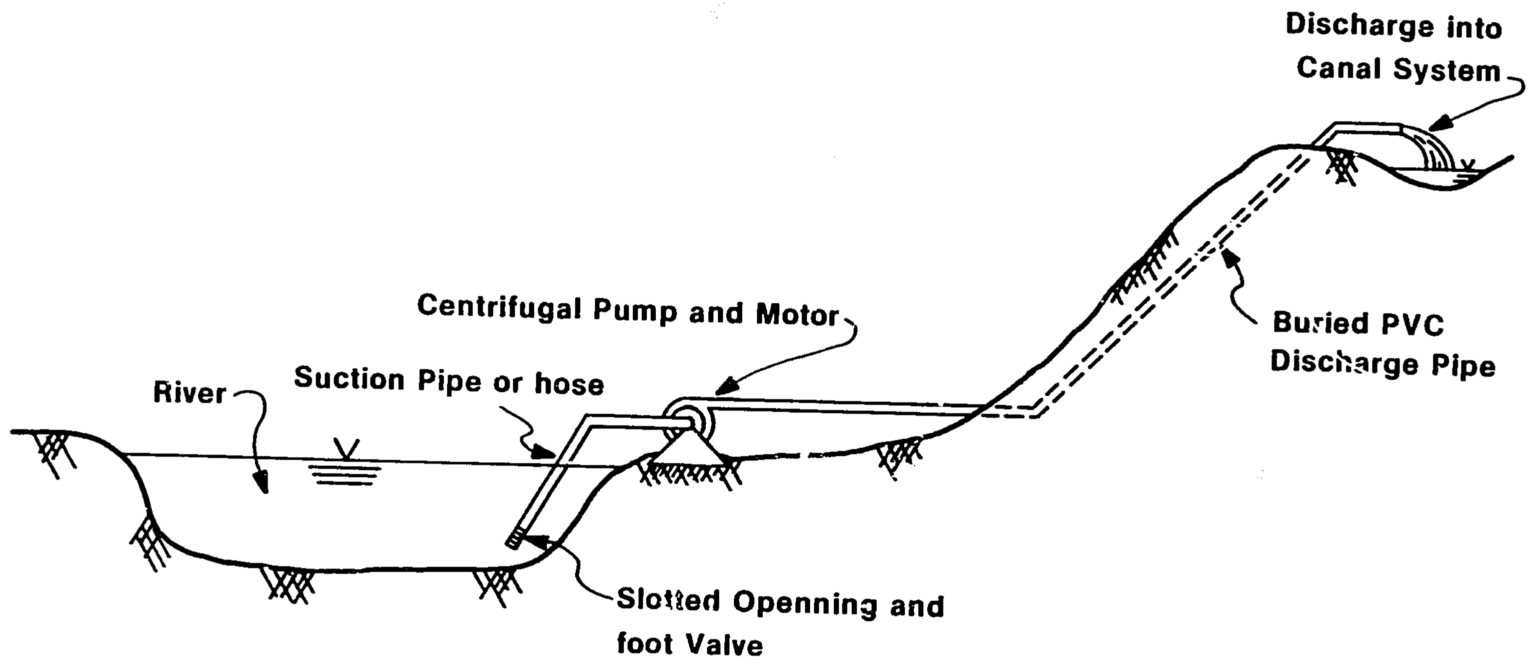

Figure 10. A lift scheme for diverting water from a river or stream.

This is assuming an irrigation water delivery 1.0 l/s/ha for 12 hours a day and a pump efficiency of 50 percent. Assuming an overall pumping plant efficiency of 13 percent (the low average found in the United States), the diesel fuel consumption would be 1.4 l/hr. An economic comparison of this alternative is also given in Appendix C.

The advantages of these three alternative methods of diversion are that they are inexpensive compared to traditional weirs; can be built, operated and maintained by the users; and they are highly divisable. This latter advantage reduces the effect of the classical headend-tailend problem by diminishing the area under command of any given structure. Thus, controlled water, as opposed to water in the river, does not have to be stretched as far. In other words, the requirements for good water management are reduced. Poorly managed water will soon flow back into the river system where it can be rediverted by a downstream diversion structure.

It is strongly recommended that the use of PVC pipe be considered as an alternative to open channels. PVC pipe is being manufactured in Indonesia by the Wavin Company under Dutch license. PVC pipe is relatively low cost, requires minimal skill to install and maintain, and can convey water to points beyond the reach of canals. Closed conduits such as PVC pipe are not recommended when the water is heavily laden with sediment and the velocities within the pipe may become too slow to keep the sediment suspended. To illustrate the relative costs of piping versus masonry channels, consider the following. The cost of one meter of PVC pipe, which will carry the same amount of water as a trapezoidal channel with a 60 cm bottom width and 1:1 side slope, will cost about 25 percent more than the canal. It is estimated that the masonry channel would typically cost about Rp. 8,000 per meter and the pipe (8 inch) would cost Rp. 10,000 per meter. However, there are a number of advantages which will make a system using pipe cheaper than that using a canal system. First, the pipeline can take the most direct route, thus reducing the required length of pipe by at least 30 percent of that required for canals which must follow land boundaries and contours. Secondly, a pipe saves about Rp. 1,000/m in land costs required for canal right-of-way. Third, maintenance is important in both systems, but it should only be about 1 percent of capital costs/yr for pipes, and as much as 5 percent per year for canals. Fourth, fittings for pipe are about 10 percent of pipe costs, while canal structures (i.e., turnouts, drops, bridges) are at least 20 percent of canal costs. And finally, the pipe life is at least twice, if not three or four times, the canal life.

Experience in irrigation water management worldwide has demonstrated that flow measurement devices are critical for good water management, yet flow measurement below the headworks of small systems is rarely seen in Indonesia. This may be in part because most small irrigation systems have been classified as nontechnical or semitechnical. It is recommended that flow measuring devices be placed at the headworks of all systems. This is particularly critical in river systems with diversion structures in series. It is further recommended that measurement devices be placed at division points along the primary canal where the measurement devices can be incorporated into the design of the division boxes. Use of the measurement devices may be facilitated if the staff gages are calibrated to read in liters per second or liters per second per hectare rather than in the usual units of flow depth.

Flow control and division structures in Indonesia generally take advantage of the hydraulics imposed by limiting the size of openings. In upgraded systems the use of proportional flow division structures has not been observed. It is interesting to note that in the village systems visited, proportional flow devices are more common. Such structures tend to be better suited for continuous flow systems, such as the rice irrigation systems of Indonesia, while the division box that is the standard engineering practice, is better suited for rotational type systems. The concept of a proportional division structure is that of dividing the flow into constant proportions regardless of the head in the canal.

Finally, many state-of-the-art innovations can be implemented in the proposed flow augmentation systems. Some of these innovations include dynamic regulation structures, level top canals and flow regulation tanks. If the flow augmentation concept is implemented along with some of these suggested innovations, surface irrigation technology in Indonesia would reach a relatively advanced state.

Groundwater Development

Background

Groundwater is generally the most productive supply of irrigation water because it can be used when and as long as needed as opposed to when available and for presented duration, as in the case of surface supplies. It is generally the "closest" water supply to the farm, and therefore the easiest to convey and apply. However, since it is separated vertically from the farm, it is not always inexpensive to develop, nor may the conductivity of the water bearing strata be high enough to provide a sufficient flow rate. Nevertheless, groundwater is an important option to irrigated agriculture, either as a primary supply or in conjunction with surface supplies to supplement the latter.

Technological Alternatives

The techniques for groundwater development currently in use range from manual lifting of water to submersible turbo-pumps. The corresponding institutional configurations range from private ownership and operation to public development and subsidy of privately operated systems to public owners and marginal systems. The technical alternatives and attendant institutional configurations associated with groundwater resources in Indonesia can be characterized as follows.

The first category is the "dug well." This technique of exploiting groundwater is being practiced fairly widely in both Java and the outer islands. Wells are excavated as open pits, usually circular in diameter, ranging from 1 to 3 meters and depths of up to 10 meters. Water is often lifted manually in some places by walking down the steps into the well to fill a container or by using a lever and counterweight mechanism. The wells typically are unlined and intercept a short depth of the water table which collects in the well for use. The lifted water is used primarily to irrigate high value commercial crops of vegetables and melons along furrows or raised beds.

The advantages of this technique are low capital cost, independence from outside agencies for construction, operation and maintenance and efficient use of the lifted water. In addition, the water is free, thereby eliminating the cash flow constraints some of the other techniques present. Farmers have complete control over the use of water within the physical limitations of the system.

The disadvantages are the human drudgery, energy inefficiency and limited capacity to irrigate. Often the entire family, including young children, must lift water to irrigate an area barely large enough to make even a subsistence living. Though the lifted water itself is used very efficiently, repetitive physical work of this nature is a very inefficient use of human effort. The area that can be irrigated is limited by the availability of family labor. Each such well typically irrigates between one-tenth to one-fourth of a hectare of land.

The next category of groundwater system is the surface-mounted centrifugal pumps which are now being used widely through a variety of institutional arrangements. The prime movers used are portable gasoline, kerosene or diesel engines. Water is lifted from 5 cm shallow tubewells up to 20 m deep. The well is drilled manually using an auger. Water is conveyed through unlined field ditches to irrigate high value polowijo crops such as groundnuts, vegetables and melons. The pumping units range in size from 3 to 10 hp, with discharges from 2 to 10 lps.

A number of alternative institutional arrangements have evolved in the use of the shallow, private tubewell. The pumping unit and the well may be owned by one family who may also "rent" either the water from its well or the pump itself to other users in the village. Similarly, a group of small farmers may pool resources to buy a pumping unit. These groups tend to be small, with 5 to 10 members, though larger groups with 30 to 40 members can be found operating somewhat larger capacity systems. The aspects of the rental arrangements are quite interesting. For example, a single user may rent the pumping unit from an individual farmer or a group within the village, or occasionally from an outside entrepreneur. The former practice is widespread in all regions where lift irrigation is being practiced. (One example of the latter was observed in Kupang where the local pump and agricultural machinery dealer was promoting the use of pumps through a leasing program.) Rents range from Rp. 500 per hour to one-third share of the crop. Fuel is arranged and paid for by the user separately.

The advantage of this technology is that it can be adopted by farmers independently and it provides them complete control over irrigation. The costs of equipment and its operation are not high and can be borne entirely by the farmer. Capital costs per hectare are relatively low where locally manufactured/assembled equipment can be used. The disadvantages of these systems are that only shallow aquifers can be tapped and access is restricted to those who can raise the necessary capital or maintain social relationships with pump owners in the village. One of the major difficulties is that farmers do not have the technical information needed to design and install pumping systems which operate efficiently.

The final groundwater system includes the deep tubewells which are being installed by the Public Works Department. These large diameter wells ([illegible] cm) are extended up to 120 m deep. A typical system would use a 25 [illegible] turbo-pump mounted at depths of up to 30 m. The prime mover used is a diesel or electric engine. The Department also constructs lined primary canals for these projects and the farmers build unlined tertiaries. These wells are designed to irrigate between 15 to 50 ha with water duties between 1 to 2 lps per ha. The Department transfers well operation to a water user association in one to three years after construction. In the Kediri-Nganjuk area in East Java, for example, 56 out of 128 wells have been handed over to the farmers for operation. During the one to three year "pre-condition" period, farmers cooperate in the well operation, learn to perform minor maintenance and agree to the rules for sharing the system. At the end of the precondition period, the users assume responsibilty for operation, maintenance and minor repair, including the salary of an operator when needed. Responsibility for major repair and replacement rests with the Department, although one observes that users are setting aside funds for contingencies.

The command area of a public system is typically divided into small blocks with a rotational arrangement for distribution between the blocks. The farmers within the block get water on demand on the day of their turn. Crops irrigated during the dry season are principally polowijo crops. The principal advantages are that due to the nature of deep tubewell technology and the economics of scale it is possible to provide the technical supervision necessary for efficient well development. Deep tubewells enable development of deeper aquifers and aquifer management is easier when pumping is under the supervision of a public agency. The potential disadvantages are organizational difficulties in O&M, farmers' dependence on external agencies for development, relatively higher capital costs, higher risk of failure, the need for imported drilling equipment and pumping machinery, possible lowering of the aquifers beyond the capacity of private development and potentially lower efficiency in the use of necessary larger volumes of water.

Developmental Issues

The technology of groundwater development in Indonesia is largely imported. The first issue raised here is, therefore, the evolution of a local industry to support groundwater development. The structural element of a groundwater program includes drilling rigs, pumps, engines, pipes and fittings.

Most drilling equipment for deep wells is imported and spares are not easily available. Deep well pumps in Central and East Java are generally submersible turbo-pumps, whereas preference for centrifugal pumps are expressed in NTB. While these large pumps are also imported as a rule, at least one local manufacturer (Rutan in Surabaya) has been licensed to assemble British turbo-pumps and fabricate some parts locally. However, some of the more precision tooled parts require a three to six month order period. Centrifugal pumps are being manufactured locally with only the shaft blanks imported. The quality of these pumps is, however, poor. Specifically, the range of designs is limited. Since the basic capacity does exist for manufacture, it is not unreasonable to expect improvement in foundary and quality testing facilities to yield better systems.

Engines for well systems present again a mixed picture. Electric motors, large and small diesel engines are being locally assembled under licensing agreements with both Dutch and Japanese firms. Many parts must be imported, but the trend toward local fabrication is increasing.

A second major issue regarding groundwater development concerns support for smaller farmer-owned systems. Not all areas can be effectively irrigated with subsurface systems or public tubewells because of typography and limited public resources. Shallow aquifers can be exploited economically by farmers and support is needed to accelerate farmer initiated development. Access to technical information and technical services such as drilling and capital are the main constraints faced by farmers. These constraints limit the scope of private initiative and result in poor system efficiencies reflected in substantial increases in costs.

Another important related issue is to financing groundwater development. At present the development of deep tubewells is entirely subsidized. Farmers pay the O&M costs once the system is handed over to them, but the project cycle costs of replacement and major maintenance are borne by the government. Farmer initiated development, on the other hand, is entirely privately financed and no subsidies are available. The alternatives of recovering all or part of the costs of public sector development and subsidizing private development need to be considered.

The fourth issue concerns the relative role of private and public sectors. Certain aspects of groundwater development can only be handled by the public sector. These are mapping of the aquifers, monitoring the aquifers, development in areas requiring mechanized drilling and the development of deeper aquifers where yields from shallow aquifers are insufficient. The development of shallower aquifers can, however, be done by individual farmers, farmer groups and outside (non-farmer) entrepreneurs. When development must take place in the public sector, the operation and maintenance can be undertaken by farmer groups, as is the practice at present. The private sector can also play a key role in equipment manufacture, financing and technical assistance. At present farmers have no access to technical information in well siting, well design and pumping system design. As a result, capital and operating costs to the farmers are three to four times as much as in a properly designed system. The poorer farmers suffer the most, as they end up buying inefficiency when they rent these poorly designed systems. The pumping equipment presently available is usually inappropriate for shallow wells. Pumps being sold are designed for medium to high (15 to 30 m) lifts, whereas a surface mounted pump lifts water from depths below 8 meters. The hydraulic efficiency of the pump will be low and the engine would be run below its rated capacity, resulting in low efficiency. Centrifugal pumps can be designed to almost any specifications, and there is no technical reason why better systems cannot be introduced.

A fifth issue concerns the management of groundwater as it enters the tertiary and field boundaries of the irrigation system. At least one alternative to the existing open ditch conveyance of pumped water is the buried PVC pipeline with risers and valves for each farm takeoff. Preliminary analyses show the costs to be substantially below masonry or concrete lined open channels. Further, the extent of lands served by a well would not be topographically limited, maintenance would be simpler and the energy recovery from the pump system could be improved. Piped water can be divided into manageable portions for field application, as opposed to the present practice of dumping the entire discharge of up to 40 lps on one field. It enables the use of water saving application technologies such as hoses, showers and sprinklers. The pipeline system could still provide for secondary water demands like washing basins and animal wallows. Finally, there is the question of groundwater development policy. Public resources can be selectively applied to provide supplemental irrigation in the tail reaches of surface systems, in places where yields from shallow aquifers are inadequate and to build farmer confidence about aquifer potential in undeveloped areas or indiscriminately to develop high potential aquifers. Exactly what mix is followed has implications for equity as well as efficiency of resource use.

Opportunities for Innovation

There are a number of opportunities for the introduction and testing of alternative groundwater technologies and institutional arrangements. Some of the possible technologies include the following:

Percolation wells. In areas where aquifer conditions are not favorable or highly variable and surface irrigation is sporadic, large diameter dug wells can be built to irrigate small land holdings. These wells can be used to irrigate paddy during the wet season when percolation rates are high and then dry season vegetables or polowijo crops when percolation rates decline. Such wells can also be built on river banks to trap the base flows where rivers dry up during the dry season.

Pit-mounted centrifugal pumps. In areas where the aquifers are beyond the suction lift of a centrifugal pump or the yield from the shallower aquifers is limited, the possibility of installing shallow tubewells inside small dug wells might be considered. This alternative expands the range of the shallow tubewell, both in terms of area commanded and aquifer depths tapped. Beyond some point, though, a submersible pump may be a better alternative.

Small centrifugal pumps and watering hose. The smallest pumps available at present are 3 hp pumps. Even smaller (1 hp), gasoline engine driven pumps might be introduced. These pumps, if properly designed, could command 1 to 3 ha, which is what the presently available 3 hp pump irrigates (because of inappropriate pump design). These pumps could be used to pump from dug wells or small cavity wells. Since flows from these small pumps (including the existing 3 hp pumps) are very small, flexible watering hoses might be used to achieve higher conveyance and application efficiencies.

Rigid PVC wells. Slotted rigid PVC pipes can be used in shallow tubewells. These wells cost less than mild steel and have low friction losses. PVC pipes are lighter and easier to transport and install.

Rigid PVC conveyance system. Rigid PVC conduits can be used in place of open channels. PVC pipes typically are cheaper than open channels, take no land for construction and are easier to install and repair. Additionally, PVC pipes allow a great deal of flexibility in system design.

Distribution system design. The present practice in public tubewells is to transport the water through large channels to irrigation blocks and dump the entire flow (often 40 lps) into each block by rotation. An alternative which can be easily developed by using buried PVC pipes is to divide the flow into units of say, 10 lps, and to irrigate more than one block at a time. Other possibilities, such as placing the pipe in a loop, might be possible. Through careful design using PVC pipes it would be possible to offer more flexibility to the farmers and effect higher water use efficiency and overall system economy.

Improved design of shallow wells. Presently shallow wells are cavity type; that is, a galvanized iron tube is taken down to the top of the aquifer but not through it. No screen is used. The well diameter typically is 5 cm. The yield of such wells is usually very small and the tube in any case cannot handle flows larger than 3 to 5 lps due to excessive friction losses. Such wells are suited to very small command areas (1 to 2 ha), using a 1 hp pump and a plastic hose to irrigate. For larger command areas, where aquifer yields are good, larger diameter (10 or even 15 cm) wells should be used. These wells should tap the entire shallow aquifer, using appropriate screens. The key point is that proper matching of the well and the pumping system to aquifer conditions on the one hand and irrigation requirements on the other is crucial for efficient use of resources in groundwater development.

Needs and opportunities exist for promoting institutional innovations for efficient and equitable use of groundwater resources. Some of these include the following:

Manufacture of pumping systems and accessories. The pumps and prime movers for shallow tubewells are generally inappropriate and available in a very limited range. A simple rule of thumb to evaluate surface mounted centrifugal pumps is that the discharge per hp ratio should be at least 4 to 5. The manufacturing capacity for centrifugal pumps is not well developed in foundry and testing facilities. Also, the designs available are limited. Improvements in manufacturing and testing facilities and introduction of a range of designs suited to the prevailing aquifer conditions and farmer needs would facilitate groundwater development in the private sector.

Entrepreneurship development. Two areas where an entrepreneurship development program can be developed are shallow well drilling and pumping equipment leasing. In both, entrepreneurs have spontaneously emerged and technical support and provision of venture capital would improve both the quality and the scope of services available to the farmers. Wells are at present drilled by village mechanics who own the drilling equipment. Because of the equipment available to them, and perhaps because of lack of expertise, they drill narrow and very shallow wells. The ultimate loser in the process is the farmer who gets an inefficient well and pumping unit and expensive water. A program of upgrading their skills and providing them access to tripod mounted manual percussion drills or mechanized augers would considerably reduce costs of irrigation from private wells.

Another program is promoting entrepreneurs who would lease pumping equipment to farmers and address the two key problems of farmers -- access to capital and technology. This approach is likely to be more effective than the alternative of credit and technical extension to the farmers because implementation would require dealing with a few individuals, who can be carefully selected and would be capable of handling technical and managerial sophistication. The process is self-regulating as competition would ensure quality and cost. In Bangladesh, for example, the price of water in the "landless pump groups experiment" has come down to about 10 percent with the entry of more entrepreneurs. This perhaps is already happening in Indonesia where the rental rates for pumps vary from place to place, the highest being in Kupang, where one dealer enjoys a monopoly. In addition, monitoring is politically more feasible because the public agencies -- and other non-government groups -- can play an adversary role. Government can play an effective regulatory function and non-government groups can be more forthright in evaluations without fear of embarrassing public agencies. Most importantly, this approach reduces farmers' risks and managerial burden which a credit program still has. The problems of equipment maintenance, equipment efficiency and fuel supply get transferred to the pump owner.

It seems conceivable that both the drilling and the pump leasing programs could be combined into a two-tier structure of entrepreneurs and their agents/employees, the latter being based in the villages.

Improvement of equipment dealership. Equipment can at present be sold by licensed dealers, but there are only a few in the field. The equipment sold too often is inappropriate, most possibly because the dealers do not know what the appropriate equipment is for the region. There is need to regulate the type of equipment sold. In India, where 80 percent of the pumps are bought against bank credit, banks regulate the equipment used by lending only for a pump suitable to a particular area. Two kinds of institutional interventions are needed: standards for equipment and accessories, and zoning of aquifers in terms of suitable equipment.

Special studies. Before promoting development of new pumping equipment, a market survey must be conducted of the need for such equipment. Such a survey would take into account farmers' irrigation needs, aquifer conditions and equipment costs and would identify gaps.

Very little is known about how private development is financed, the sources of technical services, the characteristics of the equipment leasing market and existing gaps. Future program planning would greatly benefit from research on these issues.

Studies on the performance of public and private tubewells and their respective institutional arrangements in terms of technical and economic efficiency, farmer access, reliability, equity and impact on agricultural productivity would be helpful in identifying the strengths and weaknesses. Some studies of the public wells exist, but none on private wells.

Groundwater monitoring. As development proceeds, space monitoring capabilities must be developed to safeguard against aquifer damage.

In order for these suggestions to have their fullest effect, there are three research needs that are suggested.

Small Tank Systems

In the tropical climate of Indonesia, the river runoff is characterized by two phases: (1) a high flow period with numerous flash peaks during the rainy season; and (2) a slow receding base flow during the dry season. In the dry season, the discharge approaches almost zero in rivers with small catchment areas and those of rather steep slope. The small steep watersheds result in runoff in the rivers closely related in time and intensity to rainfall. For most months even in the rainy season, periods of up to a few days without rainfall are common, resulting in corresponding periods of low runoff. Dependable irrigation flows under these conditions can be increased by the provision of small storage tanks (embungs) to store water during high flow periods, for use in periods of low rainfall and runoff.

The design Team observed only one embung in the site visits and were told that more existed in the three provinces. There appears to be no design standards for such structures in Indonesia. Consequently, the team was unable to technically assess the procedures that might be employed to plan and implement such structures. It is assumed that the same standards for design and construction being used for larger tanks and reservoirs would be applicable. This section, therefore, outlines briefly the small tank or embung technology and suggests some of the general design criteria to be applied. It does not comment on associated design or management issues since the lack of such systems precludes comparison.

Types

Although tank designs vary with location and purpose, each is basically one of two types. The "pit or dugout pond" is developed by enlarging an already existing depression or simply by excavating a pit in flatland areas. Many existing depressions are normally wet because of close proximity to the water table and can be expected to provide good water retention.

The second and most widely used type is the embankment tank. Concrete, timber and steel dams are forms of embankment, but are rarely considered for small tanks due to high costs. An earth and/or rock filled embankment is generally the easiest and least expensive ponding method for the amount of water stored and materials moved. In an earth or rockfill dam, the major portion of the embankment is pervious materials and, therefore, a water barrier is necessary. This barrier can be in the form of an internal core, or as an impervious blanket on the upstream slope.

Topography, to a large degree, influences the site, type and capacity of tank. For an embankment type pond some desirable site characteristics are:

1. Narrow valley at damsite to reduce fill and provide deep water storage which reduces evaporation losses;

2. Wide abutments for an emergency spillway with minimum excavation;

3. An alternate watercourse to allow diversion during construction; and

4. A flat valley slope upstream to minimize deep cuts in the pond area.

To insure that the water storage capacity at a selected site will be adequate for the intended use, an estimate of capacity should be made. For an embankment tank, a reasonable estimate can be made by multiplying the pond surface area by 0.4 times the maximum water depth at the dam. Topographical maps, visual inspections and preliminary surveys are valuable guides to site selection.

On-Farm Water Management

This section describes technical aspects of water conveyance, distribution and application at the farm level. Although institutional and organizational aspects were presented earlier in Section II, it may be useful at some places to briefly repeat some institutional aspects.

Water Conveyance

Government controlled projects tend to be rigid; i.e., they are relatively inflexible in altering the frequency, duration and discharge to individual outlets that enhance the irrigators' ability to optimize water use on individual fields. Village administration allows possibly better flexibility as neighbors work together to manage the entire system for their mutual benefit. One of the major problems in the traditional government built weir and primary conveyance system is that it often "overlays" upon several historically individual village systems.

The conveyance system in small-scale irrigation systems built by the Public Works Department has traditionally consisted of a main canal with tertiary channels. The main canal tends to be too long, and feeds a large number of farmers who take water directly from the main canal. Because of the inequity and maintenance problems associated with such large commands, the practice of breaking the overall command into smaller tertiary and quaternary units has become very popular.

Village irrigation systems commonly use this practice of disaggregating large commands into small management units of 5 to 10 ha size. It is not uncommon to see a tertiary channel flanked by two quaternary channels, running parallel over long distances. Such a conveyance system helps clearly define a social group of farmers, their water rights and obligations to channel maintenance. Since farmers get water only through the quaternary channels, farmer groups are responsible for maintenance of the quaternary channels. Village administration maintains the tertiary channels since water in the tertiary channels is used both for domestic and agricultural purposes.

To obtain better water control, simple gates are used at the tertiary and quaternary intake points. These gates can be locked in position whenever it is necessary to have a rotational system of water delivery. Flow regulating gates are much more commonly used at the head of the main canal. Serious omissions in the conveyance system are the lack of flow measuring devices and keeping reasonably accurate records, both at the main and farm levels. Sometimes flow measuring devices are initially provided at the diversion point, but because of inadequate attention and maintenance, these devices give inaccurate measurements. For the purpose of monitoring and evaluating the impact of the project, it will be necessary to ensure proper measurement and collection of data related to water flows.

Water Distribution and Application

During the rainy season water is generally supplied through the tertiary and quaternary channels on a continuous basis and farmers take water at their own discretion. Institutional control on the system is minimum to reduce management costs. As the water supplies decrease during the dry season, institutional control on the system is increased and farmers no longer make unsupervised withdrawal from the system. It is then distributed among the farmers under the supervision of a village irrigator, ulu-ulu, who is responsible to the village headman.

During the dry season, the most effective way of matching the decreased water supplies to the demand is to reduce the amount of land planted to rice. These cropping decisions related to authorization for rice and polowijo crops in a particular year are made at the village level by the administration and the water users association. The water allocations to the units over the dry season then follow the cropping decisions, and are implemented by the ulu-ulu and water user association. Because of close supervision and contact between the association officers and the farmers, the water distribution is somewhat on demand rather than a strict rotational basis.

Rice is primarily grown in small submerged basins during most of the growing season. These paddies are formed by bunds laid out parallel to the ground contours, with distance between bunds decreasing with increasing slope. Superimposed on the paddy pattern are the property boundaries, generally normal to the slope and to the supply channel. It is considered highly desirable for each property unit (patok) to have an individual turnout from a quaternary channel. This design criteria, in addition to the desirability of not making the quaternary channels too long, necessitates a long and narrow shape of the property units, the narrow side being parallel to the supply channel.

To apply water to the land, farmers introduce water in the basin nearest the intake point on the supply channel. Water then spills from higher paddy to lower paddy until the last paddy is irrigated. Farmers do not normally use field channels within the patok.

In the dry season, because of decreased water supplies, many farmers grow upland crops such as corn, beans, soybeans and onions. In Southern West Java province soybeans and cassava seemed to be common, whereas in Sumbawa, onions are a very popular high-value cash crop. Farmers' decision whether to grow upland crops or leave the land fallow is primarily influenced by two technical considerations. First is the expected amount of irrigation water available during the dry season for growing these crops. Though secondary crops such as cassava and green beans are commonly grown on residual soil moisture, high value crops such as onions and tomatoes are almost always irrigated. The second factor is the soil texture. Polowijo crops are usually grown by employing the furrow-and-ridge method; hence, the flat paddy lands must be converted to furrows and ridges which requires substantial labor. If the soils are predominantly light-textured, farmers can make furrows and ridges without incurring high labor costs. For heavy-textured clay soils the labor costs will be high. Also, light-textured soils have good internal drainage as compared to the heavy-textured soils and as such, under similar management conditions, yields are generally higher on light-textured soils.

Potential Improvements in On-Farm Water Management

An important aspect of water management is the use of devices for measuring water flows in the systems. For an effective monitoring of the project impact, it is imperative to include flow measuring capability and recording of the data in the design of irrigation systems. Providing simple flow regulating gates at the tertiary and quaternary intakes is usually helpful in obtaining greater operational control. The same is true for other on-farm control structures such as distribution boxes and check structures.

Disaggregating large tertiary command areas into small quarternary irrigation units is a very pragmatic use of physical technology to support organizational rules. Although the design requires greater numbers of farm distribution channels, it is helpful because the farmers' water rights and obligations to channel maintenance are then clearly defined.

In the dry season irrigation of high-value crops such as onions and tomatoes might use sprinklers and should be investigated. Sprinkler irrigation should be particularly efficient when the soils being irrigated are sandy. Similarly, trickle irrigation should be considered where perennial crops are being irrigated from groundwater sources.

SECTION IV

BASIC FEATURES OF THE LOCAL SETTING

Indonesia in General

Rainfall

The climate of Indonesia is controlled largely by the monsoons, the northwest monsoon from November to May bringing the heaviest rains and the east monsoon originating from Australia bringing little rain. The average annual rainfall is about 2,500 millimeters and is typically frontal, convectional and orographic. It varies widely between 700 millimeters and 7,000 millimeters. The higher rainfall areas are in the western part of the country and gradually decrease toward the east. This is illustrated by the difference between the provinces of West Java and East Java. Most areas in West Java have at least seven consecutive wet months (at least 200 mm of rainfall) and East Java less than seven consecutive wet months. In the far eastern islands of Nusa Tenggara there are only three or four wet months and seven to nine dry months. The monsoonal rainfall pattern is modified by topography in which humid air is pushed upward against mountain chains, causing heavy orographic rain on the windward slopes. Therefore, rainfall generally increases from the coastal areas to the mountains. For example, Jakarta on the coast has four or five wet months and four or five dry months, and the rest in between for a total of about 1,800 millimeters. Bogor, on the other hand, at a much higher elevation, has over 200 millimeters (wet) every month, for a total of over 4,000 during the year.

Temperature

Because of its equatorial location, the seasonal temperature variation is not pronounced (isothermal). The main cause of temperature variation is the elevation above sea level. As a rule of thumb, the maximum temperature decreases 0.6°C per 100 meters and the minimum temperature decreases 0.5°C per 100 meters. For example, the average maximum temperature at low elevations toward the end of the dry season is about 32 to 33°C, and only two or three degrees lower during the wet season. The average minimum temperature is slightly lower during the dry season, 22°C, than the wet season, 21°C. At the 1,000 meter elevation the average maximum temperature is about 25°C toward the end of the dry season and about 24°C during most of the year. The average minimum temperature is about 16°C during the dry season and 18°C during the wet season.

Natural Features

Indonesia has a land area of about 736,000 square miles (about 1.9 million square kilometers, of 190 million hectares) distributed among

13,667 islands, of which only about 1,000 are inhabitated. Five of the islands include nine-tenths of the land area: Sumatra, Sulawesi, two-thirds of the islands of Borneo and Irian Jaya.

The landscape is highly varied and mountains stand out in sharp relief on the larger islands. Most Indonesians live in sight of craters or volcanic cones. There are two long mountain systems which intersect in Sulawesi and Halmahera. One consists of two parallel ridges that are a continuation of the Western Burmese Chain and runs through Sumatra, Java, Bali and Timor and curves sharply in a great hook through the southeastern islands to Ceram and Buru. The second runs southwest through the Philippines into Eastern Indonesia. Thus, the mountain structure is complex and accounts for the peculiar shape of Sulawesi and Halhamera, which have ranges running north-south and east-west.

Indonesia is the most highly volcanic region in the world; over 100 peaks are active volcanoes or were active until recently. The country's highest peak is in Irian Jaya and rises to about 16,500 feet. There are many peaks over 10,000 feet. Soils formed from volcanic ash are relatively fertile and the highest population density is found in regions where there has been the most volcanic activity. Thus, Java with the most volcanoes, is by far the most densely populated of the islands.

Soils

The land area of Indonesia may be broadly classified into five land forms or systems:

1. Alluvial land;
2. Plains;
3. Hills;
4. Mountains; and
5. Miscelleneous lands -- coastal, marine soils, sands, tidal flats and mangrove swamps.

Soils of the alluvial lands are generally level and relatively fertile and well suited for irrigation development and/or for intensive rainfed crop production. They are usually fairly deep and medium to fine textured. Some areas may be sandy, gravelly, or saline, but these areas are not extensive within most alluvial lands. The main limiting factors on these lands is flooding caused by rainfall ponding and/or river overflow.

Soils of the plains zone range from shallow to deep and are found on the low terraces above the flood plain. The topography is generally undulating and the soils show some development of horizons. They are usually well drained and may be relatively fertile, depending on the type of rocks from which the soils are derived. Probably some areas in this zone are arable, but much of it may be best suited to grazing.

Soils of the hill lands are generally shallow and preclude cultivation because of the steep slopes. Most of these areas are used for grazing or perennial crops and shifting cultivation. In some areas where land is cleared and cultivation attempted, erosion is a serious problem. Overgrazing, indiscriminate burning and cutting of trees for firewood have greatly accelerated erosion.

Steep hills and mountains have a more rugged topography than the hill lands and the soils are very shallow. Cultivation, grazing or deforestation would cause serious damage to the watershed and a dense vegetative cover should be maintained.

The coastal marine soils, tidal flats and mangrove swamps are generally too saline or sandy for cultivation. Of the 35 million hectares of coastal swamp, about 10 percent has been developed for irrigation. There are many technical difficulties in using much of this land for irrigation such as salt water intrusion, maintenance of desired water table levels, etc.

Land Use

The diversity of climate, topography and soil conditions in Indonesia supports a wide range of agricultural production and land use patterns vary from region to region. Although detailed surveys are not available, it is estimated that about 10 percent of the land area (19 million hectares) is cultivated to annual and perennial crops, about two-thirds is too steep for farming and is largely forested and about 22 percent is swampland. Of the 19 million cultivated hectares, over 9 million are in rice, of which over 5 million are under irrigation. Although the area planted to rice has increased about 10 percent in the last ten years, average yields of paddy have increased from a little over 2 tons per hectare to almost 4 tons. This has been the result of improved and more irrigation, more use of fertilizer increasing from 78 to 183 kg/ha in the last ten years, greater use of high yielding varieties and more use of pesticides.

Corn is planted on about 3 million hectares, but the yields are quite low -- about 1.5 tons per hectare. About 1.5 million hectares are planted to cassava and the yields of this crop are also low -- less than 10 tons per hectare. Soybeans are grown on about 700,000 hectares with yields averaging about 900 kilos per hectare. Other important cultivated annual crops are peanuts, sweet potatoes and vegetables.

Perennial crops are grown mostly in the uplands on about one-third of the total cropland. Rubber and coconut are the most important -- a total of almost 2.5 million hectares in rubber and over 2.7 million hectares of coconut. Smallholders grow all of the coconut and over 80 percent of the rubber; the rest are in plantations. There are about 650,000 hectares in coffee, all but about 6 percent grown by smallholders. On the other hand, practically all of the 265,000 hectares in oilpalm are grown in plantations. Tea is grown on about 113,000 hectares, over 60 percent in plantations. Almost 500,000 hectares are in clove and 348,000 in kapok, all of which are grown by smallholders. Of over 400,000 hectares planted to sugarcane, about 60 percent were grown by smallholders. Other important perennial crops of smaller areas are nutmeg, pepper and cassiavera.

Agricultural Policies

Sites being considered for this project are diverse climatologically, topographically and demographically. There are, however, important similarities: all are affected by GOI's agricultural policies which stabilize and standardize prices and which provide subsidies for inputs such as fertilizer, pesticides, credit and water. Another common denominator is the dominance of paddy rice as a staple crop. A high priority of GOI's agricultural policy has been oriented toward achieving rice self-sufficiency. It appears that this goal has, at least temporarily, been achieved. A number of factors including extensive irrigation development, adoption of high yielding varieties and a recently increased relative price of rice seem to account for this achievement.

Policy analysts are predicting that if current trends persist, GOI's rice marketing organization will be forced to revise its prices downward or face the prospect of exporting high cost rice at a loss. Such a policy would make secondary crops relatively more attractive for commercial farmers, which is consistent with another government goal: food diversification. The possibility of such changes raises questions about the efficiency of projects which further expand Indonesian irrigation systems. Definitive answers to these questions are beyond reach at this time. However, the questions imply a note of caution in the use of current agricultural prices in assessing the profitability of this project: rice prices are subjected to downward pressure and the momentum of the ongoing intensification and extensification projects are likely to persist for some time, worsening this pressure. Assumed benefits must take into account this trend.

A second question -- adaptability of irrigation systems to secondary crops -- underlines a goal of this project: increased farmer control of irrigation systems. Involvement of farmers in the design, operation and maintenance of their irrigation systems is unlikely to decrease the flexibilities of the systems, and it gives farmers the opportunity to design parts of their systems specifically for secondary crops.

Regional Per Capita Incomes

Regional income disparities are an inescapable effect of economic development (at least for market economies). To some extent these disparities are constructive, as they serve to motivate reallocation of resources, including labor, from regions where their productivity is low to regions where their productivity is high. There is also a tendency for such adjustments to be uneven. Capital incomes of "backwash" regions tend to lag more progressive areas, creating a kind of negative multiplier effect. There is some plausibility in the argument that government projects may be justified in such areas on grounds of efficiency as well as equity, the argument resting on the existence of excess capacity (e.g., unemployment) in regions subjected to backwash effects. If there are excess capacities, then induced and indirect effects could in principle be counted in benefits. It is also true that certain sectors tend to be victims of "backwash" effects during economic development -- agriculture being the classic case. The disparity is not without social costs -- either underemployment in backwash regions or urban unemployment, both of which have real costs. Clearly, there is some justification for public investment in projects to mitigate extremes of regional inequalities.

The most straightforward indicators of regional wealth is per capital income. Again, the three areas where proposed projects are located are well below the national norm: two Kabupatens of West Java where project sites are located had 1978 per capita incomes of Rp. 28,627 (Ciamgur) and Rp. 50,426 (Sukabuma) -- less than one-half the average for West Java (Rp. 115,128) and less than one-third the national per capita income of Rp. 150,000. The 1978 per capita incomes of NTT and NTB were Rp. 71,920 and Rp. 78,765, respectively -- again, roughly half the national norm for the same year.

West Java

Agrometeorology

The proposed area for initial activities of the Small-Scale Irrigation Project in West Java comprises the complete catchment areas of the Cikaso, Cibuni, Cisokan and Cisadea rivers. This area extends some 75 km west to east and 40 km north to south, lies south of Sukabumi and Cianjur and is entirely within Wilayah Pengairan Bogor.

Mean annual rainfall within the proposed area varies from about 2,750 mm per year in the lower elevations to 4,250 mm per year in the upper elevations. There is a well-defined dry season extending from May through September. There is, however, a limited amount of hydrological and climatological data available for the area. Almost the entire area has been covered by up-to-date, good quality aerial photography at a scale of 1:15,000. Topographic maps have been prepared for parts of the area at a scale of 1:5,000.

At present there are approximately 11,500 ha of rice grown within the four river basins. This rice is either rainfed or irrigated through temporary diversion weirs. There appear to be no permanent diversion weirs in the area. Less than 50 percent of the area is presently double cropped. The estimated potential for development is 14,000 ha, 95 percent of which could be double cropped with proper water resources development.

Most of the soils on the level to slightly sloping lands are alluvial in origin and are generally moderately to poorly drained. Probably the most common are the dark cracking clays, Grummosols (in Soil Taxonomy, Vertisols) and the very poorly drained hydromorphic soils, called Gleysols. The latter have strongly gleyed or mottled subsoils with a high water content much of the year. Two crops of rice are commonly grown on the Grummosols and Gleysols. Because of drainage problems, rice is the most suitable crop and the potential productivity is high. Some farmers on these soils are now getting about 4.5 tons of paddy per hectare for the wet season crop and 2.5 to 3 tons per hectare for the dry season crop. Undoubtedly, the dry season crops would produce as much as the wet season crop given better water control and greater inputs.

Some of the soils on the moderate slopes as well as in more level areas have good drainage. Though they may be puddled for rice, they can grow two crops of paddy rice followed by short season secondary crops such as soybean, peanuts, mungbeans, etc. In some places in Indonesia three crops per year, or five crops in two years have been successfully grown where there is a sufficient supply and adequate management of water. A short season vegetable crop has been grown on small parcels following two crops of rice.

In the rainfed upland areas on the steeper slopes mixed perennial tree crops and cassava, largely in subsistence farming, predominate. Below Cikaso smallholder estates of hybrid coconut and rubber are being developed, 1.5 hectares per family. A processing plant for rubber has already been established. These perennial upland crops are important in stabilizing watersheds and reducing runoff.

A number of separate background studies have been undertaken covering fields of agriculture, socio-economic, hydroclimatological and technical matters. These are as follows:

Analisa perencanaan pengembangan sumber2 air Walayah Jawa Barat Selatan. July 1981, C.V. Kutamas

Hasil Analisa Tanah daerah Irigasi Cikaso, Kecametan Sagaranten, Kabupaten Sukabumi, 1981, UNPAD

Laporan Analisa Laboratorium Contoh Tanah, Air dan Sedimen Transport di daerah Irigasi Cikasi, July 1981, DPMA

Observation of Floord Cibuni River, 1981, C.V. Pembahas

Penyelidikan Geologi Tehnik & Mekanika Tanah Saluran induk Cikaso 1981, P.T. ISUDA PARANA CO eng

Reconnaissance Study Pengembangan daerah irigasi S Cibuni, Nov. 1978, sub P3SA JABAR SELATSN

Studi Kelayakan Pengembangan Wilayah Sungai Cibuni, 1982, P.T. HEGAR DAYA

Identification of Possible Irrigation Develpments in Southern West Java, Sept. 1982, PU JABAR + Snowy Mountain Engineering Corp.

Cikaso Irrigation Project Pre-Feasibility Study. May 1982. PU JABAR + Snowy Mountain Engineering Corp.

Social Characteristics

The primary social statistics for the proposed project area are given in Table 1 and taken from the publication Penentuan Lokasi Daerah miskin Propinsi Jawa Barat, Dr. Tata Funa Tanah, Agraria, Dep. Dalam Negeri, Publikasi No. 125, 1978. The data are listed at the provincial level for West Java, at the Kabupaten level for Kap. Sukabumi and Kap. Cianjur, and at the Kecamatan level for Kec. Sagarenten in Kab. Sukabumi and Kecamatans Cibinong, Pagaleran and Kadupandak in Kap. Cianjur. The data in columns are in the following categories: (1) Average Income per Capita (Inc/Cap); (2) Percentage Unemployment (5 Unempl.); (3) Proportion of Total Land which is Rainfed (% Rnfd); (4) Land Productivity in Rupiahs per Hectare (LProd.-Rp/Ha); (5) Average Amount of Agricultural Land per Household in Hectares per Household (Agl-Ha/HH); (6) Average Amount in Hectares of Landholdings per Landowner (from total landowners; L/owner); (7) Average Number of Children per Total Population (CH/Pop); (8) Population Density (Prs.Km^2); (9) Proportion of Total Land which is Sawah (Swh/YL); (10) Proportion of Total Households which are Landowners (LOWN/THHs); (11) Average Value of Livestock Owned per Household (LVSTk-R/HH): (12) Proportion of Total Land Tax which is Recovered (L Tax Rec/Tot LT); and (13) Proportion of Total Households having Homes at Least Partially Made with Concrete (ConcH/HH).

About 70 percent of the population is at least partially employed in agriculture. For Kapupaten Sukabumi only 15 percent of all farm families are devoted full-time to the land, 47 percent have one sideline occupation, 26 percent have two and 12 percent have three or more. Interestingly, the average monthly income listed in Table 1 is just over Rp. 50,000 per capital per month. Of the full time farm families this figure drops to Rp. 13,000 per capital per month and climbs to Rp. 53,000 for the one side-live group and Rp. 66,000 to the two side-live group. On the other hand, for those with three and four outside occupations, income per capita drops to Rp. 22,000 and Rp. 21,000 per month,

TABLE 1

SUMMARY SOCIAL DATA FOR WEST JAVA PROSPECTIVE SITE LOCATIONS

Location	Inc/Cap (Rp)	% Unemp	% Rnfd	LProd-Rp/Ha	AgL-Ha/Farmers	L/Owner (Ha)	CH/Pop	Prs/Km^2	Swh/TL	L/Owner/THHs	LVstK	LT Rec/TotLT	Conch/HH
West Java	30,553	23	23	217,291	.35	.75	.43	-	.32	.62	15,061	.68	.20
Kab. Sukabumi	50,426	30	31	212,994	.50	.77	.50	587	.21	.63	16,537	.79	.19
Kec.Sagaranten	38,401	34	30	230,719	.55	.89	.40	243	.09	.57	35,782	.79	.18
Kab. Cianjur	28,627	22	23	280,712	.43	.63	.49	515	.31	.80	12,360	.77	.24
Kab. Cibinong	48,873	29	18	162,388	.58	1.05	.47	170	.08	.79	11,270	.72	.005
Kec. Pagelaran	29,664	15	46	203,841	.25	.68	.44	480	.22	.79	15,539	.62	.005
Kec.Kadupandak	20,983	28	30	89,571	.69	.89	.50	462	.51	.87	18,692	.62	.005

respectively. One might suspect that farm families with three or four outside occupations are those with small holdings and might be moving toward non-farming livelihoods.

NTB - Sumbawa

Agrometeorology

The island of Sumbawa is of volcanic origin with a total land area of about 16,800 sq. km and population of approximately 750,000. Over 90 percent of the land is mountainous, and the average gradient from the mountain top to the shores varies between 5 and 10 percent. The area with agricultural potential is limited to a narrow band along the shore, up to 5 km wide, which has been deposited by alluvial sediments from the river valleys. The land capability studies have identified approximately 180,000 ha that are suitable for cultivation of agricultural crops. Of this total, 51,000 ha is of highly suitable class.

Present land use studies indicate that approximately 116,000 ha are used for agriculture. Bunded rice lands constitute about 58,000 ha, and of this total approximately 32,000 ha produce one or two crops of rice per year. The remaining lands, which are utilized for cultivation of dryland crops, constitute about 58,000 ha including plantation crops and mixed garden crops on about 6,000 ha. The total land capable of cultivation which is not presently under cultivation is 64,000 ha. The soils in these cultivable areas are generally fertile and have a desirable pH for crop production.

The climate of Sumbawa is tropical with well defined rainy and dry seasons. The wet monsoon period between November and March brings tropical rainstorms, and the east monsoon period between May and September is dry with relatively large variations in day and night temperatures. The months between the two monsoons are transition periods with variable weather conditions. The total mean annual rainfall in the low regions facing west is 1,300 mm, while 2,000 falls in the mountains. The eastern part of the island is relatively more dry with an annual mean rainfall of 800 to 1,100 mm.

The rivers on the island are steep, short and have relatively small catchment areas. The largest river is B. Beh with a catchment area of 1,300 sq. km, the second largest watershed in B. Taliwang with a drainage area of 620 sq. km. As such, the river flow is highly sensitive to the rainfall pattern, resulting in flash peaks, rapid recessions limbs and low base flow. Individual rainstorms clearly create individual pak flows since most watersheds are small. In most rivers, stage goes up from base flow level to flood level (over 3 meters) in less than one hour and usually flow is back to base flow level within a few hours. A large volume of runoff is carried downstream in that short period of time.

Groundwater is presently being exploited at a very low level on the island of Sumbawa. Much use is made of near surface groundwater for domestic purposes and for small-scale irrigation. These wells are hand dug, very shallow (3 to 4 m deep) and unreliable in the dry season. For irrigation out of these shallow wells farmers carry water by buckets and apply it to the land. The main groundwater aquifers are the alluvial plains where most of the population lives. In such areas sand and gravel aquifers are capable of safe yields of 20 to 60 lps. Some of the areas with good groundwater potential are the Bima-Raba Valley, Sila Plain east of Sila and the Sape-Simi region.

Irrigation water is presently supplied to about 35,000 ha, primarily in the rainy season, which is about 18 percent of the total cultivable land and about 28 percent of the land presently under cultivation. Only about 10,000 ha produce two crops of paddy, while the remaining 25,000 ha produce one crop of paddy, followed by reduced areas of polowijo crops.

As a result of the mountainous topography of the island, the size of individual irrigation schemes is small, varying from 100 ha to 2,500 ha. The majority of the schemes (about 70 percent) are well below 500 ha. The potential for irrigation lies in the development of many small to medium size schemes. There are numerous village irrigation systems constructed and managed by farmers where the river flow is partially diverted by means of simple weirs. However, since the majority of these rivers are non-perennial, the use of weirs is limited to providing irrigation water to supplemental rainfall during the wet season. Also, the weirs, being made of dumped rock and tree branches, periodically wash away during high river runoff. A very effective program for developing irrigation would be to help farmers improve these weir structures and to augment the water supplies in the rivers during the dry season.

Social Characteristics

Table 2, taken from Penetuan Lokasi Daerah Miskin, Nusa Tenggara Barat, Dir. Tata Gunawa Tanah, Dr. Jen. Agraria, Dep. Dalam Negeri, Publikasi No. 96, 1978, shows the social characteristic of Sumbawa. The categories listed are a subset of categories in Table 2. The data are listed at the provincial level for NTB, at the Kapupaten level for Kab. Bima and Kab. Sumbawa, and at the Kecamatan level for Kecamatans Monta, Woha, Belo (Pelaparado area), and Sape in Kap. Bima, and for Kecamatans Taliqant (Kalimontang area), Empang and Plampang in Kab. Sumbawa.

In Sumbawa the term for a water user association is "malar." In each of these four areas farmers claimed there were functioning malar for each of the village systems. These systems typically are fed by a combination of rain and diverted water from rivers or streams. Even though such systems are sometimes referred to as "rainfed," all of the systems we visited had channels for water conveyance. The Team was told that the malar traditionally have a leader and assistants by blocks and that the leadership is regularly rotated. At the Marongi site in the Empang-Plampang region there were roughly 600 hectares of rainfed and

TABLE 2

SUMMARY SOCIAL DATA FOR <u>NTB</u> PROSPECTIVE SITE LOCATIONS

Location	Inc/Cap (Rp)	LProd-Rp/Ha	AgL-Ha/ Farmers	L/Owner (Ha)	CH/Pop	Prs/Km²	L/Owner Farmers*	LVstK-Rp/HH**	LTRec/ TotLT	Conch/ HH
NTB	25,206		1.37	.71	.47	234	.85	5,150	.56	.03
Kab. Bima	26,247	109,524	.91	.63	.48	125	1.48	7,865	.59	.01
Kec. Monta (Pelaparado)	37,922	15,037	1.29	1.07	.48	42	1.29	4,952	.54	.005
Kec. Woha (Woha) (Pelaparado)	21,603	67,093	1.43	.66	.48	356	2.13	4,178	[illegible]	.005
Kec. Belo (Delo) (Pelaparado)	30,214	182,177	.77	.49	.48	158	1.60	24,536	.75	.005
Kec. Sape	20,614	114,636	.59	.58	.49	75	1.07	894	.74	.01
Kab. Sumbawa	34,227	83,018	1.51	1.30	.44	50	1.03	13,835	.79	.01
Kec. Taliwang (Kalimantang)	31,448	90,014	1.28	1.36	.48	46	.94	7,492	.70	.01
Kec Empang	32,805	[illegible]9,647	1.13	1.20	.43	26	1.01	15,266	.96	.01
Kec. Plampang	41,566	75,573	2.39	1.66	.47	16	.97	22,913	.87	.02

*Per Farmer
**x Rp. 1,000

partially irrigated sawah (one crop per year). For this area there are about 300 users, who are organized into four malar. Channel maintenance is done collectively and the brush/stone diversion is rebuilt yearly by the total membership of the four malar. Most of the farmers plant rice variety IR 36 and some plant the local six-month variety, Sumbi. In the Embang-Plampang area the most common dry season activities are producing asam Jawa, obtaining rattan and making furniture, brick-making and cutting wood for furniture. Reported paddy yields in the area were 1.0 to 1.2 ton per hectares.

Kalimontang has above-average population density for the island, fertile soils, government-protected water catchment areas, extensive rainfed sawah and farmer-built channels, apparently functioning malar and the apparent widespread desire to intensify agricultural production. Almost all farmers in this area own their own cattle and a small tree crop plot. Since tree crops require little labor, they are known as the "pensiun petani" ("farmer's pension") and are desired by all farmers. Such an incentive to diversify in this way often leads to cutting of the forested water catchment areas of irrigation systems and must be monitored.

In the Pelarado and Sape areas of Kab. Bima extensive rainfed sawah and farmer-built conveyance channels and diversion structures were also operating. Between the proposed Embung Sape (tank) and the Sape weir (about 10 kilometers) there is a series of 12 farmer-built diversions, serving roughly 1,000 hectares (300 ha which gets one paddy crop and one polowijo crop, and 300 hectares of which gets two rice crops per year).

NTT

Agrometeorology

One of the proposed project sites on Timor Island is in the Oesao Plain, which is located at the head of Kupang Bay and encompasses 22,600 hectares of flat to gently sloping land comprised of alluvial marine sediments dissected by more recent river systems. A substantial part of the plain is covered by alluvial deposits. Large areas are periodically flooded during prolonged intensive rains.

The Kupang Peninsula, jutting out of the mountains in the southwest, is the most developed part of the island. This is also a relatively arid area in comparison to the northern and northeastern hills, which tend to have more water, are cooler and greener. Approximately 285,000 ha, or 20 percent of the land area is considered suitable for agriculture under an appropriate management system. Of this, roughly half, or 137,000 ha, is in coastal plains, fans and aprons and mini depressions. Typically, these are deep soils with fine to medium texture. These soils are suited for intensive irrigated agriculture. The remaining 148,000 ha of the agricultural soils are shallow to moderately deep soils, with a smathering of small patches of deep, fine textured soils. These soils are suitable for rainfed cultivation or grassland development. These soils also tend to have the least potential for irrigation.

Several rivers crisscross the island. The two major river systems, which between them drain more than one-third of the island into the Timor Sea, are the Mina and the Banain. Other streams have catchments of a few sq.km to several sq.km. The rivers generally flow through steep slopes in their upland courses, except in mountain depressions where they meander along gentle terraces. Drainage typically is through coastal basins and fans where river slopes are very gentle and the meandering beds can sometimes be 1/2 km wide. The larger river systems such as the Mina, the Benain. The Mena, etc., are perennial, though the dry season discharge is very small. The smaller streams dry out during the dry season. Most rivers, however, carry some surface flows during the dry season.

Groundwater availabilty is highly variable due to the varying geological formations. Groundwater data presently available from the Public Works Department is only at the pre-feasibility level. According to this data some basins, such as the Aroki Plain, have shown good potential, while others do not have exploitable resources. A few artesian wells have been found.

Springs are another important source of water. Hundreds exist, some with dry season flows exceeding 100 lps. Some of these have been mapped and others are being investigated by the Public Works.

The area has a tropical monsoon climate with very distinct wet and dry seasons associated with the west-northwest and east-southeast monsoons. Wet season extends from November to April, although the beginning of the wet season and the distribution of wet days can be highly variable. Yearly rainfall varies between 700 mm in some of the coastal plains to 3,000 mm in the mountains. Rainfall is received in short intense bursts typical of the monsoon and 200 mm precipitation within 24 hours is fairly common.

A number of small irrigation schemes have been implemented by the government through the Provincial Public Works and other agencies. These typically are river diversion wiers, irrigating wet season paddy. The total area irrigated from these is between 5,000 to 6,000 ha. Numerous village systems exist, irrigating perhaps another 5,000 to 6,000 ha. These typically tend to be free intake weirs from rivers, though in some cases perennial springs, too, are being used. Many village systems along perennial rivers irrigate a second crop of paddy during the dry season. Subsistence agriculture is the principal farming system. According to the Department of Agriculture, approximately 10 percent (140,000 ha) of land is under permanent agriculture. Maize, paddy and cassava are the main crops. The island is a net importer of paddy and maize.

The Oesao Plain has a large potential for increasing crop production with irrigation. Along with the water, an improvement in agronomic practices will be required and additional inputs such as fertilizer, pesticides, etc. Better varieties adapted to the area will be needed. Some of the soils are calcerous and on these soils micronutrients may be needed such as zinc and manganese. One farmer with 6 hectares of the heavy soils said his rice yields were only 1 to 2.5 tons per acre. He believed that his problem was due to leaf hoppers, but it could be other limiting factors such as poor land preparation, not enough fertilizer, etc. Although the farmer had a tractor, this land was scattered in one hectare blocks which would be a handicap in getting the land prepared in time after the rains start. Further, the rainy season is marginal [illegible] a good crop of rice.

The region imports annually a substantial amount of rice and corn and there is opportunity to increase production. Strengthening the agricultural extension unit and timely provision of inputs, along with educational and demonstration programs, and improving market channels are some of the things that will be required. The impressive results of the BIMAS-INMAS program in increasing yields of rice and other food crops in the past few years indicate the agricultural potential in the Oesao Plain.

Social Characteristics

The following data in Table 3 are taken from Penentuan Lokasi Daerah Miskin Propinsi Nusa Tenggara Timur, Dit. Tata Guna Tanah, Dir. Jen. Agraria, Dep. Dalam Negeri, Publikasi No. 119, 1978. The data categories listed are a subset of the categories listed in Table 1. The data are listed at the provincial level for NTT; at the Kabupaten level for Kab. Ende, Kab. Kupang and Kab. Timor Tengah Selatan; and at the Kecamatan level for Kec. Ndetusuko and Kec. Marole in Kab. Ende, for Kwc. Kupang Timor in Kab. Kupang and for Kec. Amanuban in Kab. Timor Tengah Selatan.

As one goes eastward to Flores and Timor the average spatial size of dialects and tribal/kinship affiliations and gets much smaller than elsewhere in Indonesia. Social distance and antagonisms between villages therefore become very profound in NTT. Reportedly there is widespred suspicion of outsiders and government projects, which come in with their own development priorities for the villages. All of this suggests the need for a slower, more cautious approach to small-scale irrigation development, perhaps even working at the village level with assistance from PVOs in the area, such as Dian Desa or Oxfarm America.

In Timor, sawah land generally is prepared by trampling. Roughly 60 head of cattle per hectare are used. In many rainfed sawah areas the cattle are owned by a small group of landholders or merchants (many of the latter are of Chinese descent). Poorer farmers, who may own one hectare or less, typically must schedule and rent the use of the cattle, on credit, to be paid back in the form of a share of the harvested crop. This problem of debt is compounded by the traditional use of "gotong royong" (group exchange labor) in planting and harvesting. Typically, 10

TABLE 3

SUMMARY SOCIAL DATA FOR NTT PROSPECTIVE SITE LOCATIONS

Location	Inc/Cap (Rp)	LProd Rp/Ha	% Unemp	AgL-Ha/ Farmers	LTRec/ To tLT	LVstK- Rp/HH*	Swh/TL	Prs/Km^2	CH/Pop	L/Owner Farmers	L/Owner (Ha)	Conch/ HH
NTT	36,957	88,790	59	.64	.74	7,743	.01	52	.45	.46	1.47	.07
Kab. Ende	44,894	63,064	64	.50	.83	3,522	.02	90	.44	.35	1.17	.17
Kec.Ndetusu Ko	49,254	87,485	67	.54	.88	2,777	.04	38	.42	.36	1.04	.04
Kec. Maurole	70,696	76,754	98	.70	.63	3,260	.01	28	.46	.31	1.51	.02
Kab. Kupang	72,925	231,304	53	.62	.79	17,955	.02	226	.41	.52	1.04	.09
Kec. Kupang Timor	39,464	253,681	91	1.27	.80	12,045	.04	26	.39	.61	1.84	.02
Kab. Timor Tengah Selatan	41,434	80,316	50	.61	.76	12,634	.001	58	.46	.37	.40	.02
Kec. Amanuban Selatan	45,809	109,140	34	.24	1.0	20,938	.01	47	.44	.33	.46	.01

*x Rp. 1,000

to 25 farmers take turns planting and harvesting each other's fields. The day the owner has his field's turn he must provide food for all the workers and must usually borrow from creditors to do this. Apparently many farmers are in perpetual debt. When the Yayasan Indonesia Sosial tried to introduce a project in Timor to train farmers in plowing technology and offer credit to purchase cattle they were met with opposition fro the big cattle owners/creditors. Farmers who obtained cattle under the project reportedly had difficulty borrowing money from the creditors thereafter.

The so-called "Amarasi model" of land use is spreading around Timor and Flores and could have implications for farmer responsiveness to irrigation. Under this farming system farmers divide a typical 2 hectare plot into thirds. Two-thirds of the plot is planted with the fast-growing nitrogen-fixing lamtoro tree. On such a plot four or five cattle may be fattened by eating the foliage of the lamtoro. The other one-third of the plot is planted with soybean, groundnuts, cassava, sweet potatoes, etc. for one or two seasons. Then half of the two-thirds of the plot in lamtoro is cleared and planted with these crops while the previously cropped portion is replanted with lamtoro. This rotation continues, as a kind of sedentary but shifting cultivation. Studies show that this triple-pronged strategy (i.e., cattle fattening, lamtoro, vegetable crops) can increase annual incomes by 30 to 40 percent above those from traditional shifting cultivation. An irrigation project potentially could compete with this system or adopt itself to it.

NTT - Flores

The Flores component of the NTT recommendations is the proposed Mautende Project on the north coast of Flores, some 60 kilometers directly north of Ende. Most of the cultivable area is on the level to gently sloping alluvial plains and terraces of the Mautende River. The project area is estimated at 7,200 hectares, of which some 500 hectares are now under cultivation. Most of the soils appear to be varieties of Grummusols, grey to dark gray, moderately to poorly drained, clays, silty clays and clay loams. Some areas are more sandy and better adapted to crops other than paddy rice. From superficial observations of the soils it appears that most of the land should be highly productive and produce two or three crops a year given an adequate and reliable water supply and management and use of recommended agronomic practices.

The average land holdings per family in the Kapupaten is about one-half hectare. Where irrigated paddy rice is grown an average of 2.1 tons per hectare was reported. Under the BIMAS program yields are above 3 tons per hectare. One farmer in the Mautende area claimed a yield of 6 tons per hectare without additional nitrogen. This is quite possible, as there are some low areas that are high in organic matter and could supply sufficient nitrogen for high yields, at least for a few years.

SECTION V

PROPOSED PROJECT ACTIVITIES AND THEIR IMPLEMENTATION

The previous section has provided information on the agricultural, economic and hydrologic conditions in the general project areas of the three provinces of West Java, NTB and NTT. This section specifies the project activities proposed for each province and, where possible, identifies particular subprojects for consideration. The section also includes a discussion of procedures for implementing the capacitation component of the strategy as well as actions needed for monitoring, evaluation and supporting special studies.

Project Activities in West Java

Irrigation in West Java is extensive. Some of the largest and most modern irrigation systems in Indonesia are found in the districts along the north coast. Many of these systems have received considerable attention and rehabilitation over the last several decades. In the central volcanic region there also is a great deal of irrigated land on the gentle slopes of the volcanoes and in intervolcanic valleys. Much of this irrigation is in the form of small systems, many of which are under village management. In general, there is far less irrigation in the area of the province adjacent to the south coast. In fact, the southern region of the province has relatively less infrastructure development of all kinds -- roads, bridges, electricity and irrigation. It also is a less densely populated area, less agriculturally intensive and generally poorer in terms of average incomes. Provincial authorities, interested in improving this situation, have been focusing more attention on infrastructure development in the region, particularly roads, and they argue that irrigation development is a critical part of their "southern" development strategy.

Planning for irrigation development in this southern region has been aided by the presence of an Australian technical assistance group (Snowy Mountain Engineering Corporation) working with the design unit of the provincial irrigation department. As an integral part of their training effort this technical assistance team worked with the design unit to prepare a number of preliminary studies of irrigation schemes for tapping the water of several major rivers that drain in the southern region to the Indonesian Sea.

Building on this prior reconnaissance and design work, it is proposed that USAID consider focusing the small-scale irrigation project in West Java in the catchment areas served by four of these major rivers: the Cikaso, Cibuni, Cisokan and Cisadea. The region of these four watersheds extends approximately 75 kilometers east to west and 40 kilometers north to south and is located in the extreme southern portions of the districts of Sukabumi and Cianjur (see Figure 11). Administratively,

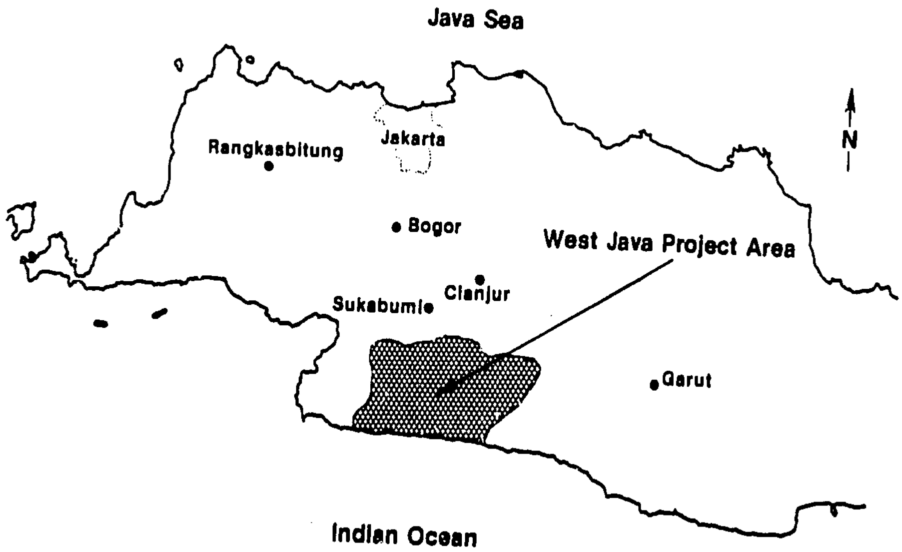

Figure 11. Location map of proposed West Java projects.

this entire region lies within the Wilayah Pengairan Bogor, which has a major suboffice in Sukabumi.

Although there is limited climatological and hydrologic data available for the project areas, as discussed in the previous section, it is reported that the mean annual rainfall in this region varies from 2,750 mm in the lower elevations (where the irrigation commands would be located) to 4,250 mm in the higher elevations. As elsewhere in these monsoon regions, there is high variability within and between years, making the use of annual means of limited value. There is a well-defined dry season extending from May through September.

Reports prepared by the Snowy Mountain group and their design unit counterparts estimate that there are approximately 11,500 hectares of wet rice being grown in these four river basins -- including (but not distinguishing between) rainfed and irrigated fields. They report that less than 50 percent of this area is double-cropped. The reports anticipate that a total of 14,000 hectares could be irrigated in this region, 95 percent of which could be double-cropped. The irrigated commands that do exist appear to be conventional village (desa) systems using temporary diversion structures. Apparently, there are no permanent structures operated by Public Works in this region.

The catchment areas of these four rivers are large and the rivers themselves deep and carry high flows of water. Consequently, none of these rivers are utilized by farmers for irrigation diversions. Rather, their simple diversion structures are located on smaller streams, some of which are non-perennial, that flow into these larger rivers.

In brief, it is proposed that the project assist the GOI in planning, designing and constructing permanent diversion structures on these major rivers and conveyance canals to move the water from the diversions to the command area. Within the command area water would be discharged from the supply canals into the natural waterways from which the village systems would divert the augmented flow into their small commands. As discussed earlier, the capacitation component of the program would assist these village systems to improve their physical facilities and institutional arrangements for utilizing the new water supply. In some instances, this would allow for existing small commands to be expanded and for new small commands to be created.

Proposed Subproject Locations

It is recommended that eight subprojects located on three of the major rivers (no subprojects are recommended for the Cisokan watershed at this time) be included in the USAID project. They are as follows:

1. Cikaso Hilir on the Cikaso River;

2. Cikaso Udik on the Cikaso River;

3. Cibuni Hilir on the Cibuni River;

4. Cibuni Udik on the Cibuni River;

5. Cikulina on the Cibuni River;

6. Cijampang Udik on the Cibuni River;

7. Cisadea Hilir on the Cisadea River; and

8. Cisadea Udik on the Cisadea River.

Since it is proposed to use a similar strategy in each of these eight subprojects, only the Cikaso Udik is discussed in detail herein. The discussion also includes an economic comparison of the Cikaso Udik and the Cikaso Hilir subprojects.

The Proposed Cikaso Udik Subproject. The proposed layout for the Cikaso Udik subproject is that basically developed by the Snowy Mountain group and their Indonesian colleagues with modifications to implement the augmentation component of the project strategy. The majority of the 3,520 ha of net irrigated area lies within a small river basin that feeds into the Cibuni River.

The Cikaso Udik weir is to be designed to have an offtake on the right bank and require a 200 m aqueduct over the Cikaso about 2.5 km downstream of the weir to enable the irrigation of 350 hectares on the right bank. The weir would have a crest length of about 35 m and a height of about 5.5 m. The main canal system would be approximately 57.3 km long with a design discharge of 4.75 m^3/s. The proposed main canal would divide with each portion following the contour of each side of the small watershed and augment the flows in the small side drainages. While the existing design study does not mention such, there may be some utility in designing regulating tanks at appropriate locations along the supply canals.

Existing village diversion structures could tap the augmented flow in these natural drainage ways. Consistent with the capacitation component of the project, assistance might be provided to these village systems to improve their diversion structures or other physical facilities as well as organizational assistance. This assistance would, for example, include aid in extending existing commands as well as creating need commands where feasible.

Thus, specific project activities that would be associated with the Cikaso subproject (and other similar subprojects in West Java) include the following:

1. Design and construction of the major weir;

2. Design and construction of the augmentation canals, including the aqueduct over the Cikaso;

3. Reconnaissance studies in the proposed command area to document the number of existing irrigation commands, the total hectarage being served, the cropping patterns and agricultural practices being used, the organizational capacities of local irrigation groups and other matters;

4. Organization of a system for providing financial assistance, technical engineering advice and institutional development support to small systems in the service area needing to improve their physical facilities; a similar system is needed for developing new small commands;

5. The organization of training programs to develop the skills of the irrigation agency staff in the effective operation of the supply canals in support of the agricultural activities of the villages' irrigation systems; and

6. Organization of a system for monitoring project performance, including the responses of the local irrigation groups to the augmented water flow. This monitoring effort should begin with a preproject baseline study that should focus on key factors such as water supplies being received by the existing systems. cropping patterns and practices, local irrigation organizatio.., levels of well-being and other variables expected to be changed by the project.

Project Activities in NTB

It is proposed that project activities in NTB be concentrated in several areas on the island of Sumbawa (Figure 12). Sumbawa is of volcanic origin with a total land area of approximately 16,800 sq.km and a population of 750,000. Over 90 percent of the island is mountainous. Much of the agricultural zone is limited to a narrow coastal area surrounding the island.

Appropriate irrigation technology is highly related to the nature of the water resources available on Sumbawa. The rivers of the island are steep, short and have relatively small catchment areas. Therefore, the river flows are highly sensitive to the rainfall pattern resulting in flash peaks, rapid recession and low base flows. Individual rainstorms can create individual peak flows since most watersheds are small. Few rivers flow throughout the dry season, the exception being those rivers with large catchments above 1,500 m in elevation. Optimum and effective use of the wet season flow in most rivers can be made use of only if the wet season flow is stored for use in the dry season.

Presently there is limited use of groundwater on the island. Typically, use is made of near-surface groundwater for domestic purposes and, in selected areas, for irrigation of vegetable crops. Such wells are hand dug, very shallow (3 to 4 m), and unreliable in the dry season. To lift water from these shallow wells farmers hand-carry water in buckets. Areas with good groundwater include the Bima-Raba Valley, the Sila Plain south of Bima and the Sape-Sumi area.

Approximately 35,000 ha are presently irrigated, primarily in the wet season, on Sumbawa. This is estimated to be 18 percent of the total agricultural land and about 28 percent of the presently cropped area. It is reported that about 10,000 ha is presently double-cropped with rice. Much of the remaining irrigated area produces one rice crop followed by a polowijo crop.

The irrigation systems in Sumbawa are small, ranging in size of command from 100 to 1,500 ha. The majority of the schemes (70 percent) are well below 500 ha. Many of these are village-managed systems based on the diversion of water from the non-perennial streams with the use of simple weirs.

The broad outline of the hydrologic and irrigation situation presented above and in the previous section provides some definition of a project strategy and ensuring activities. A major need for further development of irrigation in Sumbawa is to create water storage facilities (tanks) or to tap natural groundwater storage for both supplementary irrigation in the wet season and to support crop production in the dry season. As in the case of West Java, it is recommended that this stored water be used to augment the supplies to the existing small command, some of which might be expanded, and to create new commands

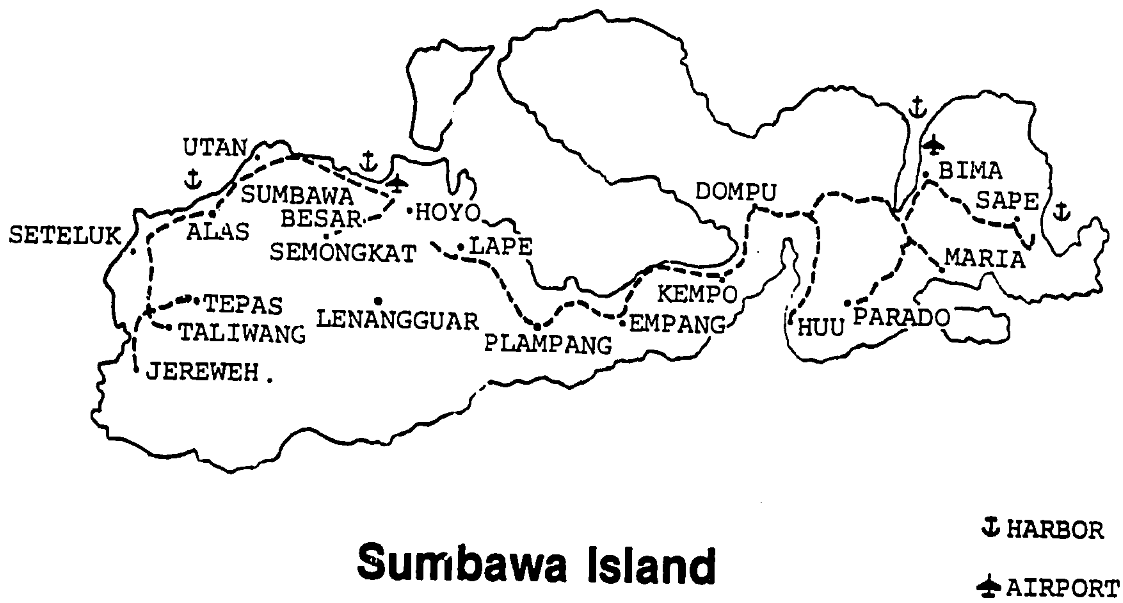

Figure 12. Sites on Sumbawa Island.

where possible. These small systems would remain, or become, locally controlled systems and be assisted through a set of capacitation activities.

Proposed Subproject Locations

It is recommended that subprojects be undertaken in four areas in Sumbawa. Each of these four areas require somewhat different technological approaches, but in each location the overall project strategy is applicable. The following paragraphs briefly describe the situation and needs in each of these areas. This is followed by a summary of the project activities that would be implemented in Sumbawa.

The Taliwang Complex. This area is located on the west coast of Sumbawa. There are two large perennial rivers in this area: the Taliwang and the Kalimontang. Public Works has already constructed a permanent weir on the Kalimontang River and two smaller weirs on the Seteluk. The proposal is to assist the GOI in constructing the weir and canal system that has been planned for the Taliwang River. No tank storage is planned because of the perennial nature of the river. The water flow diverted from the Taliwang would be used to stabilize water levels in the Taliwang Lake, thus improving opportunities for fish production, and to irrigate approximately 2,590 ha. With the subproject, it would be possible to double-crop the entire area.

The major works proposed are a diversion weir and two main canals, each about 16 km in length. The right bank canal would supply water to Taliwang Lake in addition to supplying irrigation. The left bank canal would both supply water to areas in the Taliwang command and supplement supply in a portion of the present Kalimontang command.

As presently planned, the Taliwang weir is located such that the main canals traverse a long distance (about 14 kilometers) through a very narrow valley before reaching the main command area. It is suggested that an alternative to be investigated is to site the weir lower on the Taliwang and closer to the main command area. The irrigated upstream of this new weir location could then be supplied by pumps lifting water from the river. Private farmers' groups in this area are already using small pumps to lift water to serve commands of 10 to 30 ha.

The Empang-Plampang Complex. This area is located on the narrow peninsula that joins the two major halves of the island. There are four major river systems draining this area: the Empang, the West Empang, the Plampang and the Marunge. Each of these rivers has its source in the surrounding hills at a relatively low elevation, perhaps 500 m. The catchments are short and steep and have very short response time to rainfall events. The proposal is to assist the GOI in designing, constructing and operating storage tanks (embungs) on the Empang and Plampang rivers and on the Tiu Kulit River, a tributary to the Marunge. Water stored in these tanks would be released into the natural rivers to be diverted by existing and new small-scale irrigation works. As in other locations, the program would include assistance to the small-scale systems to develop the physical and institutional capacity to effectively utilize this augmented water supply.

The total hectarage presently irrigated in this area is 2,164 ha. Irrigation is accomplished through small individual weirs that have either been constructed by farmer groups or, in some cases, by Public Works. With construction of the storage tanks it is estimated that about 2,000 ha could be double-cropped in the Empang area and about 1,100 ha in Plampang.

The Pelaparado Complex. The Pelaparado basin drains an area of about 400 sq.kms south of Bima Bay with one major river, the Pelaparado, and two tributaries, the Keli and Tonggo. The average flow in the Pelaparado in the wet season is about 500 lps, which is insufficient to irrigate the total available land. In the dry season the flow is virtually zero.

While water is short in the Pelaparado Basin, there is considerable irrigation being practiced. In addition to the typical small weir systems, farmers have dug shallow wells from which they irrigate such high value crops as onions and tomatoes. In addition, about 4,225 ha of rice are grown in the wet season.

The proposal for this project area is to augment water supplies by assisting the GOI design, construct and operate several storage tank facilities that are in the preliminary design stage and to support studies and pilot projects for the development of groundwater. As elsewhere, water from the tanks would be delivered to small, locally-managed systems and will require assistance to upgrade their capacity to use this augmented water supply. Groundwater activities could include activities such as deepening the present shallow wells and installing surface-mounted pumps to lift the water, experimental use of PVC pipes for water conveyance and the pilot installation of both shallow and deep tubewells.

The Sape-Sumi Complex. The Sape and Sumi rivers rise in adjoining valleys in the mountains west of the town of Sape at an elevation of about 1,000 m. Both rivers are highly responsive to rainfall events and during the dry season have flows of near zero. The use of water for irrigation in the wet season is high but irregular day-to-day. The proposal is to assist the GOI in designing, constructing and operating a storage tank on each of the rivers. This would be complemented by the same strategy of small system development discussed previously for other subprojects.

The storage tank on the Sape would regularize water supply to the existing irrigated area and increase hectarage in the wet season by about 500 ha. It would also allow an increase of about 600 ha during the dry season. The preliminary design of the facility on the Sumi River predicts that 1,800 ha will be converted from rainfed to double-crop paddy and 700 ha from single- to double-crop paddy.

Summary of Specific Project Activities

This section summarizes the specific project activities that would be associated with the various proposed subprojects in the four areas of Sumbawa discussed above. These include the following:

1. Design and construction of the major augmentation structures, either weirs or storage tanks;

2. Design and construction of augmentation canals (probably limited to the Taliwang complex area);

3. Reconnaissance studies in each of the proposed command areas to document the number of existing commands, the total hectarage being served, the cropping patterns and agricultural practices being used and the physical and organizational capacities of the local irrigation systems, etc.;

4. Preliminary studies regarding groundwater resources and the implementation of pilot activities for demonstrating improved dug wells and shallow and deep tubewell installation;

5. Action research to develop suitable procedures for the operation of the storage tank facilities and the training of

Public Works staff in such operations (similar efforts will be needed to develop procedures to operate the diversion weir in the Taliwang complex to serve both the lake and the irrigation command);

6. Organization of a system for providing financial assistance, technical engineering advice and institutional development support to small systems in the service area needing to improve their physical facilities (a similar system is needed for developing new small commands); and

7. The organization of training programs to develop the skills of the irrigation agency staff in the effective operation of the supply canals in support of the agricultural activities in the villages' irrigation systems.

Project Activities in NTT

It is recommended that subprojects be undertaken in two areas of NTT: on two plains in the Kupang Peninsula, or Timor Island, and in the district of Ende on the island of Flores. The situation in these two areas is very different in both physical and socio-economic characteristics; hence the proposed activities vary considerably between the two areas. The following paragraphs briefly describe the situation and the needs in each of these areas and describe the proposed project activities.

Subprojects on the Kupang Peninsula

Rivers on the Kupang Peninsula generally flow through steep slopes in their upland course except in mountain depressions where they meander along gentle terraces. Drainage typically is through coastal basins and fans where river slopes are gentle and the meandering beds can sometimes be 0.5 km wide. The larger rivers have some flow in the dry season, though the discharge is quite small, while the smaller streams are dry in this period.

With the assistance of the Canadian Government a considerable number of preliminary studies of groundwater resources have been completed. One conclusion from this work is that groundwater availability is highly variable due to the nature of the geological formations. Springs are another important source of water. Some mapping of them has been completed and Public Works continues to explore these topics.

Irrigation on the Kupang Peninsula (Figure 13) is limited but not entirely absent. This appears to be the result of several factors -- the nature of the water resources available and the difficulty of exploiting them, the relatively sparse populations which make labor for intensive agriculture difficult to obtain, and certain institutional arrangements

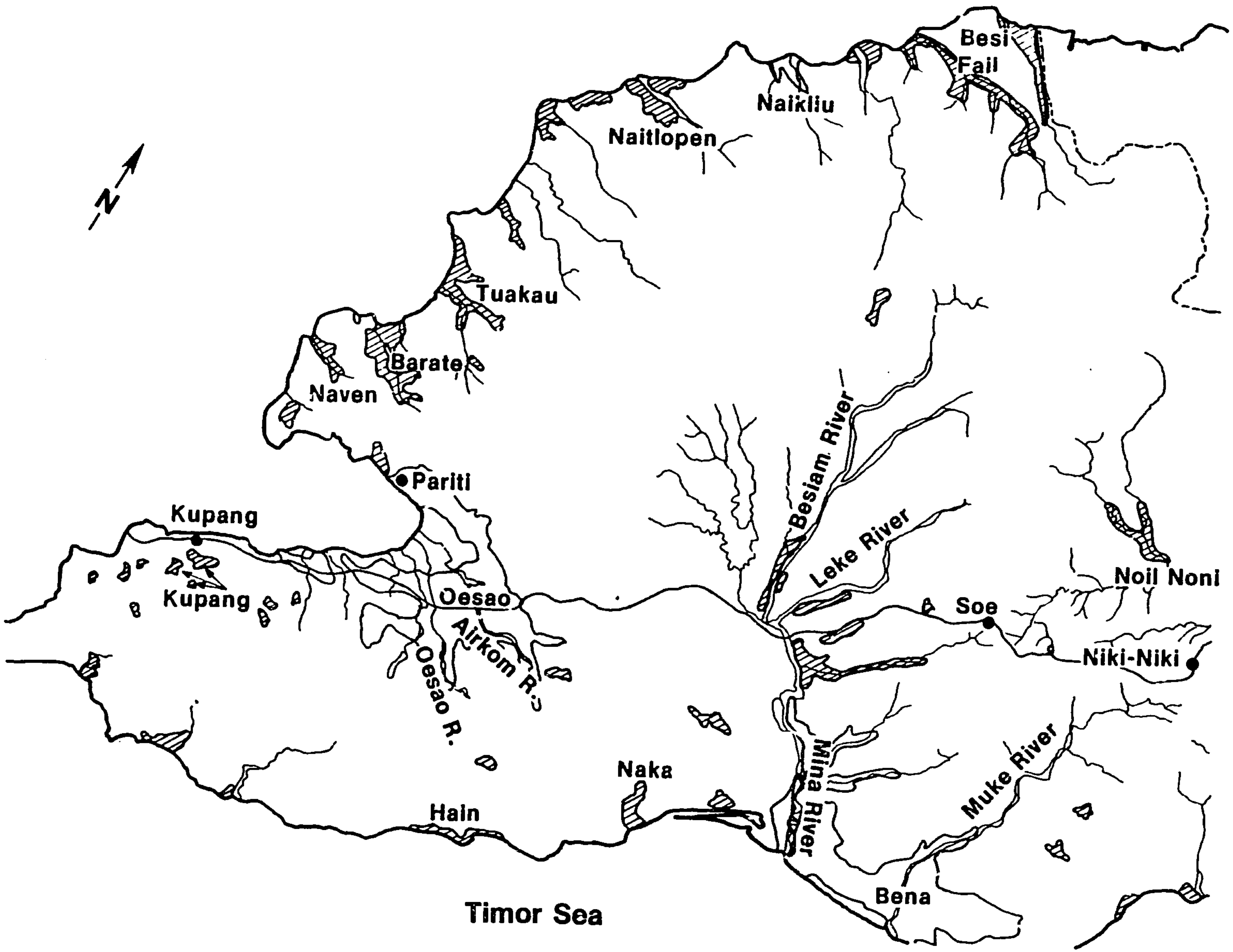

Figure 13. Site location map for NTT - Timor projects proposed for the Kupang Peninsula.

such as the concentrated ownership of livestock which are critical for wet-rice land preparation. To avoid some of these complex problems, which are judged to be beyond the scope of this project, it is recommended that in Phase I of activities on the Kupang Peninsula, activities be directed to areas in which irrigation activities are already under way. A number of small irrigation schemes exist in the area, some of which have been constructed by Public Works and others by farmer groups. In some areas farmers have also dug shallow wells for irrigation of limited garden areas. It is suggested that project activities be divided into Phase I and Phase II periods. Phase I activities would be implemented during approximately the first three years of the project. Following that period an assessment of outcomes would occur and plans made for Phase II. The following activities are recommended for implementation in Phase I.

Groundwater Augmentation on the Oesao Plain. The Oesao Plain is situated east of Kupang town facing Kupang Bay. It has a number of small weir diversion systems that irrigate paddy in the wet season, but because of the low river flows in the dry season, these support little or no dry season production. It is proposed that the project assist the GOI in identifying several existing small diversion systems suitable for the installation of pump systems for water augmentation -- particularly in the dry season, but also for supplementary wet season irrigation, if required. This pilot project would seek to demonstrate the possibility of small-system augmentation using subsurface seepage flows in the river bed. This would involve the installation of infiltration wells in selected areas on the river banks -- wells 3 to 5 m in diameter and up to 10 m in depth. An infiltration gallery would be built across the river bed to draw wet season surface flows and dry season subsurface flows into the well. Each well would be mounted with a portable diesel engine pump sized to irrigate 25 to 30 ha.

Pilot Groundwater Activities in Pariti

A second activity in the Pariti area of the Oesao Plain is a pilot effort to further develop shallow dug wells in an area where simple dug wells exist and surface irrigation schemes are not possible. In such areas farmers now use these shallow wells for domestic water supplies and limited garden areas. This pilot effort would assist villagers in developing additional dug wells, perhaps of different size and design such as large storage and percolation wells that would be partially lined. The pilot effort would also involve the use of 3.5 to 5 hp portable pumps to be used for sets of two wells.

Support of Investigations on the Bina Plain

The Bina Plain is about 100 km east of Kupang along the southern coast of the island. It is flanked on two sides by the Mina and Muke rivers and encompasses about 15,000 ha. Some exploratory bores have been drilled in the area -- one yielding saline water and the other no water. Other drilling efforts suggest the presence of potentially water-bearing strata.

Given the indefinite results that have resulted from the test boring thus far and the considerable agricultural potential that exists in this plain, it is proposed that the project support the GOI in planning and implementing pilot groundwater projects, if such are judged feasible. This may require acquiring additional drilling equipment to supplement that now available. Investigations on the Bina Plain should also include studies of the existing diversion systems and any springs that might be developed for irrigation purposes.

Subprojects on Flores Island

The district of Ende on Flores Island covers an area from the south to the north coast. The town of Ende is located on the narrow plain of the south coast and the remainder of the district consists of a mountainous central area and a large coastal plain at the north (the Mautende area) approximately 60 km from Ende.

There is approximately 3,000 ha of irrigation in Ende, 1,000 ha under the management of Public Works. The remainder is village irrigation including some extensive terraced areas in the central mountain region. All of the systems are small and divert surface waters from the various streams draining the central mountains to either the north or south coast. The Public Works Department, often using funds from the office of the Bupati, but also with funds from the Sederhana program, has over the years upgraded some village systems and converted them into small-scale systems. It has also had an active strategy, however, of providing assistance to village systems, primarily in improving their diversion structures, and allowing those systems to remain under local control.

In addition, Public Works is currently doing preliminary planning for a set of permanent weirs to irrigate approximately 7,200 ha in the Mautende Plain (some of which is presently irrigated by village diversions). As in other areas of NTT, Mautende is an area in which population is relatively sparse. Thus, planners acknowledge that irrigation development in the Mautende area is dependent upon successfully attracting population movement into the area. The Team was asked to seriously consider recommending support for this proposed Mautende project. However, after consideration and discussion the Team suggests not directly supporting that effort for two reasons. First, the Team believes that such a project would greatly stress the capacity of the local Public Works Seksi which now has direct responsibility for only 1,000 ha of irrigation and services another 2,000 ha of village irrigation. The Mautende project would increase the Seksi's responsibilities by too large a factor. Second, rapid development in

Mautende can be successful only if there is a complementary program for population resettlement. This is always difficult to achieve and other resettlement efforts on Flores have simply not worked. As an alternative, it is proposed that the USAID project provide assistance to the GOI to allow the Seksi to continue and expand this program of service to the existing village systems, including those that exist in the Mautende area. In this way irrigation development is more likely to be in harmony with actual population and labor distribution patterns.

Particularly in the Mautende area, where the course of the major rivers can change annually, the new small-scale irrigation improved diversion technologies discussed previously (improved low cost weirs, inverted weirs, pvc conveyance systems and lift pumps) may be applicable. The project's assistance should be conditional on Public Works' agreement that assistance to these village systems will be accomplished in such a manner that the independence and autonomy of the desa systems is maintained (a policy that they now seem to follow frequently).

As with the proposed activities in the Kupang Peninsula, it is recommended that these activities in Flores be implemented for a three-year period, at the end of which a review and assessment of progress would be made and activities for a next phase planned.

Summary of Specific Project Activities

This section summarizes the specific project activities that would be associated with the various proposed subprojects in the Kupang Peninsula area and Ende district, Flores. These include the following:

1. Design and construction of irrigation facilities including pump systems (the Oesao Plain and possibly the Bina Plain and Ende district), dug wells (the Pariti area of the Oesao Plain) and small diversion weirs (in Ende district);

2. Support for additional exploratory investigations of groundwater in the Bina Plain area;

3. Reconnaissance studies in each of the proposed project areas including the selected systems in the Oesao Plain (including Pariti), the Bina Plain and throughout the district of Ende. These studies should document the number of existing commands, the total hectarage being served, the cropping patterns and agricultural practices being used, the physical and organizational capacities of the local irrigation systems and other matters; and

4. Organization of a system for providing financial assistance, technical engineering advice and institutional development support to village systems in Ende district needing to improve their physical facilities.

Project Implementation

The project strategy proposed herein creates the need for planning and design focused on a larger geographical area than has been the case in the conventional planning for a Sederhana subproject. In current planning for small-scale irrigation works the design deals with the main diversion or storage facilities and the primary elements of the distribution system. What appears to be lacking is an accurate assessment of the nature and configuration of the existing irrigation facilities below this level as well as the potential for irrigation development.

Thus, to implement the proposed program strategy, important revisions in the planning and design process will be required. The Team proposes a phased project implementation process beginning in each project region with more detailed planning and design activities. It is recognized that in some of the proposed subproject locations Public Works may have various elements of the project at the detailed design stage, or even under construction. The Team does not suggest these activities be ended, or delayed, but that a review be made to determine what modifications might be required to conform to the basic elements of the project strategy.

Phase 1 - Detailed Design

It is proposed that the Small-Scale Irrigation System Project at all locations initiate, as it were, with a "Year-Zero." Upon executing the loan agreement a USAID technical assistance team should assist Public Works planners in conducting the following detailed design studies:

1. A thorough land use inventory of each watershed where a project might augment the water supply. The land use data should be determined for each existing irrigation system in the area, whether public or private. Potentially irrigable land under each system should also be identified. Aerial photos can serve as the basis of this study;

2. An operation and maintenance needs assessment should be made of each small system diversion and primary distribution channel. This information should be utilized to formulate a plan for rehabilitation requirements at the village level under the project;

3. A baseline study of the project's social characteristics should be made to identify the nature of existing user organizations and land tenure status; and

4. An integrated irrigation development plan for each watershed under the project should be developed using the results generated in the studies noted above. This plan should show

the location and alignment of structures in the entire system and how they will be integrated with the major project improvements. The plan should devise operational rules for augmentation, particularly in view of existing water entitlements and as contingency plan for periods of severe flooding or drought. Finally, a more comprehensive economic analysis should be developed which would consider the entire watershed impact including secondary impacts due to enhanced streamflow.

The time required to complete Phase 1 will vary substantially, depending upon work already completed under various projects. It will undoubtedly be desirable to accelerate the work on a number of projects so they can move into the construction phase. In fact, the manpower and budgeting constraints on an implementation agency like Public Works are such that many activities must be concurrent. Thus, Phase 1 may be completed within as little as two to three months for projects already being planned and then extended project by project over the following years of the overall project. This will require that Public Works develop a priority for potential projects and formulate a larger term plan for its integrated planning-implementation process.

Phase 2 - Augmentation

Based on the results of Phase 1, construction of the diversion, storage and conveyance structures needed to augment the water supply in the entire area of each subproject should be undertaken. Major diversions, tanks and primary conveyance facilities should be constructed and begin operation ahead of any rehabilitation at the small system level. Although the operation and maintenance needs assessment will have identified the individual system requiring attention, it is suggested that improvements not be made until after the entire augmentation development is completed except where the augmented flows are high enough to prevent construction of the diversions of the private small systems.

Phase 3 - Small System Rehabilitation

It is important to note that the strategy proposed in this paper places substantial responsibility for diversion and use of water on the village level system itself. The long-term success of this strategy requires that the individual system remain intact and therefore organize its own resources to make irrigation viable. Thus, the Team would suggest that some time be allowed for the village system to adjust to the more reliable water supply in order to establish just what they can mobilize to do and just what further support they may require. It is felt strongly that governmental intervention and assistance should be limited and based on carefully demonstrated need. This is not to say that Public Works should withhold its technical expertise from the irrigators. On the contrary, Public Works should establish a technical assistance team at the Seksi level to offer technical advice and suggest alternative measures to improve the village system.

Phase 4 - Small-Scale System Rehabilitation

Following the adjustment of the village system to the augmentation strategy, funds should be provided for the resolution of critical structural problems at the village level. Alternatives for achieving this assistance are suggested in the following section.

In many cases irrigation developmental processes end when the systems are constructed. Of course, they are operated and maintained, but they are seldom evaluated to identify the strengths and weaknesses of the planning-implementation process. The following paragraphs in this section will suggest a set of activities for monitoring and evaluation and pilot testing of alternative technologies that have already been mentioned. The Team strongly recommends that Public Works conduct critical reviews of its small-scale projects to determine how the project implementation functions might be modified and improved. The evaluation of pilot scale tests of alternative technologies might, for example, lead to changes in structural as well as operational design policies.

Monitoring, Evaluation and Testing

Preproject Baseline. Before the small-scale systems begin benefiting from what are hoped will be substantially better water supplies for irrigation, the preproject conditions should be established. Much of this information is contained in the Phase 1 task described above. In addition, however, there are a number of hydrologic measurements that need to be made. The magnitude and distribution of local streamflow (hydrographs) should be monitored to determine the existing nature of the water supply. Groundwater resources should be explored. In sample cases conveyance losses and irrigation efficiencies should be measured. A number of agronomic factors such as soil types, fertility and farming practices should be evaluated. Together with the Phase 1 data, a comprehensive picture of the preproject condition can be made. In addition, these data provide the basis for selection simulation which might yield some insights as to how the systems will react to the project. The evaluations of many donor assisted projects are limited by a failure to measure the impact of the assistance properly and little is learned to make future projects more feasible and effective.

Monitoring and Evaluation. The Team suggests that sample small systems be monitored throughout the life of the project. Measurements of cropping patterns over time will establish the expansion and intensification produced by the project. The volume of augmentation should be measured at the diversion points and compared to the diversion made at the inlets to individual systems to evaluate the augmentation as a function of its timing and in relation to the small system's individual charcteristics. The suggestion being made here is again of learning "as you go, rather than after you've finished."

Special Studies. Several tests of alternative technologies have been referenced and outlined in previous paragraphs. Replacing masonry open canals with buried PVC, pumping directly from streams, alternative run-of-the-river diversion structures and groundwater development at various scales have been suggested. Others might include automation of the peripheral canals to be self-operating or the introduction of computer assisted management for design and training. Few of these can be formulated precisely until a project begins to emerge and personnel are better trained. Certainly a number of the Public Works staff could benefit from advanced training abroad and a closer relationship with expatriate expertise would be helpful. The use of special studies and research-demonstration are ususally the best mechanisms for this type of inputs for a development project.

SECTION VI

GENERAL CONCLUSIONS AND RECOMMENDATIONS

As a concluding section of this report several issues with policy implications are reiterated. The list is not exhaustive and may not reflect an emphasis that either USAID or GOI would perceive to be important. These issues are as follows: (1) the change in Public Works development strategy and its justification; (2) ways to improve the non-government small-scale system other than through Public Works programs; (3) the opportunity to extract lessons from this project which would clarify a number of regional questions regarding the interface between the irrigation agency and the irrigator; (4) the secondary impacts of irrigation development and their importance in evaluating project feasibiity; (5) the policy of paddy and secondary cropping mix; and (6) the agronomic support of irrigated enterprises.

Shifting the Developmental Policy of Public Works

This report describes a philosophy and a means to assist the development of small-scale irrigation systems in the southern region of West Java, Sumbawa in Eastern Nusa Tenggara and Timor and Flores of Western Nusa Tenggara. It does, however, propose a different process for project implementation. It differs from the currently practiced policy of the Public Works Department, but it is not one they are completely unfamiliar with nor one that would divert their leadership role in the further development of irrigated agriculture. In fact, it can be argued that this project would enhance Public Works efforts.

In brief, the proposed development strategy is to decouple Public Works from the small-scale system which is already in operation as a private farmer or village system. This leaves the agency with a responsibility for augmenting water supplies over larger areas and providing technical assistance to irrigators covering such broad categories as groundwater development, diversion structure design, and operation and maintenance practices. It leaves the small system to be independently responsible for using the more reliable and plentiful water effectively. As the augmentation would require structural elements, so also might the village system need rehabilitation.

Current water resources development policies are generally more project-oriented than regionally focused. This project would necessitate planning strategy which first of all evaluates the needs for irrigation development within each major watershed or river basin. Then a series of initial augmentation projects would be implemented to distribute surplus water to deficit areas, thereby spreading water resources over time and space to make them more readily available. After the water supply is stabilized the agency should monitor and evaluate the entire system to see where specific interventions in the form of small projects and components thereof need to be made. This step may be particularly important in ensuring that equitable distribution of water is occurring. Then finally, the government should initiate the activities necessary to maximize the regional use of water through these identified interventions.

This project for small-scale systems does not, therefore, change the eventual outcome of an irrigation project so much as it reorders its phasing or implementation. All of the elements of existing projects could, if a need were demonstrated, be implemented in later stages of the development. It is important to note, however, that substantial savings may be possible if Public Works does not need to develop large numbers of systems involving a network of branching canals -- a likely consequence if the individual village system responds positively to the improved water supply.

Improving Village-Level Irrigation Systems

One basic component of the small-scale irrigation project should be the provision of an augmentation network to improve the amount and reliability of water supply to existing small systems and, where possible, to supply water to newly created small commands. One of the more important questions is how much improvement will be required in these village commands and the method of implementing these improvements.

One can argue that augmenting the water supply to these small systems would be the single most important factor for improving their productivity. This is a plausible argument based on the information now available concerning the ability of many farmer groups in Indonesia to manage local water supplies intensively, and in support of complex agricultural systems. Thus, there is good reason to believe that if the water supply is sufficiently improved through the augmentation component, that farmers individually and collectively will adjust decisions and procedures to utilize the new supply. However, rather than thinking that this suggests that the government not be involved, the opposite position is to argue that this is an opportune time for government assistance since a fundamentally new set of production parameters will have been created and resources of various kinds can be effectively utilized in moving to that new production curve.

It is suggested that three resources may be needed for independent small systems to adjust to the augmented water supply: (1) funds to improve or modify various components of their physical structures; (2) technical assistance in designing and constructing some of these physical changes and in identifying alternative water management procedures; and (3) institutional assistance to improve or develop rules for coordinating matters among farmers and between one local group and another, as well as government staff.

How to provide these various services is the first major issue. It seems that two principles should guide the search. First, it is not assumed that all village systems will require each of these forms of assistance, nor require them to the same degree. An adequate delivery system is one which is able to identify diversity and plan appropriate action to deal with that variation. Second, these resources, particularly the funds for construction, should be provided through channels that reinforce the local group's property relationships and avoids demobilizing them for future system operation and maintenance. In particular, this suggests that funds for the construction of village system facilities should not flow through Public Works since that would seem to repeat experiences of the Sederhana program in which local groups often were alienated from what they perceived as a "Public Works" project. Thus, the components of an assistance package would seem to be the following:

1. The provision of construction funds to the small system water users for their application to improvements. These funds may be provided in small amounts over a several year period to allow a pace of project execution consistent with local capacities and responsive to changing requirements;

2. The provision of technical engineering services to assist the irrigation group in identifying simple technical solutions to their irrigation problems. These services would apply to facilities from the village's diversion weir down to the small delivery structures in the command area; and

3. The provision of institutional services to assist farmer groups in strengthening their institutional arrangements for implementing various irrigation tasks. This type of assistance may be useful in a number of situations such as when the new water supply leads to significant extensions of the command area.

Presently there are few models for organizing the delivery of these services. However, one existing arrangement may be suggestive of possibilities. In some Public Works projects, the Tertiary Development Program, for example, Public Works has used the concept of an information team to make the first contact with villagers regarding the planned activities. Usually these teams are multidisciplinary in nature, including an engineer, an agriculturalist and an information (public relations) specialist. It may be worthwhile to modify this existing concept and create at the Seksi Office level one or more teams to provide the technical engineering and institutional services as required in the command area of the augmentation scheme. Construction costs could flow through some channel of the Ministry of Home Affairs to the local group for their "autonomous" use. A similar approach has recently been developed, "Irigasi Desa Terpadu Program," being jointly implemented by the Ministries of Agriculture and Home Affairs. This program plans to provide all three of the services identified above. Funds will flow to the village through the Bantuan desa channel administered by Home Affairs. Agriculture will recruit and train technical high school graduates to be assistants to kabupeten agriculture officials to provide the engineering services to village systems. Local motivators would be recruited at the village level to work with farmers in implementing the local projects.

Identifying the Dynamics of the Small-Scale Syst

Every irrigation project has a discrete unit to which it delivers water. The Water Management Synthesis II Project, at Utah State University at least, has called this the "Unit Command Area" (UCA). It is the point where the governmental project transfers water control to the irrigator or irrigator association. In Indonesia this notion corresponds to the small-scale system which functions through the coordination and control of the farmer-community organization. One of the most important developmental issues in this proposed project, as well as throughout the Asian region, is the dynamic nature of the unit command area. Some of the specific questions in this regard have already been alluded to; for example, how will village systems respond to more reliable water supplies?

There are a number of particular issues concerning small system dynamics that this project may be able to address. The first that will be noted is the issue of operation and maintenance. Will it be better in the absence of a government component locally, or will the O&M be more difficult owing to less channel lining and control structures? Then, what means will emerge to share the water supply, and will inequities be reduced or increased between "head enders" and "tail enders," or between the large land owner and the small? In terms of project impact, will better water supply automatically induce expansion of the irrigated area as well as intensification of the lands commanded? And finally, in each of these cases, how long does it require for the positive improvements to evolve; and conversely, how long should one wait before concluding that they are not evolving, and therefore implement assistance?

One matter of government policy naturally emerges here. When a project is implemented in an area where some of the small-scale systems are developed completely by the government and others along the same watercourse are managed as private systems, will there be recognition and support of prior "rights" or historical use so that regional equity is achieved?

Secondary Project Impacts

One of the consequences of irrigation is that in diverting water from a stream and applying it to croplands, the water flow in the stream itself is stabilized. This is the irrigation return flow process in which channel seepage and deep percolation from individual fields combine in a groundwater flow which nearly always proceeds toward the original waterway. The factor that contributes to the streamflow stability is the time required for the groundwater to reach the stream. This time has ranged from one to six months in many small areas. Consequently, the return flow from wet season irrigation may provide significant water to downstream diversions during the following dry season. Further, additional dry season irrigation would supplement the streamflow prior to the wet season, thereby assisting in the pre-plant land preparation that would otherwise wait until the rains began.

There are at least two other benefits of the return flow that are not considered in the economic analysis of a project, but which may be very valuable. The first is the enhanced groundwater development that subsurface irrigation return flows can support. In an irrigated area like some proposed for USAID financial support in the previous section, the viability of a groundwater development may be entirely contingent on the augmentation of the surface supplies.

The second benefit in this project in particular is the improved sanitation and health produced by augmentation. During several of the visits the Team made, many occasions were observed where local people were washing and bathing in the last remaining vestiges of the water. It was also apparent that the stream channel was a primary drain for all manner of human and animal wastes. As a result, the people were contacting water with very hazardous quality, even at the extent that nearby wells used for drinking water would almost assuredly be contaminated. Thus, the benefit of maintaining a higher flow of water through the various communities should produce significant health benefits.

In most cases under conditions similar to these found in West Java, NTB and NTT, the volume of irrigation return flows should be in the range of 50 to 60 percent of the water directed for irrigation. In lowland paddy areas this figure may decrease to 20 to 30 percent, while increasing to 60 to 80 percent in sandy upland areas supporting primarily rainfed rice and polowijo dry season crops. For the benefit of further irrigation investment, it would appear quite important that these secondary benefits be established.

There are, of course, a number of potentially detrimental impacts. Augmentation may disrupt the life cycle of flora and fauna in the environment of the stream channel that requires a dry period. It may create permanently wet areas which increase insect problems like mosquitos. It may lead to waterlogging in low lying tight soils, etc. However, in viewing the likely project sites, none of these potential problems were thought to be evident, primarily because of the relatively steep gradients found along the watercourses.

Policy Affecting Cropping Patterns

One of the issues raised during the Team's visit concerned the small system's flexibility to change cropping patterns. For example, what constraint would be in the way of changing from a paddy to a polowijo cropping pattern in the dry season. If the government policy were to begin discouraging paddy in favor of polowijo crops, would the strategy for small-scale irrigation system development be a limiting, neutral or a promoting factor? Would traditional government run-of-the-river systems be more adaptable than the independent village system? The answers to these questions are not clear. Certainly, where the fields are low-lying with heavy clay soils and the water table tends to remain high, the feasibility of alternative dry season crops is minimal. Further, one could expect additional irrigation on nearby lands resulting from augmented water supplies to reduce this flexibility even further. The only fact that might be ventured is that the irrigation system itself would not be structurally limiting. If it can satisfy paddy requirements, it can satisfy polowijo crops. On the other hand, paddy irrigation is simpler to manage than row crop irrigation, so the system operation might be a problem. On many of the lands this project would impact, the soils are lighter and better drained. Farmers already rotate paddy and polowijo crops using various supplemental water supplies, including hand watering. In the end, this issue must be left to a more detailed analysis.

Agricultural Issues

To achieve the maximum benefits in agricultural production associated with an improved water supply and management program, it is also necessary to consider the need for improved agronomic practices. In many instances the water input will be a major factor in increasing yields, while in others it may be less important. One wonders how much of the large increase in yield of rice in the last ten years has been due to only the water input and how much to improved agronomic practices. There appears to be little doubt that a substantial boost has come from the use of high yielding varieties, greater user of fertilizers and pesticides, etc. In any pilot or experimental scheme to test the effectiveness of methods of water supply and control, the best recommended agronomic practices should be used. What these are will need to be established individually for most areas.

In practically all of the areas which are proposed as possible sites for the irrigation project there are soils which are not suitable for rice production, but could be highly productive for a number of polowijo crops. However, if there is enough water available, the tendency for the farmer will be to grow rice even if the soils are not suitable. If it is desirable to increase the production of certain polowijo crops, then a strategy will be needed to encourage farmers to grow them, such as price incentives, subsidies, etc. The question has been raised as to how much emphasis should be given to the production of polowijo crops in the expansion of irrigated areas. If polowijo crops are to get greater attention, which should they be? Corn is also now in surplus and many of the other crops are in fairly good balance nationwide, but with substantial variation from region to region. Legume crops, especially soybeans for both human and animal feed, are still in short supply.

Apparently, soybean yields are so low (less than 1 ton per hectare) because an adapted disease resistant variety is not yet available. It should be possible to increase soybean yields with improved agronomic practices. The supply and availability of good seed is essential. In local areas special crops which have a market offer possibilities following rice if the soil can be adquately drained. For example, in the Bima area in Sumbawa, onions are grown profitably following a rice crop.

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APPENDIX A

WMS DESIGN TEAM SCOPE OF WORK

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Scope of Work - Irrigation Engineer

The Irrigation Engineer will serve as a co-leader of an interdisciplinary team formed to assist USAID/Indonesia to develop a "Small-Scale Irrigation" project.

The main function of the Irrigation Engineer is to provide a technical framework for a design/construction program which will develop irrigation systems in three provinces over the eight-year life of the project.

As irrigation system site selection is more than the evaluation of land for technical appropriateness (i.e., soil suitability, water sufficiency, etc.), the engineer must work particularly closely with the Sociologist (and co-team leader). In this way, the irrigation sites finally selected for this project will be technically consistent with greater user involvement in the development and maintenance of the system. The project proposes to construct three types of irrigation systems:

1. Simple systems using surface water sources;

2. Simple systems using groundwater as a supplemental source of water; and

3. Innovative systems employing alternative irrigation technology.

The Irrigation Engineer will be responsible for the identification by location of each type of irrigation system. In the process of identifying each system location, the Irrigation Engineer must consider the following.

System Selection

For surface systems:

1. The basis of PU's initial selection of the site (a list of "preliminary" sites chosen by PU currently exists);

2. The appropriateness of the system in terms of technical criteria such as soil suitability for irrigation, appropriateness for desired crop, adequacy of water supply if these factors were not adequately considered in (1); and

3. The desirability of developing project irrigation systems within a watershed rather than province-wide or by administrative unit.

For conjunctive-use systems:

1. Conjunctive-use systems will utilize groundwater as a supplement to existing surface flow. The groundwater itself may consist of both spring flow (as frequently found in NTT) or as pumped well water. The Irrigation Engineer will be responsible for identifying the conjunctive use sites regardless of the nature of the groundwater. However, the lift irrigation specialist will provide the bulk of the data and text related specifically to the tubewell program aspects of this project;

2. The justification for introducing the groundwater component; and

3. The identification of support infrastructure required to sustain the groundwater component.

For alternative irrigation technologies:

1. The nature and appropriateness of the irrigation technology;

2. The justification for introducing the new technology; and

3. Degree of commitment of GOI and farmers to maintaining the new systems.

Systems Design and Construction

1. The Irrigation Engineer will review the design criteria used at the central, provincial and as appropriate, at the seksi level;

2. The Engineer will assess the appropriateness of enlarging system design capability;

3. The role (or lack thereof) of quality control in system design and construction will be assessed;

4. A recommendation will be made regarding the need and nature of engineering design and construction supervision/quality control training; and

5. The Engineer will consider the role of contractor performance (from bid submission to project payment) in system construction and whether possible procedural modifications might lead to improved system construction quality.

System Management

1. The Engineer will consider the role of the water user and how PU might better involve the users in system management; and

2. Based on preliminary findings of the ongoing Sederhana Assessment Study, the role of O&M in system failure is being questioned within the Mission. The Engineer will address this issue in his assessment of O&M practices within PU and its net effect on system operability.

Scope of Work - Sociologist

The Sociologist will serve as co-team leader and share responsibility with the Irrigation Engineer in developing the Small-Scale Irrigation Project. This consultant will have primary responsibility for examining the relationship between farmers, farmer organizations and government agencies, and among different agencies within the government. The objective is to assess the extent to which present administrative and social relationships either inhibit or encourage the development and management of effective irrigation systems and what practical cost-effective steps could be taken to address constraints or build upon strengths. Specifically, the consultant should address the following issues.

System Development

1. Identification of the roles and responsibilities of different agencies at different levels of government in the selection of sites, design of system and approval of budgets;

2. Identification of opportunities to redefine roles and responsibilities of different agencies to achieve more effective system development, including an analysis of what would have to be done to achieve that redefinition;

3. Assessment of present roles, responsibilities and contributions of local organizations (water user associations, village councils, etc.) in system development; and

4. Specific recommendations on ways in which the involvement of farmers and local organizations could be increased, strategies for achieving that and an assessment of the financial and administrative costs implied. Particular attention should be given to the role of indigenous institutions.

System Management

1. Identification of the roles and responsibilities of different agencies at different levels of government in the management and maintenance of systems after construction has been completed;

2. Identification of opportunities to redefine those roles and responsibilities to achieve more effective management and maintenance, including an analysis of what would have to be done to achieve that redefinition;

3. Assessment of the present roles, responsibilities and contributions of farmers and local organizations in systems management and maintenance, and their relationship to government extension programs and sectoral agencies. Particular attention should be given to the role of indigenous institutions; and

4. Specific recommendations on ways in which the involvement of farmers and local organizations could be increased, including a strategy to achieve that and an assessment of the costs involved.

Scope of Work - Agricultural Economist

Background

The Agricultural Economist will participate as a member in a nine-man consultant team, convened to assist USAID/Indonesia in developing a small-scale irrigation sector strategy. Working with other members of the Irrigation Team and GOI colleagues, the Economist will be expected to develop a comparative economic analysis of various irrigation systems to be considered for inclusion in the strategy. The systems to be examined include small- and medium-scale gravity irrigation, lift irrigation and tubewell irrigation systems. A comparative economic analysis of each of these systems based on present and expected cropping patterns, agroclimatic data and socio-economic conditions on each of the proposed project areas -- West Java, NTT and NTB -- will be prepared. In addition, a preliminary analysis of new technologies, including, but not limited to, buried PVC pipe, sprinkler equipment and trickle irrigation will be examined. A draft report outlining his findings will be prepared for inclusion in the Team report prior to the consultant's departure.

Terms of Reference

To carry out his assigned responsibilities, the Agricultural Economist will be required to carry out a number of specific tasks. These are as follows:

1. In collaboration with the Agronomist, develop representative cropping models likely to exist now and in the future with and without irrigation, in each proposed project area. In developing the models, special attention will be paid to recent changes in cropping patterns, new crop technologies available for introduction into the project areas given the presence of

irrigation, the impact of different cropping patterns on labor demand and marketing and processing requirements;

2. Using secondary data, develop farm budgets for each of the cropping models;

3 In collaboration with the Irrigation Engineer, develop cost estimates for the three irrigation technologies in each project area;

4. Using data developed in (2) and (3), develop estimates of the internal rates of return associated with each technology in each area and recommend the most appropriate project investment mix for USAID funding; and

5. Prepare a preliminary economic evaluation of irrigation technologies likely to be effective in Indonesia and advise the Mission on the steps to be taken to carry out a more formal evaluation of the most promising alternatives. Distribution technologies to be examined will include, but not be limited to, buried PVC pipe and sprinkler and drip irrigation systems.

Scope of Work - Lift Irrigation Specialist

The GOI has identified potential sites for groundwater development within the three project provinces. It will be the responsibility of the Lift Irrigation Specialist to:

1. Assess each GOI site for suitability for the development of groundwater and recommend alternative locations as necessary; and

2. Propose a program to develop and sustain a groundwater/tubewell program in the subject area.

To expand on the above, the Lift Irrigation Specialist will consider the following issues:

Site Selection

1. The appropriateness of the site in terms of adequacy of the groundwater reserve, adaptability to the existing or proposed surface irrigation system and suitability of soil to irrigation development; and

2. The appropriatness of the site in terms of the availability of the human and financial resources required to operate and maintain the irrigation works.

Groundwater Development Program

1. In collaboration with the Agricultural Economist, develop cost estimates for tubewell programs in each area;

2. In order that lift irrigation systems may be maintained and groundwater development may be expanded, the Lift Irrigation Specialist will be responsible for developing a small-scale tubewell program to encourage all aspects of tubewell development. Included herein will be a program to facilitate pump acquisition, manufacture and/or assemble, pump distribution, parts availability and service, tubewell boring, etc.;

3. As applicable, the Lift Irrigation Specialist will work with the legal specialist to assess the effect of current laws and regulations governing groundwater development; and

4. Assess the need for user training in the various aspects of lift irrigation: pump use, operation and maintenance, well bearing, equipment finance, etc.

Scope of Work - Agronomist

The Agronomist will evaluate existing cropping patterns in the project area with the objective of increasing food production and farmer income. The Agronomist will pay particular attention to the plant/soil/water relationships under specific agroclimatic conditions, irrigation requirements and combinations of irrigated and rainfed cropping systems. He/she will make use of irrigation system improvements, whether through improved system reliability or through the introduction of new irrigation systems. The Agronomist will investigate the potential for double or triple cropping with concern not only for availability of water, but for availability of agricultural expertise.

Scope of Work for Graduate Assistants

1. Identify existing technical data and plans for groundwater and surface water systems in West Java, NTT and NTB. Attention should be given to data available within the Directorate General of Water Resources Development (DGWRD), as well as in major studies by the Canadian Government (Sumbawa and West Timor) and other donors;

2. Assess the availability and quality of data and identify specific information and data gaps. Organize the data for selection and review by the consultant team; and

3. Outline the data, criteria and decision-making processes (formal and informal) used by the Ministry of Public Works and

the Provincial authorities in selecting specific sites for groundwater or surface systems. Examples of the questions to be answered eventually: How is a command area defined? Who decides which locations have priority? How is the money allocated by location/province? What role do the farmers or local officials play in these decisions?

Secondary Scope

1. Visit Sederhana Assessment sites in West Java to analyze why the command area in the design is currently not being serviced. Make recommendations for possible improvements of a systemic nature as well as site-specific; and

2. Collect and organize labor supply, unemployment and landlessness data relevant to the three provinces.

APPENDIX B

SEDERHANA IRRIGATION LAND DEVELOPMENT PROJECT

TECHNICAL MANUALS AND GUIDELINES

(Prepared by IECO and Sinotech)

SEDERHANA IRRIGATION LAND DEVELOPMENT PROJECT
TECHNICAL MANUALS AND GUIDELINES

Subproject Identification and Evaluation

Manual on the Identification and Proposing of Sederhana Irrigation/Reclamation Projects, August 1977.

Subproject Selection for Survey and Design

Manual on the Analysis for Selection Purposes of Sederhana Irrigation/Reclamation Proposals, August 1977.

Subproject Proposal Questionnaire, August 1978.

Instruction Manual for Subproject Proposal Questionnaire, August 1978.

Technical Manuals

Preliminary Hydrological Study on Estimating Low Flow and Flow from Small Watersheds, October 1977.

Soils Manuals, Field Sampling and Testing, December 1977.

Design Manual for Canals, Drains and Related Structures: Volume 1, Text and Exhibits, and Volume II, Drawings, April 1978.

Surveying Manual, Draft, February 1979.

Seminar Notes on Design of Small Irrigation Systems for Upgrading Design Contractors, March 1979.

Design Drafting of Sederhana Subproject Drawing, March 1979.

Design Guidelines for Sederhana Irrigation Project, November 1980 (English and Bahasa Indonesia).

Technical Paper No. 1, Survey and Mapping Requirements and Procedures, June 1980 (Revised May 1981).

Technical Paper No. 2, Soil Investigaton and Evaluation, June 1980 (Revised April 1981).

Technical Paper No. 3, Hydrological Investigations and Analysis, November 1980 (Revised April 1981).

Technical Paper No. 4, Design of Free Intake Diversion Facilities, December 1980 (Revised April 1981).

Technical Paper No. 5, Design of Gabion Weir Diversion Facilities, December 1980 (Revised May 1981).

Technical Paper No. 6, Design of Masonry Weir Diversion Facilities, January 1981 (Revised June 1981).

Technical Paper No. 7, Design of Canal Intake Structures, January 1981 (Revised June 1981).

Technical Paper No. 8, Design of Drop Structures, January 1981 (Revised June 1981).

Technical Paper No. 9, Design of Chutes and Bench Flumes, January 1981 (Revised April 1981).

Technical Paper No. 10, Design of Checks, Turnouts and Division Boxes, March 1981 (Revised June 1981).

Technical Paper No. 11, Design of Elevated Flumes, April 1981 (Revised June 1981).

Technical Paper No. 12, Design of Cross-Drainage Faciltties, March 1981 (Revised June 1981).

Technical Paper No. 13, Design of Bridge Structures, March 1981.

Technical Paper No. 14, Design of Wasteways, March 1981 (Revised June 1981).

Technical Paper No. 15, Design of Sand Traps, March 1981 (Revised June 1981).

<u>Tender and Contract for Survey and Design</u>

Technical Specifications for the Design of Sederhana Irrigation Works, March 1980 (English and Bahasa Indonesia).

Technical Specifications for Survey and Mapping, March 1980.

<u>Survey and Design Contract Administration</u>

Sederhana Irrigation and Land Development Project - Guidelines for Checking Survey and Topographic Maps, March 1980 (English and Bahasa Indonesia).

Tender and Contract for Construction

Technical Specifications for Subprojects Major Works, August 1977.

Construction Contract Administration

Guidelines for Construction Supervisor (Translated from Bahasa Indonesia "Pedoman Kerja Untuk Pengawas Pekerjaan," Panti Karya, 1977).

Basic Guidelines for Construction Supervisor of Irrigation Works (Translated from Petunjuk Pokok Pengawasan Pekerjaan Irigasi, June 1980).

Operation and Maintenance

Operation and Maintenance Plan for Subproject Major Works, October 1977.

Operation and Maintenance Plan for Air Daup Subproject, Bengkulu Province, July 1978.

Operation and Maintenance Plan for Cilengis Subproject, West Java Province, July 1978.

Operation and Maintenance Plan for Biangloe IV Subproject, South Sulawesi Province, July 1978.

Operation and Maintenance Plan for Aek Simare Subproject, North Sumatra Province, July 1978.

Guidelines for Annual O&M Inspections, February 1982 (English and Bahasa Indonesia).

Subproject Monitoring

Monitoring Plan for Sederhana Irrigation/Reclamation and Land Development Project, August 1977.

Subproject Monitoring Questionnaire, October 1978.

A Management Information System to: I. Evaluate the Construction Progress; and II. Monitor the Operation, Maintenance and Use of Sederhana Irrigation, Reclamation and Land Development Subprojects, January 1979.

Project Monitoring Guidelines for DGWRD Activities, November 1980 (English and Bahasa Indonesia).

Guidelines for Inspection and Certification for Reimbursement, November 30, 1982 (English and Bahasa Indonesia).

Subproject Evaluation

Evaluation Questionnaire for Sederhana Irrigation/Reclamation Subprojects and Land Development, October 1978.

Data Management

Administration Guidelines and Recommendation for Data Management, August 5, 1981 (English and Bahasa Indonesia).

Training

Training Program Evaluation Report, December 1977.

Transfer of Knowledge Program for Local Design Contractors, May 1979.

APPENDIX C

COMPARATIVE ECONOMICS OF ALTERNATIVE RUN-OF-THE-RIVER DIVERSIONS

COMPARATIVE ECONOMICS OF ALTERNATIVE RUN-OF-THE-RIVER DIVERSIONS

Costs of Various Methods for Lifting Water in Run-of-the-River Systems

Three alternatives are considered for lifting water from rivers to adjacent lands -- weirs, pumps and pipe diversions. The comparison applies only to the situations which we hypothesize, but they give a rough estimate which is sufficient to order the alternatives in terms of their costs.

Alternative Lifting Technologies

Typical Indonesian run-of-the-river irrigation schemes are situated in valleys whose soil consists of volcanic alluvial materials washed from adjacent hillsides. Often the rivers cut steeply into the alluvial material, leaving an embankment over which water must be lifted to the irrigation systems. The most commonly used method of lifting the water is construction of a weir of 1 to 3 meters. Another method occasionally used by private farmers is construction of a pump on the river bank. The weir has the advantage of scale economics if a large flow is desired, requires minimal attention on an hour-to-hour basis and does not require fuel. Pumps have advantages of portability and flexibility in site selection, coming in many sizes. It is reasonable for a single farmer or a small group of farmers to purchase a pump to meet their unique needs.

The third technology, the pipe diversion, is one which combines some advantages of both weir and pump technologies. Basically, the diversion is made with a PVC pipe located in the bed of the river. It is located upstream of the irrigated lands where the elevation is high enough to deliver a desired quantity of water. The pipe system requires that a trench be dug at its inlet so that the intake can be surrounded with a gravel infiltration gallery. Installation is labor-intensive, but technically simple. One advantage is that it uses gravity rather than fuel. Unlike the weir, however, the pipe configuration may be sized to suit a wide range of desired flows -- up to and beyond 100 lps. Its siphon will generally be less constrained by site location than a weir, but it is not as felxible in this respect as a pump.

For purposes of comparison, consider a river wide enough to require a 25 m weir where the embankments are 3 meters high at the point of discharge. The slope of the river is assumed to be 2 percent and both pipe diversion and pump are sized to deliver 30 lps. Costs of building the weir are presumed to be Rp. 2,000,000 per meter. The economics of the typical weir, the lift scheme and the pipe diversion are shown in Table C-1.

Costs of pumping differ from those of the other alternatives in that energy costs are about double capital costs. In this case it is helpful to express these costs on an annualized per hectare basis. Using a 7.5 hp diesel pump at a combined pump-engine efficiency of 13 percent, the annualized capital costs are Rp. 316,560 (assuming a five-year life of the pump). Each hectare has a peak-load requirement of 1.8 lps, which defines the hectares served as 16.7 However, each hectare has an average requirement of 1 lps, so that the average run time of 6.7 hrs per day for 150 days, or 100 hrs per year. Fuel use is assumed to yield a total yearly fuel cost of Rp. 396,000 at Rp. 30 per liter. Therefore, annualized pump costs are Rp. 713,000 per year, or Rp. 43,000 per hectare per year.

The annualized cost of a Rp. 50,000,000 weir which lasts 15 years is Rp. 6,574,000. If this weir serves 150 ha, its per hectare cost is Rp. 43,820; for 225 ha it is Rp. 29,220; and for 300 ha it is Rp. 21,910. Note that the costs of the pump and the weir are about the same when the weir serves 150 ha. It should also be noted that given the same lift costs, the pump systems will have higher conveyance efficiencies due to their close proximity to their commands.

The per hectare annualized costs for the pipe diversion are Rp. 26,700. This is considerably cheaper than a weir accomplishing a diversion serving 150 ha. The weir has about the same per hectare cost when it is serving 225 ha. A similar pipe system in a river with a 1 percent slope would cost Rp. 54,000 per ha per year, so that at slopes flatter than about 1.5 percent pumping is more economic.

As can be seen in Figure C-1, the pipe diversion falls sharply in cost as the slope of the streambed rises. It is likely that streams of 1.5 percent to 2.5 percent will be ideal for these systems because they achieve high efficiency, but water would not be so turbulent as to disturb buried pipe. It would be possible, for example, to deliver over 100 lps through a 30 cm (nominal) PVC pipe when the streambed is sloped at 2.5 percent. This is enough to irrigate over 800 ha at a cost per hectare far below the Rp. 28,000 figure shown in Table C-1. It appears that this technology should be used on a pilot basis in the project.

Below is the cost of a 30 cm pipe diversion which, at a 2 percent slope, will deliver 113 lps to an elevation 3 m higher than the diversion point. This technology is suggested for two sites in West Java.

1. 113 lps @ 1.2 lps/ha = 93.8 ha in service area.

2. Net head gained due to elevation changes = 1.4 percent, so that for a 3 m lift the pile length is 213 m.

3. Cost/m = Rp. 24,420 + 10 percent for installation = Rp. 26,862/m.

4. Cost of pipeline = Rp. 5,772,000

   Cost of headworks = 1,383,000

   Total cost = Rp. 7,155,000 of Rp. 76,000/ha

TABLE C-1

COST OF TECHNIQUES FOR LIFTING WATER
3 METERS FROM A STREAMBED

Weir (25 m wide) Rp. 2,000,000/m x 25 m = Rp. 50,000,000	1 1/2 Hp Diesel Pump Cost of Pump & Engine Rp. 1,200,000 Annual fuel consumption: Rp. 396,000 Annualized capital cost (5 year life): Rp. 316,560	PVC Pipe Diversion 200 m; 20 cm PVC pipe @ Rp. 9,150/m = Rp. 1,830,000 Infiltration chamber: Rp. 1,383,000 Installation: Rp. 200,000 Total capital cost: Rp. 3,413,000
Total Annualized Cost: Rp. 6,573,000	Total Annualized Cost: Rp. 712,560	Total Annualized Cost: Rp. 448,720

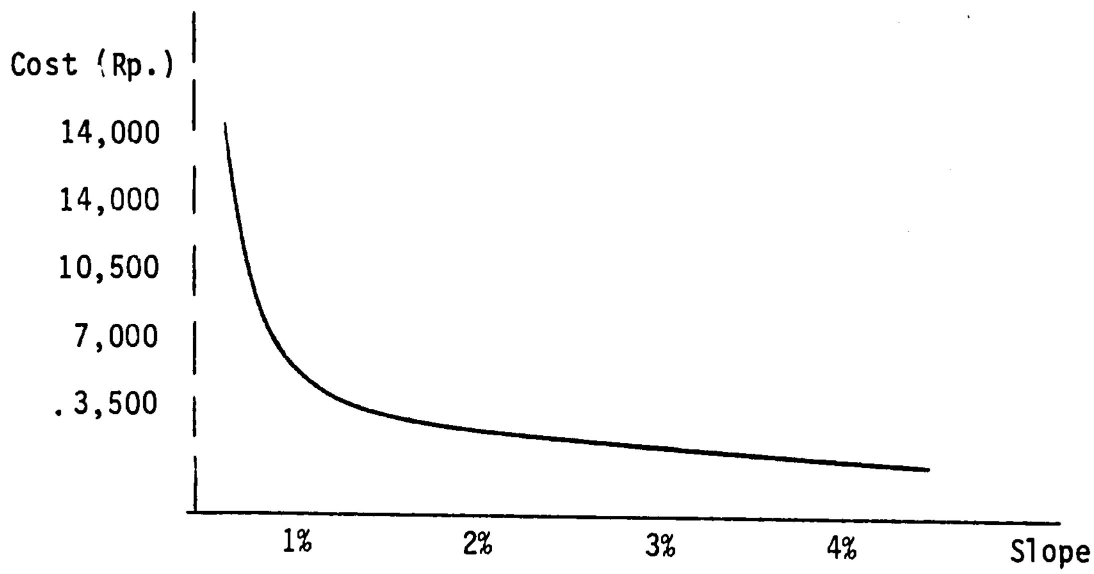

Figure C-1. Cost of pipe diversion delivering 30 lps 3 m high as a function of stream slope.

APPENDIX D

PROJECT COSTS AND BENEFITS OF SPECIFIC CROPS

PROJECT COSTS AND BENEFITS OF SPECIFIC CROPS

In order to develop at least an estimate of the economics of various projects proposed in Section V, it has been necessary to develop what may be called a generic set of calculations. Therefore, this appendix on costs is based on what information could be drawn together concerning specific projects, giving an annualized cost per hectare to be irrigated where this is possible. This figure can then be compared to a per hectare annual net benefit. This can be used to derive a cost/benefit ratio since the annualized values are just net present values of costs/benefits which have been multiplied by the same 30-year payment formula.

The following tables give costs and revenues for rice and maize production with and without irrigation and with and without the project. Note that yields and fertilizer recommendations are taken from the FENCO report on Sumbawa, while most prices are taken from a recently completed USAID project paper for upland crop production. The "bottom line" from each table can be used in a with and without benefit cost analysis. Some words of explanation are in order. Yield estimates are not unrealistically high, but they are not unrealistically low, either. Some conservatism is in order since those knowledgeable about Indonesian food policy suggest that downward pressure on several food crop prices -- especially rice -- are being exerted. Given the general lack of information about each proposed site and the uncertainties over prices, it would be silly to pretend that one cropping pattern or another will be adopted. At present, rice is the irrigated crop of choice, and it will be assumed to occupy all newly irrigated areas. This errors to the liberal side. These are shown as "economic prices" in the tables. Only on labor, agricultural chemicals and corn do these differ from the financial price.

TABLE D-1

PER HECTARE PADDY RICE PRODUCTION COSTS AND RETURNS UNDER PROJECT CONDITIONS

Cash Costs		Financial	Economic
Fertilizer	290 kg	28,500	72,610
Sevin	1.5 kg	2,250	9,000
Diazinon	1 liter	1,500	6,000
Seed	30 kg	6,000	6,600
<u>Labor</u>			
200 Man/Days		<u>105,000</u>	<u>105,000</u>
<u>Total Production Costs</u>		145,800	199,210
<u>Gross Revenue</u>			
(4.2 T/ha)		<u>630,000</u>	<u>630,000</u>
NET		484,200	430,790

Source: FENCO Report, Volume 10, and USAID Upland Rice Project Paper.

TABLE D-2

PER HECTARE IRRIGATED MAIZE BENEFITS AND COSTS UNDER PROJECT CONDITIONS

Cash Costs	Financial	Economic
Cash Inputs		
Fertilizer 250 kg	18,000	40,000
Diazinon 1 liter	1,500	6,000
Seed 25 kg	7,500	7,500
Labor		
85 Man/Days	42,500	42,500
Total Production Costs	69,500	96,000
Gross Revenue		
(2.6 T/ha)	286,000	439,400
NET	216,500	343,400

Source: FENCO Report, Volume 10, and USAID Upland Rice Project Paper.

TABLE D-3

PER HECTARE DRY LAND MAIZE BENEFITS AND COSTS (WITHOUT PROJECT)

Cash Costs	Financial	Economic
Seed	2,000	3,070
Fertilizer	2,750	7,570
Pesticides	1,800	7,200
Labor		
	22,500	22,500
Total Production Costs	29,050	40,040
Gross Benefits		
(0.8 T/ha)	88,000	135,200
NET	58,950	95,160

Source: FENCO Report, Volume 10, and USAID Upland Rice Project Paper.

TABLE D-4

DRYLAND RICE BENEFITS AND COSTS (WITHOUT PROJECT)

Cash Costs	Financial	Economic
Seed	9,000	9,000
Fertilizer	20,000	44,000
Pesticides	1,200	4,800
Labor		
75 Man/Days	37,500	37,500
Total Production Costs	67,700	95,300
Gross Benefits		
(1.6 T/ha)	240,000	240,000
NET	172,300	144,700

Source: FENCO Report, Volume 10, and USAID Upland Rice Project Paper.

TABLE D-5

BENEFITS AND COSTS OF IRRIGATED RICE WITHOUT PROJECT (CURRENT YIELDS)

Cash Costs	Financial	Economic
Seed	6,000	6,000
Fertilizer	36,000	80,000
Pesticides	2,100	8,400
Labor		
75 Man/Days	105,000	105,000
Total Production Costs	168,000	199,400
Gross Benefits		
(2.6 T/ha)	455,000	455,000
NET	287,000	255,600

Source FENCO Report, Volume 10, and USAID Upland Rice Project Paper.

WATER MANAGEMENT SYNTHESIS PROJECT REPORTS

WMS 1 Irrigation Projects Document Review

Executive Summary
Appendix A: The Indian Subcontinent
Appendix B: East Asia
Appendix C: Near East and Africa
Appendix D: Central and South America

WMS 2 Nepal/USAID: Irrigation Development Options and Investment Strategies for the 1980's

WMS 3 Bangladesh/USAID: Irrigation Development Options and Investment Strategies for the 1980's

WMS 4 Pakistan/USAID: Irrigation Development Options and Investment Strategies for the 1980's

WMS 5 Thailand/USAID: Irrigation Development Options and Investment Strategies for the 1980's

WMS 6 India/USAID: Irrigation Development Options and Investment Strategies for the 1980's

WMS 7 General Asian Overview

WMS 8 Command Area Development Authorities for Improved Water Management

WMS 9 Senegal/USAID: Project Review for Bakel Small Irrigated Perimeters Project No. 685-0208

WMS 10 Sri Lanka/USAID: Evaluation Review of the Water Management Project No. 383-0057

WMS 11 Sri Lanka/USAID: Irrigation Development Options and Investment Strategies for the 1980's

WMS 12 Ecuador/USAID: Irrigation Sector Review

WMS 13 Maintenance Plan for the Lam Nam Oon Irrigation System in Northeast Thailand

WMS 14 Peru/USAID: Irrigation Development Options and Investment Strategies for the 1980's

WMS 15 Diagnostic Analysis of Five Deep Tubewell Irrigation Systems in Joydebpur, Bangladesh

WMS 16 System H of the Mahaweli Development Project, Sri Lanka: 1980 Diagnostic Analysis

WMS 17 Diagnostic Analysis of Farm Irrigation Sysems on the Gambhiri Irrigation Project, Rajasthan, India: Volumes I-V

WMS 18 Diagnostic Analysis of Farm Irrigation in the Mahi-Kadana Irrigation Project, Gujarat, India

WMS 19 The Rajangana Irrigation Scheme, Sri Lanka: 1982 Diagnostic Analysis

WMS 20 System H of the Mahaweli Development Project, Sri Lanka: 1983 Diagnostic Analysis

WMS 21 Haiti/USAID: Evaluation of the Irrigation Component of the Integrated Agricultural Development Project No. 521-0078

WMS 22 Synthesis of Lessons Learned for Rapid Appraisal of Irrigation Strategies

WMS 23 Tanzania/USAID: Rapid Mini Appraisal of Irrigation Development Options and Investment Strategies

WMS 24 Tanzania/USAID: Assessment of Rift Valley Pilot Rice Project and Recommendations for Follow-On Activities

WMS 25 Interdisciplinary Diagnostic Analysis of a Work Plan for the Dahod Tank Irrigation Project, Madhya Pradesh, India

WMS 26 Prospects for Small-Scale Irrigation Development in the Sahel

WMS 27 Improving Policies and Programs for the Development of Small-Scale Irrigation Systems

WMS 28 Selected Alternatives for Irrigated Agricultural Development in Azua Valley, Dominican Republic

WMS 29 Evaluation of Project No. 519-0184 USAID/El Salvador, Office of Small-Scale Irrigation - Small Farm Irrigation Systems Project

WMS 30 Review of Irrigation Facilities, Operation and Maintenance for Jordan Valley Authority

WMS 31 Training Consultancy Report: Irrigation Management and Training Program

WMS 32 Small-Scale Development: Indonesia/USAID