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PILOT PROJECT FOR FARMER-MANAGED IRRIGATE AGRICULTURE UNDER THE LEFT BANK OUTFALL DRAIN (LBOD), STAGE-I PROJECT

MONITORING AND EVALUATION OF IRRIGATION AND DRAINAGE FACILITIES FOR PILOT DISTRIBUTARIES IN SINDH PROVINCE, PAKISTAN

Volume One
Objectives, Stakeholders, Approach and Methodology

Interim Report

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FOREWORD

The three pilot distributaries, one each in the districts of Nawabshah, Sanghar and Mirpurkhas under the Left Bank Outfall Drain (LBOD) Stage I Project, was selected in late November 1995 after two-and-a-half months of reconnaissance surveys of 27 potential sites. During 1996 the farmers served by each watercourse command area (total of 80) were organized into Water Users Associations (WUAs). By mid-December 1996, all of the WUAs on each pilot distributary were federated into a Water Users Federation (WUF).

In early January 1997, a major emphasis was placed on maintenance activities for each distributary during canal closure in January-February. The planning for a monitoring and evaluation (M&E) program was done in early 1997 and then the appropriate facilities were installed during March 1997. The field data collection program was underway by 1 April 1997. Farmers were trained to read the piezometers with three having been installed in each watercourse command area.

After one year of field data collection, each pilot distributary command area will undergo "surface water hydrology" and " groundwater hydrology" analyses using mean monthly groundwater recharge as the dependent parameter. This will provide valuable insight regarding the combined management of both the irrigation and drainage facilities.

This report is an Interim Report that has been prepared primarily because the initial contract for two-and-a-half years expired on 31 December 1997. A Full Report will be published after three years of field data collection.

This Monitoring and Evaluation Program was designed by Dr. M. S. Shafique. Then, it was implemented by the Field Station Staff for each pilot distributary under the supervision of Dr. Bakhshal Lashari. The Field Staff have played a major role in preparing the report for each of the distributaries. Dr. M. Akhtar Bhatti should be credited for all of the time that he spent at each of the three Field Stations helping the field staff in preparing their report, which was undertaken to facilitate their professional development.

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1. INTRODUCTION

1.1. RATIONALE

The International Irrigation Management Institute (IIMI) is implementing three pilot projects on Farmer-Managed Irrigated Agriculture since July 26, 1995, in collaboration with the Agricultural Engineering and Water Management Directorate of the Department of Agriculture, Government of Sindh. The broad purpose of these pilot projects is two fold:

(i) to test the viability of farmers managing parts of irrigation systems, more specifically distributary/minor canals, so that more efficient and equitable distribution of water can be achieved; and

(ii) to make recommendations related to future extensions on the basis of results from the pilot projects.

The three pilot projects selected from the LBOD project area, one from each of the three districts of Nawabshah, Sanghar and Mirpurkhas, are to assist farmers in undertaking Operation and Maintenance (O&M) of the combined irrigation and drainage facilities. This would be achieved through assisting farmers to organize themselves into Water Users Associations (WUAs) at the watercourse level and into a Water Users Federation (WUF) at the distributary/minor canal level. The experience gained from these pilot command areas would also help in identifying and developing an appropriate institutional process, along with legal requirements, for effective implementation on a broader scale for all of the distributaries in a canal command area.

1.2. CONCEPT

The broad concept underlying these pilot projects is that the WUAs and WUFs would eventually be accountable for the water received at the head of the distributary/minor canal, responsible for water distribution among the members, collection of water charges, along with operation and maintenance (O&M) of the combined irrigation and drainage facilities in their distributary/minor command area.

They may also adapt revised procedures on water allocation, distribution and water charges collection with the agreement of their members. WUFs would be expected to enter into agreements with their own members and the Sindh Irrigation and Drainage Authority (SIDA) for implementation of the concept.

A Joint Management Agreement (JMA) is being negotiated between the Sindh Irrigation & Drainage Authority (SIDA) and the WUFs. Under the agreement, each of the three WUFs would undertake operation of the irrigation and drainage system, collection of water charges, improve water management and drainage practices, and carry out other related activities, including the maintenance of irrigation and drainage facilities in the pilot area.

1.3. MONITORING & EVALUATION

The basic concept behind the pilot project, as outlined above, is to involve farmers in operation & maintenance of the irrigation and drainage facilities. This has never been successfully accomplished in the country. Therefore, there is a strong need and justification for monitoring and evaluating (M&E) the process employed and its impact, so that changes can be made to make the process more useful for all concerned and to the country. The expectations are that M&E would help in at least two major ways:

(i) allow the SIDA and WUFs to adjust their activities to the needs and constrains of the irrigation and drainage management turnover projects; and

(ii) provide policy-makers and planners with up-to-date information about the consequences of appropriate management changes for planning new projects that could be extended to other distributary command areas.

The Monitoring & Evaluation (M&E) activities were initiated in the project area during December 1996. The main objective was to document the on-going situation before the management turnover of the distributary canal to WUFs. As a first step, the stakeholders were identified and the objectives, approach and methodology were developed for data collection to monitor the combined irrigation and drainage facilities in the pilot areas. Following this, actual field data collection started in April 1997. This is an interim report that summarizes the M&E activities carried out so far.

2. MONITORING AND EVALUATION APPROACH

2.1. DEFINITION OF MONITORING & EVALUATION

Murphy and Spray (1982) have defined the monitoring and evaluation of agricultural change as follows: a system of data gathering, analysis and feedback of farm information during the life of a project. This definition of M&E can be adopted with some modifications to address the real intentions of the pilot testing of projects designed to bring a dramatic change in the management of selected irrigation and drainage systems.

As the testing of the Irrigation Management Turnover (IMT) model is intended for a larger scale application, the effort will have to be focused on the following three phases: (i) before; (ii) during; and (iii) after the organization of farmers for managing the selected irrigation and drainage system. In this context, the monitoring and evaluation can be stated as a system of data gathering, analysis and feedback of the irrigation and drainage management activities at different stages of an IMT pilot project (i.e. before, during and after the turnover of a selected pilot distributary/minor command area).

2.2. MONITORING & EVALUATION OF IRRIGATION MANAGEMENT TURNOVER

In specific terms, the monitoring and evaluation of pilot projects designed for irrigation management turnover at the distributary / minor canal level can be accomplished by undertaking the following four steps:

(a) data gathering in line with an agreed set of objectives for different users and agencies, which are directly or indirectly involved, or have a stake in the irrigation management turnover;

(b) determining of results and findings based on the data gathered;

(c) interpretation of the results and findings to determine whether the actual and planned outcomes match and, if not, then ascertain the reasons for unexpected deviations; and

(d) feedback aimed at providing up-to-date information to the managers, planners, policy makers and other stakeholders for taking corrective measures if required.

2.3. SCOPE OF M&E ACTIVITIES

IIMI's interest in developing and implementing M&E activities is associated with the research objectives aimed at establishing sustainable organizations of farmers to operate and maintain distributary/minor canals. This includes the combined management of irrigation and drainage facilities.

However, to establish proper linkages for future cooperation and extend the usefulness of IIMI's M&E activities, other relevant parties (stake holders) will be first identified and then their possible objectives and roles will be outlined. As a follow up of this exercise, these objectives, roles and modalities, as suggested in this first interim report of the M&E activities, will be refined and re-defined after holding deliberations with the concerned parties and experts in the field of monitoring and evaluation.

2.4. POTENTIAL STAKEHOLDERS FOR M&E

Considering the importance of these pilot projects, the following agencies and groups have been identified as stakeholders who would be interested in knowing the findings resulting from the M&E activities.

2.4.1. Farmers' Organizations (FOs)

The consequences of the pilot project are likely to impact this group of FO stakeholders most as compared with any other party. As farmers' livelihoods and future prosperity will be greatly influenced by the introduction of this new mode of irrigation and drainage management, their objectives are expected to be tied with the testing of the pilot project, productivity of irrigated agriculture, and increased agricultural productivity or profitability. So, there would likely be at least the following objectives of the FOs:

(a) pilot test the concepts of IMT by taking full management responsibility of irrigation and drainage related activities at the distributary/minor canal;

(b) improve the productivity of irrigated agriculture by ensuring reliable, equitable, and adequate access to all inputs within the projects; and

(c) reduce the delivery charges of water and other inputs by involving farmers for shouldering and sharing management responsibility for irrigation and drainage activities within the command areas of the selected distributary/minor canals.

2.4.2. International Irrigation Management Institute (IIMI)

Obviously, IIMI's immediate objective is to fulfill its consultancy obligations which are mostly related to the organization of farmers at the distributary/minor canal levels to manage irrigation and drainage activities. As IIMI is basically a research organization, its acceptance of the IMT related extension-oriented assignment in Sindh has partly happened because it offers an excellent opportunity for the organization to generate in-depth information about an issue which has both national and global interest and importance. In this stated context, the objectives of the Institute can be listed as:

(a) developing and pilot testing appropriate approaches to establish farmers' organizations at the distributary/minor canal levels for managing irrigation and drainage activities;

(b) documenting the opted IMT process, the resulting charges, and consequences of changes as they occur;

(c) identifying reasons for the positive and negative consequences of irrigation management changes implemented on a pilot basis; and

(d) assessing the sustainability of the pilot projects designed for farmer-managed irrigated agriculture.

2.4.3. Irrigation and Power Department of Sindh (PID) / Sindh Irrigation and Drainage Authority (SIDA)

The Provincial Irrigation Department (PID) in Sindh is another agency which should have a keen interest in the pilot testing of the IMT model at the distributary/minor canals. Because of the confusion that results from mis-information and mis-communication, an impression prevails as if the Department is going to be the losing party in this irrigation management turnover. Contrary to this impression, the only government agency which stands to gain most from the proposed farmers' participation is the PID. With the adjustments required for the Department to be effective under the existing financial difficulties and changes in irrigated agriculture, which have occurred during the past hundred years or so, the sharing of part of the irrigation management responsibility by the farmers becomes a gain for the Department.

In any case, the pilot testing of the IMT project has a direct impact on the Department. Obviously, the management of the PID should have objectives associated with the new mode of irrigation management, like the ones listed below:

(a) to turnover irrigation management responsibilities to the FOs from the head of the distributary/minor canals downwards;

(b) to find out if the water supplies under the management of FOs become relatively more reliable, equitable and adequate; and

(c) to identify and define its (PID's or SIDA's) new role at the level of the distributary/minor canals under the pilot projects.

2.4.4. Provincial Agriculture Department (PAD)

2.4.4.1 On Farm Water Management (OFWM)

In a setting where funding for watercourse improvements/lining is expected to decrease soon, the entities which have to accept new roles and opportunities are the provincial divisions for on-farm water management. Therefore, the on-going pilot projects are the convenient happenings for the OFWM agencies to define their roles and contributions for an effective farmer-managed irrigated agriculture. So, the possible objectives for the OFWM agencies are listed below:

(a) to organize farmers for the management of the irrigation and drainage system at the level of distributary/minor canals;

(b) to define an expanded role and modes of contributing under the IMT pilot projects; and

(c) to provide OFWM related services at the distributary/minor canal level.

2.4.4.2 Monitoring and Evaluation Cell of PAD

Irrigation management turnover is a new experience in the province and the M&E Cell would be keenly interested to gather information about the test results. In this context, possible objectives of the cell could be as follows:

(a) to monitor whether the IMT pilot projects deliver results as planned, if not, document reasons for deviations; and

(b) to analyze data and report results and findings to managers, planners and policy makers.

2.4.5. Planning and Development Department (P&D)

This provincial department has the main responsibility for processing new projects. In line with the basic function of the department, more so when new ideas such as IMT are pilot tested, there would be great interest for the following:

(a) to receive information about the results, positive as well as negative, of the pilot projects; and

(b) to make use of up-to-date information received from the IMT pilot projects in planning new projects and proposing adjustments to avoid earlier mistakes.

2.4.6. Water and Power Development Authority (WAPDA)

In the Province of Sindh, WAPDA has been entrusted with the responsibility concerning the operation and maintenance of the drainage system under the Left Bank Outfall Drain Stage 1 Project (LBOD). Considering this new function, the possible interest of WAPDA in the IMT pilot project could be described as to find out if the operation and maintenance performance of the drainage system improves within the IMT pilot projects.

2.4.7. Government of Pakistan (GOP)

At a time when financial predicaments abound and the productivity of most irrigated crops are on the decline, the Government of Pakistan (GoP) is willing to try all reasonable solutions to avert potential disaster and revitalize the economy of the country.

In this context, the pilot testing of the irrigation management turnover at the distributary/minor canal level is one solution that is being considered by the GoP. So, the Government would achieve the following in introducing the IMT concepts:

(a) create favorable conditions for farmers, PIDs, PADs and other relevant stakeholders for improving the productivity of the irrigated subsector by transferring irrigation management to farmers at the distributary/minor canal level;

(b) assess if the pilot projects will improve its net revenues from the irrigation subsector; and

(c) have feedback about the positive and negative consequences of the IMT pilot projects.

2.4.8. Commercial Banks

The commercial institutions, like banks, will have an interest in this new experiment to establish the financial capability of individual farmers. If such institutions have to support farmers in the pilot projects by providing loans, the objective of these entities would be to know about the timely payback of loans under the new IMT pilot projects.

2.4.9. Private Agricultural Input Enterprises

At present, there are many private enterprises which provide inputs such as seeds, fertilizers, pesticides, etc. to the farmers. These transactions usually take place on an individual basis. However, under the new management mode, these interactions may happen between private companies and farmers' organizations. So, the objectives for the private providers of inputs become: to determine new modes of transaction, bargaining power and the financial ability of farmers' organizations in the pilot projects.

2.4.10. Non-Governmental Organizations (NGOs)

The NGOs are getting actively involved in supporting and implementing such projects which enhance farmers' participation aimed at operation and maintenance of irrigation and drainage at the level of distributary/minor canals. This interest is also directed towards addressing environmental problems by organizing the farmers. In this context, the possible objectives are listed below:

(a) to have up-to-date information about the pilot IMT projects for quick dissemination of the findings to relevant management, planning and policy making circles;

(b) to lobby for strengthening and supporting the aspects of the IMT pilot projects which are delivering favorable results; and

(c) to help in making quick adjustments if the results of pilot projects are not in line with those intended.

2.4.11. Donor Community

The pilot IMT projects are mostly funded and supported by different donors. It is, therefore, natural for the donor's community to know how the pilot projects are expected to enhance the performance of the irrigated subsector. Moreover, the additional funding of such projects will depend on the positive results of the various experiments. The objectives of the stakeholders in the donor community could then be stated as follows:

(a) to monitor progress and receive information about the outcome of the pilot projects;

(b) to fund new projects in line with the findings of the ongoing IMT projects; and

(c) to learn if loans advanced for IMT projects can be paid back within an agreed time-frame.

2.4.12. Others

The other most important stakeholders from the irrigated sector are the organized groups of influential farmers. At present, these groups have some misunderstanding about the IMT pilot projects. They are afraid that the ongoing irrigation management transfer to the farmers' organization at the distributary/minor canal levels may create chaotic situations in the irrigated sector. For positive, as well as negative reasons, this group will be keenly interested to know about the consequences of the pilot IMT projects. In the stated context, the objectives of these groups may include:

(a) monitoring the pilot IMT projects to determine if results are being delivered as planned;
(b) establishing if the farmers organizations are capable of managing the combined irrigation and drainage system on a sustainable basis; and
(c) reporting to all concerned organizations the support needed for the FOs after the irrigation management transfer.

2.5. DATA NEEDS OF DIFFERENT STAKEHOLDERS

Section 2.4 has outlined objectives of different stakeholders in testing the irrigation management turnover at the distributary / minor canal level. In order to determine if their respective objectives are being achieved under the new management arrangement(s), each party will be interested to collect up-to-date field data. This information will be analyzed, using different indicators of performance, to determine if the level of accomplishment(s) is satisfactory, or not. The type of data collection will be refined / redefined after thorough discussion with concerned parties in the near future. Table 1 provides a preliminary list of data to be collected.

Table 2.1. Possible Data Requirements of Different Stakeholders.

Sr.#	Data Required	Departments / Organizations of Sindh or Working in Sindh											
		WUAs	IIMI	PID	OFWM & M&E Cell	P&D	WAPDA	GOP	Banks	Priv. Input Co.	NGOs	Donors	Others Groups
1	Water Users Organizations at levels: WC, Minors & Distributary	*	*		*								
2	Identification of reasons for the positive and negative results of the Irrigation Management Turnover(IMT).	*	*	*	*	*		*			*	*	*
3	Documentation the opted IMT process.		*			*							
4	Testing the idea of IMT management responsibility of irrigated agriculture at distributary/minor.	*	*	*	*	*		*			*	*	*
5	To improve productivity of irrigated agriculture by ensuring reliable, equitable and adequate access to water.	*	*	*	*	*		*			*	*	*
7	To reduce irrigation water and other inputs delivery charges by involving beneficiaries at the part of irrigation and drainage sub-system.	*	*	*	*	*	*	*			*	*	*
8	Turnover irrigation management responsibilities from the head of distributary / minor to downward.	*	*	*	*	*		*			*	*	*
9	Find out if the water supply under FOs is reliable, equitable and adequate.	*	*	*	*	*		*			*	*	*
10	New role for the irrigation department from the head of distributary / minor under the IMT pilot projects.		*	*		*		*			*	*	*
11	Organize farmers at the distributary/minor level.	*	*	*	*	*		*	*	*	*	*	*
12	New role of OFWM under the IMT pilot project.	*	*		*	*		*			*	*	*
13	Provide OFWM related services at distributary/ minor level under the new set up.	*	*		*	*		*			*	*	*
14	Monitor if the IMT pilot projects delivering results as per planned if not document reasons for deviations.		*		*	*					*	*	*
15	Analyze data collected and report results to planners and policy makers about the of the IMT Pilot Projects.		*		*	*							
16	Determine the pilot projects performed as planned and document deviations and unexpected results.		*		*	*							
17	Plan new projects and institutional arrangements with up-to-date information from the on-going project.		*			*							
18	Up-to-date information about the pilot IMT projects for quick dissemination of findings to relevant planning and policy-making circles.		*		*	*					*		*
19	Lobbying for strengthening and supporting the aspects of the IMT pilot projects which are delivering favorable results.										*		*
20	Help in making quick adjustments if the pilot project results are not in line with those intended.												
21	Monitor progress and receive information regarding pilot testing.		*		*	*					*	*	
22	Funding new projects in line with the findings of the on-going projects.							*				*	
23	Find out if loans advanced for the IMT projects can be paid back within agreed time frame work.					*		*				*	
24	Create the favorable conditions for PIDs, PADs and other relevant agencies for improving the productivity of the irrigated sub-sector.					*		*					
24	Assess pilot activities improvements in its net revenue from the irrigated sub-sectors.					*		*					
25	To have feedback about the IMT pilot projects for their strong and weak aspects.	*	*	*	*	*		*			*	*	*
26	Find out if the operation & maintenance performance of drainage improves with the IMT projects.												
27	See if IMT project increases the financial ability of the farmers to buy more inputs.		*			*				*	*		
28	Timely payback of the loans.								*			*	

2.6. PROPOSED ACTIONS FOR IIMI

As can be seen from Table 2.1, IIMI's data needs are the maximum. The reason for this maximum information requirement lies in the fact that IIMI is seeking to accomplish two types of objectives: (a) to fulfill its consultancy obligations; and (b) to produce research results relevant to IMT tests. Also, IIMI should shoulder part of the M&E responsibility of FOs during an initial period, which has to be completely transferred to the target groups by the end of its consultancy.

The methodology for the monitoring and evaluation plan of IIMI and FOs will be based on the following steps: (i) developing appropriate indicators in line with the set objectives for IIMI and FOs; (ii) data collection to make use of the indicators developed; (iii) interpretation of findings based on the derived indicators; and (iv) feedback to other stakeholders of the information generated based on the interpretation of the results.

2.7. INDICATORS FOR M&E OF IMT

2.7.1. IIMI's Indicators for M & E

The following is the list of some indicators which can be considered for the monitoring and evaluation of the IMT pilot project. These indicators are listed under each objective for both of the organizations.

Objective No. 1

To develop and pilot test appropriate approach(es) to organize farmers' organizations / water users associations at the distributary / minor canal level for managing selected irrigation and drainage related activities.

Corresponding Indicators:

* Number of FOs established; and
* Success and failure ratio of approaches applied for organizing farmers.

Objective No. 2

To document the opted IMT process, the resulting changes and their consequences as they occur.

Corresponding Indicators:

* Number of progress reports produced;
* Number of process documentation reports produced;
* Number of survey reports; and
* Number of research reports.

Objective No. 3

To identify reasons for the positive and negative consequences of irrigation management changes implemented on a pilot basis.

Corresponding Indicators:

* Ratio of distributary average daily flow rate before and after IMT;
* Ratio of average daily minor flow rate before and after IMT;
* Ratio of average daily outlet flow rate before and after IMT;
* Parameter of reliability before and after IMT;
* Parameter of equity of water distribution before and after IMT;
* Parameter of adequacy of water distribution before and after IMT;
* Ratio of maintenance exercises of distributary before and after IMT;
* Ratio of maintenance exercises of minors before and after IMT;
* Ratio of maintenance exercises of watercourses before & after IMT;
* Ratio of maintenance exercises of drains before and after IMT; and
* Ground water levels.

Objective No. 4

To assess the sustainability of the pilot projects designed for farmers-managed irrigated agriculture.

Corresponding Indicators:

* Ratio of collection of land and water charges before and after IMT;
* Number of joint ventures for input procurement before and after IMT;
* Funds collected for the irrigation and drainage management at the level of distributary / minor canals before and after IMT;
* Recovery rate of input-loans before and after IMT
* Ratio of net revenues / acre before and after IMT;
* Level of equity achieved in water distribution; and
* Degree to which FO can apply sanctions against defaulters.

2.7.2. FOs Indicators for M & E

Objective No. 1

To pilot test the idea of IMT by taking full management responsibility of irrigation and drainage related activities at the distributary / minor canals.

Corresponding Indicators:

* Number of farmers' meetings to operate distributary / minor canals / drains;
* Number of farmers' meetings to maintain distributary / minor canal / drains ;
* Collection rate of funds for managing the IMT project;
* Number of IMT related disputes resolved;
* Number of canal breaches before and after IMT, and
* Number of drain breaches before and after IMT.

Objective No. 2

To improve the productivity of irrigated agriculture by ensuring reliable, equitable and adequate access to all inputs within the pilot projects.

Corresponding Indicators:

* Ratio of crop yields before and after IMT;
* Ratio of net revenues before and after IMT;
* Number of no-supply days at the tail of the distributary / minor during the rabi and kharif seasons;
* Number of partial-supply days at the tail of the distributary / minors during the rabi and kharif seasons; and
* Ratio of water levels at selected points along the distributary / minor before and after IMT.

Objective No. 3

To reduce delivery charges of water and other inputs by involving farmers for shouldering and sharing the management responsibility for irrigation and drainage activities within the command areas of selected distributary / minor canals.

Corresponding Indicators:

* Ratio of cost reduction in water charges after IMT;
* Ratio of cost reduction in non-water inputs after IMT; and
* Ratio of loan availability after IMT.

2.8. RESOURCES REQUIRED

The M&E plan will be carried out within the financial and human resources available under IIMI's consultancy project. However, if other stakeholders wish to join in, separate arrangements can to be worked out.

3. DATA COLLECTION FOR MONITORING AND EVALUATION

In order to undertake the Monitoring & Evaluation (E&M) of the pilot projects, the required data gathering was begun from April 1997. The focus remained on capturing the actual irrigation and drainage conditions and practices in the pilot project areas (phase I covering "before the IMT" situation). The data collection activities are described below.

3.1. DISCHARGE MEASUREMENTS

In agriculture, proper management of water can only be done through improved irrigation management practices. The ideal situation is that water should be measured at each and every delivery point in the system, including the water delivered to each farmer. For an accurate, efficient and regular measurement program, it is appropriate to develop discharge ratings through calibrating existing irrigation structures on the system. In fact, any type of structure that constricts the flow (i.e. causing a backwater effect and subcritical flow upstream) can be field calibrated for discharge measurement. Calibration of delivery control structures (head regulators, outlets, etc.) is usually done for measuring the discharge by developing discharge rating equations. This ensures the actual amount of water passing through these structures is known by reading water levels. In most irrigation and drainage systems, there are numerous structures that can be calibrated for flow measurements. Measurements of water levels with reference to benchmarks established on the upstream and downstream sides of the constriction are subtracted from the benchmark elevations to determine the upstream and downstream flow depths. Using these flow depths in the developed rating equation, the discharge can be computed. Once a structure is calibrated and an appropriate discharge rating equation is developed, there is no need for using a water measuring device again and again.

Two most commonly used instruments for discharge measurements in open channels are current meters, while for tertiary watercourses, pygmy current meters are used for lined channels and Cutthroat Flumes are used for earthen channels. A current meter measures the velocity of flowing water and is widely used. Its accuracy depends upon its proper operation, adjustment and maintenance. On the other hand, a properly calibrated Cutthroat Flume can measure flow directly. The current meter can be used in all open channels, whereas, the Cutthroat Flume is used in the unlined tertiary channels.

3.1.1. Irrigation Facilities

The irrigation facilities to be handed over to FOs is composed of the secondary canal (distributary channel) and tertiary channels (watercourses). Regular observations and discharge measurements at key locations within the distributary / minor command areas, as well as on watercourses, provide necessary insights on the performance of the irrigation facilities.

3.1.1.1. Flow at Head Regulators

Head Regulators of the selected channels are gated structures. They are rectangular in shape and have adjustable gates. When the upstream water level is higher than the top of the opening of these gated structures, they are functioning hydraulically as orifices. For a rectangular gate having a gate opening, G_0, and a gate width, W, the free-flow and submerged-flow discharge will be computed using the rating equations based on field calibration, assuming that the dimensionless velocity head coefficient is unity. The velocity head coefficient approaches unity as the approach velocity to the orifice decreases to zero.

3.1.1.2. Seepage in Head, Middle and Tail of Distributary Channel

The distributary / minor length will be divided into more or less three equal sections; namely, head, middle and tail reaches. The discharge at the head regulator will be used for the head reach. This was obtained by putting the observed values of gate opening, upstream water depth and downstream water depth (where applicable) in the appropriate rating equation. The discharge of the middle and tail reaches was measured at the beginning of each reach by current metering. All of the three measurements were undertaken on the same day. This exercise was done once every month.

3.1.1.3. Flow in Outlets (Moghas)

The physical condition of the outlets were examined as to whether the outlet is functional or dysfunctional, the crest was tampered or in good condition, and the sides are damaged or in proper shape. The type of outlet was identified and the dimensions, such as width and height, were measured. The flow condition was observed to establish whether free flow or submerged flow occurs. The following criteria were used.

(a) If the water flows through the structure and does not touch its crown, the structure is termed as an Open Flume. If the water level is above the crown on the upstream side, the structure is termed as an Orifice.

(b) If water flows through an orifice and the orifice is not dipped into the water at the downstream side (the downstream water surface is below the crown of the orifice), and the water jet is visible, the flow is termed as free orifice flow.

(c) If the water flows through an orifice and the orifice is dipped into the water at the downstream side (the downstream water surface is above the crown of the orifice), the flow is termed as submerged orifice flow.

(d) In case of open flumes, discharge rating graphs were provided which can determine the flow condition by knowing the ratio of h_d, and h_u (i.e. h_d/h_u) which is the submergence, S.

According to the flow condition and the type of outlet, the equations will be identified to determine the discharge coefficient, C_d. In applying the appropriate equation for the determination of the discharge coefficient, the exponent will be kept constant. To verify the accuracy of the discharge coefficient, several measurements will be taken and the discharge coefficients will be computed. In case of a tampered outlet, the K which is equal to the cross-sectional area multiplied by C_d will be corrected to represent the actual conditions. Actual discharge measurements will be taken using Cutthroat Flumes in unlined watercourses and current meters in lined watercourses. After establishment of the benchmarks, which is the vertical distance above the crest, measuring tapes will be used for taking water level readings. The tape readings will be subtracted from the benchmark elevations for calculating the upsteam water depth h_u, and the downstream water depth h_d.

3.1.1.4. Round-the-Clock Discharge Measurements at Head Regulator and in Sample Watercourses

Discharge measurements were undertaken at the head regulator as well as at the sample watercourses. The sample watercourses were selected based on the following criteria:

(i) They represented head, middle and tail portions of the distributary; and
(ii) They also represented flow conditions having more than design, equal to design, and below the design discharges.

The measurements were continued for seven days to determine the fluctuations in the irrigation water supplies.

3.1.2. Drainage Facilities

There are different types of drainage facilities installed in the command area of the pilot distributaries. These are surface drainage, subsurface drainage (tile drainage) and vertical drainage (tubewells). A methodology to monitor each system was developed.

3.1.2.1. Surface Drainage

The network of surface drains in the pilot project areas were identified. The inflow (source) and outflow (disposal) points of the drainage effluent were located. The term "source" indicates that the inflow of the drainage effluent from the upstream command area enters into the pilot command area and the term "disposal" indicates that the outflow of the drainage effluent leaving from the pilot area (inflow at source subtracted from outflow at disposal, gives the net drainage effluent from the command area). The junction points of surface drains were also located. The discharge of the drainage effluent was measured at both points by current metering once every month.

3.1.2.2. Sub-Surface Drainage (Tile Drainage)

As the sump houses collect the drainage effluent from the tile drainage (lateral and collector drains) in the pilot areas, an inventory of all the sump houses in the pilot area was made. A set of parameters were selected to determine the performance of the system and its impact on resolving the drainage problem. Data on these parameters was collected every month on the same date so that the monthly performance of the system could be established.

Also, a comparison with the design efficiency was made. Discharges at the source and disposal points of the disposal channels were measured to determine the performance of the channels.

3.1.2.3. Vertical Drainage

3.1.2.3.1. Tubewell Irrigation

A tubewell can be an additional source of irrigation water, where they are available. The operational hours were calculated using the electric meter reading each month. The tubewell discharge was estimated by applying the weir equation or trajectory method. Knowing the hours of operation and discharge of a tubewell, its contribution can be estimated.

3.1.2.3.2. Operation of Saline Tubewells

Saline tubewells in the pilot areas were identified as to their locations. Data collection parameters were selected to address the working efficiency of the tubewells and their impact. The data on these parameters were collected every month on the same date so that their performance on a monthly basis could be ascertained and comparisons made with the design efficiency. The benefit of these tubewells were discussed with the water users organizations. The discharges were measured at the source and disposal points of the disposal channels to evaluate the performance of the disposal channels.

3.2. GROUNDWATER LEVELS

To investigate the ground water fluctuations, three piezometers were installed in each watercourse representing the head, middle and tail portions. All of the piezometers were referenced to sea level. The readings of water levels were taken on a monthly basis.

3.3. QUALITY OF GROUNDWATER

Water samples were taken on a monthly basis for water quality analysis. Total Dissolved Solids (TDS) was monitored. The detailed analysis of water quality such as TDS, Sodium Adsorption Ratio (SAR) and Exchangeable Sodium Percentage (ESP) were made on a quarterly basis.

3.5. VEGETATIVE GROWTH SURVEY

Vegetation, if present in the irrigation or drainage system, is a major source for disturbing the flow of water. Once the hydraulics of the system is disturbed, the whole system will not operate properly. A vegetative growth survey was conducted on a quarterly basis.

3.6. SURFACE DRAIN WEAK POINTS

The "weak points". refers to the banks, berms and inspection path that are not maintained as per design specifications. Furthermore, it is defined as the portion of the system which could not withstand the design pressure. The walk-thru and motor bike surveys were conducted to determine these points and show their location. By doing this activity, the maintenance of the system could be addressed properly and possible suggestions could be made.

3.7. DISPOSAL OF IRRIGATION WATER INTO DRAINAGE SYSTEM

A common practice by farmers is that when the irrigation water is not needed, they dispose of water into the drainage system, if it is available nearby their fields. A procedure will be developed to establish whether this practice is being done or not.

4. PERFORMANCE INDICATORS FOR MONITORING & EVALUATION OF IRRIGATION AND DRAINAGE FACILITIES

Performance may be considered as the degree to which a system achieves its objectives. Key indicators are proposed for Monitoring & Evaluation of irrigation and drainage performance under the current situation (i.e. before the IMT) in the pilot areas. These will be expanded in the future as the IMT is being implemented.

4.1. OLD DESIGN WATER DUTY VERSUS ACTUAL NORMALIZED WATER DUTY

In canal water allocation, the old (1930s) design water duty is normally fixed for each 1000 acres of cultivated command area (CCA). Therefore, the design discharge of the distributary and outlets differ normally in proportion to their CCA. For easy understanding of graphical presentations, as well as identifying the differences in the design water allocations, all of the discharge data in this report is normalized back to the base of cusecs per 1000 acres of CCA. Therefore, whether it is specifically mentioned or not, the discharges (old design and actual) are compared on the basis of cusecs per 1000 acres of CCA. Comparison on the basis of normalized water duties will be considered as one of the performance indicators.

4.2. RELIABILITY

Provision of reliable and equitable irrigation water supplies to the secondary and tertiary units should be a primary operational objective of an irrigation delivery system. This objective was sometimes neglected in the past when emphasis was placed on farmer participation and on-farm water management, without considering possible mismanagement upstream in the system (Plusquellec, 1988). Flows that vary in an unpredictable manner greatly complicate the performance and evaluation of farm irrigations. Farm irrigators cannot know whether on-farm or off-farm factors are responsible for an application system's performance. As the sources of flow variation are identified, structural and operational measures can be developed to reduce or eliminate them. The result will be more positive control of canal systems and delivery of known, uniform flows of water to the farm.

The term "Reliability" of water distribution indicates the ability of a system to deliver the expected water discharge in a given time span. In the context of Pakistan, a system that achieves steady state is considered reliable. However, if farmers are informed in advance about periods of canal closures or reduced flows, and those events occur as scheduled, the resulting water distribution will still be termed as reliable in spite of water deliveries being variable. A system which achieves almost steady state is considered reliable. The reliability is defined as:

$$P_D = \frac{I}{R}\sum_{R} CV_T\left(\frac{Q_d}{Q_r}\right)$$

In this case CV_T (Q_d /Q_r) is the temporal coefficient of variation of the ratio over discrete locations in a region R, in a time span T. Molden and Gates (1990) have given the performance standard for the assessment of "Reliability".

Table 4.1. Reliability Performance Levels.

INDICATOR	PERFORMANCE LEVELS		
	Good	Fair	Poor
Reliability	0.00-0.10	0.11-0.20	> 0.20

This will be used to determine the level of "Reliability" in supplying of irrigation water with time at the head regulator, as well as at outlets.

4.3. EQUITY

The equity is concerned with the uniformity of spatial distribution of water, which is usually influenced by a number of potential factors. Some of the factors which cause a non-uniform water distribution along a parent channel (e,g., distributary or minor canal) may include (Asrar-ul-Haq,1995):(i) deferred maintenance; (ii) sedimentation; (iii) excessive withdrawals by outlets; and (iv) illegal water abstractions.

The distribution of water among the outlets is the main concern at the secondary and tertiary levels. This distribution can be evaluated using the term "Equity". The term "Equity" indicates the ability of a system to deliver uniform water distribution over space (Mohammed, 1987) and is defined as:

$$P_E = \frac{I}{T}\sum_{T} CV_R\left(\frac{Q_d}{Q_r}\right)$$

When CV_r (Q_d / Q_r) is the spetial coefficient of variation of Q_d / Q_r. Molden and Gates (1990) have given the performance classes for the assessment of "Equity".

Table 4.2. Equity Performance Levels.

Indicator	Performance Levels		
	Good	Fair	Poor
Equity	0.00-0.10	0.11-0.25	> 0.25

This will be used to determine the performance level of equity in water distribution among the outlets.

4.4. WATERTABLE DEPTH

Generally, monitoring of watertable levels indicates whether the groundwater level is rising or falling. When the ground water is constantly rising, the situation would be deteriorating, resulting in a waterlogging situation. Table 4.3 gives the range of watertable depth and its effect on drainage.

Table 4.3 Water Table Depth and Rating as Used by WAPDA.

Watertable Depth (feet)	Rating
0 - 3	Very poorly drained
3 - 6	Poorly drained
6 - 10	Moderately drained
> 10	Well drained

4.5. WATER QUALITY

The water quality is an important criterium for the sodication hazard of the soil. Total Dissolved Solids (TDS), Sodium Adsorption Ratio (SAR) and Exchangeable Sodium Percentage (ESP) were monitored regularly. To evaluate the suitability of irrigation water, the criteria listed in Table 4.4 will be used.

Table 4.4. Irrigation Water Quality Criteria as Used by WAPDA.

Indicator	Useable	Marginal	Hazardous
PPM	0 - 960	960 - 1728	> 1728
EC (dS/m)	0 - 1.5	1.5 - 2.7	> 2.7
RSC (meq/l)	0 - 2.5	2.5 - 5.0	> 5
SAR (mmol/l)^(1/2)	0 - 10	10 - 18	> 18

4.6. EFFICIENCY OF TUBEWELLS

The operating hours of tubewells were estimated from the energy consumption through taking meter readings. These readings were divided by the actual days of the month to obtain the daily energy consumption and average operating hours in a day. A comparison was made between the design efficiency and actual efficiency. Energy consumption per hour is also determined.

Example Calculations

Date	**Reading of Running Hours**
27.2.97	2690.61
27.3.97	2780.38
Net Hours	2780.38 - 2690.61 = 89.77
Hours/Day =	Net Hours / No. of Days.
	89.77 / 28 = 3.20 hours/day.

Now, the operational efficiency of the tubewell is calculated by the following relation.

$$\text{Operational Efficiency (\%)} = \frac{\text{Actual running hours/Day}}{\text{Designed running hours/Day}} \times 100$$

Example

$$\text{Operational Efficiency (\%)} = \frac{3.20}{16} \times 100 = 20\%$$

It should be noted that the design hours recommended for a saline tubewell are 16 hours per day (Source: LBOD Consultants).

4.7. PERFORMANCE OF DRAINS

The drainage facilities installed in the command area of the Dhoro Naro Minor consist of surface drainage, surface drainage (tile drainage) and vertical drainage (tubewells). Their efficiency depends largely on the performance of the network of surface drains passing through the command area. Their inflow (source) and ouflow (disposal) points for conveying drainage effluent were mentioned. The term "source" indicates that the inflow of the drainage effluent from the upstream enters into the minor command area and the term "disposal" indicates that the outflow of the drainage effluent leaving from the command area. Discharges at the source and disposal points of the drains located in the command area were measured to determine the performance of the surface drains.

4.8. STATUS OF VEGETATION

Vegetation, if present in the irrigation or drainage system, is a major source for disturbing the flow of water. The vegetation was classified as follows:

Class I	Clean (vegetation less than 1 foot high)
Class II	Very little (Vegetation between 1-2 feet high)
Class III	Little (Vegetation between 2-3 feet high)
Class IV	Moderate (Vegetation between 3-5 feet high)
Class V	Thick (Vegetation greater than 5 feet in height)

4.9. SURFACE DRAIN WEAK POINTS

Data from the walk-thru and motor bike surveys will be used to determine the weak points and maintenance requirements of the system. Possible solutions could be identified.

"If you want to sense the problems, do not drive, but walk along both sides of the irrigation channel and talk with the people you meet along the way" (Skogerboe and Merkley, 1996).

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