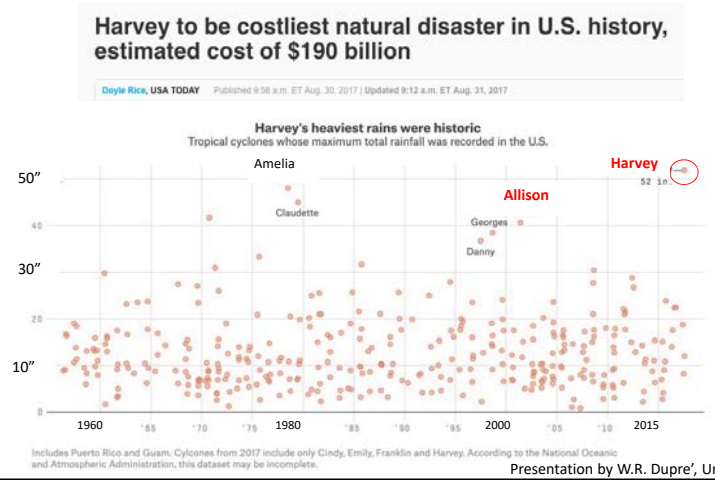
Houston Geological Society Presents

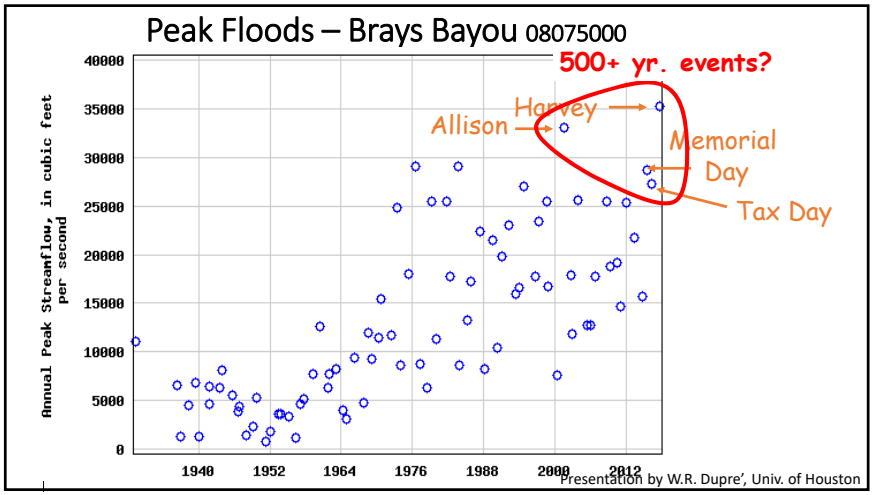
An Informational Workshop

Flooding and Floodplains in the Houston Area: Past, Present, and Future: Part 1

Presented May 18, 2018

Dr. William R. Dupre'
Professor Emeritus
Earth & Atmospheric Sciences
University of Houston
wdupre@uh.edu





Who's in Charge !?

City of Houston, Bellaire, West University, Pasadena, etc.?

Municipal Utility Districts (MUDs)?

Levee Improvement District (LID)?

Harris County?

Harris County Flood Control District (HCFCD)?

U.S. Army Corps of Engineers (USACOE)?

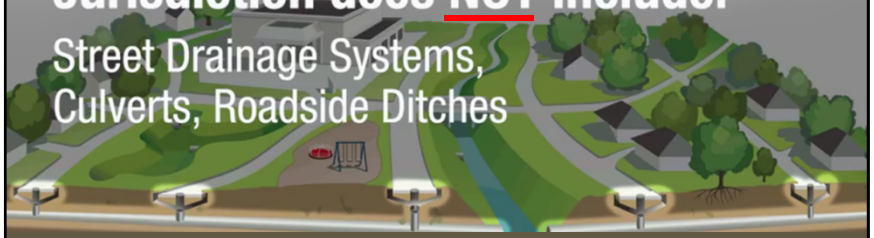
Fort Bend County?

San Jacinto River Authority (SJRA)?

Texas Dept. of Transportation (TXDOT)?

Flood Control District Jurisdiction does NOT include:

Street Drainage Systems, Culverts, Roadside Ditches



These may be owned and maintained by county precincts, municipal utility districts, the Texas Department of Transportation (TxDOT) or the city

Presentation by W.R. Dupre', Univ. of Houston

Acronyms !!

FEMA
NFIP
FIRM
SFHA
Zone A,
Zone AE,
Zone X …
LiDAR
EIA
SIA

HCFCD
FAS
FWS
NWS
NOAA
EPA
PMP
SSPEED
TSARP

LOMC
LOMA
LOMR
LID
AEP
ARI
SJRA
USACOE
MUD
CBA

Presentation by W.R. Dupre', Univ. of Houston

"Am I at risk of flooding?"

Risk is a hazard evaluated in the context of the **frequency** and **magnitude** of the event [e.g. flood].

Risk = "Frequency" x "Magnitude"

When is Bad too Bad?

It depends on the **frequency** and **magnitude** of the event, and how and what you (or society) consider an acceptable level of risk!

Presentation by W.R. Dupre', Univ. of Houston

Benefit-Cost Analysis (BCA)

- A **Benefit-Cost Ratio** (BCR): the ratio of a project's total benefits divided by its total costs. The BCR is a numerical expression of the "cost-effectiveness" of a project. https://www.fema.gov/benefit-cost-analysis
- The ***benefits of flood mitigation*** have been found to outweigh the costs by a benefit-cost ratio of 5:1 [based on a comprehensive analysis of 5,500 mitigation projects]. Thus for every dollar invested in flood hazard mitigation, $5 in benefits accrue.

www.houstonconsortium.com/p/report

Presentation by W.R. Dupre', Univ. of Houston

"Magnitude" is measured by:

1) Height/ discharge/ extent of flooding?
2) Economic damage due to flooding?
3) Number of structures flooded?
4) Number of people affected?
5) Socio-economic impact?
6) Environmental impact?

The "Event"

Consequences of the "Event"

Presentation by W.R. Dupre', Univ. of Houston

Annual Recurrence Interval (ARI)

The annual recurrence interval (ARI) of an event is the *average number of years between events of equal or greater magnitude.* Thus, the 100-year flood (or rain) is one which occurs, ***on the average***, once every 100 years.

Annual Exceedance Probability (AEP)

The probability (p) of an event of particular magnitude being equaled or exceeded any given 12-month period is:

Therefore, a 100 year flood (or rain) has a 1 in 100 (1/100=1%) probability of being equaled or exceeded any 12-month period.

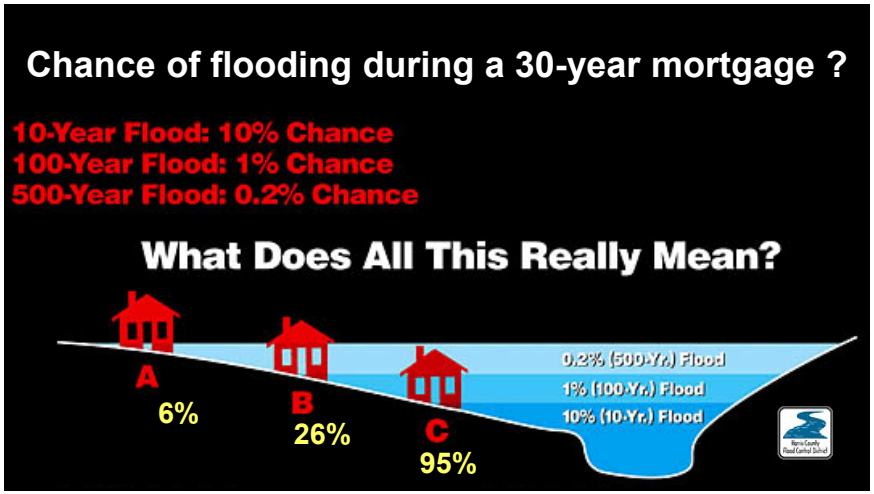
$$AEP = \frac{1}{ARI}$$

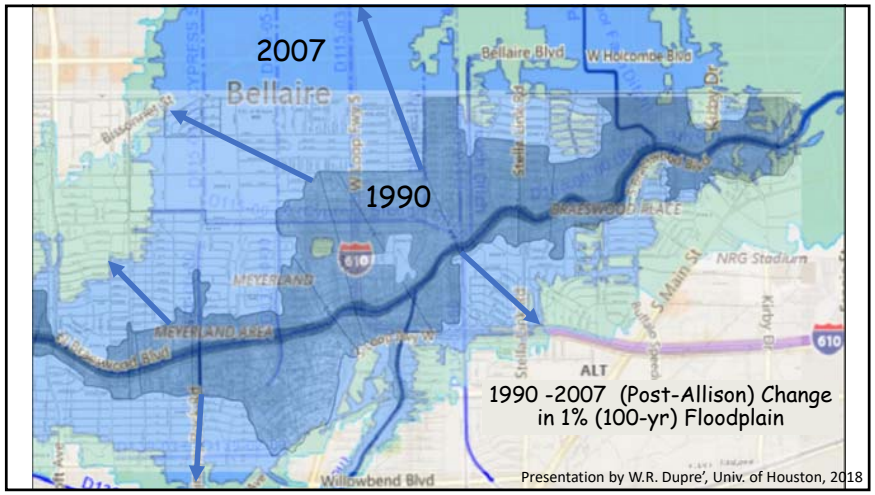
Presentation by W.R. Dupre', Univ. of Houston

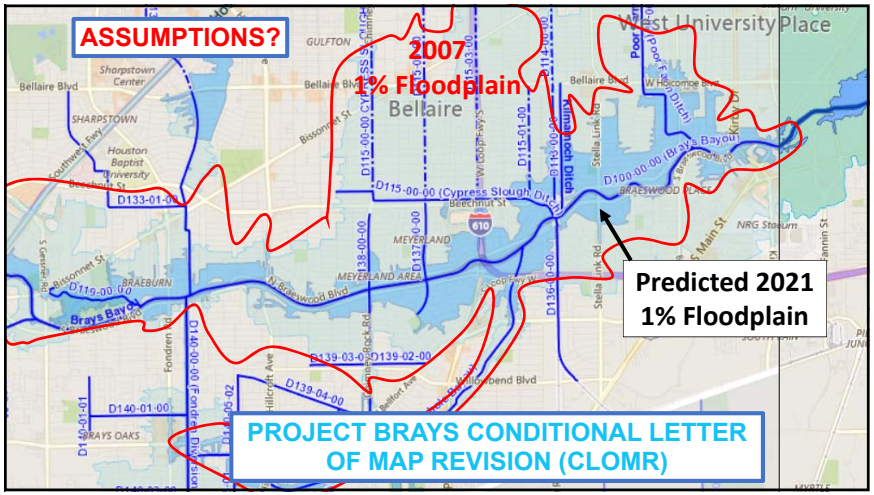
Exceedance Probability	Recurrence Interval
50%	2-Year
20%	5-Year
10%	10-Year*
4%	25-Year
2%	50 -Year*
1%	100-Year*
0.4%	250 -Year
0.2%	500-Year*

Used for flood insurance purposes

Presentation by W.R. Dupre', Univ. of Houston, 2018







Important Questions!

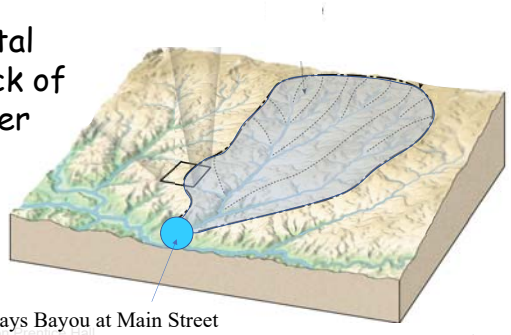
- What are the causes for past changes in flooding and the floodplain?
- What are the predictions for the future, and on what assumptions are those predictions made.
- What can we do about it?

Presentation by W.R. Dupre', Univ. of Houston, 2018

Drainage Basin* (= watershed)

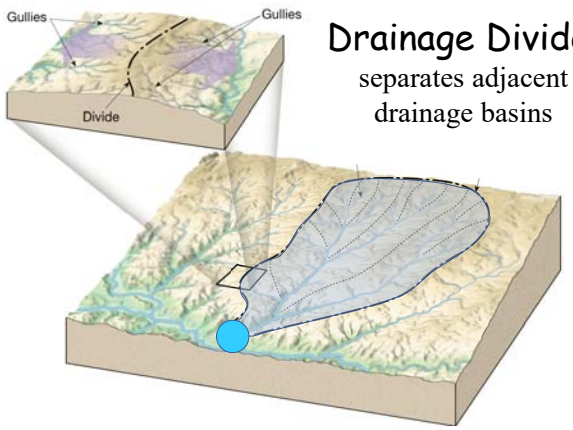
Area drained by a river at a given point* ( )

* Fundamental building block of surface water hydrology



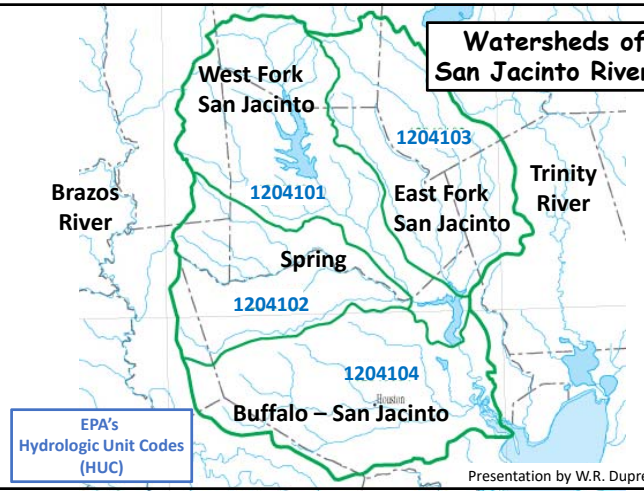
*e.g. area drained by Brays Bayou at Main Street

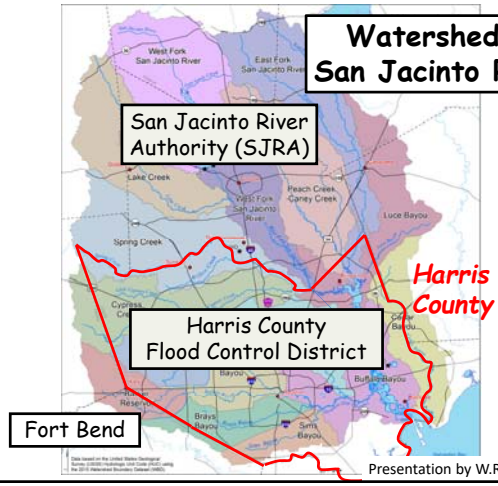
Presentation by W.R. Dupre', Univ. of Houston, 2018



Drainage Divide:

separates adjacent drainage basins

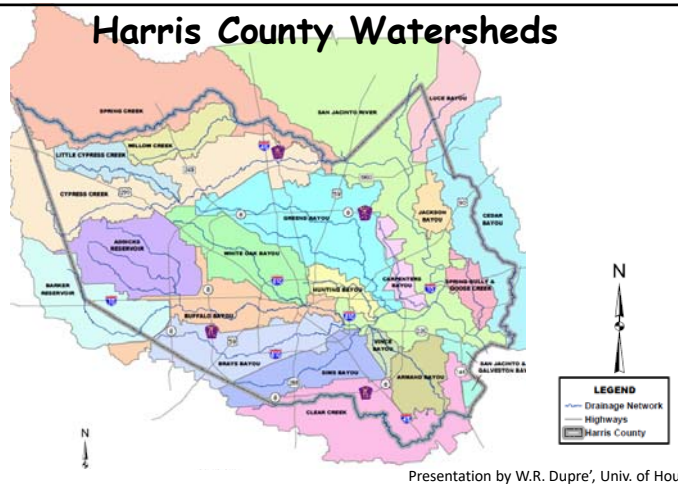




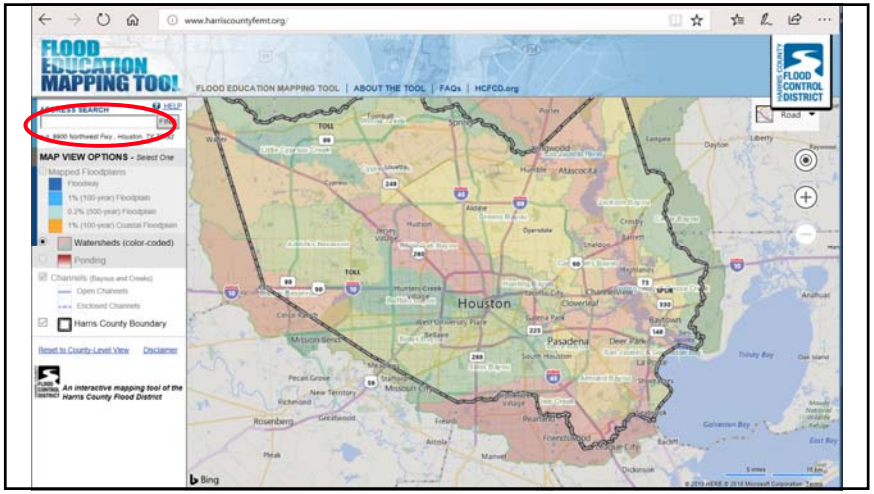
Harris County Drainage Network

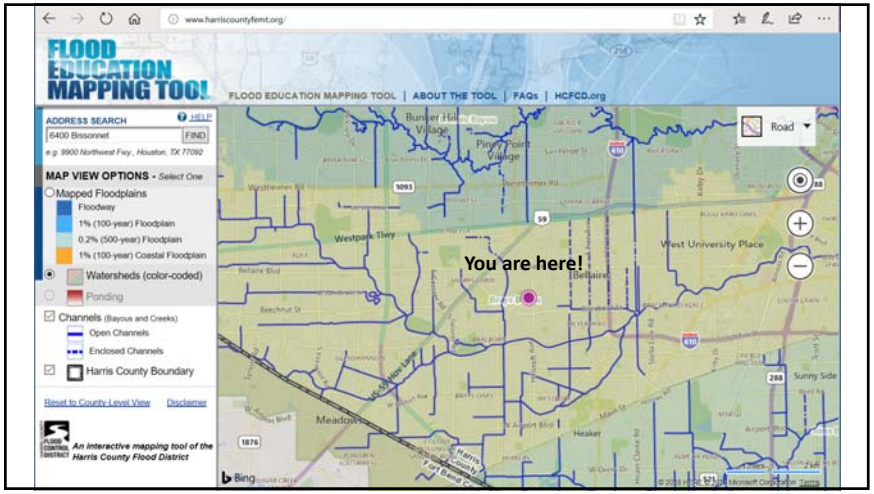
Presentation by W.R. Dupre', Univ. of Houston, 2018

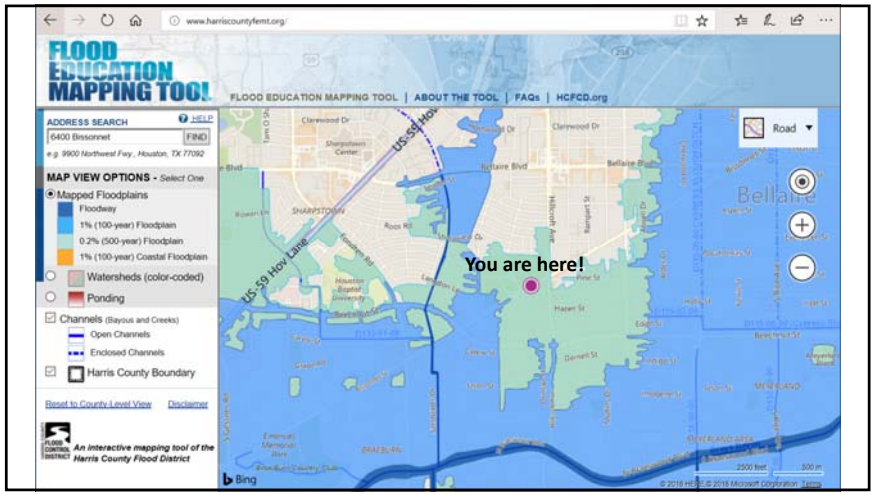
Harris County Watersheds



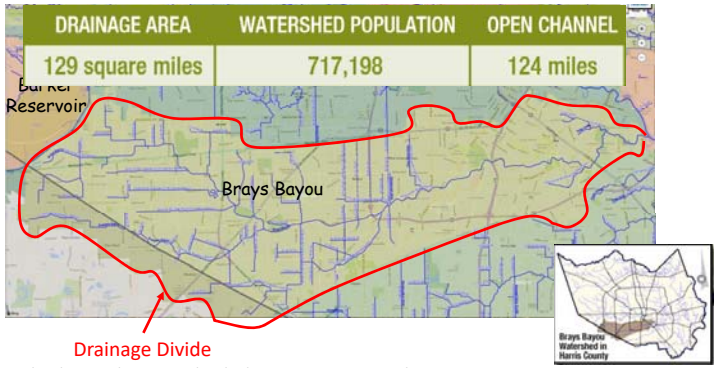
Presentation by W.R. Dupre', Univ. of Houston, 2018







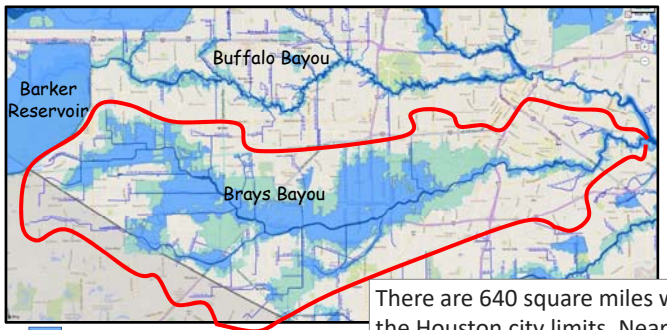
Brays Bayou Watershed



Harris County Flood Control District: Flood Education Mapping Tool
www.harriscountyfemt.org/#

Presentation by W.R. Dupre', Univ. of Houston, 2018

Brays Bayou Floodplain



AE 1% (100 year) Floodplain

X 0.2% (500 year) Floodplain

There are 640 square miles within the Houston city limits. Nearly 30% of the city is in a 100-year floodplain.

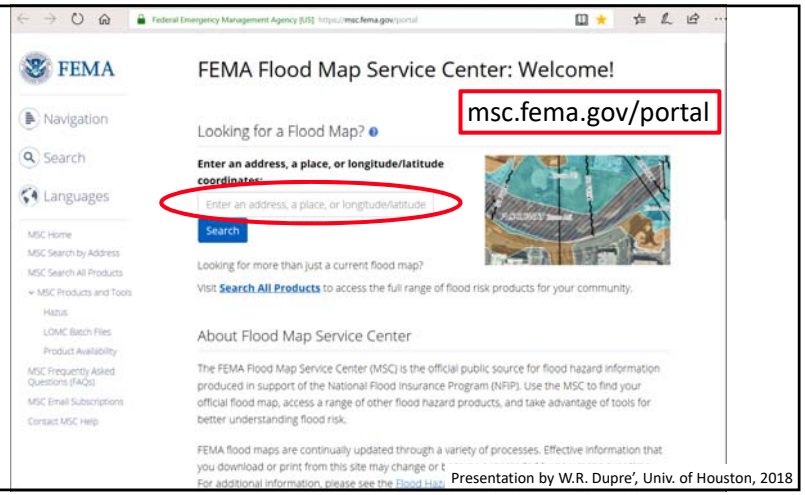
Presentation by W.R. Dupre', Univ. of Houston, 2018

FIRM's (Flood Insurance Rate Maps)

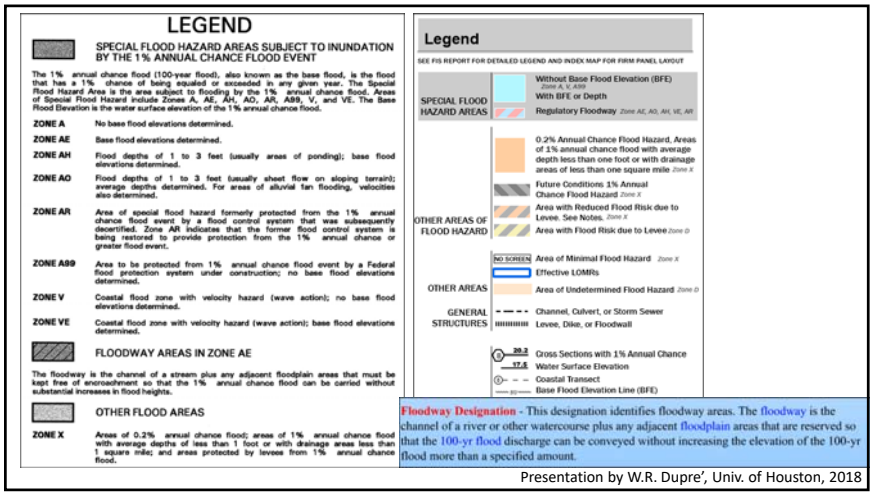
What information do they contain?

1. **Special Flood Hazard Areas** (SFHA) - subject to flooding by 1% event
   a) The **regulatory floodway**
   b) The **1% (100 year) floodplain** (Zones A & AE, etc.)
   c) The **1% coastal floodplain** (Zone V & VE)
2. The **0.2% (500 year) floodplain** (Zone X - shaded)
3. The area of **minimal flood hazard** (Zone X – not shaded)
4. **Base Flood Elevation** (BFE) lines, etc.

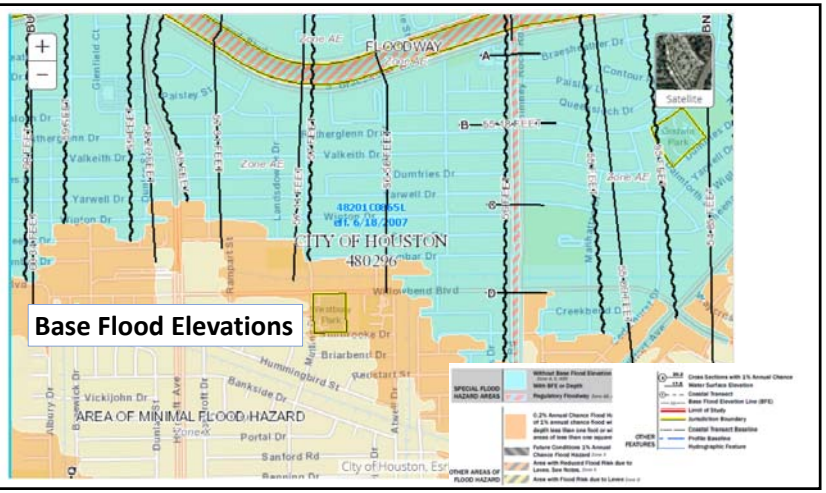
Presentation by W.R. Dupre', Univ. of Houston, 2018

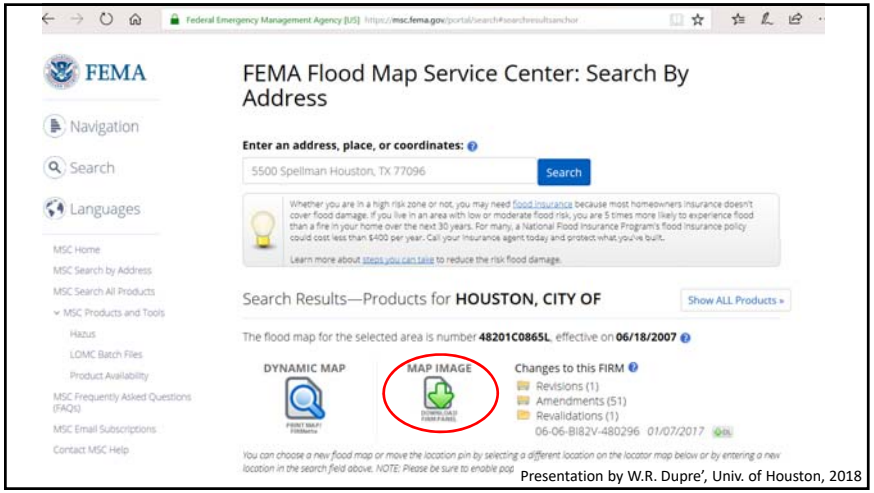


Presentation by W.R. Dupre', Univ. of Houston, 2018

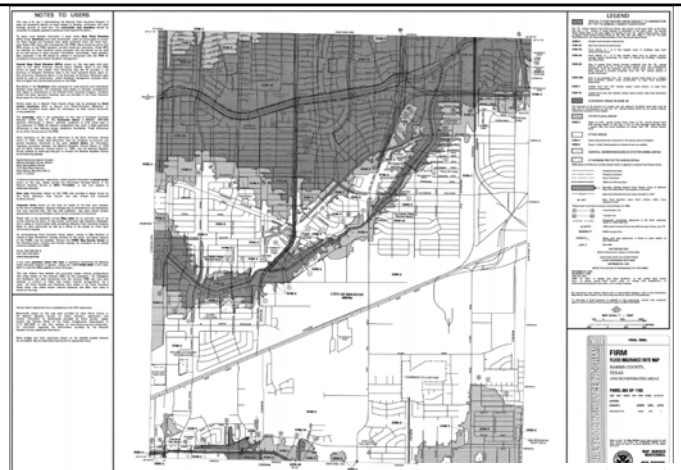


Presentation by W.R. Dupre', Univ. of Houston, 2018

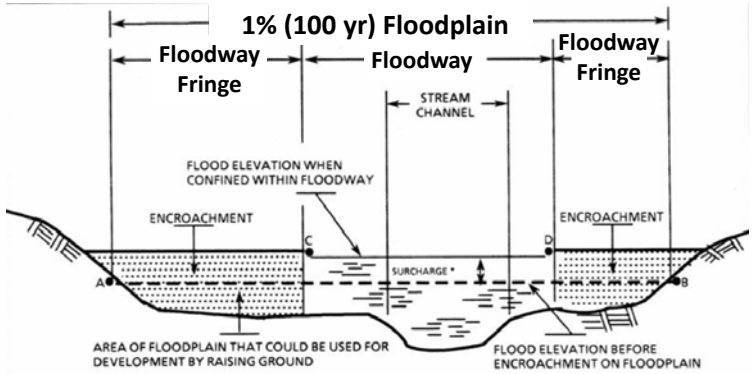




Presentation by W.R. Dupre', Univ. of Houston, 2018



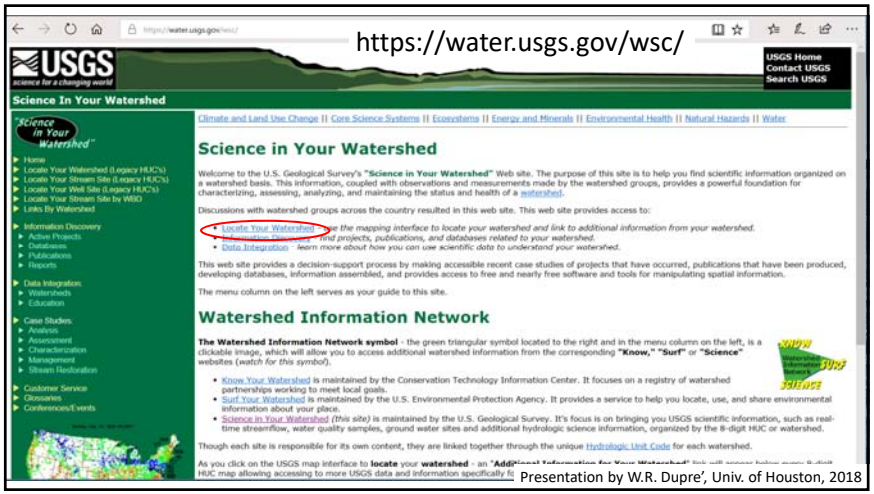
Presentation by W.R. Dupre', Univ. of Houston, 2018



Floodway – A regulatory zone within a 1 percent (100-year) floodplain closest to a bayou or creek where land development is regulated by a city or a county.

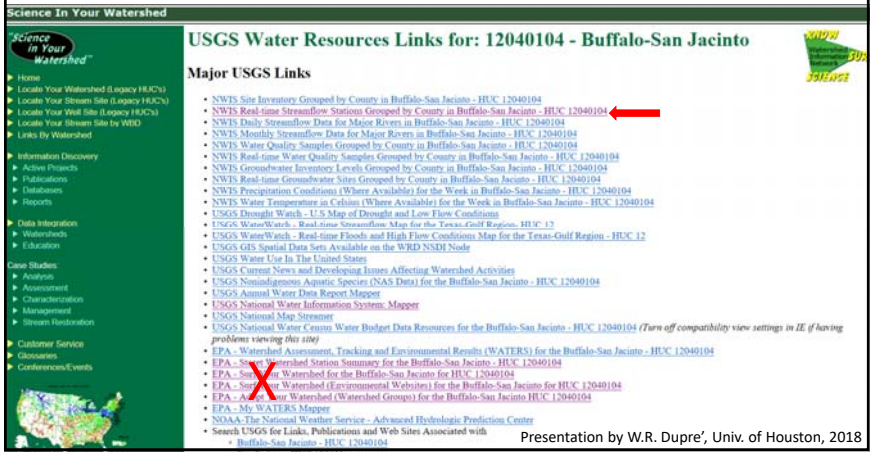
Presentation by W.R. Dupre', Univ. of Houston, 2018

https://water.usgs.gov/wsc/

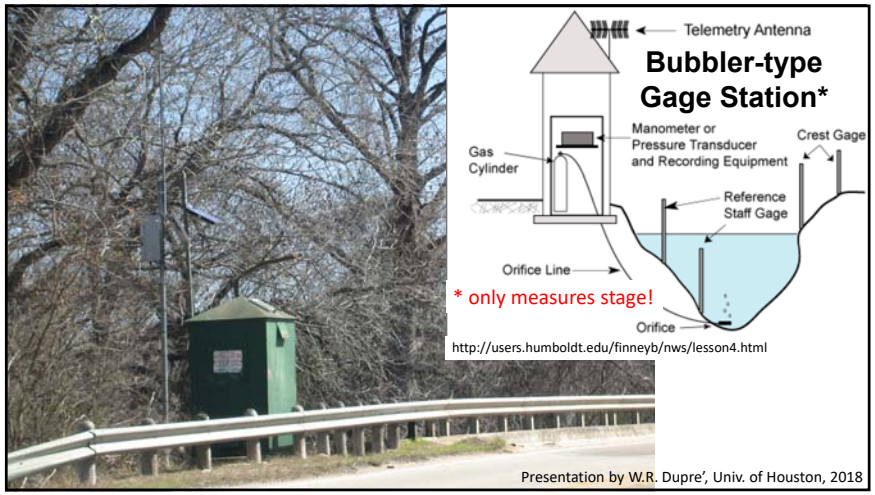


Presentation by W.R. Dupre', Univ. of Houston, 2018

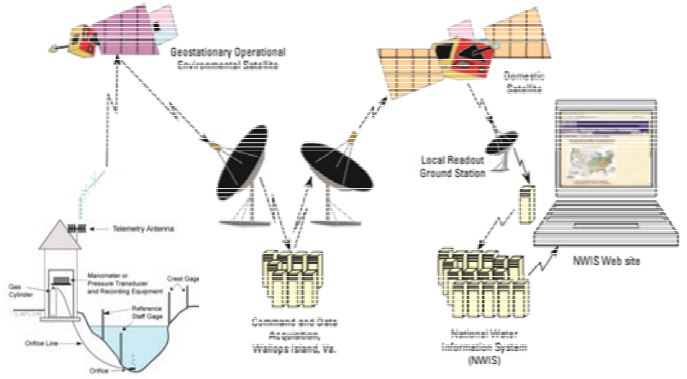
https://water.usgs.gov/lookup/getwatershed?12040104/www/cgi-bin/lookup/getwatershed



Presentation by W.R. Dupre', Univ. of Houston, 2018



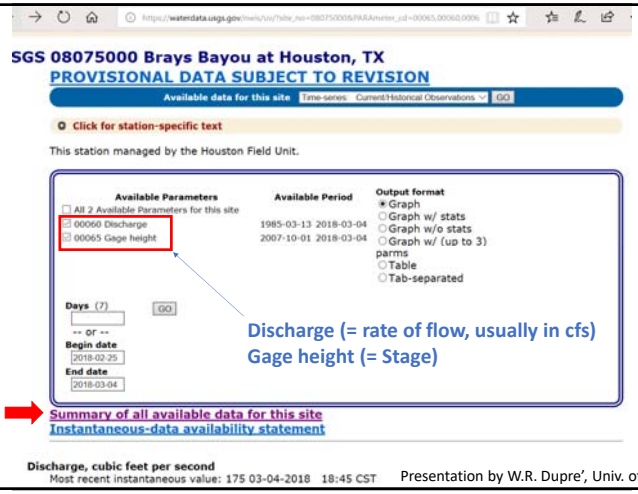
From the Stream Gage to the Internet

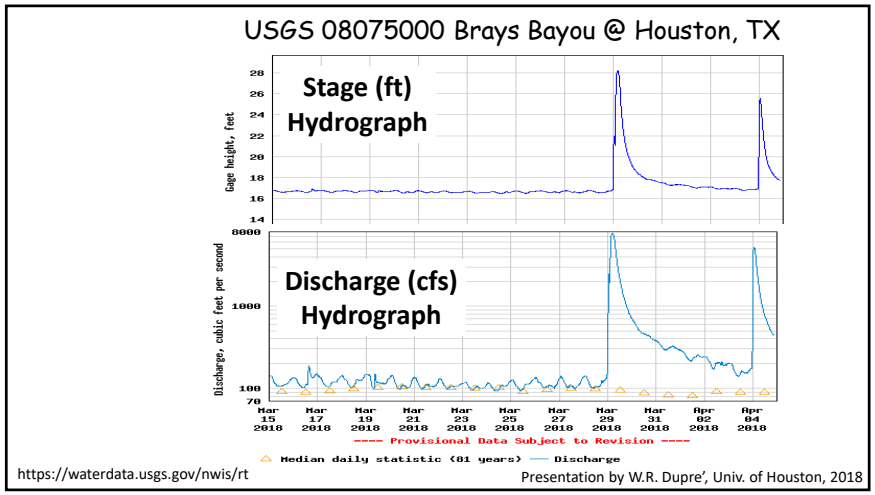


https://pubs.usgs.gov/tm/tm3-a7/pdf/tm3-a7.pdf

08074020	Whiteoak Bayou at Alabonson Rd, Houston, TX	03/04 18:45 CST	59.97	27.0	--	--
08074150	Cole Ck at Deihl Rd, Houston, TX	03/04 18:30 CST	61.94	--	--	--
		02/26 20:30 CST	--	28.6	--	--
08074250	Brickhouse Gully at Costa Rica St, Houston, TX	03/04 18:30 CST	47.53	10.1	--	--
08074500	Whiteoak Bayou at Houston, TX	03/04 18:45 CST	8.12	78.7	--	--
08074540	Little Whiteoak Bayou at Trimble St, Houston, TX	03/04 19:00 CST	19.58	13.0	--	--
08074598	Whiteoak Bayou at Main St, Houston, TX	03/04 19:00 CST	1.76	--	--	--
08074760	Brays Bayou at Alief, TX	03/04 19:00 CST	52.57	39.7	--	--
08074800	Keegans Bayou at Roark Rd nr Houston, TX	03/04 19:15 CST	60.52	--	--	--
		02/26 00:30 CST	--	60.0	--	--
08074810	Brays Bayou at Gessner Dr, Houston, TX	03/04 19:15 CST	38.88	97.2	--	--
08075000	Brays Bayou at Houston, TX	03/04 18:45 CST	16.86	175	--	--
08075110	Brays Bayou at MLK Jr Blvd, Houston, TX	03/04 19:00 CST	1.60	--	--	--
		02/22 00:30 CST	--	3,150	--	--
08075400	Sims Bayou at Hiram Clarke St, Houston, TX	03/04 19:15 CST	26.28	8.97	--	--
08075500	Sims Bayou at Houston, TX	03/04 18:30 CST	1.42	--	--	--
		02/10 21:45 CST	--	1,810	--	--
08075605	Berry Bayou at Nevada St, Houston, TX	03/04 19:15 CST	15.55	5.36	--	--
08075730	Vince Bayou at Pasadena, TX	03/04 19:15 CST	4.81	2.57	--	--
08075763	Hunting Bayou at Hoffman St, Houston, TX	03/04 19:00 CST	29.05	4.34	--	--
08075770	Hunting Bayou at IH 610, Houston, TX	03/04 19:15 CST	17.65	13.9	--	--
08075780	Greens Bayou at Cutten Rd nr Houston, TX	03/04 19:00 CST	100.18	--	--	--
		02/26 16:30 CST	--	40.5	--	--
08075900	Greens Bayou nr US Hwy 75 nr Houston, TX	03/04 18:45 CST	65.85	21.2	--	--
08076000	Greens Bayou nr Houston, TX	03/04 18:30 CST	39.09	43.6	--	--
08076180	Garners Bayou nr Humble, TX	03/04 19:15 CST	34.03	18.8	--	--
08076500	Halls Bayou at Houston, TX	03/04 19:15 CST	39.70	17.3	--	--
08076700	Greens Bayou at Ley Rd, Houston, TX	03/04 18:45 CST	1.73	--	--	--
		02/26 19:45 CST	--	820	--	--

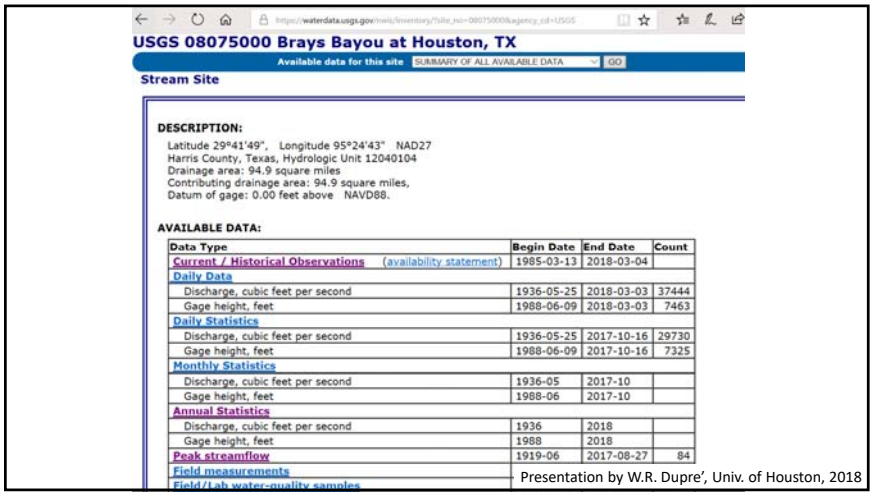
https://waterdata.usgs.gov/nwis/





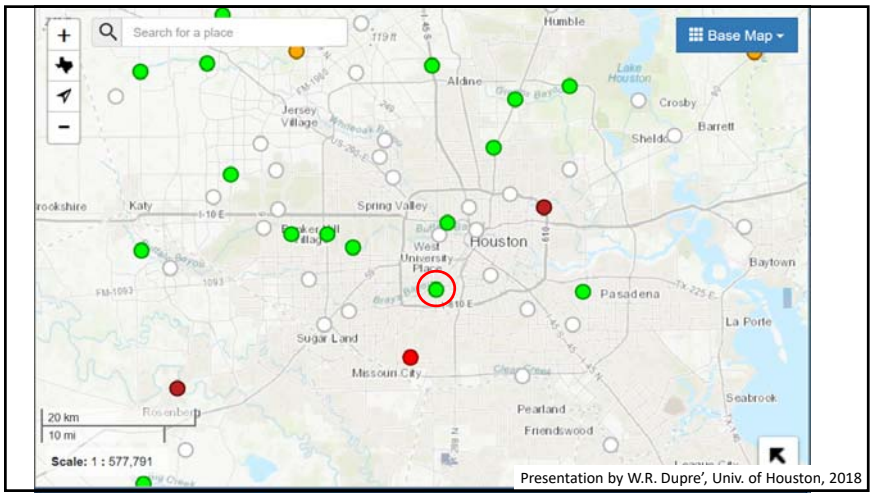
https://waterdata.usgs.gov/nwis/rt

Presentation by W.R. Dupre', Univ. of Houston, 2018

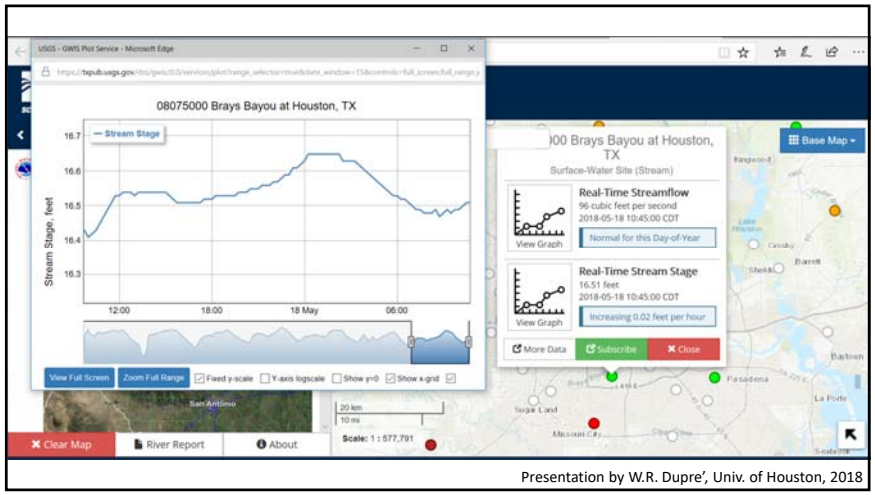


Presentation by W.R. Dupre', Univ. of Houston, 2018

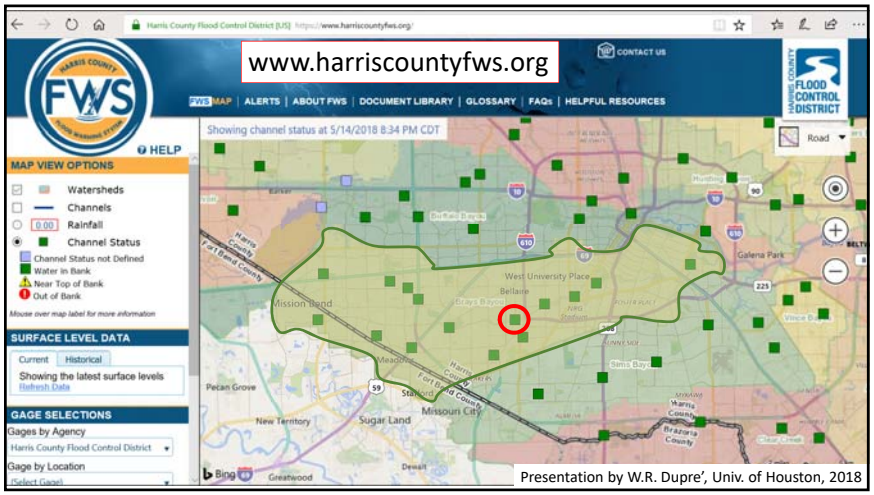
Presentation by W.R. Dupre', Univ. of Houston, 2018



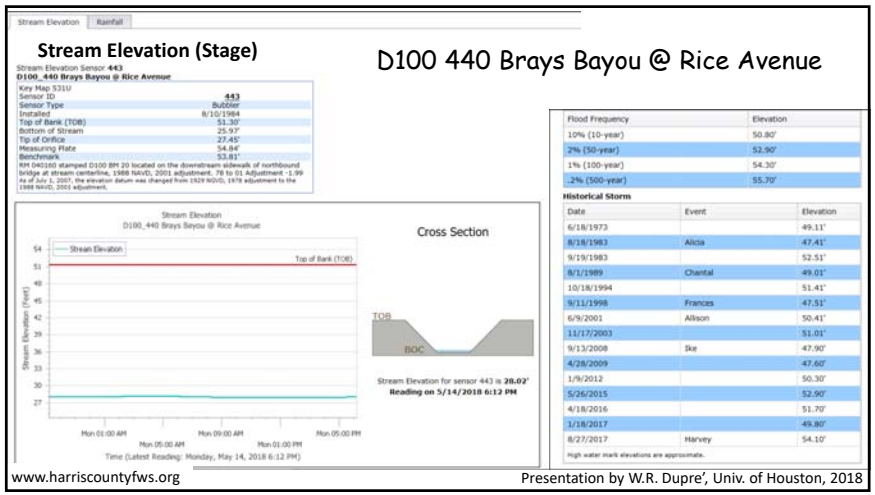
Presentation by W.R. Dupre', Univ. of Houston, 2018



Presentation by W.R. Dupre', Univ. of Houston, 2018

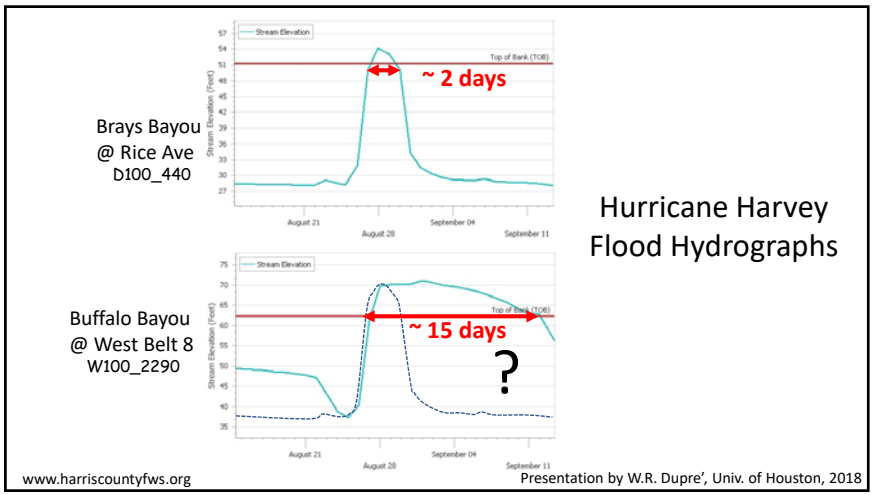


Presentation by W.R. Dupre', Univ. of Houston, 2018



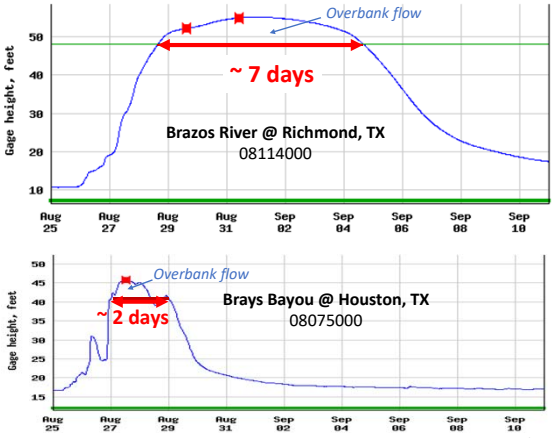
www.harriscountyfws.org

Presentation by W.R. Dupre', Univ. of Houston, 2018

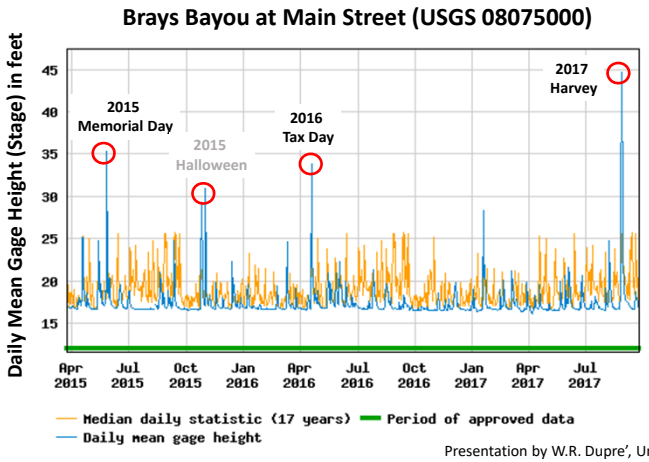


www.harriscountyfws.org

Presentation by W.R. Dupre', Univ. of Houston, 2018



Presentation by W.R. Dupre', Univ. of Houston, 2018



Presentation by W.R. Dupre', Univ. of Houston, 2018

How do you Calculate Flood-related Risk?

1) **Streamflow** Data:
- Graph-fitting curves
- Math-fitting curves

2) Regionalization (Parametric Models):
- From gaged basins to ungaged basins

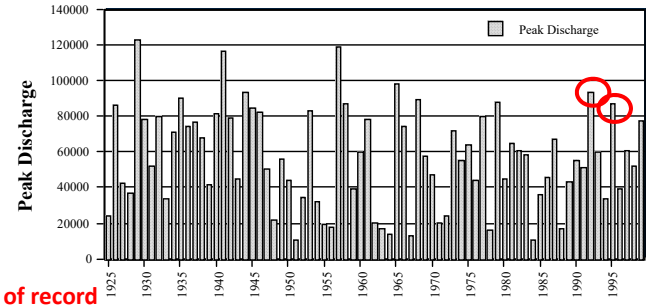
3) **Rainfall** Data:
- Digital Streamflow Models: from rainfall to runoff

4) (Probable Maximum) Flood:
- especially for high-risk projects

Presentation by W.R. Dupre', Univ. of Houston, 2018

$$RI = \frac{N+1}{m}$$

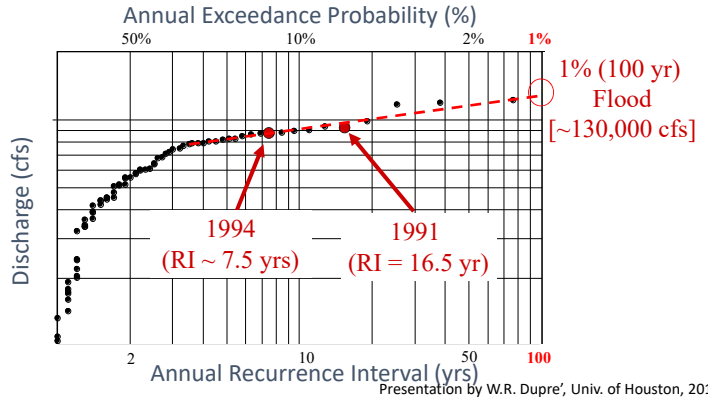
Stream Flow Data:
Peak Annual Daily Discharge Records
Brazos River at Richmond, TX

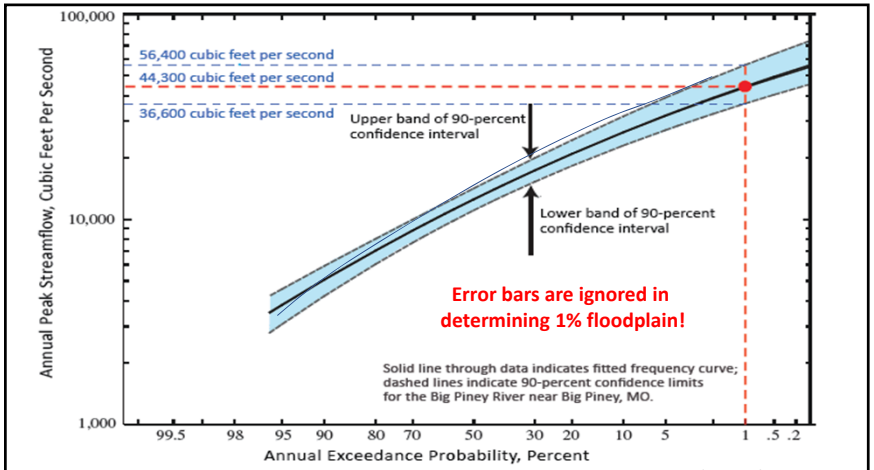


N = # yrs of record
m = rank (largest = 1)

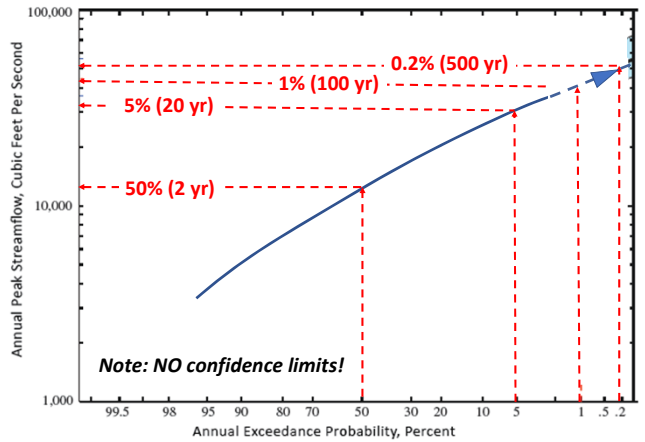
Presentation by W.R. Dupre', Univ. of Houston, 2018

Recurrence Interval Graph-Brazos River





https://water.usgs.gov/edu/100yearflood-basic.html



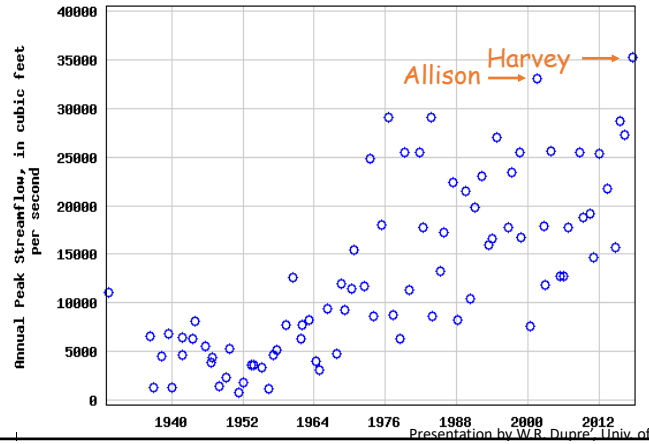
https://water.usgs.gov/edu/100yearflood-basic.html

Assumptions using Streamflow Records

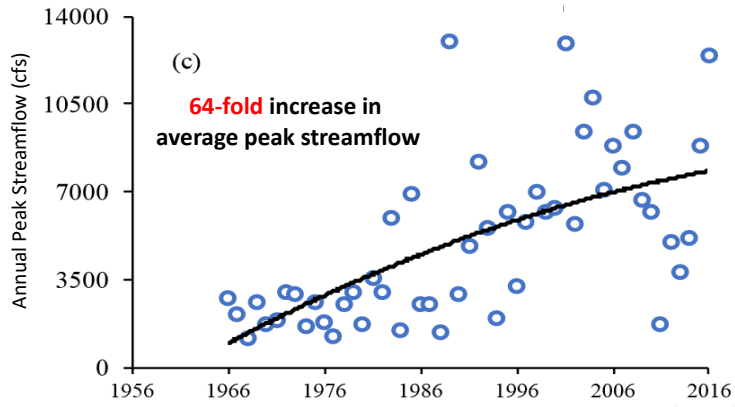
- Events are random and independent
- Only deals with overbank flooding
- No watershed changes during period of record
- Data are not affected by climatic trends

Modified after U.S. Water Resources Council

Annual Peak Discharge – Brays Bayou 08075000



Annual Peak Discharge – Greens Bayou 08075900



Berg, 2018

Rainfall

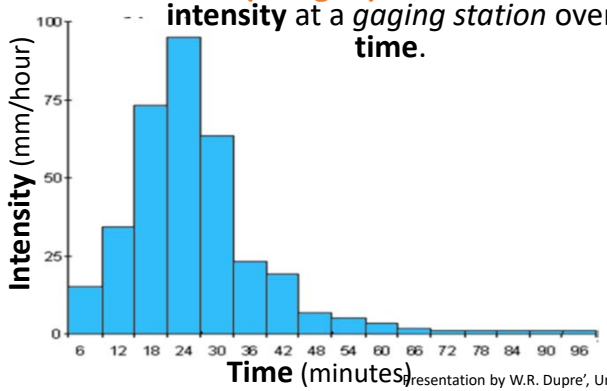
- Historical rainfall data measured by rain gages or radar (e.g. TS Allison, Hurricane Harvey).

- Frequency-based hypothetical storm (e.g. 1%).

- Standard Project Storm (SPS). – rarely used now, largely replaced by the 0.2% (500 yr) storm.

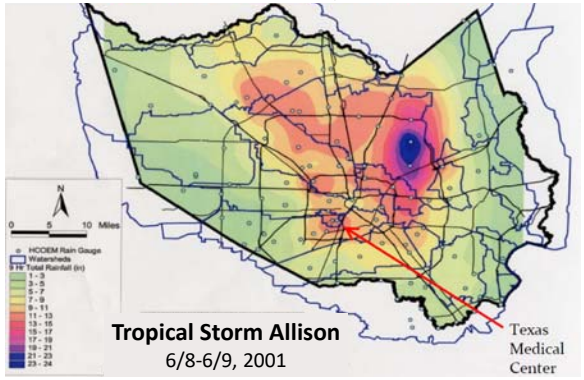
rainfall graph

A ~~hyetograph~~ plots **rainfall intensity** at a *gaging station* over **time**.



Rainfall

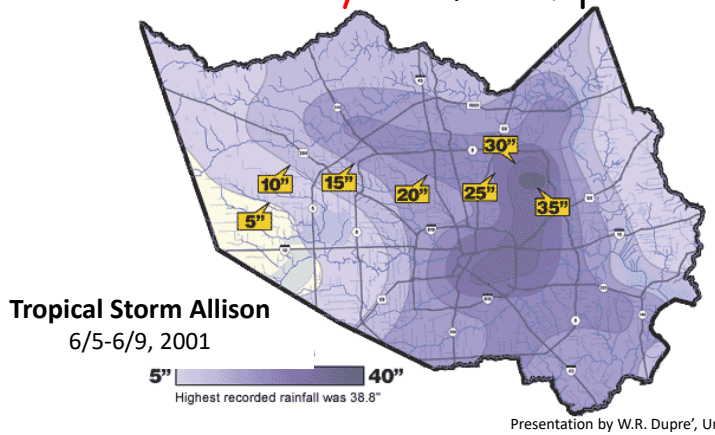
9-Hr. ~~Isohyethal~~ Map in Harris County



From Penland presentation, 2008

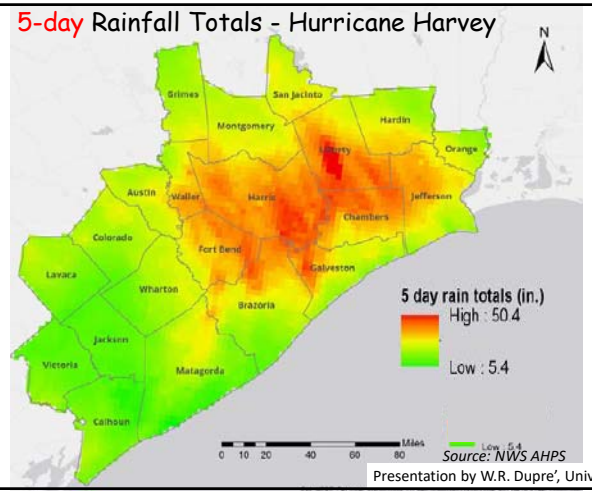
Presentation by W.R. Dupre', Univ. of Houston, 2018

5-day Rainfall Map



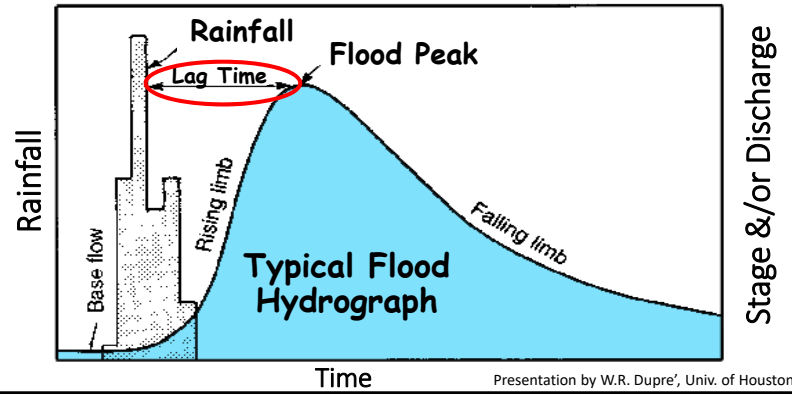
Presentation by W.R. Dupre', Univ. of Houston, 2018

5-day Rainfall Totals - Hurricane Harvey



Presentation by W.R. Dupre', Univ. of Houston, 2018

A **hydrograph** plots **stage** or **discharge** at a *gaging station* over time.



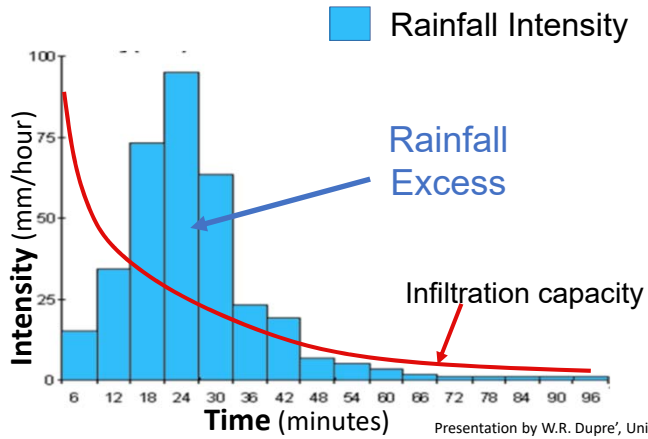
Presentation by W.R. Dupre', Univ. of Houston, 2018

Does Rainfall = Runoff?

No … only *"Rainfall Excess"?*

Rainfall Excess = Rainfall – losses*

*mainly **infiltration** & evapotranspiration (ET)



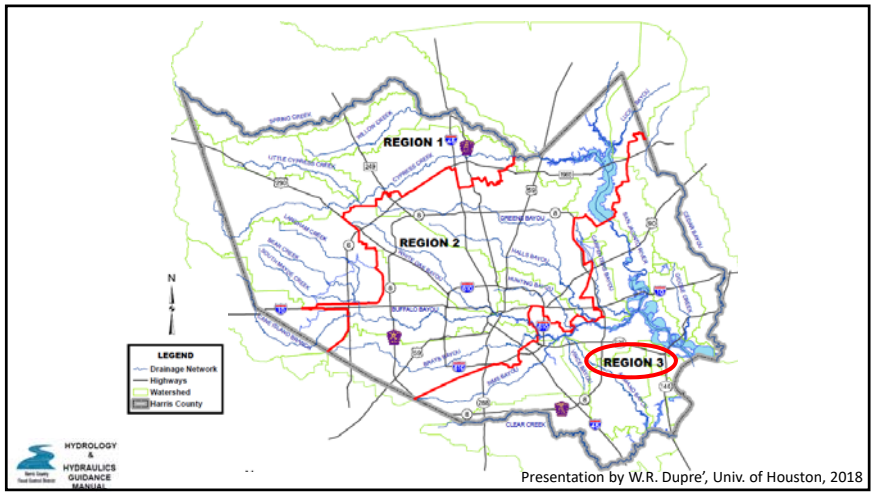
Infiltration is ….	high	low
Surface Slope	low	steep
Soil Type	sandy	clay-rich
Ppt. Intensity	gentle	heavy
Soil Saturation	low	high
Vegetation	hi %	low %
Land Use	natural	urbanized
Runoff is …..	low	high

Rainfall-Runoff Relations

For Rainfall, consider:

- Frequency
- Duration
- Intensity
- Areal distribution
- Temporal distribution

For Runoff, think "Excess Rainfall"



Presentation by W.R. Dupre', Univ. of Houston, 2018

HARRIS COUNTY HYDROLOGIC REGION 3 RAINFALL (INCHES)

Duration	Annual-Chance Event			
	10-percent	2-percent	1.0-percent	0.2-percent
5-Minute	0.9	1.1	1.2	1.4
15-Minute	1.5	1.9	2.1	2.5
30-Minute	2.1	2.7	3.0	3.7
60-Minute	2.9	3.8	4.3	5.5
2-Hour	3.7	5.0	5.7	7.7
3-Hour	4.2	5.9	6.8	9.4
6-Hour	5.3	7.7	9.1	13.1
12-Hour	6.4	9.5	11.1	15.9
24-Hour	7.8	11.6	13.5	19.3
2-Day	9.0	13.1	15.1	20.7
4-Day	10.5	14.8	16.9	22.3

Presentation by W.R. Dupre', Univ. of Houston, 2018