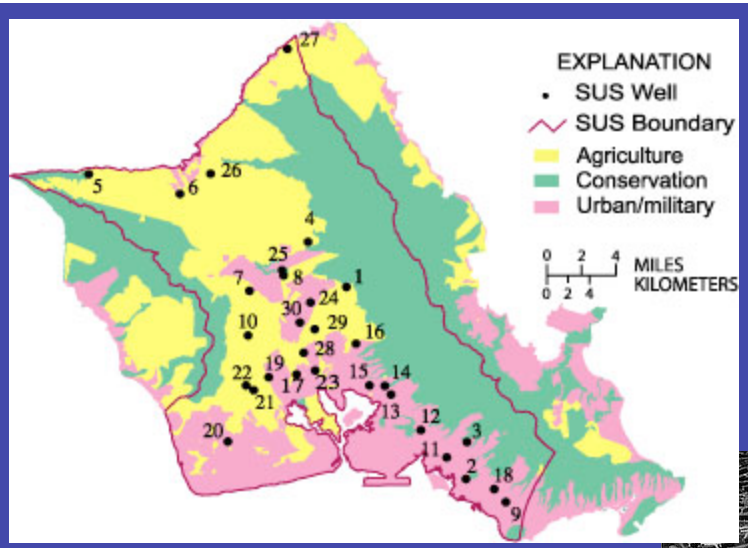
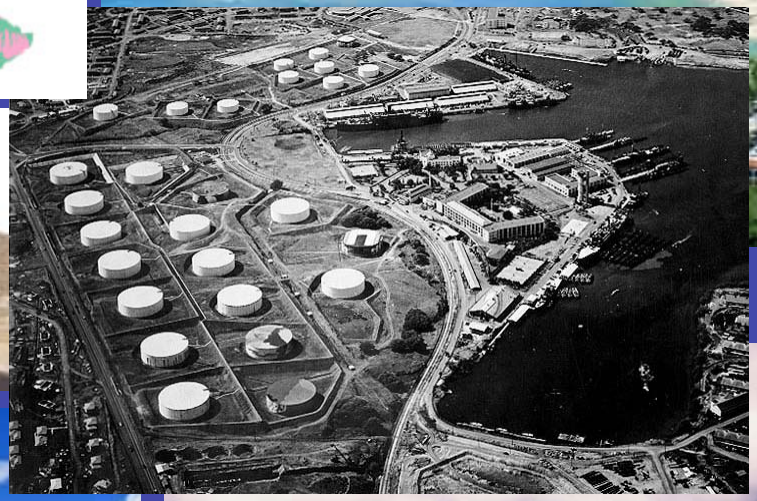

EXPLANATION
SUS Well
SUS Boundary
Agriculture
Conservation
Urban/military
0 2 4
MILES
0 2 4
KILOMETERS
27
26
5
6
4
25
8
1
7
24
30
10
29
16
28
22
19
17
23
15
14
21
13
12
3
20
11
2
18
9













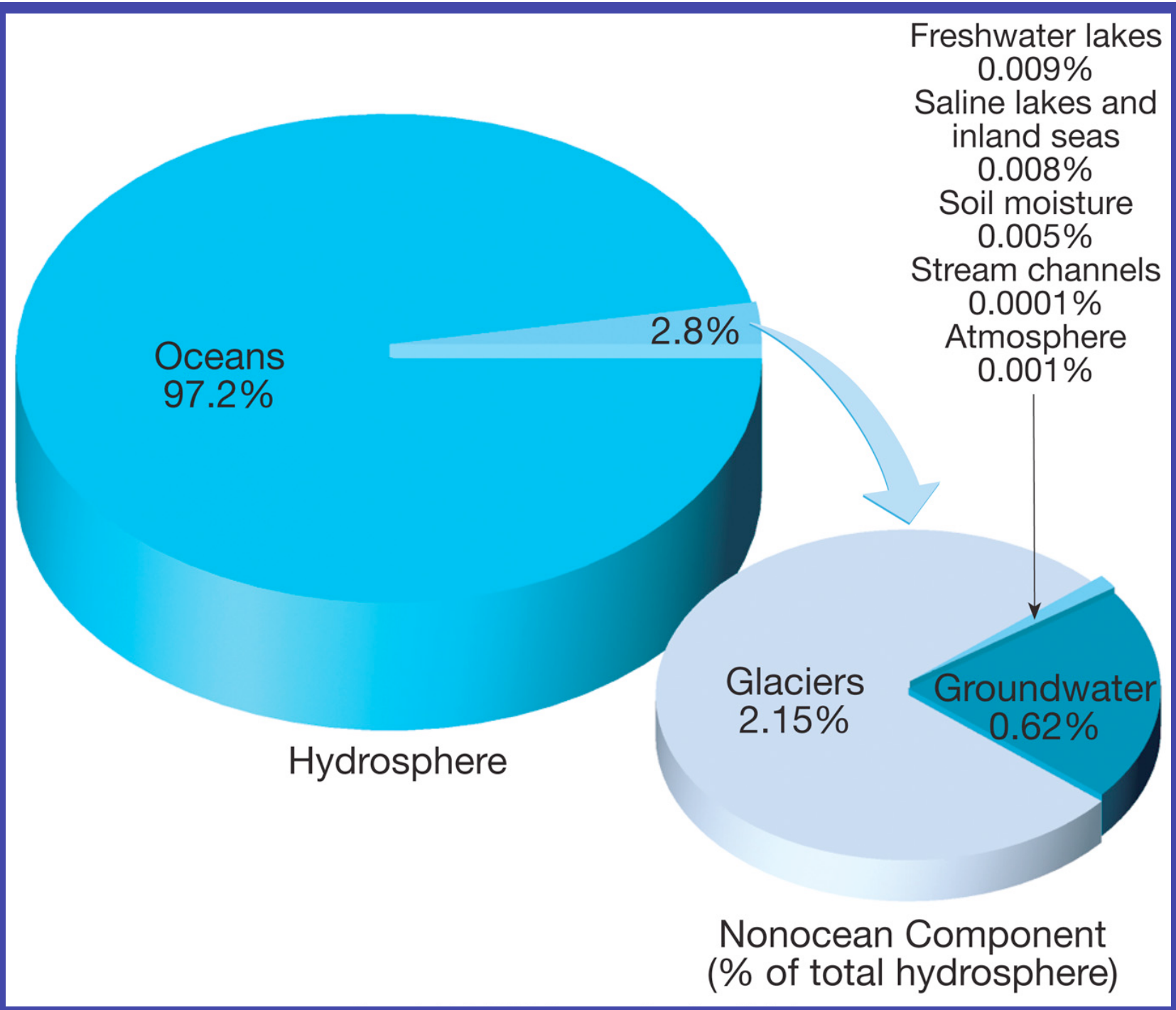


# Surface Water

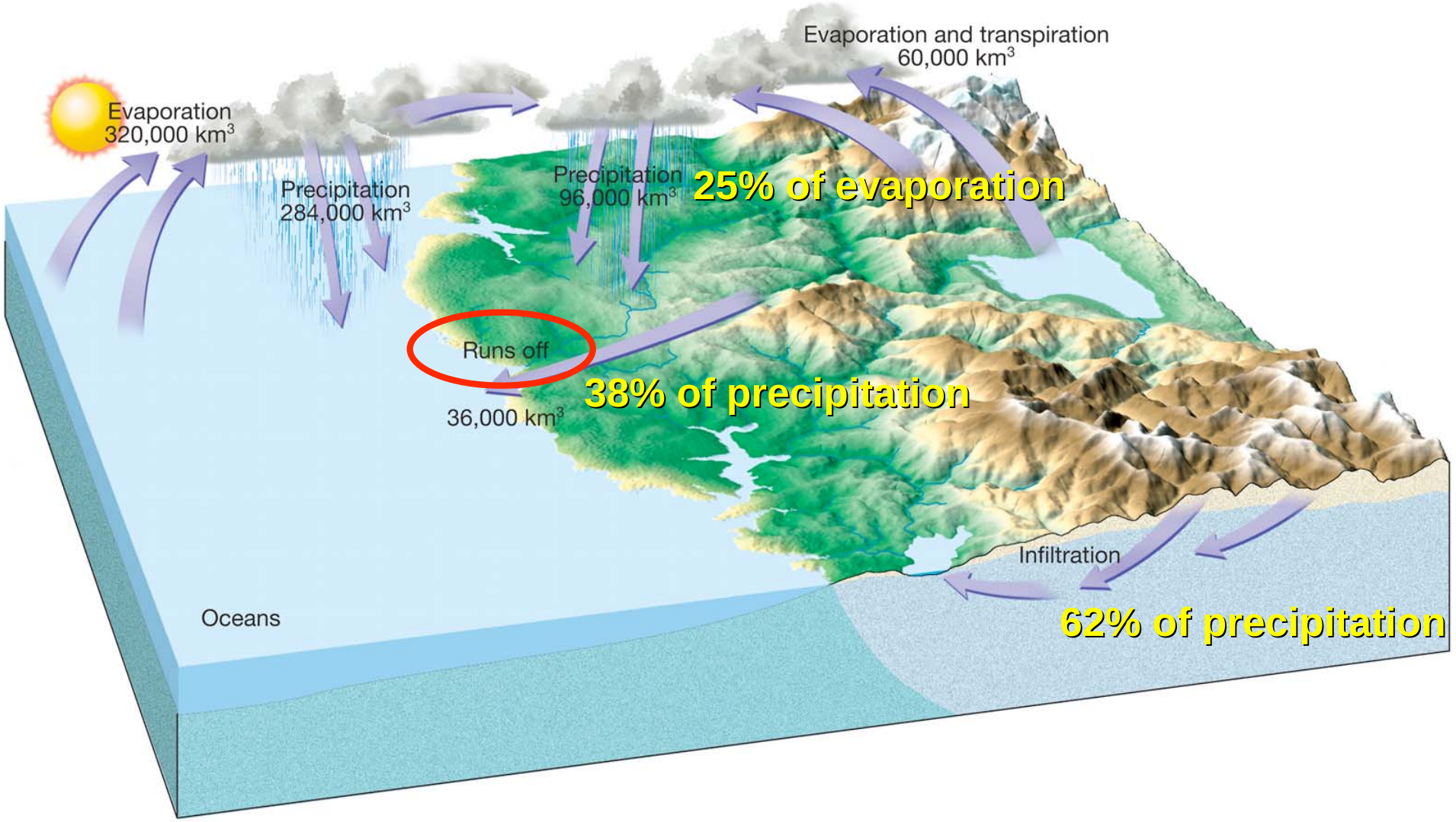


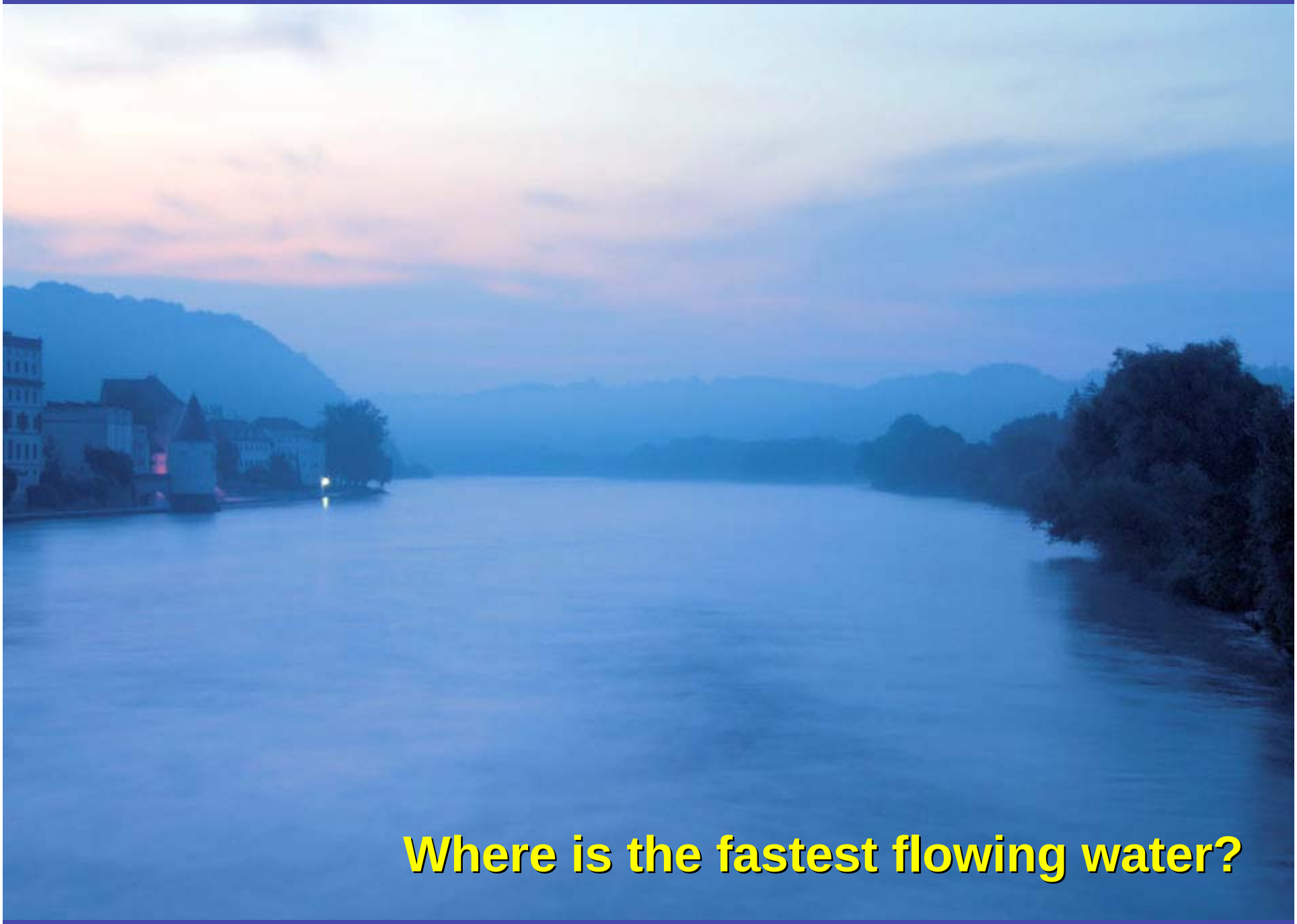




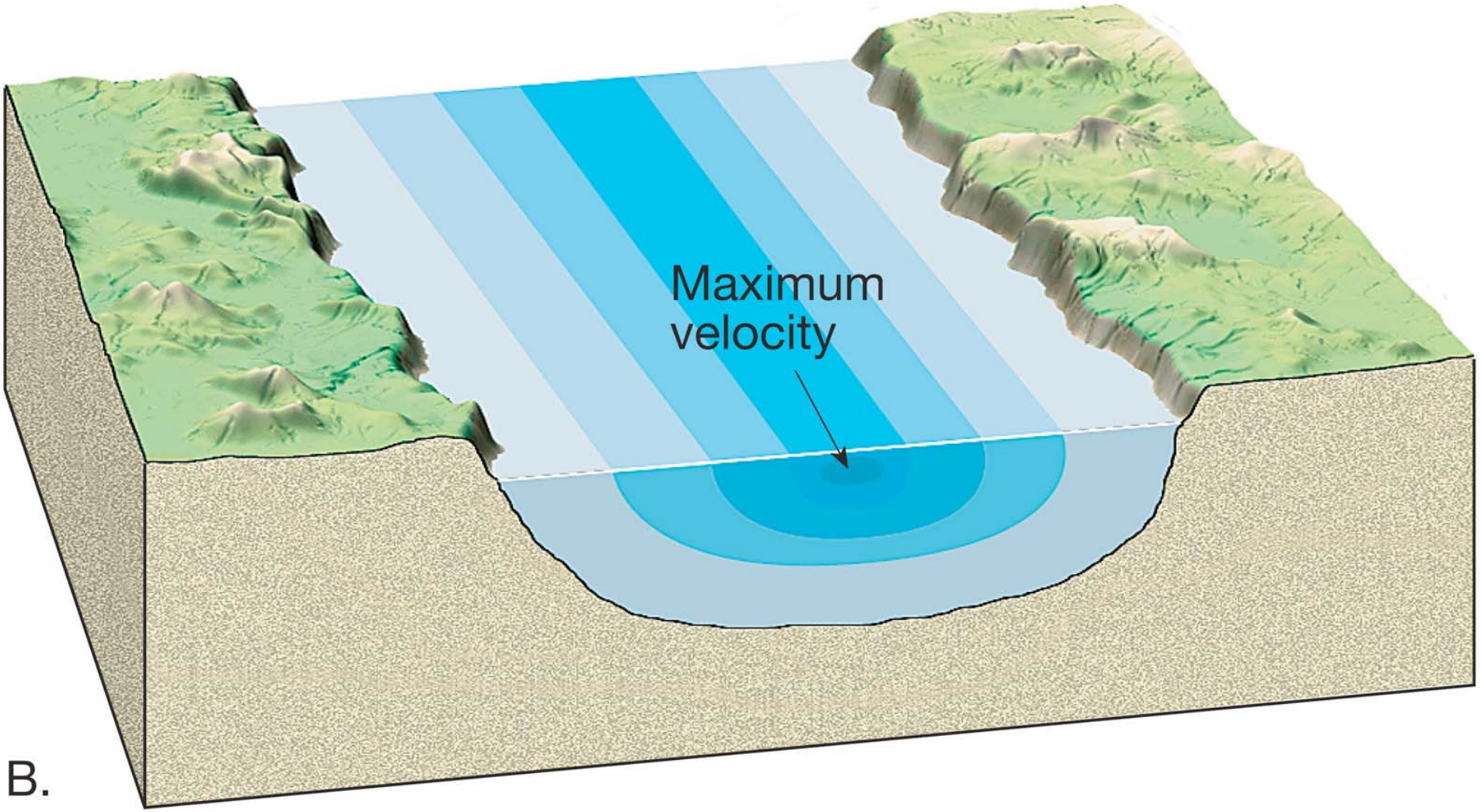

Freshwater lakes
0.009%
Saline lakes and
inland seas
0.008%
Soil moisture
0.005%
Stream channels
0.0001%
Atmosphere
0.001%
Oceans
97.2%
2.8%
Glaciers
2.15%
Groundwater
0.62%
Hydrosphere
Nonocean Component
(% of total hydrosphere)

# Earth's Water Balance

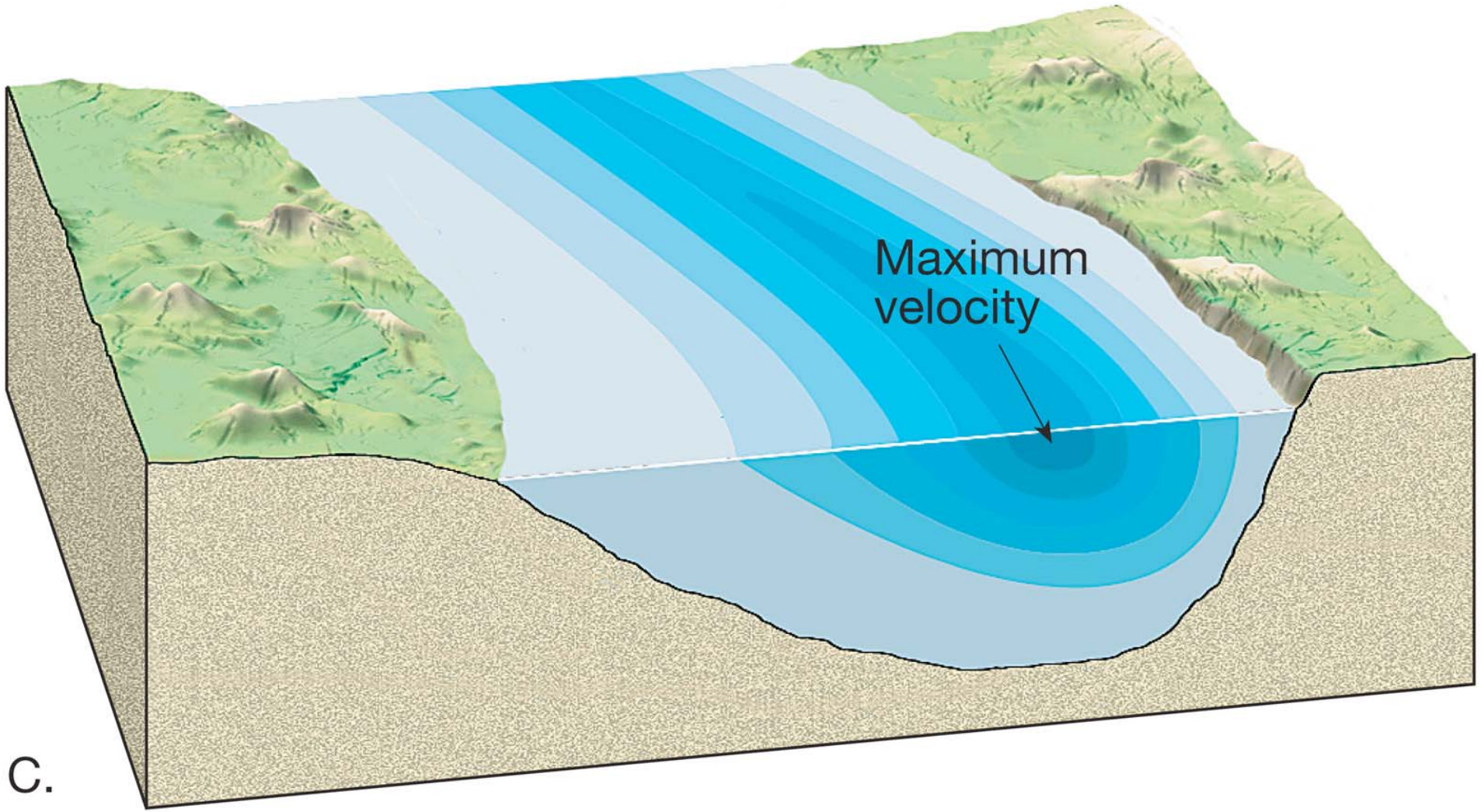


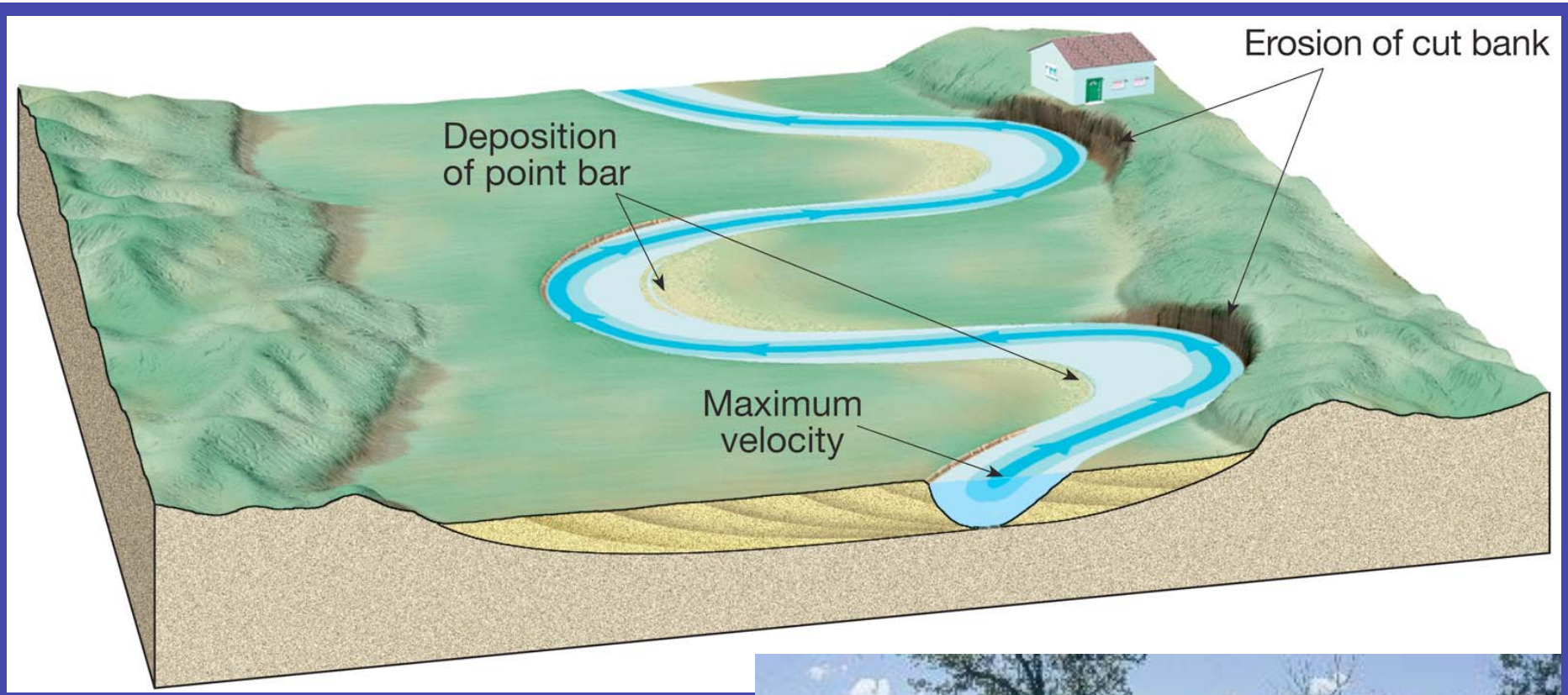

Where is the fastest flowing water?

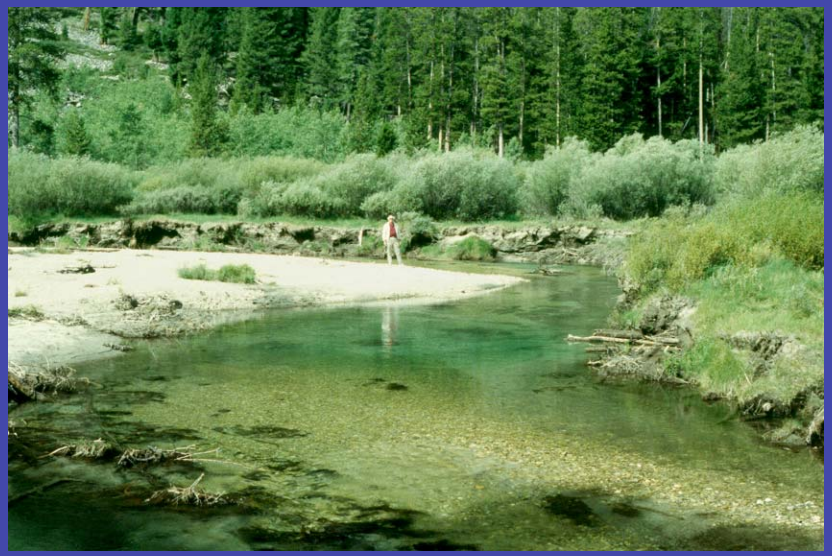
# Maximum velocity where friction is lowest



# Centrifugal force shifts max velocity to outer edges of bend

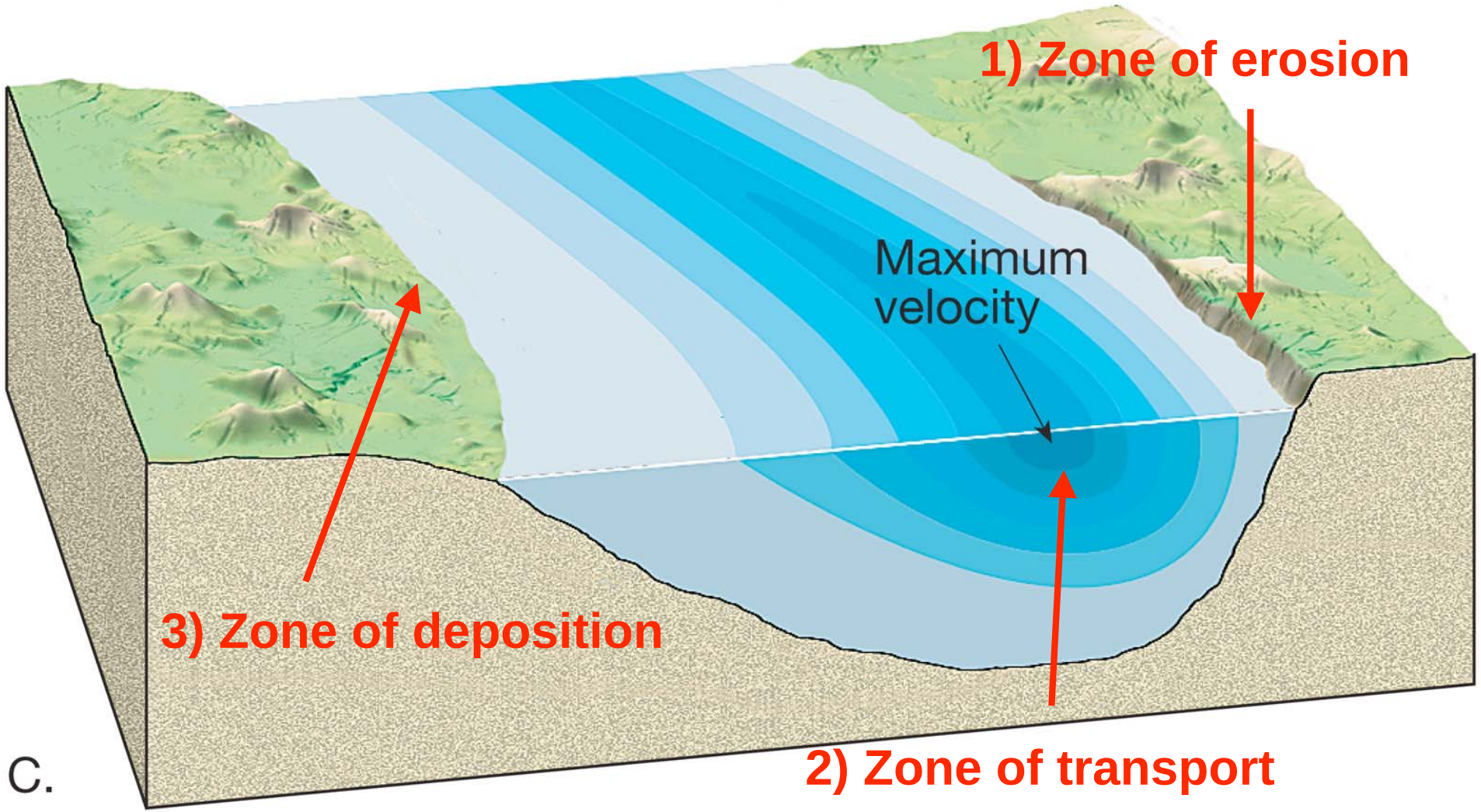



Erosion of cut bank
Deposition
of point bar
Maximum
velocity

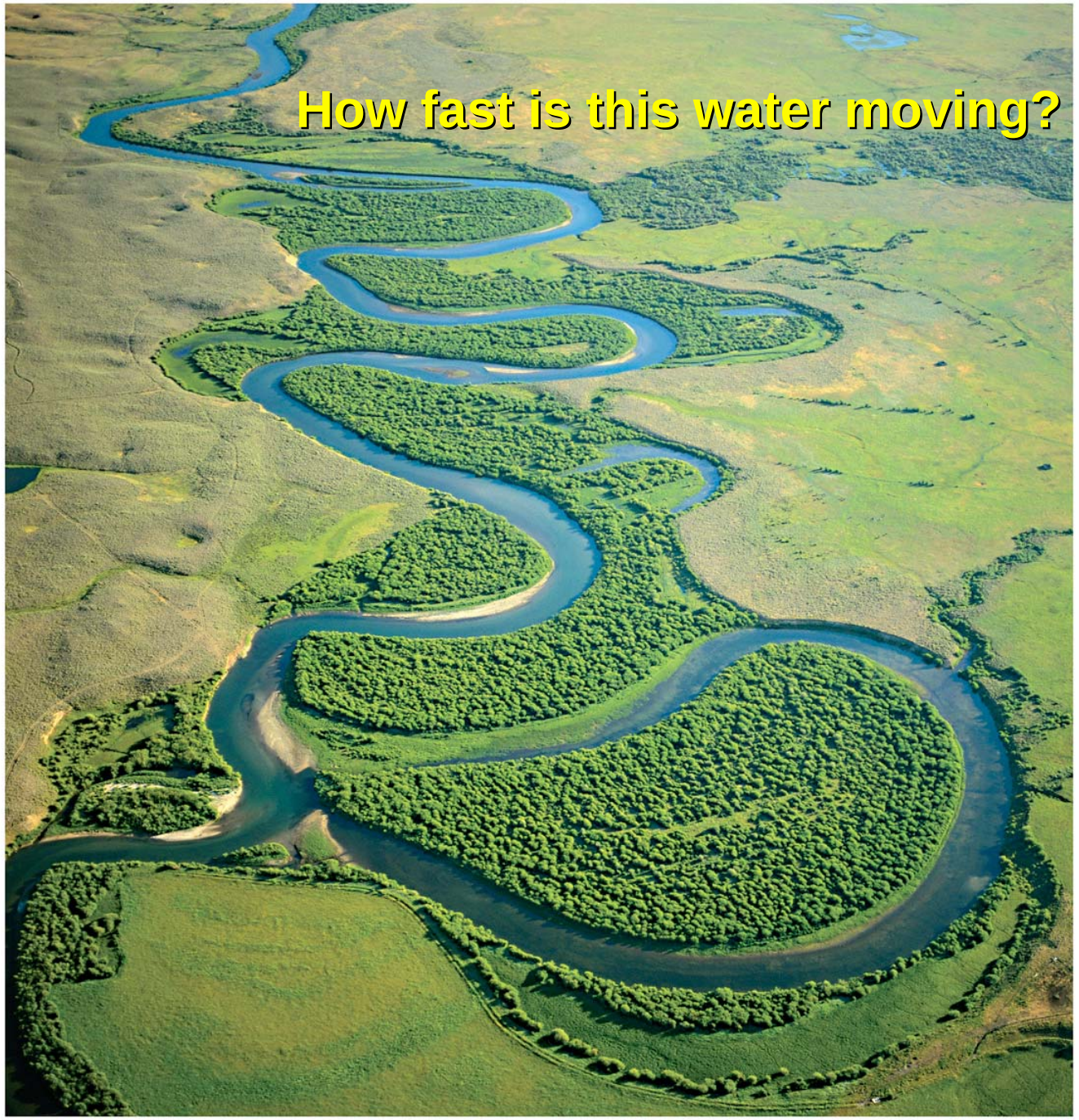


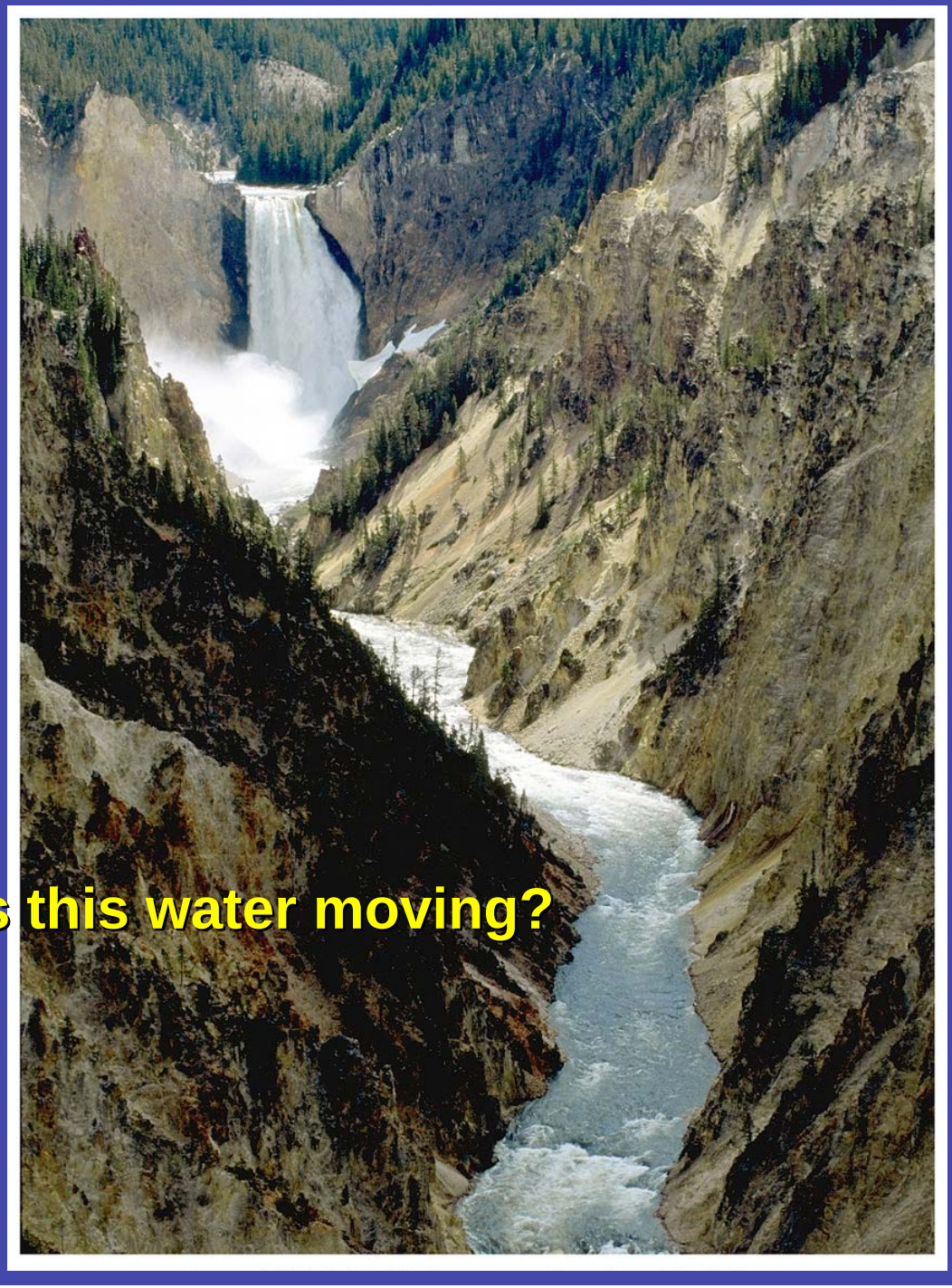


# Running water most important agent sculpting Earth's surface




## 3 zones common to all river systems

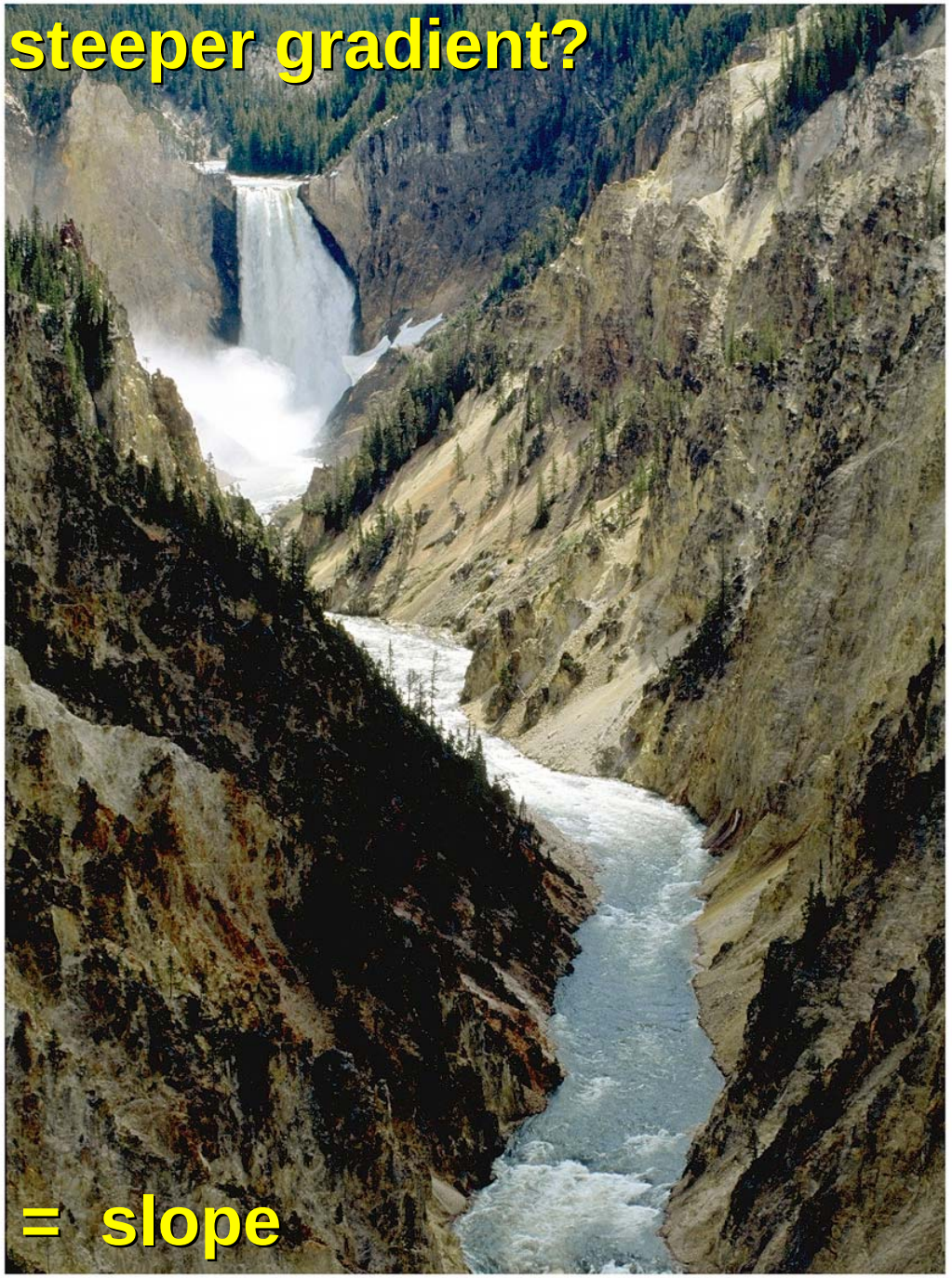

How fast is this water moving?



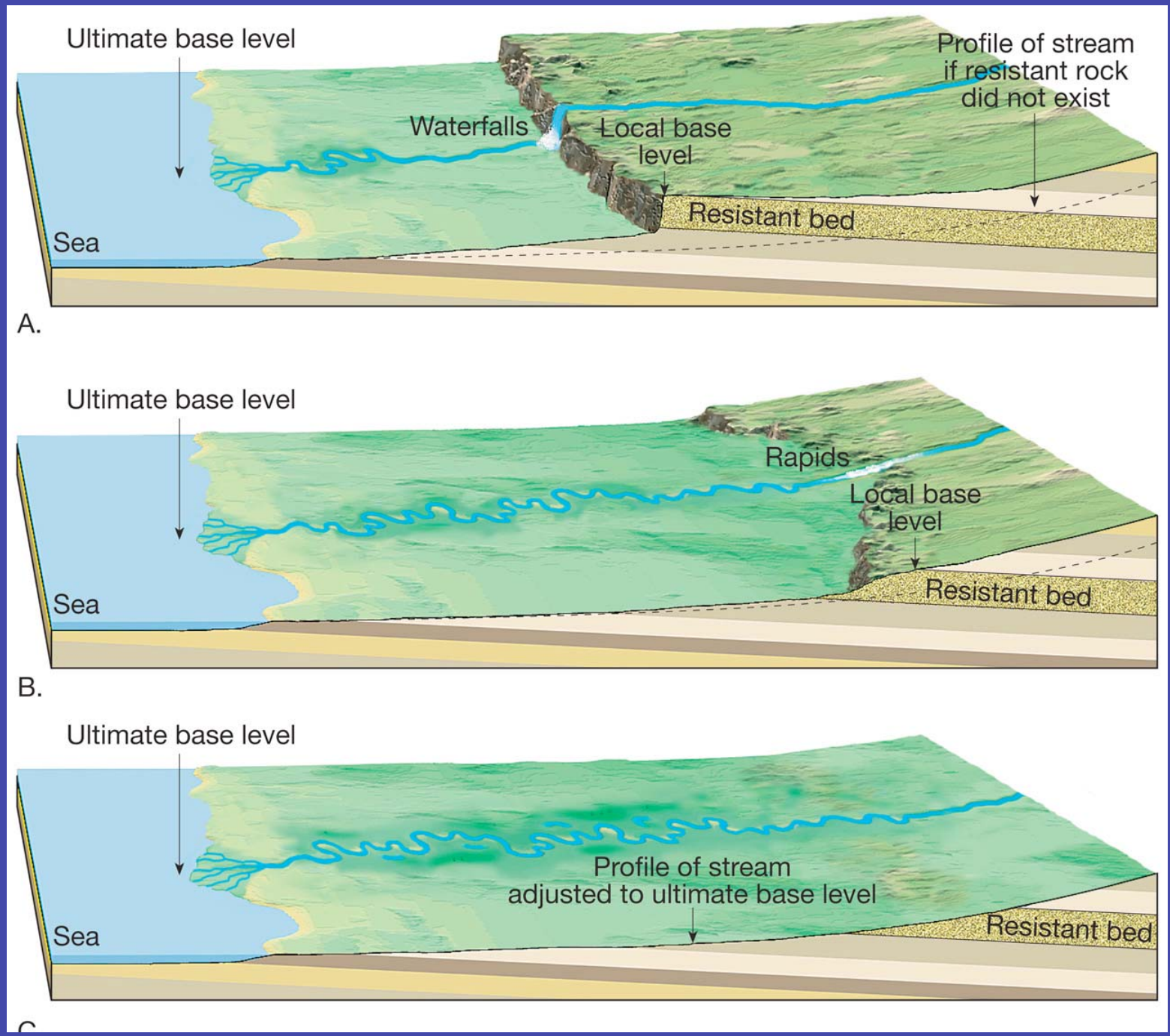
**How fast is this water moving?**

Which has the steeper gradient?





Gradient = slope


Ultimate base level
Profile of stream
if resistant rock
did not exist
Waterfalls
Local base
level
Resistant bed
Sea
A.
Ultimate base level
Rapids
Local base
level
Resistant bed
Sea
B.
Ultimate base level
Profile of stream
adjusted to ultimate base level
Resistant bed
Sea
C

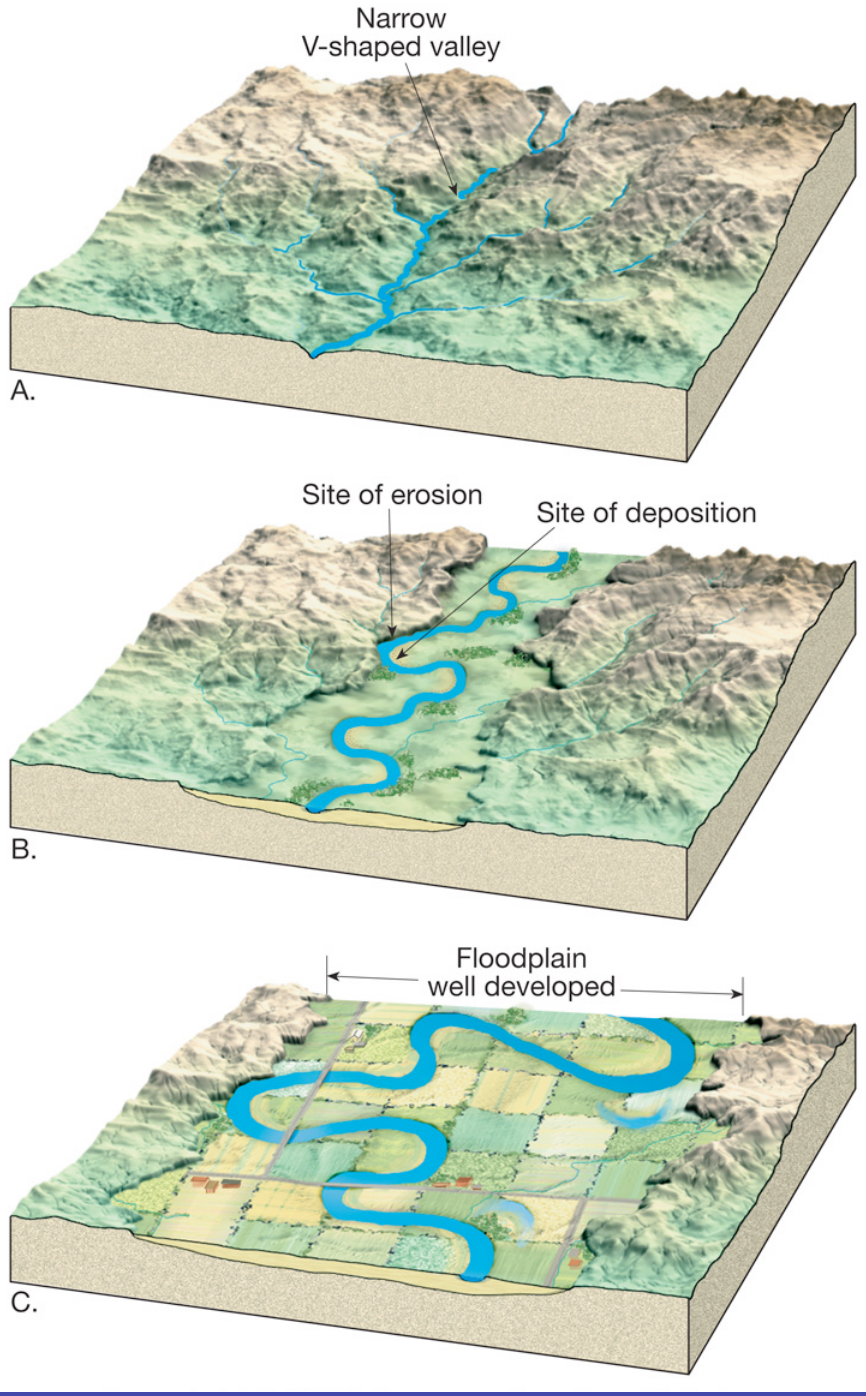
# Nile River



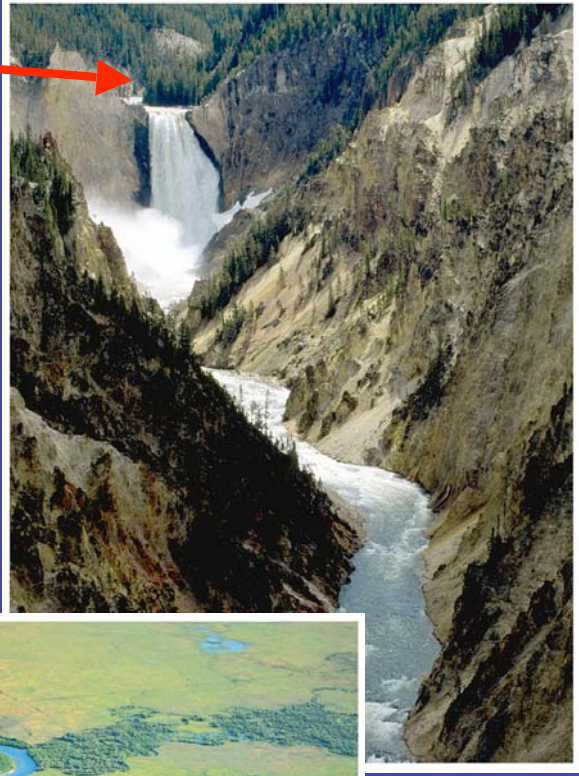


**What built the delta?**

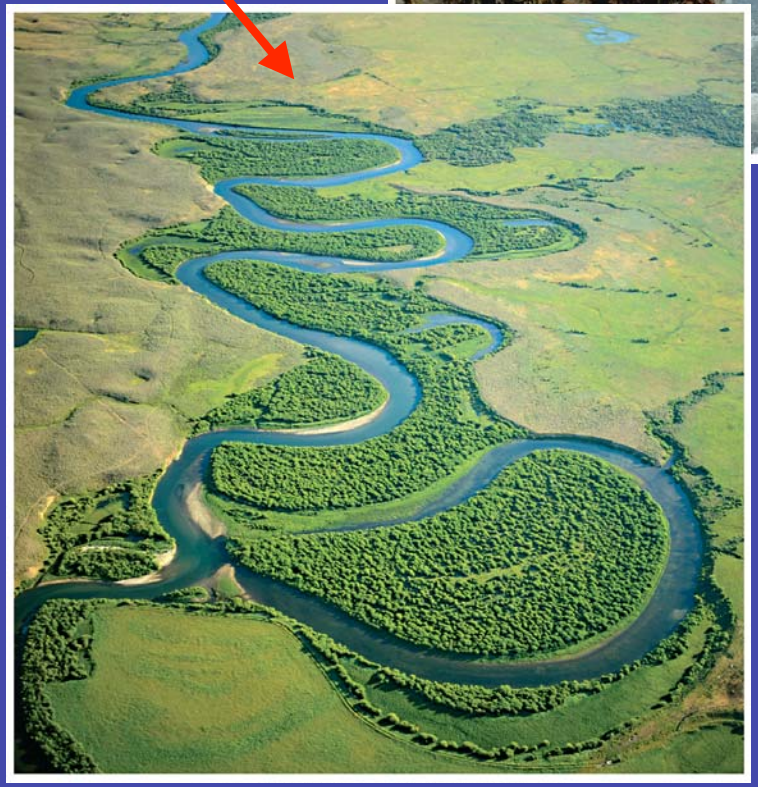
# Floodplain Development




***Immature***



***Mature***




Where are the boundaries…
…of this river?

# What built the delta?





Floodplain

River

…annual flooding

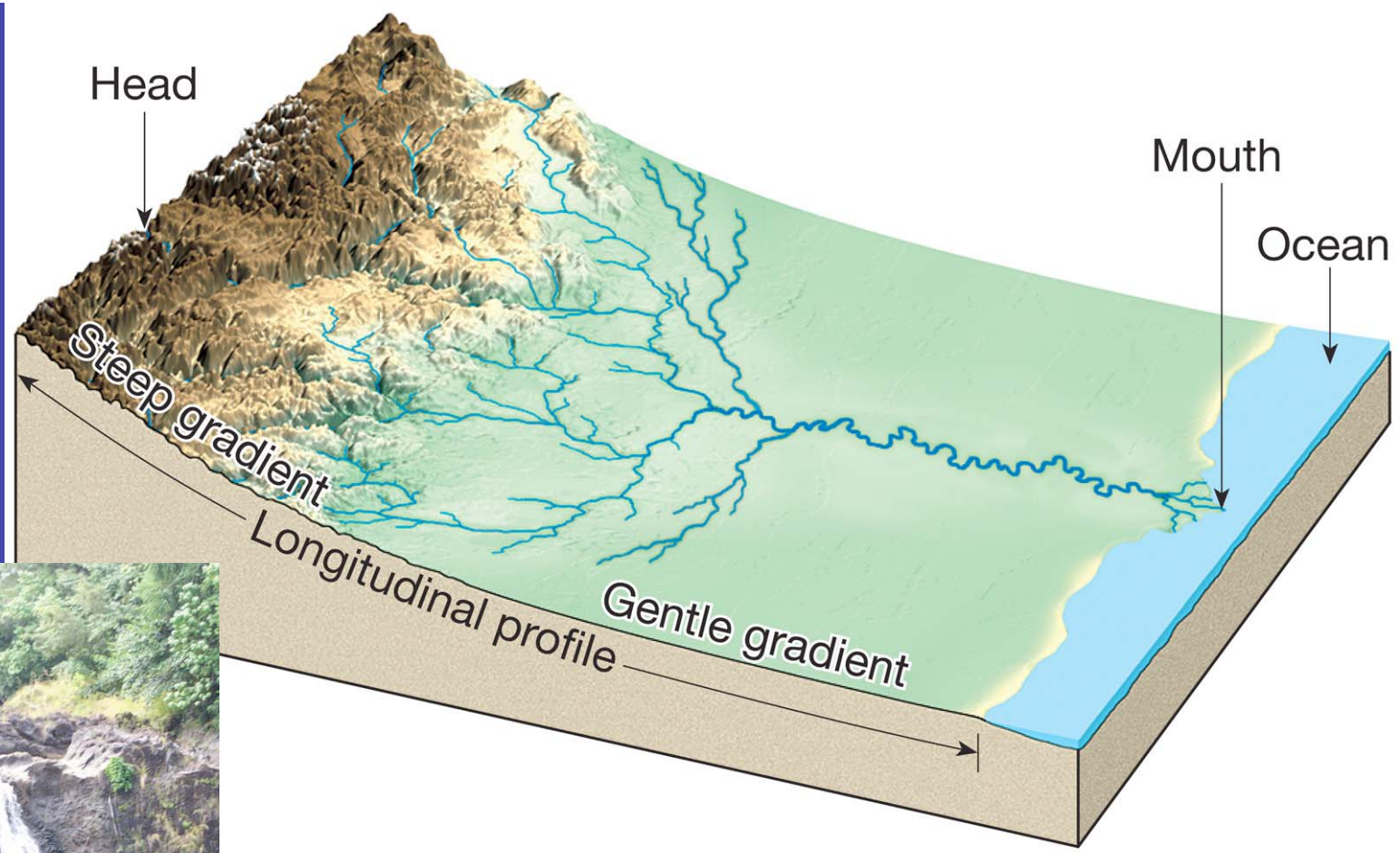
**Immature river systems:**

**V-shaped valleys**
**Steep gradients**

**Mature river systems:**

**Broad floodplains**
**Low gradients**





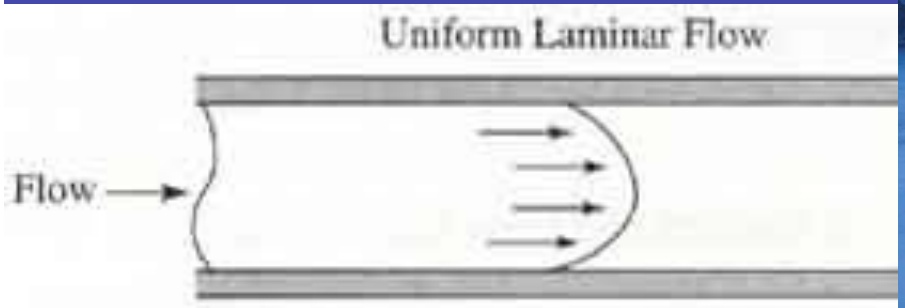

**Discharge varies 1) with stream profile**

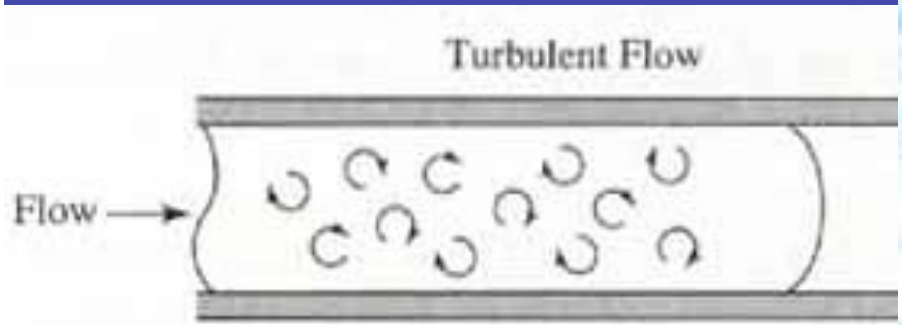
**2) and seasonally**



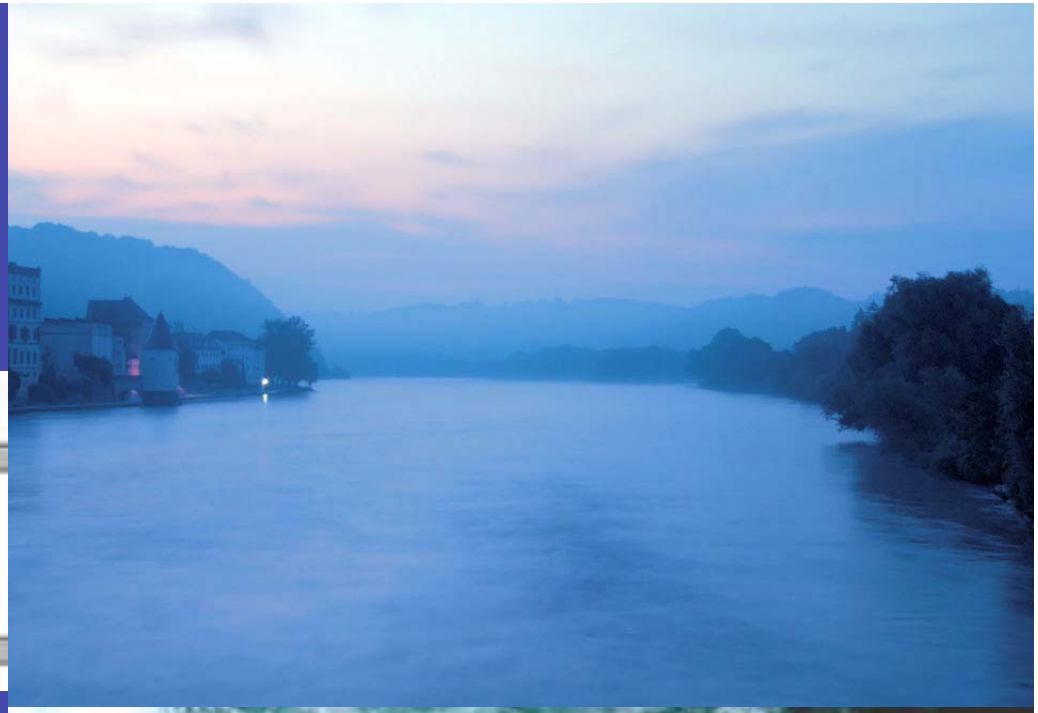
Antelope Canyon, Arizona

**Which flow regime leads to erosion?**




**Which water is moving faster?**





## Factors contributing to erosion/downcutting:

1) Location of maximum velocity

2) Turbulent vs. laminar flow

3) Stream gradient (which is a function of height above base level)

4) Discharge volume


So how does this form?

# Why do we care about river dynamics?





RECREATION





AGRICULTURE, INDUSTRY

## Logistics:

- Only 7 classes left!
- Propose to do only 2 more activities (12 total)
  Drop lowest homework/activity score
- Extra credit due May 2 (last day of class)
- Kilo Moana field trip May 1, 12-3pm, optional/free/fun!
  RSVP by Friday April 27

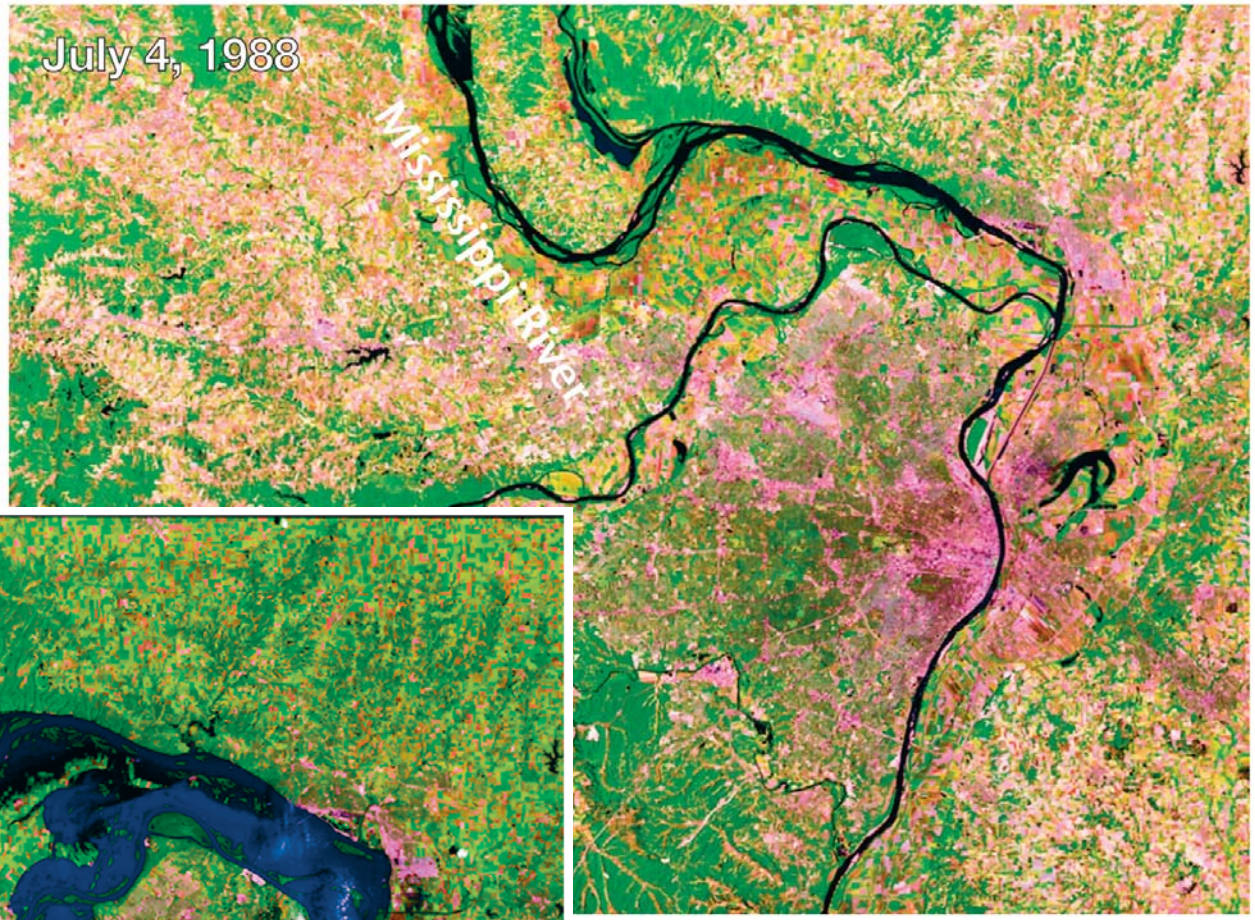


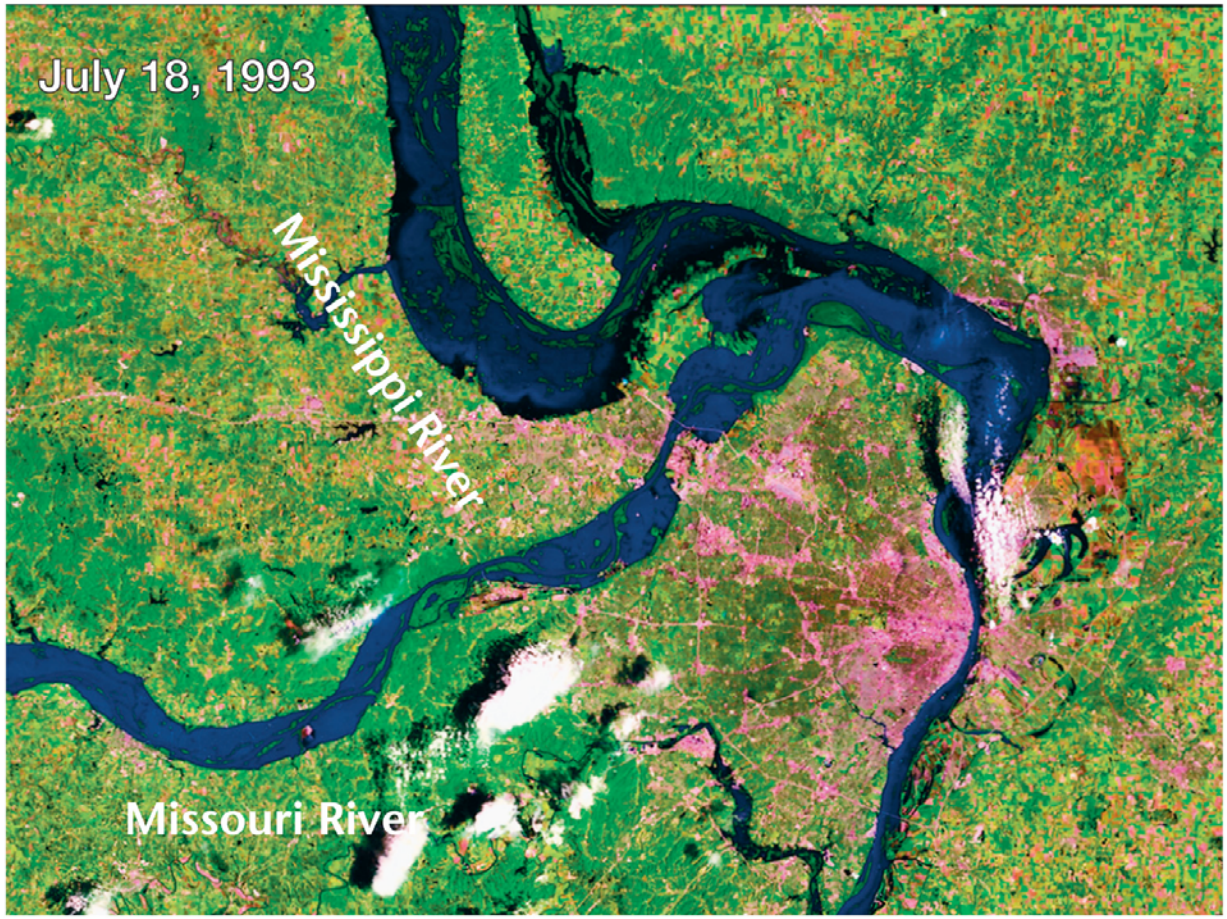


# Flood Control! - floods most destructive geologic hazard



# Missouri / Mississippi floods of 1993



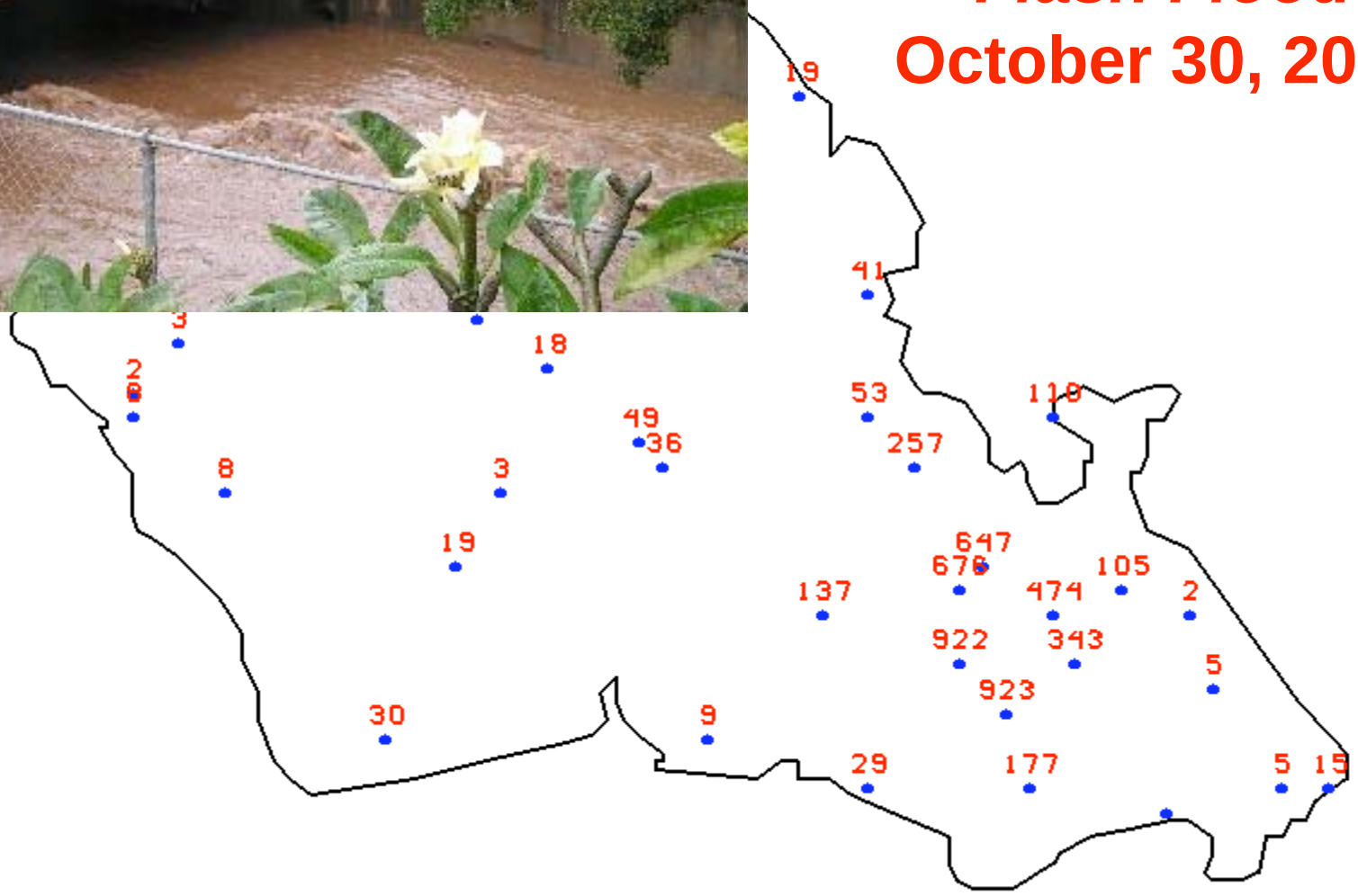




**14 million acres Inundated**

**50,000 people displaced**



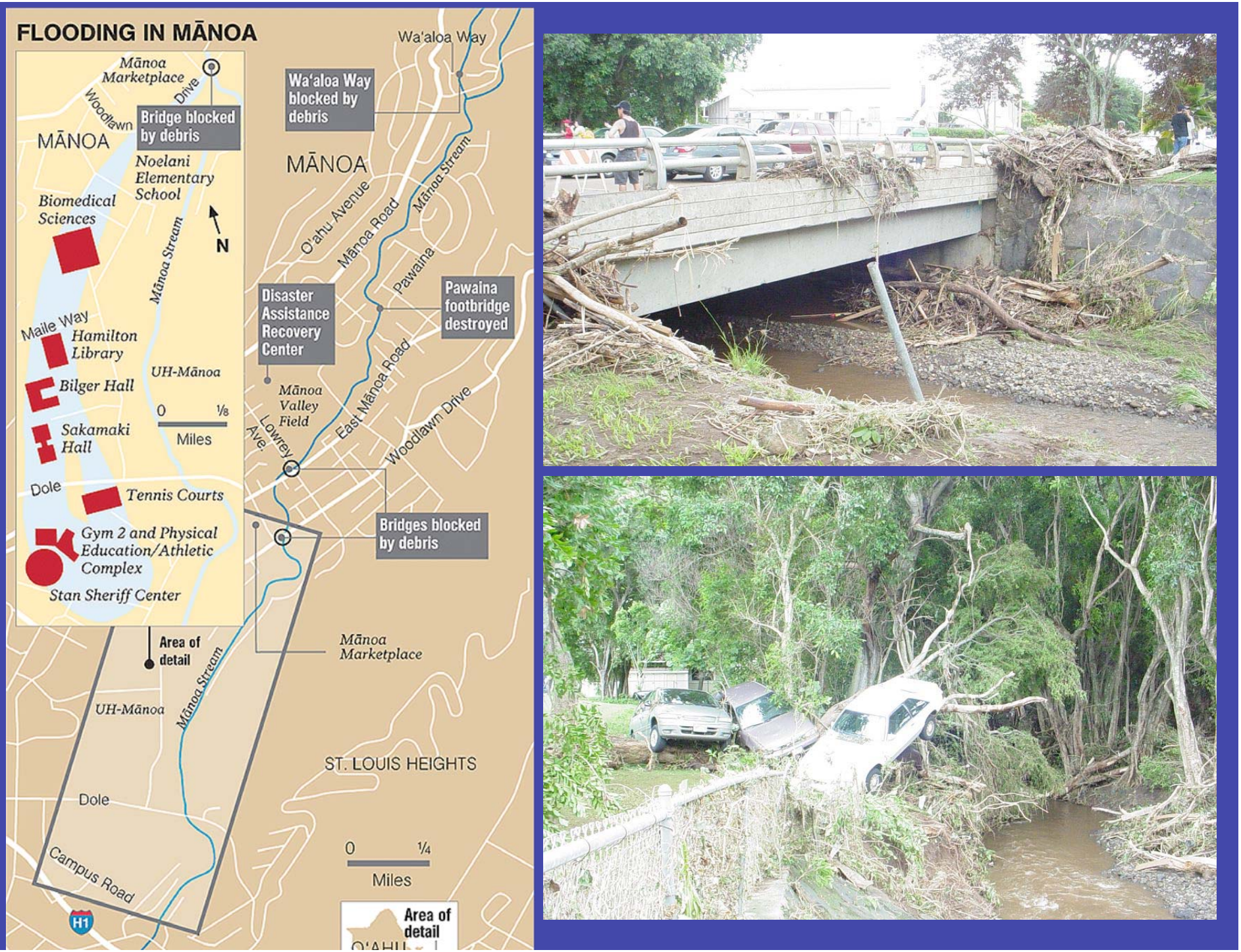
# Manoa Stream (?)
# *Flash Flood*
# October 30, 2004







**What about Manoa's topography makes flooding likely?**


FLOODING IN MĀNOA
Mānoa Marketplace
Drive
Woodlawn
Bridge blocked by debris
MĀNOA
Noelani Elementary School
Biomedical Sciences
Mānoa Stream
N
Maile Way
Hamilton Library
UH-Mānoa
Bilger Hall
0
1/8
Miles
Sakamaki Hall
Dole
Tennis Courts
Gym 2 and Physical Education/Athletic Complex
Stan Sheriff Center
Area of detail
UH-Mānoa
Mānoa Stream
Campus Road
H1
Dole
ST. LOUIS HEIGHTS
0
1/4
Miles
Area of detail
Wa'aloa Way
Wa'aloa Way blocked by debris
MĀNOA
O'ahu Avenue
Mānoa Road
Mānoa Stream
Pawaina
Pawaina footbridge destroyed
Disaster Assistance Recovery Center
Mānoa Valley Field
Lowrey Ave
East Mānoa Road
Woodlawn Drive
Bridges blocked by debris
Mānoa Marketplace



# Flood hits first in Woodlawn area of Manoa



# UH Biomedical Building









# UH Hamilton Library







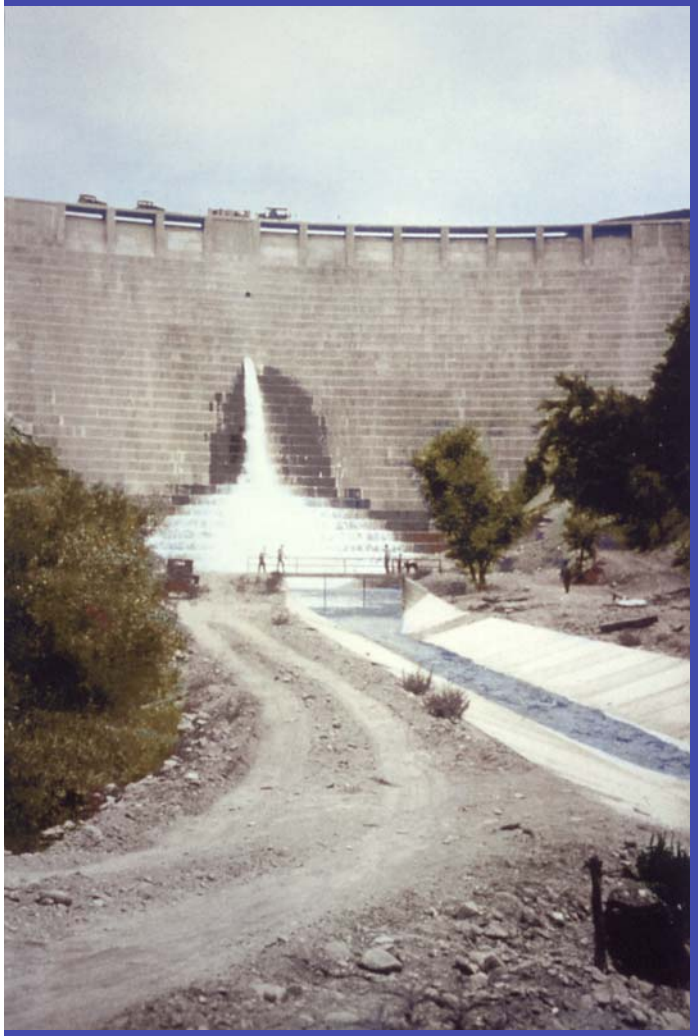
**Sakamaki Hall, Krauss Annex**

## Flash flooding:

1. Intense rainfall
2. Steep topography
3. Paved surfaces



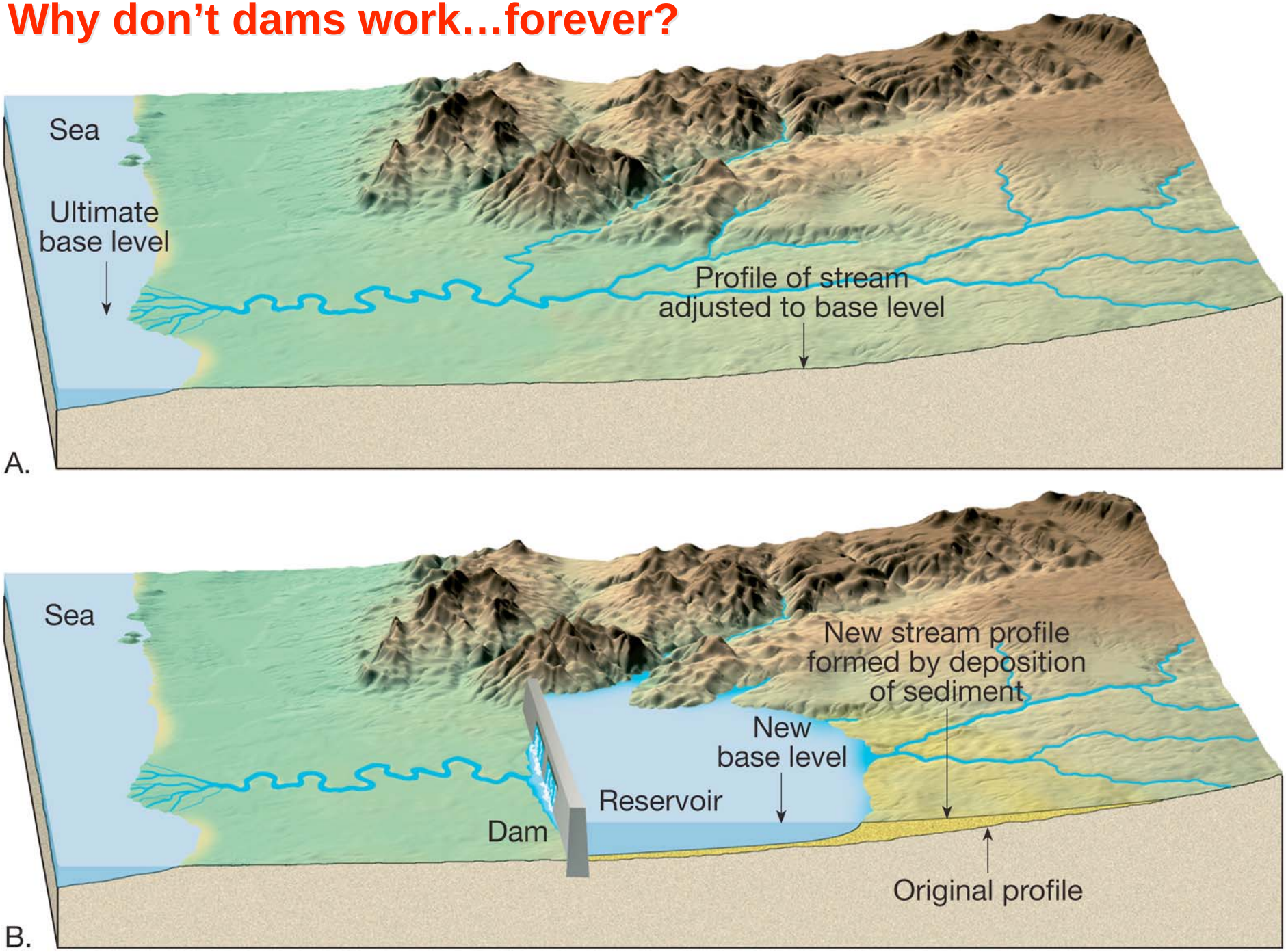
4. Rapid rise in flow levels
5. Dangerous flow velocities





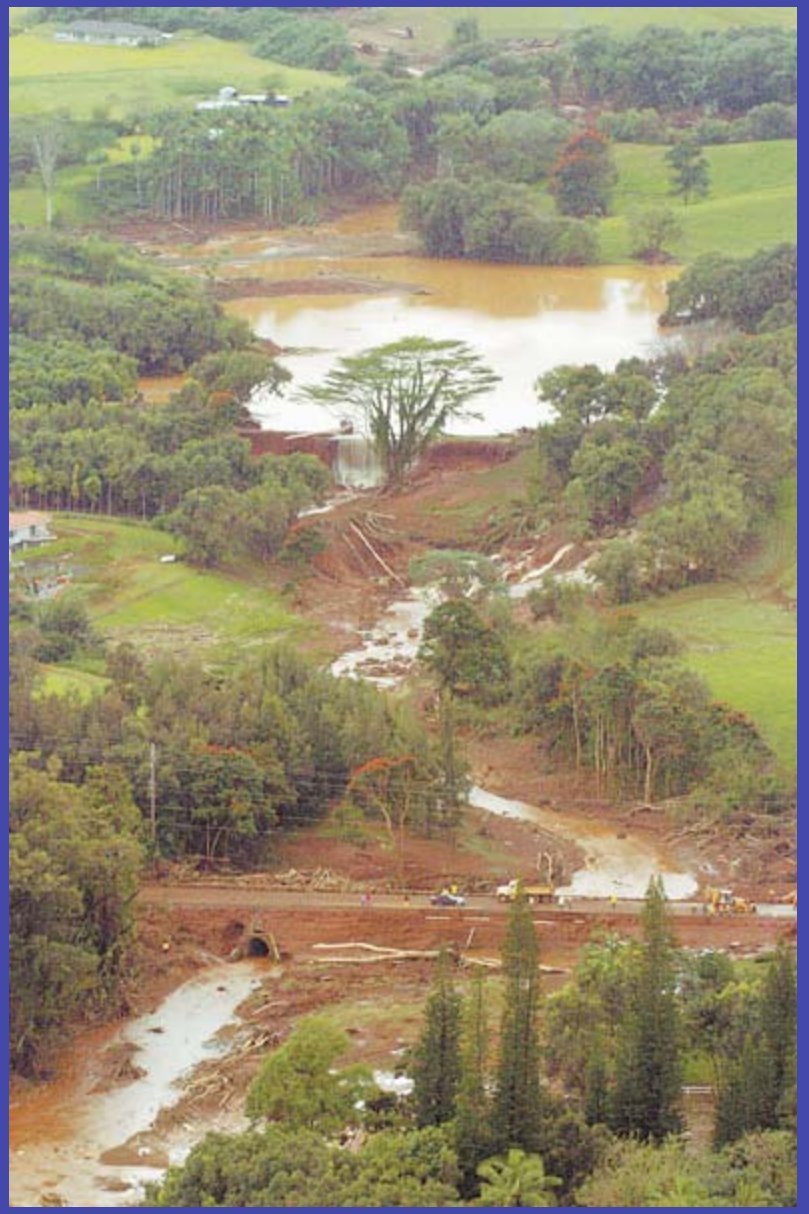
**St. Francis Dam Failure, 1928**

# Why don't dams work…forever?



# 300 million gallons



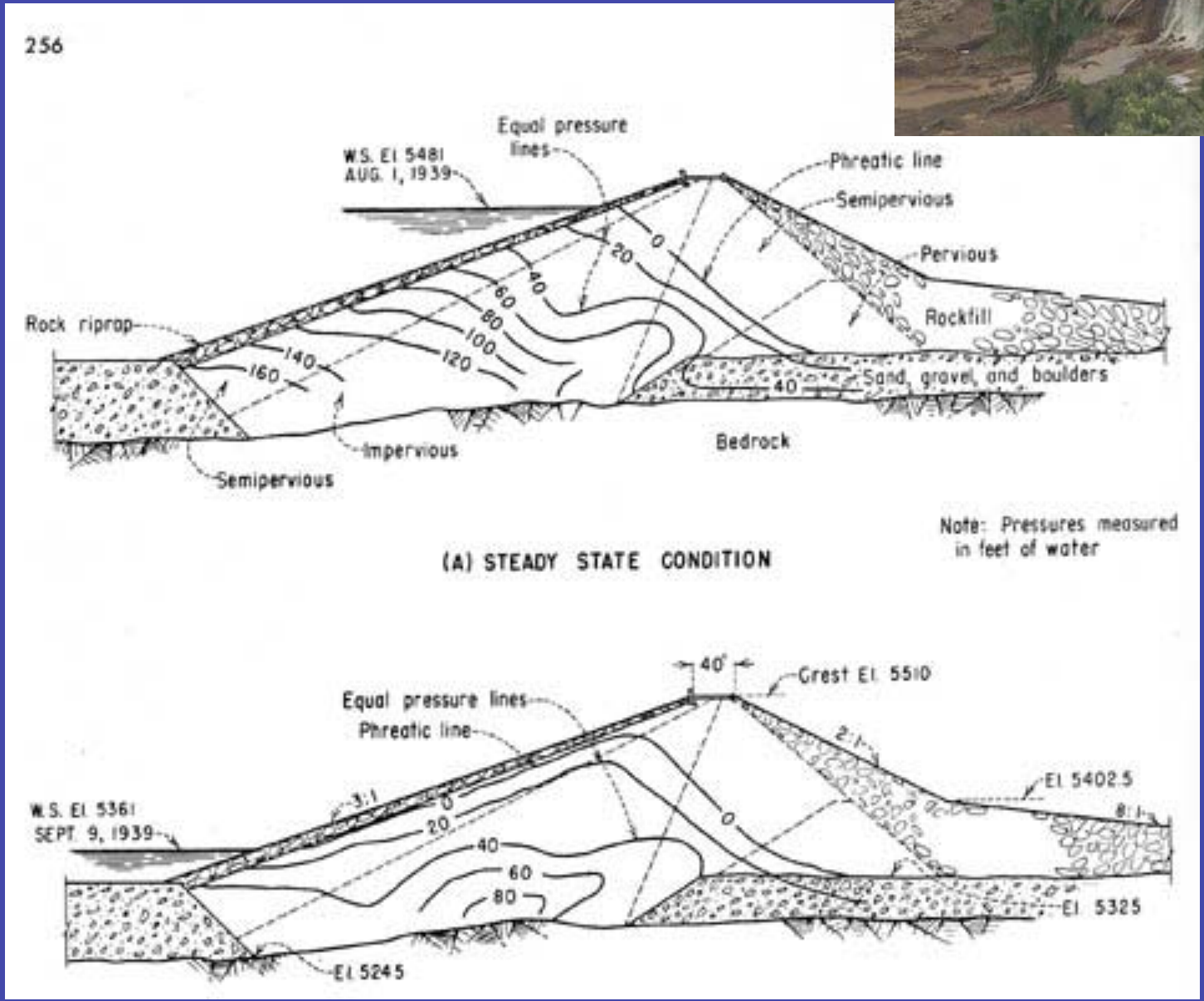





## Ka Loko Reservoir Dam Break, 2005

# Rising waters increased pressure on earthen dam

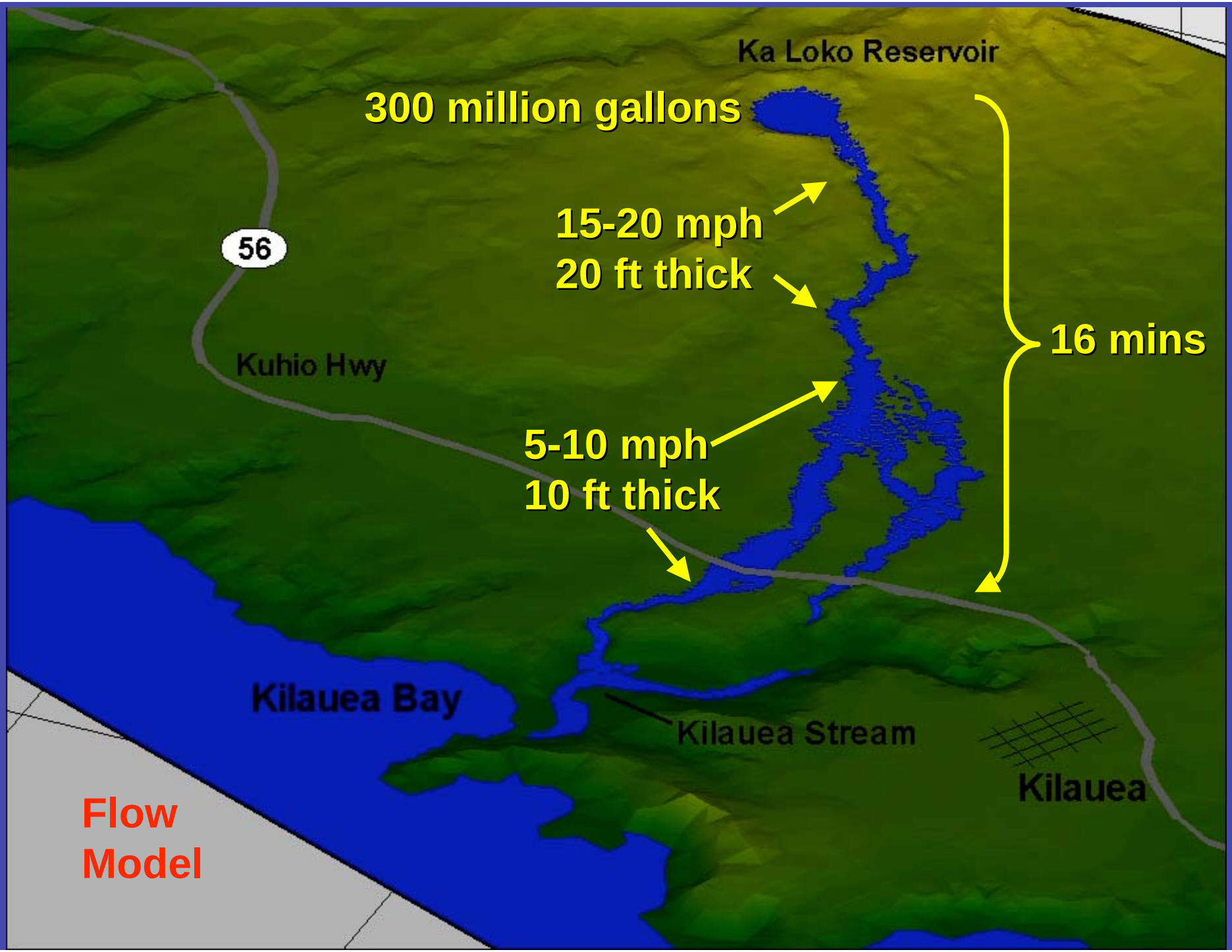





High water

increasing stress

Normal water


Ka Loko Reservoir
300 million gallons
15-20 mph
20 ft thick
56
Kuhio Hwy
16 mins
5-10 mph
10 ft thick
Kilauea Bay
Kilauea Stream
Kilauea
Flow
Model



**Floodwaters destroyed property**

**Killed 7 plus unborn infant**





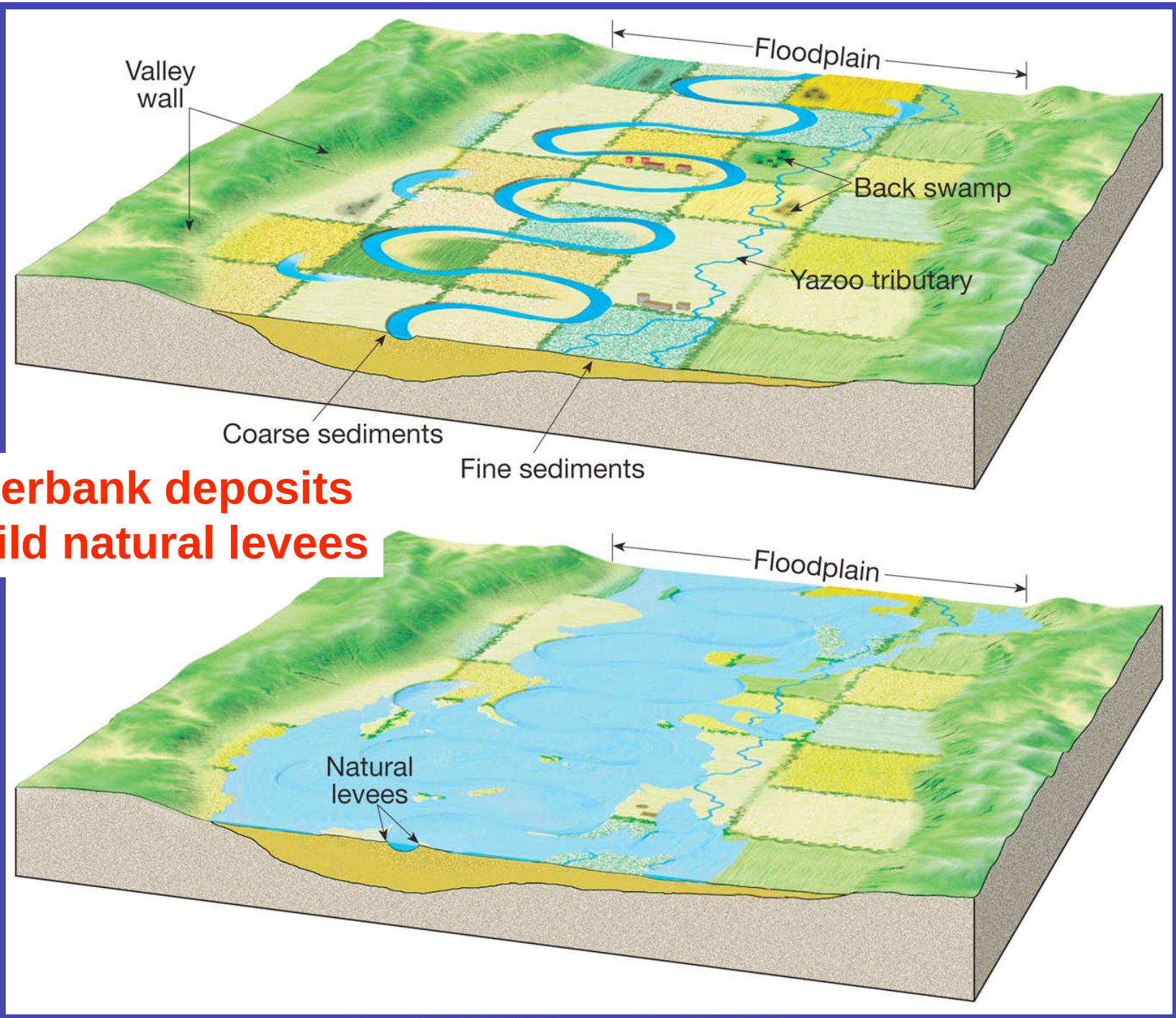
## Dam break flooding:

1. High rainfall
2. Increased water pressure
3. Dam structure inadequate



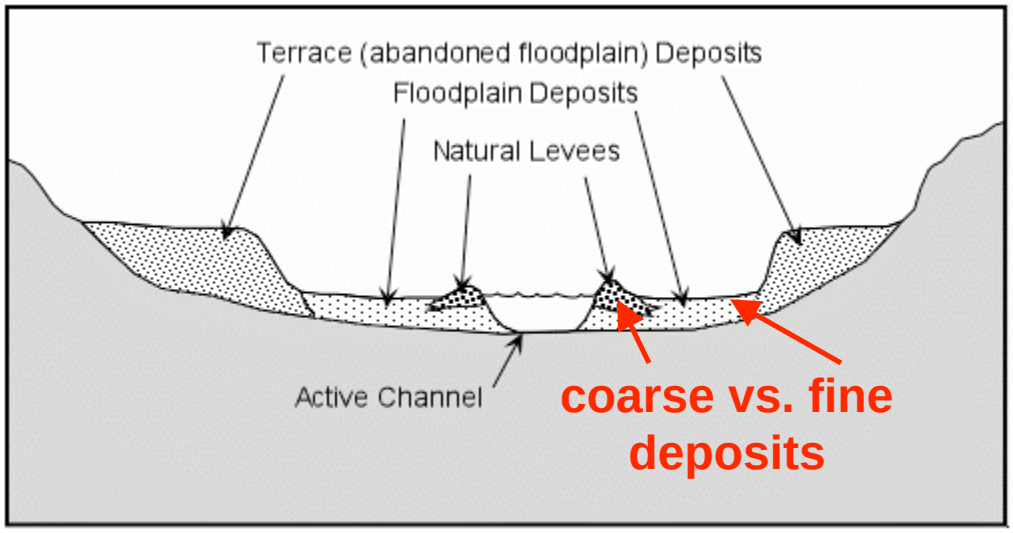
4. Dam overtopped/undermined
5. Rapid erosion/destruction of dam
6. Dangerous flow volumes/velocities


How did these alluvial fans form?




# Overbank deposits build natural levees

# Natural levees



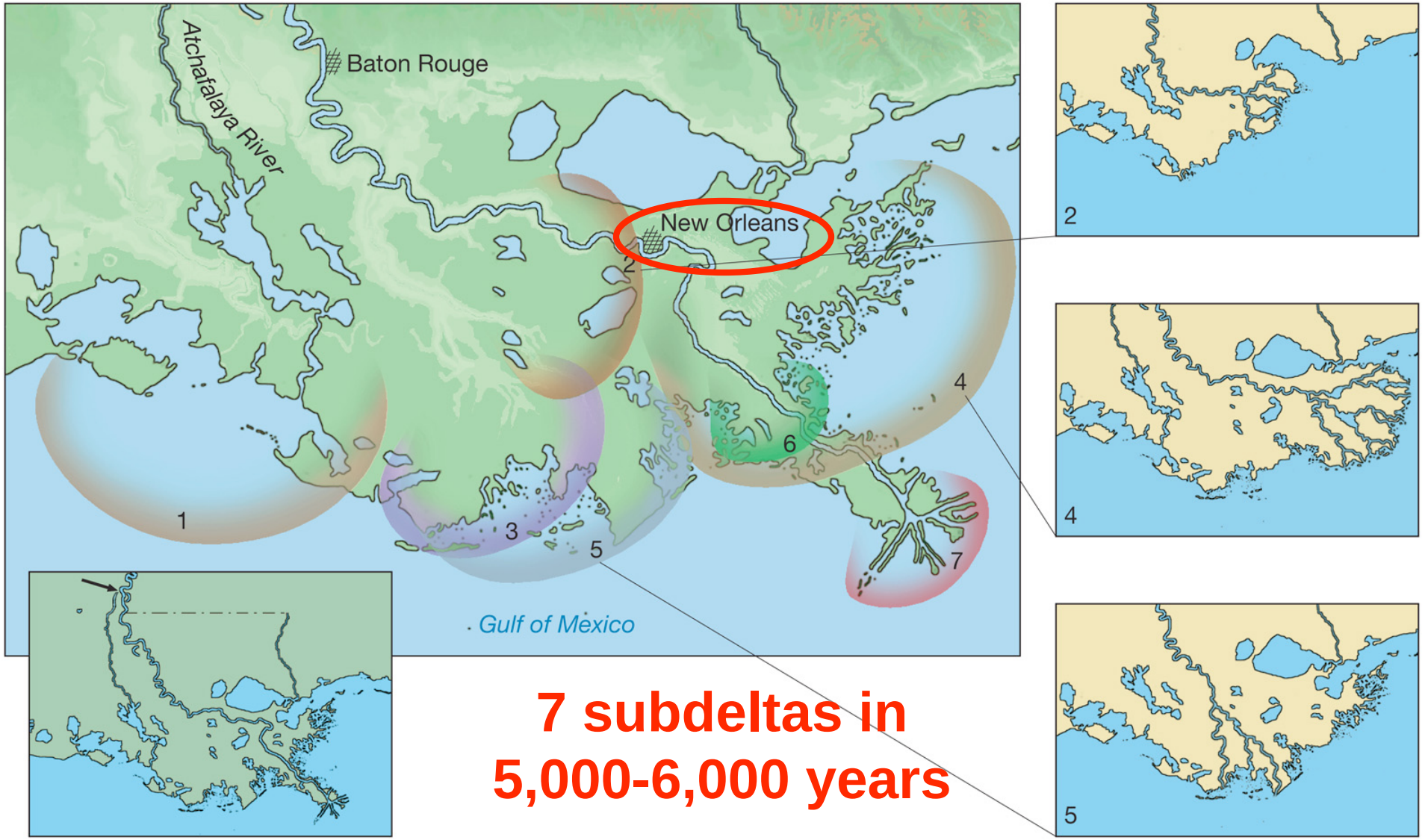
# What’s the biggest river in the U.S.?

# Mississippi drainage covers 3 million square kilometers




**This means <u>lots</u> of floodplains!**


Where is original coastline?




**7 subdeltas in 5,000-6,000 years**

**What is the shortest (i.e. steepest) route to the sea?**



**Old River control structure built 1950s**

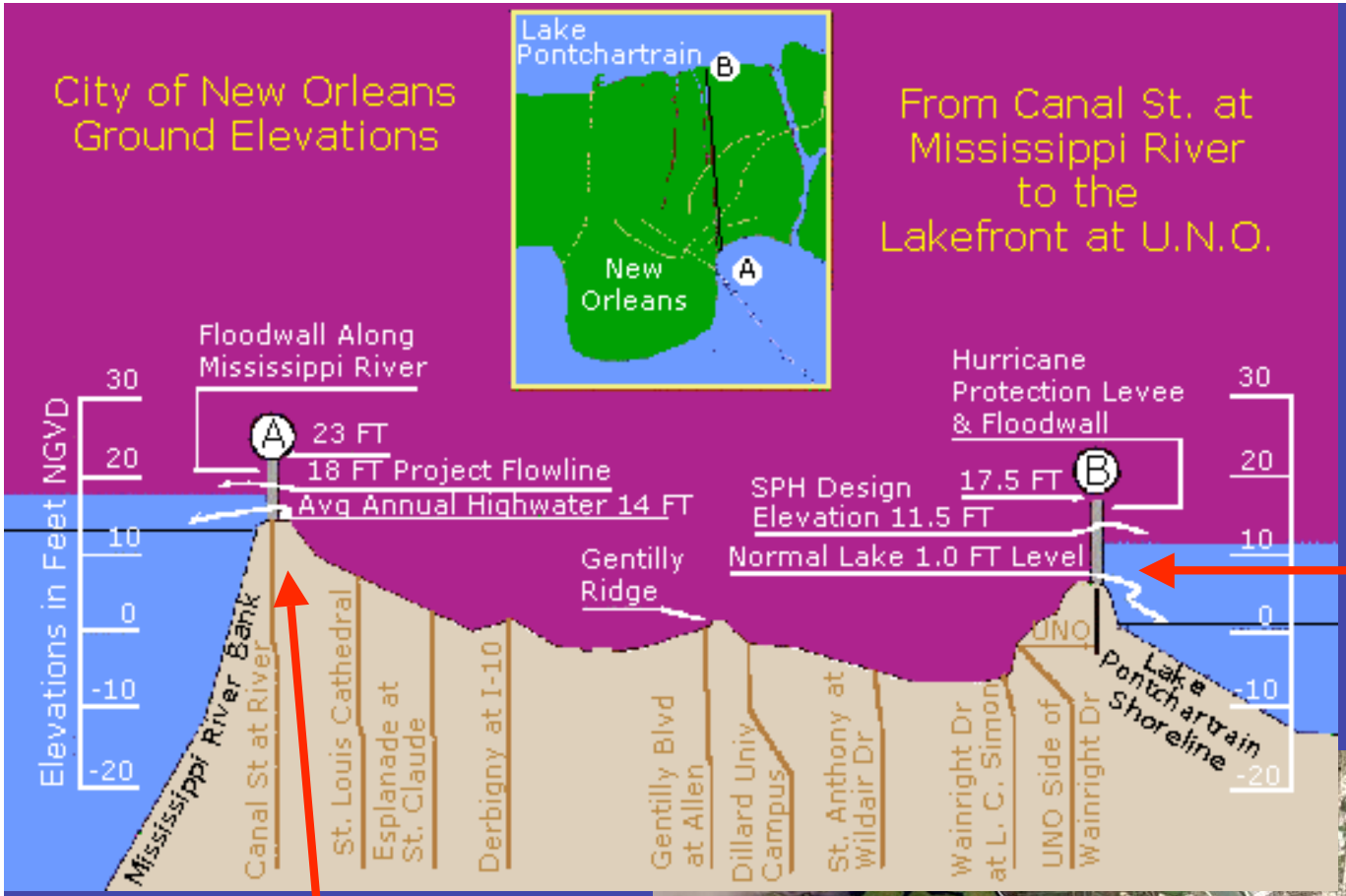
**Prevents Mississippi shifting to Atchafalaya**

**Total cost > $1 billion**



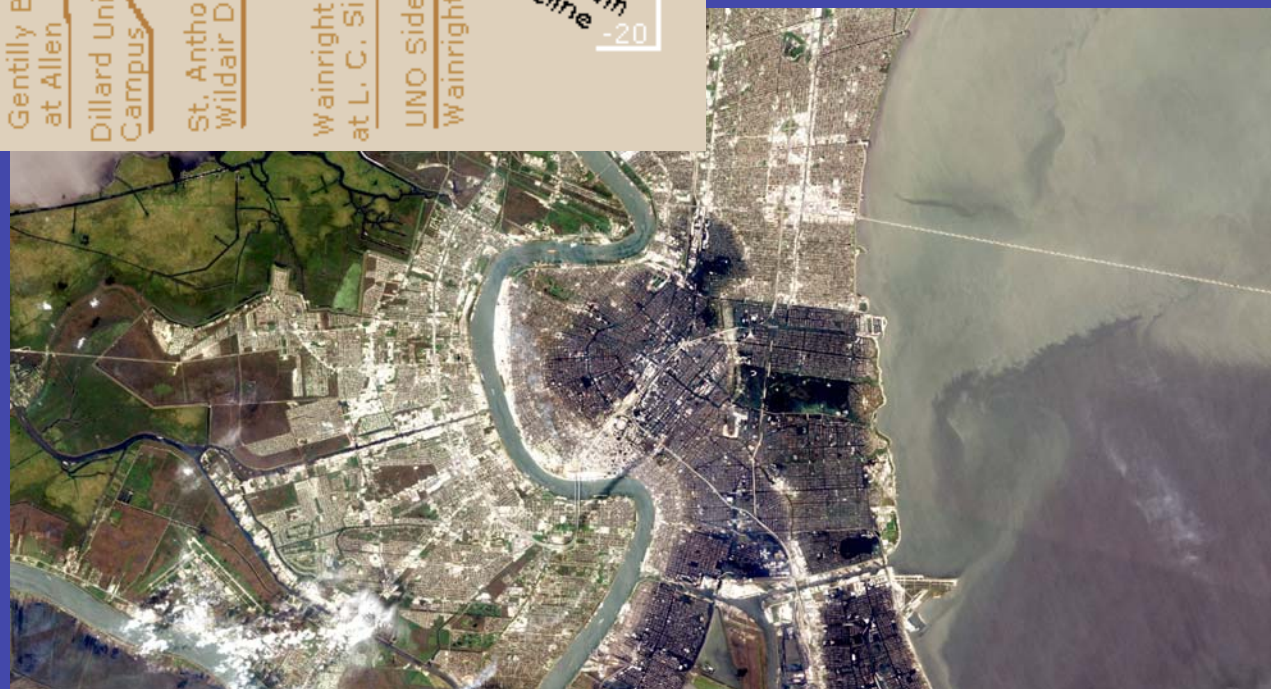


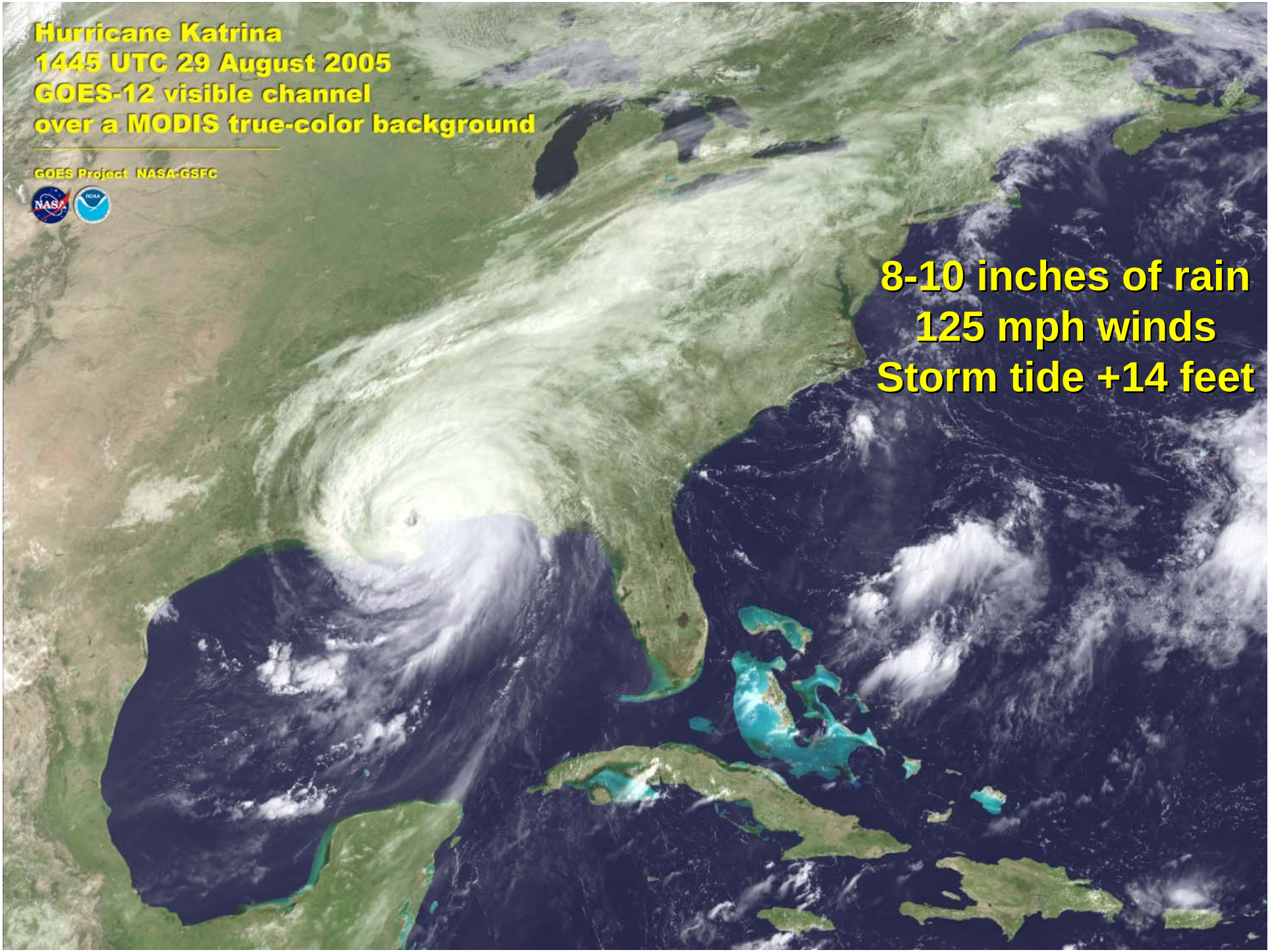
# NEW ORLEANS TOPOGRAPHY




**Lake Pontarchtrain Levee**

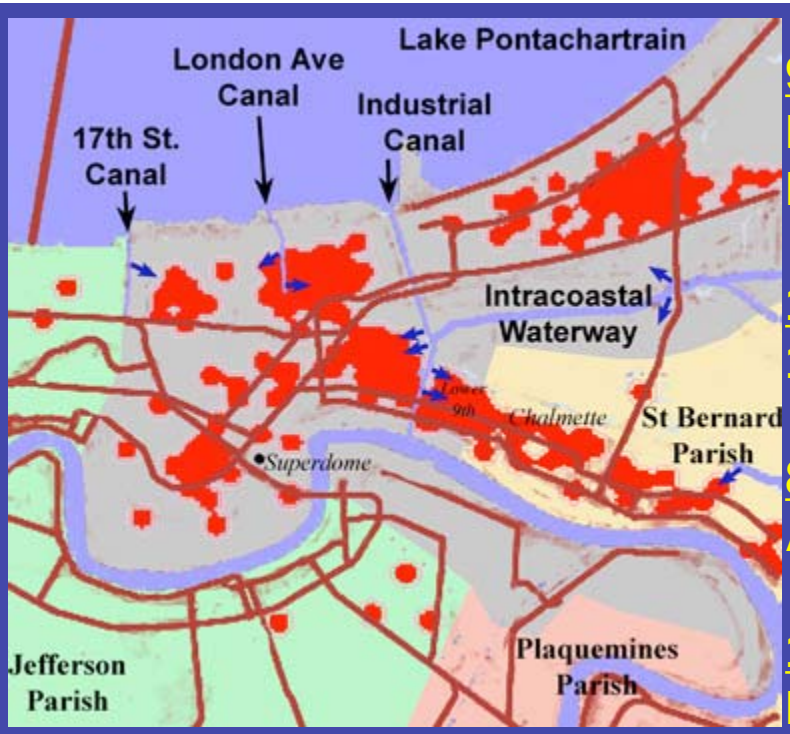
**Mississippi River Levee**




Hurricane Katrina
1445 UTC 29 August 2005
GOES-12 visible channel
over a MODIS true-color background
GOES Project NASA-GSFC
8-10 inches of rain
125 mph winds
Storm tide +14 feet



# Levee Failures




**9:00am**
**Industrial Canal**
**First pump**

**12:00pm**
**17th Street Canal**

**8:30pm**
**All pumps**

**12:00am**
**London Ave Canal**



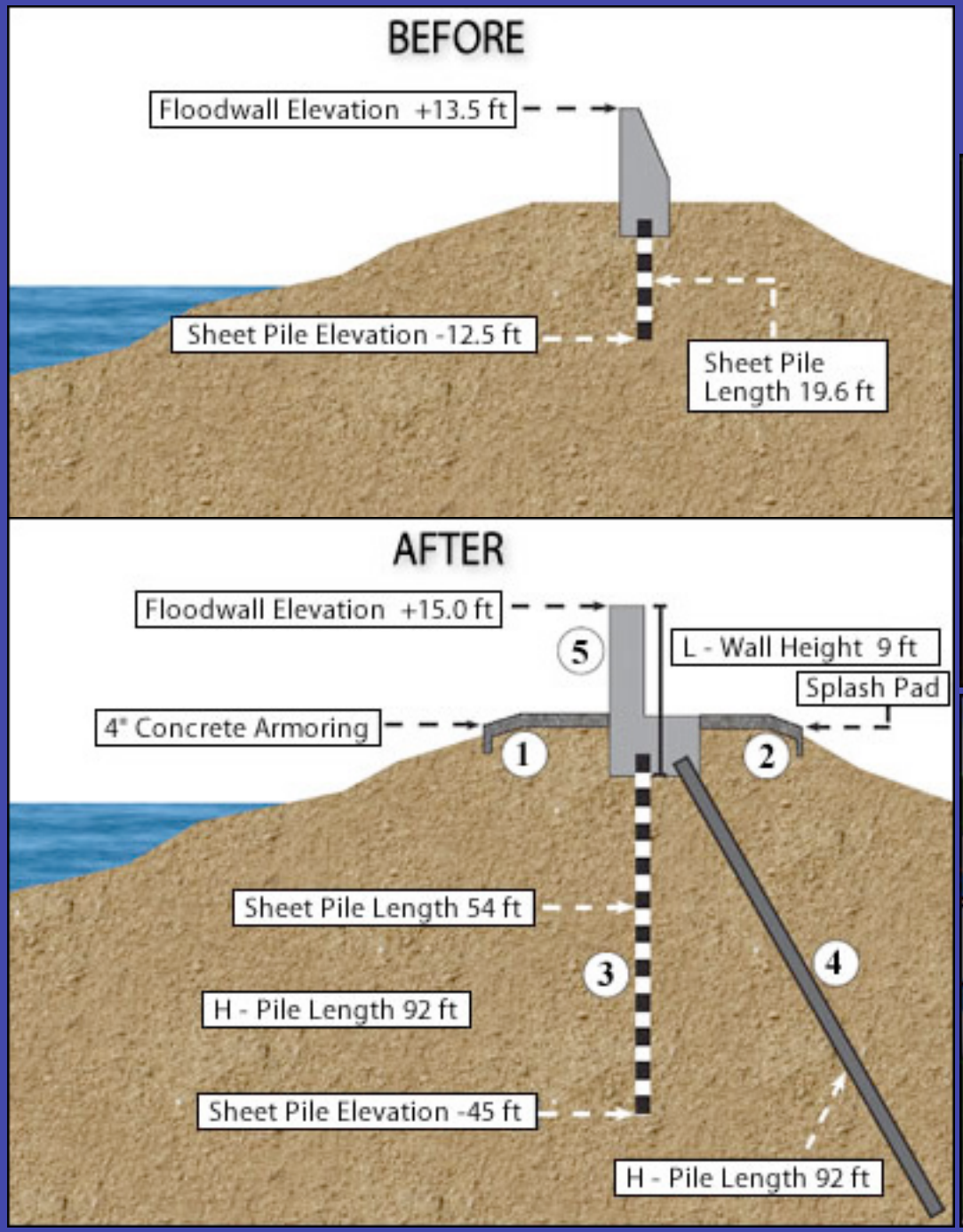





## Aftermath

**1,577 killed, 705 missing**
**$105 billion in damage**
**30 oil platforms destroyed**
**9 refineries closed**
**Massive environmental damage**






## Would you move back to New Orleans…?



