Ethiopian TVET-System

Irrigation & Drainage Construction

Level III

Based on, March 2017G.C. Occupational Standard

Module Title: Monitoring Surface Water System Operation

TTLM Code: EIS IDC3 TTLM 0920v2

This module includes the following Learning Guides

LG42: Confirm SWMP performance measures

LG Code: EIS IDC3 M12 LO1-LG-42

LG43: Monitor performance of assets

LG Code: EIS IDC3 M12 LO3-LG-43

LG44: Monitor and coordinate processes

LG Code: EIS IDC3 M12 LO3-LG-44

LG45: Confirm performance measures in river system management plan

LG Code: EIS IDC3 M12 LO4-LG-45

Instruction Sheet	Learning Guide 24

This learning guide is developed to provide you the necessary information regarding the following content coverage and topics –

- Identifying water flow requirements in surface water sources.
- Determining water quality and quantity requirements,
- Identifying environmental factorsthat may impact on water flows and quality.
- Identifying performance measuresfor the plan and operations.
- Accessing and consulting historical information's
- Requiring stakeholders.

This guide will also assist you to attain the learning outcome stated in the cover page. Specifically, upon completion of this Learning Guide, you will be able to –

- Identify water flow requirements in surface water sources.
- Determine water quality and quantity requirements, including release rates.
- Identify environmental factorsthat may impact on water flows and quality.
- Identify performance measuresfor the plan and operations.
- Access and consulting historical information's
- Require stakeholders.

Learning Instructions:

1. Read the specific objectives of this Learning Guide.
2. Follow the instructions described below
3. Read the information written in the "Information Sheets". Try to understand what are being discussed. Ask you teacher for assistance if you have hard time understanding them.
4. Accomplish the "Self-checks".in each information sheets.
5. Ask from your teacher the key to correction (key answers) or you can request your teacher to correct your work. (You are to get the key answer only after you finished answering the Self-checks).

6. If you earned a satisfactory evaluation proceed to “Operation sheets and LAP Tests if any”. However, if your rating is unsatisfactory, see your teacher for further instructions or go back to Learning Activity.
7. After You accomplish Operation sheets and LAP Tests, ensure you have a formative assessment and get a satisfactory result;
8. Then proceed to the next LG

Information sheet-1	Identifying water flow requirements in surface water sources

1.1 Introduction

Water resources are natural resources of water that are potentially useful. Uses of water include agricultural, industrial, household, recreational and environmental activities. All living things require water to grow and reproduce.

97% of the water on the Earth is salt water and only three percent is fresh water; slightly over two thirds of this is frozen in glaciers and polar ice caps.[1] The remaining unfrozen freshwater is found mainly as groundwater, with only a small fraction present above ground or in the air.[2]

Fresh water is a renewable resource, yet the world's supply of groundwater is steadily decreasing, with depletion occurring most prominently in Asia, South America and North America, although it is still unclear how much natural renewal balances this usage, and whether ecosystems are threatened.[3] The framework for allocating water resources to water users (where such a framework exists) is known as water rights.

1.2 Sources of fresh water

1.2.1 Surface water

Surface water is water in a river, lake or fresh water wetland. Surface water is naturally replenished by precipitation and naturally lost through discharge to the oceans, evaporation, evapotranspiration and groundwater recharge.

Although the only natural input to any surface water system is precipitation within its watershed, the total quantity of water in that system at any given time is also dependent on many other factors. These factors include storage capacity in lakes, wetlands and artificial reservoirs, the permeability of the soil beneath these storage bodies, the runoff characteristics of the land in the watershed, the timing of the precipitation and local evaporation rates. All of these factors also affect the proportions of water loss.

Human activities can have a large and sometimes devastating impact on these factors. Humans often increase storage capacity by constructing reservoirs and decrease it by draining wetlands. Humans often increase runoff quantities and velocities by paving areas and channelizing the stream flow.

The total quantity of water available at any given time is an important consideration. Some human water users have an intermittent need for water. For example, many farms require large quantities of water in the spring, and no water at all in the winter. To supply such a farm with water, a surface water system may require a large storage capacity to collect water throughout the year and release it in a short period of time. Other users have a continuous need for water, such as a power plant that requires water for cooling. To supply such a power plant with water, a surface water system only needs enough storage capacity to fill in when average stream flow is below the power plant's need.

Nevertheless, over the long term the average rate of precipitation within a watershed is the upper bound for average consumption of natural surface water from that watershed.

Natural surface water can be augmented by importing surface water from another watershed through a canal or pipeline. It can also be artificially augmented from any of the other sources listed here, however in practice the quantities are negligible. Humans can also cause surface water to be "lost" (i.e. become unusable) through pollution.

1.2.2 Groundwater

Groundwater is fresh water located in the subsurface pore space of soil and rocks. It is also water that is flowing within aquifers below the water table. Sometimes it is useful to make a distinction between groundwater that is closely associated with surface water and deep groundwater in an aquifer (sometimes called "fossil water").

Groundwater can be thought of in the same terms as surface water: inputs, outputs and storage. The critical difference is that due to its slow rate of turnover, groundwater storage is generally much larger (in volume) compared to inputs than it is for surface water. This difference makes it easy for humans to use groundwater unsustainably for a long time without severe consequences. Nevertheless, over the long term the average rate of seepage above a groundwater source is the upper bound for average consumption of water from that source.

The natural input to groundwater is seepage from surface water. The natural outputs from groundwater are springs and seepage to the oceans.

If the surface water source is also subject to substantial evaporation, a groundwater source may become saline. This situation can occur naturally under endorheic bodies of water, or artificially under irrigated farmland. In coastal areas, human use of a groundwater source may cause the direction of seepage to ocean to reverse which can also cause soil salinization. Humans can also cause groundwater to be "lost" (i.e. become unusable) through pollution. Humans can increase the input to a groundwater source by building reservoirs or detention ponds.

1.3 Usage and environment allocations of surface water

Inappropriate land and water management can deplete water sources, pollute water systems, contribute to soil infertility and erosion and destroy natural ecosystems. In many regions, water for irrigation is being pumped out of the ground faster than it can be replenished.

Water allocation systems serve to equitably apportion water resources among users; protect existing water users from having their supplies diminished by new users; govern the sharing of limited water during droughts when supplies are inadequate to meet all needs; and facilitate efficient water use.

Water allocations are the amount of water distributed to users (water entitlement holders) in a given year. Allocations against entitlements change according to rainfall, inflows into storages and how much water is already stored. Allocations can increase throughout the year in response to changes in the system.

1.4 Water allocation mechanisms

Allocation regimes determine who is able to use water resources, how, when and where. They are strongly conditioned by historical preferences and usage patterns, often tracing their roots to previous decades or even centuries.

Well-designed allocation regimes contribute to multiple policy objectives: economic efficiency, by allocating resources to higher value uses as well as contributing to innovation and investment in water use efficiency; environmental performance by securing adequate flows to support ecosystems services; and equity by sharing the risks of shortage among water users fairly.

The Water Rights Analysis Package (WRAP) modeling system simulates the water allocation systems described. WRAP is routinely applied in different regional and state wide planning studies, administration of the water rights permit system, and other water management activities. WRAP is generalized for application anyplace in the world.

People in various nations, regions, and local communities have developed their own sets of institutions and practices governing the sharing of water. These water allocation systems have evolved historically and continue to change. Hierarchies of water allocation systems in the U.S. and many other countries generally have the following components or features.

- The waters of international rivers and aquifers are allocated between nations based on international law, customs, treaties, and agreements.
- Certain rights are reserved for military installations and other government owned lands and facilities.
- A legally established priority system based generally on variations of the riparian or prior appropriation doctrines guides the allocation of the surface water flowing in streams and stored in reservoirs.
- A separate system of laws and customs guides the allocation of water resources in ground water aquifers.

- An administrative system that grants, limits, and modifies water rights and enforces the allocation of water resources may or may not include formal issuance of written permits to water right holders.
- Water users and water management entities implement various contracts and other formal agreements.
- Sharing of water resources may be governed by cultural traditions and informal agreements that evolve historically over many years.

Water allocation mechanisms typically vary greatly between ground-water and surface-water. From a water law perspective, ground and surface water are usually treated as separate sources. The extent to which the important hydrologic and water management interconnections are recognized varies between geographical regions.

Principles and rules of international water law are found in treaties, international custom, general principals of law, and writings of international institutions.

Effective joint multiple-nation water management will be a major determinant in achieving stability, peace, and prosperity in many regions of the world in the 21st century. Examples of the many regions with dramatic potential for either cooperation or conflict including Blue Nile River, the Jordan River shared by Israel, etc. are small stream with remarkably great historical and political importance.

1.5 Surface water rights

Legal rights to the use of stream flow are generally based on two alternative doctrines, riparian and prior appropriation. The basic concept of the riparian doctrine is that water rights are incidental to the ownership of land adjacent to a stream. The prior appropriation doctrine is based on the concept of protecting senior water users from having their supplies diminished by newcomers developing water supplies later in time. In a prior appropriation system, water rights are not inherent in land ownership, and priorities are established based on dates that water is appropriated.

1.6 Estimation of irrigation water requirement

The water that is required to irrigate a field or plot of land growing theparticular crop not only has to satisfy the evapotranspiration needs for growing the crop, but would also include the following:

- Losses in the form of deep percolation while conveying water from the inlet of the field up to its last or tail end as the water gets distributed within the field
- Water requirement for special operations like land preparation, transplanting, leaching of salts, etc.

1.7 Sources of surface water

1.7.1 Dams and reservoirs

A dam is any barrier that holds back water; dams are primarily used to save, manage, and/or prevent the flow of excess water into specific regions. In addition, some dams are used to generate hydropower. Provision of the safe retention and storage of water is the primary purpose of a dam and hence corollary to this, every dam must represent a design solution specific to its site circumstances. The design therefore also represents an optimum balance of local, technical and economic considerations at the time of design and construction.

The Planning Process involves the project proponent and the designer. At this stage, the needs that are to be met by the project and the concept of the project are identified and developed. Project objectives and requirements are determined by the following concepts.

- What is the project expected to do? Conceptual development proposals and sketches are prepared based on reconnaissance or pre-feasibility-level investigations and available information for a number of alternate site locations.
- How is the project going to work? A preliminary assessment of the water supply potential is conducted.
- Is there enough water to satisfy projected demands? Project locations with insufficient water supply potential are rejected. A reconnaissance-level

investigation would include a review of existing information (aerial photos, test hole logs, maps) and a site inspection to identify site characteristics which may constrain or support a particular development concept and to identify potential downstream impacts. Preliminary costs and benefits are estimated based on experience with other projects and available information on the project under consideration. Project alternatives are ranked to assess the relative viability of each. After discussion with the project proponent, one or two sites are selected for further preliminary engineering investigations. After the initial planning, if the project appears to be technically feasible, preliminary engineering studies are performed for one or more sites.

Preliminary engineering studies would include: topographical surveys of the dam and spillway locations and the reservoir area; a project hazard potential assessment; a geological dam site description; a geotechnical assessment; and a preliminary design, complete with cost estimate. The overall project feasibility can be assessed based on the costs and benefits of the proposed project. This final assessment completes the project planning phase. It is noted that some design activities are included in the planning phase. There is an overlap between planning and design, as preliminary designs and costs (design function) are required for the information of the proponent. Although there is an overlap between the planning and design functions, it is still convenient to treat them as separate functions. The final design, including construction drawings and specifications, is completed, documented and approved for submission to the pertinent provincial water resources agency, if this is required prior to construction.

Study, design and construction of the dam require multi- professional disciplines, resources and times. The following key factors would be critically considered to characterize the storage dams:

- When the study and design of the dam is conducted, specialized and qualified team composition are paramount like watershed management expert, hydrologist, dam engineer, geotechnical engineer, Irrigation engineer, irrigation agronomist, socio-economist and so on. Hence, without qualified and experienced staffs, studying and design of dams may not be easily completed.

- Constructions of dams are sensitive in investment cost, quality and work quantity and time utilization. Hence, to assure construction quality, time utilization and unnecessary cost encourage, high resources supplies like machineries and tools, skilled and unskilled man powers & time span of construction are required. These critical issues will be considered during study and design investigation to actual implementing areas.
- Operation and maintenance of the dams are the other issues that would be in mind during study and design investigation. Maintaining of the dam will be difficult in normal way and will be simple technically and economically to study, design and construct another new dam rather than repairing the defected existing dams.
- Therefore to avoid any substantial issues in the dam project planning and development, the following care shall be undertaken:
  - ✓ Limitation of the dam height would be appropriate at this level. Classification of the dam according to height would be essential for this manual.
  - ✓ Catchment area type & size, soil and land cover data would be very crucial. The maximum catchment area will be critically considered with respect to rainfall distribution pattern and amount, runoff yield, sediment yield and so on.
  - ✓ Location of site and topographical map is mandatory. Hence, site selection team would consider so many factors before decisions.
  - ✓ Climate and hydrology data would be required during dam planning.
  - ✓ Water demand data is very important
  - ✓ Geological data and dam site data including the hydraulic condition is also very essential.

According to the above significant issues, the minimum team compensation to execute the dam project planning and development would include the following disciplines:

- Dam Engineer
- Geotechnical/Engineering geologist

- Surveyor
- Irrigation Agronomist
- Socio-economist

1.7.2 Rivers

Rivers are used all over the world as sources of irrigation water. The most typical quality defining a river is that it flows; it is not a reservoir which contains a fixed amount of water. At each moment a new amount of water is passing any given location along the river. The flow of river fluctuates over time. The flows of some rivers fluctuate greatly over relatively short periods of time; these are mainly small local rivers which respond quickly to rainfall in their catchment area.

A catchment area is the area from which a particular river or lake receives both surface flow and drainage water originating from precipitation. Other rivers show little fluctuation or vary only over a long period of time. These are mainly rivers with a large catchment area, where the rains are spread over a greater area and for a longer period of time. River flows vary considerably, not only within a given year, but also from one year to the next. In a year with little rain during the rainy season, the river flow will be small; sometimes the river flow will cease altogether during the dry season (see Figure 1.3). The river flow will be far more in years with heavy rainfall during the wet season.

The discharge of rivers is commonly expressed in cubic meters per second (m3/s). Although the method is applied to canals, it can also be used for small rivers.

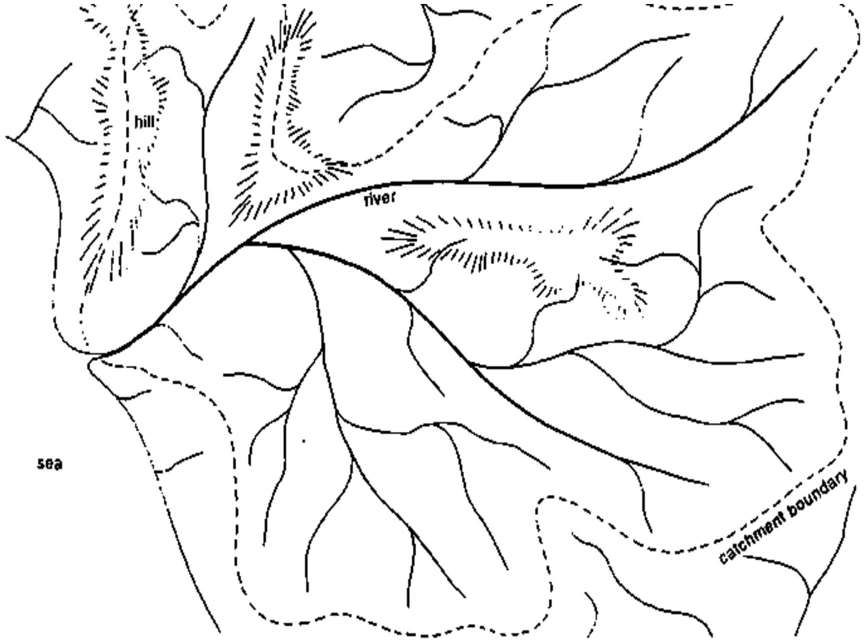


Figure-1:catchment and river relation

1.7.3 Lakes

A lake is an area filled with water, localized in a basin, surrounded by land, apart from any river or other outlet that serves to feed or drain the lake. Lakes lie on land and are not part of the ocean, and therefore are distinct from lagoons, and are also larger and deeper than ponds, though there are no official or scientific definitions. Lakes can be contrasted with rivers or streams, which are usually flowing. Most lakes are fed and drained by rivers and streams.

Natural lakes are generally found in mountainous areas, rift zones, and areas with ongoing glaciation. Other lakes are found in endorheic basins or along the courses of mature rivers. In some parts of the world there are many lakes because of chaotic drainage patterns left over from the last Ice Age. All lakes are temporary over geologic time scales, as they will slowly fill in with sediments or spill out of the basin containing them.

Many lakes are artificial and are constructed for industrial or agricultural use, for hydro-electric power generation or domestic water supply, or for aesthetic, recreational purposes, or other activities.

Healthy lakes and their shores not only provide us with a number of environmental benefits but they influence our quality of life and they strengthen our economy.

Proper lake function can ease the impact of floods and droughts by storing large amounts of water and releasing it during shortages. Lakes also work to replenish groundwater, positively influence water quality of downstream watercourses, and preserve the biodiversity and habitat of the area. When the ecological puzzle pieces of a lake come together and the lake is able to work as it should, the big picture is clear, we all stand to benefit from this important resource.

Lakes can provide us with prime opportunities for recreation, tourism, and cottage or residential living. They are also respected by many people for their historical and traditional values and may be a source of raw drinking water for a municipality. Lakes can also be used as a water supply for industry and an irrigation source for agriculture.

Figure-2:lakes and its function

Lakes are essential elements of the landscape for several reasons. They provide important habitat for wildlife including fish and other aquatic species, many species of birds, and a multitude of mammals. People enjoy lakes for their beautiful scenery and use them for recreational activities such as fishing, hunting and boating.

Lakes also provide important ecosystem services. They act as natural regulators of river flow, trapping sediments and nutrients from rivers and streams that flow into them. The riparian plants that grow along the shorelines help to stabilize the sediments and provide complex habitats for terrestrial animals.

Lakes can be divided into two basic habitats: deep, open water (pelagic zone) and bottom areas (benthic zone). The deep, open water zone is where we find free-floating organisms like microscopic phytoplankton (algae) and zooplankton (animals); and larger organisms like our many different fish species. In contrast, the benthic zone is where we find attached algae (periphyton) on the surface of rocks and other substrates, larger macro algae, macro invertebrates (e.g. insect larvae, snails, amphipods, clams, etc.), and young fish.

1.7.4 Creeks and streams

A stream is a body of water with surface water flowing within the bed and banks of a channel. The stream encompasses surface and groundwater fluxes that respond to geological, geomorphological, hydrological and biotic controls.

Depending on its location or certain characteristics, a stream may be referred to by a variety of local or regional names. Long large streams are usually called rivers.

Streams are important as conduits in the water cycle, instruments in groundwater recharge, and corridors for fish and wildlife migration. The biological habitat in the immediate vicinity of a stream is called a riparian zone. The study of streams and waterways in general is known as surface hydrology and is a core element of environmental geography.

Rivers, Streams and Creeks are all names for water flowing on the Earth's surface. As far as our Water Science site is concerned, they are pretty much interchangeable. I tend to think of creeks as the smallest of the three, with streams being in the middle, and rivers being the largest.

Most of the water you see flowing in rivers comes from precipitation runoff from the land surface alongside the river. Of course, not all runoff ends up in rivers. Some of it evaporates on the journey downslope, can be diverted and used by people for their uses, and can even be lapped up by thirsty animals. Rivers flow through valleys in the landscape with ridges of higher land separating the valleys. The area of land between ridges that collects precipitation is a watershed or drainage basin. Most, but not all, precipitation that falls in a watershed runs off directly into rivers - part of it soaks into the ground to recharge groundwater aquifers, some of which can then seep back into riverbeds.

Small streams, including those that don't flow all of the time, make up the majority of the country's waters. They could be a drizzle of snowmelt that runs down a mountainside crease, a small spring-fed pond, or a depression in the ground that fills with water after every rain and overflows into the creek below. These water sources, which scientists refer to as head water streams, are often unnamed and rarely appear on maps. Yet the health of small streams is critical to the health of the entire river network and downstream communities. These small streams often appear insignificant, but in fact are very important, as they feed into and create our big rivers.

Streams, headwaters and streams that flow only part of the year provide many upstream and downstream benefits. They protect against floods, filter pollutants, recycle potentially-harmful nutrients, and provide food and habitat for many types of fish. These streams also play a critical role in maintaining the quality and supply of our drinking water, ensure a continual flow of water to surface waters, and help recharge underground aquifers.

1.7.5 Wetlands

A wetland is a distinct ecosystem that is flooded by water, either permanently or seasonally, where oxygen-free processes prevail. The primary factor that distinguishes wetlands from other land forms or water bodies is the characteristic vegetation of aquatic plants, adapted to the unique hydric soil. Wetlands play a number of functions, including water purification, water storage, processing of carbon and other nutrients, stabilization of shorelines, and support of plants and animals. Wetlands are also considered the most biologically diverse of all ecosystems, serving as home to a wide range of plant and animal life.

Wetlands occur naturally on every continent. The water in wetlands is freshwater, brackish, or saltwater. Wetlands can be tidal (inundated by tides) or non-tidal. The largest wetlands include the Amazon River basin, the West Siberian Plain, the Pantanal in South America and the Sundarbans in the Ganges-Brahmaputra delta.

Constructed wetlands are used to treat municipal and industrial wastewater as well as storm water runoff. They may also play a role in water-sensitive urban design.

Wetland ecologists have already documented the following environmental benefits wetlands provide:

- ✓ Water purification
- ✓ Flood protection
- ✓ Shoreline stabilization
- ✓ Groundwater recharge and stream flow maintenance

Wetlands also provide habitat for fish and wildlife, including endangered species. Not all wetlands provide all of these benefits, and how your particular wetland works depends on its location and type.

Figure-3:wetland

1.8 Catchment areas

A catchment is an area of land where water collects when it rains, often bounded by hills. As the water flows over the landscape it finds its way into streams and down into the soil, eventually feeding the river. Some of this water stays underground and continues to slowly feed the river in times of low rainfall. A catchment is an area in which water falling on or flowing across the land surface drains into a particular stream or river and flows ultimately through a single point or outlet.

The idea of catchments is useful, as it is the standard functioning unit of the landscape: water, soil, plants and animals are all linked together within a catchment, and any activity that occurs within a catchment will affect the whole catchment. Healthy catchments are important for human survival, as it is where our food is grown and where all the water we drink comes from.

A healthy catchment is one that is still able to function as a catchment should. It should be able to filter and clean water as it flows overland and seeps through the ground, and there should be lots of opportunities for water to seep into the ground so that it can be used by plants.

Self-check 1	Written test

Directions: Choose the best answer and put all the answer in the answer sheet.

1. Which one of the following is **not** source of surface water? (2 pts)
    A. Rivers
    B. Reservoirs
    C. Lakes and groundwater
    D. Spring
2. Inappropriate land and water management and allocation leads to?(2 pts)
    A. Improve water resource
    B. Contribute to soil fertility
    C. Erosion
    D. Conserve natural ecosystems
3. Water allocation systems serve to?(2 pts.)
    A. Equitably apportion water resources among users
    B. Govern the sharing of limited water during droughts
    C. Protect existing water users from having their supplies diminished by new users
    D. All of the above
4. One of the following is the minimum team compensation to execute the dam project planning and development would include? (2 pts)
    A. Dam Engineer
    B. Geotechnical/Engineering geologist
    C. Surveyor
    D. Irrigation Agronomist
5. Which one of the following environmental benefits of wetlands? (2 pts.)
    A. Water purification
    B. Flood protection
    C. Shoreline stabilization

D. Groundwater recharge and stream flow maintenance

***Note:* Satisfactory rating - 5points** **Unsatisfactory - below 5 points**

Score = ___________

Rating: ____________

Answer Sheet

Name: ___________________________ Date: ________________

Answer sheet

1.
2.
3.
4.
5.

Information Sheet 2	2. Determining water quality and quantity requirements

2.1 Introduction

Water is one of the factors that limit how many people can be supported on our planet, and where they can live. Already water shortages and pollution cause widespread public health problems, and limit economic and agricultural development, as well as damaging the ecological services provided by the environment. These pressures will worsen under the twin pressures of increasing demand due to population growth (see World Demography and Food Supply) and increasing degradation of the water resource. Allied to these drivers of changes are the effects brought about by the institutional arrangements we construct to manage water and by climate change and the variability of rainfall (see Agriculture and Global change).
Irrigated agriculture is dependent on an adequate water supply of usable quality. Water quality concerns have often been neglected because good quality water supplies have been plentiful and readily available.

2.2 Irrigation water quantity and quality

1.2.1. Irrigation water quantity

A reliable and suitable irrigation water supply can result in vast improvements in agricultural production and assure the economic vitality of the region.

Precipitation, and in particular its effective portion, provides part of the water crops need to satisfy their transpiration requirements is called effective rainfall. The soil, acting as a buffer, stores part of the precipitation water and returns it to the crops in times of deficit. In humid climates, this mechanism is sufficient to ensure satisfactory growth in rain-fed agriculture. In arid climates or during extended dry seasons, irrigation is necessary to compensate for the evapotranspiration (crop transpiration and soil evaporation) deficit due to insufficient or erratic precipitation. Irrigation consumptive water use is defined as the volume of water needed to compensate for the deficit between potential evapotranspiration on the one side and effective precipitation over the crop growing period and change in soil moisture content on the other side. It varies considerably with climatic conditions, seasons, crops and soil types. Considering parameters that we consider when calculate the crop water requirements are as follows:

- **Transpiration**: The loss of water through the stomata of plants as it changes from a liquid to a gas form
- **Capillary action**: The movement of water through very small pores in the soil from wetter areas to drier areas. Water may move vertically and horizontally.
- **Evaporation:** The loss of water from the soil as it changes from a liquid to a gas form and is no longer available to crop plants
- **Evapotranspiration (ET):** The combination of water being lost from a soil through the processes of evaporation and transpiration
- **Evapotranspiration rate (ETo):** The volume of water lost through evapotranspiration in a given time period
- **Percolation:** The gravitational process of water moving downward and through the soil horizons

For a given month, the crop water balance can be expressed as follows:

ICU = ETc - P – DS

Where:

- ICU = irrigation consumptive water use needed to satisfy crop water demand (mm)
- ETc = potential crop evapotranspiration (mm)
- P= effective precipitation (mm)
- DS = change in soil moisture (mm)

Determining When to Irrigate and How Much Water to Apply

Water budgeting approach:

- When seasonal ET > precipitation, irrigation is required
- Determining site specific ETo

- The evapotranspiration rate for your farm may be determined by averaging the time period required for the evaporation of 1 inch of water from a given vessel
- Replacing ET with calibrated irrigation systems.
  - Once the ET rate of your site is determined, this known volume of water may be replaced through the use of calibrated irrigation systems that deliver water at a known rate and volume.
- Irrigation scheduling in different systems based on water budgeting approach.
  - Once the evapotranspiration rate (in gallons/week) and the water delivery rates (in gallons/ hour) of the irrigation system are known, the amount of time required to replace water lost may be calculated by dividing ET by the water delivery rate. This will provide the total number of hours required to replace the water lost through evapotranspiration. (An additional 10% should be calculated in to compensate for water loss inefficiencies.)
  - The frequency of irrigation should correspond to the time period required for the soil in the root zone of the crop to dry to approximately 50% of field capacity. Due to shallow root systems and greater susceptibility to water stress, annual crop culture often requires a higher frequency of irrigation (2-3 times/week for many crops). Established orchards, which have deep root systems and are less susceptible to water stress, often require less frequent but larger volumes of water to be delivered in each irrigation. In both situations the amount of water lost through ET is replaced. It is only the frequency of irrigation that is different.
- Advantages of water budgeting approach: Efficiency in time and water resources
- Measuring soil moisture by feel approach

Environmental Factors Influencing Frequency and Volume of Irrigation

Climate

- Air temperature: Increased air temperatures will increase the rate of ET

- Precipitation: In areas of regular summer rainfall, where precipitation exceeds ET, irrigation is seldom required. Irrigation demands are based on ET rates. Where ET exceeds precipitation, irrigation is required.
- Humidity: Increased humidity will decrease the rate of ET
- Wind: High wind speeds increase ET

Soils

- Sandy soils drain rapidly and do not hold water well
- Silty soils drain slowly and hold water well
- Clay soils drain very slowly and hold water tightly
- Loam soils both drain well and hold water well
- Well-improved agricultural soils maintain good drainage and moisture retention properties

Stage of development and crop natural history

- "Water-loving" crops (e.g., celery) demand less fluctuation in soil moisture levels Drought-tolerant crops (e.g., tomato varieties, winter squash varieties, Amaranth, etc.) may require little or no irrigation
- Maturation period: Prior to harvest, many crops (e.g., onions and garlic) require reduced irrigation inputs to encourage maturation.

2.2.2 Irrigation water quality

Conceptually, water quality refers to the characteristics of a water supply that will influence its suitability for a specific use, i.e. how well the quality meets the needs of the user. Quality is defined by certain physical, chemical and biological characteristics.

The water quality used for irrigation is essential for the yield and quantity of crops, maintenance of soil productivity, and protection of the environment. For example, the physical and mechanical properties of the soil, ex. soil structure (stability of aggregates) and permeability are very sensitive to the type of exchangeable ions present in irrigation waters.

Irrigation water quality can best be determined by chemical laboratory analysis. The most important factors to determine the suitability of water use in agriculture are the following:

- PH
- Salinity Hazard
- Sodium Hazard (Sodium Adsorption Ration or SAR)
- Carbonate and bicarbonates in relation with the Ca& Mg content
- Other trace elements
- Toxic anions
- Nutrients
- Free chlorine etc.

Even a personal preference such as taste is a simple evaluation of acceptability. For example, if two drinking waters of equally good quality are available, people may express a preference for one supply rather than the other; the better tasting water becomes the preferred supply. In irrigation water evaluation, emphasis is placed on the chemical and physical characteristics of the water and only rarely is any other factors considered important.

Irrigation waters quality standards, mg/l

Element	FAO	Nigeria
Aluminum	5.0	5.0
Arsenic	0.1	0.1
Cadmium	0.01	0.01
Chromium	0.1	0.1
Copper	0.2	0.2-1.01
Manganese	0.2	0.2
Nickel	0.2	0.2
Zinc	2.0	0.0-5.02

2.3 Water quality-related problems in irrigated agriculture

Water used for irrigation can vary greatly in quality depending upon type and quantity of dissolved salts. Salts are present in irrigation water in relatively small but significant amounts. They originate from dissolution or weathering of the rocks and soil, including dissolution of lime, gypsum and other slowly dissolved soil minerals. These salts are carried with the water to wherever it is used. In the case of irrigation, the salts are applied with the water and remain behind in the soil as water evaporates or is used by the crop.

The suitability of water for irrigation is determined not only by the total amount of salt present but also by the kind of salt. Various soil and cropping problems develop as the total salt content increases, and special management practices may be required to maintain acceptable crop yields. Water quality or suitability for use is judged on the potential severity of problems that can be expected to develop during long-term use.

The problems that result vary both in kind and degree, and are modified by soil, climate and crop, as well as by the skill and knowledge of the water user. As a result, there is no set limit on water quality; rather, its suitability for use is determined by the conditions of use which affect the accumulation of the water constituents and which may restrict crop yield. The soil problems most commonly encountered and used as a basis to evaluate water quality are those related to salinity, water infiltration rate, toxicity and a group of other miscellaneous problems.

SALINITY: Salts in soil or water reduce water availability to the crop to such an extent that yield is affected.

WATER INFILTRATION RATE: Relatively high sodium or low calcium content of soil or water reduces the rate at which irrigation water enters soil to such an extent that sufficient water cannot be infiltrated to supply the crop adequately from one irrigation to the next.

SPECIFIC ION TOXICITY: Certain ions (sodium, chloride, or boron) from soil or water accumulate in a sensitive crop to concentrations high enough to cause crop damage and reduce yields.

MISCELLANEOUS: Excessive nutrients reduce yield or quality; unsightly deposits on fruit or foliage reduce marketability; excessive corrosion of equipment increases maintenance and repairs.

2.4 Water quality guidelines

There have been a number of different water quality guidelines related to irrigate agriculture. Each has been useful but none has been entirely satisfactory because of the wide variability in field conditions. Hopefully, each new set of guidelines has improved our predictive capability. The guidelines are practical and have been used successfully in general irrigated agriculture for evaluation of the common constituents in surface water, groundwater, drainage water, sewage effluent and wastewater.

Ordinarily, no soil or cropping problems are experienced or recognized when using water with values less than those shown for ‘no restriction on use’. With restrictions in the slight to moderate range, gradually increasing care in selection of crop and management alternatives is required if full yield potential is to be achieved. On the other hand, if water is used which equals or exceeds the values shown for severe restrictions, the water user should experience soil and cropping problems or reduced yields, but even with cropping management designed especially to cope with poor quality water, a high level of management skill is essential for acceptable production. If water quality values are found which approach or exceed those given for the severe restriction category, it is recommended that before initiating the use of the water in a large project, a series of pilot farming studies be conducted to determine the economics of the farming and cropping techniques that need to be implemented.

Table 2.1 is a management tool. As with many such interpretative tools in agriculture, it is developed to help users such as water agencies, project planners, agriculturalists, scientists and trained field people to understand better the effect of water quality on soil conditions and crop production. With this understanding, the user should be able to adjust management to utilize poor quality water better. However, the user of Table 2.1 must guard against drawing unwarranted conclusions based only on the laboratory results and the guideline interpretations as these must be related to field conditions and must be checked, confirmed and tested by field trials or experience.

Table 1: Guidelines for interpretations of water quality for irrigation

Potential irrigation problem				Units	Degree of Restriction on Use		
					None	**Slight to Moderate**	**Severe**
Salinity(affects crop water availability)							
	EC_w			dS/m	< 0.7	0.7 – 3.0	> 3.0
	TDS			mg/l	< 450	450 – 2000	> 2000
Infiltration (affects infiltration rate of water into the soil. Evaluate using EC_w and SAR together)							
	= 0 – 3		**=**		> 0.7	0.7 – 0.2	< 0.2
	= 3 – 6		**=**		> 1.2	1.2 – 0.3	< 0.3

SAR	= 6 – 12	**and EC_w**	**=**		> 1.9	1.9 – 0.5	< 0.5
	= 12 – 20		**=**		> 2.9	2.9 – 1.3	< 1.3
	= 20 – 40		**=**		> 5.0	5.0 – 2.9	< 2.9
Specific Ion Toxicity(affects sensitive crops)							
	Sodium (Na)						
	surface irrigation			SAR	< 3	3 – 9	> 9
	sprinkler irrigation			me/l	< 3	> 3	
	Chloride (Cl)						
	surface irrigation			me/l	< 4	4 – 10	> 10
	sprinkler irrigation			me/l	< 3	> 3	
	Boron (B)			mg/l	< 0.7	0.7 – 3.0	> 3.0
Miscellaneous Effects(affects susceptible crops)							
	Nitrogen (NO_3 - N)			mg/l	< 5	5 – 30	> 30
	Bicarbonate (HCO_3)						
	(overhead sprinkling only)			me/l	< 1.5	1.5 – 8.5	> 8.5
	pH				Normal Range 6.5 – 8.4		

Table 2 laboratory determinations needed to evaluate common irrigation water quality problems

Water parameter	**Symbol**	**Unit**[1]	**Usual range in irrigation water**	
Salinity				
Electrical conductivity	EC_w	dS/m	0 – 3	dS/m

Total dissolved solids	TDS	mg/l	0 – 2000	mg/l
Cat ions and Anions				
Calcium	Ca^{++}	me/l	0 – 20	me/l
Magnesium	Mg^{++}	me/l	0 – 5	me/l
Sodium	Na^{+}	me/l	0 – 40	me/l
Carbonate	CO^{--}_3	me/l	0 – .1	me/l
Bicarbonate	HCO_3^-	me/l	0 – 10	me/l
Chloride	Cl^-	me/l	0 – 30	me/l
Sulphate	SO_4^{--}	me/l	0 – 20	me/l
Nutrients				
Nitrate-Nitrogen	NO_3-N	mg/l	0 – 10	mg/l
Ammonium-Nitrogen	NH_4-N	mg/l	0 – 5	mg/l
Phosphate-Phosphorus	PO_4-P	mg/l	0 – 2	mg/l
Potassium	K^+	mg/l	0 – 2	mg/l
Miscellaneous				
Boron	B	mg/l	0 – 2	mg/l
Acid/Basicity	pH	1–14	6.0 – 8.5	
Sodium Adsorption Ratio	SAR	(me/l)	0 – 15	

Self-check 2	Written test

Instructions: Answer all the questions listed below. Write your answers in the sheet provided in the next page.

1. ------- refers to the characteristics of a water supply that will influence its suitability for a specific use.
   A. Water quantity
   B. Water quality
   C. Irrigation water source
   D. Surface water
2. Amount of water used by the crop to sustain their growth stage is?
   A. Crop water requirement
   B. Precipitation
   C. Surface water
   D. Irrigation water source
3. Which one of the following are water quality-related problems in irrigated agriculture? (2 pts.)
   A. Water infiltration rate
   B. Specific ion toxicity
   C. Miscellaneous
   D. Salinity
4. ------- is a measure of the content of salts in soil or water? (2 pts.)
   A. Water infiltration rate
   B. Specific ion toxicity
   C. Miscellaneous
   D. Salinity
5. How to control water quality problems? (2 pts.)
   A. Properly used of water during irrigation time
   B. Managing different wastes released to the earth and water bodies
   C. Treating salt affected waters in different area

D. All of the above

Note: **Satisfactory rating - 4 points** **Unsatisfactory - below 4 points**

Answer Sheet

Score = ___________
Rating: ____________

Name: _________________________ Date: _______________

Short Answer Questions

1. ------------ 2. ------------- 3. ----------------- 4. -------------- 5. ------------

Information sheet 3	3. Identifying environmental factorsthat may impact on water flows and quality

3.1 Environmental flow requirements

Environmental flows describe the quantity, timing, and quality of water flows required to sustain freshwater and estuarine ecosystems and the human livelihoods and wellbeing that depend on these ecosystems. Through implementation of environmental flows, water managers strive to achieve a flow regime, or pattern, that provides for human uses and maintains the essential processes required to support healthy river ecosystems. Environmental flows do not necessarily require restoring the natural, pristine flow patterns that would occur absent human development, use, and diversion but, instead, are intended to produce a broader set of values and benefits from rivers than from management focused strictly on water supply, energy, recreation, or flood control.

Rivers are parts of integrated systems that include floodplains and riparian corridors. Collectively these systems provide a large suite of benefits. However, the world's rivers are increasingly being altered through the construction of dams, diversions, and levees. Dams and other river structures change the downstream flow patterns and consequently affect water quality, temperature, sediment movement and deposition, fish and wildlife, and the livelihoods of people who depend on healthy river ecosystems. Environmental flows seek to maintain these river functions while at the same time providing for traditional off-stream benefits.

Water management in developed nations focused largely on maximizing flood protection, water supplies, and hydropower generation. During the 1970s, the ecological and economic effects of these projects prompted scientists to seek ways to modify dam operations to maintain ecology. The initial focus was on determining the minimum flow necessary to preserve an individual species, such as trout, in a river. Environmental flows evolved from this concept of minimum flows and later in stream flows which emphasized the need to keep water within waterways.

4.1 Catchment usage and management

Catchment management is playing an increasingly important role in reducing the levels of potential contaminants in raw waters. An efficiently managed scheme will help to reduce pollution from agriculture and also help to control urban and chemical pollution from sites within a catchment. The soil, plants, animals and water all function together in a catchment – anything that affects one of these will also have an impact on the others. The health of our catchments is vital for human existence because they are where all food is grown. The catchment scale provides a framework for implementing riparian ecosystem management and can be summarized in five broad guidelines.

- Effective catchment management needs cooperation among citizens, industry, governmental agencies, private institutions, and academic organizations because of the complexity of information processing and the inherent socio environmental changes.
- Technical solutions (e.g., fish hatcheries or waste management) to specific human-generated problems must be balanced with the maintenance of environmental components providing similar ecological services.
- Resolution of issues depends on data-driven policy and management decisions rather than on only theoretical conceptualization or scientific perceptions.
- The structure and behaviour of the socio environmental system must be regulated evenly and fairly throughout the catchment.
- Both human activities and the structure and dynamics of the environmental components are fundamental elements of the catchment and must have rights to exist for the long term.

5.1 Weather and climate

The earth's climate is changing at an alarming rate, causing temperature rises and shifting precipitation patterns, resulting in more frequent and intensified extreme weather events. Water scarcity and flooding are further exacerbated, and crop water requirements may increase under these conditions. The current weather and hydrological conditions of existing irrigation and drainage systems are different from the ones that existed when the systems were developed. Existing irrigation and drainage systems will have to adjust their engineering facilities, technical approaches and management strategies to respond to these impacts effectively. Development of new irrigation and drainage systems will also need to adopt new design criteria that build on historical hydrological records but also take into consideration projected impacts of climate change.

Investments in irrigation and drainage improvements are often considered to be major climate change adaptation measures that improve resilience of agricultural production systems to climate-induced meteorological and hydrological variability and uncertainty. For example, investments in irrigation reduce the adverse impacts of rainfall variability and allow farmers to grow high-value crops even during drought years. Introduction of water-saving technologies, such as drip irrigation, also increase the efficiency of irrigation water use and water availability in the systems, thereby reducing water scarcity effects due to climate change.

Climate change will significantly impact agriculture by increasing water demand, limiting crop productivity and by reducing water availability in areas where irrigation is most needed or has comparative advantage.

Climate change will affect agriculture through higher temperatures and more variable rainfall, with substantial reductions in precipitation likely in the mid-latitudes where agriculture is already precarious and often dependent on irrigation. Water resource availability will be altered by changed rainfall patterns and increased rates of evaporation.

Climate patterns are long-term and relatively stable expressions of temperature, relative humidity, rainfall, and circulation patterns at global and regional scale. Weather is famously more variable and difficult to predict. Weather is short term, highly variable over space and time and is affected by multiple interactions between topography, land use, and local scale atmospheric processes that all occur at scales smaller than one or a small cluster of GCM grid cells.

6.1 Rainfall run-off

Water pollution is a global challenge that has increased in both developed and developing countries, undermining economic growth as well as the physical and environmental health of billions of people. Unsustainable land use and improper tillage and soil management in agriculture are increasing erosion and sediment runoff into rivers, lakes and reservoirs, with massive quantities of soil lost and transported to water bodies every year.

High rates of erosion occur in areas where precipitation is high, slopes are steep and vegetation cover is poor.

Sediment in river systems is a complex mixture of minerals and organic matter, potentially including physical and chemical pollutants. Sediments can cover and destroy fish spawning beds, clog fish gills, and reduce useful storage volume in reservoirs. Sedimentation can damage watercourses, choke streams and make filtration necessary for municipal and irrigation water supplies. It can also affect delta formation and dynamics and limit the navigability of water bodies.

figure 5. effect of runoff on environment

3.2.Chemicals

All natural water contains a range of inorganic and organic chemicals. The inorganic chemicals derive from the rocks and soil through which water percolates or over which it flows; whereas the organic chemicals derive from the breakdown of plant material or from algae and other microorganisms growing in the water or on sediments. Insecticides, herbicides and fungicides are applied intensively in agriculture in many countries.

When improperly selected and managed, they can pollute water resources with carcinogens and other toxic substances that can affect humans. Pesticides may also affect biodiversity by killing weeds and insects, with negative impacts up the food chain.

3.3.Environmental factors related to Salinity

Salinityis a measure of the content of salts in soil or water. Salts are highly soluble in surface and groundwater and can be transported with water movement.

3.2.1 Conditions that lead to salinity

- **Primary salinity**

It is produced by natural processes such as weathering of rocks or wind and rain depositing salt over thousands of years.

- **Secondary salinity**

Has occurred with widespread land clearing and altered land use, and may take the form of 'dry land salinity' or 'irrigation-induced salinity'.

- ✓ Dry land salinity occurs when deep-rooted native plants are removed or replaced with shallow-rooted plants that use less water. This vegetation imbalance leads to an increase in water passing through soil to groundwater, raising the water table and bringing salt to the surface where it can be left behind as the water evaporates.

- ✓ Irrigation-induced salinity occurs when excess water applied to crops travels past the root zone to groundwater, raising the water table and salt to the surface. Salt may also be transported across surface and groundwater systems.

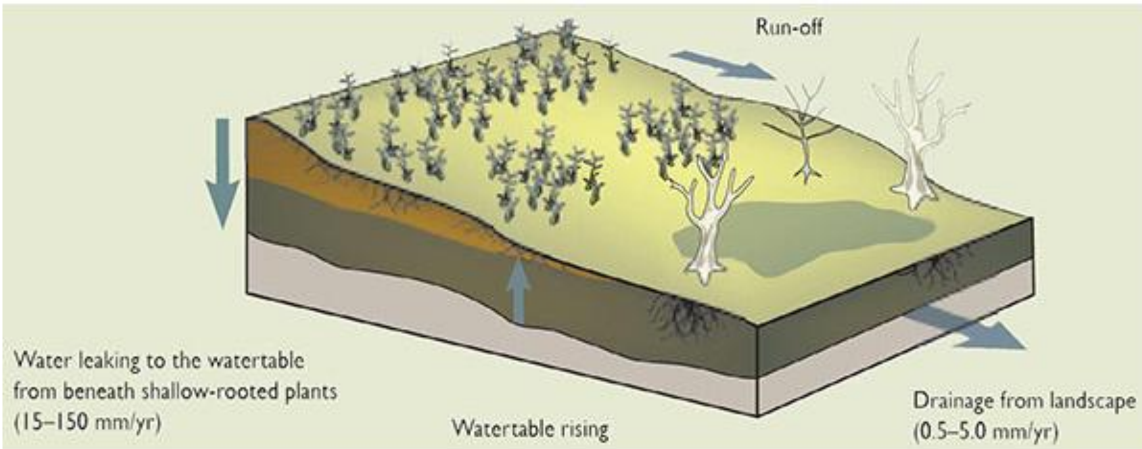


Figure-7 Movement of water across a modified landscape

3.2.2 Effects of salinity

High concentrations of salt pose hazards for the environment as well as affecting agriculture and infrastructure and therefore, the wider economy.

High levels of salinity in water and soil may cause:

- Corrosion of machinery and infrastructure such as fences, roads and bridges
- Poor health or death of native vegetation, leading to a decline in biodiversity through dominance of salt-resistant species, potentially altering ecosystem structures
- Reduction in crop yields by impairing the growth and health of salt intolerant crops.

Reduced groundcover also makes soil more prone to erosion. Eroded soil can pollute water with increased sediment, threatening:

- High value ecosystems and the plant and animal species they support
- Safety of water for both human and animal consumption.

Despite the negative effects of salinity, some aquatic environments have adapted to a range of salt concentrations and can tolerate periods of high salinity.

3.2.3 Managing salinity

Due to the complex nature and scale of salinity, a mixture of management responses is usually required.

Figure-8: Salt interception scheme

Management plans specify the best treatments for the circumstances, which are then monitored and reviewed for effectiveness.

Agricultural industries may benefit from employing more efficient farming, irrigation and drainage techniques, and redesigning the timing, volumes and locations of irrigation.

3.7 Nutrients

Nitrate from agriculture is the most common chemical contaminant in the world's groundwater aquifers. Agriculture is responsible for a large share of surface-water pollution and is responsible almost exclusively for groundwater pollution by nitrogen.

In crop production, water pollution from nutrients occurs when fertilizers are applied at a greater rate than they are fixed by soil particles or exported from the soil profile (e.g. by plant uptake or when they are washed off the soil surface before plants can take them up). Excess nitrogen and phosphates can leach into groundwater or move via surface runoff into waterways. Phosphate is not as soluble as nitrate and ammonia and tends to get adsorbed onto soil particles and enter water bodies' thorough soil erosion.

In livestock production, feedlots are often located on the banks of watercourses so that (nutrient-rich) animal waste (e.g. urine) can be released directly into those watercourses. Manure is usually collected for use as organic fertilizer, which, if applied in excess, will lead to diffuse water pollution. In many cases, too, manure is not stored in contained areas and, during significant rainfall events; it can be washed into watercourses via surface runoff.

3.8 Reservoir operations

Reservoirs are among the largest human interventions on earth. Worldwide the number of dams is staggering and still increasing. Approximately half of these dams create reservoirs for irrigation purposes, the other half have reservoirs for hydropower generation, flood control and water supply, either as single-purpose or in combination. With electricity and freshwater demand still growing, storage reservoirs are an indispensable component in the sustainable development of many countries. At the same time dams pose vast challenges with respect to social and environmental impacts, optimization of reservoir operations and dam safety. Dams modify the river regime, change water quality, trap river sediment and create a barrier for migrating fish. Reservoir creation often involves resettlement and land clearance.

Dams in Trans boundary Rivers may stir legal and political sensitivities. Climate change causes rainfall patterns to shift, leading to seasonal increases or decreases in reservoir inflow.

Reservoirs alter the natural variation in higher and lower discharges. Such flow regime changes will have an impact on the river, floodplain and estuary ecosystems. They may disturb typical riverine ecological processes such as spawning and migration of fish species. It is therefore important to study such possible adverse impacts and to take precautionary or mitigating measures. Deltares has gained much experience in assessing the impacts of flow regime changes as well as advising on flow regimes that are required to support ecosystems and ecosystem services in various projects.

3.9 Natural events

Below, we briefly review some case studies to illustrate the diverse environmental impacts of different categories of disasters, and the difficulties in precisely quantifying and monetizing these impacts.

3.9.1 Flood

Major floods create myriad effects on river-floodplain ecosystems. During periods of low flow, typically in midsummer, the rivers occupy channels. During rainy seasons, rivers spill into their floodplains, recharging the surrounding wetlands, forests, and lakes with fresh supplies of water, nutrients, and sediments.Surface water flooding happens when rain from heavy storms overwhelms local drainage capacity.

Surface water flooding is a growing challenge with climate change bringing more frequent heavy storms, new developments increasing the need for drainage, and our ageing sewerage infrastructure which is costly to maintain and upgrade.

3.9.2 Droughts

In fact, the most subtle and enduring impacts of droughts occur in the environment. The cumulative stress on wetlands, wildlife, forests, ground water, and soils cannot be measured accurately, and many effects occur slowly and over a period of years, making them extremely difficult to quantify.

The problems generated by droughts begin with changes in the quantity and quality of water available in the hydrologic system. Drought damages both plant and animal species by depriving them of food and water, increasing their susceptibility to disease, and increasing their vulnerability to predation.

Droughts also degrade water quality, shifting salt concentration, pH levels and dissolved oxygen, while increasing water temperatures. Even air quality is diminished because of increased dust and pollutants. Droughts also lead to more wildfires, while adversely changing salinity levels in coastal estuaries and reducing the flushing of pollutants.

3.9.3 Earthquakes

Although the dominant losses from earthquakes are to structures and potentially to humans, these events can also result in adverse environmental consequences.

In the most affected areas, trees, shrubs, land cover, and habitats can also be destroyed. There are currently no estimates of the environmental or ecosystem losses from earthquakes (although the national, long-term impact is probably not great).

Figure-9:earth quiqe effect

3.9.4 High Winds

High winds can sweep over large areas and cause damage to trees and plants. High winds can also help promote large-scale fires, typically in dry western areas.

Self-check 3	Written test

Instructions: choose the best answer all the questions listed below. Write your answers in the sheet provided in the next page.

1. Which one is an environmental factorthat may impact on water flows and quality? (2pts)
   A. Chemicals
   B. Rainfall run-off
   C. Weather and climate
   D. Catchment usage and management
   E. All of the above

2. High levels of salinity in water and soil may cause? (2pts)
   A. Corrosion of machinery and infrastructure
   B. Poor health or death of native vegetation, leading to a decline in biodiversity
   C. Reduction in crop yields by impairing the growth and health of salt intolerant crops.
   D. All of the above

3. Which one is a natural factor that may impact on water flows and quality? (2pts)
   A. Flood
   B. Droughts
   C. Earthquakes
   D. All of the above

***Note:* Satisfactory rating - 3 points** **Unsatisfactory - below 3 points**

Answer Sheet

Score = ___________

Rating: ____________

1. 3.

2

Information Sheet 4	4. Identifying performance measuresfor the plan and operations

7.1 Introduction

Operation of irrigation systems implies a package of organizational & economic and technical arrangements that ensure planned distribution and full use of water resources for heavy yield of agricultural crops of good quality under irrigation conditions. Therefore, during the operation of irrigation systems their state and the condition and use of irrigated lands as well as proper water use should be taken into consideration.

Operational measures include the following:

- implementation of scheduled water use practice to provide the irrigation regime required under specific meteorological conditions on certain land areas under efficient water use;
- keeping irrigation, drain and other canals, pipelines and buildings in good working order by guarding, supervision, maintenance and repair of irrigation systems;
- prevention of inflow of excess water into irrigation system and diversion of excess water;
- control of water losses in canals and improvement of system efficiency;
- organization of irrigation water accounting;
- control over proper water use and groundwater conditions;
- management of forest vegetation along canals;
- control over crop management practice on irrigated lands;
- Liquidation of salinization and waterlogging on irrigated lands.

Objects of irrigation system operation Proper development of irrigated lands and streamlined function of irrigation system operating service are indispensable conditions for gaining heavy and sustainable crop yield.

Operation of irrigation system includes:

- implementation of scheduled water use in the system and in irrigated farms;

- keeping all system components in good working order;
- Arrangement of their work in compliance with farm performance targets and depending on system operating conditions (climatic, hydrogeological, etc.);
- reconstruction of irrigation systems by adopting new techniques and technologies; control over efficient use of water and land resources;
- Improvement of ameliorative condition of irrigated lands; etc.

Irrigation systems are operated and maintained by special organizations:

- irrigation systems administrations (ISA);
- canal management organizations;
- administrations of hydro-schemes;
- Administrations of reservoirs; etc.

There are the following operating services:

- on-farm operating service that maintains irrigation network and irrigation equipment in farms-water users;
- inter-farm operating service that is in charge of the inter-farm irrigation network;
- Basin operating service that distributes water from an irrigation water source among irrigation systems.

4.1. Stakeholders and future use

To improve proper use of surface water all stakeholder from the government to the individual water user will be responsible. If we properly used surface water we achieve future design period of all water harvesting, conveying, distribution and controlling structure.

Self-check 4	Written test

Instructions: choose the best answer listed below. Write your answers in the sheet provided in the next page.

1. Which one of the following is operating irrigation service? (2pts)
   A. Inter-farm irrigation service
   B. On-farm irrigation service
   C. Basin operating service
   D. All
2. Stakeholders who are **not** responsible for operated and maintained of irrigation systems.
   A. irrigation systems administrations
   B. country government
   C. administrations of hydro-schemes;
   D. Administrations of reservoirs
3. Which one is the cause of leakage and erosion? (2 pts)
   A. Back-fill may not have been compacted sufficiently
   B. The concrete mix used in constructions may be too sandy
   C. Foundations of structures may be too weak
   D. Walls may be too thin
   E. All of the above
4. One of the following is a type of irrigation system operational measures
   A. organization of irrigation water accounting
   B. control over proper water use and groundwater conditions;
   C. management of forest vegetation along canals;
   D. all of the above

Answer

Note: **Satisfactory rating - 4 points** **Unsatisfactory - below 4 points**

Score = ____________
Rating: _____________

1.

2.

3.

4.

Information sheet 5	Accessing and consulting historical information's

8.1 Hydrological information

Hydrology is a branch of water science describing the transport and storage of water through the cycles as well as the interactions between the water and its environment. Its task is to provide water management with information needed for designing and operating aquaculture structures and systems. These systems modify the natural water regime according to the requirements of society, to avoid damages and to best utilize the water. Hence all users of water, aquaculture among them, need hydrological information produced by collecting and processing hydrological data as well as by analyzing the processes described by these data.

The information provided can be divided into two groups:

- Forecasts, prepared to inform the operators of existing hydraulic systems on the present condition of hydrological processes already in motion and the expected further development of these processes in a relatively short period (real time forecasting).
- Information required for planning, designing and constructing aquaculture structures and systems. This is composed of data on the extreme or average conditions of the hydrological processes expected to develop in the future without any limitation of time, other than the life span of the systems (design values).

In both cases forecasts have to be calculated from the hydrological data observed in the past.

5.1.1. Hydrological forecasting for operation purposes

Forecasts of flow volumes and water elevation are essential to making the most efficient use of rivers and in minimizing damage due to floods. On rivers uncontrolled by dams and reservoirs, the river forecast is the basis of flood warnings, permitting removal of people, livestock and movable goods from the flood plain, and reinforcement of fixed river structures, such as bridges. On rivers controlled or partially controlled by dams built for power production, water supply, irrigation or flood control, reliable river forecasts permit operation of the dams for maximum benefit. River forecasts are essential to the reconciliation of joint use of reservoir capacity for water supply and flood control purposes. The flood control capacity in some cases must always be available to store flood runoff, or in other cases the reservoir must be drawn down in advance of a flood, to a level which will permit accommodation of the anticipated flood volume. When a flood occurs the reservoir is restored to its normal supply level. Accurate forecasts are obviously essential because, if the reservoir is lowered too much and the water supply level cannot be restored after the flood, the water users may be short of water. Contrarily, if not lowered enough, more water may have to be discharged than would have been necessary and flood damage may result.

Hydrological forecasting is, by definition, the prediction of the occurrence of a hydrological event specified both with respect to its quantities measure and its actual time of occurrence. The following classification is made according to the purpose of a forecast:

- **Forecasting on Headwaters and Small Rivers**

For small drainage areas there are two main steps in the preparation of river forecasts. The first is to predict the volume of runoff by means of rainfall runoff correlations, and the second to forecast the distribution in time of the runoff volume. Rainfall runoff correlations can be derived from past records of storms and resulting river flows in a basin, either graphically or analytically. Such correlations permit forecasts of runoff volume from: (i) depth of storm rainfall over the watershed, (ii) a seasonal factor, (iii) an index of pre-storm moisture conditions in the basin, and sometimes (iv) storm duration.

Having determined the volume of rain and/or snowmelt which will run off, the timing of this runoff volume, and the peak flow that will result, must also be predicted.

- **Forecasting the Regime of Large Rivers**

Forecasts for large rivers and the lower reaches of principal tributaries generally make use of the dependable and consistent relationships between factors involved in stream-flow routing. The technique employed in a particular case depends upon whether the complete hydrograph is to be forecast or only the peak stage or discharge. On larger rivers the time between the end of the rainfall or snowmelt event and the occurrence of the peak of the resulting hydrograph at the point of interest is often measured in days, rather than hours as in headwater forecasting.

- **Hydrologic Data**

- ✓ Annual periodic fluctuations of stream or river water levels.
- ✓ Flood frequency design flows for 50 and 100 year intervals.
- ✓ Estimated water surface elevations on date of survey.
- ✓ Drainage area located upstream of the bridge site.
- ✓ Where unwatering of a bridge site adjacent to a stream or lake is required, give maximum water levels expected during the construction period and the possibility of controlling water levels by operation of upstream or downstream facilities.
- ✓ Information for preparation of specifications hydrographs at the TSC, including the location of gauging stations at or near the structure site and the dates for which hydrographs should be prepared. Copies of the daily discharge record should be supplied for stations with unpublished records.
- ✓ Anticipated occurrence and amounts of sediment, ice (thickness), and drift (trash).
- ✓ Analysis of water for chemical and physical characteristics and biological quality. Analysis should include a water quality analysis of intake water to include major ions and cat ions, corrosively, and parameters listed as maximum contaminant limits in the Surface Water Treatment Rule, Safe Drinking Water Act.
- ✓ Erosion protection requirements and calculated scour depths, which will be used for support structure foundation design.

5.2. Previous monitoring studies

All important previous monitoring studies are used as a source of data to improve surface water monitoring strategies.

The most common monitoring studies are

- Strength of the structure
- Available materials to construct or develop the structure
- Total duration to develop or construct the structure
- Total budget to construct or develop the structure
- Maintenance activities
- Limitation and positive impact of the overall activities

5.3. Geological data

Geological Data means all seismic, geological, geochemical or geophysical data (including cores and other physical samples of materials from wells or tests) belonging to seller or licensed from third parties relating to the Properties that can be transferred without additional consideration to such third parties (or including such licensed data in the event Purchaser agrees to pay such additional consideration), including all such data having been acquired by seller from its predecessors in title, and including, to the extent they exist, all isopach maps, contour maps, structural maps, net pay maps, whether such mapping was undertaken and created by Seller or Seller's predecessors in title, but excluding any other interpretations of such data prepared or created by Seller.

The following list of geologic design data provides general guidelines for the collection and reporting of geologic information for bridges. The data should reflect a recognition and consideration of the scope and size of bridge structure anticipated. The geologist should apply these guidelines with good judgment and sound reasoning, elaborating upon them as required by the particular geologic setting and engineering requirements. Because the collection of geologic data is a dynamic process and often continues into the preparation of final designs, all stages of the specification design geologic exploration program must be constantly coordinated with the designer through the appropriate geology office.

- A description of the regional geology.
- Compilation, summary, and reporting of Reclamation and non-Reclamation geologic information on the area with attention being paid to the sequence of explorations and historical geologic events.
- A surface geologic map of the bridge site, plotted on the topographic map of the bridge site, showing surface geology and the location of geologic sections, soil profiles, and of all subsurface explorations, including coordinates or stationing.
- A description and interpretation of site geology including physical quality and geologic structure of the foundation strata, seasonal ground water, ground subsidence, existing and potential landslide, snowslide and rock fall areas, surface water runoff; and engineering geologic interpretations appropriate to the structure involved, including the conditions expected during excavation and construction.
- Geologic logs of all subsurface exploration. An exploratory drill hole is required at each critical bridge foundation element (abutment or pier). The coordinate location and ground surface elevation of all existing and subsequent exploratory drill holes should conform to the permanent survey control system.
- Exploratory drill holes should be at least 50 feet long or extend 10 feet into competent bedrock. Logs shall include split tube blow counts at a minimum of 5-foot intervals.

5.4. Hydro-geological data

Hydrogeology (hydro- meaning water and -geology meaning the study of the Earth) is the area of geology that deals with the distribution and movement of groundwater in the soil and rocks of the Earth's crust (commonly in aquifers).

Some hypothetical, but characteristic questions asked would be:

- Can the aquifer support another subdivision?

- Will the river dry up if the farmer doubles his irrigation?
- Did the chemicals from the dry cleaning facility travel through the aquifer to my well and make me sick?
- Will the plume of effluent leaving my neighbor's septic system flow to my drinking water well?

The most common hydro-geological data used in ground water development are listed below.

- ✓ Aquifer
- ✓ Hydraulic head
- ✓ Porosity
- ✓ Water content
- ✓ Hydraulic conductivity
- ✓ Specific storage and specific yield

5.5. Land use studies

- Study of soil characteristics, land use, and drainage pattern, and the likely adverse impact of the project.
- Impact on historical monuments and heritage site.

5.6. Environmental management studies

The most common environmental management studied is classified in the following ways.

- **Air environment**
  - ✓ Quality of ambient air.
  - ✓ Wind speed, direction, humidity etc.
  - ✓ Quantity of emission likely from project.
  - ✓ Impact of the emission on the area.
  - ✓ Pollution control desires / air quality standards.
- **Noise**
  - ✓ Levels of noise present and predicted
  - ✓ Strategies for reducing noise pollution.

- **Water environment**
  - ✓ Existing ground and surface water resources, their quality and quantity within the zone.
  - ✓ Impact of proposed project on water resources.
- **Biological environment**
  - ✓ Flora and fauna in impact zone.
  - ✓ Potential damage (likely) due to project, due to effluents, emissions and landscaping.
  - ✓ Biological stress (prediction).

Self-check 5	Written test

Instructions: choose the best answer all the questions listed below. Write your answers in the sheet provided in the next page.

1. ----- is the prediction of the occurrence of a hydrological event specified both with respect to its quantities measure and its actual time of occurrence?(2pts)
   A. Hydrological forecasting
   B. Determining design parameters
   C. Previous monitoring studies
   D. Hydro-geological data
   E. All of the above
   F. None of the above
2. Which one is component of environmental management studies? (2 pts.)
   A. Air environment
   B. Water environment
   C. Biological environment
   D. All of the above
3. Which one are the most common monitoring studies in previous monitoring studies? (2 pts)
   A. Strength of the structure
   B. Available materials to construct or develop the structure
   C. Total duration to develop or construct the structure
   D. Total budget to construct or develop the structure
   E. All of the above
4. Which one is the most common hydro-geological data used in ground water development? (1 pts)
   A. Aquifer
   B. Hydraulic head
   C. Porosity
   D. Hydraulic conductivity
   E. Specific storage and specific yield

F. All of the above

5. Which one is the most commonHydrologic Data? (2pts)
   A. Annual periodic fluctuations of stream or river water levels
   B. Flood frequency design flows for 50 and 100 year intervals
   C. Estimated water surface elevations on date of survey
   D. Drainage area located upstream of the bridge site
   E. All of the above

***Note:* Satisfactory rating - 12 points** **Unsatisfactory - below 12 points**

Score = ____________

Rating: _____________

Answer sheet

1.

2.

3.

4.

5.

Information sheet 6	Requiring stakeholders

9.1 Requiring stakeholders surface water management

Surface water management needs coordinated action by all those with responsibilities for managing land, rivers and drainage systems, including national and local government, water companies, landowners and businesses.

Surface water management action plan sets out the steps the government is taking, with the environment agency and others, to strengthen surface water management by improving understanding of the risks and making sure those responsible can manage them effectively. The key themes are:

- Improving risk assessment and communication;
- Making sure infrastructure is resilient;
- Clarifying responsibilities for surface water management;
- Joining up planning for surface water management; and
- Building local authority capacity.

The environment agency will improve national surface water mapping and risk assessments. This will be through improved modelling approaches, better quality data and a better representation of the combined effects of flooding from different sources.

The potential range of stakeholders is large and their active participation should contribute to the sustainability of groundwater resources and related economic activity. The responsible groups to manage surface water are listed below

- National water commission/river basin authority (RBA)
- Surface water management organization (SWMO)
- Local water resource agency
- Water user association (WUAs)

- Environmental NGOs
- Individual users
- Surface water user groups

Stakeholder participation in some form or other is essential because it

- Disseminates understanding of issues that can be the impetus for up-scaling of good practices in the sustainable use of surface water – management decisions taken unilaterally by a regulatory agency without social consensus being often impossible to implement.
- Enables essential management activities (such as monitoring, inspection and charge collection) to be carried out more effectively through cooperative efforts and shared burdens.
- Mobilizes user self-regulatory capacity within an appropriate context – if there are many users and/ or limited institutional capacity surface water management would otherwise be impossible.
- Counteracts corruption in surface water management, whether it arises in government or amongst stakeholder themselves.
- Facilitates the coordination of decisions relating to surface water, land-use and waste management and generally reduces cross-sector contradictions.

Surface water management decisions taken with participation of stakeholders should bring**:**

- Social benefits – because they promote equity amongst users and avoid groundwater access being dominated by a few
- Economic benefits - because they encourage balance with long-term potential of the resource, avoid resource collapse and optimize pumping costs
- Technical benefits – because they usually lead to better estimates of water abstraction and more precise understanding of the groundwater balance
- Management benefits – because they trigger local stakeholders initiatives to implement demand and supply measures and reduce the cost of regulation.

Self-check 6	Written test

Instructions: choose the best answer all the questions listed below. Write your answers in the sheet provided in the answer sheet.

1. Which one are responsible groups to manage surface water? (2pts)
    A. Individual users
    B. Local water resource agency
    C. Surface water management organization (SWMO)
    D. National water commission/river basin authority (RBA)
    E. All of the above
2. Which one are benefits of Surface water management decisions taken with participation of stakeholders? (2 pts.)
    A. Social benefits
    B. Technical benefits
    C. Management benefits
    D. Economic benefits
    E. All of the above

***Note:* Satisfactory rating - 2 points** **Unsatisfactory - below 2 points**

Answer sheet

1.

2.

Score = ___________

Rating: ____________

Operation sheet 1	Determining water quality and quantity requirements

Technique of water quality and quantity requirements

Step1. Wear appropriate PPE

Step2.select necessary tools and equipment

Step3. Go to the water resource where water quality and quantity will determine

Step4.take required amount of sample of water by appropriate containers

Step5. Return to water laboratory and analysis the main water quality parameters

Step6. Compare the result with the standard guide line

Step7.decide the quality of water based on the computation for specified purpose

Step7.clean tolls and equipment and restore properly

Operation sheet 2	Identifying environmental factorsthat may impact on water flows and quality.

Identification of environmental factors that affect water quality and quantity

Step1. Wear appropriate PPE

Step2. Go to the site where environmental factors will investigate

Step3.inspect the water resource and catchment of the resource where contributing to the water resource

Step4. Identify the source of pollution

Step5. Provide mitigation measures to save water resource from pollution.

Operation sheet 3	Identifying performance measuresfor the plan and operations(Irrigation system operation stage)

At the irrigation system operation stage, the following tasks are to be solved:

Step1. Arrangement of water use and water consumption;

Step2. Arrangement of primary accounting of water;

Step3. Control of the quality of irrigated areas

Step4. Field inspection of technical condition of irrigation system components;

Step5. Governance and management of the operation stage

LAP Test	Practical Demonstration

Name: _____________________________ Date: ________________

Time started: ________________________ Time finished: ________________

Instructions: Given necessary templates, workshop, tools and materials you are required to perform the following tasks within 3day.

1. Determining water quality and quantity requirements
2. Identifying environmental factorsthat may impact on water flows and quality
3. Identifying performance measuresfor the plan and operations (Irrigation system operation stage)
4. Identify Irrigation system maintenance stage

Instruction sheet	Learning guide 25

This learning guide is developed to provide you the necessary information regarding the following content coverage and topics –

- Carrying outmonitoring and testing programs.
- Monitoring assets to ensure performance meets specifications in SWMP.
- Implementing maintenance programs to meet current and potential problems.
- Selecting and utilizingEquipment including PPE following OHS procedures.
- Monitoring assets to ensure performance meets specifications in river system management plan

This guide will also assist you to attain the learning outcome stated in the cover page. Specifically, upon completion of this Learning Guide, you will be able to –

- Carry outmonitoring and testing programs.
- Monitor assets to ensure performance meets specifications in SWMP.
- Implement maintenance programs to meet current and potential problems.
- Select and utilizeequipment including PPE following OHS procedures.
- monitor Assets to ensure performance meets specifications in river system management plan

Learning Instructions:

Read the specific objectives Learning Instructions:

1. Read the specific objectives of this Learning Guide.
2. Follow the instructions described below

3. Read the information written in the “Information Sheets”. Try to understand what are being discussed. Ask you teacher for assistance if you have hard time understanding them.

4. Accomplish the “Self-checks”.in each information sheets.

5. Ask from your teacher the key to correction (key answers) or you can request your teacher to correct your work. (You are to get the key answer only after you finished answering the Self-checks).

6. If you earned a satisfactory evaluation proceed to “Operation sheets and LAP Tests if any”. However, if your rating is unsatisfactory, see your teacher for further instructions or go back to Learning Activity.

7. After You accomplish Operation sheets and LAP Tests, ensure you have a formative assessment and get a satisfactory result;

8. Then proceed to the next LG

Information sheet-1	Carrying outmonitoring and testing programs

1.1. Resource yields

The main sources for irrigation water are groundwater from wells, surface water, drainage ponds, rain and municipal water. Drilled wells are a clean source of water for many greenhouse operations however; the water yield from drilled wells is usually limited.

Water is a major factor in successful production of greenhouse plants. An adequate water supply is needed for irrigation, pesticide application, evaporative cooling (if applicable), growing media preparation and clean-up.

It is important to base estimates of yields and cropping intensities on the foreseen amount of labour and other resources that will be devoted to the irrigated production. In producing the farm model, the assumption that households pool all resources of land, capital and labour, and allocate resources where they are most useful to the household as a whole must be avoided.

Preliminary cost estimates

Both initial capital and operating costs should be estimated. As a result of the privatization process, it is expected that farmers will pay part of any construction, operation, and maintenance costs. It is important to consider whether the level of women and men farmer's contributions and water fees is reasonable. Unreasonably high costs could lead to the selection of other technologies that are cheaper to construct, operate and maintain.

Plants require an adequate supply of moisture for optimum growth which is affected by many variables. The amount of water needed depends on the area to be watered, crops grown, weather conditions time of year and the environment control system. The design for the water supply needs to be made for the peak use time of the year.

The amount of a resource obtained from such a schedule without depleting the resource. Resource productivity is the quantity of good or service (outcome) that is obtained through the expenditure of unit resource. This can be expressed in monetary terms as the monetary yield per unit resource. For example, when applied to crop irrigation it is the yield of crop obtained through use of a given volume of irrigation water, the “crop per drop”, which could also be expressed as monetary return from product per use of unit irrigation water.

Well yield: is a measure how much water can be withdrawn from water well over a period of time.

1.2. Resource status of Ethiopian surface water

The volume of water available for irrigation must be determined. After establishing the hydrological availability, the suitability of the water sources and competing water needs within the basin should be assessed.

Suitability of the water source

In determining the suitability of the different water resources, an important consideration is the distance of farmers' homesteads from the irrigated fields. Whether a certain distance is acceptable to both women and men farmers should be discussed in meetings. The quality of the water also helps determine the suitability of the water source.

Competing water needs

In addition to the irrigation water requirements, and in order to avoid possible conflicts between different water users, the estimated need of water for other purposes such as drinking water (for both humans and cattle), and the irrigation of homestead agriculture and trees should be considered in the calculations. It is also important to identify and anticipate hydrological, infra-structural and social linkages between the different uses of water.

Apart from quantifying the amount of water required for different water uses, the timing of water provision also needs careful consideration. Non-irrigation uses of water require a different, often more frequent timing than irrigation uses. Furthermore, the quality of water becomes more important, especially when used for drinking water. A possible health impact of an irrigation scheme may be the depletion or pollution of groundwater, which in many areas is used for drinking water and washing.

It is essential that the watering of livestock is included in the overall water plan.

Livestock might be competing for scarce water, and be equally or more important for\ people's livelihoods than irrigated agriculture, thus deserving priority when water is limited.

- In the PASDEP, the achievements are:
  - ✓ 44,688 ha irrigation scheme construction was completed ;
  - ✓ 457,287 ha feasibility study and design work was completed;
  - ✓ 178,000 ha of land prefeasibility study completed
- Currently, under GTP program:
  - ✓ 96,085 ha is under construction and;
  - ✓ 99,722 ha is under study and design;
- Using surface water, planned program to be implemented in the growth and transformation period are:
  - ✓ The study and design work of 267,347 ha, and
  - ✓ Construction work of 153, 630 ha of land.

All these are medium and large scale irrigation projects

Table 9.Opportunities for Investment in the Water Sector

Basin	Irrigation Potentials (ha)	Gross Hydroelectric potential (GWh/year)
Blue Nile	815,581	78,820
Tekeze	83,368	5,980
Baro-Akobo	1,019,523	13,765
Omo-Ghibe	67,928	36,560
Rift Valley	139,300	800
Awash	134,121	4,470
Genale Dawa	1,074,720	9,270
Wabi-shebele	237,905	5,440
Denakil	158,776	----
Total	**3,731,222**	**155,102**

1.3. Flow rates

Flow rate, Q is used to specify volume of fluid flowing along a pipe (or duct), channel inside a particular time unit (seconds, hours and day). Flow happens mainly due to

1. Pressure force and
2. Gravity force.

Usually, all the fluids happen to flow inside the pipe under pressure force, and only water flows in channel under gravity.

1.3.1. Measurement of flow rate in fluids:

There are a number of good ways to measure the amount of water in a stream or a canal. What method of measurement you should use will depend on several factors,

- The accuracy of the result needed;
- The quantity of water present in the stream or canal you will measure;
- The equipment you have available to use.

Let us compare various methods. The following table will help you to compare various methods and to select the one best suited to your needs. Each of these methods is fully explained and illustrated in the following sections.

TABLE 10 Water flow measurement methods for streams or canals

Method	Water flow	Accuracy	Equipment	Remark
Quick and rough	Small	An approximate	None	For a quick estimate
Float	Small to large	Medium	Float, stakes, line, measuring stick, watch	
Float and cross section		Low to medium	Float, stakes, line, measuring stick, record sheet, watch	Best for stream with calm water
Dye, stain and cross section			Dye, stakes, line, measuring stick, record sheet, watch	
Bucket	Very small	Very high	Dam, pipe, buckets, 1 liter bottle, watch	Most accurate of all methods
Weir (triangular)	Does not vary greatly from small to large and smaller than 114 l/sec	High	Wood, sheet metal or corrugated roof sheeting, tools for working with wood or metal;	For recording flow over a period of time
Weir	Does not vary			

(rectangular0	greatly and is greater than 114 l/sec		shovel, pick, line, level, measuring stick	

2.2.1. Some of the more common methods currently in use to measure open channel flows are:

- Timed Gravimetric
- Tracer-Dilution
- Area-Velocity
- Manning's Equation / (Gauckler-Manning-Strickler Formula)
- Hydraulic Structures (Flumes & Weirs)

1.3.2. Importance of flow rate quantity in fluids:

The stream flow discharge of water in canals is central to know the quantity of water entering the reservoir through channels in a particular day, which is vital in knowing the reliable amount of water that can be supplied towards different purposes. Flow rate of fluids inside the pipes is vital to know the m3 water being supplied towards residential and industrial purposes.

1.4. Testing procedures

Constant discharge pump tests are an important investigation as the ability and sustainability of any new or increased abstraction from a well. For results to be meaningful readings must be taking at the production bore (the bore being pumped) and at least two appropriate observation bores.

1.4.1. Why we should perform pumping test

- It helps to know how much water can be extracted from a well
- It helps to determine the hydraulic properties an aquifer

- It helps to determine the suitable depth of pump
- It gives important information on drawdown level, flow rates, and unforeseen factors generated upon pumping
- It helps to regulate and optimize the extraction without adversely impacting aquifer systems

1.5. Test Procedure

This makes the time intervals easier for overnight monitoring.

- One hour before starting ensure that the water level, in all bores to be monitored, are measured and recorded.
- Ensure that all watches are set exactly the same time and that people involved in the test are familiar with how to operate the water level measuring device and read the measure to the nearest millimeter.
- Start the pump at the agreed time and adjust the flow if necessary, making water level measurements according to the schedule on the data sheets. After half an hour pumping the observation bore(s) water level should be read. Make sure the pumping rate is recorded at the start of the test and record the pumping rate regularly during the test, to ensure that the pumping rate is constant.
- Continue pumping at a constant rate for at least 24 hours (1440 minutes). A longer pump test may be required for industrial, municipal or substantial abstractions.
- Immediately at pump off, begin water level measurements in all bores as per the record sheet schedule. The ‘recovery’ phase (pump off) is as important as the pumping stage. Any loss or lack of data from this section may compromise the outcome.
- Continue for 1440 minutes or until the groundwater levels have returned to their pre-test levels.

1.6. Testing frequency

It is difficult to determine how many hours that pumping test required because period of pumping depends on the type and natural materials of the aquifer. However, 24-72 hours testing is enough to produce diagnostic data.

Tests taking longer than 24 hours may be required for large takes, such as community water supplies, or situations where it may take longer to determine effects.

Depending on the purpose of a test, a Pumping test can be performed using:

- Single well tests - generally used to describe well performance; and
- A number observation wells - which best describe aquifer response to pumping.

A single well performance test is quick, relatively simple and inexpensive to conduct.

However, a well performance test, generally, does not describe aquifer parameters in detail and is of only limited use in determining the effects of groundwater abstraction consent.

1.7. Sampling locations

Water sampling, the process of taking a portion of water for analysis or other testing, e.g. drinking water to check that it complies with relevant water quality standards, or river water to check for pollutants, or bathing water to check that it is safe for bathing or not etc. Water sampling is done to characterize the chemical, thermal, or hydrological properties of a surface or subsurface aqueous system. ... Water samples can be taken from surface a spring or geyser, a drilled well, or from a certain depth in a well. Water samples in standard sample vials.

1.8. Testing variables

Testing variable means measure the accuracy and precision of the important hydrological variable to construct or not construct the hydraulic structure.

1.8.1. Testing for outliers

Outliers are data points, which depart significantly from the trend of the remaining data. The retention, modification, deletion of these outliers can significantly affect the statistical parameters computed from the data, especially for small samples.

1.8.2. Testing for dependency/independency

The dependency check means all the items are checked to see if they can be handled independently or not (i.e., if overlapping occurs at some points between items, it is called dependency), and if statistical analysis is possible or not.

1.8.3. Testing for trend

Trend indicates the representativeness of the data for the future design period.

1.9. Land use changes

Land use change means the variability of lands from one year to the next year by naturally or human activities factors. During the selection and use of site area we consider the land use change factors. Common types of land use change will be

- Vegetation cover area change to bare land area
- Water body and wetland area change to dry land area
- Agricultural area change to forest area
- Rural area change to urban area

All the above land use change will be negative and positive impact for our hydraulic structure.

Self-check one	Written test

Name: _________________________ Date: _______________

Directions: choose the best answer all the questions listed below.

1. ----is a measure how much water can be withdrawn from water well over a period of time
   - **A.** Well yield
   - **B.** Flow rates
   - **C.** Topography
   - **D.** Suitable foundation
   - **E.** All of the above
   - **F.** None of the above
2. Why we should perform pumping test?
   - **A.** It helps to know how much water can be extracted from a well
   - **B.** It helps to determine the hydraulic properties an aquifer
   - **C.** It helps to determine the suitable depth of pump
   - **D.** All of the above
3. One of the following factors shall be considered factors when selecting the site of a dam?
   - **A.** Topography
   - **B.** Suitable foundation
   - **C.** Type suitability and viability of construction materials
   - **D.** Water tightness of reservoir
   - **E.** Accessibility
   - **F.** All of the above
4. One is not Common types of land use change
   - **A.** Vegetation cover area change to bare land area
   - **B.** Water body and wetland area change to dry land area

C. Rural area change to urban area

D. Agricultural area change to forest area

E. None of the above

Note: **Satisfactory rating - 14points** **Unsatisfactory - below 14 points**

Score = ___________
Rating: ____________

Answer Sheet

Name: _________________________ Date: _______________

Short Answer Questions

1.
2.
3.
4.

Information sheet 2	Monitoring assets to ensure performance meets specifications in SWMP.

1.10. Introduction

The major purpose of resource assessment including water resource is to examine the resource conditions in the project area and within the river basin, and the suitability of the proposed project interventions.

While a detailed assessment will be conducted at the project preparation phase, a preliminary water resource assessment at the identification phase will help to shape the project scope before going to a detailed feasibility study or project design. Main water assessment activities include assessment of water requirements, water availability and quality and analysis of water balance.

The exploitation and utilization of water for irrigation require that there are periodic evaluations of its utility and efficiency of use. This concern with performance within the irrigation sector is increasing as pressure grows on water resources in all parts of the world, and as concerns increase regarding the sustainability of irrigated agriculture systems. Any enterprise requires feedback on the management of resources and the end result in terms of increased output.

Improve on-farm performance of irrigation systems

Several international studies have shown that the performance of irrigation practices and equipment, especially in the uniformity of water application, is still too low. This is due to farmers lacking the management skills to manage their irrigation systems properly. Consequences include reductions in crop yields and a waste of water resources.

To improve irrigation performance, it is necessary not only to promote the implementation of irrigation scheduling methods, but concurrently to improve system design and performance and to enhance farmers' skills to control and manage their irrigation system more efficiently during its operation.

For the three major irrigation techniques (surface irrigation, sprinkler irrigation, and drip irrigation), the difficulties which have a significant negative effect on irrigation performance are listed. Solutions include, on the one hand,

- selecting the most appropriate technique,
- matching the local context,
- using certified equipment which has a performance meeting relevant standards and which can ensure a minimum quality for on-field irrigation
- implementing upgraded management methods for such equipment and techniques, and
- Developing skills to avoid those errors currently occurring during the ordinary operation of the system.

A Surface Water Management Plan (SWMP) is a plan which outlines the preferred surface water management strategy in a given location.

A SWMP should establish a long-term action plan to manage surface water in an area and should influence future capital investment, drainage maintenance, public engagement and understanding, land-use planning, emergency planning and future developments.

1.11. Purpose of surface water monitoring plan

The following benefits are will be achieved through undertaking a SWMP study:

- increased understanding of the causes, probability and consequences of surface water flooding;
- increased understanding of where surface water flooding will occur which can be usedto inform spatial and emergency planning functions;
- a co-ordinated action plan, agreed by all partners and supported by an understandingof the costs and benefits, which partners will use to work together to identify measuresto mitigate surface water flooding;
- identifying opportunities where SuDS can play a more significant role in managingsurface water flood risk and may also contribute to fulfilling the requirements of theWater Framework directive;

- helping to meet the requirements of the Flood Risk Regulations and the proposed Flood and Water Management Bill;
- increased awareness of the duties and responsibilities for managing flood risk of different partners and stakeholders;
- Improved public engagement and understanding of surface water flooding.

1.12. Key terminology for SWMP

- **Surface water flooding –** In this context surface water flooding includes:

✓ surface water runoff; runoff as a result of high intensity rainfall when water is ponding or flowing over the ground surface before it enters the underground drainage network or watercourse, or cannot enter it because the network is full to capacity, thus causing flooding.

✓ Flooding from groundwater where groundwater is defined as all water which is below the surface of the ground and in direct contact with the ground or subsoil.

✓ Sewer flooding*; flooding which occurs when the capacity of underground systems is exceeded due to heavy rainfall, resulting in flooding inside and outside of buildings. Note that the normal discharge of sewers and drains through outfalls may be impeded by high water levels in receiving waters** as a result of wet weather or tidal conditions;

✓ flooding from open-channel and culvert watercourses which receive most of their flow from inside the urban area and perform an urban drainage function;

✓ Overland flows from the urban/rural fringe entering the built-up area, and;

✓ Overland flows resulting from groundwater sources.

- **Surface Water Management Action Plan (or action plan) –** The SWMP action plan should outline the preferred surface water management strategy and identify the actions, timescales and responsibilities of each partner. It is the principal output from the SWMP study.
- **SWMP study** - the SWMP study is the process of producing the action plan. The SWMP studyis undertaken in order to provide the evidence base to produce the action plan.

Self-Check 2	Written Test

Instructions: Answer all the questions listed below. Illustrations may be necessary to aid some explanations/answers. Write your answers in the sheet provided in the next page.

1. What is the main purpose of surface water monitoring plan? {6pts}
2. What are the main factors which affect surface water quality?(5 pts)
3. How to check if the surface water is good or it is some problem? (8 pts)
4. What are the surface water management action plan and how to achieve those plans? (6 pts)

***Note:* Satisfactory rating - 12 points** **Unsatisfactory - below 12 points**

Answer Sheet

Score = ___________

Rating: ____________

Name: ___________________________ Date: _______________

Short Answer Questions

1. -----------------------
2. --------------------
3. -----------------------------------
4. --------------------------------------

Information sheet 3	Implementing maintenance programs to meet current and potential problems

1.13. Introduction

The irrigation network is perhaps the most costly element of an irrigation scheme and is designed to last a long time. However, all too often one finds that irrigation schemes not long constructed bear little resemblance to the original construction and design. Silt deposition, weed infestation, malfunctioning of structures and other undesirable situations make it practically impossible to control the flow in these canals. As a result, the system is unable to deliver the necessary water and distribute it equitably. It is not surprising that farmers working in those irrigation schemes sometimes feel frustrated because they know the potential benefits of irrigation and yet cannot realize their expectations.

On the other hand, there are many examples illustrating that with proper maintenance and cooperation among farmers in this task, irrigation systems may last much longer than their original designers or constructors ever envisaged. Irrigation schemes that have been in operation for centuries can be found in Spain, Egypt, Italy, Pakistan and other countries, and are a living testimony that properly maintained irrigation schemes can be of permanent benefit to many generations.

There are several reasons for poor maintenance: just to mention the most important:

- insufficient funds made available to the management;
- lack of interest by the farmers in participating or collaborating in the maintenance work;
- Poor organization of the work.

The most widespread cause for poor maintenance in public irrigation schemes is the lack of sufficient funds for servicing and repair.

The sustainability of an irrigation scheme refers to the proper functioning of the infrastructure, the people, agricultural enterprises, management and social systems in the long run. This happens if all factors are considered at planning and design of the scheme, but require regular updating with changing circumstances.

1.14. Main functions of maintenance

The Maintenance Service is entrusted with the overall responsibility for keeping the irrigation and drainage systems working in a satisfactory manner, within the limitations imposed by the initial design.

Similarly to the Operation Service, the main functions to be undertaken are:

- planning the maintenance activities;
- implementing the maintenance activities planned and those unforeseen;
- Monitoring the above mentioned activities.

1.15. Types of maintenance

There are three main types of maintenance, namely:

- **routine or normal maintenance** which includes all work necessary to keep the irrigation system functioning satisfactorily and is normally done annually;
- **Special maintenance** including repairs of damage caused by major disasters, such as floods, earthquakes and typhoons. The unforeseeable nature of such natural phenomena make it very difficult to take specific preventive action, although general safeguards can be installed in particularly prone areas, e.g. large drainage dykes in flood areas. In irrigation schemes located in places subject to these hazards, a "special reserve fund" or budget allocation should be established for repair work;
- **Deferred maintenance** including any work necessary to regain the lost flow capacity in canals, reservoirs and structures when compared to the original design. It often includes large modifications to the canal system and structures arising from important changes (cropping patterns, drainage problems, etc.) that have occurred in an irrigation scheme. In practice, it's difficult to differentiate

between so-called 'deferred maintenance' and a 'rehabilitation program'. The difference is mainly of a financial nature, because 'deferred maintenance' is normally undertaken with funds from the national budget allocated to operation and maintenance while rehabilitation program are considered as an investment and the funds come from a different source (loans, national development banks, etc.).

1.16. Maintenance responsibilities of an irrigation scheme

The responsibilities of operation and maintenance (O&M) 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 for O&M for a specified time before hand-over to farmers, the farmers should be organized and prepared for take-over well in advance. Farmers would still require assistance from the irrigation agency and the extension service in the form of training in the following areas:

- Crop production and protection
- Irrigation scheduling and in-field water management
- Schedule of scheme maintenance
- Bookkeeping and accounting
- Access to markets and market information
- Sustainability of water user groups and other management structures

1.17. Monitoring and evaluation of smallholder irrigation schemes

Once an irrigation scheme has been implemented, there is need to continuously monitor its performance, in order to identify constraints and opportunities for improved performance. There are a number of parameters that can be measured or assessed as performance indicators. These include; technical system performance, which looks at performance in terms of water use efficiencies and other related parameters; economic analyses, which evaluates economic and financial performance; as well as socio economic analyses, which evaluate the impact of economic performance on the social well-being of the people. Success resulting from irrigation development as associated with farmer participation is reflected by the socio-economic benefits accrued to the beneficiaries.

1.18. Maintenance activities

Maintenance involves periodic activities that ensure proper functioning of the irrigation scheme in the long term. Regular maintenance reduces the chance of system breakdowns and results in sustainability of the system. Some of the activities involved include:

1.18.1. Maintenance of the intake

- Flushing out the accumulated silt regularly by opening the valves for the scour pipes and flush gate;
- Stir up the accumulated silt until all the silt is washed downstream through the provided gates;
- Clean the flush screens and sluice gates;
- Replace the damaged stop logs and screens
- Grease the movable metal parts;
- All the concrete and steel parts with defects should be repaired;

1.18.2. Sedimentation Basin

- Daily cleaning of the fine screens;
- Open the wash outs regularly until clear water comes out of the basin. Stir up the accumulated silt;
- Repair or replace the worn out or damaged valve, wash outs, rubber seats and screens;
- Repair the concrete structure and metal parts where damaged;
- Tighten all the loose movable parts.(e.g. cover hinges)

1.18.3. Dam and reservoir

Maintenance activities in a reservoir itself comprise:

- controlling aquatic weeds,

- removing large debris (e.g. tree trunks) floating in the water that may damage hydraulic works,
- monitoring the water quality: not only from the salt content point of view but also from a biological standpoint in order to detect possible sources of pollution,
- Surveying the solid deposition in the bottom of a reservoir.

These activities require little time because they are periodic with the exception of aquatic weed control, which is in any case only likely to be a severe problem in tropical and semi-tropical climates. However, they are extremely important in order to detect promptly the need for corrective action.

Another frequent problem is eutrophication (over-abundance of nutrients in the water bodies) resulting in high production of blue-green algae and the associated phenomenon of lack of dissolved oxygen in the water. This problem, which is very serious if the water is used for urban water supplies, is less important when the water is used for irrigation, the main consequence of the latter being an increase of vegetation in the irrigation canals and greater weed infestation. Injecting compressed air into reservoir water has proved to be a satisfactory solution on several occasions but there are other techniques that can be applied.

The main maintenance activities for an irrigation dam are: lubrication of gates, anti-corrosion treatment, cleaning of debris, control of filters, and some other minor work. Earth dams require greater maintenance, especially the upstream slope where weed control is necessary once or twice a year. The electro-mechanical system of a dam must also receive proper maintenance, particularly electric engines, head gates, and the lighting system. The maintenance of these elements is rather specialized and the manufacturers of the equipment usually provide detailed instructions.

1.18.4. **Irrigation network**

The canals in irrigation networks are generally either of earth or concrete-lined and their maintenance characteristics are quite different.

Concrete - lined canals

Concrete-lined canals should require little maintenance, provided that they have been properly constructed and any potential problems studied (sub-pressure, gypsum soils, swelling clays, etc.) and adequate technical solutions provided. One of the main reasons for constructing concrete-lined canals is precisely to reduce maintenance operations.

The routine activities include: replacement of joints, replacement of damaged concrete slabs, weed control in joints and on the surface of concrete slabs, control and treatment of filters, control and removal of silt. In the case of concrete flumes, chemical sterilization is also needed around the supporting structures.

Under normal conditions, the silting in concrete-lined canals is not an important problem since water velocity is high and sand traps and silting basins are often provided to reduce the solid content of the water. Heavy rain may cause deposition of solid materials if the berms are not properly formed. Drifting sand may be a serious problem in schemes surrounded by desert or bare land and subjected to strong winds. The most effective way of preventing this type of silting is to install windbreaks or barriers where sand accumulates before reaching the canal.

Removal of silt from concrete-lined canals is an expensive operation because it is mainly manual. Mechanical equipment can be used when specially adapted to avoid damaging the lining. In some irrigation schemes, the technique of flushing "quick water" through the canal is used to remove silt from one place and concentrate it in another where it can be more easily removed or disposed of. For this purpose, the canal should be run at its maximum capacity to reach the highest possible velocity.

Weed control should not be a major problem in lined canals, although aquatic weeds must be periodically removed. Later in the text, guidelines are given for weed control in both lined and earth canals.

The main problem in concrete - lined canals is cracking of the lining and eventual eruption of concrete slabs due to subpressure. Apart from repairing the damaged lining, corrective action must be taken. Usually the installation of subpressure valves is enough to relieve the pressure, but this involves major work. An alternative measure can be the construction of a subsurface drainage system to lower the water level.

Earth canals

There are four main problems in earth canals requiring maintenance attention and, although they are closely interrelated, they will be treated separately.

Silting

Excessive sedimentation is perhaps the most common problem affecting the performance of earth canals. Malik (1978) identifies the following causes for canal siltation:

- excessive silt entry at the main canal intake
- disproportionate withdrawal by branches
- prolonged heading up at control points
- drifting sand
- inadequate transport capacity of channels
- re-entry of excavated material by rain and wind action
- malfunctioning of intakes
- haphazard sediment excavation
- excessive weed growth
- Wrong channel regulation.

Weed infestation

Weed infestation can seriously impede the flow of canal water not only in tropical conditions but also in semi-arid and arid climates. There are two groups of weeds:

Water infiltration

Water leaks through canal banks can be caused by burrowing small crabs and water rats or by rotting plants and roots which were not removed from the canal bank seat during construction. Ants are also known to be a problem even in concrete-lined canals. These leaks can be repaired by following the path of the leak through the bank either by hand digging or hydraulic backhoe if available and once the path has been found, the trench must be carefully backfilled and compacted. Canal leaks, if not repaired in time, can result in major breaches in banks causing far greater inconvenience and most costly repairs.

Water seepage through porous soils may also be a major concern. Seepage through banks can be considerably reduced by trenching them and burying a plastic membrane or thick slurry made from the excavated material. The trench is backfilled with sand after the barrier has been interred.

Erosion of banks

Canal banks can be eroded by heavy rainfall or wind, improper canal operation, stock grazing or passage by drinking animals, and the transit of vehicles. Heavy rainfall or wind can cause serious damage to unprotected banks. Abrupt and rapid shutting off of canal water may also contribute to erosion of the banks. The practice of leaving a canal empty during the rainy season will contribute considerably to erosion of canal slopes.

Cattle and sheep damage the channel banks in different ways (Swales 1976). Cattle tend to push the moist bank material at the waterline into the waterway when they drink. Sheep, however, graze the banks bare thereby allowing wind and rain to wash away the bank material.

Erosion of canals can be repaired by mechanical means or manually by re-building the worn canal banks. However, care should be taken to construct a proper join between the old and the new part; otherwise the canal will deteriorate at the same place.

The most effective measures are of a preventive nature: such as seeding grass mentioned earlier, fencing the canals, and constructing special places for animal watering and bathing.

Drainage network

The retention in good working order of open drains includes the following operations:

- light deforestation
- weed control in the canal section

- seeding grass in the canal section
- maintenance of flow gauges and other measuring devices
- removal of silt
- Maintenance of pumping stations where water cannot be evacuated by gravity.

For practical purposes, the maintenance of open drains is very similar to that of earth irrigation canals. However, all too often drainage networks receive much less attention than the irrigation ones. The result is that during heavy rain, when they are much needed, they do not work as they should.

Drainage maintenance should always be programmed from downstream to upstream, and as far as possible completed within an irrigation season. The intervals in regular maintenance should not exceed periods of 2-3 years between two consecutive cleanings.

1.18.5. Maintenance of pipe network

- Regular flushing out of the pipe system by opening all washouts and end caps.
- Repair leakages and bursts promptly. It is recommended to remove a short length of pipeline on each side of the damage since the defects may be extended. If in doubt, replace the whole length of pipe;
- Replace the missing, damaged or vandalized pipes;
- Tighten the leaking joint and replace the damaged coupling/fittings. Avoid over tightening of steel couplers and must be protected against corrosion;
- Repair damaged thrust/anchor block and replace vandalized or damaged posts;
- Set the pressure as per the design and replace damaged pressure regulating devices;
- Repair damaged chamber covers and frame.

3.1. Organizational structure in irrigation schemes

When several farmers are carrying out irrigated agriculture using a common point of water supply, certain tasks or activities must be properly coordinated. To ensure the smooth running of the scheme and to avoid conflicts, it is important to have an Irrigation Water Users' Association for organization and self-management. Thus irrigation schemes should be managed by a legally registered irrigation water users' association.

The organization management structure should consist of the organs described in Figure 3.1 below:

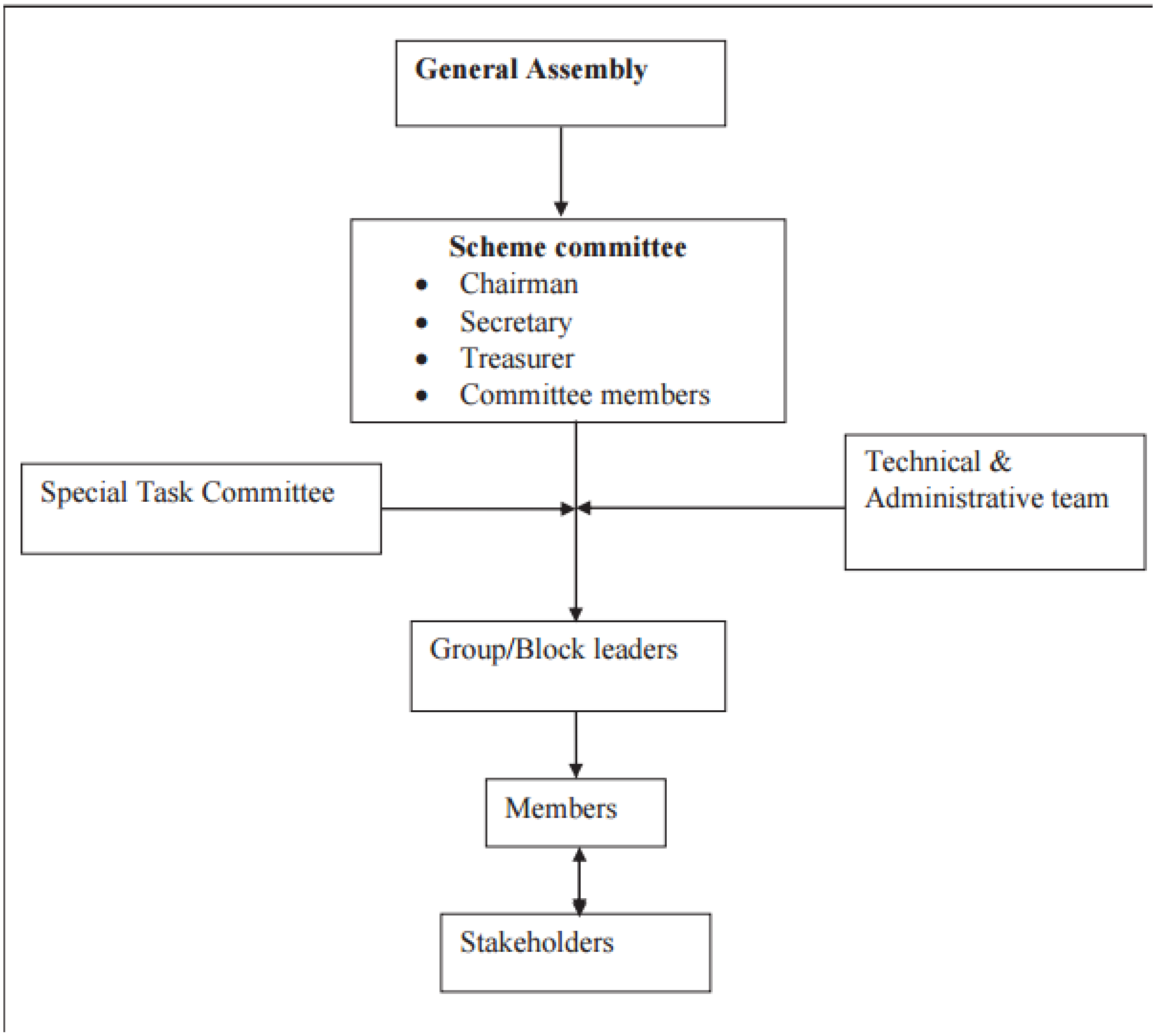


Figure-10: Illustration of the organizational structure of a group irrigation scheme

Instructions: choose the best answer all the questions listed below. Write your answers in the sheet provided in the next page.

1. One is not component of maintenance of the intake? (4pts)
   A. Clean the flush screens and sluice gates
   B. Replace the damaged stop logs and screens
   C. Grease the movable metal parts
   D. None of the above
2. In which areas farmers would require assistance from the irrigation agency and the extension service?
   A. Crop production and protection
   B. Schedule of scheme maintenance
   C. Bookkeeping and accounting Access to markets and market information
   D. All of the above
   E. None of the above
3. One of the following is component of maintenance of wash outs
   A. Repair all the damaged drains and control valves
   B. Repair all the leakages
   C. Drain the chamber
   D. All of the above
   E. None of the above
4. One of the following is common problems of earthen canal.
   A. Infiltration
   B. Weed infestation
   C. Bank erosion
   D. Silting
   E. All
5. Type of maintenance repairs of damage caused by natural disasters, such as floods and earthquakes is
   A. Routine maintenance

B. Differed maintenance

C. Special maintenance

D. All   E.   None

Note: **Satisfactory rating - 4 points**   **Unsatisfactory - below 4 points**

Answer Sheet

Score = ___________
Rating: ____________

Name: ___________________________   Date: ________________

Answer sheet

1.
2.
3.
4.
5.

4.1. Electronic monitoring and metering systems

Water metering is the practice of measuring water use. Water meters measure the volume of water used by irrigation units that are supplied with water by irrigation water supply system. They are also used to determine flow through a particular portion of the system.

Several types of water meters are in common use, and may be characterized by the flow measurement method, the type of end-user, the required flow rates, and accuracy requirements.

There are two common approaches to flow measurement, displacement and velocity, each making use of a variety of technologies. Common displacement designs include oscillating piston and notating disc meters. Velocity-based designs include single- and multi-jet meters and turbine meters.

There are also non-mechanical designs, for example, electromagnetic and ultrasonic meters, and meters designed for special uses. Most meters in a typical water distribution system are designed to measure cold potable water only. Specialty hot water meters are designed with materials that can withstand higher temperatures. Meters for reclaimed water have special lavender register covers to signify that the water should not be used for drinking.

Additionally, there are electromechanical meters, like prepaid water meters and automatic meter reading meters. The latter integrates an electronic measurement component and a LCD with a mechanical water meter. Mechanical water meters normally use a reed switch, hall or photoelectric coding register as the signal output. After processing by the microcontroller unit (MCU) in the electronic module, the data are transmitted to the LCD or output to an information management system.

Water meters are generally owned, read and maintained by a public water provider such as a city, rural water association or private water company. In some cases an owner of a mobile home park, apartment complex or commercial building may be billed by a utility based on the reading of one meter, with the costs shared among the tenants based on some sort of key (size of flat, number of inhabitants or by separately tracking the water consumption of each unit in what is called sub metering).

4.2. Manual chart-recording systems

A chart recorder is an instrument used to record various process and electrical signals. The most traditional chart recorders record data is paper. The paper is passed under a pen and the pen is deflected in proportion to the signal. The result is a graph or chart of the data.

4.2.1. Typical uses of chart recorders

Chart recorders are a familiar sight in manufacturing plants, where they track such variables as temperature, pressure, flow, pH, and humidity. Laboratories, meanwhile, use them to monitor scientific and engineering data generated in testing, diagnostics, statistical analysis, and other work requiring a graphic record.

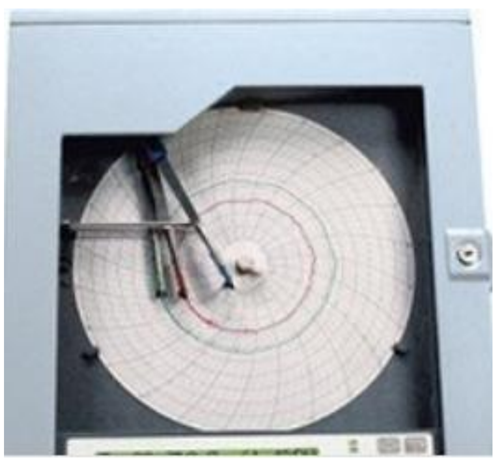


Figure-12:common chart recordes use in different aplication

- **Strip Chart Recorders**

Strip chart recorders consist of a roll or strip of paper that is passed linearly beneath one or more pens. As the signal changes the pens deflect producing the resultant chart.

Strip chart recorders are well suited for recording of continuous processes. Sections of the paper can be torn off and archived for future reference. Strip chart recorders are commonly used in laboratory as well as process measurement applications.

Figure-13:common chart recordes use in different aplication

- **Circular Chart Recorders**

A circular chart recorder records data in a circular format. The paper is spun beneath one or more pens. The pens are deflected in proportion to the varying signal resulting in a circular chart. Circular chart recorders are ideal for batch processes where a set process time is known. The charts are normally designed to rotate in standard time periods, such as 1 hour, 24 hours, 7 days, etc., although many recorders are flexible enough to accommodate non-standard time periods.

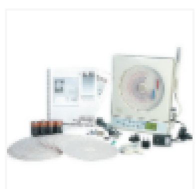


Figure14:Common chart recordes use in different aplication

- **Paperless Recorders**

Paperless recorders are one of the latest types of recorders to emerge on the market. Paperless recorders display the chart on the recorders' graphic display rather than print the chart on paper. The data can normally be recorded in internal memory or to a memory card for later transfer to a computer. The major benefit of paperless recorders is conservation of paper and easy transfer to a computer.

Figure-15:common chart recordes use in different aplication

4.3. On and off-road vehicles

One of the most significant benefits of travelling by car is flexibility. You can stop wherever you want, take any street, any shortcut that suits your commute hours. Most people like to move at their own speed and reach their destination on time, without any haste. In sparsely populated areas, owning a car is even more important, since it provides the only opportunity for travelling long distances due to a lack of public transport. On and off-road vehicles are essential to implement work activity in time and it reduce the workers up and down to monitor, operate, maintain and evaluate the irrigation activity in the field.

4.4. Communication equipment

Construction communication, within an organizational context, is to convey an instruction to influence the actions/behaviors of others, or may involve an exchange of, or request for information during a construction project. The efficiency and effectiveness of the construction process strongly depend on the quality of communication.

4.4.1. Two-Way Radios

- Motorola's flexible portfolio of two-way radios and accessories offers a range of communication solutions that meet your unique needs and help you cut through the communication obstacles you face on a daily basis.

Figure-16:Motorola's equipment

- **Motorola Digital Radios**

Audio - Digital applies error correction to eliminate noise and static and preserves voice quality over a greater range so users can hear what is being said crisp and clear.

Figure-17:Motorola Digital Radios

4.4.2. Team Communications

- Smartphone
- Computers
- Telephones
- Internet of Things

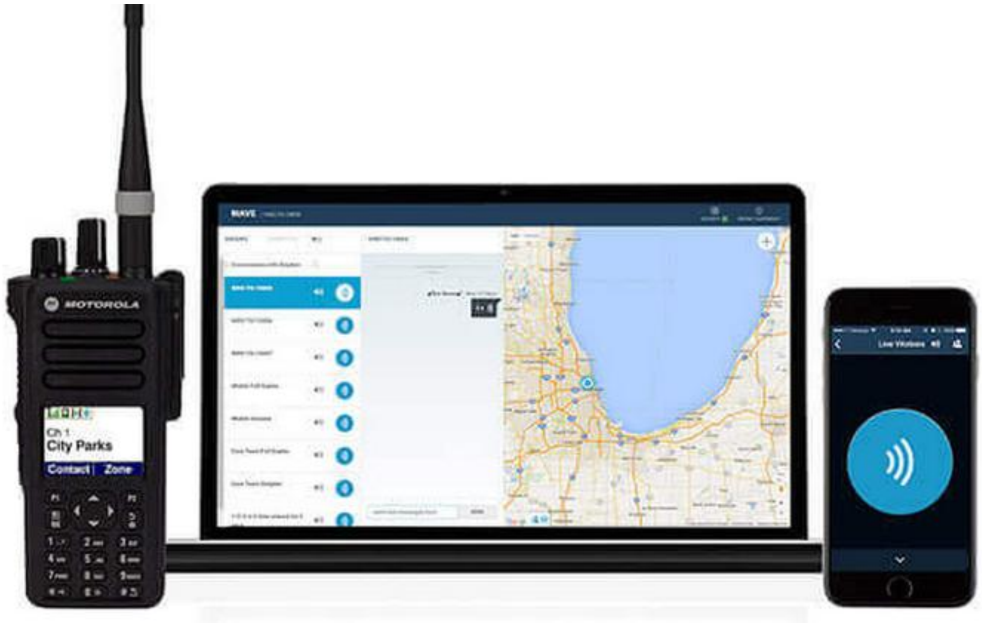


Figure-18:Team Communications

4.5. Personal protective equipment

PPE is equipment that will protect the user against health or safety risks at work. It can include items such as safety helmets, gloves, eye protection, high-visibility clothing, safety footwear and safety harnesses. It also includes respiratory protective equipment (RPE).

4.5.1. Why is PPE important?

Making the workplace safe includes providing instructions, procedures, training and supervision to encourage people to work safely and responsibly.

Even where engineering controls and safe systems of work have been applied, some hazards might remain. These include injuries to:

- the lungs, e.g. from breathing in contaminated air
- the head and feet, e.g. from falling materials
- the eyes, e.g. from flying particles or splashes of corrosive liquids
- the skin, e.g. from contact with corrosive materials
- the body, e.g. from extremes of heat or cold

PPE is needed in these cases to reduce the risk.

4.5.2. Types of PPE

- **Eyes:** will be affected by the following ways

Hazards from Chemical or metal splash, dust, projectiles, gas and vapor, radiation

Options: use Safety spectacles, goggles, face screens, face shields, visors

- **Head and neck:** will be affected by the following ways

Hazards Impact from falling or flying objects, risk of head bumping, hair getting tangled in machinery, chemical drips or splash, climate or temperature

Options: Industrial safety helmets, bump caps, hairnets and firefighters' helmets

- **Ears:** will be affected by the following ways

Hazards from Noise – a combination of sound level and duration of exposure, very high-level sounds are a hazard even with short duration

Options: Earplugs, earmuffs, semi-insert/canal caps

- **Hands and arms:** will be affected by the following ways

Hazards from Abrasion, temperature extremes, cuts and punctures, impact, chemicals, electric shock, radiation, vibration, biological agents and prolonged immersion in water

Options: Gloves, gloves with a cuff, gauntlets and sleeving that cover part or the entire arm

- **Feet and legs:** will be affected by the following ways

Hazards from Wet, hot and cold conditions, electrostatic build-up, slipping, cuts and punctures, falling objects, heavy loads, metal and chemical splash, vehicles

Options: Safety boots and shoes with protective toecaps and penetration-resistant, mid-sole wellington boots and specific footwear, e.g. foundry boots and chainsaw boots

- **Lungs:** will be affected by the following ways

Hazards fromOxygen-deficient atmospheres, dusts, gases and vapors

Options: respiratory protective equipment (RPE). Some respirators rely on filtering contaminants from workplace air. These include

- simple filtering face pieces and respirators and power-assisted respirators
- Make sure it fits properly, e.g. for tight-fitting respirators (filtering face pieces, half and full masks)

There are also types of breathing apparatus which give an independent supply of breathable air, e.g. fresh-air hose, compressed airline and self-contained breathing apparatus

- **Whole body:** will be affected by the following ways

Hazards from Heat, chemical or metal splash, spray from pressure leaks or spray guns, contaminated dust, impact or penetration, excessive wear or entanglement of own clothing.

Options: Conventional or disposable overalls, boiler suits, aprons, chemical suits

- **Emergency equipment**

Careful selection, maintenance and regular and realistic operator training is needed for equipment for use in emergencies, like compressed-air escape breathing apparatus, respirators and safety ropes or harnesses.

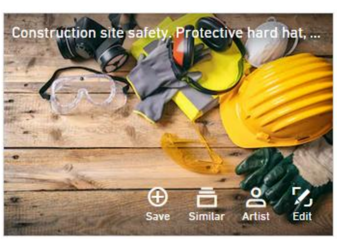


Figure-19:the most personal protective equipment

Self-check 4	Written test

Instructions: Answer all the questions listed below. Illustrations may be necessary to aid some explanations/answers. Write your answers in the sheet provided in the next page.

2. What is the main purpose of construction communication equipment? (4pts)
3. List and discuss the types of personal protective equipment?(4 pts)
4. List common hazards and control mechanisms in construction industry? (6 pts)

Note: **Satisfactory rating - 7 points** **Unsatisfactory - below 7 points**

Answer Sheet

Score = ___________

Rating: ____________

Name: _________________________ Date: _______________

Short Answer Questions

1. ____
____
____

2. ____
____
____
____

3. ____
____
____

Information sheet 5	Monitoring assets to ensure performance meets specifications in river system management plan

5.1.Introduction

Water provides the lifeblood of natural systems, societies and economies. People have lived near and on rivers, lakes, wetlands and deltas for many centuries. Rivers provide a multitude of services such as water supply, waste assimilation, fisheries, energy production, flood attenuation, spiritual, cultural and recreational benefits, and the habitat that supports a wide range of ecosystems.

The demands on rivers increasingly exceed their natural capabilities, resulting in over abstraction, pollution, alien infestation, floodplain alteration and habitat destruction. These failures are usually the consequence of poor decision-making, inadequate management and inappropriate planning. Effective basin planning is the starting point for sustainable management of river basins.

5.2.Rules of basin planning

Basin planning approaches have developed across the world in response to shifting priorities, different crises and increasing complexity in water resources management. Despite this variety, a number of key issues have emerged as central to the challenge of basin planning.

- Develop a comprehensive understanding of the entire system.
- Plan and act, even without full knowledge.
- Prioritize issues for current attention, and adopt a phased and iterative approach to the achievement of long-term goals.
- Enable adaptation to changing circumstances.
- Accept that basin planning is an inherently iterative and chaotic process.
- Develop relevant and consistent thematic plans.

- Address issues at the appropriate scale by nesting local plans under the basin plan.
- Engage stakeholders with a view to strengthening institutional relationships.

5.1. Stages and milestones in basin planning

Basin planning typically considers a range of social, economic and environmental issues. However, the range of issues needs to be narrowed down to key priorities to allow for a high-level strategy to be developed. Based on these priorities and the strategy determined, detailed implementation planning is undertaken. This basin planning process can be represented in four key stages

- Conducting a situation assessment: gaining an understanding of the current and future conditions in the basin, as well as identifying and prioritizing the key issues.
- Formulating a vision and objectives: that is, spelling out the desired state of the basin over the long term, together with goals (preliminary objectives) and principles to achieve this over time.
- Developing basin strategies: specifying a coherent suite of strategic objectives and outcomes related to protection, use, disaster management and institutional development, designed to achieve the vision.
- Detailing the implementation: defining actions that give effect to the basin strategies and should ultimately achieve the vision and objectives.

5.2. The historic phases of basin planning

The commonality between these pathways is that they typically pass through three phases:

- Uncoordinated: Early development, where ad hoc control and enforcement against minimum standards is at best applied, rather than coherent basin wide planning.

- Technical: Infrastructure development and operational planning, where technical engineering solutions are the priority.
- Strategic: Multidisciplinary planning, where economic, ecological and management solutions are applied.

5.3. Fundamental objectives of basin planning

The need for river basin planning arises due to the hydrological and ecological interconnectedness of river basins, and the multiple, and at times competing, services and functions that human societies derive from these systems. Because of the wide range of services provided by river basins, planning exercises typically need to address a broad range of issues. The following four broad groups of benefits are a valuable perspective through which to consider basin planning (Grey and Sadoff, 2005):

- environmental benefits to the 'river' – improved water quality, conserved biodiversity
- economic benefits from the 'river' – increased food, energy and manufacturing production
- reduced costs because of the 'river' – enhanced flood management
- Benefits beyond the 'river' – catalyzing wider cooperation and economic integration.

Basin planning is typically required to address all of these issues simultaneously, particularly for stressed river basins in the context of rapid economic growth. In doing so, basin planning exercises are typically underpinned by a number of fundamental principles:

- Equity: using water and enjoying the benefits of a river's services in a way that is fair and equitable amongst different groups. This can include equity between different administrative regions and between upstream and downstream areas. Considerations of social equity can also motivate basin planning that seeks to support opportunities for development in underdeveloped regions, as well as protecting and promoting the interests of socially marginalized groups.

- Environmental protection: managing water in a way that recognizes the need to maintain environmental functioning, as well as meeting the need for social and economic development. This must consider the direct development and use of the water resources, as well as the goods and services provided by these resources in to the future, ensuring that all of these can be provided into the future.
- Efficiency in development: managing water in a way that supports and promotes economic and social development, including national and strategic development priorities. As part of this, recognition is often given to the existing dependencies of communities and industries on water, and the opportunities for water conservation and demand management.
- Balance: basin planning needs to balance (trade off) competing needs and interests from the basin water resources (such as abstraction, discharge, flooding, navigation, power generation), and do so in a transparent way which provides security to water users.
- Cooperation: promoting alignment and joint action between institutions and groups with overlapping mandates and interests related to basin management.

5.4. Basin planning as an ongoing iterative process

Basin planning is an inherently chaotic, iterative and adaptive process. This is largely because of the complexity, changing conditions, limited understanding and uneven management that are typical in most basins. While this means that the entire process cannot be mapped out in the beginning, a coherent procedure and method for iteratively screening information and focusing planning attention is required to guide the process.

Effective management requires knowledge of the system to be managed and actions to be taken to achieve desirable outcomes. Planning represents the process of deciding on goals to be achieved and actions to be taken in getting there. The planning process typically poses four fundamental questions:

- Where are we now?

- Where do we want to be?
- How will we get there?
- How will we know that we are getting there?

There are a number of models outlining the planning process, but all have the same basic elements of planning (plan), implementing (do), monitoring (check) and reviewing (act). While this cycle was originally developed for business process quality improvement, the basic approach is just as applicable to river basin planning.

Figure-20:The planning process cycle

The final stage involves assessment of what to do next, based on what has been achieved. This may lead to a revision of the understanding of the problem, a modification of the activities to address the problem, or moving onto a new problem as the previous one has been addressed. This is the basis of the adaptive management process, in which planning is a continuous and ongoing part of the management cycle.

Strategic basin planning however requires a process that is more flexible, in order to enable the process to reflect and adapt to the changes in understanding and priorities of the basin's environmental, water resources, socio-economic and institutional systems. The planning process tends to be iterative, explorative and outcome oriented, but is less well suited to traditional project planning approaches. This is important to reduce the risk that detailed analysis of all issues drains resources, obscures understanding and paralyzes decision-making.

Effective basin planning processes are similar in nature to large complex information technology development processes, where the requirements of the final product are defined, but the process of getting to this is not necessarily well defined at the outset (in other words, 'what we want' is clear, but not 'how to do it'). The immediate activities may be defined, but the details of future activities are only clarified as the process unfolds, understanding improves and priorities are agreed.

The iterative nature of the planning process within a single iteration or edition of the basin plan is highlighted above. However, the longer iterative planning–implementation cycle from one basin plan edition to the next must also be recognized, as this allows priorities to shift as conditions change and issues are addressed.

Self-check 5	Written test

Instructions: Answer all the questions listed below. Illustrations may be necessary to aid some explanations/answers. Write your answers in the sheet provided in the next page.

1. The correct order of basin management cycle from the beginning to end is? (2pts)
   A. Plan, do, check and act
   B. Do, check, plan and act
   C. Act, check, do and plan
   D. Check, do, plan and act
2. One of them is **not** fundamental questions during planning process? (2pts)
   A. How will we get there?
   B. Where do we want to be?
   C. Where are we now?
   D. None of the above
3. One of them is NOT fundamental principles for basin planning exercises? (2pts)
   A. Equity
   B. Environmental protection
   C. Efficiency in development
   D. All of the above
   E. None of the above
4. What is the key stages basin planning process? (2pts)
   A. Conducting a situation assessment
   B. Formulating a vision and objectives
   C. Developing basin strategies
   D. Detailing the implementation
   E. All of the above
   F. None of the above

Note: **Satisfactory rating - 12 points** **Unsatisfactory - below 12 points**

Answer Sheet

Score = ___________
Rating: ____________

Name: _________________________ Date: _______________

1. 3.

2. 4.

Operation sheet 4	Irrigation system maintenance stage

At the irrigation system maintenance stage, the following tasks are to be solved:

1. Identify, provide and use Material, PPE and technical support of irrigation system operation
2. Carrying out of measures and identify components for restoration (improvement) of the quality condition of irrigated lands;
3. Carrying out of servicing of irrigation system components;
4. Implementation of technical maintenance of irrigation system components;
5. Implementation of repairs at the irrigation system components
6. Governance and management of the maintenance stage

7.

LAP Test	Practical Demonstration

Name: _______________________________ Date: _________________

Time started: ____________ Time finished: ____________

Instructions: Given necessary templates, workshop, tools and materials you are required to perform the following tasks within 3day.

1. Identify Irrigation system maintenance stage.

Instruction sheet	Learning guide 26

This learning guide is developed to provide you the necessary information regarding the following content coverage and topics –

- Testing and monitoring Water usage and quality according to SWMP.
- Coordinating Processes to meet SWMP requirements and targets.
- taking Action to optimise system performance
- Analysing, recording and reporting Monitoring data according to organizational procedures and statutory requirements
- Identifying and reporting Current or potential problems

This guide will also assist you to attain the learning outcome stated in the cover page. Specifically, upon completion of this Learning Guide, you will be able to –

- Test and monitor water usage and quality according to SWMP.
- Coordinate Processes to meet SWMP requirements and targets.
- Take action to optimize system performance
- Analyze, recording and reporting Monitoring data according to organizational procedures and statutory requirements
- Identify and report Current or potential problems

Learning Instructions:

1. Read the specific objectives of this Learning Guide.
2. Follow the instructions described below
3. Read the information written in the "Information Sheets". Try to understand what are being discussed. Ask you teacher for assistance if you have hard time understanding them.
4. Accomplish the "Self-checks".in each information sheets.
5. Ask from your teacher the key to correction (key answers) or you can request your teacher to correct your work. (You are to get the key answer only after you finished answering the Self-checks).

6. If you earned a satisfactory evaluation proceed to “Operation sheets and LAP Tests if any”. However, if your rating is unsatisfactory, see your teacher for further instructions or go back to Learning Activity.
7. After You accomplish Operation sheets and LAP Tests, ensure you have a formative assessment and get a satisfactory result;
8. Then proceed to the next LG

Information Sheet-1	Testing and monitoring water usage and quality according to SWMP.

1.1. Introduction

Water quality refers to the chemical, physical, biological, and radiological characteristics of water. It is a measure of the condition of water relative to the requirements of one or more biotic species, or to any human need or purpose. It is most frequently used by reference to a set of standards against which compliance, generally achieved through treatment of the water, can be assessed.

The principal reason for monitoring water quality has been, traditionally, the need to verify whether the observed water quality is suitable for intended uses. However, monitoring has also evolved to determine trends in the quality of the aquatic environment and how the environment is affected by the release of contaminants, by other human activities, and/or by waste treatment operations. This type of monitoring is often known as impact monitoring.

More recently, monitoring has been carried out to estimate nutrient or pollutant fluxes discharged by rivers or ground waters to lakes and oceans, or across international boundaries. Monitoring for background quality of the aquatic environment is also widely carried out, as it provides a means of comparing and assessing the results of impact monitoring.

The monitoring and assessment of water quality is based, ultimately, upon the fundamental physical, chemical and biological properties of water. However, water quality monitoring and assessment is a process of analysis, interpretation and communication of those properties within the wider context of human activity and use, and the conservation of the natural environment. It is not a fixed process, therefore, but is adapted in the light of local, national or international needs. The final aim is to provide information useful for management. Styles and strategies of management vary greatly, depending on institutions, resources and priorities.

The geographical limits of the area, the present and planned water uses and the present and expected pollution sources should be identified.

1.2. Objectives for monitoring

Objectives for water resource monitoring to support urban development are to:

- Establish pre-development water quality data so that the objectives for water sensitive urban design identified in BUWM (WAPC 2008) can be implemented.
- Establish baseline hydrological and hydrogeological data for pre-development conditions.
- Enable an assessment of any impact of a development on the area's hydrology and hydrogeology.

Generally no monitoring is required during the construction period. However, developers should carry out appropriate site inspections to minimize the impact of construction activities on the area's hydrology and hydrogeology.

1.3. Purpose of water quality monitoring and testing

Water quality monitoring and assessment can be conducted from a number of different perspectives which may combine the following goals in different ways:

- Uses of water. Does water meet user requirements for quantity and quality? (For example, with respect to meeting use-defined standards. In this context conservation of biodiversity may be considered a water use.)
- Influences on water quality from direct use or from other human activities or natural processes. What are these influences?
- Impacts on water quality (e.g. water as a medium for pollutant transport and exposure).
- Control and regulation of water quality. What is the capacity of water to assimilate pollutants? Are standards met? Are control strategies and management action appropriate and effective?

- How does water quality differ geographically in relation to uses and quality influences?
- How have past trends in water quality, influences and policies led to the present status?
- What factors in present water quality and in the past, present and planned activities, give an insight into future trends? What will these be?
- How does water quality influence other parts of the environment, such as marine coastal waters, soils, biota, and wetlands?

These are examples of the types of goals, answers or information that are sought in undertaking water quality monitoring. They approach water quality from different perspectives in terms of basic variables and present status, time trends and spatial differences, uses, pollution impacts and management needs for information for decisions and action. These differences will result in different approaches to the design and implementation of monitoring programs, to the selection of variables to be measured, to the frequency and location of measurements, to the additional information needed for interpretation and to the way in which information is generated and presented to meet particular information requirements.

The following is a list of typical monitoring objectives that might be used as the basis for design of sampling networks. The list is not intended to be exhaustive, merely to provide some examples.

- Identification of baseline conditions in the water-course system.
- Detection of any signs of deterioration in water quality.
- Identification of any water bodies in the water-course system that do not meet the desired water quality standards.
- Identification of any contaminated areas.
- Determination of the extent and effects of specific waste discharges.
- Estimation of the pollution load carried by a water-course system or subsystem.
- Evaluation of the effectiveness of a water quality management intervention.

- Development of water quality guidelines and/or standards for specific water uses.
- Development of regulations covering the quantity and quality of waste discharges.
- Development of a water pollution control program.

1.4. The need for information for management

When a water quality monitoring program is being planned, water-use managers or similar authorities can reasonably expect that the program will yield data and information that will be of value for management decision-making. The following are examples of the type of information that may be generated by a monitoring program:

- How the quality and quantity of water in a water body relate to the requirements of users.
- How the quality and quantity of water in a water body relate to established water quality standards.
- How the quality of water in a water body is affected by natural processes in the catchment.
- The capacity of the water body to assimilate an increase in waste discharges without causing unacceptable levels of pollution.
- Whether or not existing waste discharges conform to existing standards and regulations.
- The appropriateness and effectiveness of control strategies and management actions for pollution control.
- The trends of changes in water quality with respect to time as a result of changing human activities in the catchment area. Quality could be declining as a result of waste discharges or improving as a result of pollution control measures.
- Control measures that should be implemented to improve or prevent further deterioration of water quality.
- The chemical or biological variables in the water that render it unsuitable for beneficial uses.

- The hazards to human health that result, or may result, from poor water quality in the water body.
- How developments in the catchment area have affected or will affect water quality.
- The effects that deteriorating water quality have on plant and animal life in, or near, the water body.

The list above is not exhaustive, it merely provides examples. The information required from a monitoring program does, however, provide an indication of the type of program that should be implemented. Some monitoring programs will be long-term and intended to provide a cumulative body of information; others will have a single objective and will usually be of short duration.

1.5. Description of the monitoring area

The description of a monitoring area should consider as a minimum:

- Definition of the extent of the area,
- A summary of the environmental conditions and processes (including human activities) that may affect water quality,
- Meteorological and hydrological information,
- A description of the water bodies, and
- A summary of actual and potential uses of water.

A monitoring program commonly covers the water-course system of a catchment area (i.e. a main river and all its tributaries, streams, brooks, ditches, canals, etc., as well as any lakes or ponds that discharge into the river or tributaries). The catchment area is defined as the area from which all water flows to the water-course. The land surface that slopes in such a way that precipitation falling on it flows towards the water-course is called the topographic catchment area. In some cases groundwater enters the water-course system from a groundwater catchment area, all or part of which may lie outside the topographic catchment. Topographic and groundwater catchment areas are rarely coincident.

Since a water-course system may be very large, it is often convenient to divide the catchment into several small sub-catchments. A catchment area, and its associated watercourse, are hydrologically and ecologically discrete and, therefore, constitute a logical unit for the planning and management of water use and for the monitoring of water quality. The dynamics of upstream water quality and sources of pollution can be related to downstream effects. A description of the catchment area includes its size (in km^2), its geographical location and the identification of each water body in the water-course system.

Self-check	Written exam (multiple choose)

Name: ___________________________ Date: ________________

Directions: Answer all the questions listed below. Illustrations may be necessary to aid some explanations/answers.

1 Monitoring water resource system in the basin considers

A. Extent area

B. environmental conditions and processes

C. Meteorological and hydrological information

D. description of the water bodies

E. actual and potential uses of water

F. All

2 Types of information that may be generated by a monitoring program

A. the status of quality and quantity of water

B. impact of natural process on water quality

C. The appropriateness and effectiveness of control strategies and management

D. Control measures that should be implemented to improve water quality

E. All

3 One the following is a list of typical monitoring objectives that might be used as the basis for design of sampling networks.

A. Identification of baseline conditions in the water-course system.

B. Detection of any signs of deterioration in water quality.

C. Development of a water pollution control program

D. All

4 which one is the objectives for water resource monitoring to?

A. Establish pre-development water quality

B. Establish baseline hydrological and hydrogeological data

C. Enable an assessment of any impact of a development on the area's hydrology and hydrogeology

Note: **Satisfactory rating - 10points** **Unsatisfactory - below 10 points**

Score = ___________
Rating: ____________

Answer Sheet

Name: _________________________ Date: _______________

Short Answer Questions

1.
2.
3.
4.

Information sheet 2	Coordinating processes to meet SWMP requirements and targets

1.6. Definition of IWRM

IWRM: is a process which promotes the co-ordinated development and management of water, land and related resources, in order to maximise the resultant economic and social welfare in an equitable manner without compromising the sustainability of vital ecosystems.nb

Integrated water resources management is therefore a systematic process for the sustainable development, allocation and monitoring of water resource use in the context of social, economic and environmental objectives.

Government, households and businesses need to be properly informed about Surface water risks, in order being able take mitigating action and build resilience.

Effective surface water management requires coordinated action by all of those with responsibilities for managing land, rivers and drainage systems.

1.7. IWRM Objective

The main objective of IWRM is to achieve a balance between on the one hand the use of water as a foundation for the subsistence of a growing global population, and secondly its protection and conservation so as to ensure the sustainability of its functions and features.

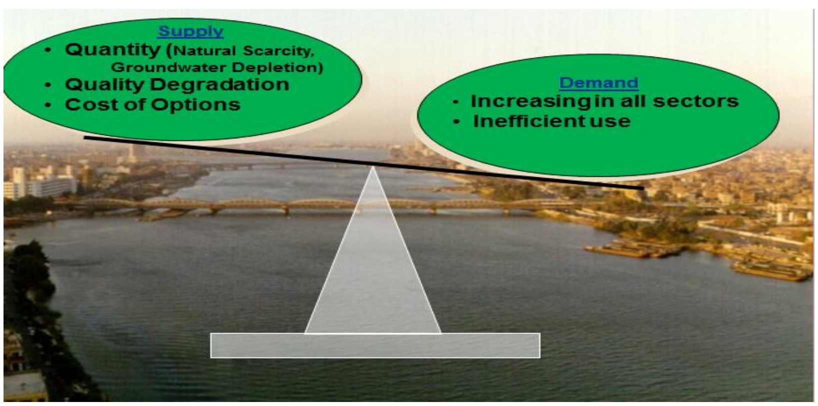
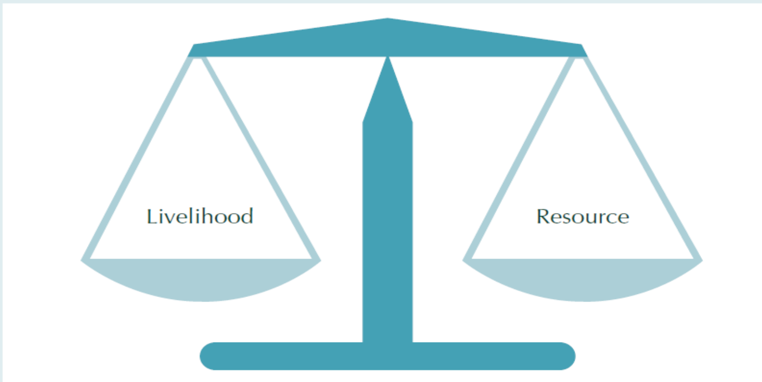


Fig2.1. the Water Balancing Act

The challenge ahead for water resources management

To strike a balance between the use of the resources as a basis for the livelihood of the world's increasing population and the protection and conservation of the resource to sustain its functions and characteristics.



1.8. Characterize of IWRM can be

- A process, not a product
- Scale independent - applies at all levels of development
- A tool for self-assessment and program evaluation
- A tool for policy, planning, and management
- A mechanism for evaluating competing demands, resource allocation, and trade-offs

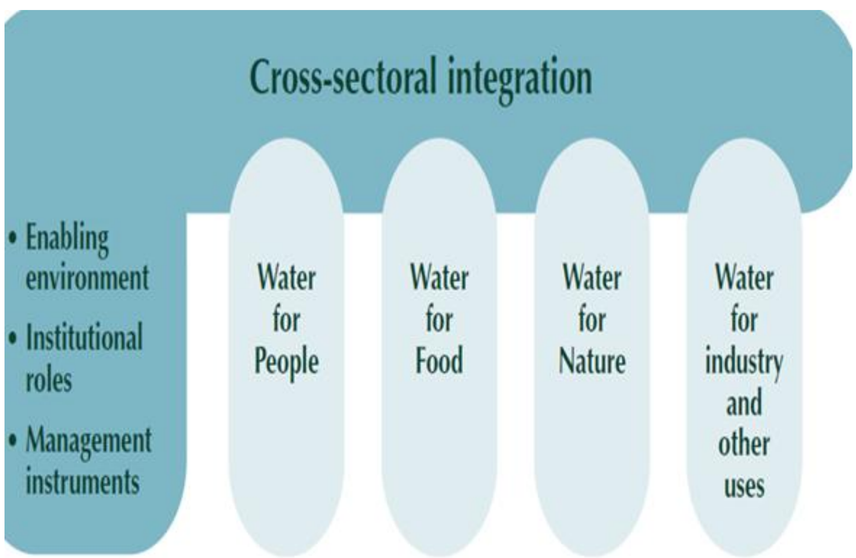
2. 2.4 Integration in IWRM

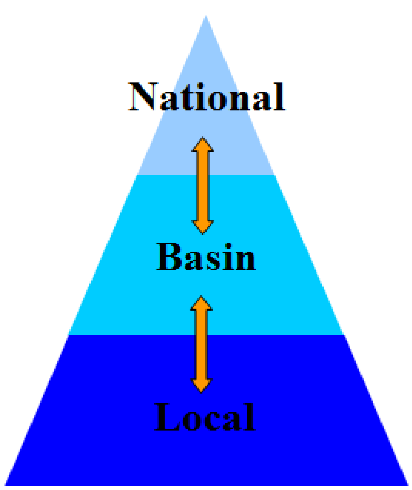
The basis for IWRM is that the many different uses of water resources are inter dependent. Integrated management means that all the various uses of water resources are considered together. Integration can be considered under two basic categories:

- **The natural system,**with its critical importance for resource availability and quality, and
- **The human system,** which fundamentally determines the resource use, waste production and pollution of the resource, and which must also set the development priorities.

Integration has to occur both within and between these categories, taking into account variability in time and space.

- **The natural system,**
  - ✓ integration of land and water management;
  - ✓ Integration of “Green water” and “blue water”;
  - ✓ Integration of surface water and groundwater management;
  - ✓ Integration of quantity and quality;
  - ✓ Integration of upstream and downstream water-related interests;
- **The human system**
  - ✓ Mainstreaming of water resources;
  - ✓ Cross-sectorial integration in national policy development
  - ✓ Integration of all stakeholders in the planning and decision process;
  - ✓ Integrating water and wastewater management;





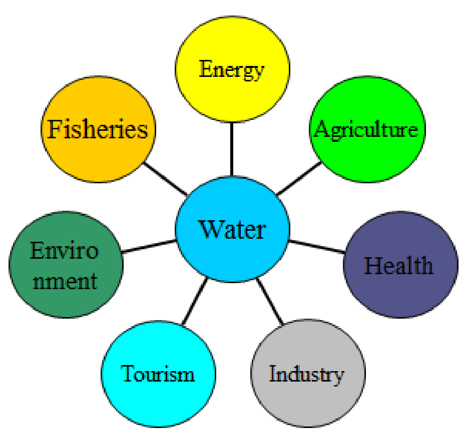


Figure-21: Integrating across levels and sectors

1.9. Benefit of IWRM

Proper application of IWRM provides significant benefits to:

- Environment;
  - ✓ Ecosystems can benefit from the application of the integrated approach to water management to have a say regarding the environmental needs in the debate on the allocation of water;
  - ✓ IWRM provides a new framework for ecosystem approach to give more attention on a system- approach to water management: - protection of upper basins (e.g., reforestation, animal husbandry, and the soil erosion control), the fight against pollution and environmental flows.
- Agriculture;
  - ✓ IWRM calls for an integrated planning so as to use the land, the water and other resources in a sustainable manner. For the agricultural sector, IWRM aims to increase water productivity (i.e. more crop per drop) in the constraints imposed by the economic and social development of a given region or country
  - ✓ IWRM can put in equation the potential for re-use of waste water from irrigation and from other sectors and the impact of agricultural re-use of municipal and industrial wastewater.
- Domestic Water Supply and Sanitation(DWSS),
  - ✓ The implementation of IWRM-based policies should mean greater security of domestic water supplies, as well as a reduction in the treatment costs when pollution is addressed more effectively.;
  - ✓ A properly applied IWRM will result in a guaranteed water security for the poor and un-served communities.
  - ✓ Focusing on the integrated management and efficient use should be a stimulus for the sector, as it will incite to a re-use, a recycling and a reduction of the waste.
  - ✓ The introduction of IWRM will improve the timely introduction of sustainable sanitation solutions meant to minimize the sources of waste production,

and the reduction of the direct effects of waste. It also solved the sanitation problems as closest as possible to its source;

- ✓ The introduction of IWRM helps in recognition of the people's rights, particularly those of the women and the poor, to a fair sharing of water resources for both production and domestic use at the household level.

- Energy;
- Industry etc.

1.10. Meteorological and hydrological information

Rainfall and ensuing run-off are of vital importance, especially when the programme includes the monitoring of fluxes or suspended loads of eroded materials. Some data interpretation techniques also require reliable hydrological information. If there is a gauging station or hydroelectric power plant near a sampling location, reliable data on river flow should be available. If they are not, estimates of flow can be based on data from the closest stream gauging station. As a last resort, it may be possible to estimate run-off from a calculation involving precipitation on the catchment area, the surface area of the catchment, a run-off factor and a time-of-flow factor. Measured values, however, are always much better than estimates. Where estimates have to be made, it is appropriate to request the assistance of experts in the hydrological services. Further information on hydrological measurements and calculation of flux is available.

Self-Check 2	Written Test

Instructions: Answer all the questions listed below. Illustrations may be necessary to aid some explanations/answers. Write your answers in the sheet provided in the next page.

1. What is IWRM? {4pts}
2. What is the purpose of IWRM?(4 pts)
3. Write the characteristics of IWRM? (6 pts)

Note: **Satisfactory rating - 7 points** **Unsatisfactory - below 7 points**

Answer Sheet

Score = ____________

Rating: _____________

Name: _________________________ Date: _______________

Short Answer Questions

1 ____

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2 ____

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3 ____

2.1. Water system optimization: concepts and methods

Managing surface water flood risks is a shared problem and everyone needs to play their part. Engineering project design and optimization can be effectively approached using concepts of systems analysis. A system can be thought of as a set of components or processes that transform resource inputs into product (goods and services) outputs. The basic concept of a system is represented in Figure 1.1.

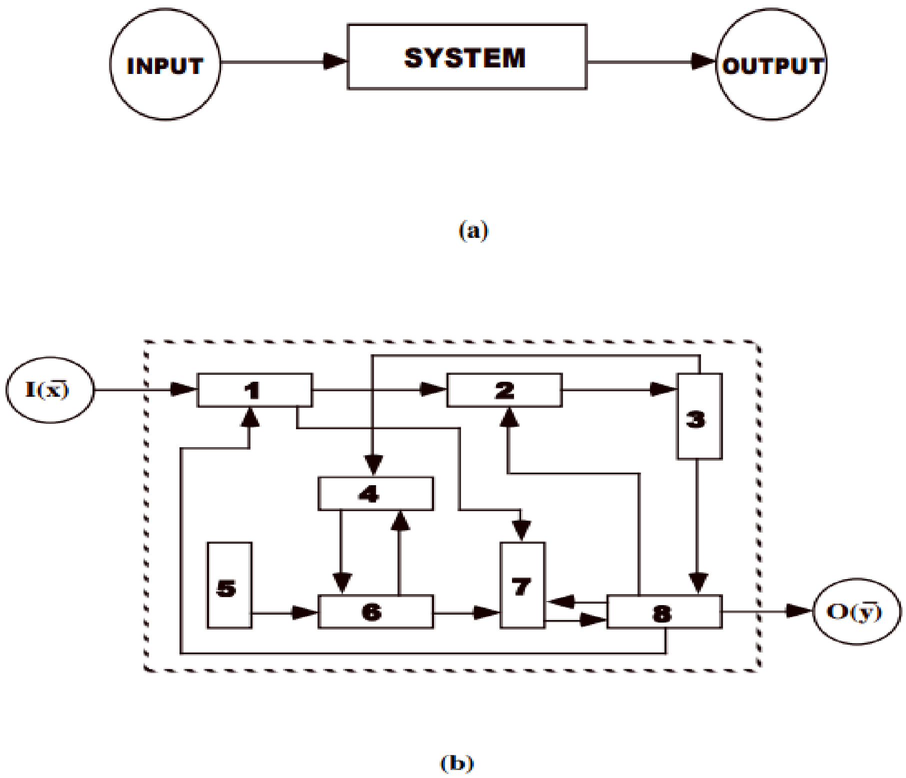

Figure 22: Representation of a System

In Figure 1.1b, the system is defined by a boundary which separates those components that are an interrelated part of the system from those outside which are part of the "environment".

For example, in a water resources system, the analyst must decide which hydrologic basin and water sources, dams, reservoir, and conveyance systems, and service areas and water uses to include in the "system".

The inputs define the flow of resource into the system and the outputs and products from the system. A system often has several subsystems. In the more detailed representation of Figure 1.2, the inputs include controllable or decision variables, which represent design choices that are open to the engineer. Assigning values to controllable variables establishes an alternative. The outputs describe the performance of the system or its consequences upon the environment. They indicate the effects of applying design and planning decisions via the input variables and are evaluated against system objectives and criteria in order to assess the worth of the respective alternatives in terms of time, reliability, costs or other appropriate units.

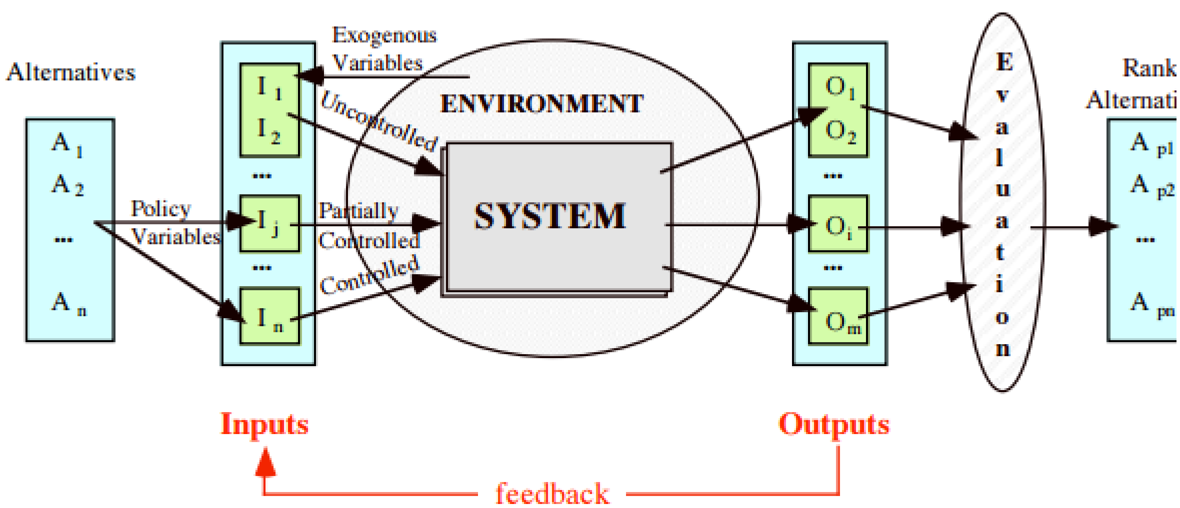

Figure 23: Detailed Representation of a System

2.2. Elements of Water Resources Systems

2.2.1. Inputs to water resources systems:

- Water sources
  - ✓ Surface sources: for example, surface water flow, sedimentation, or salt load, precipitation

- ✓ Underground sources
- ✓ Imported sources: for example, desalting water, imported water
- ✓ Reuse and recycling: for example, treated water from treatment plant, recycling water in irrigation

- Other natural resources
  - ✓ Land
  - ✓ Minerals, etc.
- Economic resources

2.2.2. Outputs of Water Resources Systems:

- Water allocation to user sectors
  - ✓ Municipal
  - ✓ Agriculture
  - ✓ Industry
  - ✓ Hydroelectric power
  - ✓ Flood control
  - ✓ Navigation
  - ✓ Recreation
  - ✓ Fish and wildlife habitats
- Quantity and quality of the water resource system
  - ✓ Flow of the stream
  - ✓ Quality of stream

2.2.3. System Decision Variables:

- Management and planning
  - ✓ Operating strategies
  - ✓ Land use zoning
  - ✓ Regional coordination and allocation policy
  - ✓ Number and location of treatment plants
  - ✓ Sequence of treatments and treatment level achieved
- Investment policy
  - ✓ Budget allocation to various subsystems

- ✓ Timing of investment: for example, stages of development, interest rate
- ✓ Taxing and subsidy strategies

2.2.4. Constraints on Systems Performance:

- ✓ Economic constraints: for example, budget, B/C ratio
- ✓ Political constraints: for example, tradeoff between regions
- ✓ Law: for example, water rights
- ✓ Physical and technology constraints: for example, probability of water availability
- ✓ Standards: system output may have to meet certain standards: for example, effluent standards from wastewater treatment plants

2.2.5. System Physical and Engineering Components:

- Planning and management system components
  - ✓ Dam and control structures
  - ✓ Levees and other protecting structures
  - ✓ Distribution or collection systems comprised of (a) canals, (b) pipes, (c) pumping stations and other control structures
  - ✓ Treatment plants
- Descriptive system components
  - ✓ Physical properties of stream: for example, roughness, slope
  - ✓ Biochemical properties of stream: for example, rate of aeration, rate of self-regeneration
  - ✓ Chemical properties of stream: for example, hardness, pH

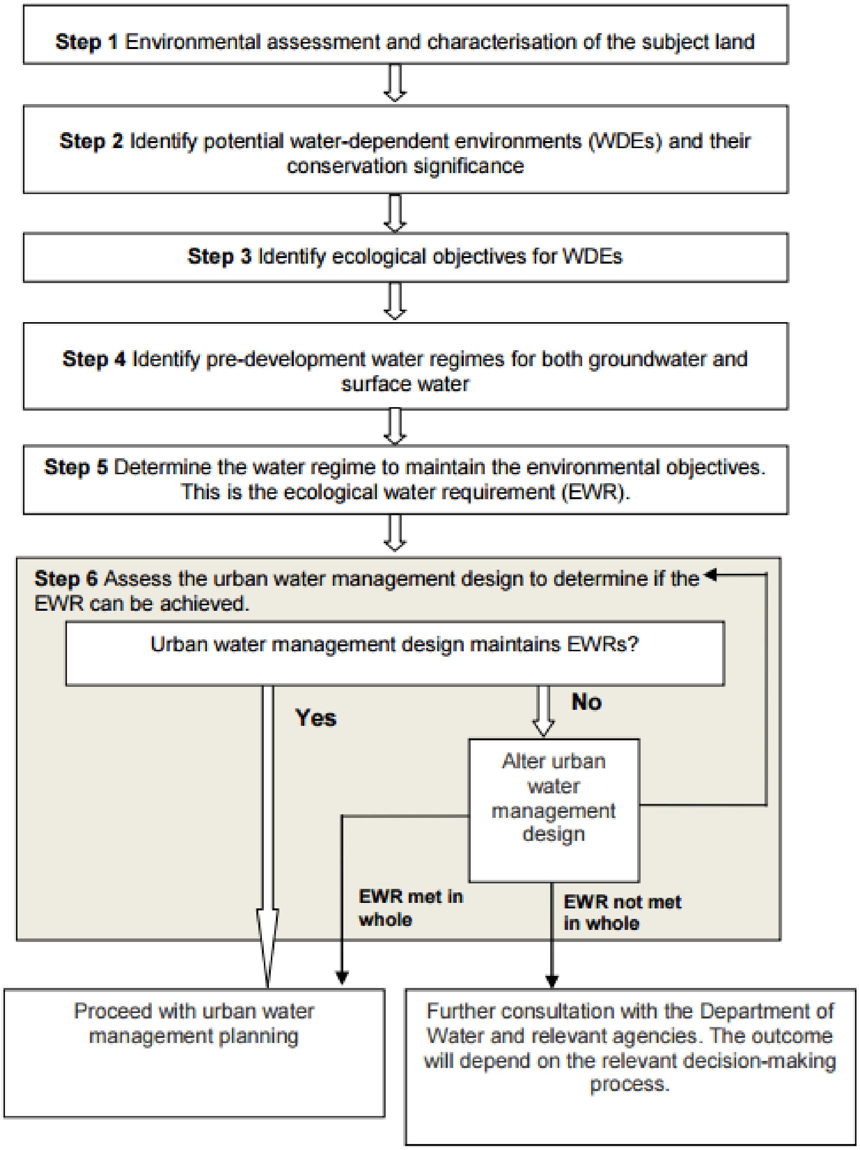

Figure 2 Process for determining ecological water requirements for water-dependent environments in urban areas

Self-check 3	Written test

Instructions: Answer all the questions listed below. Illustrations may be necessary to aid some explanations/answers. Write your answers in the sheet provided in the next page.

1. Write the most constraints to affect system performance? (5pts)
2. Write the Inputs to water resources systems? (5 pts.)
3. Write the Outputs of Water Resources Systems? (6 pts)
4. Write the System Decision Variables? (4 pts)

Note: **Satisfactory rating - 12 points** **Unsatisfactory - below 12 points**

Answer Sheet

Score = ___________

Rating: ____________

Name: _________________________ Date: _______________

Short Answer Questions

1 ____
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____
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2 ____
____
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3 ____
____

4 ____
____

Information sheet 4	2. Analyzing, recording and reporting monitored data

2.1. Important terminology

- **Data management: -** refers to the collection, storage, processing / analysis, dissemination and efficient use of information in the context of monitoring and evaluation. Data collection may take place on an ongoing basis, at regular intervals, or as part of a one-off evaluation.
- **Record-keeping: -** refers to the systematic recording of information in standardized formats. It is sometimes also understood to mean the storage of such information.
- **Collecting the data:** In dealing with any real life problem it is often found that data at hand are inadequate, and hence, it becomes necessary to collect data that are appropriate. There are several ways of collecting the appropriate data which differ considerably in context of money costs, time and other resources at the disposal of the researcher.
- **Analysis of data:** After the data have been collected, the researcher turns to the task of analyzing them. The analysis of data requires a number of closely related operations such as establishment of categories, the application of these categories to raw data through coding, tabulation and then drawing statistical inferences.
- **Hypothesis-testing:** After analyzing the data as stated above, the researcher is in a position to test the hypotheses, if any, he had formulated earlier.

2.2. Essential steps in SWMP

- Define the problem.
- Identify the system, define its elements, and gather relevant data.
- Define the system objectives and constraints.
- Generate feasible alternatives that satisfy physical, social, political, economic and legal constraints on the system and its management.

- Evaluate the alternatives for attaining system objectives and identify the most suitable among them.

2.3. Data analysis and interpretation

Developers should identify suitable methods of analysis that will help the interpretation of results. In analyzing and interpreting the data, they should consider the following:

- Preliminary data analysis over time as data are collected to ensure quality and relevance
- checking if the preliminary interpretation of data fulfils the monitoring program's objectives
- if the study was redesigned at any time, checking that new or additional data have been collected, and the data re-analysed
- applying data reduction methods (graphical, numerical and tabular summaries)
- identifying 'anomalous' observations and investigating the reason/s
- collating the results of the analysis into a concise summary
- assessing the statistical output carefully and providing a non-technical interpretation such as high, low, median readings, standard deviation and trend lines
- benchmarking data against guideline criteria to sustain local environmental values

Periodic data analysis and interpretation should be viewed as an integral component of the urban development monitoring process. Periodic reviews should be made of:

- measurement scales
- frequency of data collection
- number of replicates/duplicate samples
- Spatial and temporal coverage.

If any significant change in the water management parameters (as a result of the development) – outside of the trigger values set in the relevant water management strategy/plan – are detected during the first three years post-development, a management response and reporting to the relevant local government and the Department of Water will be required. The management response could include:

- additional sampling and analysis
- identification of the cause of the change
- measures undertaken to retrofit/manage the issue
- Evaluation of the effectiveness of management actions undertaken.

After the data analysis, the results for each parameter should be collated and summarized. The results should be interpreted in the context of the monitoring program's objectives. Values of parameters before and after the urban development that differ significantly need to be investigated and interpreted to determine if the water management strategy is effective or requires change.

Once the data interpretation is complete, the information should be written up into a report and submitted to the Department of Water and the relevant local government.

If monitoring or data analysis discovers any source of significant environmental or water management concern, it must be brought to the immediate attention of the relevant agencies, as set out in the appropriate water management strategy/plan, to determine if any management actions will be required.

2.4. Reporting

Reporting the outcomes of pre-development monitoring should be via the appropriate water management strategy/plan.

Post-development monitoring should be reported at the completion of the study period, in a form agreed to by all parties.

The developer should review all data annually and advise the Department of Water and the local government if the data show any sources of concern.

The report submitted to the department and the local government should contain the following essential components:

- an introduction, outlining previous studies in the area or related studies, and the study objectives
- a summary of the technical findings in relation to the monitoring objectives – in words that managers unfamiliar with technical detail can understand
- outline of the duration, nature and extent of the monitoring undertaken and compare the findings against the agreed monitoring design objectives
- experimental detail, describing the study location and study design, including descriptions of methods of sampling and analysis
- results – descriptive and detailed presentation of results, sometimes in combination with the discussion section
- tabulated results should be reported against the relevant trigger values and targets, with accidences clearly highlighted
- discussion of the results including data interpretation and implications for management
- conclusions drawn from the results
- recommendations for future work
- reference details for literature cited in the report
- appendices, providing laboratory reports, data tables or other information that is too detailed or distracting to be included in the main body of the report
- if there is a need for further monitoring beyond three years
- The need for any remedial action or change to water management plans.

The monitoring report should include, but not be limited to: all the results, lab certificates and QA/QC information, lithology/ geophysical logs and methodology related information identified as part of the SAP.

Self-check 4	Written test

Instructions: Answer all the questions listed below. Illustrations may be necessary to aid some explanations/answers. Write your answers in the sheet provided in the next page.

1 --------- refers to the collection, storage, processing / analysis, dissemination and efficient use of information in the context of monitoring and evaluation? (2pts)

B. Analysis of data
C. Collecting the data
D. Record-keeping
E. Data management

2 -------refers to the systematic recording of information in standardized formats?(2 pts)

B. Record-keeping
C. Analysis of data
D. Collecting the data
E. Data management

3 ----------One of them is not an essential step in SWMP? (2 pts)

A. Define the problem
B. Identify the system, define its elements, and gather relevant data
C. Climate change
D. Define the system objectives and constraints

4 Write and discuss 3 challenges of SWMP? (6pts)

***Note:* Satisfactory rating - 6 points** **Unsatisfactory - below 6 points**

1.

2.

3.

4. ---

Information sheet 5	5. Identifying and reporting current or potential problems

5.1. Important steps to identify potential problems

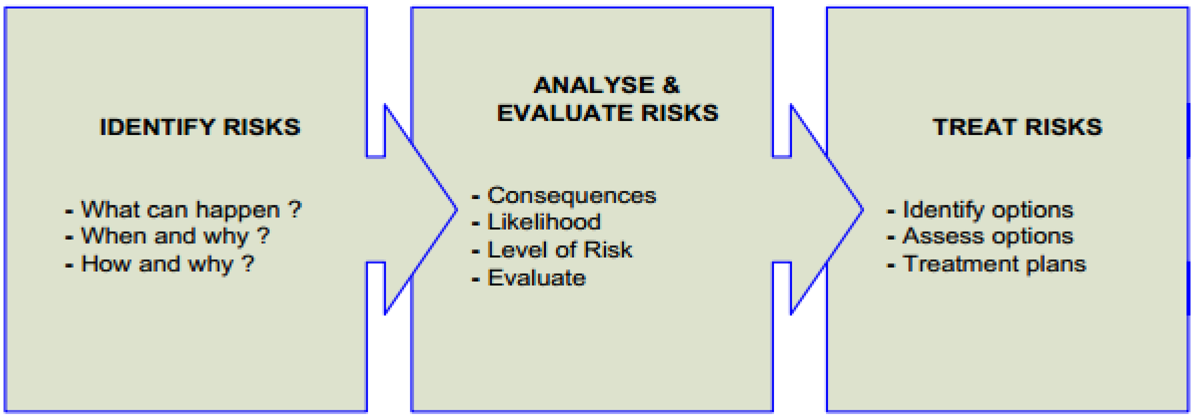

Figure 25 Risk management process

The committee identified five criteria that will be particularly helpful in addressing the region's water problems:

1. Take a regional view. Important insights will be gained by viewing the water problems of the area from a regional perspective, a perspective defined by hydrologic rather than national boundaries. Asking how water quantity and quality problems would be addressed if the region were managed as a single hydrologic unit will yield critical knowledge for good water resource management.
2. Account for the welfare of both present and future generations. The needs of both present and future generations and the status of the environment must all be considered as a matter of equity.
3. Consider all options for balancing water supplies and demands. A perceived gap between estimated future water supplies and water demands is not an adequate basis for water resources planning. Plans must be flexible and robust enough to deal with the uncertainties inherent in hydrologic phenomena, future patterns of

social organization and water use, and long-term climatic changes. Plans based solely on projections of expected discrepancies between water supplies and water demands can needlessly reduce the range of planning options to resolve the region's water problems.

4. Maintain ecosystem services to sustain water supplies through integrated planning. Water must be allocated to maintain and enhance environmental quality and biodiversity, in order to sustain water supplies and to preserve the quality of life for the study area's inhabitants.
5. Recognize the mutual dependence of water quality and quantity. Any discussion of the adequacy of water supplies must explicitly acknowledge current and future water quality. The adequacy of water supplies inherently involves issues of water quality. This principle is especially important in the study area, where water is scarce and water quality is deteriorating in many areas.

5.2. Challenges of SWMP

- Demand
  - ✓ Population growth
  - ✓ Competing needs (human, energy, industry, food, environment)
- Availability
  - ✓ Variability
  - ✓ Climate change
  - ✓ Pollution
- Extreme events
  - ✓ Floods
  - ✓ Droughts

Self-check 5	Written test

1. Criteria that will help in addressing the region's water problems are

   A. Take a regional view
   B. Account for the welfare of both present and future generations
   C. Consider all options for balancing water supplies and demands
   D. Maintain ecosystem services to sustain water supplies through integrated planning.
   E. Recognize the mutual dependence of water quality and quantity
   F. All

2. Steps to identify potential problems of SWMP?

   A. Analyze and evaluate risks, identify risks, treat risks
   B. Treat risks, analyze risks and evaluate risks, identify risks
   C. Identify risks, analyze and evaluate risks, treat risks
   D. Identify risks, treat risks, analyze and evaluate risks

Note: **Satisfactory rating - 2 points** **Unsatisfactory - below 2 points**

1.
2.

Operation sheet 1	Monitor and coordinate processes

The following three steps helpdevelopers to assess the potential risks, determine the monitoring needs and identify the appropriate level of data required to support each planning stage.

Step 1 – Assessing risks

Risks may be present to/from water resources and to/from the proposed development. Risks may vary from site to site due to:

- Soil type and topography
- Variation in rainfall regimes
- Sub-strata conditions
- The type of proposed land use change
- Increases in impervious area

Step 2 – Assessing monitoring needs

Before developing a monitoring program a review of existing data should be undertaken. This review should consider the frequency, detail and accuracy of the existing data against what is required to support the design and management processes used to control the risk; for example, catchment analysis, modeling, water management strategy design, etc.

Where additional monitoring is required, it should be noted that monitoring is an iterative process. Data should be periodically analyzed to ensure what is being collected is relevant. This may result in needing to modify the monitoring program to make it more appropriate and/or efficient.

Step 3 – Assessing monitoring requirements for planning stages

To determine what level of information is required at each planning stage, the planning decision needs to be considered in relation to the risk to water resource management and the purpose of the planning document.

To ensure the planning process is not held up due to lack of required information or data, it is important to assess at each planning stage what data is required to inform the decision and what data will be required to inform the next decision, thereby allowing any required monitoring and associated studies to be conducted in a timely manner.

Step 4 – design appropriate water resource planning system

Step 5 – implement the plan effectively

Developers and concerned body should implement and follow the progress of designed plan accordingly.

LAP-Test 1	Practical demonstration

1. Determine monitor and coordinate processes.

Instruction Sheet	Learning guide 27

This learning guide is developed to provide you the necessary information regarding the following content coverage and topics –

- Determining and evaluating water flow requirements, water quality and quantity requirements.
- Identifying environmental factors that affect water flows and quality.
- Identifying Performance measures for plan and operations.

This guide will also assist you to attain the learning outcome stated in the cover page. Specifically, upon completion of this Learning Guide, you will be able to –

- Determine and evaluate water flow requirements, water quality and quantity requirements.
- Identify environmental factors that affect water flows and quality.
- Identify Performance measures for plan and operations.

Learning Instructions:

1. Read the specific objectives of this Learning Guide.
2. Follow the instructions described below
3. Read the information written in the "Information Sheets". Try to understand what are being discussed. Ask you teacher for assistance if you have hard time understanding them.
4. Accomplish the "Self-checks".in each information sheets.
5. Ask from your teacher the key to correction (key answers) or you can request your teacher to correct your work. (You are to get the key answer only after you finished answering the Self-checks).
6. If you earned a satisfactory evaluation proceed to "Operation sheets and LAP Tests if any". However, if your rating is unsatisfactory, see your teacher for further instructions or go back to Learning Activity.
7. After You accomplish Operation sheets and LAP Tests, ensure you have a formative assessment and get a satisfactory result;

8. Then proceed to the next LG

Information sheet-1	Determining and evaluating water flow requirements, water quality and quantity requirements.

1.1. Water flow requirements

The primary objective of irrigation is to provide plants with sufficient water to obtain optimum yields and a high quality harvested product. The required timing and amount of applied water is determined by the prevailing climatic conditions, the crop and its stage of growth, soil properties (such as water holding capacity), and the extent of root development. Water within the crop root zone is the source of water for crop evapotranspiration. Thus, it is important to consider the field water balance to determine the irrigation water requirements.

Crop water requirements (CWR) are defined as the depth of water (millimeters) needed to meet the water consumed through evapotranspiration (ETc) by a disease-free crop, growing in large fields under non-restricting soil conditions, including soil water and fertility, and achieving full production potential under the given growing environment. Defining 'crop evapotranspiration' (ETc) as the rate of evapotranspiration (millimeters per day) of a given crop as influenced by its growth stages, environmental conditions, and crop management to achieve the potential crop production, then the CWR is the sum of ETc for the entire crop growth period.

For irrigated crops, the concept of CWR has to be complemented by that of irrigation water requirement (IWR), which is the net depth of water (millimeters) that is required to be applied to a crop to satisfy fully its specific crop water requirement. The IWR is the fraction of CWR not satisfied by rainfall, soil-water storage, and groundwater contribution.

Effective irrigation water management begins with accurate water measurement. Water measurement is required to determine both total volumes of water and flow rates pumped. Accurate crop water requirement assessment is a key component for correct water management.

Measurement of volumes will verify that the proper amount of water is applied at each irrigation and that amounts permitted by water management districts are not exceeded.

Measurement of flow rates will help to ensure that the irrigation system is operating properly. For example, low flow rates may indicate the need for pump repair or adjustment, partially closed or obstructed valves or pipelines, or clogged drip emitters. High flow rates may indicate broken pipelines, defective flush valves, too many zones operating simultaneously, or eroded sprinkler nozzles.

The assessment of the irrigation potential, based on soil and water resources, can only be done by simultaneously assessing the irrigation water requirements (IWR) (Figure 1).

Net irrigation water requirement (NIWR) is the quantity of water necessary for crop growth. It is expressed in millimeters per year or in m3/ha per year (1 mm = 10 m3/ha). It depends on the cropping pattern and the climate. Information on irrigation efficiency is necessary to be able to transform NIWR into gross irrigation water requirement (GIWR), which is the quantity of water to be applied in reality, taking into account water losses. Multiplying GIWR by the area that is suitable for irrigation gives the total water requirement for that area. In this study water requirements are expressed in km3/year.

Calculations of irrigation water requirements are done while preparing national water master plans or irrigation projects. In order to be able to do this, assumptions have to be made on the definition of areas to be considered homogeneous in terms of rainfall, potential evapotranspiration, cropping pattern, cropping intensity and irrigation efficiency.

1.1.1. Estimating crop water use

The determination of irrigation water requirements and irrigation schedules requires an accurate estimate of the crop water use rate. Daily and weekly crop water use estimates are needed to schedule irrigations, while longer term estimates are needed to specify the irrigation, storage, and conveyance system capacities.

Annual water use is often required to size irrigation reservoirs and establish water rights. Therefore, a procedure to predict both the short- and long-term rates of water use by a multitude of crops in varying climates is needed.

Precipitation, and in particular its effective portion, provides part of the water crops need to satisfy their transpiration requirements. The soil, acting as a buffer, stores part of the precipitation water and returns it to the crops in times of deficit. In humid climates, this mechanism is sufficient to ensure satisfactory growth in rain-fed agriculture. In arid climates or during extended dry seasons, irrigation is necessary to compensate for the evapotranspiration (crop transpiration and soil evaporation) deficit due to insufficient or erratic precipitation. Irrigation consumptive water use is defined as the volume of water needed to compensate for the deficit between potential evapotranspiration on the one side and effective precipitation over the crop growing period and change in soil moisture content on the other side. It varies considerably with climatic conditions, seasons, crops and soil types. For a given month, the crop water balance can be expressed as follows:

ICU = ETc - P - DS

Where:

- ICU = irrigation consumptive water use needed to satisfy crop water demand (mm)
- ETc = potential crop evapotranspiration (mm)
- P = effective precipitation (mm)
- DS = change in soil moisture (mm)

Potential crop evapotranspiration (ETc) is calculated on a daily basis according to the methodology described in FAO Irrigation and Drainage paper 56 (FAO, 1998):

ETc(t) = Kc x ETo(t)

Where:

- t = time step (days)
- ETc(t) = potential crop evapotranspiration on t (mm)
- ETo(t) = reference evapotranspiration on t (mm)

- Kc = crop coefficient

In order to simply the calculations, the factor Kc has been evaluated for 4 stages of a crop growth usually denoted as

- Initial stage
- Crop development stage
- Mid-season stage
- Late season stage

1.2. Water quantity requirement

It is essential to know the water requirement of a crop which is the total quantity of water required from its sowing time up to harvest. Naturally different crops may have different water requirements at different places of the same country, depending upon the climate, type of soil, method of cultivation, effective rain etc.

The total water required for crop growth is not uniformly distributed over its entire life span which is also called crop period. Actually, the watering stops same time before harvest and the time duration from the first irrigation during sowing up to the last before harvest is called base period.

For raising a field crop effectively, it is essential to supply water through artificial irrigation supplementing the rain falling over the plot of land and raising the soil moisture.

In the above section it has been indicated how the crop water need (ET crop) is determined. This water can be supplied to the crops in various ways:

- by rainfall
- by irrigation
- by a combination of irrigation and rainfall

In some cases, part of the crop water need is supplied by the groundwater through capillary rise.

- In cases where all the water needed for optimal growth of the crop is provided by rainfall, irrigation is not required and the Irrigation water need (IN) equals zero: IN = 0.
- In cases where there is no rainfall at all during the growing season, all water has to be supplied by irrigation. Consequently, the irrigation water need (IN) equals the crop water need (ET crop): IN = ET crop.

In most cases, however, part of the crop water need is supplied by rainfall and the remaining part by irrigation. In such cases the irrigation water need (IN) is the difference between the crop water need (ET crop) and that part of the rainfall which is effectively used by the plants (Pe). In formula: IN = ET crop - Pe.

In summary:

- If sufficient rainfall: IN = 0
- If no rainfall at all   : IN = ET crop
- If partly irrigation, partly rainfall: IN = ET crop – Pe

The effect of the major climatic factors on crop water needs may be summarized as follows:

- Sunshine
- Temperature
- Humidity
- Wind speed

1.2.1. Determination of the effective rainfall

When rain water falls on the soil surface,

- some of it infiltrates into the soil
- some stagnates on the surface
- While some flows over the surface as runoff.

When the rainfall stops, some of the water stagnating on the surface,

- evaporates to the atmosphere
- while the rest slowly infiltrates into the soil

From all the water that infiltrates into the soil

- some percolates below the root zone
- While the rest remains stored in the root zone.

In other words, the effective rainfall is the total rainfall minus runoff minus evaporation minus deep percolation; only the water retained in the root zone can be used by the plants, and represents what is called the effective part of the rainwater. The term effective rainfall is used to define this fraction of the total amount of rainwater useful for meeting the water need of the crops.

To estimate the fraction of the total rainfall this is used effectively. These formulae can be applied in areas with a maximum slope of 4-5%:

$Pe = 0.8 P 25$ if $P > 75$ mm/month

$Pe = 0.6 P 10$ if $P < 75$ mm/month

Where:

- P = rainfall or precipitation (mm/month)
- Pe = effective rainfall or effective precipitation (mm/month)

1.3. Water quality requirements

Irrigated agriculture is dependent on an adequate water supply of usable quality. Water quality concerns have often been neglected because good quality water supplies have been plentiful and readily available. This situation is now changing in many areas. Intensive use of nearly all good quality supplies means that new irrigation projects and old projects seeking new or supplemental supplies must rely on lower quality and less desirable sources. To avoid problems when using these poor quality water supplies, there must be sound planning to ensure that the quality of water available is put to the best use.

Conceptually, water quality refers to the characteristics of a water supply that will influence its suitability for a specific use, i.e. how well the quality meets the needs of the user. Quality is defined by certain physical, chemical and biological characteristics.

Even a personal preference such as taste is a simple evaluation of acceptability. For example, if two drinking waters of equally good quality are available, people may express a preference for one supply rather than the other; the better tasting water becomes the preferred supply. In irrigation water evaluation, emphases are placed on the chemical and physical characteristics of the water and only rarely are any other factors considered important.

Specific uses have different quality needs and one water supply is considered more acceptable (of better quality) if it produces better results or causes fewer problems than an alternative water supply. For example, good quality river water which can be used successfully for irrigation may, because of its sediment load, be unacceptable for municipal use without treatment to remove the sediment. Similarly, snowmelt water of excellent quality for municipal use may be too corrosive for industrial use without treatment to reduce its corrosion potential.

The chemical characteristics of irrigation water refer to the content of salts in the water as well as to parameters derived from the composition of salts in the water; parameters such as EC/TDS (Electrical Conductivity/ Total Dissolved Solids), SAR (Sodium Adsorption Ratio) alkalinity and hardness.

The most common parameters used for determining the irrigation water quality, in relation with its salinity, are EC and TDS. In case the irrigation water salinity exceeds the threshold for the crop, yield reduction occurs. Equations were developed to estimate the yield potential, based on the irrigation water salinity.

1.3.1. Water quality problems

Water used for irrigation can vary greatly in quality depending upon type and quantity of dissolved salts. Salts are present in irrigation water in relatively small but significant amounts. They originate from dissolution or weathering of the rocks and soil, including dissolution of lime, gypsum and other slowly dissolved soil minerals. These salts are carried with the water to wherever it is used. In the case of irrigation, the salts are applied with the water and remain behind in the soil as water evaporates or is used by the crop.

The suitability of a water for irrigation is determined not only by the total amount of salt present but also by the kind of salt. Various soil and cropping problems develop as the total salt content increases, and special management practices may be required to maintain acceptable crop yields. Water quality or suitability for use is judged on the potential severity of problems that can be expected to develop during long-term use.

The problems that result vary both in kind and degree, and are modified by soil, climate and crop, as well as by the skill and knowledge of the water user. As a result, there is no set limit on water quality; rather, its suitability for use is determined by the conditions of use which affect the accumulation of the water constituents and which may restrict crop yield. The soil problems most commonly encountered and used as a basis to evaluate water quality are those related to salinity, water infiltration rate, toxicity and a group of other miscellaneous problems.

Water quality-related problems in irrigated agriculture

Salinity

Salts in soil or water reduce water availability to the crop to such an extent that yield is affected.

Water infiltration rate

Relatively high sodium or low calcium content of soil or water reduces the rate at which irrigation water enters soil to such an extent that sufficient water cannot be infiltrated to supply the crop adequately from one irrigation to the next.

Specific ion toxicity

Certain ions (sodium, chloride, or boron) from soil or water accumulate in a sensitive crop to concentrations high enough to cause crop damage and reduce yields.

Miscellaneous

Excessive nutrients reduce yield or quality; unsightly deposits on fruit or foliage reduce marketability; excessive corrosion of equipment increases maintenance and repairs.

1.3.2. Irrigation Water Quality Criteria

Soil scientists use the following categories to describe irrigation water effects on crop production and soil quality:

Salinity hazard – total soluble salt content

Sodium hazard – relative proportion of sodium to calcium and magnesium ions

pH – acid or basic

Alkalinity – carbonate and bicarbonate

Specific ions: chloride, sulfates, boron, and nitrate.

Table 15. General guidelines for salinity hazard of irrigation water based upon conductivity.

Limitations for use	Electrical Conductivity (dS/m)*
None	≤0.75
Some	0.76 – 1.5
Moderate[1]	1.51 – 3.00
Severe[2]	≥3.00

*dS/m at 25ºC = mmhos/cm [1]Leaching required at higher range. [2]Good drainage needed and sensitive plants may have difficulty at germination.

For most irrigation waters encountered the standard SAR formula provided above is suitable to express the potential sodium hazard. However, for irrigation water with high bicarbonate (HCO3) content, an "adjusted" SAR (SARADJ) can be calculated. In this case, the amount of calcium is adjusted for the water's alkalinity, is recommended in place of the standard SAR.

$$SAR = \frac{Na^{+}{}_{meq/L}}{\sqrt{\frac{(Ca^{++}{}_{meq/L}) + (Mg^{++}{}_{meq/L})}{2}}}$$

The potential soil infiltration and permeability problems created from applications of irrigation water with high “sodicity” cannot be adequately assessed on the basis of the SAR alone. This is because the swelling potential of low salinity (ECw) water is greater than high ECw waters at the same sodium content (Table 2). Therefore, a more accurate evaluation of the infiltration/permeability hazard requires using the electrical conductivity (ECw) together with the SAR.

Table 16. Guidelines for assessment of sodium hazard of irrigation water based on SAR and ECw[2].

Potential for Water Infiltration Problem		
Irrigation water SAR	Unlikely	Likely
	———ECw[2] (dS/m)———	
0-3	>0.7	<0.2
3-6	>1.2	<0.4
6-12	>1.9	<0.5.
12-20	>2.9	<1.0
20-40	>5.0	<3.0

[2]Modified from R.S. Ayers and D.W. Westcot. 1994. Water Quality for Agriculture, Irrigation and Drainage Paper 29, rev. 1, Food and Agriculture Organization of the United Nations, Rome

Self-Check 1	Written Test

Name: _________________________ Date: _______________

Directions: Answer all the questions listed below. Illustrations may be necessary to aid some explanations/answers.

1. Which one of the following is an Irrigation water quality problem?
   A. Infiltration
   B. Miscellaneous
   C. Specific ion toxicity
   D. Salinity
   E. All
2. A portion of rainfall retain in crop root zoon and extract by root zoon is
   A. Excess Runoff
   B. Evaporation
   C. De-percolation
   D. Effective rainfall
3. Kc value of the crop is mostly high in
   A. Initial stage
   B. Crop development stage
   C. Mid-stage
   D. Maturation stage
4. Crop water requirement is equal to
   A. Evaporation from the soil
   B. Transpiration from crop leaves
   C. Evapotranspiration from command area
   D. De-percolation
5. Total amount of water required to irrigation is
   A. Evapotranspiration
   B. Evapotranspiration plus other different loss

C. Evapotranspiration plus other different loss minus effective rainfall minus residual soil moisture

D. Transpiration from the crop

***Note:* Satisfactory rating - 14points** **Unsatisfactory - below 14 points**

Answer Sheet

Score = ___________

Rating: ____________

Name: ___________________________ Date: ________________

Short Answer Questions

1.
2.
3.
4.
5.

Information Sheet 2	5. Identifying environmental factors that affect water flows and quality

3. 2.1. Environmental factors that affect water flows and quality

Environmental characteristics of river basins such as climate, topography, geology, and vegetation and the activities that occur within them affect the physical and chemical characteristics of rivers. The links between the characteristics of the drainage basin and the water and sediment quality in the river are discussed in the below section.

Rainfall and temperature are the most important aspects of climate, and both influence the aquatic environment. The amount and timing of rainfall are strongly linked to hydrological patterns within drainage basins, so seasonally varying precipitation produces seasonal differences in river discharge and patterns of flooding and thus seasonal differences in the physical and chemical characteristics of the river. In many Rivers, high flows during the summer melt result in elevated concentrations of suspended sediments and chemical species associated with sediments.

River discharge has important effects on water quality, including the dilution of dissolved substances at high flows and the suspension of sediment particles eroded from the river banks or substrate by high flows. Rainfall can also cause erosion within the drainage basin, and elevated surface flows can carry eroded sediment to the river. Flooding can result in the exchange of nutrients between flooded river banks and the river itself. Temperature influences the rate of chemical reactions as well as physical processes such as evaporation and the melting of ice and snow.

Rain and snow contain a wide variety of chemical substances that can affect the quality of the aquatic environment they eventually reach. Some substances, such as sulphuric and nitric acids found in acid rain, can lower the pH of aquatic environments. Atmospheric deposition of persistent organic pollutants, mercury, and acidifying compounds are a potential concern for health and ecological reasons.

4. 2.2. Factors affecting water supply

Climate- low levels of rainfall and high temperatures lead to water deficits. When rainfall is low, there is less water available. When temperatures are high, water evaporates and so there is less available to use. Water surpluses are common where rainfall is high and temperatures are lower.

Geology – rainfall flows down to the rocks beneath the ground. Some rocks are permeable and allow water to flow through them.

Permeable rocks can lead to less surface water. For example, limestone landscapes often have dry rivers - the rivers only exist when rain has just fallen. Permeable rocks form aquifer, which means they are stores of water.

Other rocks are impermeable. These rocks do not hold water, but they can trap it in the layers above.

Pollution – some places have plenty of water, but pollution has made it unsafe to use. Untreated sewage and waste water from factories cause problems. Groundwater is usually cleaner, although pollutants can travel down into the ground.

Over-abstraction – when water is taken from aquifers, groundwater levels fall. If the amount of water taken is greater than the amount of water falling as rain, it is called over-abstraction.

Limited infrastructures – pipelines and/or open water conveyance structure such as canal are needed to safely move water from place to place.

Poverty – even though surplus quantity and quality of water is available in Africa for different purpose, nearly 1 billion people in Africa do not have access to clean, safe and enough water. This locks them in a cycle of poverty - they cannot afford water so they become ill and when they become ill then cannot work and earn money.

Self-Check 2	Written Test

Instructions: Answer all the questions listed below. Illustrations may be necessary to aid some explanations/answers. Write your answers in the sheet provided in the next page.

1. List at list 4 environmental factors that affect water quality and explain them in detail? (8 points)

Note: **Satisfactory rating - 4 points** **Unsatisfactory - below 4 points**

Answer Sheet

Score = ___________

Rating: ____________

Name: _________________________ Date: _______________

Short Answer Questions

1. ____
____
____

Information Sheet 3	Identifying performance measures for plan and operations

3.1. Introduction

The exploitation and utilization of water for irrigation require that there are periodic evaluations of its utility and efficiency of use. This concern with performance within the irrigation sector is increasing as pressure grows on water resources in all parts of the world, and as concerns increase regarding the sustainability of irrigated agriculture systems. Any enterprise requires feedback on the management of resources and the end result in terms of increased output.

During this century there has been a dramatic increase in the area irrigated. Most of this expansion has occurred through capital investments in infrastructure for the capture, storage and distribution of water, and in the conversion of rain-fed areas into irrigable land. This type of development has created a number of groups who have a direct concern on the performance of the irrigation system: investors, policy makers, planners, managers and users. Each of these groups has to be able to assess the effectiveness of the systems in which it has a stake. To do this these groups require not only basic information about the inputs and outputs of the system, but also a framework within which this information can be processed and evaluated. This frame work has to be capable of allowing assessment of the performance in individual systems and permit comparisons with other systems and even other sectors of the economy to determine the relative utility of the initial investments and operational inputs.

Without such a framework and its associated set of indicators, performance assessment remains a subjective process that has little value for improving irrigation management. Yet, despite the frequently stated concerns with poor performance in the sector, there are few agreed indicators and no agreed framework for performance assessment.

3.2. Performance assessment

Irrigation performance assessment:

- Helps to know whether irrigation projects are performing in sustainable manner or not
- Has been prioritized as the most critical element to improve the irrigation system management (Albernethy& Pearce, 1987).
- Its importance has been understood in the last few decades (2-3) decades because of the failurity of most irrigation projects to deliver the expected performance level.

Performance assessment is a tool:

- to improve the level of service or operation between irrigation related institutions; and
- To improve the efficiency with which resources are being used.

In other words, the ultimate purpose of performance assessment is to achieve efficient, productive and effective irrigation and drainage systems by providing relevant feedback to management at all levels. As such, it may assist management or policy makers in determining whether performance is satisfactory and, if not, which corrective actions need to be taken in order to remedy the situation. To determine the related degree of satisfaction, a systematic and timely flow of actual (measured or collected) data on key parameters of a system must be compared with intended or limiting (critical) values of these data.

It is important to ensure that indicators that are selected to quantify the performance for a system describe performance in respect to the objectives established for that system. A meaningful indicator can be used in two distinct ways. It tells a manager what the current performance is of the system and, in conjunction with other indicators, may help him to identify the correct course of action to improve performance within that system. In this sense the use of the same indicator over time is important because it assists in identifying trends that may need to be reverted before the remedial measures become too expensive or too complex.

Good performance is not only a matter of high output, but also one of efficient use of available resources. According to Abernethy (1989) definition, the performance of a system is represented by its measured levels of achievement in terms of one, or several, parameters which are chosen as indicators of the system's goals. This definition carries with it a number of implicit assumptions/issues that are at the heart of the problem of performance assessment.

These are:

- Scale and audience: the "system" can be at a number of different levels, from the water delivery system upwards through the individual irrigation system, the irrigated agriculture system and up to national level. Each level has a set of goals that may or may not coincide, and each requires a different set of performance parameters.
- The extent to which performance is represented by the outputs from the system as opposed to the performance achieved in managing available resources towards specified goals. The distinction could perhaps be better demonstrated by referring to operational performance and strategic performance:
    - ✓ Operational performance is the degree of fulfillment of either a specific quantified output target, typified by such things as yield, water use efficiency, and cropping intensity, or a specific input target such as discharge, water level or timing of irrigation deliveries.
    - ✓ Strategic performance looks at the process by which available resources are utilized in order to fulfill the eventual outputs of the system, and involves assessment of the procedures by which targets are set in relation to both available resources and the objective setting process. This means that it includes evaluation of performance of individuals in matching objectives and targets, in identifying and utilizing performance parameters that effectively reflect those objectives, and in responding to unexpected changes in resource availability. While assessment of managerial performance is less neutral and more individual than assessment of output performance. it may more clearly identify ways in which performance can be improved.

3.3. Selected performance indicators

The performance of a system is represented by its measured levels of achievement in terms of one, or several, parameters which are chosen as indicators of the system's goals.

The distinction could perhaps be better demonstrated by referring to **operational performance** and **strategic performance.**

- **Operational performance** is the degree of fulfillment of either a specific quantified output target, typified by such things as yield, water use efficiency, and cropping intensity, or a specific input target such 'as discharge, water level or timing of irrigation deliveries. For comparative purposes between systems, output performance is frequently best expressed as a dimensionless ratio, or percentage.
- **Strategic performance** looks at the process by which available resources are utilized in order to fulfill the eventual outputs of the system, and involves assessment of the procedures by which targets are set in relation to both available resources and the objective setting process. This means that it includes evaluation of performance of individuals in matching objectives and targets, in identifying and utilizing performance parameters that effectively reflect those objectives, and in responding to unexpected changes in resource availability.

Selected indicators were defined to assess the performance of water management (in irrigation and drainage).

- **Water balance, water service and maintenance:** The indicators in this group refer to the primary function of irrigation and drainage; the provision of a water service to users.
- **Environment.** Both irrigation and drainage are man-made interventions in the environment to facilitate the growth of crops. The non-intentional (mostly negative) effects of this intervention are considered in this group.
- **Economics.** This group contains indicators that quantify crop yield and the related funds (generated) to manage the system.

- **Emerging indicators.** This group gives four indicators that contain parameters which need to be measured by use of satellite remote sensing. This emerging technology enables very cost-effective measurement of data.

The number of indicators needed for an assessment depends on boundary conditions and on the purpose of the assessment. It is recommended that performance is assessed from different perspectives.

Self-check 3	Written test

Instructions: I choose the best answer all the questions listed below. Write your answers in the sheet provided in the next page.

1. What is the difference between operational performance and strategic performance? (4 point)
2. What is the objective of irrigation performance assessment? (4 point)

Note: **Satisfactory rating - 4 points** **Unsatisfactory - below 4 points**

Score = ____________

Rating: _____________

Answer sheet

1.--

2. --

Operation sheet 1	Determine irrigation water need of the crop.

Step 1: Collect necessary hydro-meteorological data and analyze it.

Step 1: Determine the reference crop evapotranspiration: ETo

Step 2: Determine the crop factors: Kc

Step 3: Calculate the crop water need: ET crop = ETo × Kc

Step 4: Determine the amount of water needed to saturate the soil for land preparation: (LP)

Step 5: Determine the amount of percolation, runoff and seepage losses: (Loss)

Step 6: Determine the amount of residual soil moisture (SM)

Step 7: Determine the effective rainfall: Pe

Step 8: Calculate the irrigation water need: IN = ET crop + Loss + LP -SM–Pe

LAP-Test 1	**Practical demonstration**

1. Determine irrigation water requirement of the crop.

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