Assessment of Design Practices and Performance of Small Scale Irrigation Structures in South Region

Robel Lambisso
World Vision Ethiopia
robelwam2@yahoo.com

Abstract

Uneven distribution of rainfall in the country in general and in South region in particular makes irrigation the best way to enhance food production. Development of small-scale irrigation schemes is the best alternative as they require minimum investment & their gestation period is comparatively low. The southern region as part of the country has been implementing such schemes. Despite remarkable achievements, some of the implemented schemes have totally failed and some are performing below their capacity. A case study considering 26 existing small scale irrigation works (about 1/3rd of the total schemes) in the south region is carried out for this research work and attempt is made to understand the causes of the major problems that are related to the design consideration of the different components of the structure and identify the gap in knowledge between the current design practices and performance of the structures. The pre and post construction institutional aspects, planning aspects, social aspects, economic aspects, operation & utilization aspects are also given due attention. Some of the physically observed problems of the existing irrigation structures considered for analysis are: main canal siltation (50%), sedimentation of the headwork (42%), problem of seepage through foundation (4%), main canal seepage (33%), scouring of downstream bank (8%), drying of rivers (12%), damage on impervious and flexible apron(19%), change of river course(12%), damage of under sluices(27%) and damage on CD works(4%). Likewise, some of the planning, institutional & operation problems are lack of adequate community

participation, water right conflict among up streamers and down streamers (12%), market outlet problems (8%), proper handing over problem (31%), lack of proper training and the like. During the time of the study, 18 % the irrigation schemes of the region were not operational because of aforementioned and related reasons.

Key Words: Small scale irrigation; Performance of Structures; Design Practices

1. Introduction

The majority of population of Ethiopia is dependent on rain fed agricultural production for its livelihood. However, estimated crop production is not close to fulfill the food requirements of the country.
One of the best alternatives to consider for reliable and sustainable food security development is expanding irrigation development on various scales (whether small, medium or large) and options (diversion, storage, gravity, pumped, etc). For countries like Ethiopia where the principal component of project development (finance) is a constraint to incur huge investment for irrigation, small scale irrigation can be an alternative solution to enhance food production. This is of course without undermining the strategic importance of developing medium to large scale irrigation schemes to feed the expanding population in the foreseeable future. Development of small scale irrigation through river diversion, constructing micro dams, water harvesting structures, etc may

be considered as pragmatic approach in the contemporary Ethiopia for ensuring food self-sufficiency.

Small scale irrigation structures, owing to their relatively small investment cost, ease of construction, simplicity of operation & maintenance have been a strategic target of the country for achieving sustainable food security and self sufficiency. A number of such schemes have been designed and constructed in the previous years. However, while some schemes are performing successfully, it has been observed in various reports that some of the schemes have failed to serve the purpose for which they are intended. In line with this, recent study report for the Amhara region (Asfaw, 2004) has been used as a bench mark to conduct related study in the southern region.

To this end, this research aims to evaluate the design practices and performances of small scale irrigation structures in Southern Nations Nationalities and Peoples Regional Government. In addition to the hardware problems, institutional, planning, social and economic problems contributing to the failure are also highlighted.

The out puts of the research are believed to highlight the problems of the existing irrigation schemes and show future direction for planning, design and operation of irrigation projects.

2. Objectives

2.1 General objective

The primary objective is to investigate the cause of failure of existing small scale irrigation schemes of the region to learn a lesson and generate knowledge on practices and performances for future practical application and compile set of recommendations for planning, design, implementation and operation of irrigation schemes.

2.1.1 Specific objectives

- To conduct inventory on the success and failure cases of small scale irrigation schemes in the region.
- To categorize irrigation structures based on different problem parameters
- Investigate the causes of failure for selected structures in the region with regard to hydrologic, hydraulic design, structural design & implementation aspect.
- Investigate the existing schemes with reference to planning, institutional and operational problems
- Formulate a systematic database on attributes of irrigation structures in the region using dBASE format and Arc View GIS software. The database is basically important for efficient follow up, evaluation of projects and to assess what has been done in the subject so far.
- Investigate selected successful structures in the region and draw lessons from their success (i.e. whether any unique design practice had been adopted or not)
- Investigate failed structures and draw lessons to devise better design practices and suggest methods of rehabilitation.

3. Methodology of data collection and analysis

In this research, desk study is made on existing small scale irrigation systems and practical field visits were conducted to 15(Fifteen) sites found in the region. In the desk study, the available relevant data on 11(eleven) existing irrigation structures and post implementation review reports on the status of existing schemes in the south region is collected from the regional irrigation authority. From the study and design reports, the current design practice for irrigation structures is examined and from the practical visits undertaken on 15 sites, the extent and frequency of hardware and software problems on the schemes is assessed. In the analysis, the frequency of each problem among the sites, type of problem in each site and problem ranking

has been done. Better insights on hardware and software aspects of the problems have been acquired via interviews with community and technical personnel using relevant structured questionnaire.

To help build the geographic database, inventory is made, missing coordinates were recorded using GPS instrument, inserted in spreadsheets as dBASE (dbf-IV) and imported to the drainage and rainfall maps of the region geo-referenced and digitized for the same purpose.

4. Results and Discussion

4.1 Main Canal Siltation

Out of the 26 sites considered for the analysis, 13 are observed to have main canals highly charged with sediment. In other words, 50% of the sites are seen to suffer from the problem. The problem prevalence indicates the level of attention to be given. The silt load is observed to come either along with the river water (suspended and bed load) or as a run off from upstream nearby catchement.

The figure below shows a lined canal completely filled with sediment.

Some canals like the one shown in the figure do not have proper design. In this case, the canal does not have a sustaining bed slope and it also does not have side berms.

Fig-1 Silted main canal of Satame irrigation project

Sustaining bed slopes should be provided by conducting proper profile leveling activities.

The soil bank immediately beside the canal is frequently washed by the rain water and deposited in to the canal. Hence, deposition of large soil mass should not be allowed beside the canals and adequate berms should be provided.

As additional solutions to the problem, proper procedures of design of de-silting basins are also forwarded along with FORTRAN program written for the same purpose. Vortex vanes and excluder tunnels are also recommended in the context of experimentation and further research.

4.2 Headwork Sedimentation

This was observed at 11 of the 26 sites. Accordingly, some 42% of the sites are affected with this problem. Headwork sedimentation refers to the overall submergence of the weir proper, wing walls and appurtenant structures such as gates due to settlement of sediment and the bed level rise of the river channel. Since the phenomenon results in the course change of rivers, in some cases like Hao diversion it is seen that the main canal is completely washed away by the river water changing its course.

To minimize the problem with headwork sedimentation especially with high flow conditions and movement of sediment laden water, provision of simple intakes of gabion or rock fill may provide a solution (Novak et al, 2001). Similar recommendation has been forwarded in the study at Amhara region

(Asfaw, 2004). Despite the failure, the Lenda project of Bilate river is an example characterized by bends, locating the intake at the external bend will give better performance (Arved et. al, 1993). This is mainly owing to the reason that the inner sides of bends are liable to deposition of sediment. The figure below illustrates the case:

Fig-2 Failed Hao diversion weir

4.3 Main Canal Seepage

The problem of main canal seepage is observed on 9 of the 26 schemes considered for the purpose of the analysis. This means that the problem is prevalent on 35% of the schemes.

The seeping water is seen to ooze through the underneath of the soil and hence significant quantity of irrigation water is lost prior to arriving to the distributing watercourses. Besides the loss of valuable diverted water, the seepage moisture in the vicinity houses is also a serious problem in the area. According to the key informants of Gidabo and Gelana irrigation schemes, the schemes have never been meaningfully used for irrigation since their construction 10 years back. This is mainly because of the reason that community members living along side of the main canals do not allow diversion of water due to the excessive seepage flow in to their living houses.

of side intake with simple masonry obstruction across the river. If the stream is It is recommended to practice use of clay lining and plastic lining to reduce the seepage of irrigation water at the canal. However, this may not always be successful as it has been tried and failed in Wamole irrigation project of Sidama Zone.

The issue of canal seepage can be managed by giving due emphasis to the properties of the soil along the canal route & command area. In line with this, proper techniques of clay lining and plastic lining should be tried to reduce seepage problems in irrigation canals.

The coefficient of permeability is the most important factor that should be taken in to consideration. According to the USBR recommendation, canal lining should be carried out for soils with permeability coefficient value greater than 0.8m/day (EVDSA, 1990).

4.4 Seepage through Foundation

The foundation seepage is also observed in the region as being one of notable problems. The analysis of water seepage under the foundation is very important and must be given due attention. Failure to apply the proper sub- surface flow theories and practices may result in complete failure of the structure (Garg, 1989). During the survey, 1 of the 26 sites (4%) is seen to fail due to this problem. At the observed site, the water is totally flowing beneath the foundation of the structure resulting in the total failure of the scheme. As physically observed, the structure does not even have up stream and downstream cut offs to control the sub surface flow which induce failure due to uplift pressure or failure due to piping or undermining. The figure below shows the situation:

Fig-3 Failed Hazembara diversion weir

4.5 Damage on Intake gate and Sluice gates

Out of the 26 sites considered for the analysis, 8 are observed to have highly damaged and broken intake gates. In other words, around 31% of the sites are seen to suffer from the problem. Similarly, 7 of the 26 sites (27%) have damaged sluice gates.
The figures possibly indicate how the schemes are performing under difficult condition. The cause for the problem of gates can be mainly attributed to improper scheme operation. Provision of adequate training, proper handing over and follow up of the users is indispensable. In addition, users organized in water user association should take initiatives to generate some resource to carry out some maintenance works of this sort.

4.6 Damage on Headwork

Damage of the weir proper is observed in 1 of the 26 sites that is Lenda (4%) and 2 sites (8%) are observed to have damaged wings and eroded banks.
The following figure taken from Lenda irrigation project constructed across the Bilate river may depict the phenomena.

Fig-4 Failed Side intake constructed on Bilate River

The stability of the weir proper can be ensured by correctly following the proper procedures of the structural analysis after

identifying the various forces acting on the structure.

In some cases like Lenda, it was observed that irrigation structures with in earth quake prone areas are designed with out considering the earth quake forces. The force due to earthquake should be considered where necessary for the stability analysis.
The most important forces to consider are: Forces due to surface flows, forces due to sub surface flows, forces due to self weight and external forces like earth quake and silt pressure.
The downstream wing walls can be failed due to excessive downstream bed and bank erosion which results because of excessive energy carried by the water coming from upstream. In addition, as seen at Lenda project, outflanking of protection structures can also cause failure of wing walls. Hence proper estimation of the magnitude of flood, proper geological investigation and proper protection measures are vital in this case.

4.7 Damage on Downstream Bed

This problem is observed on 5 of the 26 (19%) of the surveyed sites and it is attributed to improper hydraulic design that arises from poor knowledge of the energy dissipation and impact of sediment on the structure (Baban, 1995 & Novak et. al, 2001). The impervious floor is designed in all cases to reduce the surface flow action that causes scouring due to unbalanced pressure in the hydraulic jump trough. Generally speaking, except very few sites, end sills are not seen at the constructed structures. These could have played significant role in controlling receding jumps and hence reducing erosive power of the flowing water (Chow, 1959). In the diversion schemes where this problem prevails, abrasion and scouring of the impervious floor is commonly observed. In addition, flexible aprons are seen to be completely washed away by the energy of flowing water. The prolonged occurrence of abrasion and scouring of downstream portion of the structure may end up in the total collapse of the structures.
Accordingly, proper design of both impervious and pervious aprons are required to control the excessive upstream energy and control structures should be provided to manage the problem of receding jump. The figure below shows the phenomena:

Fig-5 Failed Goche diversion weir

4.8 Drying of River Flows

Drying out of flow was observed at the 3 of the 26 sites considered for the analysis. In other words, about 12% of the schemes were seen having no water in their river channels. Some of the sites such as Balle have got seasonal rivers. One of the reasons causing drying out of flows is improper estimation of lean flows. The current design practice follows the procedure of float method to estimate the lean flow. It may not be wrong to use the method for preliminary works. However, the method is approximate enough to over estimate the actual flow in the river and is not reliable for important works with considerable investment. In case of over estimation, the actual flow may not be obtained to satisfy the CWR and downstream water demands which may result in complete diversion of water in to irrigation canals letting the downstream dry.

The caseof Ufute may be taken as a good example for this situation. During the survey, people living downstream of the scheme were seen complaining because of

shortage of water for their livestock. However, interviews revealed that some other sites like Jelaka became dry due to significant water use far upstream from the irrigation scheme. This situation has created some level of conflict among the far up streamers & irrigators and the phenomena showed lack of adequate social work during feasibility study and follow up. The river drying problem can be observed in the following figure:

Fig-6 Jelaka Diversion Weir

4.9 Damage on CD Works

CD- works are structures carrying discharges of a natural stream across a canal intercepting the stream. When a canal is to be taken to the watershed, it crosses a number of natural streams in the distance between the headwork and command area. As one of CD structures, an aqueduct is observed at Lenda project site. However, design was not prepared for the structure and was just constructed based on experience of masons. Hence serious scouring is observed both at up stream and downstream bed and bank of the structure. The following figure depicts the case:

Fig-7 Scouring problem on an aqueduct at Lenda Project

The features of design of cross drainage works can be summarized in the following main categories (Arora, 1996):

A. Hydraulic Design

This usually involves the following:

- Determination of the maximum flood discharge and high flood level
- Fixation of water way of the drain
- Determination of canal water ways
- Determination of uplift pressure on the floor of drain
- Design of bank connections

B. Structural Design

This usually involves the following:

- Design of the cross section of the aqueduct trough
- Design of piers and abutments
- Design of foundations

At Lenda, the calculation of the adequate water way is not carried out to allow safe passage of the drainage water beneath the main canal. This could be carried out using the formula forwarded by Lacey. For large drains, the wetted perimeter may be taken equal to the width of the river; however, for small drains like that of Lenda a contraction of up to 20% can be allowed (Arora, 1996). However, failure to carryout the calculation of the waterway may endanger the entire structure and in extreme case may even flood the nearby areas.

In the case of Lenda, determination of waterway, protection works of bed and bank, design of foundation and consideration of scour conditions are totally ignored resulting in serious erosion problems as indicated in figure-7 above.
Accordingly, it is recommended to do detail hydraulic and structural design of cross drainage works rather than simply deploying masons to build the structure.

5. Planning, Institutional, Social & Economic Problems

The above problems with such schemes are not only attributed to problems of design and construction. The software aspects of planning, institutional social & operational and economic problems are also crucially important. In the following section the highlights of each problem are presented:

5.1 Planning Problems

The planning process in the development of irrigation projects can be viewed in the light of community willingness and participation. Accordingly, good performance of the schemes is directly related to the level of involvement of community members in the planning process.
In line with this, the schemes in the region can be categorized in to two:

- Schemes implemented with due involvement of stakeholders
- Schemes implemented with out(less) participation of stakeholders

As observed during field visits, strong community participation was involved at Ufute and Doje schemes that are implemented by WVE in Kembata zone. The schemes are functioning satisfactorily and users are also happy with them. Community interview revealed that the beneficiaries clean silt from main canals with out the orders given by leaders of user association. From the very beginning, the beneficiaries adequately involved in the implementation process by providing labour and local materials and have already developed sense of ownership.
On the other hand, the situation at Goche scheme of Hadiya zone is the opposite of what has been discussed. Practically, the users had no involvement with the implementation of the project and a sort of induced development or top down development is observed there. The intended beneficiaries did not show any interest with the scheme mainly because it is not addressing their real problem. They were requesting for development of a nursery at the place where the major portion of the command area of the scheme is found. Accordingly, the scheme has now failed to fulfill the purpose to which it is intended and simply the structure is located there.
Similarly, less participation of intended beneficiaries is also observed at Ameka irrigation scheme in Hadiya zone. The beneficiaries could not participate adequately in all the phases of planning, implementation and operation mainly for reasons of location of the command area far away from their village and unsuitability of the command area soil. The location of the command area at distant place and high plasticity of the command area soil developed reluctance among intended users of the scheme. Hence, although the project is completed, no one in the area is interested to use it. The implementing government agency should have repeatedly consulted the local people starting from the project inception and site selection rather than implementing the scheme with out their involvement. In addition to this, suitability of the command area soil should have been tested in laboratory during the feasibility study.

5.2 Institutional Problems

In the implementation of irrigation schemes, various institutions are involved in the process of planning, design, implementation and operation & evaluation.
However, in some of the schemes built by NGOs and GOs the expected level of participation of various institutions is not

observed. Schemes of Satame, Hazembara, Lezembara, Hao, Jelaka & Goche can be cited as projects having no design and handing over documents. Preparation of proper design is the due responsibility of the implementing institution (WVE) and the regional irrigation authority. The absence of proper design document also resulted in creating problem to proper completion and handing over of the schemes to concerned stakeholder institutions. At this point, it is worth to mention that the main reason not to handover irrigation schemes built by WVE at Omosheleko wereda in Kembata zone is absence of proper design documents. The implementing institution may phase out from the area up on completion of agreement period and if the schemes are not handed over to the stakeholders, they may totally abandon.

It is clearly seen that the handing over problem largely results because of failure of concerned institutions to discharge their due responsibilities.

Like wise, the cooperative promotion office as an institution at zone or wereda level has a responsibility to properly organize the irrigation water users and follow up the collection of periodic contributions by users to conduct maintenance works and help sustain the project. However, almost in all the visited projects irrigation water users are just aware of this but have not yet started contributions.

The institutional problem is also manifested by the absence of follow up during the operational phase of the implemented schemes. The performance evaluation of irrigation projects built by NGOs is the duty of zonal disaster prevention and preparedness office and the woreda council. In addition to periodic reports given to these offices, these government institutions should observe the field level situation of individual schemes and should try to curb problems prior to total failure of the projects.

5.3 Social and Operational Problems

The planning and institutional problems can also be reflected in the proper operation and utilization of the implemented schemes. Establishing WUA is a task to be carried out during the planning process or right at the beginning of implementation. This important activity is carried out by the implementing institution and the respective cooperative promotion office. Failure to establish legally instituted WUA and elect leaders results in problem of proper operation of schemes. Some older projects implemented by LWF & WVE can be cited as examples where strong WUA is not established. At such schemes, activities of silt cleaning from main canal and minor maintenance on gates could not be carried out because of lack of community and resource mobilization in organized manner.

In some projects like Jelaka, social problems like conflict were also observed due to water rights. In the following sections, the issue of conflict is discussed in general and specific terms.

Conflicts due to water rights are of two types:

- Conflict among irrigators, which is not common in the region
- Conflict among irrigators and up stream settlers or down stream settlers. The conflict with up stream settlers is mainly due to diversion of same river or tributary for other irrigation or some other purpose as seen at Jelaka scheme. The riparian law that says 'first come first served' does not seem to work well in such conditions. The conflict with down stream settlers mainly occurs during low flow seasons when irrigators completely divert the stream flow to fields. This case is observed in Ufute scheme.

The issue of downstream water rights is something that should be discussed in detail during the feasibility study and failure of doing these results in creating operation and utilization problems discussed above.

5.4 Economic Problems

Most users of visited irrigation schemes in the region are characterized by low income condition at household level. Users are usually heard of complaining against the

high rates of costs of production inputs such as fertilizers and seeds. As indicated in the table below, 25 schemes of the 26 considered in the analysis generate no resource to help sustainability of schemes by conducting minor maintenance and rehabilitation activities. The reason for this is partly economic problem. However, this does not mean that irrigation schemes are not changing the life of beneficiary households. As an example, in cash crop producing areas of the region such as Sidama, users are observed to fetch considerable amount of money. During interview with beneficiaries of kedoboga irrigation scheme, it was revealed that an individual is earning up to Birr 2000 per quarter of a hectare of land per one season of cash crop.

Generally speaking, the country's food situation is characterized by food insecurity at both micro and macro levels. The major area of concern is the availability of food at household level. The country is even not able to produce most of its food requirements in normal years.

Ethiopia's national target is to achieve food security both at national and household levels. To achieve this, specific programmes are needed to address the two sides of the food security equation: availability of food through increased production and storage, and access to food through family production, purchasing on the market and through effective food transfer programme.

Small scale irrigation can lead to availability of food at household level through increased productivity, stable production and hence increases income leading to alleviation of economic problems at household level. It also appears that development of small scale irrigation schemes helps the country attain food self sufficiency at national level

6. Inventory and GIS based database building

Regional level inventory has been made to collect the information on existing schemes. The information is collected from field survey & study and design reports and other reports concerning the topic. All the information pertaining to the irrigation projects are inserted in spreadsheet as dBASE and then attached to regional maps using Arc-View GIS [Fig-8 below].

The most important advantage of the digitized maps is that they can be used as tools to store and retrieve information in Arc-View GIS windows. Information of an individual scheme can be easily accessed by clicking on the point theme representing the scheme. Like wise, any additional information can be stored in the spreadsheets attached with the point themes.

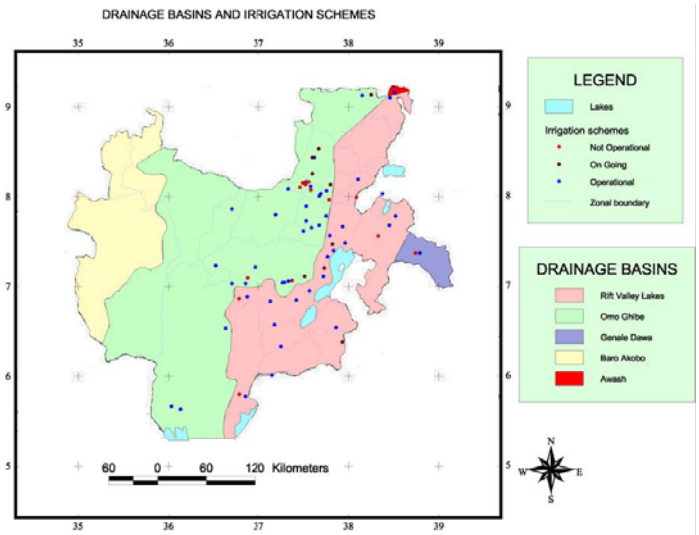

Fig-8 Distribution of irrigation schemes and drainage basin

7. Overall Conclusion

In the past, a considerable effort has been exerted by government and various agencies to promote irrigation development in the south region. However, what this research has revealed is that a considerable number of schemes (18%) have already totally failed because of the various problems discussed in the preceding sections & a significant number are performing below their capacity.

Accordingly, the government and various other agencies involved in the subject need to revise the approach towards irrigation development by:

- Integrating local research with modern irrigation development by creating mutual relationship between research and irrigation development
- Promoting irrigation development activities based on local knowledge and community participation
- Building the capacity of the technical personnel involved in the subject so that better skills can be gained in planning, design and implementation of projects
- Integrating software and hardware aspects of irrigation schemes rather than focusing largely on design and construction alone as hardware components

Failure to consider these elements may result in subsequent failure of other schemes.

References

Arora, K.R. (1996) Irrigation Water Power and Water Resources Engineering. Standard Publishers and Distributors, Delhi

Arved J. Raudkivi (1993) Exclusion and Removal of Sedimentation fromDiverted Water, Volume 6. A.A Balkema Publishers, USA

Asfaw Afera (2004) Appraisal of Current Design Practices of River Diversion Structures in the Amhara Region. Addis Ababa

Asit K., Biswas (1997) Water Resources: Environmental Planning, Management and Development. Mc Graw Hill, Newyork

Chow, V.T. (1959) Open channel hydraulics. McGraw Hill

Daniel P., Jery R. and Douglas A. (1981) Water Resource Systems Planning and Analysis. Prentice Hall Inc. Englewood cliff, New Jersey

Ethiopian Valley Development Studies Authority (1990) Preliminary Water Resource Development Master Plan for Ethiopia. Volume 2, Water and Power Consultancy Services, Addis Ababa

Garg, S.K. (1989) Irrigation engineering and Hydraulic structures. Khanna Publishers Delhi

Henry, M. and James, M.W. (1980) Applied Hydraulics in Engineering.

Hartmut K (1995) Water Management, Use and Conflict in Small ScaleIrrigation. Nairobi, Kenya

IWMI (2004) Experiences and Opportunities for Promoting Small Scale Irrigation and Rain Water Harvesting for Food Security in Ethiopia. Addis Ababa

Kinori, B.Z and Mevorach, J. (1984) Manual of Surface Drainage Engineering. Volume2, Elsevier edition, Amsterdam

Novak P., Moffat B., Nalluri C. and Narayanan R. (2001) Hydraulic Structures. Third Edition, SPON PRESS, London and Newyork

Nagar A.L, Das R.K. (1997) Basic Statistics. Third Edition, Oxford University Press, Delhi

Punmia B.C, Pande B.B. Lal (1992) Irrigation and Water Power Engineering Mehra offset press, New Delhi

Rozgar, B. (1995) Design of Diversion Weirs. John Wiley and Sons, England

Ramachandra Rao A. and Khaled, H. (2000) Flood Frequency Analysis. CRC Press, Newyork

Co-SAERSAR (2000) Headwork, Main canal and Reservoir Pond Design Report for Lasho Small Scale Irrigation Project. Awassa

Co-SAERSAR (1998) A Review on Irrigation Performance. Awassa

Co-SAERSAR (2000) Maintenances and Rehabilitation Strategies forSmall Scale Irrigation Projects. Awassa

Co- SAERSAR (1996) Study Report and Design of Diversion Weir for Eballa Small Scale Irrigation Scheme. Awassa Co-SAERASAR (2004) Inventory report on the status of 24 irrigationSchemes. Awassa

Co-SAERAR (1998) Design Report of Lamo Small Scale Irrigation Project. Awassa

WVE-Shone ADP (2001) Study and Design Report of Lenda IrrigationScheme. Hosaina