EARTH 270 – DISASTERS AND NATURAL HAZARDS (v. 2018)

Kensennuma City, Miyagi Prefecture , Japan, March 2011

PROFESSOR S.G. EVANS, PhD, PEng (Room 303, Earth Science and Chemistry (ESC) Building)

UNIVERSITY OF WATERLOO

RIVER AND COASTAL FLOODING

1999 Tar River Flooding Greenville, North Carolina

RIVER FLOODS

Flooding due to Storm Desmond (U.K.) in December 2015

2009 Philippine Floods ; in Tropical Storm Ketsana, 42.4 cm of rainfall fell on Manila in 12 hours on September 26 exceeding September monthly average. Impact = hundreds of deaths; many hundreds of thousands displaced; billions of dollars of damage


Floods in Northern England, November 2009


Flooding in Istanbul 2009


2008 Bihar Floods, India

RIVER FLOODS

- Floods occur when river discharge exceeds the capacity of the river channel
- Usually associated with heavy rains

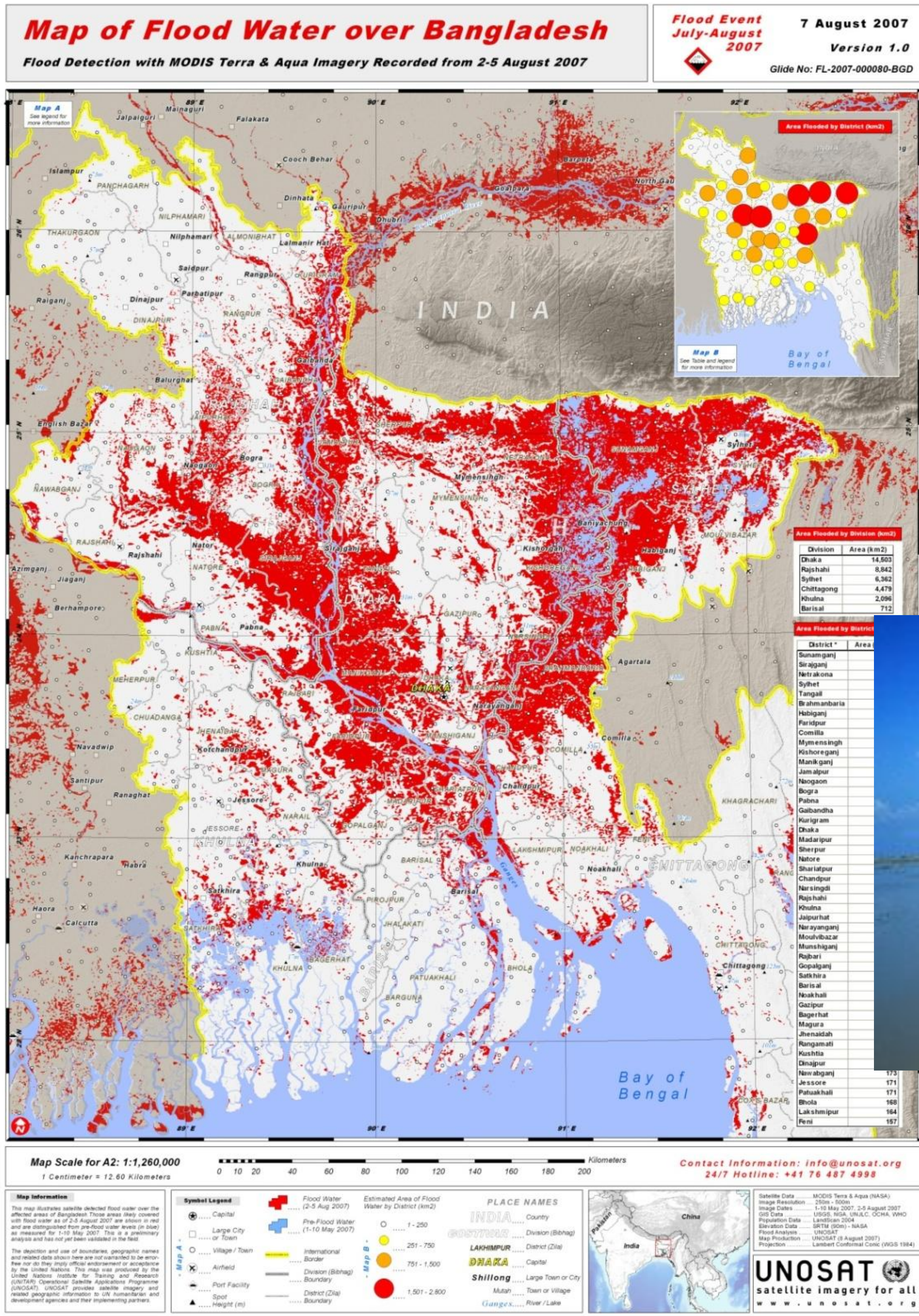
Tewkesbury UK 2007




FLOODED OUT IN LINCOLNSHIRE.—SEE PAGE 73.

Flooded out in Lincolnshire, 1869

Carlisle flooding (U.K.) – Storm Desmond, December 2015



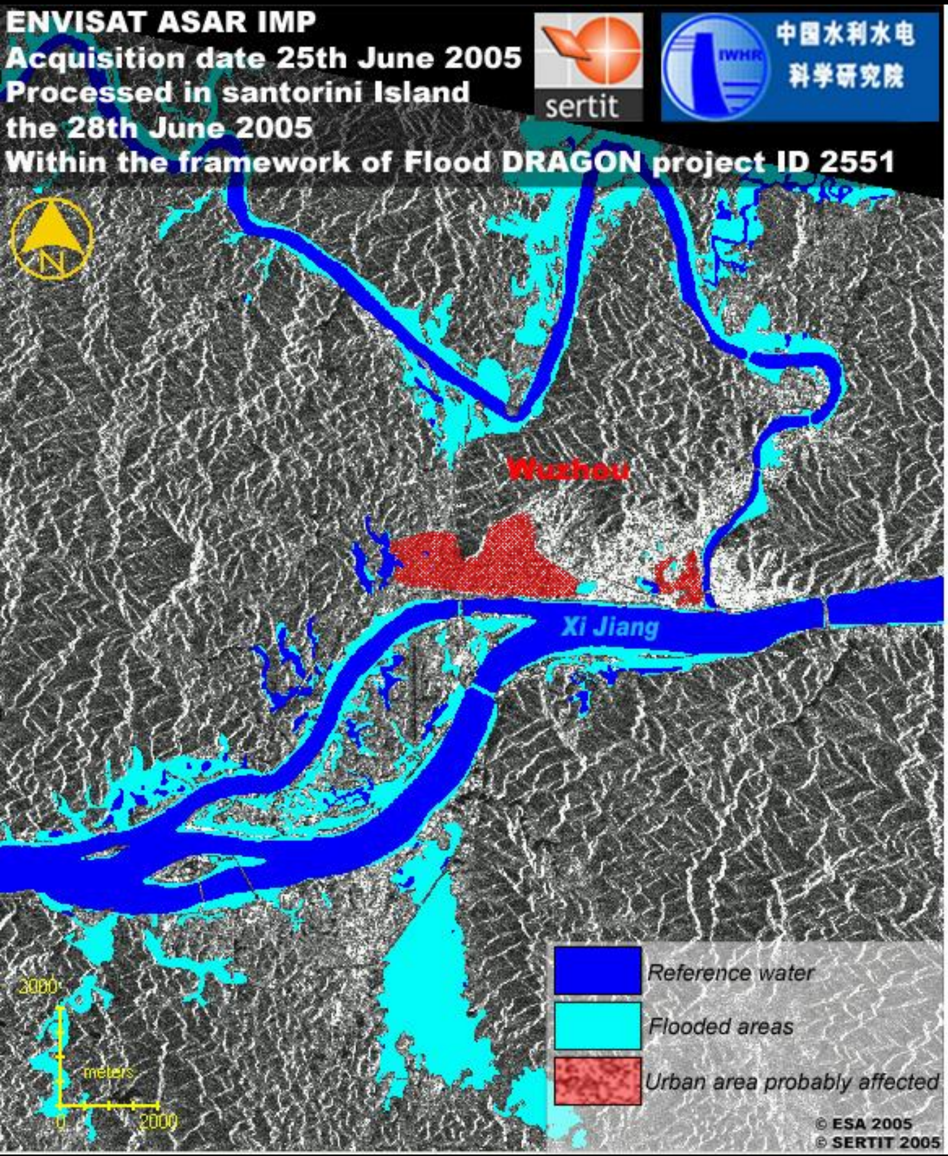
2007 FLOODS IN BANGLADESH

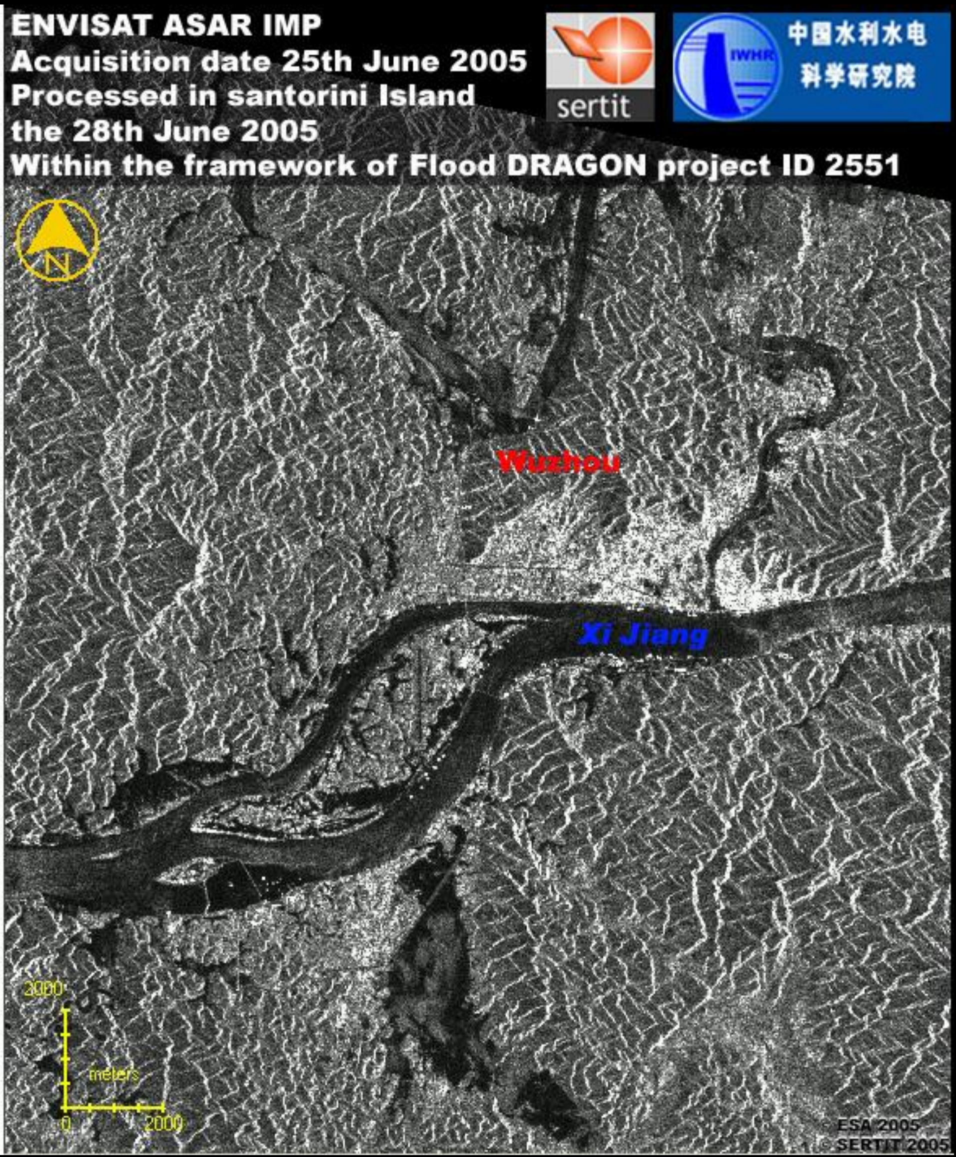
TORRENTIAL RAINS CAUSE MASSIVE FLOODS IN CHINA

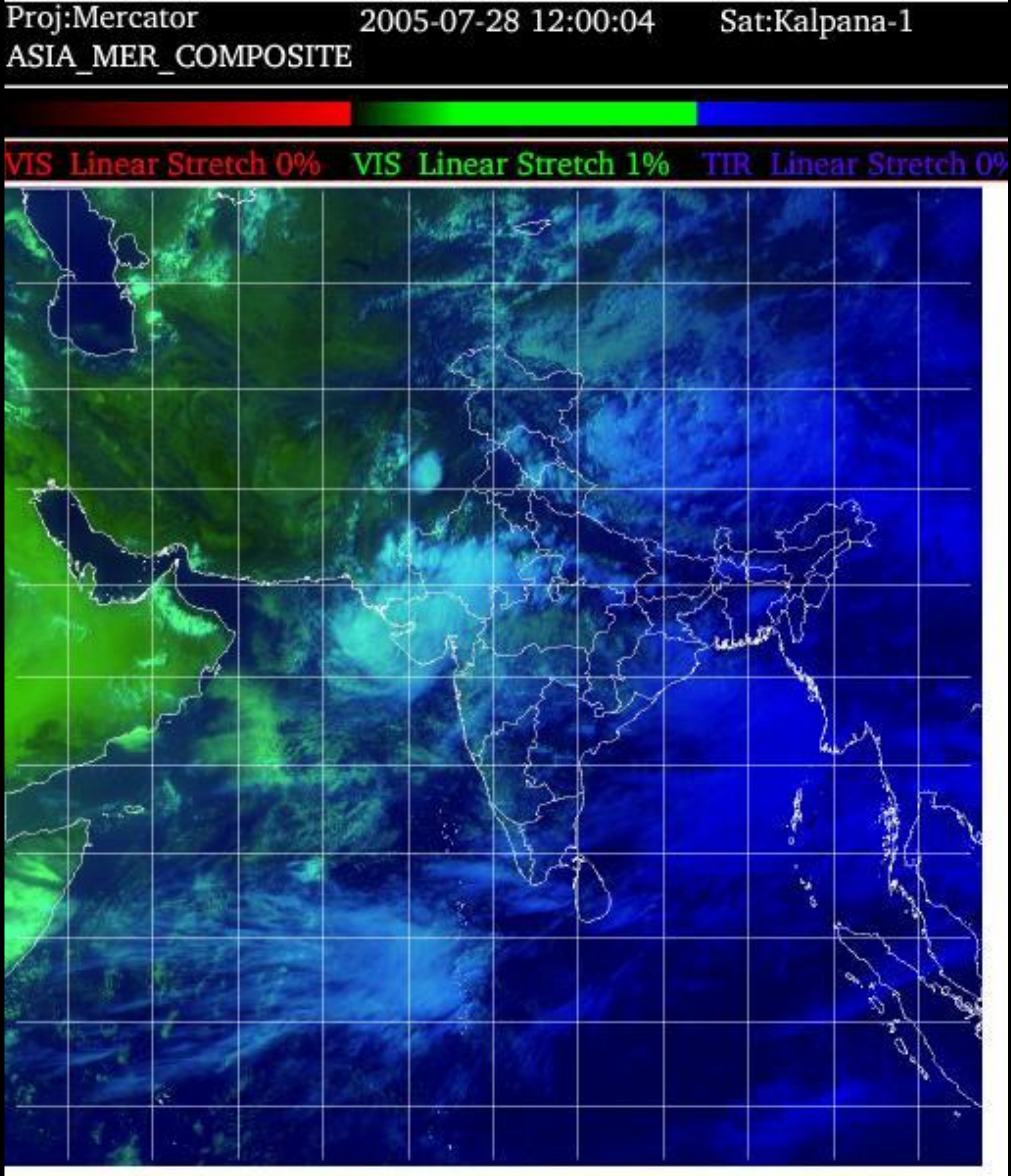
- Over 540 dead
- Over 1 M people forced from their homes
- $ 2.45 B damage
- Rains have caused destructive landslides

June 24, 2005

FLOODING ON THE XI JIANG RIVER, CHINA – JULY 2005







MUMBAI RAINS OF 2005 – WORLD RECORD RAINFALL

INDIA FLOODS – JULY 2005; VERY HEAVY MONSOON RAINS, MUMBAI (BOMBAY)

65 cm in one day (july 26)

- > 500 deaths
- Most killed in landslides
- Damage in excess of $110M

Missouri Highways and Transportation Department

Missouri Flood 1993; Jefferson City, MO.

TABLE 14.1

U.S. Flood Deaths and Damages by Decade, 1960–2004

	Decade	Deaths	Damages (In Billions of 1997$)
	1960–1969	1,297	21.808
	1970–1979	1,819	48.887
	1980–1989	1,097	33.222
	1990–1999	992	55.586
	2000–2004*	303	7.358
Totals	45 years	5,508 deaths	$166.861 billion

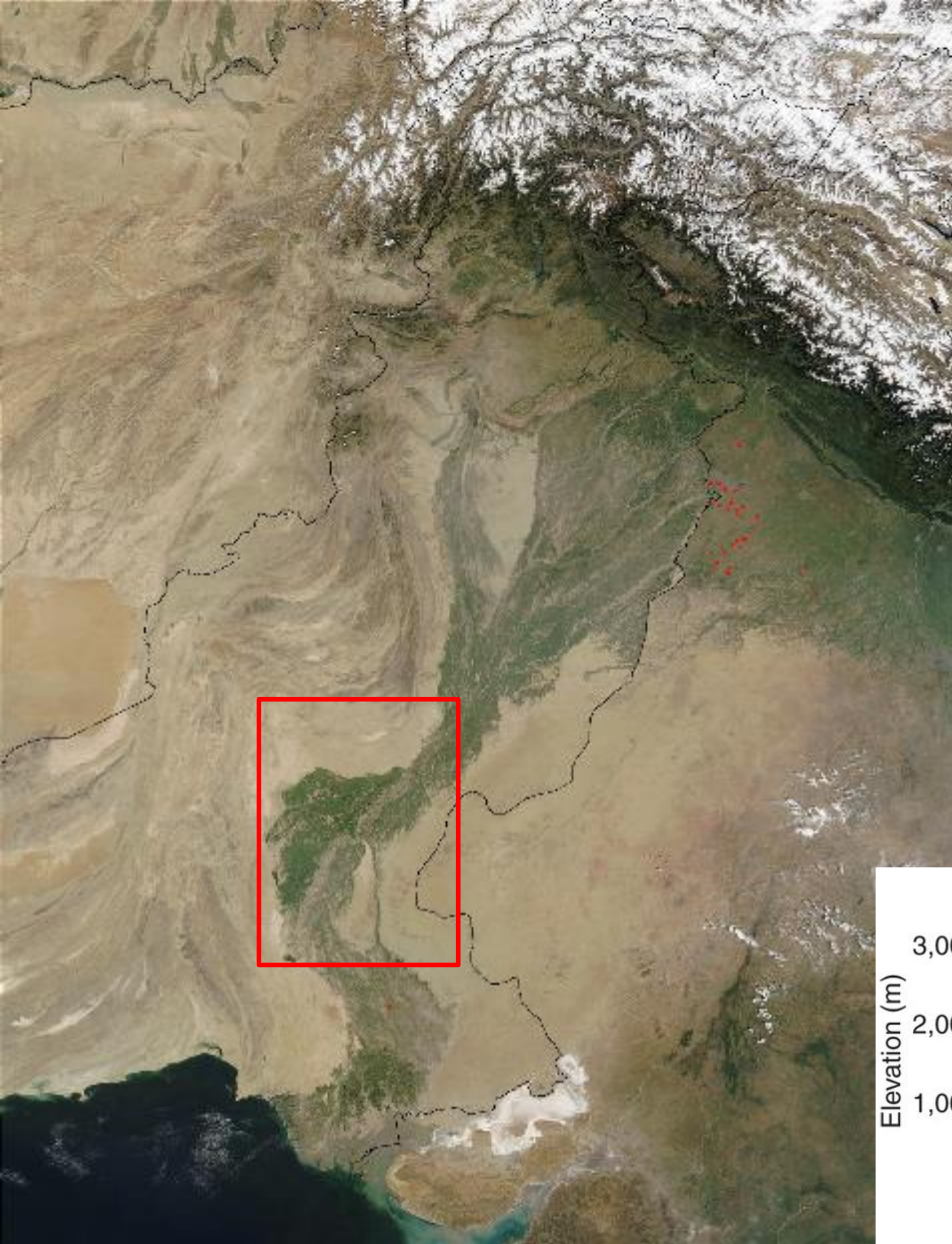
Average Deaths per Year = 122

Average Damages per Year = $3.71 billion

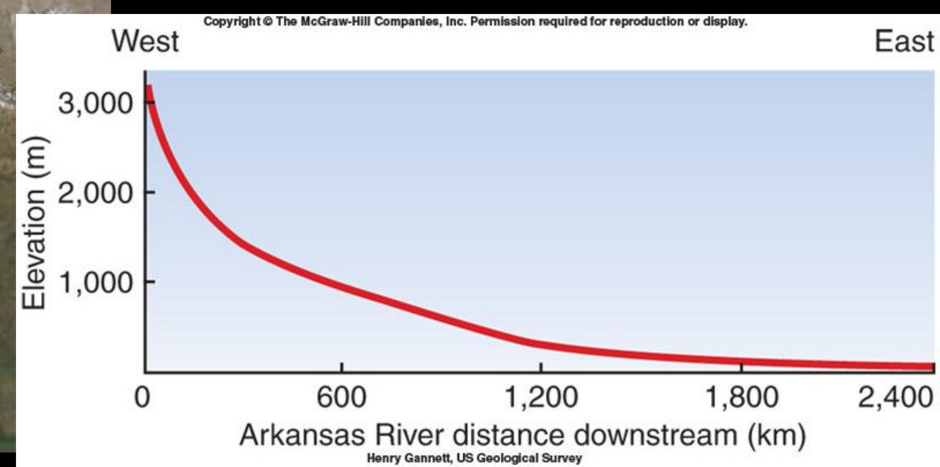
*Half decade

Data from National Weather Service, NOAA.

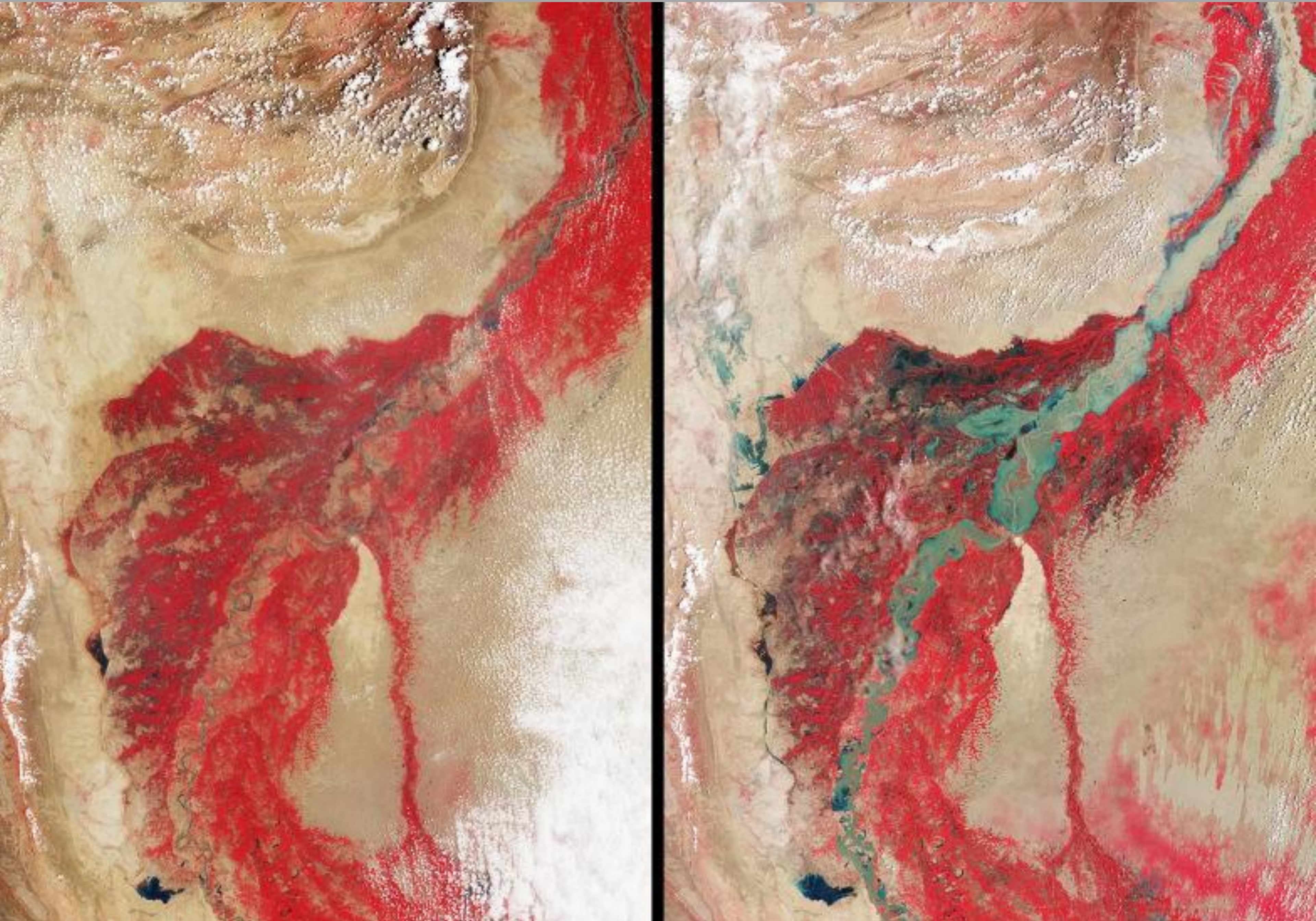
THE INDUS RIVER



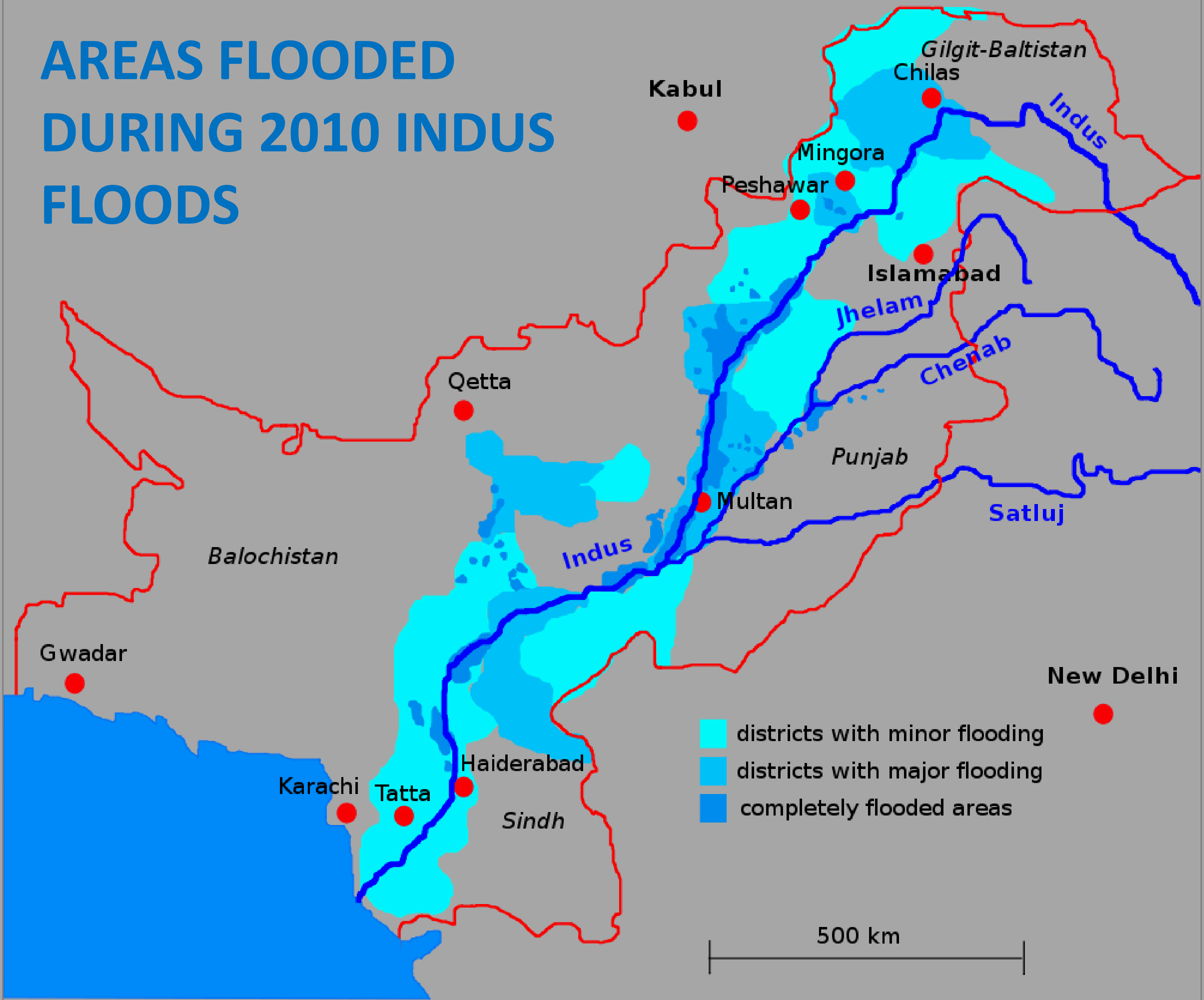
1. Drains the Himalayas
2. Removes mass from the mountain chain
3. High gradient in the mountains
4. Low gradient in the Plains
5. Delta rapidly growing because of sediment delivery
6. A geological conveyor belt



INDUS FLOODS, PAKISTAN [JULY-AUGUST 2010]



AREAS FLOODED DURING 2010 INDUS FLOODS

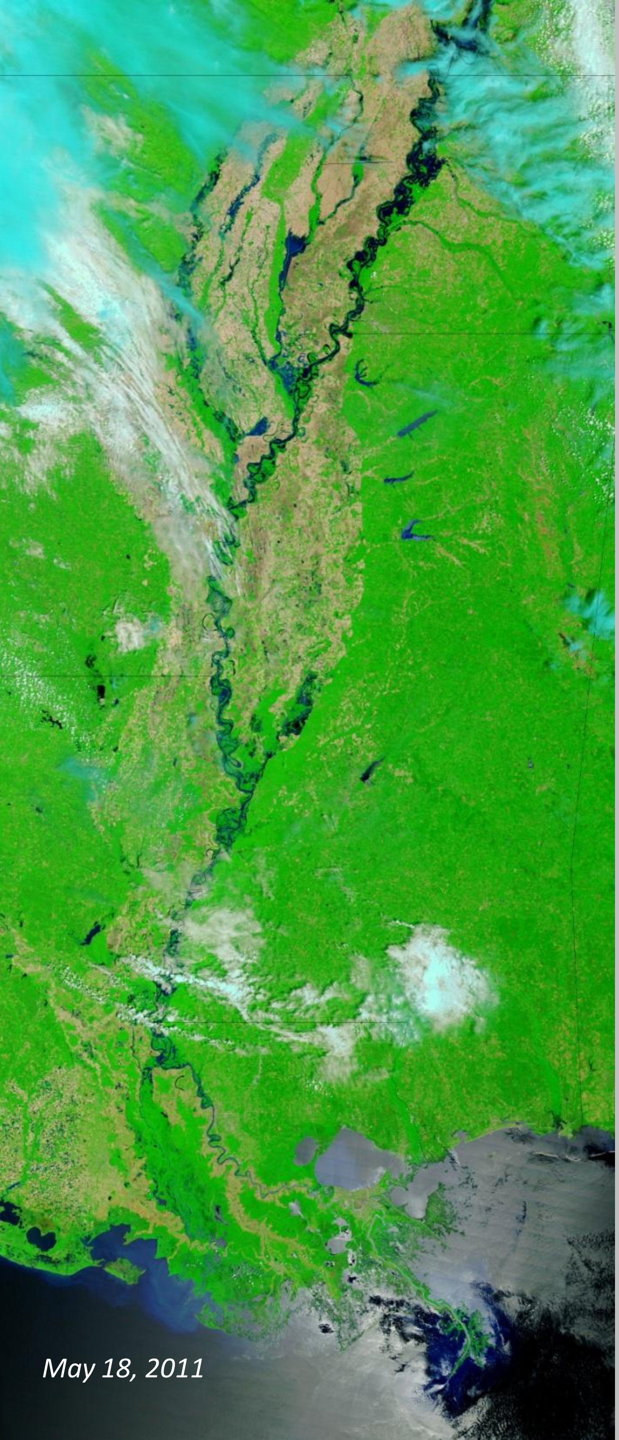


Flooding in Nowshara District, NW Frontier Province, July 30, 2010

FLOODING IN JULY-AUGUST 2010 AFFECTED 20 M PEOPLE; AT ONE POINT 1/5 OF PAKISTAN WAS UNDER WATER

FLOOD CONTROL DAM ON THE INDUS – TARBELA DAM

INDUS DELTA – ANOTHER MEGADELTA

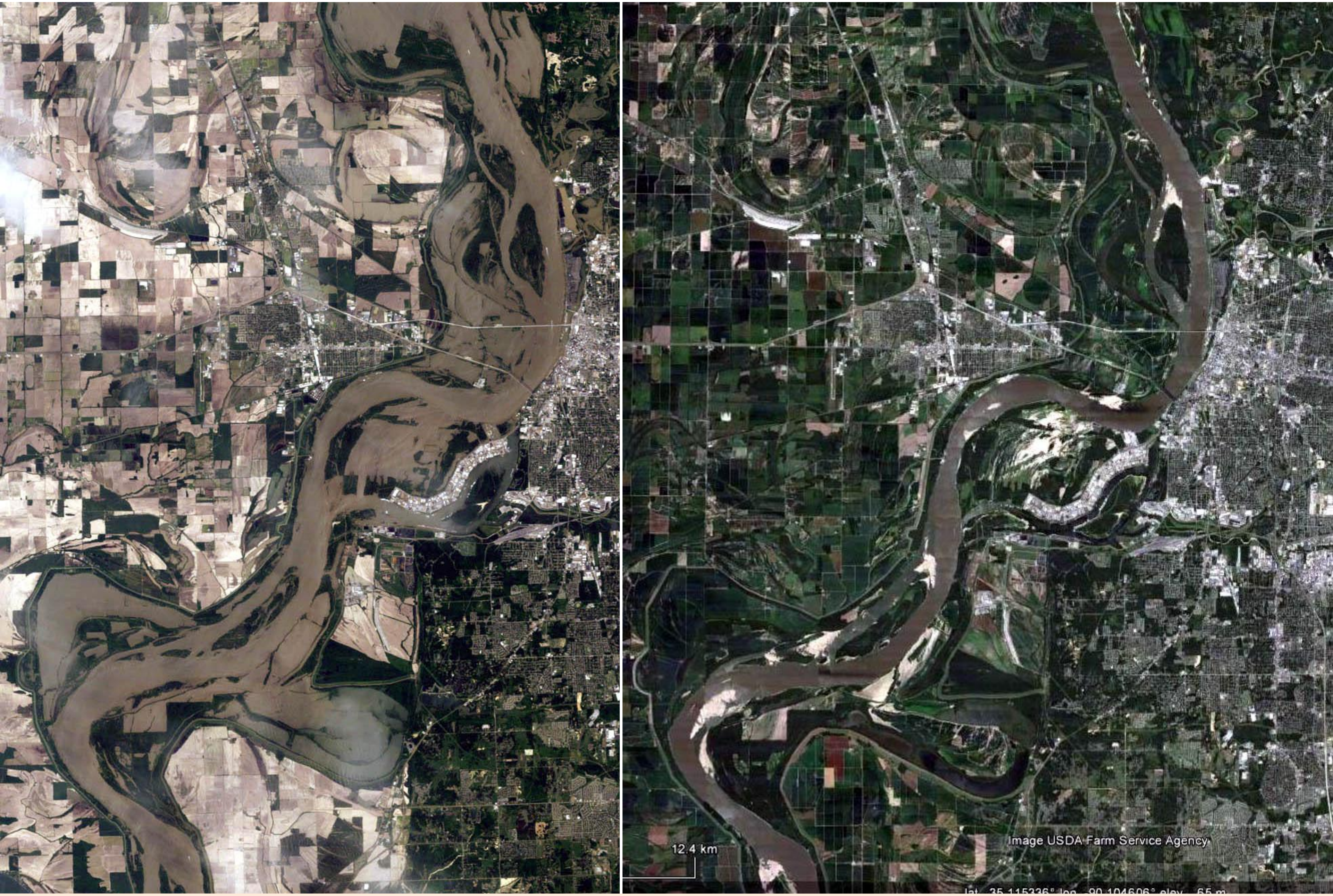


SUPER FLOODS ON THE MISSISSIPPI

2011 MISSISSIPPI RIVER FLOODS

- Comparable to the super floods of 1927 and 1993
- Morganza Spillway (completed in 1954) opened for the first time in 1973 and opened again in 2011

Mississippi Valley, north of New Madrid, Missouri , May 3, 2011



FLOODING OF THE MISSISSIPPI RIVER AT MEMPHIS, MAY 10, 2011

evaluate

- Each term, the University of Waterloo asks its students to rate their instructors and courses; your Faculty of Science course evaluation surveys are online at evaluate.uwaterloo.ca.

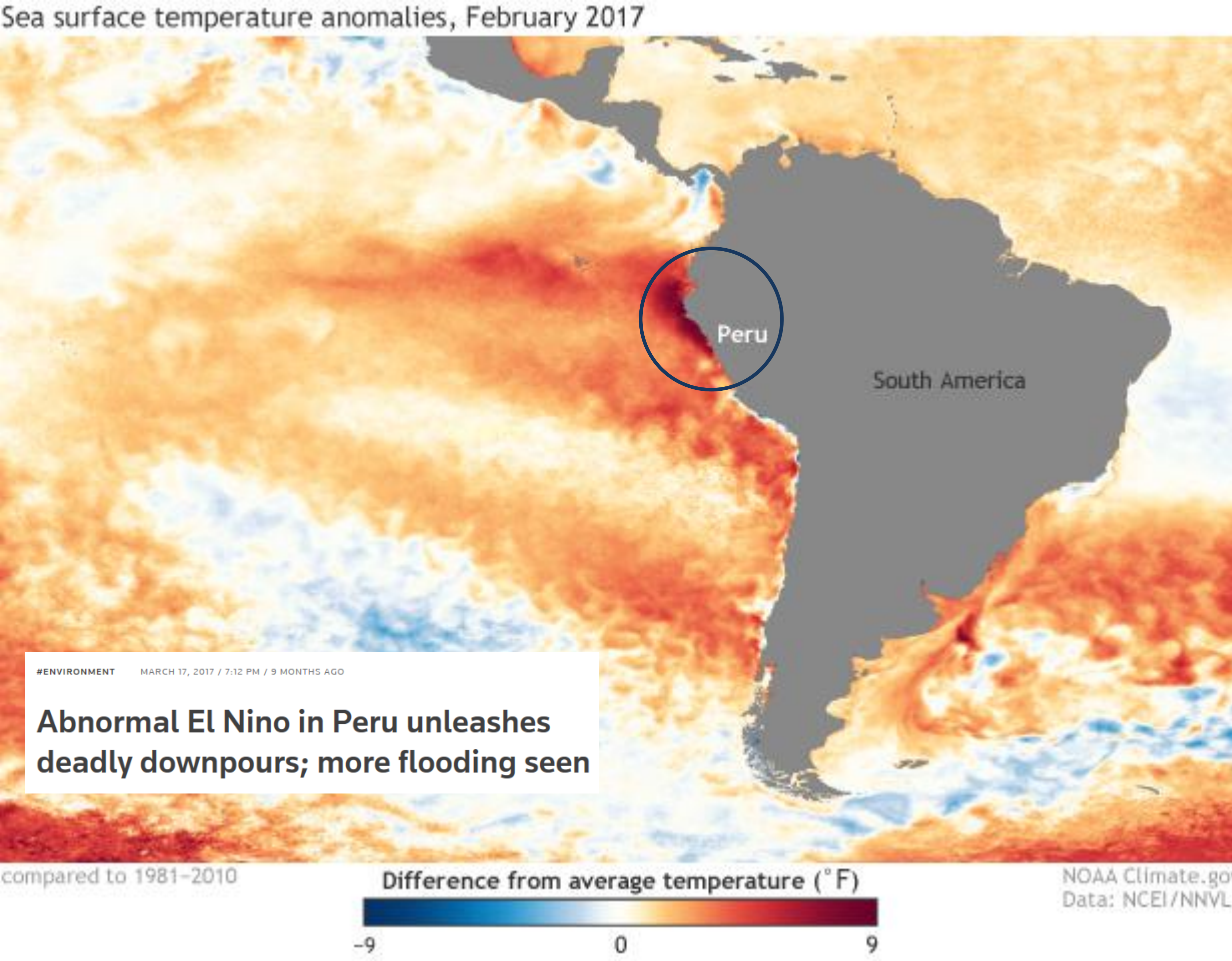
- Results are available to instructors and administrators only after grades are due.

- The results are completely **anonymous.** You need to log in to be sure you get access to the correct courses but your identifiers are not associated with your forms.

- **Your feedback matters to me because**:
  - I obtain your constructive feedback about the course and me as the instructor
  - I can use this feedback to aid with course and self-improvement
  - University administrators use student ratings as one data source when evaluating my performance

FLOODING DUE TO HEAVY RAINS [EL NIÑO AND MONSOON]

Flooding in Mumbai, August 2017


Sea surface temperature anomalies, February 2017
Peru
South America
#ENVIRONMENT
MARCH 17, 2017 / 7:12 PM / 9 MONTHS AGO
Abnormal El Nino in Peru unleashes deadly downpours; more flooding seen
compared to 1981–2010
Difference from average temperature (°F)
-9
0
9
NOAA Climate.gov
Data: NCEI/NNVL

Flooding in Lima [March 2017]

Flooding in Lima [March 2017]

Flooding in Huachipa area of Lima, March 17, 2017

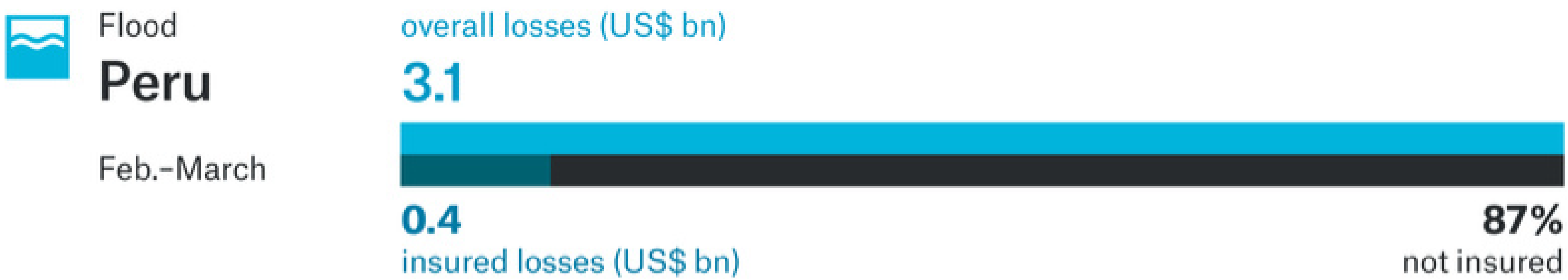
Trujillo, Peru; March 21, 2017

Floods in Peru

Following persistent rain in Peru in February and March, numerous rivers burst their banks, causing severe flooding, landslides and mudflows. Large areas in the north of the country (Piura, Paita, Ayabaca, Tumbes and Lambayeque) were devastated, and even the area around Lima was affected. The Peruvian capital, with its 10 million inhabitants, is situated on the Pacific coast, a flat region that generally experiences only slight rainfall. On dry soil with little vegetation, rainwater accumulates on the surface instead of soaking into the earth. Many people were killed in the floods, with infrastructure and more than 200,000 buildings severely damaged.

Due to the low insurance density, only a small fraction of the overall losses of US$ 3.1bn was insured. The insured loss was just US$ 380m. The insured portion was still higher than the national average: in the past, only about 9% of natural catastrophe losses have been covered by insurers.

Data from the Munich Re Insurance Company



Peru raises cost of post-floods rebuilding to nearly $8 billion

PERU 2017 GDP – $210.6B
Cost of rebuilding - ~ 4% of GDP

Pablo de la Flor, who was appointed by President Pedro Pablo Kuczynski to lead the reconstruction effort, said 38 percent of the new total will pay for rebuilding highways, roads and bridges. The rest will be used to help build homes, schools, health clinics, sewage systems and farms affected by the floods.

"Without a doubt this is the most important fiscal effort in Peru's recent history," de la Flor told a press conference.

Finance Minister Fernando Zavala said the cost increase would be included in the budget in 2019 or 2020.

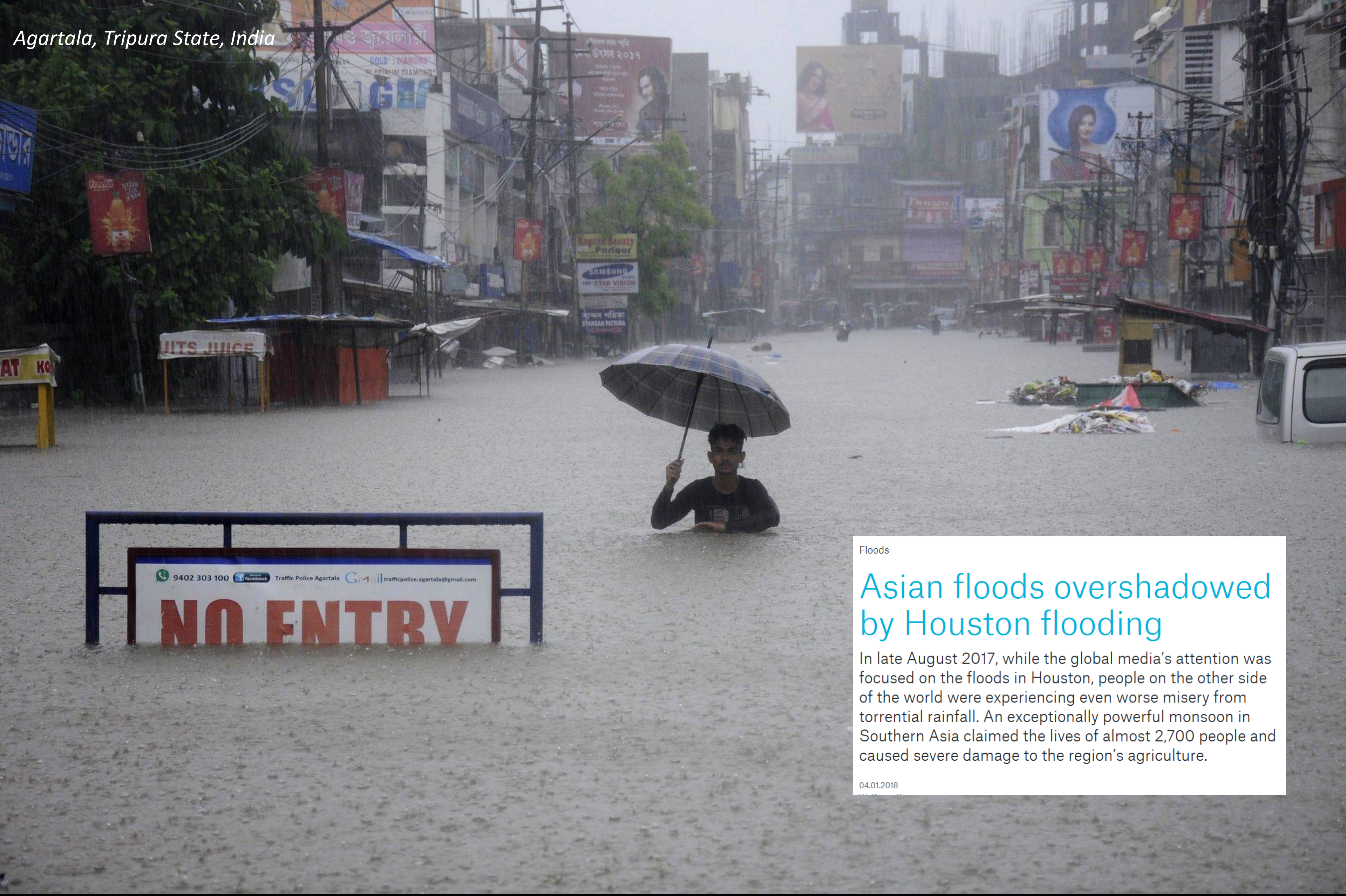
The rebuilding plan was approved by Kuczynski's cabinet on Wednesday and does not need a green light from Congress.

Early this year an unusually brutal rainy season due to a sudden warming of Pacific waters killed 162 people, slowed economic growth sharply and caused damage equivalent to 2 percent of Peru's gross domestic product.

De la Flor said the government would likely start awarding contracts at the end of the year.

Reuters, Sept 6, 2017

Agartala, Tripura State, India



Floods

Asian floods overshadowed by Houston flooding

In late August 2017, while the global media's attention was focused on the floods in Houston, people on the other side of the world were experiencing even worse misery from torrential rainfall. An exceptionally powerful monsoon in Southern Asia claimed the lives of almost 2,700 people and caused severe damage to the region's agriculture.

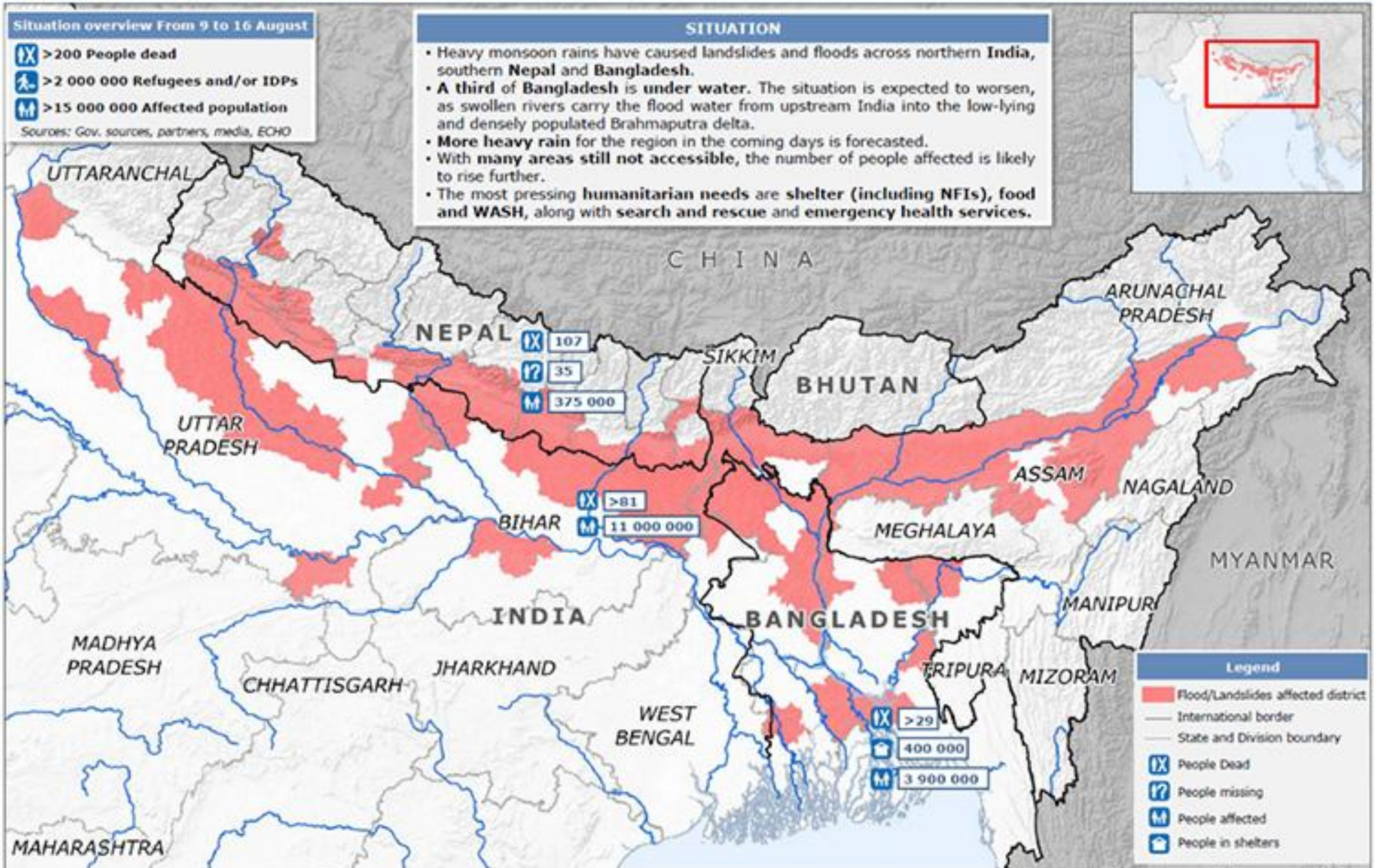
04.01.2018

MORE THAN 2,000 DEATHS IN SOUTH ASIA FLOODS, AUGUST 2017

Emergency Response Coordination Centre (ERCC) – DG ECHO Daily Map | 17/08/2017

Nepal, India, Bangladesh | Floods

European Commission | European Civil Protection and Humanitarian Aid Operations



Flooding in Assam State, India: August 2017

Monsoon South Asia
Devastating floods, almost no insurance

Munich Re

Source: Munich Re NatCatSERVICE

Floods caused by the 2017 monsoon claimed some 2,700 lives in South Asia

Flooding caused by monsoon rains in Mumbai [August 2017]

Mumbai authorities under fire over monsoon floods

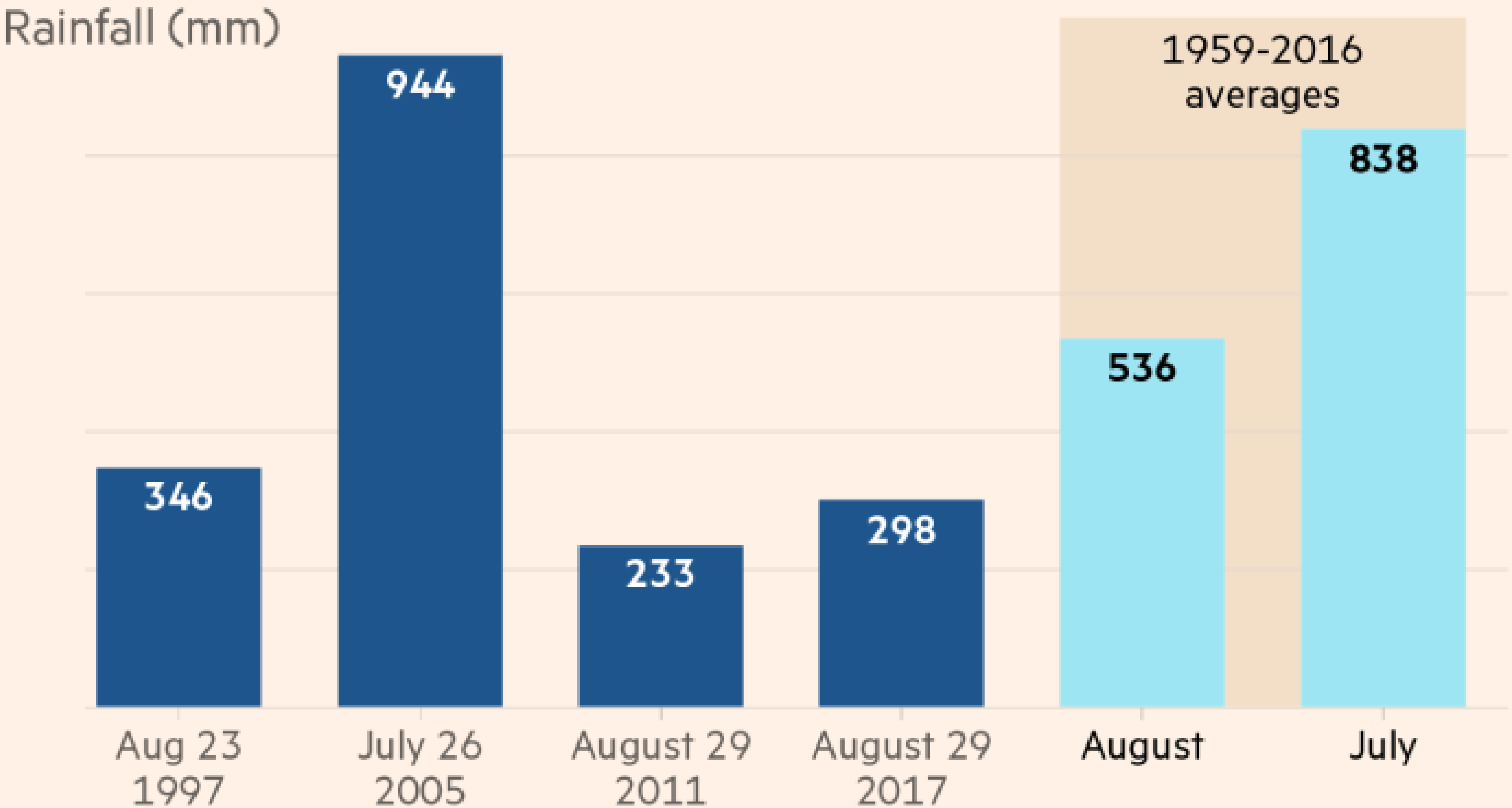
Critics ask why India's richest city is failing to defend itself against annual rains

A man wading through a water-logged road past a stranded car in Mumbai last week © Reuters

Financial Times, September 6, 2017

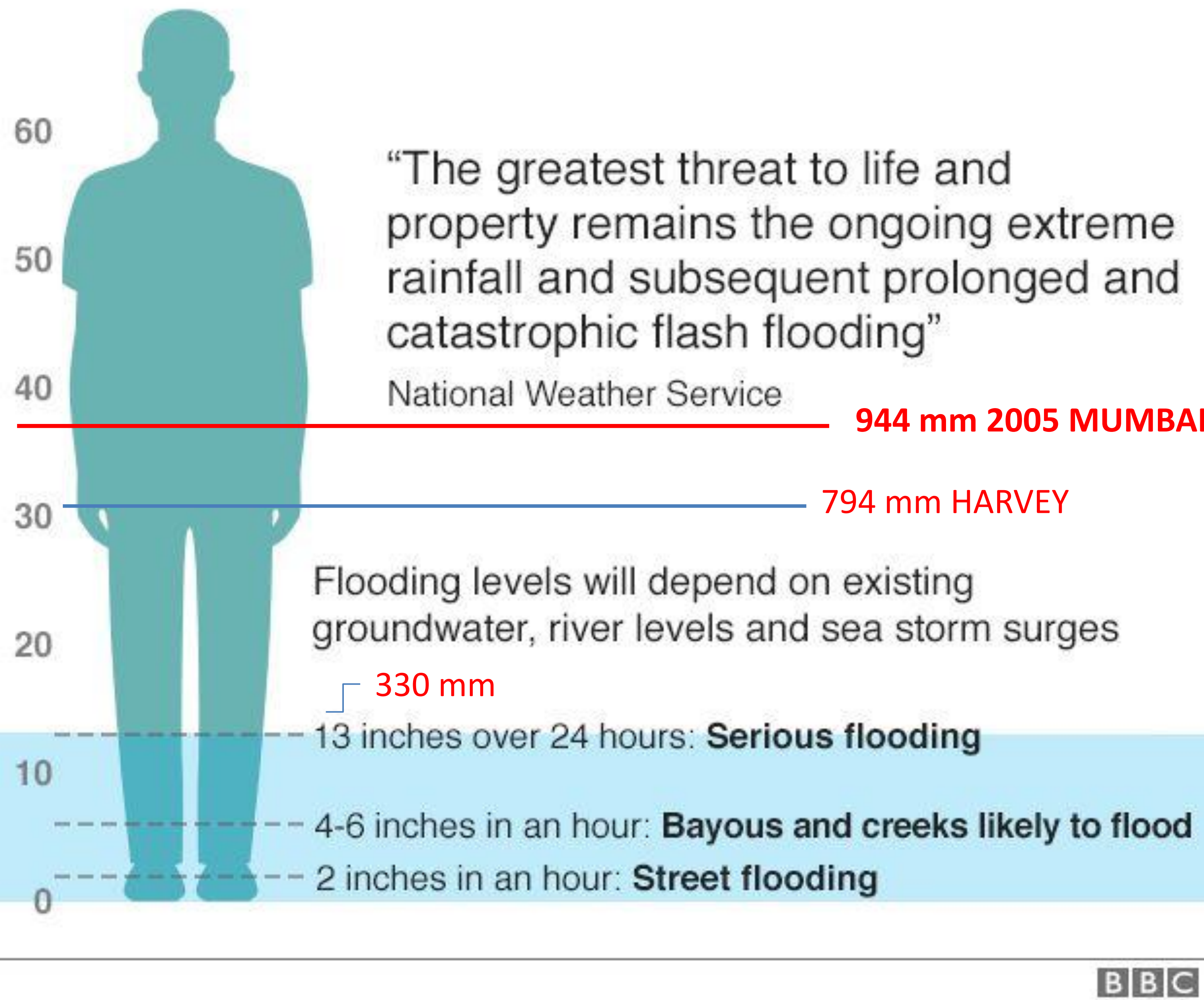
Mumbai's monsoon downpours

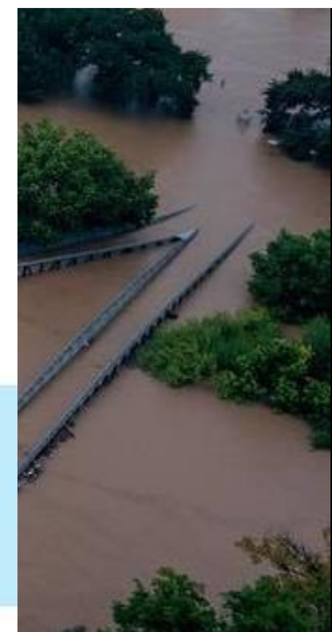
The city is prone to concentrated bursts of rain during its monsoon, with weeks' worth of average precipitation sometimes occurring in a single day.



Source: India Meteorological Department

Risks posed by heavy rainfall





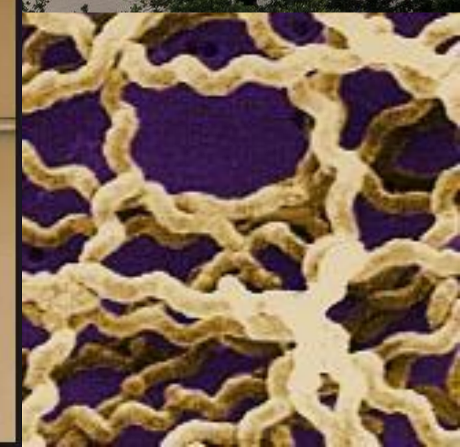
Centers for Disease Control and Prevention
CDC 24/7: Saving Lives, Protecting People™

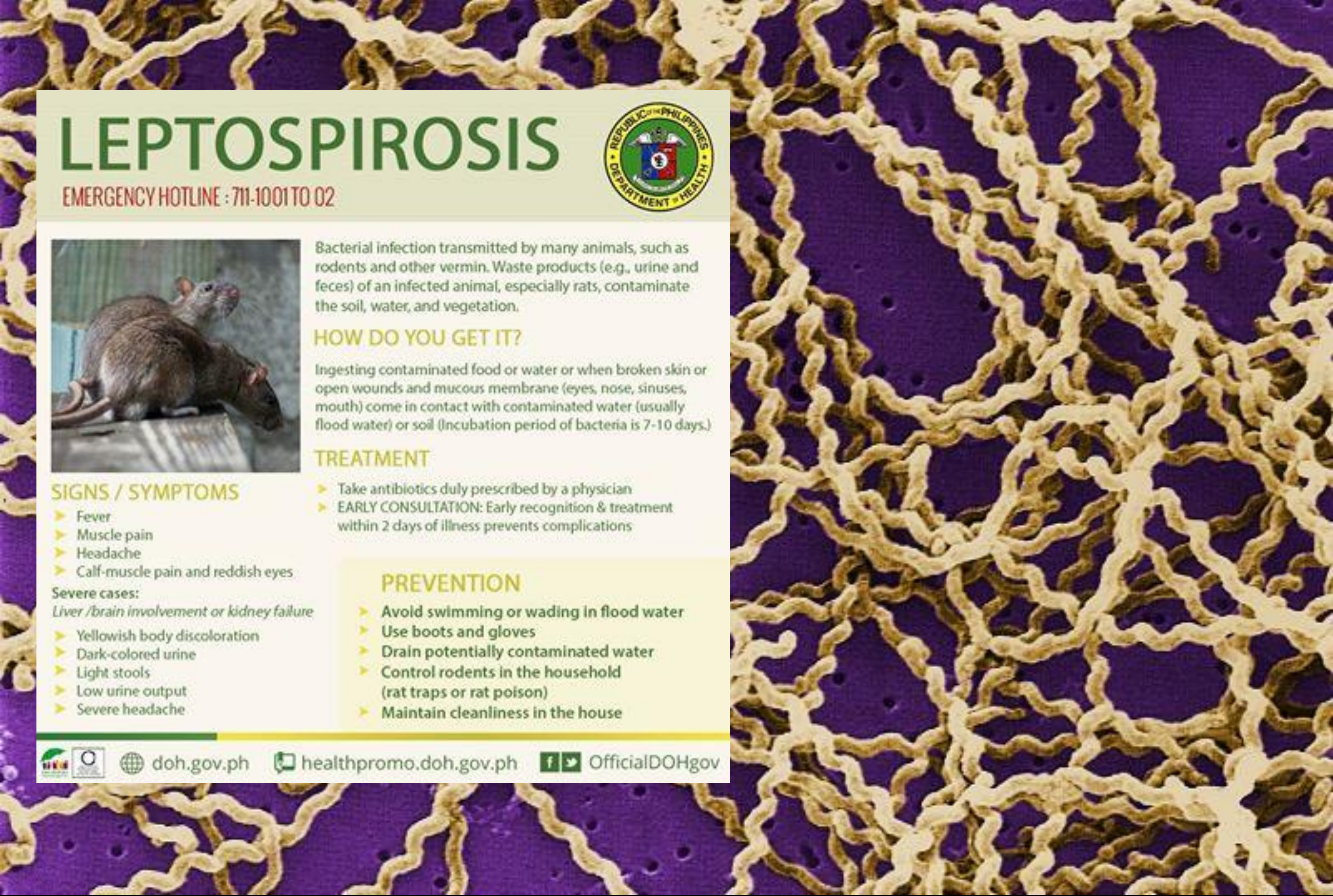
Hurricanes, Floods and Leptospirosis

Leptospirosis is a bacterial disease that can cause serious illnesses such as kidney or liver failure, meningitis, difficulty breathing, and bleeding. Cases of leptospirosis can increase after hurricanes or floods when people may have to wade through contaminated water or use it for drinking or bathing.

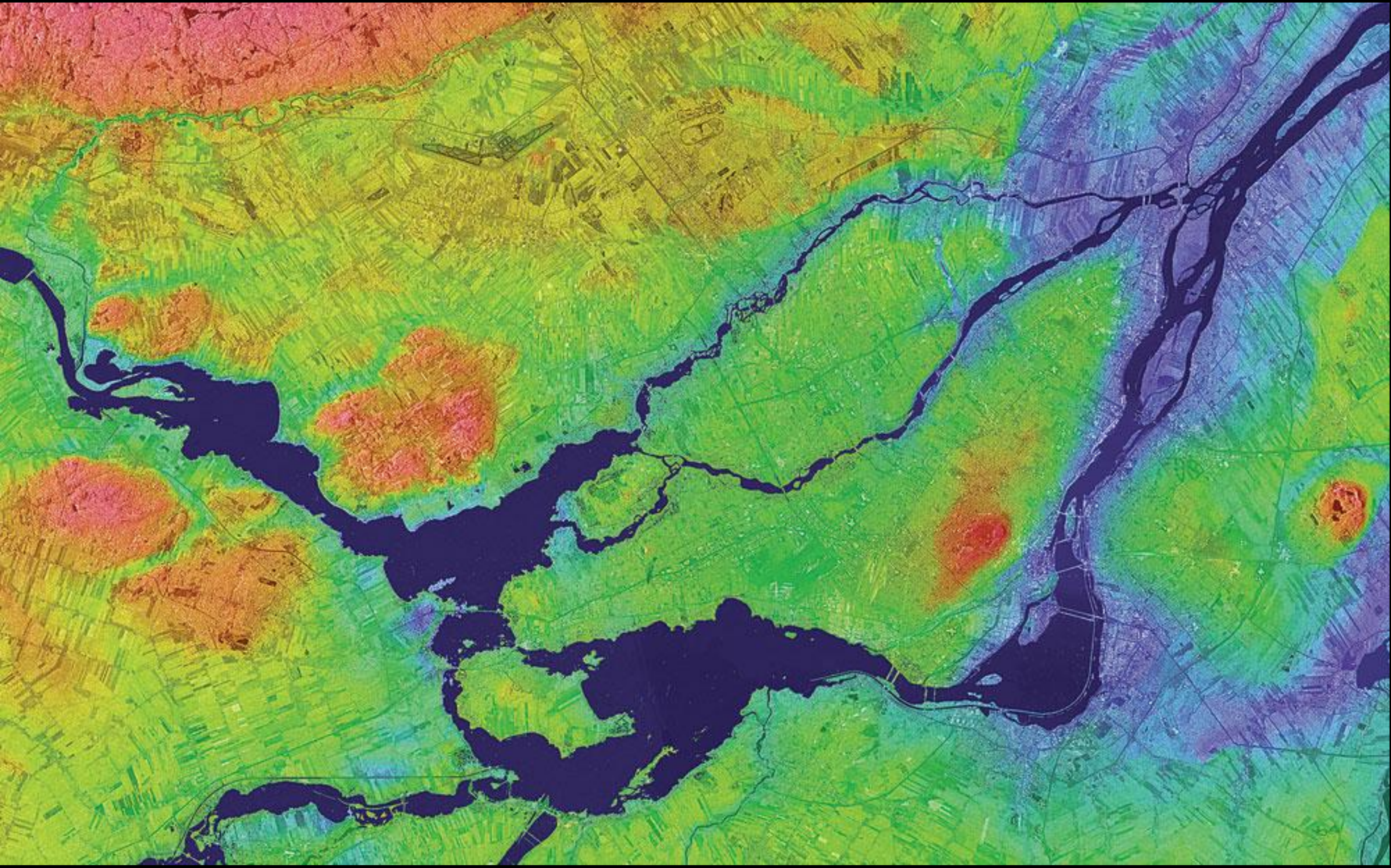
How do people get leptospirosis?

People can get leptospirosis when they have contact with water or soil containing urine or other body fluids from infected animals or if they directly touch the urine from an infected animal. A variety of animals can spread leptospirosis, including rodents, dogs, livestock, and wildlife.





Leptospirosis bacteria

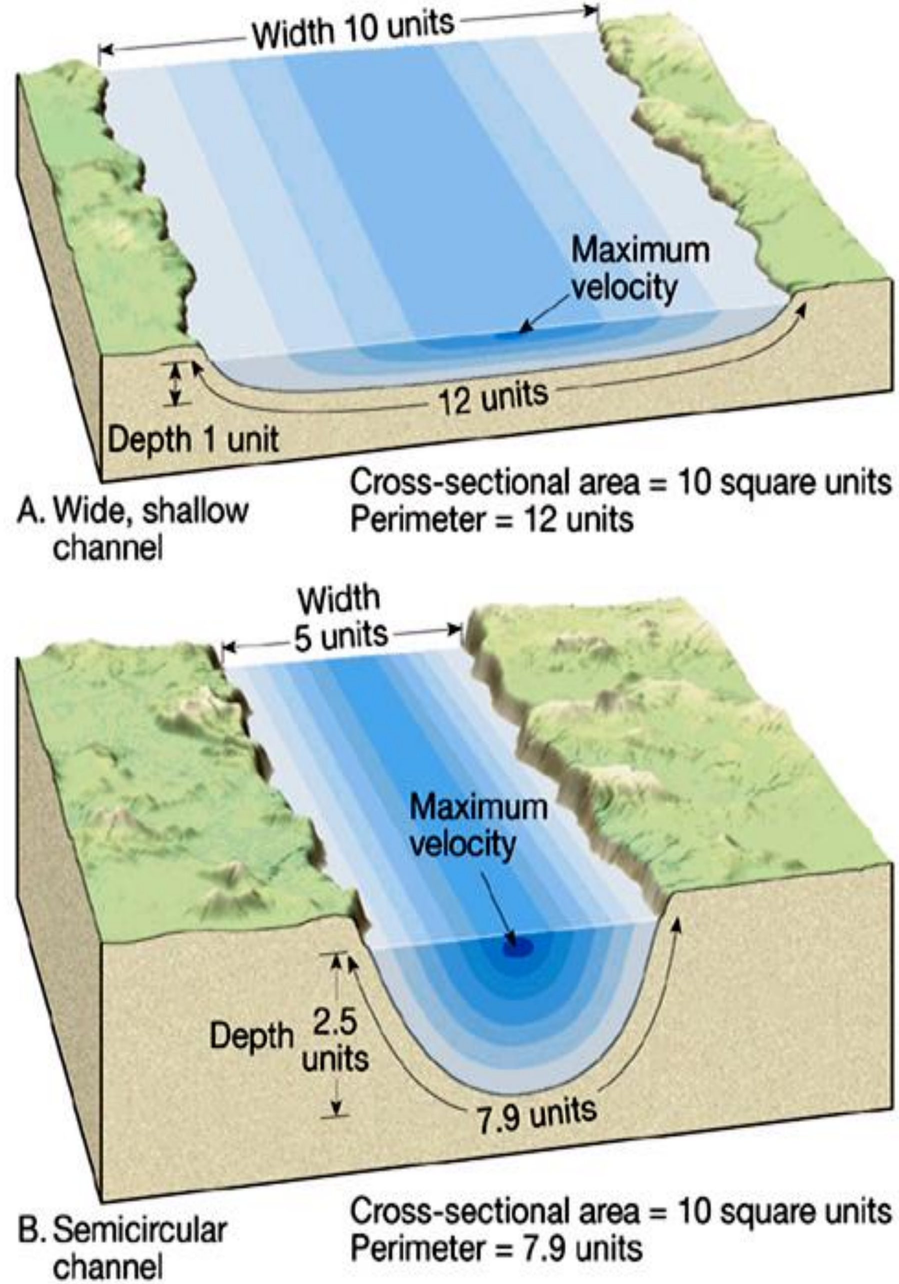


ST. LAWRENCE RIVER SYSTEM IN THE VICINITY OF MONTREAL

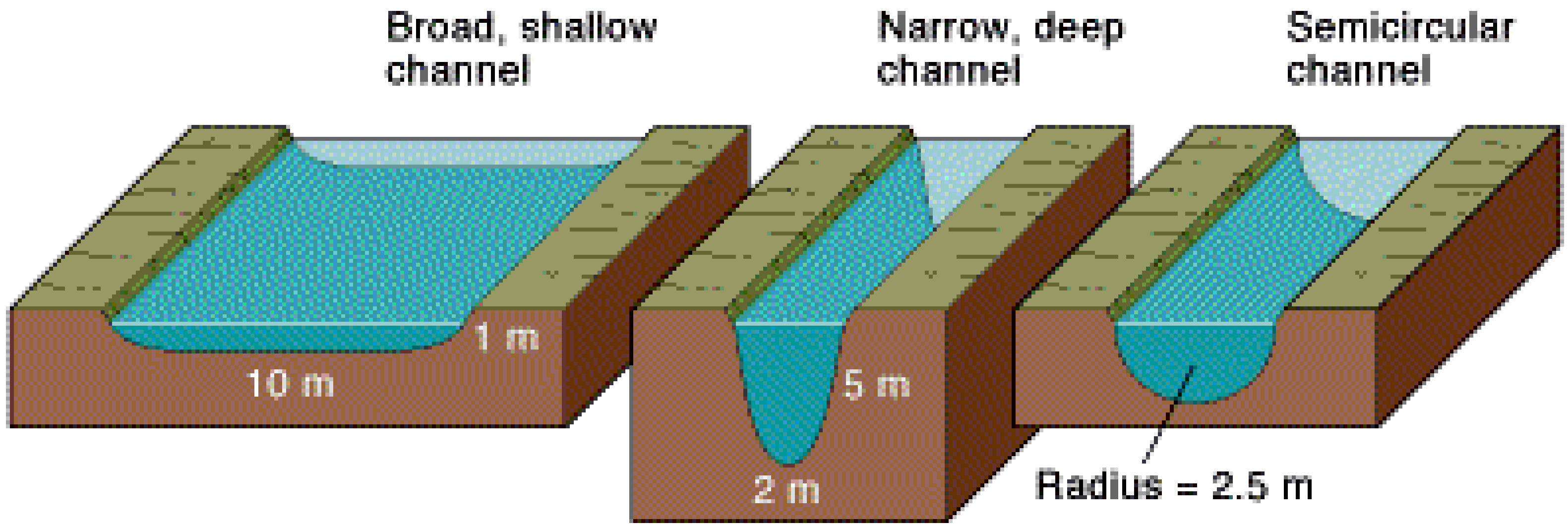
THE RIVER CHANNEL AND THE FLOOD PLAIN

CHANNEL VELOCITY

- Velocity = downstream distance traveled / time, or (m/s).
- Velocity varies considerably between various streams, and even along the same stream: depending on the channel shape, width and roughness (boulders vs sand or clay: barren vs vegetated channel.



CHANNEL DISCHARGE



	Broad, shallow channel	Narrow, deep channel	Semicircular channel
Cross-sectional area	10 m^2	10 m^2	10 m^2
Perimeter in contact with water	12 m	12 m	7.9 m

Discharge = total volume of water in a stream moving past a particular point in a given period of time.

$Q = V*A$ V = velocity A = area

All three channels have the same cross-sectional area, but a different shape. The semicircular channel has the least perimeter in contact with water, and causes the least frictional resistance to flow. If other variables, such as channel roughness, are the same, flow velocity will be greatest in the semicircular channel.

River Discharge

TABLE 10.1 **World's Largest Rivers Ranked by Discharge**

			Drainage Area		Average Discharge	
Rank	River	Country	Square kilometers	Square miles	Cubic meters per second	Cubic feet per second
1	Amazon	Brazil	5,778,000	2,231,000	212,400	7,500,000
2	Congo	Zaire	4,014,500	1,550,000	39,650	1,400,000
3	Yangtze	China	1,942,500	750,000	21,800	770,000
4	Brahmaputra	Bangladesh	935,000	361,000	19,800	700,000
5	Ganges	India	1,059,300	409,000	18,700	660,000
6	Yenisei	Russia	2,590,000	1,000,000	17,400	614,000
7	Mississippi	United States	3,222,000	1,244,000	17,300	611,000
8	Orinoco	Venezuela	880,600	340,000	17,000	600,000
9	Lena	Russia	2,424,000	936,000	15,500	547,000
10	Parana	Argentina	2,305,000	890,000	14,900	526,000

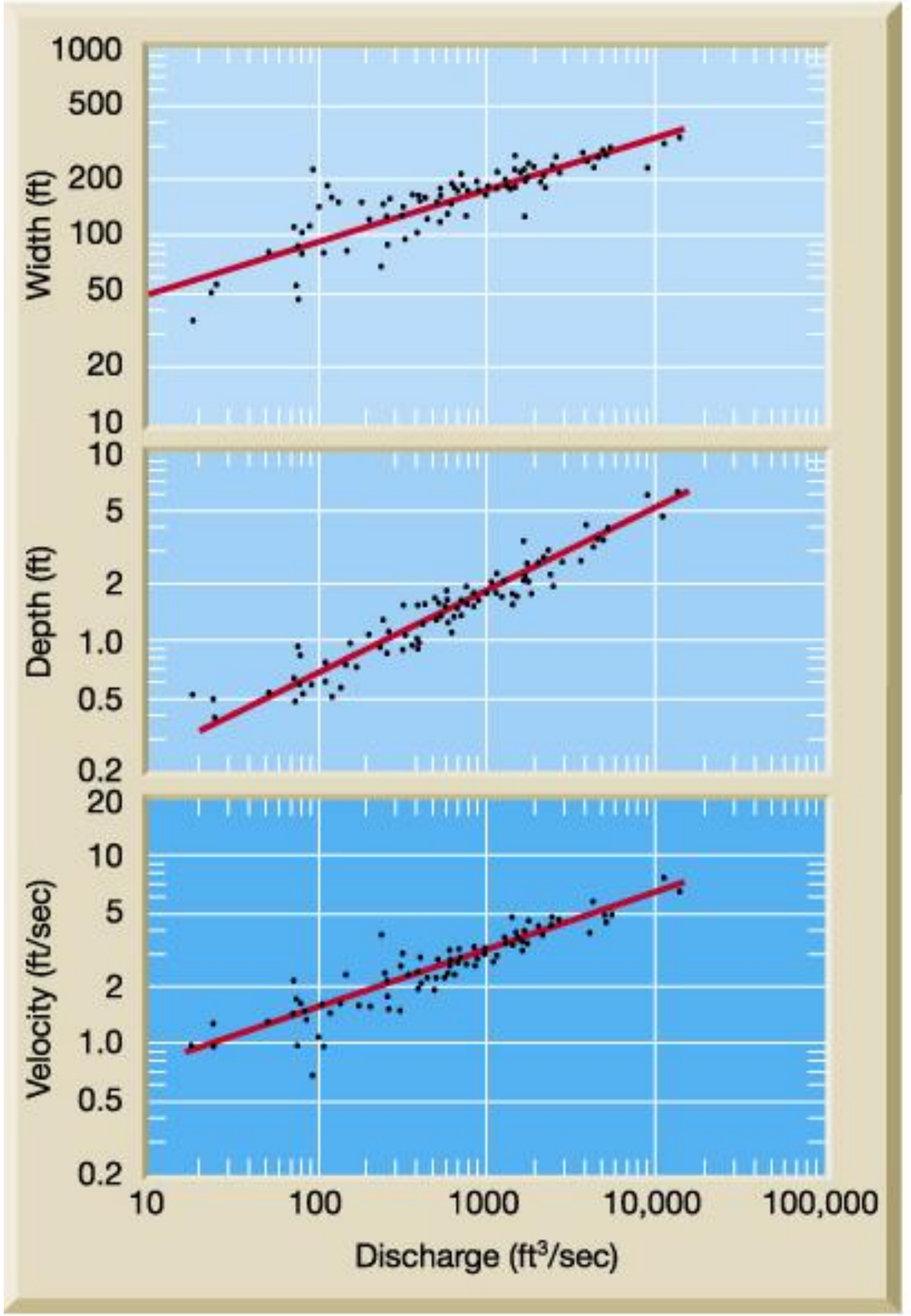
Mackenzie River **1,805,200** **9,700 m^3/s**

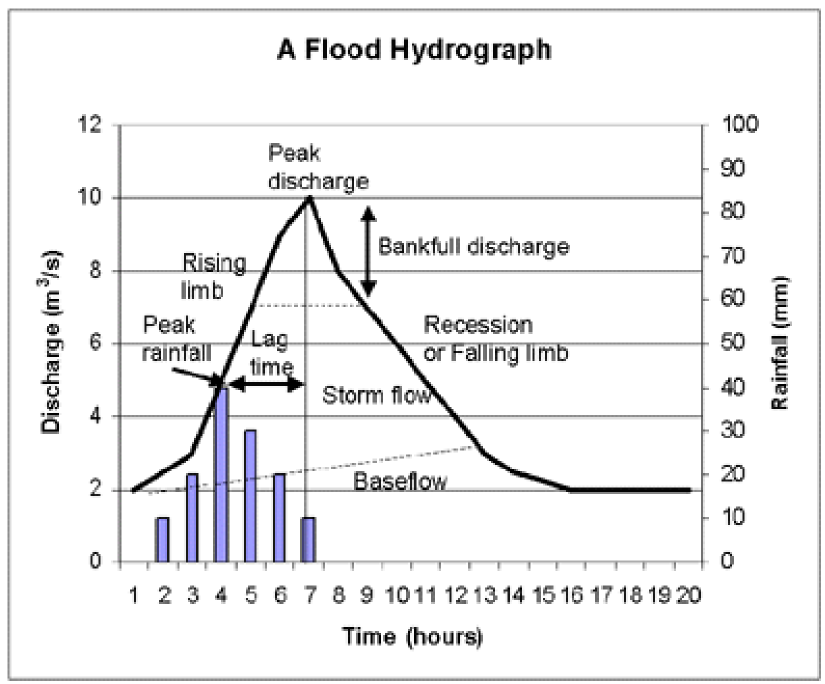
Indus **1,165,000** **6,600 m^3/s**

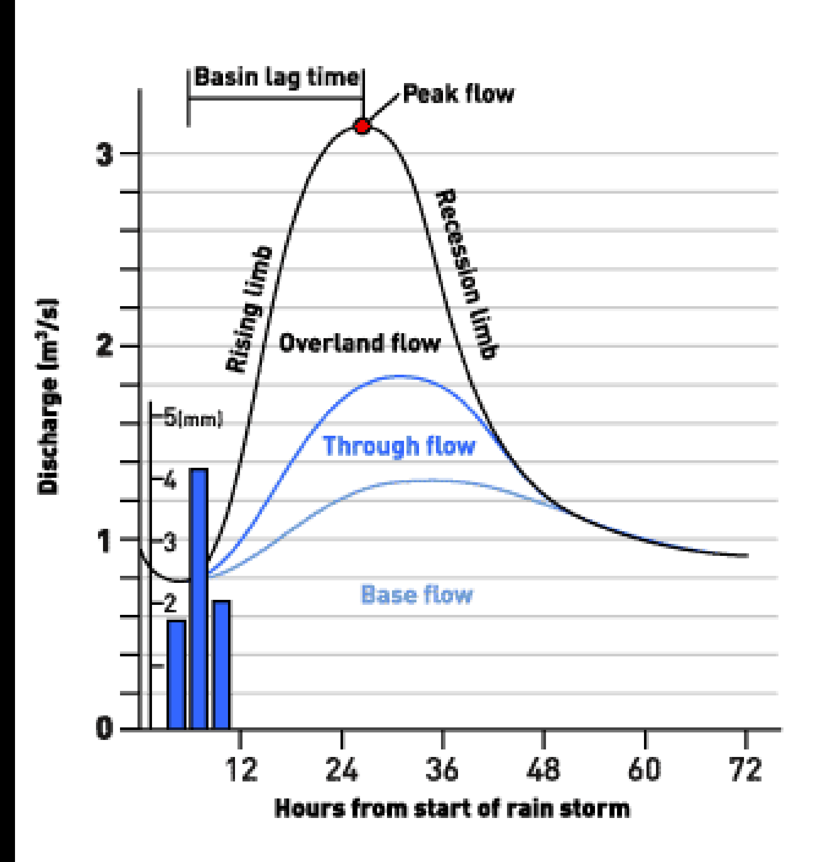
Channel Discharge Relationships

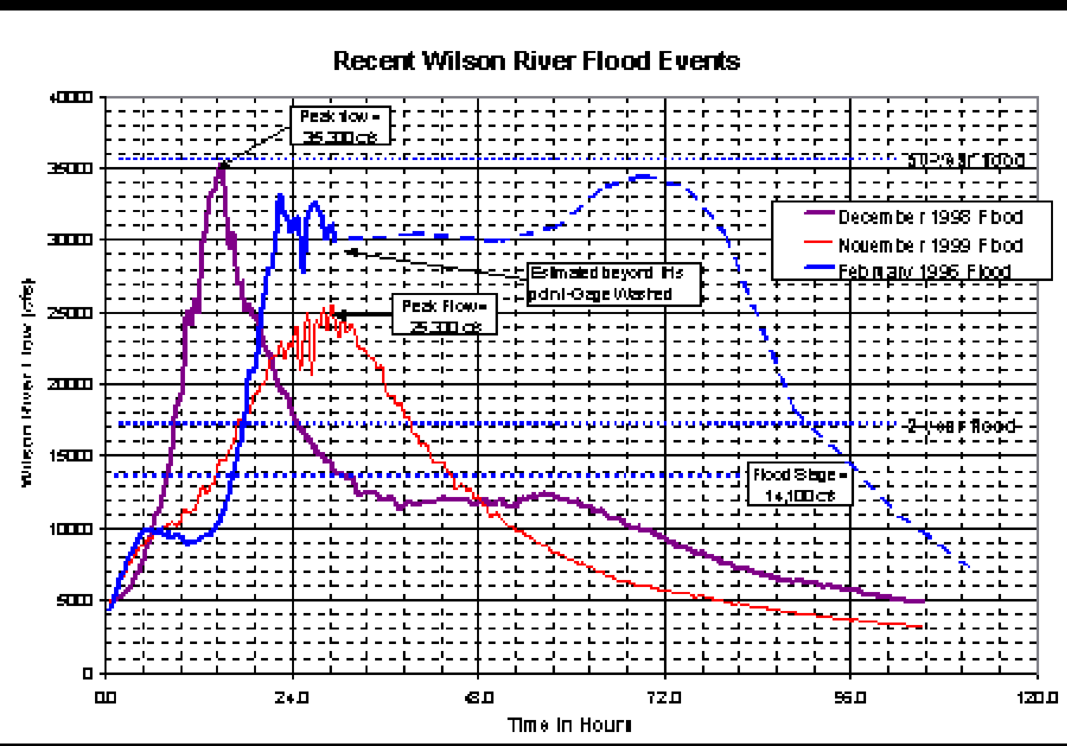
Relationship of width, depth, and velocity to discharge of the Powder River at Locate, Montana. As discharge increases, width, depth, and velocity all increase in an orderly fashion.

(After L. B. Leopold and Thomas Maddock, Jr., U.S. Geological Survey Professional Paper 252, 1953)









THE FLOOD HYDROGRAPH

THE WORLD'S LARGEST FLOODS (DISCHARGE)

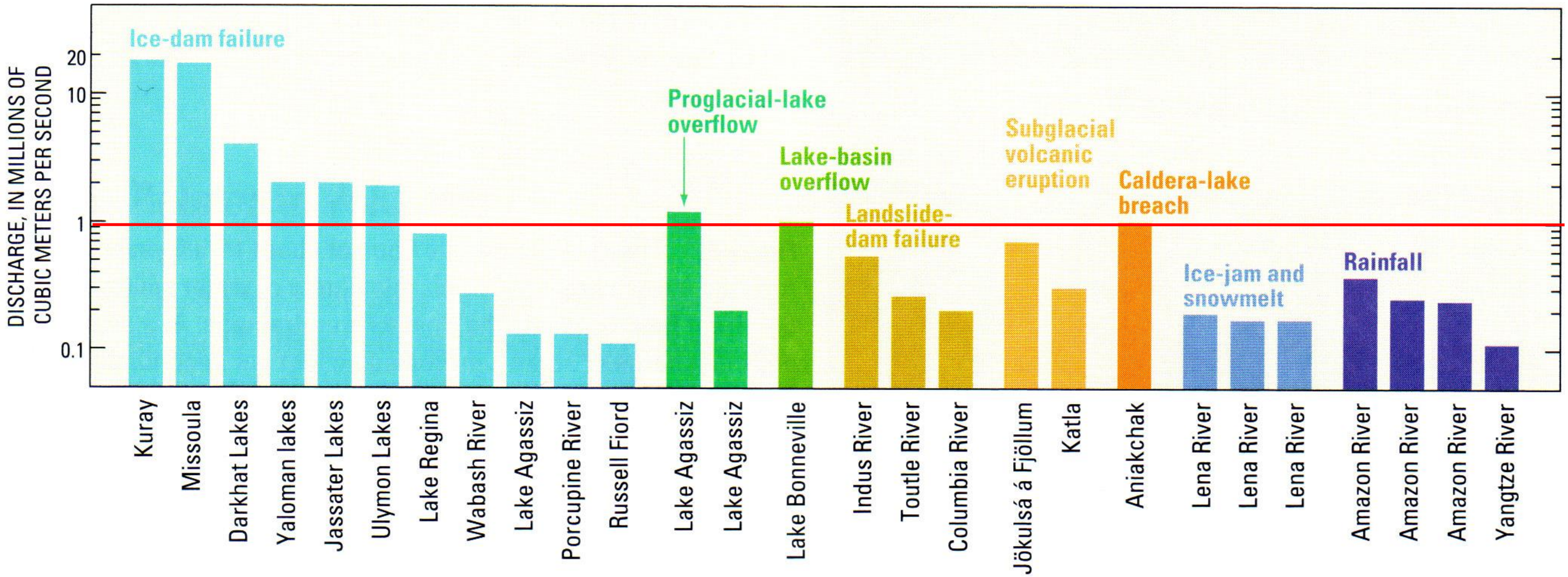
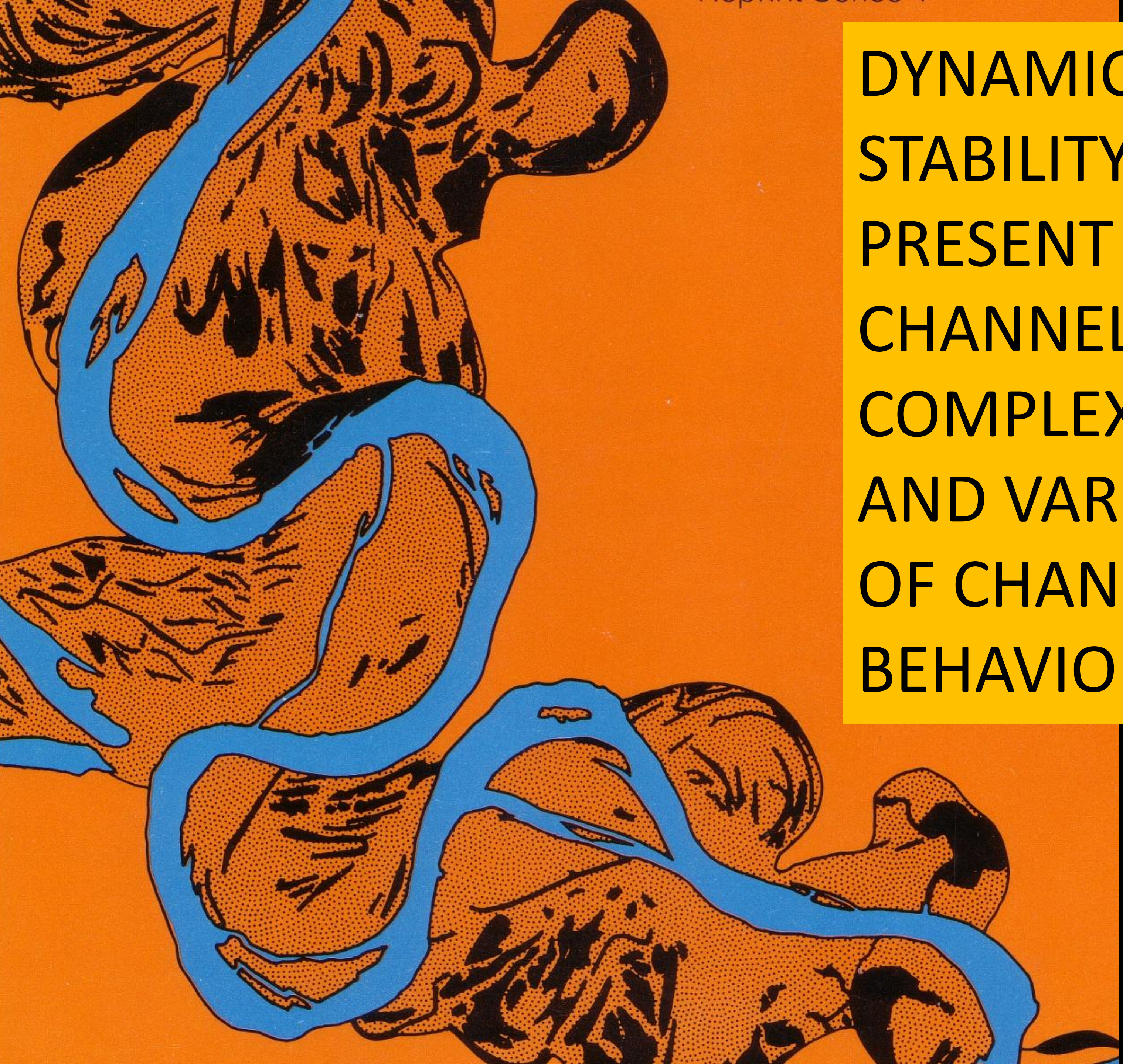
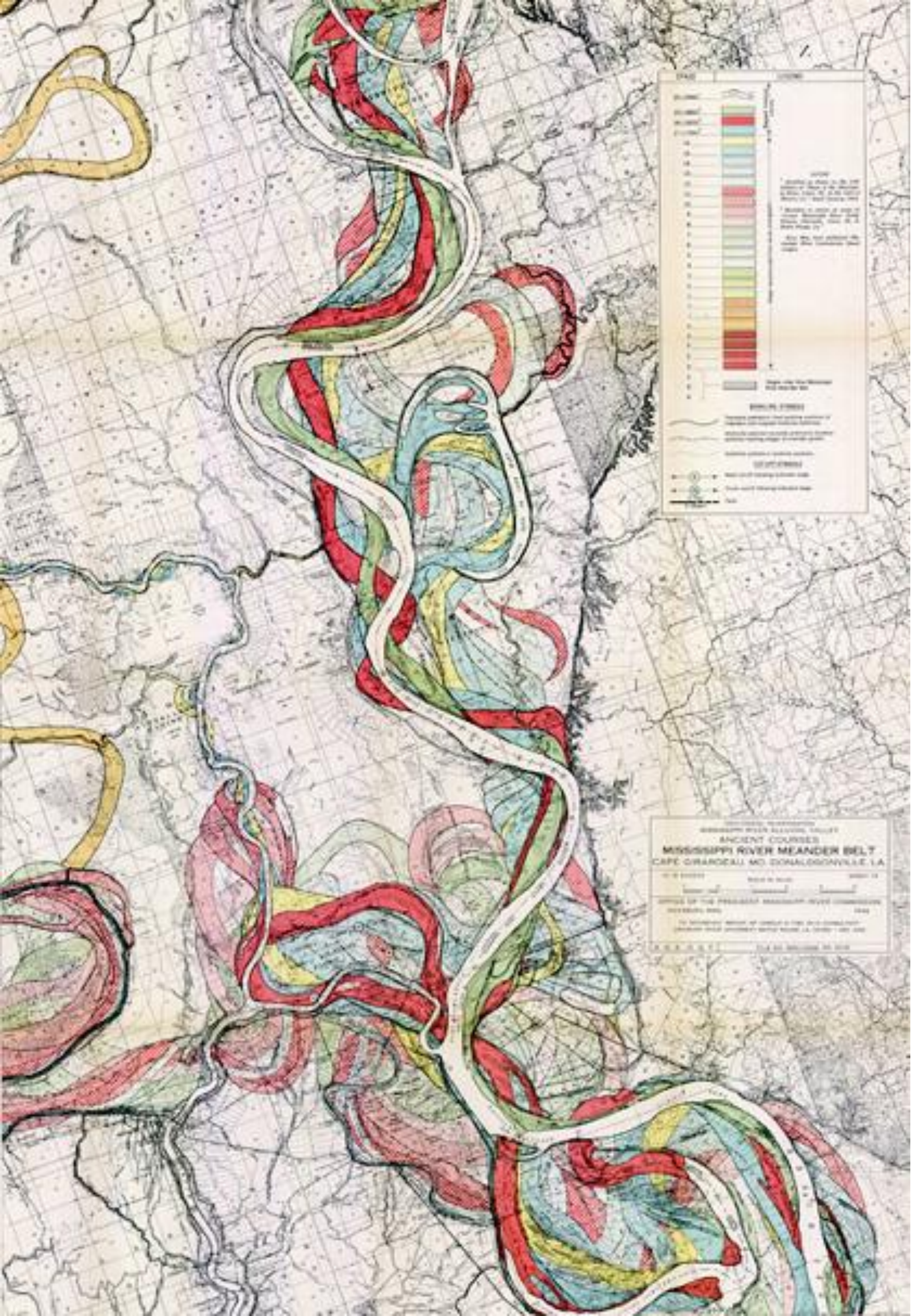


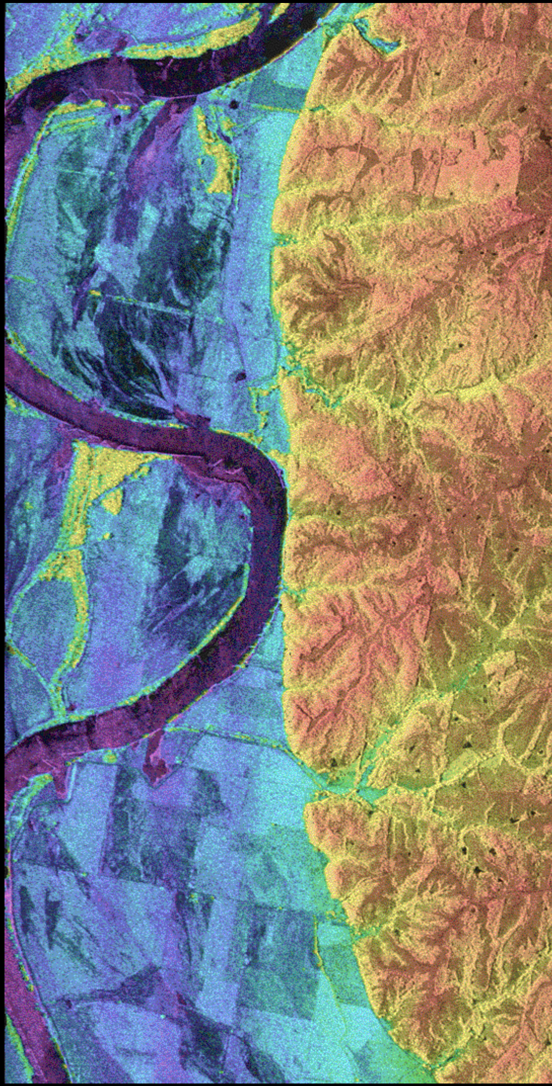
Figure 1. Most of the largest known floods of the Quaternary period resulted from breaching of dams formed by glaciers or landslides. See table 1 for details of each flood.



DYNAMICS AND STABILITY OF PRESENT CHANNEL – COMPLEXITY AND VARIABILTY OF CHANNEL BEHAVIOUR



RESULT OF MEANDER MIGRATION IN A FLOODPLAIN – MISSISSIPPI RIVER, USA (DATED CHANNEL ELEMENTS IN A MEANDER BELT)



October 4, 1993; Missouri River in flood ($20B of damage)

DFO Event # 2008-3365 - Bihar - Rapid Response Inundation Map

MODIS flood inundation limit August 24, 2008:

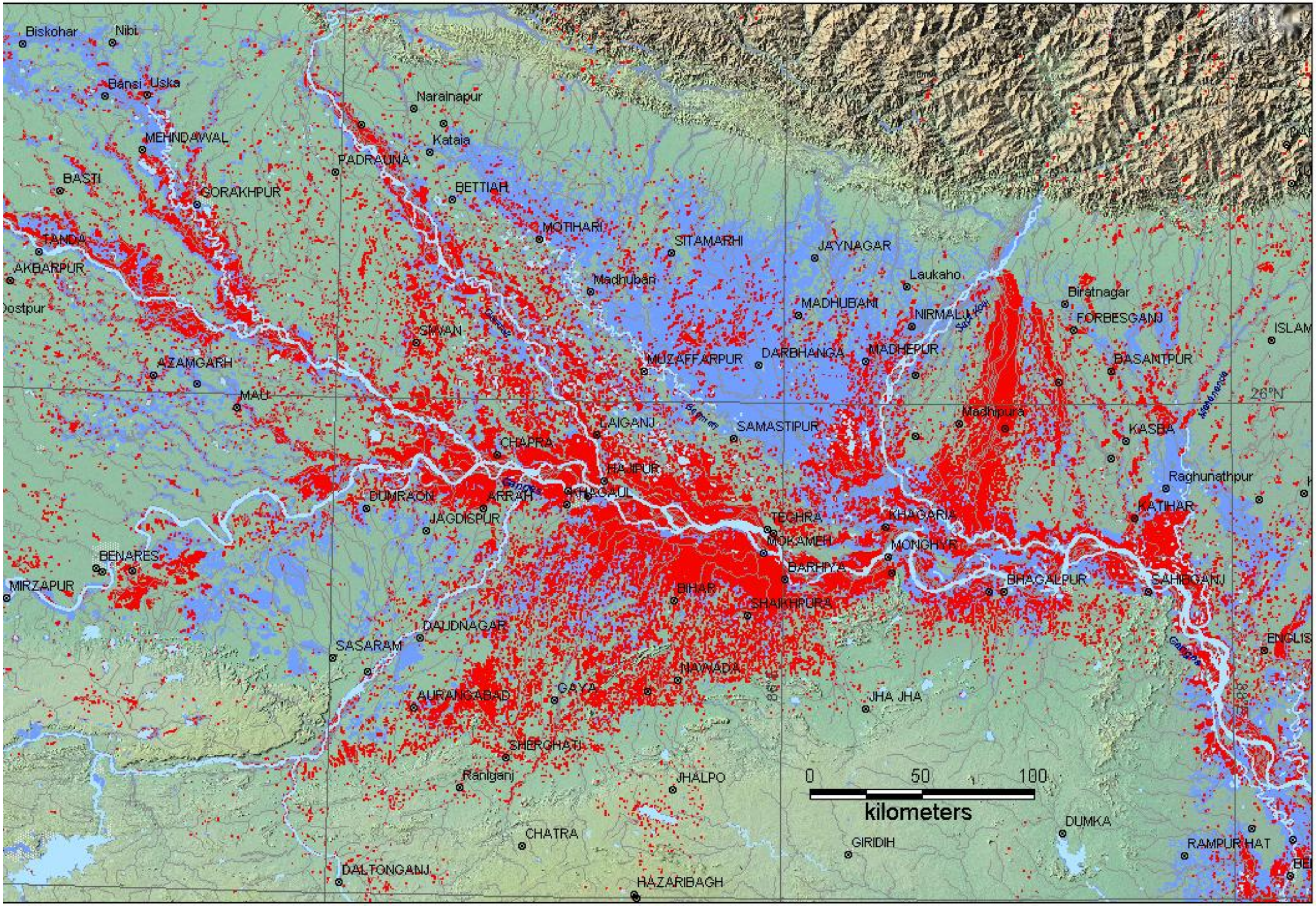
Maximum Observed Inundation Limit 2000 - 2007:

SWBD reference water:

DCW Rivers: Urban areas:

Universal Transverse Mercator Zone 45 North - WGS 84
Graticule: 2 degrees - Shaded relief from SRTM data

Dartmouth College - Hanover NH, 03755 USA
Chris Farmer & G. R. Brakenridge

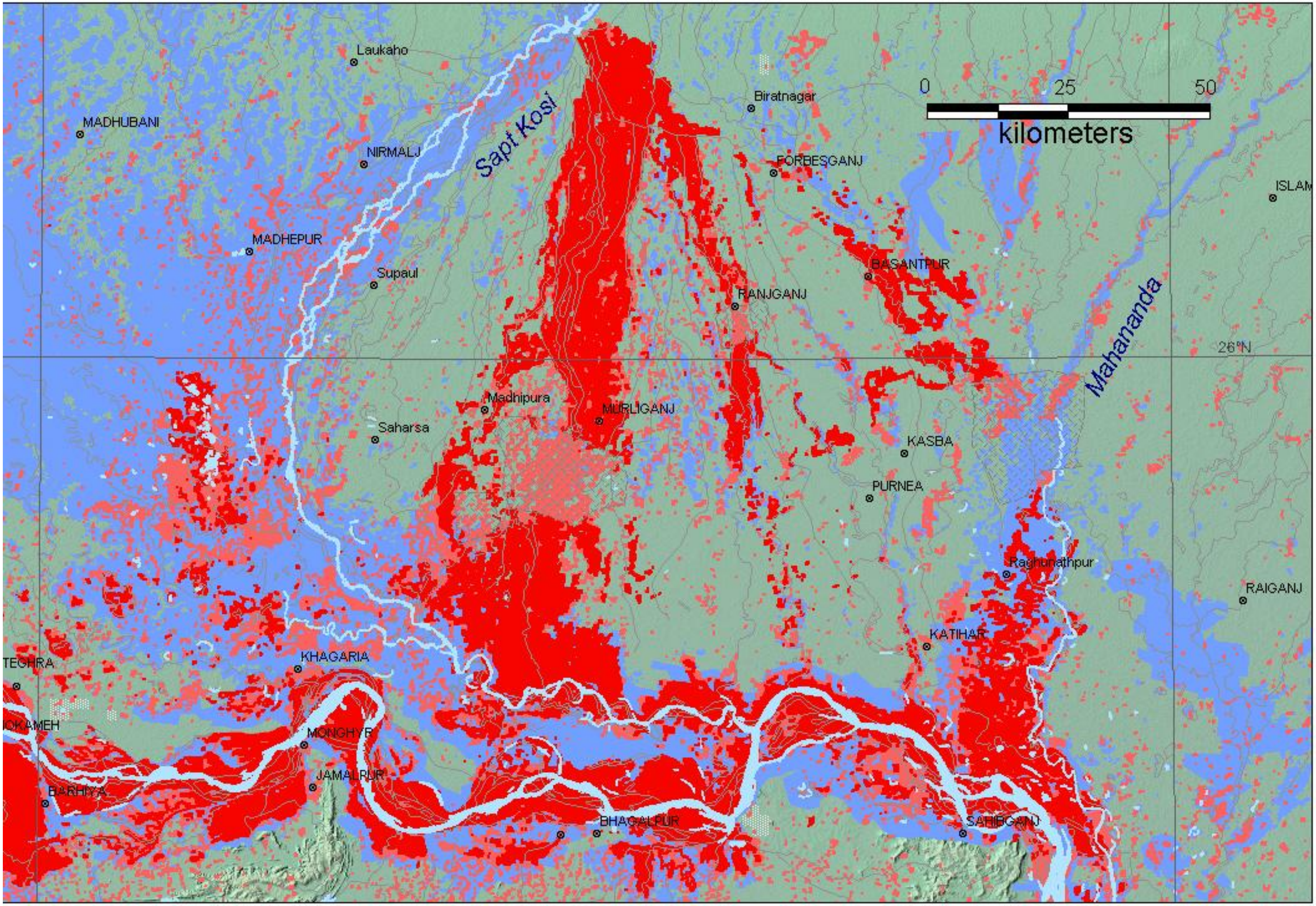


DFO Event # 2008-3365 - Bihar, India - Kosi River - Rapid Response Inundation Map

MODIS flood inundation limit September 2, 2008:
MODIS flood inundation limit August 24, 2008:
Areas Obscured by Clouds Sept 2, 2008:
Maximum Observed Inundation Limit 2000 - 2007:
SWBD reference water:
DCW Rivers: Urban areas:

Dartmouth College - Hanover NH, 03755 USA
Chris Farmer & G. R. Brakenridge

Universal Transverse Mercator Zone 45 North - WGS 84
Graticule: 2 degrees - Shaded relief from SRTM data



DFO Event # 2008-3365 - Bihar - Rapid Response Inundation Map - PREVIOUSLY UNFLOODED AREAS IN RED

Maximum Observed Inundation Limit 2000 - 2007:
Previously unflooded areas of MODIS flood inundation limit August 24, 2008:

SWBD reference water:
DCW Rivers: Urban areas:

Universal Transverse Mercator Zone 45 North - WGS 84
Graticule: 2 degrees - Shaded relief from SRTM data

Dartmouth College - Hanover NH, 03755 USA
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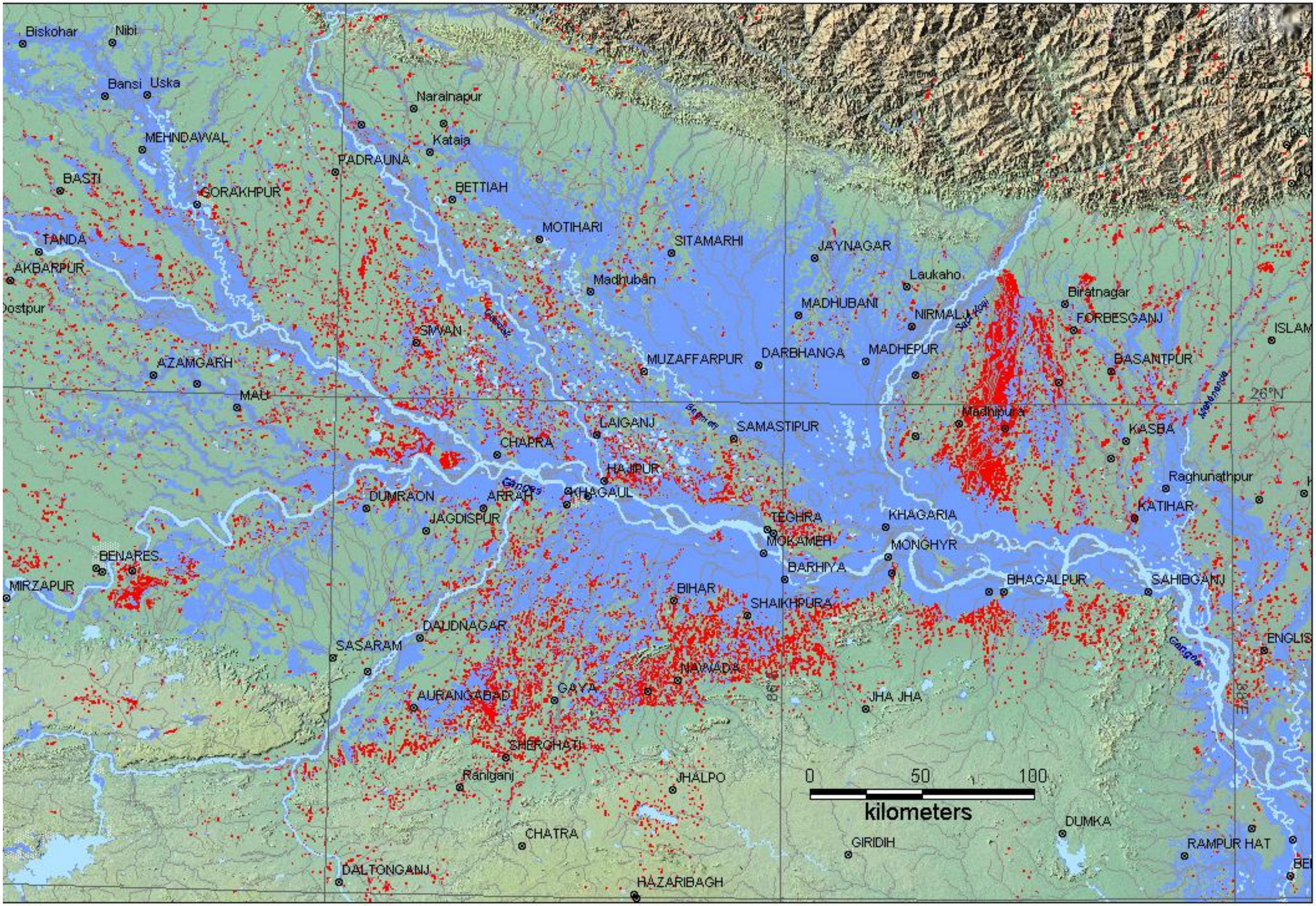
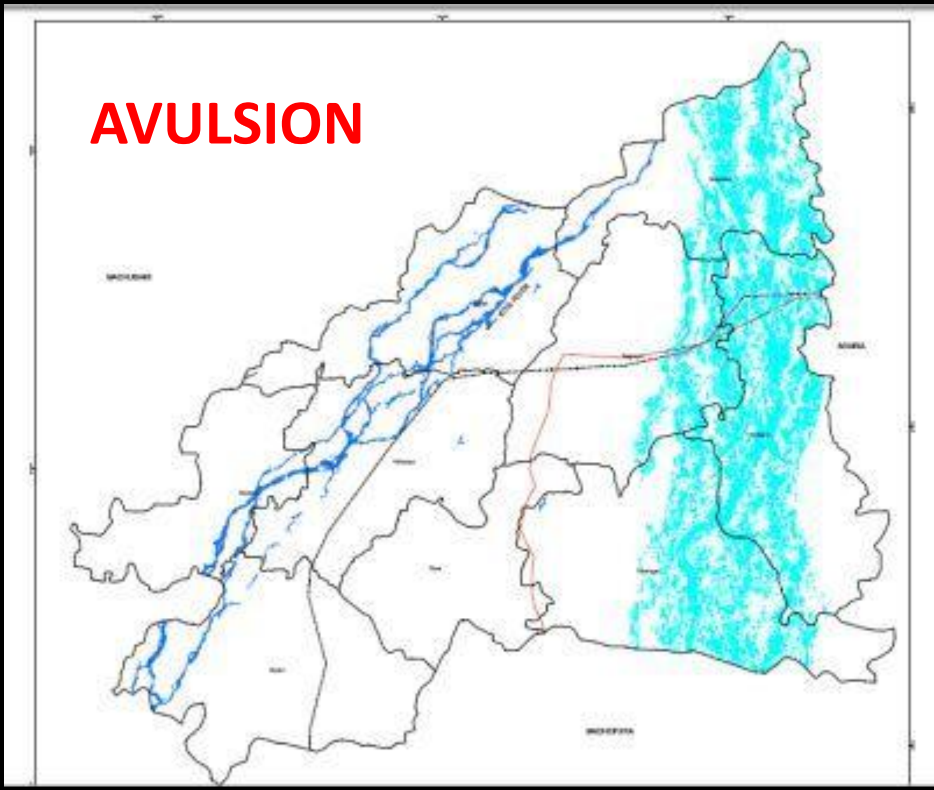


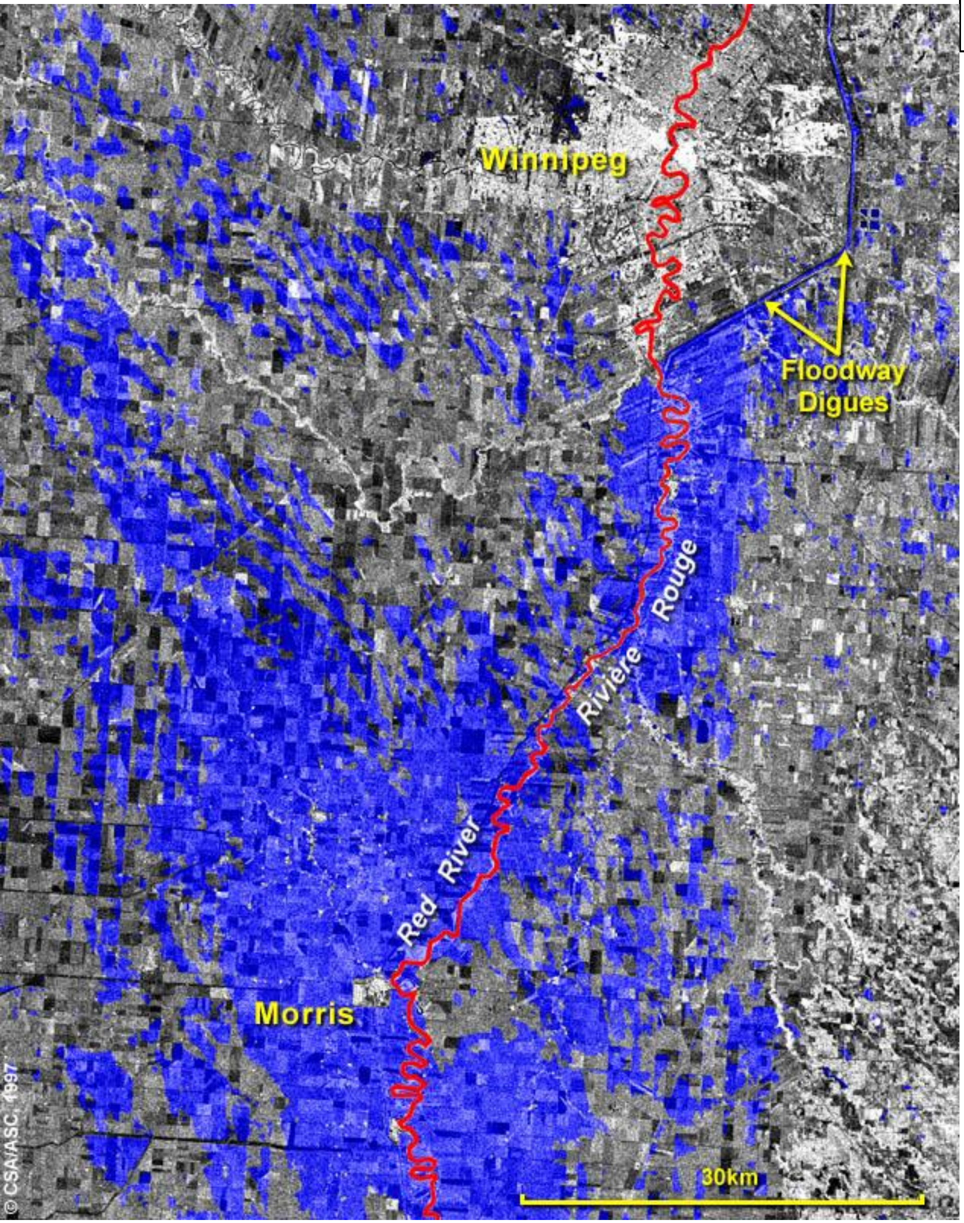


BIHAR FLOODS, INDIA, AUGUST 2008

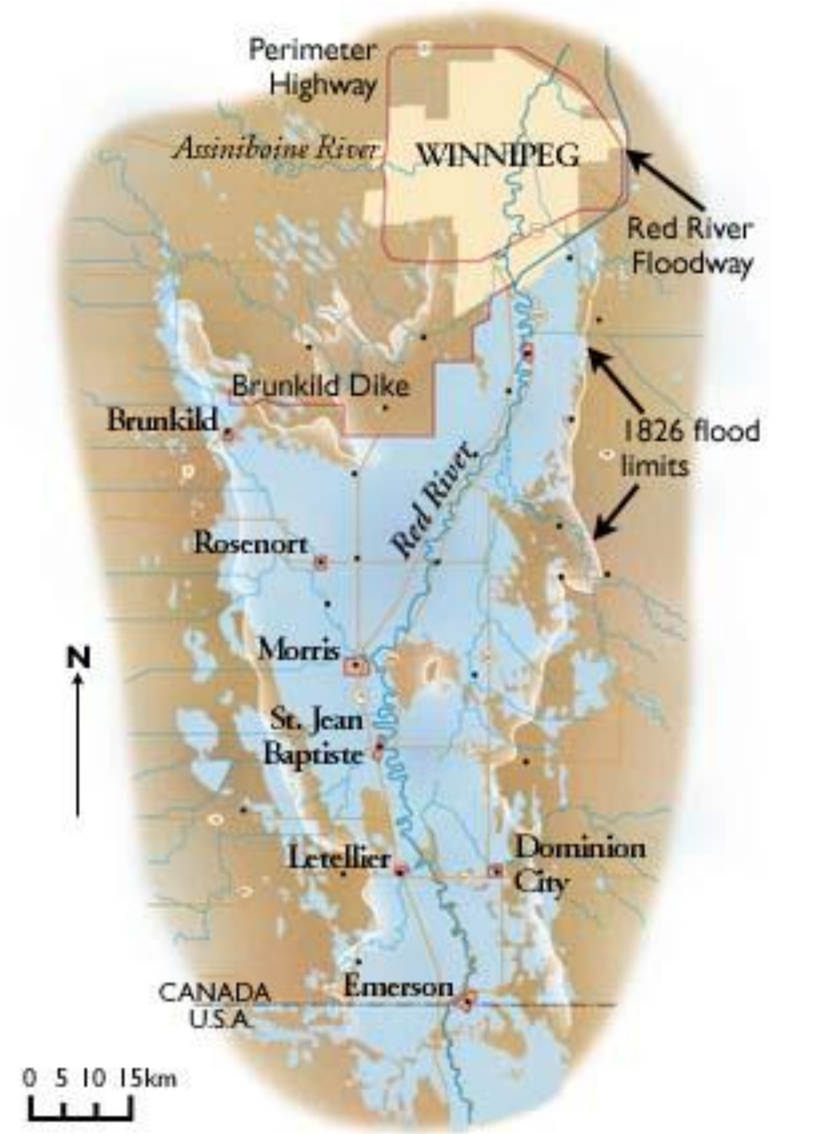
Chehalis, WA Dec 2007

Flooding

When the discharge of a stream becomes so great that it exceeds the capacity of its channel, it overflows its banks as a flood.



1997 Red River flood, Manitoba



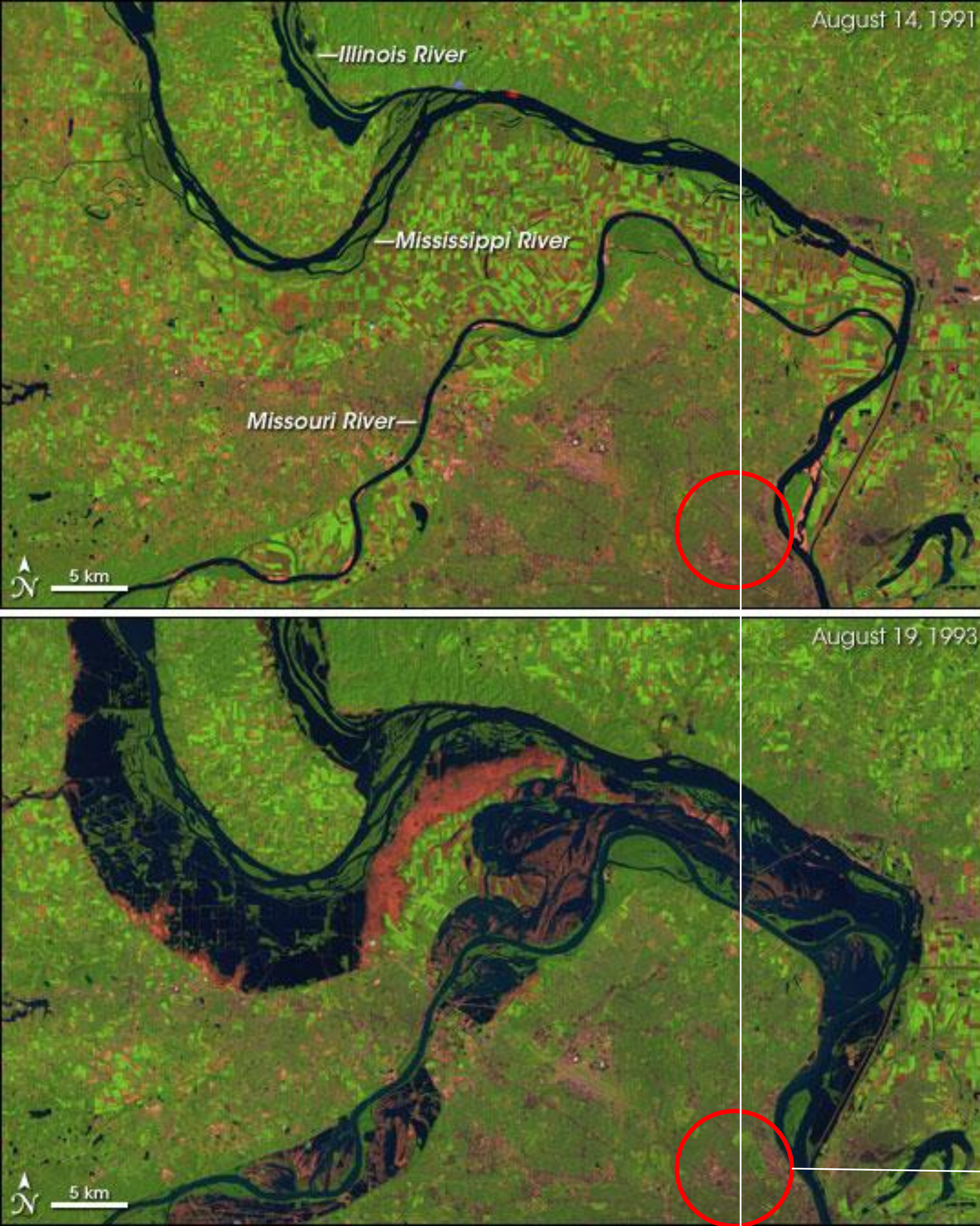
RIVER FLOOD TYPES & MECHANISMS

1. Regional ; Hydrometeorological in origin (rapid snowmelt runoff/heavy sustained or storm rainfall/rain-on-snow)
2. Local Flash Flood ; localised intense rainfall leads to flash flood in a watershed
3. Ice Jam Flood ; temporary obstruction by the build up of ice fragments within a channel (upstream flooding)
4. Constructed Dam Failure ; downstream flooding resulting from failure of a built dam (e.g., Johnstown Flood of 1889)
5. Natural Dam Formation; upstream flooding
6. Natural Dam Failure; failure of moraine, ice or landslide dam

Dresden 2002

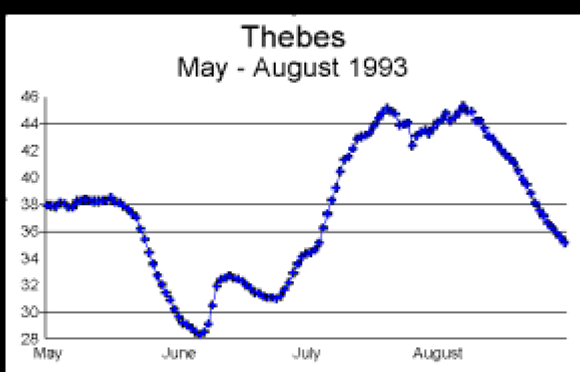
SUPERFLOODS

1993 FLOOD IN THE MISSISSIPPI BASIN



ST LOUIS, MO.

1993 MISSISSIPPI FLOOD



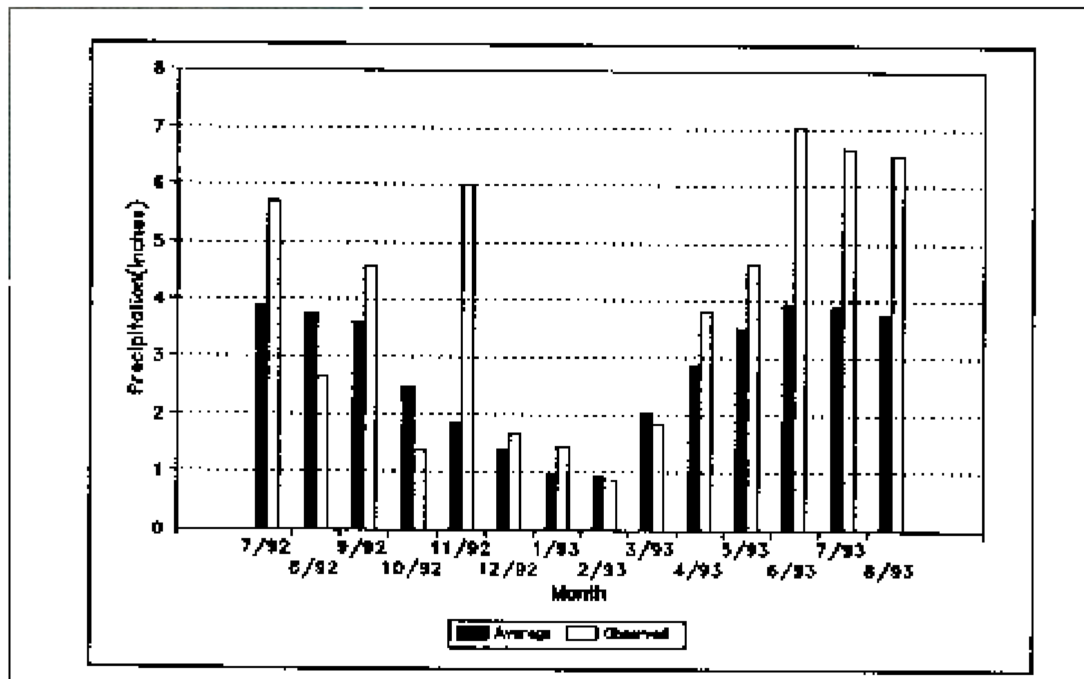
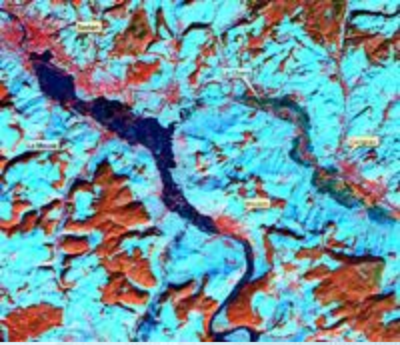


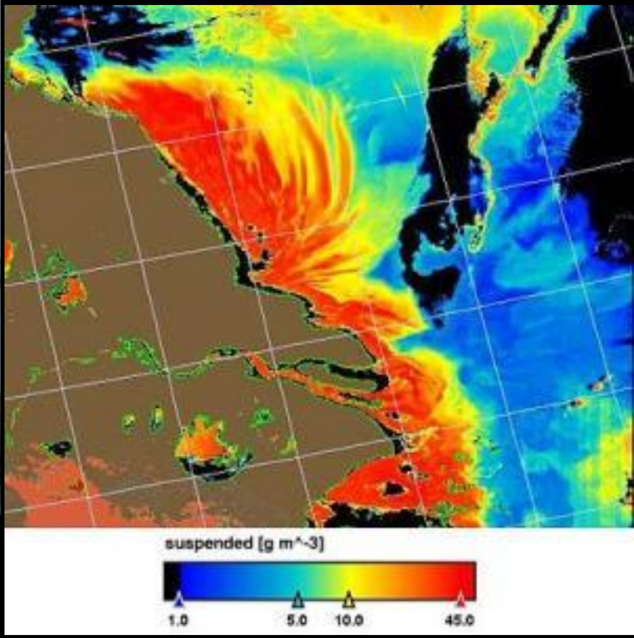
Figure 3.

FLOODS IN EUROPE AUGUST 2002 RESULTED FROM EXTREME RAINFALL - >100 deaths; damage in Germany (9 Billion Euros), Austria (3.0 Billion Euros) and Czech Republic (2.5 Billion Euros)

Numerous historical buildings and museums were underwater in Dresden. The world-famous Semper Opera House and the Zwinger (photo) could not be defended despite colossal efforts on the part of hundreds of helpers. The art treasures in museums are often not insured, as many local authorities cannot afford the insurance premiums.

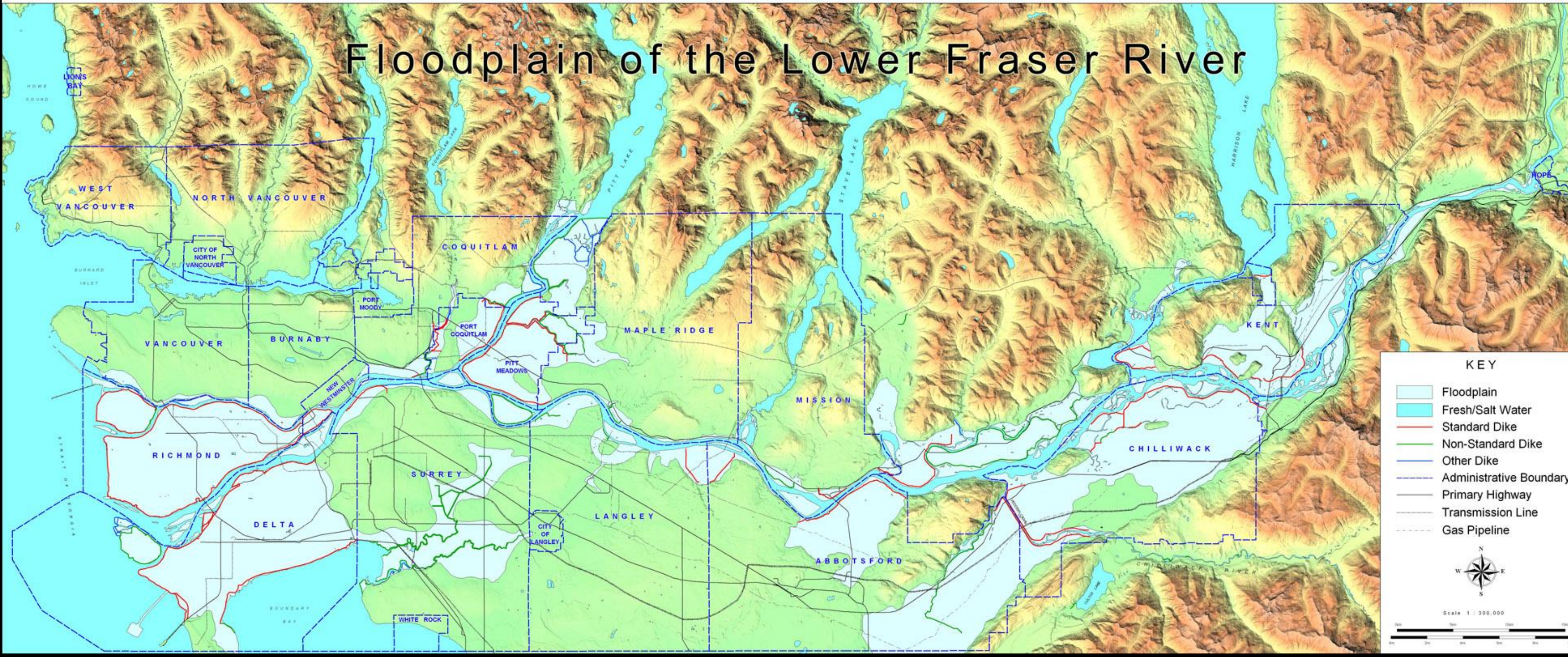


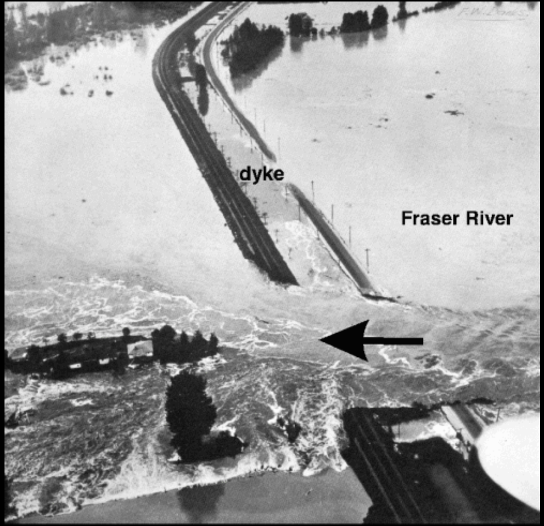
1995 Meuse Flooding, Netherlands



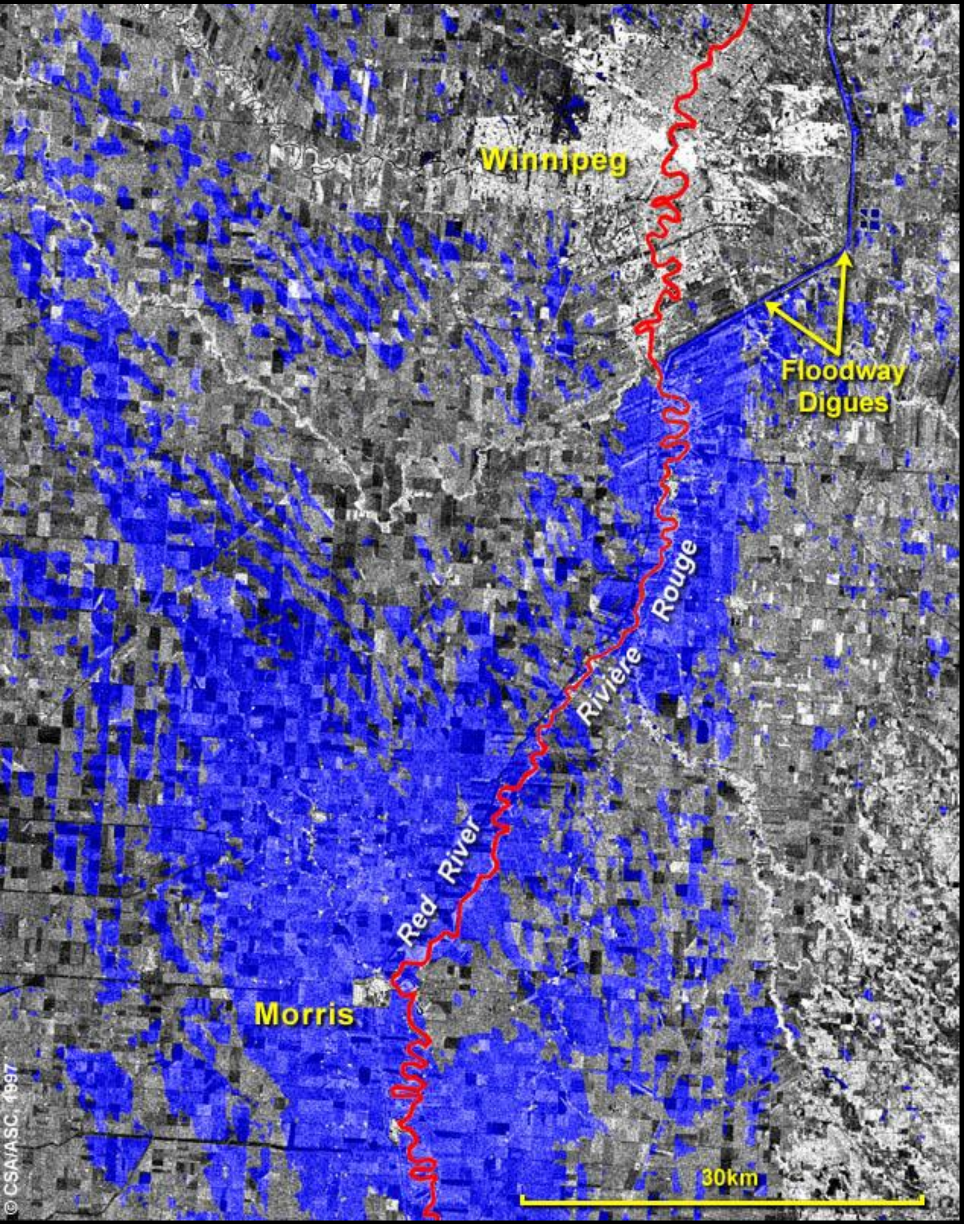
FLOODS ON THE YANGTZTE RIVER, CHINA

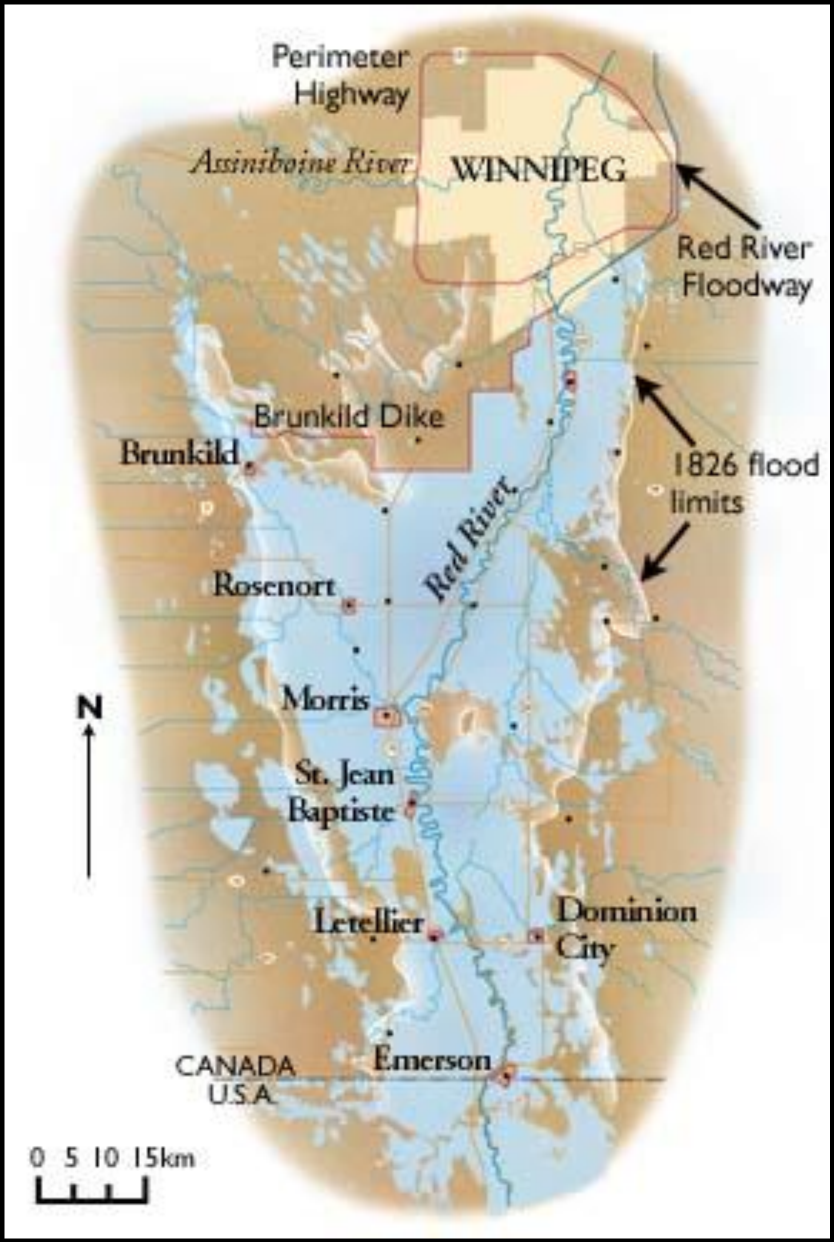

THREE GORGES DAM, CHINA





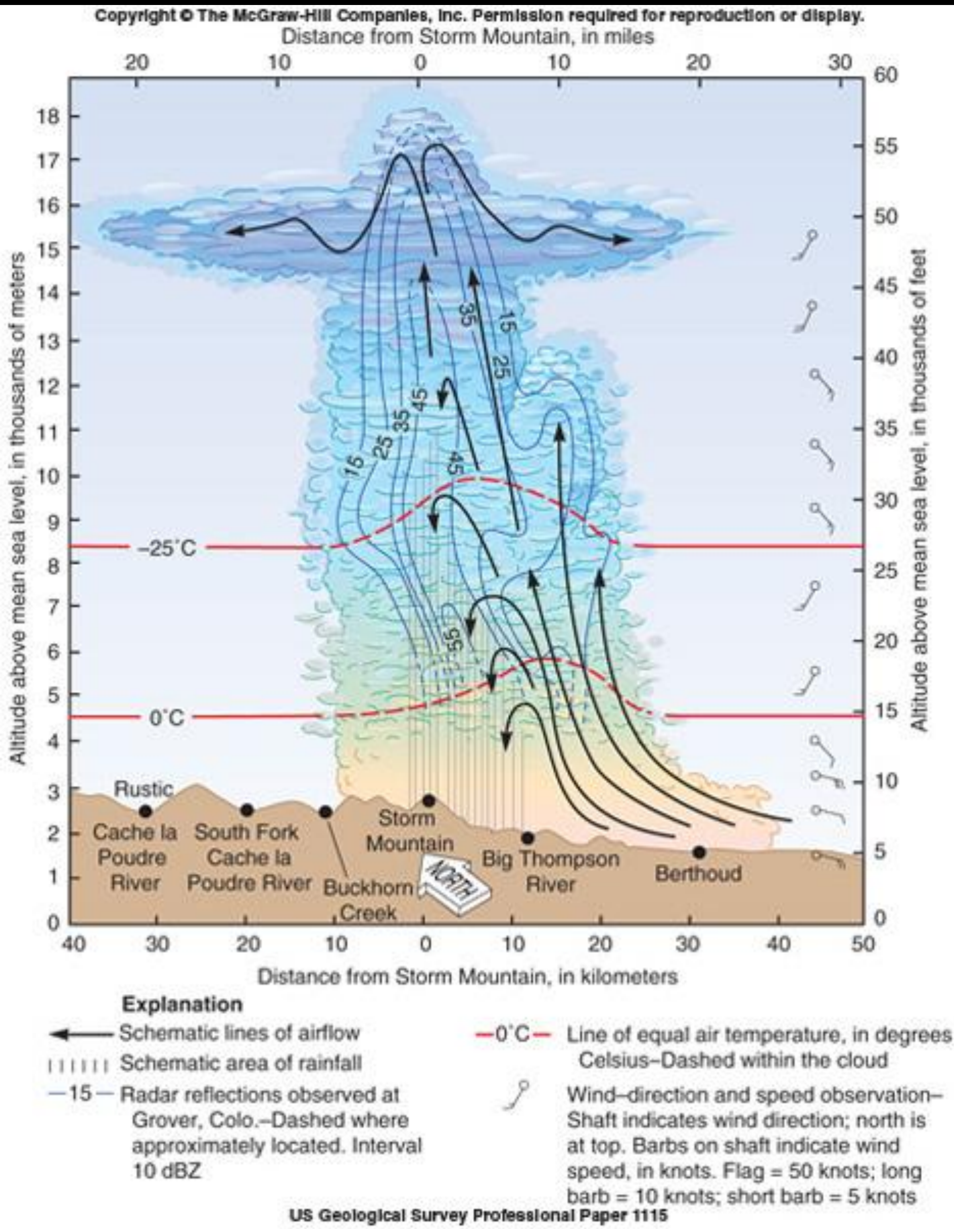
1948 FRASER RIVER FLOOD (RAIN ON SNOW)





1997 Red River flood, Manitoba

WINNIPEG FLOODWAY



Model of triggering thunderstorm

BIG THOMPSON CANYON FLASH FLOOD, COLORADO, 1976

19 cm of rain fell in 4 hours, equal to a typical year's total; flood wave ravelled at 7 m/s; Flood was 3.8 times greater than the 100 yr flood; 145 deaths; $36 M damage

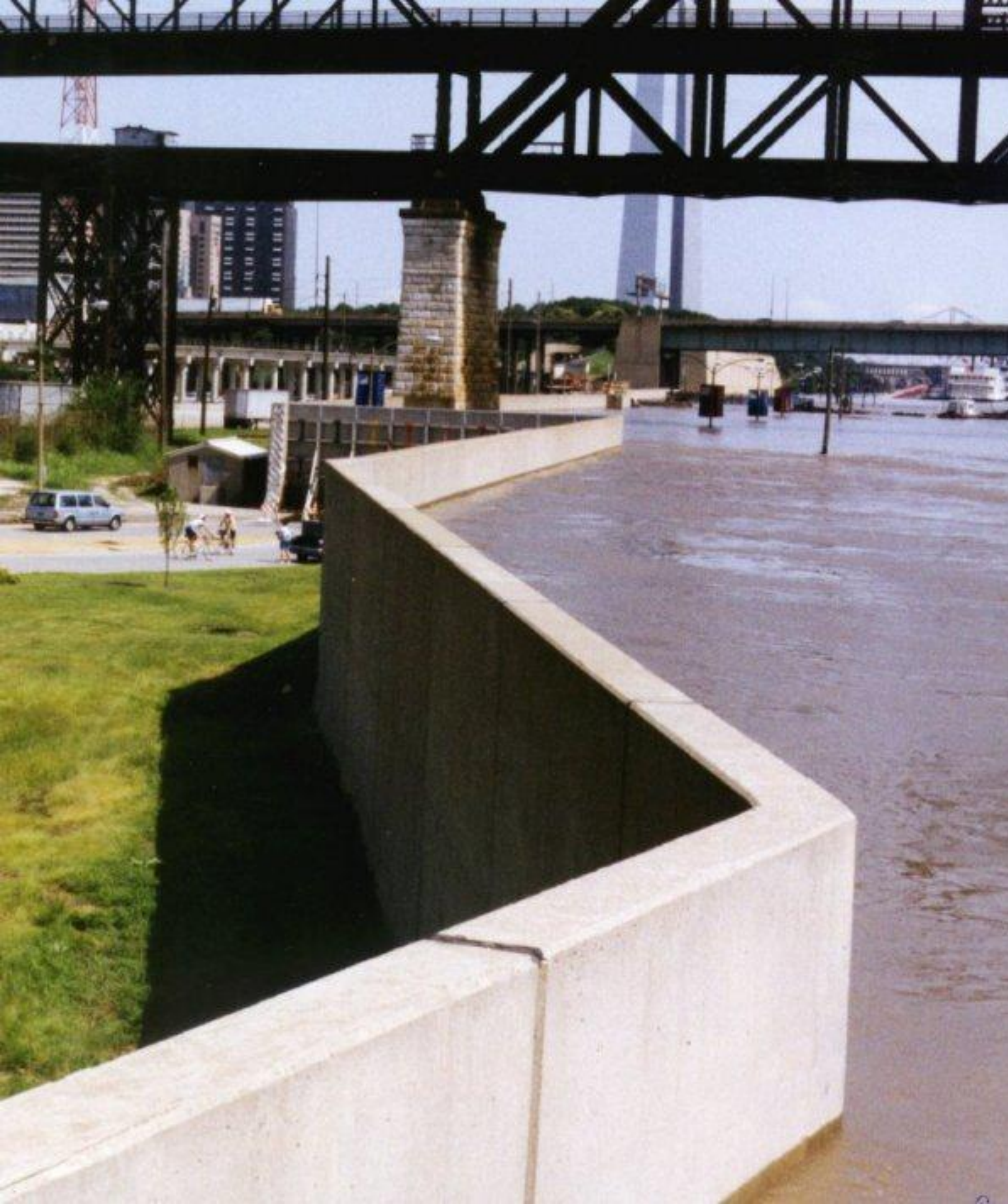
FLOOD CONTROL/MITIGATION

Strategies devised to eliminate or lessen the catastrophic effects of river floods.

1. Constructing artificial levees
2. Building flood control dams
3. Construction of floodways
4. River channelization
5. Nonstructural approaches “Floodplain Management”

The Church of The Intercession, Nerl River, Vladimir, Russia: 12th Century Flood Mitigation

LEVEE CONSTRUCTION – COMMON PRACTICE



URBAN LEVEES (FLOODWALLS)

1993 Flood stage of the Mississippi River at St Louis was only a few feet below the top of the floodwall

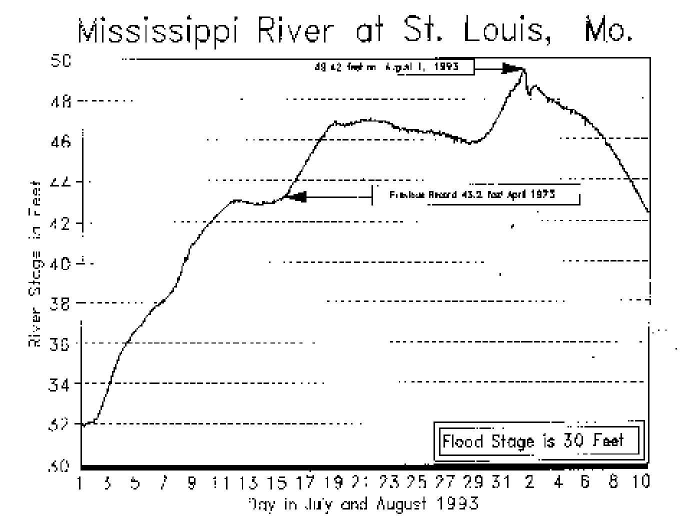
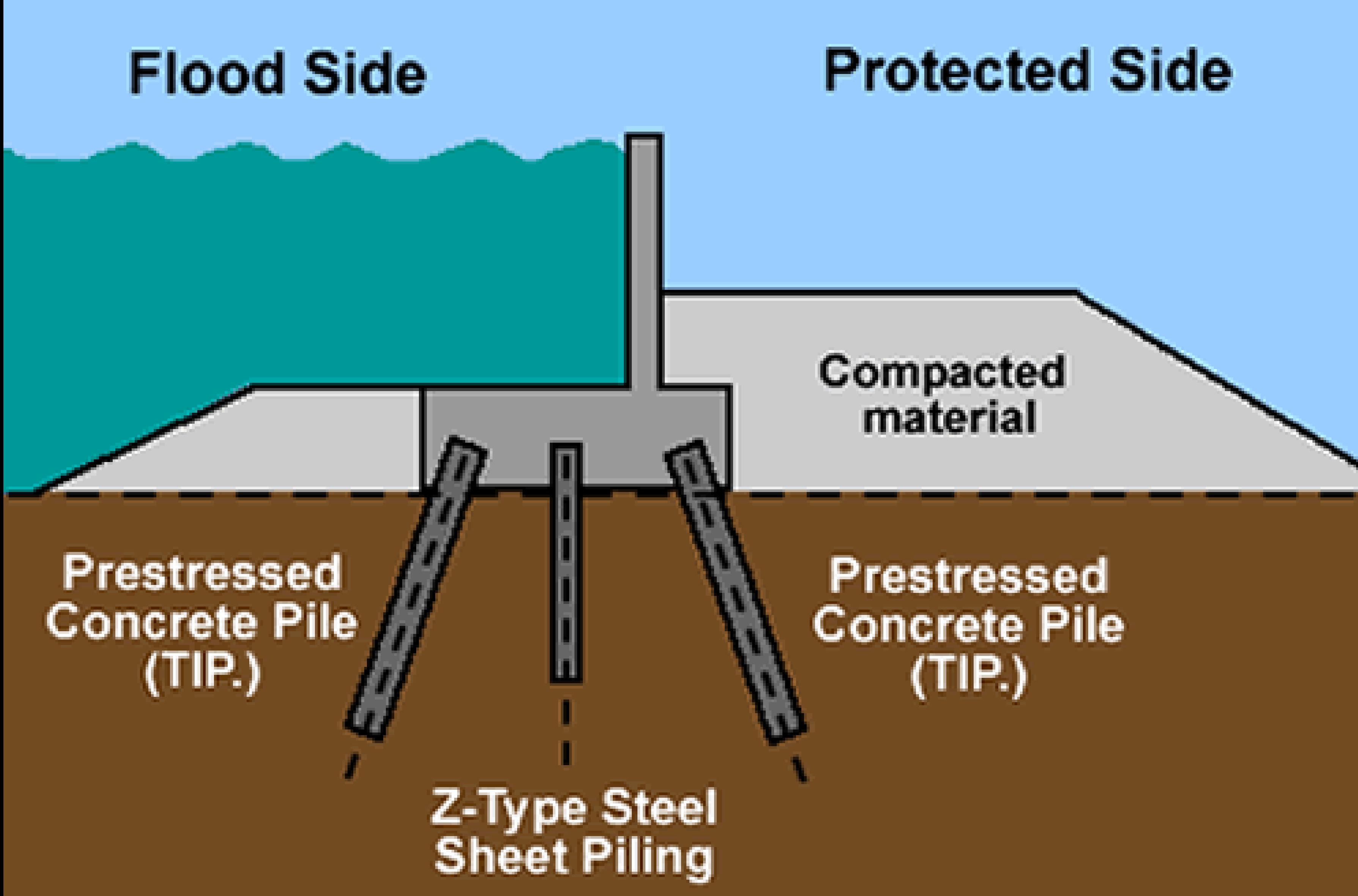
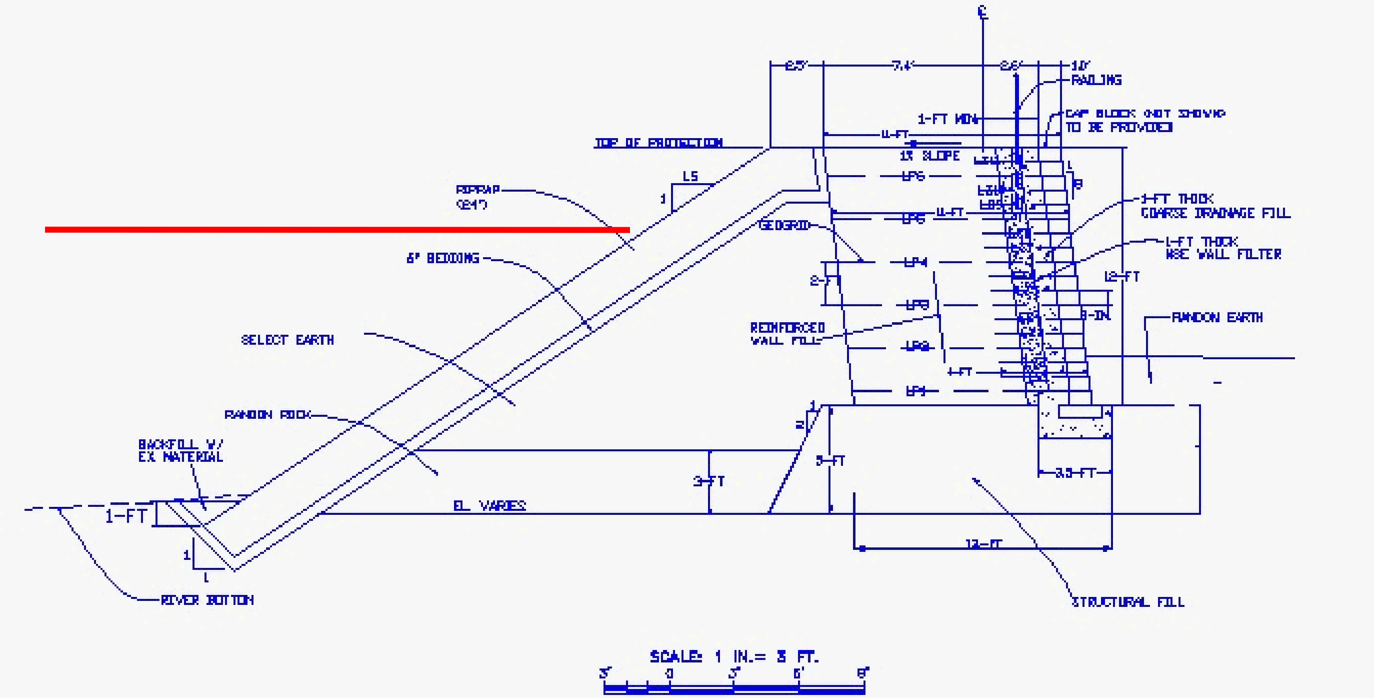


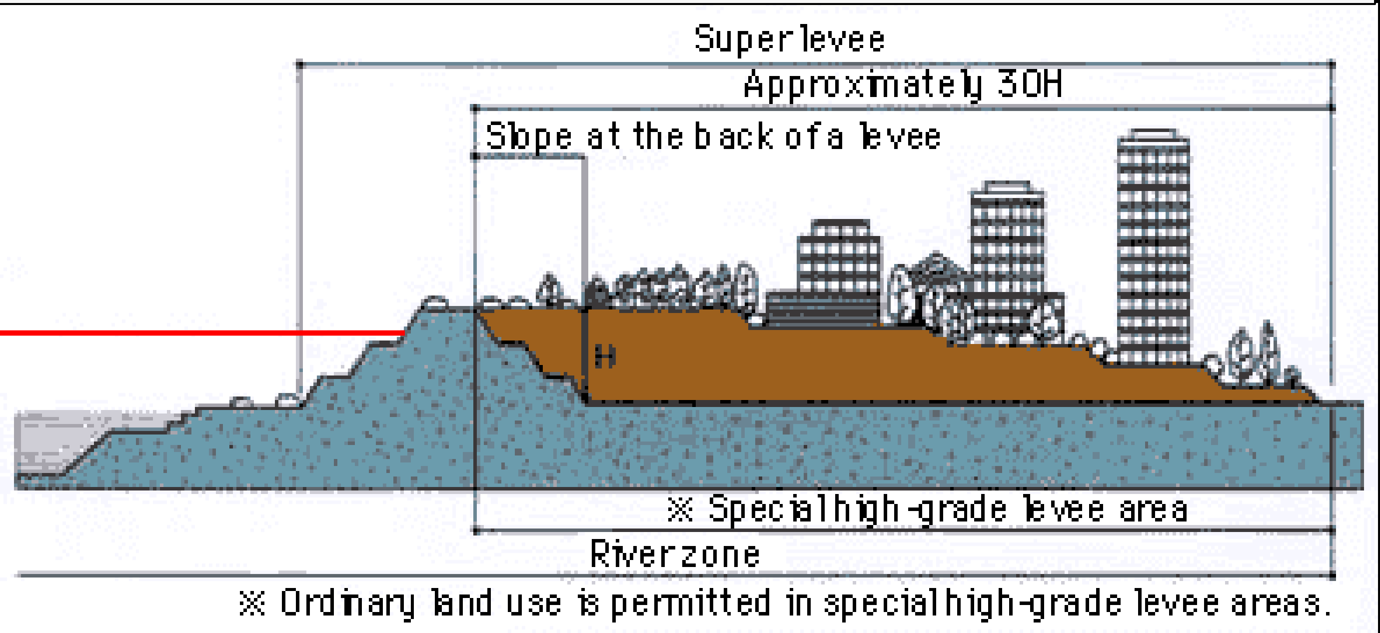
Figure 4

DESIGN OF FLOOD WALL

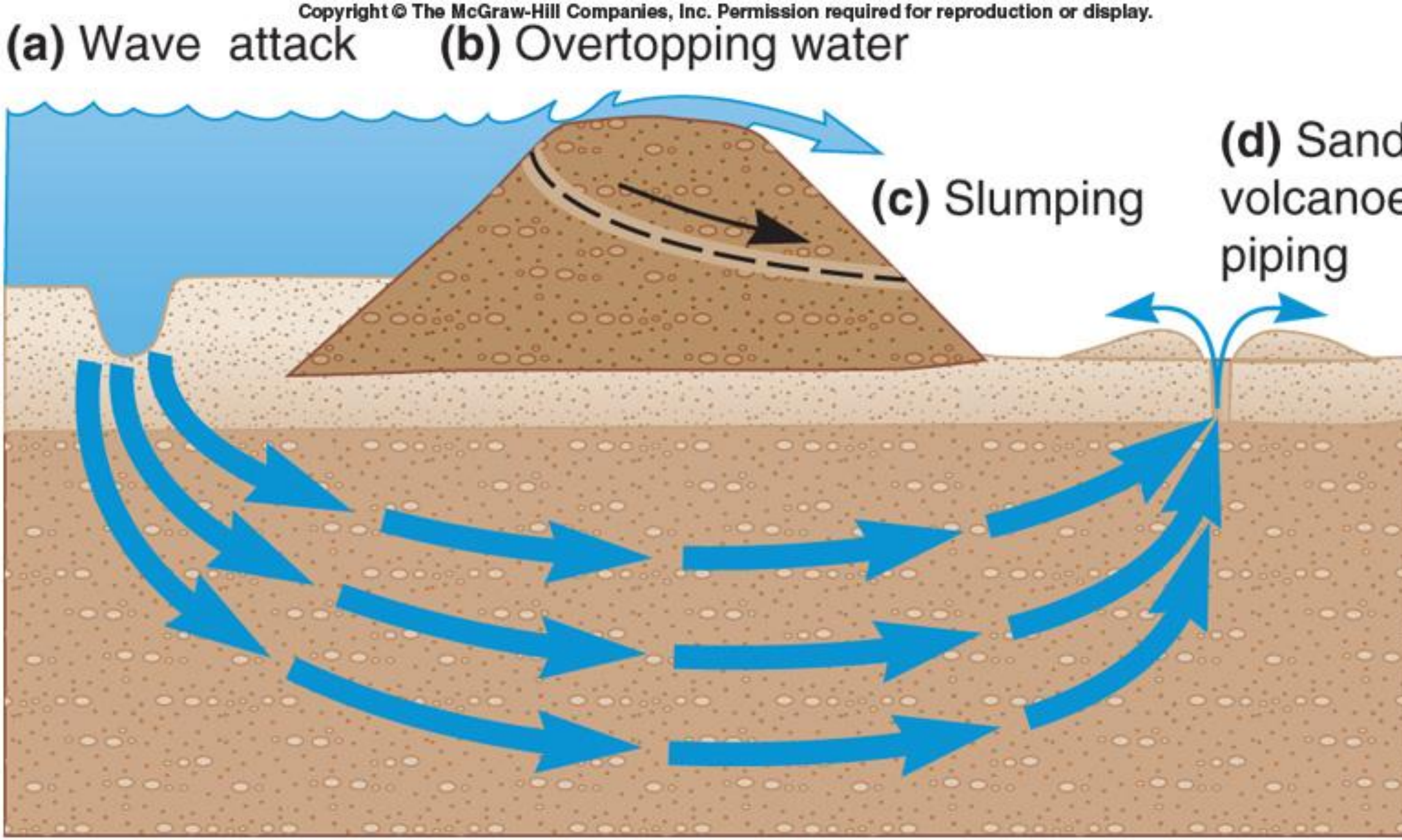


T-Wall supported on a pile foundation

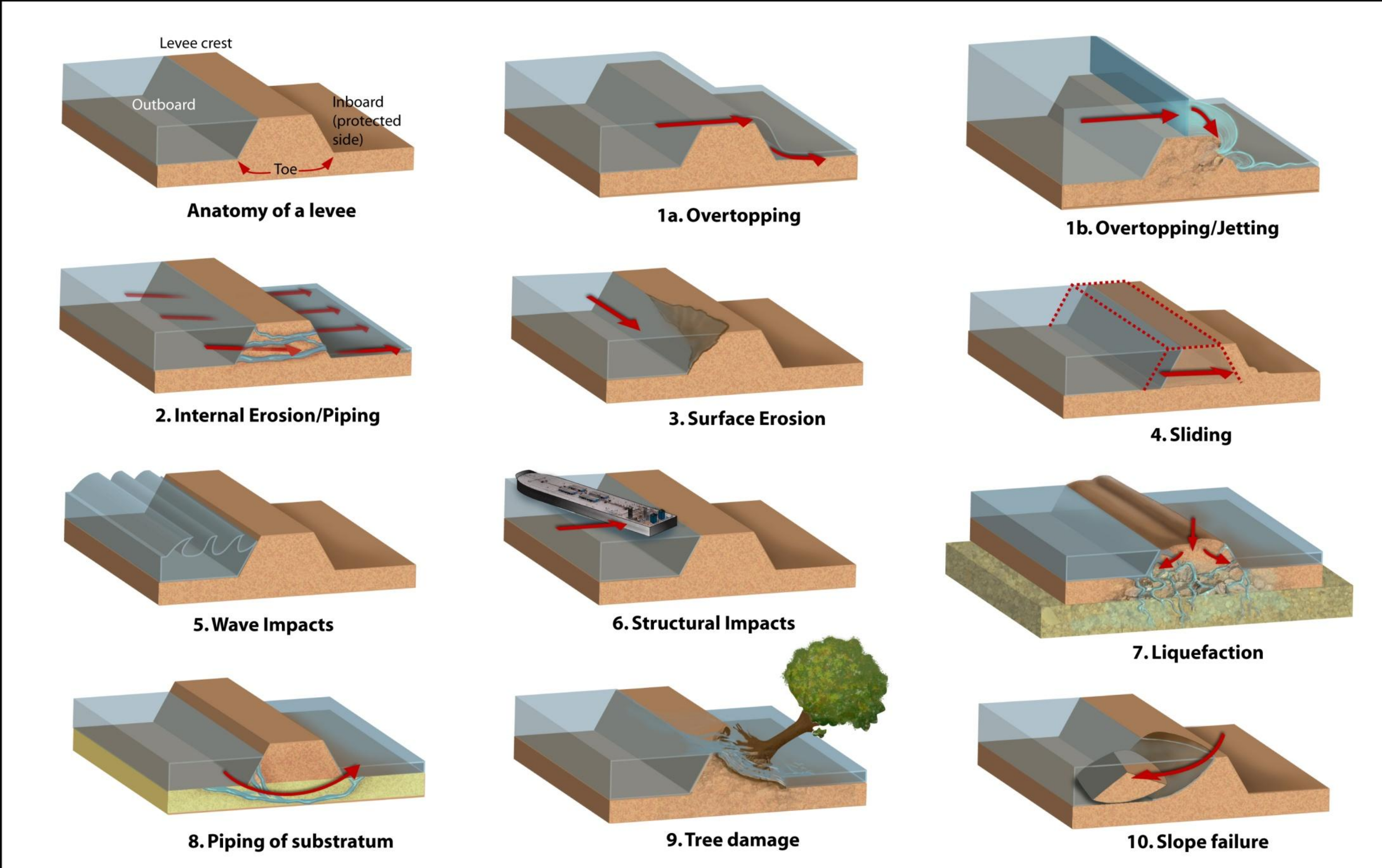




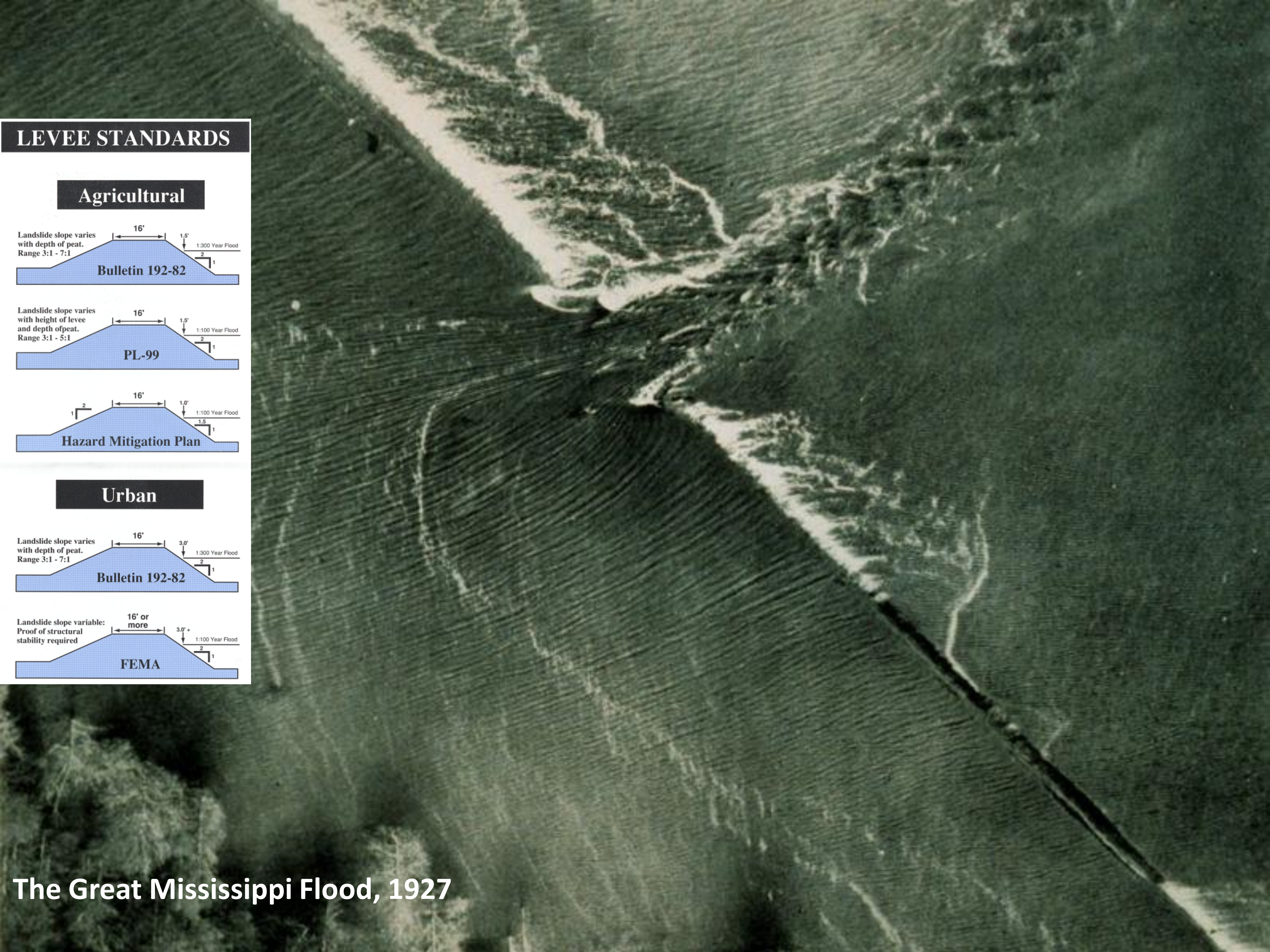
CONSTRUCTION OF LEVEES INCREASES THE CROSS-SECTIONAL AREA OF THE RIVER CHANNEL ALLOWING SAFE PASSAGE OF HIGHER DISCHARGE



STABILITY OF LEVEES A KEY COMPONENT OF FLOOD PLAIN /FLOOD MANAGEMENT



MECHANISMS OF LEVEE FAILURE



The Great Mississippi Flood, 1927

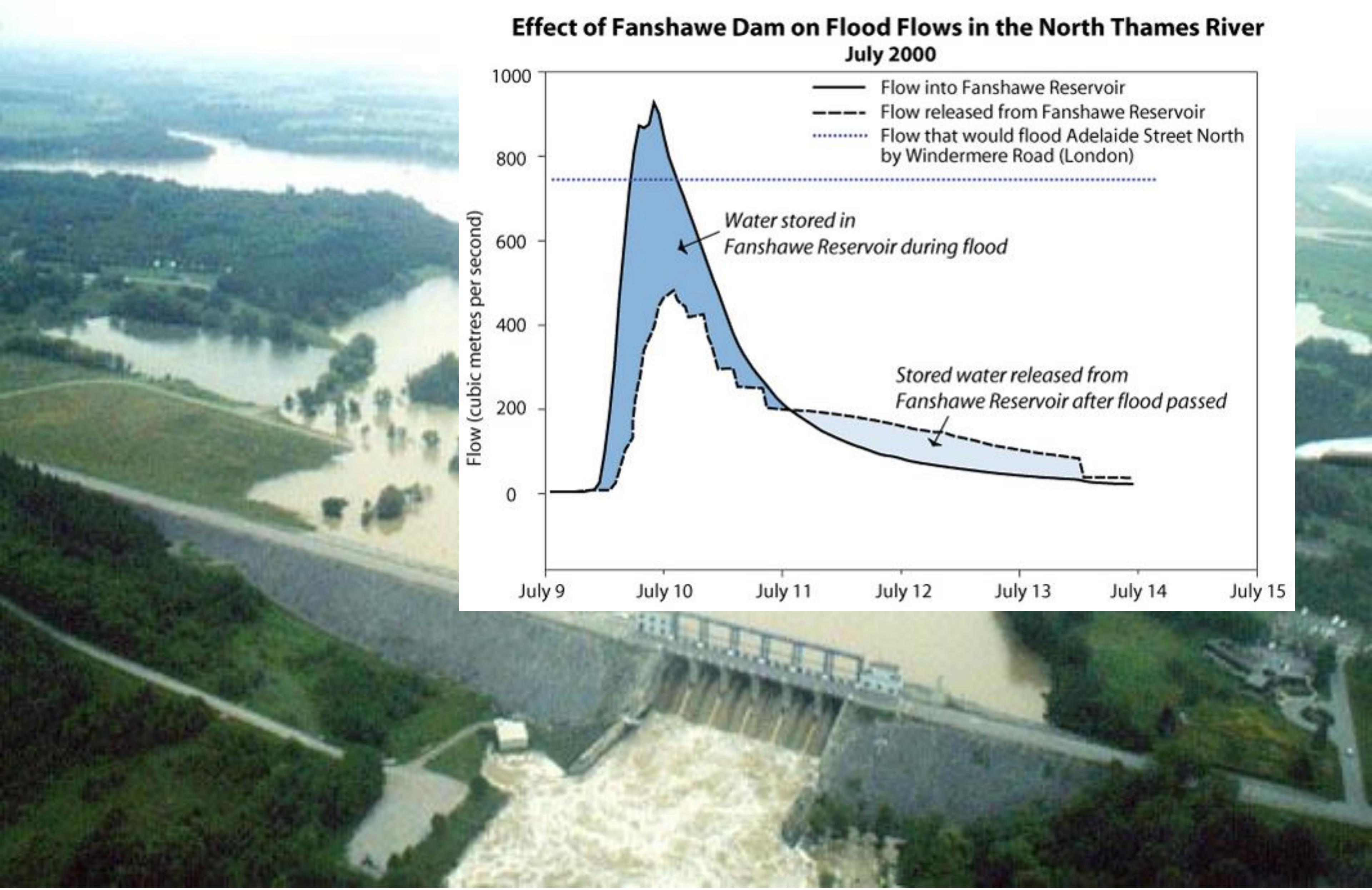
1927 Flood, Arkansas City

Flooding at Pacific, MO

Flood-control reservoirs reduce flooding downstream. Tuttle Creek Lake, July 1993

USGS


Folsom Dam, CA



Fanshawe Dam and Reservoir during 2000 Flood (Upper Thames River, ON)

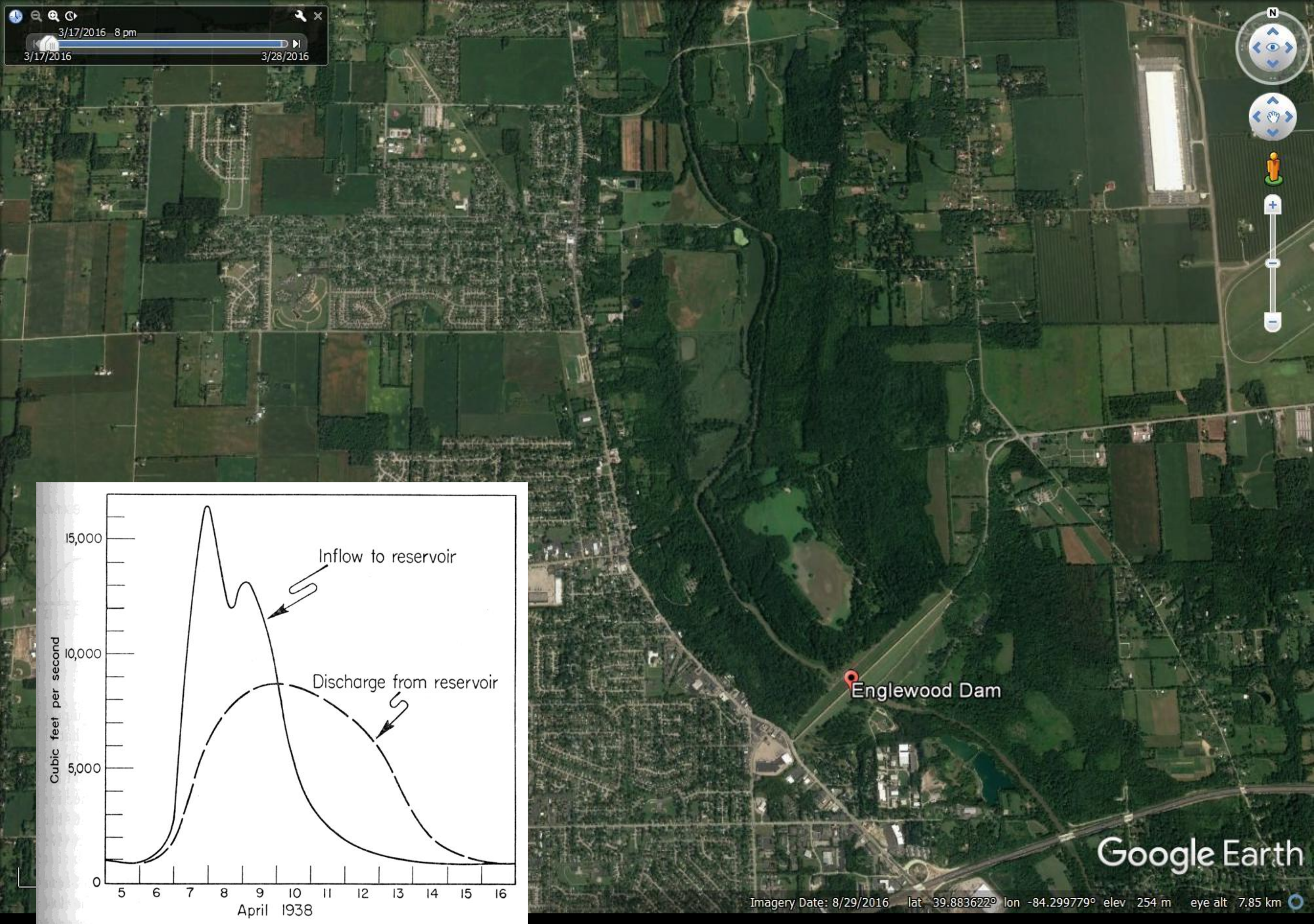


Fig. 30. Effect of Englewood, Ohio, retarding reservoir during flood of April 1938.

The Great Mississippi River Flood of 1927,
photographed in Illinois on March 25.

"The Floods of 1927 in the Mississippi Basin," Frankenfeld, H.C., 1927 Monthly Weather Review Supplement No. 29

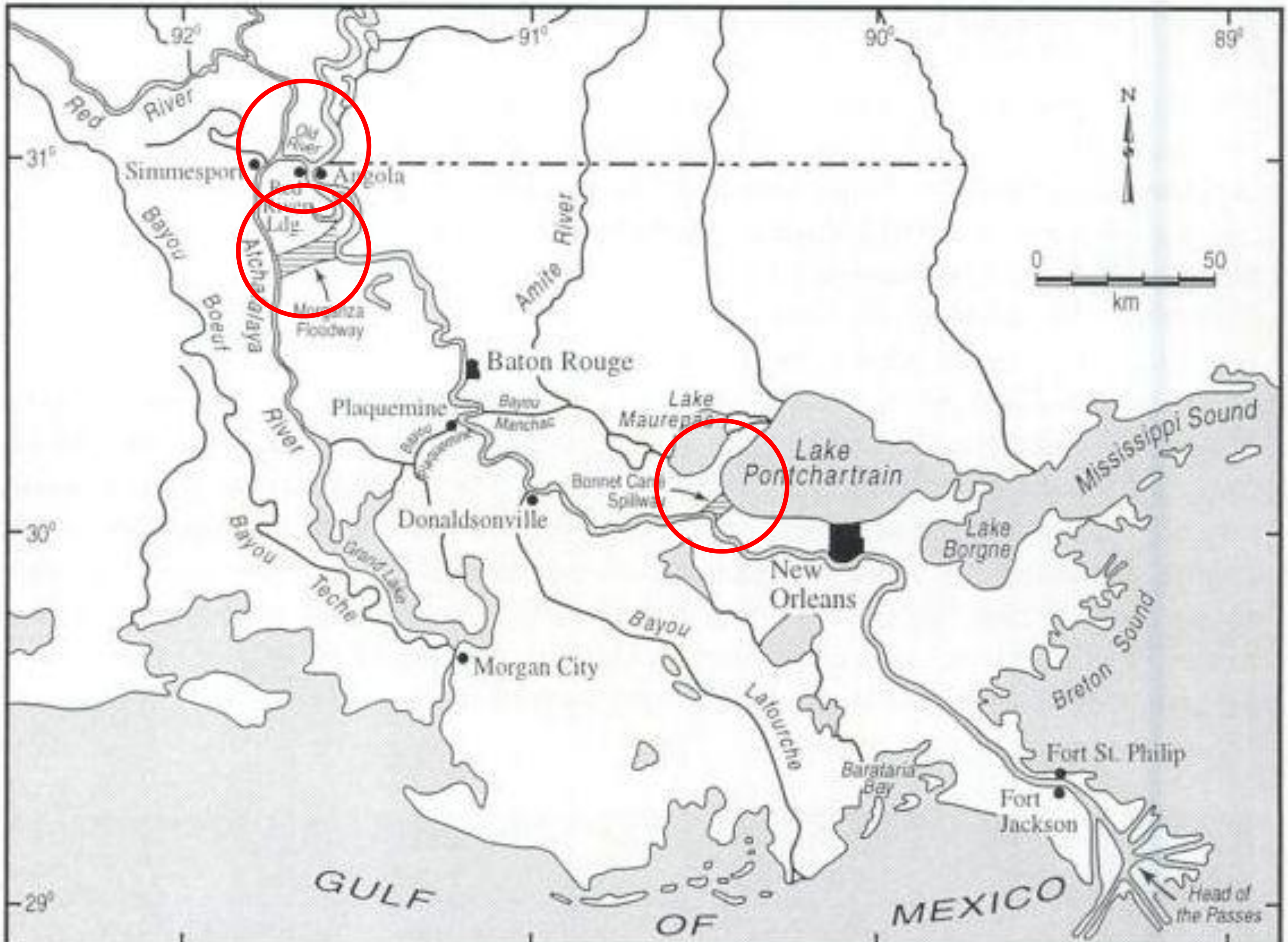
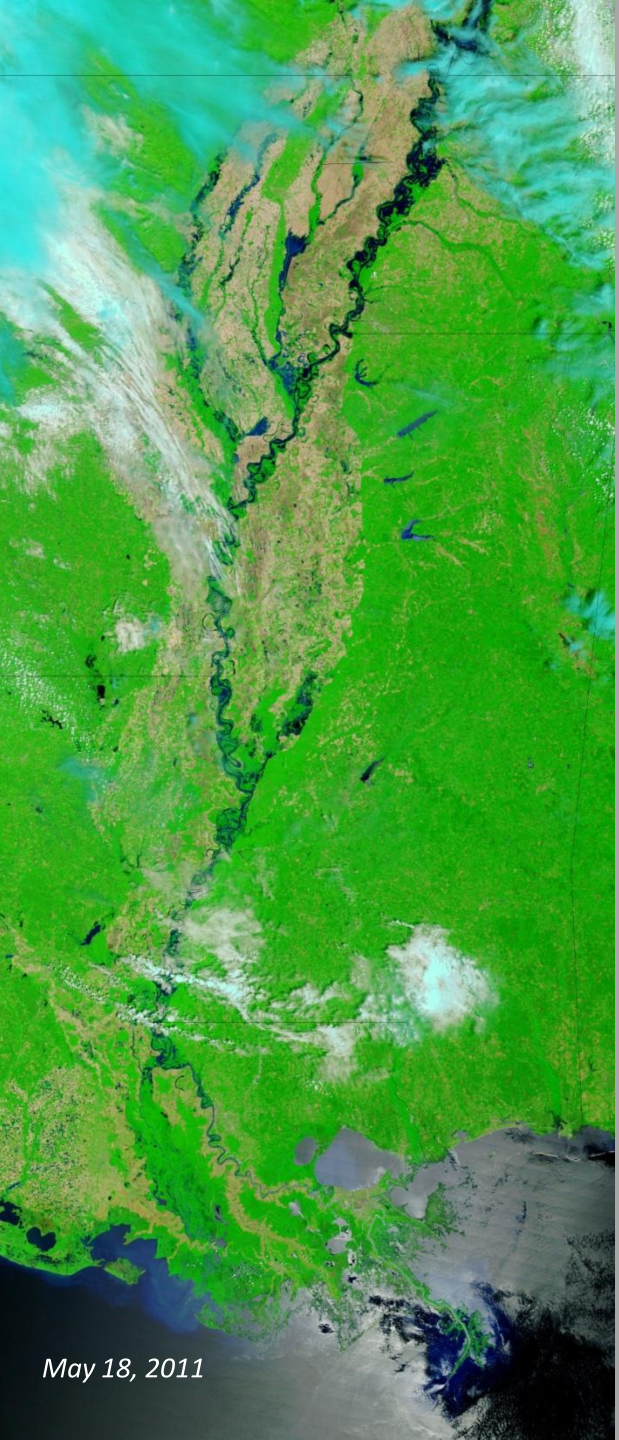


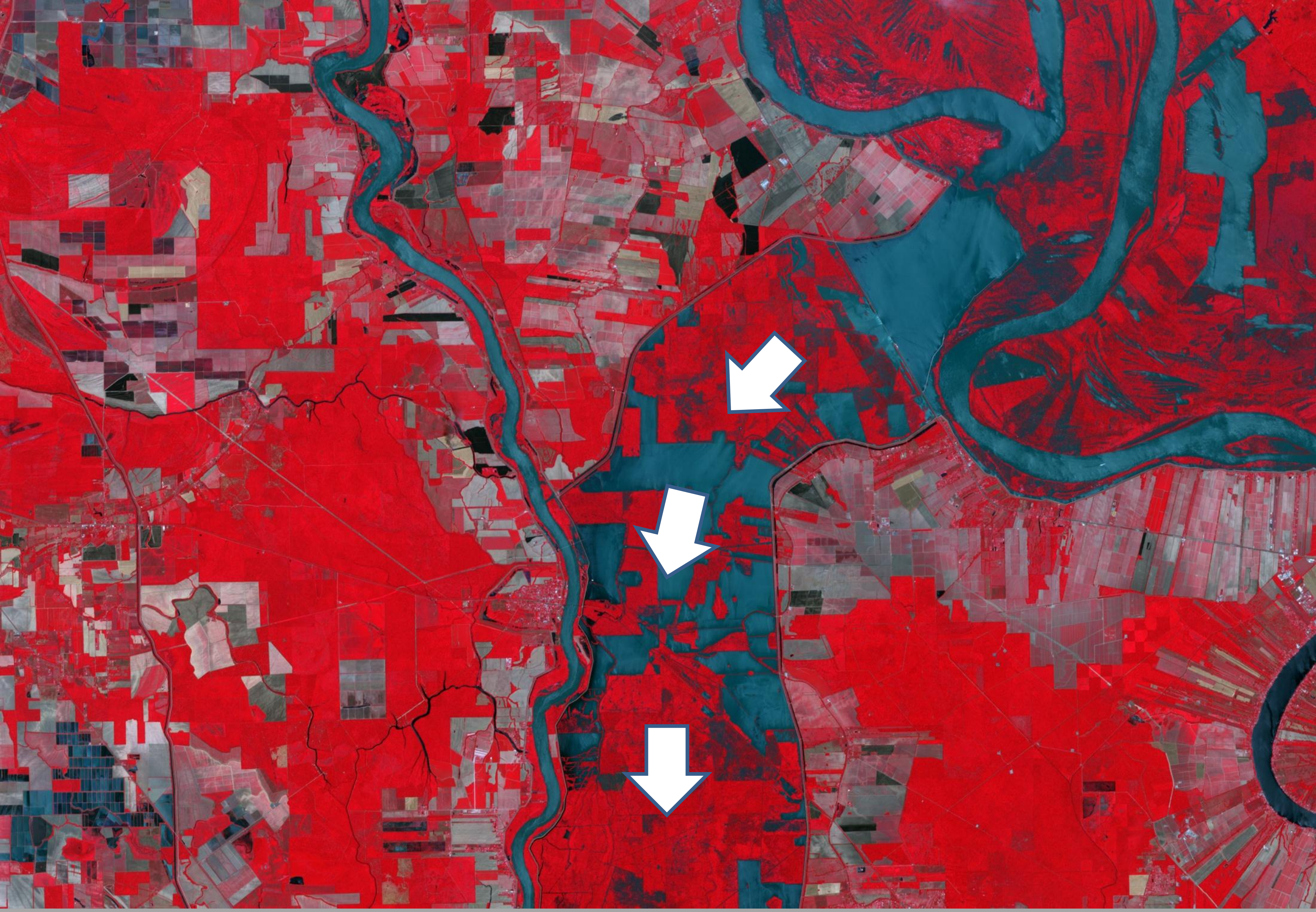
Fig. 3. The Lower Mississippi River and its distributaries and spillways.



SUPER FLOODS ON THE MISSISSIPPI

2011 MISSISSIPPI RIVER FLOODS

- Comparable to the super floods of 1927 and 1993
- Morganza Spillway (completed in 1954) opened for the first time in 1973 and opened again in 2011

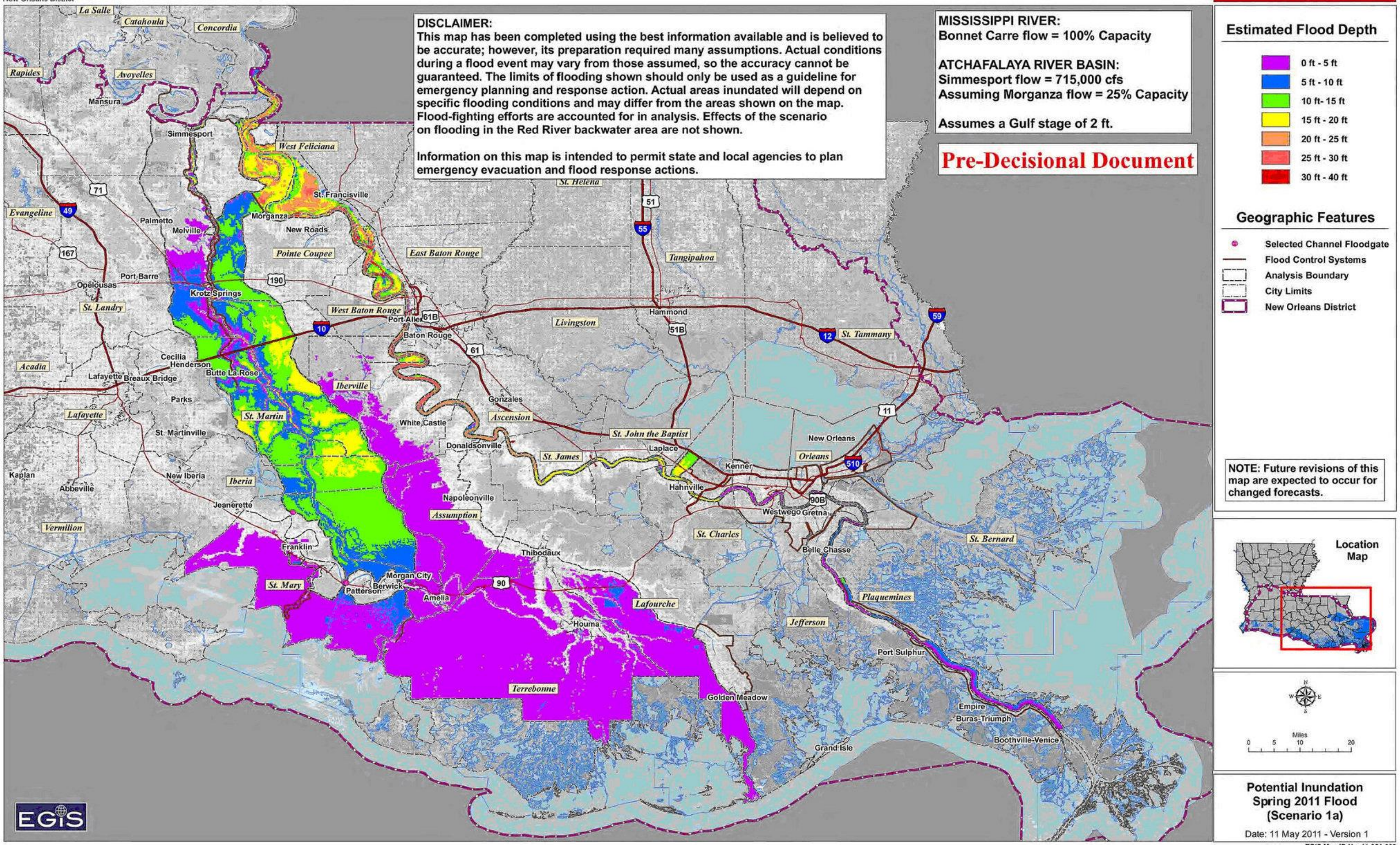


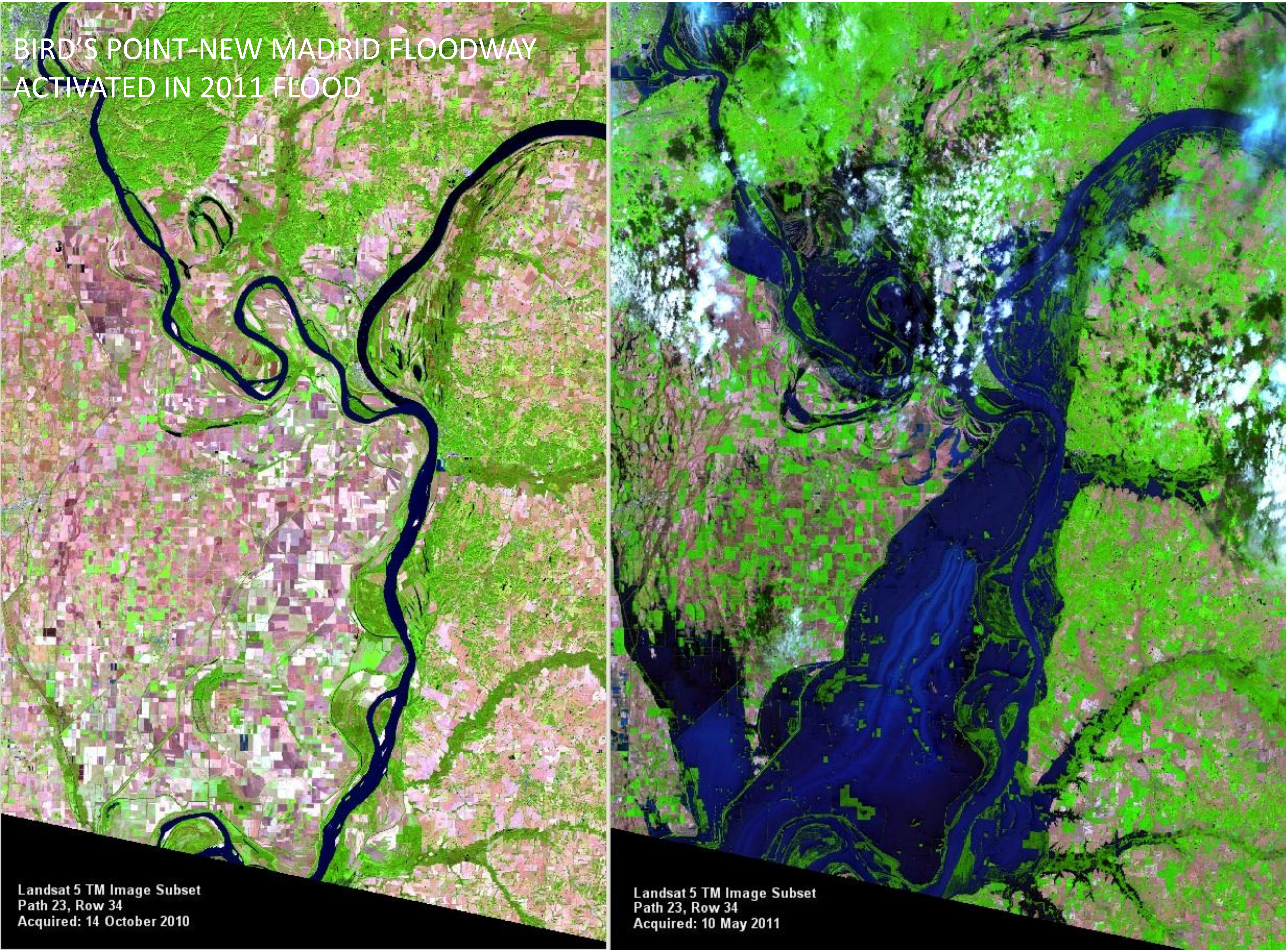
Morganza Floodway in operation, May 18, 2011

US Army Corps of Engineers
New Orleans District

Potential Inundation (Scenario 1a)

12 May 2011 @ 0800 HRS




BIRD'S POINT-NEW MADRID FLOODWAY
ACTIVATED IN 2011 FLOOD
Landsat 5 TM Image Subset
Path 23, Row 34
Acquired: 14 October 2010
Landsat 5 TM Image Subset
Path 23, Row 34
Acquired: 10 May 2011

Manggahan Floodway in operation (Manila) in 2009 Flood

UNDERGROUND FLOOD CONTROL, TOKYO

Underground discharge channel, Tokyo

THE WINNIPEG FLOODWAY

Built in response to the $125 million in damage done by the flood of 1950. 80,000 people were forced to leave Winnipeg and 20,000 were evacuated from rural areas.

A total of 47 kilometres long.

Work was completed on the dike in 1968.

Total cost for construction was $63-million.

The floodway serves to divert the Red River around the eastern edge of the city where it continues on to its final destination, Lake Winnipeg.

The floodway has saved the city from flooding 18 times.

It was estimated that without the floodway in 1997, 80 percent of Winnipeg would have been underwater and 500,000 city dwellers evacuated.

WINNIPEG FLOODWAY

RECURRENCE INTERVAL (R), RETURN PERIOD (P), ANNUAL PROBABILITY OF EXCEEDANCE (AP), ANNUAL FREQUENCY (AF)

TABLE 14.3

Top Ten Mississippi River Floods at St. Louis, 1861–2005

Date	Discharges in Cubic Feet/Second
1993 August	1,030,000
1903 June	1,019,000
1892 May	926,500
1927 April	889,300
1883 June	862,800
1909 July	860,600
1973 April	852,000
1908 June	850,000
1944 April	844,000
1943 May	840,000

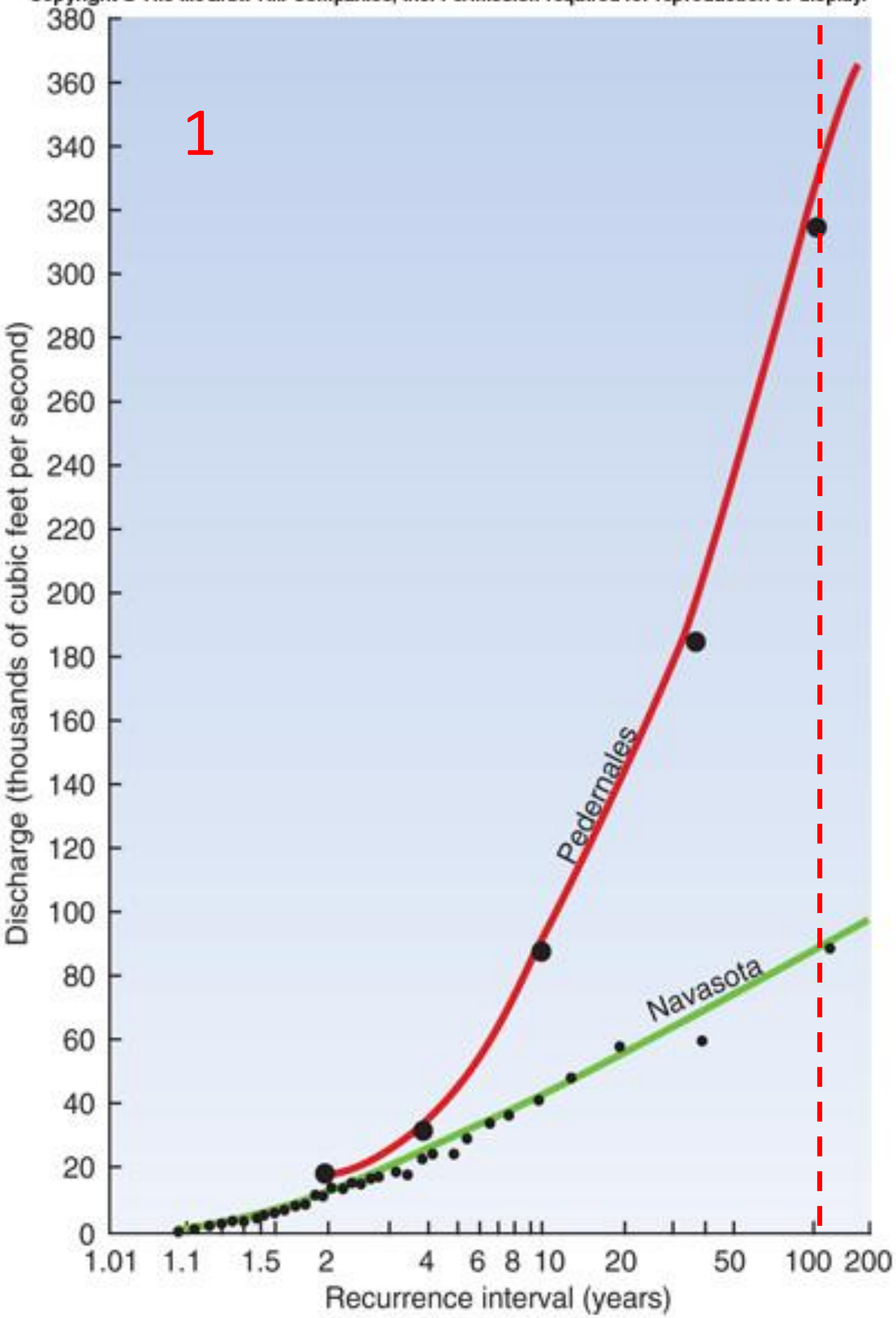
Source: *Illinois State Water Survey Miscellaneous Publication 151 (1994), Champaign.*

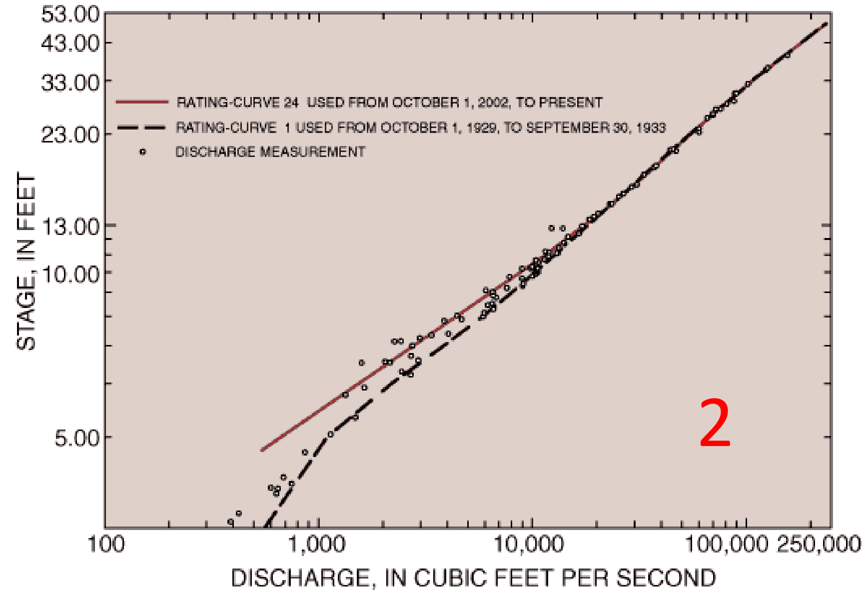
RECURRENCE INTERVAL (R) OF A GIVEN FLOOD MAGNITUDE

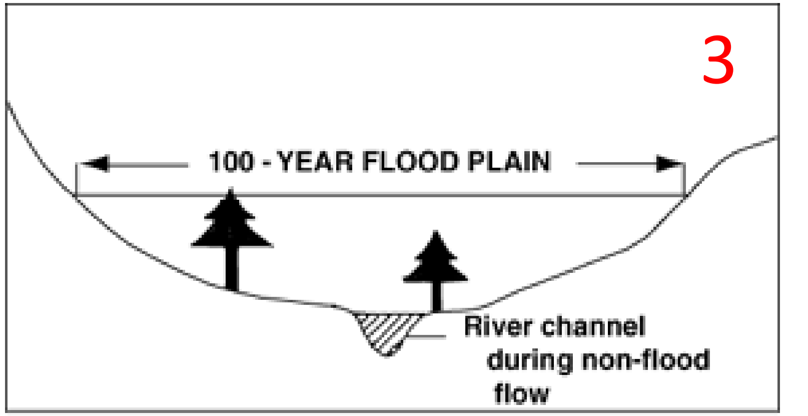
$R = (N+1) / M$

where N = length of flood record in years; M = numerical rank of each year's maximum flood discharge

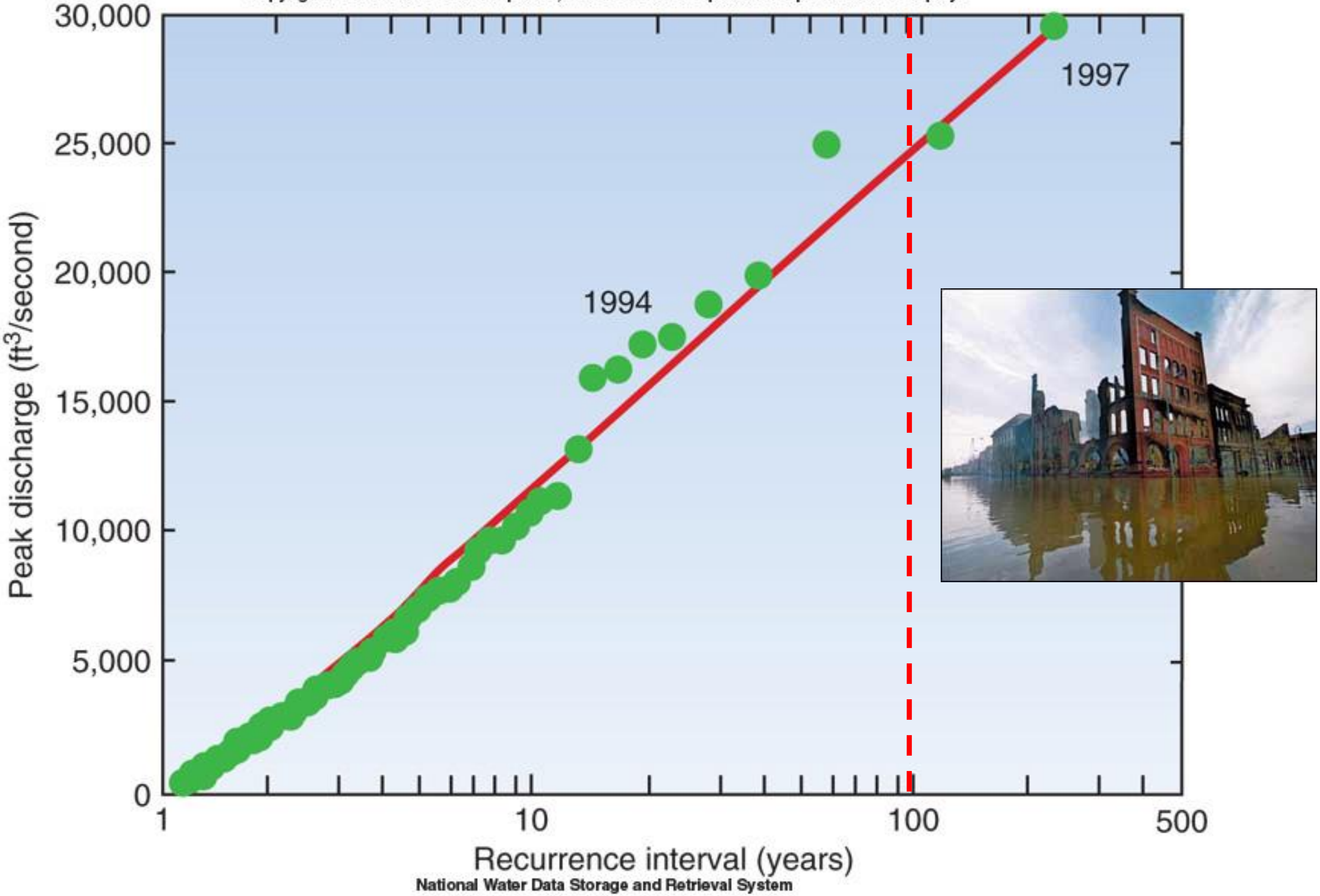
PROBABILITY OF A GIVEN FLOOD MAGNITUDE OCCURRING IN ANY ONE YEAR (ANNUAL PROBABILITY) IS RECIPROCAL OF R (OR 1/R)







FLOOD PLAINS NORMALLY ARE DRY



FLOOD-FREQUENCY CURVE FOR THE RED RIVER, FARGO, NORTH DAKOTA, 1882-1997

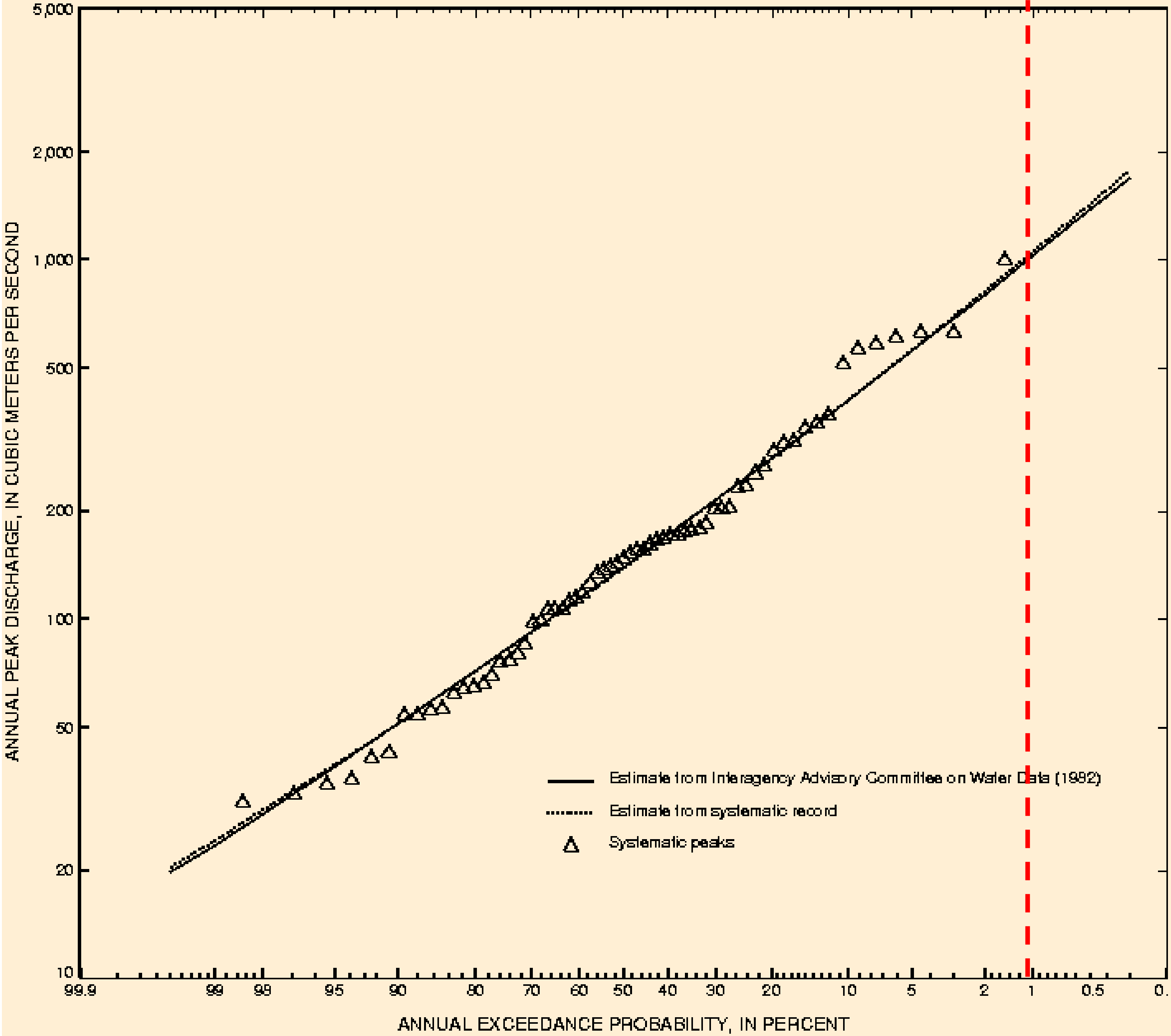
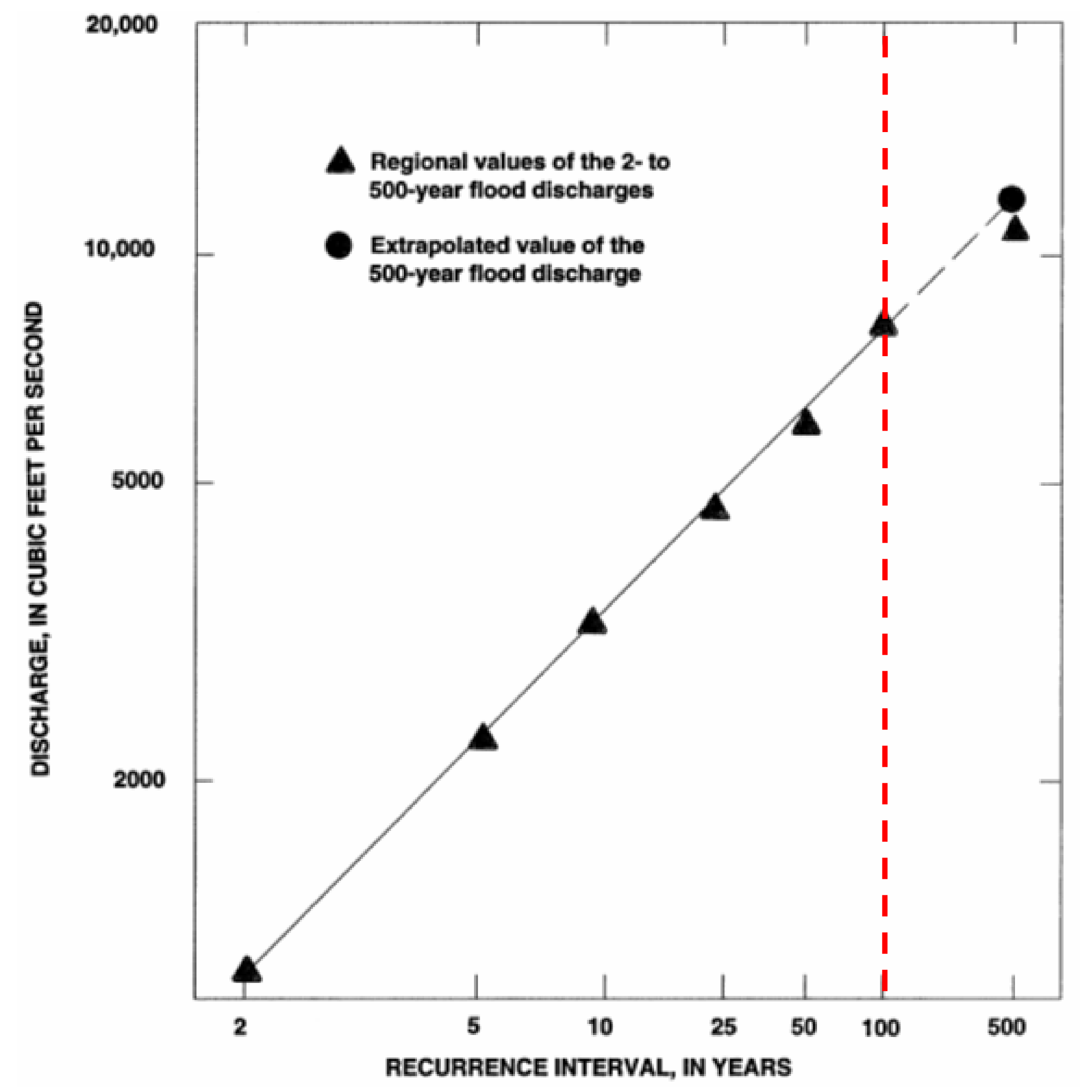
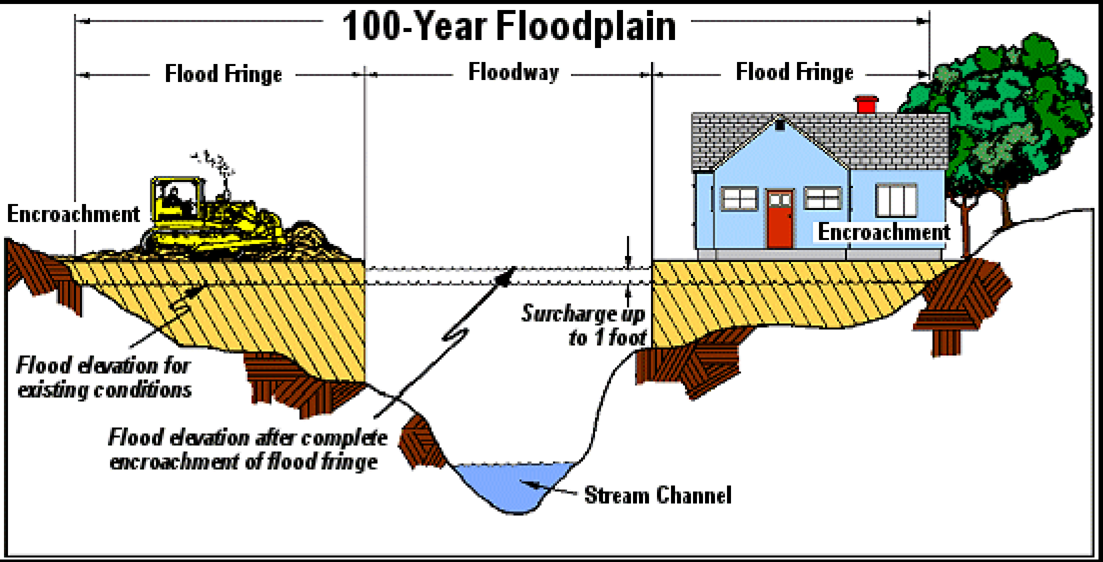
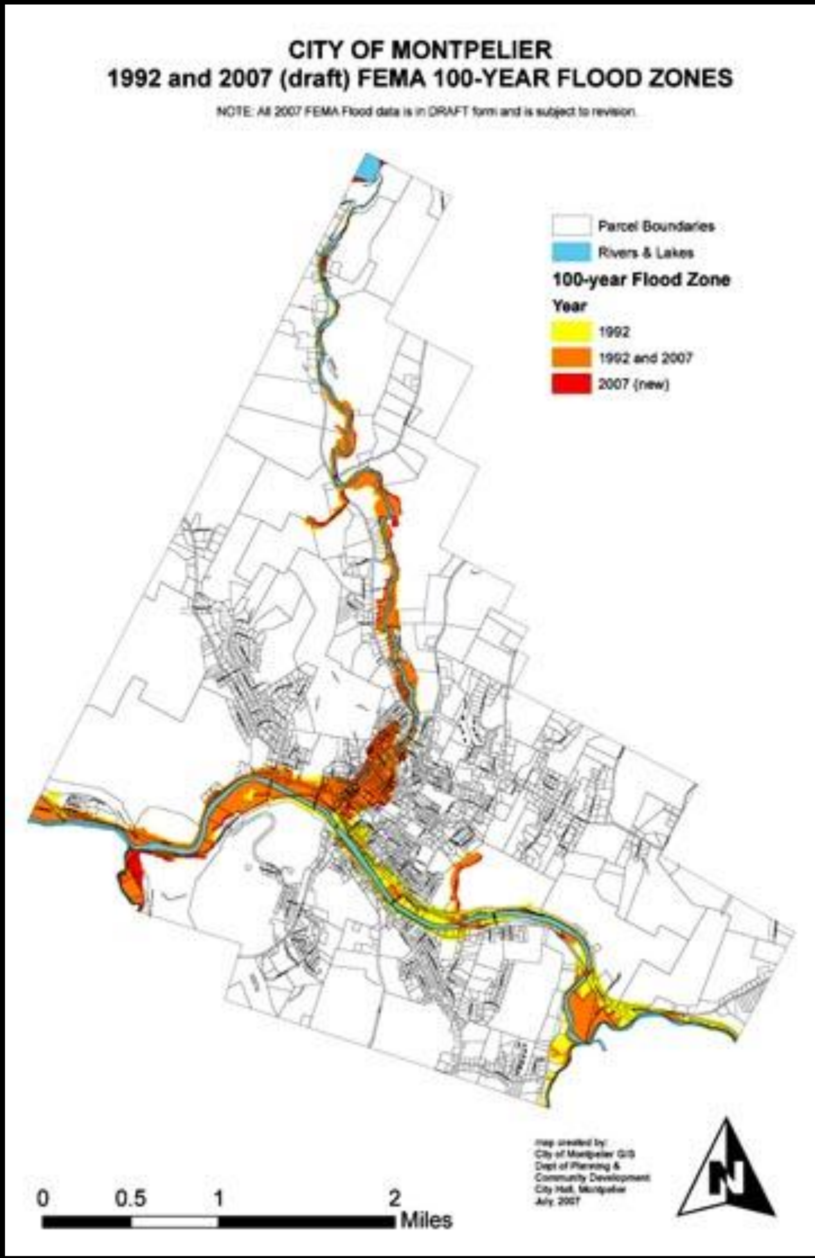


Figure 3. Flood-frequency curve for Virgin River at Littlefield, Ariz. (gaging station 09415000).

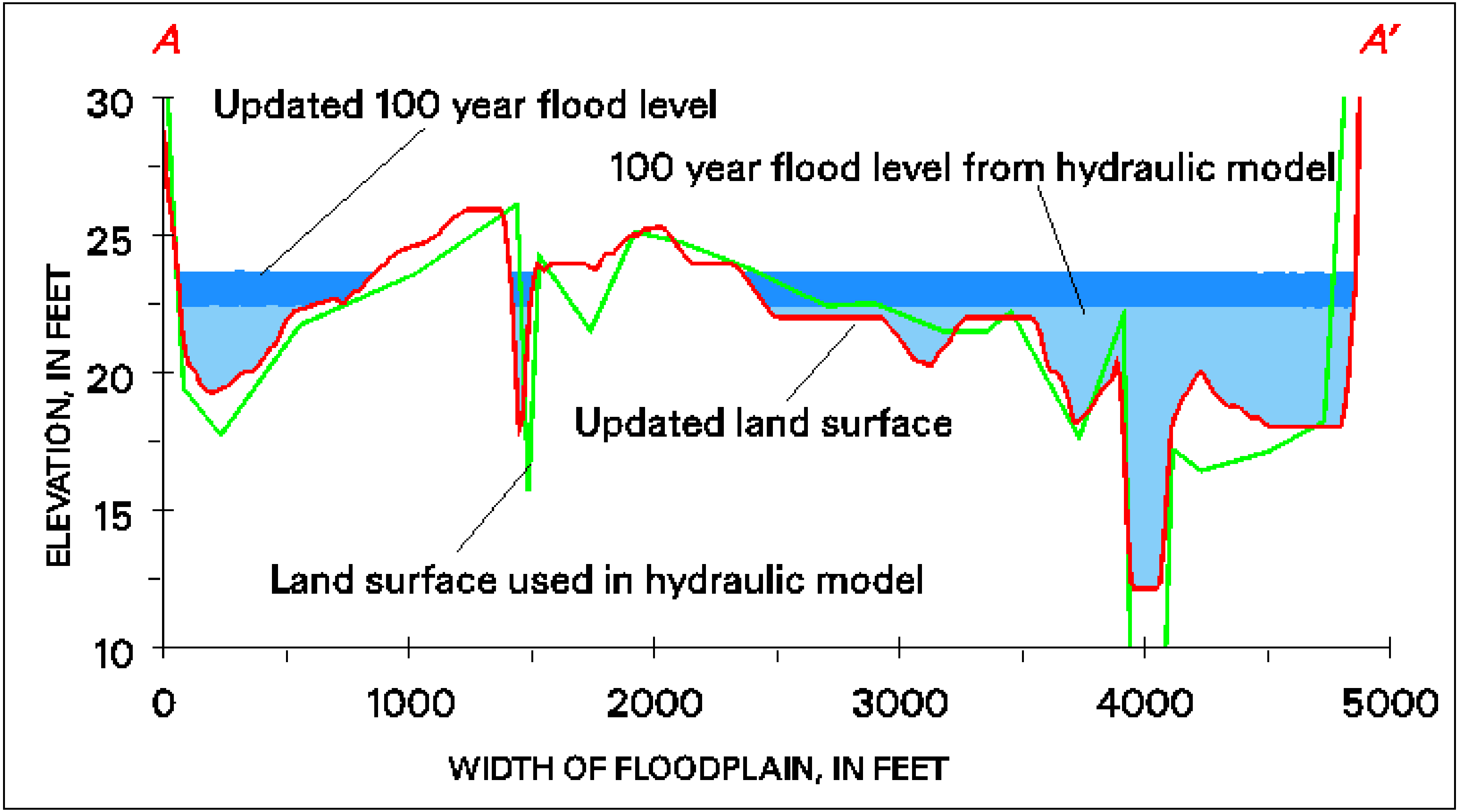


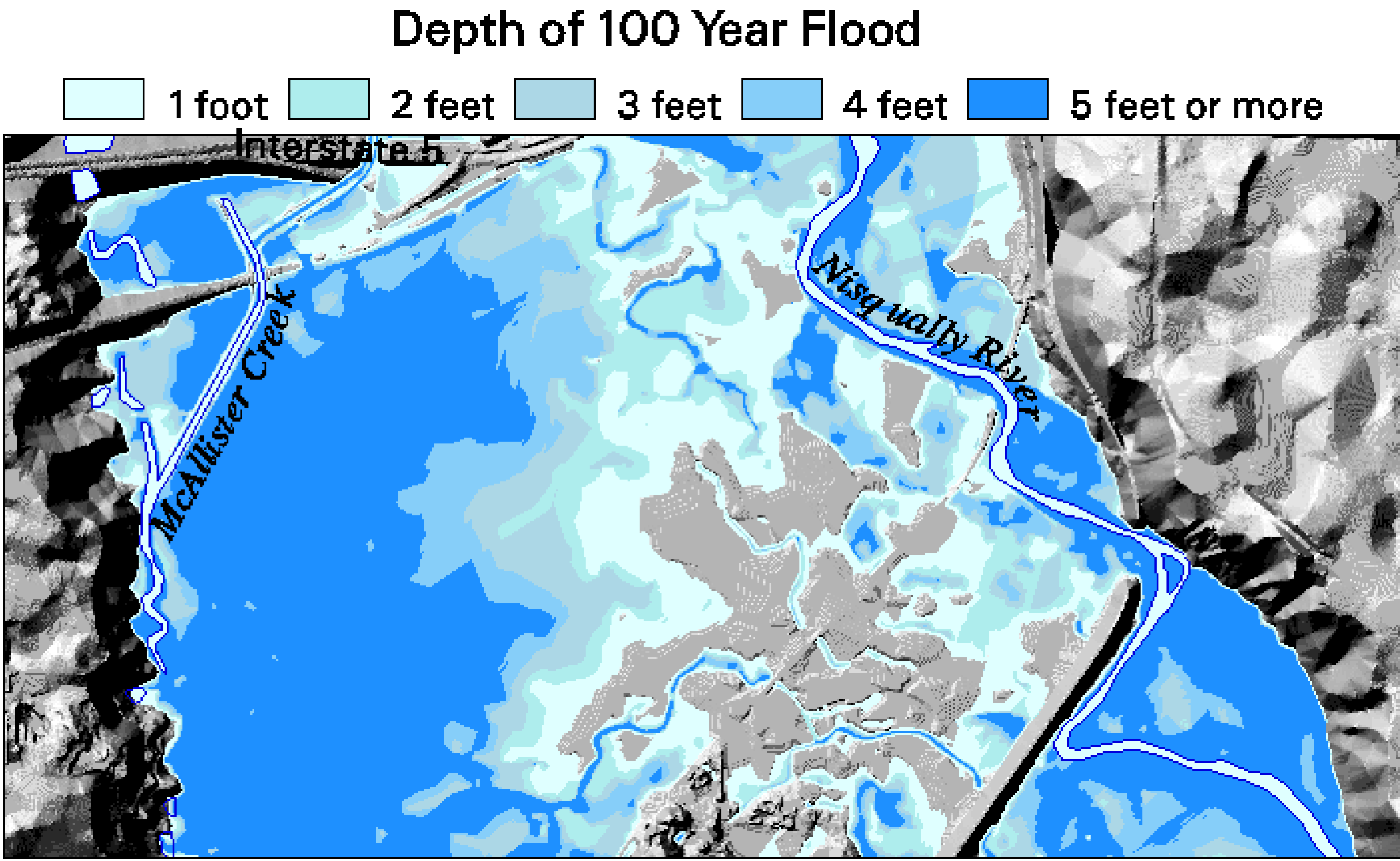
Köln, Germany 1995



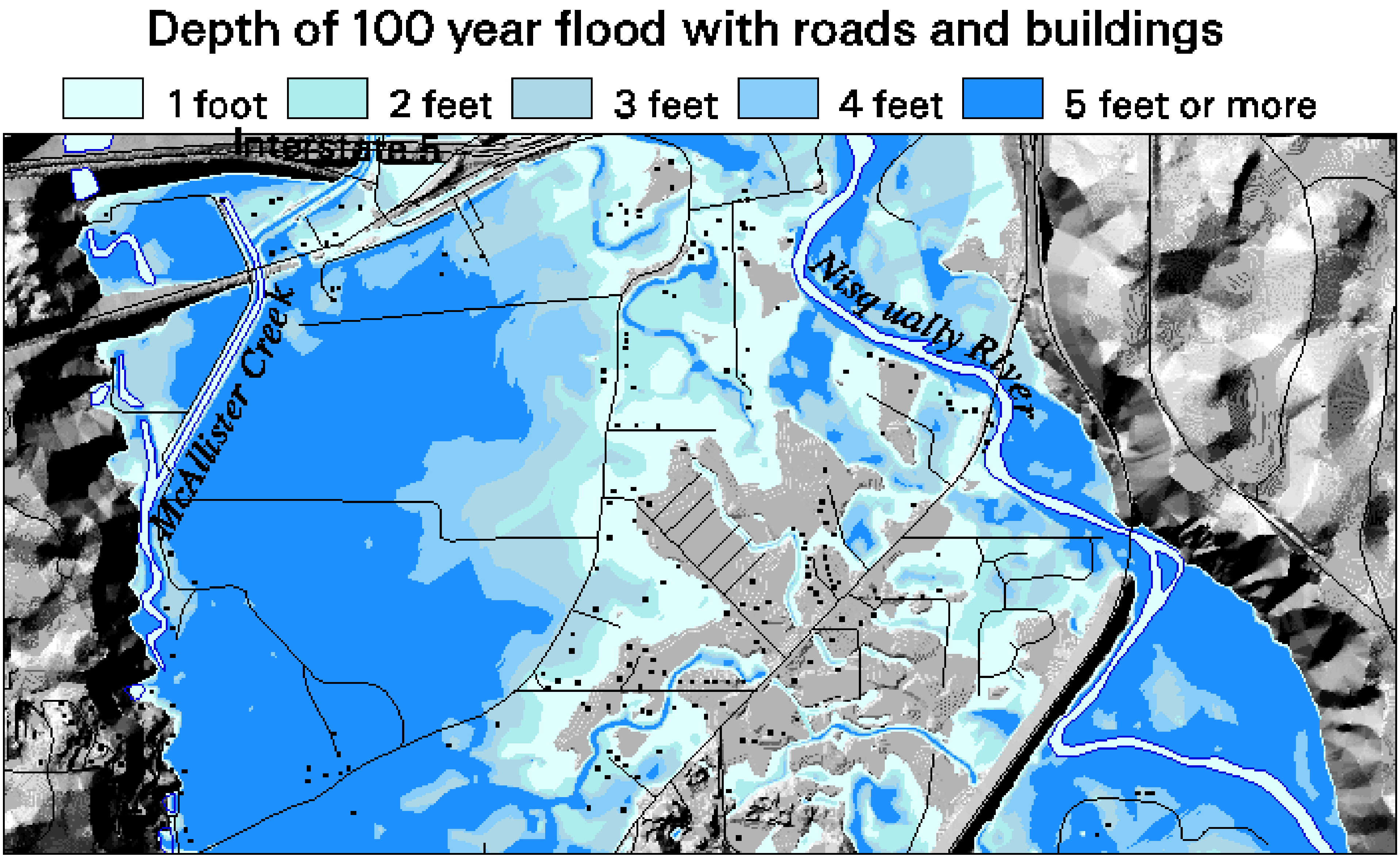


BASICS OF FLOODPLAIN ZONING


A
A′
Updated 100 year flood level
100 year flood level from hydraulic model
Updated land surface
Land surface used in hydraulic model
ELEVATION, IN FEET
30
25
20
15
10
0
1000
2000
3000
4000
5000
WIDTH OF FLOODPLAIN, IN FEET



FLOOD PLAIN MAPPING WITH GIS

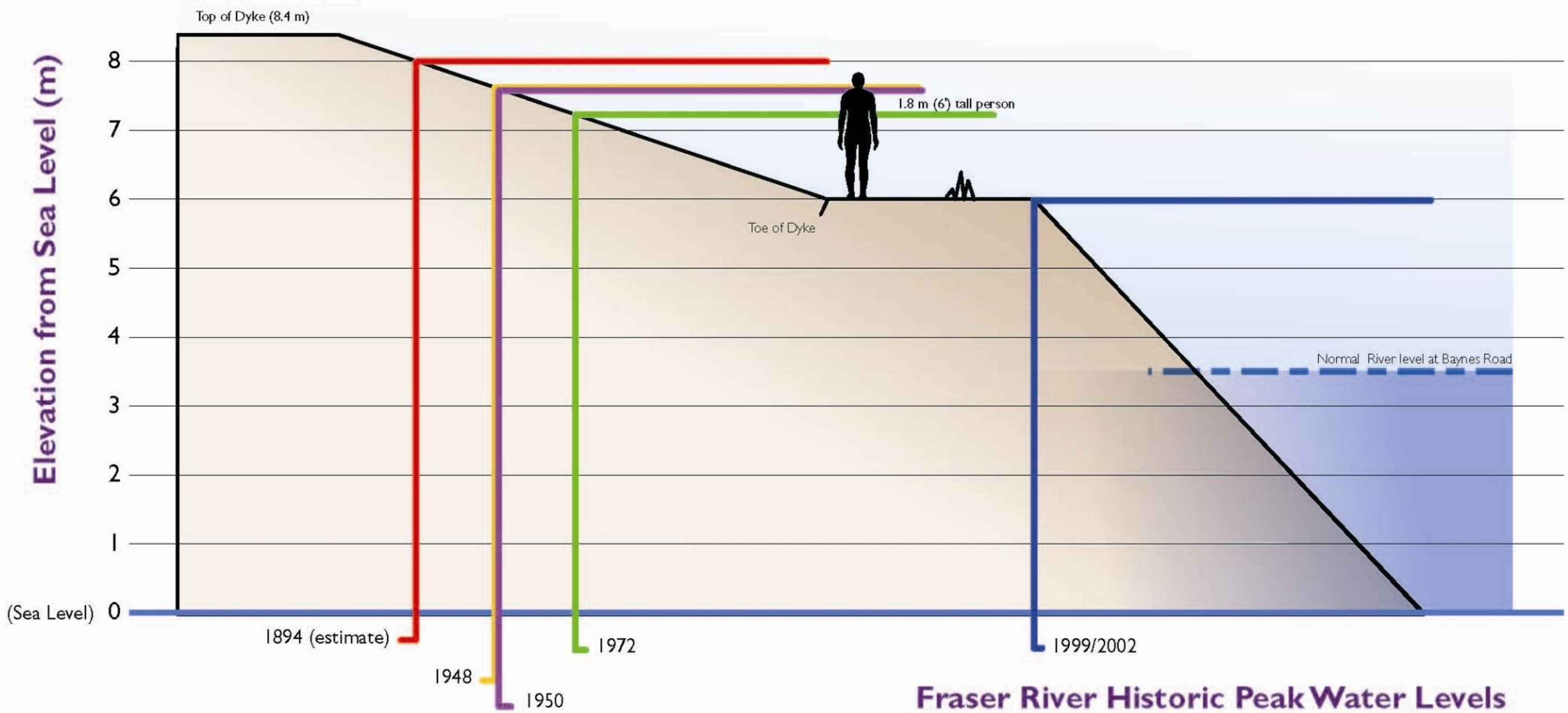


FLOOD PLAIN MAPPING WITH GIS

The 100 Year Flood Myth

The last term of measurement is frequency. This is also called the "return period" or "probability of return." The frequency is actually just how often a flood of this magnitude can be expected to occur. The frequency can be expressed as the interval of time expected to pass between occurrences of a certain size flood or the probability, expressed as a percentage, that an event of this size will occur in any given year. For instance, A FLOOD THAT OCCURS STATISTICALLY ONCE EVERY 100 YEARS ALSO HAS A 1% CHANCE OF OCCURRENCE IN ANY GIVEN YEAR. Frequency is the measurement of choice when evaluating the costs/benefits of potential solutions to flooding problems or when one attempts to look at flooding events of the same magnitude in a number of different communities.

Typical Dyke Section in Pitt Meadows (River Side Only)



Fraser River Historic Peak Water Levels
(Fraser River at Mission)

RECURRENCE INTERVAL (R), RETURN PERIOD (P), ANNUAL PROBABILITY OF EXCEEDANCE (AP), ANNUAL FREQUENCY (AF) – MAGNITUDE AND FREQUENCY

TABLE 14.3

Top Ten Mississippi River Floods at St. Louis, 1861–2005

Date	Discharges in Cubic Feet/Second
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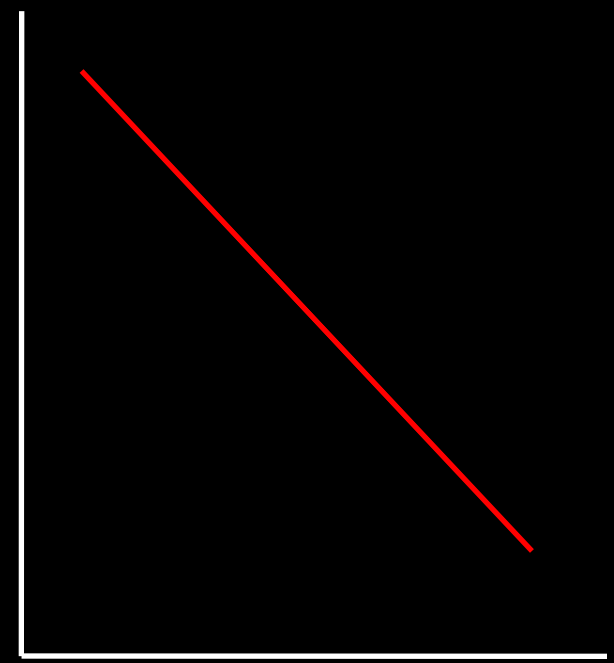
1927 April	889,300
1883 June	862,800
1909 July	860,600
1973 April	852,000
1908 June	850,000
1944 April	844,000
1943 May	840,000

Source: *Illinois State Water Survey Miscellaneous Publication 151 (1994), Champaign.*



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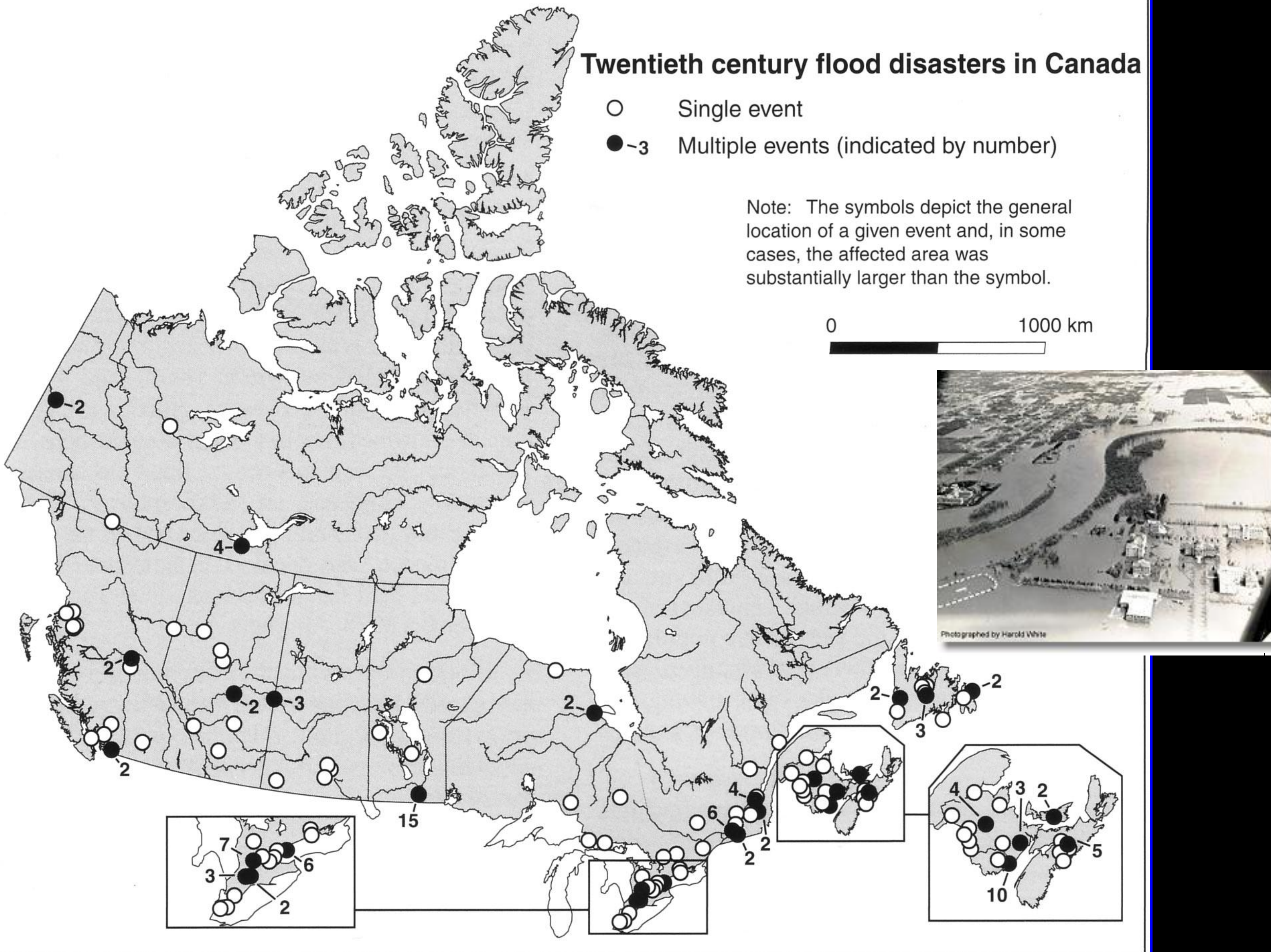
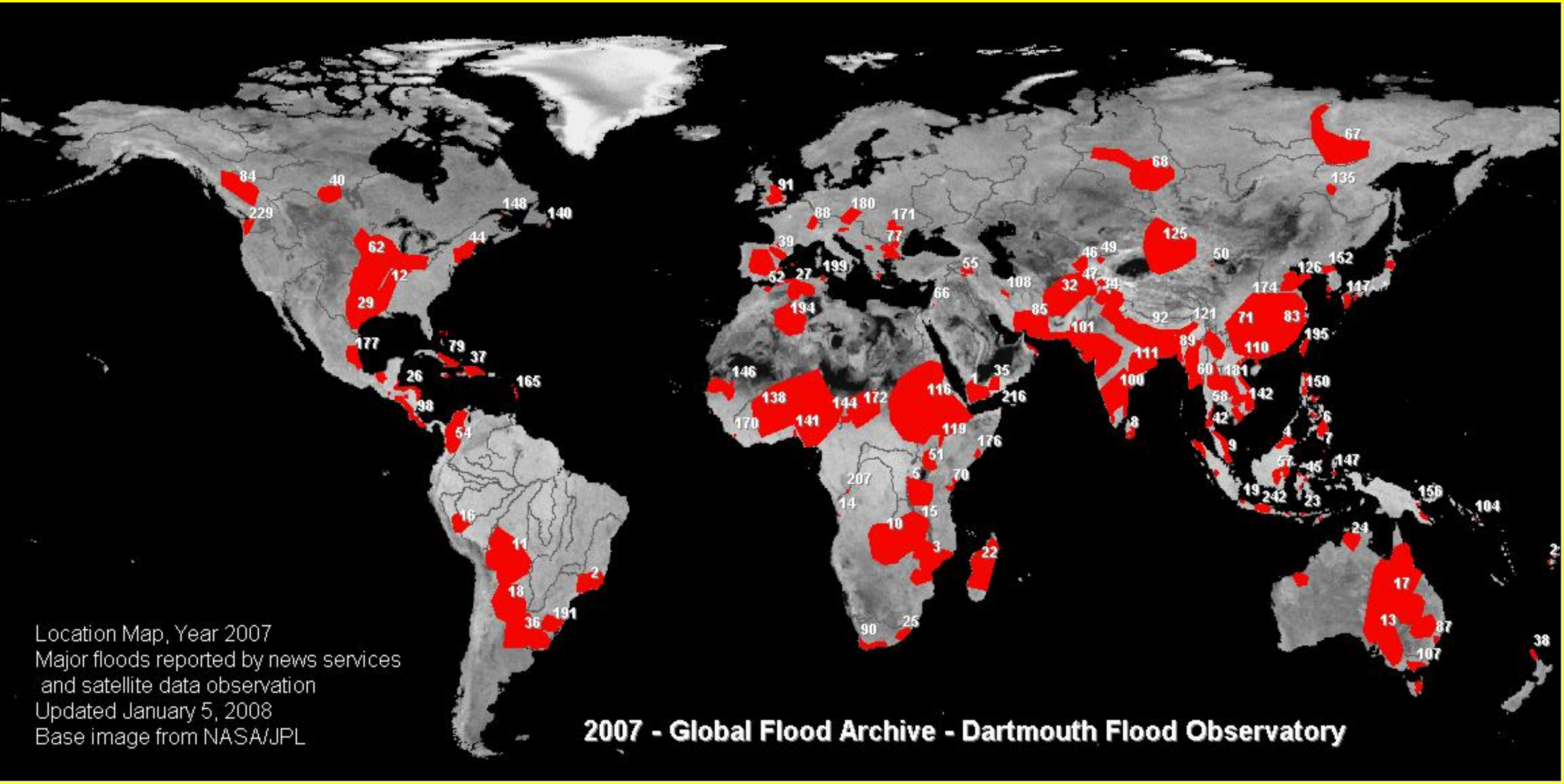
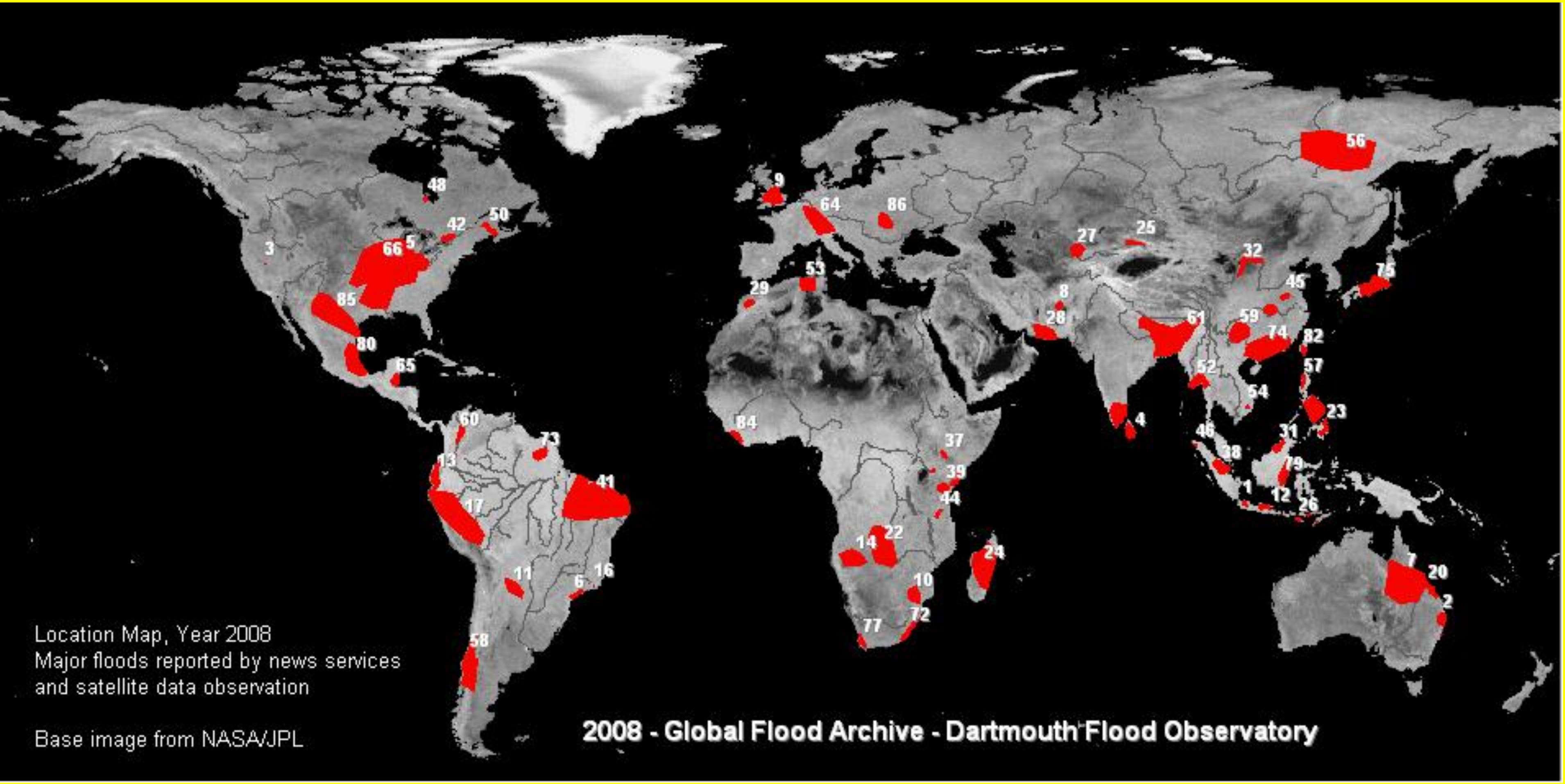
1973 April	852,000
1908 June	850,000
1944 April	844,000
1943 May	840,000

Source: *Illinois State Water Survey Miscellaneous Publication 151 (1994), Champaign.*


Twentieth century flood disasters in Canada
Single event
3 Multiple events (indicated by number)
Note: The symbols depict the general location of a given event and, in some cases, the affected area was substantially larger than the symbol.
0
1000 km
Photographed by Harold White


Location Map, Year 2007
Major floods reported by news services
and satellite data observation
Updated January 5, 2008
Base image from NASA/JPL
2007 - Global Flood Archive - Dartmouth Flood Observatory


Location Map, Year 2008
Major floods reported by news services
and satellite data observation
Base image from NASA/JPL
2008 - Global Flood Archive - Dartmouth Flood Observatory
56
9
64
86
48
42
50
3
66
5
85
80
65
53
29
27
25
32
75
45
8
28
61
59
74
82
57
52
54
23
4
84
60
73
13
17
41
37
39
44
46
38
31
79
1
12
26
14
22
24
10
11
16
6
77
72
58
7
20
2

DFO Event # 2008-3365 - Bihar - Rapid Response Inundation Map

MODIS flood inundation limit August 24, 2008:

Maximum Observed Inundation Limit 2000 - 2007:

SWBD reference water:

DCW Rivers:

Urban areas:

Universal Transverse Mercator Zone 45 North - WGS 84
Graticule: 2 degrees - Shaded relief from SRTM data

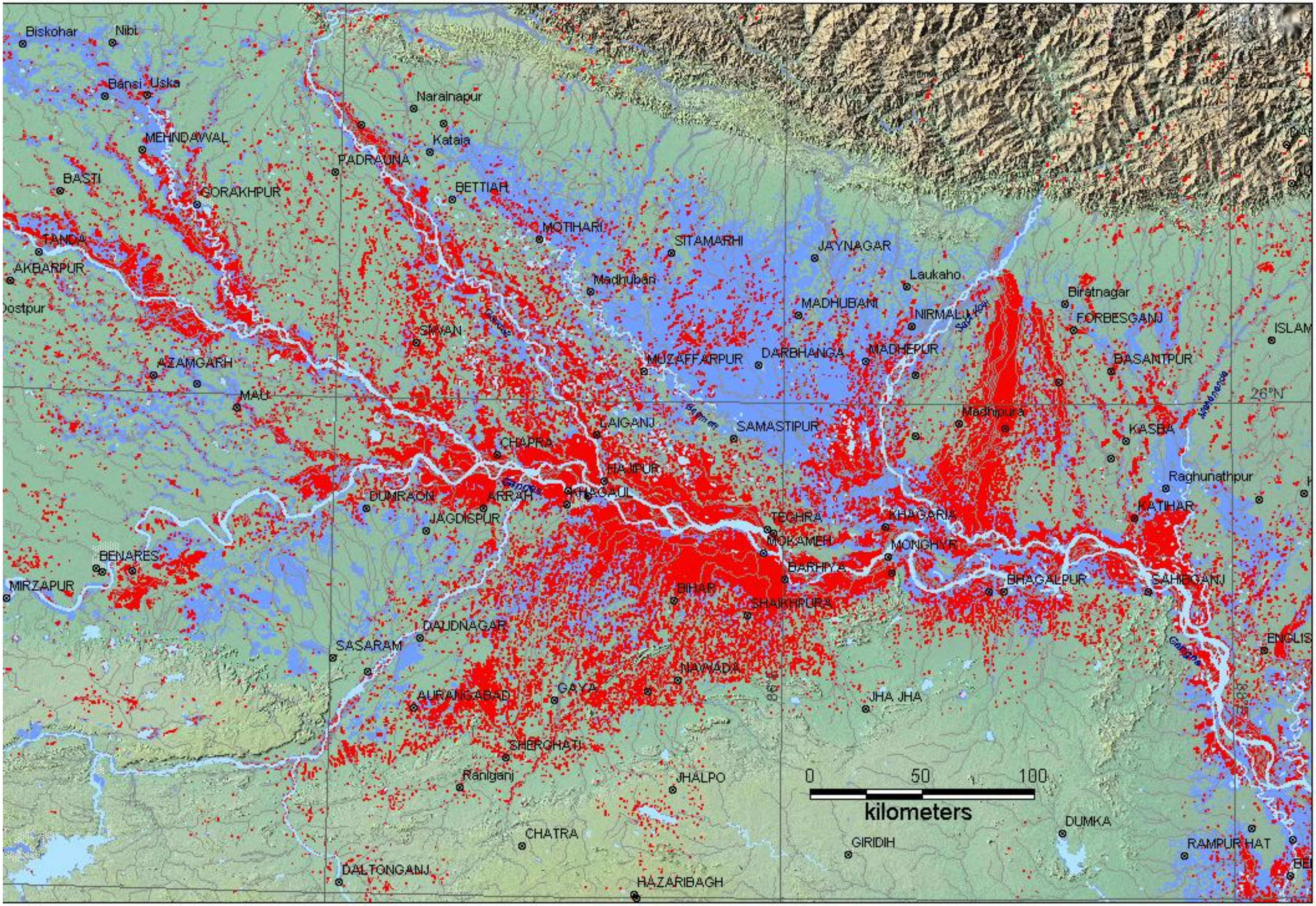
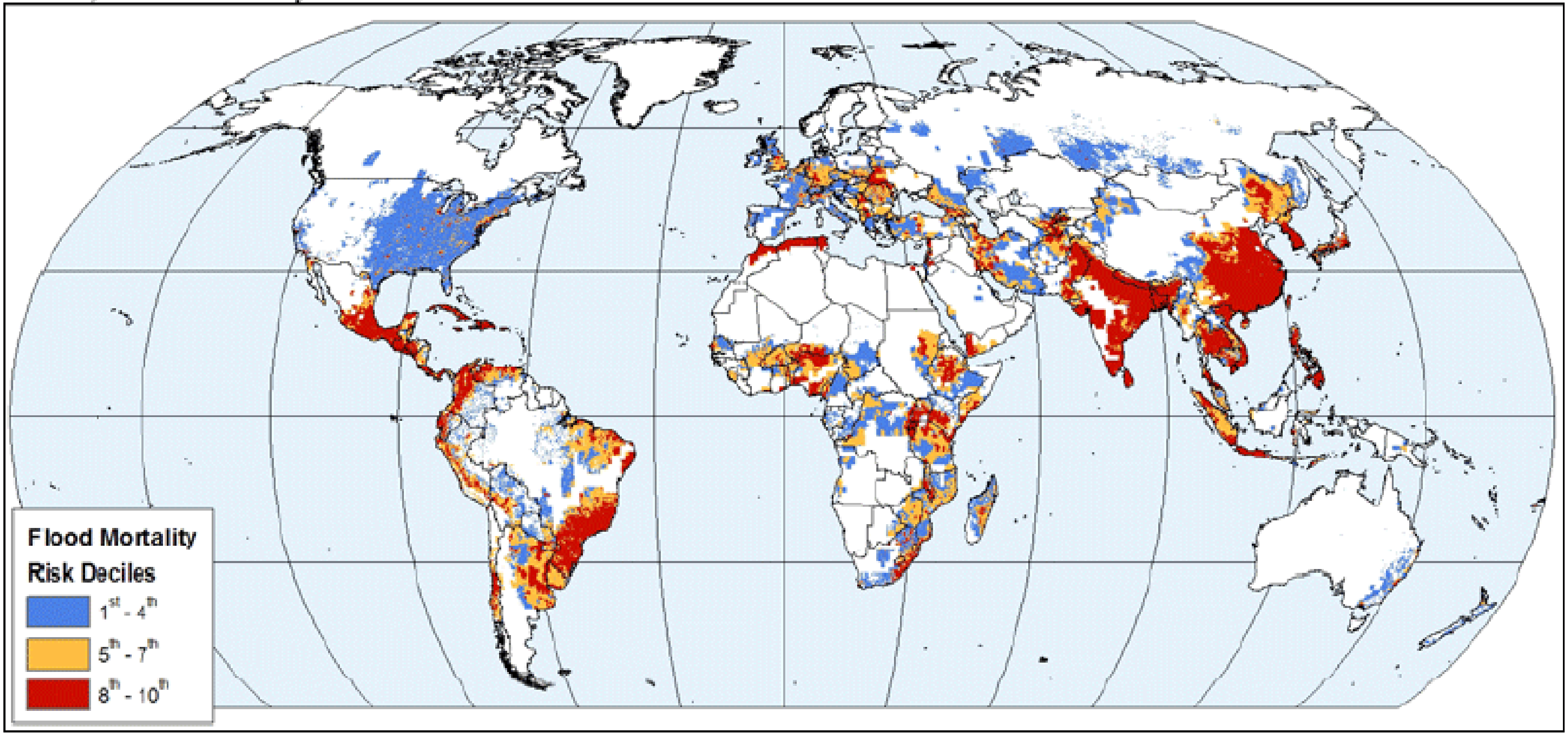
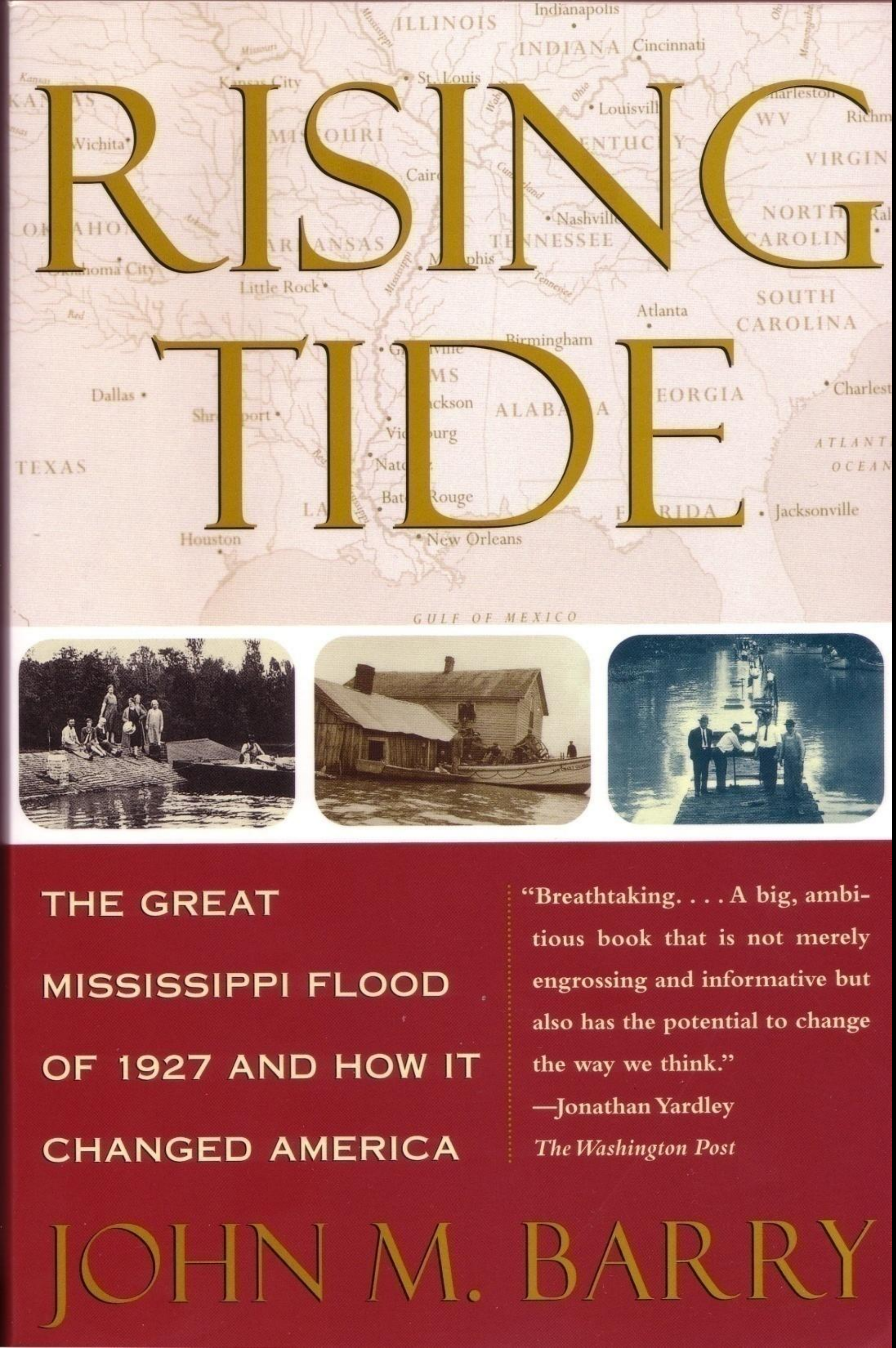


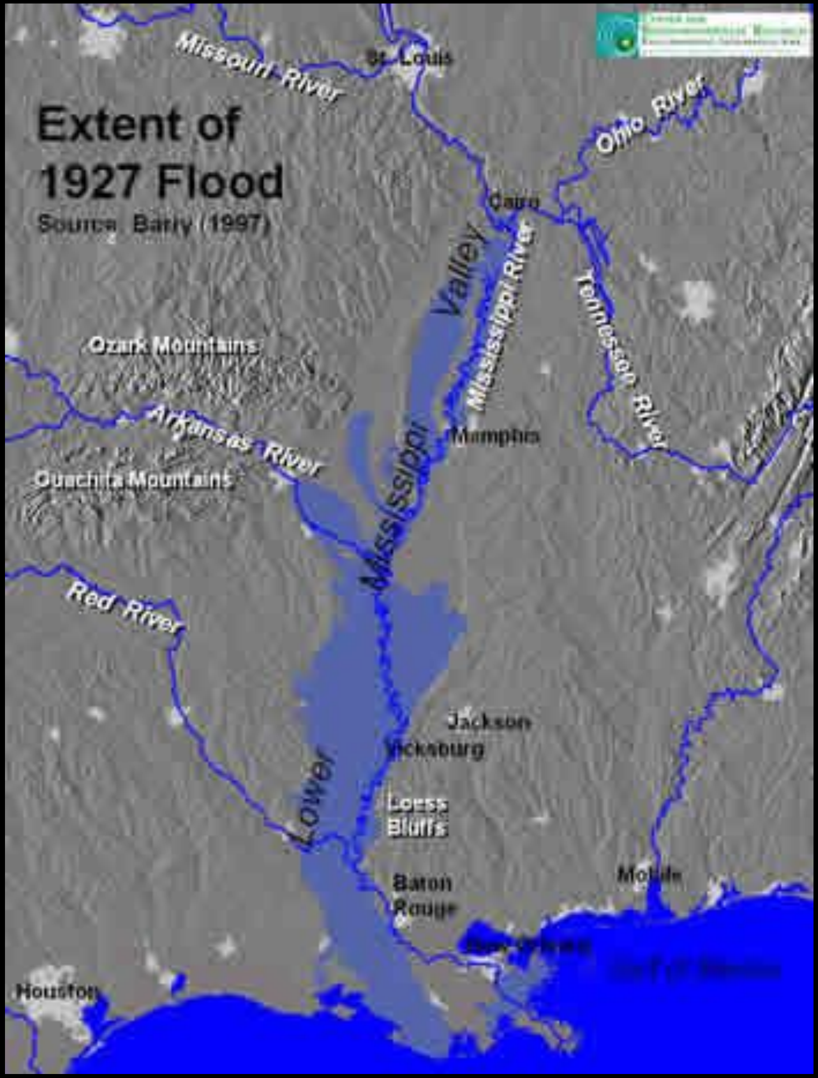
Figure 4. Global distribution of flood risk.

a) Mortality



FLOODS IN CHINA

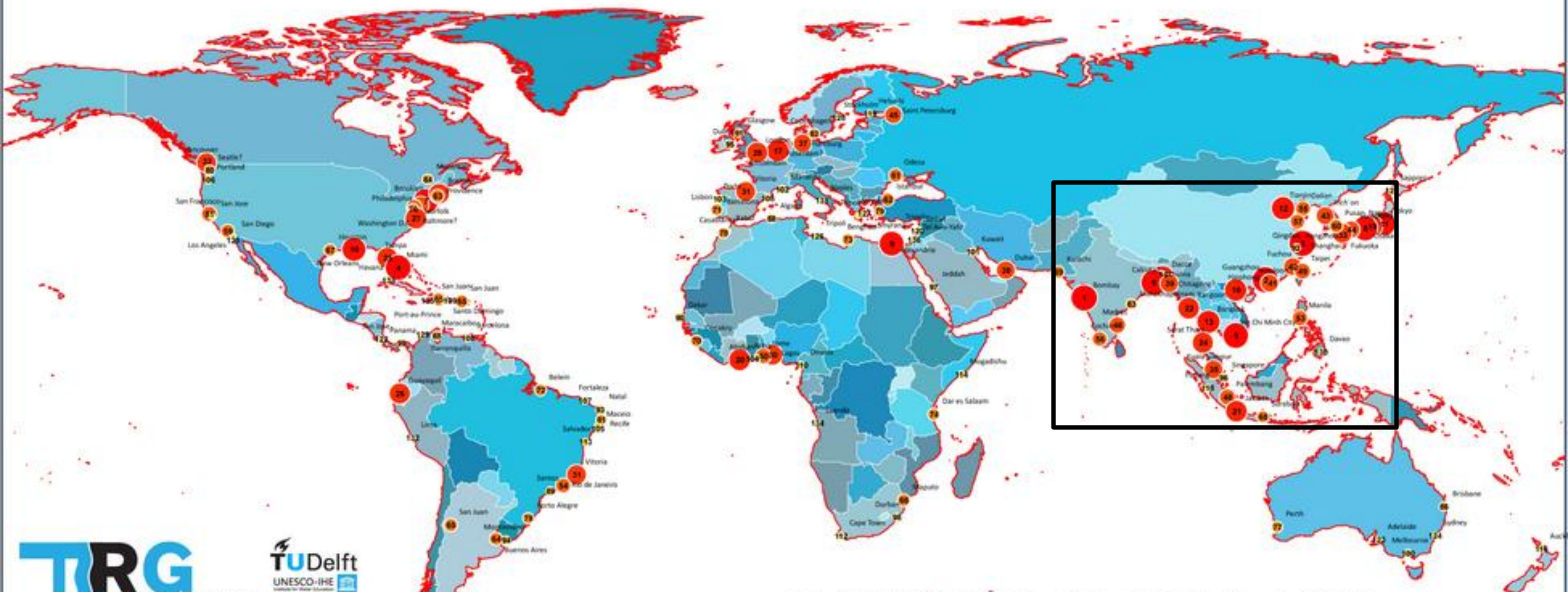

RISING TIDE
THE GREAT MISSISSIPPI FLOOD OF 1927 AND HOW IT CHANGED AMERICA
"Breathtaking. . . . A big, ambitious book that is not merely engrossing and informative but also has the potential to change the way we think."
—Jonathan Yardley
The Washington Post
JOHN M. BARRY


Extent of
1927 Flood
Source: Barry (1997)
Missouri River
St. Louis
Ohio River
Cairo
Valley
Mississippi River
Tennessee River
Ozark Mountains
Arkansas River
Memphis
Ouachita Mountains
Mississippi
Red River
Jackson
Vicksburg
Lower
Loess
Bluffs
Baton
Rouge
Mobile
Houston


TRAILER
SYNOPSIS
FLOOD
CAST & CREW
GALLERY
COPYRIGHT 2006 THE FLOOD PRODUCTIONS LIMITED / MOONLIGHTING FLOOD PRODUCTIONS (PTY) LTD /

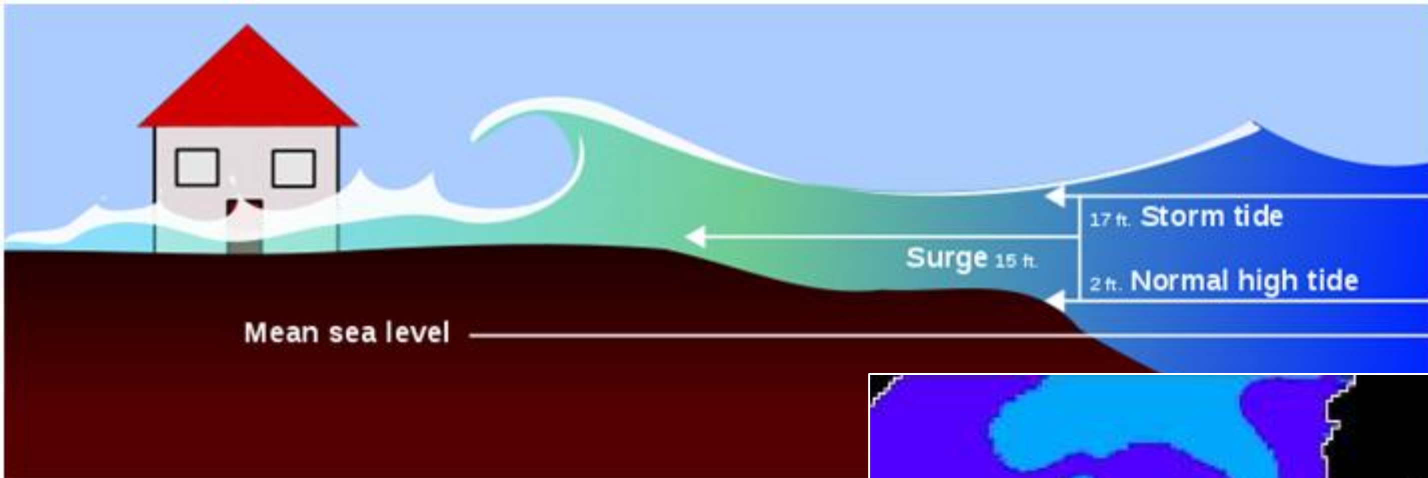
COASTAL (SEA) FLOODS

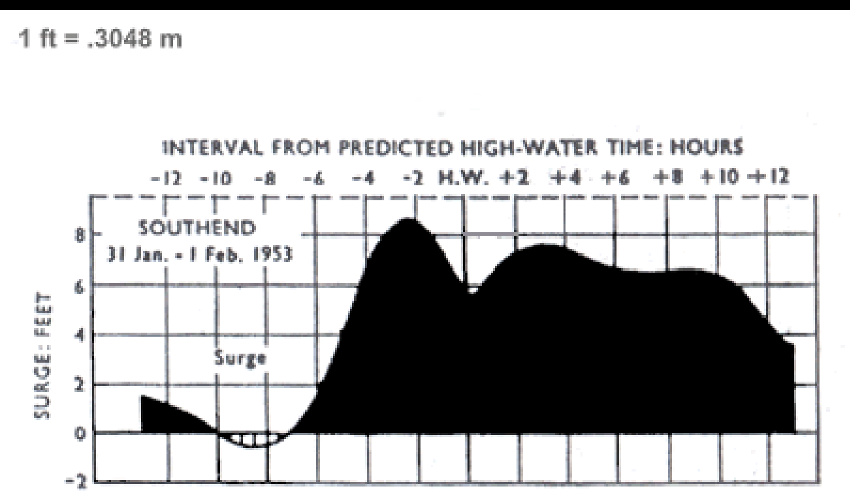
Ranking of top 130 cities exposed to coastal flooding in 2005

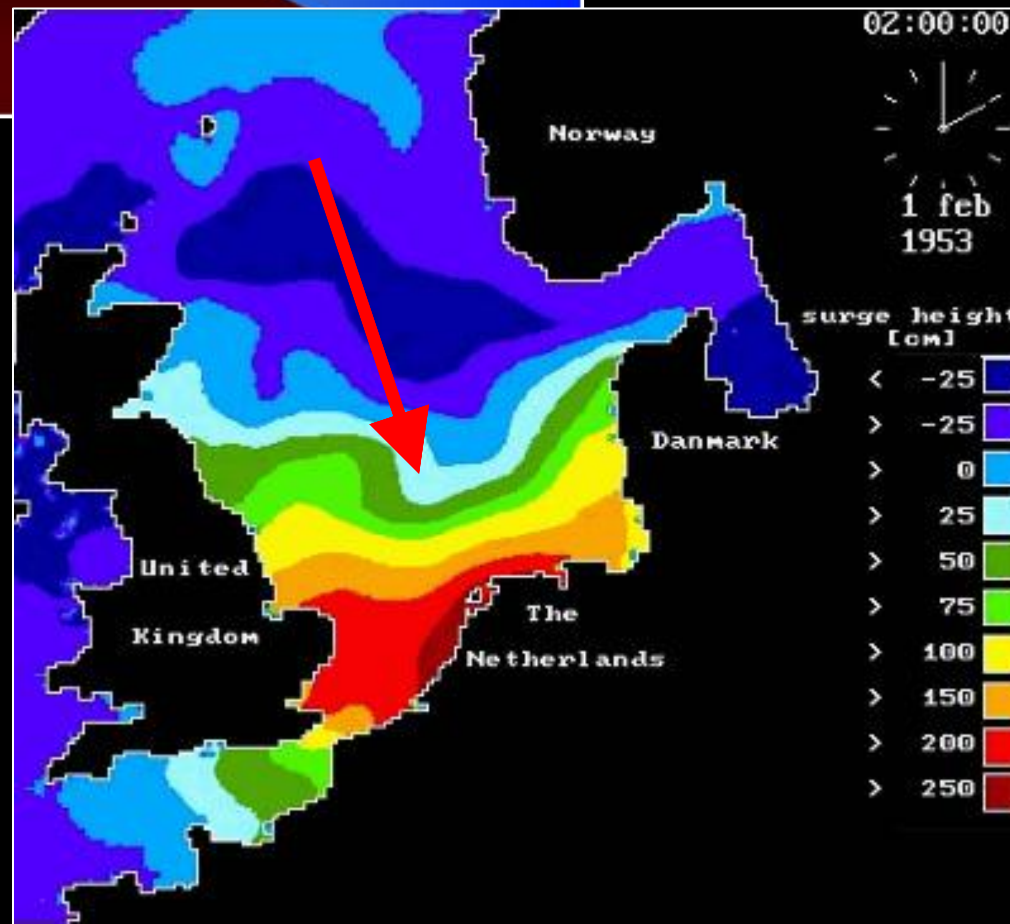


Based on: Nicholls, R. J., Hanson, S., Herweijer, C., Patmore, N., Hallegatte, S., Corfee-Morlot, J., Chateau, J. and Muir-Wood, R., Ranking of the world's cities most exposed to coastal flooding today and in the future, Organisation for Economic Co-Operation and Development (OECD), 2007

1953 NORTH SEA SURGE (~3.0 m) CAUSED CATASTROPHIC FLOODING IN ENGLAND AND THE NETHERLANDS



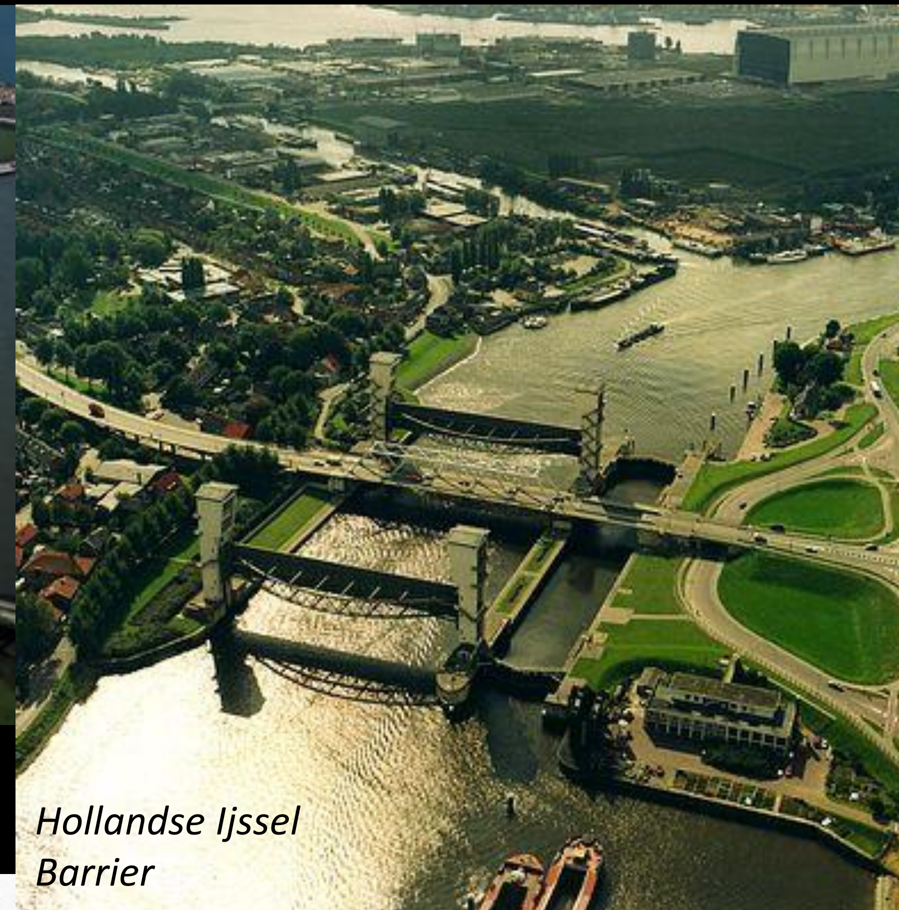




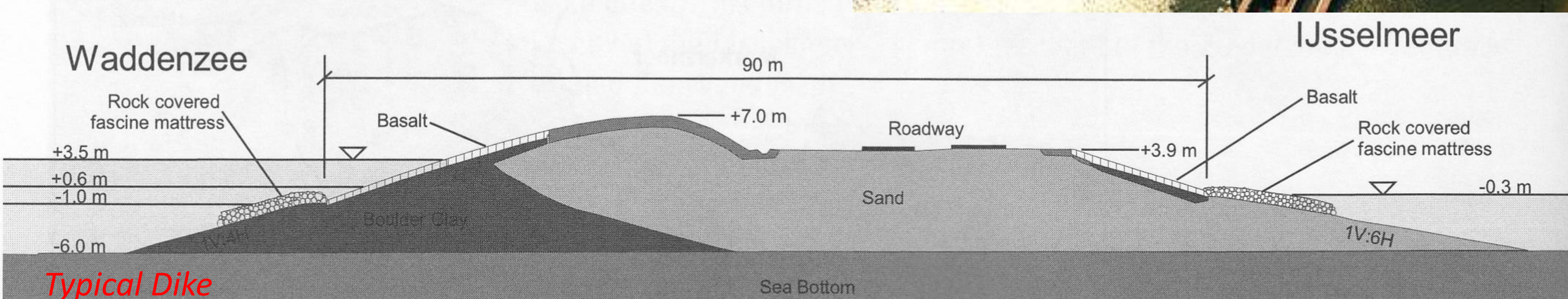
IN THE COASTAL FLOODING CAUSED BY THE STORM SURGE 1,835 PEOPLE DIED IN HOLLAND AND 307 DIED IN EASTERN ENGLAND

STORM SURGE COASTAL DEFENCES - THE NETHERLANDS

Maeslant Barrier



Hollandse Ijssel Barrier



Typical Dike