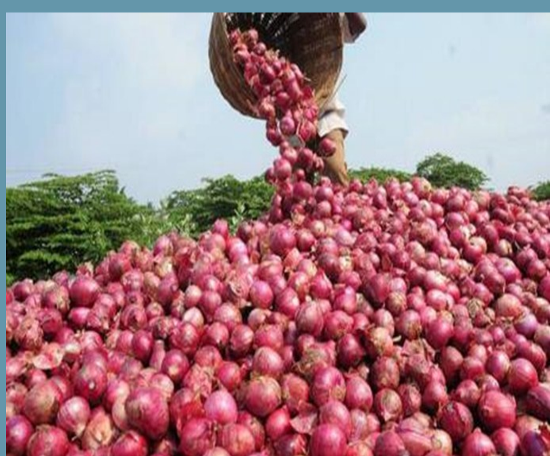
SSIGL 30

NATIONAL GUIDELINES

For Small Scale Irrigation Development in Ethiopia

Scheme Operation, Maintenance and Management



November 2018

Addis Ababa

MINISTRY OF AGRICULTURE

National Guidelines for Small Scale Irrigation Development in Ethiopia

SSIGL 30: Scheme Operation, Maintenance and Management

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National Guidelines for Small Scale Irrigation Development in Ethiopia
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DISCLAIMER

Ministry of Agriculture through the Consultant and core reviewers from all relevant stakeholders included the information to provide the contemporary approach about the subject matter. The information contained in the guidelines is obtained from sources believed tested and reliable and are augmented based on practical experiences. While it is believed that the guideline is enriched with professional advice, for it to be successful, needs services of competent professionals from all respective disciplines. It is believed, the guidelines presented herein are sound and to the expected standard. However, we hereby disclaim any liability, loss or risk taken by individuals, groups, or organization who does not act on the information contained herein as appropriate to the specific SSI site condition.

FORWARD

Ministry of Agriculture, based on the national strategic directions is striving to meet its commitments in which modernizing agriculture is on top of its highest priorities to sustain the rapid, broad-based and fair economic growth and development of the country. To date, major efforts have been made to remodel several important strategies and national guidelines by its major programs and projects.

While efforts have been made to create access to irrigation water and promoting sustainable irrigation development, several barriers are still hindering the implementation process and the performance of the schemes. The major technical constrains starts from poor planning and identification, study, design, construction, operation, and maintenance. One of the main reasons behind this outstanding challenge, in addition to the capacity limitations, is that SSIPs have been studied and designed using many ad-hoc procedures and technical guidelines developed by various local and international institutions.

Despite having several guidelines and manuals developed by different entities such as MoA (IDD)-1986, ESRDF-1997, MoWIE-2002 and JICA/OIDA-2014, still the irrigation professionals follow their own public sources and expertise to fill some important gaps. A number of disparities, constraints and outstanding issues in the study and design procedures, criteria and assumptions have been causing huge variations in all vital aspects of SSI study, design and implementation from region to region and among professionals within the same region and institutions due mainly to the lack of agreed standard technical guidelines. Hence, the SSI Directorate with AGP financial support, led by Generation consultant (GIRDC) and with active involvement of national and regional stakeholders and international development partners, these new and comprehensive national guidelines have been developed.

The SSID guidelines have been developed by addressing all key features in a comprehensive and participatory manner at all levels. The guidelines are believed to be responsive to the prevalent study and design contentious issues; and efforts have been made to make the guidelines simple, flexible and adaptable to almost all regional contexts including concerned partner institution interests. The outlines of the guidelines cover all aspects of irrigation development including project initiation, planning, organizations, site identification and prioritization, feasibility studies and detail designs, contract administration and management, scheme operation, maintenance and management.

Enforceability, standardization, social and environmental safeguard mechanisms are well mainstreamed in the guidelines, hence they shall be used as a guiding framework for engineers and other experts engaged in all SSI development phases. The views and actual procedures of all relevant diverse government bodies, research and higher learning institutions, private companies and development partners has been immensely and thoroughly considered to ensure that all stakeholders are aligned and can work together towards a common goal. Appropriately, the guidelines will be familiarized to the entire stakeholders working in the irrigation development. Besides, significant number of experts in the corresponding subject matter will be effectively trained nationwide; and the guidelines will be tested practically on actual new and developing projects for due consideration of possible improvement. Hence, hereinafter, all involved stakeholders including government & non-governmental organizations, development partners, enterprises, institutions, consultants and individuals in Ethiopia have to adhere to these comprehensive national guidelines in all cases and at all level whilst if any overlooked components are found, it should be documented and communicated to MOA to bring them up-to-date.

Therefore, I congratulate all parties involved in the success of this effort, and urge partners and stakeholders to show a similar level of engagement in the implementation and stick to the guidelines over the coming years.

H.E. Dr. Kaba Urgessa
State Minister, Ministry of Agriculture

SMALL SCALE IRRIGATION DEVELOPMENT VISION

Transforming agricultural production from its dependence on rain-fed practices by creating reliable irrigation system in which smallholder farmers have access to at least one option of water source to increase production and productivity as well as enhance resilience to climate change and thereby ensure food security, maintain increasing income and sustain economic growth.

ACKNOWLEDGEMENTS

The preparation of SSIGLs required extensive inputs from all stakeholders and development partners. Accordingly many professionals from government and development partners have contributed to the realization of the guidelines. To this end MOA would like to extend sincere acknowledgement to all institutions and individuals who have been involved in the review of these SSIGLs for their comprehensive participation, invaluable inputs and encouragement to the completion of the guidelines. There are just too many collaborators involved to name exhaustively and congratulate individually, as many experts from Federal, regional states and development partners have been involved in one way or another in the preparation of the guidelines. The contribution of all of them who actively involved in the development of these SSIGLs is gratefully acknowledged. The Ministry believes that their contributions will be truly appreciated by the users for many years to come.

The Ministry would like to extend its appreciation and gratitude to the following contributors:

- Agriculture Growth Program (AGP) of the MoA for financing the development and publication of the guidelines.
- The National Agriculture Water Management Platform (NAWMP) for overseeing, guidance and playing key supervisory and quality control roles in the overall preparation process and for the devotion of its members in reviewing and providing invaluable technical inputs to enrich the guidelines.
- Federal Government and Regional States organizations and their staff for their untiring effort in reviewing the guidelines and providing constructive suggestions, recommendations and comments.
- National and international development partners for their unreserved efforts in reviewing the guidelines and providing constructive comments which invaluably improved the quality of the guidelines.
- Small-scale and Micro Irrigation Support Project (SMIS) and its team for making all efforts to have quality GLs developed as envisioned by the Ministry.

The MOA would also like to extend its high gratitude and sincere thanks to AGP's multi development partners including the International Development Association (IDA)/World Bank, the Canada Department of Foreign Affairs, Trade and Development (DFATD), the United States Agency for International Development (USAID), the Netherlands, the European Commission (EC), the Spanish Agency for International Development (AECID), the Global Agriculture and Food Security Program (GAFSP), the Italy International Development Cooperation, the Food and Agriculture Organization (FAO) and the United Nations Development Program (UNDP).

Moreover, the Ministry would like to express its gratitude to Generation Integrated Rural Development Consultant (GIRDC) and its staff whose determined efforts to the development of these SSIGLs have been invaluable. GIRDC and its team drafted and finalized all the contents of the SSIGLs as per stakeholder suggestions, recommendations and concerns. The MoA recognizes the patience, diligence, tireless, extensive and selfless dedication of the GIRDC and its staff who made this assignment possible.

Finally, we owe courtesy to all national and International source materials cited and referred but unintentionally not cited.

Ministry of Agriculture

DEDICATIONS

The National Guidelines for Small Scale Irrigation Development are dedicated to Ethiopian smallholder farmers, agro-pastoralists, pastoralists, to equip them with appropriate irrigation technology as we envision them empowered and transformed.

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ACRONYMS

AGP	Agricultural Growth Program
CD	Agricultural Growth Program
CD	Collector Drain
CWR	Crop Water Requirement
EC	Electrical Conductivity
ET	Evapotranspiration
ETB	Ethiopian Birr
FAO	Food and Agricultural Organization
FC	Field Canal
FU	Field Unit
GAP	Good Agricultural Practices
Ge	Groundwater Table
GIR	Gross Irrigation Requirement
IDA	Irrigation Development Authority
IWR	Irrigation Water Requirement
IWUA	Irrigation Water User's Association
MC	Main Canal
NIR	Net Irrigation Requirement
O&M	Operation and Maintenance
OC	Organic Carbon
OM	Organic Matter
OMM	Operation, Maintenance and Management
OMP	Operation and Maintenance Personnel
PM&E	Participatory Monitoring and Evaluation
RIDA	Regional Irrigation Development Authority
SC	Secondary Canal
SSI	Small-Scale Irrigation
SSID	Small Scale Irrigation Development
SSIGL	Small Scale Irrigation Guideline
SSIS	Small Scale Irrigation Scheme

TC	Tertiary Canal
TU	Tertiary Unit
TUL	Tertiary Unit Leader
WIDA	Woreda Irrigation Development Authority
WMC	Water Management Committee
ZIDA	Zone Irrigation Development Authority

PREFACE

While irrigation development is at the top of the government's priority agendas as it is key to boost production and improve food security as well as to provide inputs for industrial development. Accordingly, irrigated land in different scales has been aggressively expanding from time to time. To this end, to enhance quality delivery of small-scale irrigation development planning, implementation and management, it has been decided to develop standard SSI guidelines that must be nationally applied. In September 2017 the Ministry of Agriculture (MoA) had entrusted Generation Integrated Rural Development Consultant (GIRDC) to prepare the National Small-scale Irrigation Development Guidelines (SSIGLs).

Preparation of the SSIGLs for enhancing development of irrigated agriculture is recognized as one of the many core initiatives of the MoA to improve its delivery system and achieve the targets in irrigated agriculture and fulfill its mission for improving agricultural productivity and production. The core objective of developing SSIGLs is to summarize present thinking, knowledge and practices to enable irrigation practitioners to properly plan, implement and manage community managed SSI schemes to develop the full irrigation potential in a sustainable manner.

As the SSIGLs are prepared based on national and international knowledge, experiences and practices, and describe current and recommended practice and set out the national standard guides and procedures for SSI development, they serve as a source of information and provide guidance. Hence, it is believed that the SSIGLs will contribute to ensuring the quality and timely delivery, operation and maintenance of SSI schemes in the country. The SSIGLs attempt to explain and illustrate the important concepts, considerations and procedures in SSI planning, implementation and management; and shall be used as a guiding framework for professionals engaged in SSI development. Illustrative examples from within the country have been added to enable the users understand the contents, methodologies presented in the SSIGLs.

The intended audiences of the SSIGLs are government organizations, NGOs, CSOs and the private sector involved in SSI development. Professionally, the SSIGLs will be beneficial for experienced and junior planners, experts, contractors, consultants, suppliers, investors, operators and managers of SSI schemes. The SSIGLs will also serve as a useful reference for academia and researchers involved and interested in SSI development. The SSIGLs will guide to ensure that; planning, implementation and management of SSI projects is formalized and set procedures and processes to be followed. As the SSIGLs provide information and guides they must be always fully considered and applied by adapting them to the local specific requirements.

In cognizance with the need for quality SSIGLs, the MoA has duly considered quality assurance and control during preparation of the guidelines. Accordingly, the outlines, contents and scope of the SSIGLs were thoroughly discussed, reviewed and modified by NAWMP members (senior professionals from public, national and international stakeholder) with key stakeholders in many consultative meetings and workshops. Moreover, at each milestone of SSIGL preparation, resource persons from all stakeholders reviewed and confirmed that SSIGLs have met the demands and expectations of users.

Moreover, the Ministry has mobilized resource persons from key Federal, National Regional States level stakeholders and international development partners for review, validation and endorsement of the SSIGLs.

Several hundreds of experienced professionals (who are very qualified experts in their respective fields) from government institutions, relevant private sector and international development partners have significantly contributed to the preparation of the SSIGLs. They have been involved in all aspects of the development of SSIGLs throughout the preparation process. The preparation process included a number of consultation meetings and workshops: (i) workshop to review inception report, (ii) workshop on findings of review of existing guidelines/manuals and proposed contents of the SSIGLs, (iii) meetings to review zero draft SSI GLs, (iv) review workshop on draft SSI GLs, (v) small group review meetings on thematic areas, (vi) small group consultation meetings on its final presentation of contents and layout, (vii) consultation mini-workshops in the National States on semi-final versions of the SSIGLs, and (viii) final write-shop for the appraisal and approval of the final versions of SSIGLs.

The deliberations, concerns, suggestions and comments received from professionals have been duly considered and incorporated by the GIRD Consultant in the final SSIGLs.

There are 34 separate guidelines which are categorized into the following five parts concurrent to SSI development phases:

Part-I. Project Initiation, Planning and Organization Guideline which deals with key considerations and procedures on planning and organization of SSI development projects.

Part-II. Site Identification and Prioritization Guideline which treats physical potential identification and prioritization of investment projects. It presents SSI site selection process and prioritization criteria.

Part-III. Feasibility Study and Detail Design Guidelines for SSID dealing with feasibility study and design concepts, approaches, considerations, requirements and procedures in the study and design of SSI systems.

Part-IV. Contract Administration and Construction Management Guidelines for SSI development presents the considerations, requirements, and procedures involved in construction of works, construction supervision and contract administration.

Part-V. SSI Scheme Management, Operation and Maintenance Guidelines which covers SSI Scheme management and operation.

Moreover, Tools for Small Scale Irrigation development are also prepared as part of SSIGLs.

It is strongly believed and expected that; the SSIGLs will be quickly applied by all stakeholders involved in SSI development and others as appropriate following the dissemination and familiarization process of the guidelines in order to ensure efficient, productive and sustainable irrigation development.

The SSIGLs are envisioned to be updated by incorporating new technologies and experiences including research findings. Therefore, any suggestions, concerns, recommendations and comments on the SSIGLs are highly appreciated and welcome for future updates as per the attached format below. Furthermore, despite efforts in making all types of editorial works, there may still errors, which similarly shall be handled in future undated versions.

UPDATING AND REVISIONS OF GUIDELINES

The GLs are intended as an up-to-date or a live document enabling revisions, to be updated periodically to incorporate improvements, when and where necessary; may be due to evolving demands, technological changes and changing policies, and regulatory frameworks. Planning, study and design of SSI development interventions is a dynamic process. Advancements in these aspects are necessary to cope up with the changing environment and advancing techniques. Also, based on observation feedbacks and experiences gained during application and implementation of the guidelines, there might be a need to update the requirements, provisions and procedures, as appropriate. Besides, day-by-day, water is becoming more and more valuable. Hence, for efficient water development, utilization and management will have to be designed, planned and constructed with a new set up of mind to keep pace with the changing needs of the time. It may, therefore, be necessary to take up the work of further revision of these GLs.

This current version of the GLs has particular reference to the prevailing conditions in Ethiopia and reflects the experience gained through activities within the sub-sector during subsequent years. This is the first version of the SSI development GLs. This version shall be used as a starting point for future update, revision and improvement. Future updating and revisions to the GLs are anticipated as part of the process of strengthening the standards for planning, study, design, construction, operation and management SSI development in the country.

Completion of the review and updating of the GLs shall be undertaken in close consultation with the federal and regional irrigation institutions and other stakeholders in the irrigation sub-sector including the contracting and consulting industry.

In summary, significant changes to criteria, procedures or any other relevant issues related to technological changes, new policies or revised laws should be incorporated into the GLs from their date of effectiveness. Other minor changes that will not significantly affect the whole nature of the GLs may be accumulated and made periodically. When changes are made and approved, new page(s) incorporating the revision, together with the revision date, will be issued and inserted into the relevant GL section.

All suggestions to improve the GLs should be made in accordance with the following procedures:

I. Users of the GLs must register on the MOA website: Website: www.moa.gov.et
II. Proposed changes should be outlined on the GLs Change Form and forwarded with a covering letter or email of its need and purpose to the Ministry.
III. Agreed changes will be approved by the Ministry on recommendation from the Small-scale Irrigation Directorate and/or other responsible government body.
IV. The release date of the new version will be notified to all registered users and authorities.

Users are kindly requested to present their concerns, suggestions, recommendations and comments for future updates including any omissions and/or obvious errors by completing the following revisions form and submitting it to the Ministry. The Ministry shall appraise such requests for revision and will determine if an update to the guide is justified and necessary; and when such updates will be published. Revisions may take the form of replacement or additional pages. Upon receipt, revision pages are to be incorporated in the GLs and all superseded pages removed.

Suggested Revisions Request Form (Official Letter or Email)

To: ---
From: ---
Date: ---
Description of suggested updates/changes: Include GL code and title, section title and # (heading/subheading #), and page #.

GL Code and Title	Date	Sections/ Heading/Subheading/ Pages/Table/Figure	Explanation	Comments (proposed change)

Note that be specific and include suggested language if possible and include additional sheets for comments, reference materials, charts or graphics.

GLs Change Action

Suggested Change	Recommended Action	Authorized by	Date

Director for SSI Directorate: ________________________ **Date:** _________________

The following table helps to track initial issuance of the guidelines and subsequent Updates/Versions and Revisions (Registration of Amendments/Updates).

Revision Register

Version/Issue/Revision No	Reference/Revised Sections/Pages/topics	Description of revision (Comments)	Authorized by	Date

1 INTRODUCTION

The sustainability of Small-Scale Irrigation (SSI) schemes refer to the proper functioning of the infrastructure, the people or users, agricultural enterprises, management and social systems in the long run. This happens if all factors are considered at all stages of scheme development to obtain expected outputs and attain anticipated goals. Generally, the social and institutional context of irrigation development has immense bearing on the ultimate performance of SSI schemes.

OMM problems are rarely encountered in privately owned schemes or those initiated by farmers. However, for schemes initiated by donors or governments, there is a need for close consultation between farmers and implementing agencies.

Though planning and design of SSI schemes has contribution to less efficient systems, scheme Operation, Maintenance and Management (OMM) is crucial element which is even leading to abundance of some of the SSI schemes now a days. The optimum use of irrigation water to grow maximum crop per unit of water is an essential requirement of good soil and water resources management. Irrigation water management is an integral process of storage, diversion, conveyance, regulation, measurement, distribution, application and removal of excess water and salts.

Operation, Maintenance and Management of SSI schemes consist of system hardware, system software and the system operators. The system subject to operation, maintenance and management in practice is comprised of the hardware such as the infrastructure, instruments, equipment, parts, and others, the software required for operating such hardware, and the operators who operate the system. For this reason, it is important to fully recognize that operation, maintenance and management also covers the personnel who support the hardware, software, and system operators that make up the system. Thus the system must be institutionalized for its sustainability.

SSI scheme OMM guideline is thus necessitated to address OMM issues resulting in less efficient and less productive schemes. The guideline focuses on scheme cropping plan, irrigation scheduling and water management, infrastructure operation and maintenance, organization and management, OMM costs, Capacity development needs and participatory Monitoring and Evaluation of OMM activities.

2 PURPOSE AND SCOPE OF THE GUIDELINE

2.1 PURPOSE

The main purpose of the Guideline is to:

- Guide Operation, Maintenance and Management (OMM) of small scale irrigation schemes
- Guide the preparation of scheme-level OMM manual for scheme operators and Irrigation Water User's Associations (IWUAs).
- Standardize scheme OMM approaches

2.2 SCOPE

The Guideline focuses on:

- OMM of Smallholder farmer-managed surface and pressurized irrigation schemes
- Irrigation extension practitioners and technicians handling OMM of irrigation schemes
- General OMM issues, specific OMM manuals are to be prepared according to the nature of each scheme.

3 OPERATION AND MAINTENANCE ISSUES

Scheme operation and maintenance aspects depend on the characteristics of the specific site. The responsibilities of operation and maintenance of an irrigation scheme should be clear to all parties from the outset. To assist farmers in selecting a design alternative, planners should estimate the O&M requirements at the planning stage and discuss them with farmers. If the irrigation agency is to pay or facilitate credit facility for O&M of a specified time before hand-over to farmers, the farmers should be organized and prepared for take-over well in advance. While the experience gained by the farmers during the course of planning and development is a valuable tool for the O&M of the irrigation scheme, IWUA or farmers must:

- have clear understanding of irrigation system layout plan, all irrigation infrastructures within the scheme and annual scheme operation plan set
- be aware of soil and water conservation practices necessary in command area, around the command area and within the watershed
- be aware of crop calendar, crop production and protection
- know basic principles of Good Agricultural Practices (GAP)
- know about irrigation scheduling and in-field water management
- know scheme system operation methods and procedures
- have scheme maintenance plan
- have market information
- have recording and reporting systems
- have monitoring and evaluation systems

In most cases, there is no proper scheme Operation and Maintenance guideline so far to address OM issues that challenge scheme sustainability. Most SSI scheme OM activity is not scientifically handled to attain anticipated benefits. The main responsible body for SSI scheme operation and maintenance is the IWUA or the farmer. Thus IWUAs or the farmers must always improve their capacity in order to minimize interventions on operation and maintenance from the government or other supporters

Thus the main actors (IWUAs and farmers) should have practical knowledge, and hands-on experience on scheme O&M. Implementing organization or other supporting institutions should take into consideration the background of the user groups and individual farmers. It is necessary to have appropriate guidelines, procedures and relevant material for the development of a participatory training and extension program for technical staff, extension workers and other stakeholders. This helps farmers take charge of operation, maintenance and water management at field and scheme levels. This is particularly relevant to irrigation management transfer programs, assisting irrigation water users associations in the operation and maintenance of irrigation systems, and in providing guidance on efficient water use techniques.

3.1 OPERATION ISSUES

Operation should have to be divided in to three components:

1. **Pre-main rainy season** –This is dry season and it is characterized by low flow in river. The gates should be regulated in such a way that all the available supplies are conserved and pond level is maintained. The release through the head regulator of the canal should be based on the discharge table. The discharge should be occasionally checked for accuracy by actual measurements in the canal. For any occasional flashy flood, the canal may have to be regulated not to allow excess flow in to the irrigation system. It is necessary to identify critical

structures, develop operational criteria, minimize leakages and attain proper conveyance and distribution.

2. **During main rainy season** – flood mitigation, under sluice operation or sediment control mechanisms, secure proper drainage or safety of structures (waste ways), control any scouring effects, open canal water escapes not to exceed full supply level.
3. **Post main rainy season** – sediment charge observation at the intake (shoal formation), sediment deposition or scouring in canal and structures, check cross sections and bed slope of canals and canal systematic release with available flows till anticipated intake discharge in canal is attained.

Usually updated outline of scheme like total command area, beneficiary household and land holding of each beneficiary farmer, main crop by each beneficiary, irrigation methods, type and amount of Water resources, amount of intake, layout map and all facilities related to diversion, storage, conveyance, distribution and application should be available to IWUA at scheme level. Other issues related to catchment area, drainage systems, ecology and keeping natural environments has to be clearly indicated for proper handling of the scheme.

The IWUA often operate the facility under the technical assistance of subject matter specialist either hired or supported from any stakeholder. In all cases operation responsibility must be given to well-trained personnel for the specific activity. Operation of the facility (infrastructure) related to SSI scheme is crucial aspect to the success of the facility to attain its intended purpose. The SSI scheme facilities include the headwork, the supply and drainage canal networks, roads and related appurtenant structures. The users must be well aware of the operation procedures and instructions of the facility from head-to-tail ends of the scheme for proper allocation of water to all farms according to the design and schedule set and properly keep the facility from any damages whether man-induced or natural. The users must also be aware of **when, how and for what purpose to operate the facility**. Faulty operations causes failures or result in misuse of water which in turn will have ill effects on the facility itself, crop production, land management, ecology and the physical surrounding environment. Flow division, flow storage, flow regulation and flow measurement are usually encountered in SSI scheme water management. Equitable water supply is attained under proper operation techniques set based on irrigation schedule and instructions given to the users on operation of each facility. The users must always be conscious on necessary safety measures during operation.

3.2 INSPECTION AND MAINTENANCE ISSUES

Irrigation facilities must be inspected frequently and maintained on time for its proper functioning. For instant supply canals and drainage canals must always attain designed dimensions and gradients for proper conveyance of water. If canals are not maintained on time water losses; overtopping; and canal erosion would happen. Similarly the headwork and appurtenant structures related to flood control, intake flow regulation and silt management must be inspected and maintained well. All irrigation structures have to be well inspected for any cracks, gate damages and clogging in the conveyance systems and maintained immediately. If maintenance is not handled immediately the deterioration of the facility will progress further and maintenance will be costly and difficult. Thus maintenance action shall be planned within the annual operation plan. Particularly routine maintenance is crucial for to attain proper water allocation to each plot of land within the scheme. Periodic maintenance either seasonal or annual has to be also planned to make more intensified maintenance works and if condition of the scheme get bad emergency maintenance or rehabilitation can be considered making overall assessments or study over the system.

3.3 ILL-EFFECTS OF POOR OPERATION AND MAINTENANCE

Improper operation and poor maintenance result in:

- The system failure to operate well or farmers are left with a system of limited operations
- Agriculture production and productivity falls
- Poor water supply and/or no equitable allocations
- Disputes between users
- The system fails to operate with action plans
- Continuing loss of income to farmers
- Investment is lost
- Increasing problems will arise including environmental issues
- The farmers finally fail to pay fees so that the system sustainability will be under question.

Figure 3-1 illustrates the general situation of most SSI schemes through time. Irrigation scheme introduction to an area boosts production and productivity but to sustain it and to gain anticipated benefits, the scheme must be inspected and maintained regularly. If the scheme is not maintained on time it gradually fail to serve properly and finally can be totally non-functional if not rehabilitated.

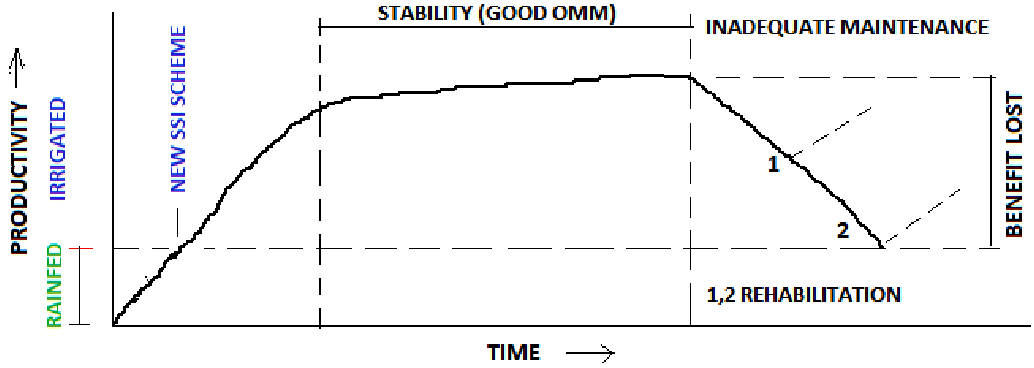


Figure 3-1 General Situations in SSI Scheme OMM

4 SOIL, CLIMATE AND HYDROLOGICAL DATA FOR SCHEME OMM

4.1 SOIL DATA

Soils of various schemes can be adversely affected by irrigation practices, thus the soil needs to be monitored to ensure sustainability and deal with fluctuations in the scheme soil quality. Irrigation water quality determines the degree of change in soil chemical property. At least soil pH, electrical conductivity (EC), organic matter (OM) and infiltration has to be monitored or updated always for proper soil, water and crop management.

The soil infiltration rate is measured on site with the help of double ring infiltromter. Electrical conductivity (EC) is measured by the conductivity meter and soil pH is measured in 1:2.5 soils: water mixture using pH meter. The organic carbon (%) is determined following the standard wet digestion method while OM is derived from OC multiplying by a factor of about 1.724. EC is a measure of soil salinity and pH is a measure of soil acidity or alkalinity and thus proper management measures are to be considered based on results obtained. Soil organic matter (OM), and the soil organisms that live on it, are critical to many soil processes. It allows high crop yields and reduces input costs. Thus OM must be monitored and updated data be used for soil and crop management.

4.2 CLIMATE DATA

Climate data must be updated for use in crop water requirement and Irrigation scheduling. The climatic data of most recent periods must be adopted for computation of crop water requirements. Some of the important data are evaporation, rainfall, temperature, sunshine hours, radiation and wind speed. At scheme level, it is usually important to install Pan and Rain gauge to measure the two important factors evaporation and rainfall for proper irrigation planning.

4.3 HYDROLOGICAL DATA

Hydrological data, mainly water availability from source, is a major concern in all cases. Thus available water from the source must be computed based on updated hydrological data. The most recent gauge readings or measurements of the water source must be used. At the same time water balance study must be done for the current water utilizations. Furthermore future demands from the water source and environmental release must be accounted. Peak flood has to be computed based on recent data or interpreted from flood marks monitored at headwork site. To utilize actual water resource data on site gauging station must be established at the project headwork.

Also river morphological changes must be inspected for any changes for proper mitigation measures in scheme operation. Construction of river barriers (headwork) may results in aggradations, degradations and meander of river course. Thus river bed levels upstream and downstream of the headwork must be taken after every main rainy season. Accordingly any change in hydraulic aspect of river flow must be checked.

5 CROPPING PATTERN AND CROP WATER REQUIREMENT

5.1 CROPPING PATTERN

Crop selection criteria

The crop type or cropping pattern is usually set based on adaptability of the crop to soil physical and chemical situations, weather conditions and water quality. On the other hand high value crops with reasonably less operation costs are selected for better revenues from given plot of land. Representative cropping patterns are usually prepared during project planning and design. However the cropping pattern, the crop water requirement and irrigation duty has to be updated for that specific crop season. It is based on the revised crop water requirement that the seasonal irrigation schedule is prepared. By selecting the right crop for the given soil conditions and climate, one can optimize yields and save water requirements for irrigation.

Cropping pattern and Intensity

Cropping pattern indicates a plan and/or schedule that determine the agronomic practices of a specific crop; to what extent (area coverage) and in what season during the year it is grown.

Cropping Intensity is the ratio of annual cropped area (sum of area under all crops in a year) to net land area times 100. Its unit is percent (%). Areas under double irrigated cropping (same area cultivated and irrigated twice a year) are counted twice. Therefore the total area may be larger than the area actually irrigated, which gives an indication of the cropping intensity.

Cropping calendar

Cropping calendar indicates the planting date and harvest date of the selected crops for irrigated agriculture. Here below is cropping calendar for Arata chufa scheme for year 2016/17.

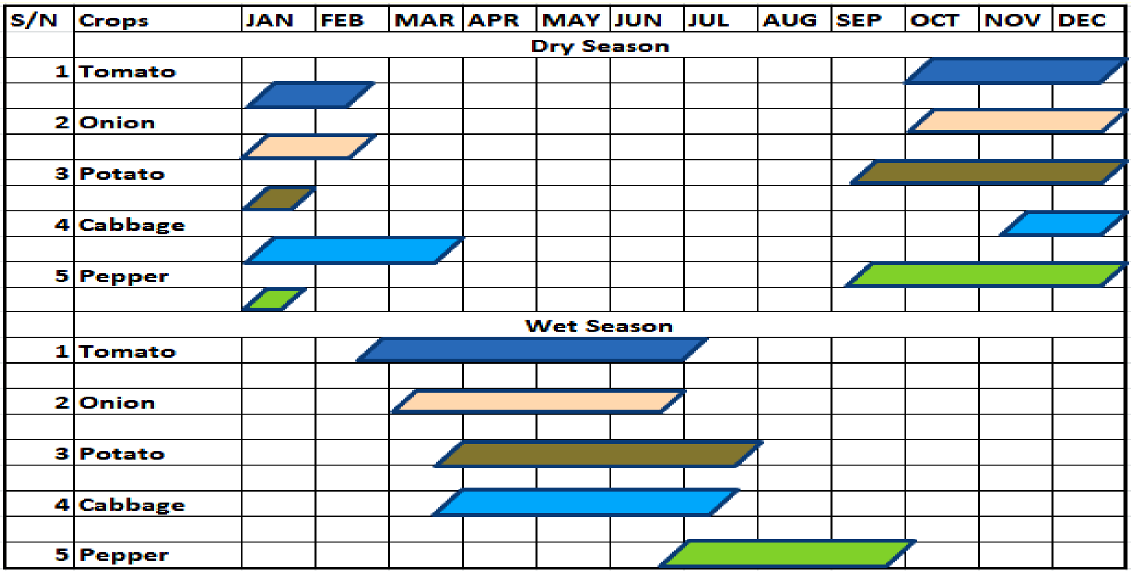


Figure 5-1Cropping calendar of Arata chufa Scheme (year 2016/17)

Crop rotation

It is the practice of growing a series of different types of crops in the same area in sequenced seasons. It is done so that the soil of farms is not used for only one set of nutrients. It helps in reducing soil erosion and increases soil fertility and crop yield.

Growing the same crop in the same place for many years in a row (Monoculture) disproportionately depletes the soil of certain nutrients. With rotation, a crop that leaches the soil of one kind of nutrient is followed during the next growing season by a dissimilar crop that returns that nutrient to the soil or draws a different ratio of nutrients. In addition, crop rotation mitigates the buildup of pathogens and pests that often occurs when one species is continuously cropped, and can also improve soil structure and fertility by increasing biomass from varied root structures.

Thus indigenous knowledge of farmers must not be overlooked in farming practices that the farmers usually rotate crops over the same plot in different crop seasons. There are numerous factors that must be taken into consideration when planning a crop rotation. Planning an effective rotation requires weighing fixed and fluctuating production circumstances, including market, farm size, labor supply, climate, soil type, growing practices, etc. Moreover, a crop rotation must consider in what condition one crop will leave the soil for the succeeding crop and how one crop can be seeded with another crop. For example, a nitrogen-fixing crop, like a legume, should always precede nitrogen depleting one; similarly, a low residue crop (i.e. a crop with low biomass) should be offset with a high biomass cover crop, like a mixture of grasses and legumes. There is no limit to the number of crops that can be used in a rotation, or the amount of time a rotation takes to complete. Decisions about rotations are made years prior, seasons prior, or even at the very last minute when an opportunity to increase profits or soil quality presents itself. In short, there is no singular formula for rotation, but many considerations to take into account.

5.2 CROP WATER REQUIREMENT

Crop water requirement (CWR) is the amount of water required by the plant to fulfill its consumptive use and is expressed in mm/day. Several factors influence irrigation water requirements as shown in Figure 5-2. Crop water requirement CWR or ETc is determined by the crop coefficient approach whereby the effect of the various weather conditions is incorporated into ETo and the crop characteristics into crop coefficient (kc). The crop coefficient depends on the crop area and its roughness, stage of growth, the growing season and the prevailing weather conditions. The effect of both crop transpiration and soil evaporation are integrated into a single crop coefficient.

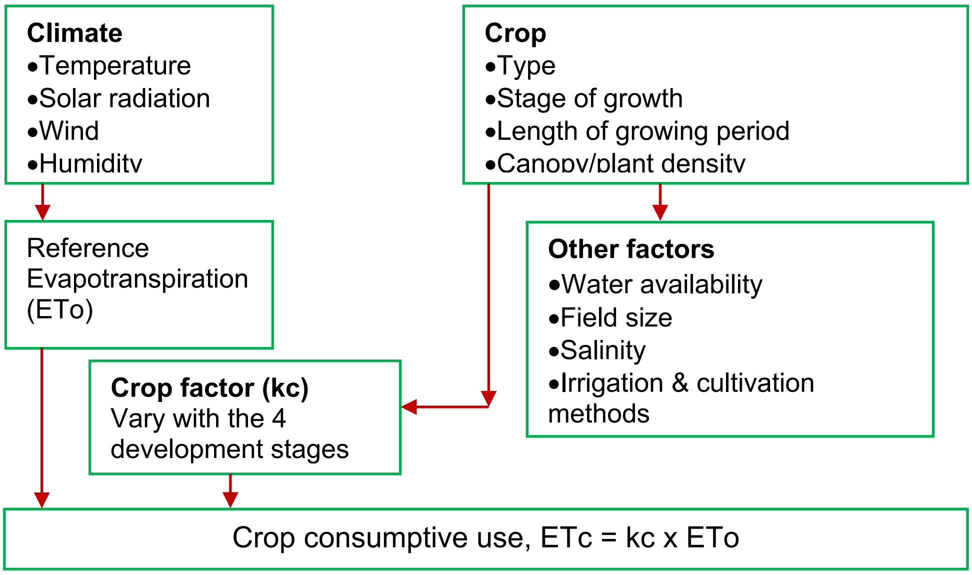


Figure 5-2: Factors Influencing Crop Water Requirements

Table 5-1 indicates sample daily crop water requirement calculation format that can be used for irrigation water management and for details about crop water requirement, guideline on Irrigation Agronomy can be referred.

Table 5-1 Sample daily crop water requirement calculation

Line Nr	Item		Source	Unit																						
1	MONTH																									
2	days in period				1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
3	Potential Evapotranspiration ETo			mm/d	4.6	4.6	4.6	4.6	5.4	5.4	5.4	5.4	6.1	6.1	6.1	6.1	6.1	6.1	6.2	6.2	6.2	6.7	6.7	6.7	6.7	6.2
4	Effective rain Re			mm/d	0	0	0	0	0	2	4	4	4	2	2	0	0	0	0	0	0	0	0	0	0	0
	Number of blocks	5																								
5	Crops and crop coefficient	1	Maize	Kc				0.3	0.35	0.42	0.68	0.89	1.01	1.11	1.1	1.01	0.78	0.65	0.6	0	0					
6		2	Maize	Kc					0.3	0.35	0.42	0.68	0.89	1.01	1.11	1.1	1.01	0.78	0.65	0.6	0	0				
7		3	Maize	Kc						0.3	0.35	0.42	0.68	0.89	1.01	1.11	1.1	1.01	0.78	0.65	0.6	0	0			
8		4	Maize	Kc							0.3	0.35	0.42	0.68	0.89	1.01	1.11	1.1	1.01	0.78	0.7	0.6	0	0		
9		5		Kc																						
10	Consumptive use	1	3*5	mm/d				1.38	1.89	2.27	3.67	4.81	6.161	6.77	6.71	6.16	4.76	3.97	3.72	0	0					
11		2	3*6	mm/d					1.62	1.89	2.27	3.67	5.429	6.16	6.77	6.71	6.16	4.76	4.03	3.72	0	0				
12		3	3*7	mm/d						1.62	1.89	2.27	4.148	5.43	6.16	6.77	6.71	6.16	4.84	4.03	3.7	0	0			
13		4	3*8	mm/d							1.62	1.89	2.562	4.15	5.43	6.16	6.77	6.71	6.26	4.84	4	4	0	0		
14		5	3*9	mm/d																						
15	Land prep./ ponding depth	1		mm/d			5																			
16		2		mm/d				5																		
17		3		mm/d					5																	
18		4		mm/d						5																
19		5		mm/d																						
20	Field Requirement	1	10+15-4	mm/d			5	1.38	1.89	0.27	0	0.81	2.16	4.77	4.71	6.16	4.76	3.97	3.72	0	0	0	0	0		
21		2	11+16-4	mm/d			0	5	1.62	0	0	0	1.43	4.16	4.77	6.71	6.16	4.76	4.03	3.72	0	0	0	0		
22		3	12+17-4	mm/d			0	0	5	0	0	0	0.15	3.43	4.16	6.77	6.71	6.16	4.84	4.03	3.7	0	0	0		
23		4	13+18-4	mm/d			0	0	0	3.0	0	0	0	2.15	3.43	6.16	6.77	6.71	6.26	4.84	4	4	0	0		
24		5	14+19-4	mm/d																						
25	Average Field Requirement			mm/d			1.25	1.60	2.13	0.82	0	0.2	0.93	3.63	4.27	6.45	6.1	5.4	4.71	3.15	1.9	1	0	0		
26	App. Efficiency Ea	0.6																								

Line Nr	Item		Source	Unit																						
27	Con. Efficiency Ec	0.8																								
28	Irrigation Duty		25/(26*27)	mm/d			2.6	3.32	4.43	1.7	0.00	0.42	1.95	7.56	8.89	13.4	12.7	7.20	9.82	6.56	4.04	2.1	0.0	0		
29	Irrigation Duty		28*0.1157	l/s.ha			0.3	0.38	0.51	0.2	0	0.05	0.23	0.87	1.03	1.55	1.47	0.83	1.14	0.76	0.5	0.2	0	0		
30	Area			ha			10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10		
31	Head Requirement		29*30	l/s			3.01	3.84	5.13	1.97	0.00	0.49	2.25	8.74	10.3	15.55	14.7	8.33	11.4	7.58	4.67	2.42	0.0	0		

6 IRRIGATION SCHEDULING

6.1 NET AND GROSS IRRIGATION WATER REQUIREMENT

6.1.1 Net irrigation water requirement

The net irrigation requirement is derived from the field balance equation:

NIR = ETc - (Pe + Ge + Wb) + LR Equation (6-1)

Where, NIR = Net irrigation requirement (mm)
ETc = Crop evapotranspiration or CWR (mm)
Pe = Effective dependable rainfall (mm)
Ge = Groundwater contribution from water table (mm)
Wb = Water stored in the soil at the beginning of each period (mm)
LR = Leaching requirement

6.1.1.1 Effective dependable rainfall

i. Dependable rainfall

Crop water requirements can be partially or fully covered by rainfall. However, while the rainfall contribution may be substantial in some years, it may be limited in other years. Therefore, in planning irrigation projects, the use of mean values of rainfall should be avoided if more than 10 years of annual rainfall data are available. In such cases, by using these data a probability analysis can be carried out so that a dependable level of rainfall is selected. The dependable rainfall is the rain that can be accounted for with a certain statistical probability, determined from a range of historical rainfall records. It can be, for example, the depth of rainfall that can be expected 3 out of 4 years (75% probability of exceedance) or, better 4 out of 5 years (80% probability of exceedance). A rough indication of rainfall probability can be obtained by grouping the rainfall data and then dividing the number of times that monthly rainfall falls within a group by the number of monthly records.

ii. Effective rainfall

FAO recommends the following formula to estimate effective rainfall.
Pe=0.8P-24 for P>70mm/month or **Pe=0.6P-10** for P<70mm/month Equation (6-2)
Where, Pe = effective rainfall (mm) and P = monthly mean rainfall (mm)
For proper water management effective rain shall be estimated for shorter periods like daily or decadal (see appendix-XII the case of Arata Chufa SSI scheme).

6.1.1.2 Ground water contribution

The contribution of the groundwater table (Ge) to the ETc varies with the depth of the water table below the root zone, the soil type and the water content in the root zone. Very detailed experiments will be required to determine the groundwater contribution under field conditions. As a rule, under most smallholder conditions high water tables are rare and as a result groundwater contribution to crop water requirements is normally ignored.

6.1.1.3 Water stored in the soil

At times, and for certain crops, planting takes place right after the rainy season. Some water (Wb) could be left in the soil from the previous irrigation, which can be used for the next crop. This amount can be deducted when determining the seasonal irrigation requirements.

However, it is important to note that water stored in the root zone is not 100% effective due to losses through evaporation and deep percolation. The effectiveness ranges from 40-90%. In most situations encountered in the planning of smallholder irrigation schemes, the project sites are located in dry areas with very low rainfall. Hence, for planning purposes, the contribution of water stored in the soil is considered negligible in most cases but if soil moisture monitoring facilities are available at scheme level initial moisture stored in the soil shall be accounted for better water management.

6.1.1.4 Leaching Requirement

The salinity in the root zone is directly related to the water quality, irrigation methods and practices, soil conditions and rainfall. A high salt content in the root zone is normally controlled by leaching. An excess amount of water is applied during the irrigation, where necessary, for the purposes of leaching. This excess amount of water for leaching purposes is called the Leaching Requirement (LR).

If mean monthly rainfall is 110mm in September, 21.3mm in October and 15.6mm in November for Onion during initial and development stages then the effective rain is given as:

Pe = 0.8 x 110-24 = 64 mm/month for September
Pe = 0.6 x 21.3-10 =2.78 mm/month for October
Pe = 0.6 x 15.6-10 = -0.64 mm<0 for November

If Ge, Wb and LR are Zero, then knowing the CWR of this period the net irrigation requirement can be computed during this period based on Equation 6-1. Note that the crop water requirement shall be computed for **shorter periods** like daily or decadal to manage water without significant yield loss. Appendix-XII illustrates the crop water requirement for Arata Chufa scheme on decadal base and similar approach can be followed for irrigation scheduling using FAO CROPWAT-8. If Evaporation and rain fall data is available on site Table 5-1 for daily crop water requirement can be used to estimate daily water needs of each field unit. Besides rain fall and evaporation data if soil monitoring facilities like Tensiometers or equipment for gravimetric soil moisture test are available, water application can be accordingly managed based on the initial soil moisture storage condition of the soil.

6.1.2 Gross irrigation water requirement

The gross irrigation requirements account for losses of water incurred during conveyance and application to the field. This is expressed in terms of efficiencies when calculating project gross irrigation requirements from net irrigation requirements as shown below:

Gross irrigation water depth (GIR) $= \frac{NIR}{E}$ **Equation (6-3)**

Where, NIR=Net Irrigation Requirement E = Irrigation efficiency

Irrigation efficiency

The movement of water through an irrigation system, from its source to the crop, can be regarded as three separate operations: conveyance, distribution, and field application.

- Conveyance is the movement of water from its source through the main and (sub) lateral or secondary canals or conduits to the tertiary off takes.
- Distribution is the movement of water through the tertiary (distributary) and quaternary (farm) canals or conduits to the field inlet;
- Field application is the movement of water from the field inlet to the crop.

In some materials the conveyance efficiency is meant to be both the conveyance and distribution efficiency and the two are considered as one. Thus the same indicative values can be considered to fix the distribution efficiency of canals within an irrigation farm. Indicative values of canal conveyance efficiency according to FAO Training Manual 4 for well-maintained canal of different length are as given below:

Table 6-1: Indicative values of canal conveyance efficiency

Canal type	Earthen canals			Lined canals
Soil Type	sand	Loam	Clay	
Canal length				
Long(>2000m)	60%	70%	80%	95%
Medium (200-2000m	70%	75%	85%	95%
Short (<200m)	80%	85%	90%	95%

The field application efficiency (e_a) mainly depends on the irrigation method and the level of farmer discipline. According to FAO Training Manual 4 some indicative values of the average field application efficiency (e_a) are given in Table 6-2.

Table 6-2: Indicative value of field application efficiency

Irrigation method	Field application Efficiency (%)
Surface irrigation (border, furrow, basin)	60
Sprinkler irrigation	75
Drip irrigation	90

A scheme overall irrigation efficiency of 50-60% is good; 40% is reasonable, while a scheme Irrigation efficiency of 20-30% is poor.

Surface irrigation is mostly adapted in farmer managed SSI schemes. It is the application of water by gravity flow to the surface of the field. Either the entire field is flooded (basin irrigation) or the water is fed into small channels (furrows) or strips of land (borders).

The selection of the method of irrigation depends on topography, crop factors, soil factors, level of technological advancement and economy. Whatever irrigation method is being chosen, its purpose is always to attain a better crop and a higher yield. Therefore proper design, construction and irrigation practice are of utmost importance.

Maintenance, the after-care of the system to keep it functionality, is often neglected. This always results in lower irrigation efficiency and thus less benefit from the irrigation system. For further details regarding the choice of irrigation methods FAO training manual-5 can be referred for further readings.

6.2 IRRIGATION DUTY

Irrigation duty is irrigation water requirement expressed as the per hectare water need of multiple crops over the command area. Thus it is Gross Irrigation Requirement divided by the command area. It can be given in mm depth of water /ha, m^3 volume of water/ha or liters per second discharge /ha. It is often given as liter per second per hectare of water.

In the previous sections, it has been explained how to determine the irrigation depth of each irrigation application (in mm) and the interval between two irrigation applications (in days). From these figures it is, however, not easy to visualize the flow rate of Irrigation water to a unit area of irrigation, for example flow rate to one hectare of land. A "rule of thumb" is given to convert an irrigation depth into a continuous water flow to given area of land.

Discharge (flow rate) is Volume of water conveyed per unit of time. For given irrigation depth, volume of water is the depth of irrigation times the area of land. Thus flow rate is the volume of water divided by the time (duration) of irrigation. If irrigation duration of one irrigation event over 1ha is 24hours or 1day then the flow rate per hectare is computed as follows. For instance 8.64 mm/day irrigation application will be:

$$Q = \frac{10{,}000\ m^2/ha * 8.64\ mm/day}{1000*24\ hr/day \times 3600\ seconds/hr} = 0.001 m^3/sec/ha = 1.0\ liter/sec/ha.$$

In other words, an irrigation application of 8.64 mm per day corresponds to a continuous water flow of one liter per second per hectare.

6.3 IRRIGATION INTERVALS

Understanding the basic concept of Soil-plant-water and atmosphere relation is critical component in proper planning and management of irrigated agriculture. The crop type, variety and development stage should be considered when assessing the evapotranspiration from crops grown in large, well-managed fields. Differences in resistance to transpiration, crop height, crop roughness, reflection, ground cover and crop rooting characteristics result in different ET levels in different types of crops under identical environmental conditions..

Factors such as soil salinity, poor land fertility and limited application of fertilizers, the presence of hard or impenetrable soil horizons, the absence of control of diseases and pests and poor soil management may limit the crop development and reduce the evapotranspiration.

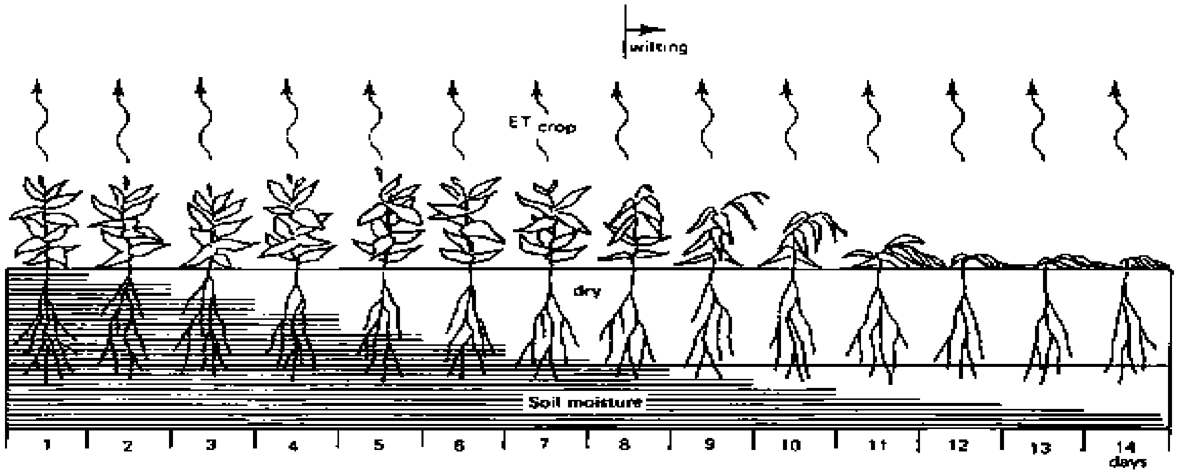


Figure 6-1: Situation of plant under no irrigation or rain

In Figure 6-1 it can be seen that, on this soil, the plants start to suffer after approximately one week. Irrigation water should be given before this happens, in order to allow for optimal production. In general this means that irrigation should at the latest take place when approximately half of the available water content of the root zone has been used by the plants. When, for example (Figure 6-2), irrigation water is given on day 5, on day 9, on day 13, etc., the plants will not suffer from water shortage.

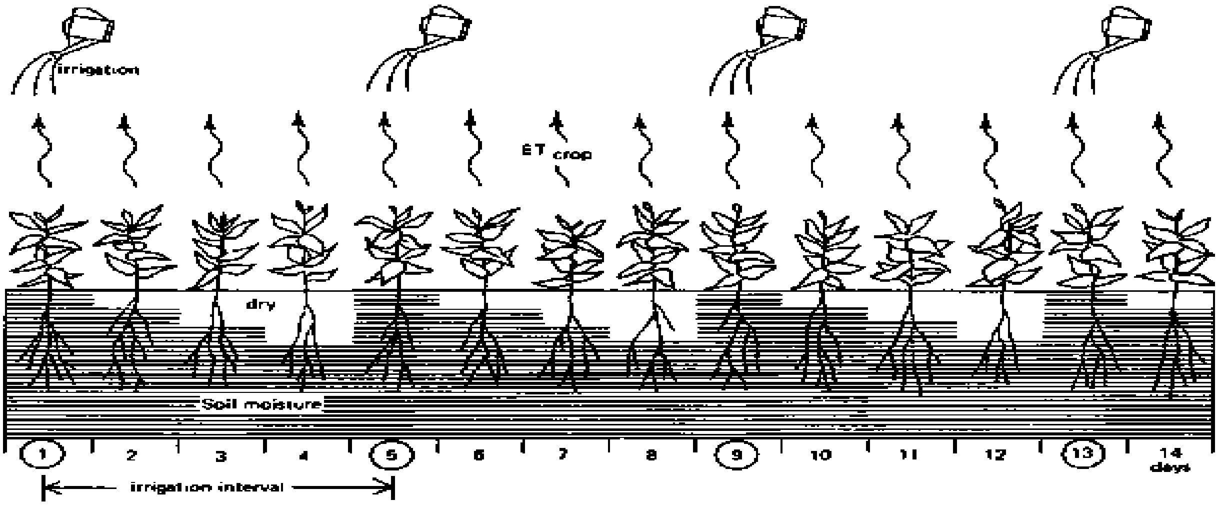


Figure 6-2: Irrigation application in intervals

The amount of irrigation water which can be given during one irrigation application is however limited**.** The maximum amount which can be given has to be determined and may be influenced by: The ***soil type***, ***root depth*** and ***irrigation method***.

The ***soil type*** influences the maximum amount of water which can be stored in the soil per meter depth for instant sand can store only a little water or, in other words, sand has low available water content. On sandy soils it will thus be necessary to irrigate frequently with a small amount of water. Clay has high available water content and hence on clayey soils larger amounts of water can be given less frequently.

Table 6-3: Typical values for the available water for different soil textures

Soil Type	Soil Texture	Available Water (AW)	
		mm/m	%
Heavy	Clay	120-200	12-20
	Silty clay	130-190	13-19
	Silty clay loam	130-180	13-18
Medium	Silty loam	130-190	13-19
	Loam	130-180	13-18
	Sandy loam	110-150	11-15
	Loamy sand	60-120	6-12
Light	Sand	50-110	5-11

Source: Field Guide on Irrigated Agriculture for Field Assistants, IPTRID (FAO), Report No.1, April 2001

Different crops have different management effective root depth and allowable depletion factor (P). In addition to crop water and irrigation requirements and soil, the root zone depth is the third parameter to be considered when preparing irrigation schedules. Like allowable soil moisture depletion, the root zone depth is another area of interesting controversies. Published data on the depth from where the crops extract most of their water differ greatly. As a rule, for most field crops

40% of the water uptake takes place from the first quarter of the total rooting depth, 30% from the second quarter, 20% from the third quarter and 10% from the fourth quarter. Agronomy guideline provides data on root zone depth and allowable soil moisture depletion levels for different crops.

It is also advisable to know:

- the crops which suffer most from water shortages; i.e. crops that will have severe yield reductions when the water is in short supply;
- growth stages during which the various crops suffer most from water shortages.

Of course, also other factors, such as, for example, the economic value of the crops may influence the decision on how best to divide the scarce water.

In general, crops grown for their fresh leaves or fruits are more sensitive to water shortages than those grown for their dry seeds or fruits.

The *three basic components* of a scheme schedule are:

- The delivery flow rate to the various canals within the system (***how much***)
- The delivery frequency or timing of the deliveries (***when***)
- The duration of the deliveries (***for how long***)

The schedule selected is a function of delivery system flexibility and farm irrigation requirements. The more flexible on-demand irrigation delivery systems may allow the farmer to specify ***flow rate, irrigation frequency*** and/or ***duration*****.** The more rigid ones, such as rotational systems, may have severe restraints on any of the components.

Characteristics of some scheduling variations are described below:

a. Rigid schedules

This schedule is usually *predetermined* by the scheme *bylaws, scheme policy, or other means*. The schedule is often determined before the start of the irrigation season-based on historical crop water requirements, or simply by allocating expected water supplies proportionally to land ownership or other criteria. Some kind of rotational schedule is usually implied. Capital costs are the least with this type of schedule, as canals and structures are designed for continuous supply at peak demand periods.

b. Rotational schedules

Fixed rotation

This schedule implies a *fixed flow rate*, *fixed irrigation frequency* and *fixed duration*. It is a type of fixed interval fixed amount schedule. Intervals are, for example, weekly, bi-weekly or monthly. The irrigation interval and amount are often determined by the peak use period on a scheme. The average allowable depletion (P) at peak use periods, along with application and distribution efficiencies, determines the amount of water delivery. This type of schedule is easy to administer from a schematic point of view. Very little communication, planning, or monitoring is required as compared to other systems.

Canals are easy to design and operate for the fixed flow rate and durations. However, except at peak, the supply does not equal demand and efficiencies are low early and late in the season. The excessive water applied early and late in the season may result in nutrient leaching, waterlogging, and salinity problems. Since cropping patterns, soils, and even climatic conditions may vary widely in a scheme, fixed rotation schedules are seldom adequate, even during peak demand periods.

Varied frequency rotation

In this *variable interval*-fixed amount scheduling method, flow rate and irrigation duration remain constant but the irrigation frequency is modified. This type of schedule represents a significant improvement over the fixed rotation type. The *interval is generally varied* in accordance with the changing water use of the crops in the scheme. For example, irrigations may be scheduled to occur when a fixed average deficit has built up in the scheme area. Mono-crop and perennial crop schemes are ideally suited for this type of schedule, provided that soils and climatic conditions in the scheme are similar. The method is suited to deep-rooted crops and soils with high water-holding capacities. Some advantages of this system are that irrigation systems (especially surface systems) are easily designed and operated for a fixed or constant depth of water application. High efficiencies are possible in early and late season (in contrast to the previous method). The disadvantages of this method are that schemes with a variety of crops, planting dates and soil types may not permit the efficiency benefits to be realized without severe consequences for yields. Even with uniform crops and planting dates, such a schedule may result in problems during germination and crop emergence unless additional irrigations are planned to insure germination and plant emergence (for example, in the case of soil crusting).

This method does not account for changing soil water reservoir or sensitivity of crops through the season. Improved communications between the irrigation management committee and water bailiffs and farmers is required.

Varied rate rotation

In this type of fixed interval-variable amount scheduling method, irrigation frequency and duration are fixed and the flow rate is varied to approximate seasonal demands. Mono-crop or perennial crop areas with deep uniform soils are best suited for this schedule. As with the varied frequency system, this method may result in greater efficiencies than with fixed rotations, as over-applications early and late in the season are minimized. However, small stream sizes are often difficult to manage in farm and scheme canals. Flow control structures must be capable of adjustment to the required rates. As surface irrigation systems are most efficiently operated for fixed application depths, this may also present a problem for farm-level management. The farmer must generally become a better water manager to deal with the efficient application of variable rate and amounts. Again, communication from the irrigation management committee down to farm-level must be adequate.

Varied duration rotation

In this fixed interval-variable amount scheduling method, the flow rate and frequency are fixed, but delivery durations vary through the season in tune with irrigation demands. Again, conditions should be similar through the scheme in terms of crops and soils. Flow rates are constant and manageable from farm to scheme levels. For surface irrigation systems, which can best be operated by applying a fixed depth of water, farmers may be able to irrigate only part of their farm at any one delivery. They must learn to sequence their irrigations between different fields and crops as the need arises. If the farmers learn to manage their variable durations, significant improvements in efficiency may result early and late season without adverse yield consequences. Communicating the irrigation durations down to farm-level is a key element in this approach.

Varied frequency and rate rotation

In this variable interval-variable amount scheduling method, only the irrigation duration is fixed and the intervals are varied in tune with crop water needs. In theory, this method would result in high efficiencies and high yields, as the crop's needs should be matched in terms of both timing and amount. However, this requires similar crops and conditions throughout the scheme area if frequency and rate are to be varied similarly throughout the scheme. It requires increased sophistication by the farmers, whose crops must fit a scheme pattern. They must also have the flexibility and knowledge to allocate water deliveries in time, place and amount on their farm. Gates and control structures must be capable of handling variable flow rates. Increased communication is required from scheme to plot level.

Varied duration and rate rotation

This fixed interval-variable amount scheduling method sets only the irrigation frequency. This method should theoretically, result in high efficiencies. It would, however, result in adverse yield consequences, except with perennial or mono-crop systems, or perhaps with deep-rooted crops on soils with high water-holding capacities. This system has the same limitations as the varied rate or duration systems. Flow structures must be capable of handling variable rates. It is difficult to plan and administer this schedule at scheme-level.

The farmer must have a flexible farm system in terms of application depths, and must have the knowledge to apply water in tune with crop requirements if the duration and rate are to be dictated at scheme-level. Again, good communication from scheme to farm-level is required.

Varied duration and frequency rotation

This combination results in a variable interval-variable amount schedule, which is theoretically in tune with scheme crop water requirements. Frequencies should be established with respect for the crop's requiring the shorter intervals, if possible. Again, similarity in cropping patterns and soils between various parts of the scheme is important.

The fixed rate allows fixed-rate delivery structures to be efficiently operated. Efficiencies can be maximized throughout the season if the farmers can develop the flexibility and knowledge to apply variable depths, or to allocate the available water to their various crops and fields throughout the season. This method also requires very good communication from scheme to farm/plot-level.

c. Flexible schedules

In a flexible schedule, the farmer has control of one or more of the three scheduling components. The degree of flexibility is dependent on the system design and the management capabilities at scheme-level. Compromises between the farmers' needs and capabilities of the delivery system are generally required. On the systems with greatest flexibility, over-sizing of canals, offline reservoirs, and automation may be required to meet demand and to avoid spillage and overtopping. On the less flexible systems (for example, restricted/arranged), the main requirements are adequate system capacities and control, along with good communication between farmers and water authorities.

d. On-demand irrigation

On-demand irrigation imposes no limits on rate, frequency, or duration of water delivery. This type of schedule implies that the water authorities impose no external controls on the water use. The system capacity is designed based on certain assumptions, for example the probability that maximum 85% of the farmers irrigate at the same time. Although this system is often ideal from the farmer's point of view, sometimes the economics of scheme implementation cannot justify such a system.

Variations of on-demand irrigation, used mostly with pressurized systems, can improve the economics of such systems. For example, limits are sometimes imposed on the flow rate and the pressure. Also at times the probability level can be based on a small group of farmers rather than individual farmers. Farmers would then be expected to rotate irrigation among themselves within each group. Such an arrangement would then be considered as a combination of a flexible and a rigid schedule.

The accurate determination of an irrigation schedule is a time-consuming and complicated process. The introduction of computer programs, however, has made it easier and it is possible to schedule the irrigation water supply exactly according to the water needs of the crops. Ideally, at the beginning of the growing season, the amount of water given per irrigation application, also called the irrigation depth, is small and given frequently. This is due to the low evapotranspiration of the young plants and their shallow root depth. During the mid-season, the irrigation depth should be larger and given less frequently due to high evapotranspiration and maximum root depth. Thus, ideally, the irrigation depth and/or the irrigation interval (or frequency) varies with the crop development.

When sprinkler and drip irrigation methods are used, it may be possible and practical to vary both the irrigation depth and interval during the growing season. With these methods it is just a matter of turning on the tap longer/shorter or less/more frequently.

When surface irrigation methods are used, however, it is not very practical to vary the irrigation depth and frequency too much. With, in particular, surface irrigation, variations in irrigation depth are only possible within limits. It is also very confusing for the farmers to change the schedule all the time.

Therefore, it is often sufficient to ***estimate or roughly calculate*** the irrigation schedule and to fix the most suitable depth and interval; in other words, to keep the irrigation depth and the interval constant over the growing season.

Common approaches of irrigation scheduling:
There are various ways of irrigation scheduling that is plant observation method, soil observation method, Schedule based on CWR calculation, estimation method and simple calculation method. In this guide line **Soil observation method** and **schedule based on CWR calculation** are discussed in detail.

6.3.1 Irrigation scheduling by Soil Observation

Soil moisture status can be determined based on observation and feel of soils. Table 6-4 provides general indication of soil moisture status of different soil textures.

Table 6-4: Soil Feel Test

Depletion of available soil moisture in % of FC	Feel or appearance of soil and moisture deficiency of water per meter of soil (mm)			
	Coarse texture	Moderately coarse texture	Medium texture	Fine and very fine texture
0	Upon squeezing no free water appears on soil but wet outline of ball is left on hand (0.0)	Upon squeezing no free water appears on soil but wet outline of ball is left on hand (0.0)	Upon squeezing no free water appears on soil but wet outline of ball is left on hand (0.0)	Upon squeezing no free water appears on soil but wet outline of ball is left on hand (0.0)
0-25	Tends to stick together slightly, sometimes form a week ball under pressure (0 – 17)	Forms weak ball, breaks easily, will not stick (0 – 34)	Forms a ball, is very pliable, slicks readily if relatively high in clay.(0 – 42)	Easily ribbons out between thumb and forefinger (50-100)
25-50	Appears to be dry, will not form a ball under pressure (17-42)	Tends to ball under pressure but seldom held together (34-67)	Forms a ball somewhat plastic, will slick slightly with pressure (42 – 83)	Forms a ball, ribbons out b/n forefinger &thumbs (50- 100)
50-75	Appear to be dry, will not form a ball with pressure (42- 67)	Appear to be dry, will not form a ball (67 -100)	Somewhat crumbly, holds together form pressure (83-125)	Somewhat pliable, will ball under pressure (100- 158)
75-100 (PWP)	Dry, loose single grained flows through fingers (67-83)	Dry, loose flows through fingers (100-125)	Powdery dry sometimes slightly crusted but easily broken down (125-167)	Hard baked cracked, sometimes has loose crumbs on surface (158 – 208)

Another method used to determine the irrigation schedule involves soil moisture measurements in the field. When the soil moisture content has dropped to a certain critical level, irrigation water is applied. Instruments to measure the soil moisture include gravimetric method, gypsum blocks, tensiometers and neutron probes. The standard pressure for field capacity (FC) is 0.33bar while for permanent wilting point (PWP) is 15bars.

6.3.2 Irrigation Scheduling Based on CWR Calculation

The following parameters will be required to determine irrigation scheduling:

- Cropping Program
- Daily water requirements of the crops (ETc) at the different stages of their growth
- Root zone depth at the different growth stages of each crop (RZD)
- Total available Soil moisture (Sa)
- Allowable soil moisture depletion level (P)
- On-site rainfall data

The cropping program provides the different crops, their rotation and the time of planting and harvesting. The ETc of each crop can be computed by CROPWAT program. The RZD of each crop at the different stages of growth can be derived preferably from local information. As explained earlier, the level of P depends on the crop and its stage of growth as well as on the soil type and irrigation system. The Sa is usually determined through laboratory analysis during the soil surveys. A rain gauge would also be required on site to record the daily rainfall received.

Irrigation frequency and duration have to be calculated for each crop of the existing cropping pattern and a sound irrigation schedule has to be put together in order to irrigate all crops at the time and for the duration they require water.

Once the irrigation schedule is known, simplifications can be introduced in order to make the schedule practical and *'user-friendly' for the farmers*, for example irrigation intervals and irrigation duration can be made uniform over a period of 14 days or a month. This is particularly important in smallholder irrigation schemes where a number of small farmers are involved, living at some distance away from the scheme. If they know the irrigation schedules for the rest of the month, they are in a better position to organize their work, household tasks and family life accordingly.

The rainfall can be taken into consideration at the time the irrigation schedule is applied. By using a *rain gauge* and by recording the amount of rainfall on a daily basis, this amount can be weighed against part of, or one or more irrigation applications. Therefore, the irrigation cycle is interrupted and a number of days are skipped, depending on the amount of rainfall, the daily water requirements and the moisture to be replenished in the root zone depth of the soil.

Irrigation Interval (frequency) is defined as the frequency of applying water to a particular crop at a certain stage of growth and is expressed in days. In equation form it reads:

$$II = \frac{Sa \times P \times RZD}{ETc} \qquad \textbf{Equation (6-4)}$$

Where: II = Irrigation interval (days)
Sa = Total available soil moisture (= FC – PWP) (mm/m)
P = Allowable depletion (decimal)
RZD = Effective root zone depth (m)
ETc = Crop evapotranspiration or crop water requirement (CWR) (mm/day)

Example

Consider onion whose average crop water requirement is 4.6 mm/day during its mid-season stage. The total available moisture of the soil is 160 mm/m, the root zone depth is 0.6 m and the allowable depletion level is 35%. How often should irrigation be applied?

$$\text{Irrigation Interval (II)} = \frac{Sa \times P \times RZD}{ETc} = \frac{160 \times 0.35 \times 0.6}{4.6} = 7.3 = 7 \text{ days}$$

7 WATER DISTRIBUTION PLAN AND DELIVERY

7.1 IRRIGATION SYSTEM LAYOUT PLAN AND INFRASTRUCTURES

Irrigation system layout plan is very critical element for proper scheme operation, maintenance and management. It is usually carefully prepared or designed under consideration of all management aspects of the scheme. As-built system layout plan is prepared including:

- Total available water from source and updated total water abstraction (m^3/s)
- Total area, net command area, area of each block, tertiary unit and field unit
- List of beneficiary in each block, tertiary unit and field unit
- Irrigation methods and irrigation hours adopted
- Updated cropping calendar and irrigation demands
- Water distribution scenario and water allocation to each block, tertiary unit and field unit.

Irrigation infrastructures are all facilities related to irrigation water supply to the system, drainage facilities and road networks within the system. The irrigation system consists of (main) intake structure or (main) pumping station, a conveyance system, a distribution system, a field application system, and a drainage system.

The (main) intake structure, or (main) pumping station, directs water from the source of supply, such as a reservoir or a river, into the irrigation system. The conveyance system assures the transport of water from the main intake structure or main pumping station up to the field ditches. The distribution system assures the transport of water through field ditches to the irrigated fields. The field application system assures the transport of water within the fields. The drainage system removes the excess water (caused by rainfall and/or irrigation) from the fields.

Different hydraulic structures are storing, measuring, regulating and distributing the flow of water to the various parts of the irrigation system. They can be simple temporary constructions (earth plugs, stones, branches) or more permanent and durable structures with gates or other regulating devices. The structures play a very important role in the effective control of water flow in the right quantities.

All the irrigation infrastructures constructed as per design or modified during construction phase has to be re-drawn under constructed conditions and **as-built system layout plan** will be prepared. All infrastructures have to be clearly indicated on the as-built layout plan. All canals have to be reviewed based on actual constructed conditions and as-built drawing for all supply and drainage canals has to be prepared. As-built drawings for the relevant structures on system layout have to be prepared with actual locations, dimensions and orientations in the system.

The as-built drawing of the scheme with scheme operation and maintenance manual is submitted to the users, implementing agency and all supporting institutions. Thus any completed irrigation scheme shall have the following before handover:

- Standard office for IWUA, (construction camp is usually transferred to IWUA).
- Illustration board describing name of the project, location of the project, hectares, discharge at intake, number of beneficiary, implementing organizations, financing organization, budget, year of construction and the like.

አራጣ ጩፋ አ.መ.ፕሮጀክት	ARATA CHUFA SSI PROJECT
የሚለማ መሬት-100ሄ	-Total Irrigable Area=100ha
ተጠቃሚ ብዛት-317 አ.ወ	-Total Beneficiary=317HH
ቦታ-አርሲ ዞን ዝዋይ ዱግዳ ወረዳ አራጣ ቀበሌ	-Location: Zone-Arsi Wereda- Ziway Dugda Kebele-Arata
የዉሃ መጠን-100ሊ/ሰ	-Intake Discharge 100l/s
የዉሃ ምንጭ-ጩፋ ወንዝ	-Source of Water =Chufa River
የግድብ ዓይነት-Weir	-Type of headwork=Weir
አማካይ ከፍታ-1700ሜ ባ.ወ.በ	-Average Altitude=1700m a.s.l
የግንባታ ጊዜ-1985	-Year of construction-1993/94 GC
የገነባዉ-አርሲ ዞን የተ.ሀ.አ.ጥ	-Constructed by: Arsi Zone NREP
የገንዘብ ምንጭ- IFAD	-Financed by: IFAD
የሕብረተሰብ ተሳትፎ- 10%	-Share of community=10%

Figure 7-1: Example of scheme illustration board (Arata chufa SSIP)

- As-built drawing album for all irrigation infrastructures including flow measuring facilities.
- Operation and maintenance manual for the specific scheme that shall incorporate operation procedures and instructions, representative cropping calendar, water distribution and management plan, maintenance plan, all organization aspects of IWUA, finance management, conflict management, record and book keeping systems, reporting systems, and management aspects for watershed, drainage, crop, soil and overall monitoring and evaluation systems.
- Clear as-built layout plan prepared in graphics (banner) of size at least 3mx3m and more preferably representation with models showing all the irrigation infrastructures. The model for an approved as-built irrigation system is constructed to help the farmers understand the scheme layout and location of plots and all facility which ensures easy understanding and management.

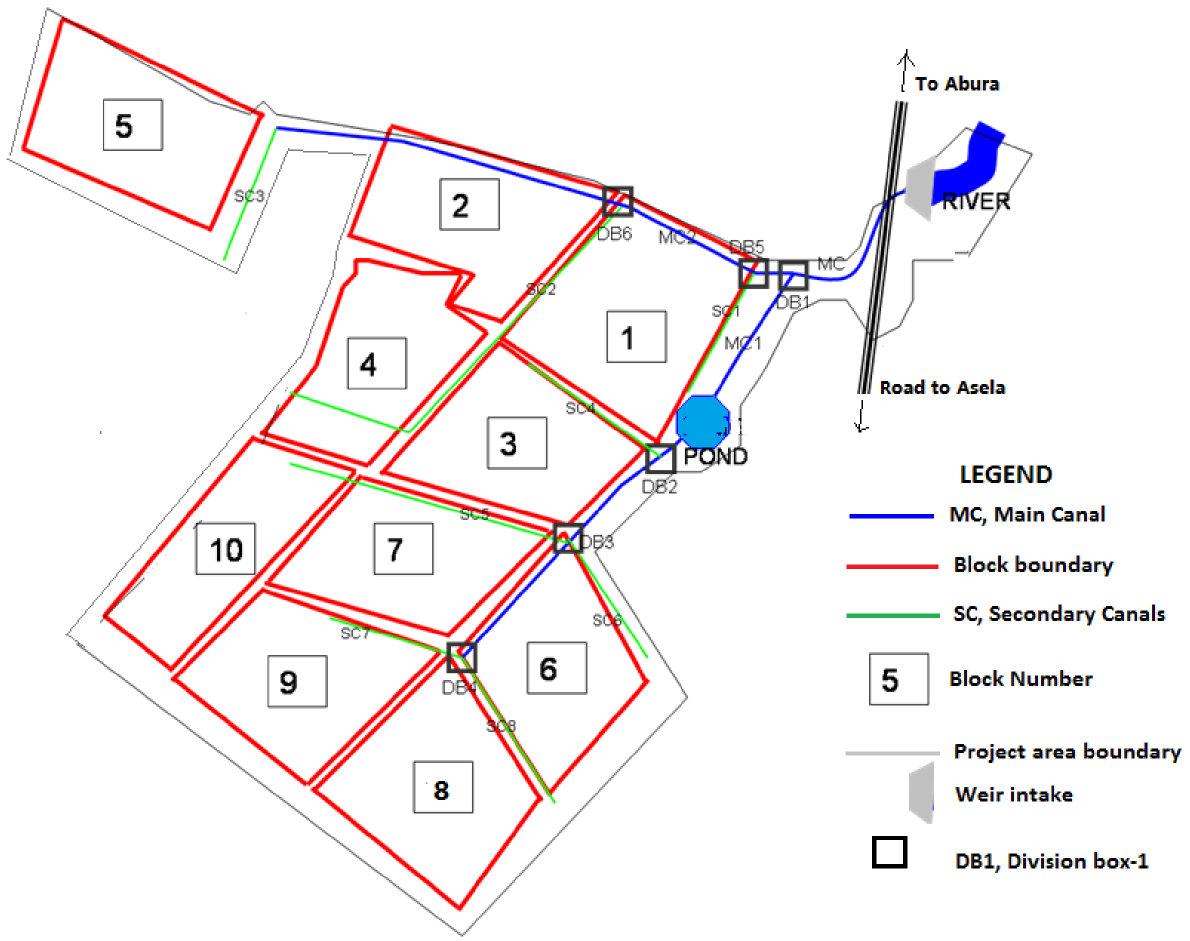


Figure 7-2: Example of as-built layout plan of scheme (Arata chufa scheme)

The system layout plan must indicate all irrigation infrastructures listed as below which depends on specific site conditions:

The headwork and related structures

Any hydraulic structure which supplies water to the off-taking canal is called a headwork. A headwork can be classed as storage and diversion headwork. In small-scale irrigation the headwork can be simple intake structure, weirs, barrages, small dams and pumping facilities.

Diversion headwork comprises of the following structures:

- The weir or barrage
- Divide wall or divide groyne
- Fish ladder
- Pocket or approach channel
- Silt control facilities
    - Scouring/ under sluices
    - Silt excluder
    - Silt extractor
    - Silt ejector
- Canal head regulators
- River training and flood protection works
    - Dyke
    - Marginal bunds and guide walls/ banks

- Seepage and uplift control facilities
  - Cut-off structures
  - Apron floors
- Flow measuring structures
  - Sharp crested or broad crested weirs with calibrated gauge
  - Flumes with calibrated gauge
- Main conveyance system or main supply canal
- Secondary conveyance system or secondary supply canal
- Tertiary conveyance system or tertiary supply canal
- Field supply systems
- Main drainage system
- Secondary drainage system
- Tertiary drainage system
- Field drainage systems
- Road networks
- Farm structures

7.2 WATER DELIVERY SCHEDULE

In SSI schemes the farmers should form an Irrigation Management Committee (IMC) or Irrigation Water User's Association (IWUA) to act as the contact between them and other stakeholders. The IWUA must have a clear annual operation plan of the scheme (Figure 7-3). This annual operation plan ***must be approved by Woreda irrigation office*** and thereby follow the achievements of the scheme based on the approved plan. IWUA or committees operate based on by-laws established and adopted by the farmers during general meetings, and also oversee the operation and maintenance of the irrigation infrastructure under the guidance and support of implementing agency.

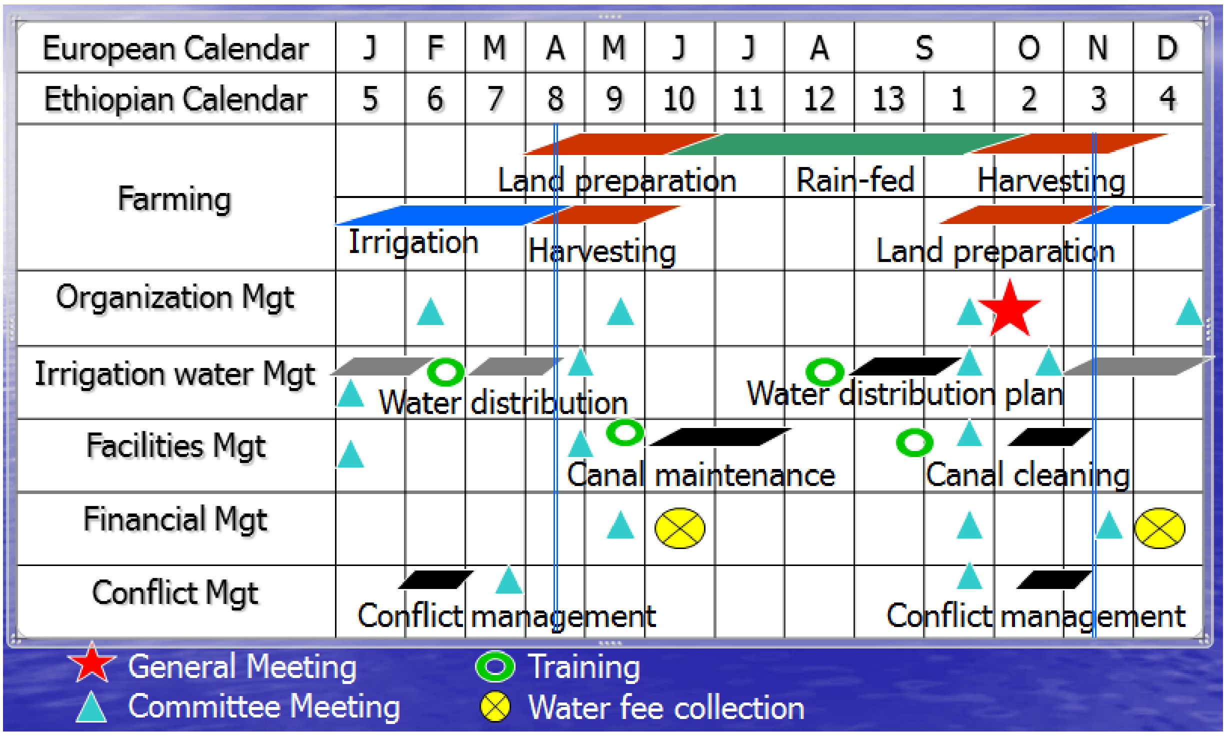


Figure 7-3: Sample annual operation plan of IWUA

The operational procedures for an irrigation system are effectively enhanced by adopting a step-by-step set of procedures for recording, reporting and directing operation for the delivery of designed discharges which are representative of the planned crop water (irrigation) requirements. Crop water requirement is dependent on cropping calendar. Always it is essential to revise the crop water requirement based on actual site conditions. The general principle of water management within an irrigation system is elaborated by Figure 7-4. The first issue is **water availability** to set cropping plan then after crop demand is computed and compared with the available flow. If demand exceeds the supply, revision of cropping area and/or crop types is essential. In all cases significant yield loss must be avoid in the cropping plan.

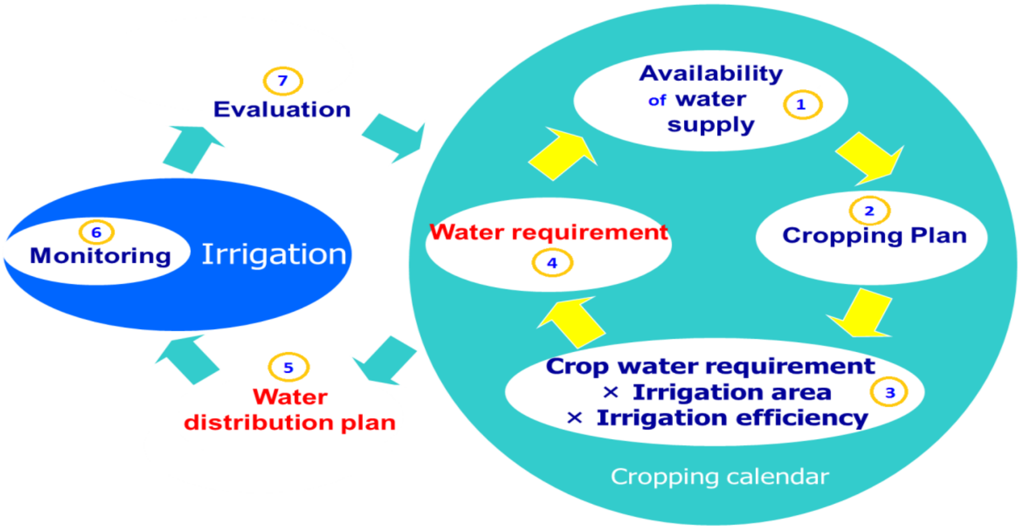


Figure 7-4: Principle of water management within the system

The step-by-step procedure for the operation of gates (Water Management) in SSI schemes:

Step 1: The Scheme IWUA in the presence of technical personnel from irrigation authority (*Irrigation Engineer/ technician*) shall ratify and update annual operation plans of the specific irrigation scheme this plan will be based on initial agreement on the cropping plan. All water users must be aware of the operation plan. The water distribution plan shall be clearly prepared based on adopted cropping plan. Water allocation plan can be based on **land size and/or crop type**.

Step-2 The IWUA chairperson, after having the Annual Irrigation Operation Plan ratified (officially approved) by the respective irrigation authority, notifies the water Management Committee (WMC) with plan of water allocations to each block, tertiary unit and field unit with accepted cropping pattern, planted area and gross irrigation needs, gate and canal discharges. This is always updated based on request (demand) from each field unit or individual farmers to attain crop water needs. The chain of command for all water management activities is Individual farmer →Field Unit Leaders (FUL) →Tertiary Unit Leaders (TUL) →Block leaders (BL) →WMC→IWUA →General Assembly.

Authorized personnel from irrigation development Authority assist operation activities of the scheme at all levels. The chain of command for supporting institution or Irrigation Development Authority (IDA) will be: Irrigation engineer or technician assigned for the scheme → Woreda Irrigation Development Authority (WIDA) → Zone Irrigation Development Authority (ZIDA) → Regional Irrigation Development Authority (RIDA)

Step 3: The WMC and irrigation technician then informs all gate keepers with the respective flow rates, gate discharges and canal discharges for all blocks, tertiary units and field units.

Step 4: The gate keepers shall be well trained on gate operation and discharge measurements to each unit of land. They have to clearly understand the annual operation plan- irrigation ***intervals***, ***timings***, ***flow rates***, and how to control water using the Gate and "Head VS Discharge" curves of measuring structures facilitated in the system. The gate keepers must understand the as-built layout plan of the specific scheme and land holding as well as location of plots of each member of the IWUA in the layout plan.

Step 5: The gate keepers must ***duly record*** the water allocation to each farm unit.

Step 6: The water allocation varies with crop growth stage and planning is based on timely demands of each farm unit. Flow measuring devices well calibrated must be installed at all points to control the discharge and the discharge versus gate opening level must be given to the gate keepers. The gate keepers will make daily records on the water allocated to each farm unit and must weekly report to WMC and the WMC shall report to IWUA and relevant irrigation Authority ***every month***.

Step 7: The IWUA and relevant irrigation authority will evaluate the allocation as per the operation plan set and make the necessary mitigations for proper water management till end of crop season.

Step 8: At the end of each crop season the IWUA shall evaluate the performance of the Water Management Committee (WMC) and other scheme management teams. Monitoring and evaluation mechanism on scheme performance has to be well established and evaluation formats for water management will be used.

Step 9: After evaluation of the past seasonal performance the scheme operational plan will be revised or new plan will be prepared based on lessons learned. At the same time ***seasonal fee collection*** will be done.

7.3 WATER DISTRIBUTION PLAN

The water distribution plan follows the overall scheme objectives and operational objectives of the main system. This is usually decided by the IWUA under consultation of supporting institution.

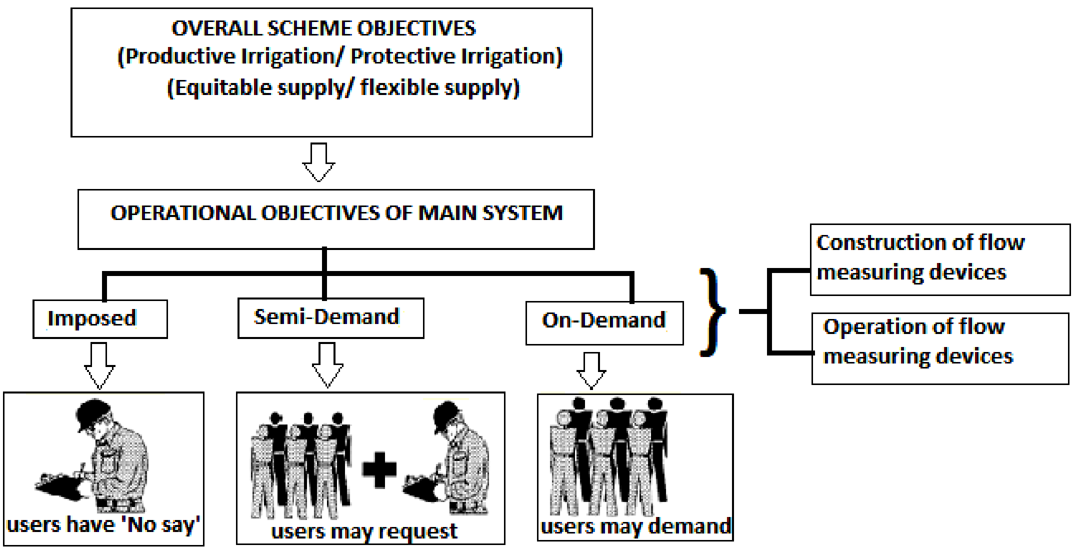


Figure 7-5 Overall scheme objectives and operational objectives of the main system

The objective of protective irrigation is famine relief by supplying water during droughts while productive irrigation is commonly applied on a 'supplementary' basis. Various ways are followed to supply water to the fields.

For instance water flowing in a secondary irrigation canal can be divided over the tertiary canal network in several ways. One way is to *divide the flow proportionally* over these tertiary canals; another is to *divide the time of supply* and thus to divert the flow to each tertiary canal in turn; and a third way is to supply a tertiary canal with water *upon request*.

The same three options apply to the flow in the main irrigation canal regarding its distribution over the secondary canals of the system: *proportional distribution*; *rotational distribution*; or *delivery on demand*. The different methods of water distribution require different structures, and how to deliver a fixed discharge to a canal, and what types of off-takes are commonly used for water supply to a branch canal.

a. Proportional distribution

Proportional distribution of irrigation water means that flow in a canal is divided equally between two or more smaller canals. The flows in these canals are proportional to the areas to be irrigated by each of them. Each canal is given a portion of the flow. These portions correspond to the portion of the total area which is irrigated by that canal. This is considered in next example, in which the flow in a main canal is divided among three secondary canals.

Example 1: What discharges should be given to the secondary canals under the following conditions of site A? Figure 7-5 below:

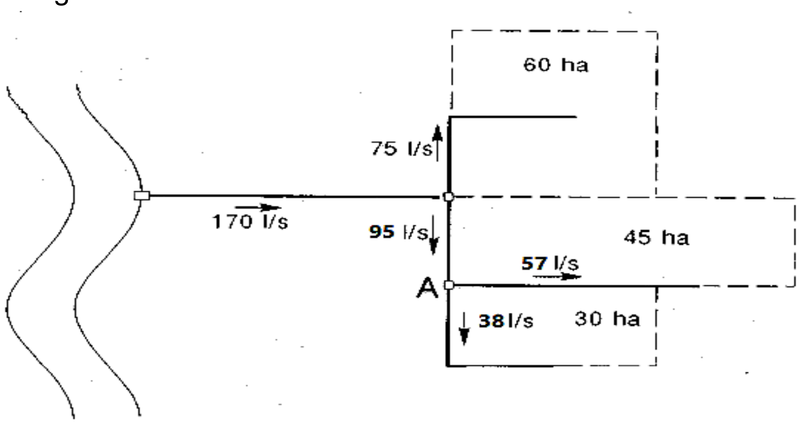


Figure 7-6: Flow divided proportionally

- The discharge in the main canal is 170 l/s.
- It is to be divided among the three secondary canals in proportion to their command areas.
- The command areas of the secondary canals are 60 ha, 45 ha and 30 ha.

The total area commanded by the secondary canals is 60 + 45 + 30 = 135 ha.

- The first canal will receive 60/135 of the 170 l/s flow, i.e., (60/135) x 170 = 75 l/s.
- The second will get (45/135) x 170 = 57 l/s.
- The third will get (30/135) x 170 = 38 l/s.

Note: The discharges in the three secondary canals are proportional to the three command areas, i.e., 75:57:38 = 60:45:30. However, these theoretical values for the discharges in the three canals will be difficult to obtain in practice, and the actual discharges would be rounded to 70, 60 and 40 l/s. Thus **calibrated flow measuring device** is needed at each division to check proportionality of the flows.

Example 2: A proportional division structure has to be facilitated for site A in the scheme shown in Figure 7-6. This structure should divide the available flow between the two canals in proportion to their respective command areas.

One canal commands an area of 45 ha, the other an area of 30 ha. A two-way flow division structure is to be used, and the separation wall will have to have a width of 0.15 m. The total available canal width at the site of construction is 0.95 m. See Figure 7-6.

How large should the canal openings be made for each command area?
The total width that is available for the flow is 0.95 - 0.15 = 0.80 m.
The total area commanded by the two canals is 45 + 30 = 75 ha. The larger canal should therefore receive 45/75 of the total; the other canal should get the other 30/75.

The openings of each canal should be proportional to their command areas. Therefore the larger canal opening should be (45/75) x 0.80 = 0.48 m wide, while the other opening should have a width of (30/75) x 0.80 = 0.32 m.

Note 1: One should remember that smaller or greater widths have a direct impact on the proportionality of the flow division.

Note 2: This calculation is only valid if the structure has a flat and level floor. Therefore care must be taken to make the floor horizontal when constructing it. If the bed of the structure is not horizontal, the division of the flow is determined not only by the difference in bed width, but also by the difference in water level.

Note 3: Care must also be taken to maintain the structure properly. If one of the flows is blocked by plant growth, silt or rubbish, the division will no longer be proportional to the width of the openings and hence to the areas served.

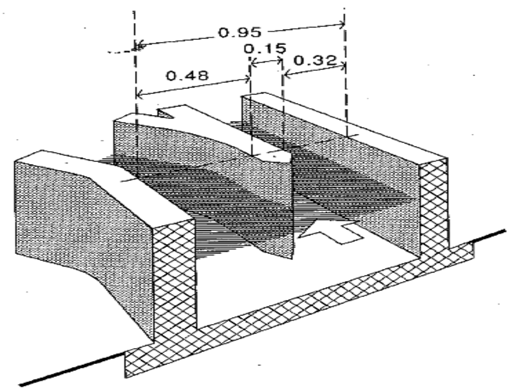


Figure 7-7: Diagram for calculation of proportional flow division

The portion of the time during which a branch canal carries water is proportional to the area served by that canal. This is illustrated in Example-3, which should be considered together with Example-1.

b. Rotational Distribution:
Rotational distribution of irrigation water means that the whole flow in an irrigation canal is diverted to the branch canal in turn. For instance, in the case of primary and secondary canals, it means that

each secondary canal is without water for part of the time and, when supplied, it transports the whole “primary” flow. The same can apply to the distribution of the flow of secondary canals into tertiary canals, and rotational distribution can be carried out within the tertiary canals.

Example-3:
How many days during each period of 7 days will each secondary canal receive water under the following conditions? (See Figure 7-7)

- The continuous flow in the main canal is to be diverted in turn to three secondary canals.
- The command areas of the secondary canals are 60 ha, 45 ha and 30 ha.

The flow in the main canal is given to the whole scheme, which has a total area of 60 + 45 + 30 = 135 ha. Each secondary block will receive the entire flow for a period within the 7 days that is proportional to its command area. The first secondary canal serves an area of 60 ha. It will carry the full flow for (60/ 135) x 7= 3 days in every period of 7 days. Similarly, the other canals will carry water for 45/135 x 7 = 2½ days, and (30/135) x 7 = 1½ days respectively in each period of 7 days.

NOTE: In this example the portions of a period that a branch canal carries the whole flow have been calculated. The first secondary canal carries the full flow for 3 days in every 7 days, but this does not mean that the irrigation interval in the fields is 7 days. This interval depends on soil type, crop, growth stage and rate of evapotranspiration. If the irrigation interval is 7 days, then the canal can be given the whole flow for 3 consecutive days. If the interval is 14 days, then the first secondary canal may carry water for 6 consecutive days, and then be dry for the other 8 days of the 2-week period.

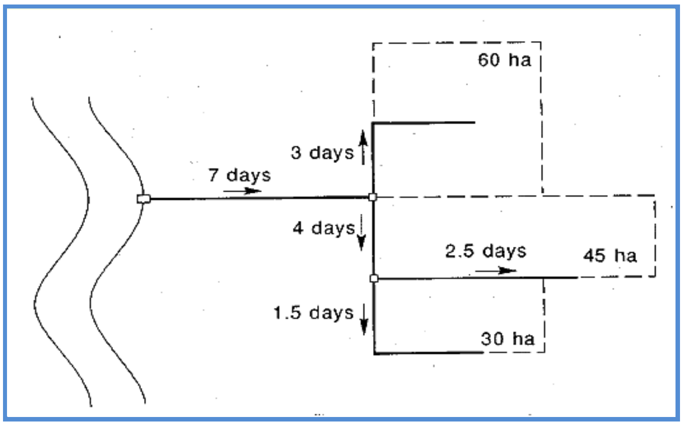


Figure 7-8: Supply time divided proportionally

Canals that are supplied with water according to a rotation schedule or on an ‘on demand’ basis must be equipped with gates at the off-take. As can be seen, the whole flow can either be directed to a branch canal at the division box, or the flow continues down the main canal for diversion at a subsequent point. Therefore, under rotational distribution, a canal which receives water should have the same capacity as the supply canal, as flow is not divided. In Example-3, each secondary canal should have a capacity of 170 l/s, which is equal to that of the main canal.

c. Delivery on Demand:
Instead of water delivery based on areas, as in proportional or rotational supply, delivery can be based on requests from farmers or a group of farmers. In such a delivery system, water is directed only to those canals where farmers have announced that they need water.

Because the demand varies, the duration or the size of flow, or both, need to be controlled to accommodate this variation.

In simple and small schemes it may only be possible to control the duration of irrigation, with no flow control. Note that the possibility of water losses increases when demand is relatively small compared to the canal capacity. In more sophisticated schemes it may also be possible to adjust the quantity of water flowing so that the flow can also be subject to request.

In order to be able to adapt flows to the requests, so-called 'cross-regulators' are needed in the canal network, by making the opening smaller or larger, the size of the flow can be set. To ensure equitable and efficient distribution, measurement is required at the flow regulating point.

The accuracy and effectiveness of water delivery with respect to demand depend on the flexibility of the system: how much water is available, taking into account other requests that have been made; what capacities have the canals; how accurately can flows be regulated; and how efficient are the operators? For such a system to work efficiently two things are needed:

- Good structures in which gate settings can be easily and accurately adjusted; and
- A team of well-trained operators.

As discussed above, water delivery or supply methods are mainly three that is **continuous, rotational and on-demand**. However, the most common in small holder SSI schemes is rotational supply of irrigation at field level.

In this guideline an illustrative example regarding water distribution plan and designing irrigation interval of SSI scheme is found useful to give clear view of water management options within farmer managed surface irrigation. One of such schemes is Arata Chufa SSI Scheme in Arsi Zone of Oromia Regional State.

Arata Chufa small scale irrigation scheme is initially designed for net irrigable area of 100 ha. The layout is divided nearly to 10 blocks of each 10ha. Total diversion during peak demands is 100l/s. Base flow of Chufa River was considered during original project design. 60ha of land is irrigated by night storage pond and 40ha is irrigated by direct flow from intake. Original design of the scheme indicates that peak irrigation duty of the project is 2.4 lit/ sec/ hectare for 10 hour irrigation per day. That means 1lit/ sec/ hectare irrigation duty for 24 hour irrigation per day. In other words 100l/s daily flow satisfies the peak demand of 100 hectare cropping plan based on design document. However, this irrigation duty has to be re-computed for the actual cropping plan of given year say 2016/17 GC and water distribution plan must be prepared for this particular year. Finally water demand and available water must balance otherwise, the cropping plan must be revised or irrigated area be changed.

Table 7-1: Designed maximum water budget to each block

Canal	Block (s)	Area (ha)	Flow (l/s)	Remark
MC	All	100	100	Intake discharge
MC-1	3,6,7,8,9,10	60	144	Flow from pond outlet
MC-2	1,2,4,5	40	96	Direct flow from intake
SC-1	1	10	24	Rotated in TC as per II
SC-2	2,4	20	48	Rotated in TC as per II
SC-3	5	10	24	Rotated in TC as per II

Canal	Block (s)	Area (ha)	Flow (l/s)	Remark
SC-4	3	10	24	Rotated in TC as per II
SC-5	7,10	20	48	Rotated in TC as per II
SC-6	6	10	24	Rotated in TC as per II
SC-7	9	10	24	Rotated in TC as per II
SC-8	8	10	24	Rotated in TC as per II

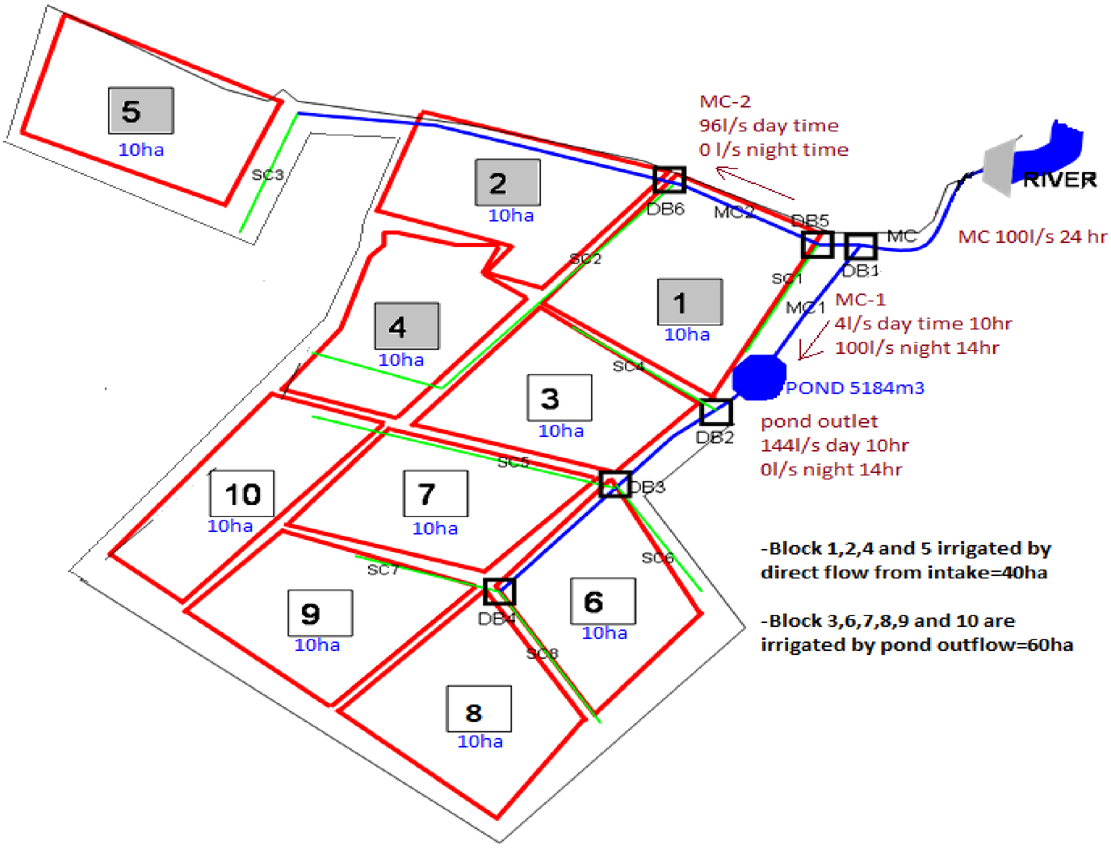


Figure 7-9: Originally designed water allocation plan for Arata Chufa SSI scheme

7.3.1 Water distribution plan for Arata chufa scheme (2016/17 cropping plan)

a. Water availability

The main factors governing water distribution plan are cropping plan (crop water requirement and available (dependable) flow from the source at intake. The CWR and scheduling for the project is as depicted above. Here below is 80% dependable flow at diversion point of Arata Chufa SSI scheme on Chufa River. Chufa River is sub-catchment within Ketar River. Ketar River is gauged while Chufa River is not gauged. Ketar River has catchment area of 3173km^2 at gauging point while Chufa River has catchment area of 629km^2 at the diversion point. The monthly 80% dependable flow of Chufa River obtained by area ratio method is indicated below. If historical river flow data is not available discharge must be measured or estimated using other methods. It is usually important to ***install gauging station*** *at SSI schemes* to use actual data obtained from discharge measurements.

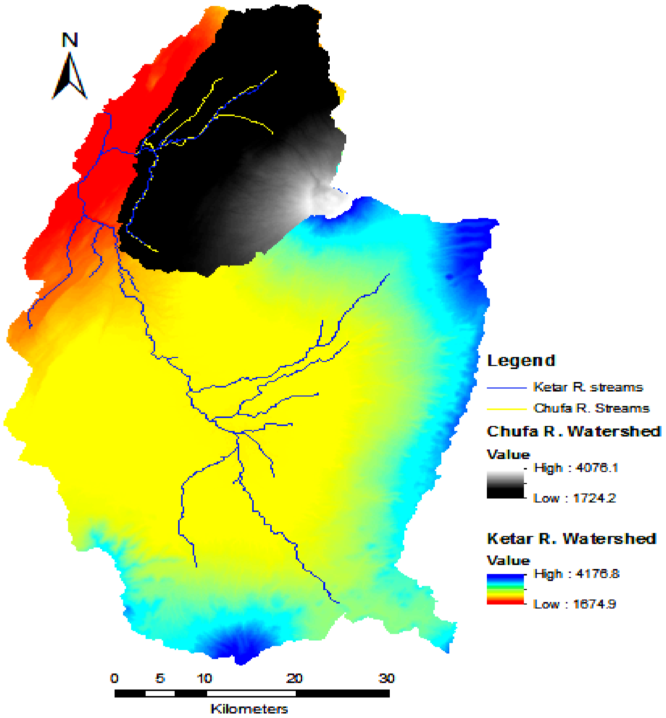


Figure 7-10: Catchment area of ketar and chufa river

Table 7-2: Monthly minimum flow data of Ketar River (m^3/s)

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1970	2.640	2.200	3.140	10.530	3.850	2.880	3.850	43.680	36.800	6.620	3.010	2.220
1971	2.310	2.100	2.000	2.100	2.100	4.760	14.620	27.630	16.620	5.980	3.700	2.760
1972	2.530	2.530	2.880	2.640	4.160	3.140	6.620	18.790	13.510	4.160	3.140	2.200
1973	1.910	1.640	1.560	1.560	1.560	1.910	3.270	19.240	16.620	4.830	2.310	1.480
1974	1.910	1.730	1.640	2.530	2.420	3.140	4.160	16.200	17.900	3.650	2.200	1.910
1975	1.730	1.560	1.190	1.330	1.190	2.530	5.980	46.160	24.240	3.270	2.760	2.310
1976	1.910	1.820	1.560	1.730	2.530	1.910	3.010	28.230	9.930	2.760	2.760	2.100
1977	2.200	2.310	1.640	2.880	3.270	3.550	6.840	29.450	11.470	8.550	5.950	3.270
1978	2.310	2.310	3.270	2.200	2.640	2.420	8.810	46.160	8.290	7.070	3.410	2.760
1979	2.530	4.830	3.010	3.850	3.550	6.400	9.360	27.630	17.040	6.190	3.010	2.640
1980	2.310	2.200	2.100	1.910	1.820	2.420	4.660	28.830	12.460	3.550	2.530	2.310
1981	2.200	2.000	2.000	13.880	3.270	2.530	3.010	45.320	41.290	5.010	3.010	2.640
1982	2.200	2.100	1.910	2.880	2.640	2.880	4.830	12.460	12.460	5.980	3.410	3.140
1983	2.039	1.987	2.184	3.310	2.837	4.214	6.306	29.070	16.820	4.905	2.747	2.220
1984	2.039	1.987	2.184	3.310	1.640	3.700	5.190	8.030	2.880	2.420	2.200	2.100
1985	1.330	1.640	1.560	2.000	3.270	25.530	3.550	23.180	16.820	4.905	1.330	1.480
1986	1.730	1.730	2.420	2.310	3.710	4.480	17.900	33.310	24.780	5.010	2.640	2.000
1987	1.640	1.560	2.100	5.190	3.270	7.070	6.190	7.300	8.030	3.270	2.000	1.910
1988	1.730	1.730	1.720	1.640	1.910	1.910	4.160	41.290	25.340	10.530	1.140	2.530
1989	2.310	2.000	2.000	3.140	2.880	2.310	4.830	15.010	16.620	5.980	2.530	2.640
1990	2.039	2.000	7.300	7.780	4.160	4.000	6.306	29.070	16.820	4.905	2.747	2.000
1991	2.000	1.910	2.420	2.760	3.010	3.010	5.580	31.340	13.880	2.760	2.310	2.000
1992	1.917	1.910	1.560	1.640	2.530	2.640	4.830	17.900	19.710	10.230	3.010	2.530
1993	2.530	2.530	2.000	2.000	6.040	8.030	7.780	28.230	17.900	7.780	3.140	2.200
1994	2.100	1.910	1.560	1.560	2.837	1.910	7.540	47.010	20.180	3.010	2.310	1.560
1995	1.560	1.400	1.480	1.820	2.420	2.000	2.310	42.880	7.780	2.880	1.910	1.730
1996	1.907	1.402	1.188	2.642	2.415	6.616	10.226	40.520	15.009	2.883	2.002	1.907
1997	2.002	1.402	0.883	3.138	1.816	2.002	5.576	17.036	6.398	2.526	3.696	1.727
1998	1.559	1.188	2.883	1.727	2.526	2.307	5.576	42.080	20.180	0.637	2.760	2.101
mean	2.039	1.987	2.184	3.310	2.837	4.214	6.306	29.070	16.820	4.905	2.747	2.220

The above table is obtained by sorting the data (Table 7-2) in descending order and analyzing the 80% dependable flow. It is always important to ***balance the supply (available flow) and the need (irrigation requirements)***. The monthly crop demands must be balanced with monthly available flows from the source for the given cropping plan within the scheme. Peak demand periods are more critical and thus care must be given for each crop not to be under water stress during the flowering and fruit setting.

Water balance study on the water source is also important to account for upstream users, downstream users and environmental release. In this case, since detail data about other demands is not indicated clearly 10% at upstream, 10% at downstream and 10% for environmental release was considered. Thus 70% of the dependable flow is taken for irrigation demand of Arata chufa irrigation scheme. Here catchment area ratio (catchment hydrological data transposition) method was used to estimate the available flows of Chufa River, this is for this particular case that actual flow data of the river was not obtained; actual flow data and demand assessment for the water balance study must be done for the particular SSI scheme.

Table 7-3: Water availability of Chufa River in m3/s

Months	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Ketar River 80% dependable flow (m^3/s)	1.730	1.640	1.560	1.730	2.100	2.307	4.160	17.900	11.470	2.883	2.200	1.910
Catchment area ratio, Chufa/ Ketar River	0.198	0.198	0.198	0.198	0.198	0.198	0.198	0.198	0.198	0.198	0.198	0.198
Chufa River 80% dependable flow (m^3/s)	0.343	0.325	0.309	0.343	0.416	0.457	0.824	3.544	2.271	0.571	0.436	0.378
Irrigation Demand (m^3/s)	0.240	0.228	0.216	0.240	0.291	0.320	0.577	2.48	1.59	0.40	0.31	0.26
Satisfies Demand?	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

b. Water demand

Cropping plan as of 2016/17 GC is as given below (Table 7-4 and Table 7-5) and updated Crop Water Requirement (Water Demand) is computed using CROPWAT-8 software and summary of scheme water demand is depicted under Table 7-6. Irrigation water distribution is also revised for this particular cropping plan.

Table 7-4: Dry Season Cropping plan of Arata Chufa SSI scheme (year 2016/17 GC)

SN	Crop	Area (ha)	Date of planting-Harvest	Total length of growth period
1	Tomato	35	01 October – 20 February	140 days
2	Onion	20	10 October – 20 February	130 days
3	Potato	20	20 September – 30 January	130 days
4	Cabbage	15	20 November-20 March	120 days
5	Pepper	10	15 September – 15 January	120 days

Table 7-5: Wet season cropping plan of Arata Chufa SSI scheme (year 2016/17 GC)

SN	Crop	Area (ha)	Date of planting-Harvest	Total length of growth period
1	Tomato	10	20 February – 10 July	140 days
2	Onion	10	25 February – 05 July	130 days
3	Potato	25	15 March – 25 July	130 days
4	Cabbage	40	20 March –20 July	120 days
5	Pepper	15	15 June – 15 October	120 days

Crop Water Requirement of individual crops in Arata Chufa Scheme computed on decadal base is indicated under Appendix XII and summary of the CWR (in mm) in each month for all crops computed by CROPWAT-8 is as tabulated below for the dry and wet seasons:

Table 7-6: Scheme Irrigation water requirements for Arata Chufa

Particular	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1. Tomato	121.9	26.4	0	0	0	0	0	0	0	36.5	83.5	121.6
2. Onion	104.5	22.6	0	0	0	0	0	0	0	36	91.9	111.1
3. Potato	85.3	0	0	0	0	0	0	0	1.7	42.7	116.4	122.8
4. Cabbage	112.5	75.5	38.6	0	0	0	0	0	0	0	15.3	81.7
5. Pepper	47.1	0	0	0	0	0	0	0	0.2	48	101.5	110.7
6. Tomato wet	0	2.6	41.8	45.5	106.7	61.3	5.6	0	0	0	0	0
7. Onion wet	0	0	29.8	36.2	93.3	54.2	4.7	0	0	0	0	0
8. Potato wet	0	0	10.5	12	102.9	75.7	2.9	0	0	0	0	0
9. Pepper wet	0	0	0	0	0	3	0	10.1	25.5	15.8	0	0
10. Cabbage wet	0	0	6.1	20.2	87.5	64.5	3.3	0	0	0	0	0
NIR in mm/day	3.3	0.9	0.6	0.6	2.6	1.9	0.1	0	0.1	1.2	2.8	3.6
in mm/month	102.2	25.3	18	19.2	80.7	56.7	3.1	1.5	4.2	35.7	83.3	112.7
in l/s/ha	0.38	0.1	0.07	0.07	0.3	0.22	0.01	0.01	0.02	0.13	0.32	0.42
Irrigated area (% of total area)	100	80	100	85	85	100	85	15	45	100	100	100
IR for actual area (l/s/ha)	0.38	0.13	0.07	0.09	0.35	0.22	0.01	0.04	0.04	0.13	0.32	0.42
Scheme efficiency	0.48	0.48	0.48	0.48	0.48	0.48	0.48	0.48	0.48	0.48	0.48	0.48
GIR in l/s/h												
24 hour per day	0.79	0.27	0.15	0.19	0.73	0.46	0.02	0.08	0.08	0.27	0.67	**0.88**
10 hour per day	1.9	0.65	0.35	0.45	1.75	1.1	0.05	0.2	0.2	0.65	1.6	**2.1**
GIR for 100ha for 10 hour/day	190	65	35	45	175	110	5	20	20	65	160	210
Monthly flow (l/s)	240	228	216	240	291	320	577	2481	1590	400	305	265
Balance (l/s)	50	163	181	195	116	210	572	2461	1570	335	145	55

For the 2016/17 GC cropping plan, based on the updated flow data of Chufa River (Table 7-3) and scheme irrigation requirement (Table 7-6), it is possible to plan on 100ha irrigation development. Thus water distribution plan is prepared based on updated CWR and Schedule of the project.

Table 7-7: Maximum water budget to each block (for 2016/17 cropping plan)

Canal	Block	Area (ha)	Flow (l/s)	Remark
MC	All	100	88	Intake discharge
MC-1	3,6,7,8,9,10	60	118	Pond outlet discharge
MC-2	1,2,4,5	40	84	Direct flow from weir intake
SC-1	1	10	21	Rotated in TC as per II
SC-2	2,4	20	42	Rotated in TC as per II
SC-3	5	10	21	Rotated in TC as per II
SC-4	3	10	21	Rotated in TC as per II
SC-5	7,10	20	42	Rotated in TC as per II
SC-6	6	10	21	Rotated in TC as per II
SC-7	9	10	21	Rotated in TC as per II
SC-8	8	10	21	Rotated in TC as per II

7.3.2 Scheme Irrigation Interval

Irrigation frequency is defined as the frequency of applying water to a particular crop at a certain stage of growth and is expressed in days. It is given in Equation 6-4 as:

II = (Sa x P x RZD)/ETc

Where:

II = Irrigation interval (days)

Sa = Total available soil moisture = FC – PWP (mm/m)

P = Allowable depletion (decimal) RZD = Effective root zone depth (m)

ETc = Crop evapotranspiration or crop water requirement (CWR) (mm/day)

The soil of Arata Chufa Scheme area is dominantly cay loam and thus its total available soil moisture for such soil was adopted from Table 6-3. The total available soil moisture (Sa) is **167mm/m** for clay loam soil.

Accordingly the irrigation interval of individual crops during each development stage in Arata Chufa scheme for the 2016/17 cropping plan is indicated below.

Table 7-8: Dry season irrigation intervals of crops in Arata Chufa Scheme (2016/2017 GC)

Crop/Stages	RZD(m)	P	Sa (mm/m)	Etc (mm/day)	II (days)	Adjusted II (days)
Tomato						
Initial	0.3	0.4	167	2.35	8.53	8
Development	0.45	0.4	167	3.21	9.36	9
Mid-season	0.6	0.4	167	4.36	9.19	9
Late season	0.7	0.4	167	3.99	11.72	11
Onion						
Initial	0.3	0.3	167	2.8	5.37	5
Development	0.35	0.3	167	3.29	5.33	5
Mid-season	0.45	0.3	167	3.97	5.68	5
Late season	0.45	0.3	167	3.66	6.16	6
Potato						
Initial	0.3	0.35	167	1.78	9.85	9
Development	0.4	0.35	167	3.07	7.62	7
Mid-season	0.5	0.35	167	4.45	6.57	6
Late season	0.5	0.35	167	3.87	7.55	7
Cabbage						
Initial	0.3	0.45	167	2.72	8.29	8
Development	0.4	0.45	167	3.22	9.34	9
Mid-season	0.6	0.45	167	4.34	10.39	10
Late season	0.6	0.45	167	4.26	10.58	10
Pepper						
Initial	0.3	0.3	167	2.13	7.06	7
Development	0.5	0.3	167	3.23	7.76	7
Mid-season	0.7	0.3	167	4	8.77	8
Late season	0.7	0.3	167	3.84	9.13	9

Table 7-9: Wet season irrigation intervals of crops in Arata Chufa Scheme (2016/2017 GC)

Crop/Stages	RZD(m)	P	Sa (mm/m)	Etc (mm/day)	II (days)	adjusted II (days)
Tomato						
Initial	0.3	0.4	167	2.6	7.71	7
Development	0.45	0.4	167	3.42	8.79	8
Mid-season	0.6	0.4	167	4.79	8.37	8
Late season	0.7	0.4	167	3.94	11.87	11
Onion						
Initial	0.3	0.3	167	3.05	4.93	4
Development	0.35	0.3	167	3.64	4.82	4
Mid-season	0.45	0.3	167	4.4	5.12	5
Late season	0.45	0.3	167	3.81	5.92	5
Potato						
Initial	0.3	0.35	167	2.17	8.08	8
Development	0.4	0.35	167	3.55	6.59	6
Mid-season	0.5	0.35	167	4.89	5.98	5
Late season	0.5	0.35	167	3.31	8.83	8
Cabbage						
Initial	0.3	0.45	167	3.03	7.44	7
Development	0.4	0.45	167	3.4	8.84	8
Mid-season	0.6	0.45	167	4.43	10.18	10
Late season	0.6	0.45	167	3.62	12.46	12
Pepper						
Initial	0.3	0.3	167	2.4	6.26	6
Development	0.5	0.3	167	2.61	9.60	9
Mid-season	0.7	0.3	167	3.44	10.19	10
Late season	0.7	0.3	167	3.38	10.38	10

7.3.3 Scheme flow rates

The irrigation interval discussed above indicates the "***when***" to irrigate. The duration of irrigation "***How long***" in this particular case (surface irrigation) is 10 hours per day. The quantity/ discharge or "***how much***" to irrigate must be answered at the same time for a given plot of land. This is given by the next formula:

Q=DA/T **Equation 7-1**

Where,

Q=stream size to irrigate given area (m^3/s)

A= area to be irrigated in m^2.

T= Time of application for each irrigation (seconds)

D= depth of irrigation application (m).

Depth of irrigation application (D) is equal to the readily available soil water (P.Sa) over the root zone (RZD). An application efficiency factor (Ea) is always added to account for the uneven application over the field or:

D=[(P.Sa)*RZD]Ea **Equation 7-2**

Hence for each development stage of the crop discharge amount must be known. This is computed under the CROPWAT-8 of irrigation scheduling and flow rates during each decade of the development stages are indicated. However, this flow rate is under the assumption that it is continuously applied to the crop. Practically, the farmers usually apply in rotations or intervals as indicated above based of soil moisture condition. Thus discharge to be applied during each application must be computed. Here below is the flow rate during each stage for the soil of the area:

Table 7-10: Field level flow rate per hectare during each development stage of the crops

Crop/ Stages	RZD (m)	Sa (mm/m)	P	Ea	D (mm)	D(m)	T (s)	A (m2)	Q (m3/s)	Q (l/s)
Tomato										
Initial	0.3	167	0.4	0.6	33.4	0.033	36000	10000	0.009	9
Dev.	0.45	167	0.4	0.6	50.1	0.050	36000	10000	0.014	14
Mid	0.6	167	0.4	0.6	66.8	0.067	36000	10000	0.019	19
Late	0.7	167	0.4	0.6	77.9	0.078	36000	10000	0.022	22
Onion										
Initial	0.3	167	0.3	0.6	25.1	0.025	36000	10000	0.007	7
Dev.	0.35	167	0.3	0.6	29.2	0.029	36000	10000	0.008	8
Mid	0.45	167	0.3	0.6	37.6	0.038	36000	10000	0.010	10
Late	0.45	167	0.3	0.6	37.6	0.038	36000	10000	0.010	10
Potato										
Initial	0.3	167	0.35	0.6	29.2	0.029	36000	10000	0.008	8
Dev.	0.4	167	0.35	0.6	39.0	0.039	36000	10000	0.011	11
Mid	0.5	167	0.35	0.6	48.7	0.049	36000	10000	0.014	14
Late	0.5	167	0.35	0.6	48.7	0.049	36000	10000	0.014	14
Cabbage										
Initial	0.3	167	0.45	0.6	37.6	0.038	36000	10000	0.010	10
Dev.	0.4	167	0.45	0.6	50.1	0.050	36000	10000	0.014	14
Mid	0.6	167	0.45	0.6	75.2	0.075	36000	10000	0.021	21
Late	0.6	167	0.45	0.6	75.2	0.075	36000	10000	0.021	21
Pepper										
Initial	0.3	167	0.3	0.6	25.1	0.025	36000	10000	0.007	7
Dev.	0.5	167	0.3	0.6	41.8	0.042	36000	10000	0.012	12
Mid	0.7	167	0.3	0.6	58.5	0.058	36000	10000	0.016	16
Late	0.7	167	0.3	0.6	58.5	0.058	36000	10000	0.016	16

7.3.4 Irrigation scheduling for pressurized systems

The application of the exact amount of water required by the crops at the right time is the main achievement of the irrigation installation. Users shall strictly follow the main elements of irrigation programming, such as water discharge/rate, operating hours and irrigation frequency for equity of water allocation as well as to achieve high water use efficiency.

The principle of scheduling in pressurized system is nearly similar to that of surface irrigation. Here major difference being the yield of drippers or nozzles per unit of time. Thus knowing the amount ("**how much or irrigation demand**") during the crop development stages, then "**when**" and "**How long**" to apply is set for the specific method of irrigation.

In pressurized systems, in most cases the systems need at least 10 to 15m head at emitter for drip and 20 to 30m head at nozzle for sprinkler. Each dripper or sprinkler has its own designed discharge rate given by manufacturer and thus the operation duration and interval is dependent on these rates. For instance drip emitters can be designed for 1l/hr to 4l/hr. Similarly there are wider ranges of sprinkler heads with discharge from 100l/hr to 1500l/hr. It should be noted that working pressure to obtain the emitter discharge (if applicable) has to be referred to manufacturer's manuals. It is also important to follow infiltration rate of the soil and land slopes before choosing appropriate emitter discharge or sprinkler discharge. In all cases water application rate must be less than soil infiltration rate.

Both drip irrigation and sprinkler irrigation water management follow instructions stated for specific project case. Thus the installed system basically governs overall system operation.

In drip system, according to crop type, the number of emitters per plot of land can be computed based on plant spacing and raw spacing and the discharge necessary for that specific plot to satisfy the demand can be applied accordingly.

For example, consider Tomato production during the dry season:
Plant spacing=60cm as per agronomic recommendation
Raw spacing (lateral spacing) = 90cm as per agronomic recommendation
Soil texture is clay loam with basic infiltration rate **14mm/hour**.

If 1ha of plot is arranged in 4 sub units of 50mx50m then 50m long lateral will have 50/0.6 plants of tomato that means 83 tomatoes. And total number of laterals will be 50/0.9=55

This means each lateral will have 83 emitters implying 83x55=4565 emitters in total per quarter (1/4) of a hectare (50mx50m=2500m^2).

If emitters of 1litre/hour flow rate (from manufacturer) are selected 4565emitters will yield 4565 liter per hour.

Table 7-11Irrigation demand of tomato field for drip system

Month	Decade	Stage	NIR	NIR	E	FIR	per ha demand	Per ha demand	daily demand for 1/4 ha or 2500m^2	Decadal demand for 2500m^2
			mm/dec	mm/day	%	mm/day	m3/day	liter/day	Liter/day	Liter
Oct	1	Init	2.3	0.23	0.9	0.26	2.556	2556	639	6389
Oct	2	Init	14.9	1.49	0.9	1.66	16.556	16556	4139	41389
Oct	3	Init	19.3	1.93	0.9	2.14	21.444	21444	5361	53611
Nov	1	Dev	20.8	2.08	0.9	2.31	23.111	23111	5778	57778
Nov	2	Dev	29.6	2.96	0.9	3.29	32.889	32889	8222	82222
Nov	3	Dev	35.1	3.51	0.9	3.90	39.000	39000	9750	97500
Dec	1	Mid	40	4	0.9	4.44	44.444	44444	11111	111111
Dec	2	Mid	40.8	4.08	0.9	4.53	45.333	45333	11333	113333
Dec	3	Mid	46.1	4.61	0.9	5.12	51.222	51222	12806	128056
Jan	1	Mid	43.2	4.32	0.9	4.80	48.000	48000	12000	120000
Jan	2	Late	44.2	4.42	0.9	4.91	49.111	49111	12278	122778
Jan	3	Late	40	4	0.9	4.44	44.444	44444	11111	111111
Feb	1	Late	24.5	2.45	0.9	2.72	27.222	27222	6806	68056
Feb	2	Late	3.4	0.34	0.9	0.38	3.778	3778	944	9444
Total										**1122778**

Demand for initial stage=101389 liter (for 30days)
Demand for development stage=237500 liter (for 30 days)
Demand during mid-season stage=472500 liter (for 40 days)
Demand during late season stage=311389 liter (for 40 days)
Total demand for 2500m^2 area=1122778 liter

Total emitter discharge is 4565liter per hour, which means the water application can be planned as depicted below:

Table 7-12 Drip system irrigation schedule for tomato field

Stage	Total demand (liters)	Hours of application	Cycles of irrigation	Interval of irrigation (days)
Initial	101389	2	11	3
Development	237500	5	10	3
Mid- season	472500	8	13	3
Late- Season	311389	6	11	4

Similarly for other crops irrigation application can be planned based on CWR and agronomic recommendations. It should be noted that irrigation application must not exceed the **field capacity** of the soil.

The determination of the field irrigation supply for sprinkler irrigation is similar to that for drip irrigation, the main difference being the detail of information required to operate the system so as to minimize the equipment required. The system can be fixed or movable. The discharge per unit of area is determined by the application rate which in turn is governed by the basic intake rate of the soil and by the number of sprinklers operating simultaneously. This latter is determined by the system layout, which in turn is largely dictated by size and shape of the field, irrigation interval and the farmers preference on number of hours per day and number of days per week the system will operate.

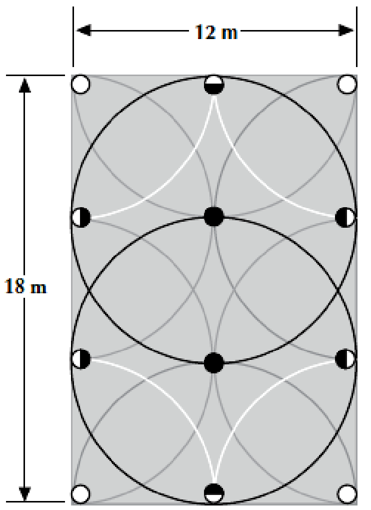


Figure 7-11: Sprinkler arrangement

Consider tomato irrigation with above sprinkler arrangement. Head spacing and raw spacing is 6m and spray diameter is 12m Area covered by above sprinklers is 216m^2. If full circle sprinkler rate is assumed 30l/min, half circle is 15l/min and quarter circle is 7.5l/min, then total discharge for the area is 180 liter/minute (sum of discharge from each sprinkler). Over the area of 216m^2 this can be converted to mm/hr precipitation rate that will be 50mm/hr. This application rate must not exceed basic infiltration rate of the soil. Thus if basic infiltration rate of soil of the area is **14mm/hour** then discharge rate of each sprinklers must be limited to 8.4litre/minute. That means total discharge for this sprinkler arrangement will be 50.4litre/minute. Hence sprinkler head of **8.4lit/min** discharge for given operating pressure will be selected from the manufacturer with spray diameter of 12m.

Table 7-13: Irrigation demand of Tomato field for sprinkler system

Month	Decade	Stage	NIR	NIR	E	FIR	per ha demand	Per ha demand	daily demand for 216m^2	Decadal demand for 216m^2
			mm/dec	mm/day	%	mm/day	m3/day	liter/day	Liter/day	Liter
Oct	1	Init	2.3	0.23	0.75	0.31	3.067	3067	66	660
Oct	2	Init	14.9	1.49	0.75	1.99	19.867	19867	429	4290
Oct	3	Init	19.3	1.93	0.75	2.57	25.733	25733	556	5560
Nov	1	Dev	20.8	2.08	0.75	2.77	27.733	27733	599	5990
Nov	2	Dev	29.6	2.96	0.75	3.95	39.467	39467	852	8520
Nov	3	Dev	35.1	3.51	0.75	4.68	46.800	46800	1011	10110
Dec	1	Mid	40	4	0.75	5.33	53.333	53333	1152	11520
Dec	2	Mid	40.8	4.08	0.75	5.44	54.400	54400	1175	11750
Dec	3	Mid	46.1	4.61	0.75	6.15	61.467	61467	1328	13280
Jan	1	Mid	43.2	4.32	0.75	5.76	57.600	57600	1244	12440
Jan	2	Late	44.2	4.42	0.75	5.89	58.933	58933	1273	12730
Jan	3	Late	40	4	0.75	5.33	53.333	53333	1152	11520
Feb	1	Late	24.5	2.45	0.75	3.27	32.667	32667	706	7060
Feb	2	Late	3.4	0.34	0.75	0.45	4.533	4533	98	980
Total										**116410**

Water Demand for 216m^2 area of tomato plot:
Demand for initial stage=10510 liter (for 30days)
Demand for development stage=24620 liter (for 30 days)
Demand during mid-season stage=48990 liter (for 40 days)
Demand during late season stage=32290 liter (for 40 days)
Total demand for 216m^2 area=116410 liter
For the above sprinkler type and arrangement yielding **50.4 lit/min** or 3024litre/hour over 216m^2 plot area, the irrigation application can be planned as depicted below:

Table 7-14 Sprinkler system irrigation schedule for tomato field

Stage	Total demand (liters)	Hours of application	Cycles of irrigation	Interval of irrigation (days)
Initial	10510	1	4	7
Development	24620	2	4	7
Mid- season	48990	2	8	5
Late- Season	32290	2	6	7

Similarly for other crops other than tomato irrigation application can be planned based on CWR and agronomic recommendations. It should be noted that irrigation application must not exceed the **field capacity (FC)** of the soil. Figure 7-12 illustrates the principle of irrigation application. Irrigation is applied when the readily available moisture (RAW) is depleted. The total available moisture (TAW) varies with the plant rooting depth during the growth period. P is management allowable depletion percentage of the specific crop.

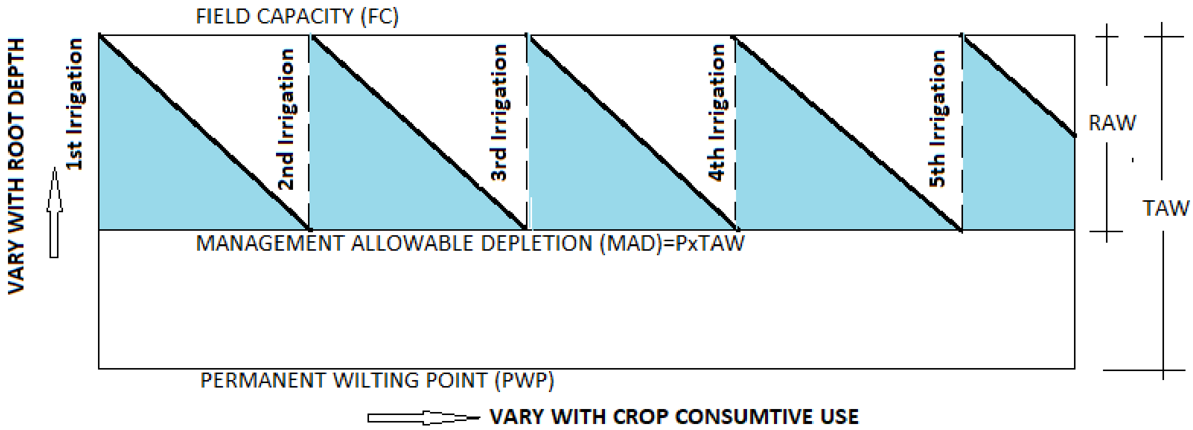


Figure 7-12 Principle of irrigation application based of soil moisture depletion

8 OPERATION OF IRRIGATION INFRASTRUCTURES

8.1 OPERATION OF HEADWORKS

8.1.1 Operation of diversion weirs and barrages

In conventional SSI schemes, the IWUA has to appoint weir operators at diversion point to guard the installations and to operate the canal head regulator and sluiceway gates in accordance with the irrigation plan of the IWUA. The head regulator is basically operated based on cropping calendar and water distribution plan set in conventional small-scale irrigation systems. Thus the gate operator shall get request for water demand for proper operation of gates. To property adjust the gate levels gate operators must have good knowledge of gate opening and corresponding intake discharges.

In spate irrigation systems normally, the head regulator gates will remain open to ensure any spate to enter the canal. During operation the canal gates will only be closed under the following conditions:

1) If all farmers in the area have received their water right.
2) In case of very big floods, to avoid damages to the infrastructure by the force of water and amount of sediments in spate irrigation systems.

A key feature for the successful operation of the canals is the proper operation of the sluiceways too. The purpose of the sluiceways is:

- To keep an open channel from the main river flow channel to the head regulators;
- To exclude sediments from the flow into the main canal.

In principle the sluiceway gates will be closed when the canal is in operation and remain open while the canal is not in operation under conventional small-scale irrigation systems.

However, in spate irrigation systems under the following conditions the sluiceway gates will be opened:

1) If the entire area has received one full irrigation gift. In this case the flow through the sluiceway will ensure to keep an open channel to the head regulator,
2) In case of large floods, to separate sand and stones from the flow into the main canal, or
3) In case of big floods to avoid damage by overtopping of the embankments.

Generally the operation and regulation for headwork can be divided into three periods:

a) Pre-main rainy season;
b) During main rainy season; and
c) Post-main rainy season.

a) Pre-main rainy season Operation
It is a low flow period and normally no wastage of water should be permitted during this period. The barrage gates/falling shutters should be regulated in such a way that all the available supplies are conserved and pond level is maintained. Any excess flow over and above the requirements through

the head regulator(s) should be released through under sluice bays and silt excluder tunnels (if any), wherever provided. The release through the head regulator of the canal should be based on the discharge tables.

The discharge tables should be occasionally checked for accuracy by actual measurements in the canal. For any flashy flood, the canal may have to be closed temporarily, if the concentration of suspended silt is in excess of the safe limit prescribed.

b) Main rainy season Operation

Normally gauges to indicate flood stage should be installed sufficiently (not less than 1000 m) upstream of the weir/barrage at suitable locations so as to ensure adequate margin of time for operation of gates at the weir/barrage site.

During low floods, the gauges should be checked and recorded every 3hour while in medium and high floods; these should be recorded every hour. The observer at the gauge upon receiving any flood warning should communicate the same to the official/officer-in-charge of the headwork and other regulation points downstream and to the Woreda officers of the neighboring Woredas. The advisability of availing wireless telephones on headworks located on major rivers for speedy transmission of flood warning should be considered.

In order to create most favorable conditions for sediment exclusion from the canal, still-pond regulation should be resorted to, as far as possible. However, in locations where canals cannot be closed for flushing, semi-still pond/regulation may be adopted as given below:

i) Still pond operation — In still pond operation, all the gates of the under-sluice bays are to be *kept closed* so as to limit the discharge flowing into the under-sluice pocket to be equal to the canal supply. The specified or required discharge only should be drawn in the canal and the surplus river discharge should be passed through the spillway bays or escapes, if provided. As the under-sluice bays are kept closed, the flow velocity in the pocket cause the sediment to settle down and relatively clear water enters the canal. However, the pocket gets silted up in this process after some time.

At that time, the canal head regulator gates should be closed and deposited silt should be flushed out by opening the gates of the under-sluice bays. The canal supply may be stopped during this scouring operation which may take about 24 h. After the silt deposits are flushed out sufficiently, the head regulator gates should be opened and under-sluice closed. This operation is desirable where the crest of the head regulator is at a sufficiently higher level than that of the upstream floor of the under-sluice bays. This still pond operation should be continued till the river stage reaches the pond level after which the under-sluice gates should be opened to avoid overtopping.

ii) Semi-still pond operation — In the semi-still pond operation, the gates of the canal head regulator are not closed for flushing of silt deposit in the pocket. The gates of the under-sluice bays should be kept *partially open* to the minimum necessary so that the bed material in the pocket could be passed downstream. The discharge in excess of the canal requirement should be passed through the under-sluice bays and silt excluder tunnels also, wherever provided.

Under no circumstances should the under-sluice gates be allowed to be overtopped. Silt ejectors in the canal should be operated as much as possible so that the chances of heavy siltation in the canal posing a problem of flushing due to its compaction are minimized.

During main rainy season month, it is important to keep a constant watch over the sediment entering the headworks, the portion thereof ejected by the extractor if any, and the sediment deposition taking place in the canal and to ensure that sediment deposition only to the extent that can be washed out early in the fair weather before the full demand develops, is allowed.

For this, the following actions should be taken:

- Sediment charge observations (both suspended sediment and bed load) should be made at least *once a day* in low floods immediately below the head regulator, below the silt ejector, if any, and at any other sensitive point lower down the canal. The frequency of observations may be increased in medium and high floods as required;
- Cross-section of the canal should be taken daily at a few sensitive points to watch the extent of sediment deposition in the canal;
- Water surface slopes in the sensitive head reach of the canal should be kept under observation daily with the help of gauges;
- The ponding upstream in the canal should be restricted to the requisite extent so as to avoid harmful sediment deposition; and
- The canal should be closed from the headworks when,
  - Sediment charge during medium/high flood is beyond specified limit and reopened when the sediment charge drops below the specified limit. Since the silt carrying capacity of the canal would govern this specified limit, it would vary from project to project and should be estimated based on actual data/ experience.
  - Sediment deposition at the sensitive points has reached the maximum permissible bed level. This limit along with the sediment charge in excess of which the canal is to be kept closed, may have to be fixed for different months during the main rainy season period in order to be able to meet the irrigation demand.

Since cross flows and vortex formations dangerously cause deep scours both on the upstream and downstream of the weir/barrage leading to washing away or sinking of cement concrete blocks and loose stone aprons, and damages to the nose and shanks of guide bunds, visual observations of the direction of current and vortex formation during low and medium floods should be made. After critically observing the effects of different patterns of gate operation on the same, the engineer-in-charge should judiciously select the correct pattern which would cause only minimum scour or minimum shoaling.

The engineer-in-charge should be conversant with the shoal formations, changing network of spill channels, etc., which cause unequal distribution of flows through different bays, cross flow near the barrage floor ends, vortex formations, etc. Gate operation of barrage structure should be attempted in such a manner that the shoal formation in the vicinity of barrage structure both upstream and downstream is avoided.

The pond level should be kept minimum required to feed the canal with the required discharge by suitably opening the gates. It should be ensured that in a high flood, all falling shutters of weirs are lowered and all gates raised clear of the water level with adequate freeboard to clear floating debris.

The operation of barrage gates/weirs shutters should preferably be based on studies and observations at various flood intensities, that is, low, medium and high, as modified by observed river behavior at site.

In this connection, for major weir/barrages it would be desirable to constitute a gate regulation committee (Headwork Team) for each weir/barrage and an irrigation technician /engineer-in-charge of the headworks.

The Committee or team should hold meetings at least once during pre-main rainy season, main rainy season (preferably twice) and after main rainy season and should review the gate operation pattern and modify, wherever necessary on the basis of the observed river cross-section on the upstream and downstream of the structure. After some years when satisfactory flow conditions are established, all the recommendations of the Committee from time to time should be compiled in the form of a manual so that guidance could be obtained by the gate operating personnel for future use in the project.

Generally with the rise in the flood discharge, step by step gate operation with gradual increase of opening from ends towards the center is sometimes recommended.

In order to keep a close watch on the river behavior and bed configuration both upstream and downstream of the barrage, river surveys should be conducted regularly, once before the floods and another after the floods. The survey should be conducted over a stretch of the river close to the Weir/barrage at least up to the end of guide bank both on upstream and downstream. The bed levels should be determined at close intervals of at least 5m depending upon the bed configuration, the pattern of gate regulation should be modified suitably to ensure safety and better hydraulic performance of the weir/barrage. Canals having trash-racks at the head regulator must be checked for entry of floating debris. The trash-racks should be kept clean, preferably by a mechanical means. Instances of collapse of trash racks due to lack of cleaning and excessive pressure built up is sometimes encountered. Where floating debris try to enter the irrigation canal head regulators, trash booms may be erected just upstream of the head regulators. Usually if irrigation is not required during main rainy season intake gates must be closed and canal water escapes opened.

c. Post-main rainy season Operation

Sediment charge observations and cross-section at sensitive points on the canal should be continued at less frequent intervals till satisfactory conditions have been established.

Still/semi-still pond operation, with sediment excluders operating, depending on the surplus water availability should be continued till water becomes reasonably clear.

When a canal is first opened, a low supply should be run for a few hours at least and the depth should gradually be increased according to the requirements. The rate of falling and lowering of the canal should be prescribed and these should not be transgressed. Silt ejector hoppers (if any) and outlet pipes may be cleaned by pressure flow or back-jetting before the canal is started for operation.

If a study of the survey data indicates that shoal formation has occurred on the upstream and/or downstream of the weir/barrage in spite of judicious operation of the gates, during normal and flushing operation of reservoir, the shoal should be removed by dredging by the use of suitable dredgers to the extent possible so that satisfactory flow conditions are established and also desired capacity is restored.

Satellite imageries may be helpful in the identifying the variations of the bank lines, flow patterns, formation of submerged shoals, etc., in the upstream pond from year to year. Studies with satellite imageries may be made and remedial measures for improving the river behavior and flow pattern may be taken up.

It is usually important to observe:

a) Morphological behavior of the river;
b) Its aggradation, degradation and meandering tendency; and
c) Sediment transport with varying level, etc.

A continuous history of river behavior and the overall performance of the barrage/weir, head regulators and river training works should be maintained on all major headworks.

8.1.2 Operation of small dams

Dams are complex structures subject to several forces that can cause failure. These forces are active over the entire life of the dam, and the fact that a dam has stood safely for years is not necessarily an indication that it will not fail. One of the forces inducing failure is seepage through the dam or its foundation. All dams seep, but if the seepage is too high in the dam it can cause a structural failure ("landslide" of the materials in the dam). If the seepage comes to the ground surface on or below the dam and exits too fast, it can carry soil out of the dam or foundation, and cause internal erosion or "piping" failure. Another way a dam can fail is by being overtopped and washed out. Overtopping is the result of having inadequate emergency spillway capacity or a clogging of spillways.

Owners of dams and operating and maintenance personnel must be knowledgeable of the potential problems which can lead to failure of a dam. These people regularly view the structure and, therefore, need to be able to recognize potential problems so that failure can be avoided. If a problem is noted early enough, an engineer experienced in dam design, construction, and inspection can be contacted to recommend corrective measures, and such measures can be implemented. Acting promptly may avoid possible dam failure and the resulting catastrophic effect on downstream areas.

In small dams outflow from storage reservoir is based on irrigation plan. An irrigation plan shall clearly be prepared based on areal and timely water demands. The operation of small dam depends on specific operation manual prepared for the site.

Operating instructions for small dams

As a general rule, operating instructions shall be availed to assure that operating personnel use the facilities according to prescribed procedures and to provide instructions to other less familiar who may have to operate facilities during emergencies. Operating instructions should be posted within protective coverings, such as clear plastics, near associated equipment so that equipment can be operated as intended. Each operating device should be permanently and clearly marked for easy identification.

Adequate physical security should be provided to preclude unauthorized tampering with and operating of equipment. Such security may include chaining and locking outside gate operators and constructing and locking adequately restrictive barriers, covers, or enclosures.

Restricted Areas

Restricted areas are those which are potentially hazardous to or subject to damage by public such as Public entry into chutes, stilling basins and hoist platforms for gates at Head Regulators, Cross Regulators, outlets, siphons, escapes should be restricted.

- Warning signs and signs prohibiting rock throwing into chutes, stilling basins and cisterns should be posted adjacent to the structure.
- Public access should be limited from the area surrounding hydraulic structure intakes and reaches of outlet channels adjacent to discharge structure subject to surging or rapid changes in water surface elevation during releases.
- Operating personnel should ensure that public entry is restricted in above area. Section Officers shall ensure that the instructions given are promptly adhered to. Cases of tempering with gates shall be promptly brought to the notice of local police and appropriate complaint shall be registered. Public entry into chutes, stilling basins and hoist platforms for gates at Head Regulators, Cross Regulators, outlets, siphons, escapes should be restricted.

Safety procedures:

Particular importance should be attached to tagging controls for equipment being serviced to prevent operation which could endanger other employees. Equally important is the requirement that two employees be in attendance while servicing gates to avoid openings or closing that could injure the workers. Irrigation engineer/ technician and IWUA should be familiar with the identity, location and telephone numbers of nearby hospitals, doctors, ambulances, rescue units which can provide medical assistance.

8.1.3 Operation of pumps and control heads

There are several types of pumps available on the market. All pump manufacturers provide users' operation and maintenance manuals specific to their pumps. These have to be closely adhered to in order to ensure the most efficient operation of the pump and avoid unnecessary pump breakdowns. In view of the wide variety of operational instructions, which can be expected for different pumps, only general guidelines can be provided here.

Manual pumps are operated by people or animals, whereas motorized pumps are operated by prime movers, engines and electric motors. In general, the principles of operation of pumps are the same. The discharge and pumping head relationship of all pumps is dependent on the type of pump and the amount of energy that the manual operator or prime mover can transfer to the pump, among other factors. Since the principles of pump operation are the same, here the general aspects of pump operation, but with specific reference to motorized pumps are dealt. Particularly in SSI schemes centrifugal pumps are more common.

Pumps in SSI schemes are operated based on demand for irrigation. The working hour also is dependent on the irrigation plan. In all cases it always necessary to follow instructions given on specific manual of the pumps.

The operating manual of any centrifugal pump often starts with a general statement, "***Your centrifugal pump will give you completely trouble free and satisfactory service only on the condition that it is installed and operated with due care and is properly maintained.***" In general there are two basic requirements that have to be met at all the times for a trouble free operation and longer service life of centrifugal pumps. The first requirement is that no cavitation of the pump occurs throughout the broad operating range and the second requirement is that a certain minimum continuous flow is always maintained during operation.

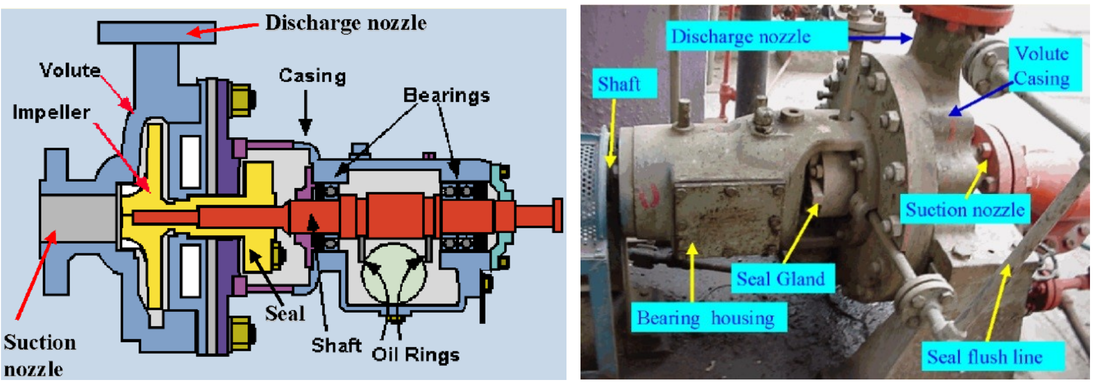


Figure 8-1: General components of centrifugal pump

Pump start-up and shutdown

There are certain procedures that are recommended by pump manufacturers before any pump start-up. Some of the pre-start-up inspections recommended immediately after pump installation are checking for correct pump-motor wiring connections, valve connections, shaft and gland clearance. It has to be remembered that starting a pump dry will cause seizing or destructive wear between the pump components. Therefore, pumps that are not self-priming or those with a positive suction lift should be primed before they are started. Different manufacturers also have specific instructions for pump shut down after operation. These have to be adhered to strictly.

Priming

While deep well pumps, such as submersible pumps, are submerged into the water and have no need for priming, the well-known horizontal centrifugal pump usually needs priming. Priming is the process of removing sufficient air from the pump and the suction pipe so that the atmospheric pressure can cause the flow of water inside the pump.

The simplest way of doing this is to displace the air in the system by filling the pump and suction pipe with water. For this purpose, a tank is connected to the pump and a foot valve to the suction pipe. The tank is filled with water when the system is operating. Before the system is switched on, the water from the tank is diverted to the pump and suction pipe via a valve.

However, the most popular priming method is the use of a manually operated vacuum pump. Other means are also available for priming, such as mechanically operated vacuum pumps and exhaust primers. At times, horizontal centrifugal pumps are installed at a dam outlet. In this case no priming is required since the water level inside the dam is higher than the level of the impeller, which forces the water to remove all the air from the suction pipe and the volute of the pump.

The pump must not be run unless it is completely filled with liquid; otherwise there is danger of damaging some of the pump components. Wearing rings, bushings, seals or packing and internal sleeve bearings all need liquid for lubrication and may seize if the pump is run dry.

Starting the pump

The pump, the motor and all units within the system must be checked well before start up. The pump is started with the gate valve opened. The pump must be filled with water before start up.

Stopping the pump

The first step is to gradually close the gate valve. This eliminates surges that may occur in case of an abrupt closure. When this has been done, the prime mover is then closed or shutdown. If the pump remains idle for a long time after it is stopped, it gradually loses its priming. Thus the operator should re-prime the pump every time before start-up.

Pump malfunctions, causes and remedies (troubleshooting)

Following are some general causes of pump malfunctioning and their remedies that can be used for on-spot trouble-shooting when pump problems are encountered. Pump manufacturers usually provide useful information, presented in Table 8-1, for identifying and rectifying problems with pumping plants.

Table 8-1: Identifying and rectifying problems with pumping plants

Symptoms	Causes	Corrections
Failure to pump	1. Pump not properly primed	1. Prime pump correctly
	2. Speed too low or high	2. Check speed, check calculations, consult with manufacturer
	3. Not enough head to open check valve	3. Check speed, check calculations, consult with manufacture
	4. Air leak	4. Check and rework suction line
	5. Plugged section	5. Unplug section
	6. Excessive suction lift	6. Check NPSH and consult manufacturer
Rapid wear of coupling cushion	7. Misalignment	7. Align
	8. Bent shaft	8. Replace
	9. Air pockets or small air leaks in suction line	9. Locate and correct
	10. Obstruction in suction line or impeller	10. Remove obstruction
	11. Insufficient submergence of suction pipe	11. Extend suction line to deeper water to the extent that NPSH allows you or excavate and deepen the area where the suction basket is located
	12. Excessively worn impeller or wear ring	12. Replace impeller and/or wear ring
	13. Excessive suction lift	13. Calculate NPSH, consult with manufacturer
	14. Wrong direction of rotation	14. Ask contractor to rectify
Driver overloaded	15. Speed higher than planned	15. Reduce speed
	16. Water too muddy	16. Raise suction
	17. Too large an impeller diameter	17. Trim impeller
	18. Low voltage	18. Voltage increment
	19. Stress in pipe connection to pump	19. Support piping properly
	20. Packing too tight	20. Loosen packing gland nuts

Symptoms	Causes	Corrections
Excessive noise	21. Misalignment	21. Align all rotating parts
	22. Excessive suction lift	22. Check NPSH, consult with manufacturer
	23. Material lodged in impeller	23. Dislodge obstruction
	24. Worn bearings	24. Replace bearings
	25. Impeller screw loose or broken	25. Replace
	26. Cavitation	26. Check NPSH, correct suction piping
	27. Wrong direction of rotation	27. Ask contractor to rectify
Premature bearings failure	28. Worn wear ring	28. Replace
	29. Misalignment	29. Align all rotating parts
	30. Suction or discharge pipe not properly supported	30. Correct support
	31. Bent shaft	31. Replace shaft
Electric motor failure	32. High or low voltage	32. Check voltage and consult power authority
	33. High electric surge	33. Monitor voltage and consult power authority
	34. Poor electric connection	34. Turn power off, clean and check connections
	35. Overloads	35. Check amperage, do not exceed full load amperage
	36. Bearing failure	36. Change motor bearing
	37. Cooling vent plugged (rodent, dirt, leaves)	37. Install proper screen
	38. Moisture or water in motor	38. Send for blow-dry and protect from environment

Control heads: All facilities at pumping station are considered as control heads. These can be the control board, the valves (gate valve, foot valve, check valve, air release valve), pressure gages, main filter unit, fertilization unit must be operated according to specific operation manual and instruction given for specific scheme.

8.2 OPERATION OF CONVEYANCE AND DISTRIBUTION SYSTEMS

8.2.1 Operation procedures and instructions

Operation procedures and instructions are the most important services that the irrigation engineer or canal and gate operators provide to farmers in the delivery of irrigation water. Ideal from a farmer's point of view is freedom in terms of:

- Timing,
- Flow-rate, and
- Duration of irrigation applications.

However, there are four reasons for flow control in Irrigation systems:

- Meeting water requirements of crops in order to achieve optimum production;
- Water savings;
- Safety of operation; and
- Recovery of operating costs.

As discussed in previous parts of the guideline, water requirements vary with the type of crop, the stage of growth, seasonal variations in climate, and daily variations in weather, especially rainfall. Both too much and too little water affect crop yields, especially at certain critical stages of growth like flowering and fruit setting. The response of irrigation supply to demand must be accurate and immediate.

The need to save water is especially important as water is scarce, water wastage in wet season can limit the area under irrigation in both wet and dry season. Systems should be operated so as to accommodate any sudden fall in demand, as at night or during a sudden rainstorm.

To ensure safe operation, the flow released into a canal should not exceed its carrying capacity, which decreases from upstream to downstream. Overtopping of canals can be avoided by means of operating escape structures provided to spill excess water into the drainage system. The spilled water can be reused further downstream but at energy cost and with the risk of using water of lesser quality.
The fourth reason for accurate flow control is to provide a basis for sound cost recovery. Farmers can be charged on volumetric basis for irrigation services and application of volumetric quota is feasible.

Control of water level in a canal system is important and the acceptable fluctuations are not very large. The four reasons for water level control are

- To keep command of the service area through gravity,
- Canal protection against deterioration,
- Canal safety and
- Flow control at off-takes

The higher the level in a canal, the larger the area which can be irrigated by gravity without pumping is an important consideration for the users. Canals are run only at full supply to ensure a constant water level at each off-take. However, to meet the requirements of modern irrigation, canals have to be operated under variable flow conditions. Since there is a direct relationship between *flow* and *water level* in a canal under uniform flow conditions, steps have to be taken to raise the level in the canal by artificial means. The next reasons for controlling water level are canal safety and protection. The water level should not exceed an upper limit in order to avoid overtopping and wasting water through escape structures. But if the water level drops too low and too fast, canals may deteriorate because of backpressure on canal lining and the instability of canal slopes in difficult soils. It is important, therefore, to keep the water level between a maximum, which is imposed for safety reasons, and a minimum, which is needed to supply the land by gravity. By keeping water levels high enough, erosion from rain falling in an empty earth canal is prevented.

The fourth reason for controlling water level variations in a canal is to facilitate the flow control and measurement of water at off-takes. The flow delivered through an off-take depends on the water level upstream. Limiting variations in the water level at canal off-takes to facilitate control of flow releases, therefore, is a crucial task.

Water level control is a basic concept, which has been incorporated into traditional irrigation schemes. Farmers have always known how to dam their streams and canals when and where necessary. The same concept is used also in the simplest design of new canals: water level is controlled through gated cross regulators.

8.2.2 Operation of intake gates related to main conveyance

There are intake gates operated with electrical system, hydraulic system, and force multiplying mechanical devices or simple manual operations. In some cases gates are made automated. It is also not uncommon to equip such gates with sensors in large scale systems.

In small scale irrigation, common types are those operated with *mechanical devices* and simple *manual operation*. Thus in this guideline it is focused on sliding intake gates operated *manually*. Usually if width of channel or board is more than 1500mm the spindle must be more than one and force multiplying system is needed.

Generally, the river discharges are widely fluctuating and operations/regulation of the gates have to be modified from time-to-time on the basis of river behavior, morphological changes, etc. Barrages are not storage structures and the waterway is designed according to design flood without any moderation. As such, during the life of barrage, it is seldom that all the gates are required to be opened fully. Gate operation, particularly during low floods is a key factor for flushing of sediments and prevention or alteration of shoal formation on the upstream and downstream of the barrage.

All lift gates should be operated at suitable intervals, preferably once in fortnight to clear the gate grooves/slots, flood passage and ensure free movement of moving parts of gate. In low supplies when openings are not desirable, rising of gates by 150 mm for a few minutes should suffice. If the gates have not been moved for a sufficiently long time, they should not be forcibly raised all at once but should be lifted by about 30 mm or so and left at that position for about 10 to 15 min till the silt deposited against the gates gets softened and water begins to ooze out. This is essential to avoid heavy strain due to corrosion of gate sliding slots.

Sequence of operation of barrages gates/weir shutters should be decided by the *irrigation engineer or technician* in charge depending on the prevailing factors, such as river behavior, shoal formation, scour, etc., both on the upstream and the downstream. However, while deciding the same, recommendations/ observations of the model studies, if any, should also be kept in view.

Operation of Under Sluice Gates Related to Main Conveyance

Under sluice gates in small scale irrigation schemes are also called silt gates. Silt gates or under sluice gates serve major role of managing silt entrance to main conveyance system. The operation of under sluice gates should be based on approved gate operation schedule for optimum silt exclusion, hydraulic efficiency and structural safety. This is mainly dependent on the rainy seasons and irrigation plan of the IWUA. The silt gates are operated by Gate operators under the consultation of *Irrigation engineer or technician* in charge of the SSI scheme O&M activities.

8.2.3 Operation of silt basin and canal water escapes

Commonly silt basin and rejection spillway (canal water escape) is designed and constructed very close to the intake facility of the headwork at a point free from maximum flood level of the river course. They serve the purpose of releasing discharges beyond FSL and silt removal that has been conveyed with irrigation water and sometimes they serve as escapes for the sake of maintenance activities at the downstream reaches. Such facility can be situated at more than one point in the system based on necessity and economic considerations.

The silt basin is usually inspected for silt accumulation frequently and flushed through the canal water escape channel based on flow conditions and farm operation and maintenance plan. The silt basin should be flushed by disturbing the silt accumulated (preferably by more than two persons) manually by wooden poles prepared for this purpose. During this operation the on-going side gate will be closed and the escape channel gate will be opened. Thus this operation shall be systematically planned not to considerably affect the water distribution plan of the scheme. At the same time any trash on screens (if any) must be removed from the on-going supply canal side.

8.2.4 Operation of cross drainage works

Cross drainage works can be siphon structures, culverts, aqueducts, flumes, level crossing, super passages and the like. Siphon structures are usually designed and constructed to cross valley where flume structure or other cross drainage structure is not found feasible. The syphon structures are mostly equipped with rejection spillway, trash rack at inlet side and silt flushing gates at lower part of the syphon pipe. Flow in such structure is usually fluctuating and is different from design flow. Thus it has to be frequently inspected and operated. Particularly when the flow is silt and trash laden, the frequency of inspection and cleaning for trash and flushing for silt gate shall not be beyond every *15days*. Flushing gate must be opened even in less frequency than 15 days if outlet flow velocity is considerably less than the incoming flow.

Likewise, other cross drainage works like culverts, supper passages, aqueducts, flumes etc. must be cleaned frequently to avoid clogging and overtopping. It is always advisable to check for any flood damages of such structures after heavy rain.

8.2.5 Operation of division box, turnout and off-take gates

The operation of the irrigation gates; i.e. the canal cross regulators and the head regulators, is a simple procedure which requires the operators to set and maintain a “constant head (depth)” of water in the canal upstream of the gated cross regulator and then opening the gated head regulator to the canal to a design setting of gate opening versus flow. The required crop water requirement discharge as per the irrigation schedule then flows to the downstream canal. The supplies passing down the parent canal and off take channel are controlled by cross regulator and head regulator respectively.

8.2.6 Flow measuring structures

Discharges can be measured with the use of discharge measurement structures, like **weirs and flumes.** Such structures with measuring gauge are usually constructed in SSI schemes to facilitate flow measurements. The **calibration and instruction given in design document** shall be followed to use such structures for flow measurement.

Canal discharges can be measured without structures, by measuring velocity of flow and sectional flow area. The fundamental equation used to quantify flow of water based on the basic principle of conservation of mass. That it takes water as an incompressible liquid, which leads to the continuity equation.

Q=VA **Equation 8-1**

Where,
Q = discharge in m^3/s
A= cross sectional area of flow (m^2)

V= velocity of flow (m/s)
Velocity of flow is given by: V=S/t
S=distance of given reach in meter
t=time elapsed between reaches

Thus this method of flow measurement is called Velocity-Area method (mean section). Here flow area is measured carefully. If the channel is of defined section like rectangular, triangular, circular, trapezoidal and the like, only flow depth and width measurement may be enough to calculate the flow area. However, if channel is not defined mean flow area must be taken within the reach of measurement at two or more points.

Measurement conditions:

- Select well defined reach and section of the canal to be measured.
- Choose non-turbulent flow reach
- Take measurements when/where wind effect is less
- Clean for weeds and debris
- Try to choose straight reach
- Take velocity measurement at different depths of flow and at different points of flow section.
- The velocity of flow can be taken using current meter or using floating materials and stop watch.
- Velocity correction factor of about 0.80 can be considered for any variations with in flow section.

Too small discharges can also be measured using constant volume containers by recording time to fill the container that gives flow volume per unit time.

8.3 OPERATION OF PRESSURIZED IRRIGATION SYSTEMS

Operation of pressurized irrigation systems basically refers to drip and sprinkler irrigation. For further details refer to Operation and Maintenance Component of Pressurized Irrigation System Study and Design Guideline.

9 MAINTENANCE OF IRRIGATION INFRASTRUCTURES

9.1 TYPES OF MAINTENANCE ACTIVITIES

Generally maintenance activities of SSI schemes can be classified as Routine or regular, Periodic, Emergency and Rehabilitation. Regular and periodic maintenance are preventive and usually incurs less costs while emergency and rehabilitation maintenance incurs much cost. Thus IWUA must usually inspect and do regular and periodic maintenances to reduce further costs of maintenances.

A. Routine or regular - It is done regularly, at intervals of week, month or the end of each crop season and beginning of the new crop season. It is done without any hindrance to the performance of the system.

B. Periodic - It is done once a year, before opening of the canal and also at the end of the canal closure and is done during non-crop season.

C. Emergency - This is done after some emergent problems, like canal breach, structure damage, gate jamming, etc. take place. The conveyance system has to be closed for attending to such repairs.

D. Rehabilitation- This is done when emergency works are not enough to bring anticipated benefits of the scheme.

i) Routine or regular maintenance

These are small-scale works done regularly over the year some are:

- Minor canal earthworks like shaping, weed removal, etc.
- Filling and compaction of burrows and cracks in canal banks
- Removal of trash and silt from in structures
- Greasing of gate operating mechanisms

ii) Periodic Maintenance

Large repairs should be planned for period when irrigation system is not under operation, some are:

- Re-sectioning of canals (both supply and drainage canals)
- De-silting
- Removing of weeds from canals
- Grass-cutting and vegetation removal from banks
- Gate repair and painting
- Repair of failed parts of structures
- Channel Protection works
- Earthworks (banking and cutting)
- Cleaning out cross-drainage culverts

iii) Emergency maintenance

Urgent maintenance plan to secure water delivery within the system some are:

- Maintenance of deteriorated headwork and appurtenances
- Re-construction of deteriorated canal sections
- maintenance of structures mainly washouts, significant damages
- Repair of landslides and canal breaches etc.

iii) Rehabilitation

Scheme rehabilitation means overall scheme maintenance. This can be the facility as well as other issues related to proper functioning of the system as a whole.

9.2 PLANNING MAINTENANCE ACTIVITIES

Planning steps for maintenance activities:

- Identify and quantify maintenance requirements/Inspection
- Prepare logistic requirements (equipment, material, human)
- Set up maintenance crews
- Schedule the works
- Mobilization of resources

Inspection and maintenance works are handled component by component. The components are from head to tail ends of the scheme. These are presented in Table 9-1 below:

Table 9-1: Nature of repair / maintenance/ for different components of SSI schemes

Component	Interval for inspections	Nature of Repair/ Maintenance	Remark
Catchments	once per month	Watershed management works	Rainy times may be more frequent than stated
Intake	Daily at the opening and closing of canal	Leakage through valves, fluctuations in water level (twice a year)	Recommend to a technical team when any damage is noticed
Diversion retaining and service structure	Once a week. Thorough inspection especially during rainy season	Erosion, retrogression, leakage through gates, deformation of gabions etc.	
Infrastructures (main conveyance and distribution system)	daily when canal is running for unauthorized use of water (in the evening)	At turnout and manhole point, canal banks, Removal of debris and trashes	Recommend to a technical team when any damage is noticed
Structures	Bi-annual	scour, stability and energy dissipation arrangements	Recommend to a technical team when any damage is noticed
Command Area	Between the end of working season and opening of working season and opening of the canal for new working season.	Thorough checking and repair of conveyance, structures, gauges (painting), painting of Notches and regulating shutters, turn outs, seepage control arrangements in the reach of high seepage removal of silt and debris pipes or culverts.	Recommend to a technical team when any damage is noticed
Command Area (general)	Once a month	Check water logging, Erosion of command area due to Spate irrigation if any, drains, boundary bunds of Spate irrigation	

Component	Interval for inspections	Nature of Repair/ Maintenance	Remark
		blocks	
	Irrigation Engineer, (once a year after rainy season)	To check the structure, review reports and suggest measures for improvements.	
	Environmentalist	Watershed management	
	By agronomist (every crop season)	Works and general ecology.	
	Medical officers (twice a year)	To check the general health, hygiene of the area and that of livestock.	
General for the entire scheme	Monitoring	Assess the improvements and constraints, capability building and extension work	

Labor and materials for repair/ maintenance

The construction materials of small-scale irrigation structures are soil, masonry or stone, steel, concrete, wood etc. Canals are constructed either by soil cut or fill, or masonry. The major problems associated with earth canals, drains are erosion, breaching and siltation. Properly designed lined canals will avoid problem of siltation, erosion and breaching, too. But depending up on the length of their service i.e. design period they need proper maintenance.

As indicated above, the IWUA has main responsibility for the management, operation and maintenance of all Irrigation infrastructures, within their main canal boundaries. Therefore, for the sustainability of the scheme, preparing rough estimated cost of labor, amount of work and construction material is essential. In general maintenance work requires high labor input and local skill. Regular and periodic maintenance works in SSI schemes are presented in table below.

Table 9-2: Regular and Periodic Maintenance Works in SSI Schemes

Work Item	Description of activities
silt removal from canals	This includes the removal of Sand, Silt and clay layers on the bottom of the canals and drain. The volume of silt removed from canals and drains could be estimated by measuring the thickness of the layer and multiplied by the bottom surface (Length x Width). This activity has to be performed *at least once in a year*.
silt removal from Pond	This removal of silt from pond has to be done *every 2 years* as the water is comparatively silt-free during irrigation periods.
Grass removal	This is cutting and removal of grass and weeds in the canals drains and embankments. This has to be done *twice a year*.
Reshaping	Shaping is to Canals (supply and drainage) and road sections. It may include all kinds of damages from traffic, human and animal activities, erosion, settlement, sloughing, riprap repair and has to be performed at *least once a year*. This has to be done by the beneficiary based on guidance given by irrigation technicians at scheme level.

Personnel needed for maintenance
Three types of personnel maybe needed for maintenance activities in SSI schemes:

Self-help - They are beneficiaries themselves or IWUA. They do not need any type of technical or financial help.

Local support- Help of crafts man like mason, plumber or a mechanic is needed for carrying out repair works and it may be met out of the financial resources of the IWUA.

Specialized support - They are mostly inspected and planned by Engineers and the IWUA.

The following norm can be indicative for some routine maintenance works:

- Silt removal 0.5 m^3 per man day,
- Grass removal 100 m^2 per man day,
- Reshaping 50 m^2 per man day

Table 9-3: Annual Labor Requirement for Regular and Periodic Maintenance of SSI Project

Facility	Maintenance	Frequency (n/yr)	Length (m)	Cross-sectional area (m^2) or m	Unit	Qty	Output (MD/unit)	MD (MD/yr)	Remark
Pond	silt removal	1	10	10	m^3	100	0.5	200	
MC	Silt-removal	1	37	0.3	m^3	11.1	0.5	23	Lined rectangular
TC	Silt-removal	1	280	0.3	m^3	84	0.5	168	Lined rectangular
MC	Silt-removal	1	1512	0.3	m^3	453.6	0.5	907	Earthen
	Grass-removal	2	1512	1.3	m^2	3932	100	40	
	Reshaping	1	1512	1.3	m^2	1966	50	40	
TC	Silt-removal	1	408	0.4	m^3	164	0.5	327	Earthen
	Grass-removal	2	408	1.3	m^2	1061	100	11	
	Reshaping	1	408	1.3	m^2	530	50	11	
CD	Silt-removal	1	2237	0.4	m^3	895	0.5	1790	Earth
	Grass-removal	2	2237	1.8	m^2	8053	100	81	Earth
	Reshaping	1	2237	1.8	m^2	4027	50	81	Earth
FC	Silt-removal	1	6000	0.05	m^3	300	0.5	600	Earth
	Grass-removal	2	6000	0.50	m^2	6000	100	60	Earth
	Reshaping	1	6000	0.50	m^2	3000	50	60	Earth

Regular and periodic maintenance works must be planned every year by the IWUA. Likewise special repairs have to be planned under the guidance of irrigation experts responsible at scheme level. Special repair is usually inspected, quantified and cost estimates based on the market price is done.

Operation and maintenance charges:
Under all cases operation and maintenance fee collection is mandatory to sustain irrigation system. The cost incurred during operation and maintenance of different components depends upon their size, structural upkeep and items needing normal repair works. It cannot be given a standard value. However, after actual involvement of labour and material for two - three years this can be known on rough basis for the scheme. Charges collected for penalties arising from non- compliance to rules of the IWUA also can be used for this purpose too. The association will set this in consultation with the beneficiaries.

Table 9-4: Regular and Periodic Maintenance Annual Plan (Sample)

Particular	Maintenance -work	J	F	M	A	M	J	J	A	S	O	N	D
MC	Silt-removal									●	●	●	
	Grass-removal			●	●					●	●		
	Reshaping										●	●	
TC	Silt-removal									●	●		
	Grass-removal			●	●								
	Reshaping									●	●		
CD	Silt-removal									●	●	●	
	Grass-removal			●	●					●	●	●	
	Reshaping										●	●	
FC	Silt-removal									●	●	●	
	Grass-removal			●	●					●	●	●	
	Reshaping										●	●	
Road	Reshaping									●	●	●	
Pond	de-silting									●	●	●	

Emergency maintenance and Rehabilitation works are to be quantified and detail cost breakdown and work plan are necessary depending on the extent of damages observed within the system. This may include earth works, Masonry works or Concrete works, Carpentry works and so on. In rehabilitation activity not only the physical facility to be studied in detail rather; the agronomic aspects, social organization, hydrological considerations and other relevant issues that brought about inefficient system with less revenues than anticipated must be seen in detail.

9.3 MAINTENANCE OF HEADWORKS AND STRUCTURES

9.3.1 Maintenance of weir, barrage, free intake and related structures

Inspection of Intakes, weirs and barrages is necessary to repair all damages and to obviate the possibility of extension of damage. Such inspection should usually be carried out annually for all underwater works after main rainy season by means of underwater lamps, sounding rods or local experiences of underwater inspection. In addition, in larger scale weirs detailed inspection in stages should be carried out using underwater videography at suitable intervals depending upon extent of damage. However in SSI schemes most cases inspection can be done under silt gates open conditions even right after the main rainy season. Repairs can be undertaken by either depleting the pond or by isolating the damaged portion by construction of ring bunds. The requisite suitable measures for upstream floor and other floors shall be suitably planned and designed.

a) Wing wall that need repair

b) Headwork that need rehabilitation

Figure 9-1: Image of head work deterioration

The repairs as necessary as a result of inspection should be carried out well before the onset of the next main rainy season. Serious defects noticed should be reported to appropriate authorities for taking remedial measures in time. The inspection and maintenance for the following works may be carried out:

a) Aprons:
1) Upstream apron and area immediately upstream of it; and
2) Downstream apron and area immediately downstream of it;

b) Impervious floors:
1) Upstream of the gates/falling shutters; and
2) Downstream of the gates/falling shutters;

c) Sediment excluding devices;
d) Canal head regulator;
e) Performance; and
f) River training works.
g) Piers/Abutments, Road/rail bridges

a) Aprons
The sounding and probing in the area should be undertaken every year immediately after the main rainy season in order to assess the scours and launching of aprons in the vicinity of structures. The non-launching portion should be carefully examined, particularly on downstream, to ensure the effectiveness of inverted filter.

b) Impervious floors
A thorough inspection of upstream and downstream floors should be undertaken after the main rainy season. The upstream floor should be inspected every year early in the fair weather season by probing and the use of underwater lamps or any local practice depending on scale of the headwork. A careful inspection of joints of the stone-sets should be done where such structures exists. Some repairs can be done underwater whereas major repairs may be undertaken by isolating the area.

The downstream basin should also be carefully inspected and the repairs carried out well in time before the onset of main rainy season. In case of deep cisterns requiring expensive cleaning and dewatering, inspection of sandy reaches can be carried out by probing but in boulder reaches where this may not be possible, dewatering, cleaning and repairs may be carried out by rotation once in *three years*. The condition of boulder-set or granite block in the case of boulder Stage River should be carefully examined, and repairs and replacements made, as found necessary. While dewatering deep downstream basins, care should be taken to ensure that the design uplift for such condition is not exceeded. This should be clearly specified in the regulation order.

c) Sediment excluding devices

A thorough inspection of roofs, ducts and mouth of the sediment excluders should be carried out every year in the fair weather with the help of divers and underwater lamps. Minor repairs may be carried out underwater and major repairs by local isolation.

d) Canal head regulator

The works should be carefully examined every year in the fair weather. The upstream floor should be examined by probing and downstream floor under dry conditions during closure or isolating the area where closure may not be possible. Visual inspection of upstream floor should also be carried out once in *three to five years* by isolating the area. All necessary repairs should be carried out in time.

e) Performance

It is essential that every year a performance report be prepared on the basis of instrument observations. The observations can be broadly classified under the following sub-heads:

a) Uplift pressure;
b) Suspended sediment;
c) Settlement;
d) Retrogression;
e) Aggradation upstream; and
f) Discharge distribution and cross flow.

Uplift pressure

The uplift pressure observation pipes are mostly embedded in the weir or barrage structure, generally in piers and flank walls in such a manner as to give representative uplift, pressure along and immediately beneath the horizontal floor and at different points along the vertical cut-off. Additional pressure pipes may be installed, if required, to determine uplift pressure at critical points in case of stratified foundations. The pipes should be numbered and a permanent record of observations should be maintained. The observed uplift pressure should be compared with the design uplift pressures with the help of a graphical plot and any needed remedial measures taken. Frequency of observation will depend upon local conditions. It may generally be enough to take observations once a month during main rainy season period and more frequently during the non-main rainy season period. It should be ensured that, a) the mouths of all pipes are kept closed by caps to obviate the chances of foreign matter findings its way into the pipes and clogging them; b) each pressure observation point is given a distinct number; and c) each pipe is frequently tested to ensure that its strainer is not choked. This can be best done with the help of an ordinary hand pump, by working it till water comes out freely.

Pressure release (drainage) pipes

The effluent/discharge coming out of pressure release/drainage pipes, where provided in the downstream floor, should be observed for its quantity as well as quality of sediment contents. Such observations may be possible only during dry season when all the gates of the compartments are closed.

This is necessary to check the efficient working of the drainage system. A correlation between head of water and discharge should be established and any large variations immediately taken notice of and suitable action taken. As presence of sediment in the effluent could lead to undermining of the foundations, immediate remedial measures should be undertaken. In extreme case, it may become necessary even to completely block the sediment discharging pipe.

Hydraulic jump profile
Strip gauges should be painted every 5 m on the wing walls and the long divide walls to observe the hydraulic jump profile of the weir under different hydraulic events and compared with design conditions. The following observations should be taken:

a) Upstream water level;
b) Downstream water level;
c) Length of the jump
c) Discharge from drainage pipes (if any); and
d) Depth of sediment on upstream and downstream floors.

Suspended sediment
During the main rainy season, water sample should be taken simultaneously upstream and downstream of the under-sluices and in the canal below the head regulator to assess the suspended sediment therein. Such observations should be taken at least *once a week* (closer intervals in case of high sediment concentration) to assess the efficiency of sediment exclusion device and to decide if any change in the mode of regulation and/or other remedial measures are required.

Settlement
Where appreciable foundation settlements are anticipated, particularly when the structure is founded partially or wholly on clay or other soft soil, surface settlement of relatively heavily loaded parts of the structure should be observed early in the fair weather *every year* and remedial measures undertaken, if necessary. This can be done by establishing permanent observation points of steel on the structure and doing precise leveling from permanent bench marks established sufficiently away from the influence of any structure.

Retrogression
Retrogression of the river bed can be expected downstream of the weir/barrage. In order that the lowering of water level at any discharge condition does not exceed that provided for in the design, it is necessary to establish gauges on both banks, one immediately downstream of the work and two more, 100 m and 200 m downstream of the first and to observe them simultaneously at least *once a day*. Remedial measures should be undertaken as and when required to ensure the safety of the structure.

Aggradation upstream
The river bed upstream of the barrage or weir is likely to aggradate resulting in increased afflux and reduction in freeboard provided in design. To determine the increase in the afflux, if any, gauges should be established on the upstream, one immediately upstream of the work and one each at 100 m and 200 m upstream of the first, and observed regularly. The afflux bunds may have to be raised, if found necessary, to restore the designed freeboard.

Discharge distribution and cross-flow

Observations should be taken to find the discharge distribution through different bays of the barrage. If there is significant cross-flow and/or difference in discharge intensities through different bays, remedial measures should be taken to check this tendency by adopting modified gate regulations, removal of shoals, etc.

Pond capacity

Where balancing storage is also provided in the barrage, soundings in the entire pond area may be made at suitable intervals for periodic review of storage capacity.

f) River training works

A detailed river survey covering the barrage/weir and river training works upstream and downstream should be carried out every year. The survey should preferably extend about *one meter* above the design flood level on both the banks on upstream side. Similarly, the survey on downstream side should extend to a length up to which *river bed changes* occur. Sufficient number of permanent reference marks should be established on both banks to facilitate superimposition of old and new survey. The changes in the river course should be examined and remedial measures taken.

The afflux bunds, guide bunds and spurs should be examined in the fair weather and necessary repairs to the bunds, pitching and aprons carried out and completed well before the onset of main rainy season. An adequate stock of boulder/stones should be maintained close to the protection works for use in emergency.

g) *Piers/abutments, road/rail bridges*

These facilities are to be inspected (particularly after main rainy time) and maintained immediately.

9.3.2 Maintenance of small dams and related structures

Because dams are subject to deterioration over time, and seemingly minor deficiencies can quickly develop into major problems, all dam components and appurtenances should be inspected and maintained regularly. Routine maintenance recommendations are provided below by dam component.

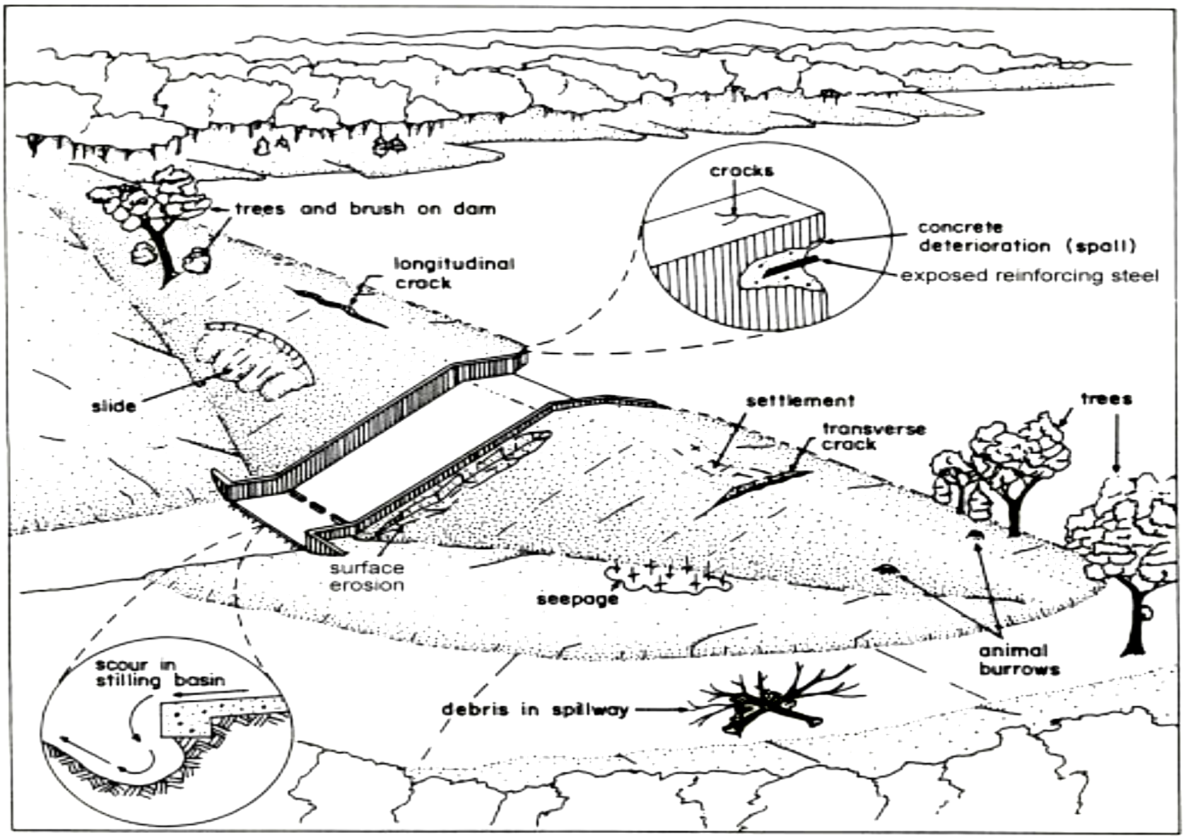


Figure 9-2: Typical dam deficiencies

Dam embankments

Recommended routine maintenance procedures and frequencies include:

a. Vegetation Control - *twice per year*

- Mow grass to maintain visibility of dam surfaces and remove woody vegetation from within 7-8m of all dam components
- Maintain a healthy stand of grass to prevent erosion and growth of woody vegetation

b. Rodent Control - *as required*

- Fumigate burrow
- Trap or eradicate rodent
- Fill entire burrow with fill material

c. Minor Embankment and Erosion Repair – as required

- Restore damaged/eroded areas with soil that is free from vegetation, organic matter, trash, large rock
- Place and compact in thin (i.e., 15cm) layers
- Install topsoil and seed

d. Erosion Protection - as required

- Install rock, vegetation or other material (concrete or asphalt) where erosion protection is missing, damaged or otherwise required

Dam spillway

Recommended routine maintenance procedures and frequencies include:

a. Vegetation Control (for grass lined emergency spillways)

- Mow grass twice per year
- Maintain a healthy stand of grass to prevent erosion
- Remove woody vegetation annually

b. Minor Earthwork and Erosion Repair - as required

- Replace missing soil with new soil that contains no vegetation, organic matter, trash or large rocks
- Place and compact in thin (i.e., 6-inch) layers
- Install topsoil and seed

c. Erosion Protection - as required

- Install rock, riprap, vegetation or other material
- (e.g., concrete or asphalt) where erosion protection is missing, damaged or otherwise required
- Check downstream spillway channel for evidence of excessive siltation or erosion

d. Concrete/Stone/Masonry Repair - as required

- Consult irrigation sector to determine appropriate repairs

Dam intake/outlet structures

Recommended routine maintenance procedures and frequencies include:

a. Trash-rack - *after every major storm*

- Remove accumulated debris
- Repair rusted or broken sections as needed

b. Mechanical - once per year

- Cycle (open and close) outlet gate valves through full operating range
- Lubricate mechanisms per manufacturer's recommendation
- Paint or grease ferrous metal surfaces as needed
- Align stem guides or brackets

c. Internal Conduit - once per year

- Check for undermining or seepage around the outlet end
- Check for corrosion or other deterioration of conduit material
- Should deficiencies be detected, obtain immediate professional guidance before attempting repairs

d. Concrete Features - once per year

- Check for misalignment, cracks, spalls, scaling, exposed steel rebar, rust stains
- Consult with supporting institution before attempting repairs

Masonry and rubble walls

Recommended routine maintenance procedures and frequencies include:

a. Vegetation Control - twice per year

- Remove woody vegetation within 7 to 8m of masonry dam structures
- Cut trees growing in masonry walls flush with face of masonry

b. Missing Stones - as required

- Replace missing or misaligned capstones in spillway
- Replace missing stone masonry in downstream and upstream walls
- Do not mortar up or seal off the spaces or openings between the stones on the downstream face of masonry or rubble walls without first consulting a qualified engineer

Miscellaneous safety and access features

Recommended routine maintenance procedures and frequencies include:

a. Maintain vehicular and pedestrian access features to allow future inspection and maintenance – once per year.

b. Check fences, locks and signs for damage – once per year.

Inspection of dam Failures

Dam failures usually result from poor design, poor quality of construction, inadequate maintenance, or a combination of the above. Although the manner in which a dam fails and the particular causes of failure are often varied and complex, failures can generally be grouped into the following three types:

Seepage/piping:

All earth dams have seepage due to water movement through the dam and its foundation, however, the rate of seepage must be controlled. Uncontrolled seepage can progressively erode soil from the embankment or its foundation in an upstream direction towards the reservoir and develop a flow conduit (pipe) to the reservoir. This phenomenon is known as "piping." Uncontrolled seepage may also weaken the soil and lead to a structural failure. Common causes of seepage/piping include rodent activity, tree roots and poor construction.

Overtopping/erosion:

Overtopping failures result from the erosive action of the uncontrolled flow of water over, around or adjacent to the dam. Earth embankments are not designed to be overtopped and therefore are particularly susceptible to erosion. Surface erosion may reduce the embankment cross-section, saturate an earth embankment and lead to a structural failure. General causes of overtopping include inadequate spillway size and/or spillway blockage by debris.

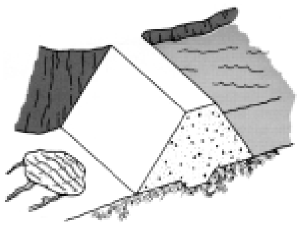
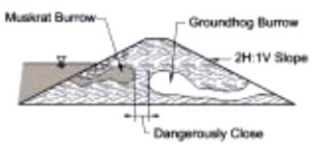
Structural:

Structural failures can occur in the dam itself or its foundation. Structural failure of a spillway, drawdown facility, concrete wall or other appurtenance can lead to a total dam failure. Cracking, settlement and slides are common signs of structural failure which often result from uneven settlement of foundation materials and/or poor workmanship during construction.

Problems, consequences, recommended actions

Various observable problems, their possible consequences, and recommended actions are grouped below by failure type.

Table 9-5: Seepage problems, possible consequence and recommended actions

Seepage/piping problem	Possible consequences	Recommended actions
Seepage Water Exiting at Abutment Contact  	Can lead to erosion of embankment materials and failure of the dam.	- Study leakage area to determine quantity of flow and extent of saturation. - Stake out the saturated area and monitor for growth or shrinkage. - Inspect frequently for slides. - Water level in the impoundment may be lowered to increase embankment safety. - A qualified engineer should inspect the conditions and recommend further actions to be taken.
Seepage Water Exiting as a Boil in the Foundation 	Continuous flows can lead to piping erosion of the foundation and failure of the dam.	- Examine boil for transportation of foundation materials, evidenced by discoloration. - If soil particles are moving downstream, create a sand bag or earth dike around the boil. This is a temporary control measure. - The pressure created by the water level within the dike may control flow velocities and prevent further erosion. - If erosion continues, lower the reservoir level. - A qualified engineer should inspect the condition and recommend further actions to be taken.
Spongy Condition at Toe of Dam 	Condition shows excessive seepage in the area. If control layer of turf is destroyed, rapid piping erosion of foundation materials could result in failure of the dam. Marked change in vegetation may be present.	- Carefully inspect the area for outflow quantity and any transported material. - A qualified engineer should inspect the condition and recommend further actions to be taken.
Rodent Activity  	Can reduce length of seepage path and lead to piping erosion failure. If rodent tunnel exists through most of the dam, it can lead to failure of the dam.	- Control rodents to prevent more damage. - Determine exact location of digging and extent of tunneling. - Remove rodents and backfill existing holes.
Seepage Water Exiting From a Point Adjacent to the Outlet	Continued flows can lead to rapid erosion of embankment materials and failure of the dam.	- Investigate the area by probing and/or carefully shoveling to see if the cause can be determined. - Determine if leakage water is carrying soil particles evidenced by discoloration. - Determine quantity of flow. If flow increases, or is carrying embankment materials, reservoir level should be

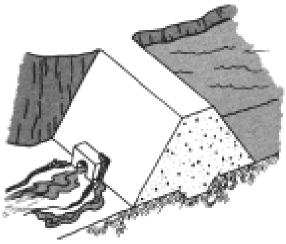
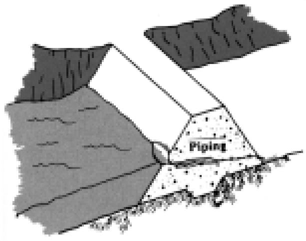
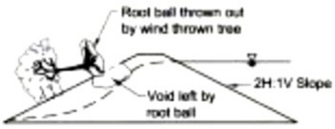
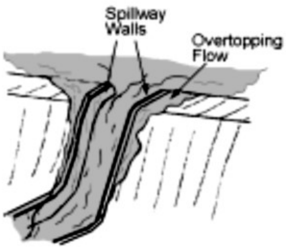
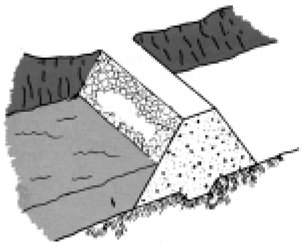
Seepage/piping problem	Possible consequences	Recommended actions
		lowered until leakage stops. - A qualified engineer should inspect the condition and recommend further actions to be taken.
Sinkhole 	Piping erosion can empty a reservoir through a small hole or can lead to dam failure as soil pipes erode. Dirty water at the exit indicates erosion.	- Inspect other parts of the dam for seepage or more sinkholes. - Identify exact cause of sinkholes. Check seepage and leakage outflows for dirty water. - A qualified engineer should inspect the conditions and recommend further actions to be taken.
Trees /Brush 	Large tree roots can create seepage paths. Brush can obscure visual inspection and harbor rodents. Decaying root systems can provide seepage paths. Wind thrown tree can create void in dam.	- Remove all trees and shrubs on and within 7-8m of the embankment. - Properly backfill void with compacted material. - A qualified engineer may be required.

Table 9-6: Overtopping problems, possible consequence and recommended actions

Overtopping/erosion problem	Possible consequence	Recommended actions
Blocked/Inadequately Sized Spillway 	May reduce discharge capacity and cause overflow of spillway and/or dam overtopping. Dam, if overtopped frequently, can erode and/or fail.	- Remove debris blockage regularly. - Measure quantity of flow depth in spillway for various rain events. - Control vegetative growth in spillway channel. - Install log boom or trash rack in front of spillway entrance to intercept floating debris. - A qualified engineer should inspect it.
Broken Down or Missing Riprap 	Wave action against unprotected areas decreases embankment width. Soil is eroded away which allows riprap to settle, providing less protection and decreased embankment width.	- Re-establish normal slope. - Place bedding and competent riprap. - A qualified engineer is required for design of bedding and riprap
Erosion	Erosion can lead to eventual deterioration of the downstream slope and failure	- Protect eroded areas with riprap. - Compacted soil and re-establishing turf may be adequate if the problem is

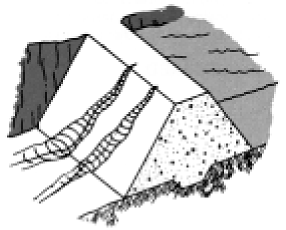
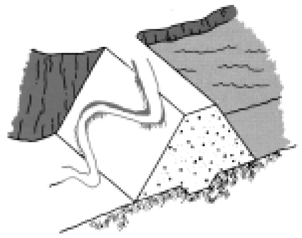
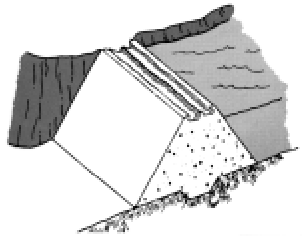
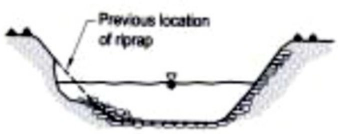
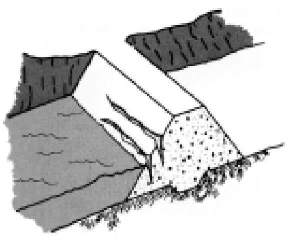
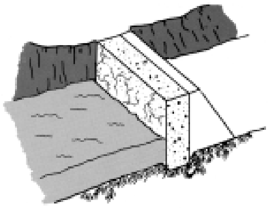
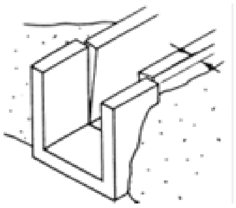
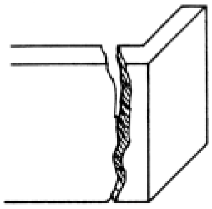
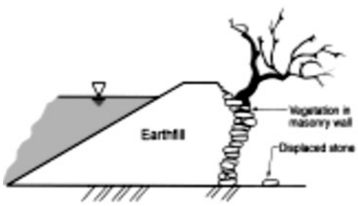
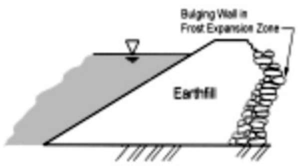
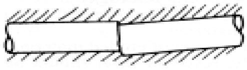
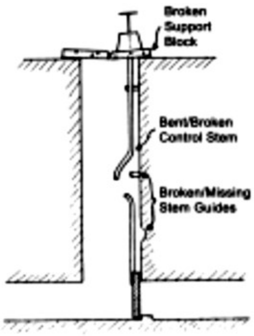
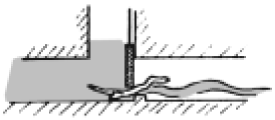
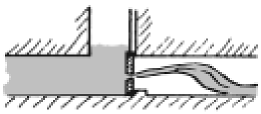
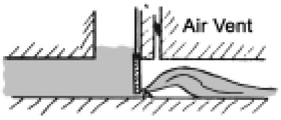
Overtopping/erosion problem	Possible consequence	Recommended actions
	of the structure. Can reduce available freeboard and/or cross-sectional area of dam. Can result in a hazardous condition if due to overtopping.	detected early. - If gully was caused by overtopping, provide adequate spillway designed by a qualified engineer.
Pedestrian/Vehicle Traffic 	Creates areas bare of erosion protection and causes erosion channels. Allows water to stand and makes area susceptible to drying cracks.	- Prohibit access using fence, signs. - Repair erosion protection with riprap or grass. - If access is needed or required, provide a formal access way designed to prevent erosion.
Ruts/Puddling Along Crest 	Allows standing water to collect and saturate crest of dam. Vehicles can get stuck.	- Re-grade and re-compact crest to provide proper drainage to upstream slope. - Install gravel or road base material to accommodate traffic.
Missing/Deteriorated Riprap Channel Lining 	Erosive action displaces channel lining and washes sediment downstream.	- Install properly graded riprap in channel lining with filter material to prevent soil from being washed out through spaces in the riprap.

Table 9-7: Structural problems, possible consequence and recommended actions

Structural problem	Possible consequence	Recommended actions
Large Cracks, Slide, Slump or Slip 	Large cracks indicate onset of massive slide or settlement caused by foundation failure. A series of slides can lead to obstruction of the outlet or failure of the dam. If massive slide cuts through crest or upstream slope, reducing freeboard and cross section, structural collapse or overtopping can result.	- Measure extent and displacement of slide. If continued movement is seen, begin lowering water level until movement stops. - A qualified engineer should inspect the condition and recommend further action.
Cracked or Deteriorated Concrete Face	Ice action may further weaken or displace concrete by freezing and thawing.	- Determine cause. Either patch with grout or contact engineer for permanent repair method. If damage is extensive, - A qualified engineer should inspect the conditions and recommend further actions to be taken.

Structural problem	Possible consequence	Recommended actions
		
Wall Displacement/Open Joints 	Minor displacement will create eddies and turbulence in the flow, causing erosion of the soil behind the wall. Erosion of foundation material may weaken support and cause further displacement. Major displacement will cause severe cracks and eventual failure of the structure.	- Reconstruct displaced structure. - Water-stops should be used at joints where feasible. - Consult a qualified engineer before actions are taken.
Large Cracks 	Disturbance in flow patterns; erosion of foundation and backfill; eventual collapse of structure. May allow entrance of water which could cause freeze and thaw damage and further weaken structure.	- Cracks without large displacement may be repaired by patching, in which case surrounding areas should be cleaned or cut out before patching. - Installation of weep holes or other actions may be needed. - A qualified engineer should inspect the condition.
Leakage Through Joints or Cracks 	Can cause walls to tip over. Flows through concrete can lead to rapid deterioration from weathering. If the spillway is located within the embankment, rapid erosion can lead to failure of the dam.	- Check area behind wall for puddling of surface water. - Check and clean drain outfalls, flush lines, and weep holes. - If condition persists a qualified engineer should inspect and recommend further actions.
Tree Growth in Masonry Walls 	Can weaken or disintegrate wall by dislodging masonry or rubble stone.	- Control excessive brush through regular routine maintenance (removal). - Remove large trees, stumps and roots under the direction of a qualified engineer.
Leaning/Bulging Masonry Walls 	Freezing/thawing of silty/clayey soils push (lean) masonry walls out of vertical alignment. Missing stones can weaken wall and lead to wall failure.	- Monitor movement over time. - Replace lost or unsuitable soils behind wall or brace downstream face with riprap or washed stone. - Replace missing stones, choke and/or chink gaps in wall. Depending upon extent of displacement/ condition, a qualified engineer may be required.
Outlet Pipe Damage:	Provides passageway for	- Check for evidence of water either

Structural problem	Possible consequence	Recommended actions
Hole, Crack  Joint Offset  Control Works 	water to exit or enter pipe, resulting in erosion of internal materials of the dam. Loss of support for control stem. Stem may buckle and break under even normal use, resulting in loss of control.	entering or exiting pipe. Tap pipe in vicinity of damaged area, listening for hollow sound which indicates a void has formed along the outside of the conduit. If a progressive failure is suspected, request advice from a qualified engineer. - Use of the system should be minimized or discontinued. If the outlet system has a second control valve, consider using it to regulate releases until repairs can be made.
Valve Leakage: Debris Stuck Under Gate  Cracked Gate Leaf  Damaged Gate Seat or Guides 	Gate will not close. Gate or stem may be damaged in effort to close gate. Gate leaf may fail completely, evacuating reservoir. Leakage and loss of support for gate leaf. Gate may bind in guides and become inoperable.	- Raise and lower gate slowly until debris is loosened and floats past valve. When reservoir is lowered, repair or replace trash-rack. - Use valve only in fully open or closed position. Minimize use of valve until leaf can be repaired or replaced. - Minimize use of valve until guides/ seats can be repaired. Check to see if air vent pipe exists and is unobstructed.

Dam maintenance summary and schedule table

This maintenance summary and schedule is intended to provide the owner with a quick reference of the recommended frequency intervals for inspecting and performing routine maintenance on the components of a dam.

Table 9-8: Dam maintenance schedule

Component	Maintenance Activity	Frequency
Embankment	Vegetation control	Twice per year, minimum
	Rodent control	Check once per year, perform as required
	Minor earthwork, erosion repair	Check once per year, perform as required
	Erosion protection	As required As required
Principal Spillway	Vegetation control	Twice per year
	Minor earthwork, erosion repair	Check twice per year, perform as required
	Erosion protection	Check twice per year, perform as required
	Concrete repair	As required
Emergency Spillway	Vegetation control	Twice per year
	Minor earthwork, erosion repair	Check twice per year

Component	Maintenance Activity	Frequency
	Erosion protection	Check twice per year
	Concrete repair	As required
Intake/Outlet Structures	Trash-rack cleaning	After every major storm
	Mechanical operation	Once per year
	Internal conduit inspection	Once per year
	Concrete features inspection	Once per year
Masonry Walls	Vegetation control	Twice per year
	Missing stones	As required
Miscellaneous Safety and Access Features	Vehicle/pedestrian access route(s) maintenance Fences, locks, signs inspection	Once per year

9.3.3 Maintenance of pumps and control heads

As discussed earlier under pump operation, there are various types of pumps and all pumps are provided with specific installation, operation and maintenance manual from the manufacturer. However the most common pumps for SSI scheme are surface centrifugal pumps driven with diesel engines or electrical motors. Thus the guideline focuses on centrifugal pumps repair and preventive maintenance aspects and procedures.

It is the role of **scheme operation and maintenance team** to perform preventive maintenance of centrifugal pumps with due collaboration of IWUA and on site irrigation engineer assigned for scheme operation and maintenance activities. Proper subject matter specialist (mechanic) shall be consulted for any failure of the pump. Pump manual and moving items for instance fuel and oil filters, air cleaners, gaskets etc. must always be availed on site.

Procedures for pump maintenance:

1. Pulling out the Motor
Note: Before making any attempt, ensure that Lock-Out/Tag-Out system has been applied; isolating circuit breakers and magnetic contactors at panel board.
a. Remove coupling cover, if required.
b. Loosen coupling nut setscrews
c. Remove all fixing bolts on the base plate that holds the motor.
d. Pull-out the motor straightly aligned away from the pump.

2. Pulling out the Pump
Note: Before making any attempt, ensure that Lock-Out/Tag-Out system has been applied; isolating valves and gate valves must be securely shut-off or closed.
a. Remove all the bolts that hold the pump on the base plate.
b. Loosen and remove all the bolts on suction and discharge flanges.
c. Pull out the pump assembly.

3. Disassembling the Pump
a. Loosen and remove all the bolts from volute, then pull out the volute cover.
b. Remove the impeller lock-nut.
c. Pull out the impeller using puller if necessary.
d. Remove flange coupling, use puller if necessary.

e. Remove mechanical seal. Be sure to measure first the correct distance of mechanical seal from the other end of the shaft before pulling it out.
Note: Ensure that lubricants (e.g. grease, oil) are removed before removing casing.
f. Remove the bolts on the casing covers.
g. Pull the shaft with bearings from the housing.
Note: Extra care must be applied during dismantling and fitting of mechanical seal.

4. Pulling out the bearing from the Shaft
a. Pull out the bearing using bearing Puller.

5. Inspection and Repair
a. Check the condition of the bearings. Worn-out and damaged bearings must be replaced.
b. Check the physical appearance of the shaft seals and oil seals and proper bearing fitness to the shaft and to the housing.
c. Damaged mechanical seals and oil seal must be replaced.

6. Recondition/Replacement of Parts
a. If there is no defective part, if necessary, Operation and Maintenance Personnel (OMP) shall perform the reconditioning or refurbishing of the parts/components of the pump.
b. Thorough evaluation of the parts or components is needed to conclude whether it can be reconditioned, or be replaced by a new one.
c. Operation and Maintenance Personnel shall re-install the refurbished/reconditioned parts/components as it was dismantled.
Note: Refurbishing and reconditioning shall be done with extra care some parts or components are delicate, fragile and sensitive to dirt.

7. Obtain Spare/Parts Procurement
a. If there is a defective part, OMP/Technician shall give the defective parts/components to the OMP/Supervisor and OMP/Supervisor should check Spare Parts Stock Room for the availability of the said parts/components.
b. If spare is not available at Stock Room, perform Purchasing of Spare Parts procedure.
c. As soon as the components/parts are available, the OMP/Technician shall perform the installation/fitting of components/parts. Installation shall be done carefully, because some components/parts are miniature, delicate, fragile and sensitive to dirt.
d. OMP/ Technician shall install/fit the new one as it dismantled.

8. Assembling the Pump
a. Install bearings and oil seals on the shaft.
b. Install the shaft on the housing.
c. Put front and back covers and tighten the bolts.
d. Install mechanical seal on correct distance from the other end of the shaft.
e. Install flange coupling on the other end.
f. Install the impeller then put and tighten impeller lock-nut.
g. Install the suction volute housing, then put and tighten the bolts.

9. Installing the Pump
a. Place and tighten all the bolts that hold the pump on the base plate.

10. Drive Motor installation and check for alignment
a. Position the motor on the base plate with its shaft and flange coupling linearly aligned with the pump’s shaft and flange coupling.
b. Slide the motor forward to the pump to connect their flange couplings and shafts.
c. Align pump and motor. Check radial and linear alignments, by using dial indicator. Adjust the motor position if necessary to attain proper alignment.

d. Put and tighten coupling setscrew
e. Put and tighten all fixing bolts on the base plate that holds the motor.
f. Apply grease and oil lubricants.

11. Test run
a. Energize and proceeds to testing.

Note: This procedure shall be evaluated every six (6) months on the first year of implementation and every year after its first year of evaluation. Revision must be done periodically or as necessary. This procedure shall be reviewed by the OMP/Supervisor and OMP Team and approved by Top Management of the Irrigation Authority.

Control heads
Control heads are those facility associated with the pumping station. These are control board, different valves, pressure regulator, water meter, fertigation units, filter units etc. All valves must be checked for proper operation. If any leakage or corrosions are observed proper gasket and lubrication has to be provided. All filter units must be maintained frequently based on quality of water source. Some of the actions to be taken are:

(1) Visual inspection - Examine for broken, bent, misaligned, worn, or loose parts and corrosion and deterioration of protective coatings.
(2) Lubrication.-Apply a suitable lubricant at all application points. Follow manufacturer's recommendations, if available.
(3) Exercising - After lubrication, operate equipment and check for any defect.

In an electrical system the control board must be checked for switches, fuses, breakers and all wiring for loose connection or insulation problems. It is also important to see ventilation, drainage and lighting conditions at pumping stations.

9.3.4 Maintenance of canals and related on-farm structures

Common problems in canal and around structures are:

Leakage: The water upstream of a structure is higher than the downstream water level. Therefore water may search for another way underneath or along the structure, or even through a crack in the bottom or sides of the structure to this lower level. The moment that water has found a small path, there is a leakage problem and at the same time it is the beginning of an erosion problem. Leaking water will enlarge the path by washing out the soil and so the leakage will increase. Finally the structure will collapse if the process is not stopped. To avoid such problem, the structure can be equipped with vertical cut-offs. They hinder the water flow along and underneath the structure. The cut-offs are part of a structure and can be driven into the bed and the embankments of a canal.

Erosion: Sections of an unlined canal immediately downstream of a structure or downstream of a lined canal section often suffer from erosion. Downstream of a structure the canal bed may suffer from a water jet that flows through a gate or pipe, or it will be caved in by water that spills over a weir. In both situations a stilling basin is needed to dissipate the energy of the incoming water. The basin should be constructed immediately downstream of the weir or pipe.

Siltation: The deposition of soil and debris can affect the functioning of a structure. If, for instance, a stilling basin collects soil deposits the available water mass diminished and energy dissipation will be less effective. Similarly in the case of soil deposits in a flow division box, the division of the flow will be less accurate due to the changes in flow velocities and water levels. Siltation is difficult to avoid. Depending on the local conditions, large sand traps could be constructed at the upper end of the main canal.

Rot and rust wooden and steel parts in structures suffer from being alternately wet and dry. The wooden parts will rot and disintegrate, while steel parts will rust, expand and get jammed in the slides. Routine maintenance is necessary to avoid these problems, or to reduce their effect to a minimum.
Maintenance activities for a canal fall into three categories:

- Routine maintenance.
- Emergency works.
- Scheme improvement.

a) Routine maintenance
Routine maintenance activities have to be repeated throughout the lifetime of canals to keep them functioning. Some of these activities are daily routines which do not require special skills:

- greasing of gates;
- removing vegetation from embankments of canals and drains;
- removing silt from canals, drains and structures.

Other routine maintenance activities require skilled artisans, such as a mechanic, a mason, a carpenter and a painter. They may be needed to do routine maintenance work such as:

- repairs to gates and measuring structures;
- repainting of steel structures;
- installation of water level gauges;
- maintenance and small repairs of pumps and engines.

Larger routine maintenance jobs are usually done between irrigation seasons, when the canals are drained. These include:

- major repair or replacement of gates, pumps, and engines;
- large-scale silt clearance from canals and drains;
- Large-scale maintenance of roads and embankments.

All routine maintenance and repair activities are to be handled (inspected, identified, sorted, prioritized, planned and implemented) by the IWUA under the guidance of irrigation technician or engineer.

b) Emergency works
Emergency works require immediate action by irrigation staff, to prevent or reduce the effects of unexpected events such as:

- Breach or overtopping of canal embankment or river dike/afflux bunds/guide bunds, causing flooding;
- A severe slope failure.
- Deterioration of the outlet culvert.
- Critical failure of pumps , causing interruption of irrigation water supply;
- Increasing uncontrolled seepage through the embankment.
- A blocked escape or outlet channel
- Natural disasters such as floods, earthquakes or cyclones.

Operational staff of IWUA as well as of the technician must be trained so that they know what to do as soon as they arrive on the scene, such as cutting off the power to an overheated pump, and closing the head regulator or operating escape in case of a canal breach. A good communication system can do much to reduce the damage.

c) Scheme improvement

The routine maintenance and emergency repairs described above are all aimed at keeping or restoring the technical infrastructure in the condition it was in when it was newly built. There are a number of reasons, however, not just to maintain the scheme in its original condition, but to gradually improve it. The main reasons are:

- A newly constructed scheme is hardly ever perfect.
- Some alterations are usually necessary to make it fully operational.
- It is sometimes better to construct a scheme at minimum capacity, with low cost structures. Then, if the scheme proves to be a success, it can be gradually expanded and the structures replaced with more permanent ones.
- Conditions change, both inside and outside the scheme. Improvements are necessary to ensure that the scheme continues to deliver services that correspond with farmers' needs.

Inspection and grading of the extent of damages is usually necessary for proper maintenance planning. A regular program of inspection and maintenance is essential to keep the infrastructure in proper working condition. Without it, canals will silt up, embankments erode, culverts will be blocked by debris and gates get out of order. *Maintenance* is often confused with *repair*, but there is a clear difference. Repair is done only after the system has broken down, and as such can be part of a maintenance program. But maintenance should be done also when the system is still working properly. In fact, a main objective of maintenance is to prevent breakdowns and the need for repairs. If the extent of damage are going to challenge scheme sustainability planning for complete *rehabilitation* of the system is mandatory.

Some examples of conditions of canal and canal structures in SSI schemes are as depicted below:

a) Washed by flood b) Collapse of stone wall c) Collapse of one side wall d) Wash out of division point

Figure 9-3 : Image of deteriorated irrigation facilities that need rehabilitation

a) Abrasion wear of plaster b) Loss of joint mortar c) Deformed spindle d) deform of gate

Figure 9-4: Image of deteriorated irrigation facilities that need repair

“Repair work” is regarded as part of O&M activities. “Irrigation facility needs preventive and early stage repair works, just like health care”

If “No” Preventive repair works, Periodically Large scale rehabilitation is necessary and needs more cost in the long run. Besides without external support, it would be difficult to sustain the scheme.

If there are routine preventive repair works, although every year O/M cost is needed, it can prevent large scale damage and rehabilitation works. It is thus more beneficial in the long run.
Repair work doesn’t require significant design and designated quality control. Generally it is simpler and smaller scale work that IWUA and irrigation technician can handle. Repair is usually restoring the facility to its former conditions.

Repair works:
Situation or condition of the irrigation facility systems varies from scheme to scheme. This means that Repair works Action Plan has to be formulated for each individual scheme. Repair works Action Plan includes following items.

- Targeted Facility
- Location of deteriorated part
- Grade/ extent of deterioration
- Selected repair work for each deterioration parts
- Cost estimation of each repair works
- Examination of repair works implementation by Irrigation technician
- Prioritization of each repair works
- Working schedule

Material preparation for repair works:
Preparation for concrete:

1. Know the type of concrete you want to make (Example C15, C20, C25….) and know the quantity of concrete you need. 1:2:4 concrete is C20 class.
2. Quantify amount of cement, sand, aggregate and water needed for the quantity of concrete.

If 1m^3 of concrete with mix ratio is 1:2:4 is needed (4/7) x 1m^3=0.57m3 is aggregate, 0.29m^3 is sand and 0.143m^3 is cement. 1m^3 cement is about ***28 sacks*** of cement. Thus 0.143m^3 of cement is about 4 sacks. However it should be accounted for shrinkage and wastage.

Thus for 1m^3 concrete (1:2:4 or C20)
Quantity of Cement =1.57x4sacks=6.3 sacks
Quantity of sand=1.72x0.29m^3=0.50m^3
Quantity of aggregate=1.72x0.57m^3=0.98m^3

3. Get all material and equipment together
4. Get measuring materials- box or bucket of known volume, note that shovel is not good measuring tool.

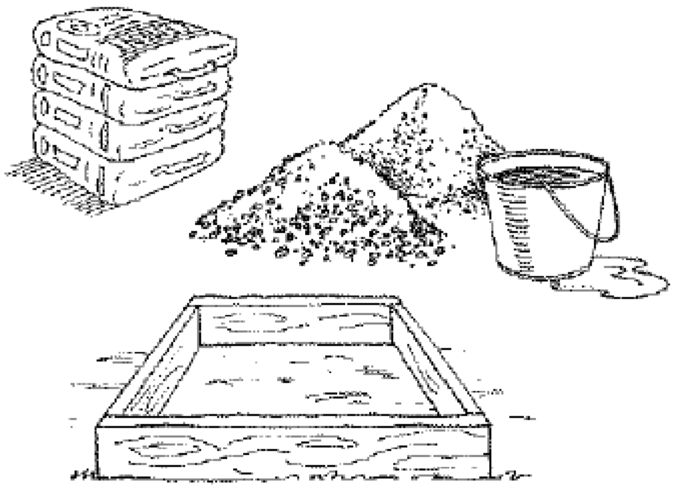


Figure 9-5 : Measuring construction materials according to proportions

5. Measure required quantities

Note: apply safety measures, do not breath in cement dust.

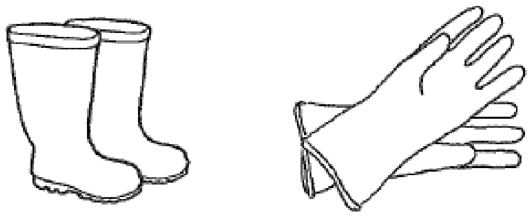


Figure 9-6: Safety measures during concrete mixing

Measure all the sand, cement and aggregate on mixing plate or other similar material.

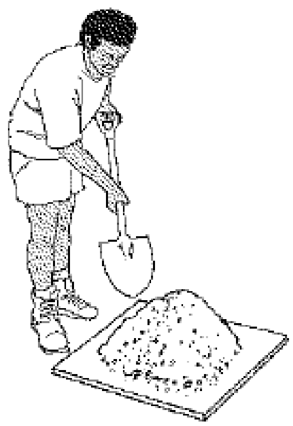


Figure 9-7: sand, cement and aggregate measured on mixing plate

7. Mix them until it looks same color
8. Gather in to a heap and form a hollow in the middle
9. Add the water slowly in to the hollow and mix the material

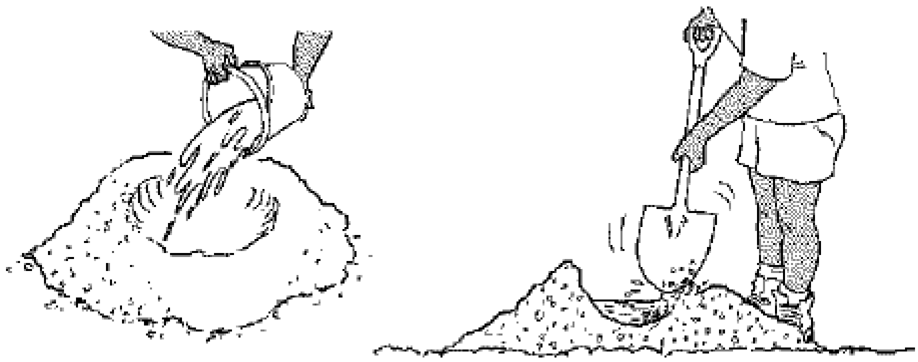


Figure 9-8: mixing concrete manually

10. Make in to a heap again, add more water and mix. Do these until you have a mix that is workable but not too wet.
11. Keep turning the mix for about 2 minutes.
12. Use the concrete and make the next batch

Note:-Strength of concrete is greatly influenced by mixing water volume.

-Mixing water volume for one cement bag (50kg) should be about 26-30 liters.
-Simple slump test can be done as follows to check quality of mix.

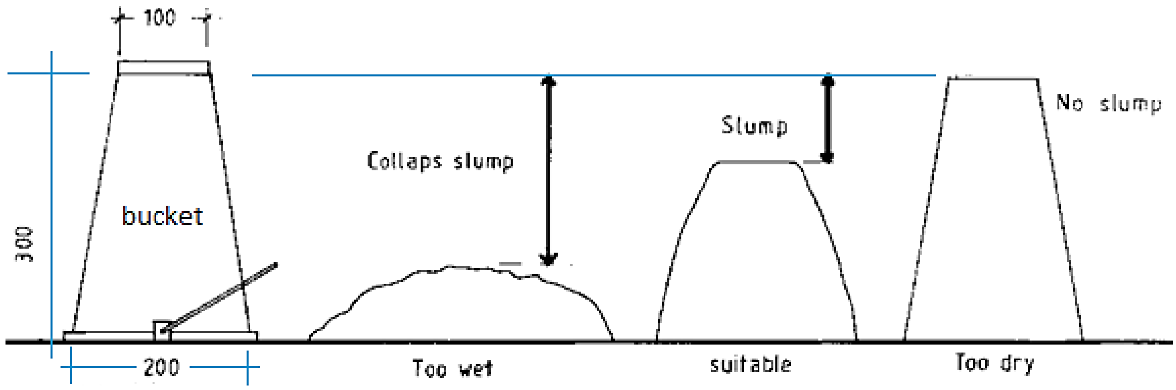


Figure 9-9: Simple method of concrete slump test

Following pictures shows bad and good example of mixed concrete. Bad concrete should not be used.

NO! NO! YES!

Source: Manual for Farmers Participatory Repair work of irrigation facilities, 2013, Tanzania

Figure 9-10: Images of hand mixed concrete

Preparation for mortar:

In similar way mortar can be prepared in 1:2, 1:3 or any desired ratio. The sand has to be of approved quality. River sand is preferred than pit sand or beach sand. At field level quality sand can be checked as flows:

1. Take a glass of water and add some quantity of sand in it. Then shake it vigorously and allow it to settle. If clay is present in sand, it will form a distinct layer at the top of sand.
2. In order to detect presence of organic impurities in sand, add sand to the solution of sodium hydroxide or caustic soda and then stir it. If color of solution changes to brown, it indicates the presence of organic impurities.
3. Take a pinch of sand and taste it. If tasted salty then there exist some salt in sand.
4. Take sand and rub it against the fingers. If fingers are stained, it indicates that sand contains earthy matter.
5. The color of sand will indicate the purity of sand. The size and sharpness of grains may be examined by touching and observing visually.
6. For knowing fineness, durability, void ratio, etc.; the sand should be examined by mechanical analysis.

Thus to prepare $1m^3$ of mortar (1:3mix) you need $1.3m^3$ of sand and about 11 sacks of cement accounting for wastage and shrinkage.
For any wet masonry construction quality stone (dense, workable and water proof) has to be used. Workable ignimbrite rock is usually preferred for masonry works. The stone must be well dressed for proper construction quality.

Practical applications in canal maintenance:

Table 9-9: Types of deterioration in field systems of SSI schemes

Facility	Typical types of deterioration
Canal Intake	Collapse, Deform, Sinking, Gap, Crack, Leakage, Abrasion, Wear, Washout, Erosion, silting, thick weeds and etc.
Gate	Rusting, Deformed, un-functioning,
Farm Road	Erosion, Deep Wheel rut, Muddy surface

Management of maintenance activities:
The objectives of maintenance management for a canal are:

- to keep the canal in good operating condition so that it will provide uninterrupted service;
- to extend the useful life of the canal;
- to achieve the above at the lowest possible cost.

In order to keep the costs down, in irrigation maintenance, an attempt should be made to reduce the need for costly repairs. The need for repair by the irrigation maintenance unit may be the result of:

1. Routine inspection by operator.
2. Periodic inspection by maintenance unit.
3. Breakdown or special repair.
4. Emergency (flood, pump failure).

Items 1 and 2 are preventive maintenance activities. While preventive maintenance represents efforts and costs, it costs much less than repair of breakdowns.
Planning maintenance works of canals
Planning maintenance activities means deciding what activities should be done, who should do them, and when to do. The preventive maintenance program - has to be developed for each individual canal. The activities performed under the preventive maintenance program can be planned in advance, indicating for each task when it should be done and by whom. Inspections for

identification of maintenance needs can also be scheduled in advance, indicating when inspections will take place and by whom. Of course, it is not possible to predict which maintenance needs will be identified through these inspections. A practical solution is to have an annual inspection as a basis for drawing up the maintenance program for the next year.

The maintenance needs identified at this annual inspection will not all have the same degree of urgency. For example, erosion of the embankment of a canal must have top priority and be corrected without delay, because failure of the canal would have serious consequences. Other activities, such as silt or vegetation removal from a canal, may safely be planned a few months later. The main factors to consider when setting priorities are the consequences of not doing the maintenance work, in terms of:

- safety; risk to human life and risk of structural failure;
- effect on crop production due to interruption of water deliveries.

The maintenance needs identified will then be scheduled into the maintenance plan according to their priority, together with the preventive maintenance activities.

General guideline for canal maintenance:

1. Embankments or earth canals

a. Erosion: Erosion involves the loss of embankment material due to wind and water action. It reduces the cross section and undermines structures, thereby impairing the safety and stability of the embankment and structures.

Erosion can be in the form of gullies down side slopes, benching due to wave action, or undercutting of structures. The gullies and benching may be initiated by animal and/or manmade traffic.

Semiannually and after heavy rains, inspect for erosion and replace lost material. Inspect groins, berms, slopes for erosion and channelization. Inspect washout of material below pitching. Check for bald areas where turfing is provided. Earth materials used to repair eroded areas should be tamped, compacted into places, and reseeded when appropriate. If trails have contributed to the erosion, the traffic causing the trails should be prevented, if possible, or controlled to minimize the creation of such trails. The use of gravel and stones/metal may be appropriate to repair minor erosion. Other embankment materials, normally of the kind removed by erosion, will be required to repair areas of extensive erosion. Rock protection on the surface of the repaired areas may be required to prevent or minimize future erosion.

b. Trees and vegetation: Trees and deep rooted vegetation on embankments create voids and provide seepage flow paths when the roots decay. Upon reaching maturity, trees are also susceptible to being toppled and shortened seepage paths in the embankment.

Semi-Annually inspect embankments and flow channels for tree, brush, and shrub growth and remove such growth by cutting at the ground line and removing the cuttings. The vegetative removal in SSIP should provide for clear openings to escape and siphons inlet and outlet channels and extend a minimum distance of 2.5m downstream from the toe of the embankment to allow proper surveillance of the embankment toe and any seepage areas which might otherwise be concealed. After removal the area shall be backfilled and compacted to prevent development of piping action. These guidelines should be applied to drains and pipes also.

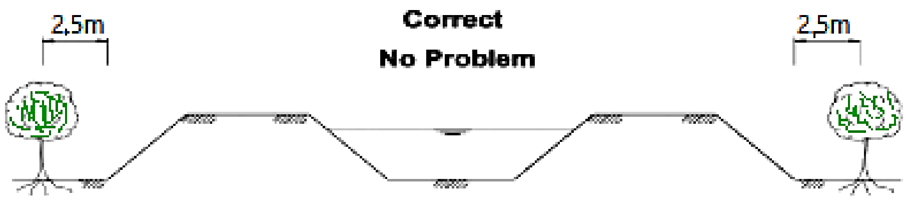


Figure 9-11: Correct positioning of trees along canals

c. Animal burrows: Animal burrows in embankments can create seepage paths and weaken the integrity of the structure. Often, animals burrow deep into the embankment which allows water to travel freely to the downstream face, thus allowing piping to occur and ultimate failure of the dam.

Monthly inspect for animal burrows, excavate burrows to the maximum extent possible, fill excavation with earth material tamped and compacted into place, and eliminate the burrowing animals, if possible. Beaver activity will become apparent through visual observation of tree cuttings. Animals should be removed immediately upon detection. Woodchucks, squirrels, rabbits, moles and muskrats can be exterminated or flushed out with smoke.

The animal burrow must be filled with soil or a mixture of water to 9 parts soil and 1 part cement. The soil mixture should be placed as deep as possible and compacted with a pole.

d. Encroachments: Encroachments may occur in various ways, including buried utilities, utility lines and poles on the embankment top and side slopes of embankments, construction of buildings on embankments, and removal of embankment material to accommodate construction or to obtain material for other use. Encroachments weaken embankments and may seriously jeopardize the integrity of the structure.

Weekly inspect for encroachments. Require removal of the structure or installation if it affects the integrity of the embankment. Removed material should be replaced with tamping and compaction efforts. No encroachments should be permitted.

e. Stability and settlement: Sloughs, slumps, bulges, depressions in the top of the bund, cracks, or other irregularities are often signs of instability and settlement of the embankment or foundation, or both. Significant settlement of the embankment may diminish the full supply depth and freeboard and increase the possibility of overtopping. Signs of instability and settlement should be reported promptly through an Engineer in charge of the work who can assess significance and suggest appropriate action to be taken. In critical situation such as imminent overtopping or failure, implement the emergency plan.

Quarterly inspect embankments for sloughs, slumps, bulges, depression, and cracks. Where traffic is permitted on the top of the embankment, the top should be surfaced with gravel or similar material, crowned, and well maintained. Ruts from vehicular traffic should be filled so that the top will be well drained and access along the top is possible at all times. Where there is settlement, the top should be rebuilt to the original design level using appropriate earth materials and sound construction particles. Inspect for slides, always Sketch, Measure, Photograph and Locate (SMPL) the extent and displacements. Look for surrounding cracks uphill, probe or measure entire area for knowing condition of surface material. Make sure there is no seepage area near the slide. Monitor continuously.

f. Seepage: Seepage occurs to some extent at almost all embankments. The monitoring and control of any seepage are essential to proper maintenance. The amount of seepage may vary from wet spots to large quality flows. Uncontrolled seepage (large flows or flows that carry sediment) indicates internal erosion, which weakens the embankment, foundation, or abutments; creates voids; and leads to embankment failure. Where possible, the quantity of seepage should be measured and recorded in a log book.

Water measurement weirs and devices may need to be constructed and installed. Other characteristics such as the clarity of seepage (that is, whether clear or carrying sediment) or discoloration of concrete and staining should also be noted. Seepage may occur at the abutments, at the downstream slopes of the embankment, or downstream from the embankment.

At least semiannually and especially during periods of canal carrying heavy discharges, inspect and record the quantity and clarity of seepage and the corresponding reservoir level in the log Uncontrolled seepage, significant increase in seepage, and seepage which is carrying sediment should be reported promptly through Superintending Engineer in charge of the work to Design Circle who can assess significance and suggest appropriate action to be taken. Inspect downstream slope for piping, sloughing, sand boils. Watch for vortex in canal water. That is the sign for piping. Watch out for growth of vegetation /greenery. It is sure sign of seepage. In critical situation such as imminent failure, implement the emergency plan.

g. Slope protection: The canal lining must be protected against destructive action. The canal lining is sometimes distressed, displaced, and impaired by various causes, including deterioration of concrete surface, settlement, or removal by man for use elsewhere, or to accommodate recreational use such as building a seat for placing a pump or a windbreak for fishing. Annually inspect the canal lining and repair and replace the same in deficient areas.

2. Concrete/masonry lined canals

The construction considered herein is that of concrete or masonry, including combination of concrete and masonry work.

The condition of concrete and masonry works is generally dependent on the quality of materials used, circumstances or quality of construction, and severity of weather exposure.
Poor quality materials and deficient composition of concrete and mortar will be evidence by scaling, spall, pop-outs, crumbling, and other forms of deterioration. Likewise, poor quality construction, such as the use of too much of water in mixes or finishing and/or permitting exposure to freezing condition before adequate curing and hardening of concrete or mortar, will lead to early and accelerated concrete deterioration.

Cracking is usual and normal in concrete works. Most cracks are superficial and not very deep or wide, and some cracks in concrete where damp or high humidity atmospheric conditions prevail, as in conduits, may selfheal or seal by chemical action as with calcium carbonate formation. In mild climates, this type of cracking is usually not a problem or detrimental to the integrity of the structure. Cracks that are deep or through a structure may be of significant concern as they can be signs of settlement, structural movement, and distress and may permit seepage or leakage of water. Sometimes when seepage or leakage occurs, staining of concrete may be noted. This may be indicative of reinforcing steel corrosion or chemical reaction of water with foundation materials or concrete and may or may not be of a serious nature. Seepage and leakage through cracks most commonly occur at portions of structures below the water level and in case of barrels of a conduit.

Expansion, contraction, and construction joints may be of concern when they become "open" and permit seepage or leakage of water. Opening of joints can be a signal of structural movement or disbanding of concrete if at construction joints. In the case of contraction joints, seepage may indicate the failure of the water-stops. Some opening or closing of joints normally occurs with temperature changes.

Annually inspect concrete and masonry surfaces for deterioration including scaling, spall, pop-outs, crumbling, and cracking. This type of deterioration may be relatively slow, and recordkeeping in the form of photographs, sketches, or notes indicating location, size, and depth of deterioration will be helpful in evaluating the severity and rate of progression. When concrete deterioration reaches embedded reinforcing steel, immediate repair is usually required.

Semiannual inspection and measurement of seepage should be performed. The quantity of seepage should be recorded in a log book. The clarity of seepage (that is, whether clear or carrying sediment) and any staining or discoloration of concrete should also be noted. Seepage may occur not only at cracks and joints but also at the abutments and downstream from the construction.

3. Embankment drains

Many embankments have drainage systems installed for collection and safe exit of seepage. Often, such systems have drain pipes terminating at or near the downstream toe of the embankment. Visible ends of such drain pipes provide easy exit of any seepage and allow observation and possible measurement of seepage flows. Such drains and exist points may become clogged with chemical deposition, sediment, or debris such that the drains cannot function effectively.

Annually inspect the ends of drainage pipes at or near the downstream toe of the embankment and clean out any debris and material that may clog the drains and exit channels. Material covering unexposed ends of drainage pipes should be removed. If animals occupy the drains, as may be the case when drains are dry, it is appropriate to clean the pipe and install large-mesh corrosion-resistant screens in the ends of the drains to preclude entry.

4. Escapes

Escapes are constructed to release floodwater or water in excess of the storage space in a canal. Escapes are important to the safety of canals, and maintenance to allow proper functioning is essential. These usually are located away from the embankment in order to preclude erosion of the embankment when spilling. Regulated escapes employ gates of various types to control the rate of flow through the escape. Structural instability is evidenced by deep cracks in slabs or walls, slab removal, foundation piping, tilting of walls, and misalignment of walls. Obstructions including debris, trash, trees, brush, and sediment diminish the flow capacities of escape structures, stilling basins, and inflow and outlet channels and may also produce undesirable erosion-producing currents. Weep holes and drainage openings are usually installed in the walls and floors of escape structures, and these often become clogged with sediment and may be occupied by animals or birds.

Annually inspect the escape structures and channels for instability, deterioration, obstructions, and erosion.

Evidence of structural instability should be reported immediately, through on site Irrigation Engineer in charge of the work that can assess significance and suggest appropriate action to be taken. Structural deterioration that is progressive and endangering the structural integrity of the canal should be repaired.

Obstructions including debris, trash, dead and live trees, and brush and sediment deposits should be removed. (Debris, trash, trees, and brush should be disposed of in accordance with forest and environmental regulations.)

Weep holes and drainage openings should be cleaned and large-mesh corrosion resistant screens installed, as appropriate, to preclude animal and bird entry. Areas of backfill settlement along walls should be repaired. Erosion around and under structures such as undercutting of concrete footings, cutoff walls, and stilling basins at the end of escapes should also be repaired.

5. Canal outlet works

Outlet works are conduits through or around an embankment used for releasing water. Regulated outlets use gates or valves for controlling the rate of flow. At unregulated conduits, the rate of flow is controlled by the size of the conduit and the height of the water in the canal above the invert, or floor, of the conduit. Conduits at embankments usually have regulating gates or valves within the upstream portion of the conduit so that flows can be shut off to prevent water from eroding the embankment in the event of failure or leakage through the conduit. Outlet works gates are susceptible to plugging with debris and sediment deposition. Thus, it is important that any trash racks in front of the gates be cleaned whenever possible and that the gates be opened periodically to flush debris and sediment.

Semiannual1y inspect the end of each outlet. The outlet end of the conduit should be inspected for breaks in the conduit, erosion of the downstream toe of the embankment, or undercutting of the outlet end of the conduit. Eroded material should be replaced and armored with suitable material. Each gate should be operated sufficiently to ensure that it is fully operable and to flush debris and sediment. Gate stems should be inspected to the waterline, and any misalignment that interferes with operation should be corrected. For gates having a vertical stem and a catwalk for access to the controls, the catwalk should be maintained so that the controls remain accessible even in emergency situations. Downstream cistern of the outlets should be inspected and debris/vegetation should be removed.

Annually and after unusually high discharges, inspect the channel downstream from the outlet works for erosion, obstructions, and undercutting of the outlet structure or the toe of the embankment. Erosion should be repaired, and obstructions including tree and brush growth should be removed.

Every 3 years, internally inspect conduits over 90 centimeters in diameter. The inspection should be for the purpose of determining the existence of breaks, leaks, cavitation, or other damage. Smaller sized conduits must be frequently inspected especially not to be clogged by trash or debris.

6. Inspection of canal works following an earthquake

If you have felt an earthquake or one having a Richter magnitude of 4.0 or greater has been reported to have occurred in the area, follow these procedures:

a. Immediately conduct a general overall visual inspection of the canal including all the structures.
b. If any portion is damaged to the extent that there is increased flow downstream, immediately implement the emergency plan. If an emergency plan is not available in the hand of IWUA, the supporting institution has to be consulted for immediate action.
c. If visible damage has occurred but has not been serious enough to cause failure of the canal/structure, make the following observations and contacts immediately:

(1) Quickly observe the nature, location, and extent of damage. The description of slides, sloughs, and sudden subsidence should include location, extent, rate of subsidence, and effects on adjoining structures, springs or seeps, and downstream channel water elevations. Also, note prevailing weather conditions and any other facts believed to be pertinent. Evaluate potential danger of failure. Document the damage, as far as possible, with photographs.

(2) As soon as possible, report should be promptly sent through Superintending Engineer in charge of the work to Design Circle who can assess significance and suggest appropriate action to be taken, or if key personnel are not available, report directly to the nodal officer. It is extremely important that the one receiving your report understands your evaluation and description of the potential hazard. A decision on further actions required must be promptly made by one of these officials.

(3) Re-inspect the site of the damage and maintain communications with the key personnel who previously received the report.
(4) If there is 'no imminent danger of failure, continue to paragraph (d). If there is imminent danger of failure, follow the emergency plan. . If an emergency plan is not available in the hand of IWUA, the supporting institution has to be consulted for immediate action.

d. Thoroughly inspect the following for damage:

(1) Both faces of the embankment/structure for cracks, settlement, or seepage.
(2) Abutments for possible displacement.
(3) Drains.
(4) Escape structure.
(5) Outlet works gate structure/chamber.
(6) Visible canal reach filled with water and downstream areas for landslides.
(7) Other appurtenant structures.
(8) Downstream channel for reduced capacity and altered flow characteristics.

e. Report findings to Superintending Engineer in charge of the work or officials reported to previously during the earthquake incident.

f. If no apparent damage has occurred to the canal, embankments, or appurtenant structures, a "No Damage" report must be made to Irrigation Engineer in charge of the work.

g. Continue to inspect and monitor the facilities for at least 48 hours, or as instructed by the Superintending Engineer in charge of the work, in the event that unobservable or delayed damage occurs.

h. Some damage to structures may not be readily apparent during an inspection immediately following an earthquake. It is possible that settlement of structures, the reactivation of old slides or the development of new slides may not occur with ground shaking and would manifest them after the initial inspection. Another inspection should be made 2 to 4 weeks after the initial inspection.

7. Inspection of canal following floods

If a situation develops whereby flooding above normal water surface elevation i.e. water surface encroaching the freeboard completely, appears imminent, immediately contact an Engineer in charge of the work. Information to be reported should include:

a. Current water surface elevation in the canal.
b. Observed rise rate of the water surface.
c. Weather conditions in the vicinity - past, present, and predicted.
d. The flow conditions above and below the canal.
e. Known conditions at upstream or downstream canal sections and position of downstream reservoirs/water bodies, location of escapes if any exist.

If all communications from the canal are lost and there is potential for flooding and subsequent failure of the canal, use the following checklist as a guide during a major flood event:

a. Check the canal water surface elevation; if at normal water surface elevation i.e. FSL, increase discharge through the escape gates or outlet works, if possible.
b. If discharge is to be increased, notification of downstream residents is essential, if possible; also, if failure is possible, warnings and alerts are necessary in accordance with the emergency action plan, if available. During a period of communication loss, warning of downstream residents by the section officer is up to his personal judgment.
c. If increased releases are deemed necessary, they should be staged, if possible, to allow the water level downstream to rise gradually and thus avoid the likelihood of persons being trapped by rising water.

However, if in the judgment of the section officer, failure is more likely with gradual increases, larger increases may be appropriate.

8. Operation and maintenance log for canal and related structures

A record should be kept for all canal and related structure operation and maintenance activities. The data should be logged by the person responsible for performance of operation and maintenance. The log can be a very useful source of information regarding past problems and solutions and can provide historical project data that may be very valuable when safety inspections and evaluations occur. The log can provide important data regarding performance of the canal, such as seepage, embankment settlement, stability, repairs, maintenance, and modifications.

Information to be recorded in the log includes the following:

a. Date and time of observations.
b. Water elevations and discharges.
c. Normal and emergency changes in operation of outlet works and/or escapes, including gate position and changes.

d. Testing and exercising of outlet and escape gates and valves, controls, and standby equipment.

e. Maintenance activities, including lubrication, cleaning, clearing debris from channels, tree removal, repairing erosion, etc.

f. Miscellaneous items pertinent to operation during emergencies or events of an unusual nature, such as earthquakes or floods.

Entries in the log should be made in ink. Errors should be corrected by crossing out the incorrect entry and adding the correct entry. A sample log is illustrated in appendix II.
Photographs should be taken of any unusual conditions observed. They should be captioned with the photographer's name, date, and descriptive information to assist later recognition and understanding of the event pictured.

Summary of canal inspection, operation, and maintenance items and their recommended frequency of performance are as follows:

Table 9-10: Summary of inspection, operation, and maintenance items

Item	Frequency of inspection
Encroachment	Weekly Inspect, remove and repair
Animal burrows	Monthly Inspect and repair, eliminate animals
Settlement, sloughs, slumps, bulges, cracks	Quarterly Inspect and repair
Erosion of embankments, around and under structures	Semiannually Inspect and repair
Outlet works	Inspect outlet ends of conduits; clean trash-racks, if possible; operate and inspect gates
Seepage	Inspect, measure, record, report, and compare with previous records
Trees and vegetation	Inspect embankments and channels, and remove deep-rooted vegetation
Concrete and masonry surfaces	Annually Inspect and repair
Drains (in embankments, foundations, galleries and spillways)	Inspect and clean
Mechanical equipment	Inspect, repair, lubricate, clean and fully exercise
Physical security	Inspect, repair and improve as Necessary
Outlet works – downstream Channel	Inspect, repair, remove obstructions
Escapes and channels	Inspect, repair, remove obstructions, clean drains, and report evidence of structural instability
Slope protection	Inspect and repair
Canal and escapes	After Heavy rains Inspect and repair
Embankment	Inspect and repair
Seepage	After Each watering Inspect, measure, record, and compare with previous records; immediately report uncontrolled seepage
Outlet works – conduits over 90 centimeters in diameter	Every 3 years Inspect and repair
Stilling basin/cisterns downstream of the structure	Every 5 years Dewater, remove debris, repair

9.3.5 Maintenance of night storage (pond) and related structures

Ponds should be inspected periodically, especially after heavy rains, to determine the need for minor repairs. Immediate repair often eliminates the need for more costly repairs later.

Rills on the slopes of the embankment and washes in the earth spillway should be filled with suitable material and thoroughly compacted. These areas should be reseeded and fertilized as needed. Should the upstream face of the earth fill wash or slough due to wave action, protective devices such as booms or riprap should be installed. If there is seepage through or under the embankment, an engineer should be consulted to recommend proper corrective measures.

The vegetative cover on the pond and earth spillway should be maintained by mowing and fertilizing when needed. Proper mowing prevents the formation of woody growth and tends to develop a cover and root system more resistant to runoff. Fences should be kept in good repair.

Appurtenances such as trash racks, pond inlet, spillway, outlet structures and gates should be kept free of trash. Burrowing animals may cause severe damage to ponds and spill-ways. If such damage remains unrepaired it may lead to failure. A thick layer of sand or gravel on the fill discourages burrowing.

The Pond must be from any contaminations. Where malaria prevails, aquatic growth and shoreline vegetation should not be permitted and special precautions in operation of the pond.
In some areas the development of algae and other forms of plant life in reservoirs may become objectionable. Generally, these are harmless, but they may cause disagreeable tastes or odors, encourage bacterial development, and make the pond unsightly.

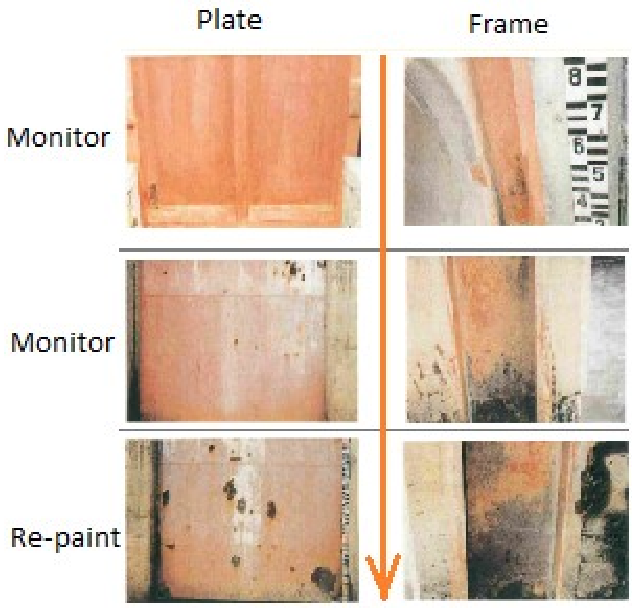
Under all cases night storage pond must be inspected and cleaned for silt accumulation and any unnecessary vegetation ***every year***. Inspection after heavy rain is ***mandatory*** under any circumstances.

9.3.6 Maintenance of gates and related structures

All cavities and angles in the gates/shutters should be kept clear of debris, driftwood, moss and silt accumulations. All drainage holes in the webs of horizontal structural members should be kept clear to drain off any accumulated water. Green stains should not be allowed to form on the steel members at the back of the gates/shutters. The gates and counter balanced boxes should hang perfectly in level and plumb. This should be checked occasionally and adjustment made as needed. In case of shutters, the chains/anchors holding them should be kept free from rust. Inspection/ maintenance of the gates depend on the type of gates provided on the barrages/weirs.

No painting is required for machined surfaces and surfaces of stainless steel, brass or bronze. These surfaces should be protected by a coating of gasoline-soluble rust preventive non-corrosive compound.

Painting shall be restored by the same type/ quality of paint as originally provided if it has proved satisfactory. Otherwise a suitable painting system can be evolved considering local conditions. The method of application for the paint and surface preparation shall be as per standard practices and with proper personnel.



Source: Manual for Farmers Participatory Repair Work of Irrigation Facilities

Figure 9-12: Reference picture when to re-paint a gate

Gate grooves and seals

Grooves and particularly their machined faces should be kept clean and lubricated well and all sticky deposits should be scraped off before application of lubricant. Efficiency of rubber seals should be tested initially after construction and at the time of closures or isolation of different portions for repairs. The horizontality and verticality of the seal seat and wall plates should be checked with spirit level and seal faces of the rubber seal should be tested to press uniformly both by light test and by use of paper strip inserts. Seals of the gate should be checked for wear and tear as well as deterioration. These should be adjusted/replaced, as necessary. Few sets of spare seals should be kept in stock and stored for emergency in such a way that these seals do not get damaged during storage with the passage of time.

9.3.7 Maintenance of public facilities

Public facilities like cattle trough, washing basin and the like if any are available in the system has to be inspected and maintained.

10 IWUA IN IRRIGATION SCHEME MANAGEMENT

10.1 IRRIGATION WATER USER'S ASSOCIATION (IWUA)

IWUAs are main responsibly body in SSI scheme operation, maintenance and management. They are established on voluntary and non-profit base from the user community. There should be committee responsible for different activities in scheme like scheme operation and maintenance, water management, management of input supply, marketing, finance, conflict etc.

Here are some of the activities to be performed in organizing IWUA:

- Identify and list beneficiary members within the command area,
- Provide the general history of the scheme to all user groups
- Discuss with individual beneficiary members about the scheme management,
- Provide awareness to members, Kebele officials & others about the advantage of IWUA for the scheme management
- Identify the felt need of members, Kebele officials and others
- Make clear to the scheme owners the roles and responsibilities of each group in scheme OMM
- Prepare the draft by-laws,
- Discuss with all members about the by-laws, future plan to find some feedbacks
- Prepare participatory future activity plans,
- Call the general meeting,
    - Ratify the by-law resolute,
    - Ratify future activity plans
    - Elect the Executive committee, Water management committee, conflict management committee, credit & input supply committee and others
- Provide the operation and Maintenance manuals to the IWUA and committee
- Discuss on licensing and legal entity of IWUA(s)
- Discuss on opening bank account and accounting systems
- Make ready financial and accounting stationeries, etc.
- Collect different fee and other payments
- Start the scheme operation and management activities

10.2 GENDER MAINSTREAMING IN OMM ACTIVITIES

The term gender refers to the socially and culturally constructed difference between men and women. Gender concerns the socially constructed roles and the resulting relationships between women and men, girls and boys etc in terms of their rights, obligations and opportunities in a specified group.

The relevance of gender concerns in irrigated agriculture emanates from the fact that in many socio-economic settings, gender has been observed to constrain increased productivity. Although resource endowment and other social factors may have a greater influence on agricultural production than gender, it is also true that within a given social and economic group, gender roles dictate the response to change and can therefore reinforce the constraints on women and men.

In IWUAs it presents data to clarify; (i) the roles played by various sub-groups, (ii) ownership of resources, (iii) pattern of resource control, (iv) decision-making, (v) benefits to various sub-groups, and (vi) power relationships among women, men and youth. The information generated from gender analysis is useful in aiding planning of development interventions and hence proper targeting with respect to allocation of responsibilities and distribution of benefits.

10.3 STRATEGIES TO ENSURE EFFECTIVE GENDER PARTICIPATION

(i) Gender analysis should be integrated in all stages of an irrigation project i.e. from identification, design, implementation, consolidation, operation and maintenance

(ii) All WUA members should be sensitized on the need to have all relevant gender groups accessing and controlling resources.

(iii) Consideration should be given on the extent to which different gender groups are interested in new irrigation technologies

(iv) Promote equality in accessing resources and services, while taking into account women's, youth's and men's priorities

(v) Ensure reasonable levels of representation of all gender groups in management, water control and decision-making.

(vi) Ensure, through affirmative action, election of women and youth representatives in key positions in WUAs. This affirmative action should be spelt out in the by-laws.

(vii) Ensure flexibility in project and scheme design as well as fair distribution of workload to various gender groups

(viii) Facilitate effective participation of all gender groups in WUA meetings. It may be necessary to meet the special gender groups in their places of work to fully understand and appreciate the prevailing social norms ascribed to the various gender groups

(ix) Empowerment of disadvantaged gender groups to effectively participate in production e.g. credit schemes

(x) Ensuring gender-sensitive extension methods like tours and demonstrations are used to bridge the gender gap.

Details regarding the organizational setups, roles and responsibilities of each and by-laws governing them are indicated in detail under Socioeconomics Guideline and SMIS Guideline on IWUA.

10.4 HEALTH AND SAFETY IN SCHEME OMM

Health and safety issues in Scheme OMM are very crucial. The operation of different facilities installed must have specific operation manual and safety measures. Handling of any farm inputs (like chemicals and fertilizers) must be based on scientific recommendations to avoid ill effects. Any water borne diseases must be mitigated according to recommendations stated in the study and design document. Any risk full areas within the scheme like power units, falls, deep water bodies etc. must be indicted with warning signs to avoid any hazards. Necessary protective wears must be used like safety boots, goggles, protective glasses, dust masks, hard hat, respirators and sleeves during specific operation and maintenance tasks.

11 OPERATION, MAINTENANCE AND MANAGEMENT COSTS

Operation, maintenance and management costs vary with nature of scheme. For instance gravity system and lift system schemes OMM costs vary widely. Surface and pressurized system OMM costs are also different. In all cases the OMM costs depend on proper functioning and durability of the facility introduced for irrigation purpose. Ease of access to parts and materials for maintenance also determines the OMM costs. Active labor availability at scheme and cost of labor influences the OMM costs.

Often SSI scheme operation, Maintenance and management costs are assumed to be covered mainly by the beneficiary. The first one or two season development may be financially challenging to farmers thus support in the form of revolving funds or any credit facility can be considered. However, here after the farmers would likely be able to collect fee for Scheme OMM costs. Fee collection is critical issue to sustainably manage SSI schemes. Thus fee can be collected based on the area developed by each farmer and/or the produce obtained during each crop season. The IWUA must be certified and have bank accounts for the fee collected and must get legal entity for further facilities like credit and input supplies. .

11.1 COST ELEMENTS

The cost elements in scheme OMM are:

a) Operation costs

- Farm implements or machinery cost
- Drip laterals dismantling and reinstall in drip system, inspection and flushing of each line and cleaning filter units
- Sprinkler head dismantling and re-fixing, flushing and cleaning filter units
- Land preparation
- Input costs (Seed, Fertilizer and agro chemicals)
- Sowing/ planting
- Irrigation water supply
- Energy or fuel cost in case of lift irrigation
- Weeding/cultivation
- Fertilization
- Protection
- Harvesting
- Packing/ transportation
- Tax

b) Maintenance costs

- This is different in surface and pressurized systems
- It is assumed about 2% of initial investment cost

c) Management costs

- This includes administration and overhead costs
- It is assumed about 2% of operation cost

11.2 COST ESTIMATES

Annual operation, maintenance and management cost estimate of Arata chufa SSI scheme is as depicted below. The cropping plan is discussed in the previous parts of the Guideline. Total area planned for development is 100ha. It should be noted that market price of the year indicated was considered for cost estimate. Crops developed over the year 2016/2017 both in dry and wet season are Tomato (45ha), Onion (30ha), Potato (45ha), Cabbage (55ha) and pepper (25ha). Total project investment cost estimated to current market price is 12,000,000 ETB.

Table 11-1: OMM cost estimate of Arata chufa SSI scheme for 2016/2017 production year

	Particular	Unit	Quantity per ha	Unit cost	Area (ha)	Total ETB)
1	**Tomato (45ha)**					
	Farm tools	lps	1	200	45	9000
	Land preparation	lps	1	1000	45	45000
	Input costs					
	seed	Kg	0.5	2000	45	45000
	DAP	Quintal	2	1100	45	99000
	UREA	Quintal	2	900	45	81000
	Chemicals	Litre	5	1000	45	225000
	sawing/planting	lps	1	1200	45	54000
	Irrigation	lps	1	6000	45	270000
	cultivation/weeding	lps	1	15000	45	675000
	hanging (material and labor)	lps	1	5000	45	225000
	Fertilization	lps	1	900	45	40500
	protection	lps	1	5000	45	225000
	Harvesting	lps	1	6000	45	270000
	packing and transport	lps	1	400	45	18000
	land tax	lps	1	200	45	9000
	SubTotal-1					**2290500**
2	**Onion (30ha)**	**Unit**				
	Farm tools	lps	1	200	30	6000
	Land preparation	lps	1	1000	30	30000
	Input costs					
	seed	Kg	6	600	30	108000
	DAP	Quintal	2	950	30	57000
	UREA	Quintal	2	850	30	51000
	Chemicals	Litre	5	300	30	45000
	Farm operations					
	sawing/planting	lps	1	4000	30	120000
	Irrigation	lps	1	8000	30	240000
	cultivation	lps	1	30000	30	900000
	Fertilization	lps	1	900	30	27000
	protection	lps	1	2000	30	60000
	Harvesting	lps	1	4000	30	120000
	packing and transport	lps	1	200	30	6000
	Land tax	lps	1	200	30	6000
	SubTotal-2					**1776000**
3	**Potato (45ha)**	**Unit**				
	Farm tools	lps	1	200	45	9000
	Land preparation	lps	1	1000	45	45000
	Input costs					

	Particular	Unit	Quantity per ha	Unit cost	Area (ha)	Total ETB)
	seed	Quintal	25	700	45	787500
	DAP	Quintal	3	950	45	128250
	UREA	Quintal	2	850	45	76500
	Chemicals	Litre	2	600	45	54000
	Farm operations					
	sawing/planting	lps	1	1000	45	45000
	Irrigation	lps	1	4000	45	180000
	cultivation	lps	1	6000	45	270000
	Fertilization	lps	1	900	45	40500
	protection	lps	1	1000	45	45000
	Harvesting	lps	1	5000	45	225000
	packing and transport	lps	1	600	45	27000
	Land tax	lps	1	200	45	9000
	SubTotal-3					**1941750**
4	**Cabbage (55ha)**	**Unit**				
	Farm tools	lps	1	200	55	11000
	Land preparation	lps	1	1000	55	55000
	Input costs					
	seed	Kg	1	1000	55	55000
	DAP	Quintal	1	950	55	52250
	UREA	Quintal	1	850	55	46750
	Chemicals	Litre	3	300	55	49500
	Farm operations					
	sawing/planting	lps	1	1000	55	55000
	Irrigation	lps	1	5000	55	275000
	cultivation	lps	1	3000	55	165000
	Fertilization	lps	1	600	55	33000
	protection	lps	1	2000	55	110000
	Harvesting	lps	1	3000	55	165000
	packing and transport	lps	1	600	55	33000
	Land tax	lps	1	200	55	11000
	SubTotal-4					**1116500**
5	**Pepper (25ha)**	**Unit**				
	Farm tools	lps	1	200	25	5000
	Land preparation	lps	1	1000	25	25000
	Input costs					
	seed	Kg	2	80	25	4000
	DAP	Quintal	2	950	25	47500
	UREA	Quintal	1	850	25	21250
	Chemicals	Litre	3	300	25	22500
	Farm operations					
	sawing/planting	lps	1	1000	25	25000
	Irrigation	lps	1	5000	25	125000
	cultivation	lps	1	3000	25	75000
	Fertilization	lps	1	600	25	15000
	protection	lps	1	2000	25	50000
	Harvesting	lps	1	3000	25	75000
	packing and transport (material and labor)	lps	1	600	25	15000
	Land tax	lps	1	200	25	5000

	Particular	Unit	Quantity per ha	Unit cost	Area (ha)	Total ETB)
	Subtotal 5					**510250**
	Total operation cost					**7635000**
	Investment cost					12000000
	Maintenance cost (2% of investment cost)					**240000**
	Management Cost (2% of operation cost)					**152700**
	Total annual OMM cost (ETB)					**902950**

12 HUMAN CAPACITY DEVELOPMENT

Construction camp is usually transferred to the IWUA to serve as office of SSI scheme management. Office facility like tables, chairs, stationery materials are importance for commencement. For the IWUA to handle the SSI scheme, in the first instant personnel from governmental or other supporting institutions working directly at scheme level must be trained well about the OMM of SSI Scheme and capacitated for better follow ups and supports to the IWUA. Next capacitating the IWUA and beneficiary farmers reduces government and other interventions to properly manage the SSI schemes. Thus continuous trainings to local level extension staffs, IWUA and beneficiary farmers in the following areas are very crucial.

12.1 TRAINING OF IWUAS

- Scheme operation, maintenance and management
- Financial management including water charge and maintenance fee collection
- Conflict management
- Book-keeping and accounting
- Marketing (inputs and outputs)
- M&E of scheme activities

12.2 TRAINING OF BENEFICIARY FARMERS

- On-farm water management (water distribution and application)
- Agronomic practices (cropping pattern, input requirement, crop production and protection, soil fertilization, Good Agricultural Practices)
- Soil and water conservation
- Post-harvest handling and management
- Operation and maintenance
- Marketing (inputs and outputs)

12.3 TRAINING OF LOCAL LEVEL EXTENSION STAFF AND SYSTEM OPERATORS

- Preparation of scheme annual operation plan
- On-farm water management (gate operation, flow measurement, CWR, Soil-Water-plant relations, irrigation scheduling, water distribution and application)
- Agronomic practices (cropping pattern, input requirement, crop production and protection, soil fertility management)
- Soil and water conservation
- Post-harvest handling and management
- Preparation of scheme maintenance plan
- Operation and maintenance including costing of equipment and materials
- Marketing (inputs and outputs)
- Value chains

Practical on-farm trainings like operation of facility, flow measurement, water application, soil and water conservation works etc. shall be given.

13 PUBLICSUPPORT SERVICES

13.1 IDENTIFY AND QUANTIFY AGRICULTURAL INPUTS

Agricultural inputs as per agronomic recommendations stated must be applied for better crop production and productivity. Seasonal and annual need or amount of all inputs like seed, fertilizer and agrochemicals and related equipment must be identified for procurement from relevant and appropriate suppliers. For this purpose cropping plan of each farmer within the SSI scheme must be known beforehand. For details regarding identifying and quantifying agricultural inputs please refer to Agronomy Guideline.

13.2 ROLE OF AGRICULTURAL SUPPORT SERVICE IN O&M

IWUA must be supported by relevant sector offices to properly run operation and maintenance activities and gain anticipated benefits from the scheme. The support can be in form of training, consultation or facilitation of supplies during the whole process of production till the produce reaches the consumer. Agricultural Support Enterprise (if any), Agriculture and Natural Resources bureau, Irrigation development Authority, Co-operative promotion office, Credit and Saving Enterprises, Research Centers, Universities, NGOs, Administrative bodies etc. must support the IWUA in:

- Facilitating supply of agricultural inputs (Agriculture and Natural Resource Bureau, Irrigation Development Authority, Co-operative promotion office via unions, co-operatives, seed enterprises, recognized suppliers for seed and chemicals etc.)
- Technical support in agricultural extension services (Agricultural Support Enterprise (if any), Agriculture and Natural Resource Bureau, Irrigation Development Authority, Research Centers and NGOs working on related areas)
- Technical support in scheme operation and maintenance (by Irrigation Development Authority)
- Facilitate resource mobilizations (Agriculture and Natural Resource Bureau, Irrigation Development Authority, Co-operative promotion office, Administrative bodies)
- Support in credit facilities (Co-operative promotion office, Micro finances and other agricultural enterprises including Development banks)
- Support in market linkage (Trade and market development office, Co-operative promotion office and other agricultural enterprises)
- Support in institutional linkage (Agriculture and Natural Resource bureau, Irrigation Development Authority and NGOs working on related areas)
- Agricultural mechanization and transformation (Agriculture and Natural Resource Bureau, Irrigation Development Authority, Rural Technology Promotion Sectors, Research Centers, Agricultural Support Agents)

14 PARTICIPATORY MONITORING AND EVALUATION OF OMM ACTIVITIES

14.1 IMPORTANCE OF PM&E OF OMM ACTIVITIES

Monitoring and evaluation of OMM activities has been a neglected subject, but must play a more important role in the future if the irrigation management process is to be improved. The process is complex, since a large number of regular, specific tasks must be performed, both concurrently and sequentially, and coordinated by a variety of professionals within available time and resource constraints. SSI scheme OMM monitoring and evaluation, describes the main requirements for a functional system, and provides a realistic framework for carrying it out. For any evaluation to be used, it must be credible-objective, accurate, and fair. Reports should be clear, unambiguous, balanced in terms of strengths and weaknesses, and contain justifiable conclusions and recommendations. For monitoring and evaluation to succeed, irrigation managers need to develop a new evaluative mind-set that enables them to appraise their projects' performance objectively, reflect on what has been learned for future use, and adjust on the basis of that knowledge whenever necessary.

14.2 MONITORING

The OMM activities must be monitored regularly via the implementing organization using well organized PM&E formats. Though the OMM activities must be monitored continuously by IWUA and local level irrigation extension workers every season, careful and detail PM&E of OMM activities must be conducted by implementing organization's Woreda office.

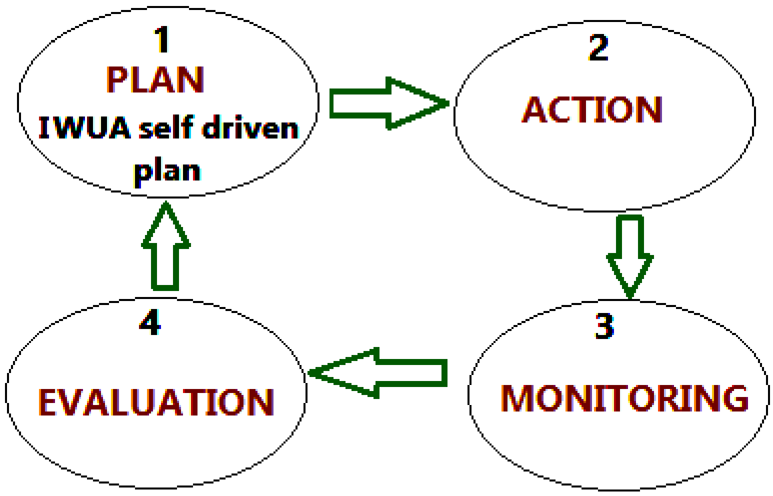


Figure 14-1: General principle of SSI scheme monitoring

Elements to be monitored in SSI Scheme OMM

- Organization and Management aspects
- Water Management
- Facilities Management (operation and maintenance)
- Financial Management
- Communication and Conflict Management
- Completion of Action Plans

Monitoring indicators

The main PM&E areas are whether water distribution carried out fairly, operation and maintenance of the facilities is planned and implemented, on area coverage, number of farmers participated, production of each farmer, fee collection and financial management, on recording and reporting systems, whether regular meetings are held to plan and solve their problems arisen in the scheme, etc. The government authorities should provide information, routine technical support and training on PM&E to scheme level technicians, IWUA and the beneficiary farmers.

Table 14-1: Monitoring elements and indicators

SN	Monitoring element	Indicator
1	Organization and Management	No/less staff turnover from IWUA
		Good acceptance from the beneficiaries
		All planned meetings held and minutes of meeting taken accordingly
		Good data management and documentation by IWUA
		Good Reporting systems
		Level of transparency is good
2	Water Management	There is water distribution plan prepared
		There are functional measuring structures within the system
		Water is allocated according to delivery plan
		No/less complain on water allocation
		All planned area has been achieved
3	Facility Management	Have annual operation and maintenance plan
		Number of members participated
		All maintenance activity achieved
		System running to anticipated level
4	Financial Management	All fee collected
		good banking and accounting systems
		All expenditure and revenue are clearly indicated
		Total revenue obtained from produces
		Have audit system
5	Communication and conflict management	No/less Conflict within IWUA
		No/less conflict between sub-committee and all beneficiary members
		There are Good communication systems (institutional)
		Input supplied on time
		Supports from stakeholders increased
		Number of trainings given increased
6	Completion of action plans	Have good action plans
		Completed annual action plans accordingly

Monitoring Method

- Monitoring OMM activities should be conducted by Woreda Irrigation Office through:
  - Field visit monitoring
  - Interview from IWUA members
  - IWUA performance reports and records

Schedule of Monitoring

- OMM monitoring activities should be carried out every year.
- Date to conduct the field visit monitoring should be scheduled after discussion with IWUA.

Execution of Monitoring

- Woreda office should conduct the field inspection and interview of the IWUA.
- “Check List for Monitoring” which is approved by implementing agency should be used (Appendix-X IWUA monitoring sheet and Appendix-XI IWUA performance sheet)

Data Analysis

All data collected must be well organized and analyzed before evaluation.

Reporting and feedback to users

All monitoring issues shall be reported and feedbacks given to user beneficiary and used for improvement of next plan.

14.3 EVALUATION

The most important factor in SSI scheme OMM evaluation is probably dependent on the perceptions of IWUA and /or counterparts on the outcome of the OMM works. In particular, it would be useful to identify successful results that meet the expectations of farmers and critical points that fell short of their expectations. Even though the project accomplishes some specific goals, the overall OMM works outcome is less valuable without their satisfaction and understanding of its achievements at the end.

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APPENDICES

APPENDIX I: Dam Inspection Check list

DAM/SCHEME NAME:__________________________________
IWUA:____
INSPECTOR: ____

Direction: Mark an "X" in the Yes or No column. If the item does not apply write "NA". If possible identify any changes since the last inspection	
DATE:	
WEATHER:	
TEMPERATURE:	

ITEM	YES	NO	YES	NO	YES	NO	YES	NO	YES	NO
1. TOP OF DAM										
a. Any visual settlements										
b. Misalignment										
c. Cracking?										
2. UPSTREAM SLOPE										
a. Adequate grass cover?										
b. Any erosion?										
c. Are trees growing on slope?										
d. Longitudinal cracks										
e. Transverse cracks?										
f. Adequate riprap protection?										
g. Any stone deterioration?										
h. Visual depressions or bulges										
i. Visual settlements										
j. Debris or trash present?										
3. DOWNSTREAM SLOPE										
a. Adequate grass cover?										
b. Any erosion?										
c. Are trees growing on slope										
d. Longitudinal cracks										
e. Transverse cracks?										
f. Visual depressions or bulges										
g. Visual settlements?										
h. Is the toe drain dry?										
i. Are the drainage wells flowing										
j. Are boils present at the toe?										
k. Is seepage present?										
1. Soft or spongy zones present?										
m. Are foundation to drain pipes										
(1) Broken, bent, or missing?										
(2) Corroded or rusted?										
(3) Obstructed?										
(4) Is discharge carrying sediment										
4. ABUTMENT CONTACTS										
a. Any erosion?										
b. Visual differential movement										
c. Any cracks noted?										
d. Is seepage present?										
5. PRINCIPAL SPILLWAY INLET										

ITEM	YES	NO	YES	NO	YES	NO	YES	NO	YES	NO
a. Do concrete surfaces show										
(1) Spalling										
(2) Cracking?										
(3) Erosion?										
(4) Scaling?										
(5) Exposed rebar?										
b. Do the joints show										
(1) Displacement or offset?										
(2) Loss of joint material?										
(3)Leakage?										
c. Metal appurtenances:										
(1) Rust present?										
(2) Broken components										
(3) Anchor system secure										
d. Trash-rack operational										
6. PRINCIPAL SPILLWAY CONDUIT										
a. Is the conduit concrete										
b. Do concrete surfaces show										
(1) Spalling?										
(2) Cracking?										
(3) Erosion?										
(4) Scaling?										
(5) Exposed rebar?										
c. Do the joints show:										
(1) Displacement or offset?										
(2) Loss of joint material?										
(3)Leakage?										
d. Is the conduit metal										
(1) Rust present?										
(2) Protective coatings adequate										
(3) Is the conduit misaligned?										
e. Is there seepage around the conduit?										
7. STILLING BASIN										
a. Do concrete surfaces show										
(1) Spalling?										
(2) Cracking?										
(3) Erosion?										
(4) Scaling?										
(5) Exposed rebar?										
b. Do the joints show:										
(1) Displacement or offset										
(2) Loss of joint material										
(3) Leakage?										
c. Do energy dissipaters or riprap areas show:										
(1) Signs of deterioration										
(2) Accumulated debris										
d. Is the channel:										
(1) Eroding										
(2) Sloughing										
(3) Obstructed?										

ITEM	YES	NO	YES	NO	YES	NO	YES	NO	YES	NO
e. Is discharged water:										
(1) Undercutting the outlet										
(2) Eroding the embankment										
8. EMERGENCY SPILLWAY										
a. Does spillway concrete show										
(1) Spalling?										
(2) Cracking?										
(3) Erosion?										
(4) Scaling?										
(5) Exposed rebar?										
b. Do the joints show										
(1) Displacement or offset?										
(2) Loss of joint material										
(3) Leakage?										
c. Is the spillway in rock or soil?(circle one)										
(1) Are slopes eroding?										
(2) Are slopes sloughing										
d. Is the discharge channel										
(1) Eroding or back cutting										
(2) Obstructed?										
(3) Is vegetative cover adequate?										
e. Has discharged water										
(1) Eroded the embankment										
(2) Undercut the outlet?										
f. Is the weir in good condition										
9. VALVES/GATES										
a. Are the valves/gates										
(1) Broken or bent?										
(2) Corroded or rusted?										
(3) Periodically maintained?										
(4) Operational?										
b. Is there a low level valve										
c. Is the low level valve operational										
10. AREA DOWNSTREAM										
a. Recent downstream development										
b. Seepage or wetness?										
Other comments/ observations (add date)										
Sketches										

APPENDIX II: Operation and Maintenance Log for canal

FOR ___________________ CANAL CHAINAGE ------------------- TO --------------------

Date	Time	Name of Recorder	Canal water depth, m	Discharge	Remarks
01/06/2016	9:00 a.m.		0.15	Gate open 6 inches	Visited canal. Everything appeared ok
10/06/2016	10:15 a.m.		0.25	Gate open 10 inches	Opened gate. Canal water surface level rising
20/06/2016	8:00 a.m.		0.45	Gate open 10 inches	4.5 Richter Scale earthquake reported 30 kms from canal. No damage seen at canal/structures.
30/06/2016	11:00 a.m.		0.8	Gate fully open	2cm of water going over escape. Wet area noted at bottom of left abutment looking downstream. 100l/s of water flowing from left toe drain and right toe drain dry.
01/07/2016	9:30 a.m.		0.8	Gate fully open	4cm of water going over escape. Minor erosion occurring escape channel. Wet area at bottom of left abutment unchanged from 26-04-16. 200l/s water flowing from left toe drain. Right toe drain dry.
10/07/2016	9:30 a.m.		0.7	Gate fully open	No flow over escape. Some repairs needed in escape channel when dry. 150 l/s flow at left toe drain. None from right toe drain. Trees were cut off of downstream slope of embankment.

APPENDIX III: List of Scheme major facilities

Woreda___________________
Scheme__________________
Date_____________________

Facility Name	Structure / type	Function	Constructed Year	Maintained/ Rehabilitated Year	Remark

APPENDIX IV: Field Inspection sheet

S/N________________________________ Date___________________________
Woreda/ Scheme_____________________ IWUA Name_________________
Facility Name_______________________ Inspector Name_________________

1	2	3	4		5	6	7	Remark
Location By name	Facility Name	structure type like Con slab, Masonry, etc.	Description of Deterioration (Scale, detail location, existing condition)		Possible Cause of deterioration	When first detected	Level/ extent of deterioration	

Note; Facilities Location map is to be attached.

APPENDIX V: Repair works Action Plan form

Woreda/ scheme Name___________________
Name of IWUA__________________________
Name of planner________________________

2	7	8	9	10	11	12	13	Remark & challenge
Facility Name	Level/ extent of deterioration	proposed measure	Approximate Cost	Priority order	Responsible body	Needed support from outside and the reason	Work Schedule	

Note: Location map, Facilities' Inspection result and Work plan should be compiled together

APPENDIX VI: Format for List of Farmers and Irrigable Land Size

No.	Name	TU No	Sex	Age	Land size (ha)	H.H Size		Signature
						Male	Female	
1								
2								
3								
4								
5								
6								
7								
8								
9								
10								
11								
12								
13								
14								
15								
16								
17								
18								
19								
20								

Note: Indicate the Group Leader

APPENDIX VII: Format for Irrigation schedule

No	Farm Plot		Irrigation period	Irrigation frequency	Water discharge (lit/s)	Remarks
	Block/TU	Irrigation area (ha)				
1	Block -1					
	TU-1					
	TU-2					
	TU-3 and so on					
2	Block -2					
	TU-1					
	TU-2					
	TU-3 and so on					
3	Block –3					
	TU-1					
	TU-2					
	TU-3 and so on					
4	Block –4					
	TU-1					
	TU-2					
	TU-3 and so on					
5	Block –5					
	TU-1					
	TU-2					
	TU-3 and so on					
6	Block –6					
	TU-1					
	TU-2					
	TU-3 and so on					
7	Block –7					
	TU-1					
	TU-2					
	TU-3 and so on					
8	Block -8					
	TU-1					
	TU-2					
	TU-3 and so on					
9	Block –9					
	TU-1					
	TU-2					
	TU-3 and so on					
10	Block -10					
	TU-1					
	TU-2					
	TU-3 and so on					
	Total					

APPENDIX VIII: Existing Cropping Pattern of the area

No	Major crops	Area (ha)	Cropping calendar		
			Land preparation	Sowing/planting time/	Harvesting time
A	Irrigation				
	1st round				
1					
2					
3					
	Total				
	2nd round				
1					
2					
3					
	Total				
B	Rain fed				
1					
2					
3					
	Total				

APPENDIX IX: Sample format for scheme inventory

Item	Name of Scheme	Arata Chufa	
General	Zone	Arsi	
	Woreda	Ziway Dugda	
	Kebele	Arata	
	IWUA	Arata Chufa	
	Water source	Chufa river	
	Command Area	Planed	Actual
	(ha)	100	99.37
	Water discharge	Planed	Actual
	(Lit/S)	100	120
	Beneficiary	Planed	Actual
	M.H.	291	298
	F.H.	26	26
	Total	317	324
	Population	Woreda	92,766
		Kebele	4,740
		scheme	
	Constructed year		
	Rainy season crop	Wheat, Maize, Teff, Barley	
	Dry season crop	Onion, Potato, Pepper, Tomato, Sugarcane, Cabbage	
	Living standard	Fair	
	Marketing	Good	
	Distance	From woreda office 15km	
		From Zone office 35km	
	Accessibility	good	
Facilities	Headwork (nos.)	1	Minor repair needed for spillway
	Main canal (m)	965	Main canal 1 (621m),main canal 2 (344m) need to be lined
	Secondary canal	2	nos.
	SC1(m)	640	Repair needed to be lined
	SC2(m)	513	Repair needed to be lined
	SC3(m)	-	
	SC4(m)	-	
	SC5(m)	-	
	SC6(m)	-	
	SC7(m)	-	
	SC8(m)	-	
	Irrigation pond(nos.)	1	Minor repair needed for gate
	Flow measuring struc.	2	Need to be maintained and calibrated
	Drop (nos.)	24	Needed repair due to small crack
	Chute(nos.)	-	
	Division box (nos.)	6	Minor repair needed for gate
	Turnout(nos.)	25	14 nos. not functional, needed repair
	Cattle trough(nos.)	-	-
	Culvert (nos.)	14	3 nos. need repair, 1 additional needed at Ch.1+080
Major Problem	1	TC-8 is not functional at Block-8 (2.5ha)	
	2	Water shortage in dry season	
	3	Leakage of water from all canals	
	4	Farm road is not good	

APPENDIX X: IWUA Activity Monitoring Sheet

Name of IWUA: ________________________

Scheme: ________________________ Woreda Office : ____________________

Year														Remarks
Month		January	February	March	April	May	June	July	August	September	October	November	December	
Categories	**Activity**													
Organization Management	Interview													
	Suggestion/ Recommendation													
	Follow-up													
Water Management	Interview													
	Suggestion/ Recommendation													
	Follow-up													
Facilities Management	Interview													
	Suggestion/ Recommendation													
	Follow-up													
Financial Management	Interview													
	Suggestion/ Recommendation													
	Follow-up													
Communication and Conflict Management	Interview													
	Suggestion/ Recommendation													
	Follow-up													
Completion of the Action Plan	Interview													
	Suggestion/ Recommendation													
	Follow-up													

Remarks: Check the cell when the events related to each category take place

APPENDIX XI: IWUA performance Monitoring Sheet

No.	Name of IWUA member	Irrigated Plot in ha	Irrigation Period		Crop yield (Qt)			Payment of fee	
			Date of Start	Date of End	Crop (1)	Crop (2)	Crop (3)	Amount in Birr	Date of Payment
Note: Bank journal shall be attached									

Prepared by: (Name) ______________________________

Authorized by: (Name) ______________________________

Signature ______________________________

Signature ______________________________

APPENDIX XII Individual Crop Water Requirements for Arata Chufa Scheme

I. Dry season irrigation requirement (CWR)

1. Tomato

Month	Decade	Stage	Kc	ETc	ETc	Eff rain	Irr. Req.
			coeff	mm/day	mm/dec	mm/dec	mm/dec
Oct	1	Init	0.6	2.26	2.3	1.4	2.3
Oct	2	Init	0.6	2.39	23.9	8.9	14.9
Oct	3	Init	0.6	2.41	26.5	7.1	19.3
Nov	1	Deve	0.64	2.61	26.1	5.3	20.8
Nov	2	Deve	0.8	3.26	32.6	3	29.6
Nov	3	Deve	0.95	3.77	37.7	2.6	35.1
Dec	1	Mid	1.11	4.22	42.2	2.2	40
Dec	2	Mid	1.15	4.23	42.3	1.5	40.8
Dec	3	Mid	1.15	4.4	48.4	2.3	46.1
Jan	1	Mid	1.15	4.57	45.7	2.5	43.2
Jan	2	Late	1.14	4.7	47	2.7	44.2
Jan	3	Late	1.02	4.24	46.7	6.6	40
Feb	1	Late	0.87	3.65	36.5	12	24.5
Feb	2	Late	0.8	3.35	3.4	1.6	3.4
					461.1	60	404.1

2. Onion

Month	Decade	Stage	Kc	ETc	ETc	Eff rain	Irr. Req.
			coeff	mm/day	mm/dec	mm/dec	mm/dec
Oct	2	Init	0.7	2.78	16.7	5.4	12.2
Oct	3	Init	0.7	2.81	30.9	7.1	23.8
Nov	1	Deve	0.74	2.99	29.9	5.3	24.6
Nov	2	Deve	0.88	3.58	35.8	3	32.9
Nov	3	Mid	1.01	4	40	2.6	37.4
Dec	1	Mid	1.05	4.01	40.1	2.2	37.9
Dec	2	Mid	1.05	3.86	38.6	1.5	37.1
Dec	3	Mid	1.05	4.01	44.2	2.3	41.8
Jan	1	Late	1.05	4.15	41.5	2.5	39
Jan	2	Late	0.98	4.02	40.2	2.7	37.4
Jan	3	Late	0.89	3.67	40.4	6.6	33.8
Feb	1	Late	0.8	3.32	33.2	12	21.2
Feb	2	Late	0.75	3.15	3.2	1.6	3.2
					434.6	55	382.1

3. Potato

Month	Decade	Stage	Kc	ETc	ETc	Eff rain	Irr. Req.
			coeff	mm/day	mm/dec	mm/dec	mm/dec
Sep	2	Init	0.5	1.67	1.7	2.7	1.7
Sep	3	Init	0.5	1.78	17.8	21.2	0
Oct	1	Init	0.5	1.88	18.8	14.4	4.4
Oct	2	Deve	0.55	2.17	21.7	8.9	12.8
Oct	3	Deve	0.76	3.05	33.5	7.1	26.4
Nov	1	Deve	0.99	4	40	5.3	34.7
Nov	2	Mid	1.14	4.67	46.7	3	43.8
Nov	3	Mid	1.15	4.54	45.4	2.6	42.8
Dec	1	Mid	1.15	4.38	43.8	2.2	41.6
Dec	2	Mid	1.15	4.22	42.2	1.5	40.7
Dec	3	Late	1.14	4.36	48	2.3	45.7
Jan	1	Late	1.04	4.11	41.1	2.5	38.6
Jan	2	Late	0.9	3.72	37.2	2.7	34.4
Jan	3	Late	0.79	3.28	23	4.2	16.3
					460.9	80.8	383.8

4. Cabbage

Month	Decade	Stage	Kc	ETc	ETc	Eff rain	Irr. Req.
			coeff	mm/day	mm/dec	mm/dec	mm/dec
Nov	3	Init	0.7	2.76	16.6	1.6	15.3
Dec	1	Init	0.7	2.67	26.7	2.2	24.5
Dec	2	Deve	0.72	2.66	26.6	1.5	25.1
Dec	3	Deve	0.84	3.2	35.2	2.3	32.8
Jan	1	Deve	0.96	3.8	38	2.5	35.5
Jan	2	Mid	1.04	4.28	42.8	2.7	40
Jan	3	Mid	1.04	4.33	47.6	6.6	41
Feb	1	Mid	1.04	4.36	43.6	12	31.6
Feb	2	Mid	1.04	4.4	44	16.1	27.9
Feb	3	Late	1.03	4.4	35.2	15.3	19.9
Mar	1	Late	0.98	4.25	42.5	12.8	29.7
Mar	2	Late	0.95	4.14	16.6	4.8	10.6
					415.3	80.5	333.9

5. Pepper

Month	Decade	Stage	Kc	ETc	ETc	Eff rain	Irr. Req.
			coeff	mm/day	mm/dec	mm/dec	mm/dec
Sep	2	Init	0.6	2.01	8	10.7	0
Sep	3	Init	0.6	2.13	21.3	21.2	0.2
Oct	1	Init	0.6	2.26	22.6	14.4	8.2
Oct	2	Deve	0.61	2.44	24.4	8.9	15.4
Oct	3	Deve	0.73	2.92	32.2	7.1	25
Nov	1	Deve	0.86	3.5	35	5.3	29.6
Nov	2	Deve	0.99	4.06	40.6	3	37.6
Nov	3	Mid	1.05	4.15	41.5	2.6	38.9
Dec	1	Mid	1.05	4	40	2.2	37.8
Dec	2	Mid	1.05	3.86	38.6	1.5	37
Dec	3	Late	1.04	3.96	43.5	2.3	41.2
Jan	1	Late	0.97	3.82	38.2	2.5	35.8
Jan	2	Late	0.91	3.75	15	1.1	13.6
					400.9	82.9	320.4

II. Wet season irrigation requirement (CWR)

1. Tomato

Month	Decade	Stage	Kc	ETc	ETc	Eff rain	Irr. Req.
			coeff	mm/day	mm/dec	mm/dec	mm/dec
Feb	3	Init	0.6	2.56	2.6	1.9	2.6
Mar	1	Init	0.6	2.6	26	12.8	13.1
Mar	2	Init	0.6	2.63	26.3	12	14.3
Mar	3	Deve	0.64	2.78	30.6	16.1	14.4
Apr	1	Deve	0.79	3.43	34.3	23	11.3
Apr	2	Deve	0.95	4.06	40.6	27.7	13
Apr	3	Mid	1.1	4.68	46.8	22.7	24.1
May	1	Mid	1.14	4.84	48.4	14.8	33.6
May	2	Mid	1.14	4.82	48.2	9.9	38.2
May	3	Mid	1.14	4.83	53.1	13.7	39.4
Jun	1	Late	1.13	4.88	48.8	17.9	30.9
Jun	2	Late	1.02	4.45	44.5	20.5	24
Jun	3	Late	0.88	3.56	35.6	25.3	10.3
Jul	1	Late	0.8	2.88	5.8	6.3	5.8
					491.4	224.7	275

2. Onion

Month	Decade	Stage	Kc	ETc	ETc	Eff rain	Irr. Req.
			coeff	mm/day	mm/dec	mm/dec	mm/dec
Mar	1	Init	0.7	3.03	27.3	11.5	14.4
Mar	2	Init	0.7	3.07	30.7	12	18.7
Mar	3	Deve	0.77	3.34	36.7	16.1	20.6
Apr	1	Deve	0.91	3.93	39.3	23	16.3
Apr	2	Mid	1.02	4.39	43.9	27.7	16.3
Apr	3	Mid	1.04	4.43	44.3	22.7	21.6
May	1	Mid	1.04	4.41	44.1	14.8	29.3
May	2	Mid	1.04	4.38	43.8	9.9	33.9
May	3	Late	1.02	4.33	47.6	13.7	33.9
Jun	1	Late	0.94	4.06	40.6	17.9	22.6
Jun	2	Late	0.86	3.73	37.3	20.5	16.8
Jun	3	Late	0.78	3.13	28.2	22.7	2.9
					463.7	212.7	247.2

3. Potato

Month	Decade	Stage	Kc	ETc	ETc	Eff rain	Irr. Req.
			coeff	mm/day	mm/dec	mm/dec	mm/dec
Mar	2	Init	0.5	2.19	8.8	4.8	2.8
Mar	3	Init	0.5	2.17	23.9	16.1	7.8
Apr	1	Init	0.5	2.16	21.6	23	0
Apr	2	Deve	0.62	2.65	26.5	27.7	0
Apr	3	Deve	0.83	3.55	35.5	22.7	12.8
May	1	Deve	1.05	4.44	44.4	14.8	29.6
May	2	Mid	1.14	4.82	48.2	9.9	38.3
May	3	Mid	1.14	4.83	53.2	13.7	39.5
Jun	1	Mid	1.14	4.92	49.2	17.9	31.3
Jun	2	Mid	1.14	4.97	49.7	20.5	29.2
Jun	3	Late	1.11	4.49	44.9	25.3	19.6
Jul	1	Late	0.98	3.54	35.4	31.7	3.6
Jul	2	Late	0.84	2.75	27.5	37	0
Jul	3	Late	0.74	2.47	9.9	12.8	0
					478.6	278.1	214.3

4. Cabbage

Month	Decade	Stage	Kc	ETc	ETc	Eff rain	Irr. Req.
			coeff	mm/day	mm/dec	mm/dec	mm/dec
Mar	3	Init	0.7	3.04	6.1	2.9	6.1
Apr	1	Init	0.7	3.02	30.2	23	7.2
Apr	2	Deve	0.7	3.02	30.2	27.7	2.5
Apr	3	Deve	0.79	3.35	33.5	22.7	10.8
May	1	Deve	0.9	3.82	38.2	14.8	23.4
May	2	Mid	1.01	4.27	42.7	9.9	32.7
May	3	Mid	1.04	4.41	48.6	13.7	34.9
Jun	1	Mid	1.04	4.5	45	17.9	27
Jun	2	Mid	1.04	4.54	45.4	20.5	24.9
Jun	3	Late	1.04	4.19	41.9	25.3	16.7
Jul	1	Late	0.99	3.58	35.8	31.7	4
Jul	2	Late	0.94	3.08	21.6	25.9	0
					419.1	236.1	190.3

5. Pepper

Month	Decade	Stage	Kc	ETc	ETc	Eff rain	Irr. Req.
			coeff	mm/day	mm/dec	mm/dec	mm/dec
Jun	2	Init	0.6	2.61	23.5	18.5	3
Jun	3	Init	0.6	2.42	24.2	25.3	0
Jul	1	Init	0.6	2.17	21.7	31.7	0
Jul	2	Deve	0.65	2.15	21.5	37	0
Jul	3	Deve	0.77	2.6	28.5	35.3	0
Aug	1	Deve	0.89	3.09	30.9	33.2	0
Aug	2	Mid	0.99	3.46	34.6	32.4	2.2
Aug	3	Mid	1	3.45	38	30.1	7.9
Sep	1	Mid	1	3.41	34.1	28.4	5.6
Sep	2	Late	1	3.36	33.6	26.7	6.9
Sep	3	Late	0.96	3.41	34.1	21.2	12.9
Oct	1	Late	0.89	3.36	30.3	13	15.8
					354.9	332.7	54.4

APPENDIX XIII: Weir/Barrage Inspection Check list

Scheme:____

IWUA:____

Inspector: ______________________________________

Direction: Mark an "X" in the Yes or No column. If the item does not apply write "NA". If possible identify any changes since the last inspection	
DATE:	
WEATHER:	
TEMPERATURE:	

ITEM	YES	NO	Details							
1. Weir body										
a. Any cracks?										
b. Lose of plasters?										
c. Erosion at toe?										
d. Damage of edges?										
e. Any spalling?										
2. Upstream and downstream aprons										
a. Any cracks? Cross or longitudinal.										
b. Any erosions or scours?										
c. Any depositions or shoals?										
d. Pressure relief holes (if any) functional?										
e. Any piping indications d/stream?										
f. Any spalling of surface?										
g. Exposed cut off upstream or downstream?										
3. Upstream and downstream protections										
a. Any displacements of materials?										
b. Any settlements?										
c. Any stone deterioration?										
d. Visual depressions or bulges?										
e. Any wash away?										
f. Any erosion after protections?										
g. Any shoals before/after protection?										
4. Wing walls, piers/ Abutments										
a. Any cracks?										
b. Any scouring?										
c. Any settlements?										
d. Any misalignments?										
e. Any slides?										
f. Visual depressions or bulges?										
g. Visual settlements?										
h. Any exposed R bars?										
i. Level of highest floods?										
5. Hydro mechanical parts										
a. Good condition of intake Gate?										
b. Good condition of silt gates or other bays?										
c. Good gate groove conditions?										
d. Good gate sill conditions?										
f. Good painting condition of gates?										
g. Oil or grease needs?										

ITEM	YES	NO	Details
h. Any misalignments or deforms?			
6. Head regulator			
a. Working properly?			
b. Any scouring before or after head regulator?			
c. Flow measuring structure functional?			
d. Any obstruction?			
e. Any deterioration?			
7. Silt Excluders, extractors and ejectors			
a. Any scouring?			
b. Any settlement in mouth or ducts?			
c. Any sediment/obstruction in off taking canal?			
d. Any cracks noted?			
f. Any other damages?			
8. Escape			
a. Escape above FSL functional?			
b. Any instability?			
b. Any deterioration?			
c. Any scouring or erosion at escape?			
9. Dykes and river training Works if any?			
a. Any damages by flood?			
b. Level of highest flood normal?			

SSIGL 30

Prepared by

GIRDC