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REPORT OF THE USAID TECHNICAL ASSISTANCE TEAM FOR ON-FARM WATER MANAGEMENT TO DIRECTORATE OF WATER MANAGEMENT RESEARCH AT RAHURI AND WATER TECHNOLOGY CENTRE FOR THE EASTERN REGION AT BHUBENESHWAR

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PROGRAM OF VISIT OF U.S. CONSULTANTS UNDER ON-FARM WATER MANAGEMENT RESEARCH SUB-PROJECT

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1. BACKGROUND

The consultancy mainly concerned reviewing the progress of research work of the Directorate of Water Management Research at Rahuri, the Water Technology Centre for Eastern Region, Bhubaneshwar, and the associated stations. It included aiding in developing and refining the future research programs of these two institutes and cooperating stations with appropriate thrusts and strategies, and in presenting, at both places, a short-term discussion-cum-training workshop appropriate to 'On-Farm Water Management' for the benefit of the scientists of the co-operating centers.

Participants in the discussion-cum-training workshop included Chief scientists from 24 stations and centers which are part of the All India Coordinated Project for Research on Water Management (hereafter referred to as the Project). ICAR, through the Directorate for Water Management, provides the coordinating function for the research stations. This Project began in 1967 with most of its efforts to date focused on the experiment station farms. The stations are scattered throughout India to represent the vast array of agroclimatic areas in the country. There is now more effort to move the focus of the research off the stations and onto live farms. This is a new major thrust to develop eight pilot sites at the minor canal level that will include demonstration of a package of technologies that has been developed.

This Project is funded through the Indian Government, mostly from ICAR. USAID provided modest funding to assist the Project including this US technical assistance team.

2. ACKNOWLEDGEMENT

The technical assistance team thanks all those from ICAR, USAID, and the several other individuals that brought us up to speed on the background of the efforts being made by the Directorate of Water Management Research, Rahuri, and the Water Technology Center, Bhubaneshwar. Their insights proved valuable in helping us understand the objectives and research needs at the many other locations not visited, but under the direction of the several chief scientists at the particular locations. We are particularly grateful to Dr. I. P. Abrol, Director General, Dr. R.K. Rajput, Project Director, Dr. B.R. Sharma, Assistant Director General, and Dr. S.R. Singh, Center Director, for their candid insight and patience with us. We also want to express our thanks to the chief scientists whom we came to know as friends as well as colleagues. We hope we do not diminish the gratitude to the others if we single out Professor Jaswant Singh for his contribution to our discussions and the dignity and professionalism he brought to them. We are also appreciative to those who organized and made arrangements for our stay and participation in the workshops at Rahuri and Bhubeneshwar.

This activity was funded through USAID and we would like to especially thank Mr. Surjan Singh, Program Specialist for Agricultural Research and Education, for sharing his thoughts related to the history of USAID's involvement in the All India Cooperative Water Management Project.

We are very appreciative of the efforts of the Winrock International and its staff, both in New Delhi and Washington D.C., for their effort in helping to bring this technical assistance consultancy to reality after many frustrating delays. We would especially like to thank Mr. Srinivus, Colon McClung, and Mrs. S. Bhatt for their handling the many details in getting us to India.

3. SCOPE OF WORK

The scope of probable work activities suggested at both the Rahuri and the Bhubaneshwar locations is in Appendix 11.4. In general the agreed format was to be interactive with senior scientists, and as such developed as the discussions progressed. As such, the two groups, while having some activities in common, also had presentations and discussions that were considerably different. For example both locations included visits to irrigation commands, but at Rahuri we also visited research farms.

At Bhubaneshwar, we had a more estensive visit to command areas and farmer fields but not to research station activities. At Bhubaneshwar, we spent more time on flow measurement and control than at Rahuri.

4. EXECUTIVE SUMMARY AND RECOMMENDATIONS

This report summarizes the three-week consultancy concerning on-farm water management by the US advisory team to the Directorate of Water Management Research, ICAR. The team participated in two discussion-cum-training workshops with chief scientist from the 24 experiment stations associated with the All India Cooperative Water Management Project. A tour was made of Project research sites at Rahuri and Bhubaneshwar.

The training workshops focused primarily on: a) flow measuring devices, b) command irrigation impacts, c) scheduling of canal operations, d) research concepts and methods, e) performance evaluation, and f) sociotechnical understanding of irrigation. The training included considerable discussion of the topics by the participants. The discussion was directed by the interest of the groups.

In addition to the tours of research sites at Rahuri and Bhubaneshwar, each of the Chief scientists briefly described research being done at his station. The team was also provided reports of the highlights and proposed research plans from each experiment station. From these presentations and reports and lively very candid informal discussion the team was able to gain a general understanding of the Project activities.

The Project has conducted a broad range of water management research throughout the country. Through its coordinated network it has been able to collect a wealth of data from the many agroclimatic areas represented by its stations. Many technologies have been developed including those for improved water application techniques, irrigation scheduling, cropping systems, and environmental impacts. Much of the research focus to date has been on water conservation technologies thatlargely have been developed on experiment station farms. There is now a new thrust to move the research to live situations in farmers fields with a particularly significant activity aimed at demonstrating a package of technologies on eight minor canals located throughout the country. There also seems to be a growing interest in drainage and management of rainwater.

Based on our brief exposure to this very complex and comprehensive Project we have made several suggestions for consideration by the Project Director and his staff. We readily acknowledge that some of the recommendations may be inappropriate and a reflection of our less than comprehensive understanding of the Project. Briefly we recommend that the following be considered:

a. Greater use of available computer software (models) developed to aid in design and operation of on-farm water management.

b. Greater emphasis be placed on networking amongst scientists.

c. Develop technologies adaptable to farmers.

d. Focus on technologies on farmers who control water supply.

e. Focus on emerging environmental concerns.

We hope that participants gained something from the workshops and that our recommendations will at least raise a dialogue on certain of these issues that seem to us to be important. In any case we have learned a great deal from this experience and from the professionals with which we were able to interact.

5. STATION RESEARCH HIGHLIGHTS AND PLANS

We were given summary reports from each of the Project stations. These were generally either reports on the research highlights or research plans for the various stations. While the reports are somewhat uneven in their detail, these reports suggest a wide range of research is being done.

Many of the reports include a brief overview of the agroclimatic conditions at the stations. This is then followed by a list of water management problems that have been observed. The main body of the highlight reports includes summaries of individual research or experimental studies. A proposed technical program for the Project is prepared by each of the stations. This includes proposed new research activities as well as those that are to be continued.

We could not pretend in the short time we have been in India to comprehend all that is in these more than thirty reports. They are summary reports that include a wealth of information with only a very brief discussions given for each project. We did not review any project completion report that would include the comprehensive findings of any specific research activity. Therefore, our comments relative to these reports are initial impressions only and may reflect a lack of understanding on our part.

Any station may have as many as 15 or more ongoing research and experimental activities. To help "outsiders" understand the research thrusts more clearly some stations have grouped these activities around general themes, usually problem themes. For example, if drainage is a problem then perhaps the five or so activities dealing with drainage are grouped together in a discussion so that it is clear how they interrelate to deal that common problem. The grouping of activities has been done to some degree at the Project level for coordination purposes.

In these reports we found details of how the research was set up and the statistical analysis, but no evidence of how the research activity design was arrived at. In particular there seemed to be a lack of reference to work that had been previously done by other researchers. Although a primary component of the Project is to study problems under the often unique agroclimatic conditions of each site, much can be drawn from similar research at different places. To be efficient each research activity should exploit as much from other related research as possible. This should include not only directly taking results from other work but also an analysis that clearly shows what the important specific issues are that are yet need to be studied and why they are uniquely different from those of past studies.

Given that resources will never be as many as needed to solve the many water management problems that have or will be identified, we believe that greater attention might be given to focusing on priority themes. The priorities would not necessarily be the same for each station, but there does seem to be some common themes that are shared by several. Such focusing would allow for more efficient research and would be very consistent with the Project theme of coordination.

We were surprised at the lack of attention given to the role of on-farm water management to chemical transport to the environment. Perhaps this is being dealt with elsewhere, but if not, perhaps some consideration should be given to at least a quantification of chemicals leaving the farm via surface flow or seepage.

6. DISCUSSION-CUM-TRAINING WORKSHOPS

We made several presentations during the two workshops. Summaries of the basic topics and subtopics are included here. Most were presented as combinations of formal presentation and informal question and discussion opportunities.

6.1 Flow Measuring Devices

Presentations on Flow Measurement and control, (Rahuri) included discussions and training on flow measuring devices for channels, particularly long-throated flumes. Chapters 4 and 5 of Bos, Replogle and Clemmens was subsequently reproduced and distributed. We had long discussions on topics such as how to measure seepage, how to measure applied water to plots that are at increasing distance from the supply channel, and how to avoid having to guess field ditch seepage losses.

Flow Control Concepts

When orifice control is used

When Weir control is used

New look at old methods of flow measurement

The force meter

Float methods

Bubble systems

Dye Dilution

Flumes

Where to measure sharp crested weirs

- Upstream
- On crest but using velocity head concept (weir sticks)
- On face of weir plate, using conversion of velocity head to improve head accuracy.

Propeller meters, concepts for trashy flows.

Total head of a long-throated flume/also by a weir stick method.

Presentation on Water Measurement (Bhubeneshwar)

One part consisted of background on where in the physical systems the flow meters they use in India fitted into the overall scheme of measurement. This was to broaden the participant's understanding of "First Principles" used in many flow meters, and to strengthen their appreciation of the uncertainty errors in measurements. Past experience has shown that the uninitiated tend to view listed error of uncertainty for a device as simply a correction that you should apply to obtain a perfect result. Again we stressed the necessity of determining the impact of the measurement on the water management item being studied. For example, water applications to plots can give useful results in many cases with flow measurement errors exceeding ±5%, and farm operations can usually be adequate with twice this error, or more. However, seepage measurements with this error would require that at least 25% water loss existed to have adequate quantification of the problem. This may require extreme lengths of channel section, and thus the ponded method may have to be used, even though it has its own problems of use and interpretation.

The presentation then shifted to the use and practice of the long-throated flumes. We did not deal much with the theory, but now feel that a little more may have helped impress the "First

Principle" aspects of these flumes. Some may feel that these devices somehow must still be field calibrated. Thus they will loose the flexibility in size, economics, and shape that make these styles of flume the most attractive open-channel flow measurement devices likely to be available for the foreseeable future. They incorporate the lowest error of uncertainty of all the open channel devices (±2%), (with the possible exception of a well designed and machined circular orifice, and a precision sharp crested weir with complete overfall, (±0.5%)). They require the least absolute head loss to operate at design maximum discharge for each size and shape, are usually the most economical to install, offer wide flexibility in matching existing channel conditions and shape, and can be designed for wide flow ranges and to avoid special backwater conditions.

We demonstrated a heavy-paper model of a flume at 20% scale that will measure up to 18 l/s at full scale. The design procedure and the size is in the handout materials. This was a size that many of the participants needed to evaluate furrows. The calibration for this size is in the handout materials.

Features demonstrated included:

-Small top troughs for leveling when splashed full of water;

-A removable and cleanable pressure sensing pipe and tube connected to a translocated stilling well that is positioned at the outlet end of the flume and allows the flume to not require precision levelling;

-An optional sidewall gauge in direct discharge units when precision leveling is used;

-Four adjustable legs for vertical alignment and leveling to achieve minimum measuring head loss;

-Plastic sheet membrane attached from the mid-flume area to guarantee a good seal with the channel without the sheet collapsing into the entrance.

We also handed out materials for building small trapezoidal flumes (Chapter 5, Bos, Replogle, Clemmens).

6.2 Command Irrigation Impacts

Farmer Innovations

Drainback irrigation method for surface systems

Difficult control parameters

Basic Physical Characteristics

Deep furrows

High intake rate soil; Final = 15 mm per hour

Flow rates: about 4 l/meter width (high)

Advance time for 200 m was about 40 min.

Then source flow is stopped; drained back

Evaluation: Uniformity Coef. 0.8

Average applied: 35 mm

6.3 Scheduling of Canal Operations

We presented a slide presentation and discussion of Delivery System Policies. This consisted of a discussion of the three items that may be adjusted by delivery authorities, the flow rate, the flow frequency, and the flow duration. These items make up the "Delivery Policy", or "Delivery Schedule." How these items are handled determines whether a schedule is flexible or rigid. Also, as is frequent in India, the flow frequency and flow duration are the same because open pipes and continuous flow are used. Most irrigation deliveries in India are by some form of rotation system. All components are pre-determined with little adjustment capability available on a request basis. Some farmers are gaining flexibility by combining the rigid deliveries with tube-well pumping.

The thrust of the presentation was the limitation that rigid schedules places on the farmer as to crop, irrigation method, and ultimate efficiencies achievable. We also examined the situations that favored their use. It was acknowledged that India is generally served with rotation systems that were probably not yet limiting efficiencies in most places. We pointed out that ultimately very high efficiency irrigation depended on flexible delivery systems and farmers that were knowledgeable in exploiting flexible systems. Capital investment and other economic considerations also seem to currently mitigate against flexible systems in India.

6.4 Research Concepts and Methods

One of the primary concerns seen by the technical assistance team is the need for clear definition of research terminology. We feel that there is still some confusion over what constitutes research as compared to technology transfer. Although both phases of technology development are equally important and appropriate for the Project we feel that it is necessary to clearly understand the difference, because some technologies are at the stage of development that is appropriate for dissemination to farmers while others are not.

The following definitions were presented for discussion:

A. Research - systematic enquiry to develop new understanding.

B. Field Research - studies carried out in the field to obtain an understanding of the functioning of an irrigation system and the factors that influence the way that it functions. (Field research was presented as an important aspect of the Project for use in identifying problems in sufficient depth so that effective solutions could be found to them).

C. Action Research - field studies of the effect of a change in the irrigation system due to an innovative intervention (any physical, organizational or mythological change in the irrigation system that can cause improved performance) on all aspects of the irrigation system. (Action Research is very similar to the term "operational research" commonly used in India. This type of research is extremely difficult to conduct, because it requires the active coordination and cooperation of system managers (e.g. farmers as well as ID staff) with scientists observing but not interfering with the intervention or the irrigation system).

D. Experimentation - trails, often comparative, of specific changes or inputs to an irrigation system for the purpose of determining "what works best". (As discussed, experimentation is an important element of research but not in and of itself research because it does not really produce new understanding, but rather quantifies our understanding. Experimentation, or the use of comparative trails, is an important aspect of the Project. In the discussions emphasis was place on the need to quantify the impact of various levels of inputs (e.g. water, fertilizer, precision land leveling) and not focus just on the maximum levels because the ability of farmers to access inputs is highly variable).

E. Demonstration - this is the application of a technology in the field that is assumed to be appropriate. (The purpose of demonstrations are for field verification and to expose the farmers to the new technology. A demonstration should not require major intervention on the part of the scientists. If the scientists are needed to "make the technology work" then clearly it is not ready for demonstration. What is more, some technologies have been found promising on the experiment station but not yet adapted to farmers environments. These technologies are not ready for demonstration until they have been refined to meet farmer needs).

F. Pilot Projects - this is the final phase of technology development when a intervention or package of interventions have been found to be appropriate and effective and acceptable to farmers given their circumstances and resources. (For pilot projects to be successful the scientists must assure that site chosen for project receives no preferential treatment. This includes assurance of more or more reliably delivered water; technical advise from professionals; assistance in financing inputs; or rehabilitated infrastructure. If preferential treatment is given a pilot site no assurance can be made of the transferability of the technology to other more typical areas. Furthermore, once the government provides subsidies to farmers in India, experience suggests that farmers will expect the government to continue the support).

A number of important issues were raised in the discussion of research methods and concepts. One of these was how to deal with the apparent gap between on-farm research and that needed in the system above the farm. One problem, if not the primary problem, identified by the group was the unreliability of water delivered to the farm level. Should the approach be to design technologies that are less than ideal but that can cope with unreliable water delivery to the farm or should it be to assume that the irrigation managers will adopted more reliable delivery systems? No consensus was reach on this issue, but it appears that a reasonable approach would be to assume that the situation will not improve greatly and develop technologies for farmers who are faced with uncertain water delivery to their farm gate. Many farmers, particularly those located at the tail of the system, will likely face poor water delivery service for a long time to come. At the same time, the Project should put its support behind efforts to improve main system management which is at the heart of many of the on-farm water management problems.

A second gap in research responsibility was identified as relating to the social and economic appropriateness of technologies. The staff of the stations are made up primarily of engineers, agronomists, and soil scientists. How do professionals in these fields deal with socioeconomic factors that should be included in technology development? Our suggestion was that they start by developing a range of technologies or different levels of a technology that allows flexibility for adaptation by farmers of different socioeconomic environments. The key element seems to be that physical science researchers have an appreciation for the importance and real existence of socioeconomic factors that will influence farmer acceptance of practices. Farmers should not be expected to adapt to the technologies as much as the technologies being adapted to the farmers.

Research at the stations has relied very heavily on experimentation. We suggest that greater emphasis on analytic exercises and modeling may result in research being done more efficiently. Some studies could be done by making use of previous research and accepted understanding of variables, which through analysis will produce results that can then be confirmed by limited field studies.

The water management field stations were created in part because of the belief that water was being wasted by farmers doing on-farm irrigation. Technologies were to be developed for the differing agroclimatic areas to help farmers conserve water. The goal of water conservation still seems to be valid. It should not be seen as the only goal, however. Some station Chief scientists reported that at times too much, not too little, water was the main concern. One Chief scientist suggested that his first, second and third priority was drainage, drainage and drainage!

The evolution of research at the stations has been from the experiment station to the farm. We believe a lot could be gained by placing greater emphasis on field studies aimed at "understanding the farm level problems in much greater depth and detail". Most of the research to date has been directed toward solutions to generally accepted generic problems such as wastage of irrigation water. We feel that a greater balance of research aimed at identifying specific problems would greatly enhance identification of potential solutions and factors which will ultimately impact on farmers willingness to support new technologies.

The Director has prepared a thoughtful concept paper relating to future field research done by the various stations. We are particularly supportive of the notion of creating uniformity in the research approaches and methods being used by the various stations. We would add two additions ideas to the Director's conceptual approach. First, data should only be collected with a clear understanding of its usefulness. Data are expensive to collect, process and store so this should not be done as a matter of routine practice unless there a clearly understood needs for the data. In any case, experience has shown that the quality of data collected is best if the collectors have a good understanding that it is important information and why. Second, research methods (including collection and analysis of data) should have enough flexibility to assure effective utility under the widely varying conditions of the Project stations. Rigid research specifications in regard to such things as data collection or analysis for the purpose of gaining uniformity among stations or statistical significance could reduce the research to where the critical research issues are external to the research.

6.5 Performance Evaluation

How can the application of a technology be evaluated in the context of actual live farming systems? What criteria should be used? These questions are particularly difficult to answer given the high degree of interactions among inputs and the variability in weather, soils and other natural factors.

In the workshop we discussed five performance factors and a number of criteria to quantify each of these. The five factors were production, equity, economic, environmental and farmer satisfaction.

Production seemed to be the most widely used performance indicator, and yield was the most common criteria for quantifying this factor. We also discussed other criteria, however, including cropping intensity, area irrigated and adoption of high-value crops. Consideration should be given to using the average yield of the highest 10 percent of the neighboring farmers as the target rather than some theoretical yield achievable only at the experiment station under ideal controlled conditions. It must also be remembered that yield comparisons are only valid for similar crops. Multicropping requires estimates of yield for each of the crops. Crop economic return can also be used as a production criteria but market fluctuations cause this to be a relatively indirect measure of water management performance.

Equity is usually not a factor for measuring on-farm water management performance. Case studies have shown, however, that farmers will not support operation of systems if they perceive them as inequitable. It was pointed out that equity can mean equal portions of water or (depending on the local concept of fairness) access to equal productivity from water. For example, farmers with sandy soils may require more water to obtain the same yield as compared to farmers with clay or loam soils. Equity will be an important performance indicator in the eight pilot minor canals to be studied.

Two issues were discussed at some length with regard to economics as a performance indicator. First, economic assessment must include not only the farmer direct cost, but the total cost to society including various subsidies and indirect costs due to environmental degradation or lost opportunities. Secondly, important issues of financing must be separated from those of economics. Many farmers were felt to be unresponsive to new technologies because of their inability to pay for inputs. Their problem was not one of failing to appreciate the potential benefits of the new technologies but rather lack of readily available cash (or labor) to pay for it.

Environmental sustainability as a performance indicator was discussed relative to water logging, salinity/alkalinity, erosion/sediment and health. The primary criteria agreed to seemed to be those related to water logging and salinity. There was, however, some discussion of how to monitor and assess groundwater sustainability, particularly in light of increased conjunctive use of groundwater via private tube wells.

Finally we talked briefly about how to quantify farmer satisfaction. We emphasized that farmer willingness to pay his/her water fees was not a good measure. Standardized surveys are also generally considered to be poor instruments for assessing farmer satisfaction. Monitoring of farmer conflict and complaints and use of unauthorized outlets and checks have been successfully used to measure farmer satisfaction.

Field methods for performance evaluation are presented in Appendix 11.3.5.

The importance of recognizing where an irrigation system is in its evolution was discussed so that reasonable expectations could be made in a performance evaluation. Expectations of farmer use of water in the early stages of a new irrigation system should be made in recognition that water is grossly abundant at the head of the system, there is little management of the water by agency staff, and farmers themselves have not recognized the value of the water. The performance (or lack thereof) is dominated by lack of information. As the system matures, there is greater recognition of the value of water and consequently it can be expected that it will be used more effectively. Farmers, however, are limited in their ability to improve system performance if it is poorly managed higher in the system. We had an extremely interesting discussion with a farmer and irrigation system engineer at Bhubaneshwar. Both the farmer and the engineer agreed that there was very little the farmer could do to improve water management on his farm until the system managers got control of the water in the conveyance system.

The importance of realizing that farmers are generally rational people (perhaps dominated by short-term economic considerations) was stress in evaluating on-farm water management performance. For example, excess water can sometimes be substituted for labor or capital and this is therefore a rational thing for farmers to do. If system water delivery to the farm gate is unreliable, farmers can be expected to "over irrigate" as a rational approach to reducing risk of crop failure. This is particularly true for paddy farmers.

We suggested that in addition to performance factors that integrate all inputs, such as yield increases, measurements should be made of water specific parameters such as water use efficiency, uniformity of application, and adequacy in the field.

In all cases, evaluators should be clear on the purpose for the evaluation. The system is being evaluated against what or whose goal? If the goal is not one that can reasonably be expected to be share by farmers, then farmers should not be expected to be performing well by the performance criteria to measure that particular goal. Agree ahead of time what the evaluation criteria are to be.

6.6 Sociotechnical Considerations

The environment under which most of the on-farm water management research has been conducted has been that of the research station where physical constraints can be controlled but social and economic constraints are largely ignored. The future research of the Project will place emphasis on developing and adapting technologies that are appropriate for use by farmers, not just well-to-do farmers but all farmers. This point is highlighted in Dr. Rajput's concept paper (Appendix 11.4). To incorporate the social and economic contexts into the on-farm water management technologies a holistic framework is needed to describe an irrigation system. Development of this framework was the focus of the discussion on sociotechnical aspects of irrigation.

The research to date has focused on physically-based technologies such as measuring devices or border strips. These are types of "structures" for irrigation management. There are also social "structures" for managing irrigation water such as water user associations, irrigation departments, or water rights. In a broad sense irrigation structures must be seen as both social and physical. In the workshop we used this idea of "structures" as the means to control water by organizational activities.

Irrigation activities were divided into three general types. Water activities that included acquisition, distribution (including conveyance and water application) and drainage. Structural activities listed as planning/design, construction, operation and maintenance. Finally organizational activities that included decision-making, resource mobilization, communication, and conflict resolution. The goal of an irrigation system is to bring water to plants with the aid of structural tools used by organizations. Organizations include any individuals or group that are involved in irrigation management.

For the technologies developed under the Water Management Research Project to be relevant they must be acceptable to farmers. Evidence to date strongly suggests that for technologies to be accepted by farmers they must be a meaningful part of the process that develops these technologies. A good measure of appropriateness of the process in this regard is whether or not farmers participate in the decision-making of the activities outlined above. Details of the sociotechnical training are presented in Appendix 11.3.4.

In the discussion a suggestion was made to relate various activities with specific categories of professionals, (e.g. farmers, irrigation engineers, extension specialists). While we concluded that certain specific activities would fall primarily on certain professionals (e.g. dam design with civil engineers) it is best that we assume decisions at all levels will be shared by all. The example was given by one of the participants that project planning (done head of say dam design) required participation by the local community to assure "social" correctness and local support.

7. STATION ORAL REPORTS AND FIELD VISITS

At Rahuri, Several demonstration projects were observed. The first had to do with crop and water management practices to about 0.4 ha of farm land while the farmer maintained control on 0.6 ha. The idea was to show that yields could be maintained or exceeded on a number of cropping situations while using less water. The wheat was planted on the research half in rows about 20 cm apart. The farm practice was to plant in rows and then to cross plant in another set of rows perpendicular to the first. They listed this as "Labor, 14 female" and the latter "Labor, 28 female", and used about 25% more seed on the cross planting.

Next we visited a farm where several 10 ft by 125 ft border strips were being irrigated. The apparent practice was to apply about 10 l/s for about 0.25 hr (0.35 cfs/(1250/43560)) or about 3 inches of water per border strip. The berms between the border strips showed some white salts.

Another field experiment concerned canal seepage flow measurements. The precision needed to use inflow-outflow methods is not in place. The canal sections are not sufficiently long enough to allow enough water loss in these sections to be accurately detected with Parshall flumes. Losses in the approximately 300 m reach assessable for study were apparently detected to be on the order of 1 or 2%. Unfortunately, this is within the probable error of the two flume measurements, and is not conclusive. Perhaps a ponding test method will give more conclusive results despite the problems of that method, which include variations between seepage of moving bed channels and ponded flow conditions. Several times during the workshop we discussed how to express seepage in small field channels. Our consensus is that when wetted perimeter controls, as may be true in large canals, then use loss per area of wetted perimeter. In small earthen field channels the number of animal inhabitants per unit length may control, and simple loss per unit channel length probably makes more sense.

We visited a wheat farm where researchers had advised the farmer on fertilizer and water regimes. The crop appeared to be excellent. There were no salinity problems apparent at this site. We had tea under a tree at the farmers residence and examined a grease gun" (actually more of an oil can) made of bamboo and used with ox carts. A locally made wooden ox-drawn planter was examined. This planter relied on a hand-feed of seed through a plastic tube. The seed rate is strictly by experienced guess.

Next we examined the outlet of the project which included a 3-inch Parshall flume. High water marks showed that it had flowed only about an inch deep since advanced practices had been implemented. No historical flow records prior to treatment were available.

We observed a drainage/salinity problem where the water table was reported to be at about 1.5 meters. The previous crop of wheat had been a near failure. The newly cleaned ditch had sufficiently lowered the water table to the present level that a good crop existed and was near to harvest. A few spots prevailed that were salt damaged.

There were three or four engineers in the group. We had long discussions on topics such as how to measure seepage, how to measure applied water to plots that are at increasing distance from the supply channel, and how to avoid having to guess field ditch seepage losses.

Each of the 24 Chief Scientists were asked to give brief overviews of their research, Time was not nearly sufficient for them to cover all of their activities, but their presentations gave us additional background as to what each was doing. These presentations were a source of many interesting discussions. Typical of these was that of Prof. Jaswant Singh, Visiting Professor/Chief Scientist, (Sher-e-Kashmir University of Agricultural Sciences and Technology, Water Management Research Center, Pounichak, Jammu-180002 (J&K) INDIA) who showed that the climatic average rainfall data could be reliably used to estimate the irrigation applications required for wheat in his area. Based on that data he determined the risk of planning for only 2 after-planting irrigations rather than the usual 4 or 5. Various other scientists presented their project highlights over the next few days.

We had marked several questions in the reports that were prepared as "Research Highlights" from each location. Some of the research findings were stated in absolute terms such as "for gram crop, plots should be 6.6 m wide and 6 m long. Increasing the length to 12 m causes decrease in yield". Although these were explained as perhaps language problems, the example led to a discussion of the desirability of stating results in a framework of causes, because, if the example were to be taken literally, it is difficult to rationalize yield changes on so small a change in dimensions. Yield change most probably was due to influences other thar dimension change, and care should be taken to not appear to attribute effects to non-probable causes without strong supporting explanations.

We visited the Delta Irrigation System on 27 March, to gain first hand knowledge of water management situations in the eastern region. We were escorted by the Chief Engineer. We visited several rice paddy situations along a main canal. The paddies were basically irrigated by taking water from field to field. Along the main canal, several spots were visible where water bubbled up at the boundary between the canal and the rice paddy. These seemed to be the basic source of water to these fields. We could find no active inlet, yet there was an active drainage flow exiting the area through a culvert under the main canal and running to more paddies on the other side of the canal. We talked to a farmer about this rice area and found that he and a couple of other workers were weeding; the paddy. They appeared to wade at about one meter intervals, reaching to either side. The effect of there walking left trails in the rice. We were not sure if these trails were intentional or an artifact of the technique. Further along we visited a rice area that used field channels to deliver water to each paddy. These field channels were typically leaky with spaces between the sod chunks used to make the berms and through animal holes. This field channel problem has not found a satisfactory solution.

8. PRIORITY RESEARCH/DEMONSTRATION ISSUES

Chief scientists were asked toward the end of each workshop to identify priority issues requiring further study. The stations are broadly separated into those in heavy rainfall areas (about four) and those in drier areas (about 20). Predictably the priorities in the wetter areas were different from those in the dry zones, but there were some common themes.

Oddly one of the most commonly identified problems was the need to manage rainfall runoff. This was seen as a problem from the standpoint of drainage and an opportunity for water conservation. Drainage was also listed as a priority concern even by some who were in areas of relatively low rainfall but high irrigation seepage losses. We believe that the most meaningful drainage research will be aimed at understanding the cause or causes for the problem (over irrigation, canal seepage, rainfall, land use changes, etc.) and to quantify these. We would place low priority on repeating experiments on crop response to improved drainage or assessment of known drainage technologies. New technologies specifically designed for small and scattered land holdings might be useful for both drainage and rainfall harvesting.

There was a perceived need to continue to do research on the broad area of irrigation methods and scheduling. Since there has already been a great deal of research on this topic it will be important to synthesize what is already known. For example many, if not most, of the stations are doing research on border strip irrigation. A few stations are working with newer technologies such as trickle and sprinkler irrigation, but as yet these seem to be adapted only to the better farms. The greatest opportunity for further research into irrigation methods appears to us to be in adapting the technology to the particular constraints of farmers with small holdings and difficult water, soil and topographic environments. In some cases there seems to be social and economic constraints to be adapted to as well. There seems also to be a need to find alternatives to field to field paddy irrigation.

A third need the was identified was that of research aimed at groundwater. Again as with rainfall, there were problems and opportunities identified for research. The opportunities centered around the use of groundwater as a conjunctive source of irrigation water. The problems related to water logging, salinity, and over exploitation. Certainly the concern for groundwater sustainability (i.e. maintaining the long term balance of groundwater recharge and discharge and a salt balance) is justified given the rapid development of private tubewells in many areas. We would add to this the concern of chemical contamination of groundwater and the serious human health effects that this could have.

A forth priority research need seemed to fall on the general category of water management under difficult environmental conditions. Specific problems mentioned included irrigation of steep lands, of areas with erratic and intense rainfall, of very small and scattered fields, management of drought-prone areas, and (most often) of farms that receive water in an unreliable fashion from the main conveyance system.

The fifth high priority issue was that of development of new cropping patterns. Again this is a topic that has been extensively research so new activities should be initiated only after clearly understanding what is yet to be learned. One specific subset of this research was most often raised by the Chief scientists and this related to introducing new crops into a rice-based system.

9. ADDITIONAL NOTES AND COMMENTS

Several additional, not necessarily discussed above, topics were mentioned during informal discussions with the scientists at Rahuri:

Irrigation System Effects

What do we measure?

Is yield the only parameter?

When do we need to evaluate final yield effects and when should we evaluate such things as water distribution, spatial variability in soils and fertilizers, etc.?

Systems may be studied for general effects uniformity using mathematical simulations field testing for water distributions

infiltration/redistribution studies.

Problems of depending on yield results

many untestable parameters may enter

may not be able to tell the "signal" from the "noise".

Our discussion on channel seepage studies:

When the wetted perimeter controls the loss rate, then it makes sense that wetted area be a parameter. This is possibly true for large canals.

When leaky gates and animal burrows, etc. control the rate of loss, then some other parameter may be just as appropriate, such as simple length of canal. This is possibly true for small canals.

Discussion on salinity studies:

How to use various sources of water whose quality may differ.

Is blending a solution for salinity, or should the water qualities be kept separate as much as practical? Their experience seemed to indicate that early plant growth, at least more sensitive plants, can benefit from good quality water until established, then may frequently tolerate poorer quality water at later growth stages.

New Directions

Roots

Water depletion

What happens to the roots?

How much energy is used each time these are revived?

Is there an optimal water use depletion?

Some work on cotton: Tentative results in USA

Do other plants respond similarly?

Can we simulate the results of drip with good surface systems?

One of us offered the possibility that really great impacts concerning the on-farm situation might be to find ways to make the delivery reliable and accurate, on the assumption that this might ultimately save water by not encouraging hording psychology. They suggested that alternately they could take the distribution as erratic and irregular and work on farm management methods that could reduce the risks. We then suggested the idea that had been mentioned to the group at Rahuri that

"if I were a farmer, I would water on contour furrows, from both ends, as a first choice, and I would water each furrow or narrow border, starting from the topmost, until I ran out of water. The bottommost furrows/border-strips would be planted to drought tolerant crops. Management procedures might be examined. For example, the system might allow alternate irrigations, perhaps usually from the top down, but occasionally from the bottom up. This might allow some adjustment for water returning earlier than needed because of rain, etc. and the salvaging of that dry area left from last time."

Concerning the suggestions of level basins that have been so widely successful elsewhere, they discussed possible limitations because of small holdings. However, we submit that many small holdings may actually be nearly level anyway, and that there may be effective practices to get them sufficiently level without laser controlled leveling. Also discussed was the idea that large areas at common levels are not necessary, and that large cuts are usually avoided because of costs. Large areas and large cuts are not necessary. What is needed is only individual plot levelling. One concern was that any soil moved might change infiltration rates so much that severe spatial variation would negate the benefits. It was pointed out that this did not seem to be a problem with experiences from other places. It is likely that the spacial variability from such effects would be much lower than the usual distribution problems of sloping, or unlevelled application methods.

We discussed at one point in the conference the utility of a four-wheeled leveling vehicle that would have four-wheel steering and a central mounted blade for small plots. The long configuration of towed scrapers mitigate against leveling 50' by 50' plots. Such a vehicle is not currently marketed, would probably be expensive, particularly if it were not mass produced, but might find utility someday.

On the last day of the workshop, we were privileged to have an engineer from the local irrigation system. He explained some of their operational trials to alleviate the tailender problems. One of these was to install open pipe outlets of various diameters, ranging up to about 6" according to services area, at three levels. The upper one-third of the canal had installations near the to the second one third had them installed near mid elevation and the final one third had them on the bottom. The idea appeared to be to force water, at times, to the lower end of the canal by simply dropping the canal level below the upstream outlets. These was good in theory but upper end users soon figured out ways to pond the water higher and receive the flow meant for the lower end. It was not clear why this was hard to police and prevent. Ultimately they settled on plastic pipes that discharge continuously to all areas. This being a rice area, this process is probably suitable. It limits movement to other crops, if and when that time comes. The water duty was stated as being 1 cfs per hundred acres. This works out to approximately 0.24" per day. His major problems are perceived as being a) water distribution and b) drainage.

A farmer was present and submitted to questioning about his rice growing operation. The questions were translated by the engineer. There were about 60 families in his village who operate about 200 acres. The farmer operated 2 acres of paddy and he gets two paddy crops a year. His yields, as he remembered them, work out to be about 4100 pounds per acre for rabi crop and 2500 pounds per acre for the karif crop. These were stated in terms of 25 and

15 bags (@ 75 kg), per acre. We were told that paddy rice yields about 60% at the kitchen level of serving. He sells about 10%. For the 10 people in his family, the yields reported work out to about 2 pounds of consumed rice per day. He uses fertilizer, two applications, the second seems to be potash, according to him, and the first was a named preparation that might have also contained phosphates.

10. RECOMMENDATIONS

1. Make greater use of available on-farm water management computer software.

Surface irrigation has been well modeled with computer-based solutions and testing by research elsewhere. The irrigation engineering literature contains many experiences with the use of such models. The models can be successfully used to examine the effects of field variables on the flow and distribution of water and to evaluate the performance of irrigation systems These models can supplement or largely replace the field studies aimed at determining when to reintroduce water to fields and the distribution uniformities due to non-levelness, flow rate per unit width, cut-off time based on advance and influence of infiltration rate changes. Thus, these models can be used to obtain the optimum inflow rates, the optimum widths and lengths of borders, and the optimum volume of application to fill the root zone, flow volumes to achieve leaching requirement, etc. Many of these on-farm water management models have been put into use friendly computer software packages and are currently used by practitioners as well as used for teaching in many universities.

Because the models depend on good input variable values, there is opportunity for improving field quantification of these variables, such as research of methods to more accurately and easily characterize infiltration, to measure and control flow rate, and to determine final water content and distribution in the soil profile, and how this distribution is viewed by the crop. To be widely applied, the soil, water, and plant interactions may need to be quickly and readily determined from inexpensive and rapid field measurements of some sort. Methods to reliably characterize these factors may be a needed and desirable line of study. Test plot measurements of advance and recession, even on well characterized soils at the research farms or selected cooperator farmer fields cannot be any more reliably transferred to the farmer's fields in general than can the model results due to the same limitations of characterizing a particular new field location. Thus field station studies could well concentrate on validating parameter estimation or field measurement methods for use in the models.

Drainage studies are again amenable to modeling of drain spacing and depth if site specific studies can again characterize local conditions of soil, water, plant and atmosphere. Recommendations of how much surface drainage is really needed, with and without overland flow for various subsoil and water table conditions may be useful. This relates to the application of contour furrow or blocked furrow practices and where they best can be used.

Many of the research studies seem to emphasize number of irrigations, with calendar time and applied volume as data. We have seen less emphasis placed on the application uniformity, which affects the timing and the total volume needed for adequacy s well as impacts on the drainage requirement. Again the models can help in the appropriate design of surface irrigation systems to deal with this interaction.

2. Strengthen professional interactions.

A primary strength of the Project is the coordination of information collected from India's many agroclimatic zones. To make this coordination effective the scientists and engineers from the various stations must be able to exchange ideas and experiences on a regular basis. We suggest that consideration be given to strengthening the professional exchange among participants in the Project. There are a number of ways that this could be done including the following possibilities (some of which may already be being done).

a. Exchange of Research Materials: The written material we were provided was primarily of a summary nature. We did not review any comprehensive project reports. These should certainly be shared amongst the stations, as we expect that they are now. We would also advise preliminary findings be exchanged between scientists working on similar topics. This should best be done in an interactive manner through letters, phone or electronic network.

b. Regular meetings to share ideas and findings: Scientists working on similar issues should have a forum for meeting at least annually or semiannually. These meetings should not be large formal meetings nor should they be seen as training. Rather they should be informally structured for a free exchange of ideas so that the scientists can clearly identify the cutting edge of the collective research they are doing. These meetings would be especially useful for sharing ideas on field research methods, many of which are developed from trial and error. One output from these gatherings, in addition to the professional enrichment, might be a summary document on a particular topic or theme. For example, such an appropriate group might be asked to focus on developing a document on methods for design and maintenance of canal lining in Black Cotton Soils or another group might develop comprehensive guidelines for on-farm water application methods based on the collective experience of all the stations.

c. Exposure to scientific developments outside of India.

Before any research effort is initiated a comprehensive review of the literature should be made and this should be summarized in both the research proposal as well as any publications of a research nature that come from it. Each of the stations and universities have libraries. The Project should develop a mechanism to network amongst the libraries through the Project staff. In this way each scientist would have access not only to his station library but to that of others as well. As in the case of available computer software, our impression is that greater use could be made of the literature both for technology transfer as well as identifying current limits of understanding of water management issues. Opportunities for Project scientists to go abroad or for scientist from other countries to interact with scientists in India should continue to be pursued.

The suggestions above should only be seen as indicative of mechanisms for professional exchange. There are certainly others, some of which may be more appropriate to the Project. It was very clear to us that the most meaningful sharing of ideas occurred between several senior scientist who had a long history of working together, who obviously had professional respect for each other, and who could share freely because they were friends. Scientists can rarely be creative or professionally challenged unless they can have a free exchange of ideas with their colleagues.

3. Select researchable topics and research methods based on relevance to farmers.

The ultimate success of the Project will be determined by the level of acceptance of new technologies by farmers. This was a message we heard at both workshop inaugurations from Vice Chancellor, Dr. S.K. Dorge, of MPVK; Vice Chancellor, Dr. Mahapatra, at OUAT; and Professor Jaswant Singh. It is also a main theme of materials developed by the Project Director related to future Project directions, including emphasis on research done on farmers fields and the eight pilot areas. We sense a degree of frustration on the part of Project scientists to deal with the link between farmers and their acceptance of the new technologies. The problem is partly one of organizational structure (although we do not have enough information to suggest that any change in that structure is advisable). The Project's responsibility for research in the irrigation system above the farm level seems vague, but there is a clear recognition that main system management radically effects flexibility to adopt new on-farm water management technologies. Should and can the Project increase its scope to main system operational issues or should it focus on technologies that are robust enough to allow farmers the flexibility to adjust to unreliable water delivery? Optimal practices that assume good water delivery to the farm are useful as a target for the future, but if demonstrated that way to farmers this will cause farmers to loose confidence in research community for failing to appreciate their (i.e. farmers') constraints. A second organizational limitation is the lack of social scientists to cooperate with in developing an understanding of farmer social, legal, economic and financial constraints. We believe this can best be handled by encouraging Project staff to be extremely sensitive to these issues, "listen to what farmers have to say", and attempt to adapt technologies to farmers' preferences rather than relying on farmers adapting to the technologies.

A great deal can be learned from farmers themselves. By observing and listening to farmers, researcher can learn what constraints they face, and also from the better farmers, possible solutions. Field research should be conducted specifically to learn about and from farmers.

4. Focus on technologies applicable to farmers who control water supplies.

Many of the new technologies that have been developed are being adopted by farmers who have tubewells, or otherwise control the water delivery to their individual fields. Perhaps in time, with the aid of farmer water user groups and better main system operation, farmers in large canal systems will have the option of using more precise and water efficient technologies. In the meantime the project might want to focus more attention on farmers that control their water supplies, or on technologies to help them gain this control.

For those farmers who have tubewells or readily available and controllable water supplies continued development of modern technologies such as trickle irrigation might be useful. Research might also be done on the potential for conjunctive use of ground and surface water (public canal and private tubewell). There seems to be a vast opportunity to explore technologies related to rainfall harvesting.

5. Focus on emerging environmental impacts associated with irrigation.

The Project appears to have an increased emphasis on environmental issues, particularly those related to water logging, groundwater mining, salinity/alkalinity and erosion. We suggest consideration also be given to research on agricultural chemical transport from fields to surface and groundwater bodies.

6. Emphasize providing packages of recommendations.

In general the research should continue to emphasize providing packages of recommendations dealing with land leveling, design of on farm irrigation systems, irrigation scheduling for specific crops, etc. Even though the current limitations of delivery systems may not allow exploitation of these, farmers are showing that they can devise ways to compensate (example: tubewells).

11. APPENDICES

Appendix 11.1 Scope of Work

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JJ. RE W-212,EE. ICAR HAS PROVIDED THE FOLLOWING SCOPE OF WORK:

QUOTE

Scope of Work of the U.S. Experts to India

The consultancy of the U.S. experts shall be mainly utilized for reviewing the progress of research work of the Directorate of Water Management Research at Rahuri and Water Technology Centre for Eastern Region, Bhubaneshwar. Their assistance shall also be sought in developing and refining the future research programmes of these two institutes with appropriate thrusts and strategies. At both the places a short-term discussion-cum-training workshop on 'On-Farm Water Management' for the benefit of the scientists of the Co-operating Centres shall also be organized.

A. Scope of Work at WTCER, Bhubaneshwar (Orissa):

I Visit to Delta Irrigation System to gain first hand knowledge of the water management problems in the eastern region.

II Discussion-cum-Training Workshop for the Chief scientists of the centres located in Eastern and Northern region. The topics to be covered shall be as under:

i) Command water requirements.

ii) Command irrigation delivery systems and their impacts on farm operations.

iii) Water control and measuring structures.

iv) Scheduling of canal operations.

v) Command area development for OFWM.

vi) Performance evaluation of irrigation systems.

vii) Socio-economic aspects of irrigation management.

III Review of the research mandate of the Institute and development of future research programme for the WTCER, Bhubaneshwar.

B. Scope of Work at Directorate of Water Management Research, Rahuri, Distt. Ahmednagar (Maharashtra)

I Visit to Mula Command Irrigation System and discussion with CADA authorities.

II Discussion-cum-Training Workshop for the Chief scientists of the southern and western Region.

i) Discussion with topics related to principles of On-Farm Water Management.

ii) methodology for conducting research on a live irrigation system.

iii) Processing of the data on various parameters.

iv) development of alternative strategies.

The scientists may also be provided some basic advance knowledge of:

i) command water requirements;

ii) water control and measuring structures;

iii) performance evaluation of irrigation systems;

iv) development of the command area for efficient On-Farm Water Management.

III Review of the research activities of the AICRP on water management and responsibilities of the Directorate on water management research.

Appendix 11.2 Participants

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11.3 Handouts

11.3.1 Chapter 4 From: Bos, Replogle, and Clemmens. 1991. Flow Measuring Flumes for Open Channel Systems. AM. Soc. Of Agr. Engineers. St Joseph, Michigan. 1991. 321 p.

11.3.2 Chapter 5 From: Bos, et al. (See Above)

11.3.2 Chapter 2 Variations in Management Structures

11.3.3 Chapter 3 Activities and Objectives of Irrigation Management

11.3.4 Handout on Field Research Methods (to be included)

11.3.5 Handout on Performance Evaluation (to be included)

11.4 Methodologies For On-Farm Water Management Research - A Concept Paper