ENGINEERING ASPECTS OF IMPACT MONITORING IN HIGH PERFORMANCE SEDERHANA IRRIGATION SYSTEMS OF INDONESIA

Ramchand Oad

Water Management Synthesis Project
Colorado State University
Fort Collins, Colorado

[1982]

ENGINEERING ASPECTS OF IMPACT MONITORING IN HIGH PERFORMANCE SEDERHANA IRRIGATION SYSTEMS OF INDONESIA

Table of Contents

ENGINEERING ASPECTS OF IMPACT MONITORING

IN HIGH PERFORMANCE SEDERHANA IRRIGATION SYSTEMS OF INDONESIA

A. Purpose of the Paper

The High Performance Sederhana Irrigation Systems (HPSIS) project in Indonesia, is designed explicitly to learn about the various aspects of farmer participation in irrigation system management. It is hoped that farmers will learn to participate in the design, operation and maintenance of their irrigation systems. Indonesian government agencies and development assistance professionals will learn how to undertake similar improvement programs in other irrigation systems. The impact of farmer participation on the system performance is to be evaluated by collecting data using standard socio-economic research techniques. In addition to socio-economic data, some engineering, water-related parameters may also be effective measures of the impact of farmer participation.

The purpose of this paper is (1) to identify such engineering parameters and indicators of physical performance of the irrigation systems (2) to describe the methods for measuring these parameters, and (3) to identify Indonesian institutions and personnel who can collect data on these parameters.

B. Farmer Motivation, Organization, and Participation

The general operating assumption in HPSIS is that water user participation through water users' associations results in better water management. While I agree with this general hypothesis, I also believe that water user participation is not a completely independent variable, but is a function of a number of factors and combinations of factors. A brief discussion of the irrigated-agricultural setting in Indonesia will help identify some of the factors affecting farmers' participatory behavior.

One might, for the sake of argument, say that there are two fundamental means of motivating farmers to organize and participate in system management. First, one can organize farmers into social groups in which cultural norms motivate action through peer pressure. In the old, Indonesian subsistence economy, where most interaction revolved around nonmonetary exchange and face-to-face transactions, one could count on gotong-royong (indigenous shared labor) to undertake the management function.

However, in a transitional situation, such as in present-day Indonesia, where the economy is more market-oriented, economic incentives are important determinants of participatory behavior of farming communities. A second strategy for increasing farmer participation, is to provide positive incentives, like increased water availability and more equitable water distribution. Thus, farmer participation is related to physical parameters such as available water supply, need for irrigation water, and equity of water distribution as well as various social and economic factors.

The positive incentives of increased water availability and equity of distribution are particularly relevant in the irrigation systems of Indonesia because of two prevailing negative factors. First, system ownership of irrigation systems passes to the government and not the farmers upon completion of construction. Second, farmers are not compensated for the loss of land because of the construction of irrigation distribution channels.

C. Key Performance Indicators

Two key indicators for measuring the impact of farmer participation on system performance are:

1. water adequacy, and

2. equity of water distribution.

The following variables, when measured, can help quantify these performance indicators.

1. Water Adequacy

Water adequacy refers to available irrigation supplies in relation to the farmers' water needs for growing crops. The concept that relates water supplied to an irrigation unit and the need for water within that unit is termed relative water supply (RWS). Relative water supply indicates water scarcity, and the consequent participatory behavior of the farmer community.*

In irrigation systems with a low relative water supply, only a few of farmers can plant a dry-season crop. Management costs are high and the benefits are small and accrue to few farmers. In such systems, the incentive for farmer participation for proper irrigation systems management should be low.

In irrigation systems with a moderate relative water supply, farmers increase management inputs for an efficient and equitable use of irrigation water. Water is constrained but is still sufficient for most farmers to grow two paddy crops a year through better organization and water control. In such water-limited irrigation systems, farmer participation tends to be high and water users' associations have a better chance of success.

---

* For details on the concept of Relative Water Supply, the reader is referred to: Ramchand Oad. 1982. "Water Management and Relative Water Supply in Irrigation System of Indonesia." Unpublished Ph.D. Thesis, Cornell University, Ithaca.

Irrigation systems with high relative water supplies are usually characterized by mountainous topography, simple irrigation technology and socially cohesive farming communities. Social cohesion is high partly because the abundance of water supplies reduces the difficulties associated with internal decision-making. Water control occurs mostly through rules based on cultural norms and values of the communities. These rules and regulations are largely enforced through social sausion rather than by building elaborate physical control structures. The question of "building" water users' associations for "system development" under HPSIS in such indigenous communities needs to be investigated from a different perspective because the incentives for farmers to participate in such activities are few.

2. Equity of Water Distribution

Equitable water distribution is technically complex in the gravity flow irrigation systems. Figures 1, 2 and 3 show the layout of a traditional gravity flow irrigation system. Water enters the primary channel through an inlet from the water source (usually a river). From the primary channel, water flows into the secondary channels, and from these to the tertiary blocks (Figures 1 and 2). A tertiary block in turn is divided into a number of individual holdings, some of which do not border on the tertiary canal (Figure 3). Farms at the head (HE) of the tertiary canal receive more water than those at the tail (TE) (Figure 2). Some farms (such as FF in Figure 3) may receive little water, and since they do not border on the tertiary canal, water must flow over the other farmers' lands before it reaches them.

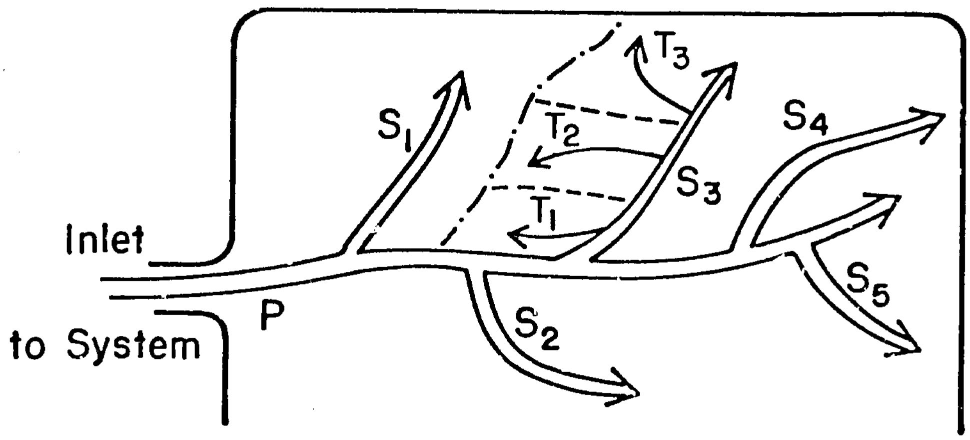

Figure 1. Irrigation system: layout of primary (P), secondary (S) and tertiary (T) canals.

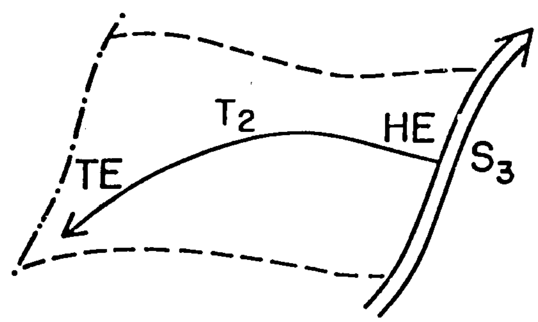

Figure 2. Farmers at head (HE) and tail end (TE) of tertiary T_2 block.

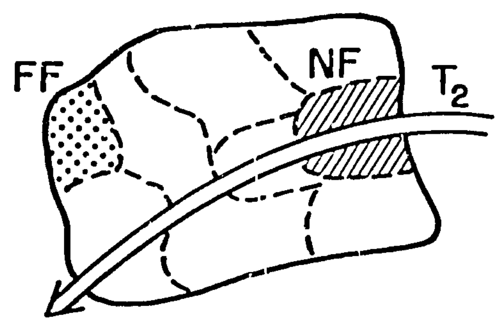

Figure 3. Landholdings near the tertiary (NF) and far from the tertiary T_2 (FF).

Source: Donald C. Taylor, "Agricultural Development Through Group Action to Improve the Distribution of Water in Asian Gravity-Flow Irrigation Systems." Teaching and Research Forum No. 1, ADC, Singapore, 1976, p. 2-3.

With such a system layout the potential for conflict is high. The system design does not permit flexibility in management decisions concerning crop diversification and staggering cultivation activities to reduce the peak demand for water. For equity and efficiency reasons, we see a growing interest in Sederhana and other irrigation projects which improve on-farm water distribution facilities.

D. Measurement of Performance Indicators

To monitor the impact of activities under HPSIS project, we need to evaluate adequacy and equity of water distribution at two levels. First, we should measure adequacy and equity of water distribution among various groups of farmers (kelompok). Second, we need to measure equity of water distribution within a group of farmers. Measurements of actual water supplies and relative water supplies can be used to monitor adequacy and equity of water distribution among various groups of farmers.

Direct evaluation of adequacy and equity within a group of farmers is a very laborious since it means measuring water deliveries to individual landholdings. Given manpower and time constraints, such detailed measurements will not be possible. A more feasible approach for evaluating adequacy and equity among individual farmers would be to document, by visual observation, the presence or absence of water in the paddies over the crop growing season. This research technique, called the paddy water status study, is a good substitute for measuring actual irrigation water supplies.*

---

* Leslie Small. "An Index to Evaluate the Effect of Water Shortage on the Yield of Wetland Rice". Mimeo, Department of Agricultural Economics, Rutgers University, New Brunswick. August 1981.

1. Relative Water Supply (RWS)

The variable RWS is defined, mathematically, as the ratio between water supplied to an irrigation unit and the need for water within that unit for growing crops.

$$RWS = \frac{\text{Rainfall + Irrigation}}{\text{(Evapotranspiration + Seepage and Percolation) Area}} = \frac{R + I}{(ET + SP)A}$$

The "irrigation unit" can be the whole irrigation system and/or a part of the system. To evaluate water adequacy and performance of an irrigation system as a whole, we need to measure RWS at the main canal level. To evaluate performance of a group of farmers (tertiary or quaternary *kelompoks*), we need to measure RWS at the tertiary or quaternary channel level. Measurement of the components of relative water supply includes the following.

Irrigation Water Deliveries--In each of the selected HPSIS sites, irrigation deliveries should be measured in the main canal and in at least three *kelompoks*. The site selected for flow measurement in the main canal should be close to the point of water diversion with steady, uniform flow. Since the flows in most of the HPSIS main canals are substantially high (around 600 lps), it is not possible to use portable cutthroat flumes or weirs. Effort should be made to use existing built-in measurement structures, if any. If there are no built-in measurement structures, one must establish current-meter gaging stations.

The site selected for a gaging station should be in a comparatively straight and hydraulically stable reach of the canal. It should not be subject to frequent changes in channel cross-section because of excessive erosion and sedimentation. It is desirable if the channel cross-section at the gaging station is lined. A lined cross-section requires less instrument calibration to establish depth-discharge relationships at the station. After the site is selected for gaging station, a flow rating curve is established based upon flow measurements by a current-meter. The rating curve is then used to determine the flow rate by measuring the depth of flow at the station.*

Simple, standard staff gages can be used to measure the depth of flow at the gaging stations. Staff gages may be either vertical or inclined. The inclined type, especially, must be carefully graduated and accurately placed to insure correct stage readings. Most permanent gages are enameled steel plates. A sample data form for recording the gage readings and the duration of flow is included in Appendix A.

At the tertiary and/or quaternary channel level, one should select at least two to three irrigation units. Some criteria for selecting the irrigation units are:

- The irrigation units should to represent head, middle, and tail of the irrigation system.
- The source of irrigation water for the irrigation units (one or two quaternary channels) should be clearly identifiable so that the flows can be measured.
- It should be possible to estimate the area of the irrigation units; the command area of the units may vary from 6-15 ha.

The quantity of irrigation water delivered to these units can be monitored by measuring water flows and the duration of flow. Portable cut-throat flumes or weirs can be used to measure the water flows. If weirs are used, efforts should be made to place them at the existing drop structures. Otherwise, they will not be popular with farmers because they back up water,

---

* For more details on Current-Meter Gaging Stations, reference should be made to: U.S. Dept. of Interior, Bureau of Reclamation. 1975. Water Measurement Manual. Water Resources Technical Publication, Denver.

particularly where the channel bed slopes are flat. Cutthroat flumes require less head loss, as compared to weirs, to pass the same discharge. Therefore, flumes often are more favored by farmers weirs.*

There are few important points worth repeating here. First, flumes should be installed in their channels with side cutoff walls (made of clay or concrete) at right angles to the flow axis of the flume, creating a square-edged entry. Standard cutthroat flume discharge tables are accurate only for this method of installation.

Second, for acceptable accuracy, the floor of the flume must be level after installation. Flumes will "settle" after being in operation for some time. Either "settling" or improper installation can cause a flume to tilt sideways (Figure 4), settle near the entrance section (Figure 5), or settle near the exit section (Figure 6). Settlement occurs most commonly near the exit section because of channel erosion immediately downstream of the flume caused by the jetting action of water. To guard against discrepancies in discharge measurement because of the settlement problems, flumes should be checked for levelness periodically throughout the data-collection period. A sample data form for recording flume data in the field is included as Appendix B.

Estimation of Water Need (Evapotranspiration and Deep Percolation)--A simple meteorological station, consisting of an evaporation pan and a standard rain gage, should be established at a representative location within each of the study sites. The evaporation pan should be a standard 4-feet class A pan

---

* For proper selection and installation of cutthroat flumes, refer to the following publications: (a) G.V. Skogerboe, R.S. Bennet, and Wynn R. Walker. 1973. Selection and Installation of Cutthroat Flumes for Measuring Irrigation Water. Colorado State University Experiment Station Technical Bulletin 120, Fort Collins. (b) Direktorat Perluasan Areal Pertanian. 1981. Cutthroat Flume. Direktorat Jenderal Tanaman Pangan, Jakarta.

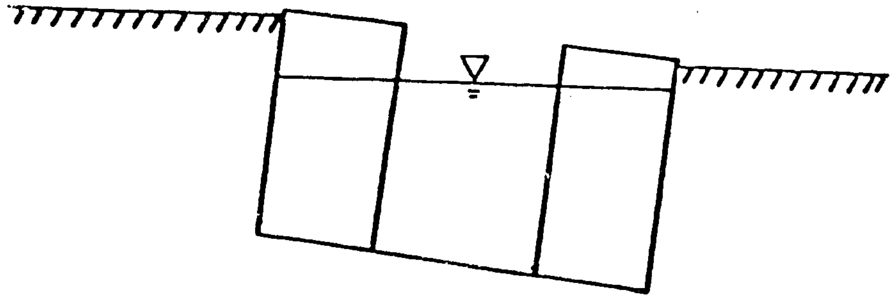

Figure 4. Cutthroat flume tilted sideways.

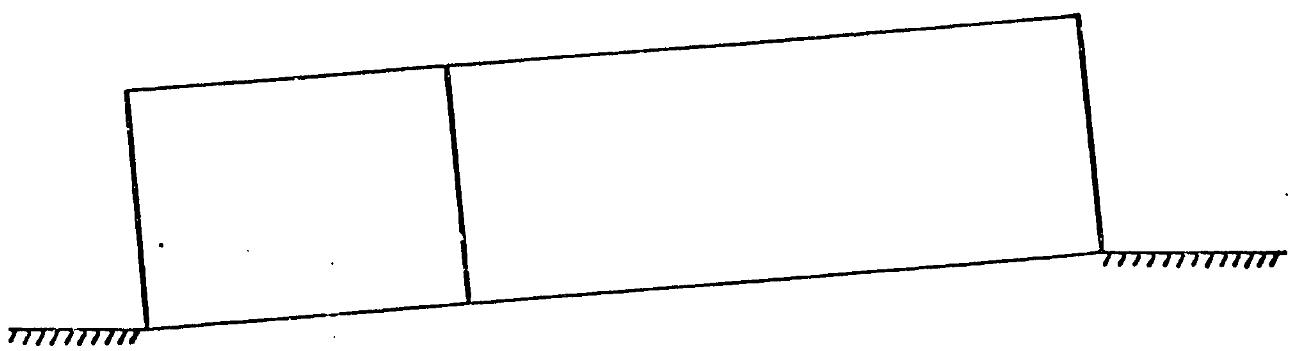

Figure 5. Settlement of Cutthroat flume at inlet section.

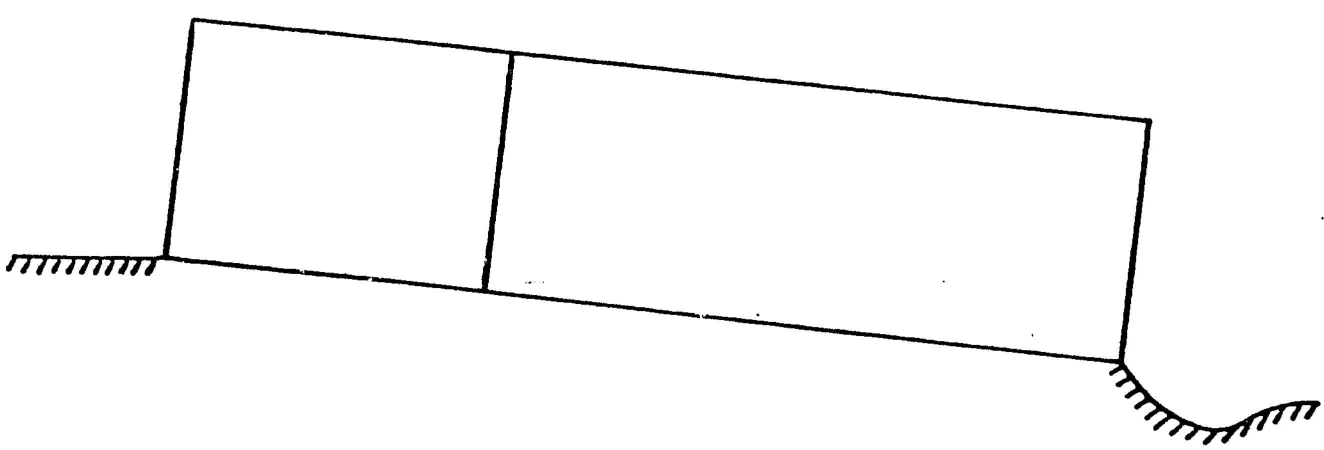

Figure 6. Settlement of Cutthroat flume at exit section.

constructed of 15 gauge G.I. sheet and painted with aluminum paint. The pan should be mounted on an open wooden stand so that the water surface in the pan is approximately 50 cm above the ground.

Water surface elevation in the pan can be measured by means of a half-meter stick with a small-bore glass tube attached to its face. The meter stick/glass assembly should be attached to a pair of support brackets welded to the inside of the pan at a 5:1 slope. A 1-mm change in actual water level in the pan is thus displayed as a 5-mm change in the inclined gauge reading. To dampen the oscillations in the glass tube due to wave action in the pan, a short length of plastic tubing, closed at the end but having a number of small perforations in its sides, should be fitted over the submerged portion of the glass tube.

The water surface elevation in the pan should be read twice a day, once in the morning and once in the evening (for example, 6AM and 6 PM). The difference in elevation minus rainfall, if any, gives the evaporation. Evapotranspiration is then calculated from the evaporation values by means of standard formulae.* However, it is well known that for the purpose of field research, evapotranspiration for rice grown in flooded paddies is approximately the same as evaporation. The evaporation pan data can be recorded according to the format shown in Appendix C.

The second component of water demand is seepage and percolation (SP) stemming from the practice of submerging paddy lands with water. SP is measured in the field by treating the paddy as a large bottomless tank and measuring the subsidence of the water surface in the paddy on days when there

---

* Direktorat Perluasan Areal Pertanian. 1981. Evaporation Pan Class A, Sloping Gage, Paddy and Well Observation. Direktorat Jenderal Tanaman Pangan, Jakarta. February. p. 1-3.

is no surface inflow or outflow. Subtracting the pan evaporation rate from this value gives SP.

Measuring the change in paddy water surface elevation poses two major problems. The first and more tractable of these is the actual measurement of the water surface elevation. This can be accomplished by driving into the paddy soil an H-shaped wooden frame having a pair of brackets designed to take an inclined gauge.* The inclined gauge is similar to the one described for use in measuring evaporation pan water levels. In this instance, however, the stick should be a full meter long.

The second problem is being aware of any inflows or outflows which might occur during the period between sloping gauge readings. This is probably the most difficult problem facing what is otherwise a reasonably accurate technique for determining seepage and percolation rates in the field. One way of insuring awareness of any inflows and outflows is to position topless cans at the spots where paddy bunds are typically opened to permit inflows and outflows. The cans are then inspected each time a water level reading is made on the sloping gauge. A full or partially full can indicates flow during the previous time period; an empty can indicates no flow. Following each inspection, the cans should be emptied. Presence or absence of water in the cans should be noted on the data forms along with the actual readings for water surface elevation.

A more accurate but difficult alternative may be to ask the farmer managing the sample paddy about any scheduled irrigation inflows and outflows. The farmer responses should be promptly recorded in the data forms. A sample form for recording seepage and percolation measurements is included as Appendix D.

---

* Direktorat Perluasan Areal Pertanian, op.cit.

2. Paddy Water Status (PWS)

To evaluate equity of water distribution within a group of farmers, we need to document the status of water in a few selected paddies. These sample paddies can be selected at the head, middle, and tail of the channel supplying irrigation water to the group. The paddy water status observation is simply an indication of whether, on a given day, there was standing water in the paddy or the soil was dry. A sample form for recording PWS data is included in Appendix E.

For purposes of analysis, a paddy is assigned a water shortage factor (WSF) of 0 for the day when there is standing water, and a WSF of 1 when there is no standing water. Summation of the water shortage factors, from the transplanting date to 15 days before harvest gives the water stress index (WSI) for that paddy. Mathematically, this can be expressed as:

$$WSI = \sum_{0}^{15\ DBH} WSF$$

The practice of counting the water shortage factors up to 15 days before harvest (DBH) is based on the assumption that the paddies are intentionally drained and left to dry for 15 days so as to allow harvesting. The period can be changed based on the actual practices of the farmers in different HPSIS sites.

Water stress index is thus a good substitute for knowing the actual availability of irrigation water to various farmers within a group. Knowing the WSI values for the sample paddies, we can perform standard statistical tests to evaluate equity of water supply and how it changes as a result of farmer participation in irrigation systems.*

E. Implementation of the Engineering Data Collection Activity

1. Personnel and Institutional Linkages

The engineering data collection activity should be set up as a part of the Impact Monitoring (Benchmark Data Collection) study. That study has been designed as an interdisciplinary examination of changes taking place is HPSIS sites. To realize full benefits of the engineering data, however, that data should be managed and analyzed along with the socio-economic data that will be collected by the regional universities. It is imperative that the overall coordination and data analysis responsibility should lie with one institution and one group of persons at the institution.

The unification of data management and analysis does not necessarily mean that engineering and socio-economic data need to be collected by the same people. In fact, collection of the different types of data may logically be assigned according to institutional strengths. For example, the socio-economic data can be collected by the regional universities and the engineering data by others. One possible approach is for the Ministry of Agriculture (MOA) to take responsibility for collecting the engineering data. The Land Development Directorate (Direktorat Perluasan Areal Pertanian, Jakarta) of MOA has some persons who have research experience in water-related measurements. These individuals should be able to select appropriate measurement sites in the HPSIS systems, and train workers to operate and read the instruments, record the data, and send the data forms to the appropriate places.

---

* Ramchand Oad and Gilbert Levine. 1981. The Spatial and Temporal Distribution of Irrigation Water in Indonesian Irrigation Systems. Paper presented at the 1981 Winter Meeting of American Society of Agricultural Engineers, Chicago.

The Land Development Directorate has said it can make arrangements with the provincial and kabupaten (district) MOA offices to install the instruments and then supervise data collection. In order to begin collecting engineering data effectively, discussions between the Central and the Provincial MOA offices in a few of the HPSIS provinces should begin as soon as possible. Initial selection of provinces and sites should be made in part based on the feasibility of working with the MOA offices (at provincial or kabupaten levels) and the willingness and capacity of the local offices to participate in this activity.

In addition to the organizational requirements mentioned above, a certain amount of equipment is needed to carry out the water measurements, including:

Cutthroat Flumes	:	20 x 90 cm
Weirs	:	V-notch or rectangular
Sloping Gages		
Staff Gages		
Wooden posts for fixing staff gages.		

Most of the provincial MOA offices already have cutthroat flumes, weirs, and sloping gages, all of which can be used for the research activity under HPSIS. Therefore, the following instruments need to be acquired:

Cutthroat Flumes	:	30 x 90 cm
Staff Gages		
Wooden Posts		
Current Meter.		

To minimize the costs of buying new equipment for measuring water, attempts should be made to locate existing equipment that may not be in current use. Both MOA and Public Works should be able to help in this regard.

2. Manpower

The Ministry of Agriculture is conducting a Training Workshop for selected staff members from various provinces during June 20-25, 1983. This is an excellent opportunity to introduce the staff members to the objectives of HPSIS and the engineering data collection activity. By adding a few more days, if necessary, the staff members should receive basic training in the use of various water-measuring instruments and supervision of data collection.

Some proposed topics and related activities are:

- The inderdisciplinary approach for analyzing irrigation systems.
- The HPSIS activity is primarily designed as an exercise to learn about the impact of farmer participation on system performance.
- Describe interdisciplinary approach for analyzing irrigation systems.
- Engineering measurements: Describe principles of water measurement, and their purpose and use in monitoring socio-economic behavior of farmers.
- Instruments and Methods: Demonstrate installation of various water-measuring instruments like flumes, weirs, evaporation pan and sloping gage.
- Data collection and supervision in field.

For daily reading of the instruments, we will need to hire instrument readers will be needed on a full-time basis. At least one instrument reader will be necessary for one study site. These instrument readers will be responsible for proper maintenance, daily reading of the instruments, and proper recording of the data. An estimation of their work load would be as follows:

- Recording staff gage readings in the main canal at least twice a day; once in the morning and once in the evening.
- Recording evaporation pan data, twice a day.
- Recording rainfall, if any.

- Recording irrigation water deliveries through about 6 cutthroat flumes/weirs.
- Reading about 10 sloping gages for measuring seepage and percolation.
- Recording paddy water status in sample paddies.

The instrument readers can be of STM, SPMA or SMA educational level. Important criteria for their employment should be their ability to live in the villages, basic knowledge about irrigated-agriculture, and respect farmers as equals. These professionals should be employed through MOA provincial offices so that there is a definite line of accountability.

A suitable person from the Water Management Section of Provincial MOA should be in charge of the instrument readers' activities. The officer in charge should visit the research sites at least twice a month. During these visits he should check the instruments to see whether they are properly installed, check the data recording forms with the instrument reader, and discuss any other concerns of the instrument reader.

If MOA does take managerial responsibility for water measurements, it should ensure that someone at the MOA/Pusat level will be the overall supervisor. This position is very important, because the individual will have to make sure that instruments have been correctly installed, that they are being correctly managed by the Diperta staff, and that data are being collected correctly and sent to the analysts. This supervisor will have to work closely with the provincial data collectors, the regional universities, and the central team that does the overall analysis for the Impact Monitoring study.

The collection and analysis of engineering data is one of three research activities that need to be coordinated to bring about a coherent description and analysis of HPSIS. The Impact Monitoring data collection and

Process Documentation will be conducted by three different institutions and different groups of professionals. Analysis of the socio-economic and engineering data will have to be interdisciplinary in nature. The importance of coordination and professional exchanges of information and views among the various research groups cannot be overemphasized. It is, therefore, especially important that the research activities be effectively managed at the Center and that the central and field personnel be aware of each other's needs and constraints.

3. Estimated Expenses

Following is a broad first estimation of yearly expenses for the engineering data collection activity.

(a) Salaries and Travel

Salary for Instrument Readers at Rp. 50,000/month, one person for each study site

50,000 x 12 x 15 sites	=	9.0 M Rupiah

Transportation within the study sites (bikes)

50,000 x 15	=	0.75 M Rupiah

Supervision by Kabupaten MOA (at least one visit per site per month)

20,000 x 15 x 12	=	3.6 M Rupiah

Supervision by Provincial MOA office

25,000 x 8 x 12	=	2.4 M Rupiah

Data collection and Coordination at the Central MOA Office

	=	3.0 M Rupiah

Travel by personnel from Central Coordinating office in Jakarta to HPSIS sites

150,000 x 15 x 3	=	6.75 M Rupiah
Sub-Total (a)	=	25.5 M Rupiah

(b) Equipment

Small Current Meter, approx. US $1600	=	1.6 M Rupiah
Staff gages, rain gages and any additional flumes		3.0 M Rupiah
Miscellaneous instruments	=	3.0 M Rupiah
Sub-Total (b)	=	7.6 M Rupiah
Total of (a) and (b)	=	33.1 M Rupiah
Approximate conversion*	=	33,000 US $
Contingencies at 15%	=	5,000 US $
Total	=	38,000 US $

(c) Additional

At least one small desk-type computer will be necessary for data storage and analysis.

Apple III with Printer and necessary software = 6,000 US $

(d) External Consultants

1. Irrigation Water Management Specialist: for the duration of the project (about 2 years).

* $1 US = 950 Rp.

Appendix A: Data Form for Current-meter Gaging Station

Name of the Irrigation System:
Site of the Gaging Station: (Main or secondary canal)

Date	Time of Reading	Gage Reading (cm)	Duration of Flow (hr/day)	Discharge (lps)*	Volume of water (m^3/day)**

*Discharge corresponding to a gage reading will be calculated from the stage-discharge relationship established by a current-meter.

**Daily volume of water passed = Discharge * Duration of flow.

Appendix B: Discharge Measurement by Cutthroat Flume

Name of the Irrigation System:
Site of the Flume Installation:
Flume Dimensions: (20 x 90 cm or 30 x 90 cm, etc.)

Date	Time of Reading	Upstream Scale Reading Ha (cm)	Downstream Scale Reasing Hb (cm)	$S = \frac{Hb}{Ha}$	Duration of Flow (hr)	Discharge (lps)

Appendix C: Evaporation Pan Data

Name of Irrigation System:
Place of Location:
Type of Pan: (Whether Class A or other...)

Date	Time of Reading	Reading on Inclined Gage (cm)	Difference in Readings on Inclined Gage (cm)	Evaporation* (mm)
	6 A.M.			
	6 P.M.			

*For a 1:5 inclined gage, Evaporation (mm) = Difference in readings on inclined gage (cm) x 2.

Appendix D: Seepage and Percolation Data

Name of the Irrigation System:
Name of the <u>kelompok</u>:
Identification of the paddy where instrument is located:

Date	Time of Reading	Reading on the inclined gage (cm)	Height of water in Paddy[1] (m)	Difference in Ht. of water (mm)	Daily Evaporation (mm)	Daily Se page & Percolat (mm)
	6 AM					
	6 PM					

* Height of water in paddy (mm) = Reading on the inclined gage in cms. x 2.

Appendix E: Paddy Water Status

Name of the Irrigation System:
Name of the tertiary canal:
Name of the *kelompok*:

Sample Paddy Number	Days of the week or month						
	1	2	3	4	5	6	7
1	F	F	E	E	F	F	F
2	E	F	F	F	E	E	E
3							

F = Paddy has standing water.

E = No standing water or the soil is dry.