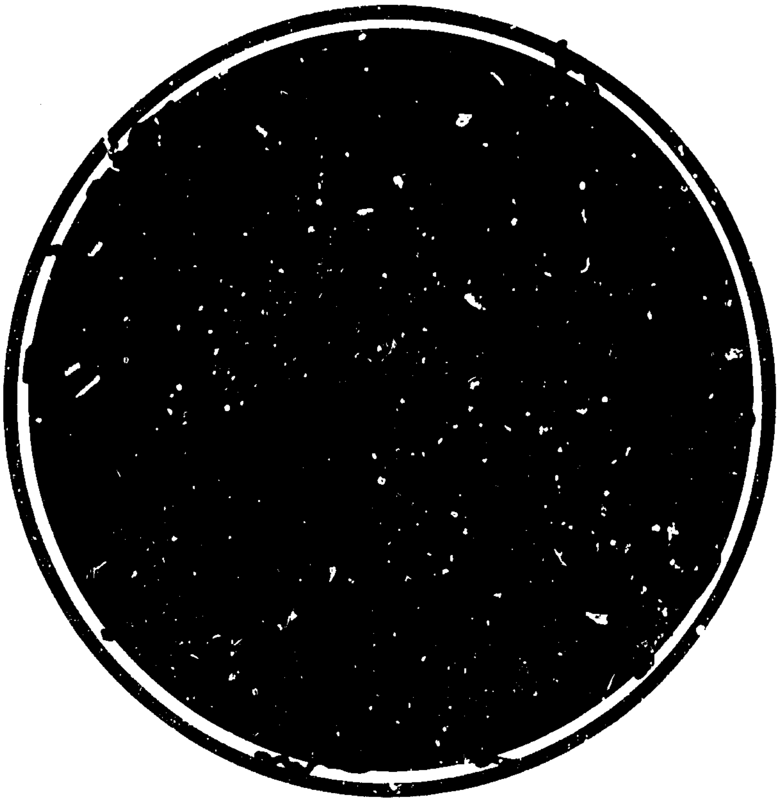

IRRIGATION DEVELOPMENT OPTIONS AND INVESTMENT STRATEGIES FOR THE 1980'S

BANGLADESH

USAID

WATER MANAGEMENT SYNTHESIS PROJECT

WMS REPORT 3

BANGLADESH/USAID

IRRIGATION DEVELOPMENT OPTIONS AND INVESTMENT STRATEGIES FOR THE 1980'S

This study is an output of
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WMS Report 3

PREFACE

Great emphasis is being placed worldwide on effective and efficient use of irrigation water. The direct result of improving yields and extending irrigated land area is increased food production.

Conserving the quality and quantity of irrigation water deserves more attention to expand agricultural production. Improving on-farm water management directly benefits more rural poor and landless laborers by increasing income and employment.

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

The key objective is to provide services in irrigated regions of the world for improving 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, contact the Water Management Synthesis Project for information about the project and any of its services.

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FOREWORD

The purpose of this report is to identify areas of strength and weakness in past performance of irrigation programs in Bangladesh; and to identify priorities of AID's future assistance in the development of irrigated agriculture for the region throughout the 1980's.

This report is the product is the activities of a multidisciplinary study. The team members are:

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Max K. Lowdermilk, Water Management Extension Specialist
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The team visited Bangladesh between July 11 and 25, 1980, and had discussions with many Bangladesh Government officials and professional officers; USAID Mission personnel; and personnel for FAO, IRDP, CARE, Bangladesh Rice Research Institute and the Mennonite Mission. The team also visited field irrigation facilities and projects near Dacca and near Bogra and discussed irrigation successes and problems with local farmers and local politicians.

This irrigation sector review deals with current programs, development opportunities and investment strategies such as the following: extensive versus intensive development; improved water management and utilization of irrigation potential; integration of agricultural and hydraulic infrastructure and services (command area development); water user organizations and social constraints; economic returns and beneficiary groups in various irrigation subsectors; irrigation financing and subsidy; and cost data on various levels of project development versus actual intensities of cropping under these levels.

The team wishes to acknowledge the cooperation it received from the Government of Bangladesh, the attention and time of the various people visited and the excellent support from the AID Mission and the extensive use of needed reports and library facilities. We want to give special thanks to Dan Jenkins and Charles Antholt, who accompanied us on our many interviews and field visits, and to Director Frank Kimball for his time and efforts in our behalf.

SUMMARY AND RECOMMENDATIONS

Very clearly, there is a substantial opportunity to increase production in Bangladesh, given the abundant water resources. Thus, irrigation must be considered a priority in the country's development. Unfortunately, the donor financed irrigation schemes which have already been put in place fall short of realizing the desired level of output. Thus, the economic benefits (and probably the social benefits as well) are considerably less than costs. Furthermore, the necessary production levels for achieving food self-sufficiency in the future are far from being realized.

The disappointing output for most irrigation projects is to a major extent due to the general lack of attention which has been given to: equitably distributing project developed water supplies to the individual farmers' fields; and assisting the farmers in managing the irrigation water, along with other necessry inputs.

The discharge from a typical gravity canal outlet, low lift pump, or deep tubewell is about 2 cfs (900 US gpm or 60 lps). In Bangladesh, farm holdings and fields range between 1 and 5 acres (0.4 and 2 ha) and a 2 cfs supply should be sufficient to irrigate 80 to 160 acres (32 to 64 ha), depending on the crop, season and percentage of time the water is flowing. Thus, potentially 50 to 100 farmers can be supplied from a 2 cfs source. To accomplish this requires an extensive watercourse (channel or pipe) system to distribute water from the source to the fields plus coordinated management. Since watercourses are not normally provided, water is distributed by flowing from field to field (paddy to paddy); and lacking coordinated management (through such enterprises as water user associations), the average area irrigated from a 2 cfs source is only about 40 acres. Furthermore, field to field distribution is only practical for rice paddy irrigation where a large supply of low cost water is available.

The main text contains additional descriptive and background information for the recommendations which follow. The review team presents these recommendations as kinds of objectives for AID's investment policy to emphasize in irrigated agriculture during the decade of the 1980's in Bangladesh.

1. The team recommends that the proposed Rural Irrigation Works Project which is designed to produce and test model projects should be totally overhauled to reflect:

    a. An appreciation and exploration of alternate design possibilities.

b. An organizational structure which integrates government agencies necessary to successful implementation of the project.

c. Training and monitoring programs which are better integrated into the Bangladesh system.

2. The team believes that the proposed Nobagana Integrated Land and Water Use Study Project is unrealistically ambitious considering the complexity of developing four major components (irrigation, fisheries, village industries and agricultural practices on non-irrigated land) simultaneously. Furthermore, the irrigation component is even more difficult than the existing deep tubewell projects which are severaly underutilized and a procedure for improving their performance is still to be tested (see Recommendation 1). Therefore, we recommend that the project be restructured and/or simplified before proceeding further.

3. The general consensus seems to be that a substantial technology for rainfed paddy production is not yet available, but it is likely to be so, well within the next five year period. It is too early to determine: (a) the yield and income potential of that technology; and (b) the relative profitability of investments in delivering that technology compared to investments in irrigation. Reliance on rainfed agriculture leaves much of Bangladesh without year long crop production and limits production to those periods when sufficient moisture is available. Therefore, the soil and climate resource goes unused for six months or more every year. In addition to increased production, irrigation affords a degree of insurance against unusual drought periods. Furthermore, one of the principal resources in Bangladesh is a cheap and readily available water supply. Therefore, the study team recommends that AID provide some development assistance for rainfed agriculture, but places a major emphasis on irrigation project development and improvement.

4. At the present time, the economic benefits of supplemental irrigation have not been thoroughly investigated. It is highly likely, however, that supplemental irrigation with existing pump operations is economically feasible, especially under those circumstances where there is no competition between seasons or between crops within seasons. For the most part, however, pump operated

systems should be designed for operation in all seasons (year-round).

Clearly, there is strong evidence that any gravity canal system designed for dry season irrigation should be organized and managed to provide full season irrigation. However, there is not sufficient evidence available at present to advocate building gravity canal systems with only a supplemental irrigation capability for paddy.

5. It is quite clear that the planned-for potential of none of the irrigation alternatives, large or small, has been achieved. There are long lists of possible causes, but in all cases these are either informed judgments, hypotheses or pure speculation. There have been no attempts to determine if the costs of increasing the irrigable area can be justified by the potential benefits. Indeed, some consultants are even suggesting that it may be more economical to sink new tubewells than to improve the distribution systems and bear the organizational and increased water management costs on existing installations.

   There is strong evidence to suggest an opportunity to increase irrigation from existing projects. There is no available information to evaluate the capital and operating (energy and management) costs and benefits associated with choosing that particular development option. The study team recommends that investigations of these costs be undertaken in an organized, professional manner. A project might be developed with this as its objective (giving special emphasis to energy use efficiency).

6. Bangladesh is committed to an irrigation program which includes both very large and very small projects (i.e., individual irrigation units). The available evidence to date shows that small scale projects in the less flood prone areas of the country have higher rates of return than large projects. Given AID experience with larger projects and the evidence favoring small projects (as well as the considerable support being given for the larger gravity-pump systems by other donors), AID should not provide financing for large scale projects in Bangladesh at this time.

7. The team recommends that AID encourage development of the private sector in Bangladesh when it appears consistent

with their capability and the equity concerns of government. (In reality, it is likely that irrigation will be developed jointly in the private and governmental sectors).

8. The study team suggests that the Mission avoid involvement with integrated land and water management projects which do not have a strong monitoring and problem solving capability. This may depend ultimately on the Government of Bangladesh's commitment to facilitating projects of this nature. Integrated projects should reflect experience gained by donors who have been funding these types of projects. Given the Mission's lack of experience with integrated projects and the present restructuring of in-house supportive research and monitoring capability, the team suggests that the Mission concentrate efforts on direct irrigation projects with adaptive research and institutional building components.

9. The opportunities for investment in the provision of software to support irrigation development in Bangladesh appear great. Training and demonstration activities might be provided through short courses, grants to other agencies involved in institution building, fellowship programs construction of schools and buildings, preparation of training materials specific to local conditions, sponsoring of country and regional seminars and workshops. In addition, adaptive research to improve farm water delivery efficiency and equity and field irrigation application practices is needed. Studies and planning for comprehensive agricultural resource (rainfed as well as integrated) development are also essential.

10. The failure of all types of projects in meeting projected outputs can in part be attributed to inadequate water distribution to the field. Therefore, the review team recommends that AID emphasize on-farm delivery in any project which they might undertake. The team cautions against acceptance of any system without first assessing the costs (including hardware, energy, organizational and management) per unit of command area. As an example, for tubewell projects, costs of different combinations of well size and distribution systems for serving the respective command areas should be assessed.

11. The effect of irrigation development on the roles of

women in the Bangladesh social system has not been seriously considered in project planning and implementation. This seems an unfortunate oversight because undoubtedly women play important roles in decision making, in organization and are a part of the agricultural labor force. The survey team recommends that the role and contribution of women in irrigation project planning and implementation be seriously considered. The team feels this will be to the benefit of all of the projects.

12. The rural population in Bangladesh is grossly malnourished; and irrigation can enable the growing of vegetables during all seasons. This can materially improve the nutritional status of the farm families. Both ongoing and proposed irrigation projects have unrealized potential for vegetable production. The review team recommends that exploitation of the potential for vegetable production be considered when developing new projects. Systems should be designed and managed to provide irrigation water to family garden areas during all seasons.

BANGLADESH/USAID

IRRIGATION DEVELOPMENT OPTIONS AND

INVESTMENT STRATEGIES FOR THE 1980'S

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INTRODUCTION AND BACKGROUND

The Government of Bangladesh has established an objective of food grain self-sufficiency as soon as possible, and no later than 1985. This will require an essential doubling of production. There is little, if any, new land to cultivate; hence, the increased food must come from intensifying production by significant improvements in the control of excess water, irrigation expansion and improved agricultural husbandry. The GOB has recognized the benefits that can come from irrigation and has indicated irrigation will play a major role in meeting the goals established in the second Five Year Plan.

The country is blessed with an abundance of renewable surface and groundwater throughout most of the land. Irrigation can provide crop insurance during periods of drought in the wet season and extend the crop growing season over the entire year. It also increases the potential for increased yields from high yield varieties, greater benefits from fertilizers and allows for a greater variety of crops which can greatly contribute to a better nutritional diet for the malnourished.

Thus, we feel the policy of AID should be to participate in the irrigation development. The projects supported should be of such a size and nature as to be managed by AID and the GOB. These projects should fit into the master plan for the development of irrigation for the country and supported by many donors.

The country of Bangladesh has a population of approximately 88 million (1980) and 24 million acres of cultivatable land. This is roughly 3.2 persons per cultivatable acre. The population density is over 1400 per square mile, making Bangladesh the most densely populated country in the world. Over 90 percent of the total population are rural and 75 percent are actively engaged in agriculture. The average annual rate of population growth is estimated to be between 2.4 and 2.7 percent. By the year 2000 the poplation is estimated to reach approximately 130 million with an accompanying decline in the rate of growth to approximately 1.6 percent.

Generally, except as limited by water, year around cropping is possible. Annual rainfall varies from 50 inches in the southwest up to 220 inches on the northeast. There are typically three cropping seasons: (1) the early monsoon (aus); (2) the main monsoon (amon); and (3) the winter dry season (boro). The great majority of the rainfall comes during the monsoon season. During the winter dry season (roughly November through mid-April) the rainfall over most of the country ranges between 2.5 to 4.5 inches.

In total, the quantity of water which flows through Bangladesh is tremendous. Counting the average inflow from the Ganges, Brahmaputra and Meghna Rivers and average rainfall, there is typically enough water each year to cover the country to a depth of some thirty feet.[1] In fact, large sections of the country (some 6 to 10 million acres) are flooded during a normal rainfall year.

Cropping patterns and paddy varieties have been evolved to fit the climatic conditions (Figure 1). Nevertheless, crop production throughout the year is threatened by problems associated with:

1. Water shortage during the early monsoon months due to insufficient quantity and poor distribution of rainfall.

2. Abnormal flooding and occasional cyclones during the main monsoon.

3. In some years, drought during the main monsoon season.

4. Very low rainfall in the winter months.

The data presented in Table 1 shows the extreme variations in rainfall (for five stations) throughout Bangladesh. The data were compiled at Utah State University using thirty years of record from the World Meteorological Organization. It is striking that zero precipitation was reported in each month at some time during the thirty years of record at all stations. This probably results from an error in reporting or recording the rainfall. The probability analyses showed extreme variability in precipitation amounts during the rainy season with a high probability of serious excess. Furthermore, there is almost no rain in the dry season, which makes rainfed cropping extremely hazardous in the winter and spring.

The water resources of the country are: groundwater which is substantial over the vast majority of the nation; river inflow from India; natural rainfall; numerous oxbow lakes left behind by the ever-wandering Ganges-Brahmaputra and Megha Rivers; tanks; and residual soil moisture. Except for groundwater recharge, it is generally not feasible to store monsoon ruunoff because suitable reservoir and tank sites are not available.

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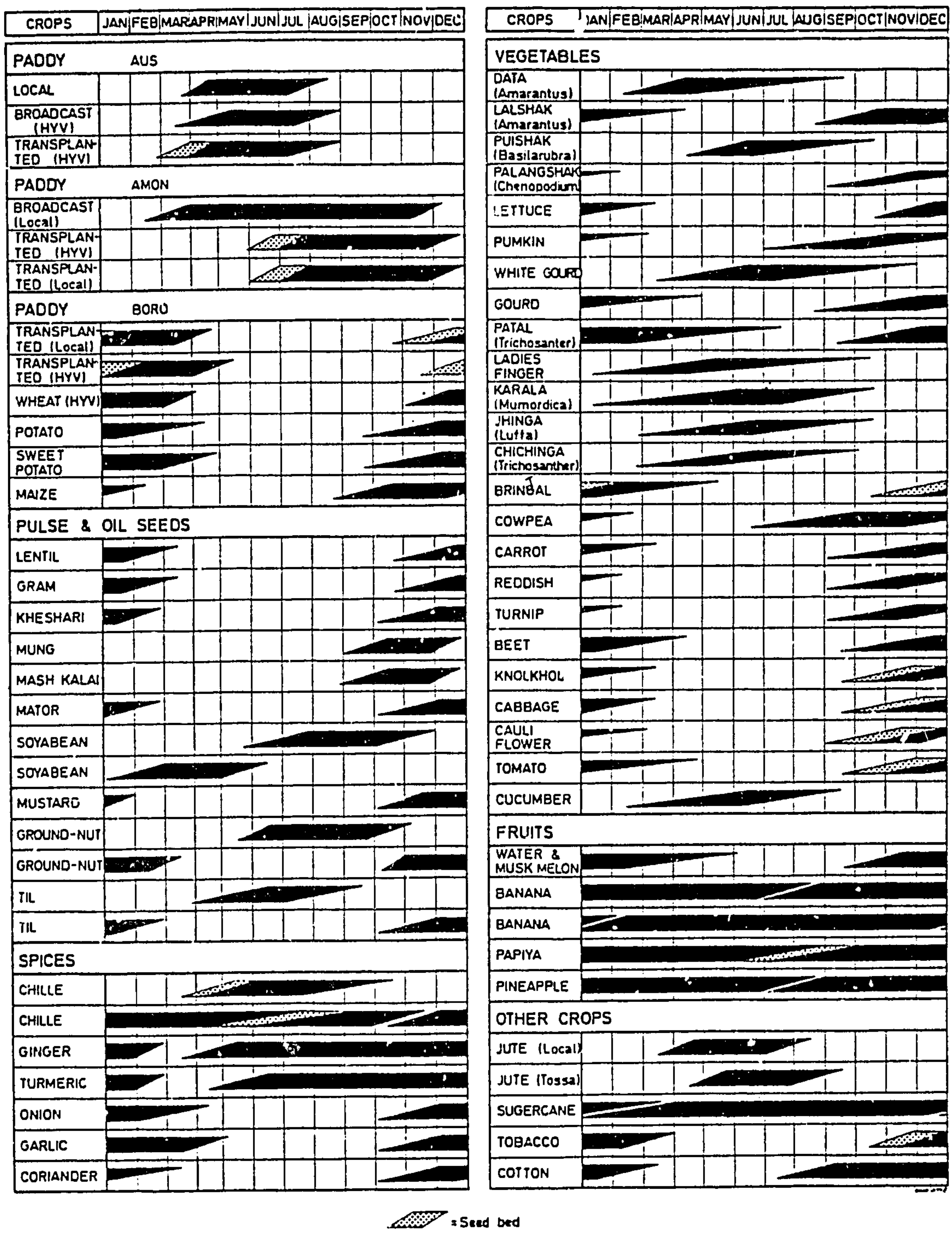
[1]Based on 870 MAF from river inflows and 703 MAF from rainfall. In contrast, average annual evaporation is approximately 132 MAF.

Figure 1.

CROP CALENDAR OF BANGLADESH
EXISTING CROPPING PATTERNS



EXISTING CROPPING PATTERNS:

1. AUS / JUTE + T. AMON
2. AUS + T. AMON + KHESARI (LATHYRUS)
3. JUTE + KALAI (PULSE)
4. AUS AND T. AMON MIXED
5. AUS + MUSTARD / PULSES / RABI VEGETABLES / TOBACCO / COTTON / POTATO
6. AUS AND ARHAR (CAJANUS) / TIL (SESAMUM) MIXED
7. B. AMON
8. AUS AND B. AMON MIXED
9. BORO
10. SUGARCANE
11. SUMMER VEGETABLES + MUSTARD / PULSES

Table 1. Climatic data for a thirty year period at five stations in Bangladesh.

BOGRA BANGLADESH — EL= 20 LAT= 24 51 N LONG= 89 23 E KS=13.5

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANN
PM	14.	17.	27.	63.	195.	322.	317.	351.	275.	180.	13.	2.	1776.
PMI	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	1124.
P79	0.	1.	0.	4.	118.	165.	219.	202.	174.	75.	0.	0.	1329.
P60	2.	7.	11.	30.	166.	240.	282.	297.	220.	107.	0.	0.	1657.
PMX	113.	76.	117.	305.	411.	619.	554.	722.	699.	634.	292.	39.	2594.
TMC	18.3	20.4	25.2	28.9	28.9	28.8	28.8	28.8	28.8	27.1	23.0	19.5	25.5
HM	73.	63.	58.	57.	76.	86.	83.	87.	87.	85.	79.	76.	76.
SC	70.	82.	87.	89.	66.	51.	56.	49.	49.	52.	62.	66.	65.
PD	0.	2.	2.	9.	128.	181.	231.	222.	184.	82.	0.	0.	1398.
ETP	95.	115.	175.	209.	198.	171.	184.	165.	145.	129.	103.	91.	1780.
ETDF	95.	113.	172.	199.	70.	-10.	-48.	-57.	-39.	47.	103.	91.	738.
MAI	.00	.02	.01	.05	.65	1.06	1.26	1.35	1.27	.64	.09	.00	.79

CHITTAGONG BANGLADESH — EL= 14 LAT= 22 21 N LONG= 91 50 E KS=12.5

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANN
PM	10.	23.	58.	116.	285.	507.	642.	572.	344.	228.	56.	17.	2858.
PMI	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	1851.
P79	0.	0.	9.	39.	131.	371.	368.	361.	210.	120.	0.	0.	2356.
P60	0.	4.	25.	71.	231.	420.	550.	485.	278.	165.	7.	0.	2704.
PMX	69.	117.	276.	355.	635.	950.	1527.	780.	759.	579.	321.	146.	4277.
TMC	19.9	23.6	25.6	27.7	28.3	27.8	27.5	27.6	27.8	27.3	24.1	20.7	25.7
HM	79.	77.	79.	82.	85.	89.	83.	91.	89.	89.	85.	83.	85.
SC	57.	60.	57.	53.	48.	41.	41.	38.	41.	41.	48.	52.	48.
PD	0.	1.	12.	45.	152.	381.	406.	387.	224.	127.	1.	0.	2429.
ETP	95.	111.	146.	158.	167.	150.	153.	141.	133.	119.	99.	89.	1560.
ETDF	95.	110.	134.	113.	15.	-232.	-253.	-246.	-91.	-11.	97.	89.	-180.
MAI	.00	.01	.03	.28	.91	2.55	2.66	2.75	1.69	1.09	.01	.00	1.56

JESSORE BANGLADESH — EL= 7 LAT= 23 10 N LONG= 89 13 E KS=12.9

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANN
PM	14.	23.	35.	88.	182.	275.	313.	307.	197.	136.	22.	16.	1603.
PMI	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	937.
P79	0.	0.	0.	29.	89.	169.	238.	179.	141.	60.	0.	0.	1257.
P60	1.	7.	17.	43.	140.	248.	281.	258.	162.	90.	1.	0.	1395.
PMX	127.	133.	166.	320.	699.	674.	538.	615.	510.	509.	124.	18.	2275.
TMC	18.2	20.7	25.9	29.6	29.9	29.3	28.5	28.6	28.7	27.2	22.7	18.9	25.7
HM	77.	70.	67.	69.	79.	87.	89.	91.	91.	87.	81.	81.	81.
SC	61.	70.	74.	71.	59.	46.	42.	38.	38.	46.	56.	56.	55.
PD	0.	1.	4.	31.	100.	185.	247.	196.	145.	66.	0.	0.	1286.
ETP	93.	110.	165.	191.	190.	164.	159.	146.	130.	124.	101.	86.	1659.
ETDF	92.	109.	162.	160.	91.	-21.	-88.	-50.	-15.	57.	101.	86.	683.
MAI	.00	.01	.02	.16	.52	1.13	1.56	1.34	1.12	.54	.00	.00	.78

NARAYANGANJ BANGLADESH — EL= 8 LAT= 23 37 N LONG= 90 30 E KS=13.0

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANN
PM	14.	22.	46.	161.	265.	346.	348.	364.	242.	171.	29.	19.	2012.
PMI	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	1438.
P79	0.	0.	7.	63.	152.	216.	258.	250.	170.	60.	0.	0.	1740.
P60	0.	14.	30.	103.	206.	270.	292.	323.	200.	113.	1.	0.	1855.
PMX	95.	73.	149.	325.	544.	866.	672.	727.	451.	605.	177.	24.	2630.
TMC	13.6	22.2	26.6	28.7	29.1	29.0	28.7	28.8	29.2	28.2	24.5	20.9	26.3
HM	75.	68.	67.	78.	82.	85.	86.	85.	85.	83.	79.	77.	79.
SC	65.	74.	75.	61.	55.	50.	49.	50.	50.	54.	60.	62.	59.
PD	0.	3.	12.	71.	163.	227.	265.	265.	176.	71.	0.	0.	1764.
ETP	99.	116.	169.	173.	182.	170.	171.	168.	150.	136.	108.	95.	1736.
ETDF	99.	113.	157.	102.	18.	-57.	-94.	-98.	-26.	64.	108.	95.	481.
MAI	.00	.03	.07	.41	.90	1.33	1.55	1.58	1.17	.52	.00	.00	1.02

SRIMANGAL BANGLADESH — EL= 21 LAT= 24 19 N LONG= 91 44 E KS=13.0

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANN
PM	13.	34.	84.	225.	437.	519.	340.	340.	380.	192.	43.	3.	2503.
PMI	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	191
P79	0.	1.	19.	133.	324.	367.	236.	239.	186.	79.	0.	0.	2256.
P60	1.	11.	55.	193.	410.	444.	295.	295.	272.	151.	3.	0.	2426.
PMX	76.	142.	249.	514.	663.	823.	530.	605.	411.	424.	205.	22.	3269.
TMC	17.2	19.5	24.3	27.3	27.7	28.2	28.5	28.3	28.2	26.4	22.2	18.4	24.7
HM	90.	81.	76.	78.	84.	89.	90.	90.	91.	91.	93.	92.	87.
SC	41.	57.	64.	61.	52.	43.	41.	41.	39.	39.	36.	37.	46.
PD	0.	3.	27.	146.	342.	383.	248.	251.	204.	94.	1.	0.	2315.
ETP	72.	94.	147.	167.	171.	155.	157.	150.	125.	110.	76.	67.	1494.
ETDF	71.	91.	120.	22.	-171.	-229.	-92.	-101.	-75.	16.	76.	67.	-205.
MAI	.00	.03	.18	.87	2.00	2.47	1.59	1.67	1.59	.86	.01	.00	1.55

Heading	Description
PM	Mean monthly precipitation in mm
PMI	Minimum monthly recorded precipitation (30 years)
P79	The 79 percent probability of precipitation occurrence
P60	The 60 percent probability of precipitation occurrence
PMX	Maximum monthly recorded precipitation
TMC	Mean monthly temperature in degrees Celsius
HM	Mean monthly percent relative humidity
HMC	Percent relative humidity calculated from sunshine
S	Percentage of possible sunshine
SC	Percentage of sunshine calculated from HM
PD	Dependable precipitation - the 75 percent probability of precipitation occurrence
ETP	Potential evapotranspiration
ETDF	Potential evapotranspiration deficit (ETP - PD)
MAI	Moisture availability index (PD/ETP)

Crop production can be greatly increased through proper irrigation and water control by:

1. Providing supplemental irrigation during the early monsoon (aus) season.

2. Flood control and supplemental irrigation during the main monsoon (amon) season.

3. Irrigation during the winter dry season (boro season).

4. Growing a greater variety of crops including vegetables.

Flood Protection and Drainage

The flood control and drainage problems in Bangladesh are unique. Virtually the entire country is on a large active delta, and roughly half the area is subject to flooding. In some areas flooding supplies water for both monsoon and dry season crops and cultivation practices and varietal selection have been developed for the average flood environment. Nevertheless, in many years there is substantial abnormal flooding which damages both crops and facilities. Therefore, embankments and drainage improvements have an important role in water resource development in Bangladesh. Within the area protected by embankments (about 3.3 million acres as of 1977) farmers cultivate monsoon paddy crops with greater success and are said to be investing more heavily in High Yielding Varieties (HYV) and fertilizer and other yield increasing inputs.

Irrigation and Increased Production

To increase yields significantly, irrigation must be accompanied by the associated complimentary inputs, i.e., HYV's and fertilizers. If these inputs are not provided, then the impact of irrigation will be less or possibly even negative. Typical farm irrigation and management practices give the following yields, according to the Bangladesh Rice Research Institute (BIRRI). Their estimates are a reflection of actual results obtained by farmers on reasonably well managed fields and do not represent a potential established on the experiment stations.

Boro. In Boro season both local and HYV rice are grown under irrigated conditions. Paddy yields of 3 to 4 tons per acre can easily be obtained under good management. It is not possible to grow Boro rice without irrigation.

Aus. Usually, rice is grown under rainfed conditions and per acre yield of paddy is about 2 tons. Supplemental irrigation typically gives a 25 percent yield increase. Prolonged drought is unusual in aus season (April to July), but it does happen, as shown in Table 1.

Transplanted Aman. Usually, this crop is also grown under rainfed conditions, but occasionally there is a drought in September or October during the critical growth stages of panicle initiating or booting. Yield reduction depends on the severity of drought and under rainfed conditions paddy yields of 1.5 to 2 tons per acre can usually be obtained. However, with supplemental irrigation 50 percent yield increases hav been recorded; thus, with assured irrigation water, paddy yields of 2.5 to 3 tons per acre can be obtained.

The acreage under irrigation in Bangladesh during the past five seasons is given in Table 2 and the total acreage of rice (both rainfed and irrigated) grown in each season is shown in Table 3. Table 4 shows the yields per acre per season and the total rice production in Bangladesh is given in Table 5.

The production of wheat over the past 20 years is shown in Table 6. There have been dramatic increases in per acre production in the past five years. These have been made possible by HYV's, irrigation and fertilizer. In many cases wheat is being grown (a dry season crop) on land that formerly was in rice. However, the soil texture and moisture regimes during the winter dry season favor wheat production, i.e., irrigation requirements are less and returns are greater to the farmer.

Very clearly, there is a substantial opportunity to increase production with irrigation given the abundant water resources. Irrigation must be considered a priority in the country's development.

HISTORY OF USAID IN IRRIGATION DEVELOPMENT

What follows is a brief description of the irrigation development programs and projects in which USAID has apparently been involved. Also included are comments on the applicability of the projects and recommendations for future action.

There are no reliable records of all the irrigation projects in which USAID has been involved. This is likely the result of

TABLE 2

ACREAGE IRRIGATED BY DIFFERENT METHODS
(Millions of Acres)

	Gravity Schemes	Low Lift Pumps	Deep Tubewells	Shallow Tubewells	Hand Tubewells	Traditional Methods	Total
1974/75	.08	1.3	.14	.03	-	1.8	3.4
1975/76	.09	1.3	.18	.03	.006	1.7	3.4
1976/77	.09	1.1	.18	.03	.015	1.4	2.9
1977/78	.14	1.3	.35	.08	.025	1.8	3.7
1978/79	.16	1.4	.51	.11	.027	1.7	3.9

TABLE 3

ACREAGE OF PADDY BY SEASONS
(Millions of Acres)

	1976/77	1977/78	1978/79	1979/80
Early Monsoon (Aus)	7.9	7.8	8.0	7.5
Main Monsoon (Aman)	14.4	14.3	14.3	
Winter Dry (Boro)	2.1	2.7	2.7	
Total	24.4	24.8	25.0	

Source: Bangladesh Bureau of Statistics

TABLE 4

YIELDS PER ACRE BY SEASON
(Maunds per acre of rice equivalent)

	1976/77	1977/78	1978/79	1979/80
Early Monsoon (Aus)	10.3	10.8	11.2	10.2
Main Monsoon (Aman)	13.1	14.2	13.9	
Winter Dry (Boro)	21.3	22.6	19.8	

1 Long ton = 27.22 Maunds
1 Maund = 82.2 pounds

Source: Bangladesh Bureau of Statistics

TABLE 5

RICE PRODUCTION BY SEASONS
(Millions of long tons of rice equivalents)

	1976/77	1977/78	1978/79	1979/80
Early Monsoon (Aus)	3.0	3.1	3.3	2.8
Main Monsoon (Aman)	6.9	7.4	7.4	
Winter Dry (Boro)	1.6	2.2	1.9	
Total	11.5	12.7	12.6	

Source: Bangladesh Bureau of Statistics

TABLE 6

PRODUCTION OF WHEAT

Year	Total Acreage (Millions)	Total Production (Millions Long Tons)	Yield/Acre Maunds
1960/61	.14	.03	6.2
1964/65	.13	.03	6.4
1969/70	.30	.10	9.5
1974/75	.31	.12	10.1
1975/76	.37	.21	15.8
1976/77	.40	.25	17.6
1977/78	.47	.34	20.0
1978/79	.65	.48	20.2
1979/80		1.00[e]	

One Long Ton = 27.22 Maunds
One Maund = 82.2 Pounds
e = estimate

Source: Bangladesh Bureau of Statistics

lost records during the war of separation and the fact that many AID records were maintained in West Pakistan.

Ganges-Kobadak Project, Kushtia Unit, Phase I

This is primarily an irrigation project completed in 1970 with flood protection and drainage improvement aspects. It covers a gross area of 220,000 acres, of which 120,000 are irrigable. Irrigation is provided by pumping water from the Ganges River into a gravity canal system. The main feature of the project includes 46 miles of main channel and pumps with a total capacity of 1250 cusec. At the present time the project is estimated to irrigate between 30,000 and 65,000 acres.

Coastal-Embankment Project, Phase I

The Coastal-Embankment Project is located along the shore of the Bay of Bengal in the coastal districts of Bangladesh. By virtue of the land location and elevation and many water passages, the land is subject to periodic tidal inundation and monsoon floods. The project comprises 86 polders which will provide protection to about 2.7 million acres through construction of 2,250 miles of embankment and 800 sluices.

Country Master Plan

Development of a country-wide Master Plan for Irrigation, Drainage and Flood Protection. This program, completed in 1964 under contract by International Engineering Company, Inc. of California, identified and described a total of 51 irrigation, drainage or flood protection projects which would result in increased agricultural production. There were canal diversion projects, deep tubewell projects and embankment type flood control projects. Some of the projects were multipurpose associated with hydro development.

The overall objective of this Master Plan was to include an irrigation capability which would provide sufficient food production to meet in-country requirements for 20 to 25 years (approximately 1985).

The Dacca-Demra Project

This project was reportedly undertaken by USAID in the

1960's. No project documentation exists in the Mission. The team visited the supposed project site and obtained the impression of a multi-dimensional project which included a flood control/road embankment, land leveling and the provision of a pumping station and irrigation canals. The project may have included four villages.

Small Scale Irrigation

According to reports, there is a large demand for hand pumps for shallow wells and local manufacturers already produce 135,000 hand pumps per year. This active project is designed to finance the manufacture and distribution of 240,000 irrigation hand pumps at a farmer cost of $70 per pump and $3.45 for installation. The expected rate of delivery is 40,000 pumps per year. This is to be accomplished by: providing funds to the Bangladesh Government to purchase raw materials needed for manufacturing pumps; provide a credit program with minimal stipulation for loans; and advertising (by radio) the availability of both credit and pumps.

The pumps are targeted for rice and wheat irrigation on farms of one acre or less. Assuming a 120 day season, one-third acre of land will require 640 hours of pumping, or 5.3 hours per day. The food energy produced will be 20 times the human energy for pumping. A financial analysis from the farmer's viewpoint was made and even with rice prices at an extremely low level, the farmer owning one-third acre or more would show a profit after three years.

It is expected that there will be a 13 percent interest rate on loans and a 29 percent default rate, although the latter may improve with the addition of more loan officers. Therefore, the BDG is subsidizing the distribution of these pumps. the Bangladesh Krishi Bank will require $1M/year to maintain credit operations. In the first year, the IRDP will borrow $1.38M worth of pumps from UNICEF, to be repaid in local currency, and in the remaining years it will borrow about $1M/year from the Bangladesh Bank. The interest and default rates will be the same for the IRDP. The BDG will absorb all local costs of constructing the 120,000 additional pumps for which AID is providing raw materials.

Assuming (conservatively) a five year life for the pumps, the B/C for the project is 2.2 at 15 percent and the IRR is 85 percent. Terms for farmer loans are: no down payment; repayment in three equal installments after each dry season harvest; 13 percent interest; and pledging of the farmer's land as collateral.

This project is currently more than one year behind schedule.

Difficulties arose with pump design and with dealing with import procedures. Procuring all components of the pump and pipes proved to be a formidable task. As of June 1980, 6,000 pumps had been procured. However, contracts have been let which should produce results in the near future.

In the conduct of this project AID has shown the capacity to identify and solve problems so that the project might go forward. The team also notes that the original proposal was well documented with results from the Mission's research efforts.

Rural Irrigation Works

This project, which is still in the Project Paper planning stage, would construct and operate small scale irrigation systems (which would be developed to increase the command areas of existing water supplies) through the Rural Works Program of the Government of Bangladesh. To date, a consultant has selected 30 projects from a list of 90 deep tubewell (DTW) projects for planning and design. Any one of these 30 projects is referred to as a sub-project. Sub-projects to be developed will serve as models of design and operation for the Ministry of Local Government, Rural Development and Cooperatives (MRD) and to water users groups. Therefore, economic justifiability was not considered to be a primary factor in the selection of the sub-projects. Furthermore, the social and economic background data about the beneficiaries were not used to select the sub-projects.

To date, 23 sub-projects have been designed. They are to serve as demonstrations for promoting command area development -- ultimately for the country. Water distribution channels are standardized to carry 2 cfs flow, which is the typical outpout of a DTW. The channels are to be lined with locally made bricks and to have a masonry turnout for each three to five acre block of farmland. Water scheduling will be done in each block by roster which "will be published and updated from time to time and will be posted at the pumphouse or another convenient location."

The evaluation team does not understand how any single sub-project structure could serve as a national model without meeting the test of a financial analysis and field evaluation. In particular, water saving practices such as lined canals and masonry turnouts should be shown to pay. Furthermore, block rotational irrigation design, which has been selected, requires farmer organization which has not been tested. There is no evidence to establish that this is the design which will minimize distribution costs (where distribution costs equal expenditures on structures plus land taken out of production plus operation and maintenance charges plus organization and transaction costs).

The team recommends that if this project is to produce model projects it must be totally overhauled to reflect:

1. An appreciation and exploration of alternate design possibilities.

2. An organizational structure which integrates government agencies necessary to successful implementation of the project.

3. A training program which is better integrated into the Bangladesh system.

The Nabaganga Integrated Land and Water Use Study

This project, which is still in the Project Paper preparation stage, is for a target area of 90,000 acres serving a population of 202,500. At present, 2,700 acres are irrigated from the Nabaganga River. The primary goal of the project is to "significantly improve the income of farmers, especially poor land owners, tenants and landless laborers in the project area."

The primary components of the project are: (1) irrigation of 20,000 acres (one-half boro rice, one-half wheat) with lowlift pumps from the Nabaganga Reservoir; (2) development of fisheries in the Nabaganga Reservoir; (3) development of village industries; and (4) the establishment of an improved agricultural practices program on surrounding 70,000 acres of nonirrigated land. Four 100 acre pilot farms will be used to establish management and organization structure for the remainder of the project.

The team believes this project is unrealistically ambitious considering the complexity of developing the four components simultaneously. Furthermore the irrigation component is even more difficult than the existing deep tubewell projects which are severely underutilized, and a procedure for improving their performance is still to be tested. Therefore, we recommend that the project be restructured and/or simplified before proceeding further.

DEVELOPMENT OPTIONS

The team has chosen to consider the so-called issues as outlined in the paper prepared by Dr. Lavine (copy appended) as a listing not of issues, but of development options. It was anticipated from the start that a single option for irrigation development would not likely be appropriate. Rather, what would be required is a mixture of options consistent with current country needs, political realities and AID capabilities.

Irrigation and Rainfed

It is not possible to calculate the profitability of past investment in irrigation with the data readily available for analysis. However, it is clear that across all fronts results have been less than planned. Major canal projects were completed late and those under construction are behind schedule. Irrigated acreage is almost always less than the potential command for the quantity of water and irrigable area available. Typically, even relatively simple deep tubewell projects irrigate less than the planned for acreage (about one-fourth to one-third of expectations) because of inadequte infrastructure to maintain and operate the pumps and the lack of water distribution networks from the wells to the individual fields. Clearly, a realistic analysis of the benefits from irrigation in Bangladesh cannot be taken from project planning documents.

A total social accounting of irrigation investment in the country has not been carried out. Very little systematic monitoring or evaluation of existing projects has been going on. No one would argue, however, that planned for outpout increases have been achieved.

On the other hand, over the last five years the availability of irrigation water for the winter dry season (boro) has resulted in an average annual output of 2.094,000 long tons of rice equivalent. Valued at 1978/79 farmgate prices, this is approximately 5.95 billion Takas (approximately $411 million U.S.).[2]

There is an accumulating body of evidence in Bangladesh to suggest that significant increases in rainfed paddy production is a

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[2]Based on 1 long ton = 27.22 mds of rice, and an average farm gate price for Boro paddy of 104.46 TAKAS/MD.

real possibility. In the first place, of the 25.0 million cropped acres of paddy in the 1978/79 cropping season, a typical year in terms of planted acreage, 22.3 million acres, or 89 percent, were rainfed. These are the early (aus) and main monsoon (aman) paddy crops. Although yields may be limited in these seasons, compared to the winter dry season (which is irrigated) because of available sunlight, they represent a substantial production base.

Secondly, ongoing research with cropping systems at the Bangladesh Rice Research Institute suggests potential for greater rainfed crop production by way of new varieties currently under field testing. These varieties are bred specifically for characteristics which will be appropriate for average environmental conditions during the monsoon season. Field tests showed yields and income increases even though fertilizer and pesticides were applied below recommended levels. The release of these new varieties can be expected within the next several years.

In addition, there is strong evidence of substantial production increases from the application of zinc sulphate and sulphur in some regions of the country. Taking advantage of these production possibilities will require attention to the well-known packages of inputs and practices: fertilizer availability, credit, seed multiplication, demonstration plots and so forth.

The general concensus seems to be that a substantial improved technology for rainfed paddy production is not yet available, but it is likely to be so, well within the next five year period. It is too early to determine: (1) the yield and income potential of that technology; and (2) the relative profitability of investments in delivering that technology compared to investments in irrigation. Reliance on rainfed agriculture leaves much of Bangladesh without year long crop production and limits production to those periods when sufficient moisture is available. Therefore, the soil and climate resource goes unused for six months or more every year. In addition to increased production, irrigation affords a degree of insurance against unusual drought periods. Furthermore, one of the principal resources in Bangladesh is a cheap and readily available water supply. Therefore, the study team recommends that AID provide development assistance for both rainfed agriculture and irrigation projects.

Wet Season and Year Round Irrigation

Typically, wet season, or so-called supplemental irrigation, has the following characteristics:

1. Water is provided through a river diversion or pump system with or without associated reservoir storage facilities. Storage facilities are often needed because river flow is lowest when the demand for water is highest, but this is not likely the case in Bangladesh.

2. For paddy, the per acre irrigation requirements are low compared to dry season irrigation, even in the driest years.

3. The marginal productivity per inch of water declines over the full range of the supplemental water requirement. In the same way, the marginal productivity per acre inch of system delivery capacity declines. This means that there are two reasons for spreading a given amount of water over a large area: the per acre requirements are low, and average returns to water increase. The major factors which are acting to restrict the increase in the command area are cost incentives, cost of the distribution system and cost (management) of organizing for water control and incentive for those already reserving water to take the risks involved with expansion.

4. Very typically, paddy systems which have been designed for supplemental irrigation have a limited capability for year round irrigation (which means irrigating a dry season crop). The reasons for this are both the availability of water compared to the total command area and the distribution systems are not designed to carry the larger quantity of water required per acre during the dry season.

   In contrast, systems which are designed for many different crops and full season capability require greater water storage (reservoir or underground) and have the capability of transporting the higher per acre requirements. It is fair to say that a system which can supply the dry season command area can certainly provide supplemental rainy season irrigation -- except in the case of wells as limited by falling water tables. That is, the supply of groundwater may be such that tradeoffs must be made between dry and rainy season irrigation.

In 1978/79, 52 percent of the total irrigated acreage in Bangladesh was irrigated by engine or motor driven pumps (low lift pumps, deep tubewells and shallow tubewells). Originally these pumps were only operated during the winter dry season (boro season) because the organization which supports the pumping operations with fuel and maintenance was not set up for other seasons of the year.

This situation appears to be changing since the last four rice crops in Bangladesh have suffered from drought. Experiments in supplemental irrigation at the Bangladesh Rice Research Institute during the early and main monsoon seasons showed 54 and 10 percent increase, respectively, in paddy yield from very limited supplemental irrigation. Water shortages had occurred during the very critical reproductive stages, and therefore returns to small quantities of supplemental rainy season irrigation were high. Such experiments have provided sufficient evidence for the Government to initiate the process of making wet season pump irrigation available when required.

Pump Irrigation. It is possible that with existing pump operations, supplemental irrigation can proceed with no difficulties, but the following should be considered:

1. Additional pumping at existing sites may lower the water table below the depth at which shallow tubewells, using centrifugal pumps, can operate, particularly if full dry season potential is ever achieved.

2. Existing pump capacity, if not limited by topography, should be able to supply supplemental irrigation to a greater number of acres during the rainy than the dry winter season. Thus, more extensive distribution systems and new farmer organizations may be needed.

3. Irrigation can provide timely germination of crops prior to the beginning of the rainy season in order to take full advantage of the wet season for crop production.

4. The probability estimates of when supplemental irrigation might be required in the various climatic regions of the country have not been made; therefore, there is no basis for computing the economic benefits from investment in a supplemental irrigation capacity.

In summary, at the present time the economic benefits of supplemental irrigation have not been thoroughly investigated. It is highly likely, however, that supplemental irrigation with existing pump operations is economically feasible, especially under those circumstances where there is no competition between seasons for the available water supply. There are no studies which compare the marginal benefit of limited water supply between seasons or between crops within sesons. For the most part, however, systems should be designed for operation in all seasons (year-round).

Traditional Irrigation. Traditional irrigation methods, doones and hand pumps irrigate approximately 43 percent of the total irrigated area (see Table 2). This is recorded as dry season irrigation. It seems very likely that cultivators have been using these same techniques for supplemental irrigation when the need arises.

Gravity Fed Canal System. Canal systems have been designed primarily for dry season irrigation. There are no comparative analyses of full irrigation vesus supplemental irrigation canal systems; however, given the exising river flows, it is very likely that canal systems have sufficient water supply for monsoon irrigation.

Clearly, there is strong evidence that any gravity canal system designed for dry season irrigation should be organized and managed to provide full season irrigation. However, there is not sufficient evidence available at present to advocate building gravity canal systems with only a supplemental irrigation capability for paddy.

Expansion vs. Intensification

An expansion versus intensification development option for irrigation depends upon the existence of irrigation projects which have not achieved their design potential. The option clearly exists in Bangladesh. As mentioned earlier, history of irrigation investment is a continuous record of schemes which have failed to meet planned potential. But it is not clear whether this is because of incomplete planning, project execution, and implementation; due to rational adjustments to economic, social and environmental realities; or a combination of the above.

Wells and Pumps. The ares typically being irrigated by a deep tubewell are shown in Table 7. The areas being irrigated by the publicly financed deep tubewells and low lift pumps are far below the planned-for (potential) command areas. For example, a typical, deep tubewell discharges 2 cubic feet of water per second (cfs) and has a potential capacity to irrigate 90-120 acres during the dry season when operated only 12 hours per day. However, the five year national average area irrigated by such a well is only 44 acres and the pumps are operated less than an average of six hours per day.

TABLE 7

AVERAGE AREA IRRIGATED BY TYPE OF WELL/PUMPS

Type	Average Irrigated Area/Well 1978/79	Average Over 5 Yrs. 1975-79	5-Year Range
Deep Tubewell (DTW)	54.1	44.0	54.1-36.8
Shallow Tubewell (STW)	10.4	7.5	10.4-5.8
Low Lift Pump (LLP)	40.0	37.6	40.0-36.1
Hand Tubewell (HTW)	.32	.47	.32-.64

Source: Bangladesh Water Development Board, Bangladesh Agricultural Development Corporation, Integrated Rural Development Program

*Program started in 1975-76, 4 year average and range-acreages estimated.

Deep Tubewells (DTW's). These tubewells are six to eight inches in diameter and are drilled to a depth of over 160 ft. The wells are equipped with 1.5 and 2.5 cusec submersible turbine pumps, engines and pumphouses. Installed costs range from Tk 125,000 to Tk 225,000. Where possible, electric pumps are preferred to diesel because they are simpler to operate and maintain, and also make rural electrification more feasible. (However, the reliability of an electric supply source should be considered before promoting a general plan to utilize electric pumps.) A pump group or cooperative only pays a highly subsidized rental charge of Tk 1200 per year plus the cost of spare parts, fuel, oil and an operator's salary.

Reasons cited for the failure of the DTW's to irrigate their potential command areas include:

1. Grossly inadequate distribution systems between the well and the land which can potentially be irrigated with the flow available.

2. Mismatching of well and pump capacity. Many pumps are suspected of pumping far less water than the pump ratings.

3. Improper well siting. The well is often sited on the land of the manager and organizer of the cooperative rather than on the basis of topography. Irrigated acreage may therefore be limited by topography. Alternative siting may be done on the basis of topography with no reference to the organization and demand for irrigation water by farmers in the command area.

4. Command ares of 90 to 120 acres require organization of too many farms. (Approximately 50 percent of all farms are less than 2 acres and 25.0 percent are less than 1.5 acres.)

5. Farmers waste water (some claim because the cost of water is set too low to the cultivator).

6. Lack of uniformity in area irrigated (skipped plots).

7. No system of extension and agricultural development (supply of HYV, fertilizer and other input) after wells are completed.

8. Lack of an integrated approach to water development and management, i.e., failure to see irrigation as a complete physical, economic and social system and not providing the necessary inputs to integrate the total package.

9. Failure to run the pump more than four or five hours per day because of inadequate maintenance, fuel supply and availability of spare parts. Furthermore, there is a feeling that pumps must be rested!

10. Lack of a capability to organize farmers to manage the total system including efficient water application at the field level.

11. Large water losses in the field-to-field delivery system.

12. Fragmented holdings of very small sizes with no right-of-way for the water distribution system.

Low Lift Pumps (LLP). These diesel and electric powered centrifugal and axiel flow pumps are designed to discharge 1 to 5 cfs from surface water supplies. They are supplied to groups and cooperatives on an annual rental basis for pumping from streams, khals and ponds. Basic rental charges are highly subsidized and vary with the size of pump. The Bangladesh Agricultural Development Council provides repair services and the charges are assessed and there are penalties for negligence and carelessness. The group must also pay for fuel, oil and the operator's salary.

In 1976/77, only 28,224 LLP's were placed in service, although 40,500 pump sets were available for use. Reasons for lack of use and problems of the LLP program are cited as:

1. Grossly inadequate field distribution systems.

2. Lack of interest in irrigation due to low product prices and high input costs.

3. Unavailability of surface water for pumping in the drier years.

4. Conflict leading to dissolution of groups.

5. Pump life is too short (60 percent of potential) due to poor maintenance.

6. Lack of support for farmer groups.

7. Plus most of the other comments associated with DTW's.

Shallow Tubewells (STW). STW's are equipped with diesel engines which drive with centrifugal pumps having a discharge of from 1/3 to 1 cfs. The Bangladesh Agricultural Development Corporation sells STW pump sets to groups and individual farmers at cost (approximately Tk 19,500). The buyers also must pay all operation and maintenance charges. STW's are cheaper, easier to install and maintain and require a much smaller pump, motor and distribution system than DTW's for optimal utilization.

Hand Pumps. These pumps were discussed under the description of the USAID-financed Small Scale Irrigation (handpump) Project.

Canal Gravity System. It is difficult to determine whether gravity systems are being operated up to planned (or actual) potential. There is evidence, however, that the record is not good.

Banges Kobadak System. The USAID-financed Banges-Kobadak Phase I Project has cost more than 85 million U.S. dolalrs since 1959. It was to have provided a net increase in irrigated acreage in the command area of 220,000 acres. As of 1978, this project was listed officially as irrigating 64,608 acres. Unofficial reports speculate that the actual irrigated acreage may be about half that amount. A variety of reasons have been cited for the poor performance of the project. these include: (1) heavy siltation at the intake and pumping station; (2) inadequate electrical supply for the pumps; (3) command area per unit of discharge is too great; (4) grossly inadequate field distribution systems; plus (5) most of the other comments which were mentioned in connection with DTW's.

Flood Control Project. The Coastal Embankment Project is a typical flood control project which consists of a system of dikes and drainage sluices to protect land in the coastal area from flooding by saline water at high tide. The program was begun in 1960. More than 2,300 miles of embankment have been completed. According to World Bank reports, only a fraction of the full potential of the embankments have been realized. What is said to be required are improved water management practices, agricultural support services, rural infrastructure and, in short, a system-type integrated approach to development.

Summary. It is quite clear that the planned for potential of none of the irrigation alternatives, large or small, has been achieved. There are long lists of possible causes, but in all cases these are either informed judgments, hypotheses or pure speculation. There have been no special studies made to clearly document the difficulties. There have been no attempts to determine if the costs of increasing the irrigable area can be justified by the potential benefits. Indeed, some consultants are even suggesting that it may be more economical to sink new tubewells than to improve the distribution systems and bear the organizational and increased water management costs on existing installations.

There is strong evidence to suggest an opportunity to increase irrigation from existing projects. There is no available information to evaluate the capital and operating (energy and management) costs and benefits associated with choosing that particular development option. The evaluation team recommends that investigations of these costs be undertaken in an organized, professional manner. A project might be developed with this as its objective (giving special emphasis to energy use efficiency).

Large Projects vs. Small Projects

A large irrigation project is one in which water is drawn from a single source and distributed by an extensive cnaal system over an area of 1,000 to 1,000,000 plus acres. Canals are measured in miles rather than in feet. The area irrigated is often large enough that cultivators never visit the water source in their lifetime. A project which may require a similar total investment but is a collection of many small sub-projects in a geographical area (i.e., a project to sink 500 tubewells) is not what is meant here as a large project.

Some possible benefits of a large project may be summarized as follows:

1. They provide a means to utilize a large and variable water source such as rivers which have flows which vary from season to season and year to year.

2. They permit effective use of scarce managerial and technical skills.

3. They appear to permit economies of size to be realized in operation and maintenance by concentrating resources.

4. They are more easily financed through foreign donors because large investments can be made with limited supervision.

5. They generate more benefits during the construction period because of the more massive investments which must be made.

Some of the negative dimensions of large projects are:

1. They inevitably require the use of external consultants.

2. They often have major environmental impacts; for example, relocating villages inundated by reservoirs.

3. They require main system management and extensive farmer user organization to utilize the water effectively.

4. In addition, large projects have all the same on-farm water distribution and management complications as do small projects.

In contrast, small projects (including a large collection of small sub-projects under a single large financing scheme) have the fol wing advantages very large projects:

1. Quicker returns to invested capital.

2. Better opportunities for mobilizing local resources and minimizing impacts.

3. Easier to organize for effective water management because the main system is eliminated and fewer cultivators per unit are involved.

In Bangladesh, irrigation has been targeted by both the government and major donors as one of the major development activities for achieving food self-sufficiency by 1985. The irrigation investment strategy in Bangladesh has been heavily influenced by the designers of the 1964 Master Plan funded by USAID. Completion of this plan was originally estimated to cost $2.1 billion U.S. and called for some 50 major projects which would have jointly provided flood control and drainage for about 12.1 million acres. Irrigation was to be supplied at a later date to 7.9 million acres. Schemes completed so far (1979) provide full or partial flood protection for 3.37 million acres and irrigation for 150,000 acres.

Recently (April 1979), a joint team of the World Bank/Government of Bangladesh reviewed irrigation development in the country. The objective of the review was to facilitate and redirect water resources development strategy with a view toward meeting food grain self sufficiency by 1985. Overall, the study team recommended that devlopment should focus on immediate impact on food grain production rather than on long term flood protection and drainage.

It was determined that if food self-sufficiency was to be achieved, a minimum of 4.85 million acres would need to be irrigated by 1984/85. This minimum requirement assumed a relatively high production response to irrigation. A more realistic requirement was felt to be 5.7 million acres. The types of irrigation facilities which would be required to meet the 5.7 million acre objective are shown in Table 8.

A large portion of the increase, 1, 500,000 acres, would primarily come from large gravity and/or pump systems and the remainder from smaller scale irrigation facilities., It was felt by the Bank review team that this high a level of development over the next five years is not achievable; consequently, they suggest a reduced target for gravity/primary pumping schemes of 800,000 acres for a total of 4.85 million irrigated acreages by 1984/85.

What has evolved since the 1964 Master Plan and its almost total emphasis on large scale projects is a joint strategy which recognizes the importance of small scale irrigation projects. In fact, the role of small scale irrigation seems to be more limited by government uncertainty regarding groundwater supplies and sites for low lift pumps than by a preference for the larger systems. This suggests the need for sufficient groundwater survey data to delineate where STW's should be employed.

An interesting relationship is pointed to in the Bank report, which is that in Bangladesh the rate of return from irrigation/flood control investments are inversely related to the per acre capital investment cost, which is found to be largely a function of flooding as well as utilization of man-made (railway and roads) and natural barriers, as flood protection embankments.

What emerges, then, is a situation in which the higher returns to investment in irrigation are from small scale projects in the less flood prone regions of the country.

A review of externally financed schemes by the World Bank demonstrates the relationship between size of scheme and cost and returns, as shown in Table 9.

Another factor which appears to be opting strongly for small scale irrigation is the problem of farmer organization for water management. The organizational requirements for a deep tubewell are not likely significantly greater than those at a turnout of a large gravity system. However, as the size of the water supply decreases with shallow tubewell and low lift pumps, the organizational requirements for water management decreases. The ultimate is the hand pump for which there is no organizational component for farm level water application.

This does not mean, however, that the organization necessary to supply the farmer with the whole range of inputs and services necessary to achieve the potential of irrigation has decreased. It may, in fact, have increased for some services such as maintenance and repair and fuel distribution.

While the organizational costs and energy budget may favor hand pumps, shallow tubewells (and probably low lift pumps) appear to be less costly to operate on a per acre basis than hand pumps, as demonstrated in Table 10.

<u>Summary</u>. Bangladesh is committed to an irrigation program which includes both very large and very small projects (i.e., individual irrigation units). The available evidence to date shows that small scale projects in the less flood prone areas of the country have higher rates of return than large projects. Given

TABLE 8

IRRIGATION FACILITIES PROJECTED FOR MEETING ESTIMATED NEEDS

Types of System	Acreage 1975/79 (000)	Acreage 1984/85 (000)
Gravity/Primary Pumping	110	1,660
Low Lift Pumps (LLP)	1,431	1,700
Deep Tubewells (DTW)	152	940
Shallow Tubewells (STW)	77	440
Hand Pumps (HP)	200	170
Traditional	1,000	800
TOTAL	2,720	5,710

TABLE 9

COSTS AND RETURNS OF SELECTED IRRIGATION SCHEMES

Type of Scheme	Sample Size	Capital Investment Per Acre (US$)	Internal Rate of Return
Small Scheme	10	< 110	30-50%
Minor Scheme	3	110-170	28-30%
Medium Scheme	7	300-1000	14-16%

Source: The Government of Bangladesh and the World Bank, Bangladesh Review of the Bangladesh Water Development Board, Report No. 2327-BD, April 2, 1979

TABLE 10

COMPARATIVE COST PER ACRE
HANDPUMP VS. SHALLOW TUBEWELL

	Handpump	Shallow Tubewell
Capital Cost	TK 1000	TK 20,000
Life of Unit	5 years	5 years
Amortized Capital Cost	200	4,000
Operating Costs	1,500	6,230
Maintenance	50	990
Total Cost/Annually	1,750	11,220
Command Area	0.5 acres	6 acres
Cost Per Acre	TK 3,500* (US$233)	TK 1,870 (US$125)

*If the opportunity cost of family labor operating the pump is assuming zero, then the per acre costs are reduced to TK 500 (US$33). This is probably not a valid assumption. Of course, increasing the efficiency of the pump would have a similar cost reducing effect.

Source: USAID Project Paper, "Proposal and Recommendations for the Review of the Development Loan Committee." Bangladesh: Smale Scale Irrigation I, AID-DLC/P 2162 Annex B.12.

USAID experience with larger projects and the evidence favoring small projects (as well as the considerable support being given for the larger gravity-pump systems by other donors), USAID should not provide financing for large scale projects at this time.

Government vs. Private

The conventional wisdom in Bangladesh at the present time is that a number of the organizational and supply issues would be overcome if both the supply side and pump operation were turned over to the private sector. This may well be, but there has been no systematic analysis of the most effective roles for the Government and the private sector in irrigation development.

Advocates of complete reliance on the private sector need to recall that there are two sides to the coin: (1) the efficiency argument which incorporates the "invisible hand"; and (2) the distributional implications implicit in a private sector economy which may not be acceptable on equity grounds and/or because of political realities. More than likely, a mixed strategy will eventually emerge in which the private sector will play an important, but not the total, role. It is reported that private investment in water resource development activities has been hindered by ambiguities in national water laws.

Summary. The team recommends that USAID encourage development of the private sector when it appears consistent with their capability and the equity concerns of government. (In reality, it is likely that irrigation will be developed in both the private and governmental sectors.)

INVESTMENT STRATEGIES

This section discusses the investment strategies developed in the Levine paper (copy appended). There is no attempt to devise a simple strategy, but rather, to point towards a mixture of strategies.

Direct and Indirect

Up to this time, USAID has had no experience in indirect investment in irrigation. Indirect investment refers to irrigation as a component of a larger systems approach to development. Typically, such projects are referred to as integrated rural development, integrated area development, and so forth.

The general argument for indirect investment is that direct investment most often fails to meet output objectives because, as is well known, irrigation must be accompanied by a vast number of other inputs and services to achieve development and the desired production goals. The systems approach is generally accepted as the way to integrate activities so as to achieve development goals.

The evaluation team suggests that USAID avoid involvement with integrated projects which do not have a strong monitoring and problem-solving capability. This may depend ultimately on the GOB commitment to facilitating projects of this nature. Integrated projects should reflect experience gained by donors who have been funding these types of projects.

Hardware and Software

As shown in Table 11, the quantity of hardware (investment in physical facilities, plant and equipment) which is proposed for Bangladsh over the next five years, is substantial. Most of the financing for this development, particularly surface irrigation, will be provided by outside donors (IDB, ADB, etc.).

TABLE 11

IRRIGATION DEVELOPMENT IN BANGLADESH - 1980/85

Type of Irrigation	Acres to be Irrigated	Number of Units
Surface Irrigation	760,000	
Low Lift Pumps	57,000	23,000
Shallow Tubewells	1,230,000	125,000
Deep Tubewells	890,000	14,000
Hand Tubewells	80,000	330,000
Drainage/Flood	1,500,000	

Source: Bangladesh 5-year plan.

Software refers to research, training and management modes of improved irrigation systems. The following recommendations dealing with irrigation in Bangladesh have been taken from the team's review of numerous reports, documents, conversations with AID and GOB officials, project managers, technicians of many organizations, and interviews with key farmer informants and extension workers. These recommendations are provided in summary form and should be viewed as ways to find solutions to problems raised in this report.

1. Irrigation system analysis and adaptive research is needed to:

    a. Determine how the present irrigation systems work in order to identify priority problems which constrain production.

    b. Determine conveyance efficiencies, field application efficiencies and how on-farm improvements (conveyance channels, field outlets, other farm structures and land leveling) can improve the use of water.

2. Improved recording and use of agroclimatic and soil data is needed for:

    a. Estimating irrigation requirements throughout the year.

    b. Soil moisture and fertility management, and crop and farming practices selection for both irrigated and rainfed farming.

3. Economic analyses are needed which have a farm management focus to ascertain costs and returns to irrigation.

4. Analyses of the human and fossil fuel energy costs of alternative types of irrigation should be undertaken.

5. Needed social, legal and institutional studies include assessment of:

    a. Methods to get the benefits of irrigation to small farmers, tenants, sharecroppes and homesteaders.

    b. Water policy and codes related to land and water rights, and forms of farmer organizations which will work most effectively within the rural social structure.

c. Present water policy and codes to identify and remove constraints in the efficient use of water.

d. Where and under what conditions farmers cooperate in the use of collective goods. (Evaluations of the CARE, FAO and other programs to ascertain what forms of cooperation are emerging.)

e. The proposed costs of legal water user associations under the cooperative, societies or other existing legislation.

f. The linkages between farmers and organizations designed to serve them to ascertain quantity and quality of services provided.

g. Effective forms of extension services such as conventional extension system, training and visitation approach, use of paraprofessionals or farmers in extension, and roles for farm water management advisors.

6. Estimates of groundwater resources and recharge to develop a coordinated and rational pump and surface water use and management program.

7. Examination of water quality in selected ares to determine the effects of pumping on salt water intrusion in rivers and groundwater systems and the resulting consequences for irrigated agriculture and fisheries.

8. An updated national water resource development strategy is needed which will address planning capabilities and management problems as well as provide guidance for physical planning.

9. An inventory of organizations in Bangladesh (including research institutes, training centers and universities) should be made to assess the institutional capability for long-term irrigation improvement. At present, very few understand the need for and application of interdisciplinary methods of on-farm water management in its entirety. This is because irrigation has been dominated by civil works which simply provide water to command areas and practically no attention has been given to getting the water to the plants.

Special training programs (and institutions which utilize the trained manpower) must be developed if there is to be a long term focus on irrigation in Bangladesh which will solve problems at the farm level. Training should provide skills in priority problem identification, development of solutions, assessment of technologies, and planning, implementation monitoring, and evaluation of irrigation systems. The mode of training should be interdisciplinary and include some academic graduate training for a few selected positions. However, the main focus should be on short-term, in-service training for engineers, mechanics, economicsts, sociologists and extension workers to assist farmers.

Selection of trainees is important: ideally, selection criteria should include a period in the field for the first trainees with existing programs. Initially, academic training should be for a selected number who will find positions in organizations committed to on-farm water management. A corps of initial trainees may need one year of overseas training in professional programs. Where overseas degree training is involved, the thesis should be done in Bangladesh on problems relevant to improving the irrigation system. Special observation training tours for selected individuals should be made available in third countries to learn what developments are taking place.

The opportunities for investment in the provision of software to support irrigation development in Bangladesh appear great. Training and demonstration activities might be provided through short courses, grants to other agencis involved in institution building, fellowship programs, construction of schools and buildings, preparation of training materials specific to local conditions, sponsoring of country and regional seminars and workshops. In addition, adaptive research to improve farm water delivery efficiency and unity and field irrigation application practices is needed. Studies and plannng for comprehensive agricultural resource (rainfed as well as irrigated) development are also essential.

Main System and On-Farm

The failure of all types of irrigation projects, large and small alike, to even come close to meeting projected outputs can in part be attributed to the lack of adequate on-farm water delivery systems. There are no studis which have carefully documented the exact causes of failure and led to recommended changes on the basis of those studies. However, there is an abundance of untested solutions to the "on-farm problem," such as land reform and field consolidtion, construction of water conveyance systems, collective farming and rotational irrigation.

The review team recommends that AID emphasize on-farm delivery in any projet which they might undertake. The team cautions against acceptance of any system without first assessing the costs (per unit area which can practically receive water) including the organizational costs involved; and benefits including the value of assured production during drought periods and greater employment opportunities.

Early vs. Late

The early versus late investment strategy is not particularly relevant under present circumstances in Bangladesh. It is true that some of the very large projects have developed in stages. In those cases, it is possible that lessons learned in earlier stages might be applied in the second and later stages. This requires a capability of learning from earlier experiences and remembering the lessons. The evaluation process, coupled with personnel changes, mitigate against any possible advantage in entering a project at its later stages. Then, too, the later stages of a large project are often quite dissimilar to the early ones and for all practical purposes are actually separate projects.

Easy vs. Difficult

There is clearly an order of difficulty in the irrigation projects currently under way and under consideration in the Mission. From easiest to most difficult, the team ranks the projects as:

1. Handpump project.

2. Small scale irrigation project (proposed).

3. Integrated land and water management project (proposed).

Here, a degree of difficulty is seen to have a direct relationship with the management and organizational component of the project. To an extent, the complexity of management and organization depends on how the project was formulated and not with differences in the overall development task in the project area. For example, the handpump project does not concern itself with how the farmers can most effectively allocate the water from their handpumps, the supply and use of complimentary inputs, the possible role of women in vegetable gardening and the pumps' impact on that role, and so on.

It is not at all obvious in this case that the size of the project payoff is positively related to the degree of project difficulty. The analysis provided of expected project benefits are not sufficiently great to establish any probable relationships.

Given the Mission's lack of experience with integrated land and water management projects and the present restructuring of in-house supportive research and monitoring capability, the team suggests that the Mission concentrate efforts on direct irrigation projects with adaptive research and institutional building components.

ADDITIONAL OBSERVATIONS

The current irrigation projects and project proposals have given minimal attention to the important areas of: using irrigation water on crops other than paddy, particulary vegetables; the impact of the new irrigation technology on women and the impact of irrigation on nutrition.

Vegetable Production

Vegetable production and consumption can potentially raise the nutritional status of the people of Bangladesh, particularly the rural poor. Often vegetables are grown during the winter season on small plots tended by women. Provision for irrigation water and improved varieties and hubandry techniques have the potential of substantially contributing to nutritional status. Handpumps in particular may be very appropriate for household vegetable gardening. In fact, the pre-project survey of handpump users which was done to establish the benefits from handpumps, showed that 27 percent of the handpumps were being used to irrigate at least some vegetables.

All of the projects, both ongoing and proposed, have the potential for vegetable production. The survey team recommends that exploitation of the potential for vegetable production be considered when developing irrigation projects.

The Role of Women

The effect of irrigation development on the roles of women in the Bangladesh social system has not been sriously considered in project planning and implementation. This seems an unfortunate oversight because undoubtedly they play important roles in decision making, organization, and are a part of the agricultural labor force.

The survey team recommends that the role and contribution of women in irrigation project planning and implementation be seriously considered. The team feels this will be to the benefit of all of the projects. To date, attention to women's roles has been cursory at best.

Nutrition and Irrigation

The extent of hunger and malnutrition in Bangladesh is indicated in Figure 2. the 1975/76 Nutritional Survey of Rural Bangladesh revealed that:

1. Children between 1 and 15 years are receiving less than the minimum calorie requirement, and the greatest deficiency is with the younger children.

2. The calorie intake of lactating and pregnant mothers is deficient by 32 percent.

3. Calcium deficiencies are extreme for all children, for most severe is the 1 to 3 years age group, which receive only 32 percent of the recommended minimum requirement.

4. A 50 percent deficiency of Vitamin A is prevalent in all age groups.

5. The consumption of Vitamin C is below the recommended amounts, especially in the younger age groups.

6. Surprisingly, except for the less than 3 year old age group, minimum recommended protein requirements are adequately met. However, there is a general deficiency of riboflavin.

In summary, the rural population is grossly malnourished. This is particularly true of the young, pregnant and lactating women. Irrigation can enable the growing of vegetables which can materially

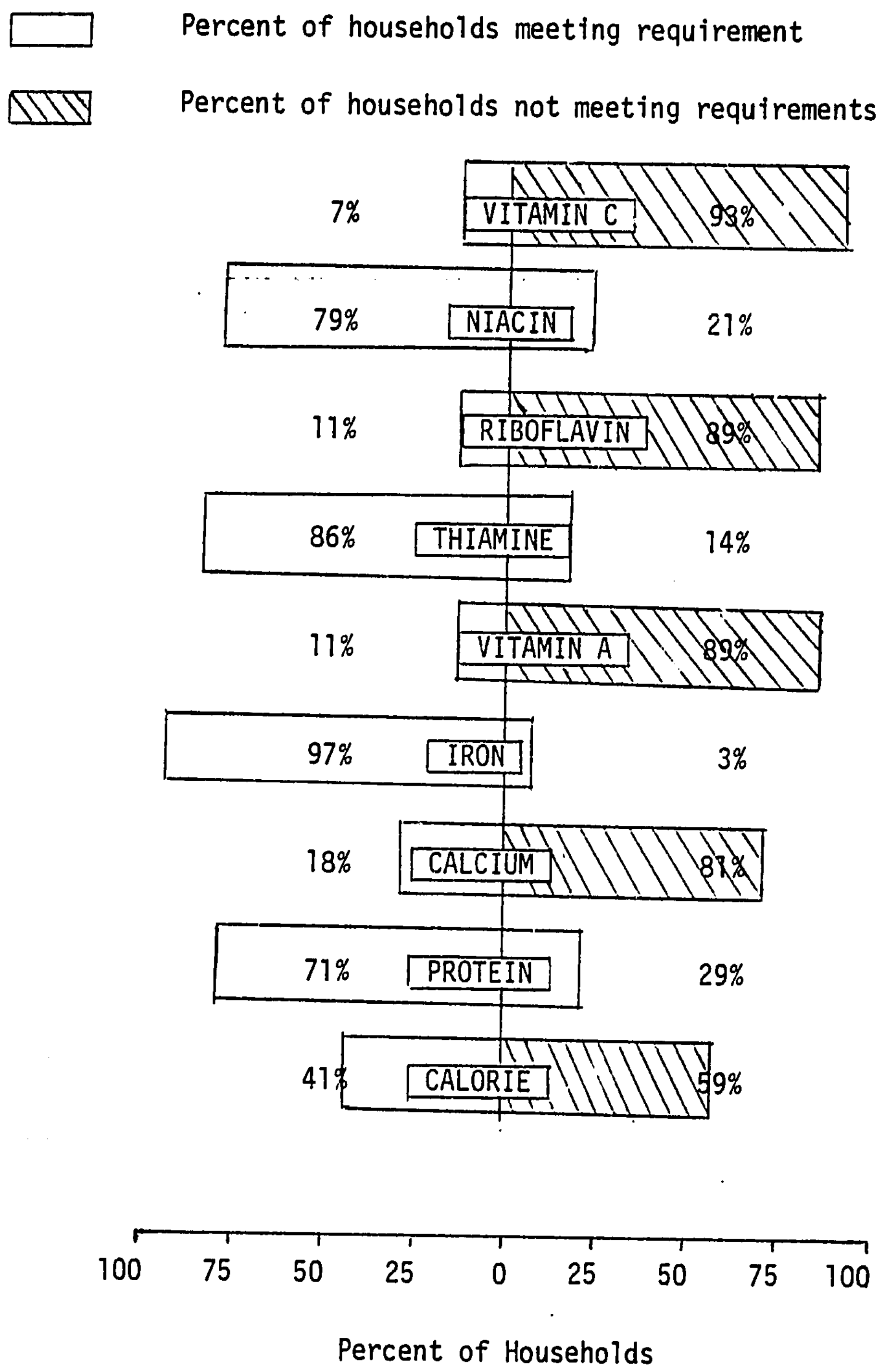

Figure 2. Percent of households meeting and not meeting different nutritional requirements.

improve the nutritional status of the farm families.

An extended program of vegetable production should be included in all irrigation project designs and extension programs. Vegetables offer the best means of providing a balanced diet for the rural family. The irrigation systems should be designed and managed to provide family garden areas with irrigation water during all seasons. One way to measure the success of an improved irrigation project area would be to monitor and evaluate changes in food consumption and nutritional status of the food deficient socio-economic strata in the villages to appraise the equity of benefits derived from the projects.

APPENDIX A

IRRIGATION DEVELOPMENT AND STRATEGY ISSUES FOR THE ASIAN REGION

by

Gilbert Levine
Cornell University

IRRIGATION DEVELOPMENT AND STRATEGY ISSUES
FOR THE ASIAN REGION

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Introduction

This preliminary paper has been prepared at the request of AID and is intended to identify the issues associated with the attempt to use irrigation to increase agricultural production while benefitting the rural poor of Asia. This is being done in the context of a growing view that irrigation development will be a major, and perhaps the primary mechanism, for agricultural and rural development in Asia in the forthcoming decade. In reflection of this view, the governments in the region are making massive investments in irrigation and related work; they are planning even greater ones in the future. These governments are being assisted in their development efforts by many international lenders and donors, including USAID. Actual investment estimates are difficult to arrive at, but world-wide irrigation and related water investments are anticipated to be on the order of $100,000,000,000 with a significant percentage to be in the Asian region. Within the past few months alone, announcements of irrigation loans to the Philippines and Indonesia represent projects approximating $200,000,000 in each country.

Irrigation investment represents a significant share of AID's spending in Asia, although it is a relatively modest proportion of the total spending on irrigation in the region. Thus, maximum effectiveness of the USAID inputs can occur only if there is a clear understanding of the choices available for development direction and of the options available for implementing the development decisions.

To a major extent, the decisions about development direction are the responsibility of the governments in each of the countries in the region, though inevitably the international funding community influences these decisions. The decisions about the most effective ways to use USAID resources to assist the national government must reflect, however, USAID mandates and experience.

This draft paper exploring the development and strategy issues is the first stage of a process by which, it is hoped, a set of irrigation investment strategies will be developed by USAID which derive from the considered judgment of those knowledgeable in the field and from a careful review of USAID experience with projects in the region.

To illustrate the issues most clearly, they will be presented in this draft in sharper contrast than they actually exist. It is anticipated that the strategies that ultimately result from these deliberations necessarily will be more flexible to accommodate the specific circumstances in each country. In addition, the issues will be categorized separately, but it is obvious that they overlap and interrelate. Nevertheless, we hope this combination of emphasis and sharpness will make the clarification of choices easier.

Two broad sets of issues are considered, those relating to the development emphasis and those that explore possibilities for USAID strategy. Five issues are identified in each category and each will be discussed separately. The development issues are: (a) irrigation vs. rainfed; (b) wet season vs. year-round; (c) expansion vs. intensification; (d) large projects vs. small; (e) government vs. private. The potential investment strategies include: (a) direct vs. indirect; (b) hardware vs. software; (c) main system vs. on-farm; (d) early vs. late; (e) easy vs. difficult. In addition to these relatively specific issues, two more general ones are raised which relate to the historical context of irrigation development.

Development Issues

Irrigation vs. Rainfed

While the underlying assumption of this entire effort is that massive irrigation development is and will take place, the implications of this emphasis should be recognized. This is especially true given the USAID primary objective: to increase production in ways that improve the welfare of small farmers and the landless. In general, where the major objective is agricultural production and where there is a significant problem of water deficiency, there are two basic development alternatives: to maximize the utilization of natural rainfall; to irrigate. Where significant sources of water exist, either as surface or subsurface supplies, there tends to be a strong emphasis on irrigation development.

The arguments in favor of this approach start with the conclusion that a reasonable water environment is essential for increases in agricultural production. It is assumed to follow, and there are studies to support this, that irrigation is the best way to obtain this improved environment. The argument is buttressed by the early emphasis in the major international research centers dealing with rice and wheat on technologies appropriate for irrigated conditions. It is further held that irrigation development can result in more rapid productivity increases, both because public investments can be made efficiently and because the reduced risk of water deficiency, resulting from irrigation, will provide the incentive to "risk-avoiding" farmers to adopt new technologies and to make the investments that make the new technologies productive.

The case for irrigation is strengthened by the argument that with limited technical and extension manpower, a focus on the more limited areas served by irrigation facilities would have a greater and more rapid effect than a more dispersed program.

The arguments for more consideration of the potentials of greater use of natural rainfall tend to center on the issues of equity -- the greater sharing of investment resources among the rural population, especially those who are relatively disadvantaged. For example, in Table 1 the income status of irrigated farms vs. resettlement farms in Nam Pong indicate that the farmers in the irrigated areas are better off than the farmers in the resettlement areas. These latter farmers were forced to give up their land to provide water for the farmers downstream and are growing progressively poorer while the farmers in the irrigated areas are becoming richer. Similar examples can be cited in the Mada area of Malaysia, the UPRIS area in the Philippines, as well as others.

Along with the equity consideration is the question of relative economics. It is argued that the marginal returns from investment in improvements in on-farm rainfall utilization are higher than those actually achieved by many irrigation projects (in contrast to theoretical achievements). Additionally, it is held that the shifting of emphasis at the International Centers, from the environmentally favored production situations to the less-favored circumstances, will result in significant increases in productivity potential undr these rainfed situations. Some of the results from the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) and from the International Rice Research Institute (IRRI) are examples. In the latter institution, the development of very short-season rice varieties increases the probability of being able to produce high yields with modest improvements in on-farm rainfall management.

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In addition to the major arguments in favor of more balanced evaluation of the merits of rainfall utilization (if not a bias toward it) the potentially adverse impacts on the natural environment and upon human health of irrigation development are raised. Schistosomiasis is endemic in many parts of the region, often at critical levels; other internal parasites, such as hookworm, have been found to increase with irrigation, particularly irrigation of the perrenial type.

Wet Season vs. Year-Round Irrigation

Two broad types of irrigation capability can be categorized: irrigation to supplement natural rainfall and irrigation to provide essentially all of the crop water needs. Each has its relative advantages and disadvantages.

Historically, in much of Asia the early systems developed in proximity to flowing streams and other relatively easily developable water resources and require little more than simple diversion structures, usually of the temporary character. Over time, conveyance and distribution channels were added to irrigate areas further from the water source. With larger areas and more people served, maintenance of the diversion structures became easier, though interest in more permanent structure generally increased. With more investment and more organization the systems became an integral part of the much of the agricultural production activity. Under population and other economic pressures the command areas of many of these systems has increased to the point where the normal variation in river flows and in the natural rainfall prevents adequate supplemental irrigation and significant year-to-year variation in production results. The data from North and Northeast Thailand presented in Table 2 illustrate this pattern.

Systems of this type usually have very little capability for dry season irrigation (often less than 10 percent of the nominal command area).

In much of the region, to provide full year-round irrigation capability it is necessary to provide significant storage capacity or access to an appropriate groundwater reservoir. When sufficient storage or groundwater capacity exists, dry season production increases over time and may become major proportion of the total production. Table 3 illustrates the case of central Thailand where dry season production now represents almost 50 percent of the wet season production.

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The benefits from an emphasis on supplemental irrigation include: relatively low unit development costs, thus spreading available investment resources to the largest number of individuals; greater stability of wet season production, encouraging inputs of other production resources; maximum utilization of existing experience and expertise; increased opportunity for staged development, including use of varying levels of technology.

The benefits from an emphasis on total irrigation capability include: maximum utilization of the irrigation and agricultural input infrastructure; greater opportunities for diversification of cropping opportunity, increasing the potential magnitude and stability of agricultural income; increasing the incentive for adoption of more productive technologies; making greater use of the available natural resources.

Again, the major disadvantages to complete irrigation are extensions of the disadvantages associated with irrigation by comparison to rainfed agriculture. Basically these relate to the questions of equity and environmental impact. The provision of year-round irrigation capability by access to either surface or groundwater reservoirs involves much greater unit area investments than are associated with supplemental irrigation systems. Costs associated with year-round capability may be an order of magnitude larger than those associated with supplemental irrigation. Even when the storage type projects are economically justifiable, they represent a concentration of resources into relatively limited area with a relatively small set of beneficiaries. Thus, there is a substantial benefit to a relatively small group. In addition to the direct benefit to the beneficiary group, however, is an indirect adverse impact on the non-beneficiary farmers. This results from the lower price for the commodities produced on the fully irrigated land. The irrigation farmers on this land, as the result of the income from two or more crops, can reap substantial economic benefits even at lowered prices per harvested unit. The single crop farmers find their incomes reduced as a result of the lower crop prices (obviously, the farmers on rainfed land are even more seriously affected). The differential between the farmers on the fully irrigated land and those on the supplementally irrigated or rainfed lands can be substantial.

The environmental impact, and particularly the health effects mentioned previously, are exacerbated under a complete irrigation system. The periodic drying of fields and channels, characteristic of supplenetal irrigation and rainfed areas, does not occur to an extent sufficient to avoid the extension of Schistosomiasis and similar water related diseases. These can seriously reduce the benefits anticipated from the project investments.

Expansion vs. Intensification

In many of the countries of the region, the existing irrigation systems are not being utilized to their potential. The reasons include: physical problems, e.g., serious deterioration of the physical infrastructure, excessive use of irrigation water, salinization of the land area, etc. Economic problems, e.g., a lack of profitability for the crops being grown, difficulties with obtaining credit and other inputs, etc. and social problems, e.g., land tenure arrangements which discourage utilization, caste or other social differences which affect access to production resources, etc. In some situations, as suggested previously, there may be a lack of storage capacity to permit year-round utilization. At the same time that there is this significant degree of under utilization of the existing irrigation system, there are opportunities for the development of new projects.

New systems present a sign of progress that has strong political appeal, both internally and externally, and which may have a more general psychological value. Potential benefits may be more easily identified and the requisite technical skills more easily mobilized than in the improvement of existing systems. particularly when new and larger scale external resources, both financial and technical, are available. High quality central design teams can be obtained and concentrated. Construction operations can be managed more easily.

The rehabilititiation and/or intensification process, on the other hand, requires detailed information about many dispersed situations. The manpower requirements for obtaining this field information, for designing the improvements and for supervising scattered site construction, while not necessarily of the sophistication required for new projects, still are very demanding. For the same amount of financial investment, many more technical personnel may be required for effective rehabilitation than for a new project development.

The direct benefits to be derived from the new projects, in principle, can be estimated more easily than those from intensification and/or rehabilitation. This is especially true where the new projects include dry season irrigation capability or are in arid zones. By contrast, the identification of benefits from improved supplemental irrigation systems is much more difficult.

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While the relative magnitudes of benefits to be derived from given investments in new vs. intensification efforts is in question, there is little doubt about the actual beneficiaries from the investment. These will be more readily identified in new systems and generally will be fewer in number than in areas being intensified., Similarly, the type of benefit will differ; new systems usually will result in significant increses in land value and changes in cropping intensity and/or type of crop production. Intensification through improvements in system infrastructure and operation is likely to have a lesser impact on land value and less radical, though frequently very important impacts on cropping practice.

The relative impacts on equity are difficult to generalize. In those areas where the existing social structure is resonably egalitarian either type of project should provide for reasonable equity, at least within the project area. Where tradition has estblished strong socio-economic differences, the potential to redistribute the benefits from project investment probably is greater in new projects than in rehabilitation or intensification of existing projects. This potential generally is unlikely to be realized, however, unless specific actions are taken to overcome the tendency for the more powerful to capture the benefits of public investment.

Large Projects vs. Small

The issue of large vs. small projects is widely recognized, but not easily resolved. In part, this is due to the complexity of factors, political, economic and technical that enter into the decision making calculus, but it is also due to the lack of information about the efficiency and effectiveness of small projects.

Some advantages and disadvantages of large projects, as compared to small projects, follow. Large projects frequently are necessary for the effective utilization of relatively large but variable water supplies. To stabilize the supply, a large reservoir may be required; this stabilized supply can then be utilized to serve a relatively large area.

The larger projects permit more efficient and effective use of limited managerial and technical skills. In many of the countries in the region, there are individuals with relatively high level expertise, but their numbers are small. Drawing these individuals together within the context of large-scale development permits the utilization of these skills most effectively. While there is a feeling of validity to this argument, there also is a potential for adverse impact. In mobilizing local design and managerial talent for the Upper Pampanga river project, the Philippines drew from its existing system the most competent engineers and administrators. These were concentrated in the single 80,000 hectare area and their impact was substantial. At the same time, however, no evaluation of the impact of the removal of this resource from the existing systems was made. It is at least arguable that an intelligent, vigorous and knowledgeable individual can make a more significant contribution in a position of major individual responsibility in a relatively small project than as a member of a team in a larger project.

A counterpoint to the issue of utilization of local capability is the requirement for external consultants that almost always accompany large projects. The technical requirements and time constraints usually associated with large projects almost invariably necessitate the use of external consulting firms. While these bring special resources to the developing countries, they also bring the lack of local experience and knowledge of the local culture and of the local political situation. At least in part as a result of this combination of skills and deficiencies, large project design is heavily oriented to technical questions.

Projects for a large area permit more economical use of the physical elements of the system. Both the operation and maintenance are more economical when there is a relatively high investment per hectare served and there is more than one crop per unit area. In principle, this seems valid, but difficulties frequently are encountered with large systems in the region. In serving the small farming units typical of the area to achieve the anticipated multiple cropping potential, it is assumed that there must be a very extensive terminal distribution system. Operation and maintenance requirements at this level are almost always delegated to farmers; it is anticipated that the farmers will be grouped into some type of water-user association. The effectiveness of these groups varies widely from country to country within the region and there are very few examples of successful integration of farmer groups and centrally administered systems. As a result, operation and maintenance remain major problems in large scale systems.

Large projects are more easily financed. While the situation is changing, as exemplified by the Sederhana program in Indonesia and similar programs in some of the other countries in the region, generally it has been easier to obtain external financing for large projects than for small ones. A variety of reasons for this can be cited: many international loans cover the foreign exchange component of the project and since large projects tend to have a relatively larger foreign exchange component they are favored for funding; the accounting and oversight requirements associated with the

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international loans are more easily accommodated within a large concentrated project than within a set of dispersed smaller projects; the documentation for adequate consideration of the project (basic hydrology, technical details, economic projections, etc.) are more easily developed for large relatively compact projects than for smaller projects.

Large projects generate major benefits during the construction period as well as after project operation. Depending upon the mode of construction, labor can represent a relatively large percentage of the input needs. Since both unskilled and skilled labor are required, there can be a significant stimulus to employment during the construction period. This stimulus, however, is not necessarily beneficial in the long term. Unless managed carefully, there is a boom-bust aspect to large project manpower mobilization. Accompanying this mobilization may be a disruption of traditional labor patterns with both wages and occupational choices affected.

Within recent years, many of the problems associated with large projects have been identified and there is growing recognition of the potential associated with smaller irrigation systems. These potential benefits include: more rapid development and utilizationl opportunities for the mobilization of local resources, both capital and labor; minimization of large area environmental impacts; broader dispersal of investment resources; the potential for greater involvement of the local community in system operation and maintenance.

It has been demonstrated that not all of the potential benefits associated with large projects have, in fact, been obtained, and it is becoming clear that not all of the potential benefits associated with small projects are being obtained. The lack of definitive studies of the relative impacts on production and equity of comparable investments in large and small projects makes it difficult to differentiate between them. While there is a growing presumption that small projects provide greater opportunities for equitable distribution of benefits, and, within the constraints of equivalent water supplies should have greater productivity, the specific evidence to support this view is very limited.

Government vs. Private

The question of the realative roles of the private and public sector in irrigation and water resource development is one that has grown in importance during the past 10 years. The major impact of the private sector in tubewell development, with significant financial resources being mobilized where little were thought to exist, the examples of more effective utilization of private water facilities and the more numerous examples of difficulties associated with public systems have increased interest in the private sector.

However, private development usually has taken place in environmental situations where the technological component for water capture and use is relatively small -- readily available groundwater, lands adjacent to streams, etc. Bangladesh appears to have large areas where these conditions exist (though with other constraints), but the full extent of this potential in the region is yet to be documented. The degree to which private development can be extended to more difficult environmental situations is not well defined. In addition, the impacts of this relatively uncontrolled development on both the natural and social environments have not been studied. Groundwater depletion is one example of the type of problem that can result from uncontrolled private development. The region has some interesting examples of government assisted private, or at least semi-private or communal development (for example, in the Philippines), which should be helpful in clarifying the relative role of the public private sectors. In addition, it must be recognized that failures of private irrigation efforts are not unknown, especially where the projects are cooperative efforts among more than a very few farmers.

In this set of development alternatives the potential conflict between production and equity objectives is relatively sharp, particularly where groundwater is the primry water source. There is significant evidence to suggest that private irrigation development results in greater agricultural production and more valuable (economically) production. At the same time, most programs fostering private development tend to favor those individuals or groups who have greater resources, and more political power and are among the more advantaged. Thus, unless policies and practices to reverse this tendency are established and implemented, the equity objective is likely to be sacrificed to the production objective. At the same time, the relative production impact is not clear, if the equity policies are applied and effective.

Investment Strategies

Direct vs. Indirect

While it frequently is assumed that irrigation development will have a positive impact beyond the immediate boundaries of the command area projects may be developed essentially as individual activities or as a part of a formal area development program. Direct investment in specific projects, by contrast to indirect investment through support of the broader development efforts has both advantages and disadvantages.

There are many examples of direct investment in both large and small irrigation projects in the region, e.g., the Gal Oya project in Sri Lanka, the UPRIS in the Philippines, the Sederhana program in Indonesia, etc. This type of investment is relatively straightforward, though not without difficulties. For the individual project, such as Gal Oya, the outputs from the investment can be classified relatively sharply; the terms of reference for the consultants can be established relatively precisely; the schedule for activities predicted within reasonable limits.

The more complex type project, such as the UPRIS, makes for more difficulties in the specification of outputs, activities and schedules, but again the project is confined to the command area and to those activities more or less directly connected to the irrigation development and to the related agricultural practice.

External investment in small systems usually occus in a package form, in which the small projects are grouped for programmatic purposes, even though each may be a distinct individual project. This type of program investment frequently is considerably more difficult to specify and to carry through effectively (though it may be more productive). The dispersed nature of the projects imposes more difficulties in collection of essential information for design and construction -- and ultimately for monitoring and evaluation. To reduce the burden on this external lender, responsibility for project implementation usually is left with the host country, while oversight and evaluation is focused on the general program.

Direct project investment has two potential weaknesses, one relating to the probability of successful implementation of the project and the other relating to the probability of achieving the desired impact. A successful project results from an appropriate combination of project design, support infrastructure and governmental policies. While these are recognized in most project papers, individual project designs must assume that any weaknesses in the collateral elements of support infrastructure and/or policy identified during the design process will be rectified. For example, if there is a signficiant problem with the availability of fertilizer in the project area, as a result of distribution problems or basic inadequacies of supply, the project documents may identify this as the problem which, if uncorrected, would adversely affect project success, but would then proceed on the basis of the assumption that the problem would be corrected. To the extent that this assumption is not valid, the anticipated results of the project would not occur.

On the impact side, investment in individual projects puts an emphasis on the direct beneficiaries within the limited area covered by the project and considers the larger community only in relatively general terms. Outputs usually are specified in terms of production increases, changes in employment potential and in on-farm and/or family incomes, within the project area. Secondary benefits and costs for a greater area may be estimated, but usually are not evaluated with much emphasis. Yet these may be very significant, especially with respect to those in the lower economic levels, as suggested earlier in the discussion of rainfed vs. irrigation development emphasis.

An investment strategy that focuses on area development projects has the potential for minimizing the disadvantages of the direct project approach, but has its own problems. A few examples of area development programs exist in the region. the Bicol Development Program in the Philippines, the Muda Agricultural Development Authority (MADA) in Malaysia and the Mahaweli Development Project in Sri Lanka are major examples.

These types of developments suggest a very extended investment time horizon, a complex set of activities, major problems in implementation, significant requirements for close interaction between the lender agency and the host country government agencies and the ability, on the part of the government and the lender to modify the development plans as experience is gained. These requirements for flexibility and continuity are not characteristic of most investment activities and must be recognized and accommodated from the outset.

Even with an area approach the difficulties associated with the individual project emphasis may not be overcome. For example, in the Mahaweli Development Project, agroclimatic and soil classifications suggest appropriate areas for the production of rice and for upland crops of various types. Notwithstanding this knowledge, the farmers, in response to the economic incentives produced by national policies toward rice and crops such as chiles, produce rice on lands much more suitable for upland crops. Project response is to try to provide structural capability to limit water deliveries at the individual farm level (approximately 4 hectares), a very expensive investment with a questionable probbility of success. Even though the project is regional (even national) in scope, and even though it has broad development objectives, it has encountered and not been able to resolve the same type of difficulty more typically encountered with the more narrowly defined and more geographically imited irrigation projects.

Hardware vs. Software

Broadly speaking, irrigation systems are composed of two types of components: the physical infrastructure (hardware) and the management (software); elements of the management component include the development of operational plans and the capability to modify them; an operational structure that provides for appropriate information collection handling, analysis and decision making; a system for performance monitoring; programs for training of system personnel and the farmer-irrigators; the development and utilization of appropriate farmer organizations, etc.

Usually within any one project, the development costs associated with the physical infrastructure are much larger than those related to the development of management capability. (This is not always the case, especially for small projects. Even in the larger projects, it is probable that the need for investment in the management component is underestimated.) Thus, from the standpoint of the lending agency, it is easier to invest a specified sum of money in the physical works of the project, or in those projects which have a proportionally greater amount of physical infrastructure (e.g., storage-type projects). From the project paper stage to final accounting, the entire process in dealing with the hardware is much simpler than the corresponding process for the software.

Experience in the region shows recent growth and concern for the software elements of irrigation projects, reflected in greater emphasis on the training of irrigation department staff, on the development of farmer irrigation associations and on the articulation of the activities of these associations with the irrigation agency operations. In dollar terms, this emphasis is a small proportion of the total irrigation investment in the region. Thus, an investment strategy that emphasizes software will place greater demands on lender agency staff time -- for project development, for implementation and for monitoring, for many of the same reasons indicated for a strategy that emphasizes small projects. These demands are both in terms of the customary accountability activities associated with project investment and in terms of technical expertise. Since the recognition of the major importance of the software components, and of the difficulties resulting from their inadequate consideration is relatively recent, there is a very limited corps of expertise available to deal with these aspects. This

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limitation exists within the major lending and donor agencies, and within the consulting community at large. Thus, an emphasis on the software components requires significant professional development on the part of all concerned.

In addition, given the current state of knowledge, there must be recognition that trial and error will be an integral part of all programs focused in this area.

Main System vs. On-Farm

Irrigation systems extend from the capture of the basic water supply to its utilization on the farm. Historically, government developed systems were first conceived as hydrologic-hydraulic systems, emphasizing the movement of the water in the primary canal system. More recently, the agricultural utility of the water has become an essential component of system design and operation. In a limited number of cases at the present time there is recognition of the varied roles of the farmer and user and of the need to recognize and to utilize farmer knowledge and skills.

In many projects, the systems are considered in two parts: the main system and the "on-farm" portion. On-farm frequently means "beyond the turnout" or that portion of the system that exists beyond the point at which the water is under the nominal control of the governmental authority. Thus, it frequently includes a significant proportion of the project distribution system and may include part of the conveyance system. In addition, it includes all those activities which actually occur on the agricultural holdings.

Within the region, governmental responsibilities for these two parts of the irrigation systems may be assigned to different agencies; a department of public works frequently has responsibility for the main system and a department of agriculture has responsibility for the on-farm portion. The latter may have opertional responsibilities, as in the case of Agrarian Services in Sri Lanka, for minor irrigation or be primarily involved in the complementary activities, such as providing credit and/or other production inputs and in the provision of the services associated with agricultural extension.

Obviously, the two portions of irrigation systems must be integrated for a successful project. However, the activities, agencies involved and expertise required may be considered separately and, in projects of significant size or in program terms, there can

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be an investment strategy that emphasizes one or the other. Typically, the World Bank has emphasized the main system, though there are some projects that have dealt with the on-farm phase (e.g., the extension of Mogha improvements initiated by the Colorado State University project in Pakistan). A significant proportion of the Asian Development Bank projects have emphasized the on-farm components, with a relatively heavy emphasis on the institution of rotational irrigation and farmer irrigation associations.

Early vs. Late

Irrigation projects come to fruition over time and with different types of inputs provided as the projects evolve. Many of the projects become productive much later than planned (even in the Western United States there is an expression that "it is the third farmer who makes a go of an irrigation farm") and the later inputs frequently were not anticipated in the original plans.

Investing in the early stages of project development permits the lender agency to have maximum input into critical decisions about scope, type, clientele, objectives, etc. In addition, visability and identification with the project are more complete when there is an early association. At the same time, however, uncertainties are at their greatest and the time to productive utilization the longest.

Investment in the later stages of project development has fewer opportunities for influencing the major decisions, but may have more opportunities for relatively rapid demonstrable response. For example, early involvement with the Chao Phya project in Thailand, either in the Bhumiphol Dam or in the construction of the primary canal system, showed relatively low irrigation benefit-cost ratios. Subsequent investment in the Sirikit Dam and in the extension of the secondary and tertiary canal system, with a resultant increase in dry season utilization, has at least partially captured the results of that earlier investment and this is reflected in relatively high benefits. In this case, however, it would not be possible to shift development emphasis from the relatively more prosperous Cental Plain farmers to the poor Northeast, or to make other significant changes that might be desired.

The stage of investment also influences the type and amount of required expertise, with the broadest range required for early involvement. At the same time, however, because later involvement frequently is associated with lower unit costs, there may be proportionally more staff involvement per dollar invested.

Easy vs. Difficult

Projects vary in their difficulty, though the full extent of any project's difficulty rarely is known at the outset. Project size, complexity, physical feasibility, political impact and data uncertainties are among the many elements that suggest whether a project will be relatively easy or relatively difficult to implement successfully.

Projects vary in their potential payoff. While not a one-to-one correlation, frequently the higher potentials are associated with the riskier projects. Thus, a lending agency often is faced with a choice of investing in relatively sure projects with low or modest anticipated outputs, or of supporting projects of more uncertain outcome, but whose potential impact is relatively large.

Lending agencies which require that repayment come from the project itself will tend toward the easier, more certain projects. Those which require repayment from the country, and not necessarily from the project, may be more venturesome, but if their charter is primarily economic will still emphasize the projects with more certain economic outputs. Lending and donor agencies with broader objectives have a wider option.

The Evolutionary Context of Irrigation Development

The issues, as presented in the preceding sections, do not explicitly consider the implications of the development alternatives within the context of a country's or region's stage of irrigation development. This omission should not be construed as evidence of a lack of importance assigned to this factor, but only a result of the attempt to present as sharply as possible the extremes of available choices.

It would be a mistake, however, not to comment upon what may be two of the most important factors affecting the appropriateness of a particular development strategy.

It can be argued that the evolutionary pattern of irrigation development generally precedes from rainfed agriculture to irrigation supplemental to the wet season in those areas where the water supply can be developed and utilized easily. As the cultivated rainfed area expands to less desirable areas, the area of supplemental irrigation expands with more difficut supplies developed and with more conveyance and distribution infrastructure constructed. Some dry season capability becomes available and is utilized on the most accessible areas. As the pressure on the land increases, there is an intensification of utilization of the supplemental irrigation and greater emphasis on the development of dry season capability through storage type systems and/or groundwater. In each stage of this development, there is a balance between the forces -- economic and social -- which act to encourage the expansion and intensification of irrigation and those which act to resist its development. Increasing land prices, higher product prices, increased population pressure and the need for more land efficient techniques of production all act to encourage irrigation development. Increasing cost for water supply development and for physical infrastructure of irrigation, social concern for the concentration of governmental investment, the availability of undeveloped land and a lack of population pressure all act to limit irrigation development.

Programmed irrigation development assumes that this normal pattern of autonomous response to socio-economic forces can be superceded by an imposed pattern of development which either brings supplemental irrigation into areas not yet under significant land pressure, or more frequently, introduces dry season capability more rapidly than would otherwise occur. It is not obvious that this will result in the magnitude nor type of utilization typically anticipated in the project designs. In fact, there is at least some evidence to suggest that the availabiity of irrigation or of dry season capability dos not insure anticipated utilization and that the actual pattern of use more nearly approximates what might be expected in the evolutionary pattern of development. For example, there are a number of areas in Latin America where supplemental irrigation has been introduced, with variable levels of utilization. Similarly, dry season capability in the central plain of Thailand was not significantly utilized for 10 years, and even now, almost 15 years later, represents less than 50 percent of the wet season production.

To the extent this very brief analysis is valid there is an implication that programmed irrigation development must be accompanie by a very careful analysis of the stage of evolutionary devel ment, and a wide range of governmental policies and programs mus be adjusted before effective utilization of the irrigation investment could be reasonably expected.

Coupled with the evolutionary development of the irrigation sysems themselve, is the evolution of governmental attitudes or perceptions about the systems. Three stages of governmental view can be identified. In the early stages of governmental irrigation development, the systems are viewed as hydrologic-hydraulic systems. The emphasis is upon the water, its capture and conveyance. Typically, there is little understanding of the agricultural use of the water and the design, construction and operation of the systems are the responsibilities of an engineering based governmental organization. The second stage in governmental view of irrigation systems is when the agricultural utility of the water is recognized and information about soils, crops and other agronomic elements are incorporated into the design and operation of the systems. By contrast to the headwater down approach of the first stage, there is now a command area upward approach to the design. The third stage perspective recognizes that the farmer is an active participant in the utilization of irrigation capability and that farmer needs, as well as soil and crop needs, must be recognized in system design, construction and operation. It is my impression that Sri Lanka is just starting to move from the first to the second stage; the Philippines and Indonesia are just starting to move from the second to the third stage. It is my view that there is an underlying assumption inherent in the programs for irrigation development that the governmental policies and bureaucracies can be moved rapidly toward the third stage. It is not obvious that this can in fact happen, nor is it obvious that the irrigation bureaucracies can be moved from the first stage to the third without passing through the second for some significant period. Again, there are evidences that establishing the forms for farmer participation does not automatically result in the type of participation necessary for effective utilization of the system's capability. The agencies look upon farmer participation in much the same way that company unions were looked upon by the industrial sector in the United States during the early period of union organization. There is significant evidence to suggest that a lack of effective farmer participation in those systems where there is an intent to utilize irrigation water efficiently will result in significant problems and a relatively high probability of failure.

If the ideas proposed here are valid, then irrigation investment of a programmed character must either be very selective or must consider a much wider range of factors for inclusion in design considerations than is customary. It must be recognized that implementation and successful operation will be difficult and will require more flexibility than is currently considered necessary. Even with this more open view, the degree of "modernization" than can be instituted is open to question.

Conclusion

As indicated at the outset, this initial exposition of development and investment strategies is intended only to open the discussion about AID's future directions in investment in irrigation in Asia. This paper provides no answers, nor suggestions for what is appropriate. It is anticipated that the forthcoming field visits, coupled with the subsequent discussions with USAID field staff and other professionals and academics, will refine and amplify the choices, and ultimately will result in a statement of policy.

Table 1

Income Status of Irrigated Farms vs. Resettlement Farms in Nam Pong

Type of Farm	Paddy Ylds (Ton/ha)	Gross Income from Crops (Baht)	Annual Household Expenditure (Baht)
Irrigated	2.27	14,342	8,318
Resettlement	1.00	7,383	8,255

Source: Seutrong, Supachi, et al., 1979. Socio-Economis Studies, Bangkok. Nam Pong Environmental Management Research Project, Working Document Number 9. As cited in Johnson, S.H., 1979. Major Policy Issues in the Development of Irrigation in Thailand. Paper presented at the Annual Conference of the Agricultural Economic Society of Thailand.

Table 2

Thai Paddy Rice Production - North and Northeast
(Thousand Metric Tons)

Crop Year	Wet	Dry	Wet	Dry
1968/1969	2587	63	3190	2
1969/1970	3840	-	4580	-
1970/1971	4070	-	4920	-
1971/1972	3557	-	5434	-
1972/1973	2665	45	4189	9
1973/1974	3898	85	4610	24
1974/1975	3780	92	3773	22
1975/1976	4125	19	5321	5
1976/1977	3972	139	4671	15
1977/1978	3549	142	3538	18
1978/1979	4772	240	5261	65

Source: Thailand, Ministry of Agriculture and Cooperatives, Division of Agricultural Economics. As cited in Johnson, S.H., 1979, ibid.

Table 3

Thai Paddy Rice Production - Central
(Thousand Metric Tons)

Crop Year	Wet	Dry
1968/1969	3415	109
1969/1970	3926	-
1970/1971	3642	-
1971/1972	3850	-
1972/1973	3772	675
1973/1974	4531	864
1974/1975	3988	800
1975/1976	3657	983
1976/1977	3948	1144
1977/1978	4003	1338
1978/1979	4132	1927

Source: Thailand, Ministry of Agriculture and Cooperatives, Division of Agricultural Economics. As cited in Johnson, S.H., 1979, ibid.

APPENDIX B

THE WATER BALANCE FOR BANGLADESH*

by

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*This appendix is added for the purpose of illustrating a methodology and for providing background information that can be used in evaluating and comparing rainfed agricultural benefits with those from irrigation. Monthly probabilities of precipitation occurrence provide significant basic resource information. The use of daily rainfall records can be used to calculate 10 day and other short time period precipitation probabilities. These more detailed studies are strongly recommended as part of future agricultural development planning.

THE WATER BALANCE FOR BANGLADESH

by

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It is much easier to evaluate the potential of a given area or country for development when an inventory of the resources for development can be made available. Rainfall and climate can be quickly and easily evaluated as a resource.

Table 1 of the main report presents rainfall probabilities and the climate at five loctions. By using the data in Table 1 a regression equation was developed for estimating the 75 percent probability of precipitation occurrence, PD, in mm per month from mean monthly precipitation, PM. The equation can be written:

$$PD = -32 + 0.76 \times PM \qquad (1)$$

The coefficient of determination, R^2, is 94 percent.

Mean monthly values of precipitation for 33 locations in Bangladesh, including the five given in Table 1, are presented by Wernstedt.[1] From the mean amounts of precipitation, values of PD can be estimated from Equation 1.

The estimated values of potential evapotranspiration, ETP, given in Table 1, were used to prepare isolines of ETP for each month. These map values of ETP then made it possible to estimate the moisture availability index, MAI, for the remaining 28 locations (MAI = PD/ETP). MAI values estimated from Wernstedt's data were rounded so as to indicate a lower degree of precision than those from Table 1 of the main report. Values of MAI for the 33 locations are given in Table B-1.

Under "Symbol" (the last column of Table B-1) the value 6/4 indicates a rainy season of six months with excessive rainfall during four months. Excessive rainfall is defined as that for a month in which the MAI value exceeds 1.35.

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[1]Wernstedt, Frederick L. "World Climatic Data." Climatic Data Press, 1972, 522 p.

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At 17 of the 33 locations rainfall is excessive for three or more months. In all but two locations the rainy season is of six or more months duration.

Table B-1 clearly indicates that first priority needs to be assigned to water management as related to rainfed agriculture. Yields under irrigation for crops grown during the rainy season cannot be expected to differ significantly from those produced in areas where flood control, surface drainage and adequate use of fertilizers are generally well organized.

At 16 locations rainfall is favorable for a rainy season general crop and at 17 locations favorable for a rainfed rice crop. Based upon these considerations it seems logical that irrigation will be economically justifiable only in those locations and under such conditions that a dry season crop can be profitably produced. In the short run efforts to develop and finance the appropriate technology for managing and utilizing the excessive rainfall can be expected to provide greater returns on invested capital than will be possible from irrigation.

Equation 1 was derived from data for those months for which values of MAI were equal to or greater than 0.33. Lower rainfall amounts have little value for agricultural production and produce inconsistent relationships.

The MAI ratios presented in Table B-1 provide a convenient index for technology transfer with respect to practices of surface drainage, fertilization and selection of crops and varieties.

TABLE B-1. THE WATER BALANCE FOR BANGLADESH

Station	Lat.N	Long.E	Item	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Symbol
Barisal	22°42'	90°22'	PD	0	44	144	288	326	297	205	118	0	
			MAI	0	0.25	0.90	1.80	2.10	2.05	1.60	1.00	0	6/4
Barkal	22°42'	92°23'	PD	12	93	169	335	335	335	250	111	1	
				0.10	0.60	1.00	2.25	2.25	2.40	1.90	0.95	0	7/4
Bogra	24°51'	89°22'	PD	2	9	128	181	231	222	184	82	0	
			MAI	0.01	0.05	0.65	1.06	1.26	1.35	1.27	0.64	0	6/1
Brahman-baria	23°59'	91°07'	PD	21	75	183	250	200	192	143	101	0	
				0.10	0.45	1.05	1.55	1.20	1.20	1.00	0.80	0	7/1
Chandpur	22°08'	91°55'	PD	18	66	141	245	243	263	169	71	0	
				0.10	0.40	0.85	1.65	1.55	1.90	1.15	0.60	0	6/3
Chitta-gong	22°20'	91°50'	PD	12	45	152	381	406	387	224	129	1	
			MAI	0.08	0.28	0.91	2.55	2.66	2.75	1.69	1.09	0.01	6/4
Comilla	22°28'	91°10'	PD	8	88	208	332	275	285	224	140	0	
				0.05	0.60	1.25	2.15	1.80	1.95	1.70	1.15	0	7.4
Cox's Bazar	21°26'	91°59'	PD	0	29	190	553	677	561	305	177	16	
			MAI	0	0.20	1.15	3.80	4.50	4.00	2.35	1.50	0.15	6/5
Dacca	23°43'	90°25'	PD	15	68	155	235	214	232	152	60	0	
			MAI	0.10	0.40	0.85	1.40	1.25	1.35	1.00	0.45	0	7/1
Dinajpur	25°38'	88°38'	PD	0	4	110	231	264	236	196	72	0	
			MAI	0	0	55	1.30	1.40	1.40	1.35	0.60	0	6/2
Faridpur	23°36'	89°50'	PD	0	65	174	230	225	205	155	105	0	
			MAI	0	0.35	0.90	1.40	1.30	1.30	1.05	0.80	0	7/1
Habiganj	24°23'	91°25'	PD	44	141	266	357	255	260	206	105	0	
			MAI	0.30	0.90	1.50	2.25	1.50	1.60	1.50	0.85	0	7/5

TABLE B-1 Continued.

Station	Lat.N	Long.E	Item	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Symbol
Jamalpur	24°55'	89°56'	PD	0	35	165	260	234	239	207	74	0	
			MAI	0	0.15	0.85	1.55	1.35	1.45	1.45	0.55	0	6/3
Jessore	33°10'	89°13'	PD	4	31	100	185	247	196	145	66	0	
			MAI	0.02	0.16	0.52	1.13	1.56	1.34	1.12	0.54	0	6/1
Karimganj	24°52'	92°20'	PD	115	308	395	568	409	399	325	144	0	
			MAI	0.80	2.10	2.40	3.80	2.75	2.65	2.50	1.30	0	8/6
Khulna	22°48'	89°33'	PD	0	37	108	204	257	196	137	85	0	
			MAI	0	0.20	0.60	1.30	1.65	1.35	1.05	0.70	0	6/1
Madar-ipur	23°10'	90°12'	PD	13	55	142	219	219	210	139	62	0	
			MAI	0.10	0.30	0.80	1.35	1.35	1.40	1.00	0.50	0	6/1
Maijdi-court	22°52'	91°06'	PD	8	36	218	514	457	395	306	162	3	
			MAI	0.05	0.25	1.30	3.30	2.95	2.70	2.25	1.35	0.05	6/4
Mymen-singh	24°45'	90°24'	PD	0	71	206	312	253	276	237	118	0	
			MAI	0	0.40	1.10	1.90	1.45	1.70	1.60	0.90	0	7.4
Naogaon	24°47'	88°56'	PD	0	0	78	197	193	172	181	60	0	
			MAI	0	0	0.40	1.15	1.10	1.05	1.25	0.45	0	6/0
Narayan-ganj	23°37'	90°30'	PD	12	71	163	227	265	265	176	71	0	
			MAI	0.07	0.41	0.90	1.33	1.55	1.58	1.17	0.52	0	7/2
Nawab-gani	24°36'	88°17'	PD	0	0	60	157	183	169	120	38	0	
			MAI	0	0	0.30	0.90	1.00	1.00	0.85	0.30	0	4/0
Noakhali	22°51'	91°06'	PD	2	43	195	386	381	387	286	136	4	
			MAI	0	0.30	1.20	2.50	2.45	2.65	2.10	1.15	0.05	6/4
Pabna	24°00'	89°15'	PD	0	10	105	190	171	187	146	96	0	
			MAI	0	0.05	0.55	1.15	1.00	1.15	1.50	0.75	0	6/1

TABLE B-1 Continued.

Station	Lat.N	Long.E	Item	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Symbol
Putua-khali	22°21'	90°21'	PD	11	43	163	395	434	361	248	125	4	
			MAI	0.05	0.30	1.00	2.65	2.90	2.60	1.90	1.05	0.05	6/4
Rajshahi	24°22'	88°36'	PD	0	0	74	185	183	167	157	40	0	
			MAI	0	0	0.35	1.10	1.00	1.00	1.10	0.30	0	5/0
Ramgarh	22°59'	91°43'	PD	8	87	156	329	330	342	215	84	4	
			MAI	0.05	0.55	0.90	2.20	2.20	2.45	1.65	0.75	0.05	7/4
Rangpur	25°45'	89°15'	PD	0	32	198	362	295	232	200	95	0	
			MAI	0	0.15	1.00	2.10	1.65	1.35	1.40	0.80	0	6/3
Saidpur	25°47'	88°54'	PD	0	9	141	266	281	249	209	60	0	
			MAI	0	0.05	0.70	1.50	1.55	1.45	1.50	0.50	0	6/4
Satkhira	22°43'	89°06'	PD	0	18	111	192	239	207	144	82	0	
			MAI	0	0.10	0.65	1.25	1.55	1.45	1.10	0.70	0	6/2
Siraj-gunj	24°27'	89°43'	PD	0	34	147	218	205	212	149	81	0	
			MAI	0	0.15	0.75	1.30	1.20	1.30	1.00	0.60	0	6/0
Srimangal	24°19'	91°44'	PD	27	146	342	383	248	251	204	94	1	
			MAI	0.18	0.87	2.00	2.47	1.59	1.67	1.59	0.86	0.01	7/5
Thakur-gaon	26°02'	88°28'	PD	0	15	118	303	352	281	259	56	0	
			MAI	0	0.10	0.60	1.80	2.00	1.75	1.80	0.45	0	6/4