Water Requirements & Evapotranspiration

Information contained in this presentation came from the National Engineering Handbook Irrigation Guide

Water Requirements & Evapotranspiration

- Water requirements require a measurement of the rate of crop water use.
- Both short and long-term rates are important for proper irrigation designs and management.
- Two factors are involved in crop water usage.
  - Crop Evapotranspiration
  - Auxiliary special water needs

Water Requirements & Evapotranspiration

- Crop evapotranspiration is influenced by several major factors:
  - Plant temperature
  - Ambient air temperature
  - Solar radiation (sunshine duration/intensity)
  - Wind speed/movement
  - Relative humidity/vapor pressure
  - Soil water availability

Water Requirements & Evapotranspiration

- Direct measurement methods for ETc include:
  - Aerodynamic method
  - Detailed soil moisture monitoring
  - Lysimetry
  - Plant porometers
  - Regional inflow-outflow measurements

Water Requirements & Evapotranspiration

- Selecting the method to determine ET depends on:
  - Location, type, reliability, timeliness, and duration of climatic data.
  - Natural pattern of evapotranspiration during the year; and
  - Intended use intensity of crop evapotranspiration estimates.
- Four methods are recommended by the NRCS
  - Temperature method
  - Energy method
  - Radiation method
  - Evaporation pan method

Water Requirements & Evapotranspiration

- Reference Crops have already been established:
  - 2-year-old alfalfa at approximately 18 inches
  - Clipped grass 4 to 7 inches tall
- ETc = ETo x Kc
- Crop evapotranspiration = Potential evapotranspiration x Crop coefficient

Water Requirements & Evapotranspiration

- Crop evapotranspiration-

  The amount of water used by the crop in transpiration and building of plant tissue, and that evaporated from adjacent soil or intercepted by plant foliage. It is expressed as depth in inches or as volume in acre inches per acre. It can be daily, peak, design, monthly, or seasonal. Sometimes referred to as consumptive use (CU).

Water Requirements & Evapotranspiration

- Potential evapotranspiration **(ETo)**-

  The maximum Evapotranspiration that will occur when water is not limiting. In some methods of computing evapotranspiration, it is measured as evaporation of water from a free surface. When used as reference crop evapotranspiration, it is for either well watered short grass or alfalfa. Care should be used in determining which factors are used. Preferred term is reference evapotranspiration.

Water Requirements & Evapotranspiration

- Crop coefficient **(Kc)-** A factor used to modify potential evapotranspiration:

(1) Ratio between crop evapotranspiration (ETc) and the reference crop (ETo) when crop is grown in large fields under optimum growing conditions, or ETc = Kc times ETo.

(2) The ratio of the actual crop evapotranspiration to its potential evapotranspiration.

Water Requirements & Evapotranspiration

- Determining Kc values requires separating cropping seasons into specific growth and development periods.

  ***Initial*—**Between planting or when growth begins and approximately 10 percent ground cover.

  ***Crop development*—**Between about 10 percent ground cover and 70 or 80 percent ground cover.

  ***Mid season*—**From 70 or 80 percent ground cover to beginning of maturity.

  ***Late*—**From beginning of maturity to harvest.

Water Requirements & Evapotranspiration

- **Net irrigation water requirement (NIWR) -** The depth of water, exclusive of effective precipitation, stored soil moisture, or ground water, that is required for meeting crop evapotranspiration for crop production and other related uses. Such uses may include water required for leaching, frost protection, cooling, and chemigation.

Water Requirements & Evapotranspiration

- NIWR is defined as: (all values are depths, in inches)

  Fn = ETc + Aw – Pe – GW – ∆SW, where:

  - Fn = net irrigation requirement for period considered
  - ETc = crop evapotranspiration for period considered
  - calculations. These maps and tables would be local
  - Aw = auxiliary water-leaching, temperature modification, crop quality
  - Pe = effective precipitation during period considered
  - GW = ground water contribution
  - Precipitation maps
  - ∆SW = change in soil-water content for period considered

Water Requirements & Evapotranspiration

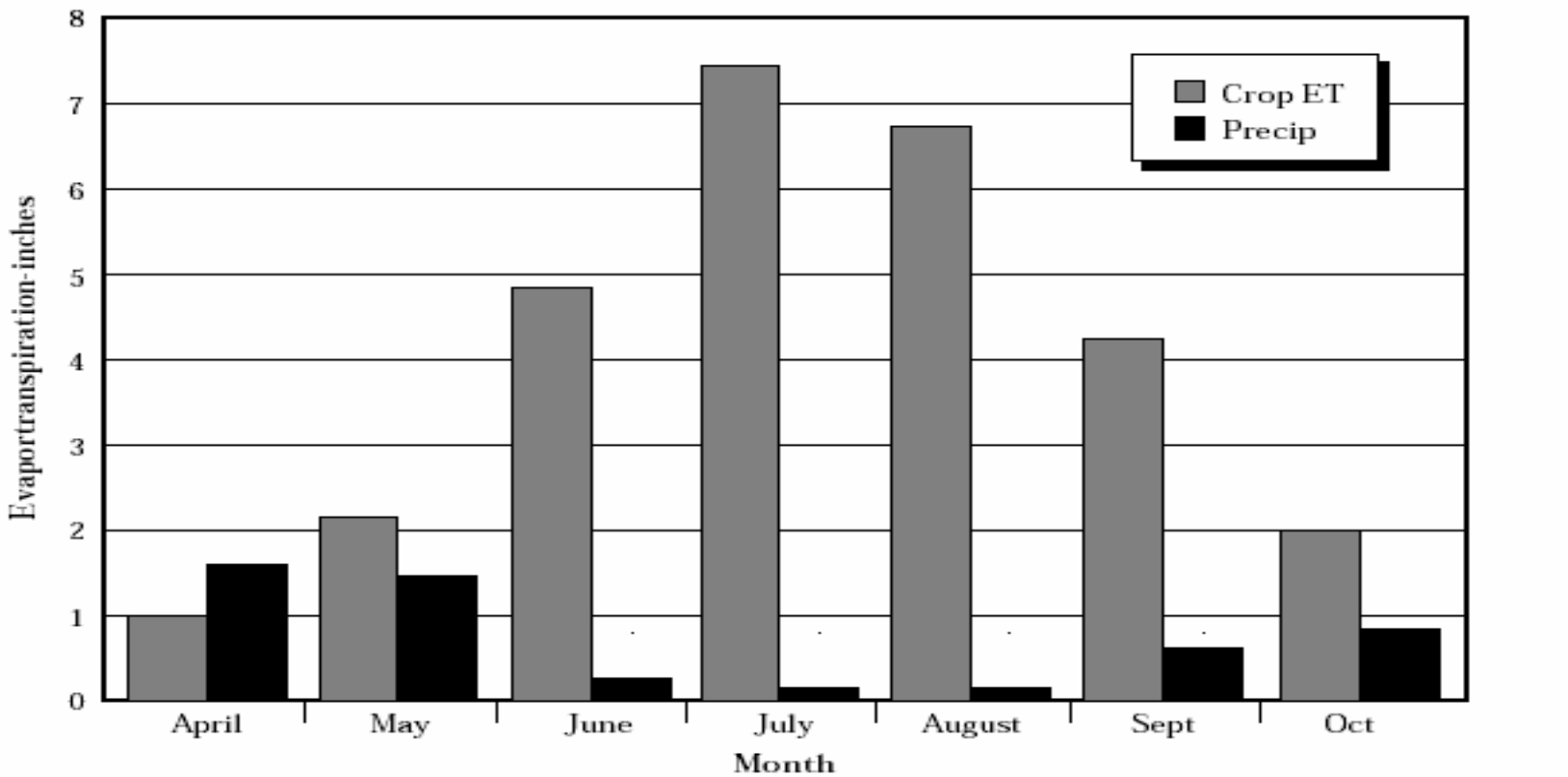
- Along with meeting seasonal irrigation needs, systems must also be able to supply water in drier periods.
- Water supply is often expressed in acre inches per hour which can be converted to gallons per minute.
- (1 ft^3/s = 1 ac-in/hr =450 gpm)
- (QT = DA) where:
  - Q = flow rate, acre-inch per hour
  - T = time, hours
  - D = depth, inches (water applied or crop ET)
  - A = area, acres

Water Requirements & Evapotranspiration

- ***Note:*** Where precipitation exceeds crop evapotranspiration, an opportunity exists for leaching of nutrients and pesticides. This may occur if soil moisture is at field capacity so that precipitation will provide the excess soil water available for leaching. These displays are then basic water budgets in graphic form.

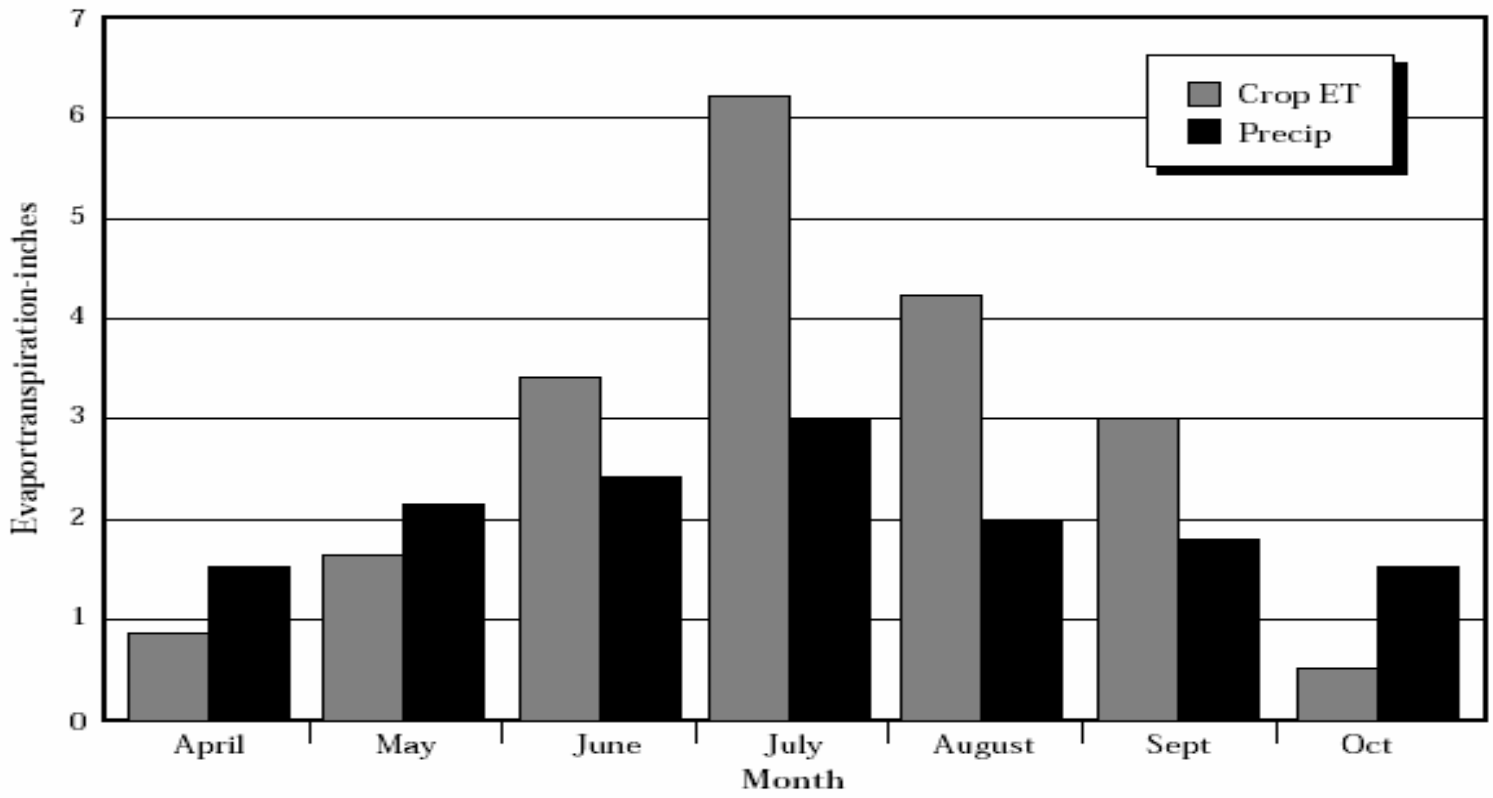
Water Requirements & Evapotranspiration

Figure 4–1 Example monthly crop evapotranspiration, arid climate in normal year



Water Requirements & Evapotranspiration

Figure 4–2 Example monthly crop evapotranspiration, subhumid climate in normal year



Water Requirements & Evapotranspiration

- Management Allowable Depletion (MAD)- MAD is the greatest amount of water to be removed by plants before irrigation so that undesirable crop water stress does not occur.
- Historically, an allowable depletion of between 30 and 60 percent of the soil Available Water Capacity (AWC) has been used for management purposes.

$$\frac{\text{MAD} \times \text{Total AWC for crop root zone in inches}}{\text{Daily } ET_c \text{ rate in inches/day}}$$

Water Requirements & Evapotranspiration

- Auxiliary special water needs include the following:
  - Leaching requirement for salinity and sodicity management
  - Frost protection (fruits, citrus, berries, vegetables)
  - Bud delay
  - Crop and soil cooling
  - Wind erosion and dust control
  - Chemigation
  - Plant disease control
  - Seed germination

Water Requirements & Evapotranspiration

- Water availability for irrigation is directly linked to its quality.
- It must be evaluated on its suitability for the intended use.
- Specific uses can have different water quality needs.
- If contaminants are present, type and concentration must be determined.

Water Requirements & Evapotranspiration

- Irrigation water contaminants in agriculture include:
  - Dissolved salts (salinity and sodicity)
  - Suspended sediment
  - Gypsum
  - Natural toxic elements
  - Nematodes
  - Water-borne diseases

Water Requirements & Evapotranspiration

- Tailwater from surface irrigation can be reused, however it to can have contaminants such as:
  - Agricultural fertilizers
  - Pesticides
  - Sediment
  - Organic material
  - Salinity
  - Chlorides

Water Requirements & Evapotranspiration

- Good quality water promotes maximum yield if good soil and water management practices are used. With lesser quality water, soil and cropping problems can be expected, unless appropriate management practices are adopted.
- High quality water may be required for irrigating certain specialty crops because of required crop quality or soil contaminant standards or to meet interstate transportation and marketing requirements. Nursery potted plants is one example.

Water Requirements & Evapotranspiration

- Physical contaminants and organic particles can adversely affect some irrigation systems. They also present challenges for design of screening devices that will satisfactorily remove contaminates.
- Physical contaminants include:
  - Suspended debris
  - Moss
  - Submersed aquatic plants and aquatic animals
  - Algae and Bacterial slime are organic particles
- Each of these can inhibit proper water flow.

Water Requirements & Evapotranspiration

- Physical barriers to lessen irrigation obstruction include:
  - Filters
  - Screens
  - Trash racks
  - Rotating screens
  - Flush filters

Water Requirements & Evapotranspiration

- Other water quality problems need to be considered:
  - Extreme temperature water
  - Tailwater
  - Drainage effluent
  - Pesticides
  - Toxic ions (ie., salts, heavy metals, and other elements)

Water Requirements & Evapotranspiration

Definitions associated with water requirements, evapotranspiration and water quality.

Water Requirements & Evapotranspiration

- **Algicide** Any substance that will kill or control algae growth.

Water Requirements & Evapotranspiration

- **Available water capacity (AWC)** The portion of water in a soil that can be readily absorbed by plant roots of most crops, expressed in inches per inch, inches per foot, or total inches for a specific soil depth. It is the amount of water stored in the soil between field capacity (FC) and permanent wilting point (WP). It is typically adjusted for salinity (electrical conductivity) and rock fragment content. Also called available water holding capacity (AWHC).

Water Requirements & Evapotranspiration

- **Evaporation** The physical process by which a liquid is transformed to the gaseous state, which in irrigation generally is restricted to the change of water from liquid to vapor. Occurs from plant leaf surface, ground surface, water surface, and sprinkler spray.

Water Requirements & Evapotranspiration

- **Non-saline sodic soil** A soil containing soluble salts that provide an electrical conductivity of the saturation extract (ECe) less than 4.0 mmhos/cm and an exchangeable sodium percentage (ESP) greater than 15. Commonly called black alkali or slick spots.

Water Requirements & Evapotranspiration

- **Saline soil** A non-sodic soil containing sufficient soluble salts to impair its productivity for growing most crops. The electrical conductivity (ECe) of the saturation extract is greater than 4 mmhos/cm, and exchangeable sodium percentage (ESP) is less than 15; i.e., non-sodic. The principal ions are chloride, sulfate, small amounts of bicarbonate, and occasionally some nitrate. Actually, sensitive plants are affected at half this salinity, and highly tolerant ones at about twice this salinity.

Water Requirements & Evapotranspiration

- **Saline-sodic soil** Soil containing both sufficient soluble salts and exchangeable sodium to interfere with the growth of most crops. The exchangeable sodium percentage (ESP) is greater than or equal to 15, and electrical conductivity of the saturation extract (ECe) is greater than 4 mmhos/cm. It is difficult to leach because the clay colloids are dispersed.

Water Requirements & Evapotranspiration

- **Sodic soil** A non-saline soil containing sufficient exchangeable sodium to affect crop production and soil structure (including soil intake) under most conditions of soil and plant growth. The lower limit of the saturation extract exchangeable sodium percentage (ESP) of such soils is conventionally set at 15.

Water Requirements & Evapotranspiration

- **Total dissolved solids (TDS)** The total dissolved mineral constituents of water.

Water Requirements & Evapotranspiration

- **Infiltration rate is** the downward flow of water into the soil at the air-soil interface. Water enters the soil through pores, cracks, wormholes, decayed-root holes, and cavities introduced by tillage. The rate at which water enters soil is called intake rate or infiltration rate.
- **Permeability** (1) Qualitatively, the ease with which gases, liquids, or plant roots penetrate or pass through a layer of soil (2) Quantitatively, the specific soil property designating the rate at which gases and liquids can flow through the soil or porous media.

Environmental Concerns

Environmental concerns

- Negative and positive environmental impacts are caused by irrigation. These impacts include:
  - Transport of chemicals
  - Consumptive use by plants
  - Pollution hazards by fertilizers, pesticides, fuels, and other contaminants
  - Obstructed wildlife migration patterns

Environmental concerns

- Water can transport chemicals through the soil and off the field.
- Runoff water from irrigation can carry sediment from soil erosion, nutrients, pesticides, animal waste, and other soil surface pollutants into surface water.
- In most cases quality of water from irrigation runoff is lower than that of the original supply. Pollutants can result in damages to other down-slope irrigated areas, to fish, wildlife habitat, cities, and industries.

Environmental concerns

- Water consumptively used by plants is not available for other in-stream uses.
- To understand the impacts on in-stream flows, ground water, and springs, consumptive use, non-consumptive use, and local water right laws must be understood as they apply to agricultural.

Environmental concerns

- Care in handling and storage of fertilizers, pesticides, fuels, lubricants, and solvents is necessary to avoid polluting ground and surface water.
- Care must be taken to prevent chemical and fuel spills at chemical and fuel storage facilities, chemical mixing areas, chemical application equipment wash areas, and especially at the irrigation pumping plant site.

Environmental concerns

- Some open channel irrigation water conveyance systems can obstruct normal wildlife migration patterns.
- In some areas, canal seepage and deep percolation in fields can dissolve naturally occurring toxic soil elements, such as salts and selenium. The toxic elements in the soil-water solution can then move into ground and surface water.

Environmental concerns

- The process by which a pollutant is detached and delivered to ground or surface water (and into air) takes place in three basic stages:
  - Availability
  - Detachment
  - Transport
- Pollution concerns from irrigation activities result from using an unsuitable irrigation system, using poor operation techniques, or making poor irrigation water management decisions,

Environmental concerns-Availability

- Pollutant materials must be available in a form that has the potential to become a concern.
- Chemicals, fertilizers, and pesticides vary not only in quantity, but in degree of their availability.
- Availability is often measured in half life (half life is when 50 percent of the original chemical is still available).
- The amount and placement of chemicals (availability) at the time a runoff or deep percolation event occurs are significant.

Environmental concerns-Detachment

- Pollutant materials must be detached from their original location (or made mobile) before they can become a pollutant in receiving water.
- Absorption, dissolving and detachment of chemicals in the soil mass and water, is dependent on:
  - Type of chemical and concentration in soil water solution
  - Strength of ionic bonding to soil particles
  - Quality of irrigation water and soil-water solution as to type and concentration of chemicals (salinity, pH), soil texture, organic matter content, soil erodibility, temperature, biological activity, pesticide persistence

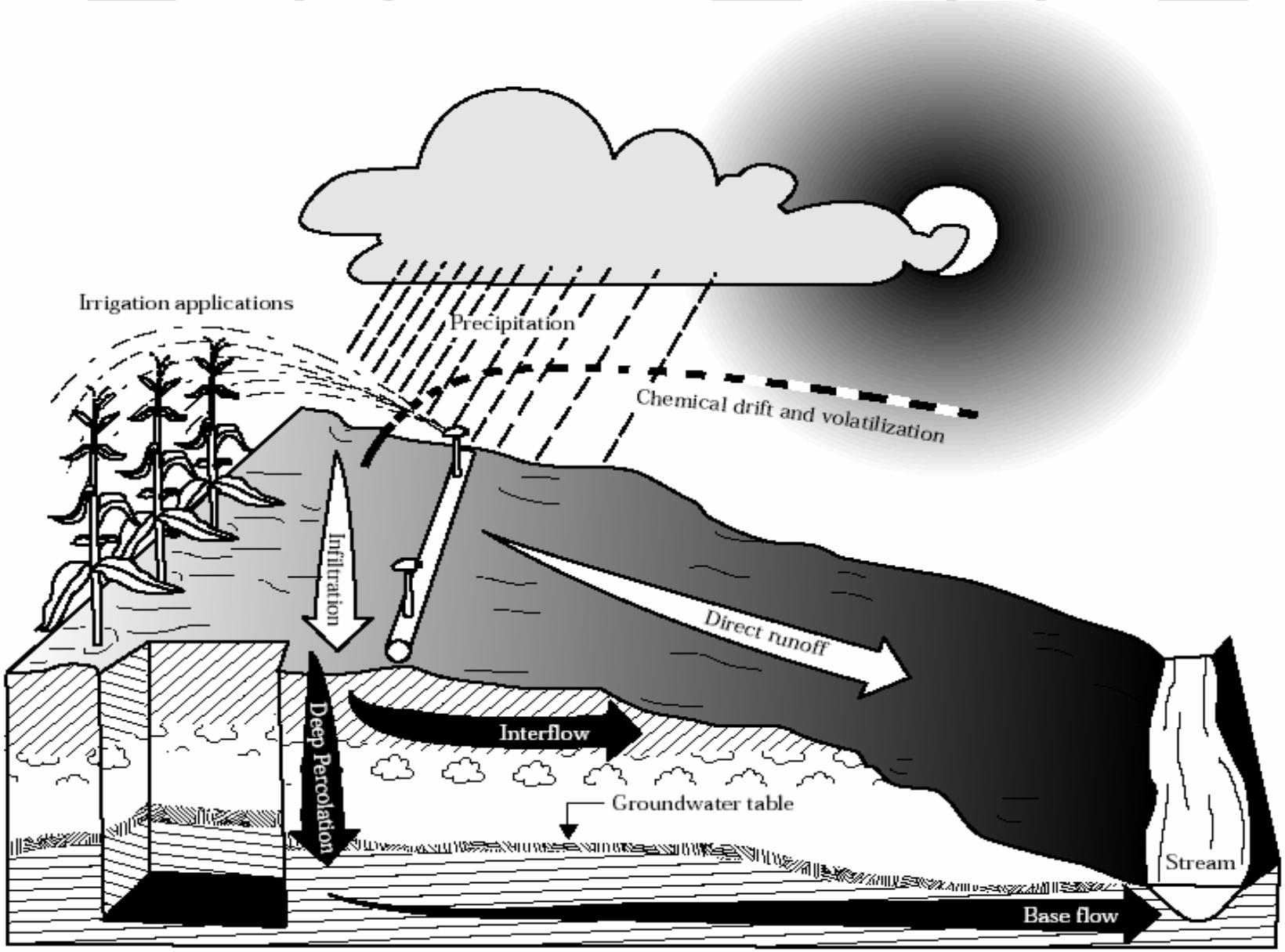
Environmental concerns-Transport

- Agricultural pollutants are typically transported in water as surface runoff or deep percolation.
- Some substances are lost through wind drift and volatilization when using sprinkle irrigation systems for chemigation.
- The particular pathway by which a pollutant leaves the field depends on the soil, hydrology of the field, irrigation system used, and level of irrigation water management.

Environmental concerns

- Factors affecting chemical pollutant availability,

Availability	Soil, land use, substance input, management practices.
Detachment	Irrigation application rate, furrow and border inflow stream rates, soil erodibility, soil bonding of chemicals, and surface condition (cover, residue, clodiness, surface depressions).
Transport	Runoff energy, runoff volume, sediment particle size and specific gravity, organic matter of surface soil, water holding capacity of upper soil profile and vadose zone, infiltration of soil surface, hydraulic conductivity characteristics of soil profile and vadose zone, and chemical properties of soil profile and vadose zone.
Site	Undulating topography, vegetation in flow path, distance of flow path to surface stream and/or depth to water table, concentration in water of particulate, organic and inorganic materials.


Irrigation applications
Precipitation
Chemical drift and volatilization
Infiltration
Direct runoff
Deep Percolation
Interflow
Groundwater table
Stream
Base flow

Environmental concerns

Types of pollutants

Particulates	Organics	Inorganics
Sediment sand silt clays	**Livestock waste** manure bedding and litter material spilled and undigested feed fecal coliform **Plant residue**	**Chemicals** fertilizers—nitrates, phosphorus, potassium pesticides—herbicides, insecticides, fungicides, miticides, nematicides **Salts** sodium, calcium, magnesium, potassium, carbonates, bicarbonates, sulfates, chlorides **Other** boron, arsenic, selenium, heavy metals, engine fuel, lubricants, pumping engine exhausts

Environmental concerns

- Conservation practices for pollution control and reduction.
- Potential pollutants can be controlled or eliminated by:
  - Reducing or eliminating the source
  - Reducing availability
  - Decreasing detachment or transport process

Environmental concerns

Pollution control

- Reduction of source
  - Nutrient management
    - A soil testing program can show residual amounts of fertilizer available, thereby avoiding overapplication.
  - Pest management
    - Application of pesticides should be coordinated with irrigation applications to allow necessary time to be effective in controlling pests without being washed from the surface of leaves by spray.

Environmental concerns
Pollution control

- Reduction of availability:
- The irrigation decision maker can optimize nutrient availability by:
  - Managing fertilizer through proper rates and timing
  - Monitoring the buildup of available nutrients in the crop root zone
  - Incorporating fertilizers
  - Using proper irrigation water management

Environmental concerns

Pollution control

- Reduction in detachment:
  - The loss of nutrients and pesticides by detachment of soil particles (i.e., erosion) is important for inorganic chemicals whose major environmental chemical forms are strongly or weakly held by soil particles.
  - Increased soil organic matter decreases the potential for detachment of nutrients and pesticides.
  - Erosion control is an essential component of a resource plan.

Environmental concerns

Pollution control

- Reduction in transport:
  - Chemicals that dissolve readily are transported easily with excess irrigation water.
  - Chemigation near the end of an irrigation application helps keep chemicals near the soil surface.
  - Onfield soil erosion with furrow irrigation systems can be controlled by:
    - Using proper furrow inflow streams, reducing irrigation grades
    - Maintaining crop residue on the soil surface with adequate crop rotations and conservation tillage methods and equipment
    - Reducing tillage operations

Environmental concerns

Pollution control

- Tools for planning and followup include:
  - Determining soil and irrigation water salinity levels; i.e. electrical conductivity of soil-water extract (ECe) and irrigation water (ECi).
  - Determining nitrogen content of animal waste.
  - Quick readings of in situ soil moisture; i.e., neutron moisture gauges (probes), tensiometers, TDR probes, electrical resistance blocks, feel and appearance of soil, and Speedy Moisture Meter.
  - Quickly and easily determining stream flow using digital current meters.
  - Measuring stream flow depth using resistance tapes or pressure transducers.
  - Providing on-the-spot analysis and information using laptop computers and portable printers.

Environmental concerns

Benefits of Irrigation

- Environmental and socioeconomic benefits from irrigation can include contributions to:
  - Local and national economies
  - Livestock capacity
  - Alternative use of potential pollutants
  - Utilization of agricultural and municipal wastes
  - Activities involving small farm ponds
  - Activities involving large storage reservoirs
  - Ground water and wet areas
  - Local climate and aesthetics
  - Wind erosion prevention

Environmental concerns

Costs and Benefits

- Costs consist of:
  - Actual cost of installing irrigation and waste management systems and associated conservation practices
  - Cost of operation and maintenance of systems and practices.
  - Cost of capitol (money used) used to purchase, install, and operate systems. Interest on borrowed money or money diverted from other investments is a project cost.