WATER DIVERSION PROJECTS

■ **CASE STUDY**

The Colorado River Basin—An Overtapped Resource

The Colorado River, the major river of the arid southwestern United States, flows 2,300 kilometers (1,400 miles) through seven states and eventually to the Gulf of California (Figure 13-14). During the past 50 years, this once free-flowing river, which gets its water mostly from snowmelt from the Rocky Mountains, has been tamed by a gigantic plumbing system consisting of 14 major dams and reservoirs (Figure 13-15) and canals that supply water to farmers, ranchers, and cities.

This system lies in a mostly desert area within the rain shadow (Figure 7-7, p. 145) of California's mountain ranges. It provides water and electricity for more than 25 million people in seven states. The river's water is used to produce about 15% of the nation's crops and livestock. It also supports a multibillion-dollar recreation industry of whitewater rafting, boating, fishing, camping, and hiking.

The river supplies water to some of the nation's driest and hottest cities. Take away this tamed river and Las Vegas, Nevada, would be a mostly uninhabited desert area; San Diego and Los Angeles, California, could not support their present populations; and California's Imperial Valley, which grows a major portion of the nation's vegetables, would consist mostly of cactus and mesquite plants.

Lake Mead behind Hoover Dam (Figure 13-14) supplies about 90% of water for the desert city of Las Vegas, Nevada—one of the country's fastest growing urban areas. In 2008, U.S. researchers Tim Barnett and David Pierce estimated that there is a 50% chance that by 2021, Lake Mead will run dry because of greater water demands and decreased flow of the Colorado River due to increased drought and evaporation of water.

There are four major problems associated with use of this river's water. *First,* the Colorado River basin includes some of the driest lands in the United States and Mexico (Figure 13-4). *Second,* for its size, the river has only a modest flow of water. *Third,* legal pacts signed in 1922 and 1944 allocated more water for human use in the United States and Mexico than the river can

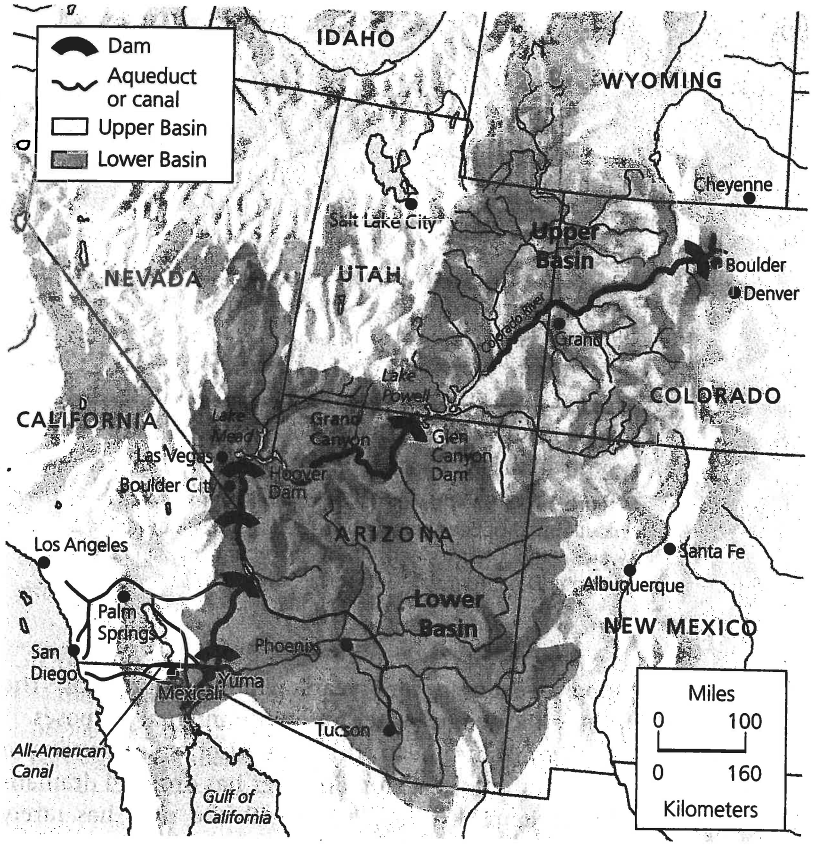
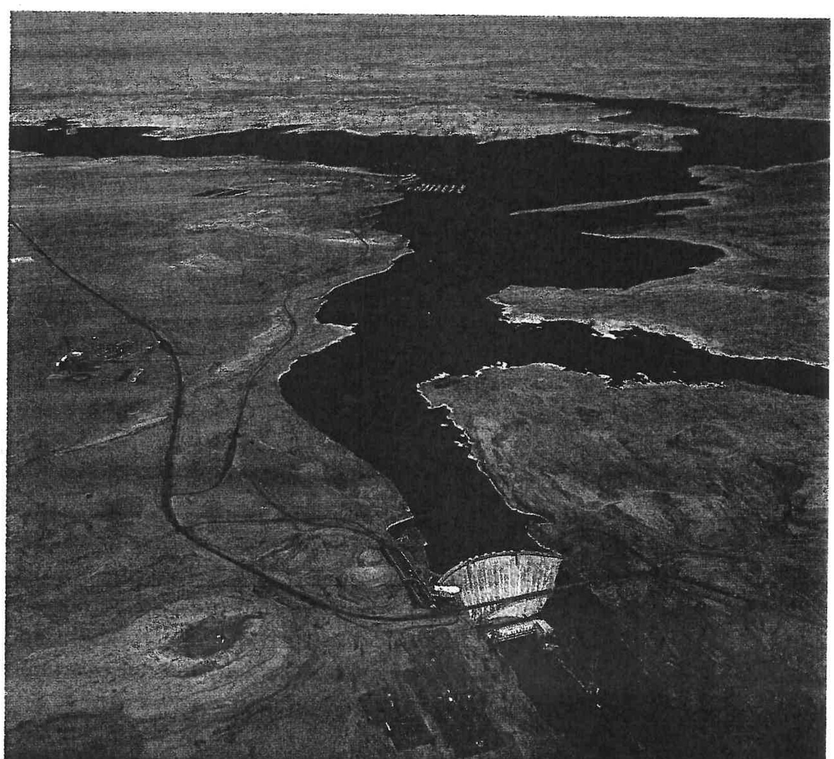


Figure 13-14 The *Colorado River basin.* The area drained by this basin is equal to more than one-twelfth of the land area of the lower 48 states. Two large reservoirs—Lake Mead behind the Hoover Dam and Lake Powell behind the Glen Canyon Dam—store about 80% of the water in this basin.



Jim Wark/Peter Arnold, Inc.

Figure 13-15 Aerial view of Glen Canyon dam built across the Colorado River in 1963 and its reservoir called Lake Powell, the second largest reservoir in the United States.

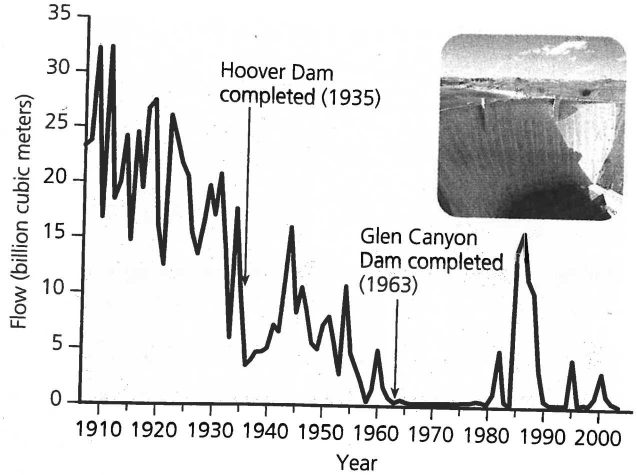


Figure 13-16 The flow of the Colorado River measured at its mouth has dropped sharply since 1905 as a result of multiple dams, water withdrawals for agriculture and urban areas, and prolonged drought (Data from U.S. Geological Survey).

supply—even in rare years without a drought. The pacts allocated no water for environmental purposes.

Fourth, since 1905, the amount of water flowing to the mouth of the Colorado River has dropped dramatically (Figure 13-16). Since 1960, the river has rarely made it to the Gulf of California because of the many dams, the increased water withdrawals, and a prolonged drought in the American Southwest, which is projected to last throughout this century. This threatens the survival of species that spawn in the river and species that live in its estuary near the coast.

The water available from the Colorado is likely to decrease even more because of climate change caused by global warming. According to projections, as the climate continues to warm, mountain snows that feed the river will melt faster and earlier and evaporate in greater amounts.

If some of the Southwest's largest reservoirs empty out during this century, the region could experience an economic and ecological catastrophe with political and legal battles over who will get how much of the region's greatly diminished water supply. Agricultural production would drop sharply and many people in the region's booming desert cities, such as Phoenix, Arizona, and Las Vegas, Nevada, likely would have to migrate to other areas. Withdrawing more groundwater is not a solution because water tables beneath much of the area served by the Colorado River have been dropping, sometimes drastically, due to overpumping (Figure 13-9).

Traditionally, about 80% of the water withdrawn from the Colorado has been used to irrigate crops and raise cattle. The U.S. government paid for the dams and reservoirs and has supplied many farmers and ranchers with water at low prices. These government subsidies have led to inefficient use of irrigation water on thirsty crops such as rice, cotton, and alfalfa in this water-short area.

In addition, as the flow of the Colorado River slows in large reservoirs behind dams it drops much of its load of suspended silt. This deprives the river's coastal delta of much needed sediment and causes flooding and loss of ecologically important coastal wetlands. The amount of silt being deposited on the bottoms of the Lake Powell and Lake Mead reservoirs is roughly 20,000 dump truck loads every day. Sometime during this century, these reservoirs will probably be too full of silt to store enough water for generating hydroelectric power or controlling floods.

Some researchers argue that the seven states using the Colorado River should enact and enforce strict water conservation measures and sharply increase the price of water from the river. They also suggest measures to slow population growth and urban development, stop subsidizing agriculture in this region, shift water-thirsty crops to less arid areas, and stop building golf courses and growing green lawns in desert areas. People living in or moving to areas served by the river would have to realize that they are living in a desert and must adapt to their environment by drastically reducing their water usage.

These problems illustrate the challenges faced by governments and people living in arid and semiarid regions with shared river systems, as population growth and economic development place increasing demands on limited or decreasing supplies of surface water. Without major changes in water policies and management to drastically increase the efficiency of water use, the future for large numbers of people in such areas may dry up.

THINKING ABOUT
The Colorado River

What are three measures you would take to deal with the problems of the Colorado River system? How would you implement them politically?

■ CASE STUDY
China's Three Gorges Dam

China's Three Gorges Dam, built across the Yangtze River, is the world's largest hydroelectric dam and reservoir. Two kilometers (1.2 miles) long, the dam was built at a cost of at least $25 billion. Like all dams, it has created benefits and harmful effects (Figure 13-12).

When its giant reservoir fills, the dam will be able to produce an amount of electricity equal to that of 22 large coal-burning or nuclear power plants, enough electricity to provide power for a city 10 times as large as the U.S. city of Los Angeles, California. This will help to reduce China's dependence on coal and its emissions of the greenhouse gas CO_2.

The dam will also help to hold back the Yangtze River's floodwaters, which have killed more than 500,000 people during the past 100 years—including 4,000 people in 1998. The estimated cost of damage caused by the 1998 flood alone equals the cost of the entire dam project. In addition, the dam will enable large cargo-carrying ships to travel deep into China's interior, greatly reducing transportation costs, and increasing trade in a relatively poor region of China.

When filled, the 600-kilometer-long (370-mile-long) reservoir behind the dam will cover an area almost equal in length to the distance between the U.S. cities of San Francisco and Los Angeles, California. This enormous reservoir will flood one of China's most beautiful areas, including 1,350 cities and villages and thousands of archeological and cultural sites. It will displace about 5.4 million people.

Some scientists contend that the slower flow of water in the reservoir will continually release huge amounts of sediment that will shorten the projected life of the reservoir and limit the flood-prevention capacity of the dam. In addition, productive farming regions below the dam will no longer receive annual deposits of nutrient-rich sediment.

Because the dam is built over a seismic fault, some geologists worry that it might collapse and cause a major flood that would kill millions of people. Engineers claim that the dam can withstand the maximum projected earthquake. Yet, some 80 small cracks have already been discovered in the dam.

Another problem is that plant and animal matter rotting underwater in the gigantic reservoir will release methane gas—which is a much more potent greenhouse gas than CO_2—into the atmosphere. The hydroelectric power generated by the dam will allow the Chinese to avoid some additional CO_2 emissions by not having to build as many new coal-burning power plants. But the reservoir's methane emissions will offset these savings in CO_2 emissions.

Opponents of the dam also claim that it will convert the Yangtze River to the world's largest sewer, because most cities and factories along the river dump their untreated sewage and other wastes directly into it. Opponents estimate that the hidden long-term harmful environmental and social costs of the dam project will be close to $75 billion—three times the direct cost of the project. Critics claim that it would have been cheaper, less disruptive, and safer to build a series of smaller dams.

THINKING ABOUT
The Three Gorges Dam

Do you think that the benefits of the Three Gorges Dam will outweigh its harmful effects? Explain.

13-4 Is Transferring Water from One Place to Another the Answer?

▶ **CONCEPT 13-4 Transferring water from one place to another has greatly increased water supplies in some areas, but it has also disrupted ecosystems.**

California Transfers Massive Amounts of Water from Water-Rich Areas to Water-Poor Areas

Tunnels, aqueducts, and underground pipes can transfer stream runoff collected by dams and reservoirs from water-rich areas to water-poor areas, but they also create environmental problems (**Concept 13-4**).

One of the world's largest water transfer projects is the *California Water Project* (Figure 13-17, p. 330). It uses a maze of giant dams, pumps, and aqueducts to transport water from water-rich northern California to water-poor southern California's heavily populated agricultural regions and cities. This project supplies massive amounts of water to areas that, without such water transfers, would be mostly desert.

For decades, northern and southern Californians have feuded over how the state's water should be allocated under this project. Southern Californians want more water from the north to grow more crops and to support Los Angeles, San Diego, and other growing urban areas. Agriculture consumes three-fourths of the water withdrawn in California, much of it used inefficiently for water-thirsty crops such as rice and alfalfa growing in desert-like conditions.

Northern Californians counter that sending more water south degrades the Sacramento River, threatens fisheries, and reduces the river's power to flush pollutants out of San Francisco Bay. They also argue that much of the water sent south is wasted. They point to studies showing that making irrigation just 10% more efficient would provide enough water for domestic and industrial uses in southern California. But low water prices, mostly because government subsidies make it uneconomical for farmers to invest in improving irrigation efficiency.

According to a 2002 study by a group of scientists and engineers, projected global warming will sharply reduce water availability in California (especially

Figure 13-17 The California Water Project and the Central Arizona Project. These projects involve large-scale water transfers from one watershed to another. Arrows show the general direction of water flow.

southern California) and other water-short states in the western United States, even in the best-case scenario. Some analysts project that sometime during this century, many people living in arid southern California cities, as well as farmers in this area, may have to move elsewhere because of a shortage of water.

Pumping more groundwater is not the answer, because groundwater is already being withdrawn faster than it is replenished in much of central and southern California (Figure 13-9). According to many analysts, it would be quicker and cheaper to reduce water waste by improving irrigation efficiency, not growing water-thirsty crops in arid areas, and raising the historically low price of water to encourage water conservation.

■ **CASE STUDY**

The Aral Sea Disaster

The shrinking of the Aral Sea (Figure 13-18) is the result of a large-scale water transfer project in an area of the former Soviet Union with the driest climate in central Asia. Since 1960, enormous amounts of irrigation water have been diverted from the inland Aral Sea and its two feeder rivers to create one of the world's largest irrigated areas, mostly for raising cotton and rice. The irrigation canal, the world's longest, stretches more than 1,300 kilometers (800 miles).

This large-scale water diversion project, coupled with droughts and high evaporation rates due to the area's hot and dry climate, has caused a regional ecological and economic disaster. Since 1961, the sea's salinity has risen sevenfold and the average level of its water has dropped by 22 meters (72 feet). It has lost 89% of its volume of water and has split into two major parts (Figure 13-18, right). Water withdrawal for agriculture has reduced the two rivers feeding the sea to mere trickles.

About 85% of the area's wetlands have been eliminated and roughly half the local bird and mammal species have disappeared. In addition, a huge area of former lake bottom has been converted to a human-made desert covered with glistening white salt. The sea's increased salt concentration—three times saltier than ocean water—caused the presumed extinction of 26 of the area's 32 native fish species. This has devastated the area's fishing industry, which once provided work for more than 60,000 people. Fishing villages and boats once located on the sea's coastline now sit abandoned in the middle of a salt desert (Figure 13-19).

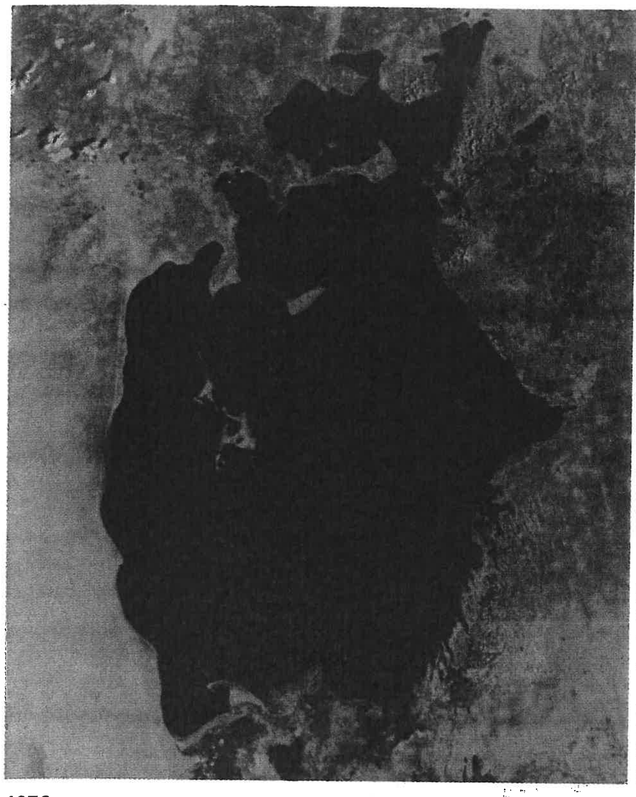
Winds pick up the sand and salty dust and blow it onto fields as far as 500 kilometers (310 miles) away. As the salt spreads, it pollutes water and kills wildlife, crops, and other vegetation. Aral Sea dust settling on glaciers in the Himalayas is causing them to melt at a faster than normal rate—a prime example of unexpected connections and unintended consequences.

Shrinkage of the Aral Sea has also altered the area's climate. The once-huge sea acted as a thermal buffer that moderated the heat of summer and the extreme cold of winter. Now there is less rain, summers are hotter and drier, winters are colder, and the growing season is shorter. The combination of such climate change and severe salinization has reduced crop yields by 20–50% on almost one-third of the area's cropland.

To raise yields, farmers have used more herbicides, insecticides, and fertilizers, which have percolated downward and accumulated to dangerous levels in the groundwater—the source of most of the region's drinking water. Many of the 45 million people living in the Aral Sea's watershed have experienced increasing health problems—including anemia, respiratory illnesses, liver and kidney disease, eye problems, and various cancers—from a combination of toxic dust, salt, and contaminated water.

To make matters worse, Soviet scientists who were engaged in top-secret biological warfare studies buried hundreds of metric tons of deadly anthrax bacterial spores and other deadly toxins on an island in the Aral Sea. As the lakeshores receded, this island grew and joined the mainland in 2001. There is concern that any surviving disease organisms could reach people via fleas or infected rodents or by their removal and use by terrorists.

Since 1999, the United Nations and the World Bank have spent about $600 million to purify the area's drinking water and upgrade irrigation and drainage systems. This has improved irrigation efficiency and flushed salts from croplands. A dike completed in 2005 has raised the average level of the small Aral by 3 meters (10 feet) and decreased its salinity, allowing substantial fishing of several species. Some artificial wet-



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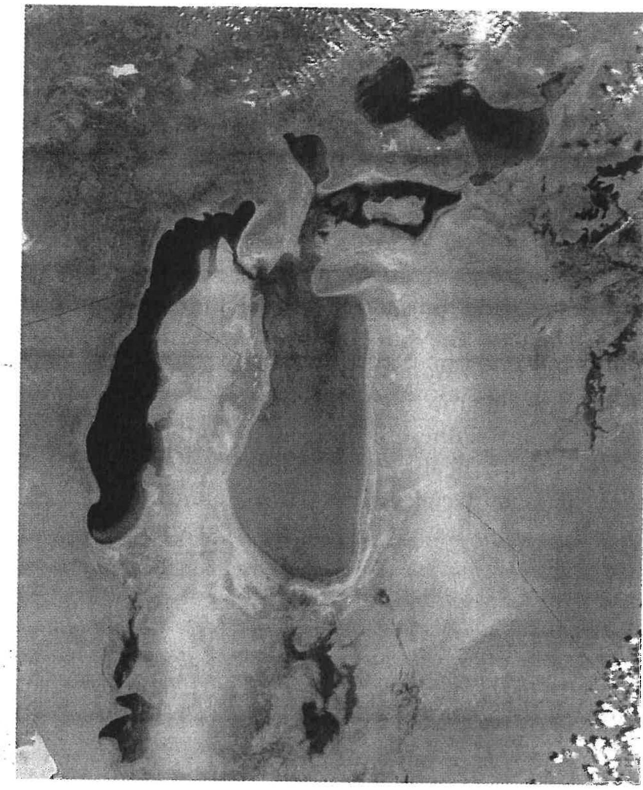

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Figure 13-18 Natural capital degradation: the *Aral Sea* was once the world's fourth largest freshwater lake. Since 1960, it has been shrinking and getting saltier because most of the water from the rivers that replenish it has been diverted to grow cotton and food crops (**Concept 13-4**). These satellite photos show the sea in 1976 and in 2006. It has split into two major parts, little Aral on the left and big Aral on the right. As the lake shrank, it left behind a salty desert, economic ruin, increasing health problems, and severe ecological disruption. **Question:** What do you think should be done to help prevent further shrinkage of the Aral Sea?

lands and lakes have been constructed to help restore aquatic vegetation, wildlife, and fisheries.

The five countries surrounding the lake and its two feeder rivers have worked to improve irrigation efficiency and to partially replace water-thirsty crops with others requiring less irrigation water. As a result, the total annual volume of water in the Aral Sea basin has been stabilized. Nevertheless, experts expect the largest portion of the Aral Sea to continue shrinking.

China Plans a Massive Transfer of Water

The Chinese government has begun a massive engineering project to transfer water from three of its southern river basins to its populous and parched northern provinces. This $62.5 billion South–North Water Transfer Project will use a series of canals, dams, reservoirs, and pumping stations to supply water to the north for irrigation and drinking.

One route, which is more than 1,000 kilometers (620 miles) long, will transfer about 2% of the flow of the Yangtze River to the north; it began supplying water to Beijing in 2008. Work on a second, equally long route is proceeding, while construction of a third,

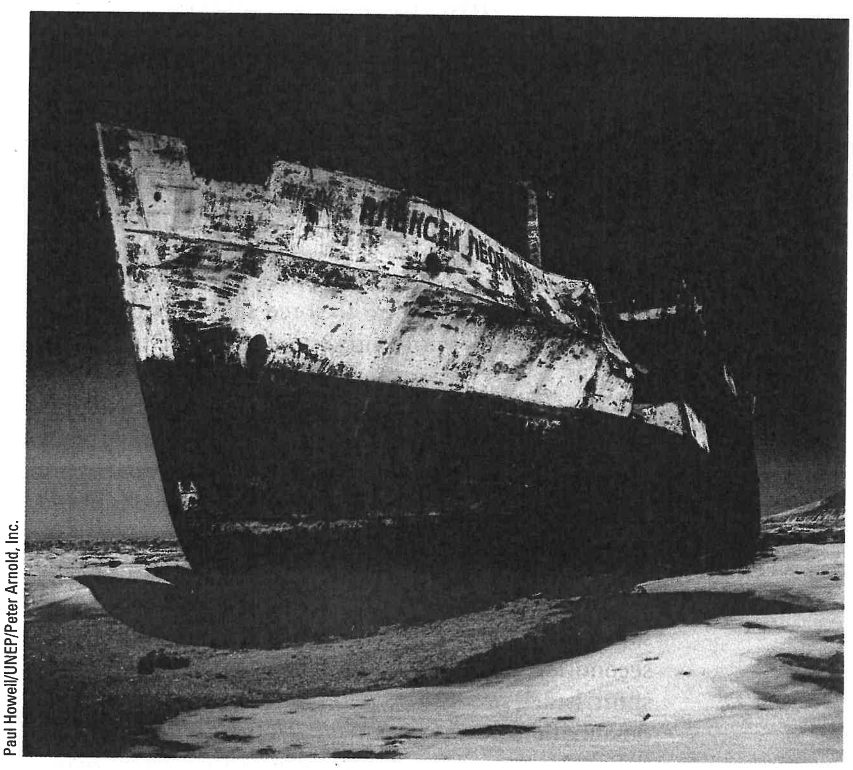

Figure 13-19 Ship stranded in desert formed by shrinkage of the Aral Sea.