After reading this module you should be able to

- describe the major sources of groundwater.
- identify some of the largest sources of fresh surface water.
- explain the effects of unusually high and low amounts of precipitation.

Groundwater can be extracted for human use

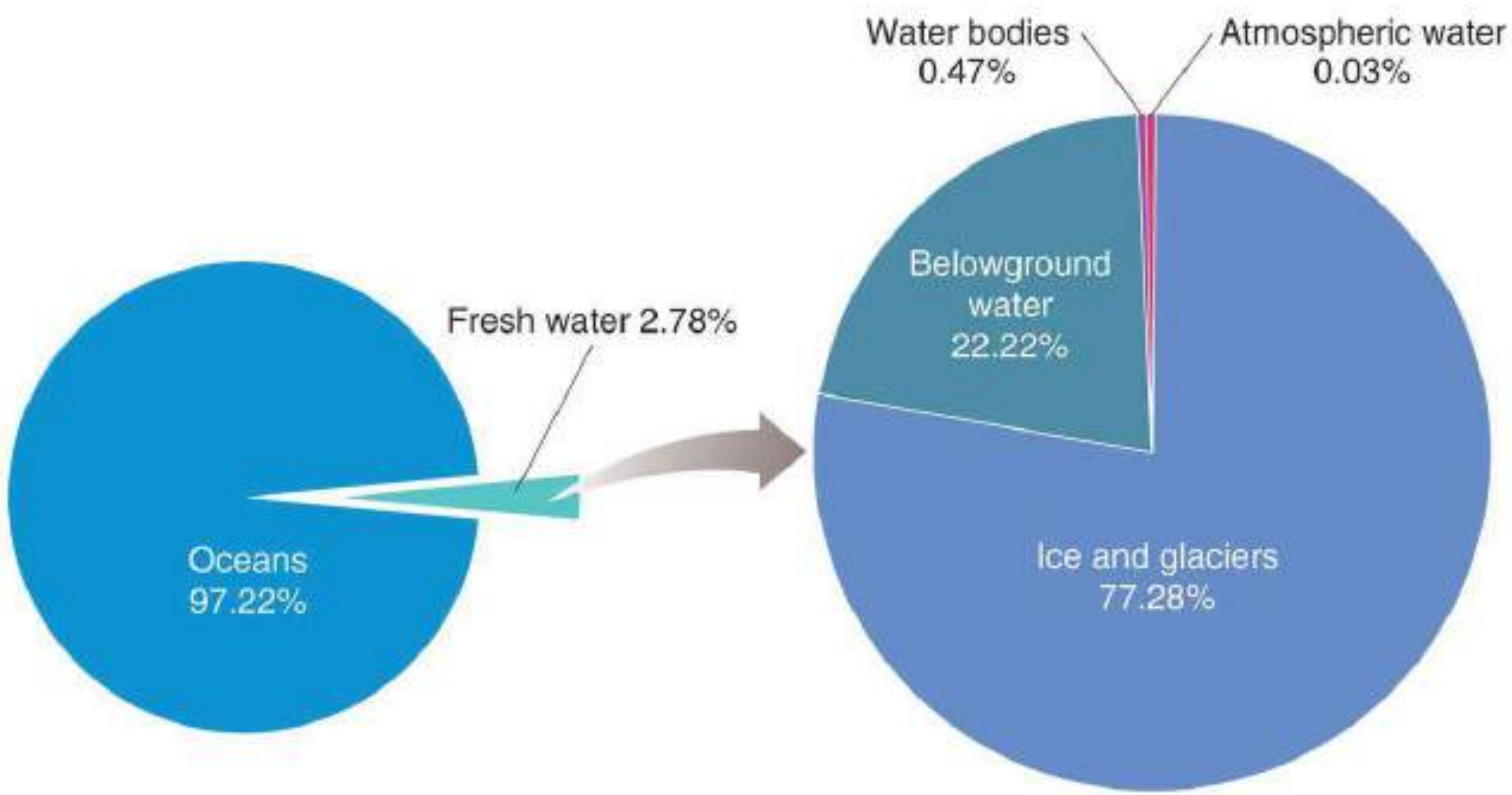


Figure 26.1
Environmental Science for AP®, Second Edition
Data from R. W. Christopherson, Geosystems, 7th ed. Pearson/Prentice Hall, 2009

Distribution of water on Earth. Fresh water represents less than 3 percent of all water on Earth, and only about three-fourths of that fresh water is surface water. Most of that surface water is frozen as ice and in glaciers. Therefore, less than 1 percent of all water on the planet is accessible for use by humans.

Groundwater

- **Aquifer** A permeable layer of rock and sediment that contains groundwater.
- **Unconfined aquifer** An aquifer made of porous rock covered by soil out of which water can easily flow.
- **Confined aquifer** An aquifer surrounded by a layer of impermeable rock or clay that impedes water flow.

Groundwater

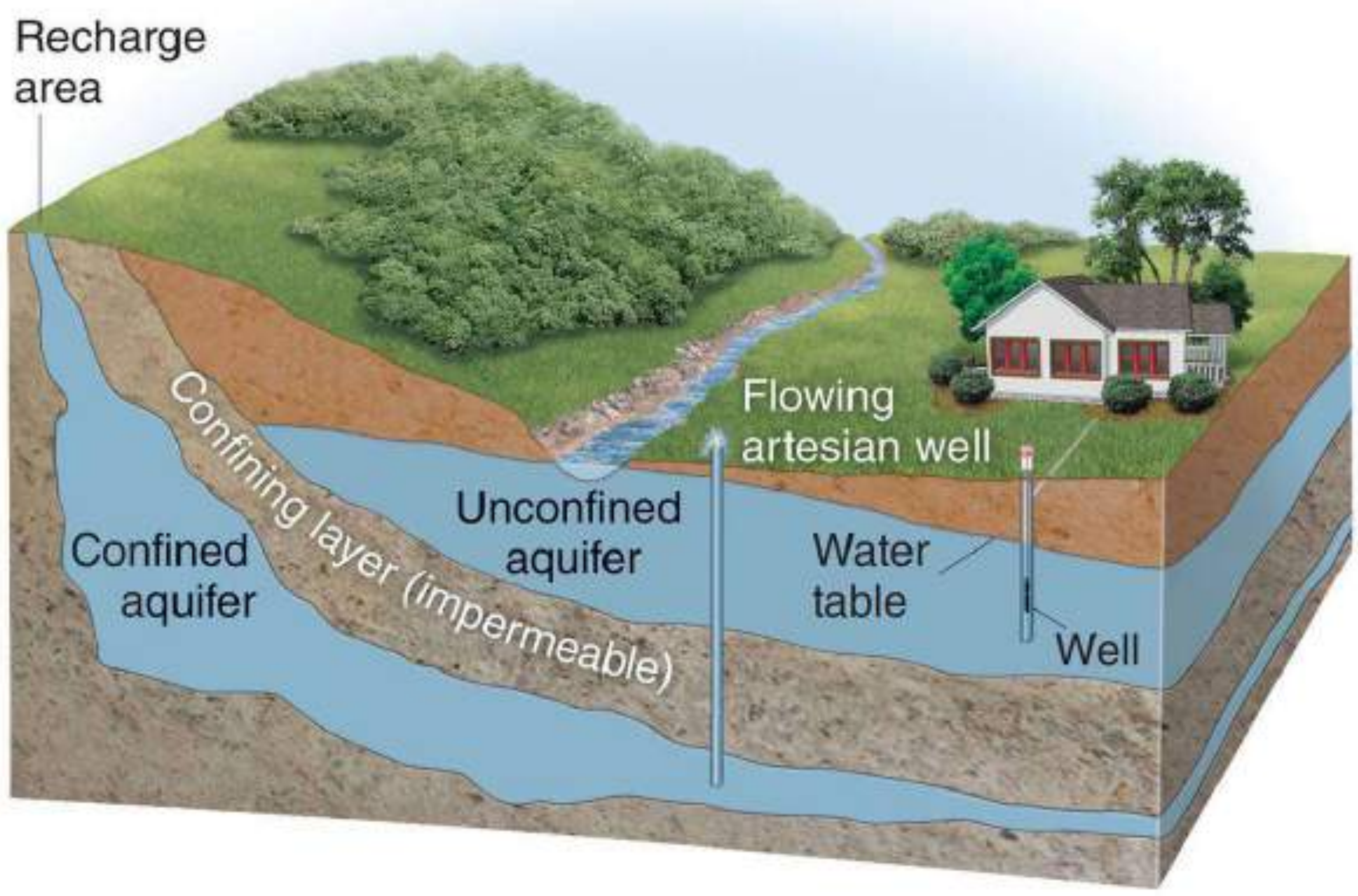


Figure 26.2
Environmental Science for AP®, Second Edition

Aquifers. Aquifers are sources of usable groundwater. Unconfined aquifers are rapidly recharged by water that percolates downward from the land surface. Confined aquifers are capped by an impermeable layer of rock or clay, which can cause water pressure to build up underground. Artesian wells are formed when a well is drilled into a confined aquifer and the natural pressure causes water to rise toward the ground surface.

Groundwater

- **Water table** The uppermost level at which the water in a given area fully saturates rock or soil.
- **Groundwater recharge** A process by which water percolates through the soil and works its way into an aquifer.
- **Spring** A natural source of water formed when water from an aquifer percolates up to the ground surface.
- **Artesian well** A well created by drilling a hole into a confined aquifer.

Groundwater

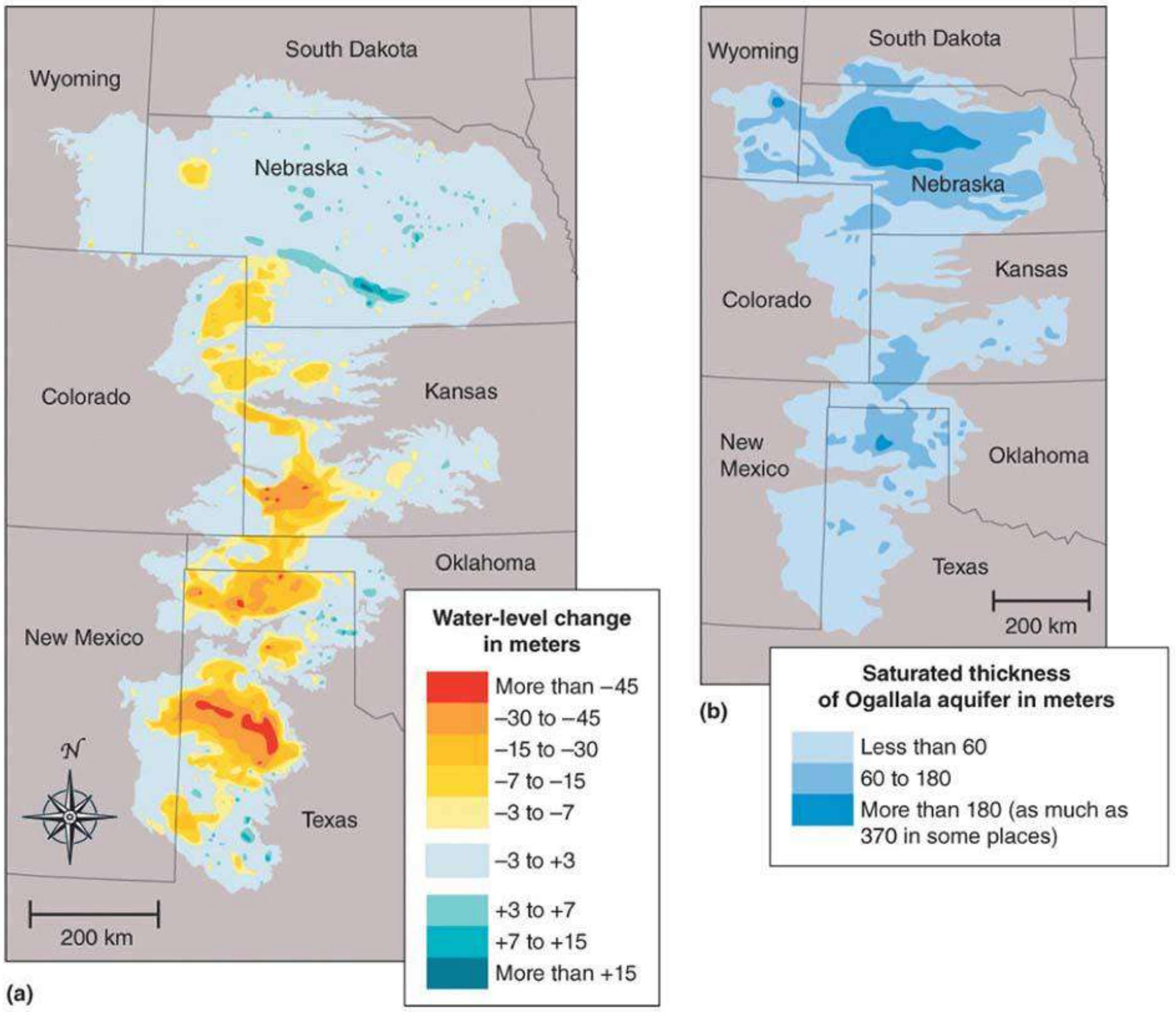


Figure 26.4
Environmental Science for AP®, Second Edition
Data from http://pubs.usgs.gov/fs/2004/3097/ and http:// ne.water.usgs.gov/ogw/hpwlms/

The Ogallala aquifer. The Ogallala aquifer, also called the High Plains aquifer, is the largest in the United States, with a surface area of about 450,000 km^2 (174,000 $miles^2$). (a) The change in water level from 1950 to 2005, mostly due to withdrawals for irrigation that have exceeded the aquifer's rate of recharge. (b) The current thickness of the aquifer.

Groundwater

- **Cone of depression** An area lacking groundwater due to rapid withdrawal by a well.
- **Saltwater intrusion** An infiltration of salt water in an area where groundwater pressure has been reduced from extensive drilling of wells.

Groundwater

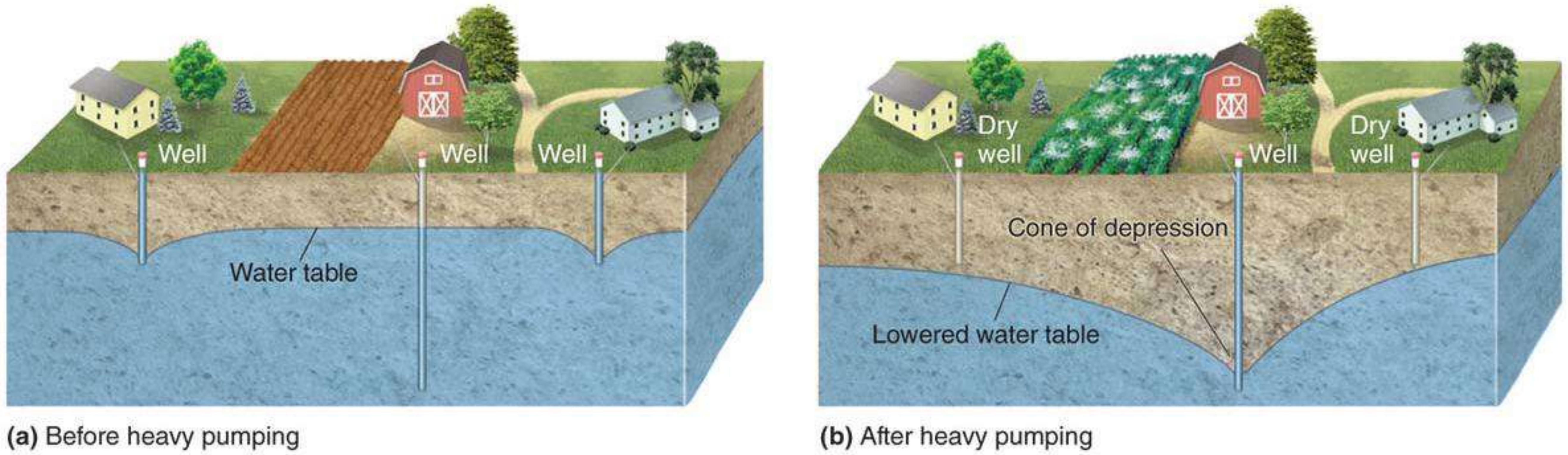


Figure 26.5
Environmental Science for AP®, Second Edition

Cone of depression. (a) When a deep well is not heavily pumped, the recharge of the water table keeps up with the pumping. (b) In contrast, when a deep well pumps water from an aquifer more rapidly than it can be recharged, it can form a cone of depression in the water table and cause nearby shallow wells to go dry.

Groundwater

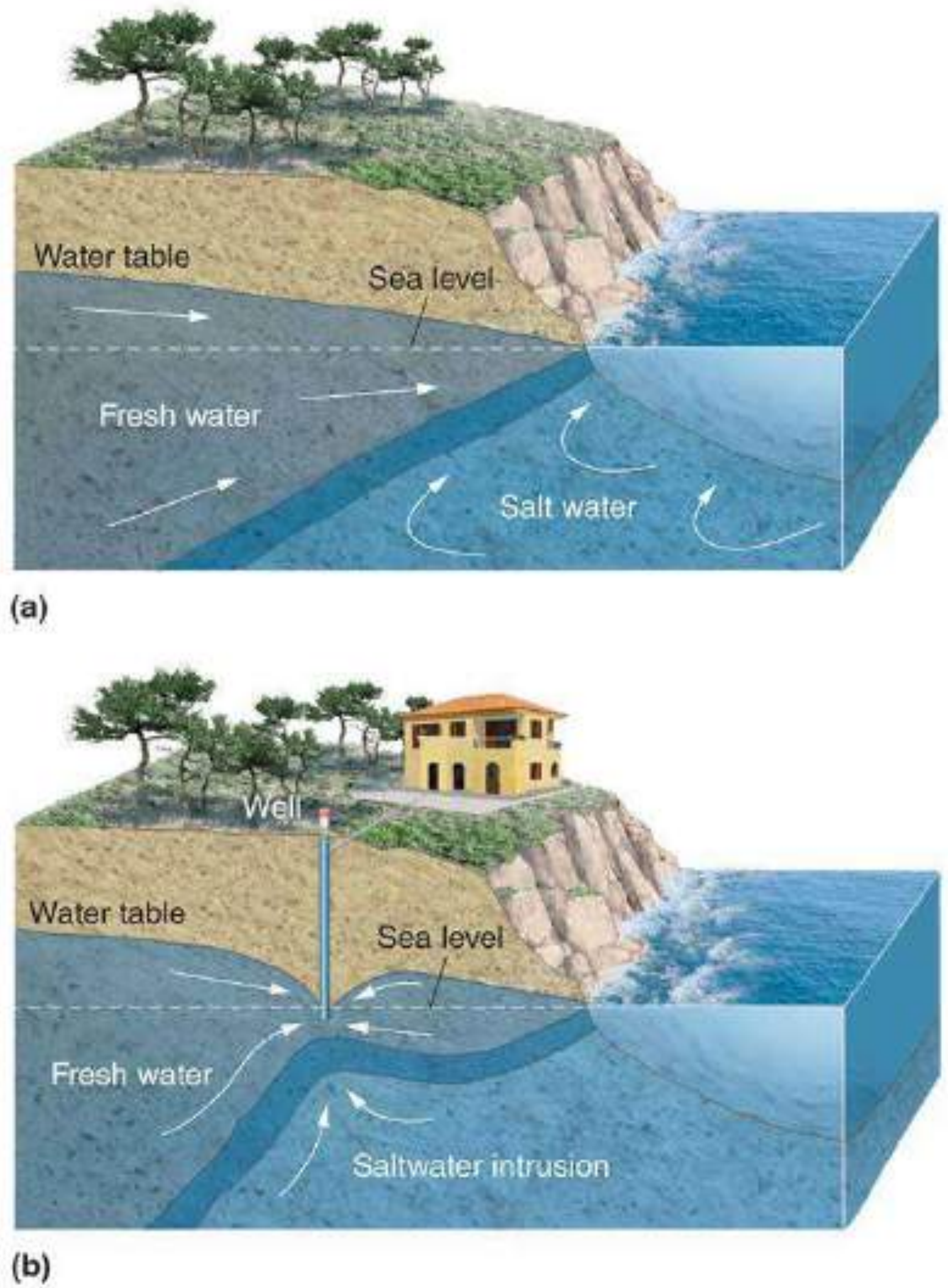


Figure 26.6
Environmental Science for AP®, Second Edition

Saltwater intrusion. (a) When there are few wells along a coastline, the water table remains high and the resulting pressure prevents salt water from intruding. (b) Rapid pumping of wells drilled in aquifers along a coastline can lower the water table. Lowering the water table reduces water pressure in the aquifer, allowing the nearby salt water to move into the aquifer and contaminate the well water with salt.

Surface water is the collection of aquatic biomes

- Surface water is water that exists aboveground and includes steams, rivers, ponds, and wetlands.
- Early human civilizations typically settled along major rivers.
- **Floodplain** The land adjacent to a river.

Surface Water

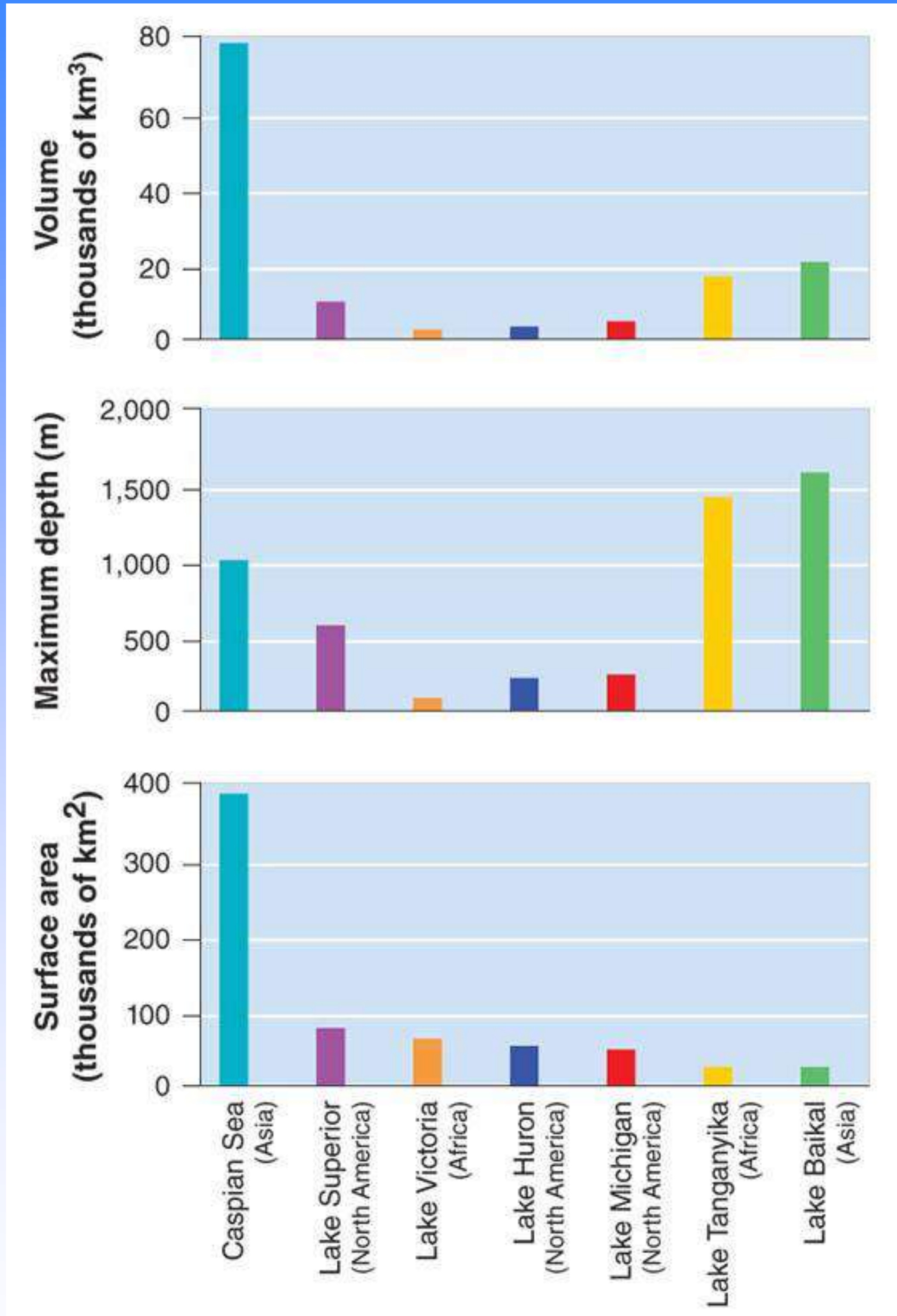


Figure 26.7
Environmental Science for AP®, Second Edition
Data from http://wldb.ilec.or.jp/LakeDB2/

The world's largest lakes. Measurements of surface area, depth, and volume are shown for each lake.

Atmospheric water produces precipitation

- Although the atmosphere contains only a very small percentage of the water on Earth, that atmospheric water is essential to global water distribution.

- **Impermeable surface** Pavement or buildings that do not allow water penetration.

Module 27
Human Alteration of Water Availability

After reading this module you should be able to

- compare and contrast the roles of levees and dikes.
- explain the benefits and costs of building dams.
- explain the benefits and costs of building aqueducts.
- describe the processes used to convert salt water into fresh water.

Levees and dikes are built to prevent flooding

- **Levee** An enlarged bank built up on each side of a river.
- **Dike** A structure built to prevent ocean waters from flooding adjacent land.

Dams are built to restrict the flow of streams and rivers

- **Dam** A barrier that runs across a river or stream to control the flow of water.
- **Reservoir** The water body created by a damming a river or stream.
- **Fish ladder** A stair-like structure that allows migrating fish to get around a dam.

Aqueducts carry water from one location to another

- **Aqueduct** A canal or ditch used to carry water from one location to another.

- In the United States, both Los Angeles and New York City depend on aqueducts to meet their daily water needs.

- The consequences of water diversion can be severe.

Aqueducts

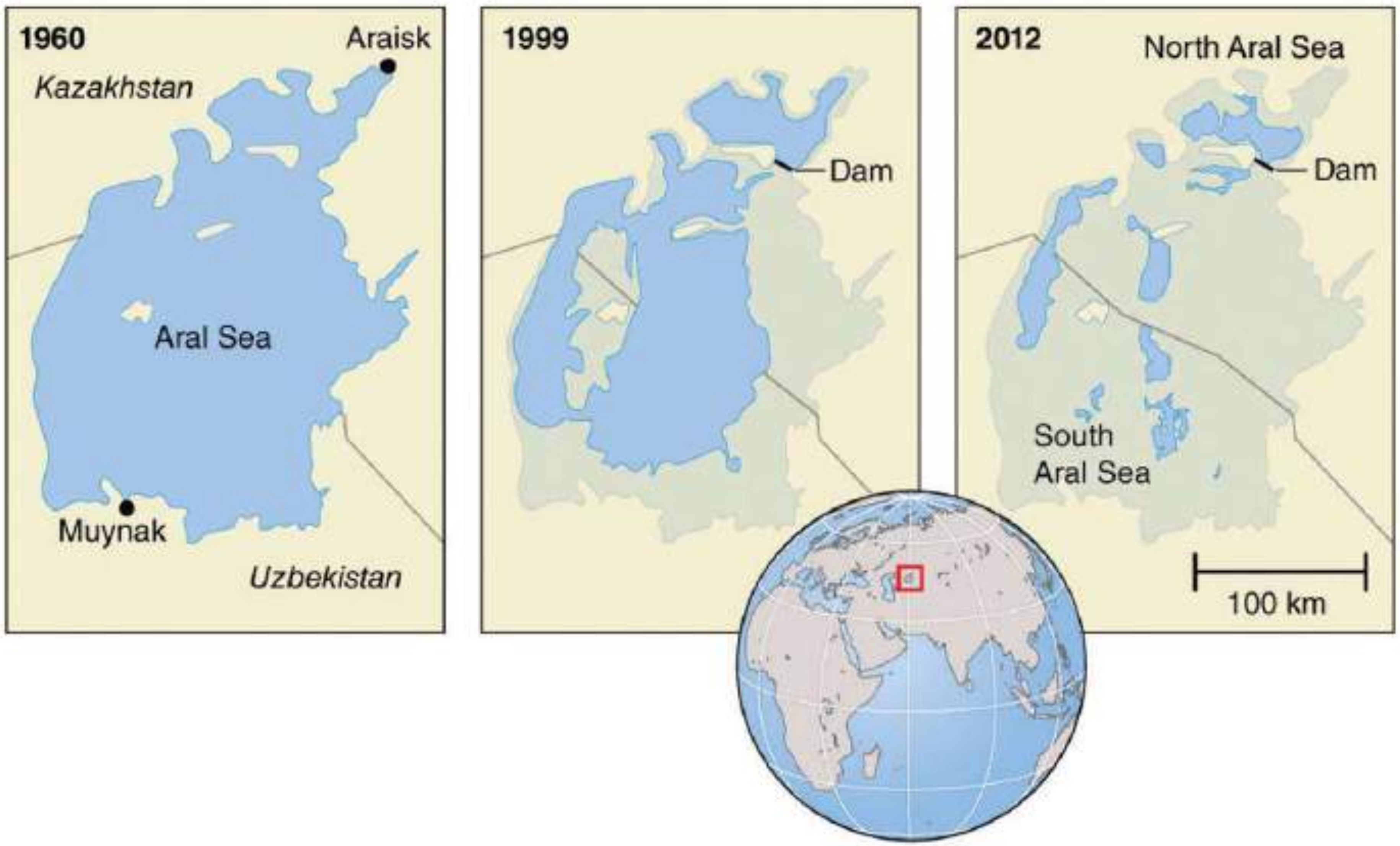


Figure 27.5
Environmental Science for AP®, Second Edition

Consequences of river diversion. Diverting river water can have devastating impacts downstream. The Aral Sea, on the border of Kazakhstan and Uzbekistan, was once the world's fourth largest lake. Since the two rivers that fed the lake were diverted, its surface area has declined by 60 percent and the lake has split into two parts: the North and South Aral seas.

Desalination converts salt water into fresh water

- **Desalination** The process of removing the salt from salt water. *Also known as* **Desalinization**.
- **Distillation** A process of desalination in which water is boiled and the resulting steam is captured and condensed to yield pure water.
- **Reverse osmosis** A process of desalination in which water is forced through a thin semipermeable membrane at high pressure.

Desalination

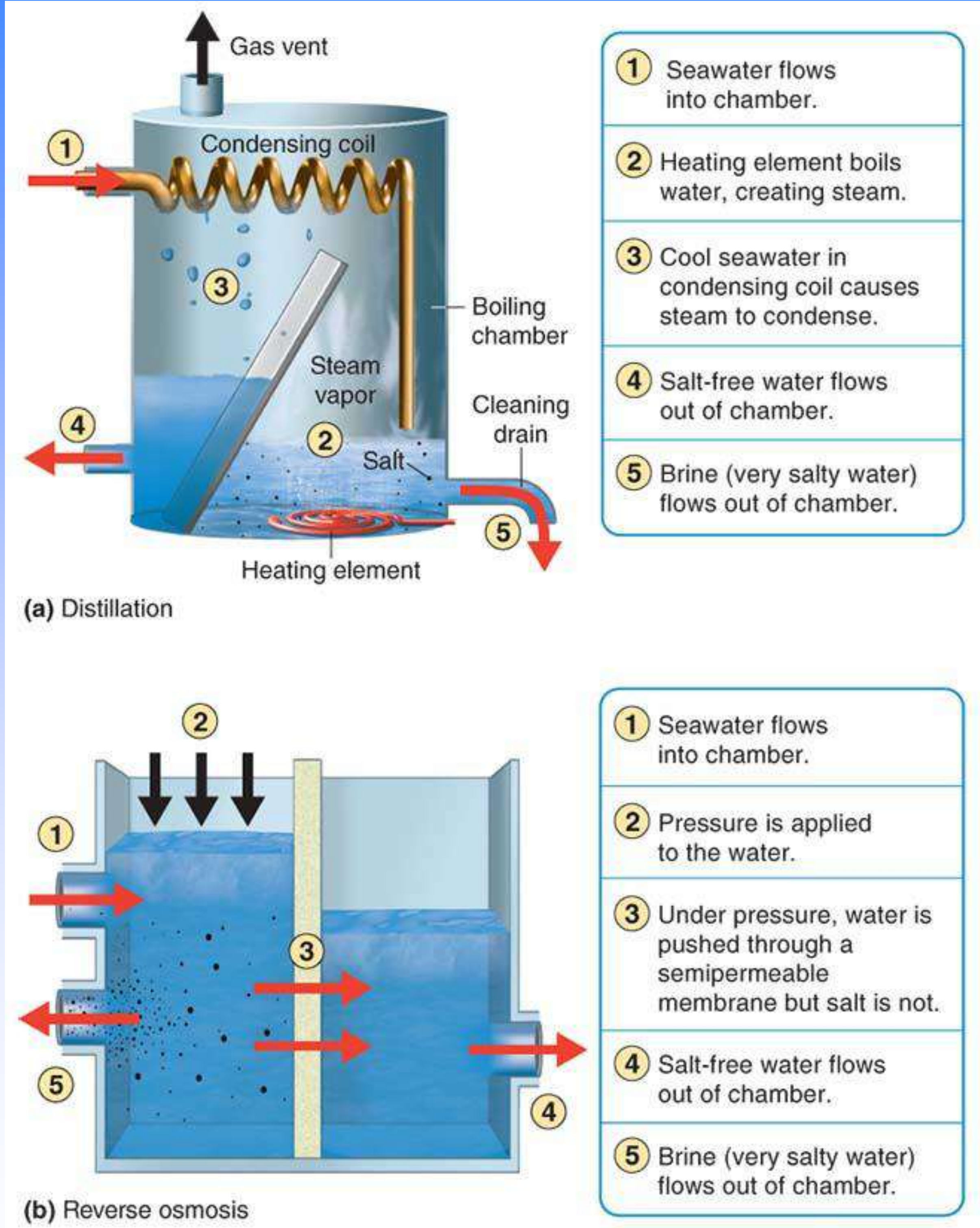


Figure 27.6
Environmental Science for AP®, Second Edition

Desalination technologies. Salt water can be converted into fresh water in one of two ways. (a) Distillation uses heat to convert pure water into steam that is later condensed, leaving the salt behind. (b) Reverse osmosis uses pressure to force pure water through a semipermeable membrane, leaving the salt behind.

Water Availability

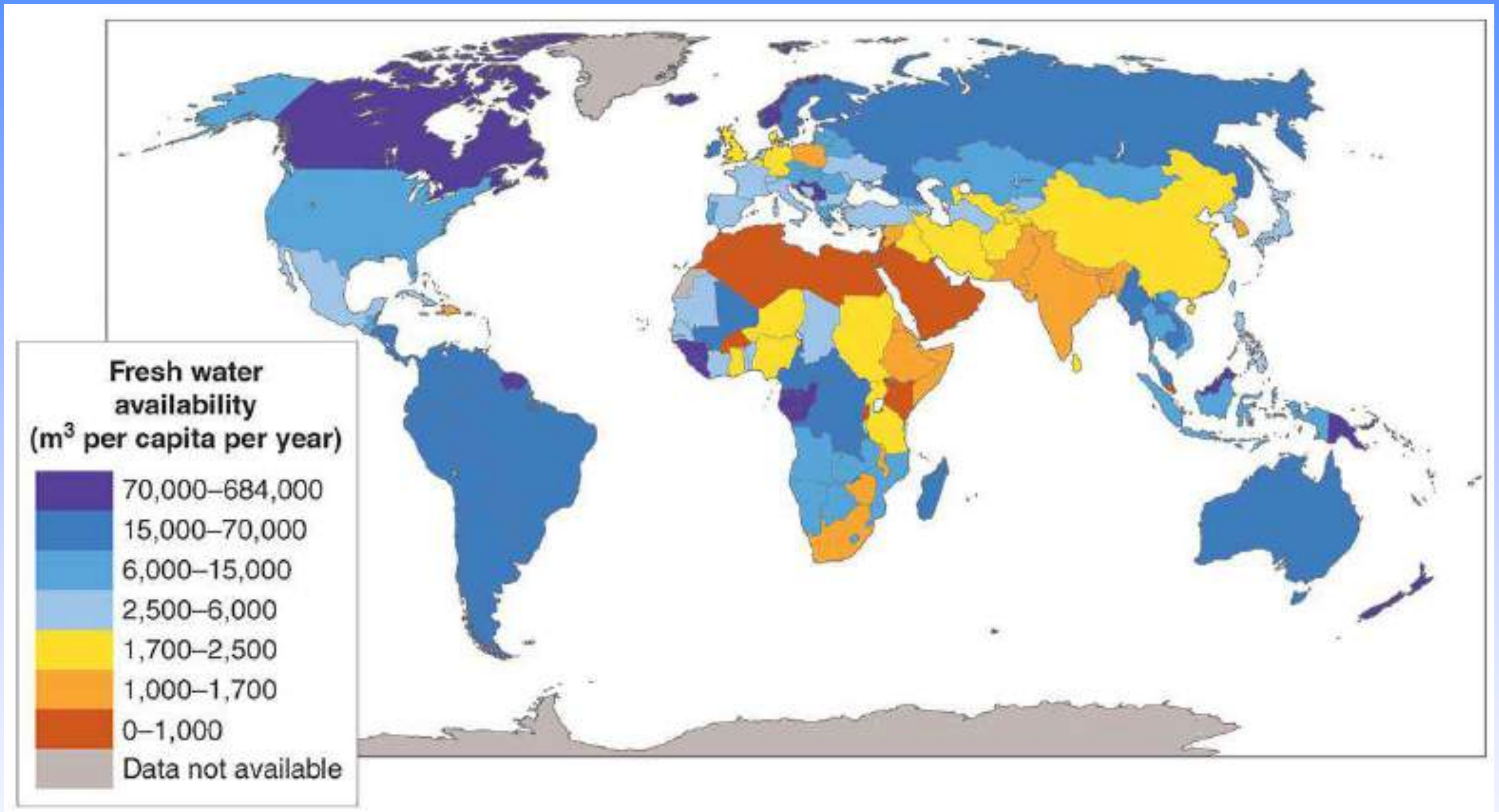


Figure 27.7
Environmental Science for AP®, Second Edition

Water availability per capita. The amount of water available per person varies tremendously around the world. North Africa and the Middle East are the regions with the lowest amounts of available fresh water.

Module 28
Human use of Water Now and in the Future

After reading this module you should be able to

- compare and contrast the four methods of agricultural irrigation.
- describe the major industrial and household uses of water.
- discuss how water ownership and water conservation are important in determining future water availability.

Water is used for agriculture

- **Water footprint** The total daily per capita use of fresh water.
- Around the world, more water is used for agriculture than anything else.
- The daily use of water per capita varies dramatically among the nations of the world.

Water Footprint

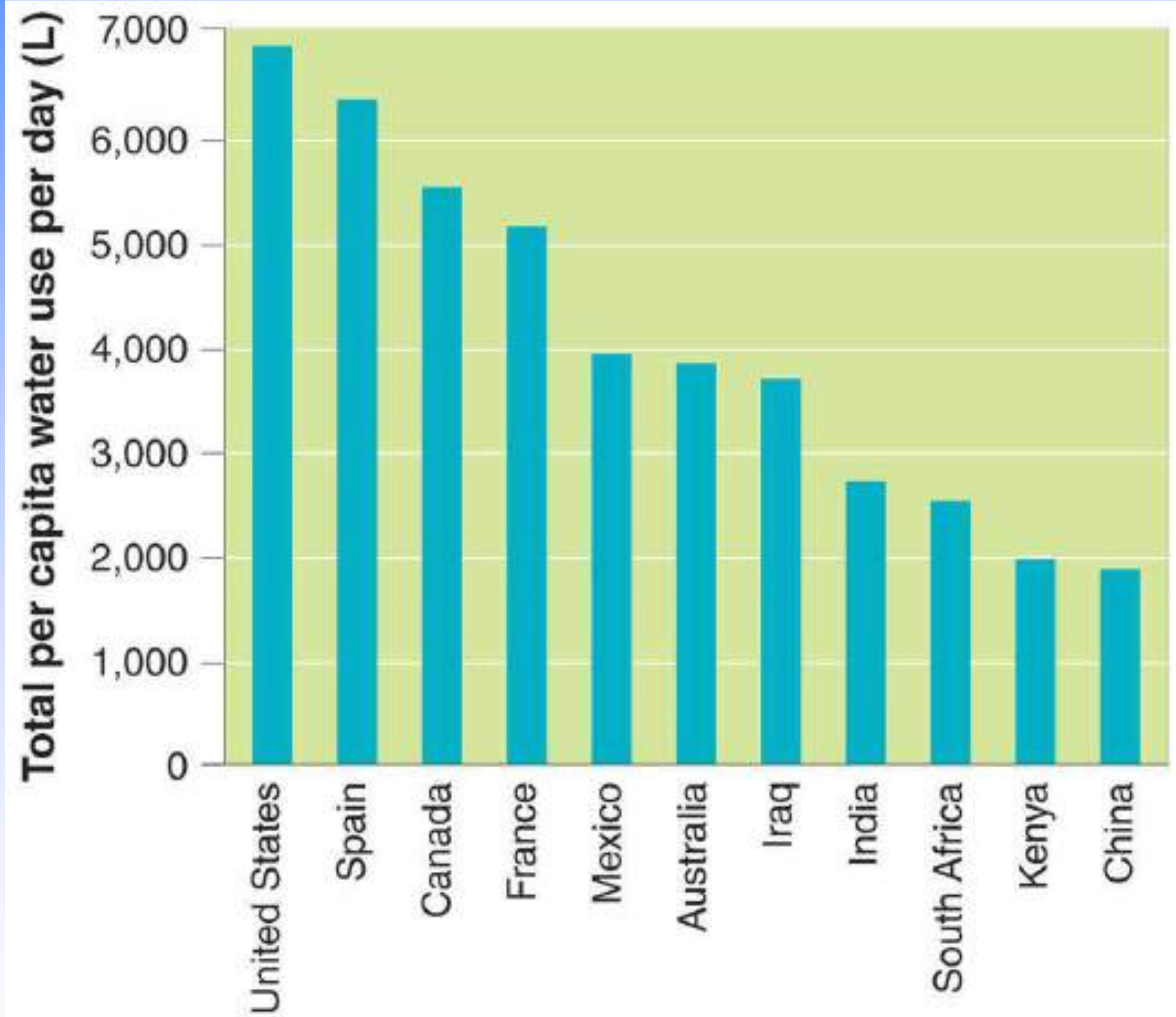


Figure 28.1
Environmental Science for AP®, Second Edition

Total per capita water use per day. The total water use per person for agriculture, industry, and households varies tremendously by country.

Irrigation

- Technological advances have made water use for crops more efficient.

There are four types of irrigation:

- Furrow: a trench that is flooded with water
- Flood: the entire field is flooded with water
- Spray: an apparatus sprays water across a field
- Drip: a slow dripping hose is laid on or buried beneath the soil

Hydroponic Agriculture

- **Hydroponic agriculture** The cultivation of plants in greenhouse conditions by immersing roots in a nutrient-rich solution.

An alternative to irrigation, hydroponic agriculture is more expensive but has several advantages:

- Requires little or no pesticide use.
- Uses up to 95 percent less water than traditional irrigation.
- Crops can be grown year-round.

Water is also used for industrial processes and households

After agriculture, the most common use of water is for industry and households.

Industrial Water Use

Water is required for many industrial purposes:

- Generating electricity
- Cooling machinery
- Refining metals
- Making paper

Household Water Use

- Household water use accounts for 10 percent of all water used in the United States.
- Per capita household water use varies dramatically among nations.

Household Water Use

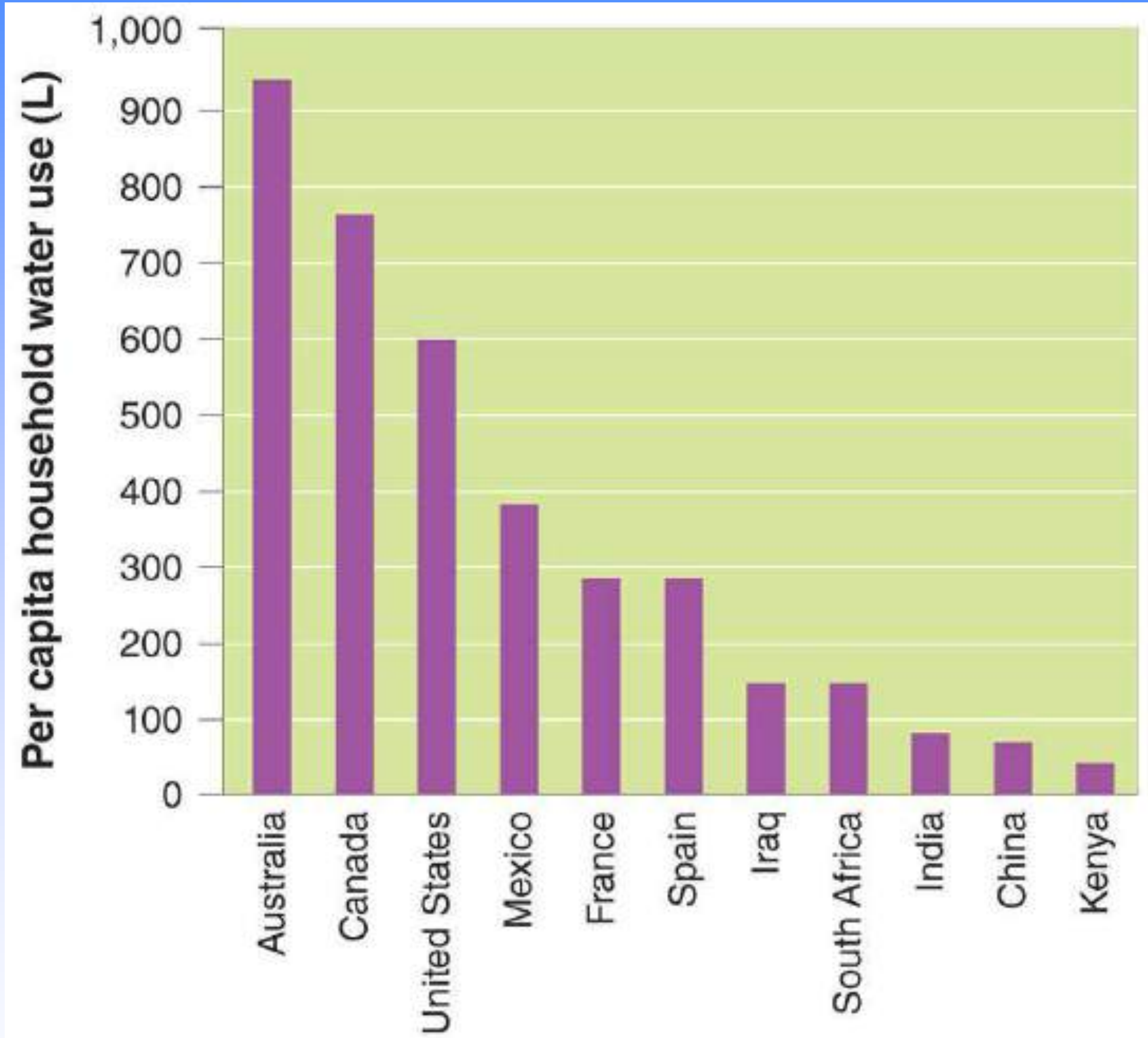


Figure 28.5
Environmental Science for AP®, Second Edition
A. K. Chapagain and A. Y. Hoekstra, Water Footprints of Nations, Vol. 1, Main Report, UNESCO-IHE. Research Report Series #16, 2004

Household per capita water use per day. The amount of household water use per capita is different from that of total water use.

Household Water Use

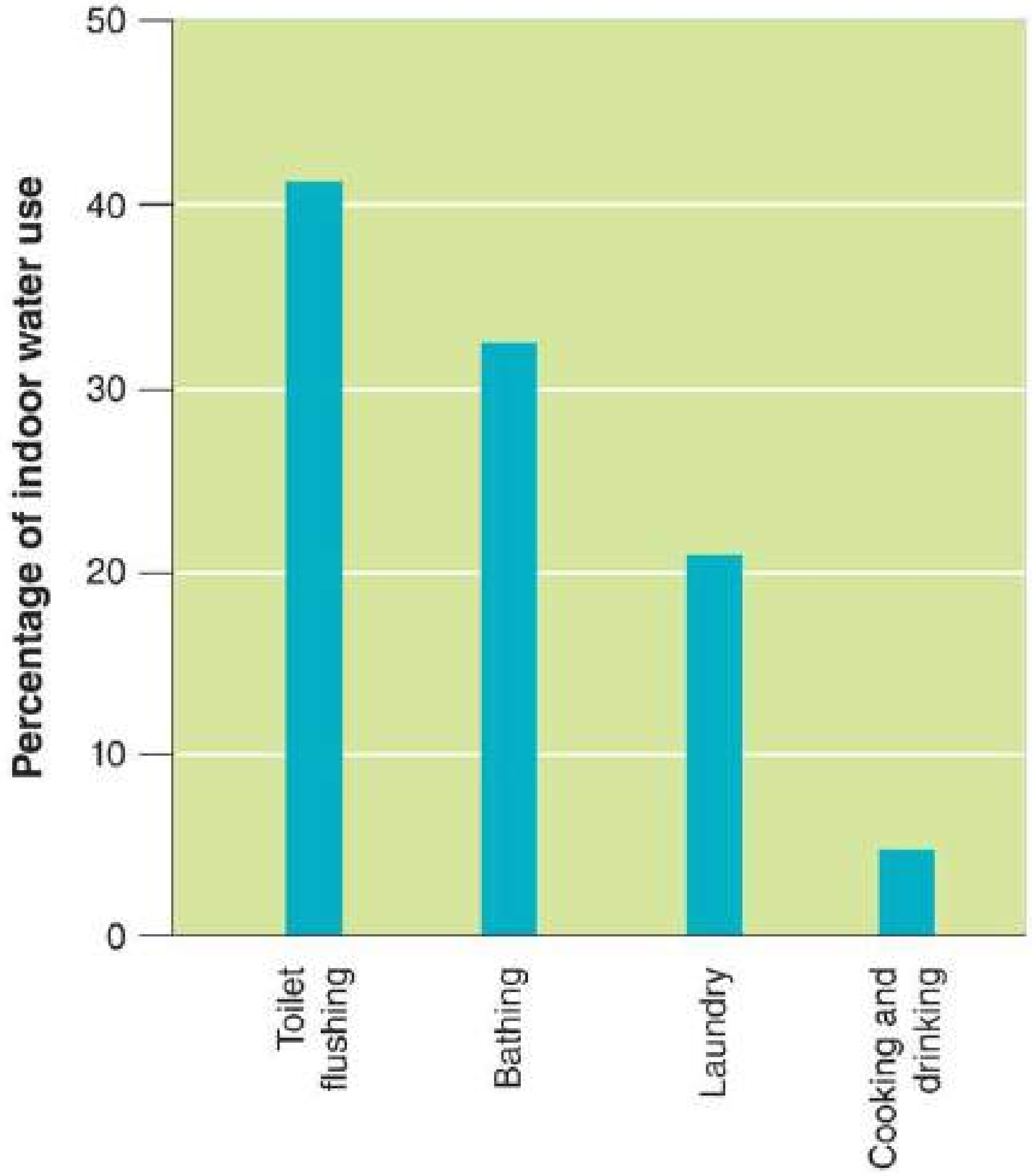


Figure 28.6
Environmental Science for AP®, Second Edition
Data from U.S. Environmental Protection Agency, 2003, http://esa21.kennesaw.edu/activities/water-use-overview-epa.pdf

Indoor household water use. Most water used indoors is used in the bathroom

The future availability of water depends on water ownership and water conservation

- Throughout the world, issues of water ownership and water rights have created conflicts.
- Many countries have found ways to conserve water through improved technology.
- **Gray water** Wastewater from baths, showers, bathrooms, and washing machines.
- **Contaminated water** Wastewater from toilets, kitchen sinks, and dishwashers.

CONTENT

- What is Ground Water.
- What is Artificial Ground Water Recharge.
- Advantages of artificial recharge.
- Why Artificial Recharge.
- Identification Of Areas For Recharge.
- Quality of source water .
- Methods of artificial recharge.
- Conclusion.
- References.

Ground water

1)Groundwater is the underground water which occurs in the saturated zone of earth surface.

2)Cracks and pores in existing rocks makes this ground water reservoir.

3)Ground water utilized through wells and tube wells.


A water crisis is looming.

WATER SCENARIO

TODAY
AND
BEFORE

IN 2025

Present water availability

- India's population is 16% of the world population, whereas, water resources are only 4% that of the world.
- Present water demand is 1122 billion m^3 (Surface water690 billion m^3 and groundwater 432 billion m^3).
- By 2010, groundwater demand would increase to 710 billion m^3.
- By 2050, it would be 1180 billion m^3 i.e. less than availability.
- Out of 236 blocks, 204 blocks are over-exploited due to above situation. The demand in 2025 would be doubled, we can imagine scenario of 2050.
- In Rajasthan, total water availability is 10382 million m^3 at present, whereas the requirement is 12999 m^3.

Future Water Scenario

- Water availability will be to 1 person out of 3.
- Water quality will become unsafe in majority of the places.
- No food to 1/3 of the population.
- Many water borne diseases like Fluorosis, Dementia, Diarrhea, Cancer etc. will be order of the day.
- There will be fight for water between
  - Man to man.
  - City to city.
  - State to state.
  - Country to country
  - Possible third world war?

What is Artificial Recharge

- Artificial recharge is the process by which the ground water recharge is augmented at the rate much higher then those under natural condition of percolation.

Advantage of artificial recharge

- To enhance the groundwater yield in depleted the aquifer due to urbanization .
- Conservation and storage of excess surface water for future requirements.
- To improve the quality of existing groundwater through dilution
- To improve bacteriological and other impurities from sewage and waste water by natural filtration , so that water is suitable for re use .

Why Artificial Recharge

- In most low rainfall areas of the country the availability of utilizable surface water is so low that people have to depend largely on ground water for agriculture and domestic uses.
- So in order to improve the ground water situation it is necessary to artificially recharge the depleted ground water aquifer.

Identification of areas for recharge

- Where ground water level are declining due to over exploitation.
- Where substantial part of aquifer has already been desaturated i.e. regeneration of water in wells and hand pumps is slow after some water has been drawn.
- Where availability of water from wells and hand pumps inadequate during the lean months.
- Where ground water quality is poor and there is no alternative source of water .

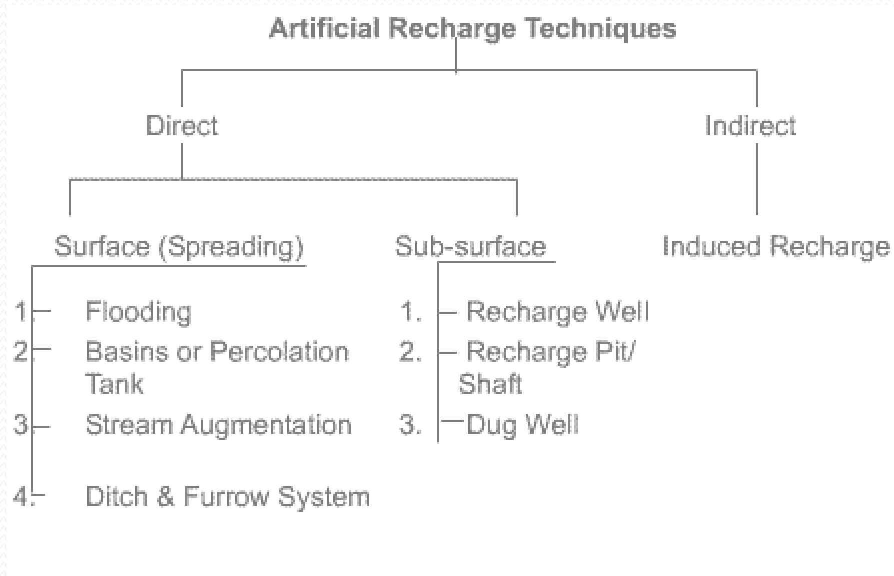
Quality of source water

- Problems which arise as a result of recharge to ground water are mainly related to the quality of raw waters that are available for recharge and which generally require some source of treatment before being used to recharge installations.
- A major requirement of waters that are to be used in recharge projects is that they be silt free.

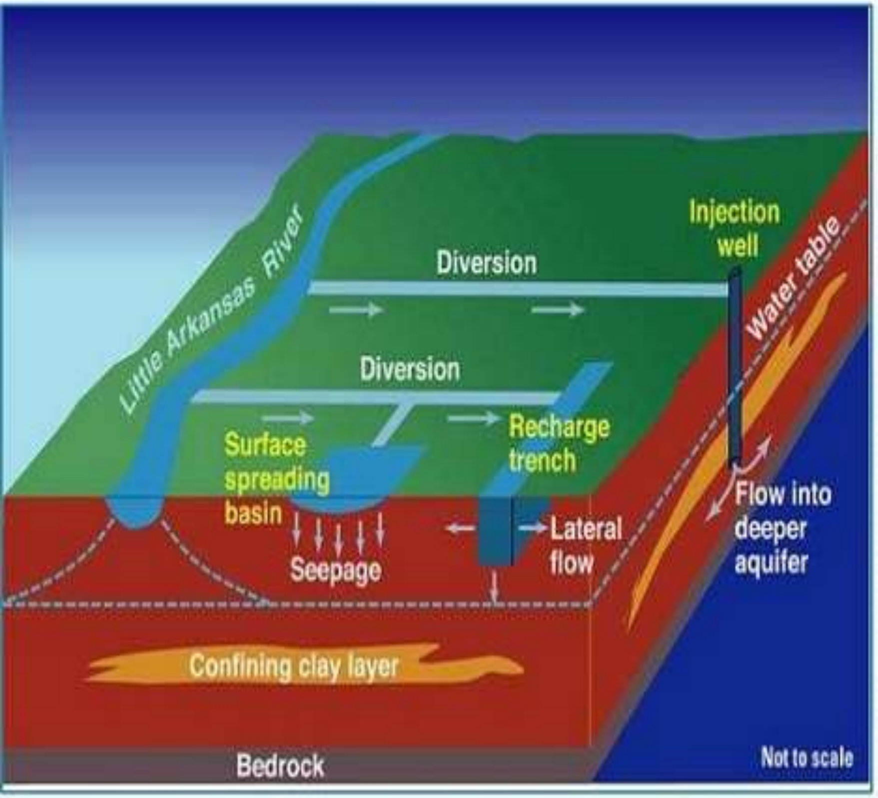
Methods of Artificial Recharge

- Artificial Recharge is the Process by which the Groundwater is augmented at a rate much higher than those under natural condition of replenishment.

- The techniques of artificial recharge can be broadly Categorized as follows:



Surface (spreading) method



Source: www.indiawaterportal.org

Figure 1 : surface spreading basin

- These methods are suitable where large area of basin is available and aquifers are unconfined without impervious layer above it .
- The rate of infiltration depend on the nature of top soil , if soil is sandy the infiltration is higher than those of silty soil .
- The presence of solid suspension in water used for recharge clogs the soil pores leading to reduction in infiltration rate i.e. recharge rate
- Water quality also affects the rate of infiltration . The various spreading methods are as below:-

Flooding

- This method is suitable for relatively flat topography.
- The water is spread as a thin sheet .
- It requires a system of distribution channel for the supply of water for flooding .
- Higher rate of vertical infiltration is obtained on areas with undisturbed vegetation and sandy soil covering

Basin & Percolation tanks

Fig. A percolation tank about to get dry towards beginning of summer. Location: Village: Ralegan Siddhi, District: Nagar, Maharashtra State.

Source: www.indiawaterportal.org

- This is the most common method of artificial recharge.
- In this method , water is impounded in series of basins or percolation tank ,
- The size of basin may depend upon the topography of area, in flatter area will have large basin .
- This method is applicable in alluvial area as well as hard formation .
- The efficiency and feasibility of this method is more in hard rock formation where the rocks are highly fractured and weathered

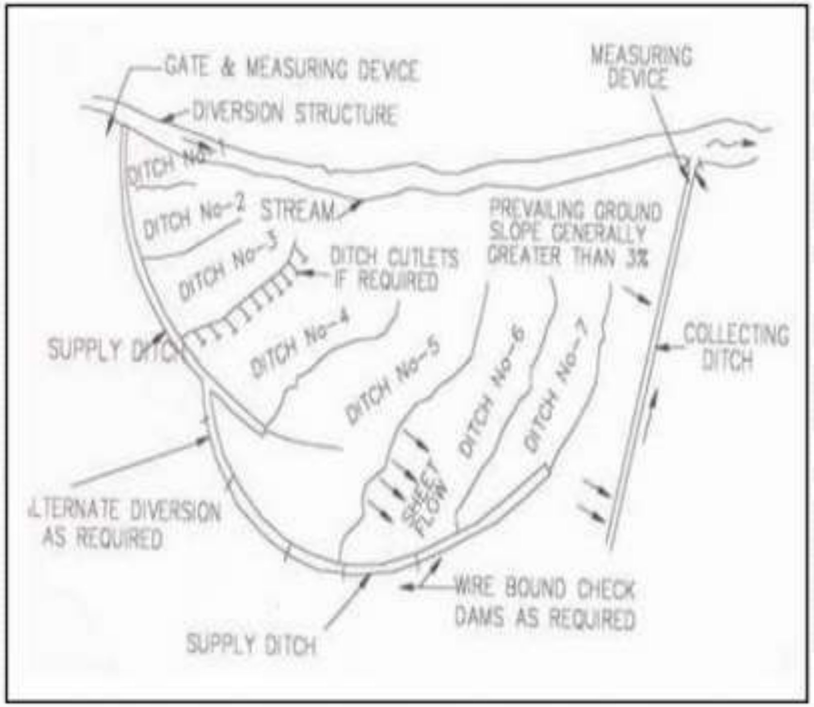
Stream Augmentation

Source: www.indiawaterportal.

Figure 3 : Check dam

- Seepage from natural stream or rivers is one of the most important source of recharge of the ground water reservoir.
- When total water supply available in the stream /river exceeds the rate of infiltration ,the excess is lost as runoff .
- This runoff can be arrested through check bunds or widening the steam beds thus larger area is available to spread the river water increasing the infiltration .
- The site selected for check dam should have sufficient thickness of permeable bed or weathered formation to facilitate recharge of stored water with in short span of time.
- The water stored in these structures is mostly confined to stream course and height is normally less than 2m. To harness maximum runoff, a series of such check dam may be constructed.

Ditch & Furrow System

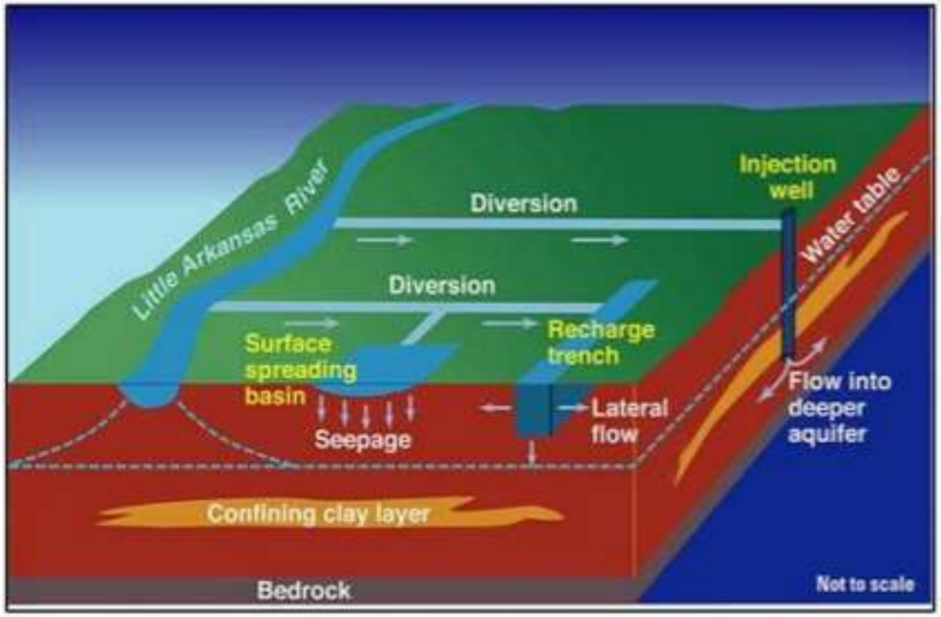


Source: megphed.gov.in

Figure 4 : Ditch and Furrow System

- In areas with irregular topography ditches or furrow provide maximum water contact area for recharge .
- This technique consists of a system of shallow flat bottomed and closely spaced ditches/ furrow which are used to carry water from source like stream/canals and provide more percolation opportunity.
- This technique required less soil preparation less is less sensitive to silting.

B.Sub – Surface Method

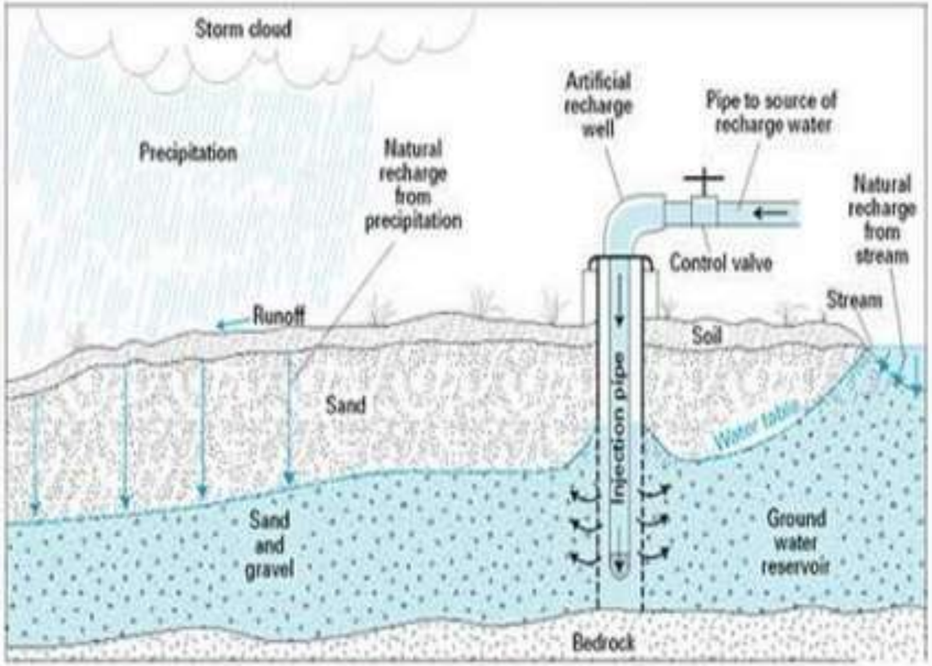


Source: www.indiawaterportal.org

Figure 5 : sub surface method

- In this method the structure lies below the surface and recharges ground water directly.
- The important structures commonly use are recharge wells, recharge shaft, dug wells etc

Recharge well

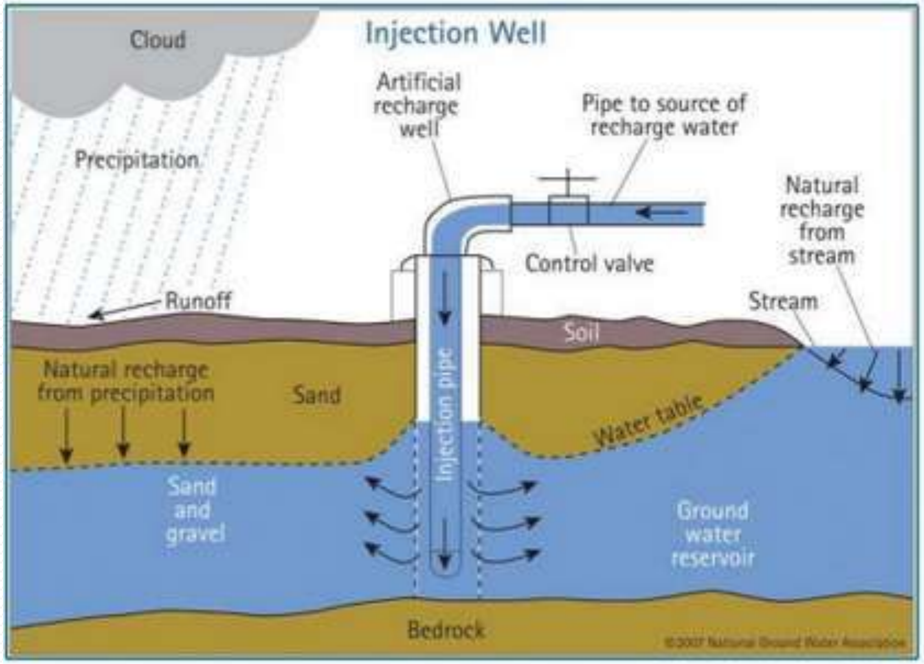


Source:www.ngwa.org

Figure 6 : Injection well

- Recharge wells can be of two types-
- (a) Injection well, where water is " pumped in" for recharge and
- (b) Recharge well, where water flows under gravity.

(a) Injection Well



Source: www.ngwa.org

Figure (7) : Injection well

- The injection wells are similar to a tube well.
- This technique is suitable for augmenting the ground water storage of deeper aquifers by "pumping in" treated surface water.
- These wells can be used as pumping wells during summers.
- The method is suitable to recharge single aquifer or multiple aquifers.
- The recharge through this technique is comparatively costlier and required specialized technique.

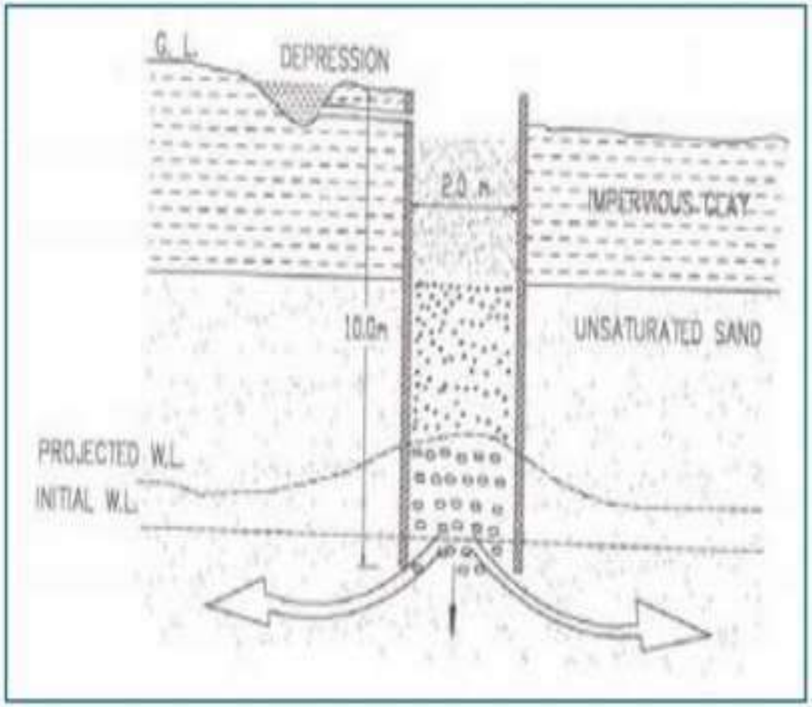
Recharge Well

Source: www.indiawaterportal.org

Figure 8 : Simple Recharge well

- The recharge well for shallow water table aquifers up to 50 m are cost effective because recharge can take place under gravity flow only.
- These wells could be of two types, one is dry and another is wet.
- The dry types of wells have bottom of screen above the water table. In such well excessive clogging is reported due to release of dissolved gasses as water leaves the well and on other hand redevelopment methods have not been found effective in dry type of well.
- The wet types of wells are in which screen is kept below water table. These wet type wells have been found more successful.

2.Pitch & Shafts

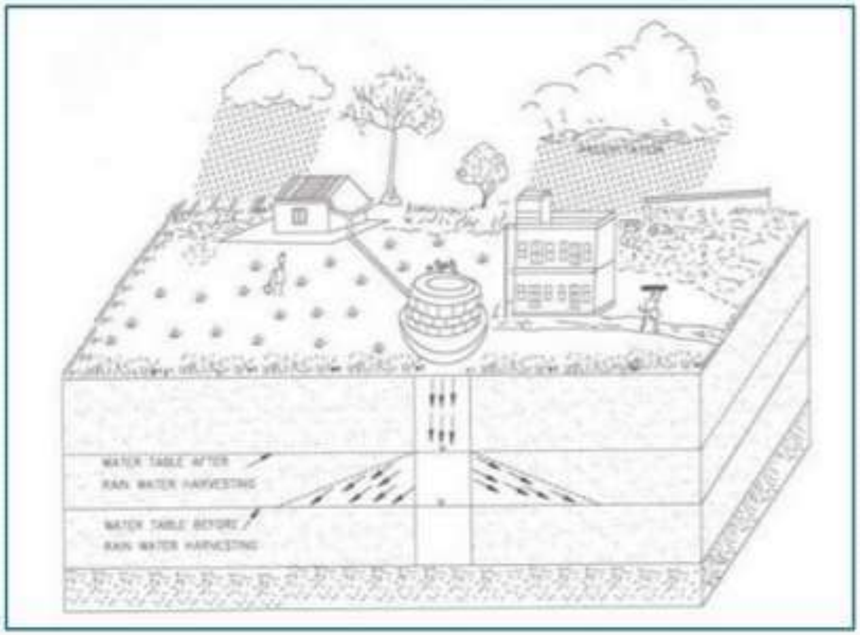


Source: megphed.gov.in

Figure(9) : Vertical recharge shaft

- In area where impervious layer is encountered at shallow depth the pits & shafts are suitable structure for artificial recharge.
- These structures are cost effective to recharge the aquifer directly.
- The diameter of shaft should normally be more than 2m to accommodate more water.
- The advantage of shafts/ pits structures is that they do not requires large pieces of land like percolation tank & other spreading method.
- There are practically no losses of water in form of soil moisture and evaporation like other methods of spreading.

Dug Wells

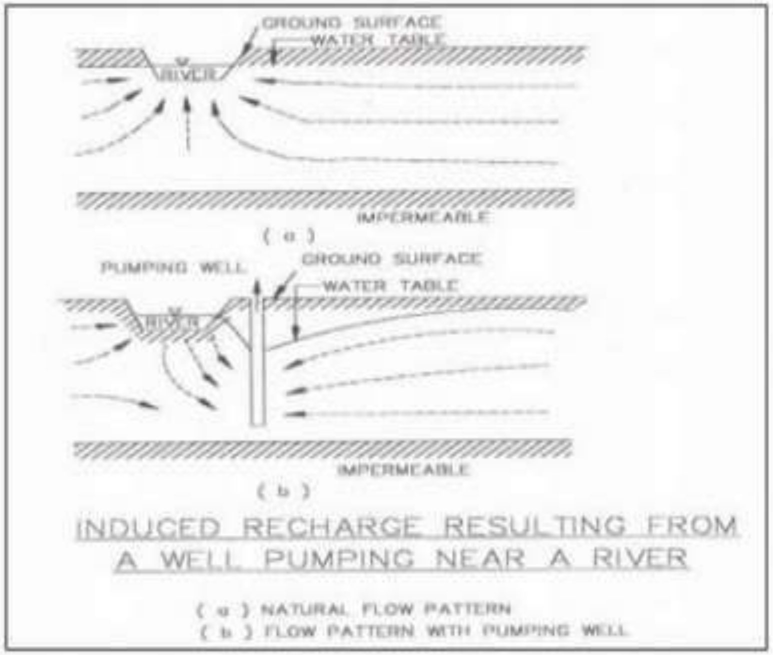


Source: megphed.gov.in

Figure (10) : Recharge through Dug Wells

- In alluvial as well as hard rock areas there are thousand of dug wells have either gone dry due to considerable decline of water levels.
- These dug wells can be used as recharge structure storm water and other surplus water from canal etc. can be diverted into these structure to directly recharge the dried aquifer.
- The water for recharge should be guided through a pipes to the bottom of well to avoid entrapment of bubbles in the aquifer.

C. Induced Recharge



Source: megphed.gov.in

Figure (11): Induced Recharge

- It is an indirect method of artificial recharge involving pumping from aquifer hydraulically connected with surface water such as perennial streams, unlined canal or lakes.
- The heavy pumping lowers the groundwater level and cone of depression is created . Lowering of water levels induces the surface water to replenish this ground water .
- This method is effective where stream bed is connected to aquifer by sandy formation .

Conclusion

- Thus it can be concluded that artificial recharge give the reduction of runoff, increased availability of groundwater especially in summer month , increase in irrigation , revival of springs, improvement of groundwater quality .
- Yet even full development of artificial recharge , ground availability would remain limited .
- Though ground water recharge scheme either naturally or artificially may not the final answer.
- But they do call for the community effort and create the spirit of cooperation needed to subsequently manage sustainably ground water as a community resource.

Thank you

9

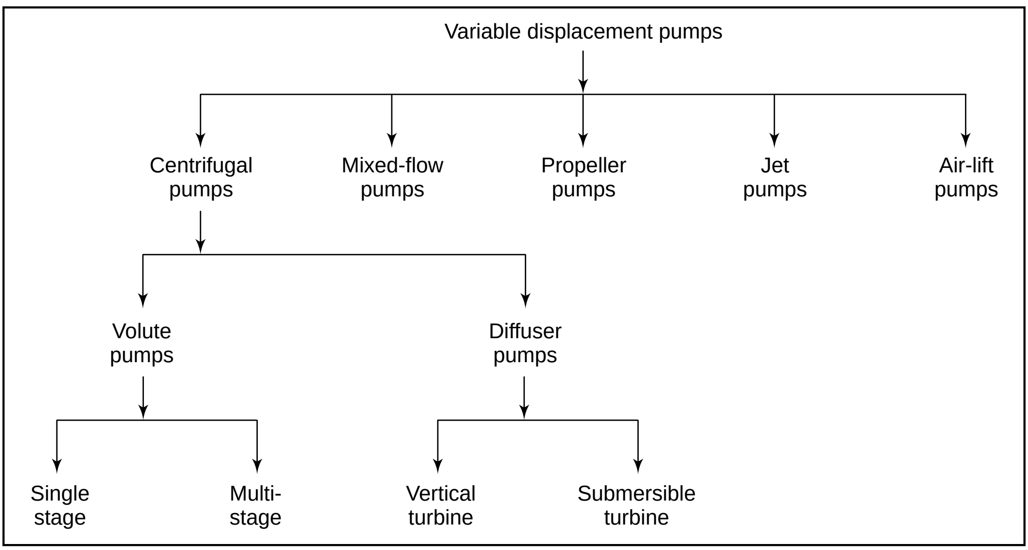
Variable Displacement Pumps and Accessories

The distinguishing feature of variable displacement pumps is the inverse relationship between the discharge rate and the pressure head. As the pumping head increases, the discharge rate decreases. Unlike positive displacement pumps, variable displacement pumps require the greatest input of power at low heads because of increase in discharge as the pumping head is reduced.

Variable displacement pumps of the impeller type, including centrifugal, mixed-flow and propeller pumps, are predominantly used in irrigation and drainage pumping. They are also common in drinking water supply systems operated by electric motors or engines. They use a rotating impeller to pump water. They are available for use under widely varying operating conditions, including low to high discharge and operating heads.

9.1 CLASSIFICATION OF VARIABLE DISPLACEMENT PUMPS

The broad classification of the commonly used variable displacement pumps is shown in the following chart:



9.2 CENTRIFUGAL PUMPS

Centrifugal pumps are used to pump water from reservoirs, lakes, stream and shallow wells. They are also used as booster pumps in irrigation pipelines.

9.2.1 Principles of Operation

A centrifugal pump may be defined as one in which an impeller rotating inside a close-fitting case draws in the liquid at the centre and, by virtue of centrifugal force, throws out through an opening or openings at the side of the casing. The underlying hydraulic principle is the production of high velocity and the partial transformation of this velocity into pressure head. In operation, the pump is filled with water and the impeller rotated. The blades cause the liquid to rotate with the impeller and, in turn impart a high velocity to the water particles. The centrifugal force causes the water particles to be thrown from the impeller into the casing. The forward flow through the impeller reduces pressure at the inlet, allowing more water to be drawn in through the suction pipe by atmospheric pressure or an external pressure. The liquid passes into the casing, where its high velocity is reduced and converted into pressure and the water is pumped out through the discharge pipe. This conversion of velocity energy into pressure energy is accomplished either in a volute casing or in a diffuser.

The principle of operation of a centrifugal pump can be explained through the example of swinging a pail (Fig. 9.1). When a pail filled with water is swung in a circle, in a vertical or horizontal plane, the water stays in the pail because of the centrifugal force. This makes the pail seem very heavy. If the pail has a hole in it, the water would spurt out with considerable force. If it were possible to connect this hole to a hose and to elevate the hose vertically, several meters in the air, water in the pail would be discharged through the hose.

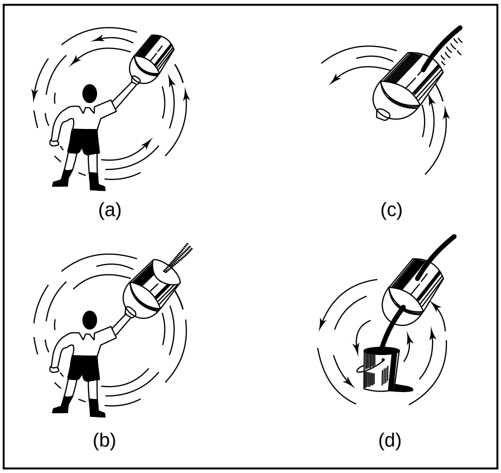


Fig. 9.1 Elementary principle of the centrifugal pump
Courtesy: Kelly and Lewis (1962)

In the next step, suppose a cover is put on the pail and a hose is connected with the cover on one side and a pail of water on the ground on the other. A centrifugal pump, in principle, would be developed. The centrifugal force of the water in the rotating pail will force the water out of the discharge hose, thus creating a partial vacuum in the rotating pail. This vacuum will cause a transfer of water from the stationary pail to the rotating pail. This is because atmospheric pressure on the surface of the water in the stationary pail forces the water into the vacuum of the rotating pail. Theoretically, such a system would continue to operate, provided no air enters with the water from the stationary pail.

The swinging pail is readily duplicated in a practical construction in which a set of rotating blades, or vanes, commonly called an impeller, is used. The impeller vanes act as the arm and pail. They ‘sling’ the liquid and impart centrifugal force and velocity. The impeller is arranged to rotate inside a casing which gathers the liquid from the suction entrance and directs it to the discharge opening.

Parts of a Centrifugal Pump

A centrifugal pump is a rotary machine consisting of two basic parts–the rotary element or impeller and the stationary element or casing (Fig. 9.2). The impeller is a wheel or disc mounted on a shaft and provided with a number of vanes or blades which are usually curved. The vanes are arranged in a circular array around an inlet opening at the centre. In some pumps, a diffuser consisting of a series of guide vanes of blades surrounds the impeller (Fig. 9.3). The impeller is secured on a shaft mounted on suitable bearings. The shaft usually has a stuffing box or a seal, where it passes through the casing wall (Fig. 9.4). The stuffing-box packing are generally made of asbestos or organic fibre. The casing surrounds the impeller and is usually in the form of a spiral or volute curve with a cross-sectional area increasing towards the discharge opening.

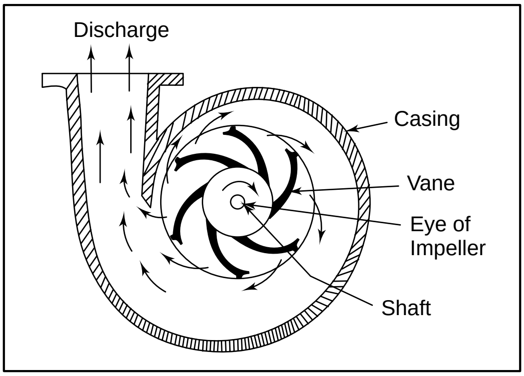


Fig. 9.2 Volute type centrifugal pump

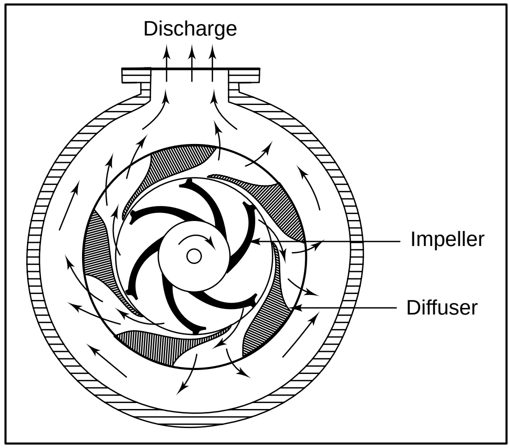


Fig. 9.3 Diffuser type centrifugal pump

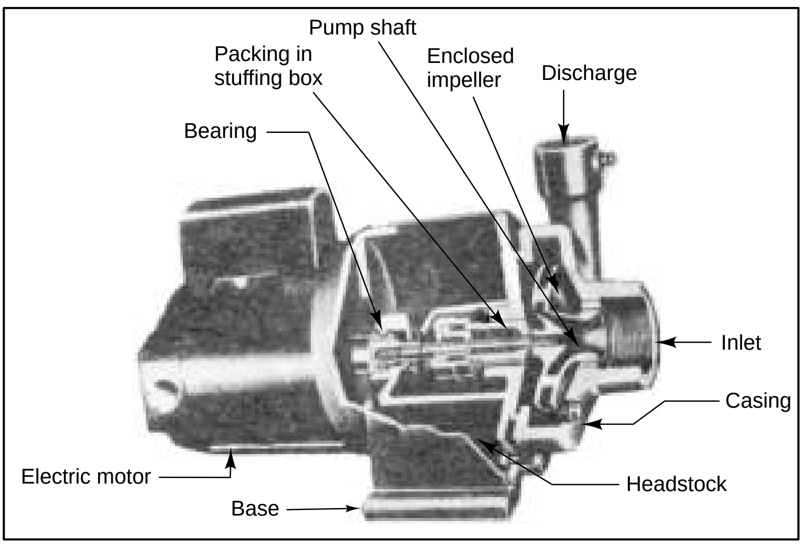


Fig. 9.4 Cut-away section of a horizontal centrifugal pump coupled to electric motor as a single unit

By changing the shape of the vanes, different characteristics are obtained. By enlarging the diameter of the inlet eye and the width of the impeller, the quantity of water that a pump can deliver against a given head is increased.

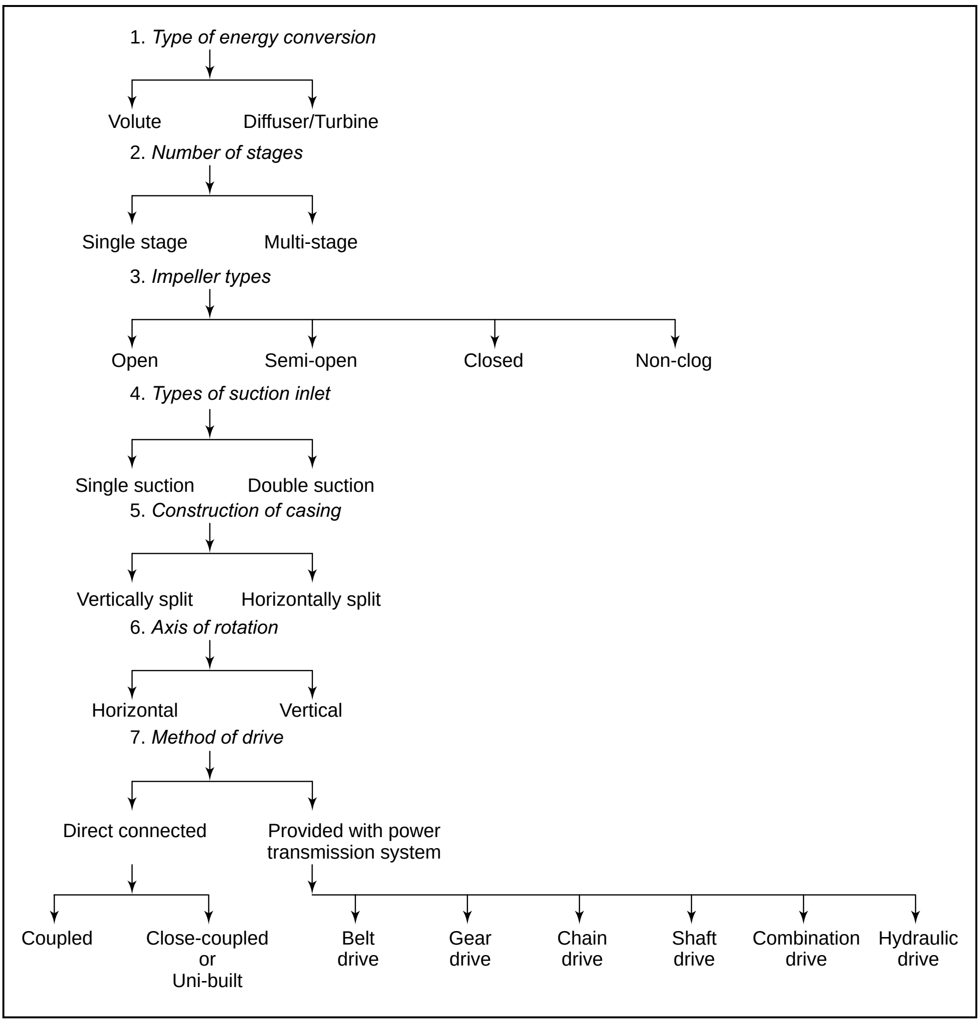
The leakage of water past an impeller, from the high pressure delivery side to the low pressure inlet area, results in considerable loss of energy. Hence, a sealing ring is provided between the impeller and the pump casing. The sealing ring may be a simple ring of close clearance or an elaborate labyrinth ring.

A bed plate is provided at the base of the pump body for mounting the pump and the driving motor or engine, thus providing a foundation on which they can be installed as a unit.

9.2.2 Classification

Centrifugal pumps are built in a wide variety of types. They may be classified into the following, on the basis of the type of energy conversion, constructional features, axis of rotation and method of drive.

Classification of Centrifugal Pumps



Volute Centrifugal Pumps

Most of the irrigation pumps used in India and other developing countries are of the volute type. The volute pump (Fig. 9.2) has a casing made in the form of a spiral or volute curve. The volute casing starts with a small cross-sectional area near the impeller periphery, which increases gradually towards the pump outlet. The casing is proportioned to reduce gradually the velocity of water, as it flows from the centre of the impeller to the discharge end, thus changing the velocity head into the pressure head to lift water to the required height.

Diffuser or Turbine Pumps

In a turbine-type pump, the impeller is surrounded by diffuser vanes (Fig. 9.3). The diffuser vanes, like the impeller vanes, are curved and gradually enlarge to the outer end where the liquid enters the pump casing. In a diffuser pump, a major part of the conversion of velocity energy into pressure energy takes place between the diffuser vanes. The diffuser vane casing was introduced in the design of pumps adopting the water-turbine practice, where the diffusion vanes are indispensable. Hence, these pumps are often called turbine pumps.

The choice between volute-type and turbine-type pumps varies with the conditions of use. Ordinarily, the volute-type pump is preferred for medium and large capacity and medium and moderately high head applications. Turbine pumps are usually used for high head conditions. Similarly, turbine pumps are most suitable in deep tube wells because of their design advantage where the diameter of the pump is small.

Single-Stage and Multi-Stage Pumps

A single-stage pump is one in which the total head is developed by a single impeller. A multi-stage pump has two or more impellers on a common shaft, acting in series in a single casing (Fig. 9.5). The liquid is conducted from the discharge of the preceding impeller, or stage, to the inlet of the following

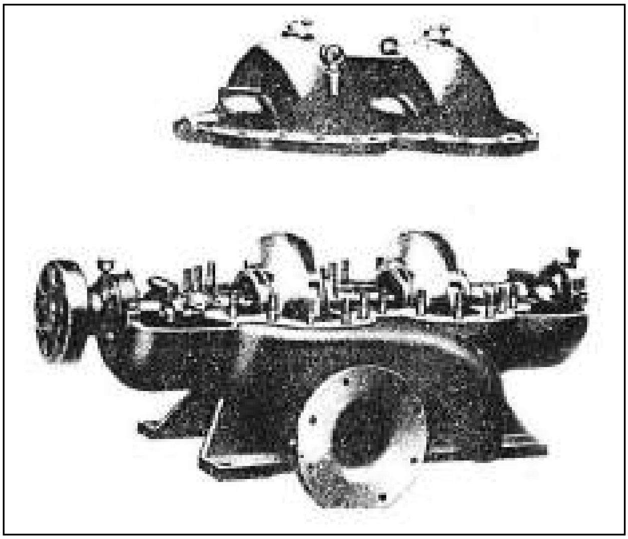


Fig. 9.5 A two-stage horizontal centrifugal pump with top cover lifted up
Courtesy: Lee Howl & Co. Ltd., London

impeller, causing an increase in the pressure head as it passes through each stage. The use of multi-stage pumps is a standard practice in volute as well as turbine type pumps for operation under high heads.

For a given type of impeller, the characteristics exhibited by a multi-stage pump are as follows:

1. The head and power requirements increase in direct proportion to the number of stages (impellers).
2. The discharge capacity and efficiency are almost the same as for a single stage of the pump operating alone.

Types of Impellers

The design of the impeller greatly influences the efficiency and operating characteristics of centrifugal pumps. Centrifugal pump impellers used in irrigation practice may be open, semi-open or close (Fig. 9.6). An *open impeller* consists essentially of a series of vanes attached to a central hub. It is used to pump water having considerable amounts of small solids. There is a minor reduction in efficiency

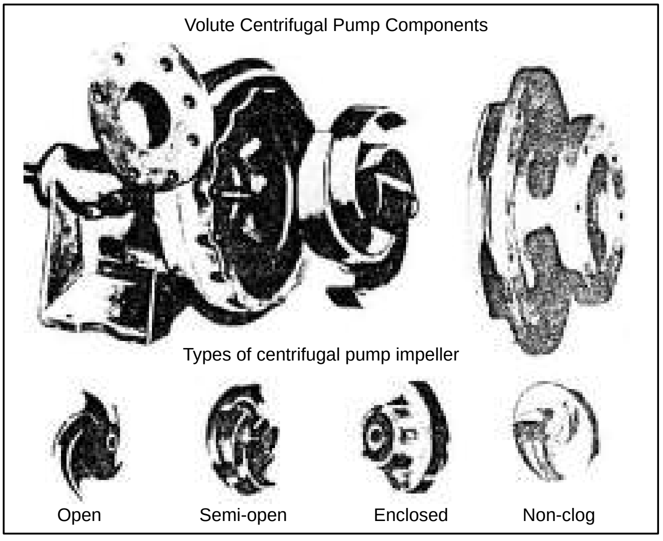


Fig. 9.6 Top: An exploded view of a volute-type horizontal centrifugal pump
Bottom*:* Types of impellers used in centrifugal pumps
Adapted from: Goulds Pumps Inc. (Olmstead, 1965)

when open-type impellers are used. A *semi-open* (or semi-enclosed) impeller has a shroud or side wall at the back. It can be used to pump water having some amount of suspended sediments. It is more efficient than open impellers. In an *enclosed impeller*, the vanes are enclosed between shrouds or side walls on either side. It is designed to pump clear water. Enclosed impellers develop somewhat higher efficiencies, especially in high pressure pumps. They are most efficient amongst the three types of impellers.

For pumping ordinary water, centrifugal pump impellers may be made of bronze or cast iron. To handle brackish or salt water, gun metal impellers are commonly used. Impellers for light duty could be made of rigid plastic materials.

Non-Clog Impeller Pumps

Non-clog pumps (Fig. 9.7), are specially designed for sewage service. They have vanes which are well rounded at their entrance ends and have large passage-ways between the vanes. They can handle sewage water containing solid particles, rags and other impurities.

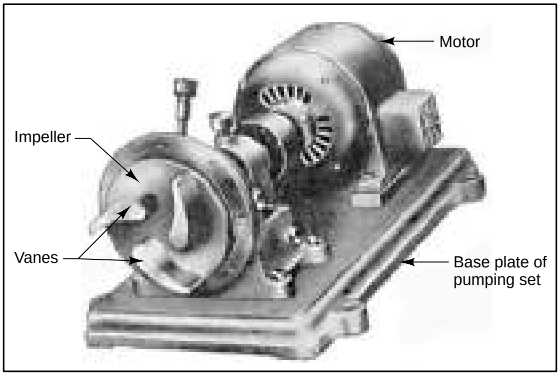


Fig. 9.7 Exposed view of a non-clog volute centrifugal pump coupled to an electric motor
Courtesy: Albany Engg. Co. Ltd.

Single-Suction and Double-Suction Pumps

In a single-suction pump, the liquid enters the impeller from one side only. In a double-suction pump, it enters from both sides. A double-suction impeller is similar to two single-suction impellers cast back to back. It is, theoretically, in axial hydraulic balance, making a thrust bearing unnecessary. However, due to manufacturing difficulties, double-suction pumps are not as common as single-suction pumps.

Horizontal-Split and Vertical-Split Casing Pumps

According to construction of the casing of a centrifugal pump, they are classified as horizontal-split casing (Fig. 9.4) or vertical-split casing (Fig. 9.8) pumps.

Horizontal Centrifugal Pumps

A horizontal centrifugal pump has a vertical impeller mounted on a horizontal shaft (Fig. 9.5). This type of pump is most commonly used in irrigation. It costs less, is easier to install and more accessible for inspection and maintenance. Its main limitation is that the pump is located above the water surface and the suction lift is limited to about 6.5 m.

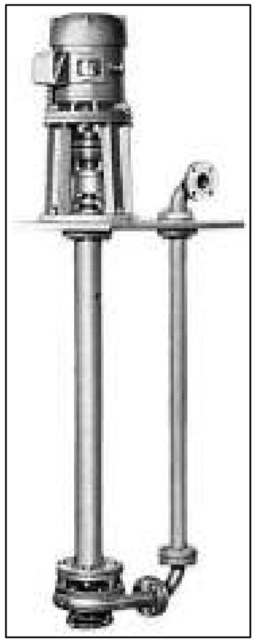


Fig. 9.8 A vertical submersible type volute centrifugal pump driven by a Vertical drive electric motor
Courtesy: Lee Howl & Co. Ltd., London

Vertical Centrifugal Pumps

A vertical centrifugal pump has a horizontal impeller mounted on a vertical shaft. This type of pump has the advantage that it can be lowered into the well, thus overcoming the problem of limited suction lift, as in the case of a horizontal centrifugal pump. Further, the vertical shaft is extended to the top of the well where the power unit is located. Volute-type vertical centrifugal pumps may be either submerged or exposed. The body of an exposed pump is usually set in a sump, at a level that will accommodate the suction lift.

In a submerged pump, the impeller and suction entrance remain submerged below the water level. Thus, the pump does not require priming. However, this arrangement is not popular in irrigation practice due to the difficulty in lubricating the bearings. Volute-type vertical centrifugal pumps are usually limited to pumping from sumps or pits. Hence, they are often referred to as sump pumps.

Close-Coupled Monoblock Pumps

Close-coupled pumps (Fig. 9.9(a) and (b)) often called monoblock pumps, are built with a common shaft and bearing for the pump and prime-mover, so as to form a single compact unit (Fig. 9.10). They are commonly used with electric motor driven pumping sets of small to medium capacity. They have the advantage of a slightly higher efficiency due to the elimination of transmission losses and compactness. The major problem is the difficulty in removing the electric motor for repair. Hence, monoblock pumps are generally limited to small-size, usually 1 to 5 hp units.

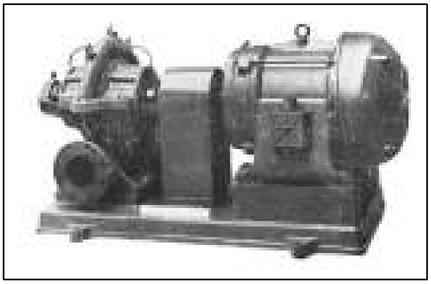


Fig. 9.9(a) A horizontally split volute centrifugal pump coupled to an electric motor. Note the protective shield over the couplong
Courtesy: Albani Engg. Co. Ltd.

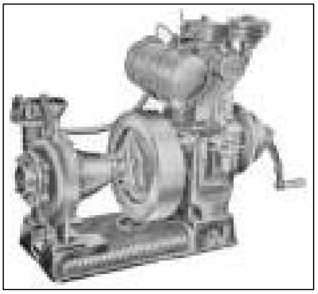


Fig. 9.9(b) A horizontal centrifugal pump coupled to a vertical diesel engine
Courtesy: Kirloskar Brothers, Ltd. Pune, (Anon., 1962)

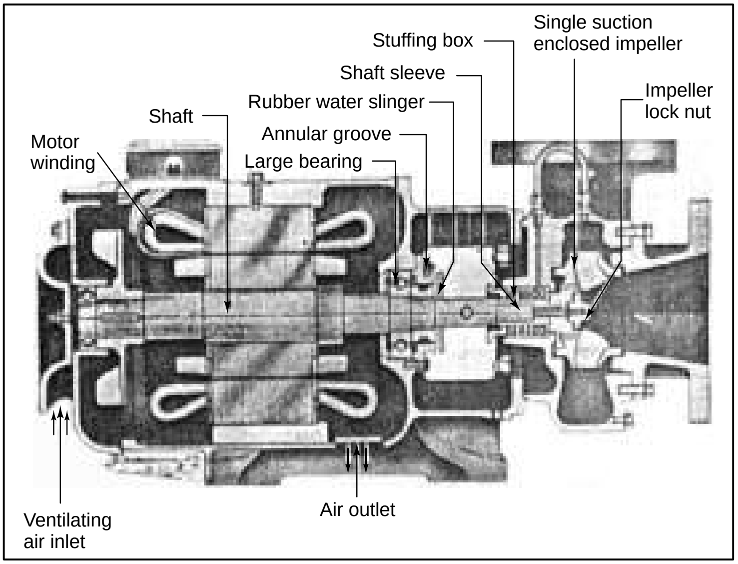


Fig. 9.10 Sectional view of a motor driven monoblock horizontal volute centrifugal pump
Courtesy: Worthington Simpson Pumps, Best & Co., Chennai

Pumps with Flexible Coupling

In this type, the pump is mounted directly to its driver through a flexible coupling. Flexible couplings are most commonly used to connect the pump shaft to the motor or engine shaft. They permit minor misalignment of the shafts. The removal of the power unit from the pump for repair is easy.

Pumps Connected with Belt, Gear, Shaft or Chain Drives

In many situations, especially in case of engine-driven pumping sets, the pump has to be located close to the water level in a well or stream, but it is not covenient to locate the engine close to it. In such a case, a suitable power transmission system is to be adopted. The power transmission systems commonly used are belt (Fig. 9.11), chain, gears and shaft. Suitable combinations of two or more of the above drives are also sometimes required. Among the various drives, belt drive is the most common. In belt drive, the pump is provided with a pulley head.

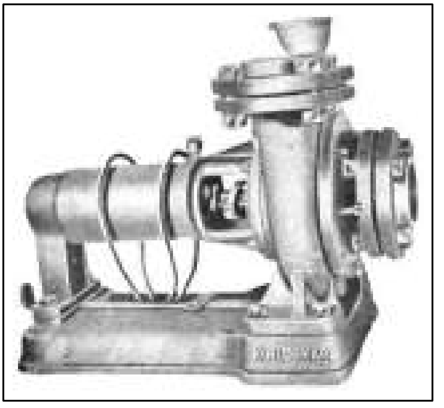


Fig. 9.11 A belt-driven horizontal volute centrifugal pump provided with fast and loose pulleys
Courtesy: Kirloskar Brothers Ltd., Pune (Anon., 1962)

9.3 FRICTION HEAD IN PIPE SYSTEM

The head losses in piping installations include the energy or head required to overcome the resistance of the pipeline and fittings (including strainer, valves, elbows, bends, reducing sockets and tees) in the pumping system. A friction head exists on both the suction and discharge sides of a pump, and varies with the rate of flow of water, pipe size, condition of the interior of the pipe and the material of which the pipe is made.

Loss of Head Due to Friction in a Pipe

Loss of head due to friction in a pipe, between two points at a distance l apart is given by the formula

$$h_f = \frac{4flv^2}{2gd} \tag{9.1}$$

where, f = coefficient of friction for the pipe, fraction
l = length of pipe, m
d = diameter of pipe, m

The friction coefficient f depends upon the smoothness or roughness of the pipe surface. The value of f is less if the pipe is new and smooth. It may be determined by carrying out the actual test, using Eq. (9.1). The value of f is calculated for observed values of h_f, l, v and d. The head loss in galvanized iron pipes and rigid PVC pipes of different sizes, under varying discharge rates, is given in Table 9.1 and 9.2, respectively.