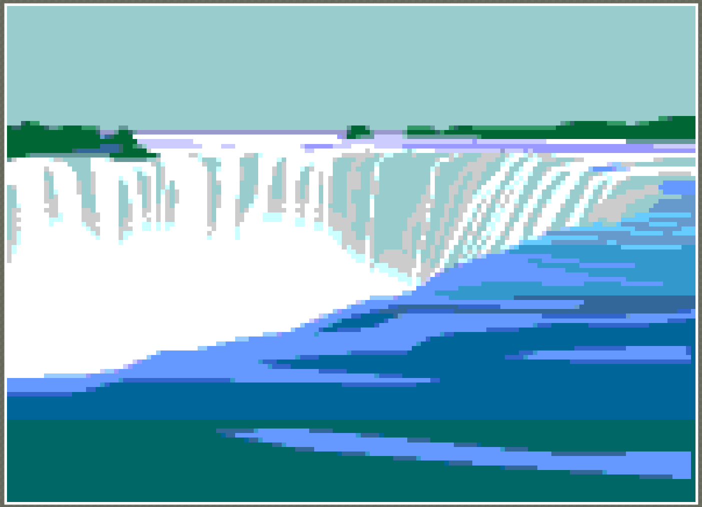
Dronacharya Group of Institution

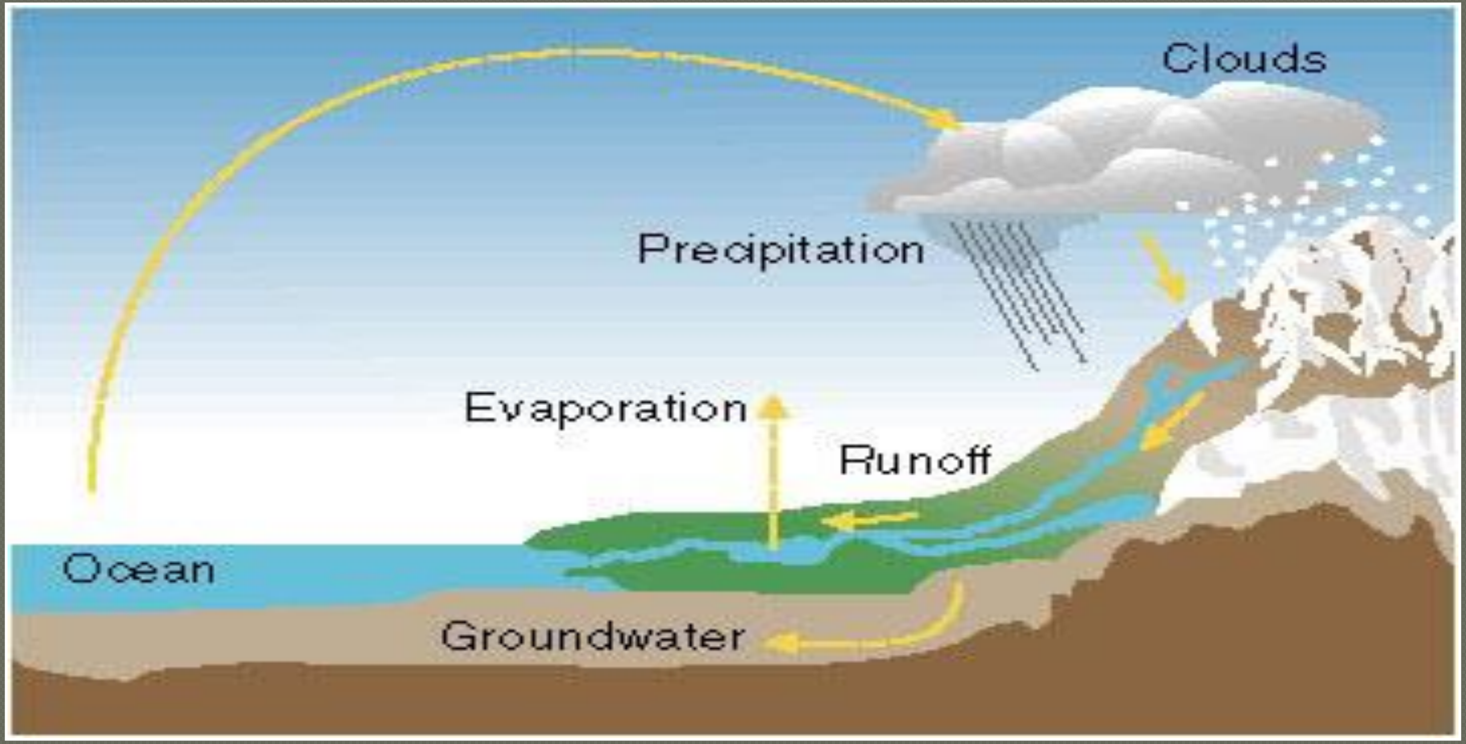
Powerplant Engineering

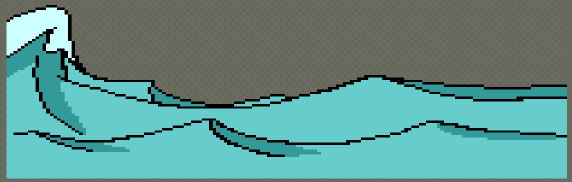
UNIT -2
Hydroelectric Powerplant

Hydroelectric power (often called hydropower) is considered a **renewable energy source.** A renewable energy source is one that is not depleted (used up) in the production of energy. Through hydropower, the energy in falling water is converted into electricity without "using up" the water.

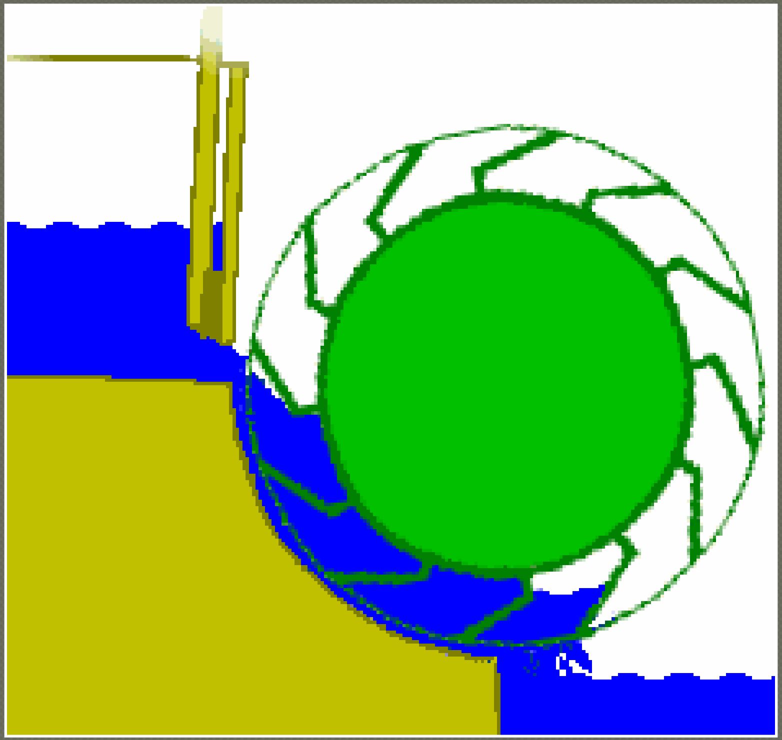


Hydropower energy is ultimately derived from the sun, which drives the **water cycle**. In the water cycle, rivers are recharged in a continuous cycle. Because of the force of gravity, water flows from high points to low points. There is **kinetic energy** embodied in the flow of water.





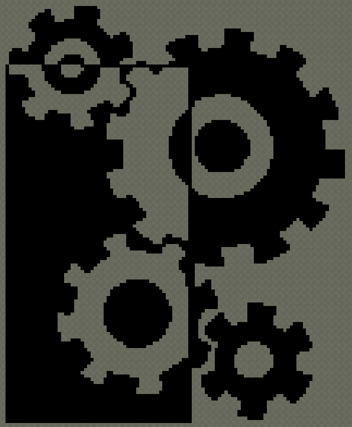
Kinetic energy is the energy of motion. Any moving object has kinetic energy.



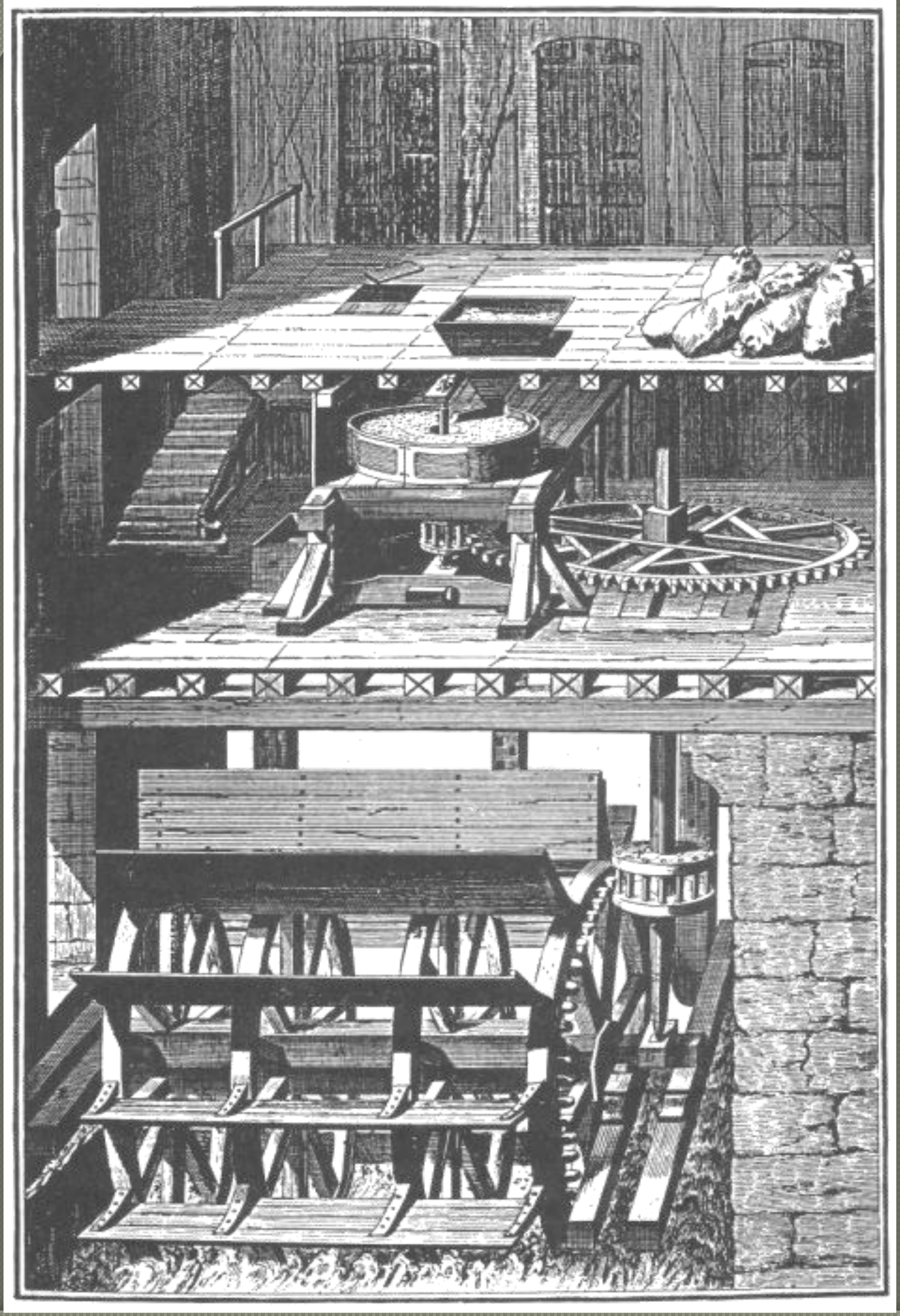
Humans first learned to harness the kinetic energy in water by using **waterwheels**.

A waterwheel is a revolving wheel fitted with blades, buckets, or vanes.

Waterwheels convert the kinetic energy of flowing water to **mechanical energy**.

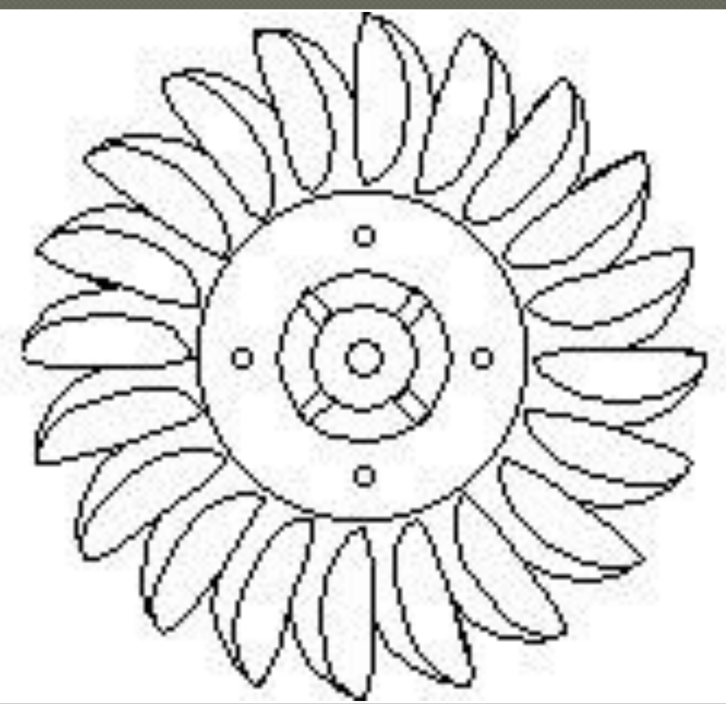


Mechanical energy is a form of kinetic energy, such as in a machine. Mechanical energy has the ability to do work. Any object that is able to do work has mechanical energy.

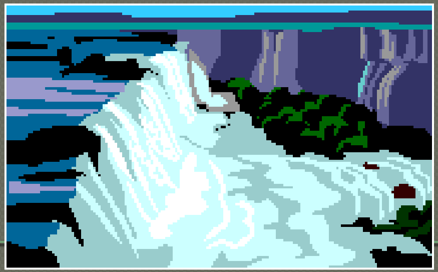


Early waterwheels used mechanical energy to grind grains and to drive machinery such as sawmills and blacksmith equipment.

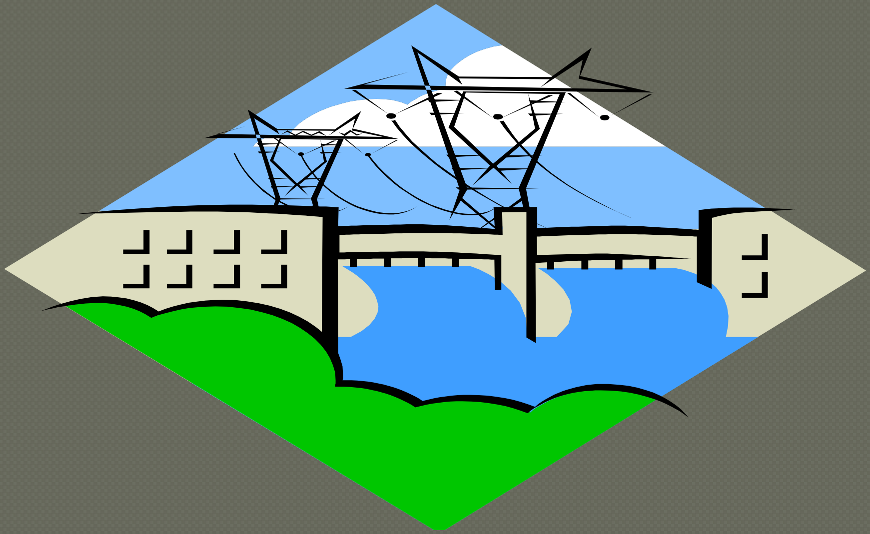
Waterwheel technology advanced over time. **Turbines** are advanced, very efficient waterwheels. They are often enclosed to further capture water's energy.



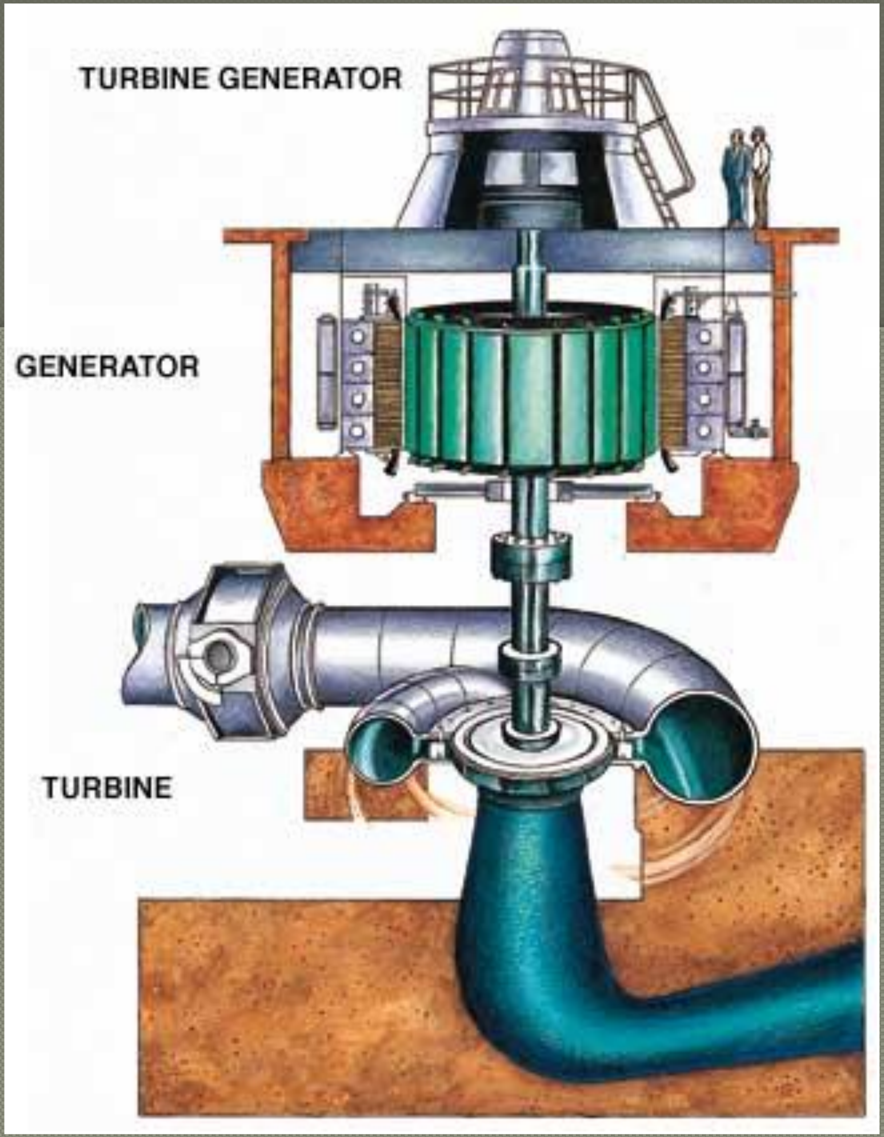
Not long after the discovery of electricity, it was realized that a turbine's mechanical energy could be used to activate a generator and produce electricity. The first hydroelectric power plant was constructed in 1882 in Appleton, Wisconsin. It produced 12.5 kilowatts of electricity which was used to light two paper mills and one home.



Hydroelectric power (hydropower) systems convert the kinetic energy in flowing water into electric energy.



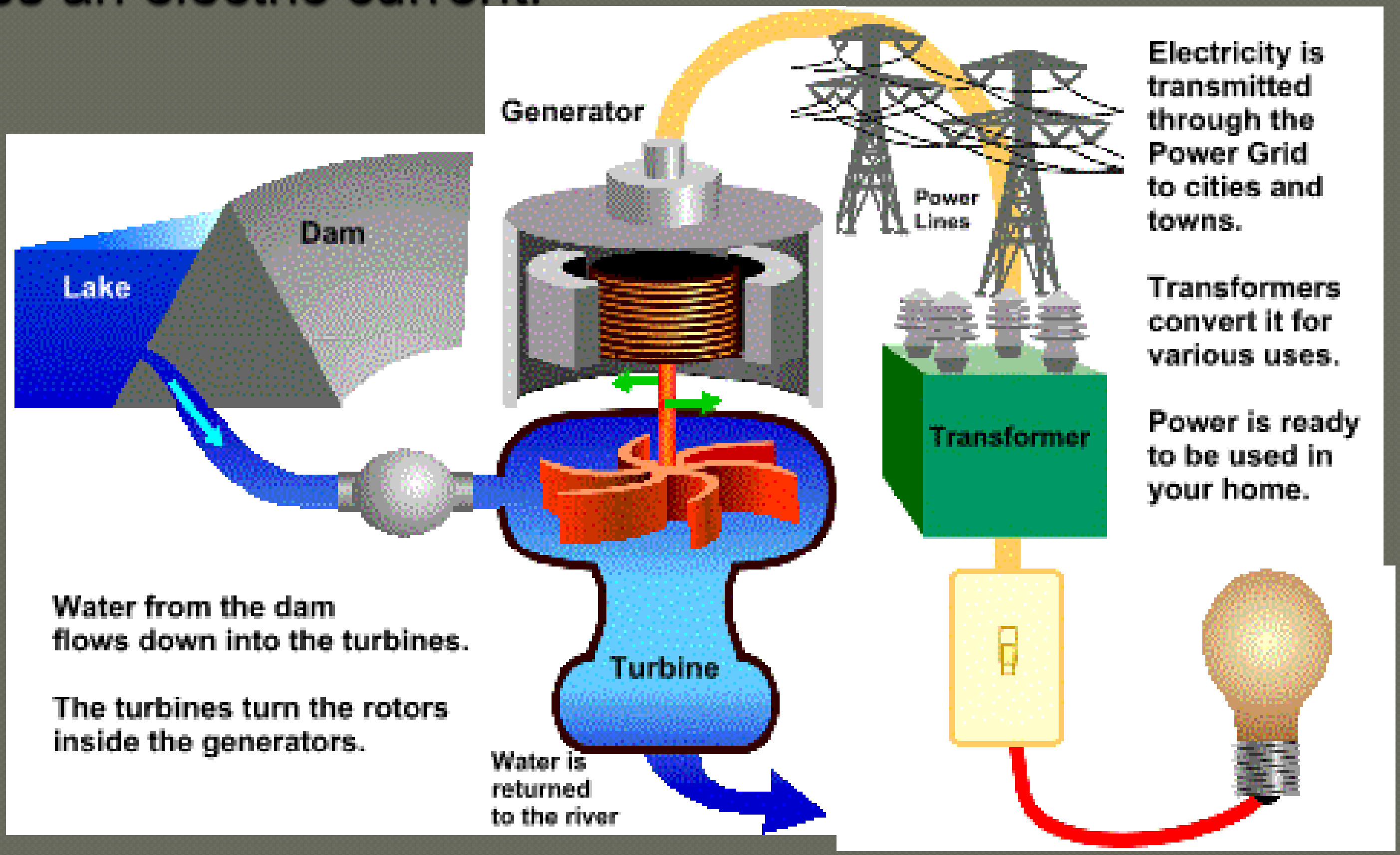
How a Hydroelectric Power System Works - Part 1



Flowing water is directed at a turbine (remember turbines are just advanced waterwheels). The flowing water causes the turbine to rotate, converting the water's kinetic energy into mechanical energy.

How a Hydroelectric Power System Works – Part 2

The mechanical energy produced by the turbine is converted into **electric energy** using a turbine generator. Inside the generator, the shaft of the turbine spins a magnet inside coils of copper wire. It is a fact of nature that moving a magnet near a conductor causes an electric current.



How much electricity can be generated by a hydroelectric power plant?

The amount of electricity that can be generated by a hydropower plant depends on two factors:

- **flow rate** - the quantity of water flowing in a given time; and
- **head** - the height from which the water falls.

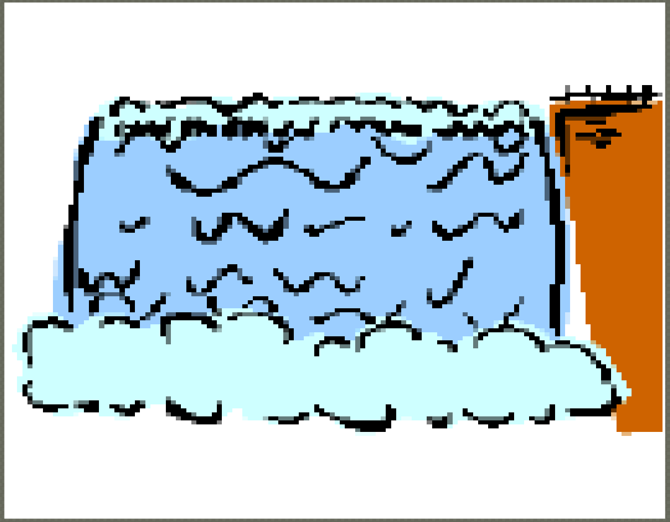
The greater the flow and head, the more electricity produced.

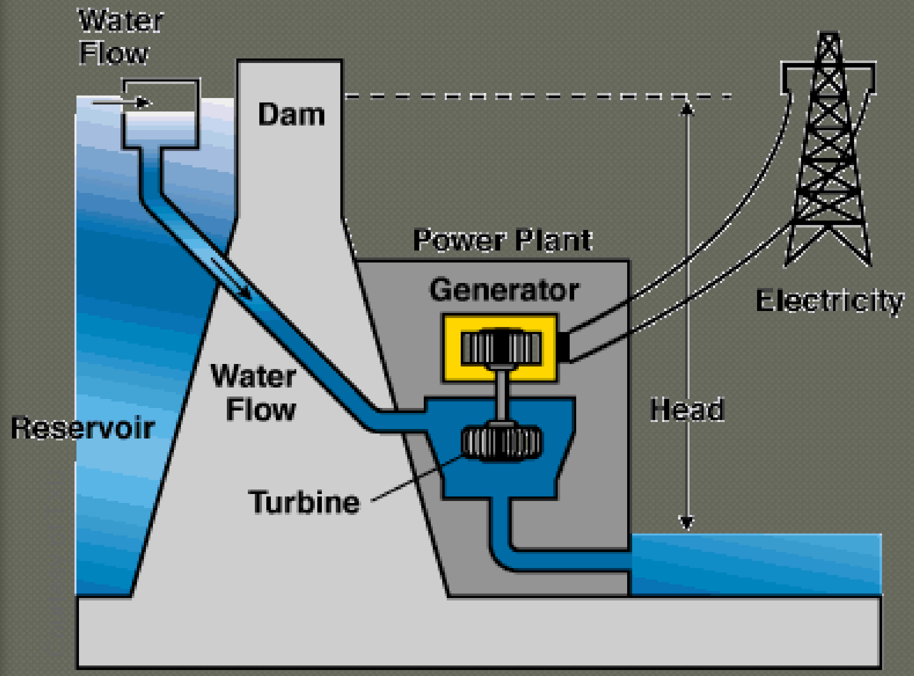
Flow Rate = the quantity of water flowing

When more water flows through a turbine, more electricity can be produced. The flow rate depends on the size of the river and the amount of water flowing in it. Power production is considered to be **directly proportional** to river flow. That is, twice as much water flowing will produce twice as much electricity.

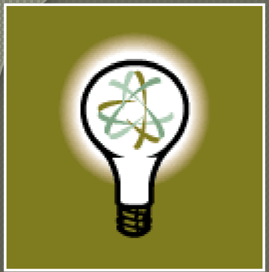
Head = the height from which water falls

The farther the water falls, the more power it has. The higher the dam, the farther the water falls, producing more hydroelectric power. Power production is also **directly proportional** to head. That is, water falling twice as far will produce twice as much electricity.





It is important to note that when determining head, hydrologists take into account the pressure behind the water. Water behind the dam puts pressure on the falling water.



A standard equation for calculating energy production:

$$\text{Power} = \frac{(\text{Head}) \times (\text{Flow}) \times (\text{Efficiency})}{11.8}$$

Power = the electric power in kilowatts or kW

Head = the distance the water falls (measured in feet)

Flow = the amount of water flowing (measured in cubic feet per second or **cfs**)

Efficiency = How well the turbine and generator convert the power of falling water into electric power. This can range from 60% (0.60) for older, poorly maintained hydroplants to 90% (0.90) for newer, well maintained plants.

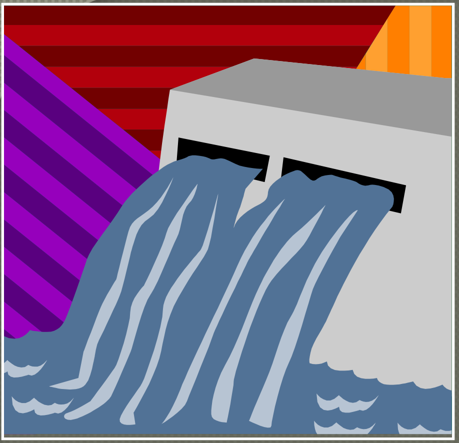
11.8 = Index that converts units of feet and seconds into kilowatts

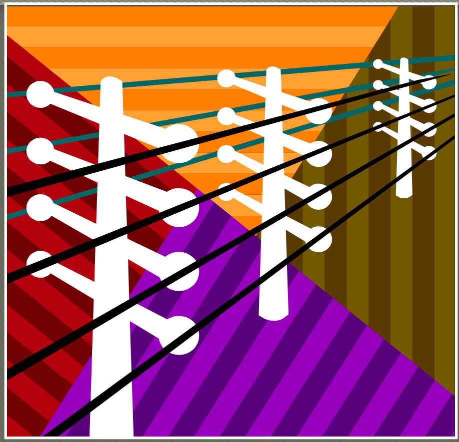
As an example, let’s see how much power can be generated by the power plant at Roosevelt Dam, the uppermost dam on the Salt River in Arizona.

Although the dam itself is 357 feet high, the **head** (distance the water falls) is 235 feet. The typical **flow rate** is 2200 cfs. Let’s say the turbine and generator are 80% efficient.

$$\text{Power} = \frac{(\text{Head}) \times (\text{Flow}) \times (\text{Efficiency})}{11.8}$$

$$\text{Power} = \frac{235\text{ft.} \times 2200 \text{ cfs} \times .80}{11.8}$$





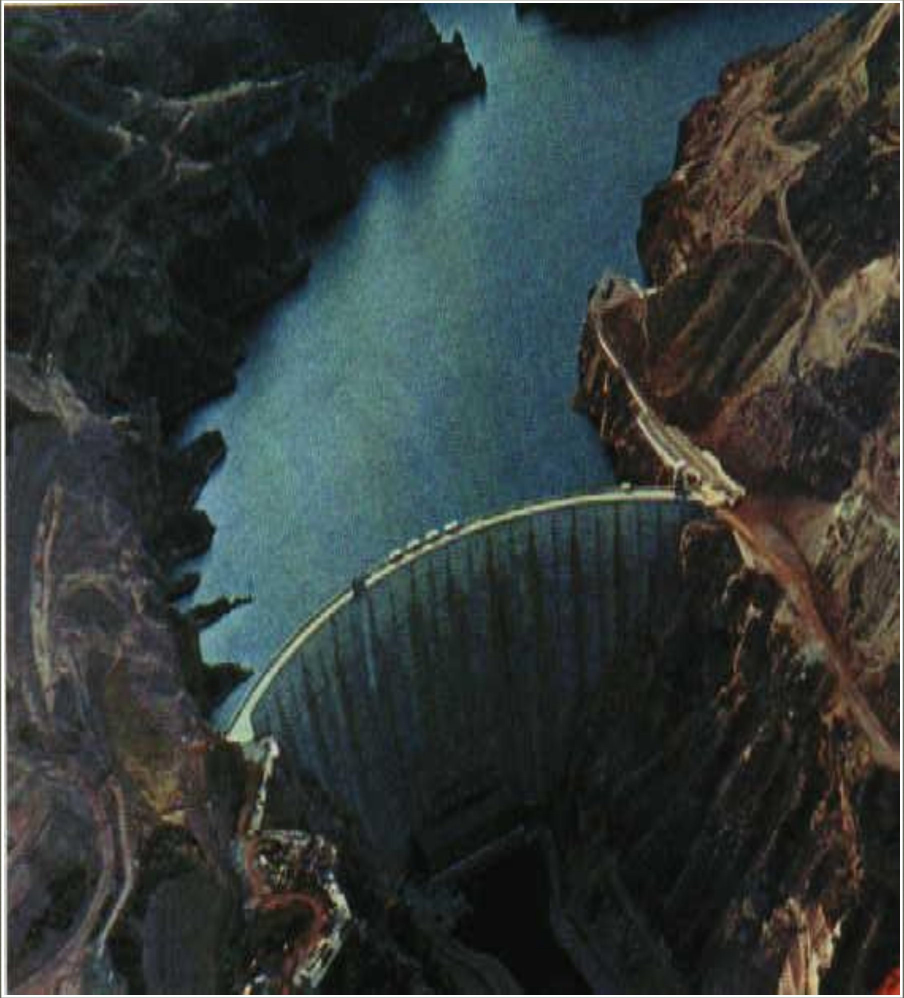
$$\text{Power} = \frac{517{,}000 \times .80}{11.8}$$

$$\text{Power} = \frac{413{,}600}{11.8}$$

Power = 35,051 kilowatts (kW)

Roosevelt’s generator is actually rated at a capacity of 36,000 kW.

High-head Hydropower



Tall dams are sometimes referred to as **"high-head"** hydropower systems. That is, the height from which water falls is relatively high.

Low-head Hydropower

Many smaller hydropower systems are considered **"low-head"** because the height from which the water falls is fairly low. **Low-head** hydropower systems are generally less than 20 feet high.

Environmental Considerations

High-head hydropower systems can produce a tremendous amount of power. However, large hydropower facilities, while essentially pollution-free to operate, still have undesirable effects on the environment.

Installation of new large hydropower projects today is very controversial because of their negative environmental impacts. These include:

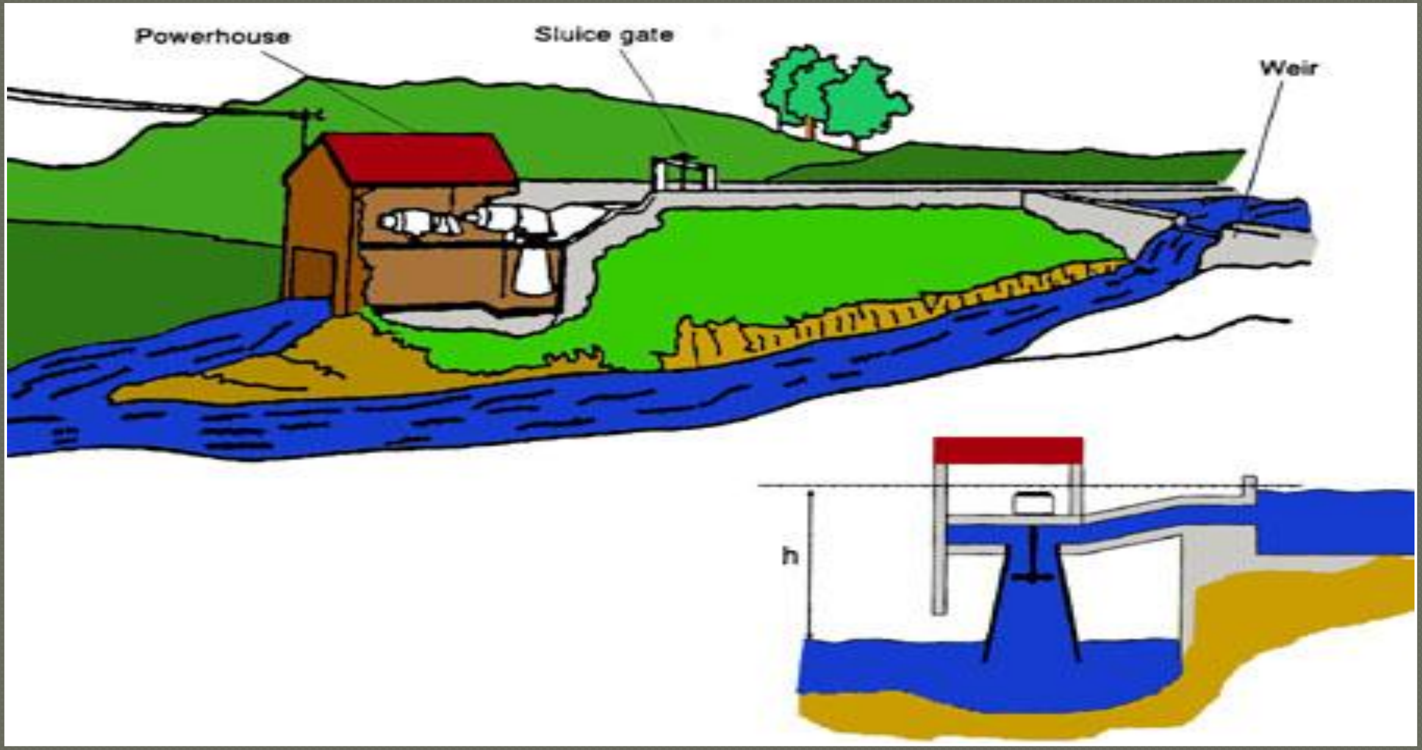
- ✓upstream flooding
- ✓declining fish populations
- ✓decreased water quality and flow
- ✓reduced quality of upstream and downstream environments

Glen Canyon June 1962

Glen Canyon June 1964

Low-head and Low Impact Hydropower

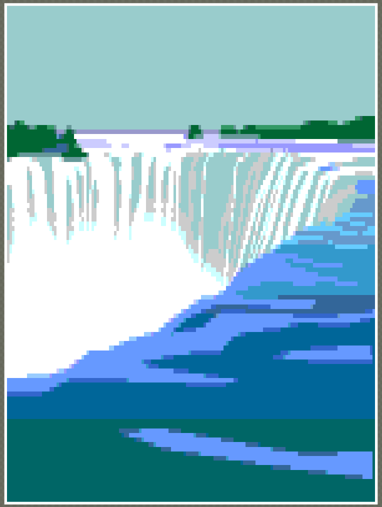
Scientists today are seeking ways to develop hydropower plants that have less impact on the environment. One way is through low-head hydropower. Low-head hydropower projects are usually **low impact** as well—that is, they have fewer negative effects on the environment.



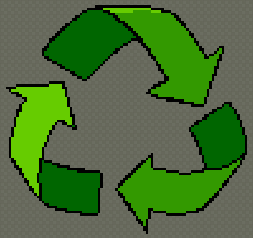
Example of a low-head, low impact hydropower system.

Low Impact Hydropower

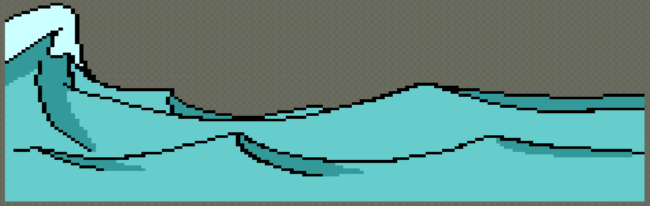
A hydropower project is considered **low impact** if it considers these environmental factors:



- river flow
- water quality
- watershed protection
- fish passage and protection
- threatened and endangered species protection
- cultural resource protection
- recreation
- facilities recommended for removal



Because the water cycle is continuous, hydropower is a renewable energy source.



The future of hydropower lies in technologies that are also environmental friendly.

end part one

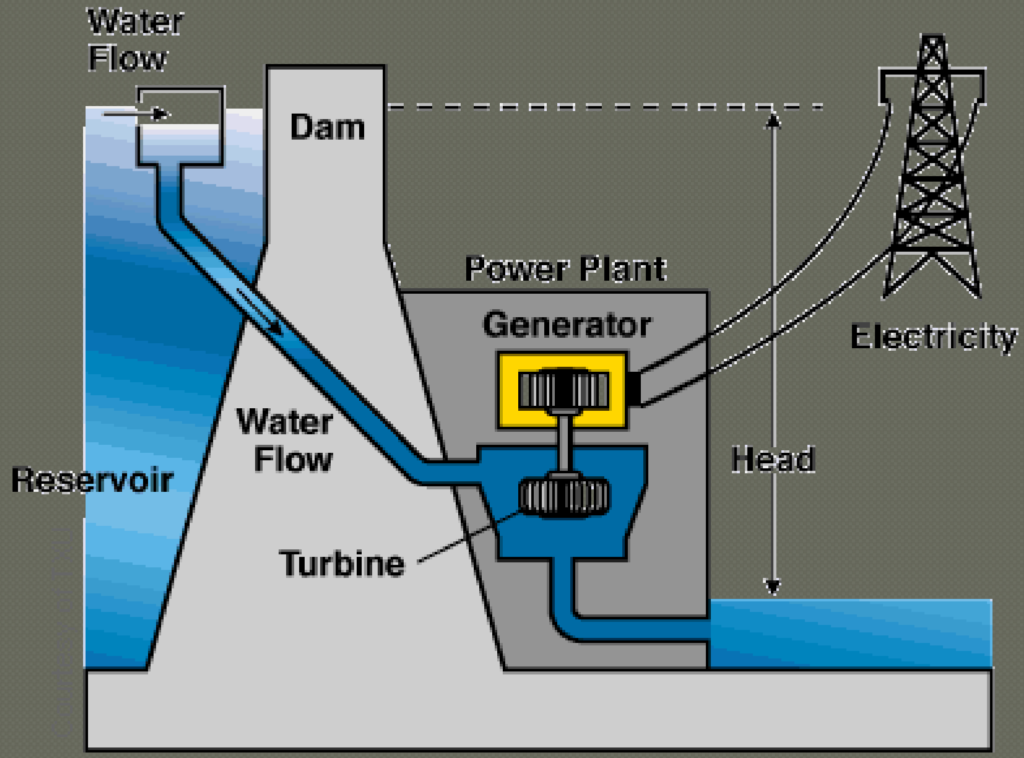
Renewable Energy Education

Unit 3: Low Impact Hydroelectric Power

Lesson 1
INTRODUCTION TO HYDROELECTRIC POWER
Part Two

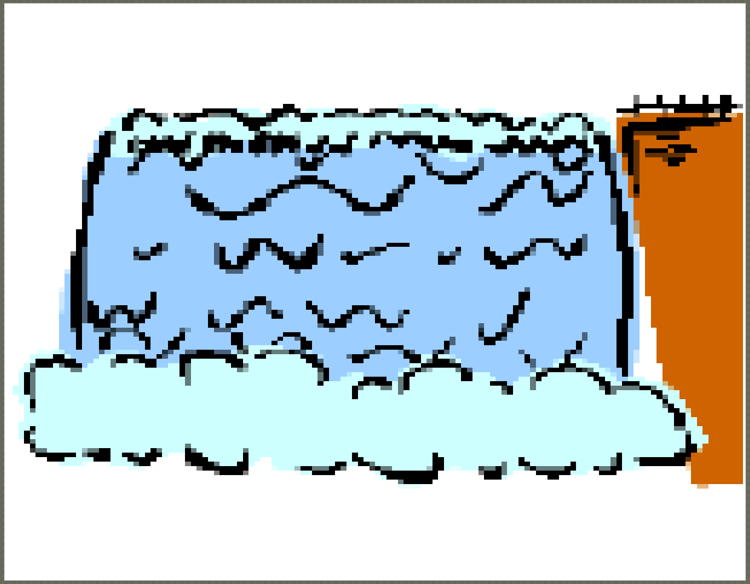
Part One Review

How a Hydropower System Works



Flowing water is directed at a turbine which (inside the generator) spins a magnet inside coils of copper wire. This produces an electric current.

Part One Review
Flow Rate and Head

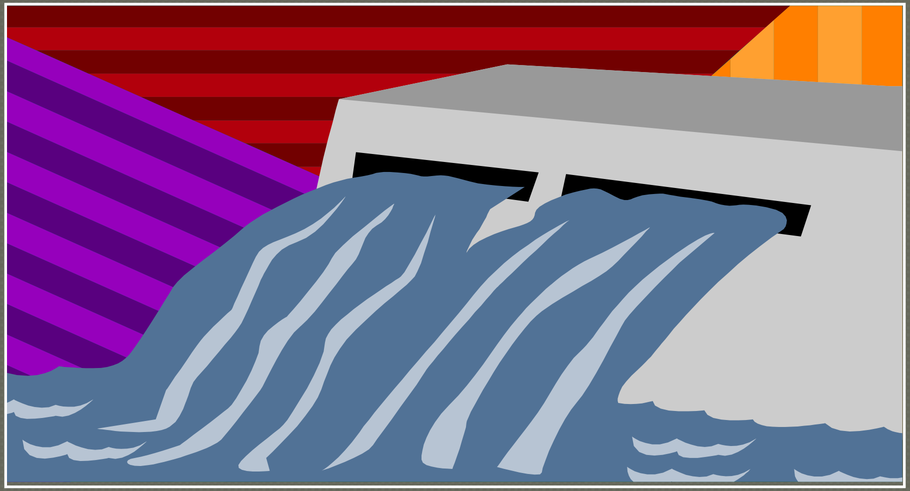


The amount of electricity produced depends upon the amount of water flowing (flow rate) and the height from which water falls (head).

There are high-head and low-head hydropower systems. Low-head hydropower systems are generally less than 20 feet high.

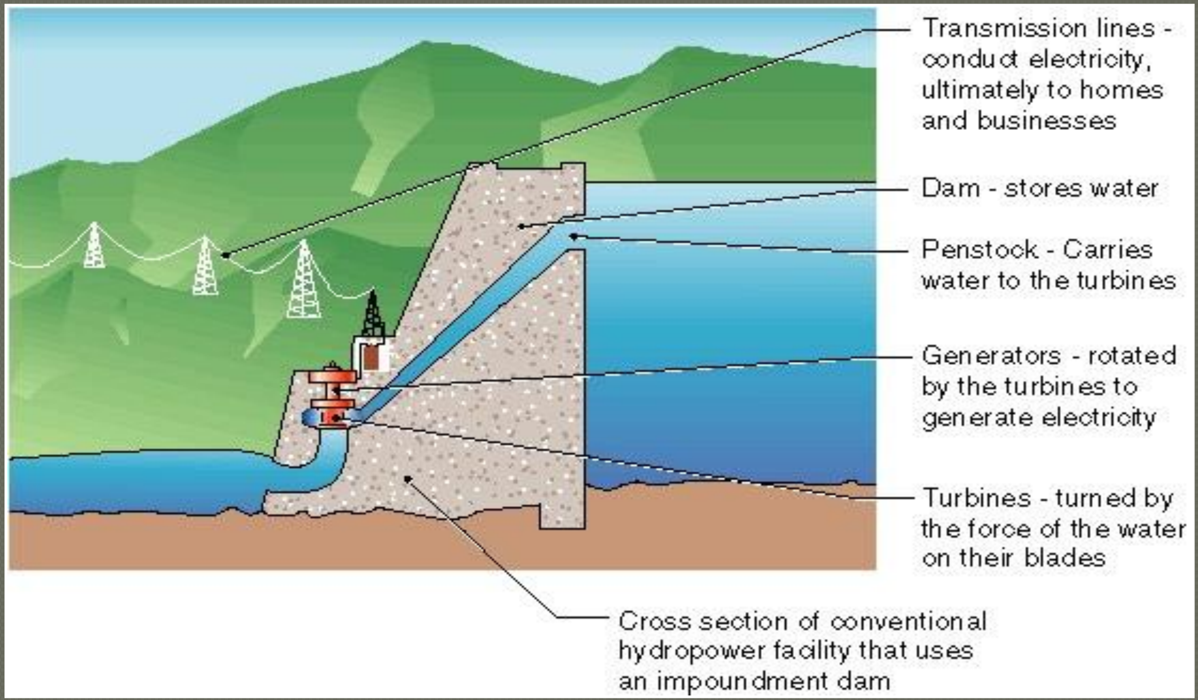
In addition to being high- or low-head, there is a variety of different types and sizes of hydropower facilities!

Types of Hydropower Facilities



The two primary types of hydropower facilities are the **impoundment system** (or dam) and the **run-of-the-river system**.

Impoundment System

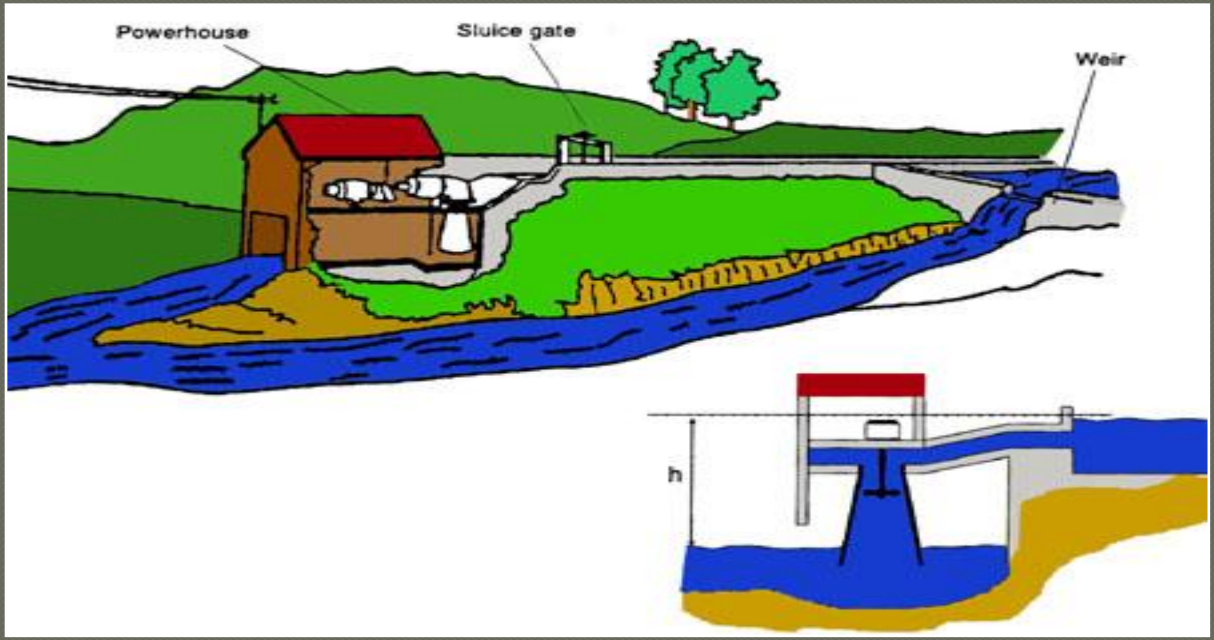


An impoundment is simply a dam that holds water in a reservoir. The water is released when needed through a penstock, to drive the turbine.

This illustration shows the parts of a standard hydroelectric dam. Most large, high-head hydropower facilities use impoundments.

Run-of-the-River Hydropower System

A **run-of-the-river** system uses the river's natural flow and requires little or no impoundment. It may involve a diversion of a portion of the stream through a canal or penstock, or it may involve placement of a turbine right in the stream channel. Run-of-the-river systems are often low-head.

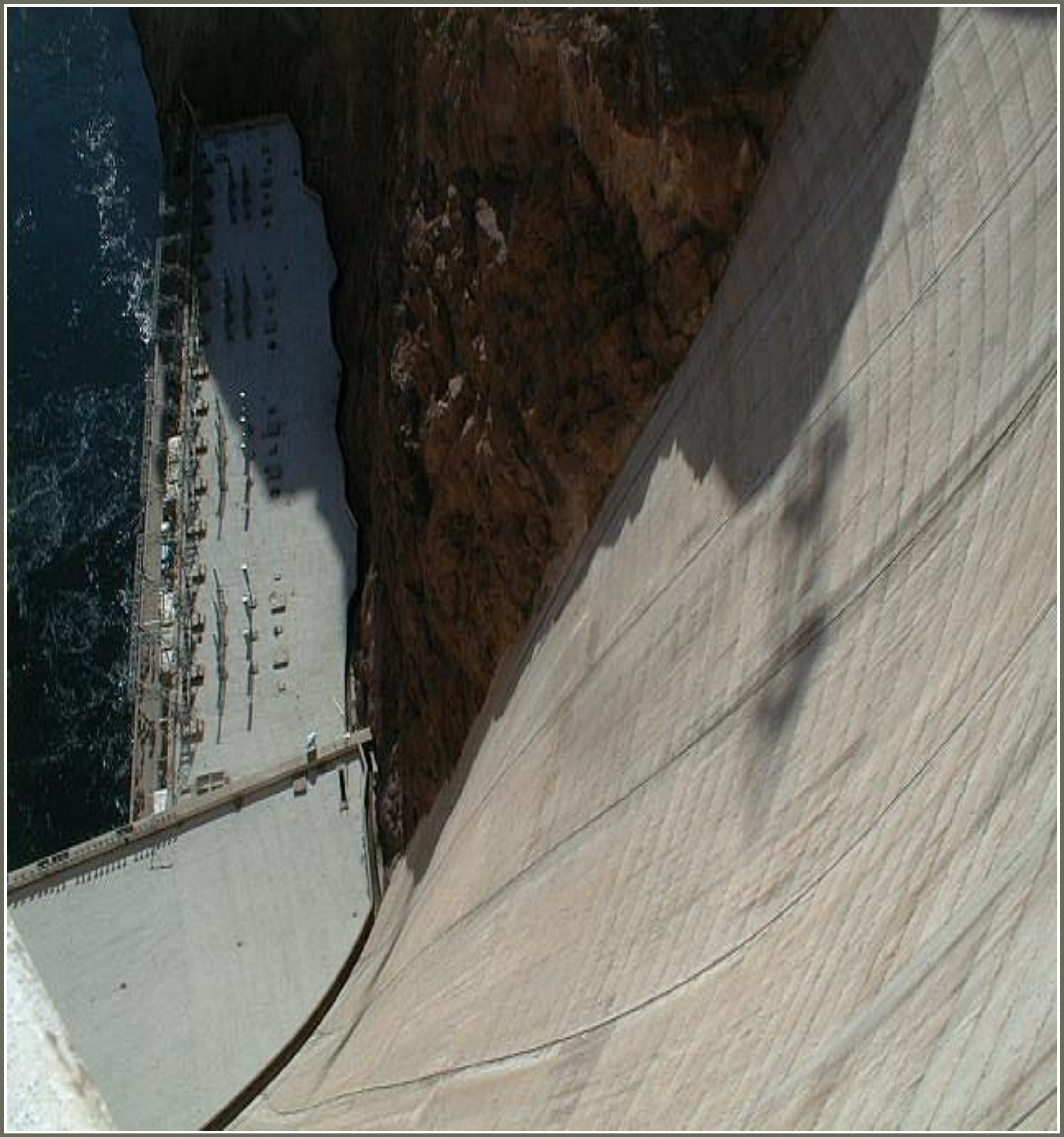


Hydropower Plants Also Vary in Size

There are large power plants that produce hundreds of megawatts of electricity and serve thousands of families.

There are also small and micro hydropower plants that individuals can operate for their own energy needs. The Department of Energy classifies power plants by how much energy they are able to produce.

Large Hydropower



A large hydropower facility has the capacity to produce more than 30,000 kilowatts (kW) of electricity.

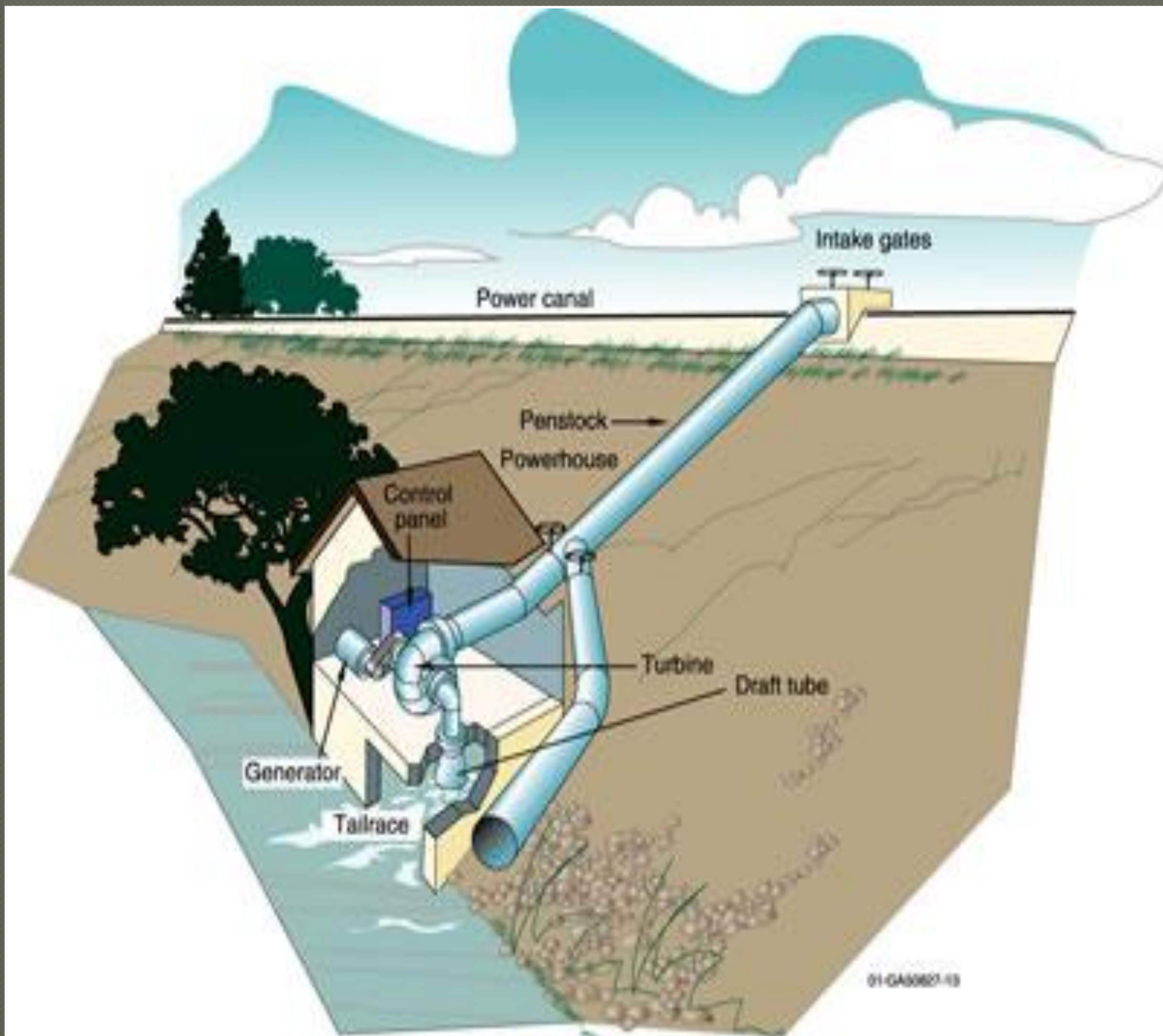
The majority of hydropower systems in the U.S. fit in this category. Large hydropower systems typically require a dam.

Small Hydropower

Small hydropower facilities can produce
100 – 30,000 kilowatts (kW) of electricity.

Small hydropower facilities may involve a small dam, or be a diversion of the main stream, or be a run-of-the-river system.

Micro Hydropower



Micro hydropower plants have the capacity to produce 100 kilowatts (kW) or less.

Micro-hydro facilities typically use a run-of-the-river system.

Hydropower in Arizona

For a primarily desert state, Arizona has a surprising number of hydroelectric facilities. The largest of our hydroelectric dams are on the mighty Colorado River. There are also four dams with hydroelectric facilities on the Salt River.

Colorado River Hydroelectric Dams

Glen Canyon Dam

Height: **710 ft.**

Head: **583 ft.**

Flow: **33,200 cfs** combined

Capacity: **1.3 million kW** (total from 8 generators)

Hoover Dam

Height: **726 ft.**

Head: **576 ft.**

Flow: **NA**

Capacity: **2.1 million kW** (total from 19 generators)

Lower Colorado River Hydroelectric Dams

Davis Dam

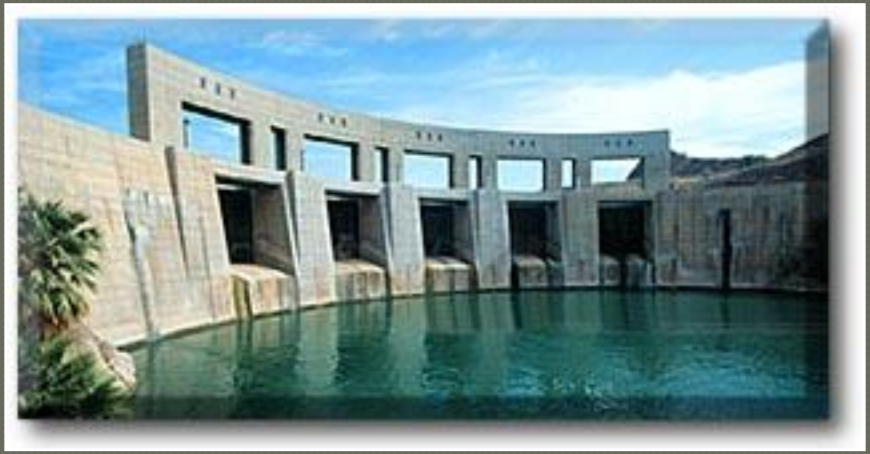
Height: **200 feet**

Head: **140 feet**

Flow: **31,000 cfs** total

Capacity: **240,000 kW**
(total capacity from 5 generators)

Parker Dam



Height: **320 feet**

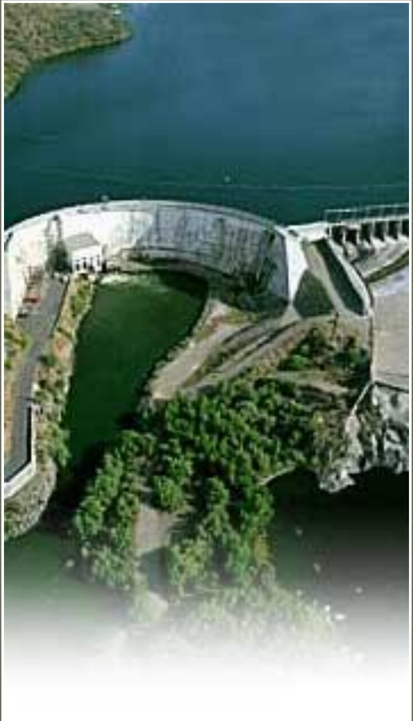
Head: **80 feet**

Flow: **22,000 cfs** total

Capacity: **120,000 kW**
(total capacity from 4 generators)

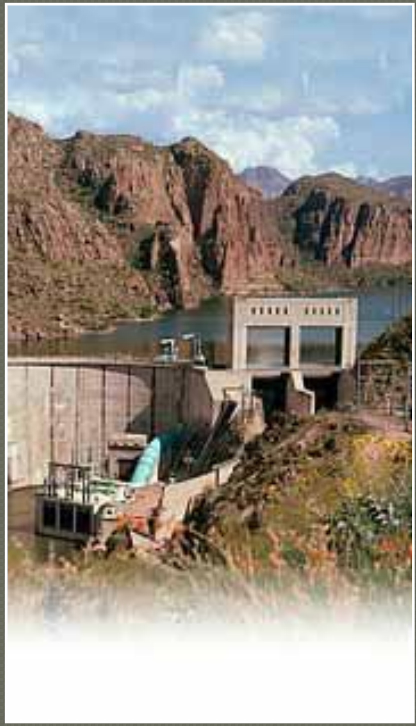
Salt River Hydroelectric Dams

Stewart Mountain



Height: **212 ft.**
Head: **110 ft.**
Flow: **2200 cfs**
Capacity: **13,000 kW**

Mormon Flat

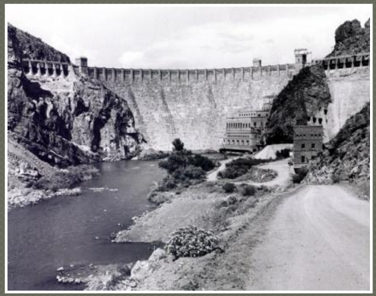


Height: **224 ft.**
Head: **130 ft.**
Flow: **Unit 1 - 1200 cfs**
Unit 2 - 6500 cfs
Capacity:
Unit 1 - 10,000 kW
Unit 2 - 60,000 kW

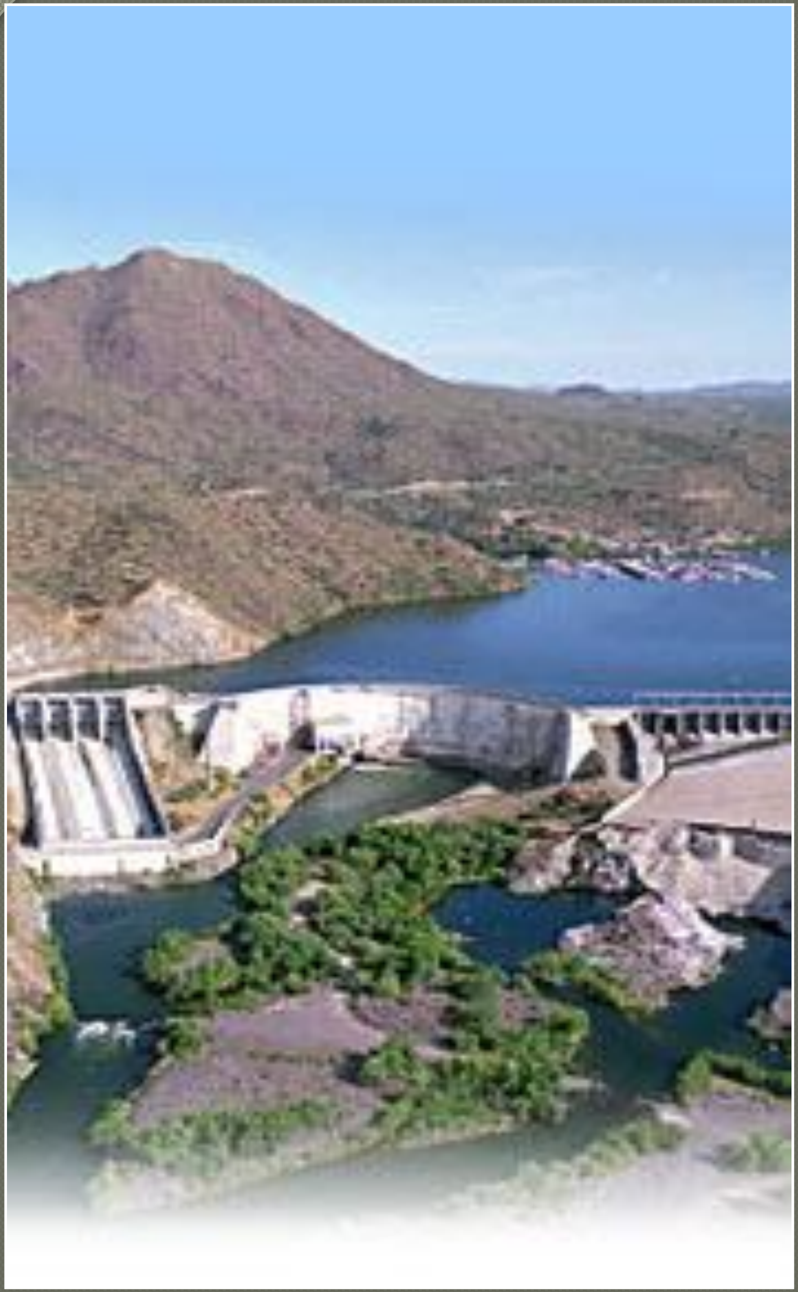
Horse Mesa

Height: **305 ft.**
Head: **260 ft.**
Flow: **Units 1-3 - 600 cfs ea.**
Unit 4 - 6500 cfs
Capacity:
Units 1-3 – 10,000 kW ea.
Unit 4 - 115,000 kW

Theodore Roosevelt

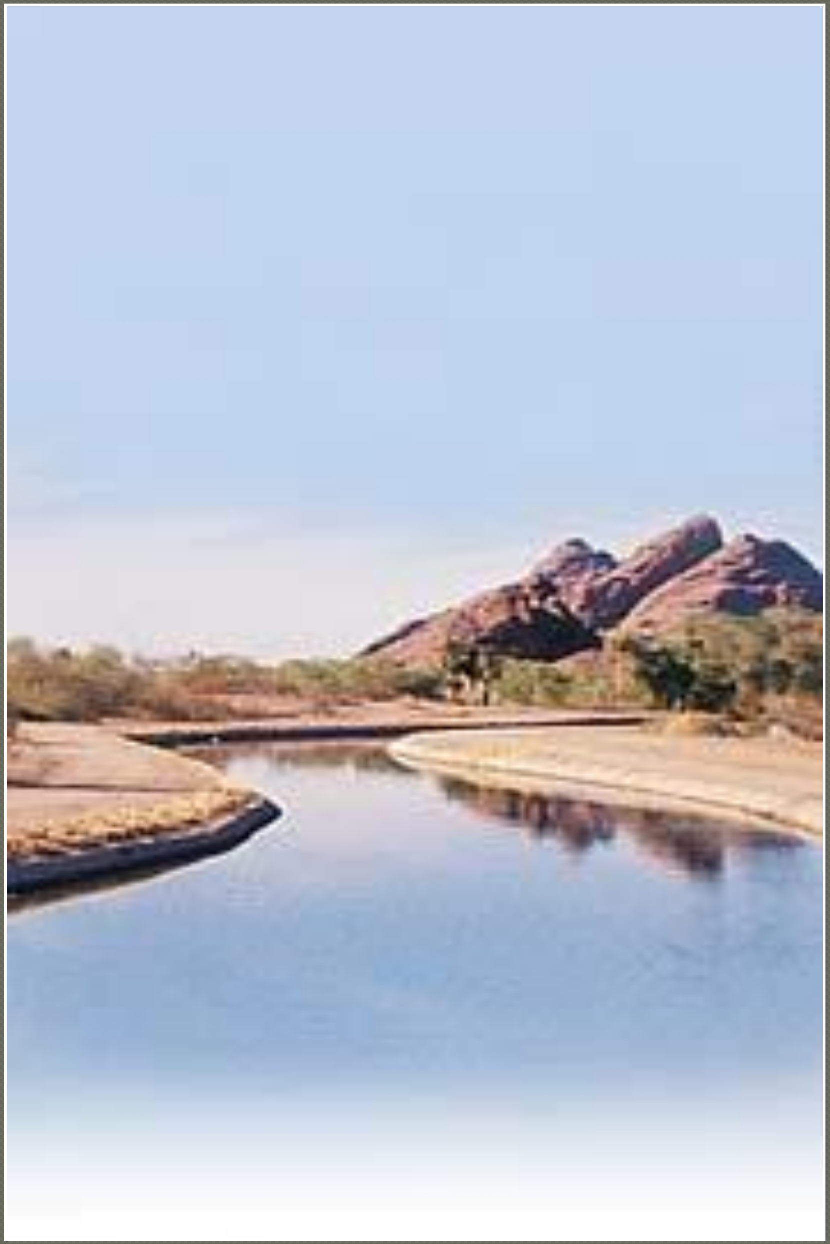


Height: **357 ft.**
Head: **235 ft.**
Flow: **2200 cfs**
Capacity: **36,000 kW**



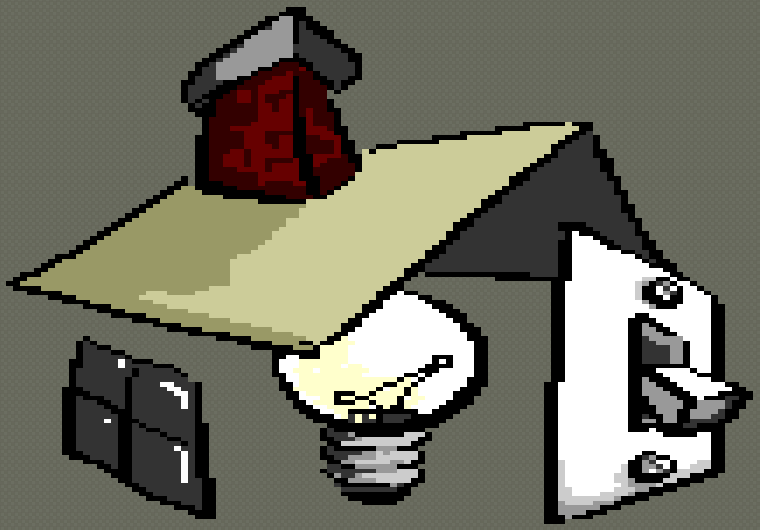
All of the previous hydropower facilities are considered **high-head**. And except for Stewart Mountain Dam (which produces only 13,000 kW), all are considered large hydropower projects.

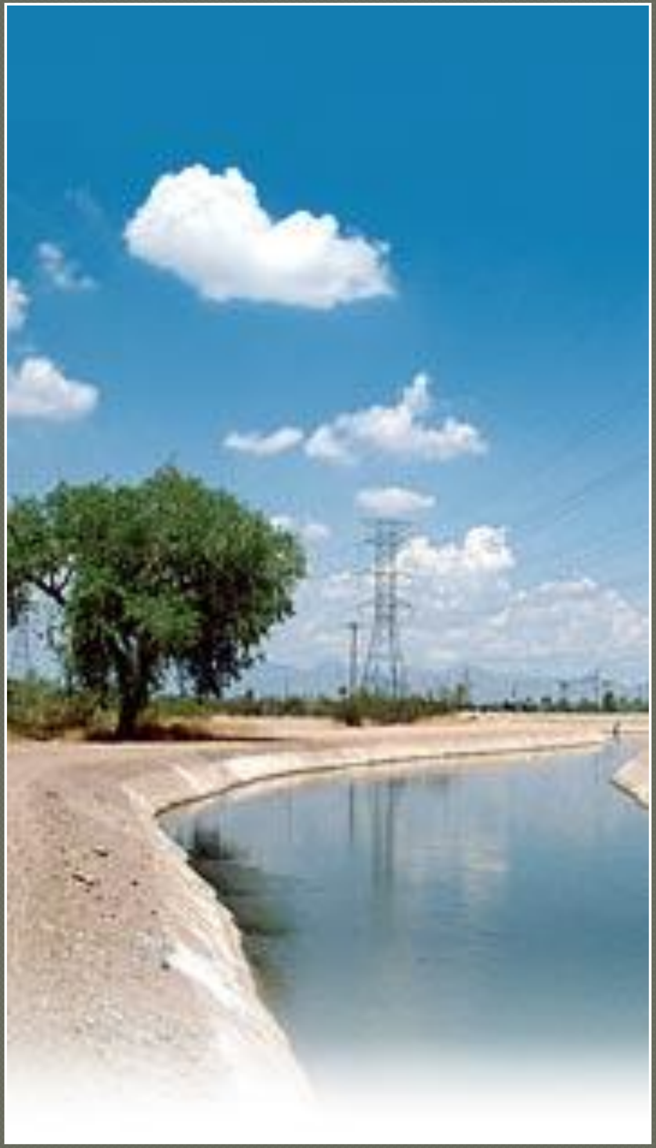
It is important to note that all of Arizona’s dams also serve the role of water storage and flood control as well as hydropower.



The dams on the Salt River play a tremendous role in delivering water to the Phoenix area. A series of nine canals with an additional 924 miles of lateral “ditches” deliver water from the Salt River throughout the Valley for domestic and irrigation uses.

With all that water flowing around the Valley
is there potential for hydroelectric
power generation?





Hydropower in the Valley

Yes! There are three small hydropower facilities in the Phoenix metro area, taking advantage of the power of water!

These are the Crosscut Hydroelectric Plant, the South Consolidated Hydroelectric Unit, and **Arizona Falls**.

At each of these sites there is enough water, and a change in elevation, giving enough flow and head to generate hydroelectric power.

South Consolidated Hydroelectric Unit

- constructed in 1981 on the South Canal
- 35 foot drop
- 1,400 kW capacity

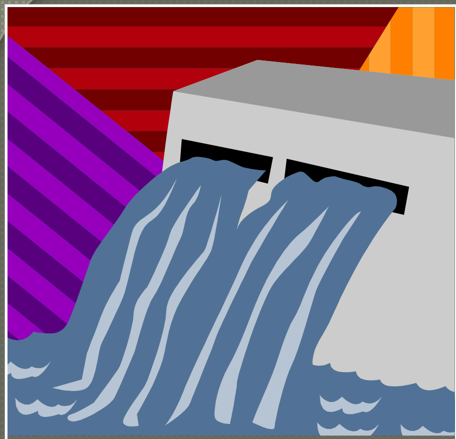
Crosscut Hydroelectric Plant

- began commercial operation in 1915 on the Crosscut Canal
- 116 foot drop
- 3,000 kW capacity

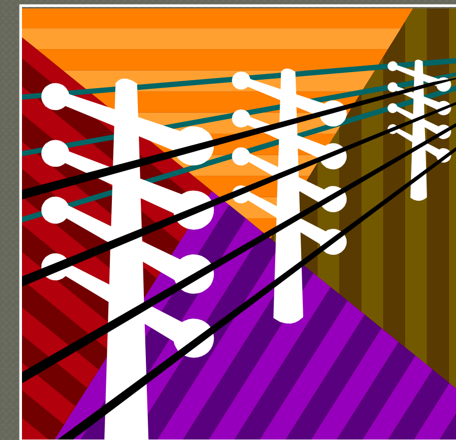
Arizona Falls, a low-head hydropower system, is the Valley's newest hydroelectric generation station. An exciting example of a low impact, renewable energy source, Arizona Falls is open to the public as a place to experience water and its contribution to our energy and water needs.

Arizona Falls, located on the Arizona Canal, is also an interesting historical site. First constructed in 1902, it was the Valley's first hydropower plant.

The falls attracted numerous visitors and were a place to picnic and have parties. The original power plant was dismantled in 1950. The site was recently restored for both recreation and energy.



How much electricity does Arizona Falls generate?

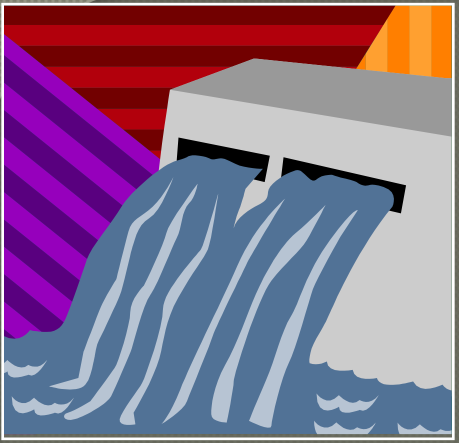


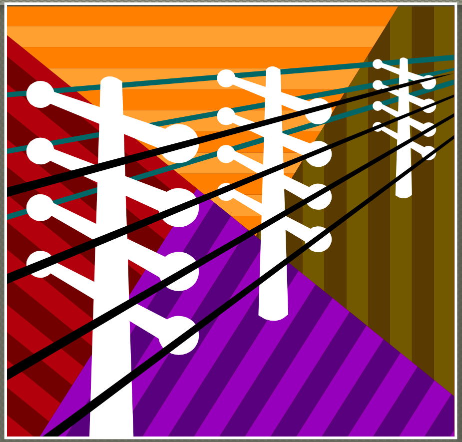
The falls are 19 feet high and the average flow rate is 550 cfs. Let’s assume the turbine and generator are 90% efficient.

Let’s use the equation:

$$\text{Power} = \frac{(\text{Head}) \times (\text{Flow}) \times (\text{Efficiency})}{11.8}$$

$$\text{Power} = \frac{19 \text{ feet} \times 550\text{cfs} \times .90}{11.8}$$



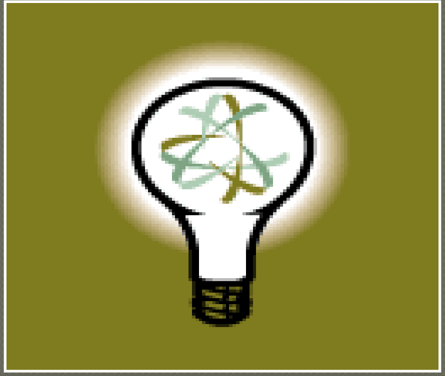


$$\text{Power} = \frac{19 \text{ feet} \times 550\text{cfs} \times .90}{11.8}$$

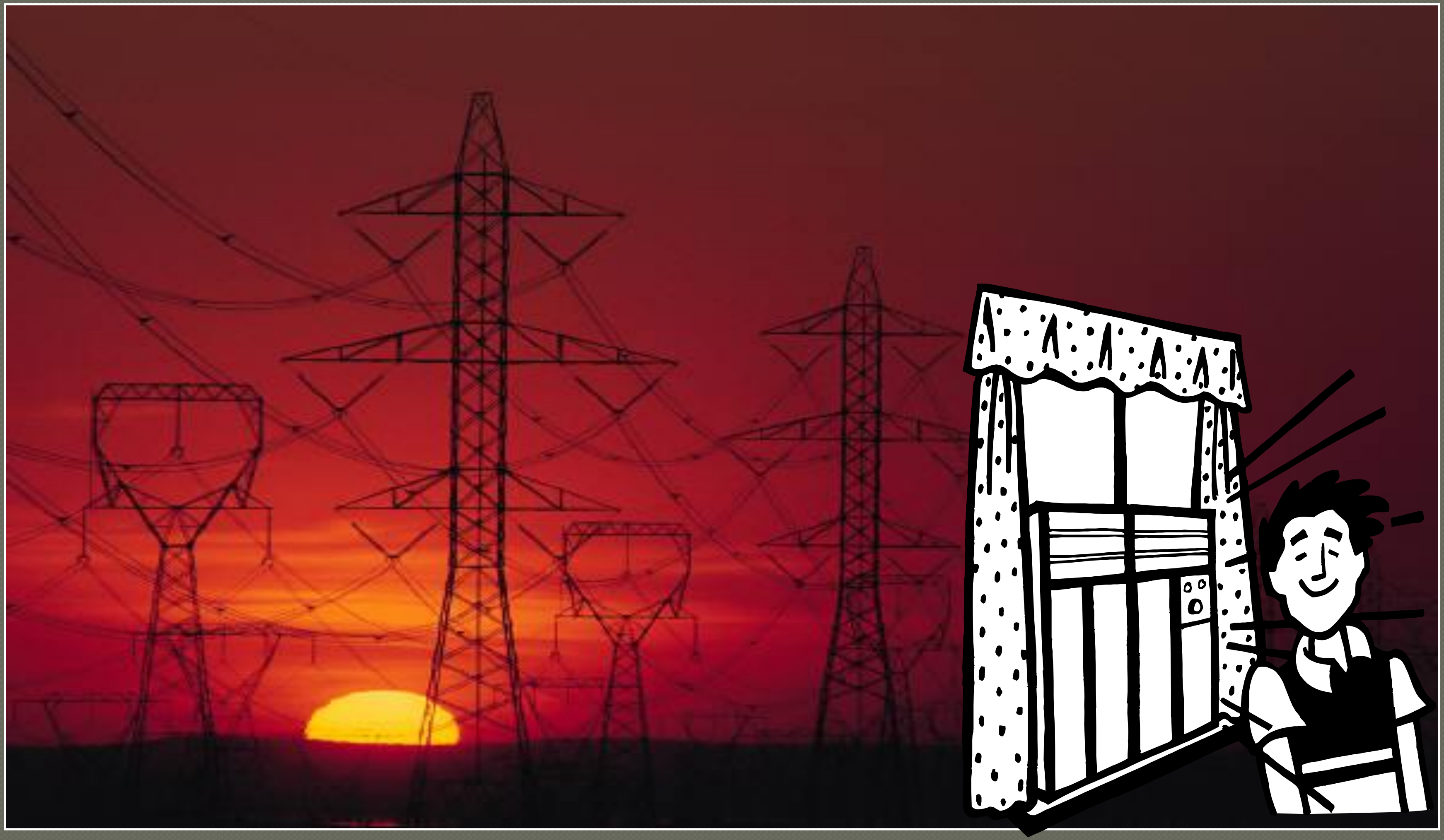
$$\text{Power} = \frac{9405}{11.8}$$

Power = 797 kW

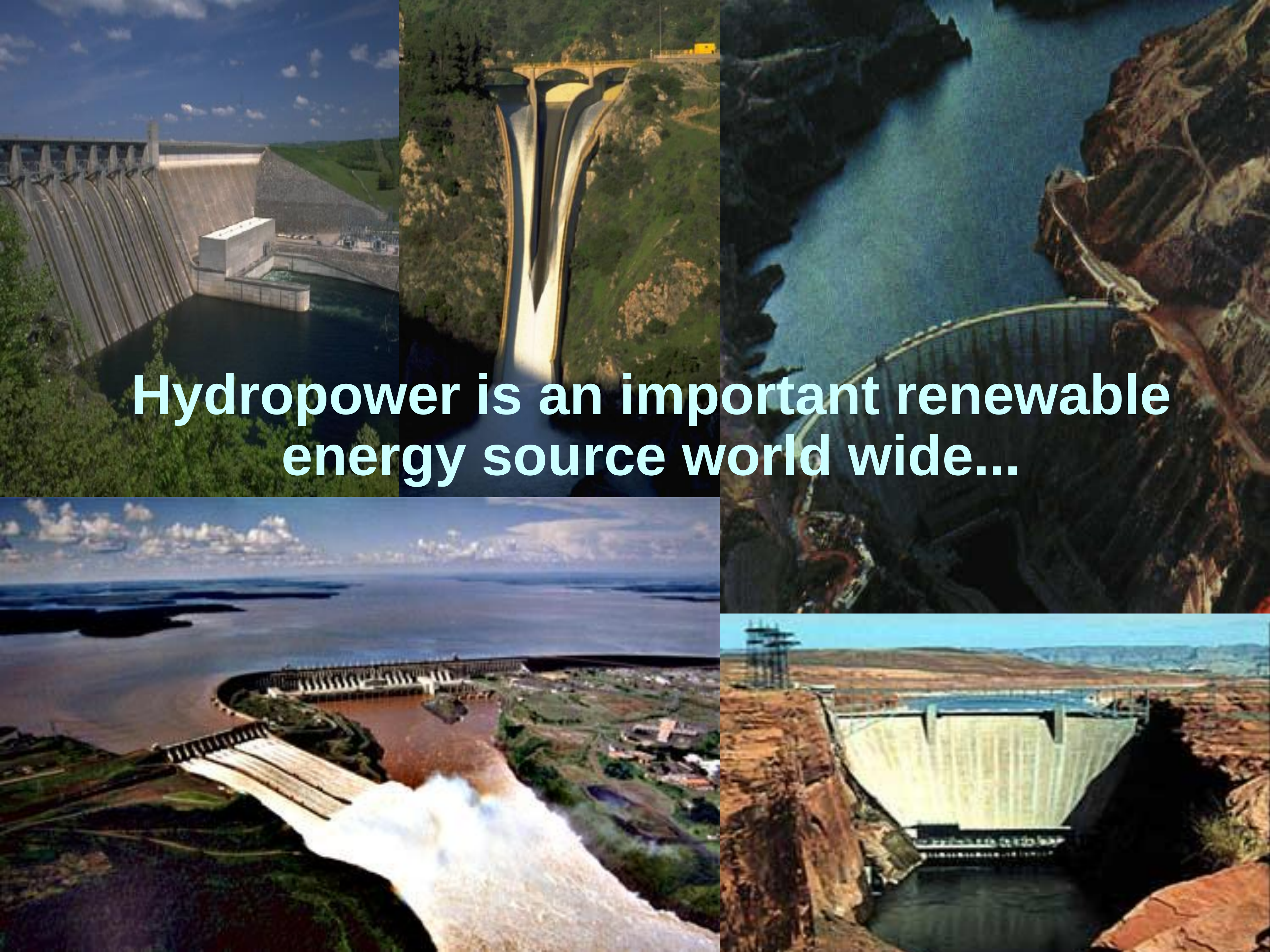
(The generator's capacity is actually rated at 820 kW.)

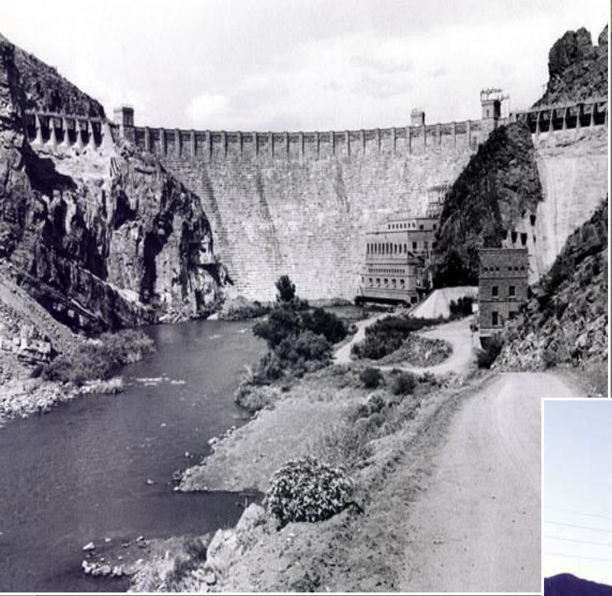


SRP

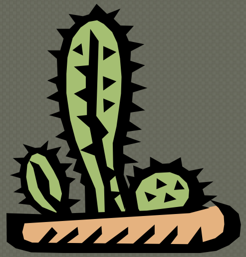


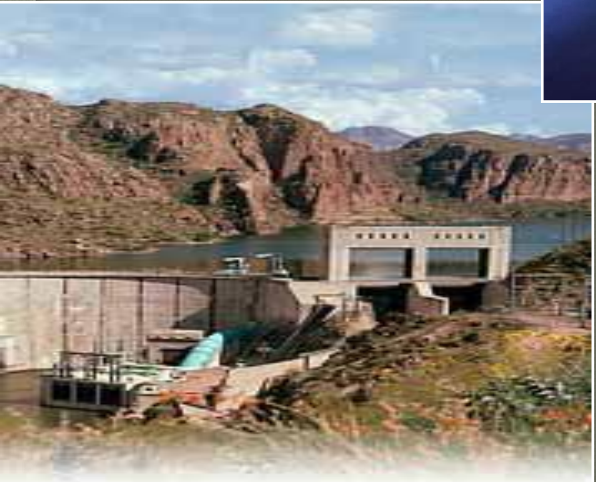
Because water delivery is the first priority, electricity produced at Arizona Falls is used mainly to supplement high electricity demands in the summer.


Hydropower is an important renewable energy source world wide...



Even here
in our desert home,





we can experience
new, renewable
technologies with the
power of water!