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ENVIRONMENTAL SYSTEMS AND SOCIETIES
STANDARD LEVEL
PAPER 2

SPECIMEN PAPER

2 hours

RESOURCE BOOKLET

INSTRUCTIONS TO CANDIDATES

- Do not open this booklet until instructed to do so.
- This booklet contains **all** of the resources required to answer question 1.

Figure 1 — Fact File on Glen Canyon

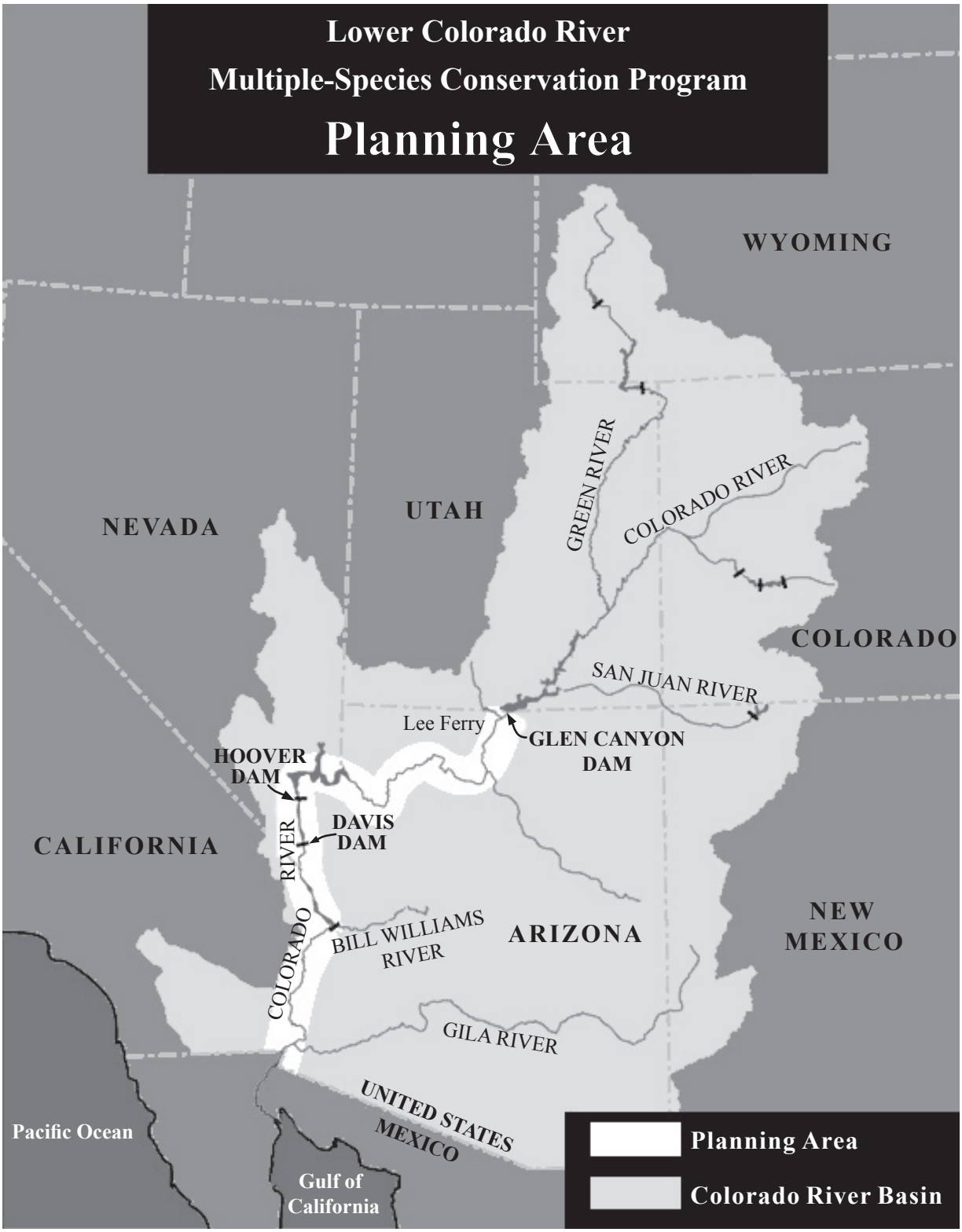
Initial cost: $300 million (in 1963)
Ongoing costs: estimated between $11– $29 million
Height: 216 m
Completed: 1963
Amount of Glen Canyon flooded by Lake Powell: 299 km

Economic benefits:

- The Colorado River provides water for more than 30 million people and without Glen Canyon Dam a lot of this water would be "wasted".
- Glen Canyon Dam allows the southwest of the United States to be developed and populated far more than the pre-dam conditions.
- 85 % of the water is used for irrigation for agricultural production enabling arid regions to become fertile agricultural lands and economically viable.
- Because of the high productivity of these areas, many people in the United States are provided with fruits and vegetables all year round.
- The Glen Canyon Dam power station represents a cheap source of hydroelectric power for much of the southwestern United States and for parts of Mexico, including many poor rural and Native American communities.
- The water supply enabled development of the town of Page, Arizona, which currently has over 8200 residents.
- 4 million visiting tourists (often en route to the Grand Canyon and Monument Valley) bring in $2.5 million each year.
- Many jobs depend on the tourist industry. The largest employers are the National Park Service and the Navajo Generating Station.
- Lake Powell itself provides fishing, boating, water-sports and camping to tourists each year.
- Downstream, recreational fisheries have been improved. Non-native trout have done especially well, further attracting tourists to one of the finest trout fishing sites in the southwest.
- Altered flows provide excellent rapids and runs for rafters and kayakers each year.

[Source: Adapted from the article *"Large Dams in the Western United States"*, produced by Environmental Science students at Kenyon College in 1989, www2.kenyon.edu/Projects/Dams/index.html]

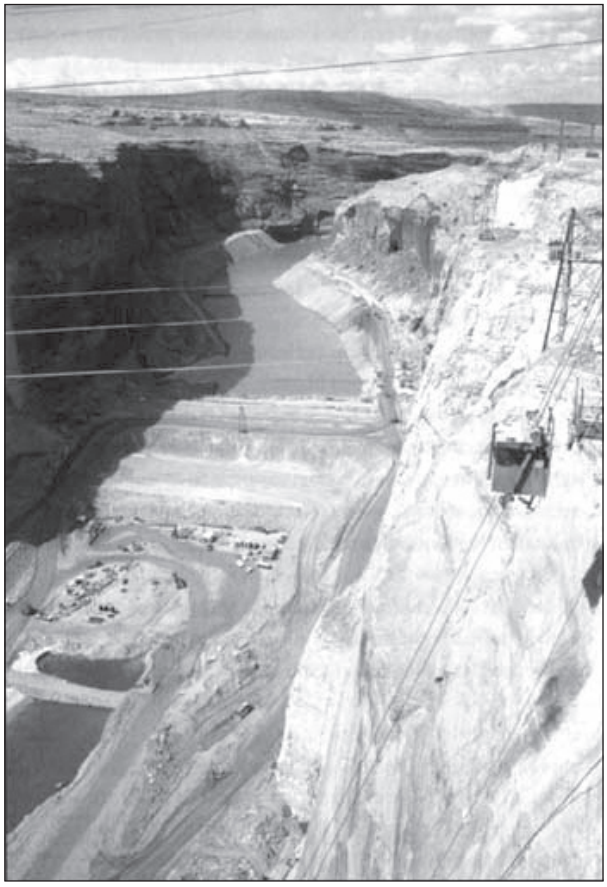
Figure 2 — Map of the Lower Colorado River

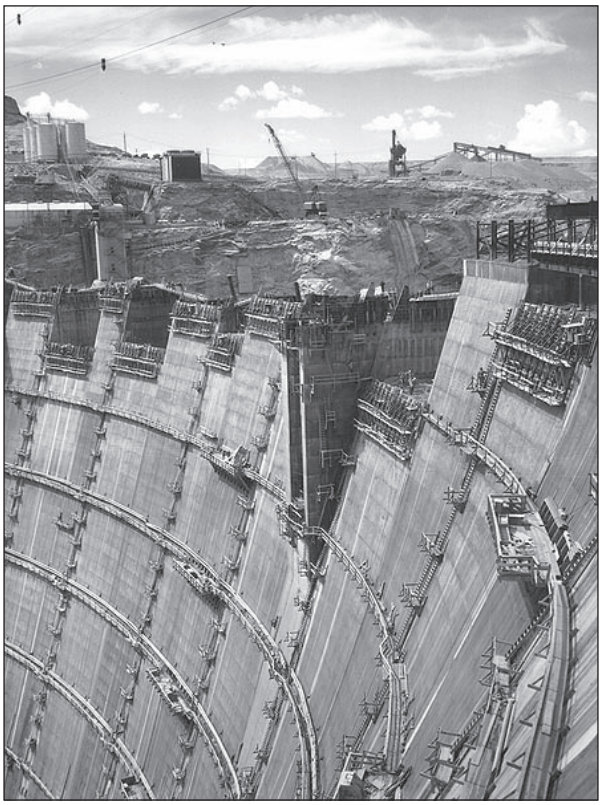


[Source: www.lcrmscp.org/corivmap.gif]

Turn over

Figure 3 — Photographs of Glen Canyon Dam under construction, Lake Powell is behind





[Source: United States Bureau of Reclamation]

Figure 4 — The advantages of hydroelectric power (HEP)
Adapted from a website produced by the National Hydropower Association (US)

A major source of energy

* The United States is the second largest producer of hydroelectric power (HEP) in the world.
* HEP contributes 8–12 % of the United States' electrical generation.
* Globally, one-fifth of electricity is generated from HEP.

Clean and renewable – a sound environmental choice

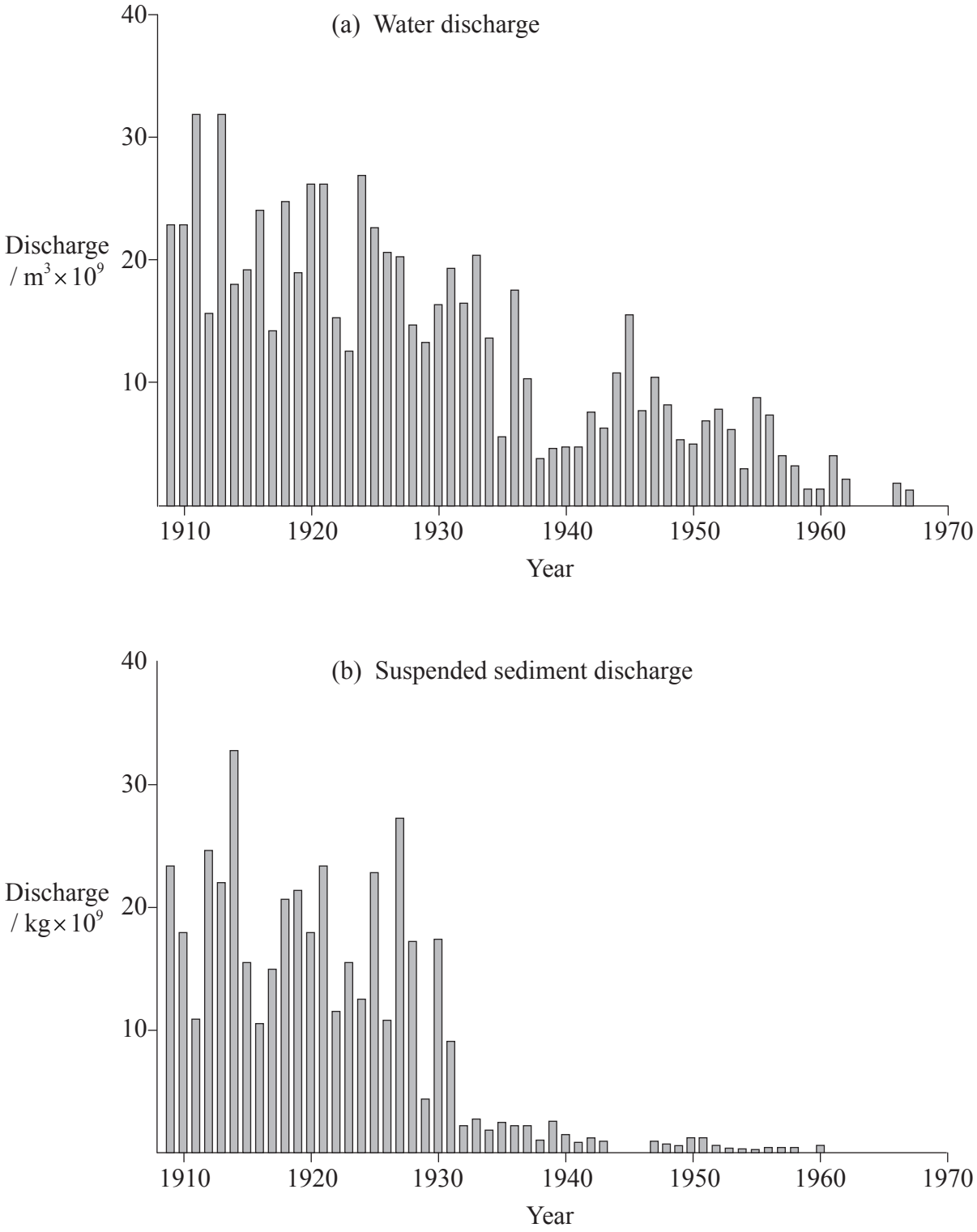
* 93 % of Americans believe HEP is important for meeting future electricity needs.
* HEP is a renewable source of electricity. HEP accounts for 80 % of the United States' total renewable electricity generation making it the leading renewable energy source.
* In 1999, HEP avoided the release of an additional 77 million metric tons of carbon equivalent into the atmosphere. This is equivalent to the annual exhaust of half of the cars on United States roads.
* HEP projects can enhance wetlands and support healthy fisheries. Wildlife preserves can be created around reservoirs, which can provide stable habitats for endangered or threatened species.

Reliable, efficient, secure… and fun!

* Today's HEP turbines are capable of converting 90 % of available energy into electricity – that is more efficient than any other form of generation.
* HEP's operational flexibility – its unique ability to change output quickly – is highly valued and will become even more so in a competitive market. Its unique voltage control, load-following and peaking capabilities help maintain the stability of the electric grid ensuring economic growth and a high quality of life.
* HEP adds to national security. Water from rivers is a purely domestic resource that is not subject to disruptions from foreign suppliers, production strikes or transportation issues.
* There were a total of 81 million recreation user days provided by licensed HEP projects in 1996. Boating, skiing, camping, picnic areas and boat launch facilities are all supported by HEP.

[Source: Adapted from United States National Hydropower Association, www.hydro.org/hydrofacts/facts.asp]

Figure 5 — Historical water discharge and suspended sediment discharge trends as a result of the construction of dams along the Colorado River (including Glen Canyon Dam)



[Source: The United States Geological Survey in Schwarz *et al*., (1991), published in Goudie, *The Human Impact on the Natural Environment*, Blackwell, 1993, page 182]

Figure 6 — The chief environmental impacts of dams

Impacts due to existence of dam and reservoir:
1. Reservoir in place of a river valley (loss of habitat).
2. Changes in downstream morphology of riverbed, delta, coastline due to altered sediment load (increased erosion).
3. Changes in downstream water quality: effects on river temperature, nutrient load, turbidity, dissolved gases, concentration of heavy metals and minerals.
4. Reduction of biodiversity due to blocking of migration of fish (*e.g.* salmon) and because of above changes.

Impacts due to pattern of dam operation:
1. Changes in downstream hydrology: (a) change in total flows; (b) change in seasonal flows (*e.g.* spring flood becomes winter flood); (c) short-term fluctuations in flows (sometimes hourly); (d) change in extreme high flow and low flow.
2. Changes in downstream morphology caused by altered flow pattern.
3. Changes in downstream water quality caused by altered flow pattern.
4. Reduction in riverine/floodplain habitat diversity, especially because of elimination of floods.

[Source: P McCully (1996), *Silenced Rivers, The Ecology and Politics of Large Dams*, London: Zed Books as produced on www.idsnet.org/Resources/Dams/Development/impact-enviro.html]

Figure 7 — Dam impacts

Grand Canyon and Glen Canyon Dams

Physical Properties

The Grand Canyon is 446 km long, 1.5 km deep and 30 km wide.
Shaped by the Colorado River the Grand Canyon was declared a world heritage site in 1919.
Hoover Dam was created in 1941 flooding the lower 20 % of the Grand Canyon.
Glen Canyon Dam was completed in 1963, 24 kms upstream from the Hoover Dam.
No formal environmental impact study was carried out on either of the dams.
Glen Canyon Dam now traps 95 % of the sediments carried by the Colorado River.
Downstream, soil and river fertility is compromised by a lack of organic enrichment from sediment deposition.
River beach and bar erosion is now a problem downstream.
Water temperature downstream is a constant 8 °C because water is extracted from the dams at a depth of 60 m – this water is cold, not having been heated by the sun as surface water would be.
Prior to damming water temperature ranged from 3 °C to 27 °C.
Regulated flows currently keep the Colorado River in Grand Canyon fluctuating between 228 – 570 cubic meters per second ($m^3 s^{-1}$). Before the Glen Canyon Dam, flows fluctuated between 86 – 2571 $m^3 s^{-1}$.

Biological Habitats

River Otter and Muskrat are now absent from the Grand Canyon.
Squawfish, Roundtail Chub and several other species have disappeared.
Many birds (*e.g.* Western Willow Flycatcher), lizards and invertebrates have been lost from the system.
Non-indigenous, generalist, plant and animal species are invading including fish: several exotic trout species, Bluegill, Sunfish and Channel Catfish are now present in the system.
The truncation of the habitat corridor between the Hoover and Grand Canyon Dam has interrupted migration routes and is leading to genetic isolation of certain indigenous species.
Due to the constant cold temperature of the river downstream blue-green algae and Cladophora have replaced the natural warm water food web. The temperature variation would previously trigger native fish reproduction and maintain native insect populations.
The Colorado River runs through Mexico and its delta area was classified as an International Biosphere in 1992. Since the Glen Canyon Dam was built water rarely reaches the delta area.

People and Culture

Indigenous Havasupi people inhabit the Grand Canyon basin.
Navajo and Hualapai people possess land in the Grand Canyon.
Hopi and Zuni have sacred rites in the Grand Canyon.
The presence of the dams have made indigenous people dependent on its water; a trait not previously apparent in their culture.
River erosion is causing the destruction of archaeological sites.

Figure 8 — What is a good dam? A checklist

The following is an edited list of suggestions from *International Dams Newsletter*, 1986.

1. No dam should be built until an adequate assessment of its likely environmental effects has been undertaken *and* made available to the public.

2. Water-development projects should only be undertaken if they can be shown to benefit large sectors of the population instead of the urban elite.

3. Schemes should favour labour-intensive rather than capital-intensive economic activities.

4. They should produce food crops for feeding the local population rather than for export.

5. They should not compromise public health and safety.

6. They should not adversely affect national parks, heritage sites, areas of scientific and educational importance, tropical rainforests or areas inhabited by species threatened with extinction.

7. They must be viable for a minimum of 100 years. They should only be built where it can be guaranteed they will not silt up.

8. They should not be built if their associated irrigation schemes are likely to lead to the salinisation of agricultural land.

9. The funding should be based on sustainable long-term resource enhancement rather than short-term resource exploitation.

10. They should not involve displacing indigenous people from their homelands and endangering their culture, unless compensation is provided and they are better off than before the project.

11. There must be no potential significant engineering or safety problems.

12. They should not be built where they are likely to inflict significant damage to estuarine or ocean fisheries.

13. They should not be built if they are likely to significantly harm the environment of a neighbouring country without its full consent.

[Source: Edited from *International Dams Newsletter,* 1986]