ENVIRONMENTAL IMPACTS OF DAMS

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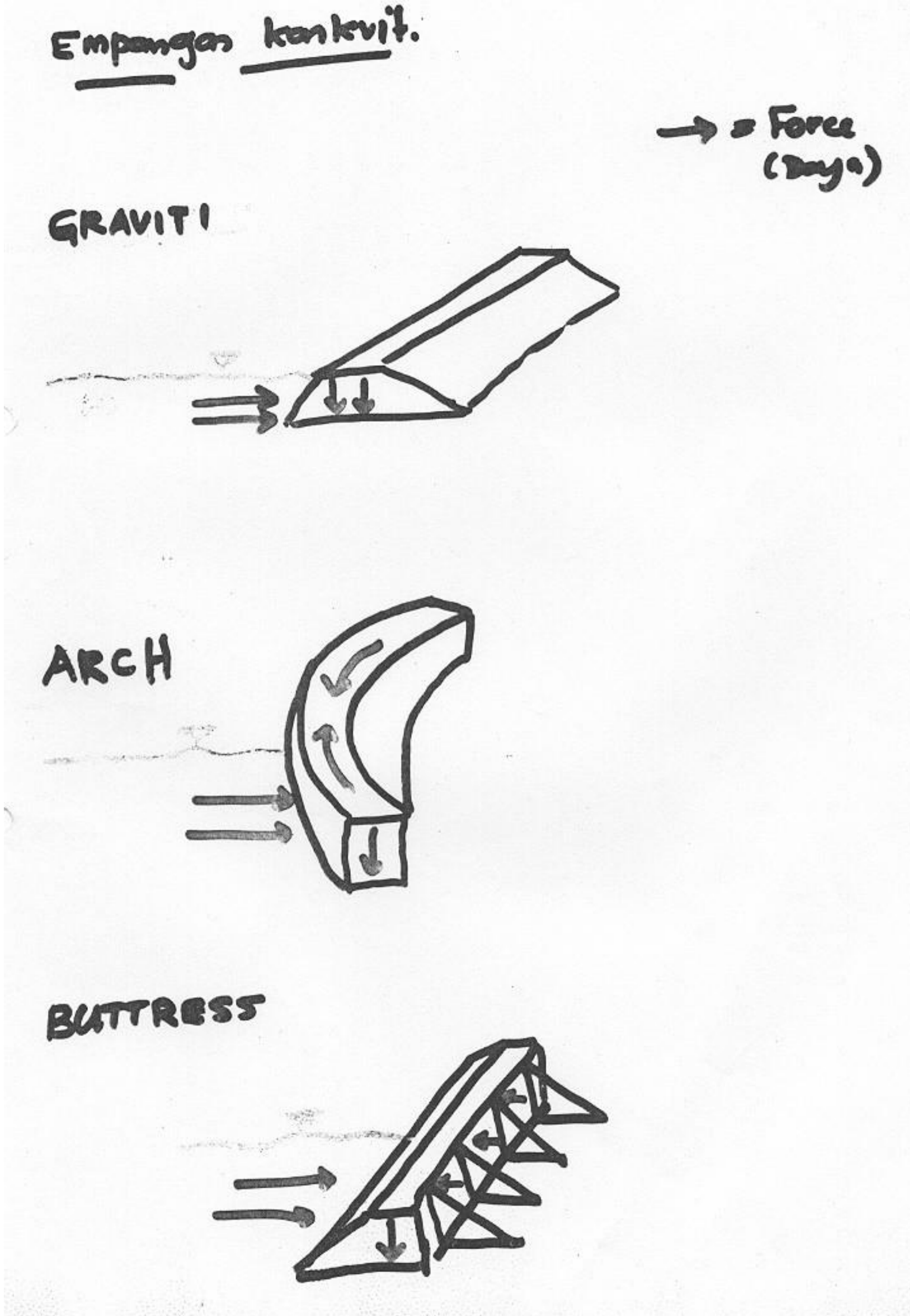
DAMS

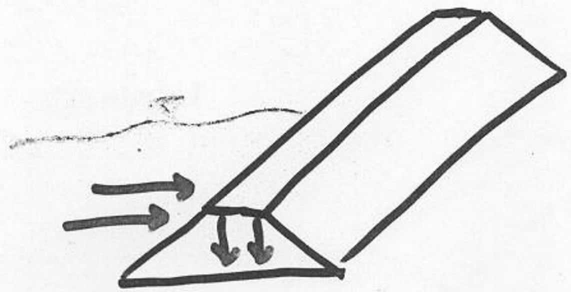
- **Dams are built for a variety of purposes:-**
  - **Water supply (sumber air)**
  - **Hydroelectric power generation (tenaga hidro)**
  - **Flood control (kawalan Banjir)**
  - **Recreation (rekreasi)**

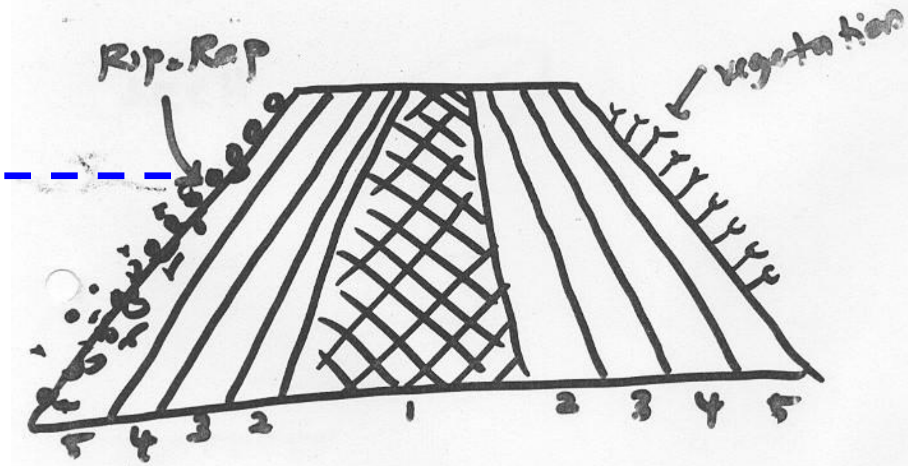
Concrete Dam



Embankment

EMPANGAN TAMBAKAN



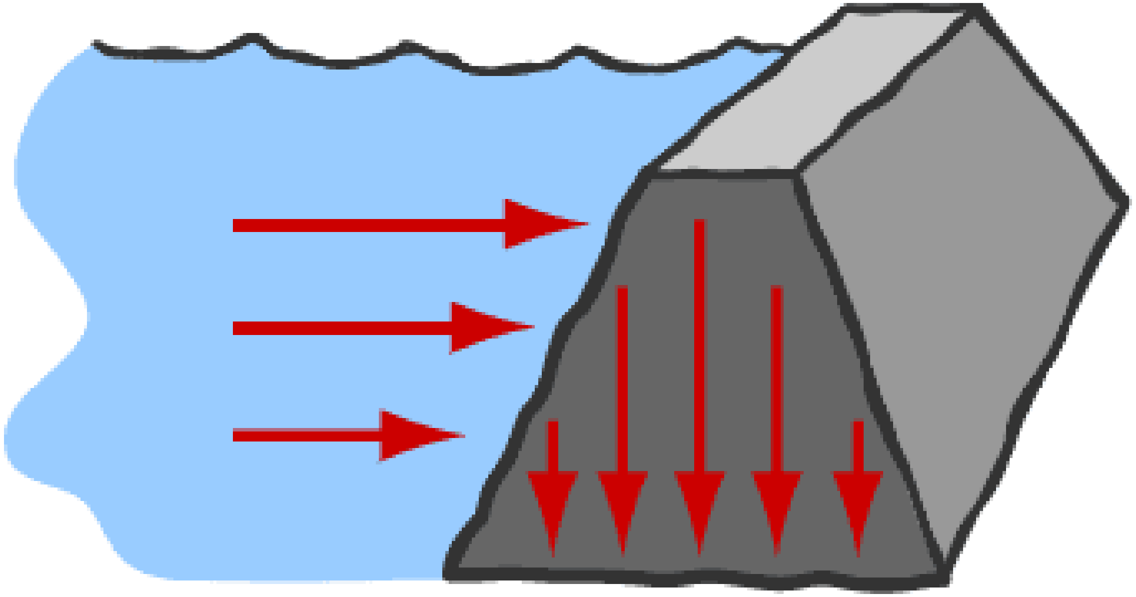


1 - clay core
2 - silty sand
3 - sand - gravel
4 - Rock fill (rolled) - 75mm - 750mm
5 - Dumped rock fill - D > 450 mm

Types of Dams

- **Gravity dam**
  - **Solid masonry that resists the forces made against them by their <u>weight</u>**
  - **Forces of water and sediment are stabilized by the vertical component of the dam's weight**
  - **The underlying rock must be sufficiently strong to resist stresses**

Gravity dam

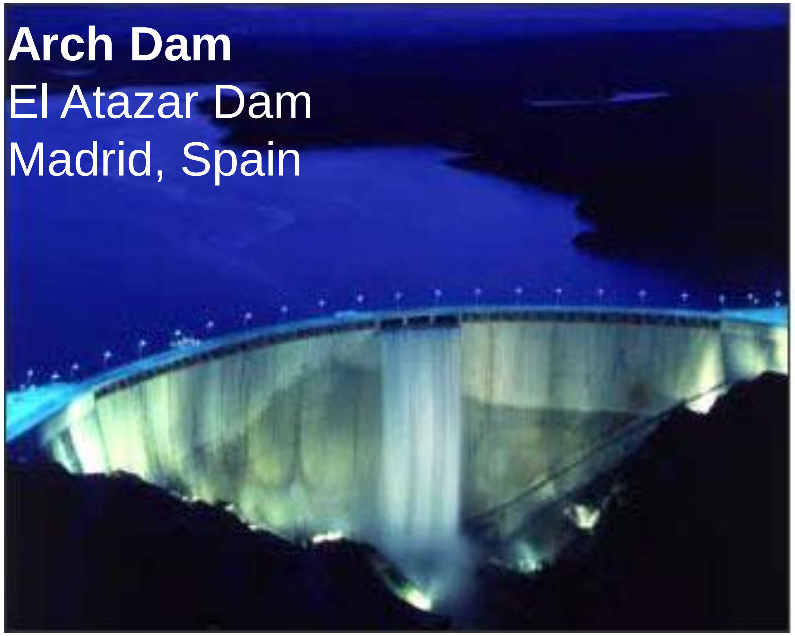


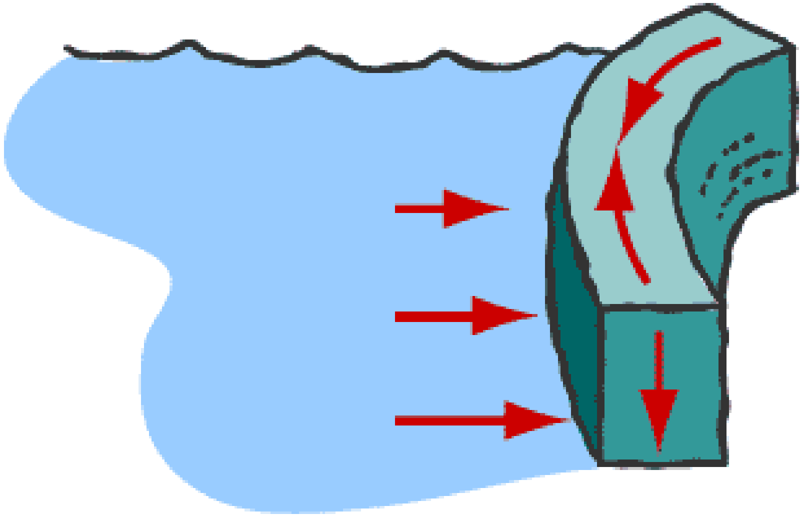
Gravity Dam: Forces
Water pushes against the gravity dam,
but the heavy weight of the dam pushes
down into the ground and prevents the structure from falling over.

Types of Dams

- **Arch dam**
  - **The transmission of large forces to the rock abutments by the arching action of the dam geometry**
  - **Thinner than gravity dams**
  - **Structural strength derives from the masonry and arcuate shape rather than sheer weight of the dam**
  - **Hoover Dam:**
    - ***Arch graviti dam* (combination)**
    - **The top is supported by arch**
    - **The bottom by gravity**

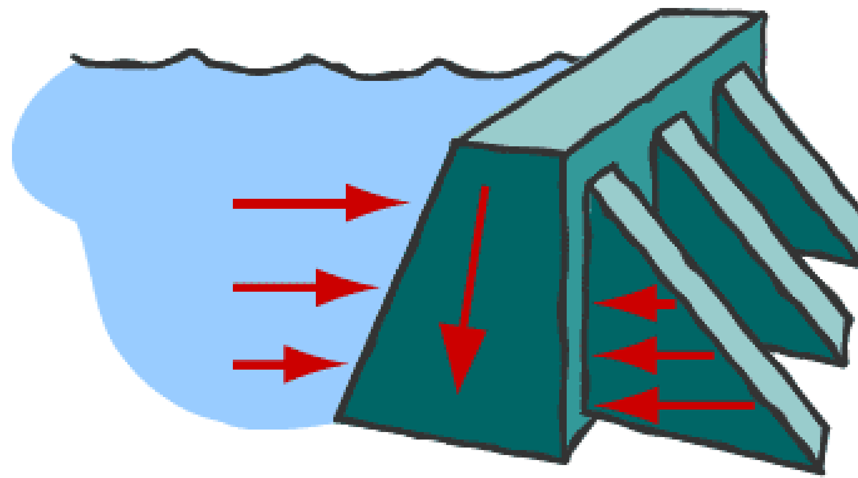
Arch dam





Arch Dam: Forces
The arch squeezes together as the water pushes against it.
The weight of the dam also pushes the structure down into the ground

Buttress Dam

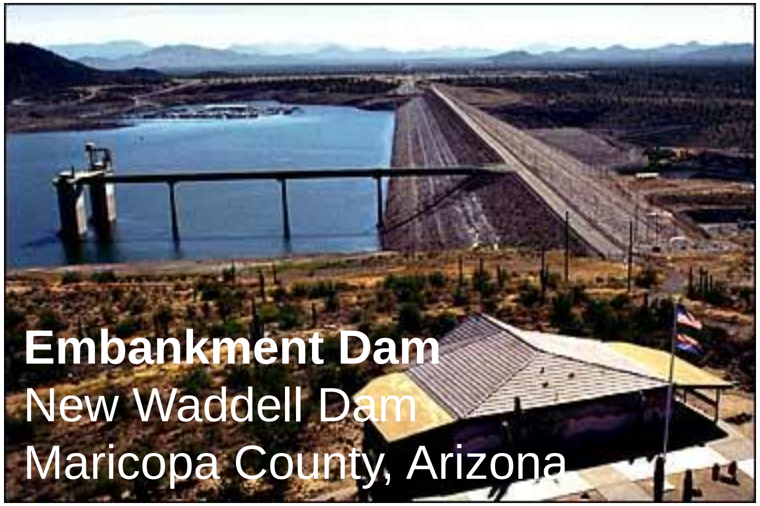


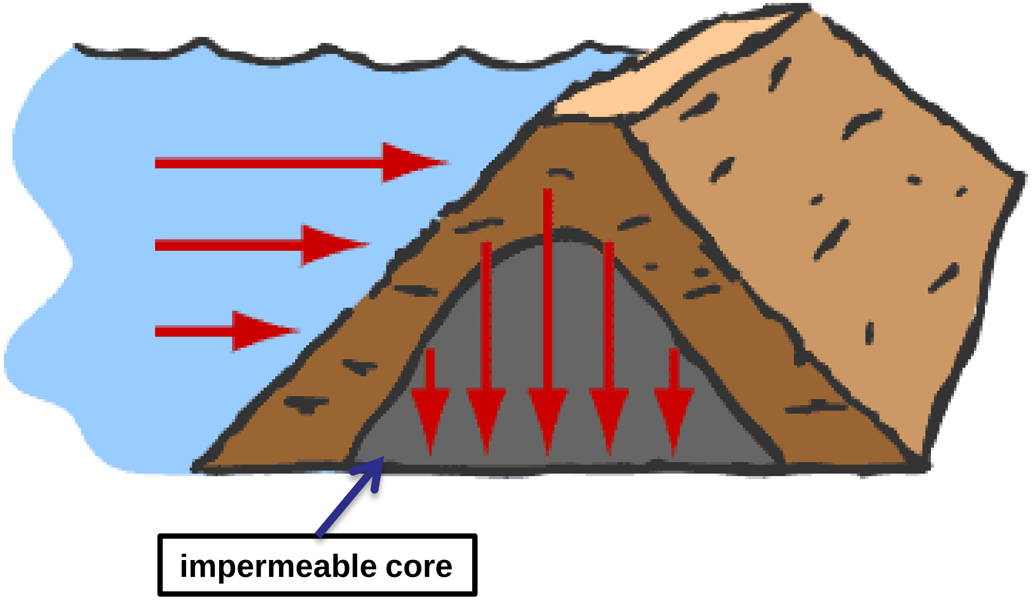
Buttress Dam: Forces
Water pushes against the buttress dam, but the buttresses push back and prevent the dam from toppling over.
The weight of the buttress dam also pushes down into the ground.

Types of Dams

- **Embankment dam**
  - **Constructed using <u>excavated materials</u> placed without addition of binding materials**
  - **Materials obtain near site**
  - **Earthfill dam (tambakan tanah)**
    - **Compacted earth (soil) + impermeable core**
  - **Rockfill dam (tambakan batuan)**
    - **Compose of rock fragments + inner core of impermeable materials, blanket, membrane**
  - **Buttress dam (jenis sokongan)**
    - **Use less material**

Embankment dam





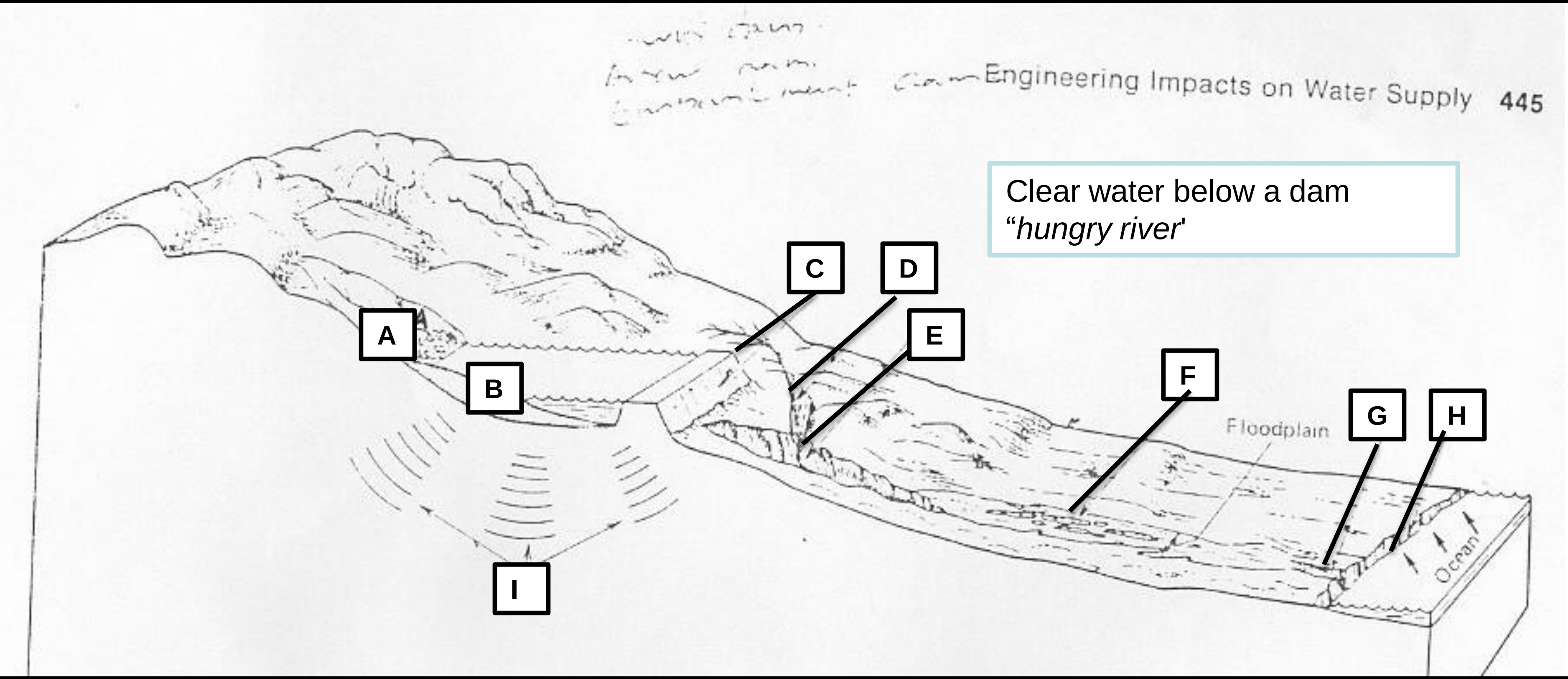
Embankment Dam: Forces
Water pushes against the embankment dam,
but the heavy weight of the dam pushes down into
the ground and prevents the structure from falling over.

Environmental impact of DAM

Effects of Dams

1) Reservoir and upstream sedimentation
2) Downstream erosion
3) Downstream impacts from diminution of sediment supply
4) Water table changes
5) Ecological changes
6) Earthquakes
7) Failure

Diagrammatic sequence of impacts



A – upstream siltation that buries town
B – sedimentation in the dam
C – Dam
D – New cycle of erosion in tributaries
E- channel erosion immediately downstream from dam
F – Channel filling and flooding from deposits eroded at E
G – Erosion in channel
H- Erosion of shoreline deprived of sand nourishment because of entrapment of sediment by the dam
I – Earthquakes caused by pore water pressure changes and stresses from the weight of the dam, water and sediments

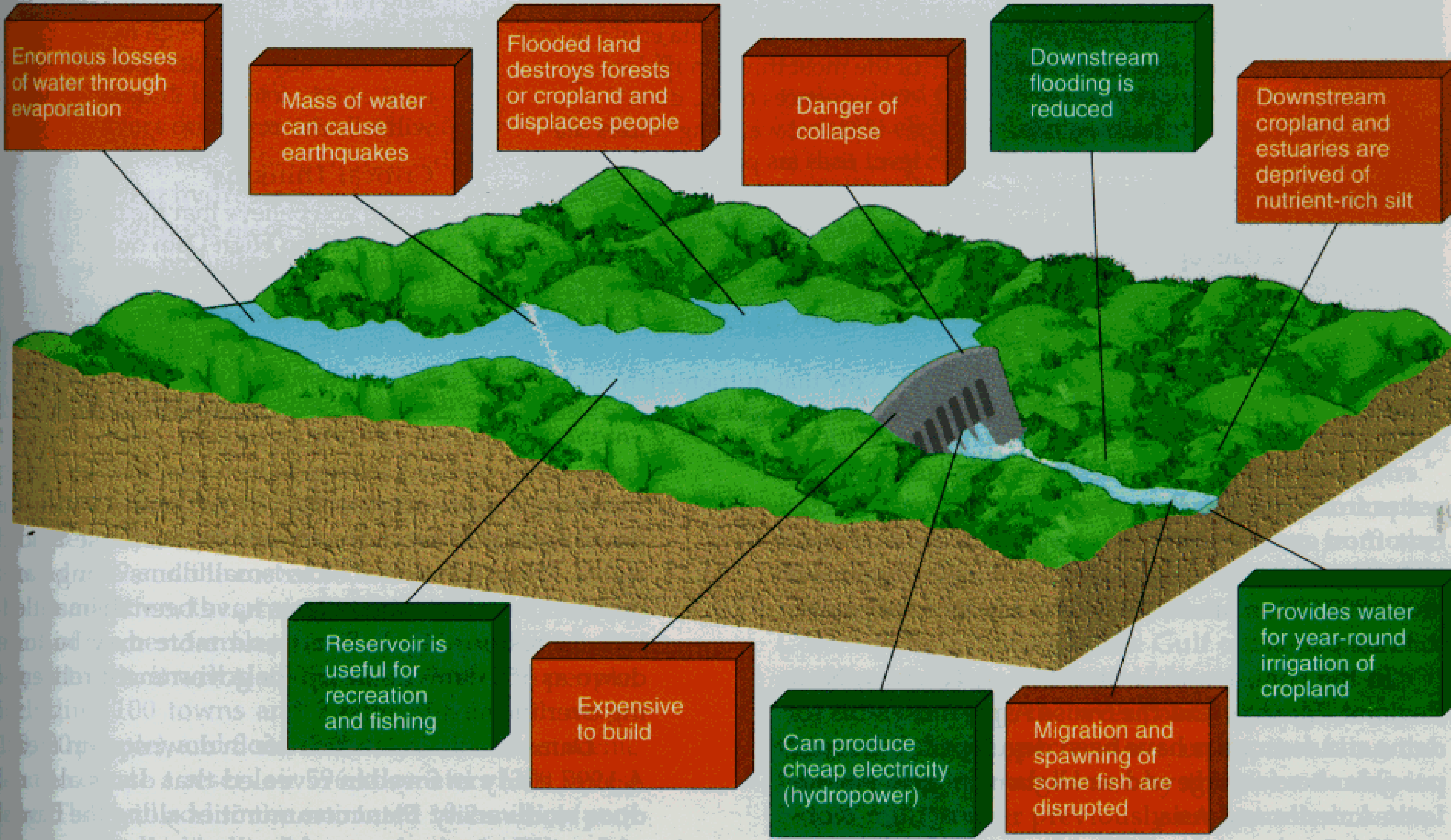


Figure 13-10 Advantages (green) and disadvantages (orange) of large dams and reservoirs, which can be used to produce electricity.

Disadvantage

Advantage

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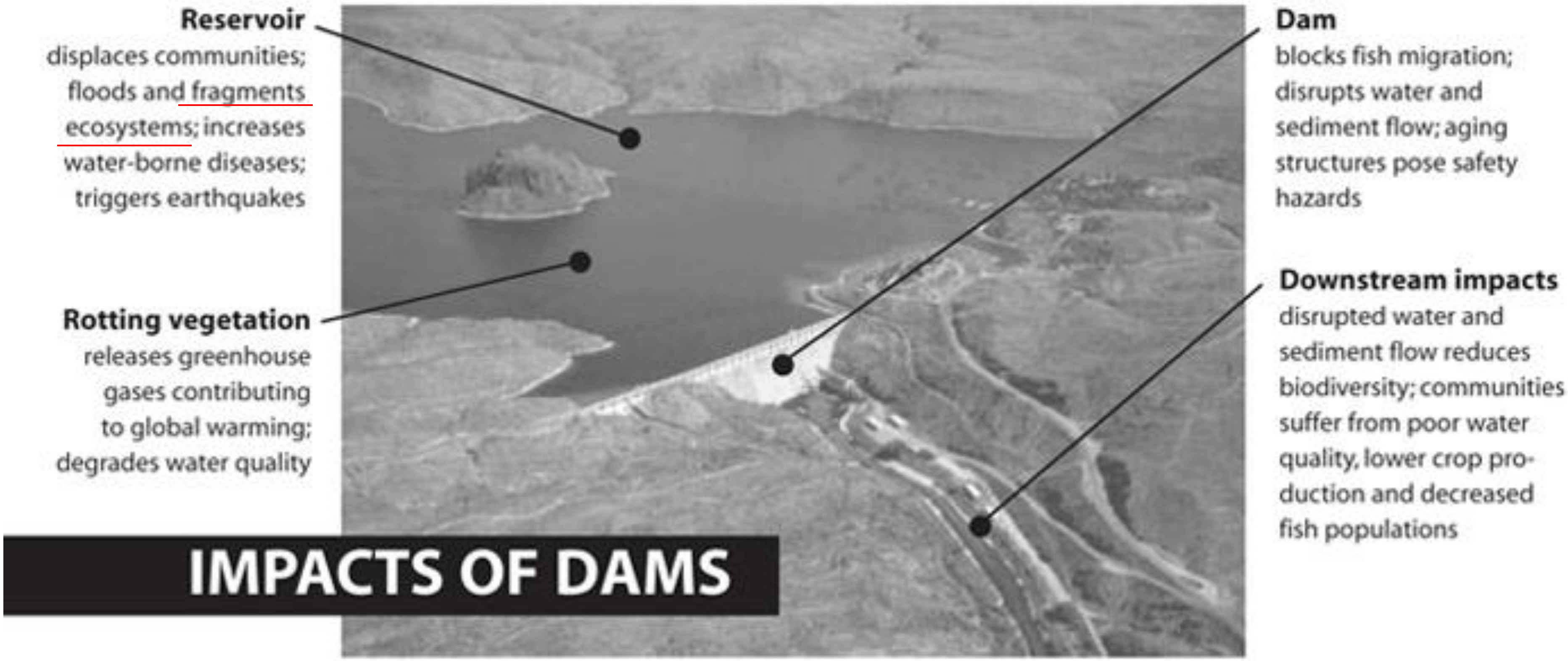
Fragments ecosystems

- isolating populations of species living up and downstream
- cutting off migrations and other species movements
- isolating the river from its floodplain



1. Reservoir and upstream sedimentation

- **A reduction of flow velocity as river enters standing water, resulting deposition of sediment (man-made delta).**

- **The life span of reservoirs is being shortened by the influx of silt and sediment loads**

1. Reservoir and upstream sedimentation

- **Examples:-**

1. **The Tarbela Dam in Pakistan (1975)**

   World's largest earth & rockfill dam

   Siltation in < 50 years

2. **The Anchicaya Dam in Columbia (1955)**

   21 months later, 25% filled with sediment

   7 years, lost capacity to store water

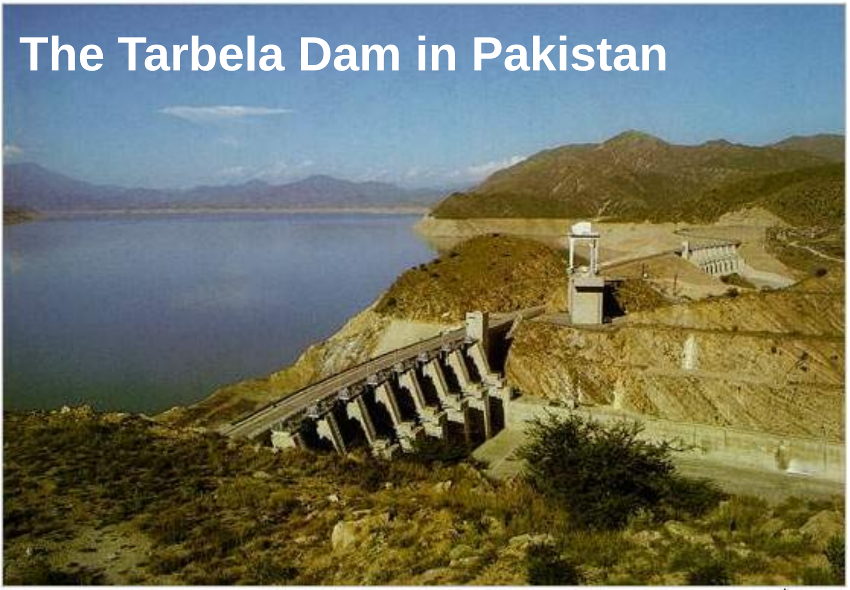
3. **The Shihmen Reservoir in Taiwan (1963)**

   Predicted to last 71 years

   After 6 years, lost 45% of its capacity due to siltation

4. **Lake Nasser of the Aswan Dam, Egypt**

   Traps 13 million m^3 that formerly was deposited in the floodplain and Delta of the Nile



gupshup.org

Shihmen Reservoir , Taiwan

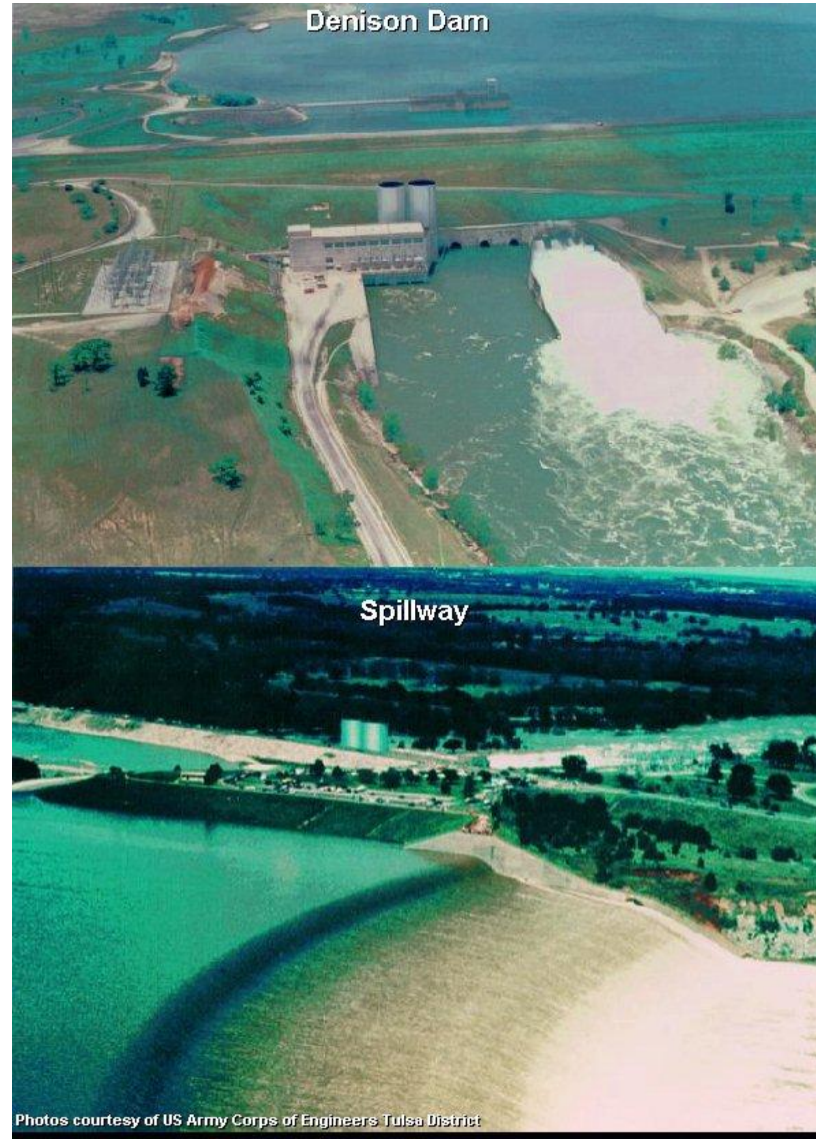
2. Downstream erosion

- **New character of water released from the dam**
  - **Devoid in sediment; chemistry and temperature are also changed; <u>high velocity</u> – "hungry river"**
  - **Dams alter water quality both upstream and downstream of the structure. :**
    - **water temperatures,**
    - **dissolved oxygen levels (kandungan oksigen terlarut),**
    - **Turbidity (kekeruhan) and**
    - **Salinity (kemasinan),**

2. Downstream erosion

- **Eg: Texacoma Reservoir (Denison Dam) in 1960s**
  - **386 million tons of sediment; 20% is sand (i.e. 77 million tons) were deposited in the reservoir**
  - **The amount of sand deposited = the amount eroded from the North Canadian River below the dam**
  - **Deprived of sediment;**
    - **<u>clear water eroded the streambed</u> 1.5-2.1 m in the first 16km and**
    - **caused <u>channel erosion</u> of 5.4x10^6 m^3 in the 160km downstream.**

DENISON DAM


Denison Dam
Spillway
Photos courtesy of US Army Corps of Engineers Tulsa District

2. Downstream erosion

- **Hoover Dam:**
  - **Lowering of river channel by 3 m**
  - **Channel siltation occurs further downstream when eroded materials are deposited**
  - **Choking of the channel and severe flooding problems.**
- **Rio Grande River, New Mexico:**
  - **During 30-year period, siltation plume advanced upstream from the reservoir**
  - **Depositing 3 m of material & burying village of San Marcial**

2. Downstream erosion

- **Glen Canyon Dam in Colorado River (built 1963):**
  - **Downstream erosion of 6 m**
  - **Changed the character of the rapids**
  - **New erosion cycle in some tributaries due to change in base level conditions.**

- **Aswan Dam, Egypt:**
  - **Downstream erosion of 3 m**

3. Downstream impacts from diminution of sediment supply

- Sediment starvation in natural systems
- 13 million m^3 of upstream sediment is deposited in **Lake Nasser**
  - This sediment provide nutrients; silt & renew soil for cultivation
  - Silt: formerly supplied 22% of fertilizing materials needed as plant nutrients
  - Compensated by more than 2 million ton of chemical fertilizers
  - Terrible losses in brick making industry
  - Erosion of the Nile Delta
  - Lower flow: saltwater wedge to move farther inland
    - Affecting groundwater condition & permitting soil salinization

3. Downstream impacts from diminution of sediment supply

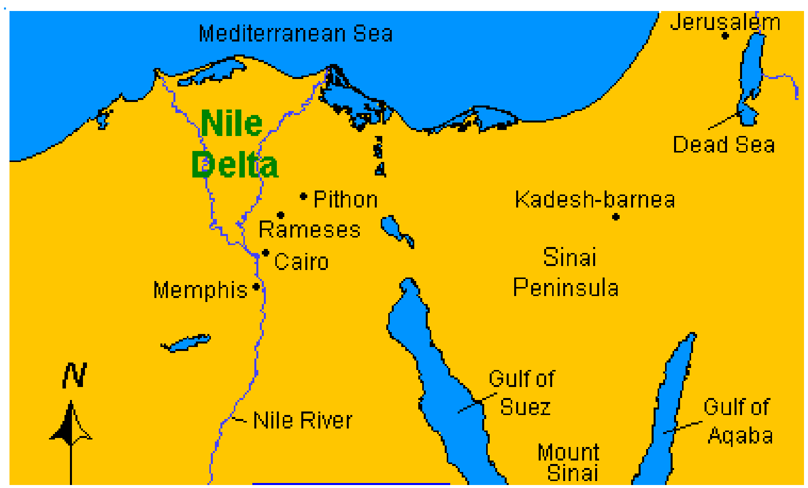
- The **Lake Volta Dam in Africa**
  - – 48km upstream advance of saline water; drastic changes in the estuarine environment
  - – Destroyed salt industry downstream from the dam
- Reduction in channel capacity
  - – Eg: **Clatworthy Reservoir in River Tone** (Somerset, England)
    - Channel capacity below dam was reduced to 54% of original capacity
- Coastal erosion along shorelines that formerly depended on sand nourishment from inland rivers

Hungry Plains

. . . especially in the part called the Delta, it seems to me that if . . . the Nile no longer floods it, then, for all time to come, the Egyptians will suffer.

Herodotus

History, c.442 B.C.



Home to almost all of Egypt's people

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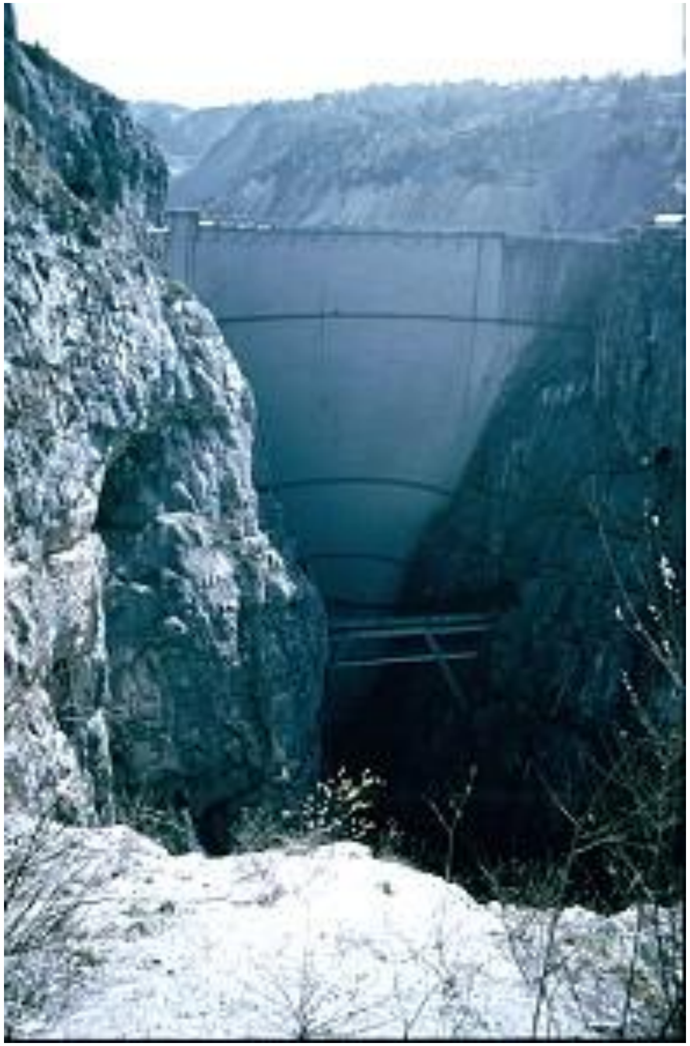
4. Water table changes

- **Groundwater condition are changed both upstream and downstream of the dams**

- **New water table due to lowering/raising of water in downstream channel/reservoir**

- **Become sites for landsliding**
  - **Eg: Vaiont Dam in Italy**



The Vaiont Dam disaster (Italy)

- a small rock slide in 1960 should have been a warning
- in 1963, 240 million m^3 of rock fell into the lake, bursting the dam and killing 3,000 people

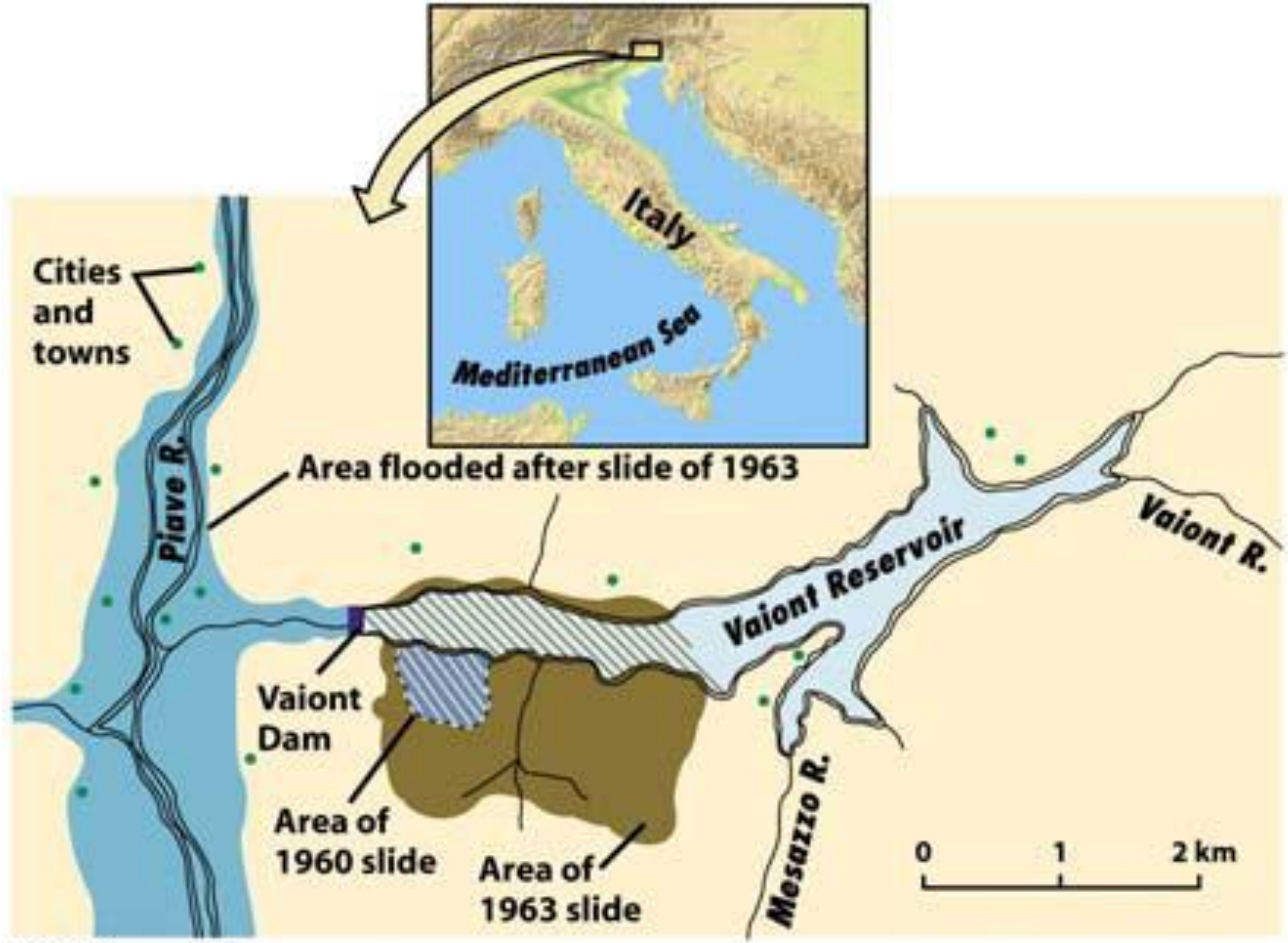


Figure 16-28
Understanding Earth, Fifth Edition

5. Ecological changes

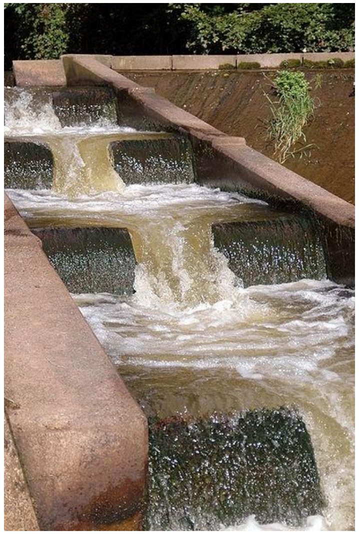
- **Dams may destroy the habitat of special flora and fauna**

- **Water from impoundments is physically and chemically altered**
  - **pH; dissolved solids; water temperature**
  - **Chemical changes: ferrous, sulfide ions, low oxygen**

Fragments ecosystems

- Dam acts as barrier between the upstream and downstream habitat of migratory river animals

- Reduced salmon populations by preventing access to spawning grounds upstream



“fish ladder”

6. Earthquakes

Reservoir-Induced Seismicity (RIS)

- **Extra water pressure** created in the micro-cracks and fissures in the ground under and near a reservoir.

- When the pressure of the water in the rocks increases, it acts to **lubricate faults** which are already under tectonic strain, but are prevented from slipping by the friction of the rock surfaces.

- the International Commission on Large Dams recommends that RIS should be considered for reservoirs **deeper than 100 meters**.

6. Earthquakes

Reservoir-Induced Seismicity (RIS)
Seismik Janaan Takungan

A leading scholar on this topic, Harsh K. Gupta, summarized his findings on RIS worldwide in 2002:

- **Depth of the reservoir** is the most important factor, but the **volume of water** also plays a significant role in triggering earthquakes.
- RIS can be **immediately noticed during filling** periods of reservoirs.
- RIS can **happen immediately after the filling of a reservoir or after a certain time lag**.

Many dams are being built in seismically active regions, including the Himalayas, Southwest China, Iran, Turkey, and Chile

6. Earthquakes

Reservoir-Induced Seismicity (RIS)

- **First discovered in Greece 1931**
  - **Marathon Dam in Greece**
- **40 cases have been identified worldwide**
- **U.S. Lake Mead, Hoover Dam reservoir**
  - **100 earthquakes recorded**
  - **May 1939 ; 5.0 M**
- **Koyna Reservoir, India**
  - **6.3 M; killed 200 people**

The Zipingpu Dam

Zipingpu Dam

Giant Dam May Have Triggered Sichuan Quake

By Shai Oster

Originally published in *The Wall Street Journal*

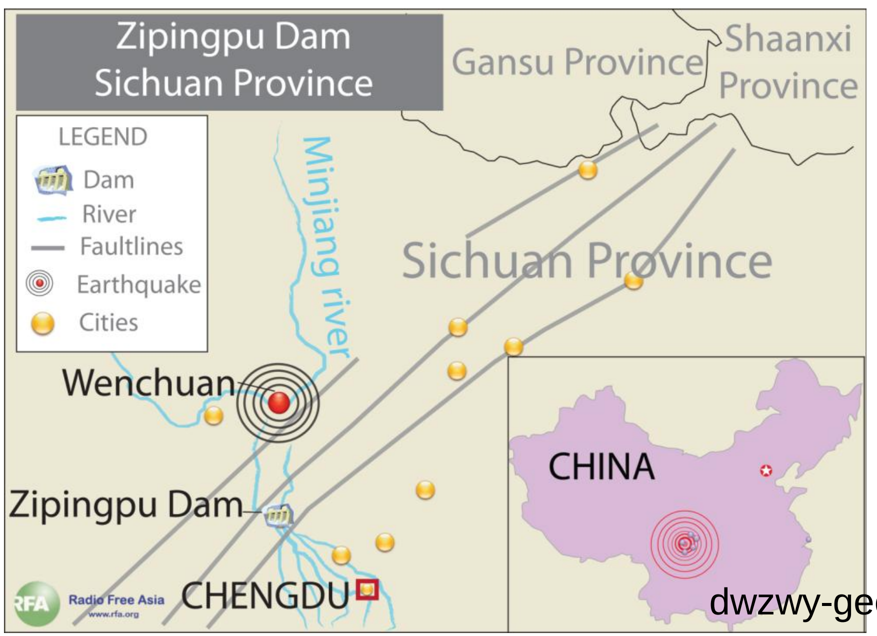
BEIJING - Chinese and U.S. scientists are examining the possibility that a giant dam may have triggered the earthquake that killed some 80,000 people when it struck Sichuan province nine months ago, raising questions about ambitious dam-building projects across China's earthquake-prone western regions.

Chinese Earthquake May Have Been Man-Made, Say Scientists

By Malcolm Moore

Originally published in *The Telegraph*

An earthquake that killed at least 80,000 people in Sichuan last year may have been triggered by an enormous dam just miles from the epicentre.



The Zipingpu Dam
5.5 km away from the epicenter ; 7.9 magnitude.
It killed about 80,000 people.

The dam was built 500 m from the earthquake's fault line

The tragic Sichuan Earthquake of May 12, 2008

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Scientific research on RIS

Reservoir-Induced Seismicity (RIS)

- Kerr, R. and Stone, R. (2009), "A Human Trigger for the Great Quake of Sichuan?." *Science* 323: 322
- Gupta, H.K. (2002), "A review of recent studies of triggered earthquakes by artificial water reservoirs with special emphasis on earthquakes in Koyna, India." *Earth-Science Reviews* 58: 279-310
- Chen, L.Y. and Talwanim P. (1998), "Reservoir-induced Seismicity in China." *Pure and Applied Geophysics* 153: 133 - 149
- Assumpção, M. et al. (2002), "Reservoir-Induced Seismicty in Brazil." *Pure and Applied Geophysics* 159 (1-3): 597-617

7. Failure (1)

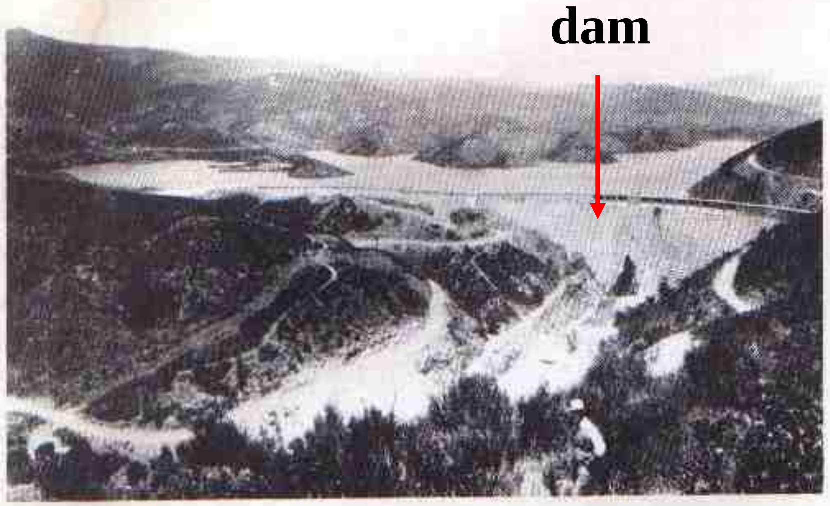
- **There is no guarantee of dam safety during/after construction**

- **The siting of a dam at a safe location is as important as the construction and materials that go into the dam**

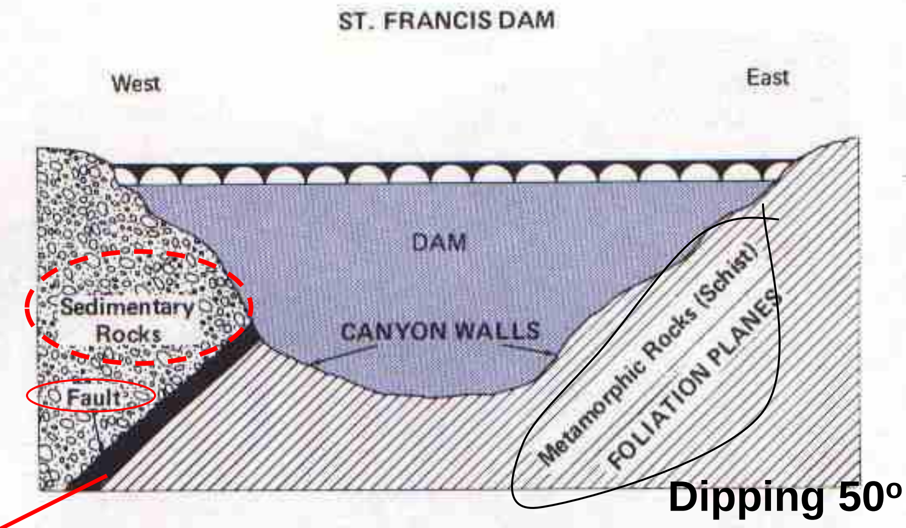
7. Failure (2)

- **St Francis Dam (March 13, 1928)**
  - **No geologic investigation before construction -** every dam site has unique geological characteristics
  - **Foundation: 2/3 is Mica Schist 1/3 freshwater conglomerate that contained gypsum veinlets**
  - **The rock was strong when dry but disintegrated when wet**

Geologist knows a dam site better !!



(a)



San Francisquito fault: a branch of San Andreas fault

Figure 3.16
St. Francis Dam (a) prior to failure; (b) geology along the axis of the dam; and (c) after failure. (Photos courtesy of Los Angeles Department of Water and Power.)

(c)

- **12 March 1928**
- **500 dead**
- **Geological factors**
- **The science of Eng. Geol**

- **“this substrate was totally <u>inappropriate</u> for a dam footing, and failure of fractured and <u>weathered conglomerate</u> was the major cause of the dam failure”.**

- **“D*on’t blame anyone else, you just fasten it on me. If there was an error in human judgment, I was the human*.”**

  -- William Mulholland, dam’s chief engineer & architect

7. Failure (3)

- **The Elwha River dam in Washington**
  - **It was footed on gravel**
  - **Due to reservoir pressure, the material was scoured, the lake emptied, and the dam left hanging above the channeled portion.**

- **The Hales Bar Dam on Tennessee River**
  - **It was built on limestone**
  - **Cost much more than planned because of extensive grouting to prevent seepage losses**

7. Failure (4)

- **The Hondo Reservoir, New Mexico**
  - **Shale and gypsum beds which contained sinkholes**
  - **The dam had to be abandoned**

- **The Teton Dam**
  - **Failed because of piping in the volcanic foundation.**

Tangerang Dam Burst Kills at Least 93 Jakarta Indonesia March 27, 2009

lack adequate monitoring

- The dam up to 16 metres (52 ft) high which was built by Dutch colonial authorities in 1933.
- The dam failed on 27 March 2009 with resulting floods killing at least 93 people.
- The flood could have been prevented had local authorities not neglected the recommendation of American engineers which recommended the reinforcement of the dam and possible evacuation of the lower villages located at the very bottom of the dam.
- Local government neglected to follow up, resulting in the ancient dam's failure.

The damaged Boluokeng power station dam in Yingde City of southern China's Guangdong Province

Dams

- **Careful & complete geologic mapping/testing;**

1. **Evaluation of the valley/site (slope stability)**

2. **Identification of possible problems**

   - active faults; fracture zones; adverse soil conditions

3. **Prediction rate of sediment accumulation**

4. **Assessment of building material for construction**

Foundations for dams according to rock types

- **Igneous rocks**
  - **Granite & pyroclastic rocks**
  - **Satisfactory for dam**
  - **Except leakage along fractures**
  - **Fractures can be "grouted" filled with a mixture of cement, sediment, water**

- **Metamorphic rocks**
  - **Good foundation**
  - **Best; foliation is parallel to the axis of dam**

- **Sedimentary rocks**
  - **Trouble: limestone (cavities) and shale (deform & settle when loaded)**
  - **St. Francis Dam: wetting of sedimentary rocks in foundation**

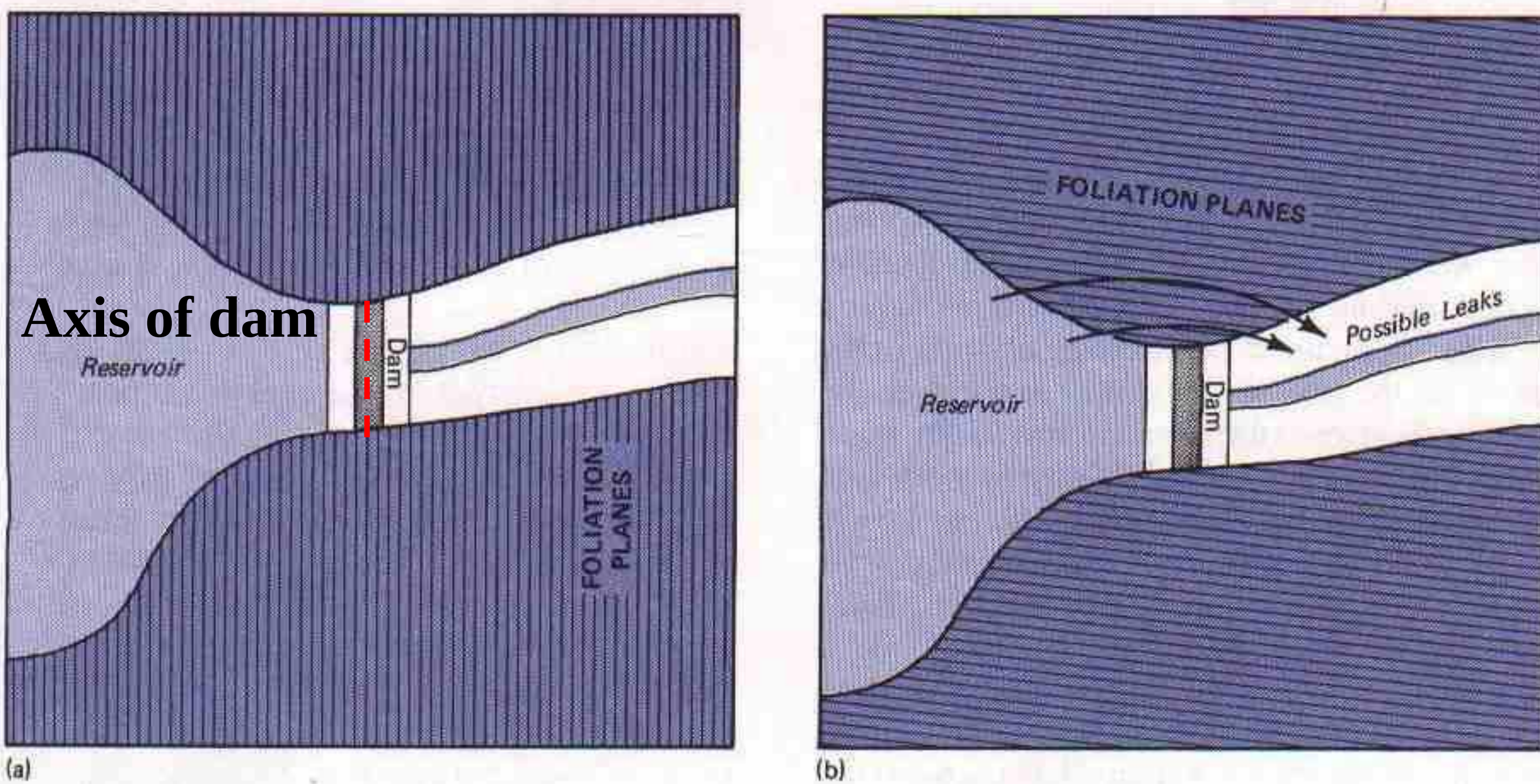


Figure 3.15
Two possible orientations of foliation in metamorphic rocks at a dam and reservoir site. The most favorable orientation of the foliation is shown in part (a), where the foliation is parallel to the axis of the dam. The least favorable orientation is where the foliation planes are perpendicular to the axis of the dam, as shown in (b).

Bakun Hydroelectric Project

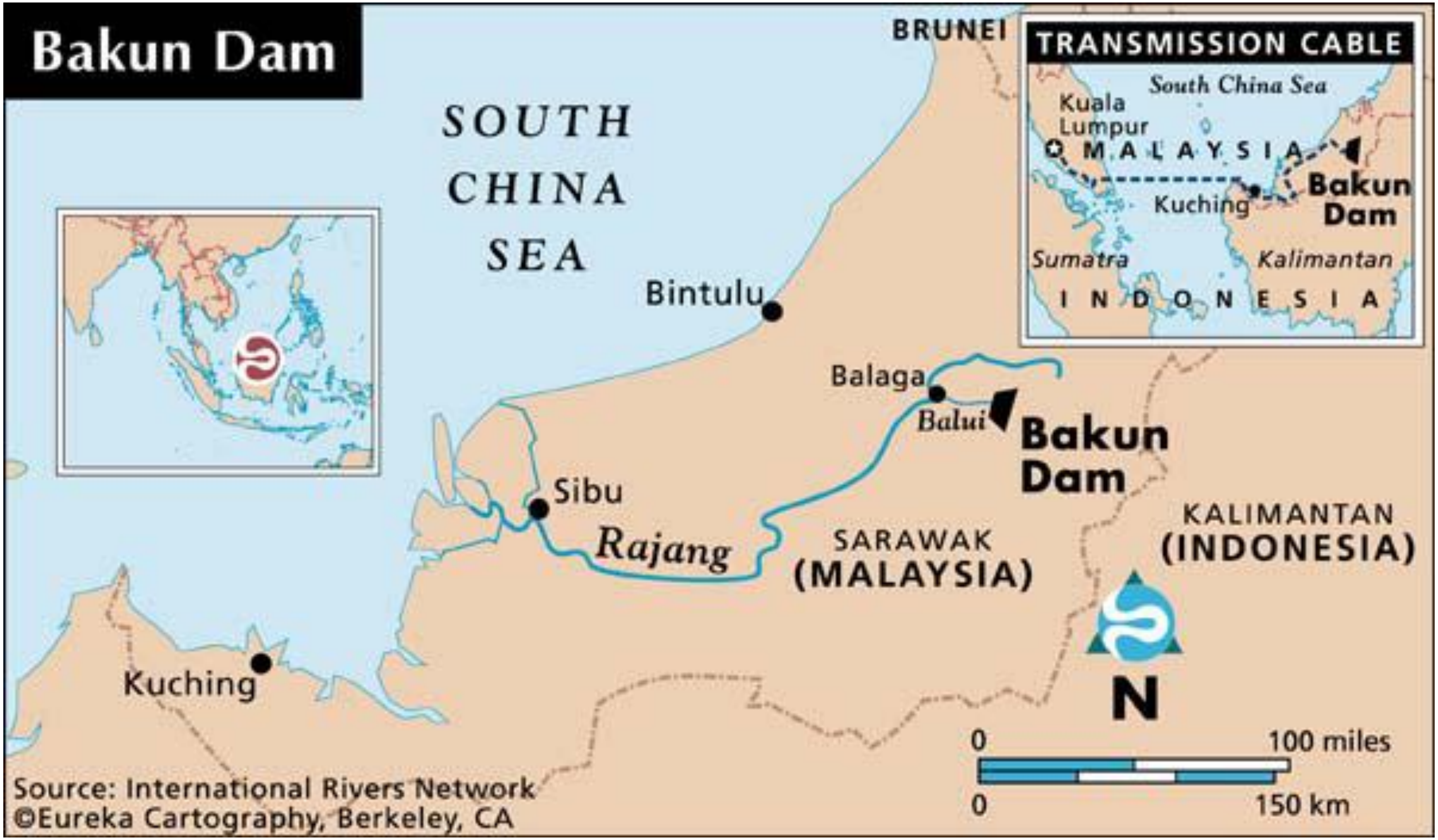
The history of the Bakun Hydroelectric Project extends back more than thirty years, and includes the following phases:

- early 1960s: initial survey of the hydro potential of Sarawak
- late 1970s - early 1980s: detailed examination of the Bakun Site, and preparation of development proposals
- 1986: decision by national government to build the project
- 1990: postponement of the project
- 1993: renewal of the project
- 1994: awarding of project contract to Ekran Berhad
- 1996: construction begins
- 1997: probable completion of diversion tunnels
- 2003: projected date of completion

New Date: September 2007

Aug 2009 – still not complete (90%)!!

Bakun Dam (map)



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Bakun Dam

- Rockfill dam
  - is defined as an embankment dam that relies on rockfill as the major structural element.
    - (1) Concrete face rockfill dam (CFRD). -- Bakun
    - (2) Earth core rockfill dam (ECRD)
- The largest rockfill dam in the world
- The largest dam in Asia outside of China
- to generate 2,400 megawatts of electricity
- 30% of the generated capacity consumed in East Malaysia and the rest sent to Peninsular Malaysia
- 668 km of overhead transmission lines in East Malaysia, 643 km of underseas cable and 458 km of cable in Peninsular Malaysia

The end