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Irrigation Systems and Schemes

Irrigation Systems in Bulgaria.
Structure and Elements of an Irrigation System.
Classification of Irrigation Systems

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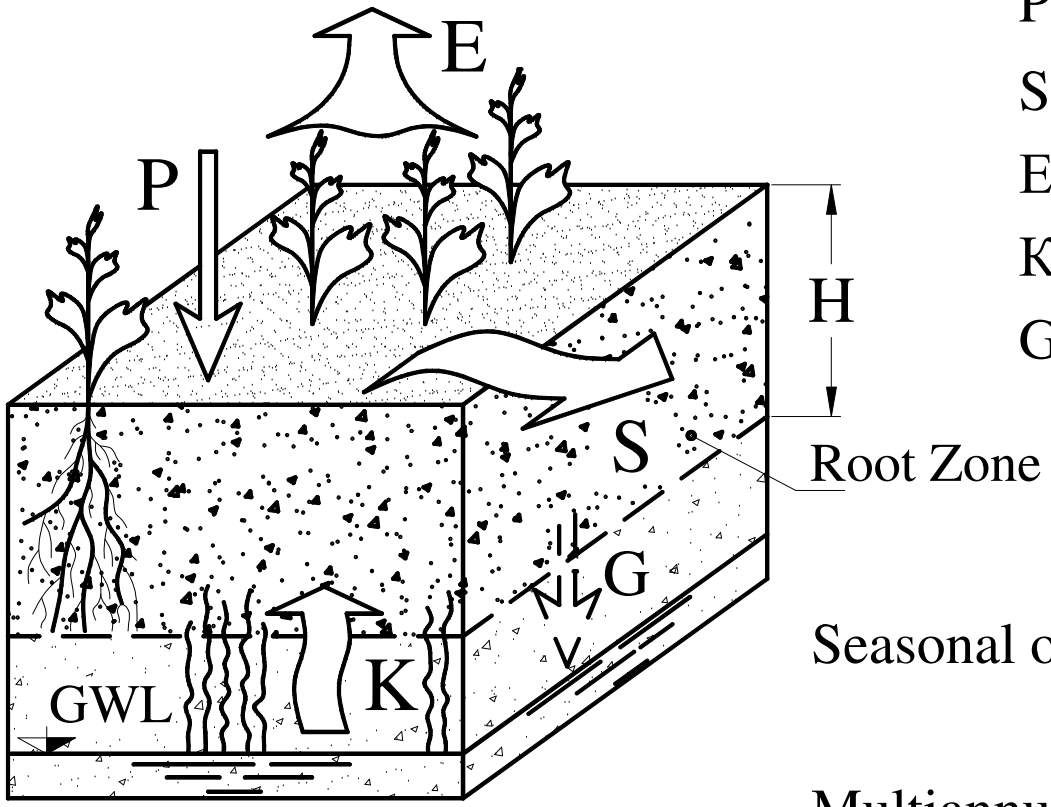
1. General Information

- ***Irrigation*** – artificial application of water to soil according to crop requirements during the vegetation (crop) period.
- **Crops** use water from the soil, so the soil can be regarded as a reservoir.
  - ➢ the soil reservoir should be filled up in a regular basis
  - ➢ there are 2 major ways to fill in the soil reservoir:
    - ✓ by rainfall
    - ✓ by irrigation

1. General Information

- **Necessity of Irrigation**
  - ➢ Based on *Inflow to Outflow* Ratio
    - ✓ Soil volume – e.g. 1 ha area, 1 m depth



P – Precipitation;

S – Surface Runoff;

E – Evapotranspiration;

K – Capillary Rise

G – Gravitational water

$$Inflow = P + K$$

$$Outflow = E + S + G$$

Seasonal or annual ratio: $\eta_i = \frac{Inflow}{Outflow}$

Multiannual mean value: $\eta = \frac{\Sigma \eta_i}{n}$

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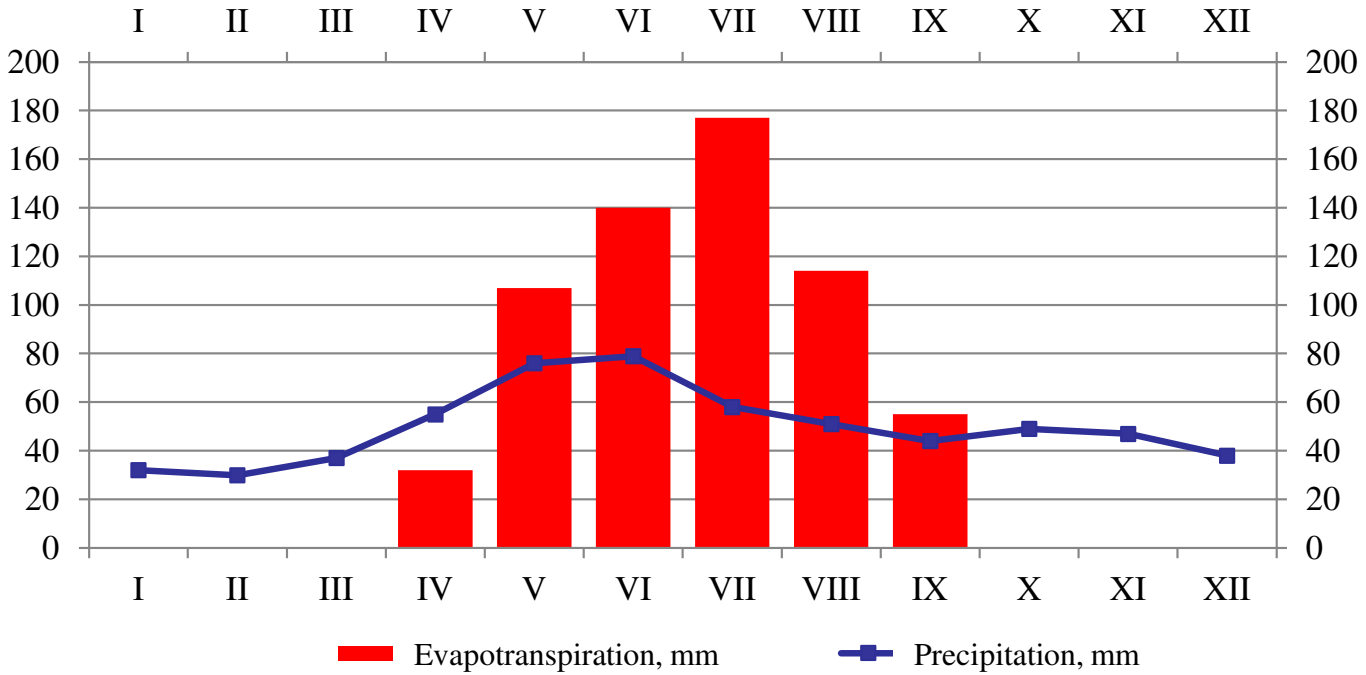
1. General Information



N.B. Average data for Bulgaria.
ET is estimated only for the crop period.

- If $\eta > 1$ – superfluous water; necessity of ***drainage***
  - ✓ Excess rainfalls and/or bad natural drainage (e.g. impervious soil);
- $\eta < 1$ – insufficient water; necessity of ***irrigation***
  - ✓ Lack of or insufficient rainfalls; due to high soil permeability;
- $\eta_i > 1$ **and** also $\eta_i < 1$ for different years – ***transitional case*** – *sometimes irrigation, sometimes drainage is needed.*

1. General Information

- It is possible to have $\eta \approx 1$ on annual basis, but to have the rainfall only outside the crop period ($\eta < 1$ for crop period).

- **Semi-arid areas** – areas, where the rainfall is almost sufficient or it makes possible growing of (some) crops without irrigation.
  - the irrigation is known as ***supplementary irrigation***
  - *in Bulgaria* **wheat** can be grown without irrigation
    - nowadays **sunflower** is grown as a "**rainfed**" crop
    - in some years and in some regions **maize** is also **rainfed** crop

- **Arid areas** – where the rainfall is insufficient and the irrigation is a must for agriculture.
  - in these areas all the yield is a result of irrigation

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1. General Information

- **Effect of Irrigation on Yield of Major Crops in Bulgaria**

Crop	Yield (rainfed)	Yield (irrigated)	Additional Yield	Average Irrigation Requirement M_{avrg}
	t/ha	t/ha	t/ha	m3/ha
Wheat	3,0 - 3,5	4,0 - 5,0	1,0 - 1,5	600
Corn (Maize)	4,0 - 5,5	9,0 - 11,0	5,0 - 5,5	2000
Sunflower	1,5 - 2,8	3,0 - 4,0	1,2 - 1,5	1200
Sugar beet	35,0 - 55,0	50,0 - 75,0	15,0 - 20,0	2400
Alfalfa	5,0 - 8,0	9,0 - 16,0	4,0 - 8,0	2400
Soy bean	1,0 - 2,0	2,5 - 4,0	1,5 - 2,0	2400
Gherkins	2,5 - 3,0	25,0 - 30,0	23 - 27	3000
Tomatoes	3,0 - 4,5	35,0 - 45,0	32 - 40	3600
Pepper	2,5 - 3,5	25,0 - 35,0	23 - 32	4200
Cabbage	5	40	35	3200
Potatoes	6,0 - 11,0	15,0 - 21,0	9,0 - 10,0	1800
Apple	5,0 - 7,0	15,0 - 20,0	10,0 - 13,0	3000
Peach	7,5 - 10,0	17,5 - 18,0	8,0 - 10,0	2400
Wine Grape	5,5 - 6,0	9,0 - 9,5	3,5 - 4,5	1800
Strawberries	3,0 - 5,0	9,0 - 15,0	6,0 - 10,0	3600
Forages	15 - 25	40 - 55	25 - 30	2300

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1. General Information

- Irrigation is regarded as an activity of *general public benefit (interest)*
  - Irrigation water delivery is not profitable in lots of places in the world
- **Benefits and ill effects of irrigation**
  - **Benefits**
    - ✓ A tool for Draught Management
    - ✓ Increase of crop yields (in some instances – assures all yields)
      - National economy development and general prosperity
      - Sustainable economy
    - ✓ Possible multipurpose use of water
      - e.g. Hydro-power generation + Irrigation

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1. General Information

- **Benefits (not typical for Bulgaria)**
  - ✓ Domestic Water Supply + Irrigation
  - ✓ Inland navigation (need of huge canals)
  - ✓ Afforestation
- **Ill effects**
  - ✓ Water pollution with nitrates, phosphates, etc. from fertilizers
    - polluted water goes to groundwater and to surface water (rivers, lakes, etc.)
  - ✓ Salinization of soil – in hot climates
  - ✓ Water-logging due to over-irrigation (yields decrease)

1. General Information

- **Basic Equitation of Irrigation**

$$F.M = Q.T$$

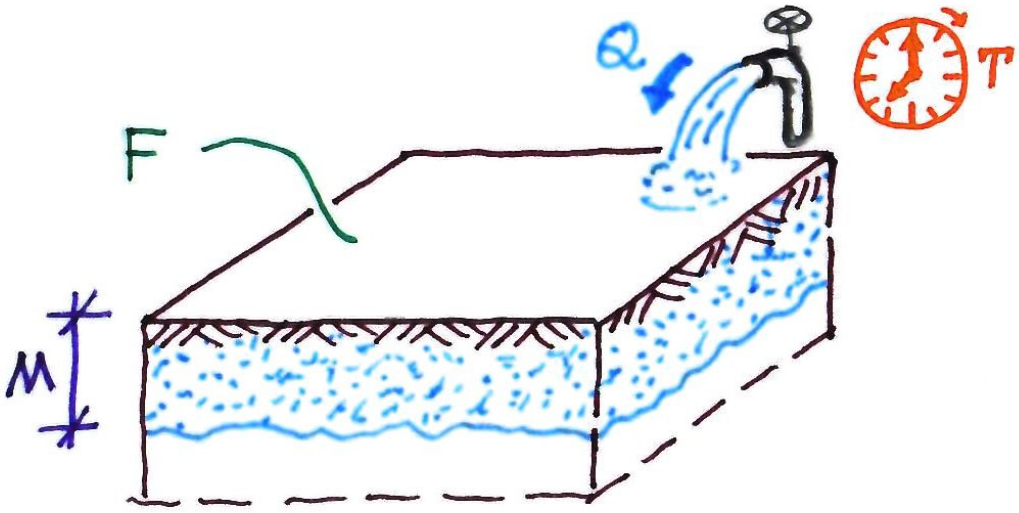
F – irrigated area, ha;

M – gross irrigation requirement, m^3/ha;

Q – irrigation flow rate (discharge), m^3/h

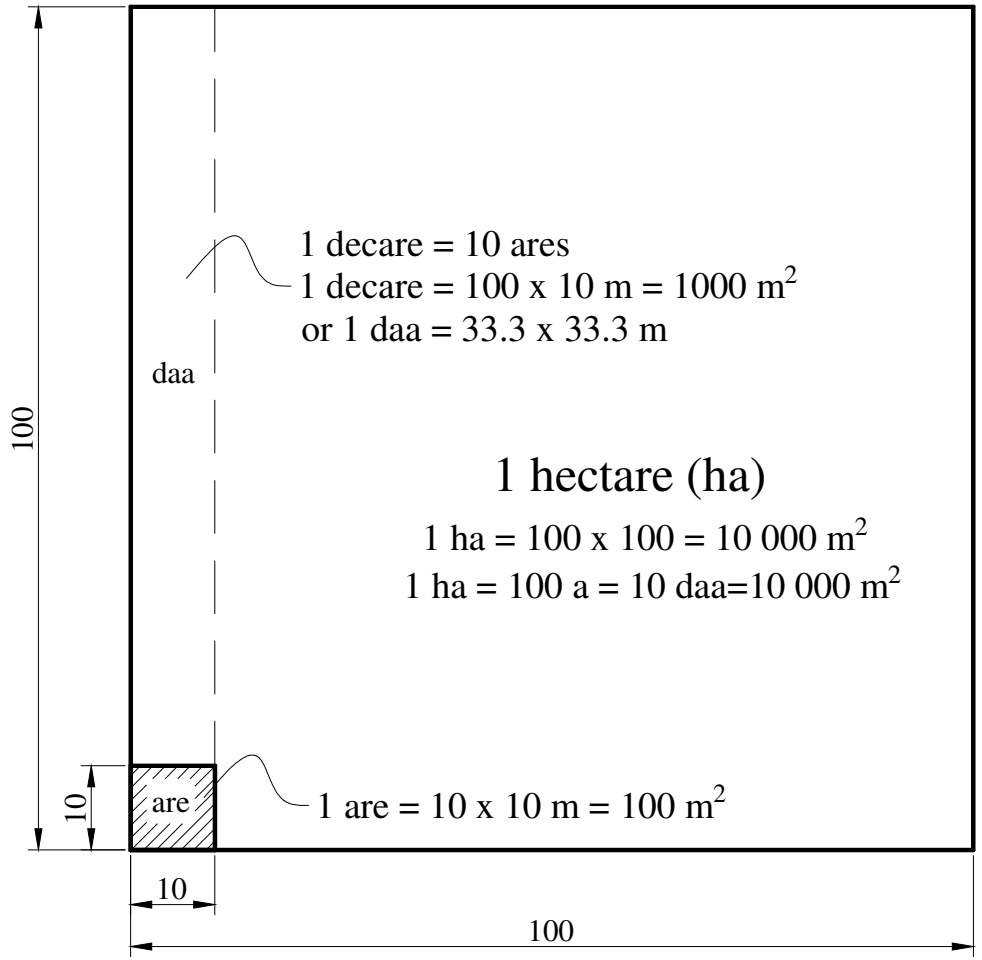
T – supply duration (time), h.

i.e. **Volume needed (M.F)**
should be equal to
Volume supplied (Q.T)



1. General Information

- **Area units**
  - **1 a (1 are)**
    - ✓ 1 are = 100 m^2.
  - **1 ha (1 hectare)**
    - ✓ from Greek "hecta" which means "hundred"
    - ✓ **1 ha = 100 a = 10 000 m^2.**
    - ✓ also 1 ha is equal to the area of a square having side size of 100 m.
  - In some countries, e.g. Turkey, Israel and Bulgaria, a unit ***decare*** is used
    - ✓ originates from Greek word "deca" which means "ten"
    - ✓ 1 decare (1 daa) = 10 a = 0.1 ha



N.B. US unit **acre** is:
1 acre ≈ 0.4 ha (≈ 4047 m^2)

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1. General Information

- **Irrigation Requirement**
  - ***Net Irrigation Requirement*** (M_{net}) is the volume of water which is needed by plants for the entire crop period or irrigation season.
    - ✓ For **Semi-areas**, it represents the *additional* amount of water to be delivered to plants, i.e. in addition to rainfall.
    - ✓ For **Arid areas** it represents the actual amount of water delivered
    - ✓ M_{net} does not include the losses of water during its delivery.
    - ✓ **Usually Net Irrigation Requirement is expressed as volume of water per 1 ha (m^3/ha)**
    - ✓ In some countries - expressed in ***millimetres of water layer*** (**mm**) which is standing over the ground and which does not evaporates or infiltrates into soil
      - similar to expression of rainfall
      - **1 mm = 1 ℓ/m^2 = 1 m^3/1000 m^2 = 10 m^3/ha.**

1. General Information

- **Irrigation Requirement**
  - ***Gross Irrigation Requirement*** (M_{gr}) it includes the water losses during the processes of delivery and application.
    - ✓ The losses are taken into account by means of the *efficiency* of different parts of the system.
    - ✓ M_{gr} can be estimated on the level of farm, of IF or IS, thus the respective efficiency is used

$$M_{gr} = \frac{M_{net}}{\eta_A} \text{ or } M_{gr} = \frac{M_{net}}{\eta_{IF}} \text{ , or } M_{gr} = \frac{M_{net}}{\eta_{IS}}$$

where η_A is the application efficiency;

η_{IF} – the Irrigation Field efficiency;

η_{IS} – the Irrigation System/Scheme efficiency

N.B. More on efficiencies is presented in next lecture

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1. General Information

- **Flow Rate (Discharge)**
  - ***Flow rate*** or ***Discharge*** is the volume of water per unit of time, which passes through a given cross section (of a canal, or a pipe).
    - ✓ In SI units: **m^3/s**
    - ✓ In Bulgaria it is also expressed in **ℓ/s** (liters per second)
      - **1 m^3/s = 1000 ℓ/s.**
    - ✓ In Western Europe it is typical to express the flow rate (discharge) in cubic meters per hour – m^3/h.
      - **1 m^3/h = 1000 ℓ per 3600 s = 0.278 ℓ/s**
      - **1 ℓ/s = 3.6 m^3/h**
    - ✓ Flow rate can also be expressed in **ℓ/min**, etc.
    - ✓ The US units usually are **gpm = gallons per minute** or **cfm = cubic feet per minute.**

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2. Irrigation Systems

- Irrigation System (IS)
  - a complex of hydraulic structures and networks designed to operate together as a system for abstraction and delivery (conveyance and distribution) of water for irrigation
- Irrigation Systems (in BG) or Irrigation Schemes (US English)
  - *Large scale* systems for abstraction and delivery of water to smaller units (farms or small scale irrigation systems)
- Irrigation Fields (in BG) or Irrigations Systems (US English)
  - *Small scale* irrigation systems for distribution of water between farms.
  - Each IS includes in its area many Irrigation Fields (in special case – one Irrigation Field).

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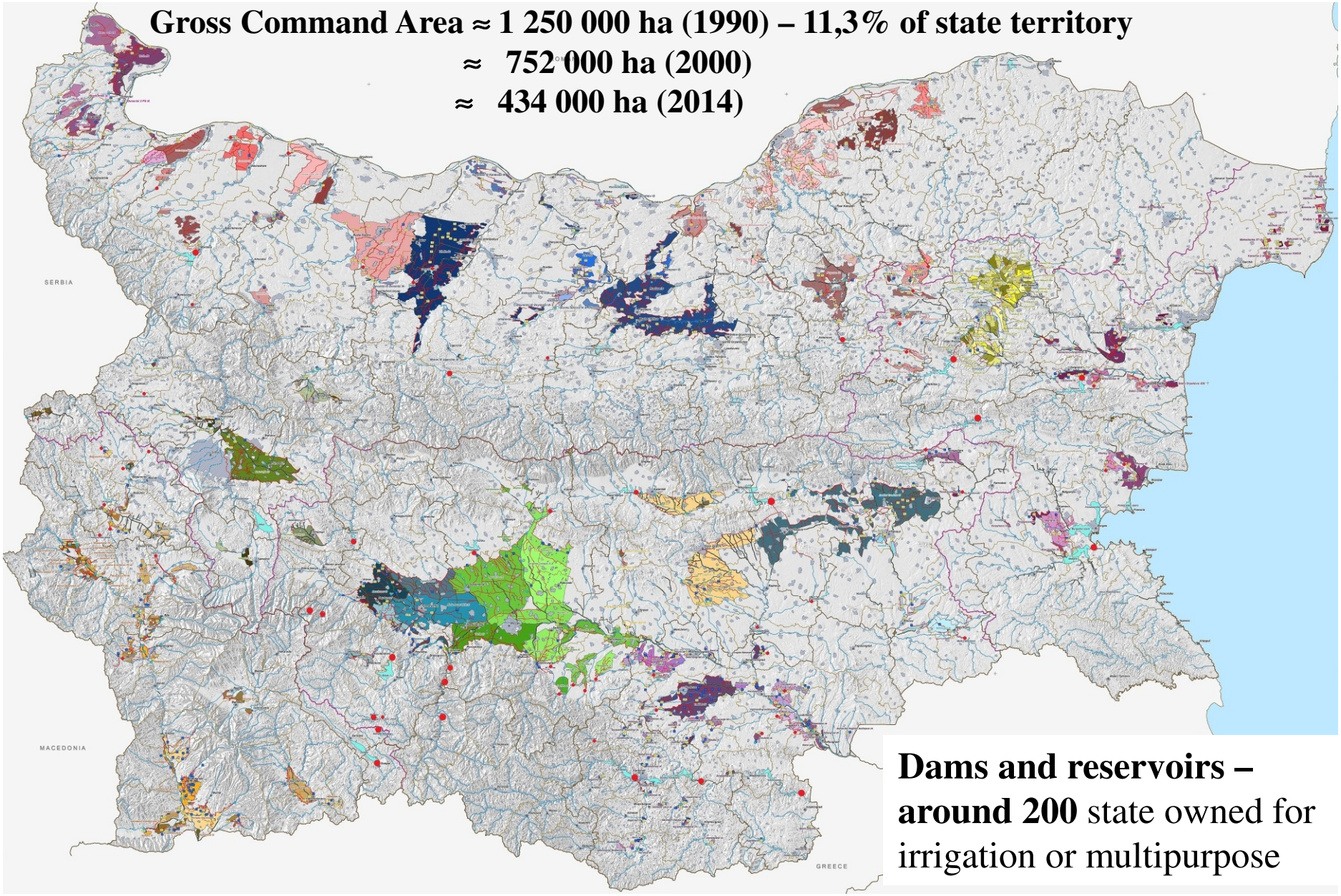
2. Irrigation Systems

- **Irrigation Systems (IS) in Bulgaria**



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2. Irrigation Systems

- **Irrigation Systems in Bulgaria**
  - Number of ***Irrigation Systems*** – 232;
  - Total gross command (constructed) area **434 000 ha** (year 2014)
    - ✓ around **4%** of the state territory
  - Water Intake Structures (Headworks) – 420;
  - Derivation supply canals – 530 km;
  - Conveyance and distribution open canals – 5 441 km (75% of them lined);
  - Irrigation Pumping Stations (PS) – 188;
  - Pressure pipelines (of PS and others) – 2 238 km;
  - Regulating Reservoirs – 612;
  - Buried pipe network – 9 269 km.

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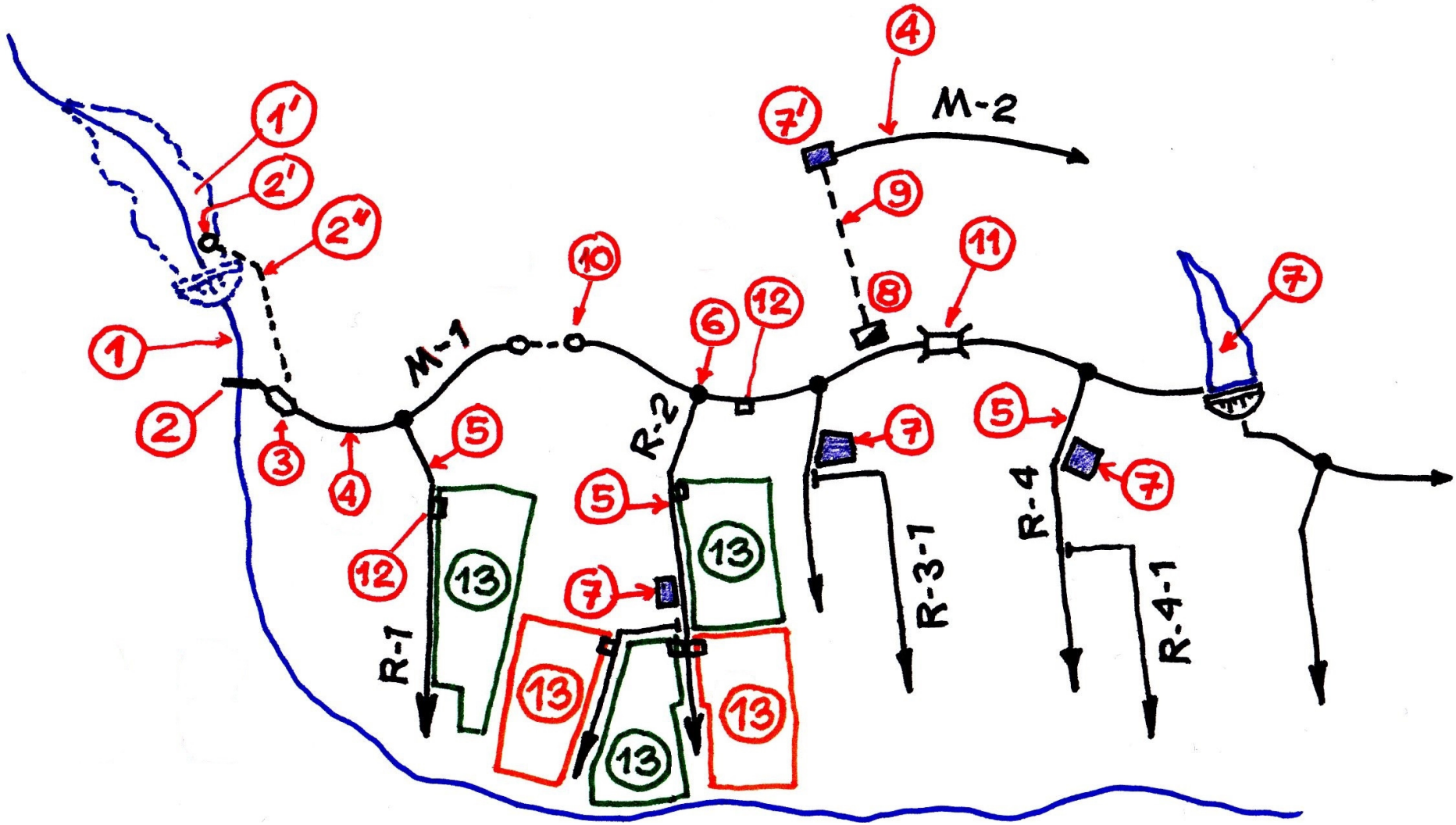
3. Structure and Elements of IS



1- River; 1'-Reservoir
2- Headworks; 2' – Intake tower
2" – Conveyance tunnel
3-Settling basin
4- Main Canal
5- Secondary Canals
6-Turnouts (Division Boxes)
7-Regulating Reservoirs
7'-Regulating reservoir of a Pumping Station
8-Pumping Station (Lift Type)
9 – Pressure pipeline; 10 – Inverted Siphon
11 – Aqueduct; 12 – Intakes for Irrigation Fields (13)

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3. Structure and Elements of IS

- Water Source
  - River ① or Reservoir (Dam Lake) ①'
  - Groundwater – abstraction through wells

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3. Structure and Elements of IS

- Water Intake Structure
  - ➢ Diversion Dam (Headwork) ②
    - ✓ whether or not the water source is a reservoir

  - ➢ Water Intake Tower ②' – only in case of a reservoir

3. Structure and Elements of IS

- Water Purification Structure ③ - Settling Basin
  - ✓ If needed, near the Water Intake

- Conveyance Tunnel ③'
  - ✓ May be needed in case if the water source is a reservoir

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3. Structure and Elements of IS

- Delivery (Conveyance and Distribution) Network
  - ➢ Main Canal ④
    - ✓ the primary canal; delivers water to whole command area;
    - ✓ usually an open canal, lined;
    - ✓ it is possible to have more than one Main Canal;

3. Structure and Elements of IS

- Delivery (Conveyance and Distribution) Network
  - ➢ Secondary Canals (Distributary canals) ⑤;
    - ✓ deliver water to customers (farms, irrigation fields, etc.);
    - ✓ usually open canals, lined;
    - ✓ some parts may be constructed as tunnels or pressurized pipelines;
    - ✓ branches are also Secondary canals not Tertiary

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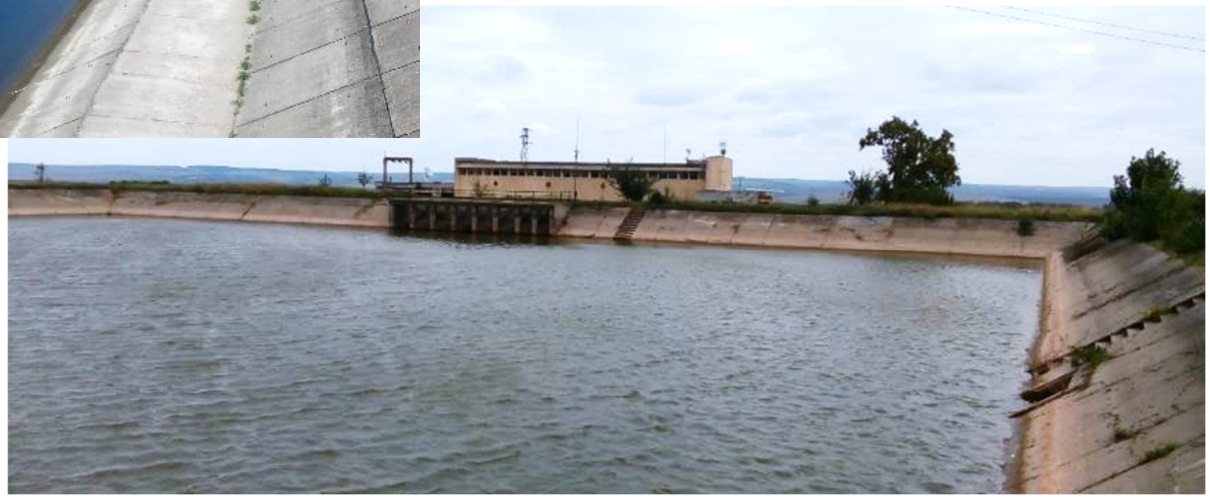
3. Structure and Elements of IS

- Delivery (Conveyance and Distribution) Network
  - ➢ Division Boxes (Turnouts for Secondary Canals) ⑥
    - ✓ check structure – at canal, to control flow depth (head)
    - ✓ discharge regulating structures – at offtakes

3. Structure and Elements of IS

- Delivery (Conveyance and Distribution) Network
  - ➢ Regulating reservoirs – at canal network ⑦ or at discharge end of the pipelines of Lifting type Pumping Stations ⑦'

Regulating reservoir "Krichim"



Regulating reservoir of PS; A Booster type PS uses the regulating reservoir as a water source

3. Structure and Elements of IS

- Delivery (Conveyance and Distribution) Network
  - ➢ Regulating reservoirs ⑦
    - ✓ also called Buffer / Balancing / Compensating Reservoirs;
    - ✓ located in the second half of the water route;
    - ✓ by means of these reservoirs the flow is regulated, i.e. they help to ease (synchronize) water delivery;
    - ✓ built as small dams or artificial lakes (with dikes);

It is advisable to locate Regulating reservoir "offline" of the canal

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3. Structure and Elements of IS

- Delivery (Conveyance and Distribution) Network
  - ➢ Pumping Stations - PS ⑧
    - ✓ Pressure pipelines ⑨

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3. Structure and Elements of IS

- Delivery (Conveyance and Distribution) Network
  - ➢ Inverted Syphons ⑩
  - ➢ Aqueducts (11)
    - ✓ used to cross small rivers, gullies, roads, railroads, etc.

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3. Structure and Elements of IS

- Delivery (Conveyance and Distribution) Network
  - ➢ Turnouts (12)
    - ✓ Water intakes from Main or from Secondary Canals
    - ✓ Use for delivery of water to farms or Irrigation Fields
    - ✓ Usually have sliding gates to regulate the discharge
    - ✓ They may be constructed with pipes

3. Structure and Elements of IS

- Irrigation Fields (BG) or Irrigation System (US) – (13)
  - ➢ Irrigation Field (IF) - technologically separated unit of the IS.
    - ✓ It has only one intake structure from main canal network
    - ✓ It has its own distribution network – **tertiary (canal) network**
  - ➢ Each IS comprises of many irrigation fields (IFs)
  - ➢ In Bulgaria, in the past, each IF was designed for one irrigation method
    - ✓ IF for surface irrigation
    - ✓ IF for sprinkler irrigation
    - ✓ IF for drip/micro irrigation

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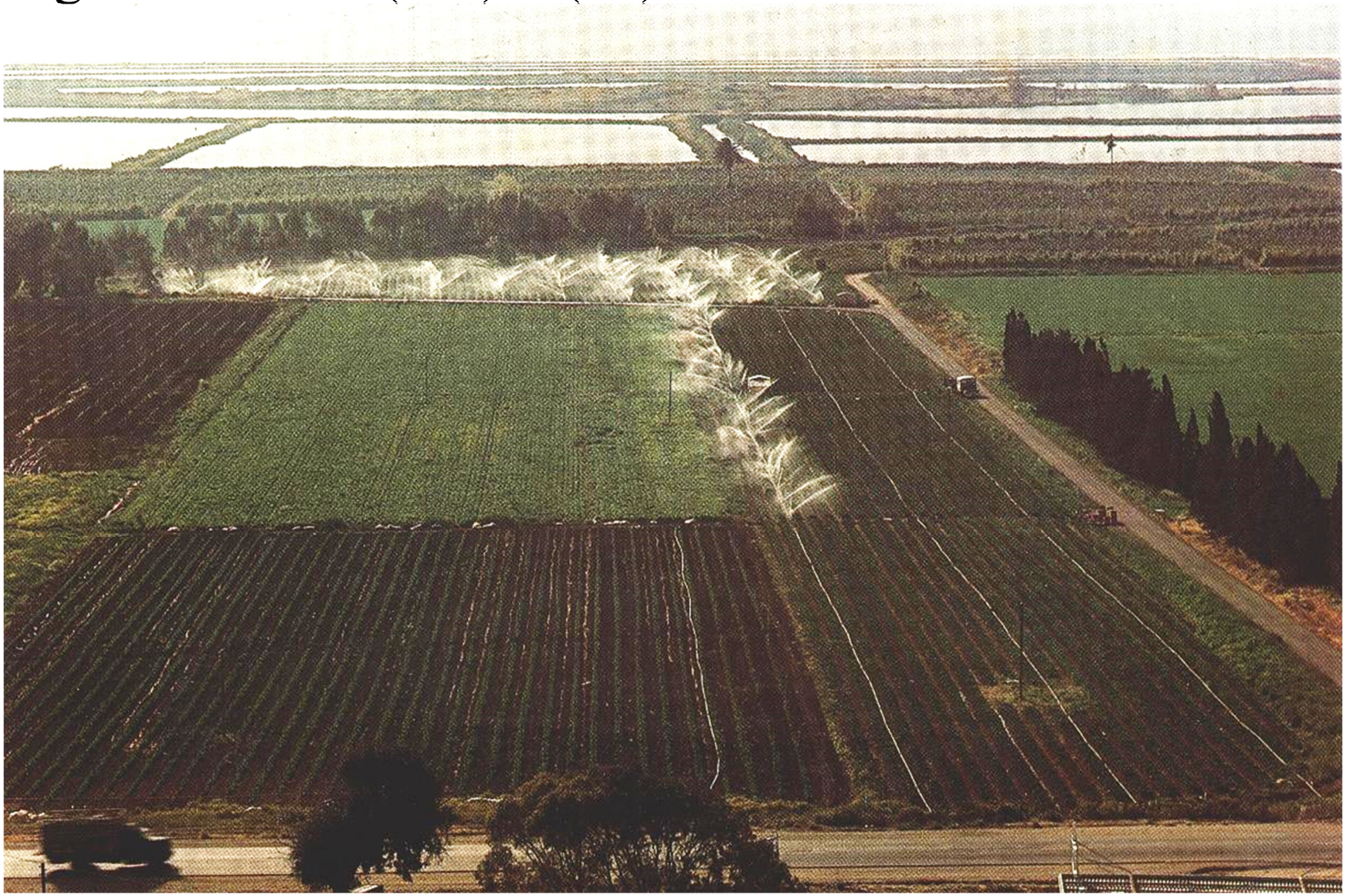
3. Structure and Elements of IS

- Irrigation Fields (BG) – (13)



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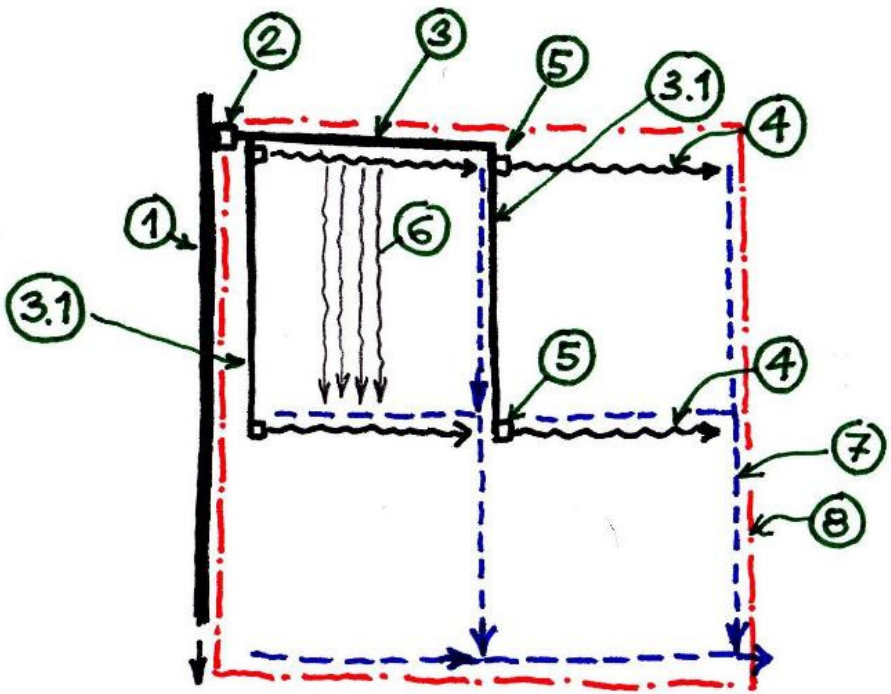
4. Irrigation Fields

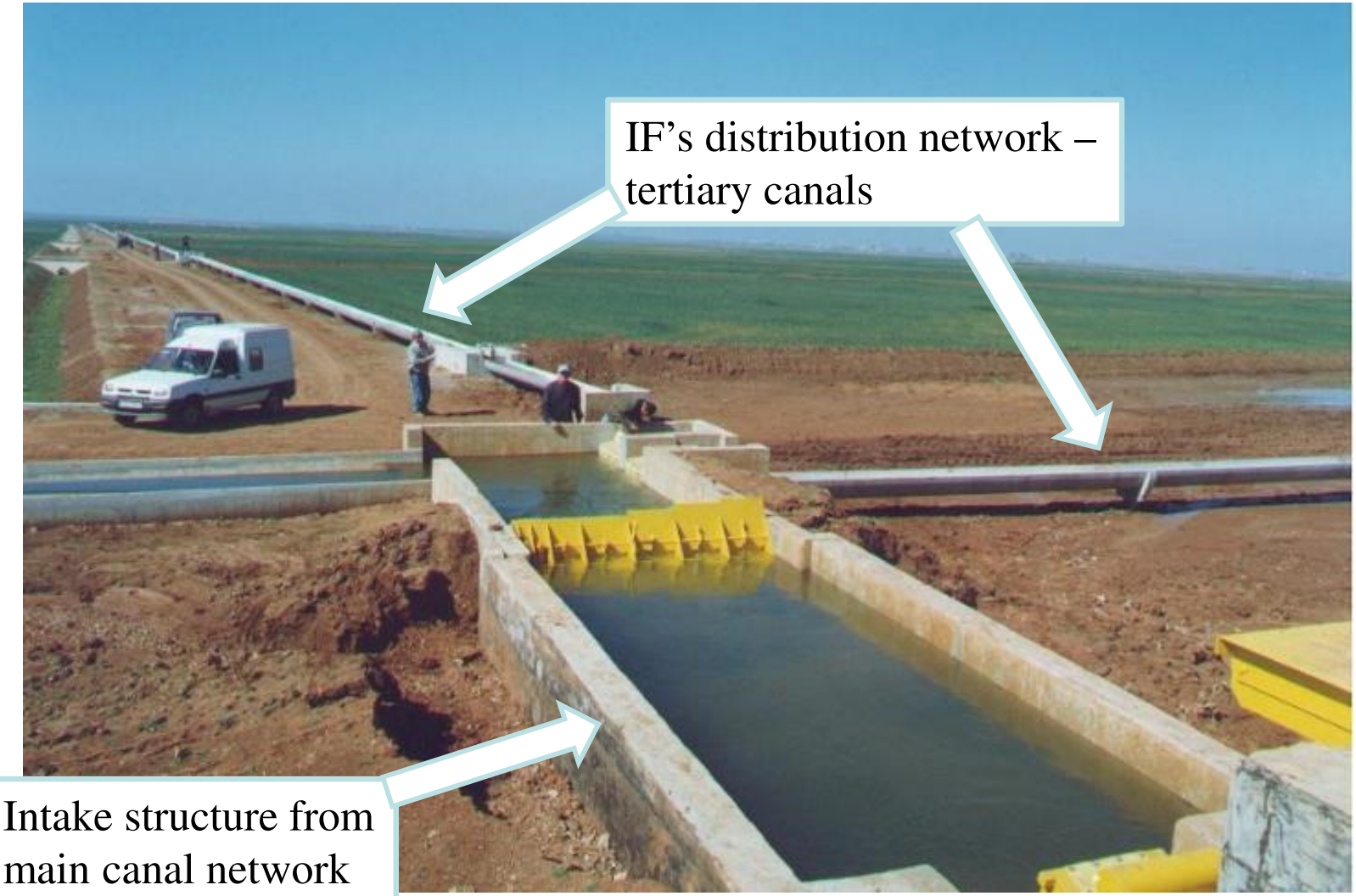
- **IF for surface irrigation**



- Main or Secondary canal ①
- Turnout for IF ②
- Tertiary network - ③ and (3.1)
  - ✓ Internal Canal Network *or*
  - ✓ Distribution Network of IF
    - ✓ usually consists of open canals;
    - ✓ usually canals are lined.
- Watercourses ④
  - ✓ earthen/unlined canals
- Turnouts ⑤ of tertiary network
- Furrows ⑥
- Drains ⑦ and boundary ⑧

4. Irrigation Fields

- **IF for surface irrigation**



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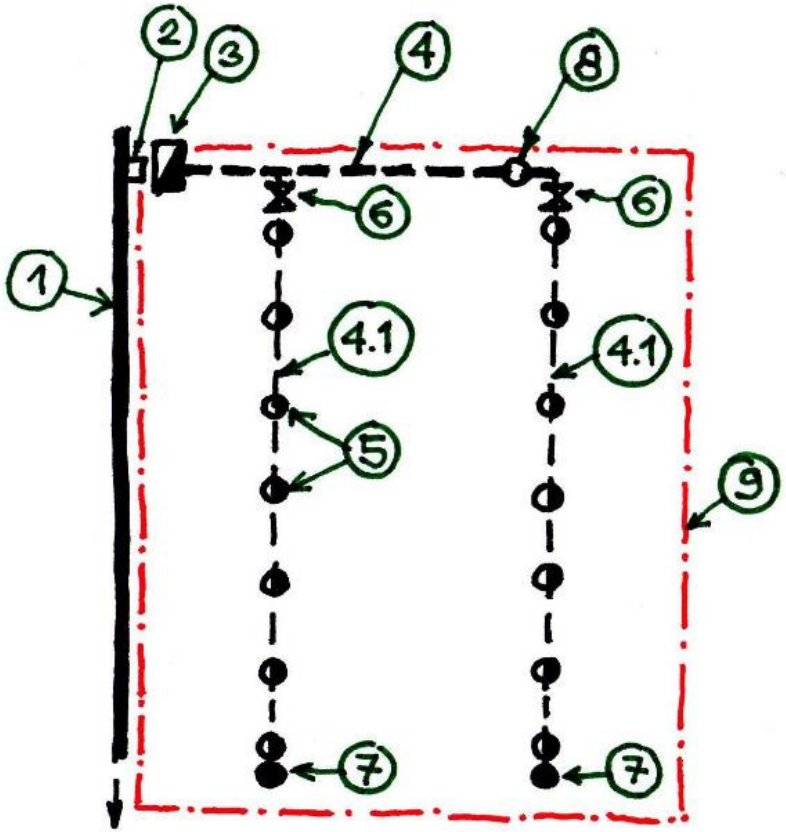
4. Irrigation Fields

- **IF for sprinkler irrigation**



- Main or Secondary canal ①
- Turnout for IF ②
- Sprinkler (Booster) Pumping Station - ③
- Tertiary network - ④ and (4.1)
  - ✓ Distribution Network of IF
  - ✓ usually consists of buried pipelines
- Irrigation hydrants ⑤
  - ✓ for sprinkler equipment / machines
- Gate Valves (stopcocks) ⑥
- Drains ⑦
- Air vents ⑧ and boundary ⑨

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4. Irrigation Fields

- **IF for sprinkler irrigation**

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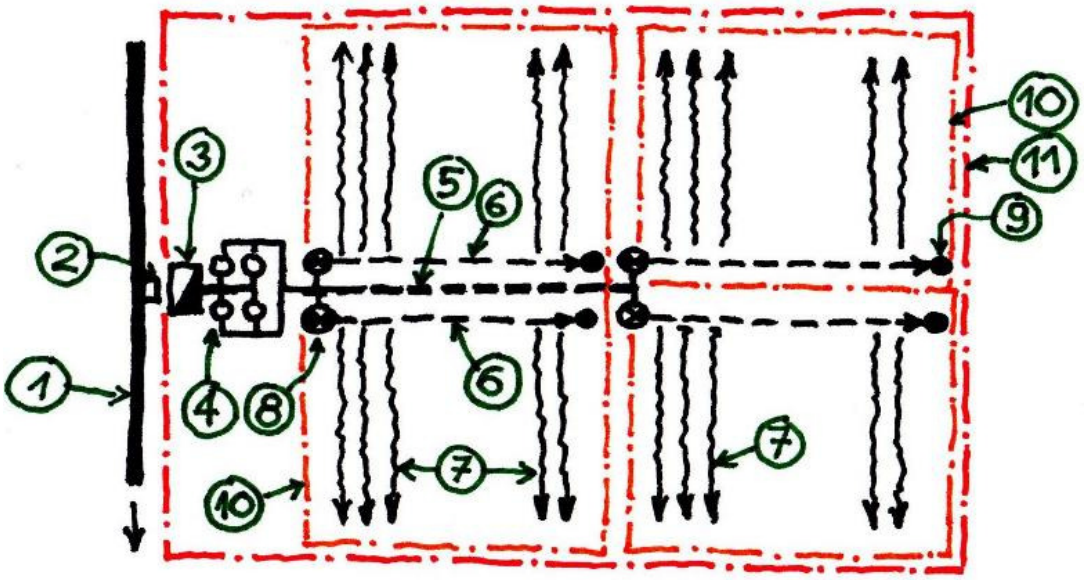
4. Irrigation Fields

- **IF for drip/micro irrigation**



- Main or Secondary canal ①
- Turnout for IF ②
- Booster Pumping Station ③
- Filters ④
- Mainline ⑤
- Manifolds ⑥
  - ✓ usually are buried pipelines
- Hose lateral ⑦
  - ✓ with drip emitters or microsprayers
  - ✓ usually above ground
- Block valve ⑧
- Drains ⑨
- Block boundary (10)
- IF boundary (11)

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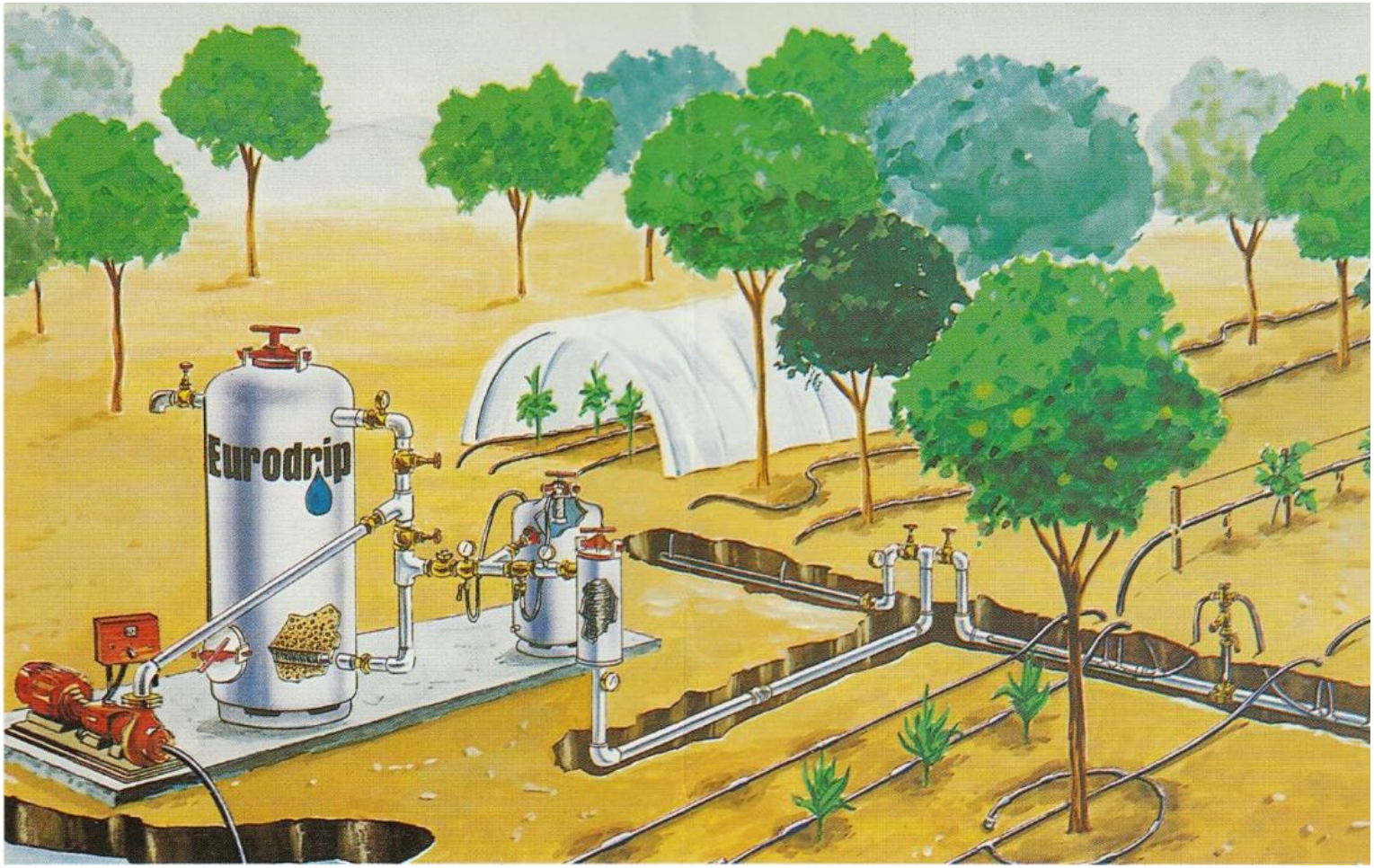
4. Irrigation Fields

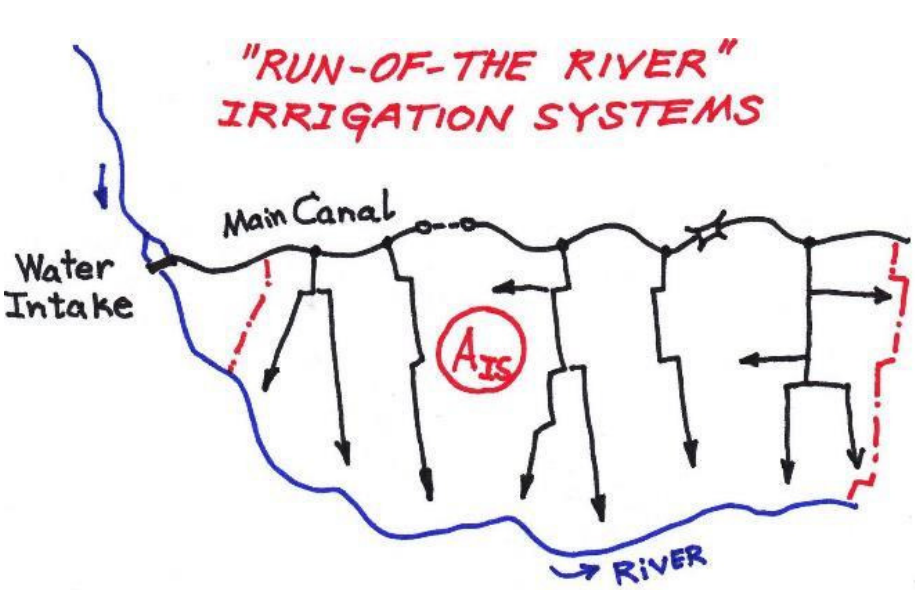
- **IF for drip/micro irrigation**

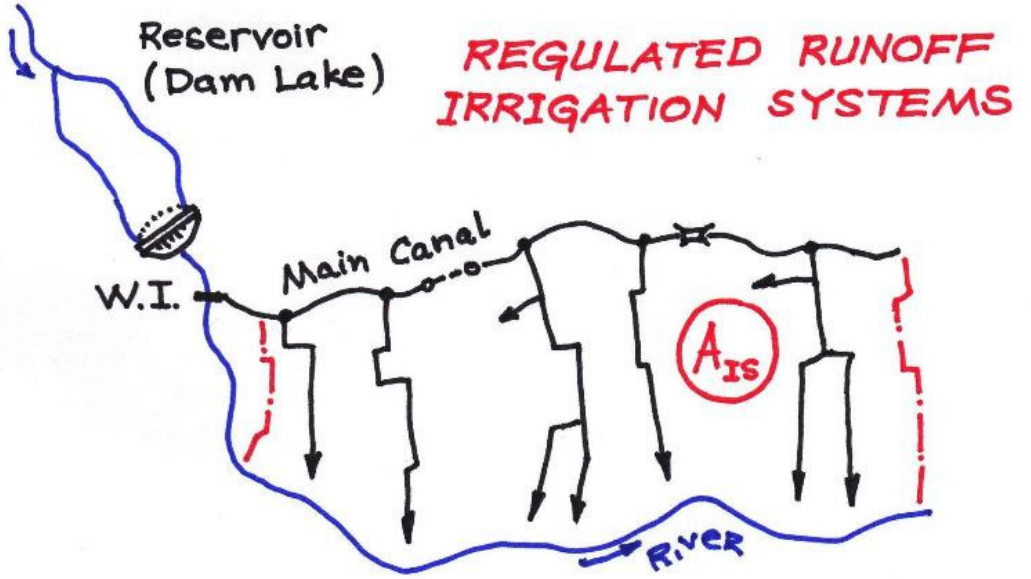


- Suitable for:
  - Row crops (especially vegetables)
  - Perennials (orchards, vineyards)

5. Types of Irrigation Systems

- **According to water source**
  - "***Run-of-the-river***" **IS** – water is diverted directly from the river
  - ***Regulated runoff*** **IS** – water is supplied from a reservoir
    - ✓ Directly from the reservoir or
    - ✓ By releasing water and diverting it downstream by means of Headworks (water intake structure)





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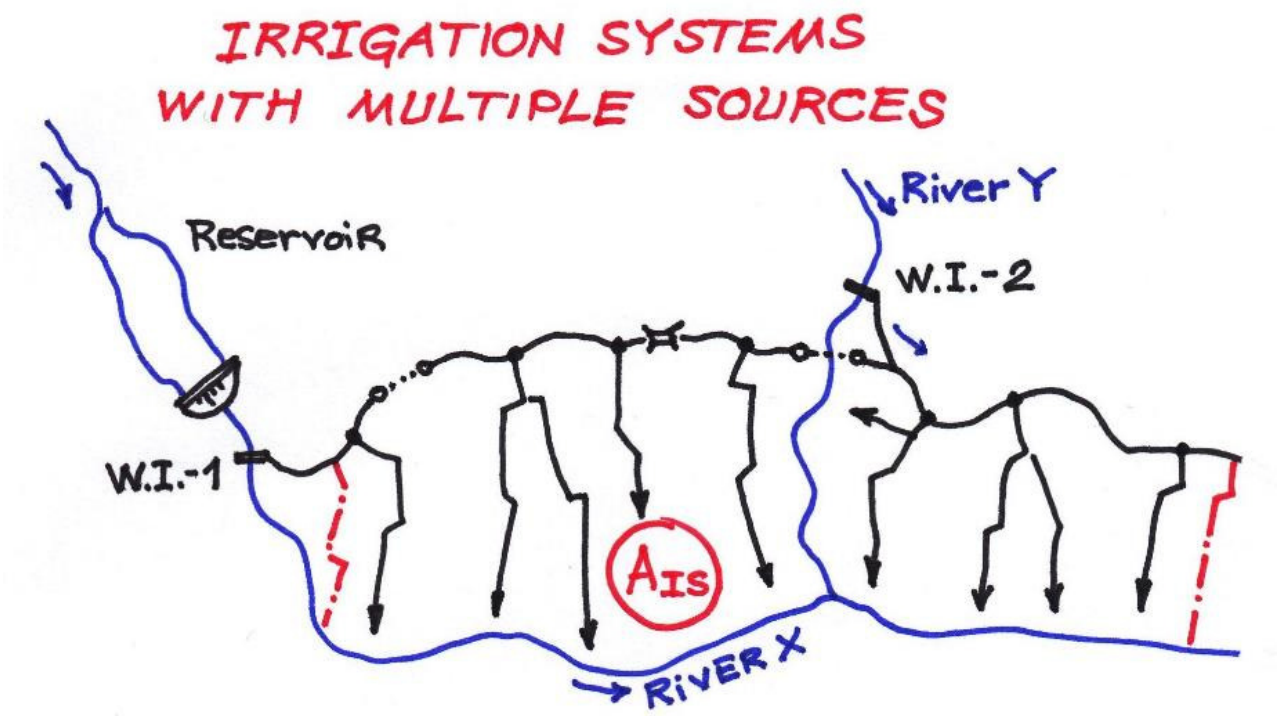
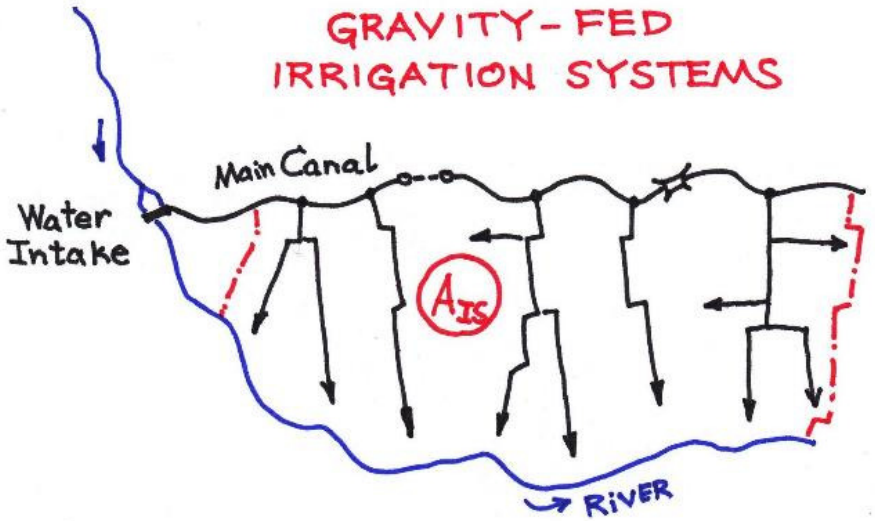
5. Types of Irrigation Systems

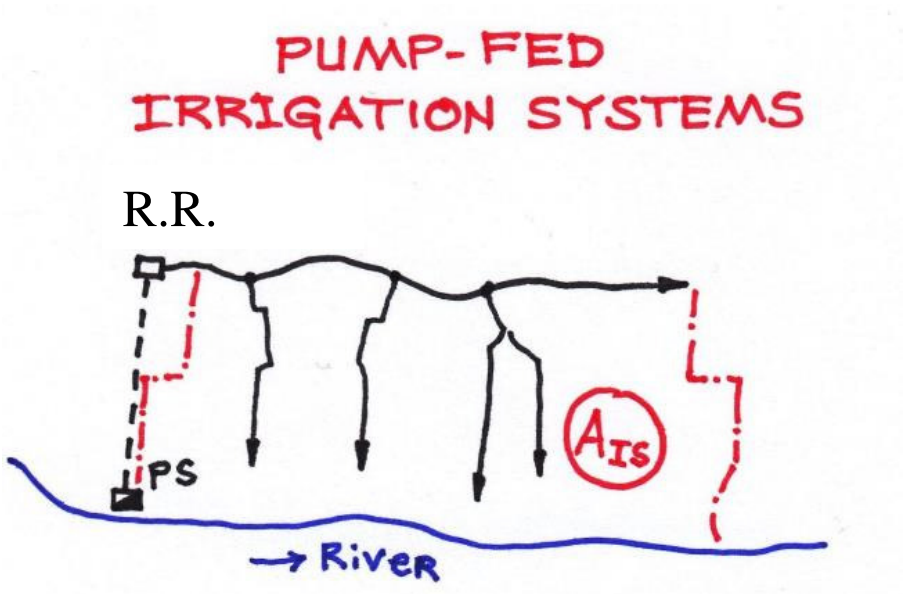
- **According to water source**
  - ***Multiple Source IS*** – more than one water source is used



5. Types of Irrigation Systems

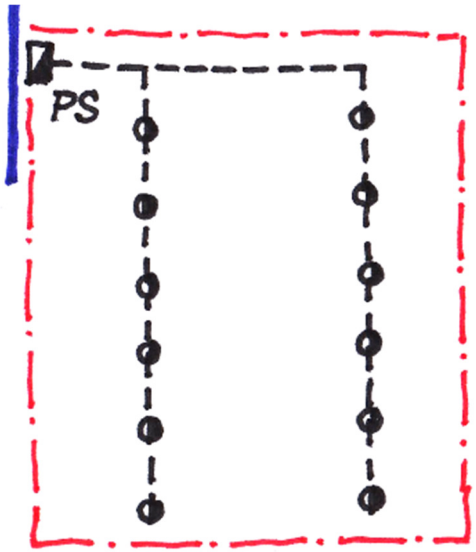
- **According to way of water delivery**
  - **Gravity-fed IS –** all the Command Area can be supplied by irrigation canals
    - ✓ they can be either Run-of-the-river, or Regulated runoff IS
  - **Pump-fed IS –** all the Command Area can be supplied by irrigation canals
    - ✓ Abstraction from rivers
      - – they can be either *Run-of-the-river*, or *Regulated runoff* IS
    - ✓ Abstraction of groundwater



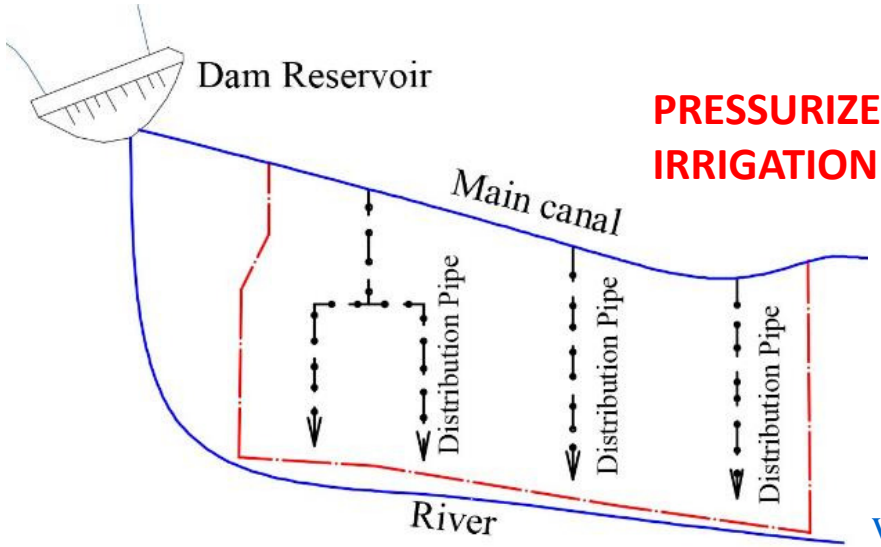


5. Types of Irrigation Systems

- **According to way of water delivery**
  - **Pressurized IS –** all the network is made of pipes; flow is pressurized by Booster Pumping Station
    - ✓ small scale IS, consisting of one Irrigation Field



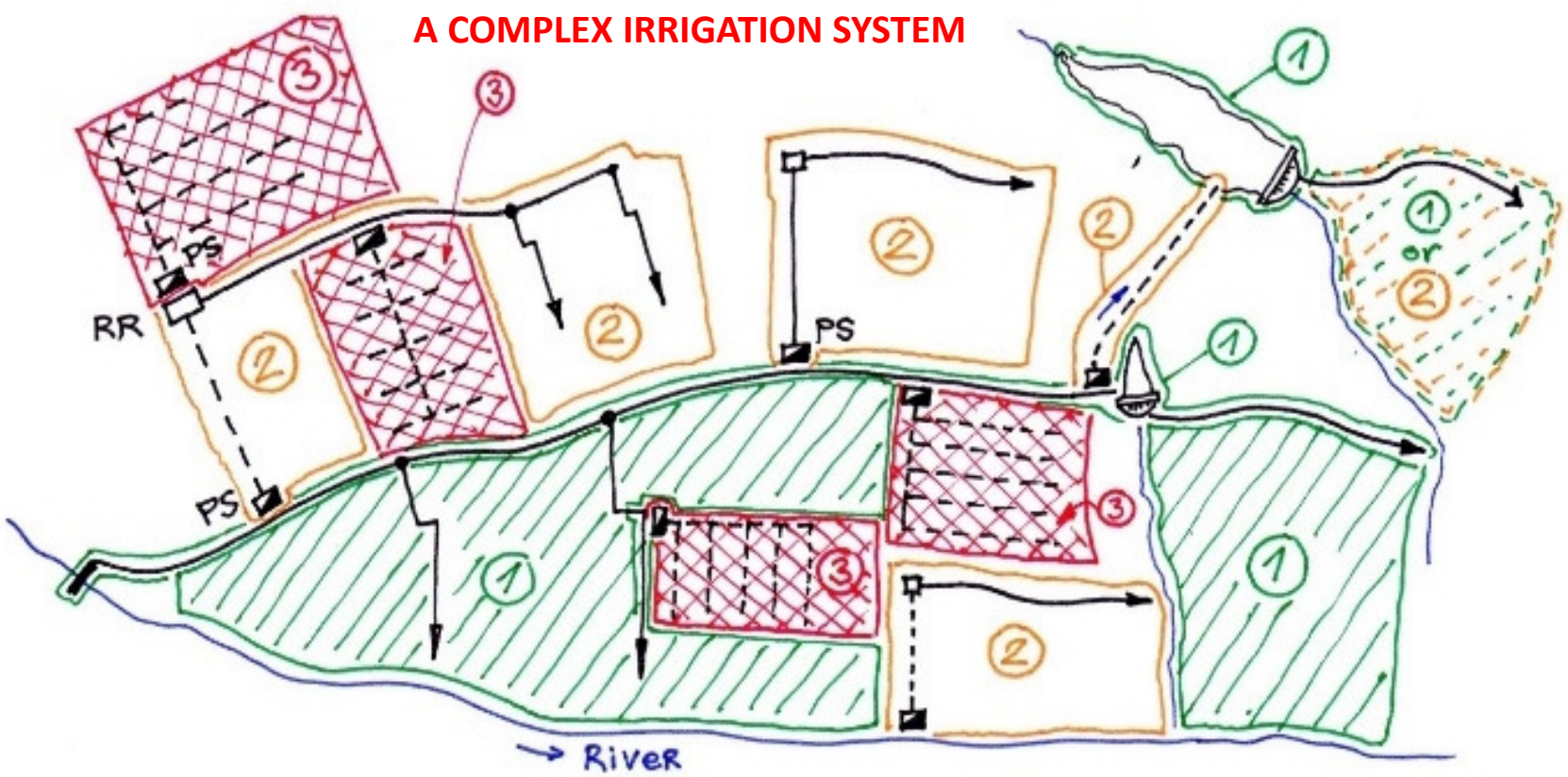
  - **Pressurized by gravity IS -** mixture of above mentioned 3 types of IS
    - ✓ Regulating reservoir or Dam Reservoir can pressurize the whole IS.
    - ✓ In some instances a Main Canal can be present – either gravity-fed, or pump-fed
    - ✓ Distributaries – pipes with pressurized flow



PRESSURIZED BY GRAVITY IRRIGATION SYSTEM

5. Types of Irrigation Systems

- **According to way of water delivery**
  - ➢ **Complex IS –** when different parts of the system are supplied in different ways
    - ✓ these IS consist of different ***subsystems***



Co-funded by the
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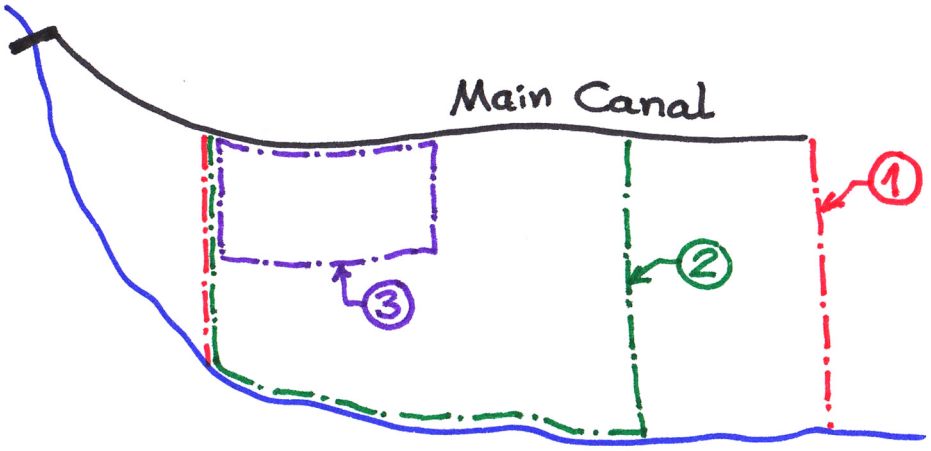
5. Types of Irrigation Systems

- **Subsurface irrigation**
  - **Natural subsurface irrigation**
    - ✓ leakages from irrigation canals, rivers, lakes, etc.
      - – in plain areas
      - – limited spatial effect
  - **Artificial subsurface irrigation**
    - ✓ Individual irrigation systems or schemes
    - ✓ Specially designed drainage systems
      - – In Bulgaria called ***Double-acting drainage systems***
      - – Need special soil and terrain conditions
      - – Very expensive

6. Irrigation System Parameters and Indicators

- **Irrigation System Areas**
  - **Command area** ① (also **Constructed area**) – the area that can be irrigated by IS network *according to original design* of the system/scheme
  - ***Gross Command Area*** – total area within the boundary of IS, incl. canals, roads, reservoirs, forests/green areas along canals and roads, etc.
  - ***Net Command Area*** ① – includes only area which is *cultivable* within the boundaries of IS.
    - ✓ When speaking of IS area, we mean *Net Command Area*



6. Irrigation System Parameters and Indicators

- **Irrigation System Areas**
  - **Suitable area** ② (also named **Equipped area**) – area fit for irrigation, i.e. area to which water can be delivered at present
    - ✓ usually smaller than constructed area, because of the damage of some structures and networks
    - ✓ there is ***Gross*** and ***Net Suitable area*** ②;
  - **N.B.** Not all ***Net Suitable Area*** is actually cultivated/planted every year
  - **N.B.** Not all ***Net Suitable Area*** is irrigated every year
  - **Irrigated area** ③ – area actually irrigated in a given year
    - ✓ usually smaller than **command** and **suitable** area, because of the crops actually grown within the IS boundary.