Modeling Flood Hazards

Objectives

- **6.1 Define the nature of flooding as a hazard and its impacts.**
- **6.2 Understand the factors that influence the nature and characteristics of flooding.**
- **6.3 Explain how flooding is measured.**
- **6.4 Understand the development of assessments of risk for flood hazards in the United States and the National Flood Plain Management Program.**
- **6.5 Provide examples of models used in examining the risk of floods in the National Flood Plain Management Program.**
- **6.6 Explain the elements of a Flood Insurance Study (FIS).**
- **6.7 Explain the elements of a FIRM (Flood Insurance Rate Map) and how to use a FIRM to determine the risk of flooding for a specific piece of property.**
- **6.8 Understand the capabilities of HAZUS-MH Flood program.**

Nature of Flooding

- A flood is a natural event for rivers and streams.
- A flood is any relatively high stream flow that overflows the natural or artificial banks of a stream.
- It is considered a <u>temporary condition</u> of partial or complete inundation of normally dry land areas.
- Flooding typically results from large scale weather systems generating prolonged rainfall or on-shore winds.

Floods

- Hundreds of floods occur each year, making it one of the most common hazards in the United States.
- Floods occur in all 50 states, even in extremely dry areas of the U.S. Flash floods characterized by rapid on-set and high velocity waters occur in areas of Arizona.

Financial Impacts

- Floods are the most chronic and costly natural hazard in the United States, causing an average of $5 billion damage each year.
- Damage from floods results from a combination of the great power of flowing water and the concentration of people and property along rivers.
- The costliest flood disaster in the U.S. history was the 1993 event in the Upper Mississippi River Basin, which affected nine Midwestern States.

Fatalities

- On the average, 140 fatalities occur annually as a result of flooding.
- Most injuries and deaths occur when people are swept away by flood currents.
- Between 1985 and 1999, nearly 561,000 people died in natural disasters, according to data collected by Munich Reinsurance.
- According to the Chinese government, 90% of the 30,000 deaths from floods in 1954 were a result of communicable diseases like dysentery, typhoid, and cholera that struck in the aftermath of floods.

Conditions that affect the impact of floods

- Impermeable Surfaces
- Steeply sloped drainage areas
- Constrictions
- Obstruction (bridges and culverts)
- Debris
- Contamination
- Soil saturation
- Velocity
- Topography
- Ground cover
- Basin Size

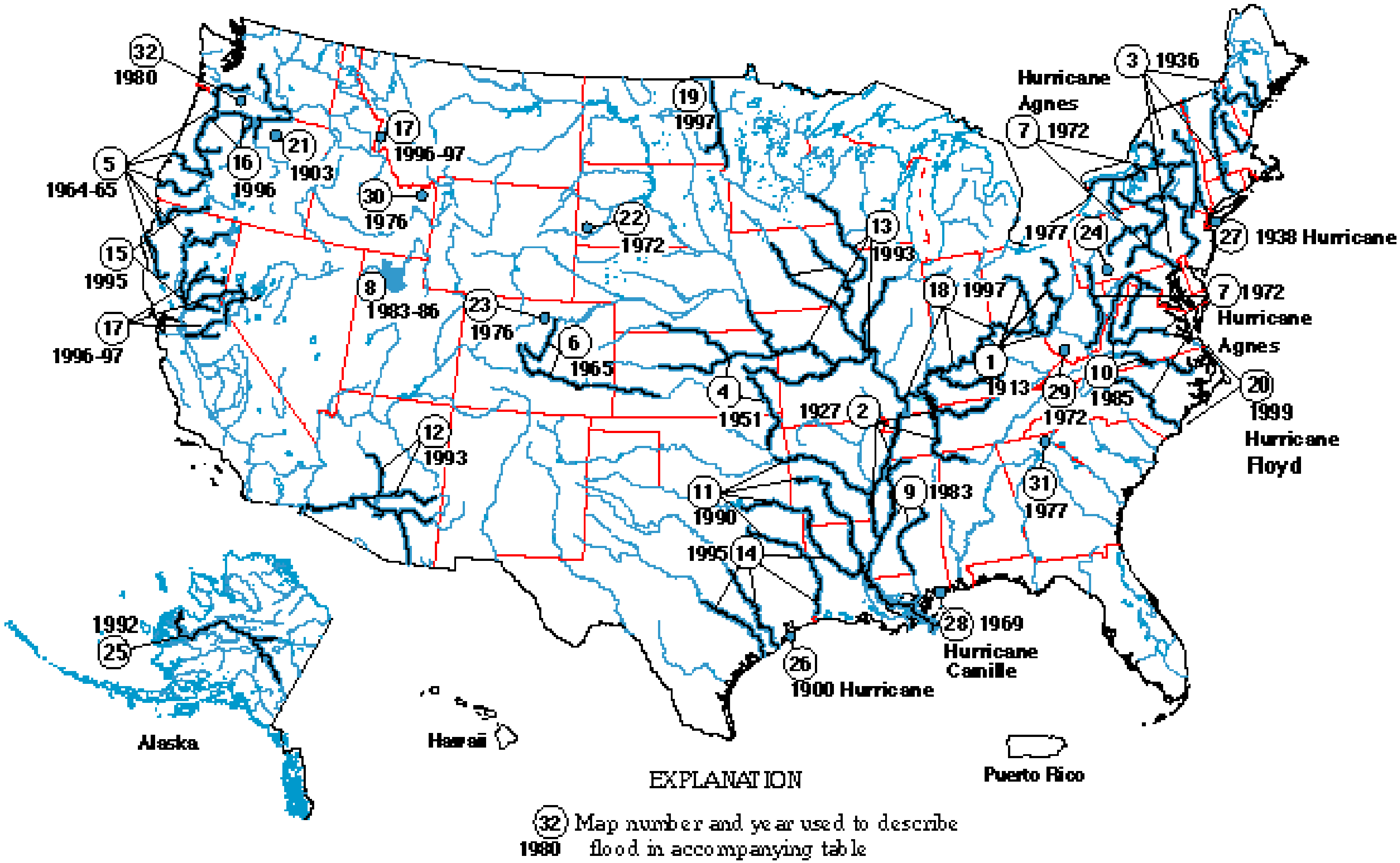
Floodplains

- Floodplains are lowlands, adjacent to rivers, lakes and oceans that are subject to recurring floods.
- A floodplain is a strip of relatively flat land bordering a stream channel that is inundated at times of high water.
- Floodplains in the U.S. are home to over nine million households.
- Most injuries and deaths occur when people are swept away by flood currents and most property damage results from the inundation by sediment-filled water.

Significant Floods of the 20th Century

[M, million; B, billion]

Flood type	Map no.	Date	Area or stream with flooding	Reported deaths	Approximate cost (uninflated)	Comments
Regional flood	1	Mar.–Apr. 1913	Ohio, statewide	467	$143M	Excessive regional rain.
	2	Apr.–May 1927	Mississippi River from Missouri to Louisiana	unknown	$230M	Record discharge downstream from Cairo, Illinois.
	3	Mar. 1936	New England	150+	$300M	Excessive rainfall on snow.
	4	July 1951	Kansas and Neosho River Basins in Kansas	15	$800M	Excessive regional rain.
	5	Dec. 1964–Jan. 1965	Pacific Northwest	47	$430M	Excessive rainfall on snow.
	6	June 1965	South Platte and Arkansas Rivers in Colorado	24	$570M	14 inches of rain in a few hours in eastern Colorado.
	7	June 1972	Northeastern United States	117	$3.2B	Extratropical remnants of Hurricane Agnes.
	8	Apr.–June 1983 June 1983–1986	Shoreline of Great Salt Lake, Utah	unknown	$621M	In June 1986, the Great Salt Lake reached its highest elevation and caused $268M more in property damage.
	9	May 1983	Central and northeast Mississippi	1	$500M	Excessive regional rain.
	10	Nov. 1985	Shenandoah, James, and Roanoke Rivers in Virginia and West Virginia	69	$1.25B	Excessive regional rain.
	11	Apr. 1990	Trinity, Arkansas, and Red Rivers in Texas, Arkansas, and Oklahoma	17	$1B	Recurring intense thunderstorms.
	12	Jan. 1993	Gila, Salt, and Santa Cruz Rivers in Arizona	unknown	$400M	Persistent winter precipitation.
	13	May–Sept. 1993	Mississippi River Basin in central United States	48	$20B	Long period of excessive rainfall.
	14	May 1995	South-central United States	32	$5-6B	Rain from recurring thunderstorms.
	15	Jan.–Mar. 1995	California	27	$3B	Frequent winter storms.
	16	Feb. 1996	Pacific Northwest and western Montana	9	$1B	Torrential rains and snowmelt
	17	Dec. 1996–Jan. 1997	Pacific Northwest and Montana	36	$2-3B	Torrential rains and snowmelt
	18	Mar. 1997	Ohio River and tributaries	50+	$500M	Slow-moving frontal system.
	19	Apr.–May 1997	Red River of the North in North Dakota and Minnesota	8	$2B	Very rapid snowmelt.
	20	Sept. 1999	Eastern North Carolina	42	$6B	Slow-moving Hurricane Floyd.
Flash flood	21	June 14, 1903	Willow Creek in Oregon	225	unknown	City of Heppner, Oregon, destroyed.
	22	June 9–10, 1972	Rapid City, South Dakota	237	$160M	15 inches of rain in 5 hours.
	23	July 31, 1976	Big Thompson and Cache la Poudre Rivers in Colorado	144	$39M	Flash flood in canyon after excessive rainfall.
	24	July 19–20, 1977	Conemaugh River in Pennsylvania	78	$300M	12 inches of rain in 6-8 hours.
Ice-jam flood	25	May 1992	Yukon River in Alaska	0	unknown	100-year flood on Yukon River.
Storm-surge flood	26	Sept. 1900	Galveston, Texas	6,000+	unknown	Hurricane.
	27	Sept. 1938	Northeast United States	494	$306M	Hurricane.
	28	Aug. 1969	Gulf Coast, Mississippi and Louisiana	259	$1.4B	Hurricane Camille.
Dam-failure flood	29	Feb. 2, 1972	Buffalo Creek in West Virginia	125	$60M	Dam failure after excessive rainfall.
	30	June 5, 1976	Teton River in Idaho	11	$400M	Earthen dam breached.
	31	Nov. 8, 1977	Toccoa Creek in Georgia	39	$2.8M	Dam failure after excessive rainfall.
Mudflow flood	32	May 18, 1980	Toutle and lower Cowlitz Rivers in Washington	60	unknown	Result of eruption of Mt. St. Helens.


32 1980
5 1964-65
16 1996
21 1903
17 1996-97
30 1976
19 1997
22 1972
15 1995
8 1983-86
23 1976
6 1965
17 1996-97
12 1993
4 1951
1927 2
11 1990
1995 14
13 1993
18 1997
1 1913
9 1983
3 1936
Hurricane Agnes
7 1972
1977 24
27 1938 Hurricane
7 1972 Hurricane Agnes
10 1985
29 1972
20 1999 Hurricane Floyd
31 1977
28 1969 Hurricane Camille
26 1900 Hurricane
1992 25
Alaska
Hawaii
Puerto Rico
EXPLANATION
32 1980 Map number and year used to describe flood in accompanying table

Measuring Floods

It is important to recognize that there is actually a range of floods, other than just the 100-year flood.

An annual flood is a type of flooding event that is expected to occur in any given year.

A house located close to a flood source might experience some level of flooding every 5 to 10 years.

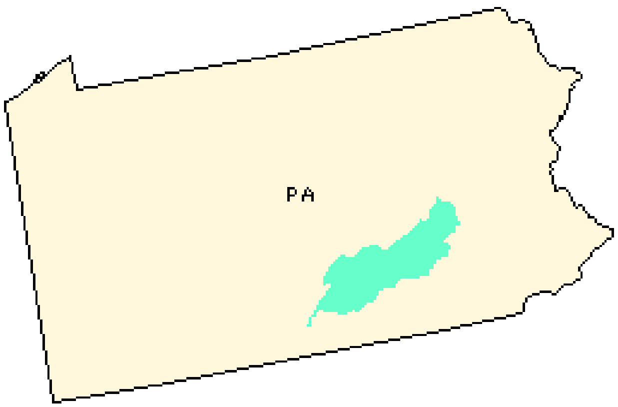
The level or depth of flooding is determined by the probability.

Geography of Drainage Areas

- Water-Resources Regions (USGS has designated 21 in the U.S.)
- Water-resources Sub-regions (222 sub-regions)
- Each water-resources sub-region is drained by a river system, a reach of a river and its tributaries. It is also referred to as a closed basin or a group of streams forming a drainage area.
- We often refer to water-resources sub-regions as watersheds or drainage basins.

Measuring Drainage Areas

Upper Mississippi Sub-Region



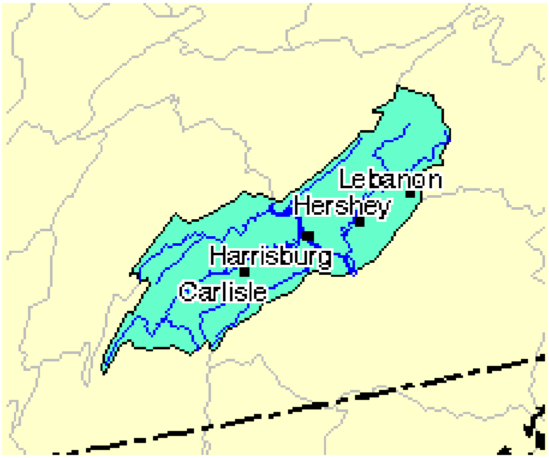
Hydrologic unit

- This is a geographic area representing part or all of a surface drainage basin or area as delineated by the U. S. Geological Survey on State Hydrologic Unit Maps. Each hydrologic unit is assigned a hierarchical hydrologic unit code consisting of 2 digits for each successively smaller drainage basin unit.
- Example in Mid-Atlantic Water Resources Region - Pennsylvania:

  Name: Lower Susquehanna-Swatara

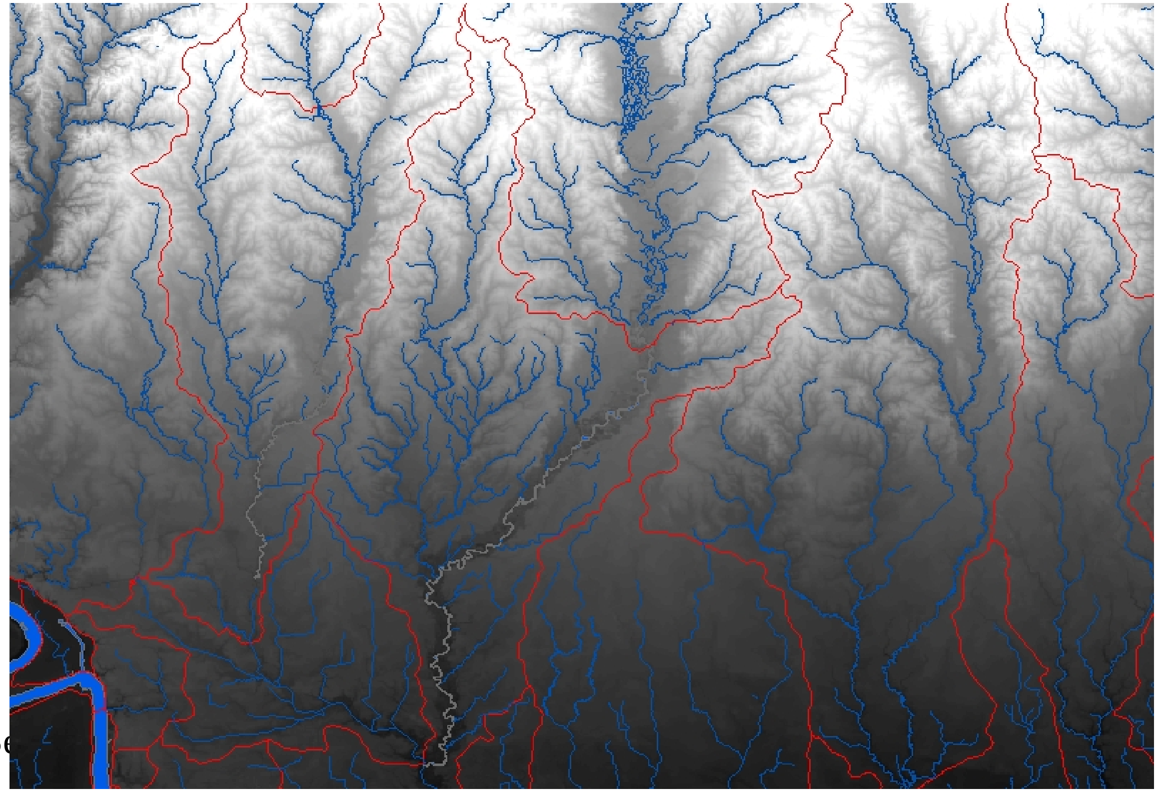
  USGS Cataloging Unit: 02050305

  See: http://cfpub.epa.gov/surf/huc.cfm?huc_code=02050305



- **Hydrology** is the science that deals with the properties, distribution and circulation of water on the surface of the land, in the soil and underlying rocks and in the atmosphere. It also refers to the flow and behavior of rivers and streams.

- USGS DEM showing water features (blue) and water drainage area boundaries (red)

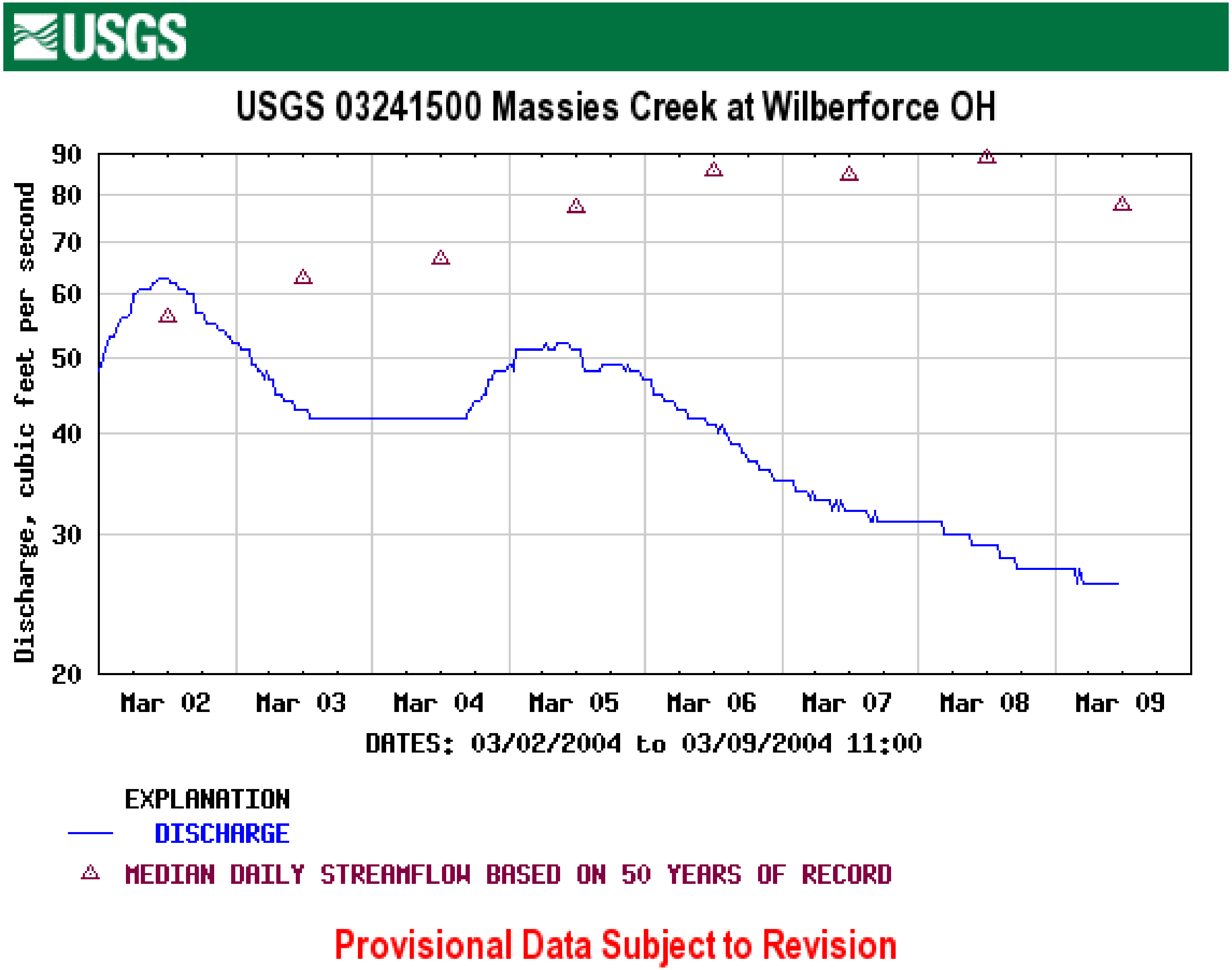


Se

- **Discharge** is a term that is related to the concept of “hydrology” since it characterizes the volume of fluid passing a point of a stream or river or hydrologic unit per unit of time, commonly expressed in cubic feet per second, million gallons per day, gallons per minute, or seconds per minute per day. Flood modeling programs require as an input the discharge or volume of water in a river or stream.

- **Stage -** Height of the water surface above an established point, such as in a river above a predetermined point. The stage is measured in a common reference or datum plane – which is a horizontal plane to which ground elevations or water surface elevations are referenced (sea level).

- A **Hydrograph** is a graph showing variation of water elevation, velocity, stream flow, or other property of water with respect to time. It shows a **Mean discharge (MEAN)** of individual daily mean discharges of a stream during a specific period, usually daily, monthly, or annually. The **Mean** is the arithmetic average of a set of observations.


USGS
USGS 03241500 Massies Creek at Wilberforce OH
Discharge, cubic feet per second
90
80
70
60
50
40
30
20
Mar 02
Mar 03
Mar 04
Mar 05
Mar 06
Mar 07
Mar 08
Mar 09
DATES: 03/02/2004 to 03/09/2004 11:00
EXPLANATION
DISCHARGE
MEDIAN DAILY STREAMFLOW BASED ON 50 YEARS OF RECORD
Provisional Data Subject to Revision

Development of a National Flood Program

- The Federal Government has been heavily involved in risk assessment of flood hazards since the early 1960’s.
- The Tennessee Valley Authority (TVA) and the U.S. Army Corps of Engineers (USACE) were early leaders in this initiative to understand the impacts of floods.
- Congress authorized the National Flood Insurance Program in 1968 with the enactment of the National Flood Insurance Act.
- Under this legislation, flood insurance was made available at affordable rates to individuals as long as the local community adopted ordinances to regulate development in designated (mapped) flood hazard areas.

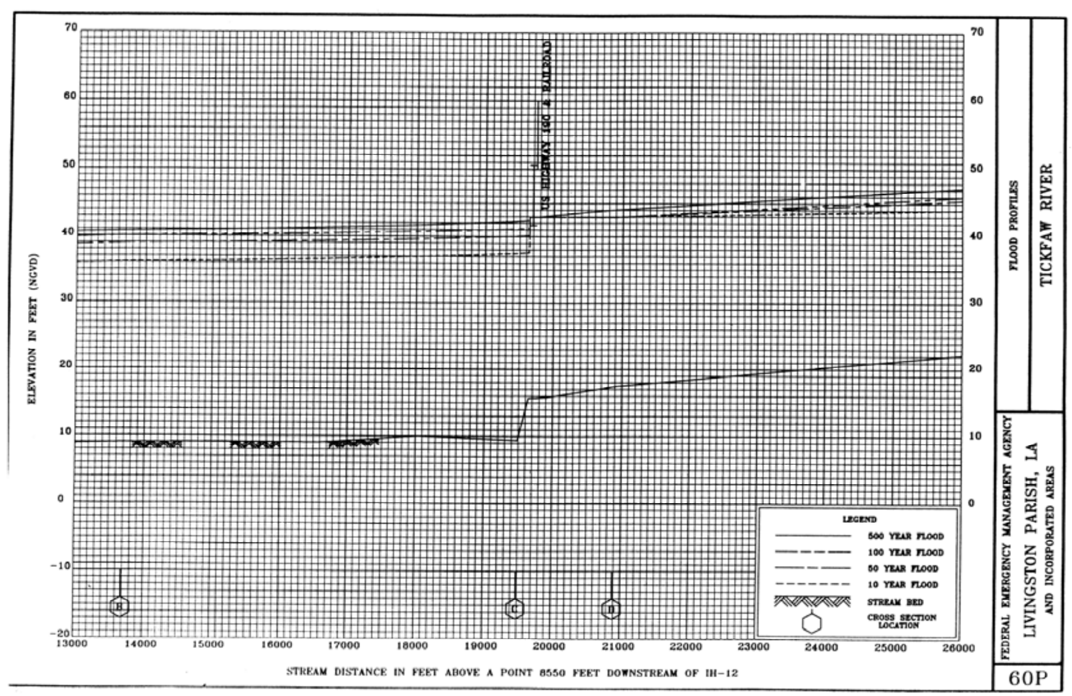
- In the early years of this program, HUD was designated to administer the program.
- In 1983, HUD convened a group of experts to advise on the best standard for risk assessment and management.
- The group including federal agencies agreed on the 100 year or 1percent annual chance of flood as the standard for floodplain management.
- This standard was considered to represent a degree of risk and damage worth protecting against, but was not considered to impose stringent requirements or burdens of excessive cost on property owners.

Modeling Flood Hazards

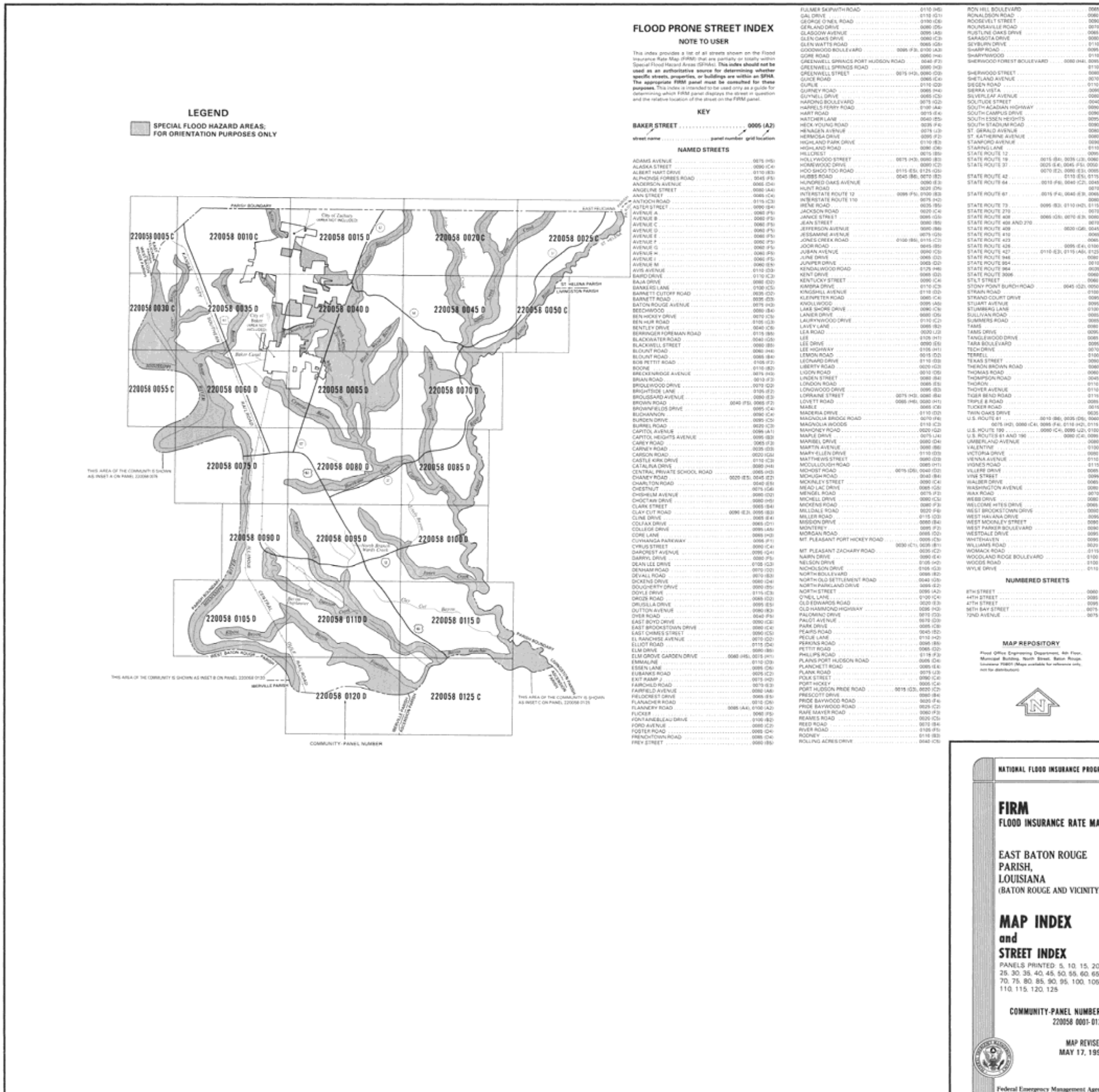
- The most widely used flood modeling program is HEC-RAS (Hydrologic Engineering Center's River Analysis System)
- Developed by the U.S. Army Corps of Engineers
- Used for calculating water-surface profiles for steady, gradually varied flow in natural or man-made channels.
- It has the capacity to determine a profile for a riverine water feature and takes into account bridges, stream junctions, culverts, weirs, spillways and other structures in a flood plain.
- It may be used to assess the change in water surface due to channel improvements or levees.
- For the unsteady flow component, the program examines storage areas and connections between storage areas.
- HEC-RAS is a primary input for FEMA's HAZUS-MH Flood Riverine program.

Flood Profile

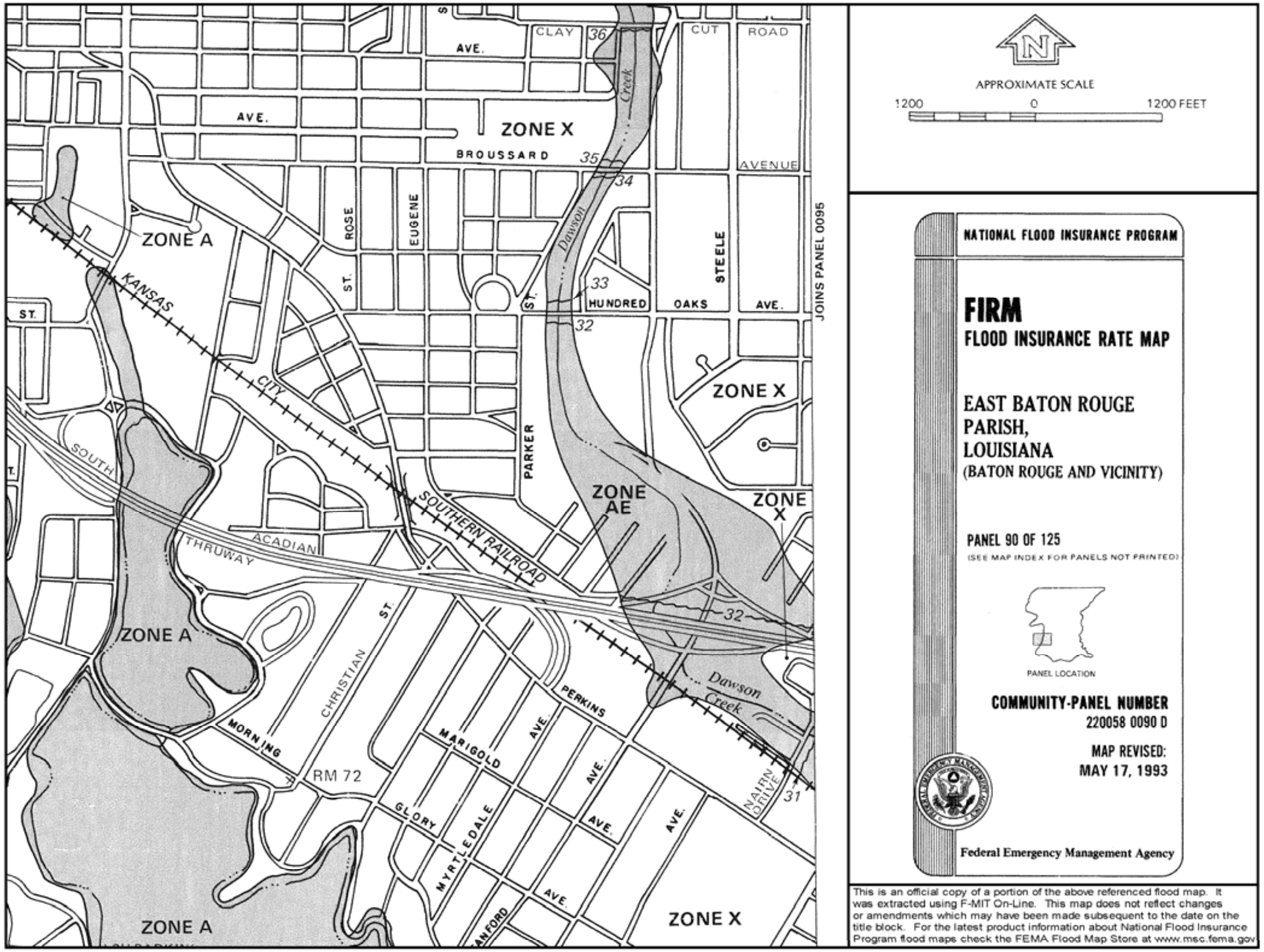
- A flood profile is a graph reflecting flood elevations along the centerline of a water feature
- Included in a flood insurance study (FIS)



FIRM Index Map

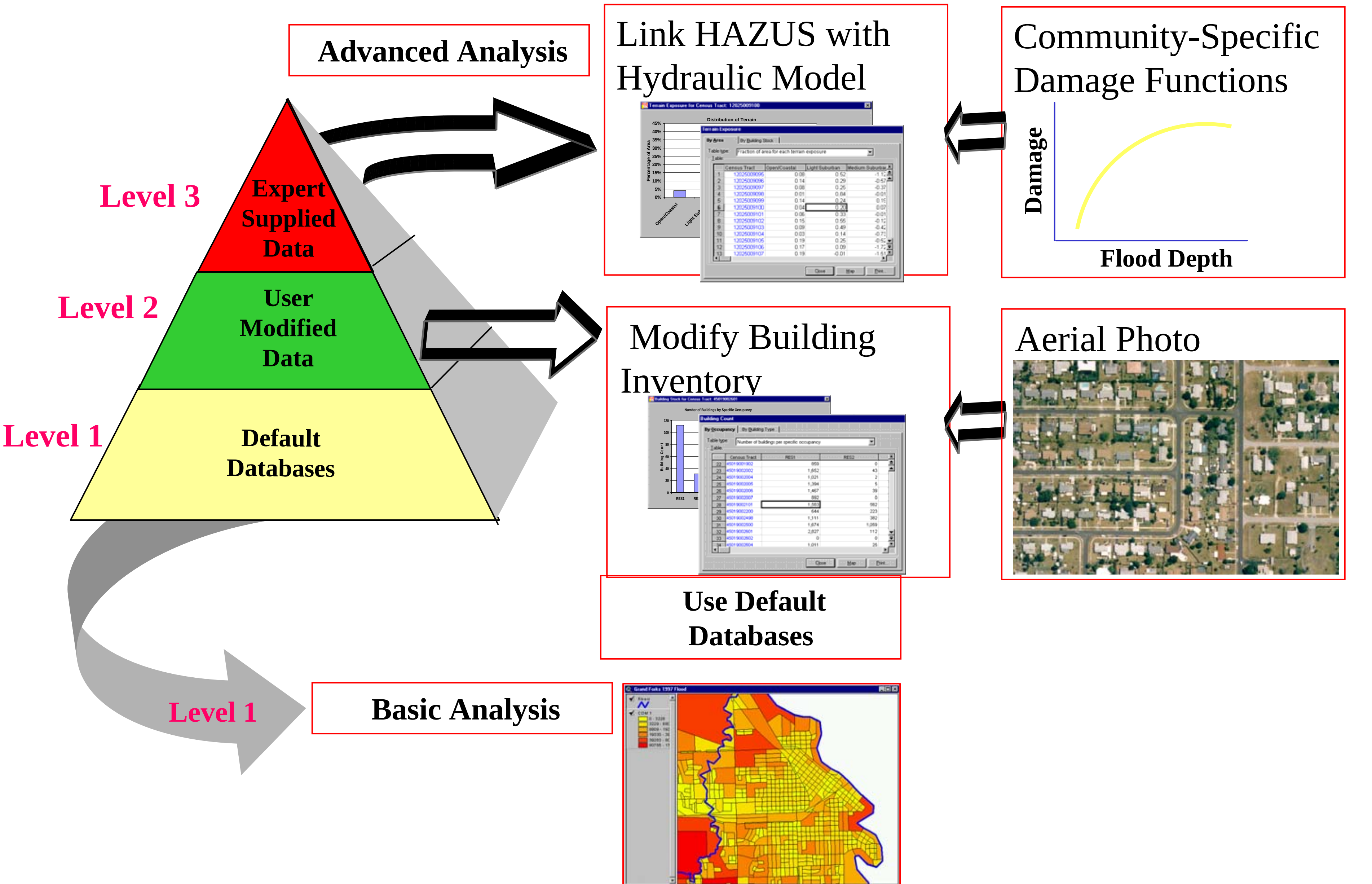


Flood Insurance Rate Map

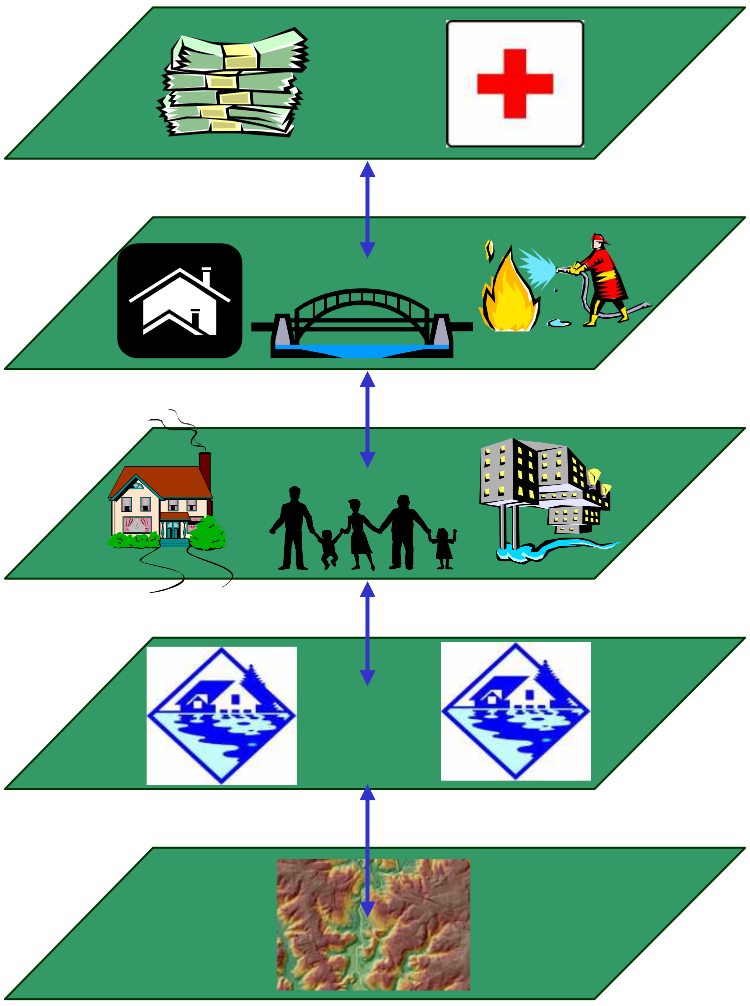


Modeling Flood Hazards using HAZUS-MH Flood

HAZUS®MH Levels of Analysis



HAZUS-MH Flood Methodology



4. Estimate Losses

3. Compare local stock to the extent of the flooding

2. Determine nature and extent of flooding using hydraulic and hydrology data for a water feature

1. Clarify land contour using a (USGS DEM)

HAZUS-MH Flood Outputs

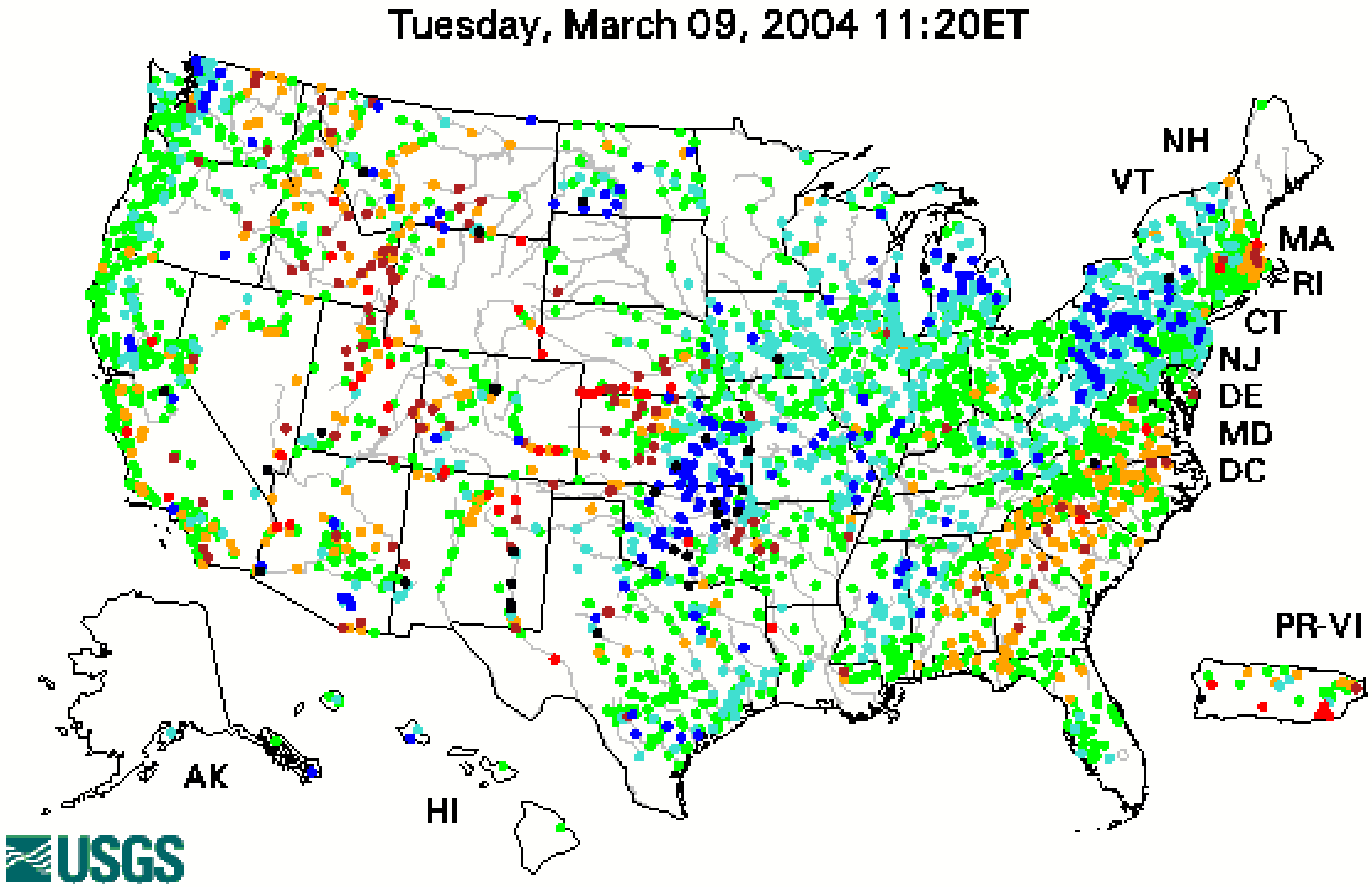
- Hazard maps showing floodplain
- Infrastructure Damage
- Population Impacts (casualties and shelter requirements
- Indirect economic losses
- Building stock loss for
  - Residential
  - Commercial
  - Industrial
  - Education
  - Government

HAZUS-MH Flood Modeling

- Riverine
  - Hydrologic analysis
  - Hydraulics analysis

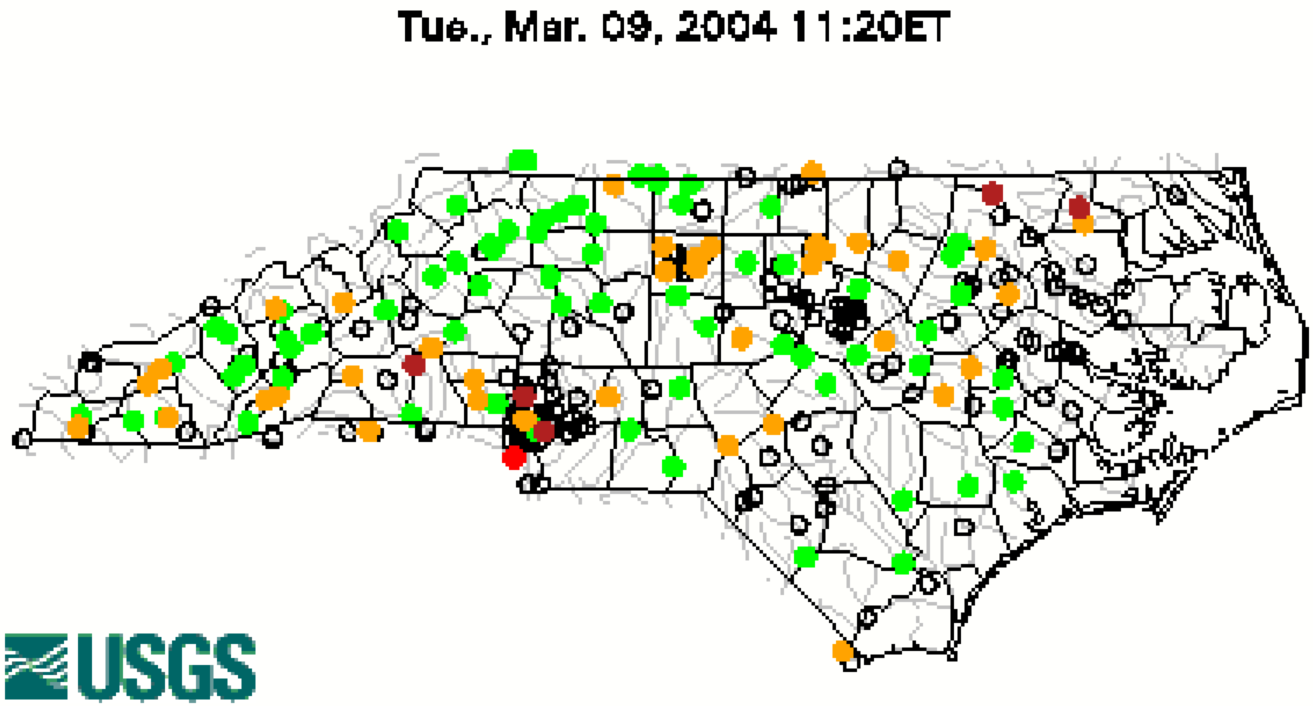
Riverine Hydrologic Analysis

- Requires a discharge-frequency for each water feature (reach) in the study region
- Use National Flood Frequency Program - regression equations for un-gauged reaches –
- Use USGS gauged reaches to derive flood discharge frequency curves



- Presently about 7,000 stations are active.
- Go to http://water.usgs.gov/waterwatch to review active state stations currently in use.

North Carolina USGS River Gage Stations



- The map depicts stream-flow conditions as computed at *USGS* gauging stations. The colors represent real-time stream flow compared to **percentiles** of historical daily stream flow for the day of the year. This map represents conditions relative to those that have historically occurred at this time of year. Only stations having at least 30 years of record are used.

National Flood Frequency Program

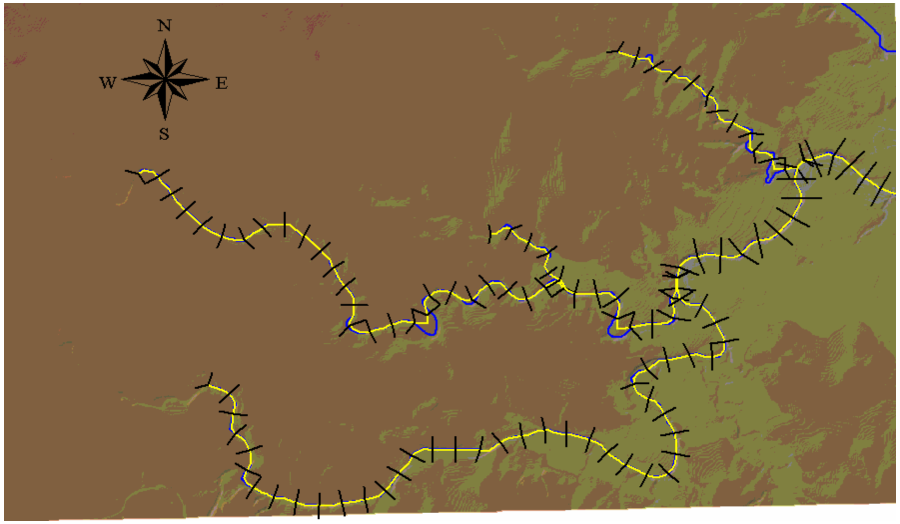
- Estimates of the magnitude and frequency of flood-peak discharges and flood hydrographs are used for a variety of purposes, such as the design of bridges, culverts, and flood-control structures, and for the management and regulation of flood plains.
- These estimates are often needed in locations where no observed flood data (such as the U.S.G.S. Stream Gages) are available.
- To provide simple methods of estimating flood-peak discharges, the U.S. Geological Survey (USGS) has developed and published regression equations for every State, the Commonwealth of Puerto Rico, and a number of metropolitan areas in the United States.
- In 1993, the USGS (FEMA and the Federal Highway Administration) compiled all statewide and metropolitan area regression equations into a microcomputer program titled the National Flood Frequency (NFF) Program.

Flood Modeling

- Riverine
  - Hydrologic analysis
  - Hydraulics analysis

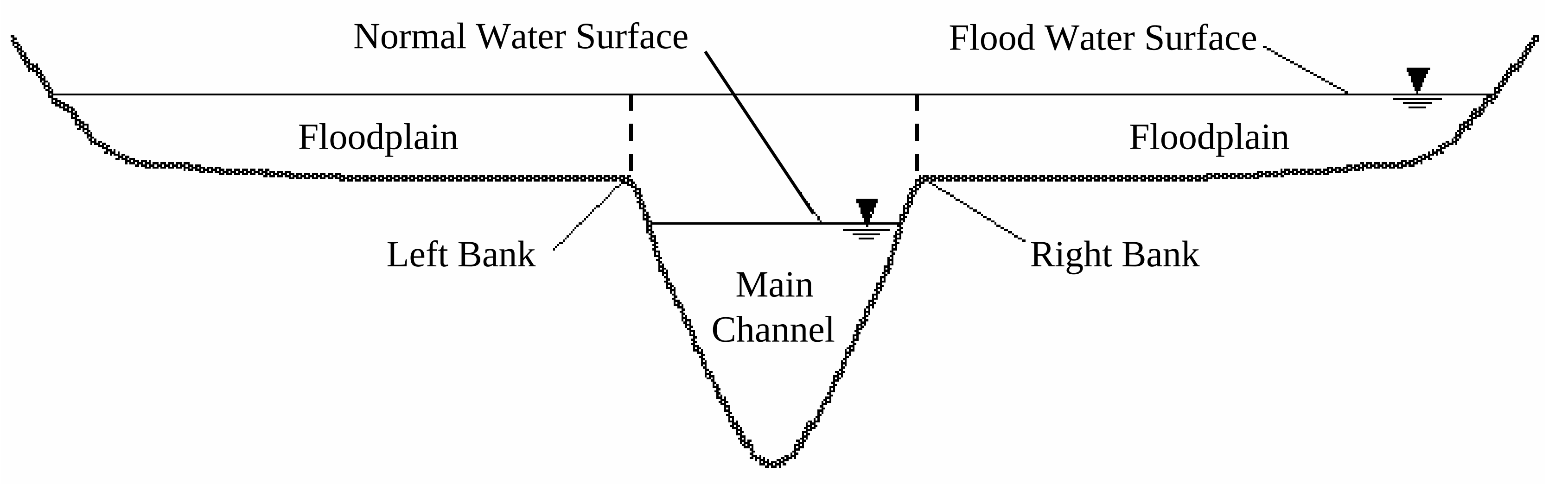
Riverine Hydraulic Analysis

- The process of determining the depth of flooding for a specific flooding event at a location (cross section) on a water feature
- Computes flood elevations for each cross section using HECRAS.
- Interpolates elevations between cross-sections as needed.



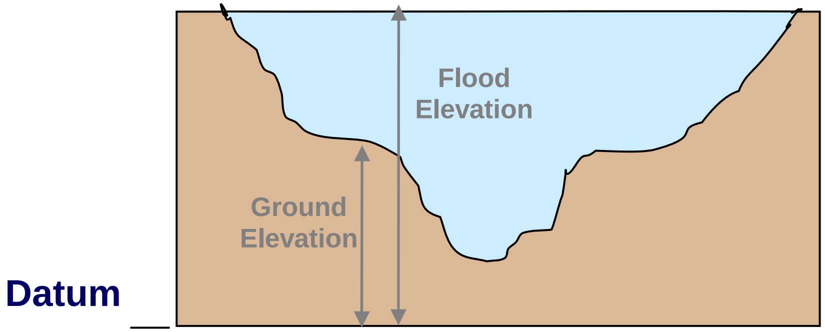
Riverine Hydraulic Analysis

1. **Flood depth** computed in HECRAS for each cross section
2. Flood depth computed for each return period (50, 100, and 500 year flood frequency)



HAZUS®MH Flood Depth Determination

Use GIS (ArcGIS) to subtract **ground surface** from **flood surface**



Flood depth grid then computed for each frequency (50, 100, and 500 year)

Determine **flood depth** throughout the study area

Benefits

- HAZUS-MH allows user to:
  - IDENTIFY vulnerable areas that may require planning considerations
  - ASSESS level of readiness and preparedness to deal with a disaster before disaster occurs
  - ESTIMATE potential losses from specific hazard events (before or after a disaster hits)
  - DECIDE on how to allocate resources for most effective and efficient response and recovery
  - PRIORITIZE mitigation measures that need to be implemented to reduce future losses (what if)

Applications in Emergency Management