Lecture # 7

Introduction to Hydropower Engineering

Introduction

- Power is the basic necessity for the development of a country
- Per-capita consumption of electric energy is deemed as an index of the standard of living in a nation in the present-day-world.
- Development of large, medium and small scale industries depend upon electric power generation.
- This necessitates to utilize the present resource of energy with utmost care and with maximum efficiency.

Introduction

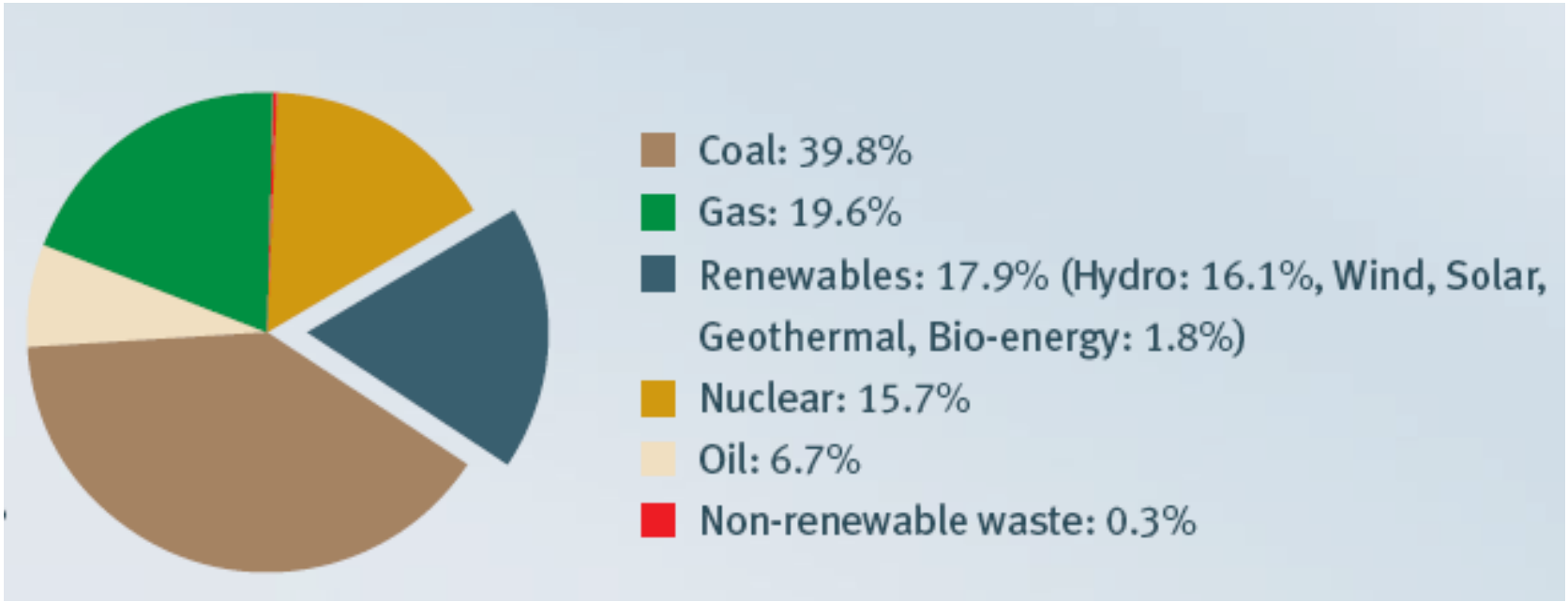
Country	Power Production (Million KW) (1992)	Per Capita Consumption (KWH)
USA	335	6230
JAPAN	320	5350
UK	265	3045
INDIA	110	985

Introduction

- Energy Resources:
  - Fossil Fuel (oil, gas, and coal etc)
  - Wind
  - Water in Rivers
  - Waves and Tides in Ocean
  - Solar Energy
  - Atomic/Nuclear Energy

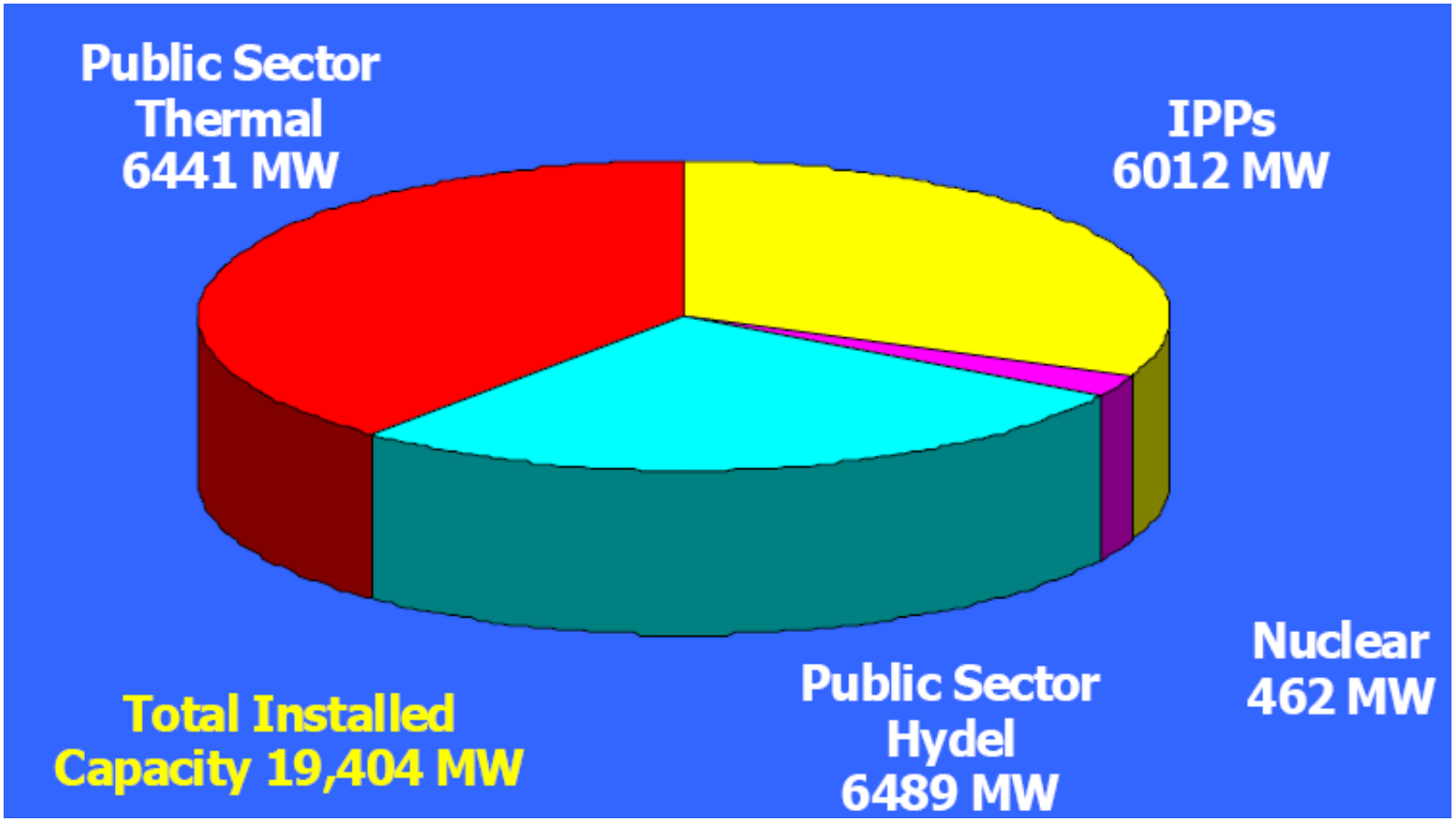
With good planning and management, hydropower is a catalyst for the sustainable improvement of people's lives.

Introduction



Power Generation Pattern of the world

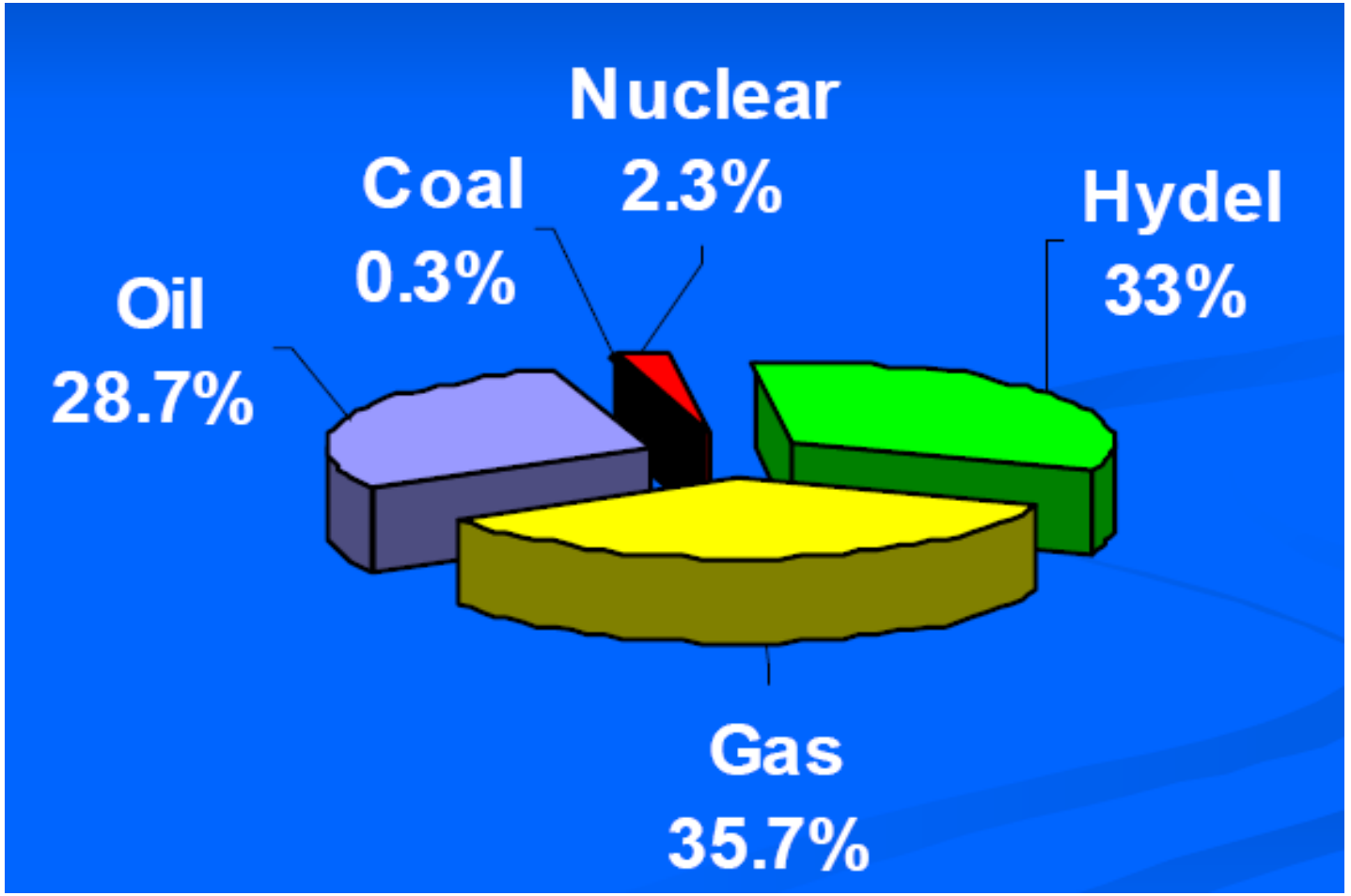
Power Sector Installed Capacity of Pakistan



As of (2004)

Hydropower Potential in Pakistan = 41,000 MW (approx.)

Power Sector Installed Capacity of Pakistan



Power Generation Pattern of the Pakistan (2004)

Access of population to electricity in Pakistan = 62%

Classification of Energy Resources

- **Renewable Energy:** These are sources of energy produced continuously in nature and will not get exhausted eventually in future. e.g., Hydel Energy, Solar Energy, Tidal Energy, Geo-thermal Energy and Biomass.
- **Non-Renewable Energy:** These are sources will get exhausted eventually in future. e.g., Energy from Fossil Fuel.

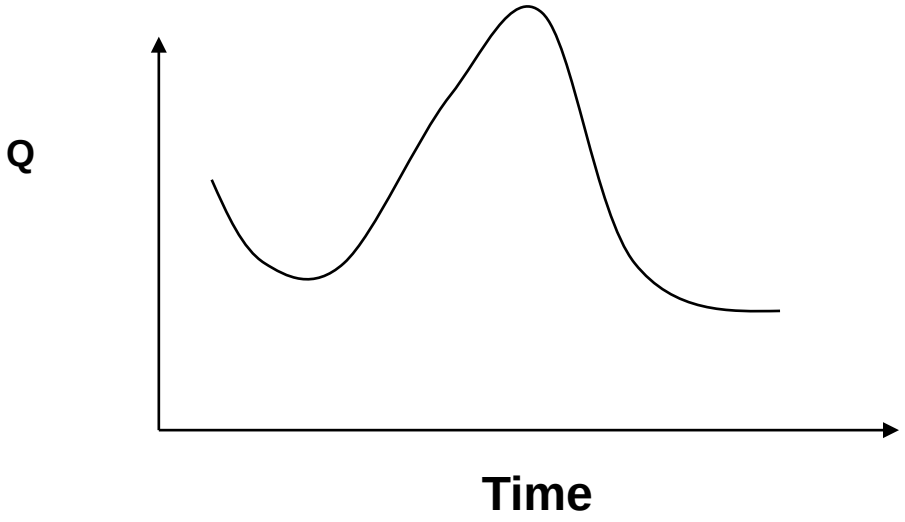
- **Conventional Energy:** Fossil Fuels, Hydel Power, Nuclear Energy
- **Non-Conventional Energy:** Solar Energy, Wind Energy, Tidal Energy, Ocean Thermal Energy, Geothermal Energy and Biomass.

- **Commercial Energy:** Coal, oil, gas, Hydel Energy, Nuclear
- **Non- Commercial Energy:** Wood, wastes etc

Classification of Energy Resources

- **Based on net yield of energy:**
- **Primary Energy Source:** The energy source which provides a net source of energy.
  - E.g. coal, natural gas, uranium, oil.
- **Secondary Energy Source:** From this source, the yield of energy is less than input.
  - E.g. Solar, Wind, Tidal, Water Energy.
- **Supplementary Energy Source:** If the net energy yield provided by the energy source is zero, it is called supplementary energy source.
  - E.g. thermal insulation.

Hydropower (Hydel Power)



$P=\gamma QH$

Where

P= Hydropower

Q = River discharge

H= Available head

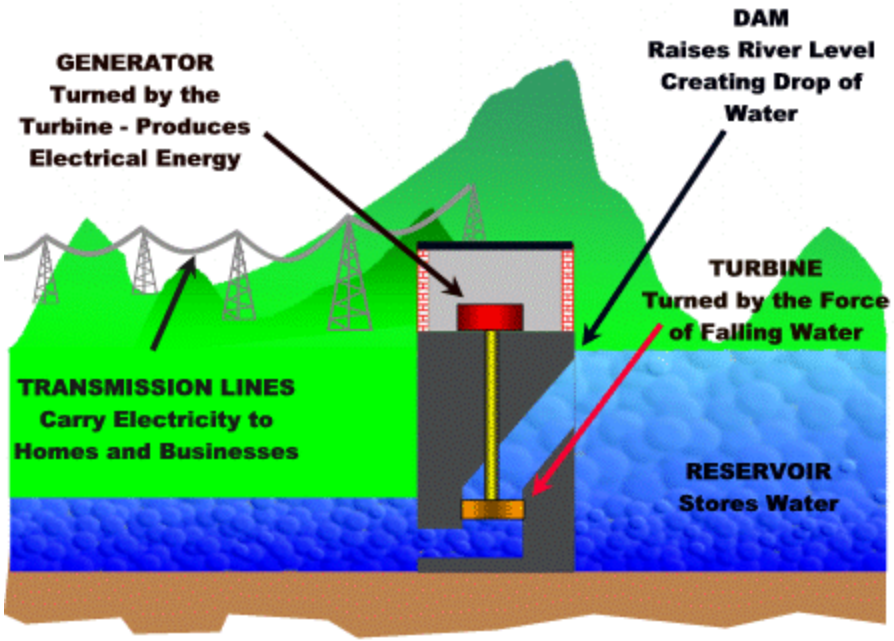
✓ **Hydropower** is extracted from the natural potential of usable water resources.

✓ If the water is available in the river as above, then for the production of energy reservoirs are made so as to make availability of water throughout the year

About one quarter of the world's power requirement is at present derived in this way.

How the Hydropower Works

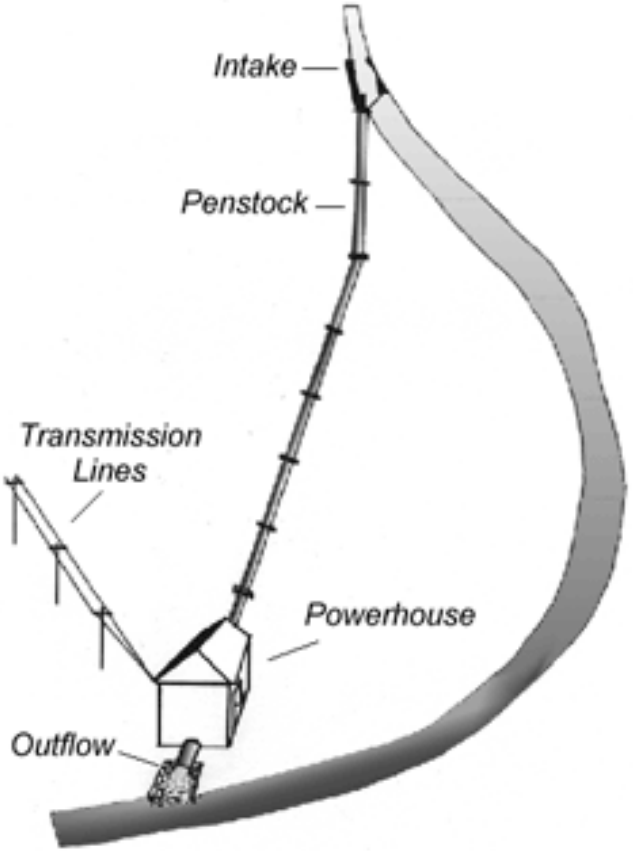
- Hydropower plants capture the energy of falling water to generate electricity. A turbine converts the kinetic energy of falling water into mechanical energy. Then a generator converts the mechanical energy from the turbine into electrical energy



With good planning and management, hydropower is a catalyst for the sustainable improvement of people's lives.

Essential Elements of Hydropower Station

- Interception of water
- Conveyance of water
- Power Station
- Safe Disposal of used water
- Transmission of electricity



Hydropower Offers a High Level of Service supporting better performance of other technologies

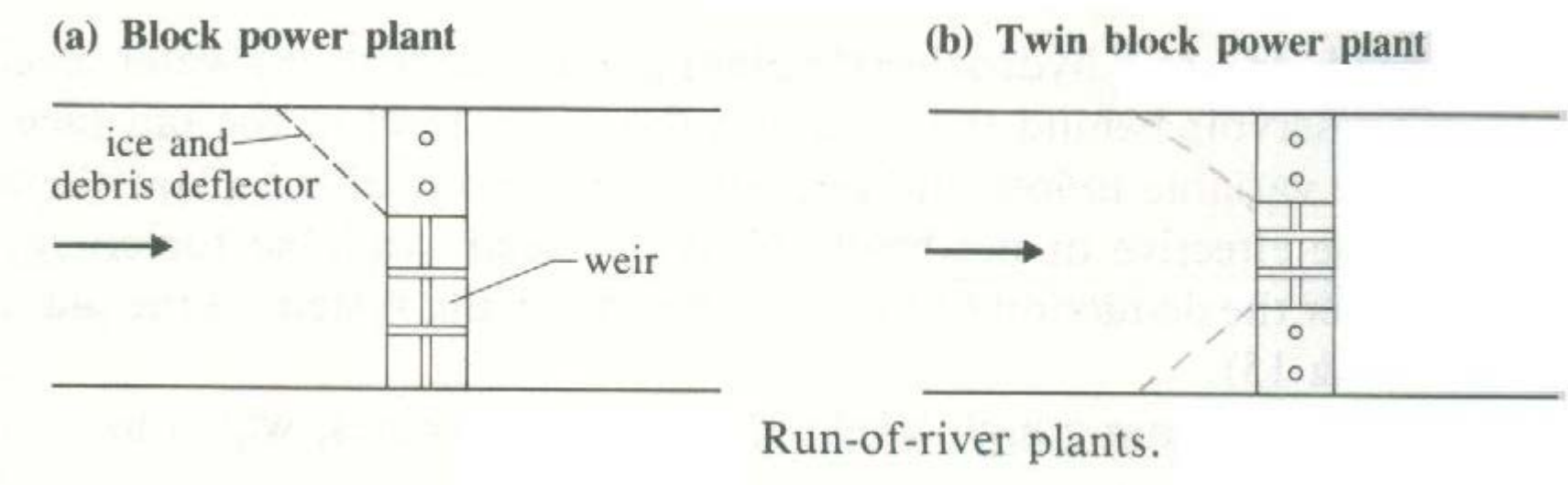
- **EFFICIENCY** Hydropower shows the:
  - Best conversion rate (~90%) due to the direct transformation of hydraulic forces to electricity
  - Most favorable energy payback ratio considering the amount of energy required to build, maintain and fuel a powerplant compared with the energy it produces during its normal life span
- **FLEXIBILITY:** Thanks to the storage of potential electricity in reservoirs, hydropower:
  - Has the capacity to provide base and peak-load
  - Is the ideal back-up source for intermittent electricity sources such as wind and solar
  - Optimizes efficiency of less flexible fossil or nuclear generating options has the capacity to follow demand fluctuations almost instantly
  - Offers a quick response to failings in power grids

Hydropower Offers a High Level of Service supporting better performance of other technologies

- **RELIABILITY: Hydropower is:**
  - A proven and well-advanced technology based on more than a century of experience the backbone of an integrated renewable grid
  - A clean source of renewable energy with the capacity to make a significant contribution to the world's ever-growing need for electricity

Types of Hydropower Development

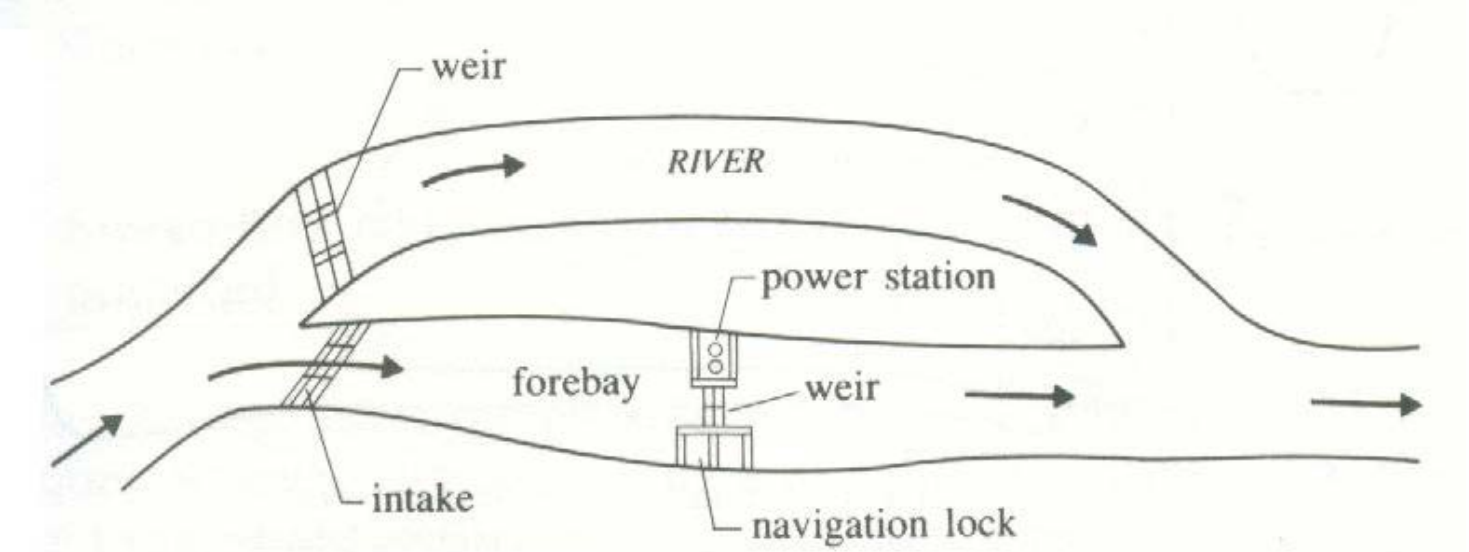
- **Run-of-River Plant (Local Development)**
  - A weir or barrage is built across the river and the low head is used to generate power.
  - It has very limited storage capacity and can only use water when available
  - Its firm capacity is low, because water supply is not uniform throughout the year, but it can serve as a base load plant



Run-of-river plants.

Types of Hydropower Development

- **Diversion Canal Plant**
  - The flow from impounding water in the river upstream of the barrage is diverted into a power canal which rejoins the river further downstream with power station located either next to the intake or with the canal or at the outlet.

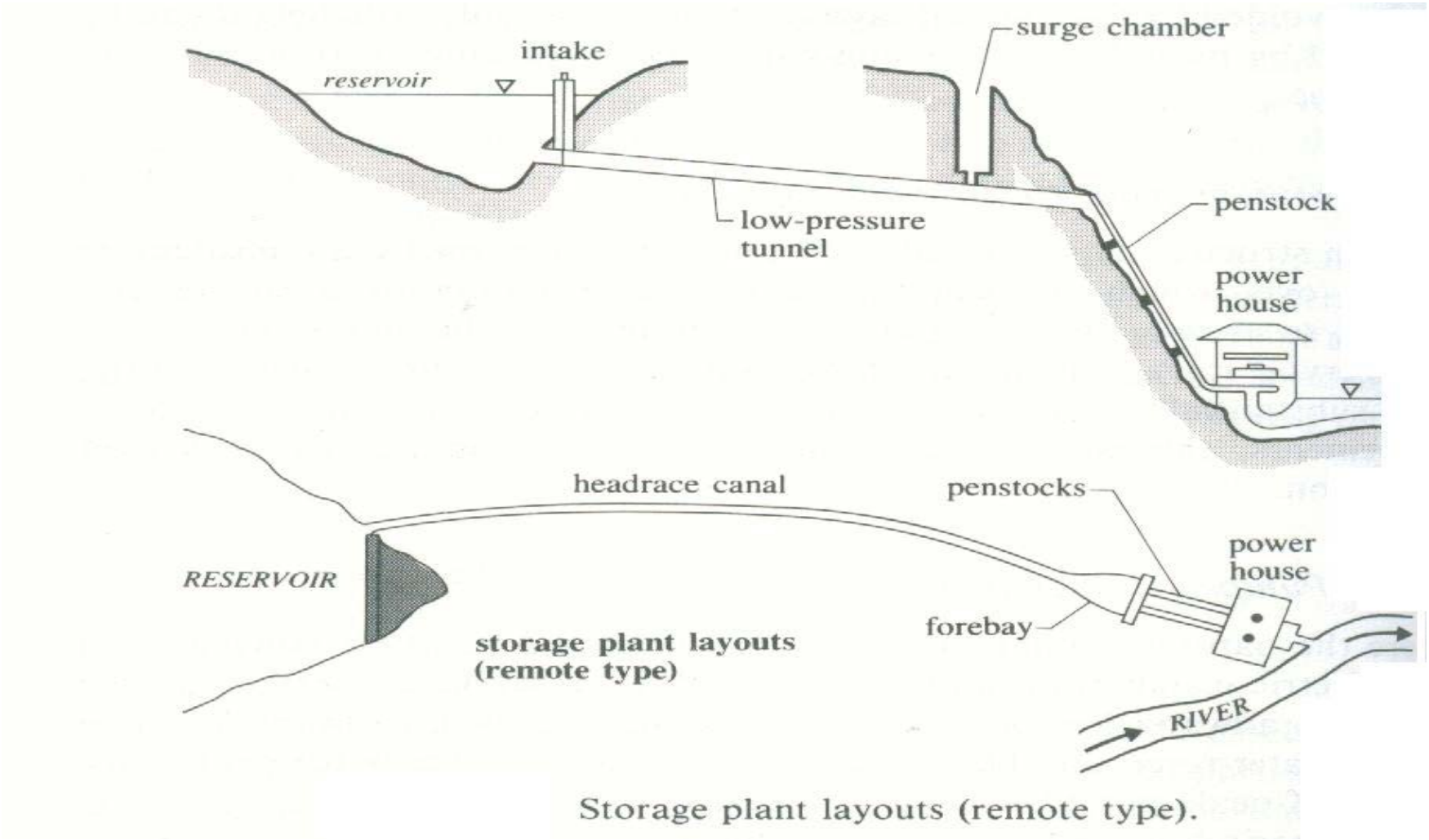


Diversion canal plant.

Types of Hydropower Development

- **Storage Plant**
  - The dam structure is separated from the power station by a considerable distance over which the water is conveyed, generally by a tunnel and pipeline, so as to achieve medium or high heads.
  - The reservoir storage upstream of the dam increases the firm capacity of the plant substantially, depending upon the run-off and power requirements.
  - The plant may be used as a base-load and/or peak-load installation.

Types of Hydropower Development



Storage plant layouts (remote type).

Types of Hydropower Development

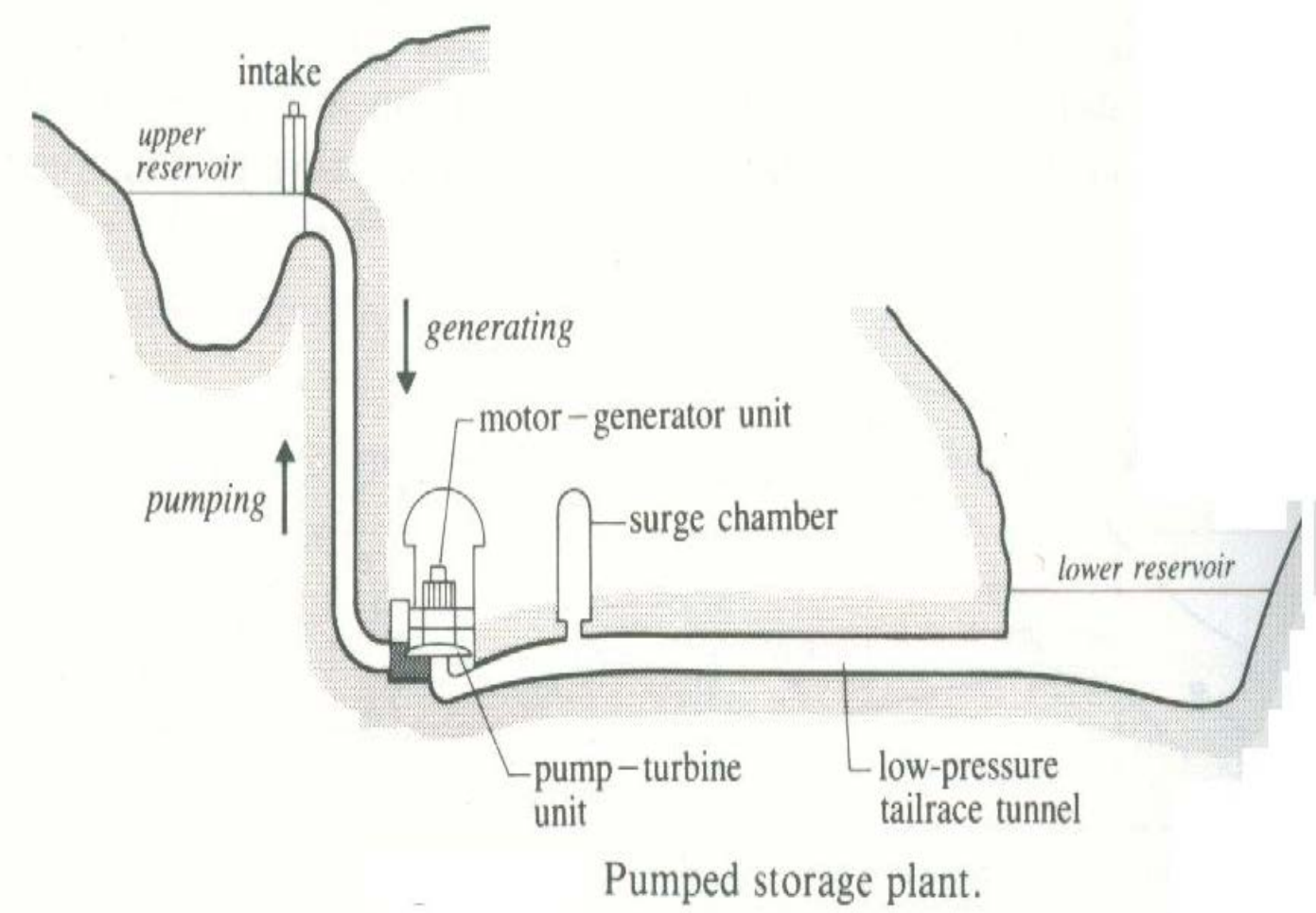
- **Pump Storage Plant**

  - Where the natural annual run-off is insufficient to justify a conventional hydroelectric installation, and where it is possible to have reservoirs at the head-and tail water locations, the water is pumped backed from lower to the head water reservoir.

  - This kind of plant generates energy for peak load, and at off-peak periods water is pumped back for future use.

  - A pumped storage plant is an economical addition to a system which increase the load factor of other systems and also provides additional capacity to meet the peak loads.

Types of Hydropower Development



Pumped storage plant.

Head Classification of Hydropower Plants

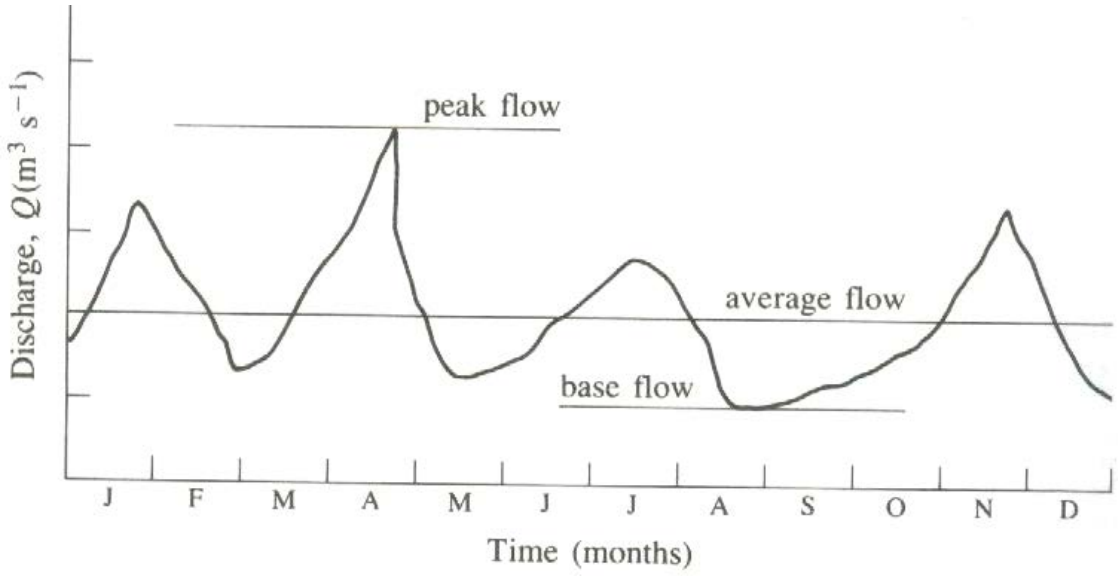
- Low Head Scheme
  - < 50 m
- Medium Head Scheme
  - 50 to 300 m
- High Head Scheme
  - >300 m

Stream Flow Data Essential for the Assessment of Water Power Potential

- The Following hydrological data are necessary;
  - The daily, weekly or monthly flow over a period of several years, to determine the plant capacity and estimated output which are dependent on the average flow of the stream and its distribution during the year
  - Low flows, to assess the primary, firm or dependable power.

Stream Flow Data Essential for the Assessment of Water Power Potential

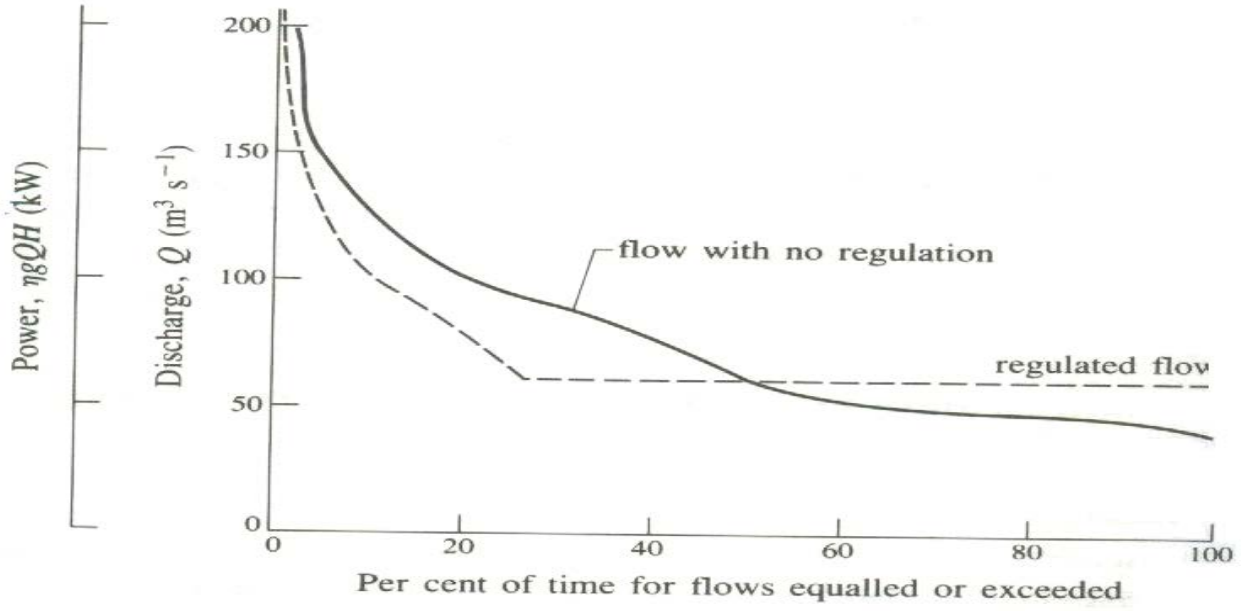
- **Stream Data Analysis:**
- A typical stream flow hydrograph, including a dry period from which the frequency of occurrence of a certain flow during the period can be calculated.



Streamflow hydrograph.

Stream Flow Data Essential for the Assessment of Water Power Potential

- **Flow Duration Curve:**
- It is a plot of the stream flow in ascending or descending order and its frequency of occurrence as a percentage of time covered by the record.



Flow/power duration curve (power scale multiplying factor = ηgH)

Stream Flow Data Essential for the Assessment of Water Power Potential

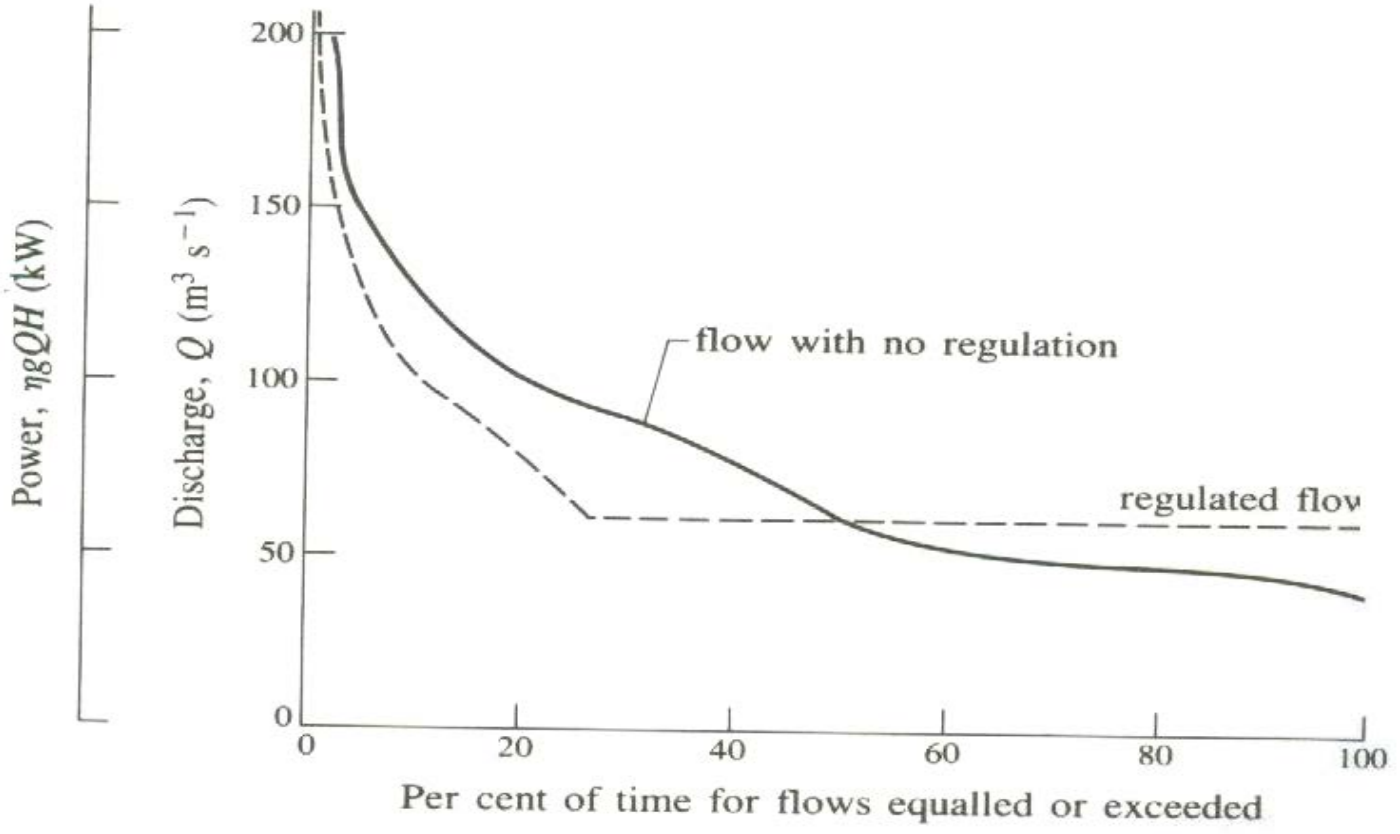
- **Power Duration Curve:**

- If the available head and efficiency of the power plant are known, the flow duration curve may be converted into power duration curve.

- The power which is available for 95% to 97% of the time on the reservoir regulated scheme is usually considered Primary of Firm power.

- All the power in excess of primary power is called Secondary or Surplus Power.

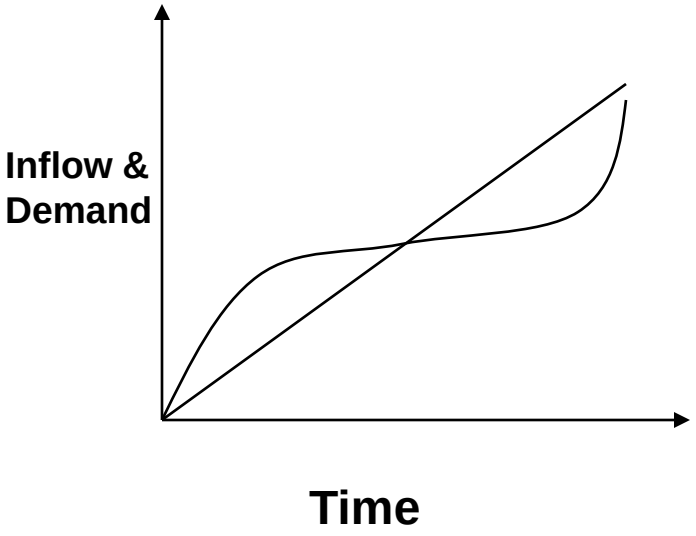
Stream Flow Data Essential for the Assessment of Water Power Potential

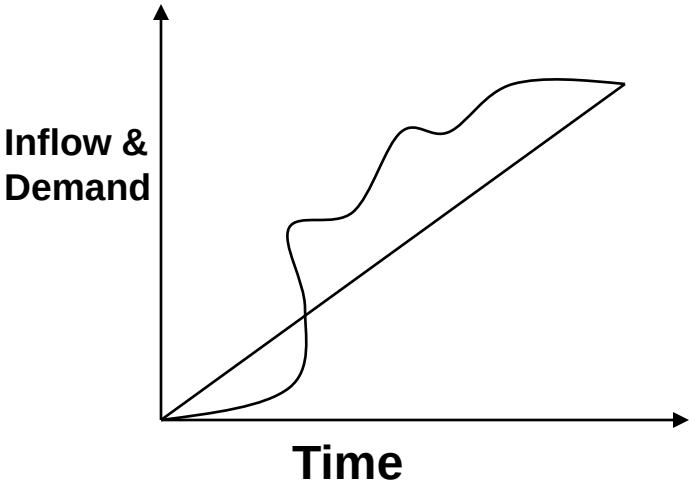


Flow/power duration curve (power scale multiplying factor = ηgH)

Stream Flow Data Essential for the Assessment of Water Power Potential

- **Mass Curve:** is the curve of accumulated total inflow against time.
- **Demand Curve:** is the curve of accumulated total demand against time.





Mass curve is used to estimate storage requirements and useable flow for power production.

Why Hydropower is Backbone to Sustainable Energy?

- **Hydropower is a renewable source of energy**
  - Hydropower uses the energy of flowing water, without depleting it, to produce electricity; therefore, all hydropower projects – small or large, run-of-river or storage –meet the definition of renewable.
- **Hydropower supports the development of other renewable energies**
  - Hydropower facilities with reservoirs offer unique operational flexibility in that they can respond immediately to fluctuating demand for electricity. Hydropower's flexibility and storage capacity make it the most efficient and cost-effective way to support the deployment of intermittent renewables such as wind or solar power.

Why Hydropower is Backbone to Sustainable Energy?

- **Hydropower fosters energy security and price stability**
  - River water is a domestic resource and, unlike fuel or natural gas, it is not subject to market fluctuations; moreover, hydropower is the only major renewable source of electricity, and its cost-effectiveness, efficiency, flexibility and reliability help optimize the operation of thermal plants.
- **Hydropower contributes to freshwater storage**
  - Hydropower reservoirs collect rainwater, which can then be used for drinking or irrigation. By storing water, they protect aquifers from depletion and reduce our vulnerability to floods and droughts.

Why Hydropower is Backbone to Sustainable Energy?

- **Hydropower improves electricity grid stability and reliability**
  - The management of electricity grids depends upon fast, flexible generation sources to meet peak power demands, maintain level system voltages and quickly restore service after a blackout. Electricity generated from hydropower can be placed on the grid faster than any other energy source. Hydropower's ability to go from zero power to maximum output rapidly and predictably makes it exceptionally good at meeting changing loads and providing ancillary electrical services that maintain the balance between electricity supply and demand.

Why Hydropower is Backbone to Sustainable Energy?

- **Hydropower helps fight climate change**
  - The life cycle of hydropower produces very small amounts of greenhouse gases (GHGs). By offsetting GHG emissions from gas, coal and oil fired power plants, hydropower can help slow global warming. Although only 33% of potential hydro resources have been developed, hydropower currently avoids burning 4.4 million barrels of oil-equivalent daily, worldwide.
- **Hydropower can reduce pollution**
  - Hydropower plants produce no air pollutants. Very often, they replace fossil-fuelled generation, thereby reducing acid rain and smog. Moreover, hydropower projects do not generate any toxic by-products.

Why Hydropower is Backbone to Sustainable Energy?

- **Hydropower makes a significant contribution to development**
  - Hydropower facilities bring electricity, roads, industry and commerce to communities, thereby developing the economy, improving access to health and education, and enhancing the quality of life. Hydropower is a technology that has been known and proven for over a century. Its impacts are well understood and manageable through mitigation and enhancement measures. It offers vast potential and is available where development is most needed.

Why Hydropower is Backbone to Sustainable Energy?

- **Hydropower means clean, affordable power**
  - With an average life span of 50 to 100 years, hydro-power projects are long-term investments that can benefit several generations. They can easily be upgraded to incorporate the latest technologies and have very low operation and maintenance costs.
- **Hydropower is a key tool for sustainable development**
  - Hydropower projects that are developed and operated in an economically viable, environmentally sound and socially responsible manner represent sustainable development at its best, that is, development that meets the needs of the people today without compromising the ability of future generations to meet their own needs.

Lecture # 8

Numerical Problems:

Problem # 1:

The avg. monthly flows of a stream in a dry year are as follows:

Month	Discharge (m^3/sec)
January	117
February	150
March	203
April	117
May	80
June	118
July	82
August	79
September	58
October	45
November	57
December	152

Numerical Problems:

Problem # 1:

It is intended to design a hydroelectric power plant using the following data:

Net head at plant site = 20 m

overall efficiency of turbine = 90 %

- Plot flow and power duration curves and calculate the firm and secondary power available from this source if the maximum useable water is limited to 150 m^3/sec.
- it is intended to develop at a firm rate of 15 Mwatt either by providing a storage or by providing a stand by diesel with no storage. Determine minimum capacity of reservoir and of the diesel unit.
- How much flow is available for a particular %age of time.

Numerical Problems:

Problem # 2:

Average annual flows in river indus at a proposed dam site is 120 BCM. The dam is to be built on a varying head from 50 m to 100 m on the turbines, estimate:

- Water power potential from this proposed hydal power station if overall efficiency of turbines is 88% and that of generator is 92%. Find the electrical energy available on the scheme in kWH per year in one year. The hydrological data suggests that avg. head available for six months is 50 m, for next three months, 80 m and for rest of the months is 100 m.