The University of Zambia
School of Engineering
Dept. of Civil & Environmental Engineering

CEE 4412: Environmental Engineering I

Water Supply – Water Transport and Distribution

JMT
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Summary of a Water Supply System

- Comprise the following:-
  - A source
  - Treatment facilities
  - Storage
  - Transport
  - Distribution

COMPONENTS OF A WATER SUPPLY SYSTEM

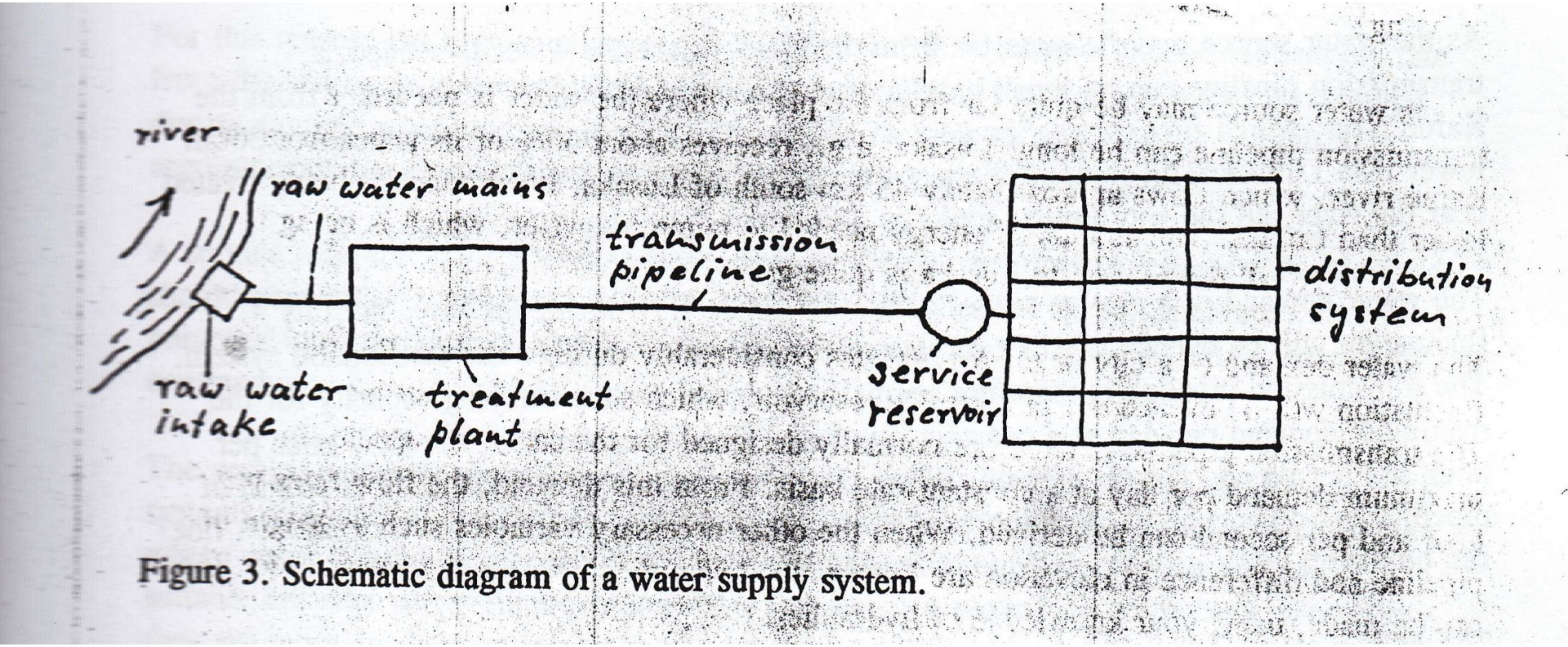
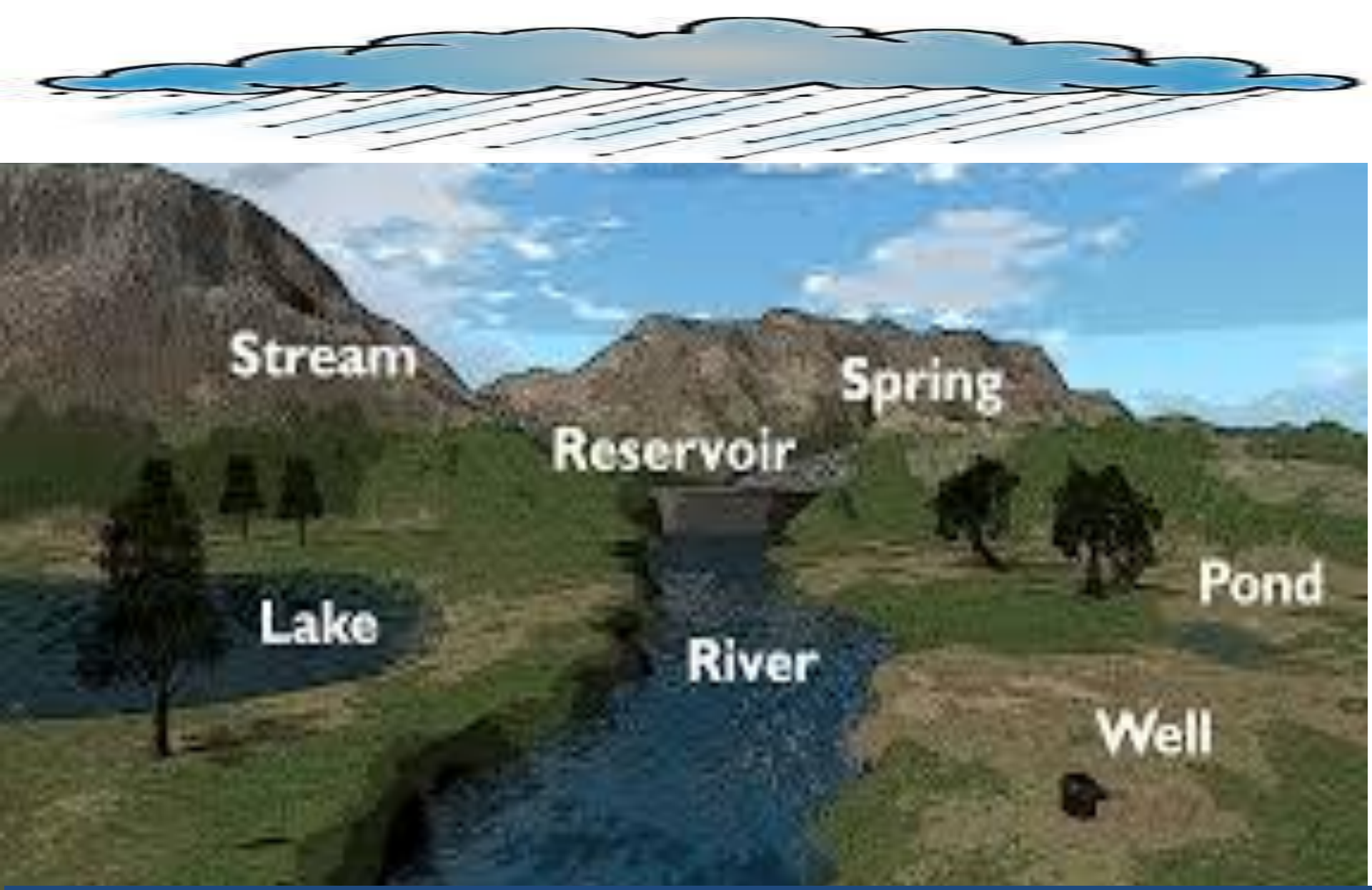


Figure 3. Schematic diagram of a water supply system.

Source/Treatment/Transmission or Transport/Storage/Distribution

Transmission + Distribution = Delivery System

WATER SOURCES



Source: Modified from Google Images

Water Sources: Comparisons

- Groundwater is usually of a better quality
- Can be supplied directly without treatment

Water Sources: Characteristics

- Good water source is always wrt the purpose for which it is to be used. For domestic purposes it should:
  - be free from pathogenic bacteria;
  - have low concentrations of compounds that are acutely toxic or that have serious long term effects such as lead (guidelines to be observed);
  - Aesthetically acceptable (clear and free from compounds that cause offensive odour and taste;
  - Not saline; and
  - Neither corrosive nor scale forming in piping or staining of clothes.

Water quality considerations in Design – Source Characterisation

Parameter characterisation	Excellent source	Good source	Poor source	Rejectable source
Average BOD_5 (mg/l)	0.75- 1.5	1.5 - 2.5	2.5 - 4.0	>4
Average coliforms (MPN)/100ml	50 - 100	100 – 5000	5000 - 20000	>20000
pH	6 - 8.5	5 - 6, 8.5 – 9	3.8-5, 9-10.3	<3.8, >10.3
Chlorides (mg/l)	<50	50 – 250	250 - 600	>600
Flourides (mg/l)	<1.5	1.5 – 3	>3	-

- Why do we use the above parameters in characterising source? Why not suspended solids?

Choice of a Water Source

Some Factors to Consider

- Adequacy
- Reliability
- Quality
- Location (defines energy requirements which can affect recurrent operational costs)

- In most cases, water quality will not meet guideline values.
- As it is not practical to abandon all polluted sources, water is subjected to treatment!!

Summary of a Water Supply System

- After treatment in the plant, water needs to be transported to where it is required
- This requires a pipelines and pipe networks
- Also requires pumps, valves and other appurtenances

Water Delivery Systems

- Can be divided into two categories
  - Transport and
  - Distribution

Objectives of transport and distribution systems

- To supply adequate water to meet demand
- To supply non-degraded quality of water
- The above objectives should be satisfied at acceptable cost.

Components of a water delivery system

- Basic part of a water transport and distribution system comprising various types of pipes, joints, fittings and connections that operate together with miscellaneous control equipment (like valves). The following are the pipes in a delivery system:
  - Trunk main (Big pipe sizes)
  - Secondary main
  - Distribution main (to residential and to fire hydrants)
  - Service pipe

Components

- TRUNK MAIN: transports water from the water treatment plant to the distribution area (Transport).
- SECONDARY MAIN: provide the basic structure of the distribution network.
- DISTRIBUTION MAIN: Distribution mains carry water from the secondary mains to the smaller consumers. Theses are usually laid along the roads and streets.
- SERVICE PIPE: from the distribution main to the consumer/customer.

Water Transport

- Comprise main transmission lines (TRUNK MAIN)
- They do not serve consumers directly. (Only in very special cases?)

- Can branch
- At the end of the system, there is often some central storage (Why? To even out fluctuations).

Water Distribution System

- Consists of a network of smaller pipes with numerous connections that deliver water directly to the users

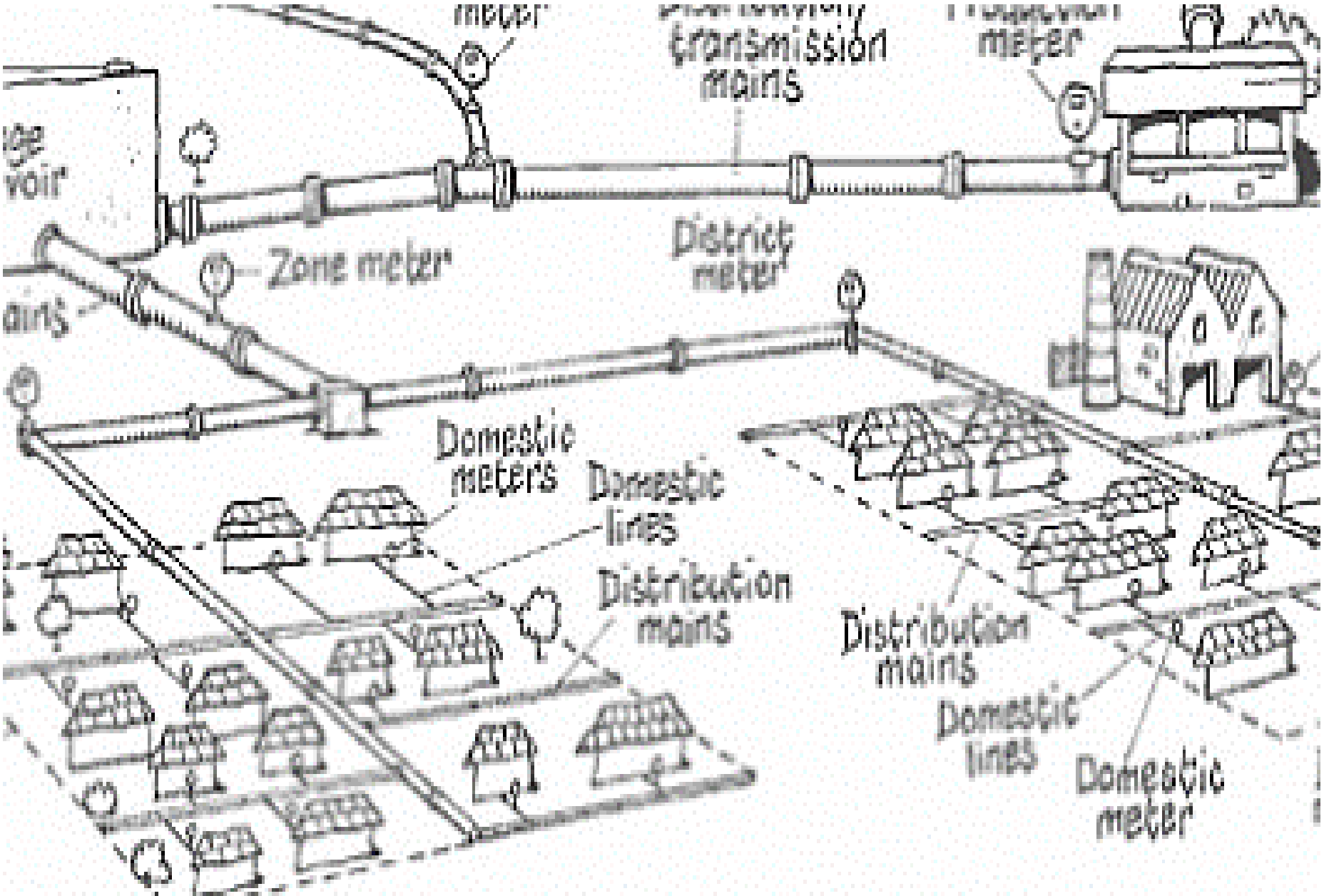
- Flow variations in distribution systems are much larger as compared to water transport

- Optimal operations is through use of reservoirs, water towers, pumping stations, valves etc.

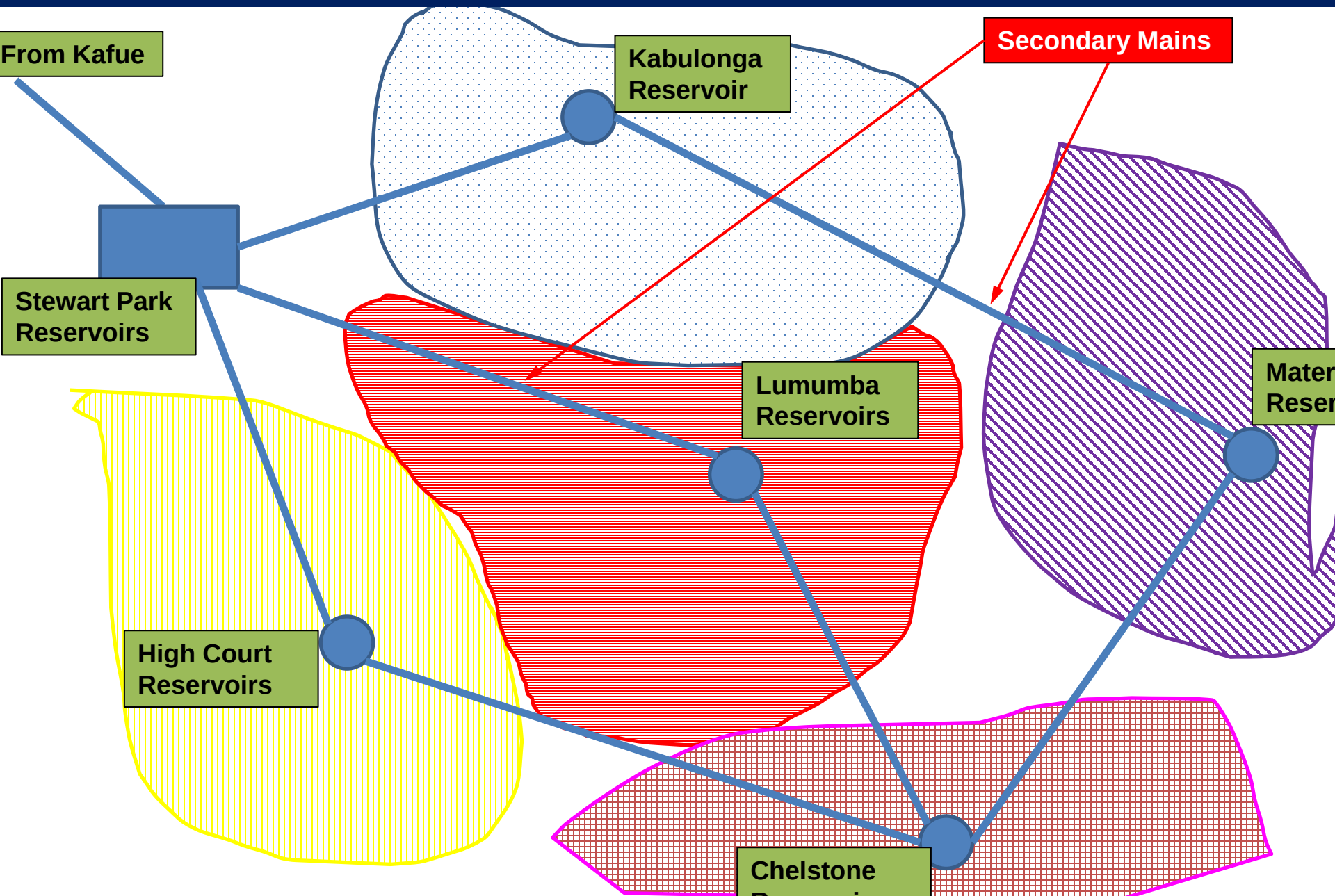
Water Distribution

- End of service pipe is the end point of the distribution system. It can terminate into:
  - A Public connection – where the pipe terminates in one or more taps and water is consumed directly (e.g. public standpipe, fire hydrant, etc)
  - Private connection: Pipe terminates at a stopcock of a private installation (domestic, commercial, industrial, etc). Utility's responsibility ends at this point (Metered)

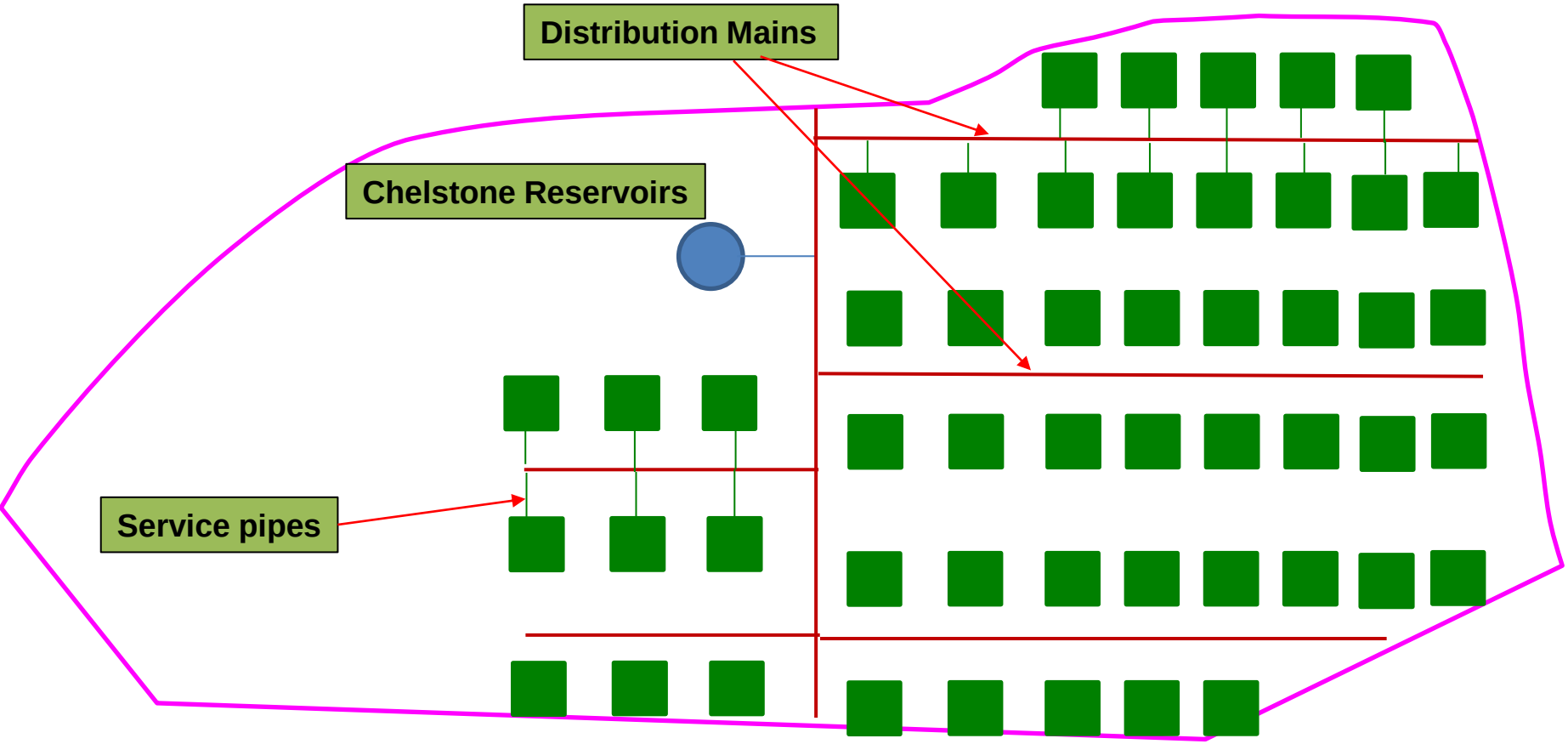
Water Distribution



Water Distribution - Secondary Mains



Water Distribution

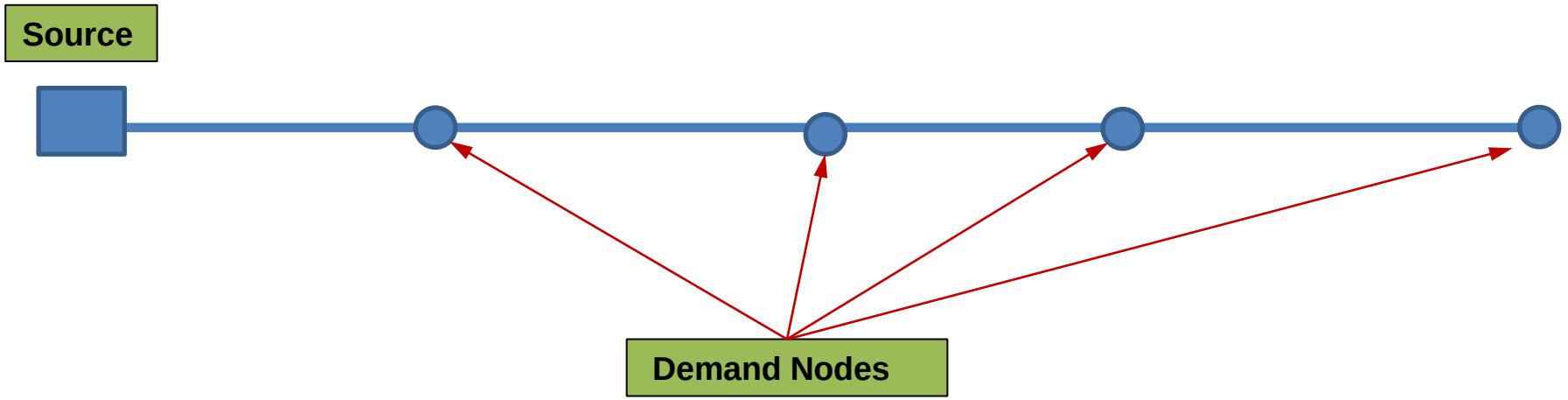


Types of Distribution Networks (Network Configurations)

- Network configuration is the way the pipes are laid within the distribution area. Four types can be distinguished as follows:
  - Serial
  - Branched
  - Grid/Looped
  - Combined

Serial Network

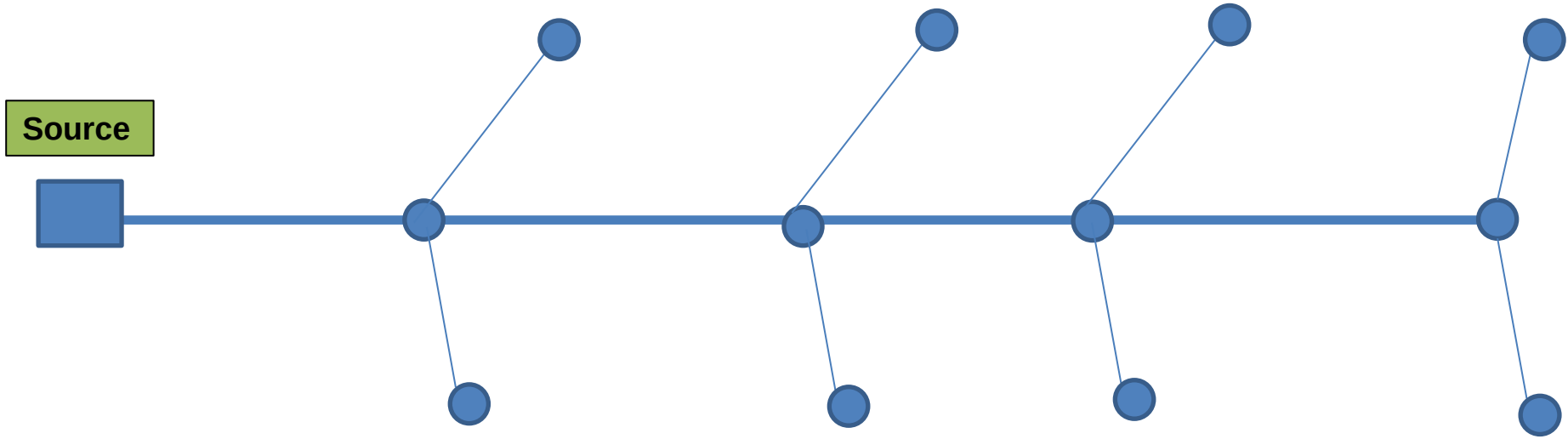
- A network without branches or loops. It generally has only one source, one dead end and a couple or more demand points (called demand nodes).



- All the nodes are linked by two pipes; a supply link upstream and a distribution link downstream.
- Flow is in one direction; from supply point. Design is based on principles of single pipe calculations.

Branched

- Network with one supply source and several (dead) ends.
- The intermediate nodes in the system are connected by one supply link upstream and one or more distribution links downstream.

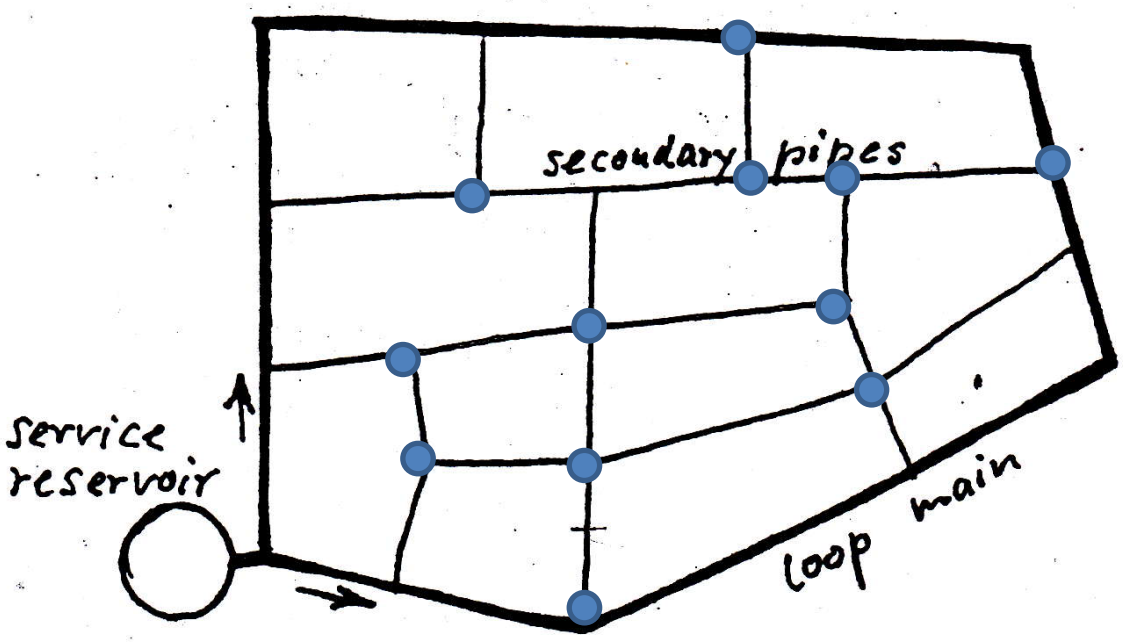


Disadvantages of Serial and Branched Networks

- They have low reliability
- Risk of system getting contaminated during shutdown is high (as there will be no flow at all)
- Accumulation of sediments
- Expansions may cause pressure problems in system

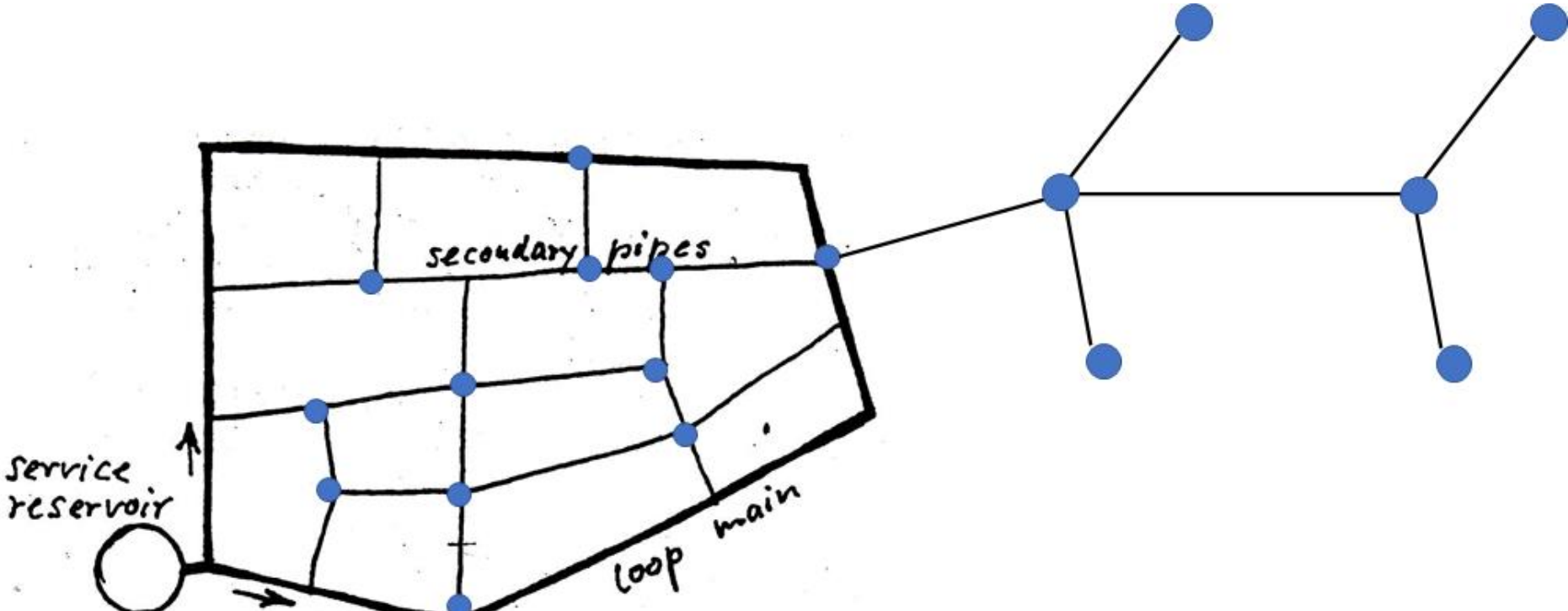
Grid or Looped Network

- A system where all the demand nodes are supplied from more than one pipe.
- This eliminates dead ends in the system
- Also improves reliability of the system
- But complicates the hydraulic calculations)



Combined Network

- This is a network where the central part is looped while the supply of localities or outskirts is either serial or branched.
- This is the most common type.



Distribution Systems

- The physical works that deliver water from the water source to the intended end point or user.

- Therefore it is a combination of the network and the means by which water is moved in the system

- The means by which the water is moved in the system is what predominates when we talk about in water distribution systems

Types of Distribution systems

- Gravity Distribution System: System that takes advantage of the topography in the distribution of the water.

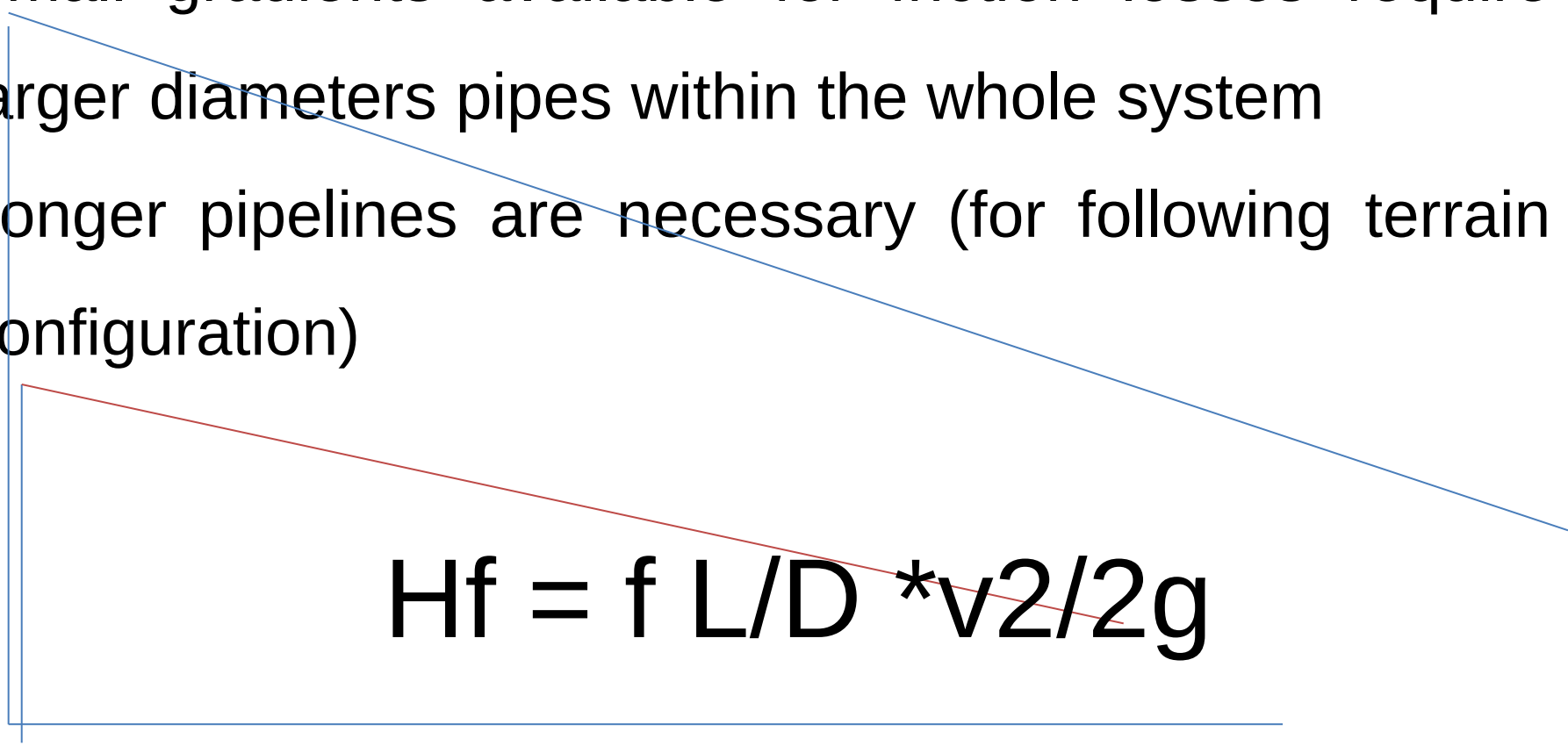
ADVANTAGES

- No energy costs
- operation is simple
- low maintenance costs
- no sudden pressure changes (pressure surge which occurs in pumped systems)

Gravity Distribution Systems

DISADVANTAGES:

- Less flexible for future extensions (limited head)
- Small gradients available for friction losses require larger diameters pipes within the whole system
- Longer pipelines are necessary (for following terrain configuration)



$$Hf = f\ L/D\ *v2/2g$$

Pumped Distribution Systems

- Pumped Distribution System: System that operates without or with limited water storage facilities (water towers) in the distribution system. This means the pumping has to follow the demand patterns.

ADVANTAGES

- they are flexible for future extensions
- gradients available for friction losses are large and hence small diameter pipes can be used
- shorter pipelines can be used as the system need not follow terrain configuration

Pumped Distribution Systems Cont’

DISADVANTAGES:

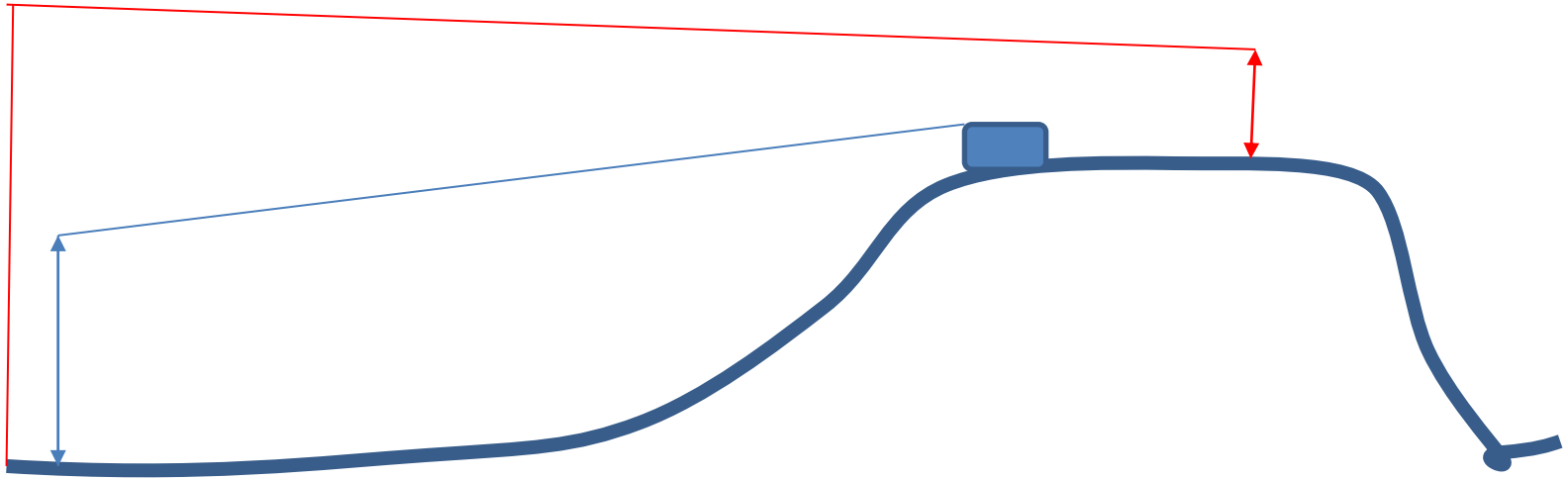
- They need a lot of electric energy
- Operation and maintenance is complex
- High maintenance costs
- The system is prone to pressure surges

COMBINED DISTRIBUTION SYSTEMS

- Operate with reservoirs and pumping stations.
- Storage in this case has considerable volume provided for balancing of daily variations in consumption and as a buffer for irregular situations.
- Most common systems for large distribution areas. (e.g. Lusaka)

Pressure Zones in Distribution Systems

- A pressure zone is an area of service supplied by a source or a number of sources that provides a constant hydraulic gradient.



- Where the topography is very uneven, pressure zones can be used (for both technical and economical reasons).
- Excessive pressures in the pipes will be avoided and at the same time, the cost of the project is reduced in that reasonable pipes can be used (not high pressure resistant ones that would be expensive)

Design of water transport and distribution systems

- Design criteria for water distribution systems can be classified either as:
  - Non hydraulic criteria
  - Hydraulic criteria

Non Hydraulic Criteria

- Technical /Engineering (Feasibility, - availability, type of pipes, system layout, Reliability, flexibility)
- Financial (Cost, Interest, Inflation ..)
- Socio-economical Criteria (Benefits, etc)
- Environmental

Hydraulic Design Criteria:

PRESSURE CRITERION

- Looks at adequacy of pressure in the system
- A minimum pressure of 5-6mwc above the highest tap in the system is required (15 - 25mwc above the street level)

Hydraulic Design Criteria:

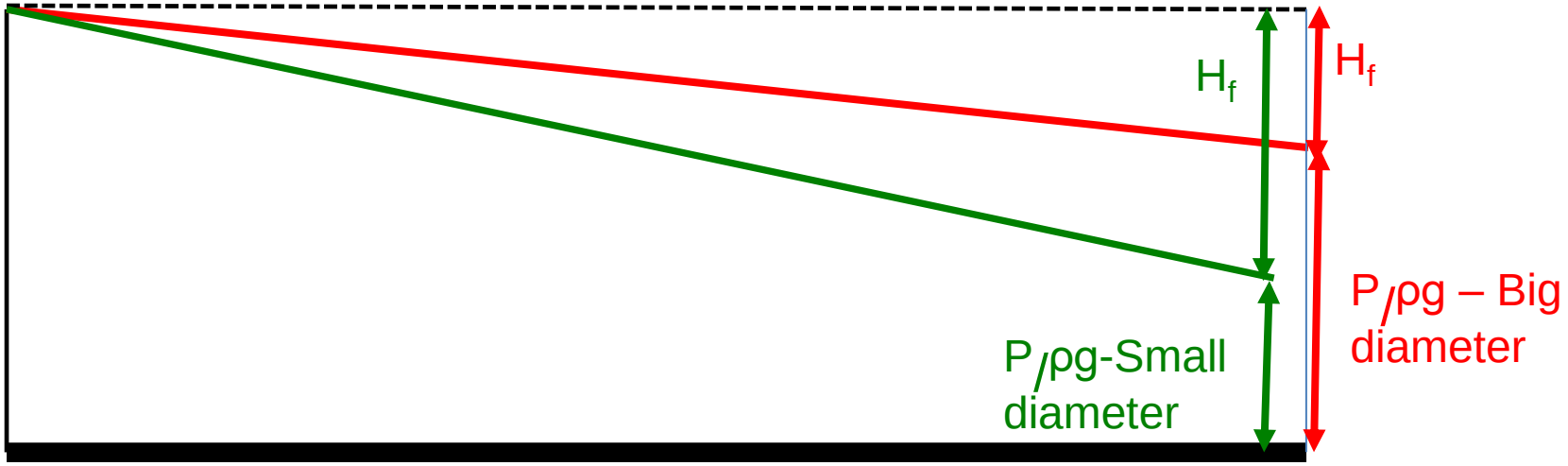
PRESSURE CRITERION

- Very high pressures to be avoided (Pressure is direct proportional to leakages; Impacts on quality of pipes).
- Generally, the pressure should never be above 60 - 70mwc (Differs from country to country – Remember pressure is a water quality parameter in a delivery system!!).
- (ZS 668 – Management of Non Revenue Water in Water Supply Systems – Code of Practice)

Hydraulic Design Criteria

VELOCITY CRITERION

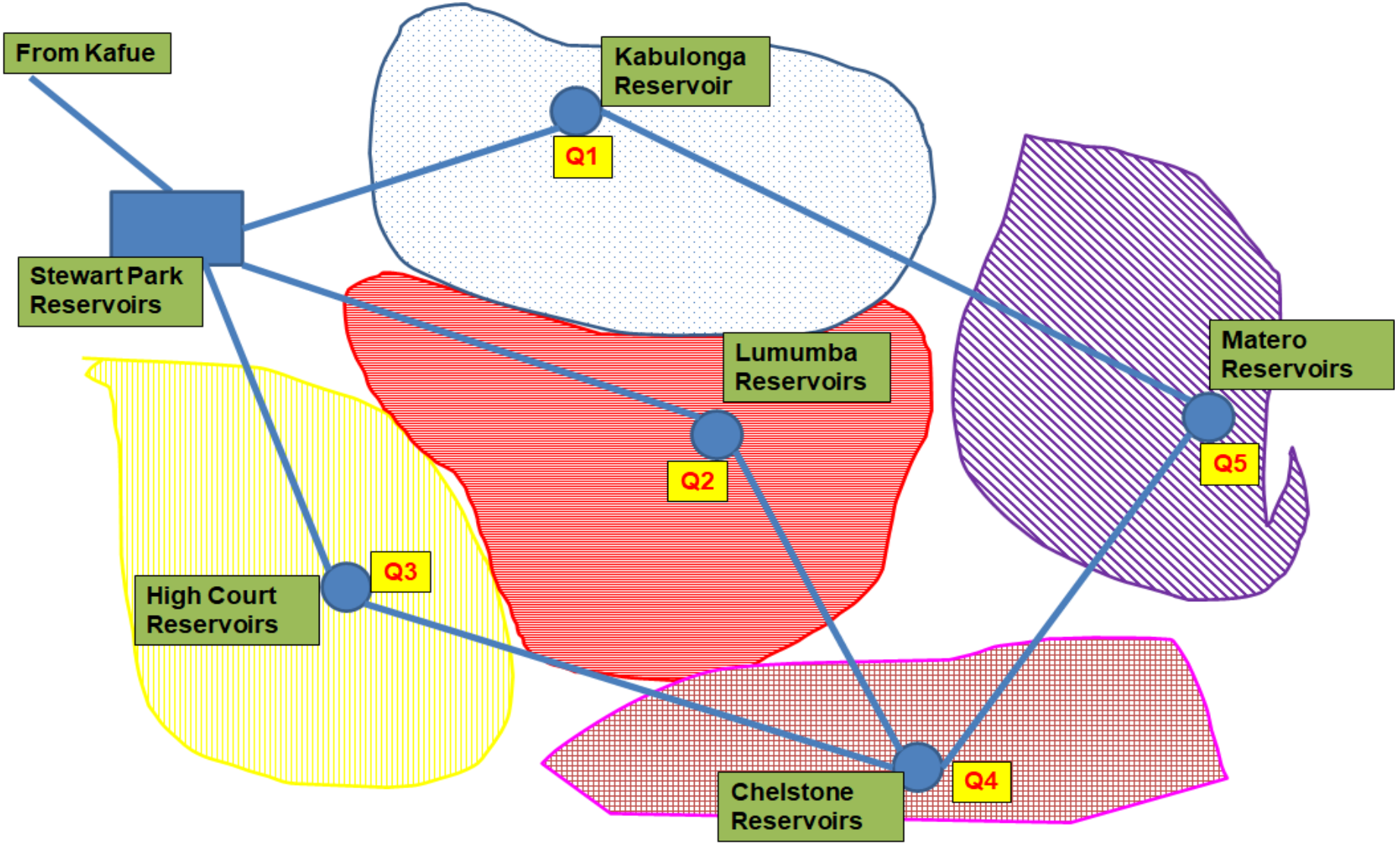
- Very high velocities are undesirable as they induce head loss.



- Very low velocities are also undesirable for hygienic reasons (long retention times in the system).
- Minimum velocity should be about 0.5m/s
- Maximum velocity should be about 1.5m/s.

Design of Water Distribution Systems and Networks

- Known data are locations and quantities of supply and demand points in the distribution area (allocation of demand to a node)



Design Of Water Distribution Systems and Networks

- Known data are locations and quantities of supply and demand points in the distribution area (allocation of demand to a node)

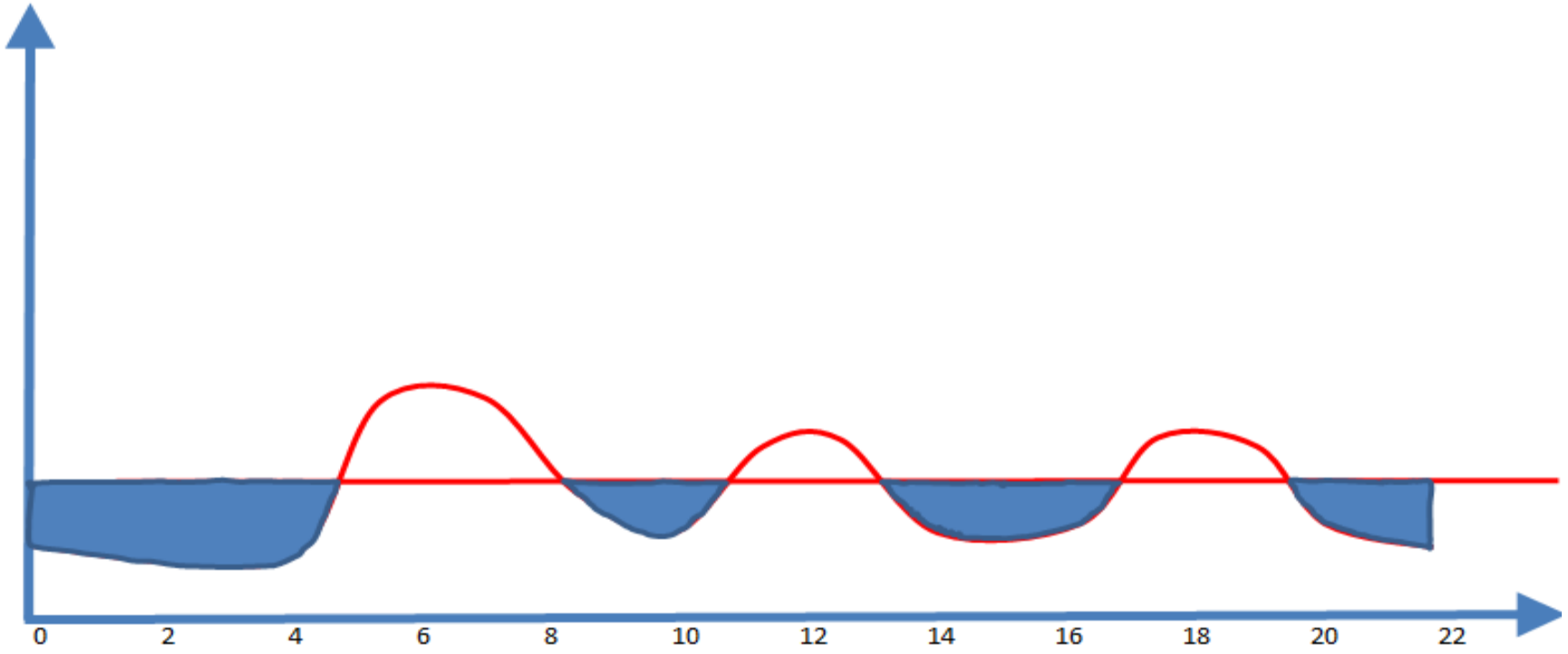
- This takes into consideration local population densities, coverage, existence of different demand categories, large consumers, etc). With this information the definition of the main route can be laid out (need to decide on the configuration).

- After the network is spread over the area, pipe sizing and analysis of hydraulic behaviour is next. This is usually achieved through the use of computer software (WaterGEMS, WaterCAD, EPANET etc)

Water Storage

PURPOSES OF STORAGE

- Meeting variations in water demand
- Providing a reserve supply in case of emergence



Classification of storage tank

- Elevated
- Ground Level
- Underground

Classification of storage tanks

- Elevated
- Ground Level
- Underground

Determination of storage volume

- Based on demand variation over a period of 24 hours for the worst conditions.
- This means the demand will be based on a day within a year when demand is highest
- 20-40 % of maximum daily average demand

Water supply in Rural and Peri-urban areas

END

THANK YOU