RESEARCH ASSITANCE FOR IWASRI CAPACITY BUILDING[1]

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ABSTRACT

International Waterlogging and Salinity Research Institute (IWASRI) was created with the broad objective to conduct, manage and coordinate research on waterlogging and salinity. The Dutch Government, through its bilateral cooperation programme, provided support to IWASRI. With a long twelve years (1988-2000) cooperation, IWASRI research was carried out with the collaboration of International Land Reclamation and Improvement (ILRI) of The Netherlands. During this period IWASRI staff carried out many studies with the technical and financial assistance of ILRI staff. Shallow drainage can reduce the drainable surplus, reduce the need for irrigation supply and cost of installation. Evaluation of Pipe Drainage Systems showed that the field drainage design could be decreased from initial 3.5 mm/d to the value of 1.5 mm/d. Field experiments showed that geo-synthetic as drain envelope material could safely replace the usual gravel envelope materials. Use of synthetic envelopes were much more economical compared with the granular envelopes. Spatially varying drainage needs can be detected through application of groundwater modeling approach.

Due to O&M problems drainage benefits as expected at the time of design cannot be fully achieved. Farmers might be ready to pump from pipe drainage sump for irrigation, but they will not pump continuously for drainage. Good communication with the farming community throughout the project is essential for project success. There is lack of understanding to involve small farmers in the planning, design and O&M of system.

Interceptor drains and canal lining cannot prevent the need of installation of drainage system. Due to excessive operational cost, the interceptors do not justify the large investments.

Marginal and hazardous water can be used for reclamation of salt-affected soils with the application of gypsum/organic matter and leaching. The joint research conducted by IWASRI/NRAP Engineers/Scientists has improved knowledge and capabilities significantly. IWASRI research shows its value for money.

1 INTRODUCTION

The mandate of IWASRI is to conduct, manage, and coordinate research on the control of waterlogging and salinity. This includes work on related water management. In 1988 the Dutch Government, through its bilateral cooperation program started support to IWASRI. In the years 1988 through 2000, part of IWASRI's research was conducted in collaboration with the ILRI under the Netherlands Research Assistance Project (NRAP).

IWASRI is involved in many ongoing and planned drainage and irrigation projects. The range of subjects that are studied by IWASRI is wider than just the technical issues; such as: (i) Studies on drainage design criterion and operation and maintenance issues are carried out. Model studies are being done to save on expensive fieldwork and to be able to predict the effects of contemplated measures; (ii) Work on water quality and environment is being done which is increasingly important, because of the negative effects of pollution on agricultural production and health; (iii) Action research on farmer’s participatory drainage is being conducted; and (iv) Farmers are also helped with the cultivation of salt tolerant vegetation and crops. In areas where reclamation is not feasible, the 'bio-saline' approach to impede waterlogging and salinity is being applied.

In 1995, the formation of the autonomous Provincial Irrigation and Drainage Authorities (PIDA’s) was approved. This ultimately lead to the involvement of the water users in the management and operation of irrigation and drainage system of Pakistan.

An important goal of IWASRI is to ensure that all end-users, particularly the farmers, are informed on the practical use of the research results being generated. This involves conducting programmes of technology transfer, with inputs from a wide range of disciplines and the rural communities themselves. The concrete outputs of a research Institute are reports, papers, and published recommendations, and IWASRI started, from the early beginning, a series of publications. IWASRI Internal Report 2003/01 presents the impressive list of published material: about 191 Publications (‘blue cover’), almost 363 Internal reports (‘yellow cover’), and about 320 papers published in national and international Journals and Conferences Proceedings.

2 IWASRI-NRAP JOINT RESEARCH AND LESSONS LEARNED

2.1 Drain Envelope Work

The drain envelope research originated from the initial construction problems in Fourth Drainage Project. It appeared that although the standard design specifications had been followed, the crushed rock used as envelopes did not satisfy the requirements in the field and lines became choked. Upon these problems research in both the field and laboratory was started, including work on the use of synthetic envelopes. After IWASRI research the use of synthetic envelopes is now accepted by designers and contractors. Lessons for future use are; (a) The earlier standard design rules for granular (gravel) envelopes did not apply for the very fine soils of the Indus Basin; (b) The subsequent IWASRI-NRAP research led to refinement of the design standards for the soils encountered in large parts of Pakistan; (c) Field experiments showed that geo-synthetic envelope materials could safely replace the usual gravel envelope materials for the prevailing soil conditions when properly designed and installed; and (d) Use of synthetic envelopes results in: (1) Less material cost in comparison to gravel envelopes; (2) Reduced construction cost because installation is faster; (3) Less logistic problems; (4) Easier quality control of pipe-laying.

The use of synthetic envelopes is expected to result in savings. In the project, about 800 km (500 miles) of drains have been laid, with 15% collectors and 85% laterals. The applied envelope material was gravel, with an assumed 0.15 m thickness around the laterals, and a thickness of 0.20 m around the collectors, in a 0.45 m and 0.6 m wide trench, respectively. This worked out, with a unit cost of gravel of US$ 19.7 per m^3 (FDP Design Memorandum) to US$ 3.25 M. The estimated cost for the synthetic is US$ 1.8 M. The savings to be obtained when using synthetics would be about US$ 1.4 M. Installation will speed up with synthetics as well by 25%: the trench box will be less wide, which implies a smaller excavation area. Quality control of pipe-laying is also easier with synthetic envelopes and this helps in improving construction quality.

2.2 Evaluation of pipe drainage systems

The cost of pipe drainage is high, and any possible savings should be realised. The evaluations of pipe drainage systems conducted by IWASRI have shown that the field drainage design discharge could be lower than its initial value. Two decades ago, the initial field drainage design discharge in Pakistan was chosen as 3.5 mm/d (East Khairpur), as there was no experience at all with pipe drainage. Now, research experience has advanced to the stage where 1.5 mm/d is acceptable as a starting point for design. FESS project was initially (early 1990s) designed for 2.7 mm/d, but IWASRI-NRAP could reduce it to 1.5 mm/d (IWASRI, 92/6). The Khushab SCARP drainage system, the last one before FESS, was designed at 1.8 mm/d, mentioning IWASRI work in its design report (EUROCONSULT-NESPAK, 1990). Similarly, Mardan SCARP was designed for a field drainage design discharge of 3 mm/d, but nearby Swabi SCARP, subject to similar climatic and other conditions, was designed at 2 mm/d, also referring IWASRI.

The savings that result from a lower drainage design discharge cannot be directly proportional to that reduction, but nevertheless an estimated indication of savings can be given. Assume that, for a certain area, two designs are made, one based on 3 mm/d and the other on basis of 1.5 mm/d: if the system designed for 3 mm/d has a drain spacing of 300 m, a system designed for 1.5 mm/d will have a drain spacing of over 500 m. This implies that taking a drainage design discharge of half the initial value will result in a construction cost that will be about one-third lower. Taking into account the investments in drainage during the last decade, this results in hundreds of millions of Rupees have been saved already. Pipe drainage systems, although more expensive, are better for the environment than tubewell drainage systems. Generally, the shallow groundwater quality in pipe drainage systems improves (or at least remains constant) whereas the deep groundwater quality does not improve. In areas drained by tubewells the trend is that effluent quality deteriorates, except near canals.

Pipe drainage systems have been evaluated to show both ‘technical’ and ‘socio-economic’ benefits, including: (1) Controlled the water table; (2) Decreased soil salinity; (3) Increased crop yield (wheat and sugarcane); (4) Decreased abandoned land area; (5) Increased cropping intensity; (6) Increased income, with households in non-saline areas better off in terms of assets; (7) Improved situation for women, landless and tenants (livestock conditions also improved); (8) Decreased workload for women; (9) Enrolment of children (aged 5-15 years) is significantly higher in non-saline area than in saline area, with boys better educated than girls; (10) Improved drinking water quality in the villages where the drainage system is working continuously; (11) Re-immigration towards the farms after reduction of waterlogging and salinity. There is an urgent need for better maintenance of drainage as well as farmers’ participation and co-operation to own it.

2.3 Operation and Maintenance (O&M point of view)

Most of the systems require pumping due to flat areas. The O&M of such systems remains difficult because of financial and technological difficulties. The Government of Pakistan cannot continue to fund the O&M of the entire irrigation and drainage system, in conditions where, for instance, in the fiscal year 1992, the operation of tubewells in the Punjab absorbed more than 50% of the available O&M funding, even though the wells were operated on a very limited basis. Also, in Sindh, the cost of operation of the LBOD drainage system is more than the Government can budget: the annual cost for O&M amounts to Rs.600 million (1993 prices, equivalent to about US$ 20 M), with a construction cost of Rs.24,000 million (US$ 800 M).

Formally, operation and maintenance of drainage systems is to be taken care of by the Provincial Irrigation Departments, a few years after completion of the systems. However, these Departments do not receive additional funds when they are handed over the additional charge of O&M of the drainage systems, and therefore, the systems could not be operated and maintained as necessary. This is among the main problems of drainage management in Pakistan where the surface drainage system is not functioning properly due to poor maintenance. Similarly, operation and maintenance of drainage tubewells and pipe drainage systems (where pumping is needed) is not done as per design criteria. The main reasons include lack of sufficient funds; power failure; mechanical problems; lack of farmers' cooperation. Due to this very often the drainage benefits expected at the time of design cannot fully be achieved.

The role of the surface drainage system in groundwater drainage is neglected in Pakistan. One of the first actions (during 1994/5) in the construction of Fourth Drainage Project was the cleaning (desilting) of the open drainage system. The subsequent groundwater table drop indicates the enormous influence that surface drains have for groundwater drainage, provided at proper depth and with design capacity.

The Government cannot continue to inject funds into irrigation and drainage projects forever and the users will have to pay their share as well. Preferably, and that seems to be a growing consensus now in Pakistan, should the both main systems of irrigation and of drainage be managed by the Government. Somewhere in between, the users of the system should become involved in the management. The GOP has plans and policies ready in this direction (NESPAK/MMI, 1995). PIDA's, Provincial Irrigation and Drainage Authorities, are becoming autonomous bodies to manage the system.

However, we cannot expect too much of this 'social approach' in a short time. Farmers might be ready to pump for irrigation, but they will not pump 'continuously' for drainage. The resource base of the small farmers is very narrow. Small farmers cultivate about 45% of the land in Pakistan. They typically have a farm size of less than 5 acres and they have virtually no own resources. Moreover, they are even offered lower than market prices of Pakistan for some of their produce, or have to pay water cess when not even receiving canal water. Pakistan market prices are much lower than the international market. Sincere involvement of farmers takes time. This is what we experience in the recent IWASRI/NRAP 'Participative Approach to Drainage' work. Several current, hurried, attempts to promote 'participative' approaches in on-farm drainage have little chance of real success quickly. Even with a functioning main drainage system, and a favourable attitude of users and bureaucracy, it would be time-consuming. There seems to be, at decision-taking level, a lack of understanding of what it takes to involve farmers, especially with the objective to involve farmers in the planning, implementation, and O&M of drainage systems.

2.4 Interceptor Drains

Seepage from the irrigation canals is considered the major cause of waterlogging in Pakistan. And because of this, seepage reduction measures as interceptor drains and canal lining have been proposed and installed in several systems in Pakistan. An interceptor drain is a drain (either an open ditch or a buried pipe) to intercept seepage from a neighbouring parallel canal or stream. Such drains can be installed on one side (as often in sloping land) or on both sides of the canal (as usually in flat areas).

The reasoning behind recharge reduction measures is that if seepage is the main cause of waterlogging, prevention or reduction of that seepage should eliminate or reduce the waterlogging. The purpose of the IWASRI-NRAP research into interceptor drains was to investigate those for their effectiveness in reducing drainage requirement. The effect of interceptor drains was studied at several locations in three irrigation systems in Pakistan: along the Chashma Right Bank Canal, in the Fordwah Eastern Sadiqia South Project, and in the Left Bank Outfall Drain project.

Interceptor drains were installed for one or more of the reasons: (a) To intercept a significant part of canal seepage to reduce drainage requirement of adjacent lands; (b) To relieve an area from waterlogging due to a canal; (c) To provide supplemental water for irrigation; and (d) To have a beneficial effect on the stability of side-slopes of a canal. Interceptor drains are usually the upstream and downstream lines (parallel to the canal) connected to a sump from where the water is pumped. The idea is that the pumped water is the seepage from the canal and the most important performance parameter for an interceptor drain from the viewpoint of seepage interception is the percentage net interception:

$$Rate\ pumped\ \ from the\ sump - \frac{induced\ seepage\ rate}{initial\ seepage\ rate}$$

A review of literature gave a percentage of net interception of about 30% (including both flat and sloping lands). In 1977, WAPDA electric analog model study to test the feasibility of interceptor drains for the FESS area gave a percentage net interception of 34%. The results of that study showed that the seepage were more than double due to the construction of the interceptor drains. This implied that to recover 0.5 cusec net, 2.7 cusec had to be pumped, which would be very inefficient. Moreover, there will only be a net recovery of seepage when more water than the induced seepage is pumped back into the canal. However, when the farmers locally use all discharge of the interceptor drain sump, we actually have increased the seepage from the canal, which implies even greater suffering for tail-end farmers. To prevent any decrease of water availability to tail end farmers, at least the quantity of induced seepage should be pumped back. For the study discussed here, this implied that only half of what would be pumped could be used for supplemental irrigation. In FESS, the estimate of net intercepted seepage of the trial drain along the Malik branch (FESS) was 19%, on the basis of a seepage measurement (by ponding test) and the measured discharge of the drain.

In the design of a drainage system often rules-of-thumb are applied to estimate the values of components of the water balance of the system to be drained, in the absence of measurements. An example of such estimations for the Fourth Drainage Project (FDP) near Faisalabad in the Punjab, Pakistan. The rules-of-thumb estimates a contribution of canal and distributary losses of 0.45 mm/d. The expected relative contribution of the various components of the need for drainage: the losses of canals and distributaries are a part of the total recharge to groundwater. The data arrive at an overall 0.45 mm/d “seepage contribution” to the recharge.

The decades-long record from an automatic water level recorder in Dunga Bunga (FESS) shows that the rise of the groundwater table in FESS has been highest in the period of 1950 to 1960. That rise is about 6000 mm in 10 years, which is an average of 1.6 mm/d. With an assumed specific yield of 10% this actually implies an average total net recharge (from the entire irrigation system and rainfall) of 0.16 mm/d. Also the measurement of seepage by IWASRI in the FESS area points to far less seepage than the rules-of-thumb seem to suggest, that the average seepage value for the smaller canals is about 3% of their inflow. For the Malik Branch canal it was 1% of the inflow. Let us assume that the average for all canals is 2% of the inflow. The initially planned water duty for the area was 3 cusec/1000 acres (1.8 mm/d), but may have increased since the commissioning of the Mangla Dam to 5 cusec/1000 acres (3 mm/d). If the seepage from the canals is about 2% of the inflow, and we take the higher value of 3 mm/d for the inflow, the ‘seepage contribution’ to the recharge will be 0.06 mm/d.

Both the values of 0.16 and 0.06 mm/d are lower than the assumed 0.45 mm/d. But let us, nevertheless, assume that the seepage conditions in the FESS area are the same as in the FDP area and that the canal seepage contributes 0.45 mm/d to the ‘drainage requirement’ of the area. The chosen field drainage design discharge for FESS is 1.5 mm/d of which the 0.45 mm/d is about 30%. It could then be argued that, if all seepage could be recovered, the drainage requirement could be taken 30% lower. If, however, only a part of the seepage can be recovered, the possible reduction will be less. If the net interception of seepage would be 33%, the possible reduction in the field drainage design discharge could only be 10%, from 1.5 mm/d to 1.35 mm/d. Because drain spacing is proportionate to the square root of the design discharge, the spacing could then only be increased by 5%. This implies that if the net interception of seepage is about 30% in real-life practice, the influence of interceptor drains on the drainage requirement of adjacent agricultural land would be marginal. However, because the seepage is far lower than the rules-of-thumb suggest the influence of interceptor drains on the reduction of drainage requirement in FESS will be negligible.

The results of the studies show that the net percentage of intercepted seepage was too low to have a significant effect on the drainage requirement. Besides, the operation of the system, with pumping required, is an added headache for the institution responsible for operation of the system. The total cost budgeted for interceptors in FESS was about US$ 20 M. The IWASRI research results point out that interceptors should not be used as a standard measure to recover seepage from canals.

The research results on interceptor drains came, in fact, just in time to have a bearing upon the thinking on their use for reduction of drainage requirement in FESS. The interceptor drainage studies have shown that in conditions of deep, permeable, aquifers and flat lands, as in the Indus plain of Pakistan (and similar conditions elsewhere), their effectiveness in intercepting seepage is low, less than 30%. To expect that operation of one or two drain lines parallel to a canal would at least partly solve the drainage problem of an entire area would indeed be expecting too much. Another important factor is that due to the Indus plains being very flat, drainage has to be pumped. Installation of interceptor drains in FESS as planned, would have led to enormous recurrent operation cost, in conditions when the cost of operating tubewells in the Punjab absorbs more than 50% of the available O&M funding.

Ponding tests on the Malik Branch canal were carried out because a high seepage volume was expected from the canal. The result, however, shows low seepage rates: 0.27 m/d (0.9 ft/d) in the head reach to 0.04 m/d (0.13 ft/d) for a downstream reach, commensurate with about 1% of the inflow at the head. Based on these results, the plans to line a part of the Malik branch were abandoned.

2.5 Groundwater Modelling Approach to Drainage Design

It appeared to be impossible to make a water balance of a sump in FDP. The area of influence of a sump turned out to be beyond its physical limits. The reason for this was the highly permeable, phreatic, aquifer. Upon this observation the joint IWASRI-NRAP groundwater study started. The developed approach is a combination of ‘inverse’ modelling (finding recharge from known water table elevations) and the ‘decomposition’ approach (finding recharge from deduction of losses from rainfall and head deliveries). The seasonal net recharge values based on the decomposition approach were ‘tuned’ with the inverse modelling results. This has an advantage that all recharge and discharge components are looked at in an integrated way.

Application of the groundwater model approach as an addendum to drainage design, enables the detection of spatially varying drainage needs, which was previously impossible. For FDP, such a study was carried out. The model operates on basis of 32 nodal areas, selected on basis of groundwater level observations. The size of these nodal areas varies from 0.3 to 3.0 km , with an average size of 1.6 km^2. The total model area extended over some 66 km^2. In the actually implemented drainage system for FDP, drainage is installed in 21 nodal areas. The IWASRI results show that only 11 of those areas are in urgent need of drainage. Such results indicate that the application of this approach has enormous savings potential. Application of the groundwater approach, as an addendum to drainage design, enables the detection of spatially varying drainage needs. The 'tuning' procedure that is part of the developed approach gives the advantage to check on the rules-of-thumb used for estimation recharge from rainfall and the irrigation water supply system.

2.6 Participatory Drainage Pilot Study

IWASRI-NRAP entered into a partnership with an NGO with a long-term perspective and probable sources for long-term funding for farmers', participatory drainage. Good and clear communication with the farming community is essential. This includes training on drainage. The benefits of the participatory drainage system include higher yields (except for rice) and a larger area cultivated. The farmers seem ready to pump for irrigation but they will not pump 'continuously' for drainage. The outlook of IWASRI staff on the participatory approach to drainage has been significantly influenced. Even with a well-functioning main drainage system and a favourable attitude of users and bureaucracy, application of the participatory approach to drainage would be time-consuming. There is, at decision-taking level, a lack of understanding of what it takes to involve small farmers in the planning, implementation, and O&M of drainage systems.

The cost of the system was Rs.3,180,863 for 112 ha. This is equal to a very reasonable Rs.28,400 per ha (with 1 US$ equal to Rs.54, this implies US$ 526 per ha). The contribution of the farmers, including e.g. labour and foregone crop compensation, amounts to Rs.212,100.

3 CAPACITY BUILDING OF IWASRI

NRAP provided assistance for human resources development, provision of office and laboratory/field equipment and upgradation of IWASRI Library.

3.1 Training

Higher Education

NRAP funded for 49 participants for training/short courses in national/international institutes, such as: (i) Short courses=34 (ICID=20, Others=14); (ii) MSc/M.Phil=13 (National=8, International=5); (iii) Ph.D.=2 (National=1, International=1).

Participation in Seminar/Workshops/Symposia

NRAP also funded 76 participants for seminar/workshops, 20 for national and 56 for international participation in various events.

GIS training

NRAP also funded for 7 participants in GIS Training 4 participants in National and 3 in International Institutes.

3.2 Computers, Equipment (Laboratory and Field)

NRAP provided funds for 8 computers and laboratory and field equipment, like drain envelop testing equipment and material, watertable recorders, tensio-meters, silicon kit etc.

3.3 Library

A local training on library management was sponsored by NRAP and Software "DRAIN" was also provided for cataloguing and quick reference and maintenance of record. Technical books/reports/journals were sponsored by NRAP.

4 CONCLUSIONS

4.1 Research not disseminated is research not done

If there is one overall Lesson learned, it is that research not published is research not done, and likewise, research not disseminated is research not done. It appears necessary to continuously discuss the findings of research and field trials. The country has invested billions of Rupees to manage and improve land and water. The experience at IWASRI has made it very clear that a modest investment in research could yield large benefits. We should also not forget that lessons are also learned at several other places as, for instance, in ongoing implementation projects. The lessons learned there are often also valuable. The fact that research has considerable benefits does not automatically imply that research will make the required efforts cheaper. But, the investments will be more effective, more sustainable and directly targeting whatever areas are in need of investment.

4.2 Capacity building with joint research

The joint research of the last 12 years (1988-2000) has significantly increased the knowledge and capabilities of every engineer and scientist involved. The *Project Purpose* of the later phases of IWASRI-NRAP was enhanced *technical and social research capacity to combat waterlogging and salinity*. Without doubt this has been achieved to a great extent.

4.3 Benefits of research

It will always be difficult to quantify the direct benefit of research in monetary terms. Realizing that potential savings, in hindsight, as well as actually saved expenditure by a better design, is not cash in hand, but we are confident that the IWASRI research shows that it is *value for money*. The cost of having a partner like IWASRI is more than justified.

4.4 Impact of a research phase in an ongoing implementation project (FESS)

The Fordwah Eastern Sadiqia South Irrigation and Drainage project is unique because it is the first-ever project that started with a research phase in which obvious improvements were implemented in the area, but in which also the effectiveness of certain measures, and the necessity for these measures could be investigated. This led to great advantages because it prevented ineffective or unnecessary investment. The research results on the benefits of interceptor drainage for reduction of drainage requirement have, for instance, been achieved within the framework of the first phase of the FESS project. The impact of the FESS research results include the considerably adjustment of the plans for the lining and interceptor drainage component. The areas in urgent need of drainage have been identified. The approach chosen for the FESS project is extremely useful because it makes a project more flexible. Issues not considered during the planning of the project, for whichever reason, can be accommodated relatively easy.

5 RECOMMENDATIONS

It is further suggested to study; (1) Model runs to replay conditions at already installed interceptor drains, for investigation of: (i) seepage from canals; (ii) net interception of seepage at interceptor drainage sites; (iii) possibility to control the water table adjacent to the canal; (2) Continued monitoring of pilot areas and existing systems for possible refinement of the design discharge; (3) Social impact assessment of drainage; (4) Width of influence of large open drains; (5) Influence of maintenance of open drains on groundwater table; (6) Improved methods of maintenance of surface drains; (7) Quantification of the impact of the choked surface drainage system on waterlogging.

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