WATER POLLUTION AND ITS MANAGEMENT
UNIT IV
18CEO405T

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ROLE OF POLLUTION CONTROL BOARD

- Classifying water of the central/state
- Laying down, modifying or annulling effluent standards for (a) sewage/trade effluents (b) the quality of receiving water resulting from discharge of effluents
- Laying down standards of treatment of sewage/trade effluents to be discharges into a stream.
- Evolving economical and reliable methods of treatment of sewage/trade effluents, methods of utilization in agriculture, and efficient methods of disposal on land in certain cases;
- Reviewing the disposal system of sewage effluents, works and plants for sewage treatment or in connection with the grant of any consent;
- Making, varying or revoking any order (i) for prevention, control or abatement of discharge of waste into streams or wells (ii) requiring any person concerned to construct new systems for the disposal of sewage/trade effluents or to modify, alter or control water pollution.
- Advising the government(Central/State) with respect to the location of an industry whose operation is likely to result in water pollution.

ROLE OF POLLUTION CONTROL BOARD

- The Water Act prohibits any person from knowingly causing or permitting the entry of
- (i) any poisonous, noxious or polluting matter, directly or indirectly, into any stream or well or water or on land
- any other matter into any stream which may tend, either directly or in combination with similar matters, to impede the proper flow of the water of the stream in a manner leading or likely to a substantial aggravation of pollution due to other causes or of its consequences.
- CPCB/SPCB is responsible for determining whether the matter is poisonous, noxious or polluting or any other matter.

HIERARCHY - POLLUTION CONTROL BOARD

POWER OF POLLUTION CONTROL BOARD

- The central pollution control board is vested with the following powers:
- The Central Pollution Control Board (CPCB) is empowered by section 18 of the Water (Prevention and Control of Pollution) Act, 1974 to give directions to the state pollution Control boards.
- The CPCB has powers to perform any on the functions of the state pollution SPCB (State Pollution Control Board) in case of non-compliance of any directions given by the CPCB.
- The CPCB is empowered to issue directions under section 33A of Water Act, 1974 to direct the closure, prohibition or regulation of any industry, operation or process or the stoppage or regulation of supply of electricity, water or any other service.

POWER OF STATE POLLUTION CONTROL BOARD

- The SPCB has the following powers conferred on it by the Water (Prevention and Control of Pollution) Act, 1974:
- Power to obtain information (section 20)
- Power to take samples of effluents for analysis (section 21)
- Power of any entry and inspection
- Power to impose restrictions on new outlets and new discharges
- Power to refuse or withdraw consent for the establishment of any industry, etc (section 27)
- Power to carry out emergency operations in case of pollution of stream or well (section 32)
- Power to make applications to the courts for restraining apprehend pollution of water in streams or wells.
- Power to give directions

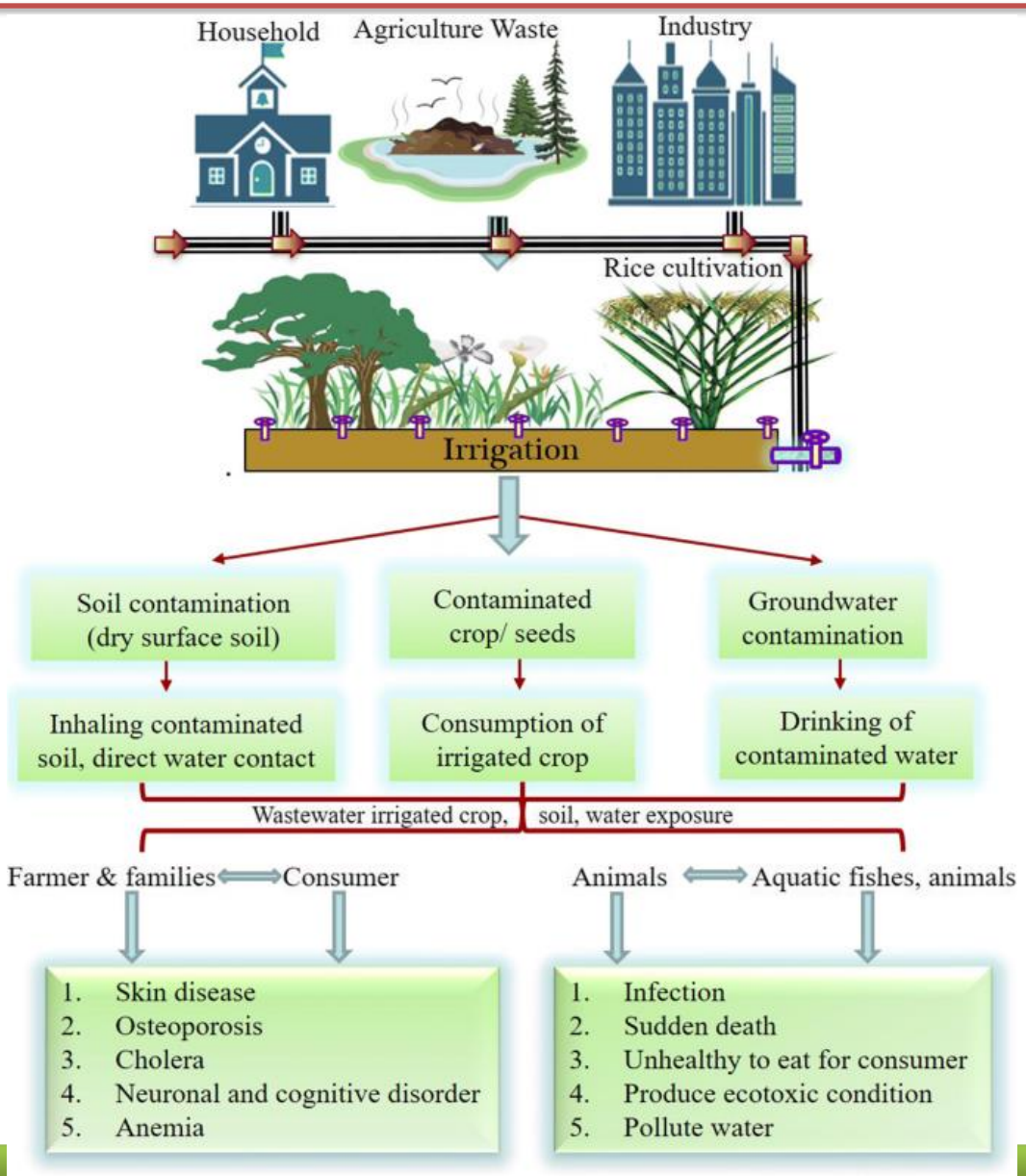
THE WATER CESS ACT, 1977

- The act came in existence on December 7, 1977. It provides for the levy and collection of a cess on water consumed by persons carrying certain industries and by local authorities, with the view to augment the resources of the Central and State Boards for prevention and control of water pollution.
- The Act extends to the whole of India except the State of Jammu and Kashmir. It is consisted of 17 sections. The salient features of the Act are as follows.
- 1. There shall be levied and collected a cess calculated on the basis of the water consumed. The cess shall be payable by
- (a) Every person carrying on any specified industry
- (b) Every local authority
- Schedules I and II of this Act give the list of specified industries and rates at which the cess is to levied respectively.
- Affixing meters for measuring water quantity used and the furnishing of returns for water use by the industry and local authority.

THE WATER CESS ACT, 1977

- 3. The proceeds of the cess levied shall first be credited to the consolidated fund of India and Central Government to pay Central and State Boards from time to time, from this proceed.
- Provision of penalty not exceeding the amount of cess in arrears, for non-payment of cess within the specified time. False return filing shall attract the penalty of imprisonment up to six months.
- The Central Government may make rules for carrying out the purposes of this Act.

IRRIGATIONAL APPROACH IN WASTEWATER CONSERVATION



IRRIGATIONAL APPROACH IN WASTEWATER CONSERVATION

Wastewater Irrigation

Benefits

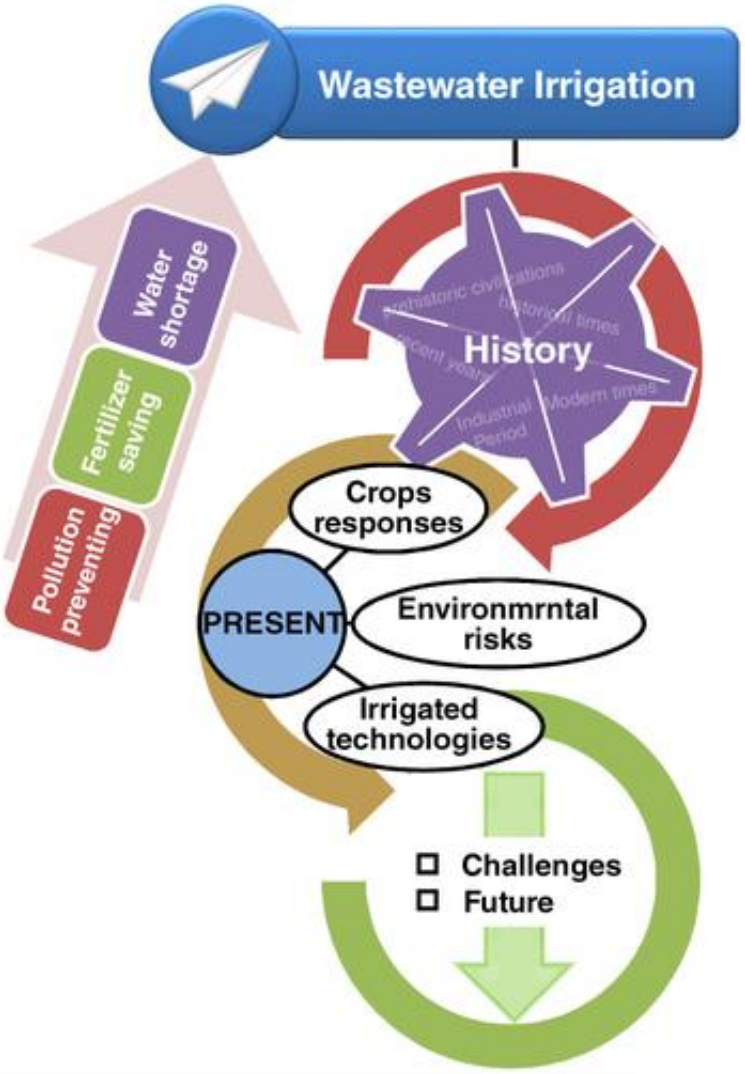
- Improved N, P, K levels in soil;
- Increased soil microbial activity;
- Enhanced soil organic matter;
- Better physical structure of soil;
- Reduced fertilizer application cost

Disadvantages

- Increased soil contamination;
- Increased foods contamination;
- Raised pathogens level;
- Raised nonmaterial;
- Increased antibiotics;
- Increased heavy metals in soil and

Wastewater

Urban water	Treated water	Reclaimed (recycled) water
Domestic effluent from commercial establishments Industrial effluent Storm water and other urban run-off	Processed by treatment plant up to certain standards in order to reduce its pollution or health hazard.	Treated wastewater that can officially be used under controlled conditions for beneficial purposes, such as irrigation.



LEGAL ACTION AGAINST DEFAULTER/POLLUTER

- The command and control approach towards water pollution is evident from the permit system under the Water Act.
- Consent of the CPCB/SPCB is required to establish any industry, operation or process, or any treatment and disposal system etc., which is likely to discharge sewage/trade effluent into a stream or well or on land, to use any new altered outlet or new sewage discharge.
- Contravention of these two provisions is punishable with imprisonment for a term between 18 months and six years as well as fine.

LEGAL ACTION AGAINST DEFAULTER/POLLUTER

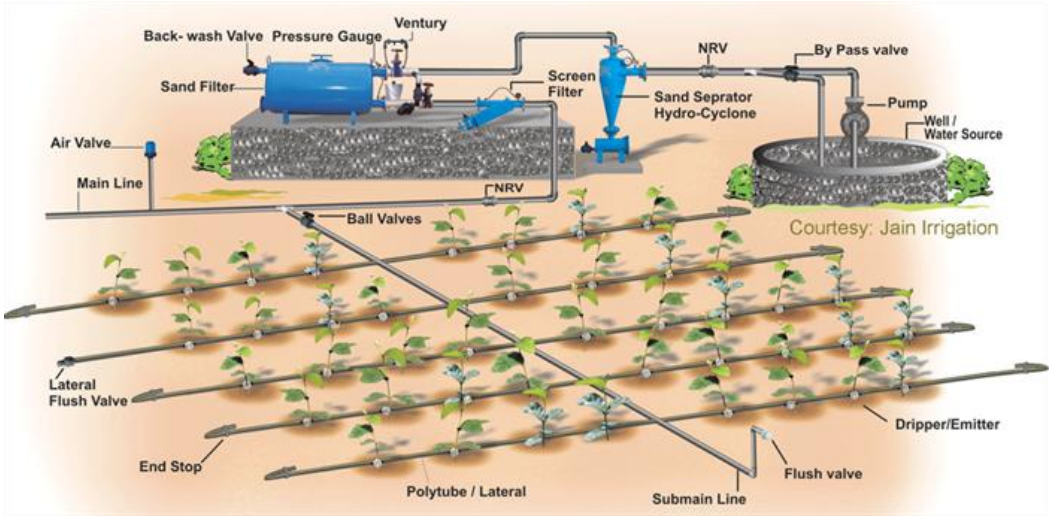
- CPCB/SPCB has been granted certain powers to prevent and control water pollution
- It can undertake certain emergency measures to remove and dispose the polluting matter, or to remedy or mitigate pollution caused by the polluting matter or issue orders immediately restraining or prohibiting the polluting activity.
- It can apply to the courts to restrain apprehended water pollution in streams and wells. The court may direct a potential polluter to desist from causing pollution or direct a potential polluter to desist from causing pollution or direct an actual polluter to remove the polluting matter.
- In case of non-compliance with the latter direction, the CPCB/SPCB may be authorized by the court to undertake the removal, disposal and recover the expenses from the polluter.
- It can direct closure, prohibit or regulation of any industry, operation or process, or to stop or regulate supply of water, electricity or any other service.

MANAGEMENT STRATEGY USED FOR WATER CONSERVATION

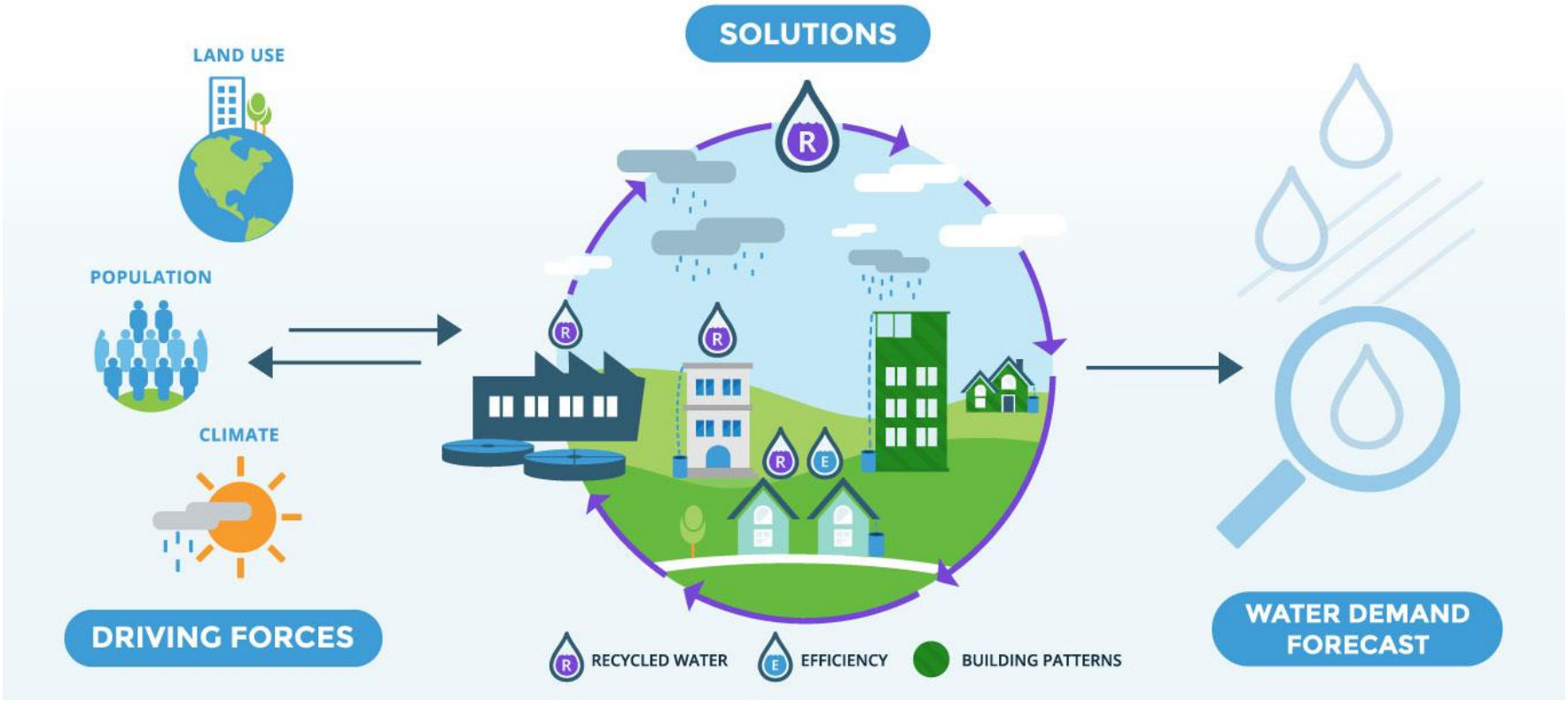
- Comprehensive approach to water resource management
- 1. Reduce overall use
- 2. Reducing water waste
- 3. Recycling used water for other purposes
- Water consumption:
- Modify agricultural water practices to minimize evaporation and seepage
- Industrial recycling and reuse of water on-site
- Making water conservation part of daily life.

MANAGEMENT STRATEGY USED FOR WATER CONSERVATION

- Water conservation refers to reducing usage of water and recycling of waste water for different purposes such as cleaning, manufacturing and agricultural irrigation.
- Water conservation includes the policies, strategies and activities to manage fresh water as a sustainable resource to protect the water environment and to meet current and future human demand.



MANAGEMENT STRATEGY USED FOR WATER CONSERVATION



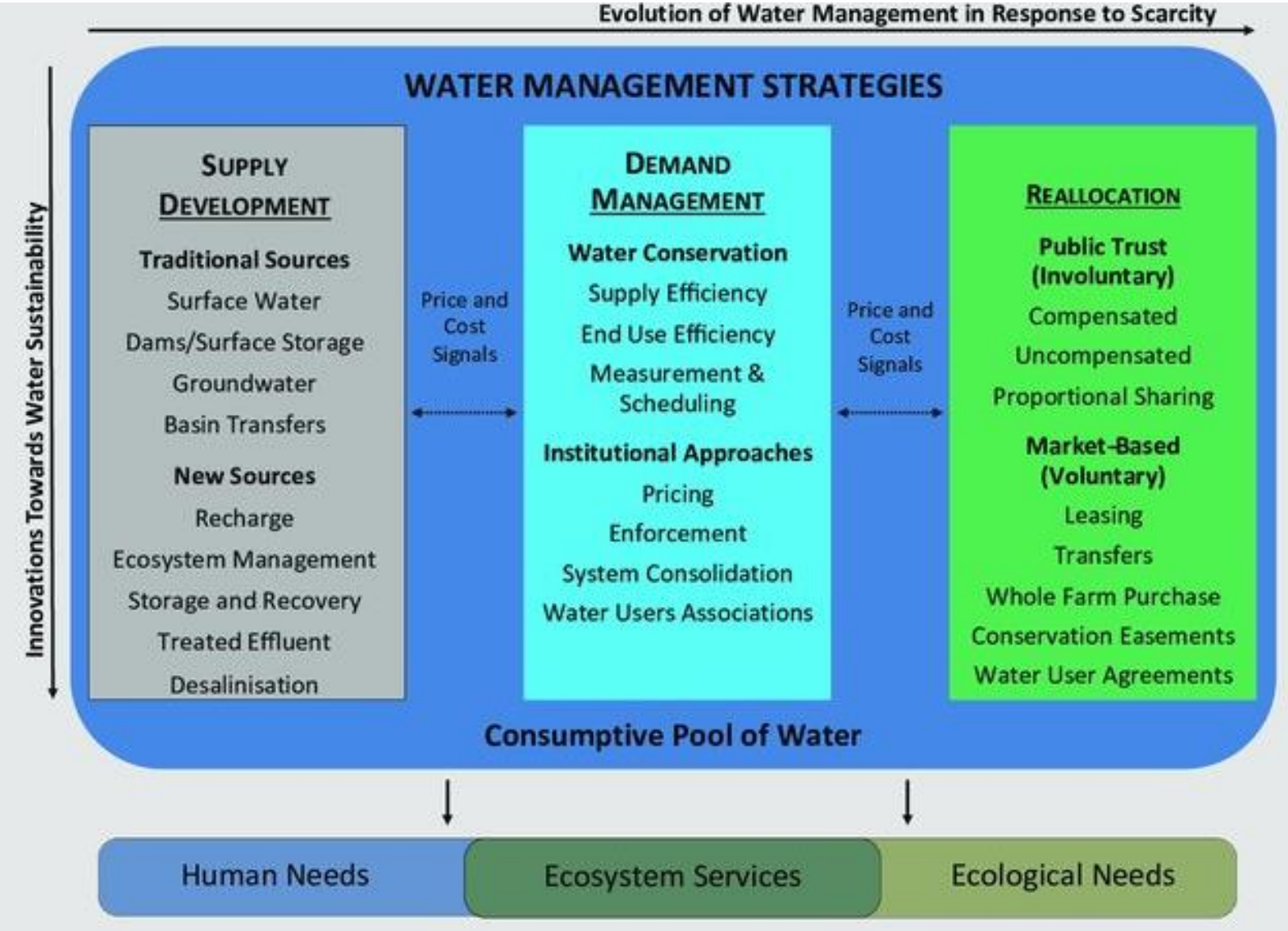
MANAGEMENT STRATEGY USED FOR WATER CONSERVATION

Aim	Strategy	Purpose	Techniques and structural measures
Improve water use efficiency by increasing water available to the plant roots	Soil and water conservation	Concentrate rainfall around crop roots	Bunds, ridges, broad-beds and furrows, micro basins, runoff strips Planting pits
		Maximize rainwater infiltration	Terracing, contour cultivation, conservation agriculture, dead furrows, staggered trenches
	Evaporation management	Reduce non-productive evaporation	Dry planting, mulching, conservation agriculture, inter-cropping, windbreaks, agroforestry, early plant vigor, vegetative bunds
	Water harvesting	Mitigate dry spells with supplementary irrigation, protect springs, recharge groundwater, enable off-season irrigation, and permit multiple uses of water	Surface micro dams, subsurface tanks, farm ponds, percolation dams and tanks, diversion and recharging structures
Improve water productivity by increasing productivity per unit of water consumed	Integrated soil, crop, and water management	Increase proportion of evapotranspiration flowing as productive transpiration and so obtain "more crop per drop"	Increase plant water uptake capacity through conservation agriculture, dry planting (early), improved crop varieties, optimum crop spacing, soil fertility management, optimum crop rotation, intercropping, pest control,

MANAGEMENT STRATEGY USED FOR WATER CONSERVATION

- Identify conservation goals
- Develop a water-use profile and forecast
- Evaluate planned facilities
- Identify and evaluate conservation measures
- Identify and assess conservation incentives
- Analyse benefits and costs
- Select conservation measures and incentives
- Prepare and implement the conservation plan
- Integrate conservation and supply plans, modify forecasts
- Monitor, evaluate, and revise program as needed.

MANAGEMENT STRATEGY USED FOR WATER CONSERVATION



MANAGEMENT STRATEGY USED FOR WATER CONSERVATION

Reduce water demand

Improve operational efficiency

Increase water supply

Management strategy used for water conservation

Improve water supply

Promote resource stewardship

MANAGEMENT STRATEGY USED FOR WATER CONSERVATION

- 1. Reduce water demand:
- **Agricultural water use efficiency:** Agricultural water use efficiency involves improvements in technologies and management of agricultural water that result in water supply, water quality, and environmental benefits. Efficiency improvements can include on-farm irrigation equipment, crop and farm water management, and water supplier distribution systems.
- **Urban water use efficiency:**
- Urban water use efficiency involves technological or behavioural improvements in indoor and outdoor residential, commercial, industrial, and institutional water use that lower demand, lower per capita water use, and result in benefits to water supply, water quality, and the environment.

MANAGEMENT STRATEGY USED FOR WATER CONSERVATION

- **2. Improve operational efficiency:**
- **Conveyance:** Conveyance provides for the movement of water. Specific objectives of natural and managed water conveyance activities include flood management, consumptive and non-consumptive environmental uses, water quality improvement, recreation, operational flexibility, and urban and agricultural water deliveries. Infrastructure includes natural watercourses as well as constructed facilities like canals, pipelines and related structures including pumping plants, diversion structures, distribution systems, and fish screens. Groundwater aquifers are also used to convey water.
- **System re-operation:**
- System re-operation means changing existing operation and management procedures for such water facilities as dams and canals to meet multiple beneficial uses. System re-operation may improve the efficiency of existing uses, or it may increase the emphasis of one use over another. In some cases, physical modifications to the facilities may be needed to expand the re-operation capability.

MANAGEMENT STRATEGY USED FOR WATER CONSERVATION

- **2. Improve operational efficiency:**
- **Water transfer:**
- **A water transfer is defined in the California Water Code as a temporary or long-term change in the point of diversion, place of use, or purpose of use due to a transfer or exchange of water or water rights. A more general definition is that water transfers are a voluntary change in the way water is usually distributed among water users in response to water scarcity. Transfers can be from one party with extra water in one year to another who is water-short that year.**

MANAGEMENT STRATEGY USED FOR WATER CONSERVATION

- 2. Increase water supply
- Conjunctive Management and Groundwater storage
- Conjunctive management is the coordinated operation of surface water storage and use, groundwater storage and use, and the necessary conveyance facilities. Conjunctive management allows surface water and groundwater to be managed in an efficient manner by taking advantage of the ability of surface to capture and temporarily store storm water and the ability of aquifers to serve as long term-storage.
- Desalination – Brackish/ Seawater
- Desalination is a water treatment process for the removal of salt from water for beneficial use. Desalination is used on brackish (low-salinity) water as well as seawater. In California, the principal method for desalination is reverse osmosis. This process can be used to remove salt as well as specific contaminants in water such as trihalomethane precursors, volatile organic carbons, nitrates, and pathogens.

MANAGEMENT STRATEGY USED FOR WATER CONSERVATION

- 2. Increase water supply
- **Precipitation enhancement**
- Precipitation enhancement, commonly called “cloud seeding,” artificially stimulates clouds to produce more rainfall or snowfall than they would naturally. Cloud seeding injects special substances into the clouds that enable snowflakes and raindrops to form more easily.
- **Re-cyled municipal water**
- Water recycling, also known as reclamation or reuse, is an umbrella term encompassing the process of treating wastewater, storing, distributing, and using the recycled water.
- **Surface storage Regional/Local**
- Surface storage is the use of reservoirs to collect water for later release and use. Surface reservoirs can be formed by building dams across active streams or by building off-stream reservoirs where the majority of the water is diverted into storage from a nearby water source.

MANAGEMENT STRATEGY USED FOR WATER CONSERVATION

- 2. Improve water quality
- **Drinking water Treatment and distribution**
- Drinking water treatment includes physical, biological, and chemical processes to make water suitable for potable use. Distribution includes the storage, pumping, and pipe systems to protect and deliver the water to customers.
- **Groundwater/Aquifer remediation**
- Groundwater remediation involves extracting contaminated groundwater from the aquifer, treating it, and discharging it to a water course or using it for some purpose. It is also possible to inject the treated water back into the aquifer.
- Contaminated groundwater can result from a multitude of sources, both naturally occurring and anthropogenic. Examples of naturally occurring contaminants include heavy metals, high TDS, and high salinity from specific geologic formations or conditions.
- Groundwater can also be contaminated from anthropogenic sources with organic constituents, inorganic constituents, and radioactive constituents from many point and non-point sources. These anthropogenic sources include industrial sites, mining operations, leaking tanks and pipelines, landfills, impoundments, dairies, agricultural and storm runoff, and septic systems.

MANAGEMENT STRATEGY USED FOR WATER CONSERVATION

- 2. Improve water quality
- Matching quality to use
- Matching water quality to water use is a management strategy that recognizes that not all water uses require the same quality water. One common measure of water quality is its suitability for an intended use, and a water quality constituent is often only considered a contaminant when that constituent adversely affects the intended use of the water.
- High quality water sources can be used for drinking and industrial purposes that benefit from higher quality water, and lesser quality water can be adequate for some uses, such as irrigation. Further, some new water supplies, such as recycled water, can be treated to a wide range of purities that can be matched to different uses.
- Pollution prevention
- Pollution prevention can improve water quality for all beneficial uses by protecting water at its source, reducing the need and cost for other water management and treatment options.
- By preventing pollution throughout a watershed, water supplies can be used, and re-used, for a broader number and types of downstream water uses. Improving water quality by protecting source water is consistent with a watershed management approach to water resources problems.

MANAGEMENT STRATEGY USED FOR WATER CONSERVATION

- 2. Improve water quality
- **Urban Run-off management**
- Urban runoff management is a broad series of activities to manage both storm water and dry weather runoff. Dry weather runoff occurs when, for example, excess landscape irrigation water flows to the storm drain. Urban runoff management is linked to several other resource strategies including pollution prevention, land use management, watershed management, water use efficiency, recycled water, protecting recharge areas, and conjunctive management (combined use of surface and ground water systems to optimize resource use and minimize adverse effects of using a single source).

MANAGEMENT STRATEGY USED FOR WATER CONSERVATION

- **2. Promote resource stewardship**
- **Agricultural land stewardship**
- **Agricultural lands stewardship broadly means conserving natural resources and protecting the environment by land managers whose stewardship practices conserve and improve land for food, fiber, watershed functions, soil, air, energy, plant and animal and other conservation purposes.**
- **It also protects open space and the traditional characteristics of rural communities. Further, it helps landowners maintain their farms and ranches rather than being forced to sell their land because of pressure from urban development.**

MANAGEMENT STRATEGY USED FOR WATER CONSERVATION

- **2. Promote resource stewardship**
- **Economic incentives:**
- **Economic incentives are financial assistance and pricing policies intended to influence water management. For example, economic incentives can influence the amount of use, time of use, wastewater volume, and source of supply.**
- **Economic incentives include low-interest loans, grants, and water pricing rates. Free services, rebates, and the use of tax revenues to partially fund water services also have a direct effect on the prices paid by the water users.**
- **Governmental financial assistance can provide incentives for resource plans by regional and local agencies. Also, government financial assistance can help water agencies make subsidies available to their water users for a specific purpose.**

MANAGEMENT STRATEGY USED FOR WATER CONSERVATION

- **2. Promote resource stewardship**
- **Ecosystem restoration:**
- **Ecosystem restoration can include changing the flows in streams and rivers, restoring fish and wildlife habitat, controlling waste discharge into streams, rivers, lakes or reservoirs, or removing barriers in streams and rivers so salmon and steelhead can spawn.**
- **Ecosystem restoration improves the condition of our modified natural landscapes and biotic communities to provide for the sustainability and for the use and enjoyment of these ecosystems by current and future generations.**

MANAGEMENT STRATEGY USED FOR WATER CONSERVATION

- **2. Promote resource stewardship**
- **Flood plain management:**
- **Floodplain management reduces risks to life and property and benefits natural resources. Floodplain management accepts periodic flooding and generally is a preferred alternative to keeping rivers in their channels and off floodplains.**
- **Seasonal inundation of floodplains provides essential habitat for hundreds of species of plants and animals, many of them dependent on periodic floods. There are also benefits to the economy, agriculture, and society to keeping rivers and their floodplains connected, including water quality improvements and groundwater recharge.**
- **Floodplain management also entails limiting the amount and type of development in a floodplain.**

MANAGEMENT STRATEGY USED FOR WATER CONSERVATION

- **2. Promote resource stewardship**
- **Recharge area protection:**
- **Recharge area protection includes keeping groundwater recharge areas from being paved over or otherwise developed and guarding the recharge areas so they do not become contaminated.**
- **Protection of recharge areas, whether natural or man-made, is necessary if the quantity and quality of groundwater in the aquifer are to be maintained. Existing and potential recharge areas must be protected so that they remain functional and they are not contaminated with chemical or microbial constituents.**
- **Urban landuse management**
- **Effective urban land use management consists of planning for the housing and economic development needs of a growing population while providing for the efficient use of water and other resources.**
- **The way in which we use land – the type of use and the level of intensity – has a direct relationship to water supply and quality.**

MANAGEMENT STRATEGY USED FOR WATER CONSERVATION

- **2. Promote resource stewardship**
- **Water dependent recreation:**
- **Water-dependent recreation includes a wide variety of outdoor activities that can be divided into two (2) categories.**
- **The first category includes fishing, boating, swimming, and rafting, which occur on lakes, reservoirs, and rivers.**
- **The second category includes recreation that is enhanced by water features but does not require actual use of the water, such as wildlife viewing, picnicking, camping, and hiking.**

MANAGEMENT STRATEGY USED FOR WATER CONSERVATION

- **2. Promote resource stewardship**
- **Watershed management:**
- **Watershed management is the process of evaluating, planning, managing, restoring, and organizing land and other resource use within an area of land that has a single common drainage point.**
- **Watershed management tries to provide sustainable human benefits, while maintaining a sustainable ecosystem. Watershed management assumes that a prerequisite for any project is the sustained ability for the watershed to maintain the functions and processes that support the native ecology of the watershed. This does not imply that a goal is to return to an undisturbed condition.**
- **Instead it implies an integration of human needs and environmental needs that allow the watershed to sustain ecological integrity over time while providing for sustainable community needs. It is recognized that watersheds are dynamic and the precise makeup of plants, animals, and other characteristics will change over time.**

INDUSTRIAL APPROACH IN WATER CONSERVATION

- **Reason to conserve water:**
- 1. Reduced costs—water costs account for 1–2 percent of a business' overhead. Saving water can help reduce overhead costs.
- 2. Increase in future water prices—water prices are set to rise above inflation. Saving water now will reduce costs in the future.
- 3. Production efficiency—using water efficiently will make additional water available for future production.
- 4. Tax benefits—many government agencies and water utilities provide rebates, grants, and tax relief to encourage water conservation. Tax benefits keep money where it belongs, in your pocket.

INDUSTRIAL APPROACH IN WATER CONSERVATION

- **Industrial approach in water conservation:**
- Water is a vital component of many industrial operations, and is utilized for a wide range of purposes in industrial processes. With an increasing requirement for water as a result of a reduction in the available water resources, it is becoming increasingly necessary to implement water conservation measures in industrial processes so as to guarantee sustainable industrial development.
- In recent years, there has been considerable development of systematic methods to minimize the use of freshwater and the production of wastewater by industry in response to increasingly stringent environmental regulations, economic driving forces and public concern over the quality of the environment.
- The process integration approach is one method that is often used to implement water recycling: in this approach, a flow of recycled water is used in an operation that produces a high level of contaminant.

INDUSTRIAL APPROACH IN WATER CONSERVATION

- **Industrial approach in water conservation:**
- Two main groups of methods are used for the systematic design of water-recovery networks: rigorous graphical targeting approaches and mathematical-based optimization techniques.
- A systematic approach to designing optimal water recycling in an industrial plant comprises two main tasks. The first task is to define the maximum amount of recycling that is possible, and the second task is to design alternative recycling networks that will allow the operations to meet the water recycling target.

INDUSTRIAL APPROACH IN WATER CONSERVATION

- **Industrial approach in water conservation:**
- Nearest-neighbor principle to design minimum freshwater networks for fixed contaminant load problems and fixed flow rate problems.
- The minimum water target using the water cascade analysis (WCA) technique, which is a numerical alternative to the graphical water targeting technique and can quickly yield an accurate estimate of the minimum water target, the pinch-point locations, and the water allocation target for maximum water recovery.

GROUNDWATER MANAGEMENT

- Groundwater management involves planning, implementation, and operation necessary to provide safe and reliable groundwater supplies. This necessitates groundwater management at a basin scale.
- Groundwater management objectives typically focus on aquifer yield, recharge, and water quality (i.e., groundwater quantity and quality) as well as on socio-economic, legal, and political factors. After the proper evaluation of available water resources in a basin and the preparation of alternative management plans, action decisions can be made by suitable government or public agencies.

GROUNDWATER MANAGEMENT

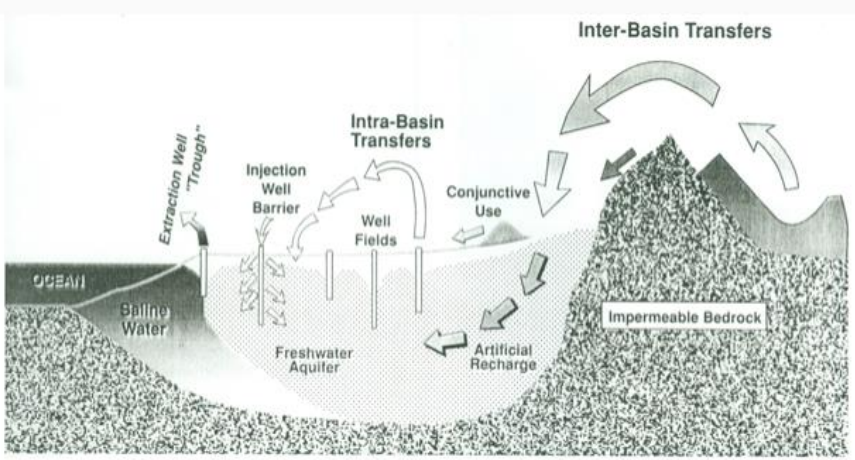
- **Basic concepts of groundwater management:**
- To manage a groundwater basin, a proper knowledge of the quantity of water that can be developed is a prerequisite. Determination of available water within a basin requires the evaluation of the elements constituting the water cycle. Therefore, the most fundamental approach to groundwater management is based on water balances within a groundwater basin. The water balance equation (or hydrologic budget) for a groundwater basin can be written as:

$$R + \frac{Q_i}{A} - ET - \frac{Q_o}{A} - \frac{Q_p}{A} = \pm \Delta S$$

- Where, R = recharge to groundwater [L/T], Q_i = surface-water inflow into groundwater storage in the basin [L^3/T], A = area of the basin [L^2], ET = loss of groundwater due to evapotranspiration [L/T], Q_o = groundwater outflow from the basin (groundwater outflow into surface water) [L^3/T], Q_p = total groundwater pumping from the basin [L^3/T], and ΔS = change of groundwater storage in the basin [L/T]. The values of these parameters are considered over a specific period of time for which the groundwater balance is sought.

GROUNDWATER MANAGEMENT

- **Salient features of groundwater management:**
- A well-organized plan is essential to any groundwater management program, because it relates all necessary tasks, resources and time. During the preparation of a groundwater management plan, the knowledge of possible management techniques plays an important role, among other information.
- Groundwater management techniques such as 'conjunctive use of surface water and groundwater', 'artificial recharge of groundwater and seawater barriers', 'interbasin transfer of water', 'intrabasin transfer of water', 'indirect recharge through avoidance of pumping', and 'control well fields'



GROUNDWATER MANAGEMENT

- **Conjunctive use of groundwater and surface water:**
- Conjunctive use of surface water and groundwater is a management technique designed t maximize the use of available water resources.
- The major objectives of conjunctive use technique are:
- (i) to maximize net benefits,
- (ii) to increase reliability of supply,
- (iii) to enhance overall efficiency of a water system, and
- (iv) to minimize the degradation of ecosystems/environment.
- It requires a coordinated operation plan for both surface water and groundwater designed to mee demands while ensuring maximum water conservation.
- Conjunctive use plans vary from percolation of natural stream flows to complex programs involvin inter and intrabasin water transfers, with facilities for recharge, extraction, and distribution.
- Some important benefits of conjunctive use are:
- (i) reduced surface-water storage facilities,
- (ii) water conservation,
- (iii) smaller surface-water networks, and
- (iv) less evaporation loss.

GROUNDWATER MANAGEMENT

- **Artificial recharge of groundwater and seawater barriers:**
- Storing surface water into underground formations as groundwater for future use is an established practice in a conjunctive-use program.
- Groundwater recharge is accomplished by inducing percolation of surface water, thereby replenishing underlying aquifers.
- When pumping near coastal areas creates depressions in groundwater levels, seawater migrates into the inland and contaminates underlying freshwater aquifers.
- Protection of coastal aquifers against seawater intrusion requires some kind of seawater barriers such as a ridge of 'protective groundwater elevations' constructed through the use of a line of injection wells (recharge wells) along the seashore or a 'pumping trough' to intercept intruding seawater.

GROUNDWATER MANAGEMENT

- **Interbasin transfer of water:**
- In many areas of the world, low precipitation rates, coupled with limited natural surface-water supplies necessitate the import of water from far distances. For example, the California aqueducts bring water hundreds of miles from the areas where surface water is abundant to the southern semi-arid region.
- This water is either consumed directly or stored in groundwater reservoirs for later recovery. This transfer of water can be done on a seasonal basis, and if sufficient surface-water supplies are available, it can change the dynamics of water utilization.
- Generally, the water management technique, 'interbasin transfer of water' involves huge expenses and raises serious environmental issues. Therefore, proper planning and analysis are essential prior to the adoption of this water management technique.

GROUNDWATER MANAGEMENT

- **Intrabasin transfer of water:**
- Complex geologic conditions exist in most groundwater development areas. For example, it may be possible to overdraft one area while excessively recharging another, and still not exceed the safe-yield values predicted by regional groundwater budget calculations.
- Therefore, a detailed basin investigation and analysis is necessary to delineate the areas of excess or deficiency and effectively design optimum pumping, distribution, and recharge programs. This management technique is usually less expensive and more environment friendly (i.e., reduced environmental impact) than the 'interbasin transfer of water.

GROUNDWATER MANAGEMENT

- **Indirect recharge through avoidance of pumping:**
- This is one of the innovative groundwater management techniques, which makes use of an indirect method of recharge. This technique encourages or requires groundwater users to purchase imported water instead of pumping groundwater.
- In fact, this is equivalent to recharging the basin by the quantity of water not pumped. Such water management programs are made effective by keeping the costs of imported water supplies equal to or less than the pumping costs. They are implemented periodically by groundwater basin managers to regulate groundwater levels.

GROUNDWATER MANAGEMENT

- **Control well fields:**
- Another technique used to conserve groundwater is through the use of 'control well fields'. Control well fields are strategically placed to produce interference effects for the control of hydraulic gradients and induce desirable groundwater-flow directions.
- Control well fields typically control outflow from basins or restrain contaminant plumes. Well head protection (WHP) strategy used in many developed countries is one example of groundwater management by using the technique of control well fields.
- Besides the above-mentioned groundwater management techniques, the specialized techniques like Soil-Aquifer Treatment (SAT) and River Bank Filtration (RBF) are also promising techniques, among others, for managing water-quality problems at a basin or sub-basin scale.

GROUNDWATER MANAGEMENT

- **Artificial recharge of groundwater:**
- In order to augment the natural supply of groundwater, people artificially recharge groundwater basins.
- Artificial recharge can be defined as "augmenting the natural movement of surface water into underground formations by some method of construction, by spreading of water, or by artificially changing natural conditions.
- Various methods have been developed for artificial recharge, including water spreading, recharging through pits and wells, and pumping to induce recharge from surface water bodies such as rivers and lakes.
- The choice of a particular recharge method depends on several factors such as local topography, geologic and soil conditions, amount of water to be recharged, and the ultimate use of water. Under special circumstances, the value of land, water quality, or climate can be important factors in the selection of recharge methods.

GROUNDWATER MANAGEMENT

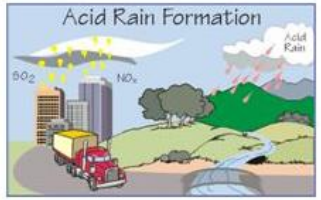
- **Artificial recharge of groundwater:**
- **(1) Maintain or augment the natural groundwater as an economic resource.**
- **(2) Coordinate operation of surface and groundwater reservoirs.**
- **(3) Combat adverse conditions such as progressive lowering of groundwater levels, unfavourable salt balance, or saline water intrusion.**
- **(4) Provide subsurface storage for locally available surplus surface water or imported surface water.**
- **(5) Minimize or prevent land subsidence.**
- **(6) Provide a localized subsurface distribution system for established wells.**
- **(7) Provide on-site treatment and storage for the reclaimed wastewater for subsequent reuse.**
- **(8) Conserve or extract energy in the form of hot or cold water.**

ENVIRONMENTAL INDICATORS

- Environmental indicators: Describe the behaviour of separate components of the environment (.g., air quality, water pollution, etc.,)
- Environmental indicators quantify and simplify information on environmental issues in order to make this information useable and publicly known.
- Environmental indicators most frequently represent a change in condition over a period of time or geographic area.
- Indicators that compare conditions over time (e.g trend analysis) are useful to illustrate factors such as extreme events, seasonal changes, and responses to management actions.

Environmental Indices

1. I_{GW} – global warming
2. I_{SF} – smog formation
3. I_{OD} – ozone depletion
4. I_{AR} – acid rain
5. I_{INH} – human inhalation
6. I_{ING} – ingestion toxicity
7. I_{CINH} -human carcinogenic inhalation
8. I_{CING} – carcinogenic ingestion toxicity
9. I_{FT} – fish toxicity



ENVIRONMENTAL INDICATORS

- Environmental indicator helps to provide an insight into the state of the environment or human health.
- Indicators are developed based on quantitative measurements or statistics of environmental condition that are tracked over time.
- Environmental indicators can be developed and used at a wide variety of geographic scales, from local to regional to national levels.
- By monitoring the environment using indicators, any government can better share meaningful environmental information with the public, and help ensure that high-quality environmental decisions are made by government and the public.

ENVIRONMENTAL INDICATORS

- Environmental indicators should be considered as a subset of sustainable development indicators which are meant to track the overall sustainability of a society with respect to its environmental, social and economic integrity and health.
- Environmental indicators are used by governments, non-government organizations, community groups and research institution to understand the trends in the environment.

ENVIRONMENTAL INDICATORS

- An environmental index is the combination of multiple sources of information about an environmental system from potentially varying attributes of that system (e.g. in stream processes, ecological processes, species richness, vegetation, etc.,)
- Environmental indices are typically developed to provide an overall snapshot of some feature of the environment system but they are also used to compare similar environmental systems.
- Construction of an environmental index requires careful consideration of several important aspects of the individual environmental indicators.

ENVIRONMENTAL INDICATORS

- **Steps involved in construction of environmental indices:**
- Defining a theoretical framework for supporting indicator selection
- Data preparation
- Standardization of the potentially disparate indicators so that they can easily be combined into an index.
- Weighting and aggregation of the individual indicators
- Robustness and sensitivity of the decisions made in constructing and environmental index.

TYPES OF ENVIRONMENTAL INDICATORS

- Indicators used to assess ecosystem health fall under one of three categories
- 1. Physical
- 2. Chemical
- 3. Biological
- Physical and Chemical indicators are measures of the physical and chemical components of the ecosystem, whereas biological indicators refer to organisms, species, or communities whose characteristics show the presence of specific environmental conditions.
- Air pollution indicators
- Biodiversity indicators
- Ecosystem integrity
- Sustainable use
- Climate indicators
- Energy indicators
- Water indicators

TYPES OF ENVIRONMENTAL INDICATORS

- **Air pollution indicators:**
- Ammonia emission, Heavy metal emissions
- **Biodiversity indicators:**
- Species of national interest
- Species diversity
- **Ecosystem integrity**
- Marine Trophic Index of seas
- Nutrients in transitional, coastal and marine waters
- **Sustainable use:**
- Forest: growing stock
- Agriculture: Nitrogen balance

- **Climate indicators**
- Production and consumption of ozone depleting substances
- Greenhouse gas emission trends
- **Energy indicators**
- Renewable primary energy consumption
- Progress on energy efficiency
- **Water indicators**
- Use of freshwater resources
- Nutrients in freshwater

WATER QULAITY INDEX

- Assessment of water quality can be a complex process undertaking multiple parameters capable of causing various stresses on overall water quality.
- To evaluate water quality from a large number of samples, each containing concentrations for many parameters is difficult.
- Traditional approaches to assessing water quality are based on the comparison of experimentally determined parameter values with the existing guidelines.
- Hence, water quality indices are such approaches which minimises the data volume to a great extent and simplifies the expression of water quality status.
- Water quality index can be evaluated on the basis of various physical, chemical and bacteriological parameters. Numerous water quality indices have been formulated all over the world which can easily judge out the overall water quality within a particular area promptly and efficiently.
- US National Sanitation Foundation Water Quality Index (NSFWQI), Canadian Council of Ministers of the Environment Water Quality Index (CCMEWQI), British Columbia Water Quality Index (BCWQI), and Oregon Water Quality Index (OWQI)

WATER QULAITY INDEX

- Role of Water Quality Index (WQI)
- WQI numerically summarizes the information from multiple water quality parameters into a single value.
- The single value can be used to compare data from several sites and also used to analyse the trends over a single site.
- Water quality Interpretation:

Water Quality Index Range	Water Quality Rating
90-100	Excellent
70-89	Good
50-69	Medium
25-49	Bad
0-24	Very Bad

BASIC PROCEDURES FOR WQI DEVELOPMENT

- 1. Variable selection
- 2. Variables transformation with the use of statistical techniques. Thus brings all the parameters into same scale and units.
- 3. Assigning weights. In general experts opinion is considered for assigning the weights.
- 4. Generate cumulative index
- 5. Assessment and water quality classification

TYPES OF WATER QUALITY INDEX

- 1. National Sanitation Foundation Water Quality Index (NSFWQI) :
- 2. Oregon Water Quality Index (OWQI):
- 3. British Columbia Water Quality Index (BCWQI)
- 4. Canadian Council of Ministers of the Environment (CCME) Water quality Index
- 5. Recreational Water Quality Index
- 6. Water Quality Index

TYPES OF WATER QUALITY INDEX

- **1. National Sanitation Foundation Water Quality Index (NSFWQI) :**
- **Brown et al. developed a water quality index paying great rigor in selecting parameters, developing a common scale, and assigning weights for which elaborate Delphic exercises were performed. This effort was supported by the National Sanitation Foundation (NSF) and that is why also referred as NSFWQI.**

Additive index- $\mathrm{WQI} = \sum_{i=1}^{n} W_i Q_i$

$\mathrm{I} = \sum_{i=1}^{n} I_i W_i$

Where, $\sum_{i=1}^{n} W_i = 1$, $\mathrm{I_i}$= Sub-index of each parameters, $\mathrm{W_i}$= Weighting factor, $\mathrm{Q_i}$ = is the rating value of parameter i and n= Number of sub-indices.

TYPES OF WATER QUALITY INDEX

- **Oregon Water Quality Index (OWQI):**
- OWQI expresses water quality by integrating measurements of eight water quality variables. The Oregon Water Quality Index, developed by the Oregon Department of Environmental Quality (ODEQ) in the late 1970s and updated several times since then is another frequently used WQI in public domain. OWQI was updated in 1995 by refining the original sub-indice, adding temperature and total phosphorus sub-indice, and improving the aggregation calculation.

$$\mathrm{WQI} = \sum_{i=1}^{n} SI_i W_i$$

- Where, SIi= Sub-index of each parameters, Wi= Weighting factor, n= Number of sub-indices.

TYPES OF WATER QUALITY INDEX

- **British Columbia Water Quality Index:**
- British Columbia water quality index was developed by the Canadian Ministry of Environment in 1995 as increasing index to evaluate water quality. This index is similar to Canadian Council of Ministers of the Environment Water Quality Index (CCMEWQI) where water quality parameters are measured and their violation is determined by comparison with a predefined limit (discussed in section vi below). It provides possibility to make a classification on the basis of all existing measurement parameters.

$$BCWQI = 100 - \left(\sqrt{\frac{F_1{}^2 + F_2{}^2 + F_3 / 3^2}{1.453}} \right)$$

- The number 1.453 was selected to give assurance to the scale index number from zero to 100.It is important to note that repeated samplings and increasing stations increase the accuracy of British Columbia index.

TYPES OF WATER QUALITY INDEX

- **Canadian Council of Ministers of Environment Water Quality Index (CCMEWQI):**
- **The Canadian Council of Ministers of the Environment(CCME) has developed a Water Quality Index (WQI) to simplify the reporting of complex and technical water quality data.**
- **The CCME WQI is a science-based communication tool that tests multi-variable water quality data against specified water quality benchmarks determined by the user.**

$$WQI = 100 - \left(\sqrt{\frac{F_1^{\,2} + F_2^{\,2} + F_3^{\,2}}{1.732}} \right)$$

Where:

F_1 represents Scope: The percentage of variablesthat exceed the guideline or the number of variables whose objectives are not met

F_1= [No. of failed variables /Total no of variables]*100;

F_2 represents Frequency: The percentage of individualtests within each variable that exceededthe guideline or the frequency by which the objectives are not met

F_2= [No of failed tests/Total no of tests]*100;

F_3 represents Amplitude: The extent (excursion)to which the failed test exceeds the guideline or the amount by which the objectives are not met

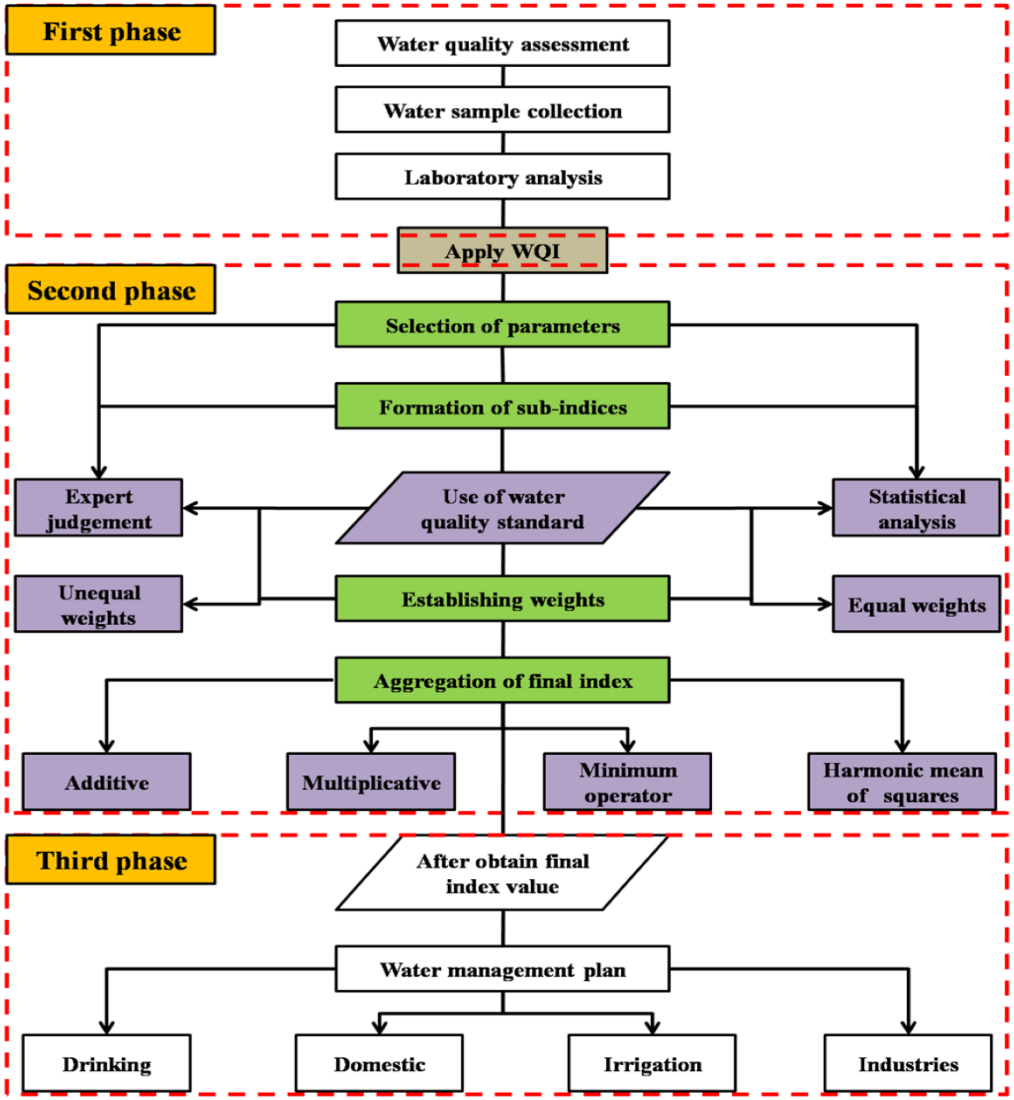
(a) $excursion_i$ = [Failed test value/$Objective_j$]-1

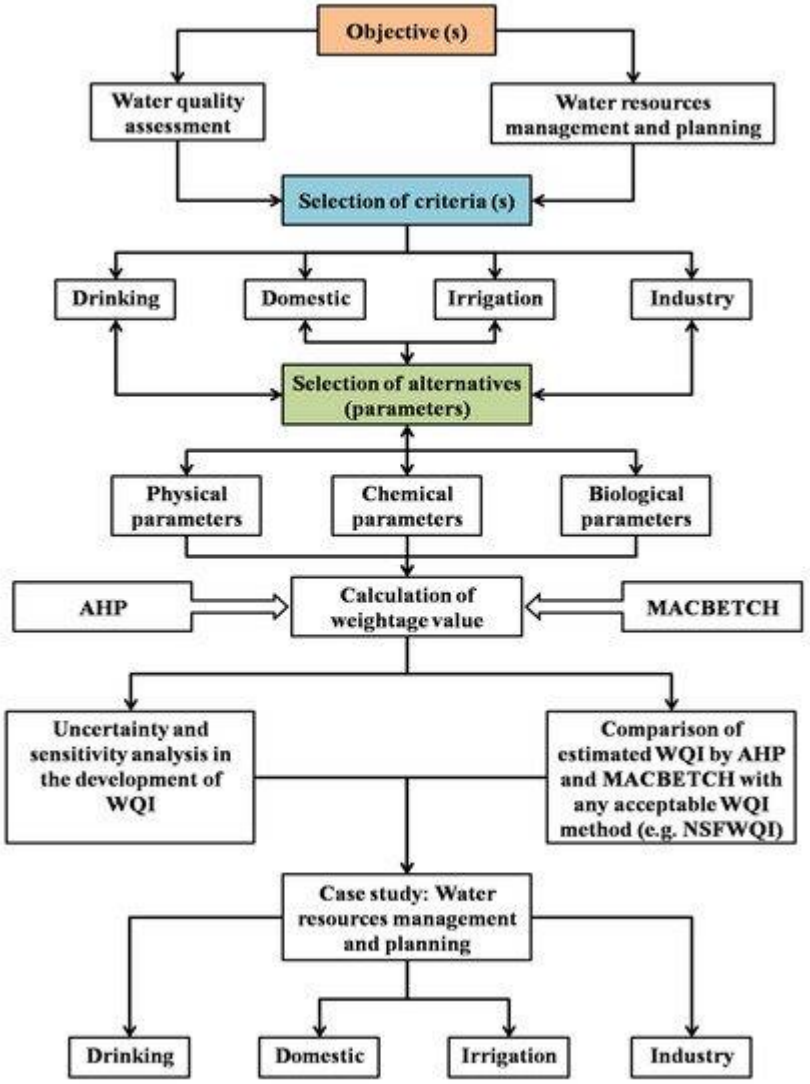
(b) nse = $\sum_{i=1}^{n} Excursion$/No of tests

(c) F_3= [nse/0.01nse+0.01]

The constant, 1.732, is a scaling factor(square root of three) to ensure the indexvaries between 0 and 100.

WATER QULAITY ASSESSMENT





PUBLIC PARTICIPATION IN WATER MANAGEMENT

- Water Quality at Home
- *Use Environmentally Friendly Cleaning Products*
- *Use Household Water Wisely*
- *Use Household Energy Wisely*
- *Compost Your Lawn Clippings, Yard Debris, and Food Wastes*
- *Recycle and Reuse Household Goods instead of Throwing Them in the Trash*
- *Be Mindful of Your Use of Pesticides, Herbicides, and Fertilizers in Home Landscaping*
- *Educate and Involve Your Children, and Set a Good Example*

PUBLIC PARTICIPATION ON WATER CONSERVATION

- **Awareness on water conservation**
  - Maintain and improve quality of water
  - Collection and treatment of waste water effluents
- **Pollution check**
  - Encourage natural regeneration of vegetation and supplementing with artificial regeneration
- **Sustainable water utilisation**
  - Minimise domestic water consumption
  - Recycling of waste water
  - Improved irrigation methods

PUBLIC PARTICIPATION ON WATER CONSERVATION

- **Rain water harvesting**
  - Roof top rainwater harvesting
  - Revival of traditional water harvesting structures
  - Micro-catchment water harvesting
  - Recharge structures for wells and bore wells
- **Strategies to support water conservation**
  - Some of the strategies that can support water conservation activities and tackle the water scarcity problem include:
  - Instead of waiting for somebody else to start conserving, let us, as an individual, take the first step towards conserving water
  - There are a lot of ways that we can conserve water at our home, industries and agricultural fields.
  - Wasting water has become a significant environmental problem, both at consumer and industrial levels.

PUBLIC PARTICIPATION IN WATER MANAGEMENT

- **Public Involvement**
- **Public participation can contribute to planning by providing:**
  - Incorporation of community values
  - Formulation of better plans
  - Assurance of reasonable costs
  - Public acceptance and support
  - Resolution of controversies over the plan.

PUBLIC PARTICIPATION TECHNIQUES

	Benefits	Drawbacks
Advisory Groups		
An advisory group consists of a group of citizens who give advice to an agency developing a plan.	• Transfers information to community and facilitates feedback • Formulates solutions • Clarifies goals, objectives, and issues • Increases access to representatives of varied interests	• Time-consuming participation • Some group members may dominate • Group may feel like a rubber stamp • Group may have difficulty establishing credibility • Group can become relied upon as sole public participation technique
Public Information Programs		
Public information programs are carried out on a continuing basis. Press releases, mailings, advertisements, displays, radio and television presentations, films, and legal notices are involved.	• Communicates basic information • Reaches a large number of citizens	• One-way communication • Can appear as "public relations" propaganda • Does not by itself constitute a public involvement program

PUBLIC PARTICIPATION TECHNIQUES

	Benefits	Drawbacks
Open Information Meetings		
Open information meetings present technical or programmatic elements to a general audience before or during the life of a project. Audiovisual presentations, briefings, and seminars are types of information meetings.	• Conveys information with opportunity for immediate public comment • Identifies problems and recommends courses of action • Presents opportunity to answer citizen questions	• Limitations on time which can be spent discussing issues • Domination of some participants • Often needs experienced and skilled staff to run effective meetings • Difficulty in conveying technical information at a meeting
Public Hearings		
Public hearings include a formal agency presentation, citizen presentation, and an official record of the proceedings. Public hearings are required in most governmental decision making.	• Provides forum for citizens to gain information or challenge decisions • Gives opportunity for formal, "official" comments	• One-way communication • Vocal minorities may dominate • Technique may appear as a token effort

PUBLIC PARTICIPATION TECHNIQUES

	Benefits	Drawbacks
Task Forces		
The task force aids in solving specific problems. It is usually linked to a large ongoing participatory body such as an advisory group.	• Focuses attention on specific issues • Can develop recommendations in short time • Promotes group interaction among different interests	• May not represent the public adequately • Sometimes requires a lot of staff time
Surveys		
Surveys can range from personal interviews to telephone and mail questionnaires.	• Provides direct contact with public • Reaches a larger number of people than are usually involved in projects • Can promote interest in a project	• Usually does not give opportunity for in-depth discussion • Personal and telephone interviews use up a lot of staff time • Unless carefully planned, surveys usually do not generate a significant response
Citizen Training		
Training is normally provided through short courses, workshops, and gaming simulations.	• Gives citizens a better understanding of technical issues • Better equips citizens to advise on projects • Enhances perspectives on project objectives, decisions, and constraints	• Reaches only a relatively few citizens • Difficult to plan and run an effective technical training program for citizens • May take on the appearance of "busy work"

AWARENESS OF DOMESTIC USAGE FOR CONSERVATION OF WATER

- The aim of raising public awareness for water issues is to engage the public in topics such as:
- water conservation; hygienic water use; or preservation of ecosystems.
- Other issues are the development of self-regulating water institutions, increasing the willingness to pay or contribute to water services; awareness for planning for emergencies; and strengthening political will.
- Ideally, public awareness is not a one-way communication, but an interaction of many active stakeholders, who influence each other and provide social control by mutually reinforcing agreed sets of values.
- Awareness can be raised through a variety of channels which should be coordinated in a bigger communications strategy.
- Those channels include water campaigns, engaging with environmental NGOs and community groups, making information available to the general public through inventories, for example, and providing information to the public through product labelling etc.

AWARENESS OF DOMESTIC USAGE FOR CONSERVATION OF WATER

- Product labelling or environmental certification is a useful tool for raising awareness.
- "Blue" and "green" labels have been used in water saving devices and eco-friendly products and services
- They have encouraged changes in consumption patterns and triggered industries to adopt new standards in often essentially traditional markets like plumbing fixtures or water conveyance

PUBLIC WATER CONSERVATION CAMPAIGNS

- Public water conservation campaigns raise awareness in all levels of society about the importance of saving water to cope with its scarcity and ensure sustainability.
- The aim is to change citizen attitudes and behaviour to improve water use efficiency.
- This is done through education and awareness campaigns on the socioeconomic and environmental benefits of water conservation and different conservation methods.
- Communication means include traditional and social media, as well as direct communication such as workshops, presentations, stakeholder dialogues, etc.
- Other means such as economic incentives can also be employed

Source: https://www.ctc-n.org/technologies/public-water-conservation-campaigns

PUBLIC WATER CONSERVATION CAMPAIGNS

- Campaigns can use a number of communication methods:
- Direct use of conventional media (printed media, TV, radio) and/or non-conventional media (messages on water bills, games, transport tickets, comic books, etc.), through the visual and performing arts;
- Organization of large events and/or endorsement by celebrities (generating media attention);
- Use of existing networks (religious networks, social movements, NGO networks, business associations);
- Use of logos (e.g. a water drop) to give identity to the campaign.

PUBLIC WATER CONSERVATION CAMPAIGNS

- **Public water conservation campaigns implementation**
- Preparation and execution of public awareness campaigns requires a multidisciplinary team, including water experts, building and construction experts, and social marketing, communication and outreach and education professionals.
- A thorough analysis of local public water systems and consumer habits is typically undertaken (often using household surveys) to identify potential water savings and primary targets for consumer behaviour patterns.
- This includes identification of main target groups for awareness campaigns, for example local water utility companies, households, workplaces, large businesses, etc.
- Campaigns can also establish water conservation goals to facilitate tracking of progress and achievement of objectives.
- Critical components of planning and executing a campaign include communication protocols and materials organization and production, and establishment of partnerships with media, schools, local NGOs, etc. for effective dissemination.

Source: https://www.ctc-n.org/technologies/public-water-conservation-campaigns

ENVIRONMENTAL BENEFITS OF PUBLIC WATER CONSERVATION CAMPAIGNS

- Reduces end water-use, in turn reducing pressures on water utilities, local freshwater sources and the environment.
- Requires less energy for abstraction, transport and treatment, mitigating greenhouse gas emissions.
- Socioeconomic Benefits
- Reduces water costs for utilities and end users.

Source: https://www.ctc-n.org/technologies/public-water-conservation-campaigns

OPPORTUNITIES AND BARRIERS OF PUBLIC WATER CONSERVATION CAMPAIGNS

- **Opportunities**
- Better understanding of water conservation is likely to promote greater sustainable behaviour amongst citizens
- Inclusive approach encourages stakeholders and organizations to engage and work together
- Results in climate resilience: adaptation and mitigation benefits, such as water source protection, water use reduction and mitigation of greenhouse gasses
- Relatively low cost-technology with wide reach

OPPORTUNITIES AND BARRIERS OF PUBLIC WATER CONSERVATION CAMPAIGNS

- **Barriers**
- Certain conservation techniques such as water recycling need associated education on correct use to ensure safety and minimizing health threats from potential contamination
- Success can be impeded due to public scepticism and lack of understanding about the impacts of personal water-use on overall supplies
- Success often relies on individual behaviour on private properties, which can be difficult to monitor and measure, revealing only changes in combined impacts

Source: https://www.ctc-n.org/technologies/public-water-conservation-campaigns