National Weather Service
Flood Class 2016

SKYWARN

National Weather Service Mission

- The National Weather Service (NWS) provides weather, ***hydrologic***, and climate ***forecasts and warnings*** for the United States, its territories, adjacent waters and ocean areas, ***for the protection of life and property*** and the enhancement of the national economy. NWS data and products form a national information database and infrastructure which can be used by other governmental agencies, the private sector, the public, and the global community.

Tonight's Topics

- Area of Responsibility
- Flood Facts & Flood Safety
- Water Monitoring / Basic Hydrology
- Flood Forecasting / Basic Meteorology
- Types of Flooding
- Local Flood History

Break

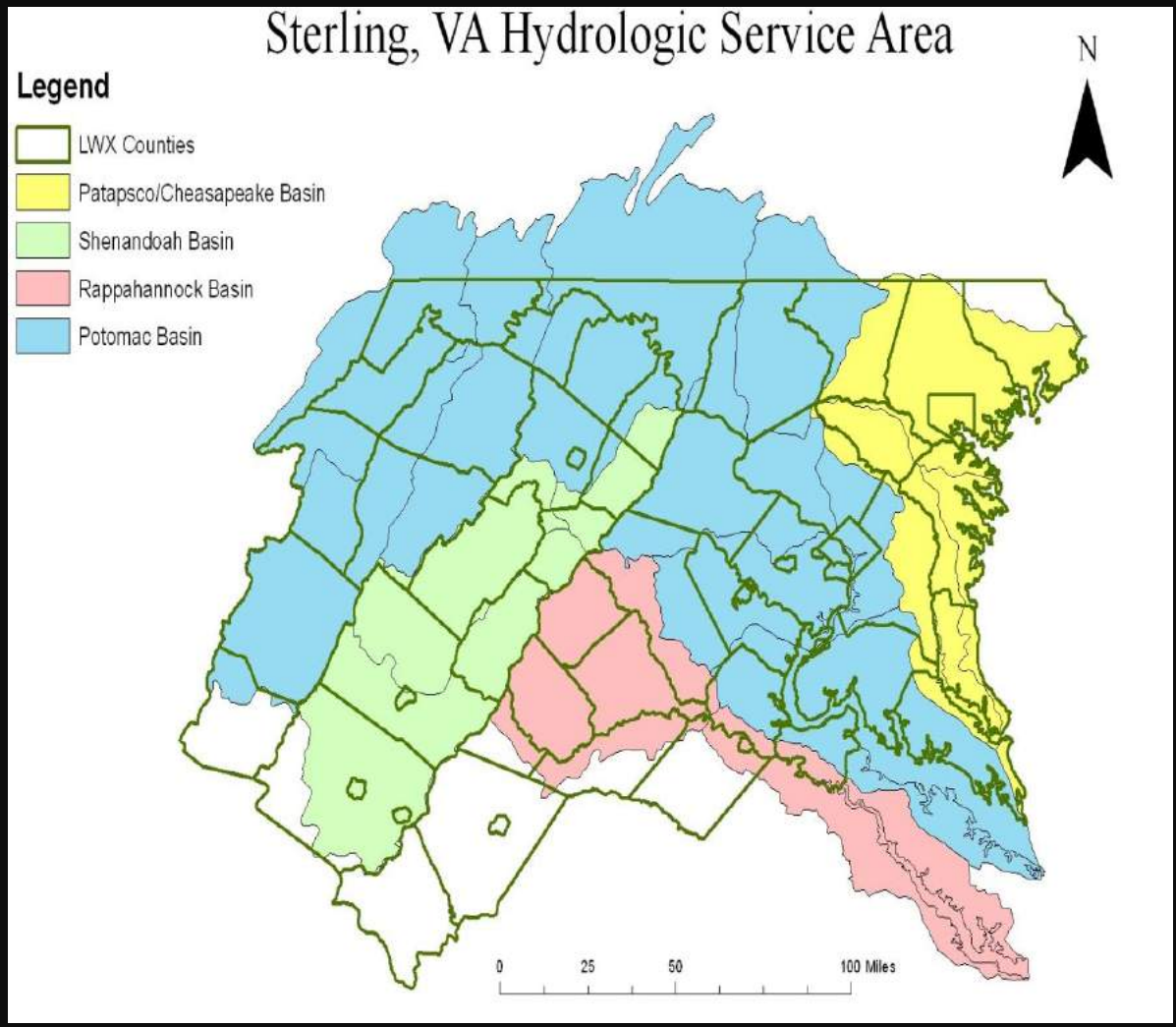
- NWS Products
- Observations
- Role of Spotters
- What to Report
- Case Studies
- Review

NWS Service Delivery

Facilities

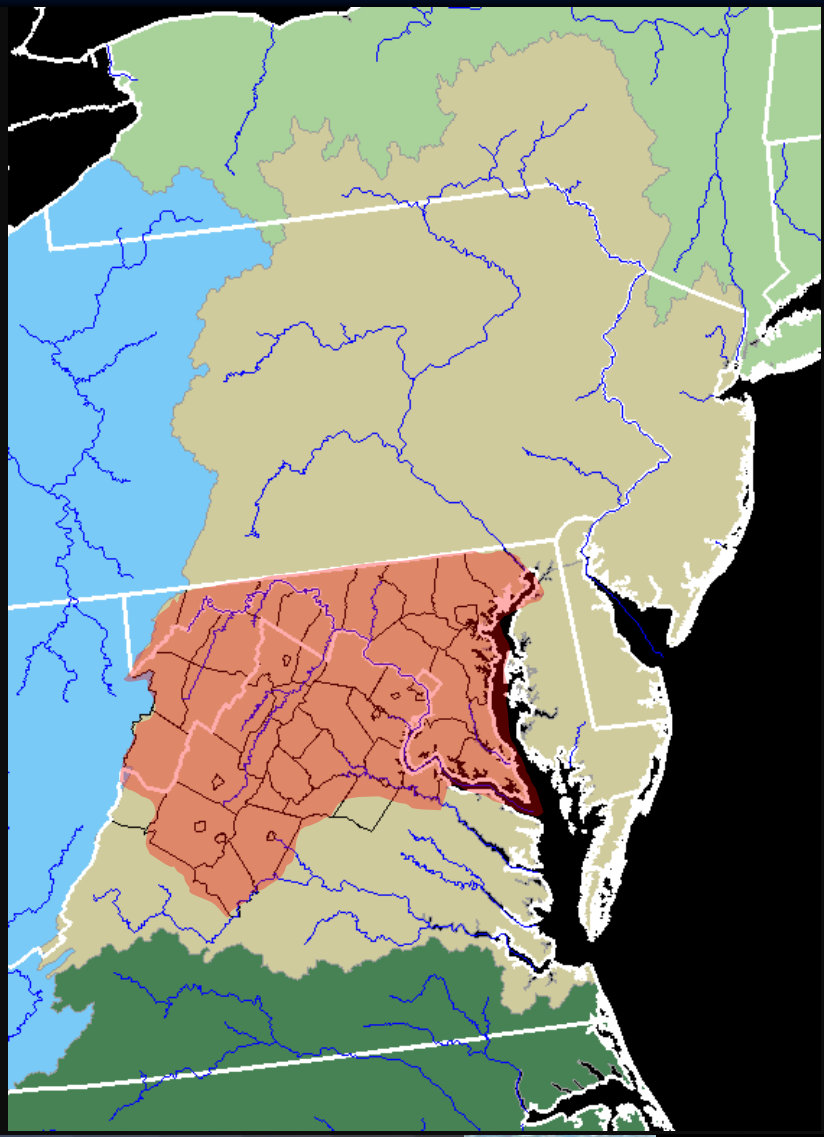
Areas of Responsibility

- **County Warning Area (CWA)**
  Flash Flood
  - 43 Counties in 3 states
  - District of Columbia
  - 12 Independent Cities
  - MD Chesapeake Bay
- **Hydrologic Service Area (HSA)**
  River Flood
  - Potomac Basin
  - Shenandoah Basin
  - Rappahannock Basin
  - West Chesapeake



Hydrologic Staffing

- **Weather Forecast Office**
  - 1 Service Hydrologist
    - *Not all offices have this!*
- **River Forecast Centers**
  - Hydrologist-in-Charge
  - Service Coordination Hydrologist
  - Developmental & Operations Hydrologist
  - 3 or 4 Hydrometeorologists
  - 4 to 9 Hydrologists



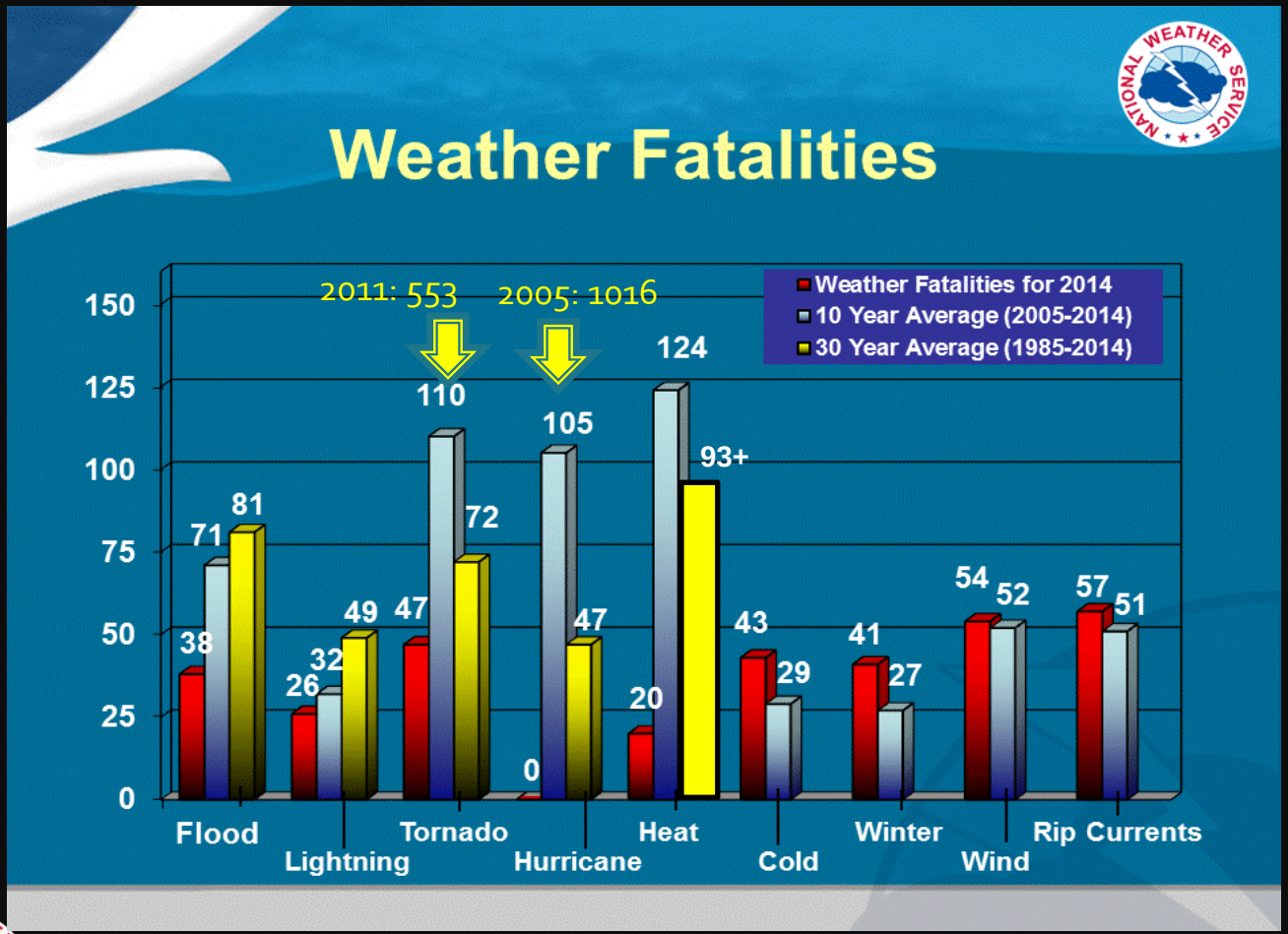
Flood Facts

- Most flood fatalities occur in cars
- Most flood fatalities occur at night
- Most flood fatalities <u>can be avoided!!!</u>

Upper Marlboro, MD & Fairfax, VA – Sept. 2011

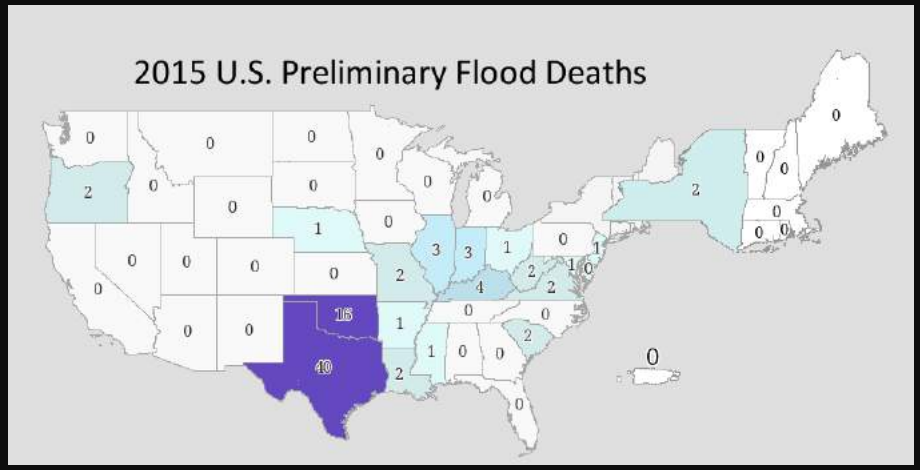
Floods – a major weather killer

- On a long-term basis, floods are the #2 cause of death when weather plays a role, behind heat.



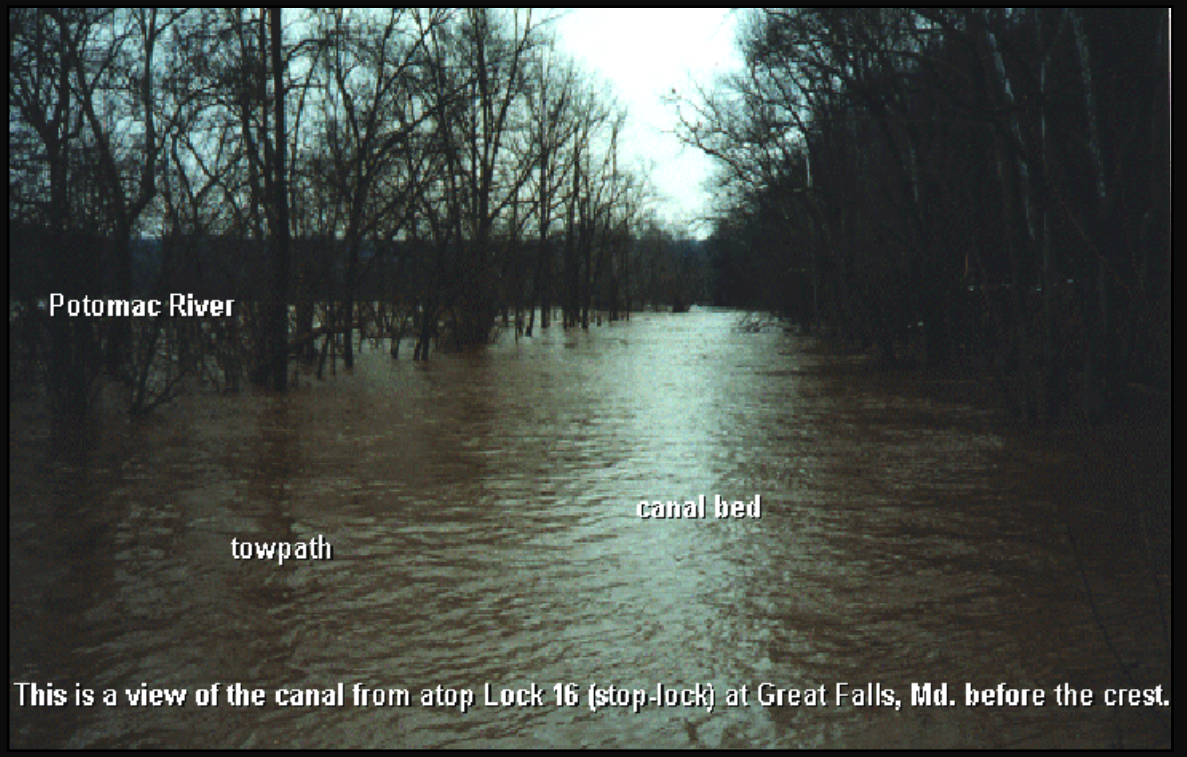
Flood Fatalities

- In 2015 (through late August), there were 86 flood fatalities (above the long-term average).
  - 40 of these were in Texas
  - Two-thirds were male
    - This is consistent year after year
  - A little more than half (52%) were vehicle-related
    - This is a little lower than usual
  - Other determined causes:
    - 19% walking or hiking
    - 9% were all in one house that got swept downstream
    - 8% were in boats (including evacuation boats)



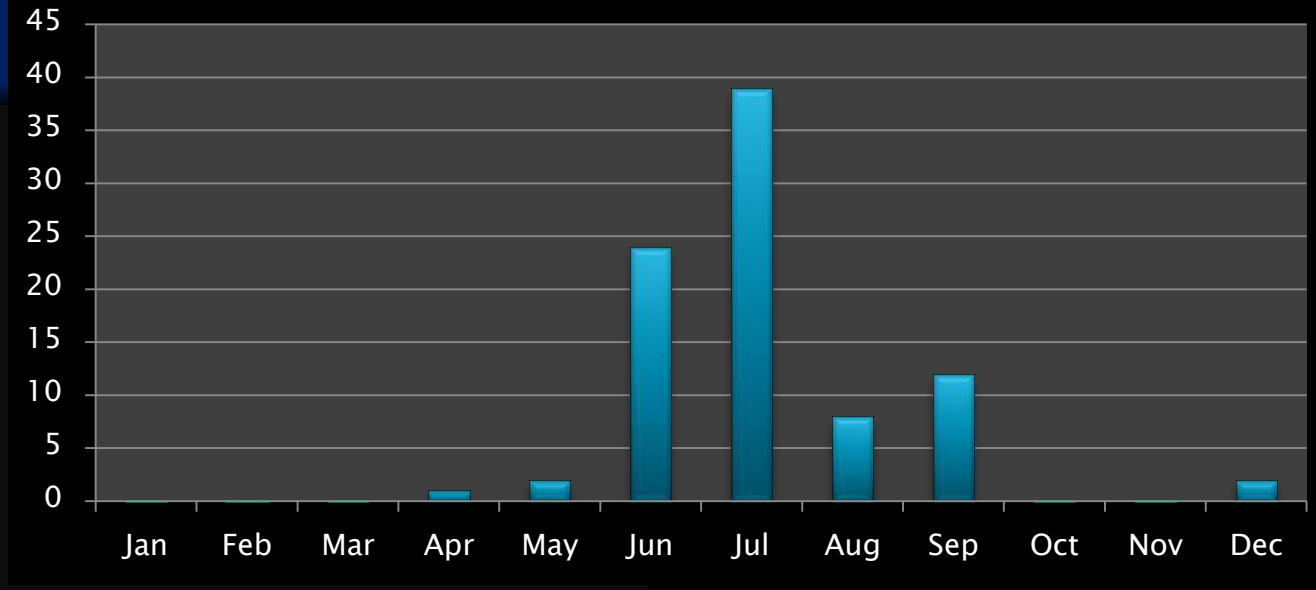
Flood Damages

- Average: $8 billion per year!
- 2014: $2.9 billion
- In 2014 and 2015, 2/3 of all Presidentially-declared disasters were at least in part flood-related

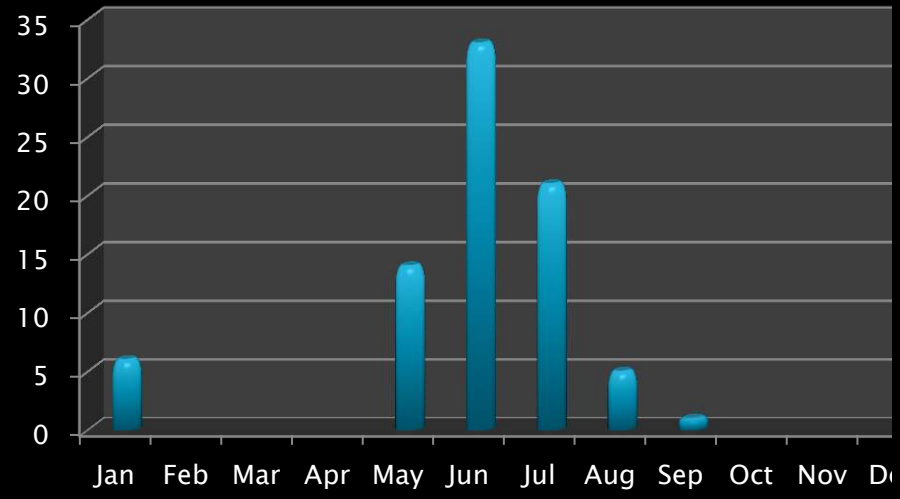


Great Falls, MD
1996

Flash Flood Warnings in 2015 by month

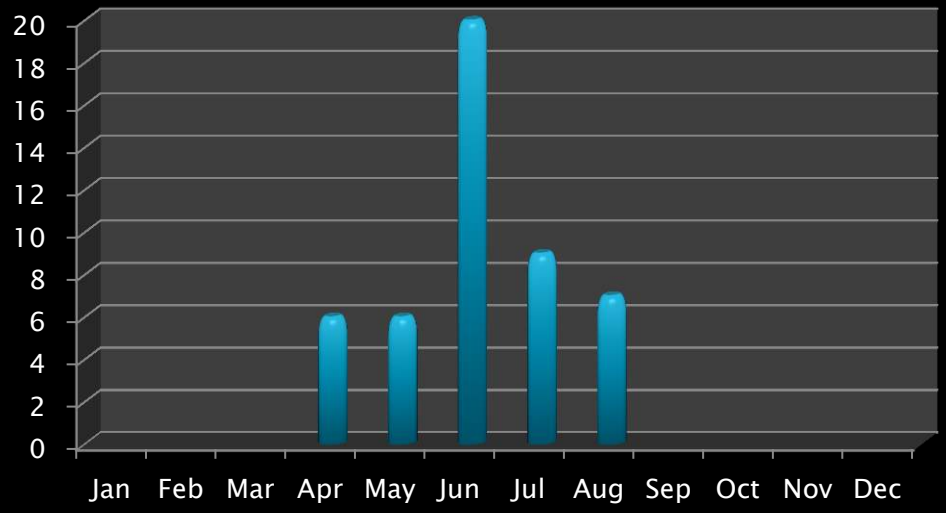


FFWs in 2013 by month



67% of warnings issued before June 30th

FFWs in 2014 by month



68% of warnings issued before June 30th

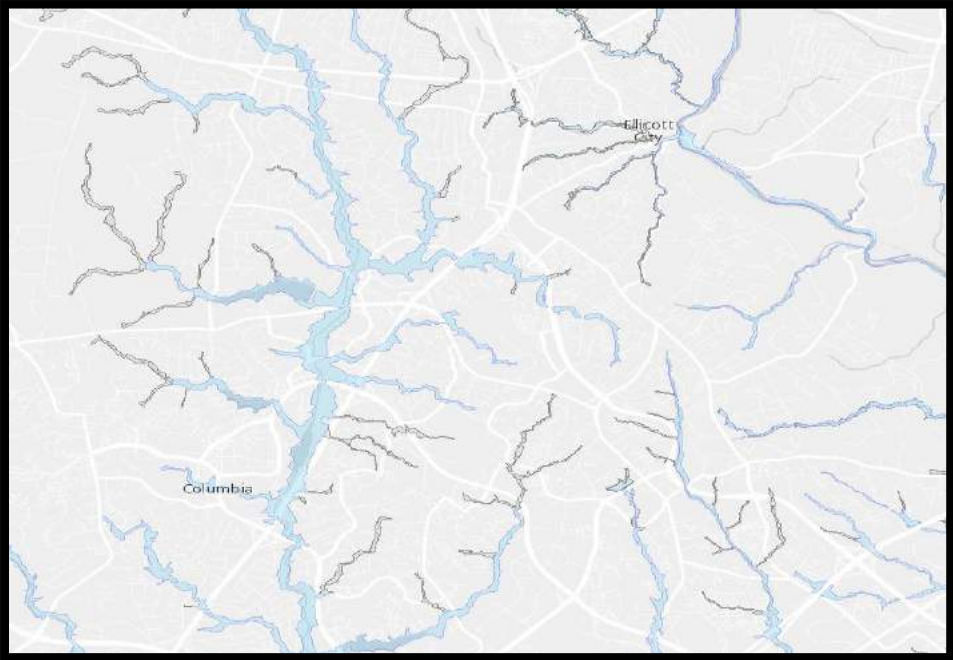
Flood Safety

- **Take Appropriate Action!**
- Better forecasts and earlier warnings won't help prevent loss of life and property unless people act.
- Plan ahead – Identify where to go if told to evacuate. Choose several places (a friend's home or a motel, or a designated shelter)
- Never try to drive, swim, walk, or run through a flooded area
- Children should not play in flooded areas

River Road, Falmouth, VA
March 2011

Know Your Risk

- **Check the FEMA Flood Maps to see if you are in a flood zone…**
  - Maryland: http://www.mdfloodmaps.net
  - West Virginia: http://www.mapwv.gov/flood/
  - National: https://www.floodsmart.gov
- Flooding is not limited to these flood zones! Always consider flood insurance!



Turn Around, Don't Drown!

- If you come upon flood waters, STOP! TURN AROUND AND GO ANOTHER WAY!
- Only 6 inches of fast-moving water can knock you off your feet
- 2 feet of water will float an average size car…less water for smaller cars
- Bottom line: never assume there is a safe way to drive through water

Turn Around, Don't Drown!

Average weight of vehicles:

Compact:
3,000 pounds

Midsize:
3,500 pounds

Large:
4,350 pounds

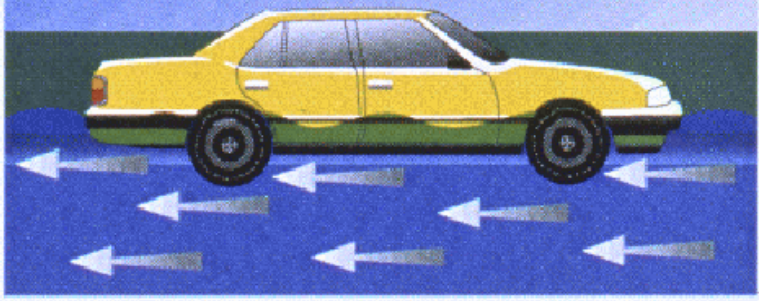
Small SUV:
3,500 pounds

Large SUV:
5,500 pounds

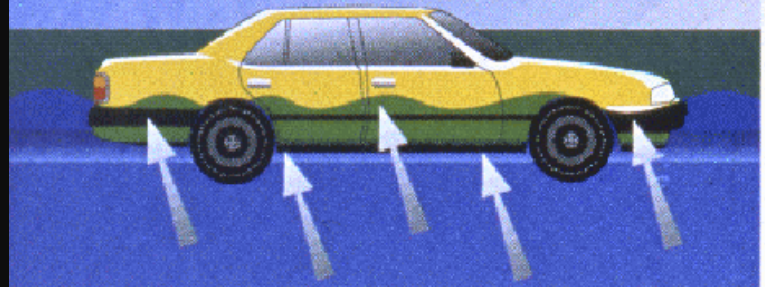
Pickup:
4,500 pounds

Water weighs 62.4 lbs per cubic foot and in a flood can flow downstream at 5 to 10 mph.

When a vehicle stalls in the water, the water's momentum is transferred to the car. For each foot the water rises, 500 lbs of lateral force are applied to the car.

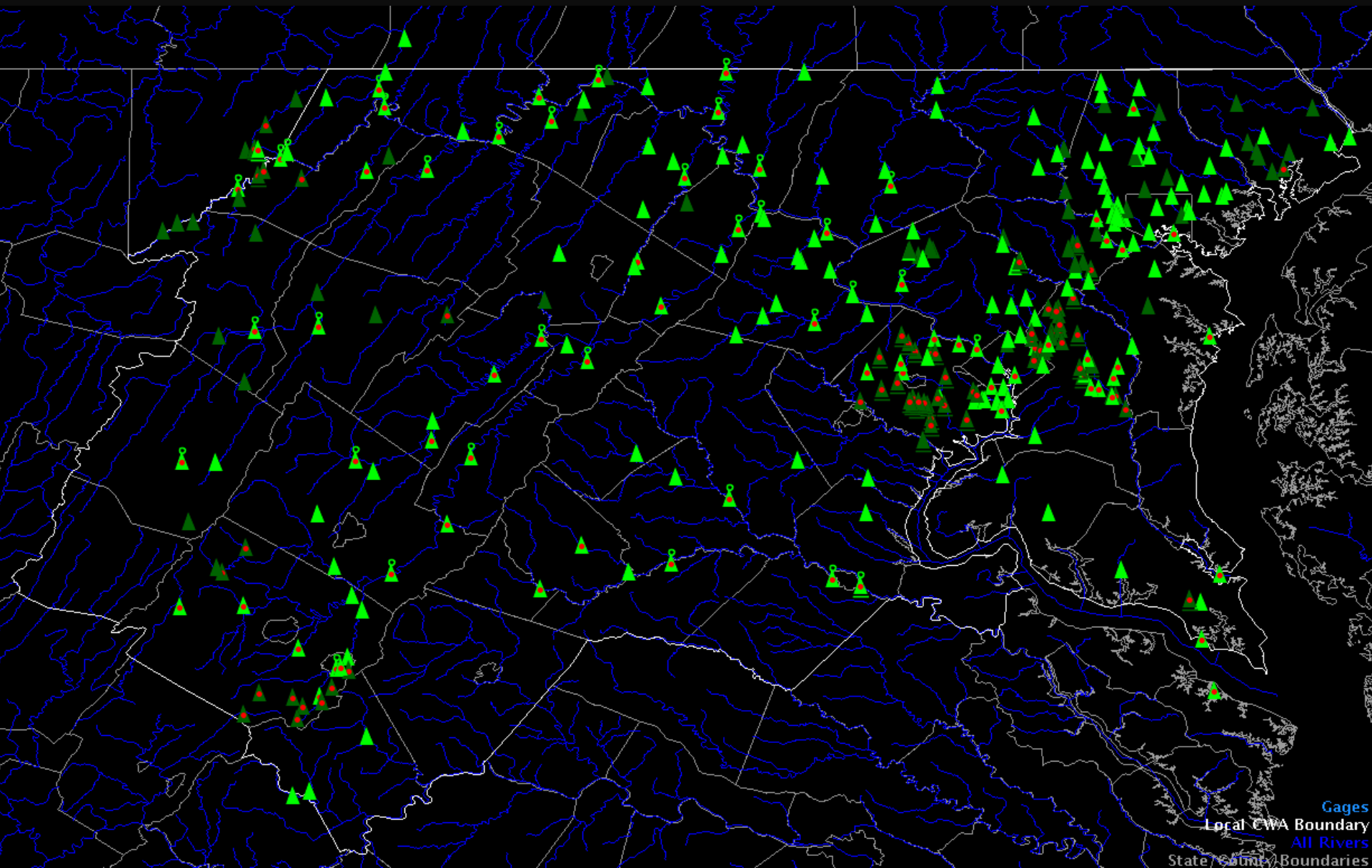


The biggest factor is buoyancy. For each foot the water rises up the side of the car, the car displaces 1500 lbs of water. In effect, the car weighs 1500 lbs less for each foot the water rises.

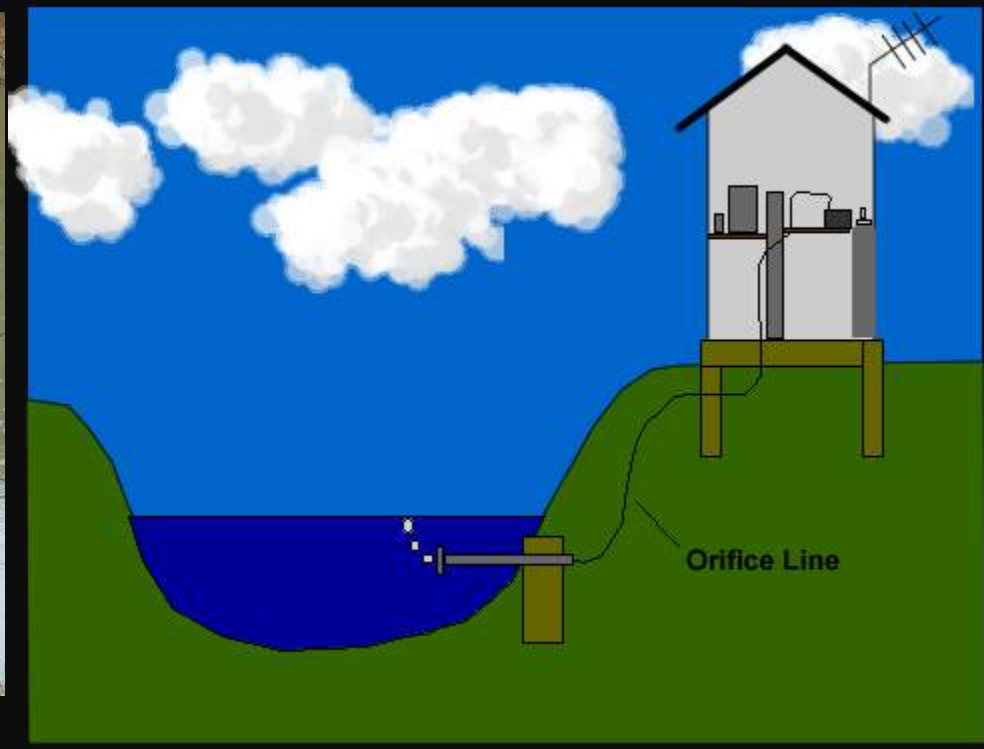


Two feet of water will carry away most automobiles!

River & Lake Gauges

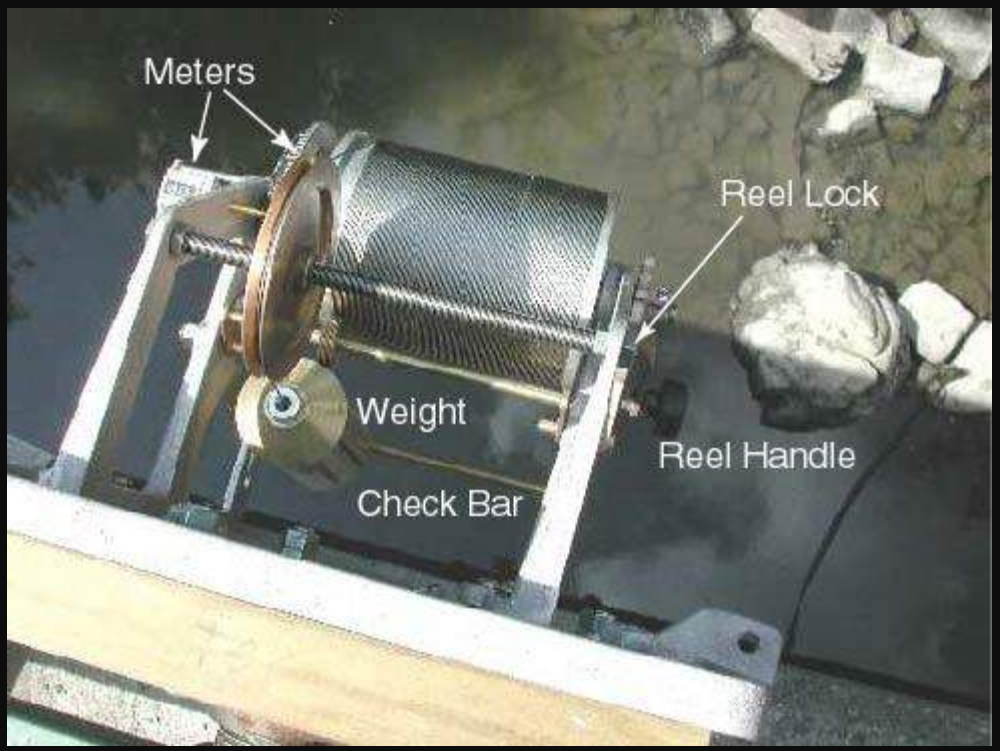


How are water levels measured?

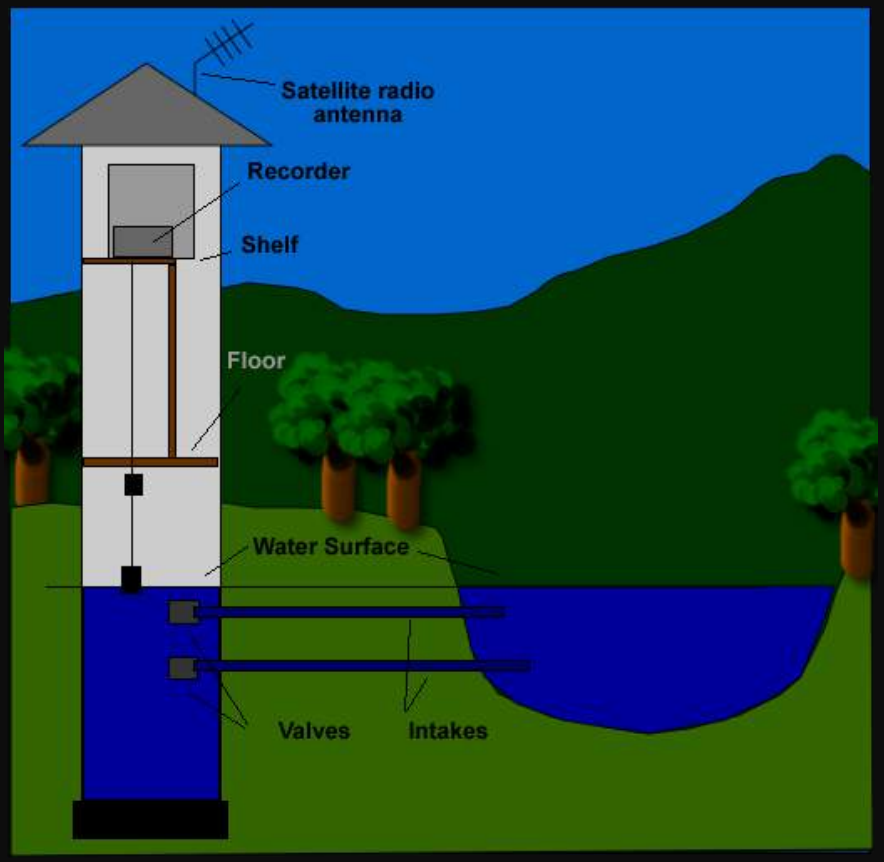


From left:
Staff Gauge
Crest Gauge
Radar Gauge
Pressure Transducer/Bubbler

How are water levels measured?

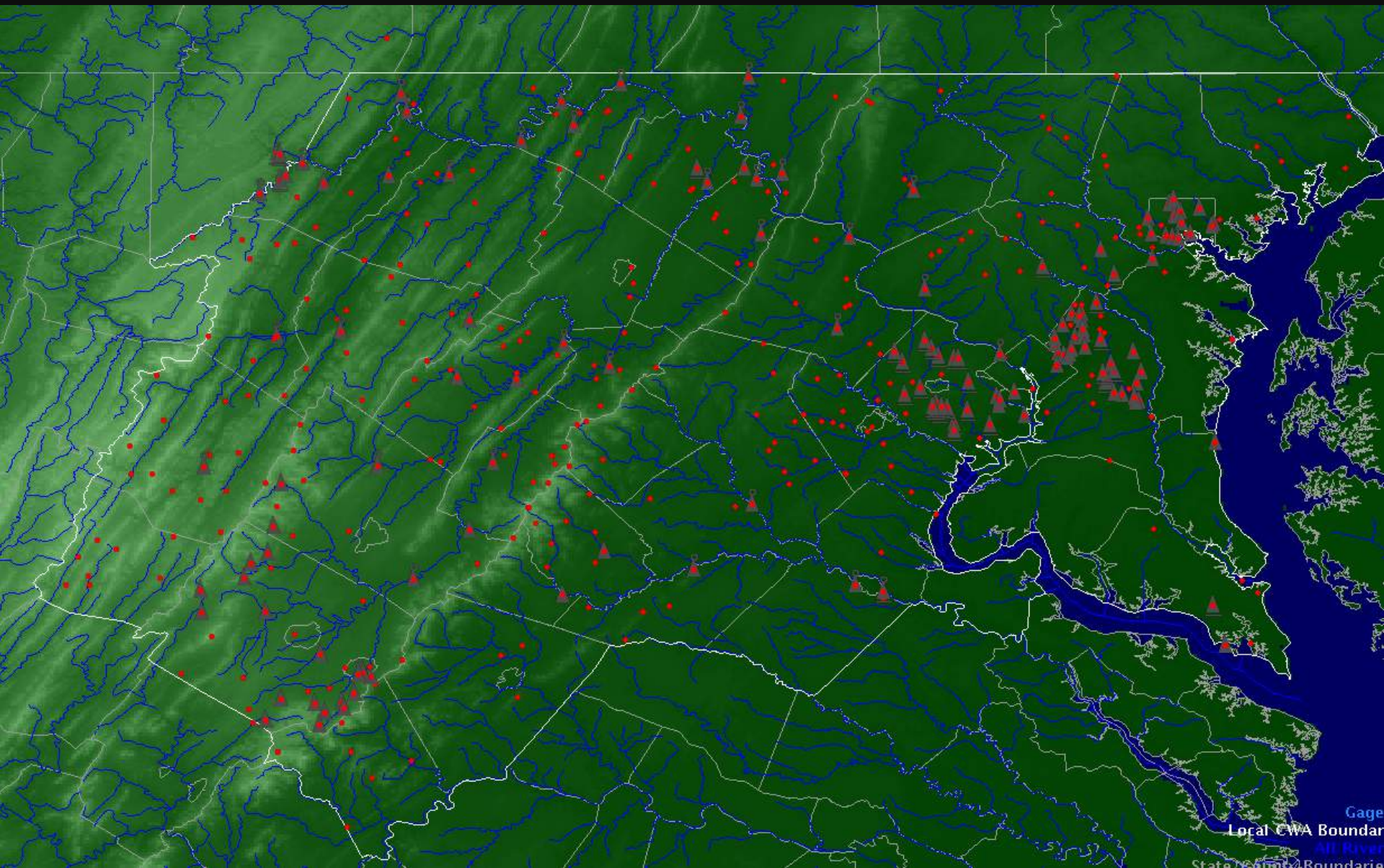


Wire Weight Gauge

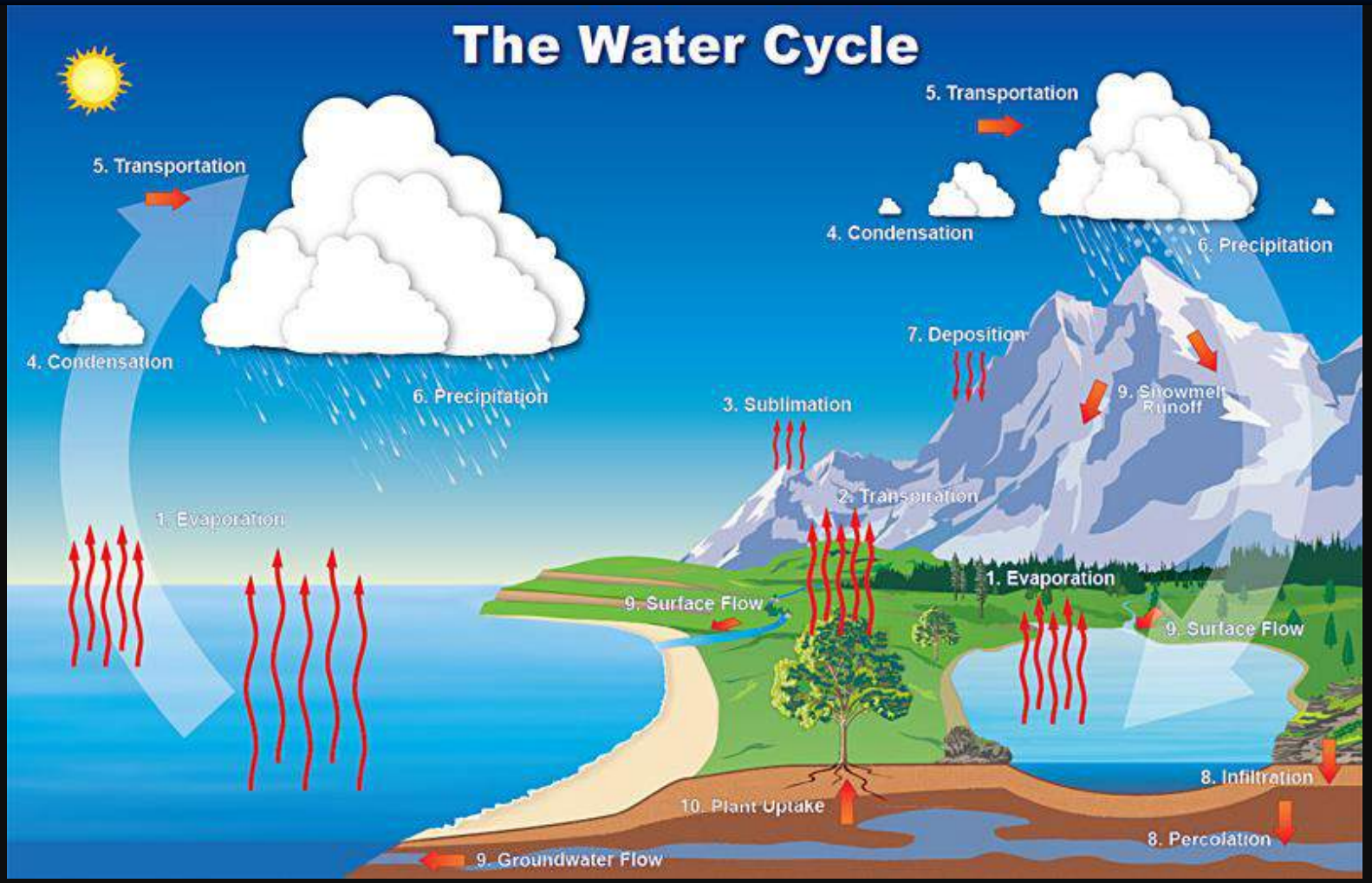


Stilling Well / Float

Precipitation Monitoring



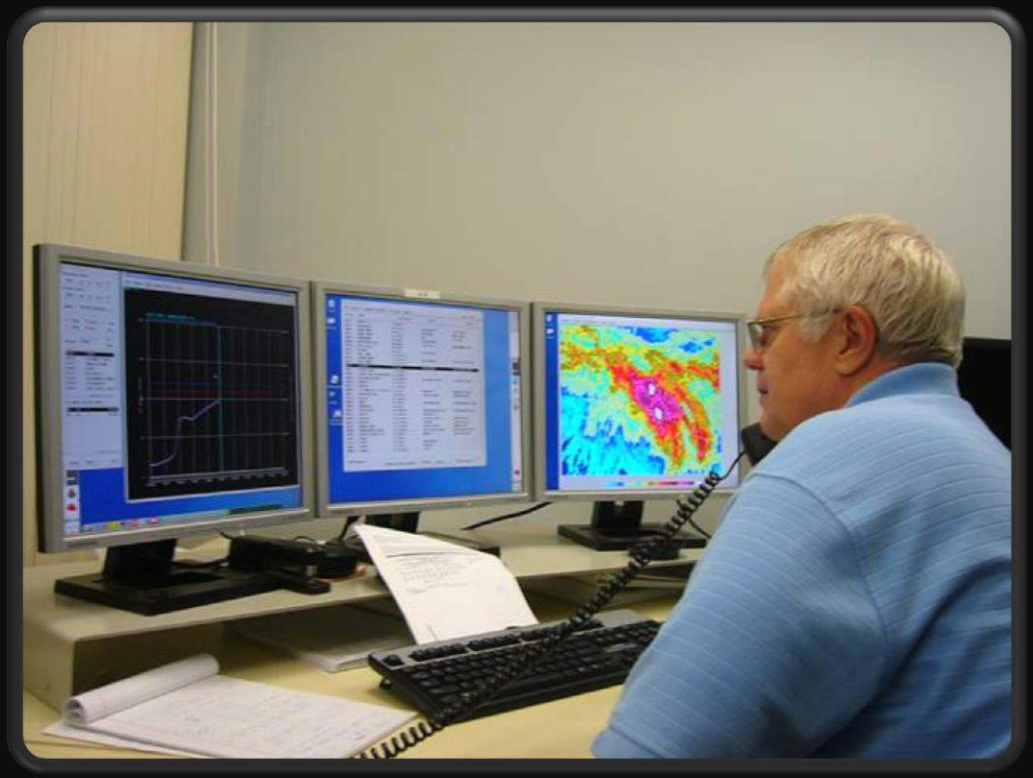
Basic Hydrology



http://polaris.umuc.edu/cvu/envm/hydro/hydrologic.swf

How do we forecast flood potential?

- Pre-event assessment *"antecedent conditions"*
- Consider areas more prone to flooding
- Forecast expected rainfall
- Put it all together!



Pre-event assessment

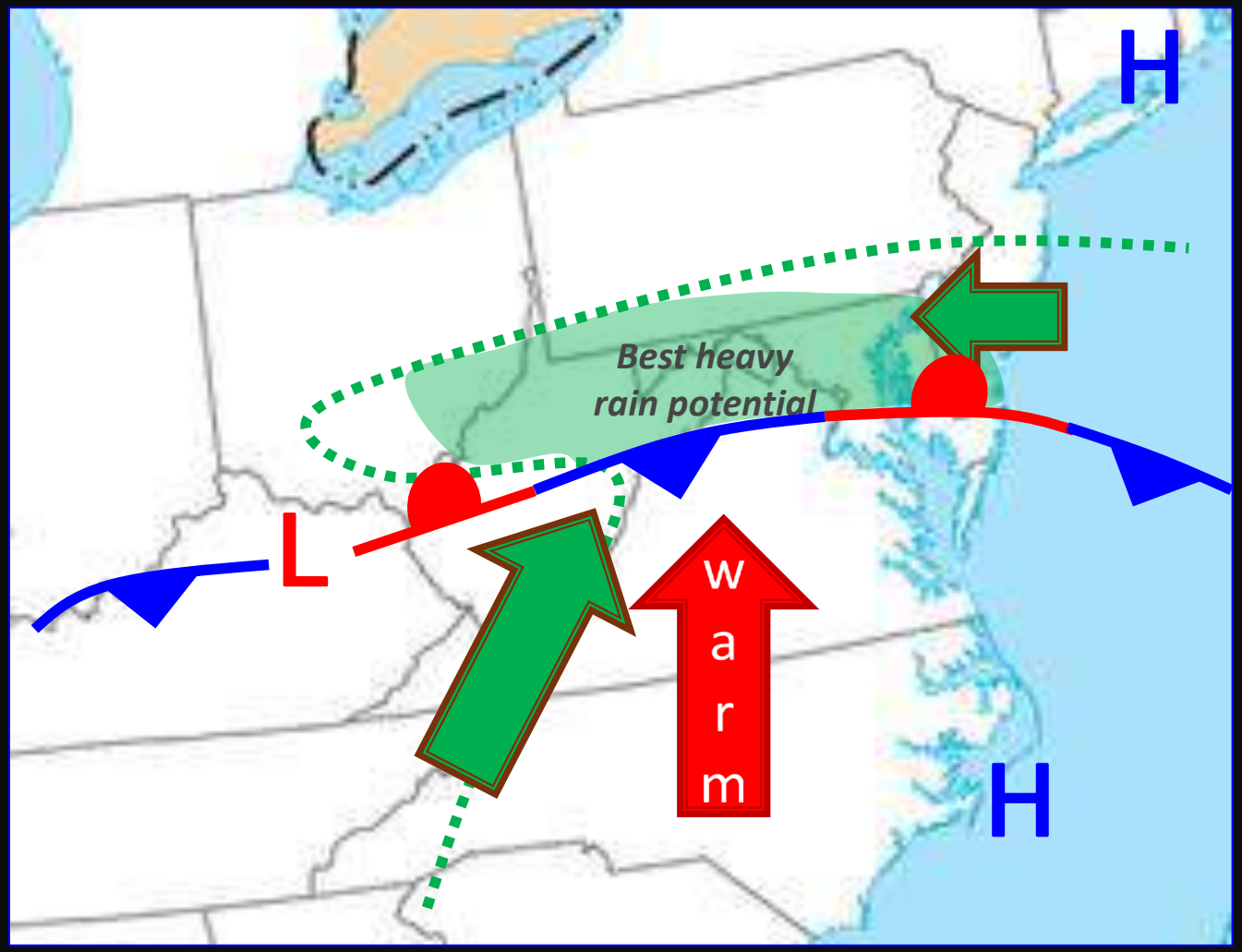
Questions to ask / items to check:

- Is the ground/soil wet or dry?
- What type of soil exists? (sandy, clay, frozen)
- Are streams at baseflow or elevated?
- What is the topography of the area?

- More questions based on time of year
  - Have the trees leafed out yet?
  - Is there snow on the ground? Will the snow melt?
  - Could plowed snow or fallen leaves clog drainage systems?

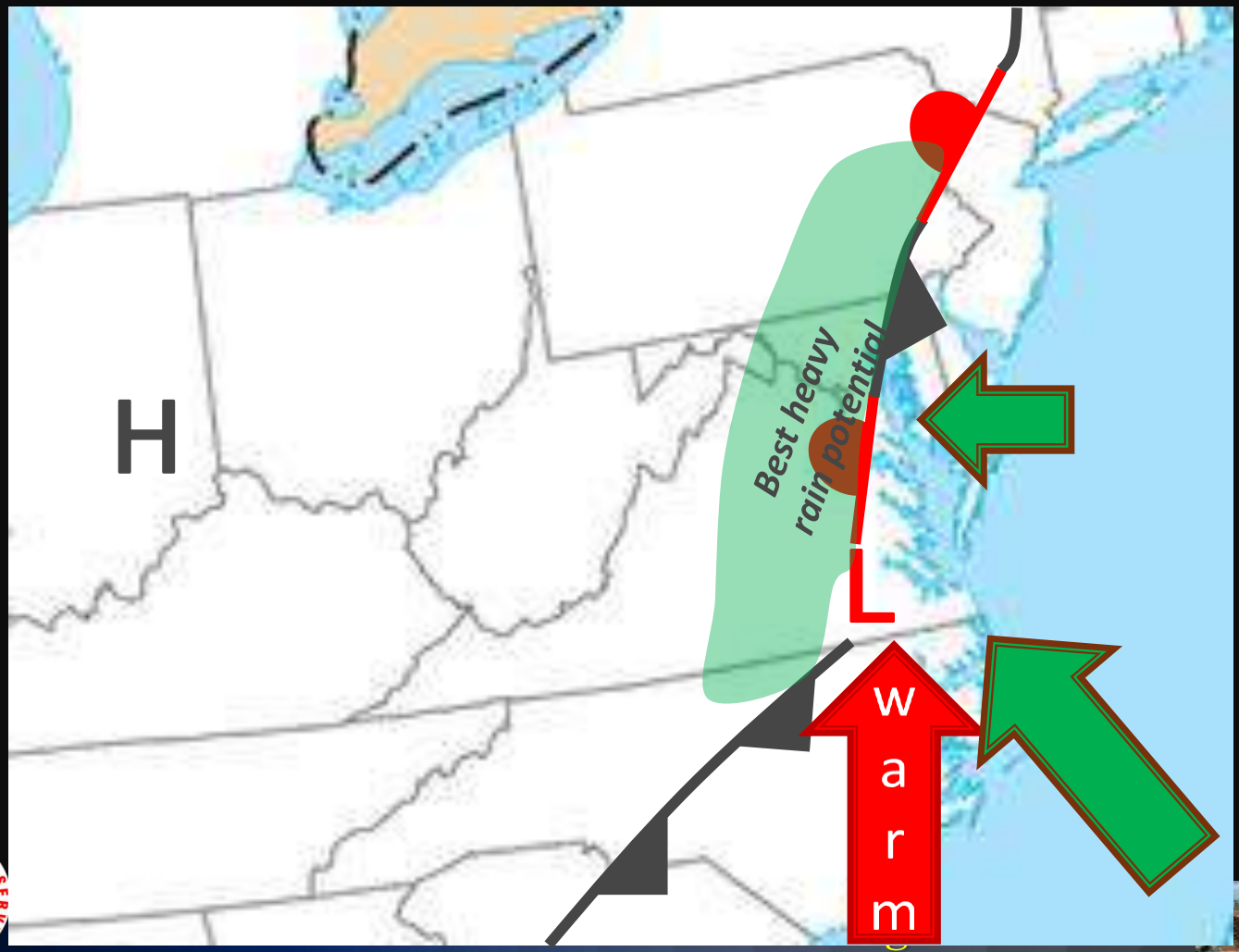
Favorable Weather Patterns

- Slow-moving or Stationary Fronts



Favorable Weather Patterns

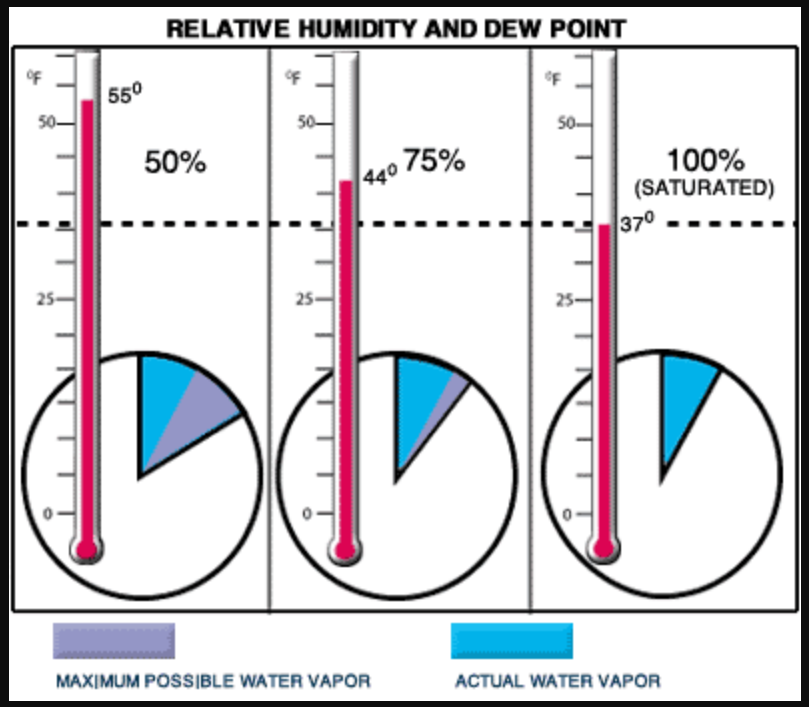
- Slow-moving or Stationary Fronts
  (this could also be the sea breeze!)



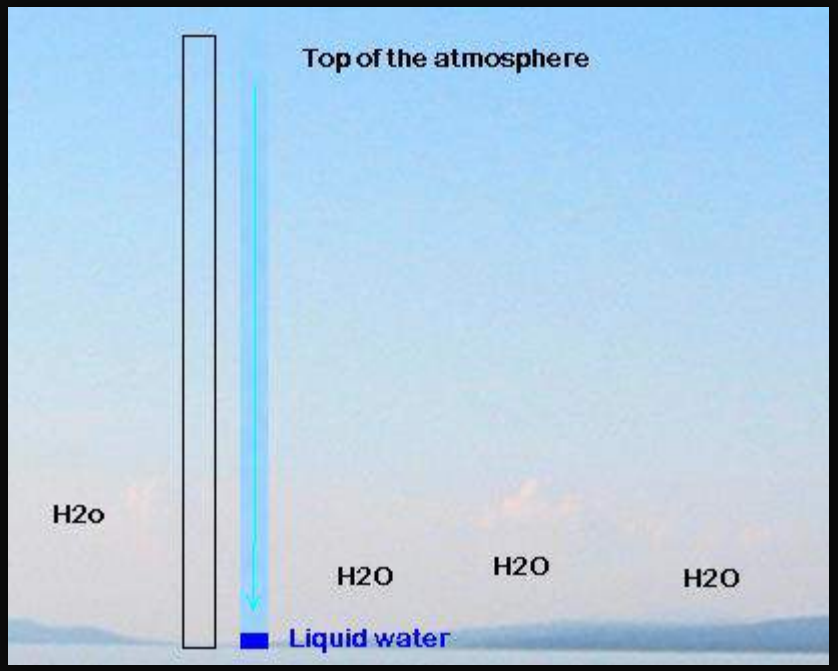
Favorable Weather Patterns

- High Moisture Content

Dewpoint

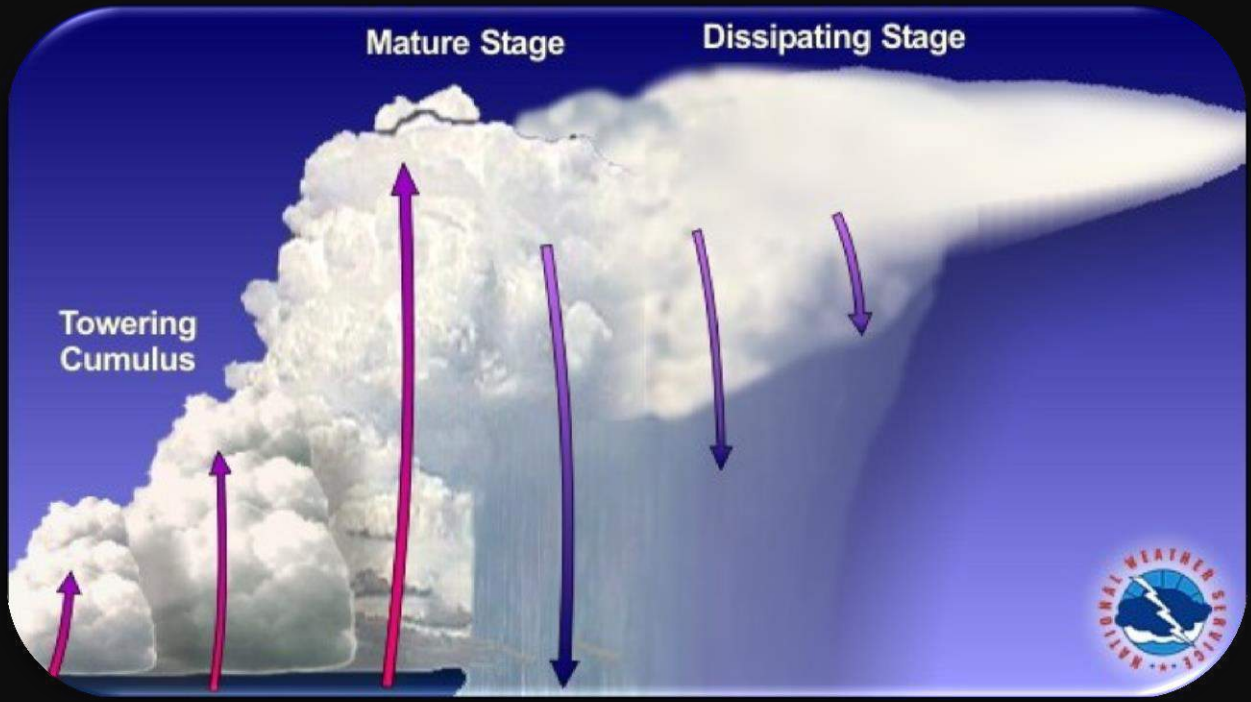


Precipitable Water



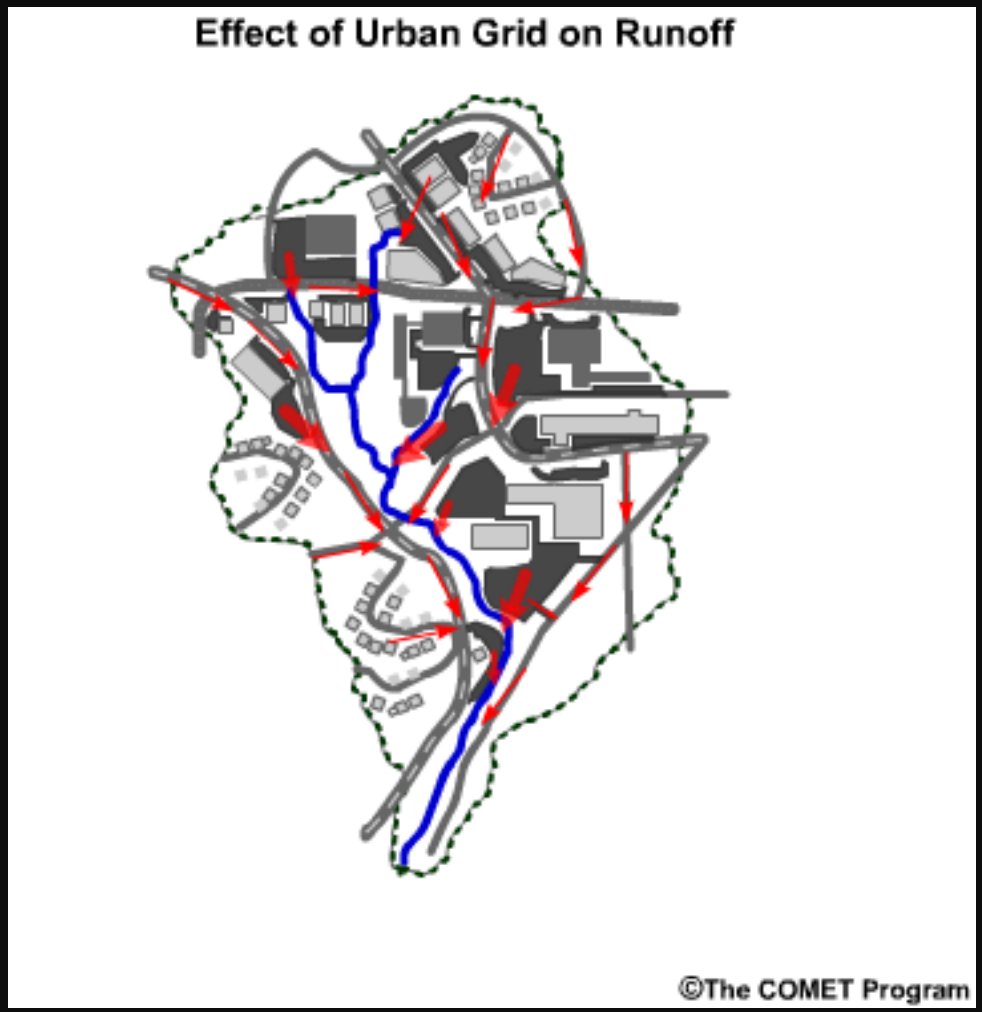
Favorable Weather Patterns

- Slow-moving & Training (Repeating) Thunderstorms



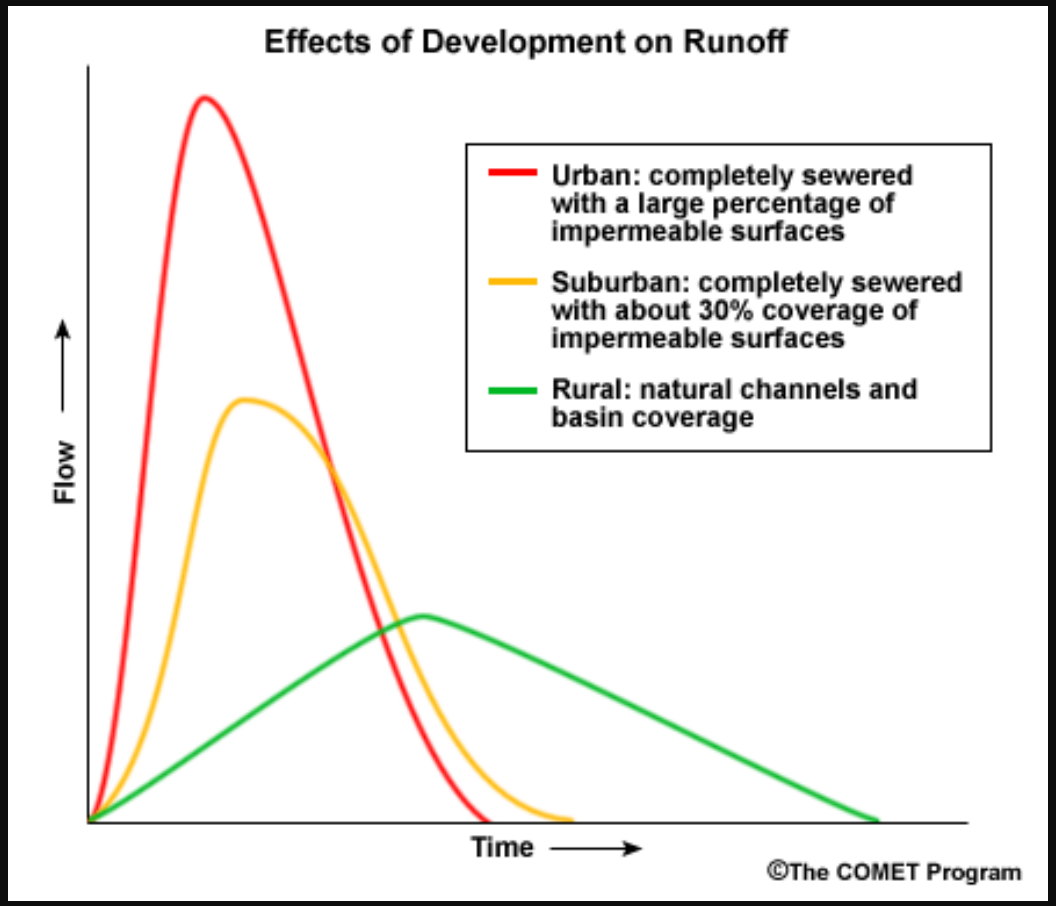
How Urbanization Effects Flooding

- Anything that cannot be absorbed into the soil becomes *runoff*.
- In an urban area, where surfaces like concrete and asphalt are impermeable, <u>everything</u> becomes runoff!



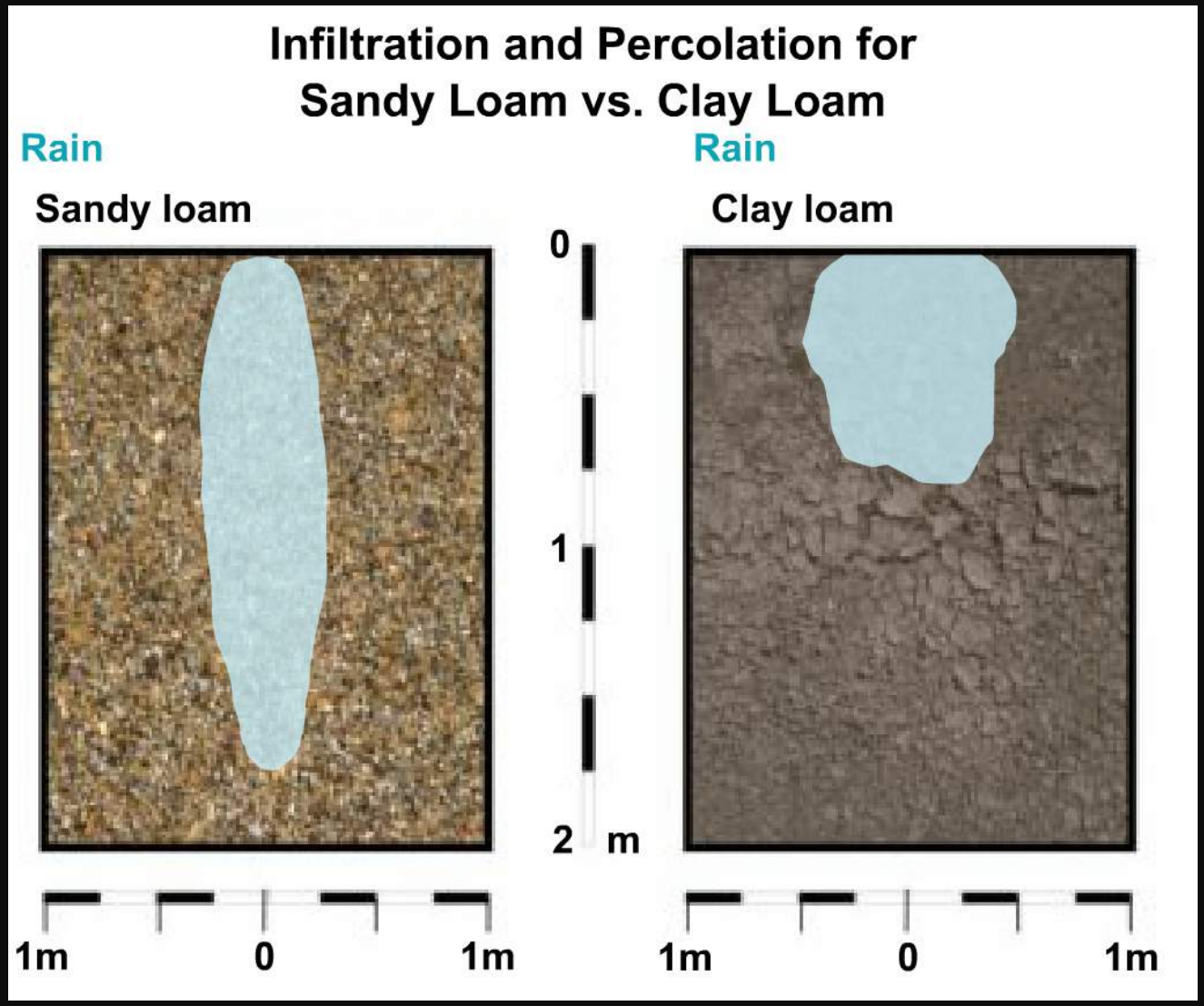
Bigger, Faster, Better?

- The good:
  - The stream reacts faster, and thus may be less susceptible to a prolonged event.
- The bad:
  - The stream rises higher due to runoff, and thus may be more susceptible to a high intensity (but relatively short duration) event.



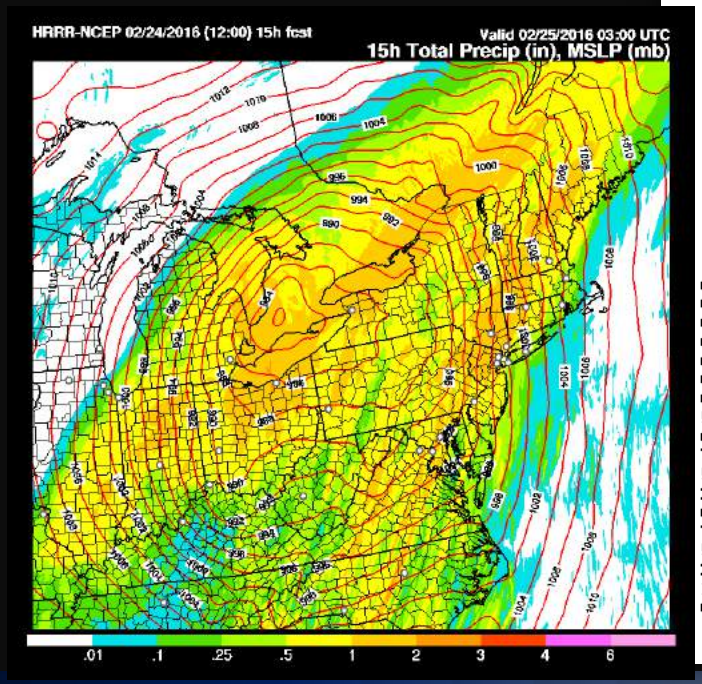
Soil Type Effects

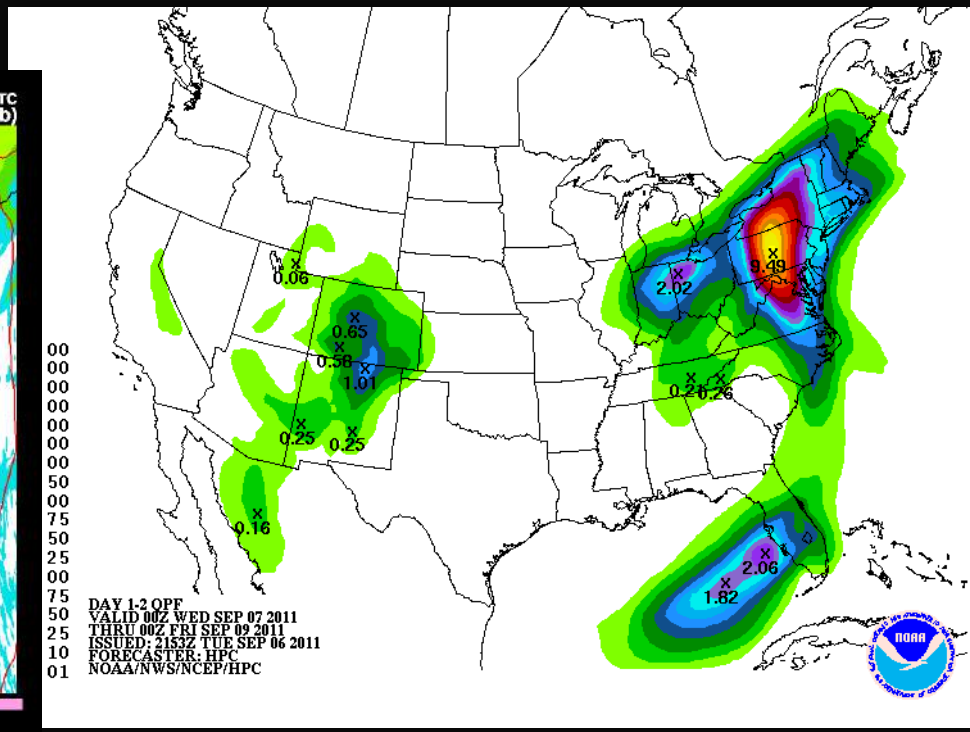
- Sandy soils accept rainwater deeper into the ground faster, thus taking longer to approach saturation and leading to less flood susceptibility.



Making a Rainfall Forecast

- We begin with national precipitation forecasts from the NWS Weather Prediction Center (WPC).
- We then localize this – especially in the first 6-12 hours as we get the best idea of where the heaviest rain will occur.





Putting It All Together

- Once we have forecast the amount of rainfall expected…we have to combine this forecast with the antecedent conditions, as well as <u>how quickly</u> the rain is expected to fall.

Flood vs. Flash Flood

- **Flash Flood** - a *rapid and extreme* flow of high water into a normally dry area, or a rapid water level rise in a stream or creek above a predetermined flood level, *beginning within six hours of the causative event* (e.g., intense rainfall, dam failure, ice jam). However, the actual time threshold may vary in different parts of the country. Ongoing flooding can intensify to flash flooding in cases where intense rainfall results in a rapid surge of rising flood waters.

- **Flood** - any high flow, overflow, or inundation by water which causes or threatens damage.

Source: NWS Instruction 10-950 dated December 4, 2012

What makes a flash flood?

- Typical Flash Flood Characteristics
  - Caused by convection (thunderstorms or intense showers)
  - More isolated compared to flooding
  - Response time is short, usually 1-2 hours, but as little as 15 mins. in urban areas (compared to 6-12 hours for flooding)
  - Swift Water Rescues, road closures (especially major roads), creeks and streams flood within an hour or two of the causative event
  - Occurs more frequently in urban areas and in terrain

Flash Flood debris near Front Royal, VA – 2011

When does flash flooding occur?

- Can occur anytime – day or night.
- Approximately two-thirds of all flash flooding occurs at night.
- Most flash flood fatalities occur at night!
- Flash Flooding is NOT restricted to only mountainous areas.

Location, Location, Location!

- Creeks
- Streams
- Ravines
- Washes
- Gullies
- Urbanized areas
- Underpasses
- Poor Drainage Areas

Flash Floods – What to Report

- River or stream flows out of banks and is a threat to life or property.
- Person or vehicle swept away by flowing water from runoff that inundates adjacent grounds.
- A maintained county or state road closed by high water.
- Approximately six inches or more of flowing water over a road or bridge.
  - This includes low water crossings in a heavy rain event that is more than localized (i.e., radar and observer reports indicate flooding in nearby locations) and poses a threat to life or property.

See water where it doesn't belong, but it doesn't meet these criteria? Report it anyway, but please don't call it a flood! Be as descriptive as you can when you report.

Flash Floods – What to Report

- Dam break or ice jam release causes dangerous out of bank stream flows or inundates normally dry areas creating a hazard to life or property.
- Any amount of water in contact, flowing into or causing damage of an above ground residence or public building and is runoff from adjacent grounds.
- Three feet or more of ponded water that poses a threat to life or property.
- Mud or rock slide caused by rainfall (could possibly occur in a burned area with only light-moderate rainfall).

See water where it doesn't belong, but it doesn't meet these criteria? Report it anyway, but please don't call it a flood! Be as descriptive as you can when you report.

Special Cases – Debris Jams

- Occasionally, floating debris or ice can accumulate at a natural or man-made obstruction and restrict the flow of water.
- Water held back by the ice jam or debris dam can cause flooding upstream.
- Subsequent flash flooding can occur downstream if the obstruction should suddenly release.

Special Cases – Ice Jams

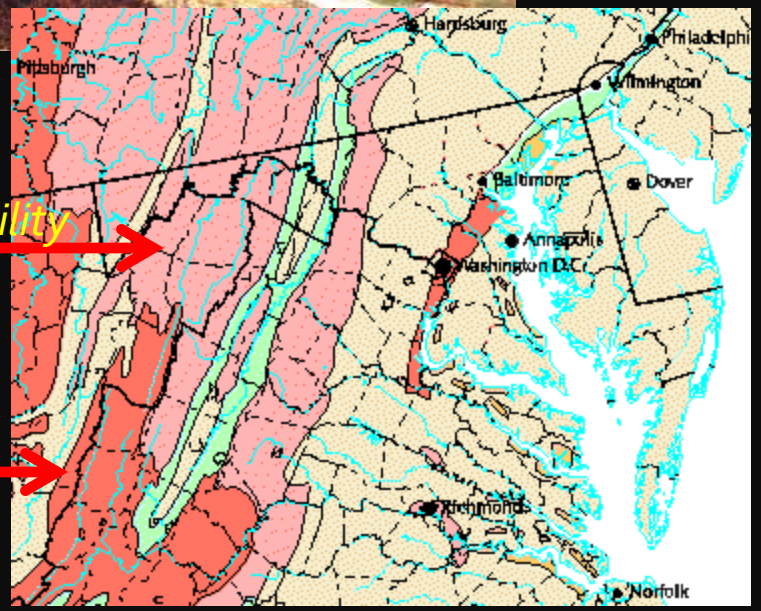
Chunks of ice collect in river channels and may ultimately stop the flow of water.

Ice can collect at a bridge and create an ice jam.

Water backs up behind the ice jam and subsequent flooding results.

Special Cases – Mudslides/Landslides

- In significant rain events in higher terrain, a mudslide or landslide can be triggered.
- This isn't the rain rushing down the slope; it's the land rushing down the slope.



High susceptibility to landslides

High occurrence of landslides

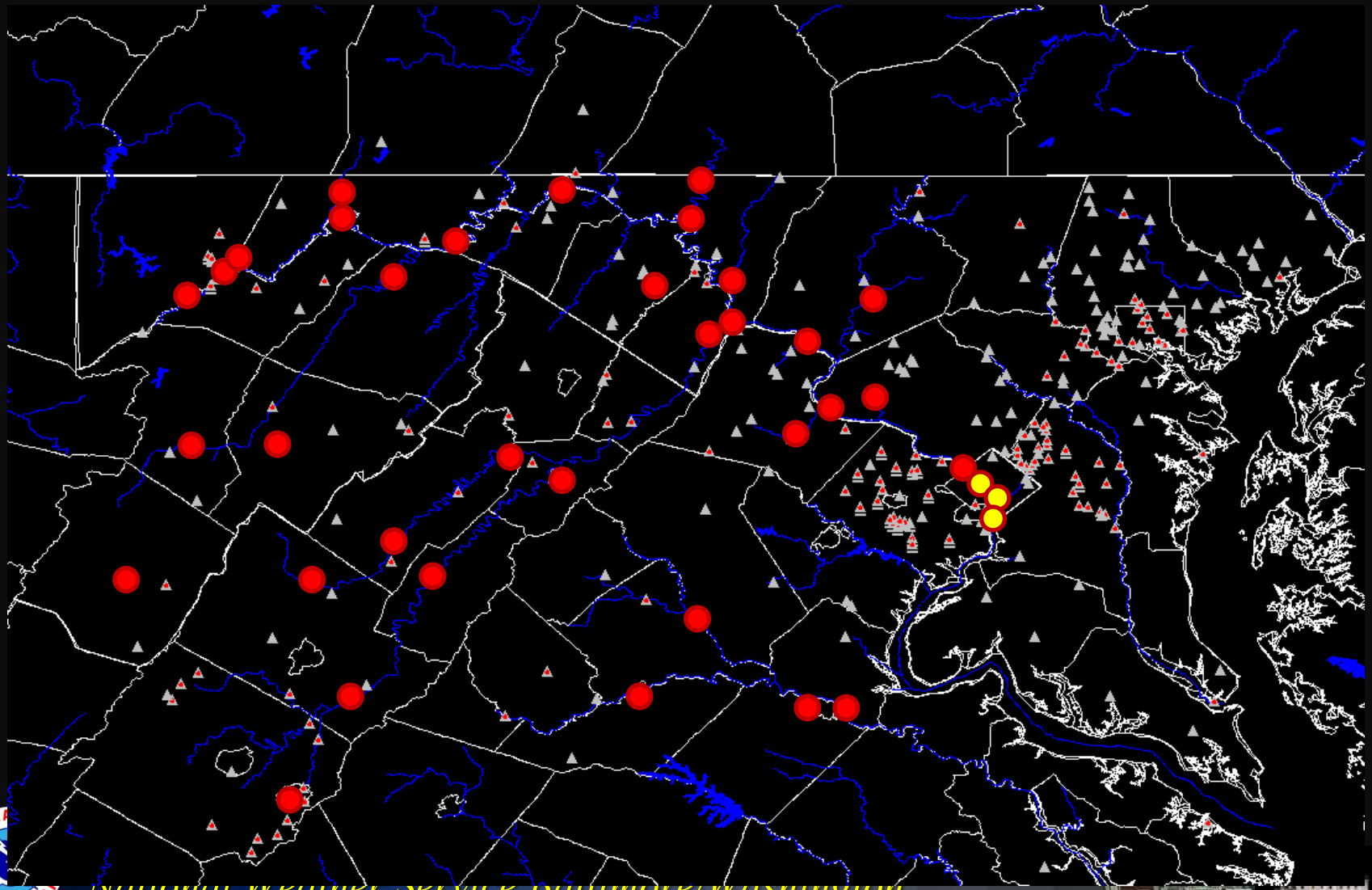
What's this "Areal" Flood?

- NOT = "a real" flood
- NOT = "aerial" flood

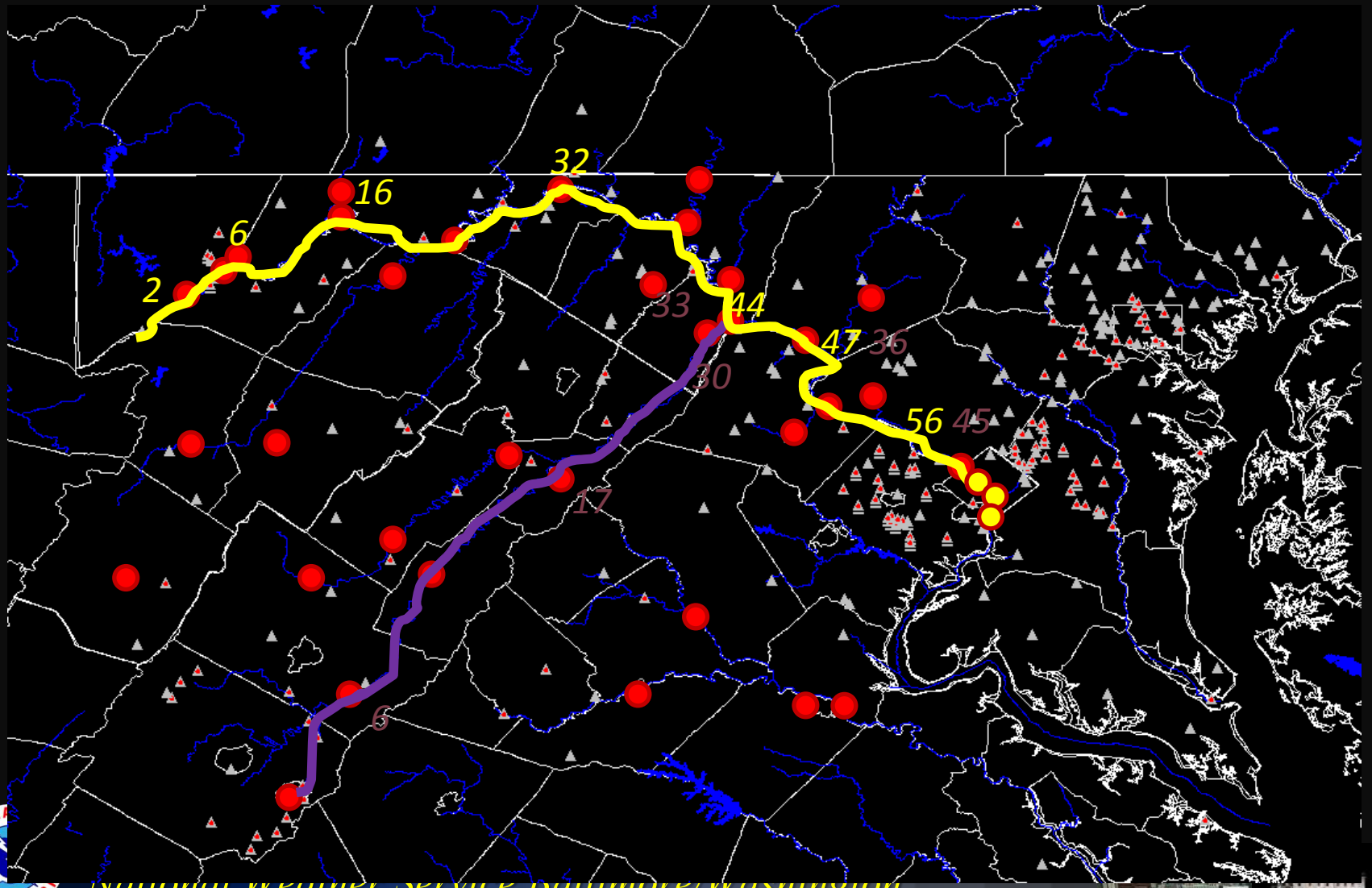
- Flooding that covers an area.
- Flash Flooding typically affects a *very* small area. Areal flooding is slower to develop (usually > 6 hours) and usually affects a larger area.

- But…other than the time constraint, the "what to report" is exactly the same.
  - *(We'll go over it again in the second half of the presentation.)*

River Flood Forecast Points



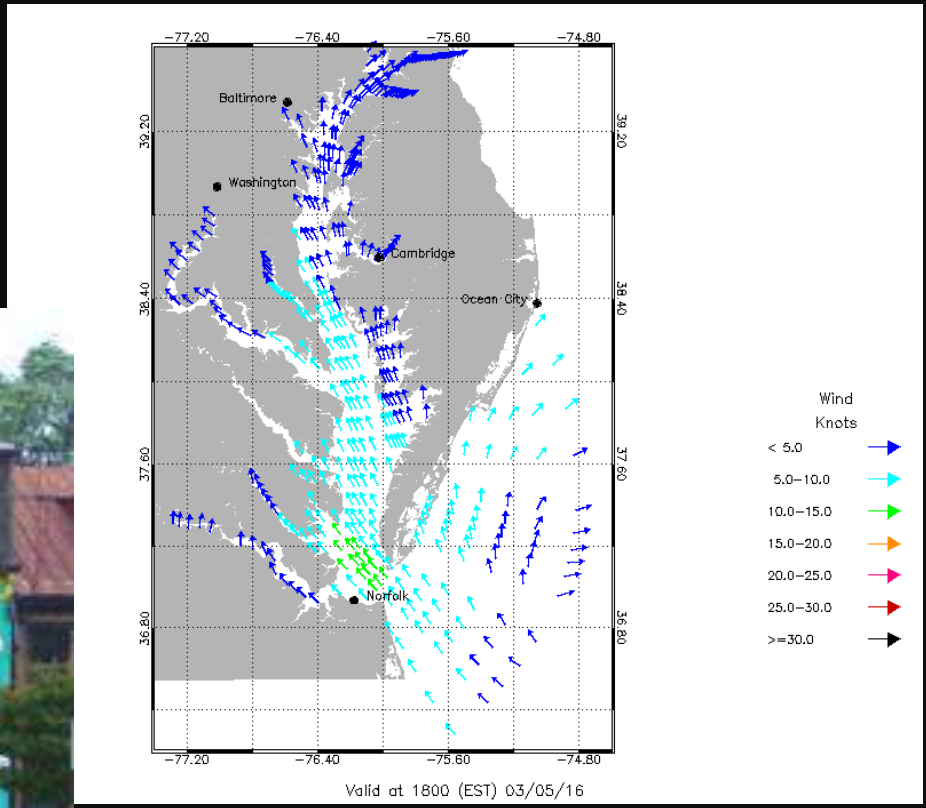
Travel Times (in hours)



Coastal Flooding

- Prolonged onshore flow
- Storm Surge from Tropical Systems

Annapolis, MD



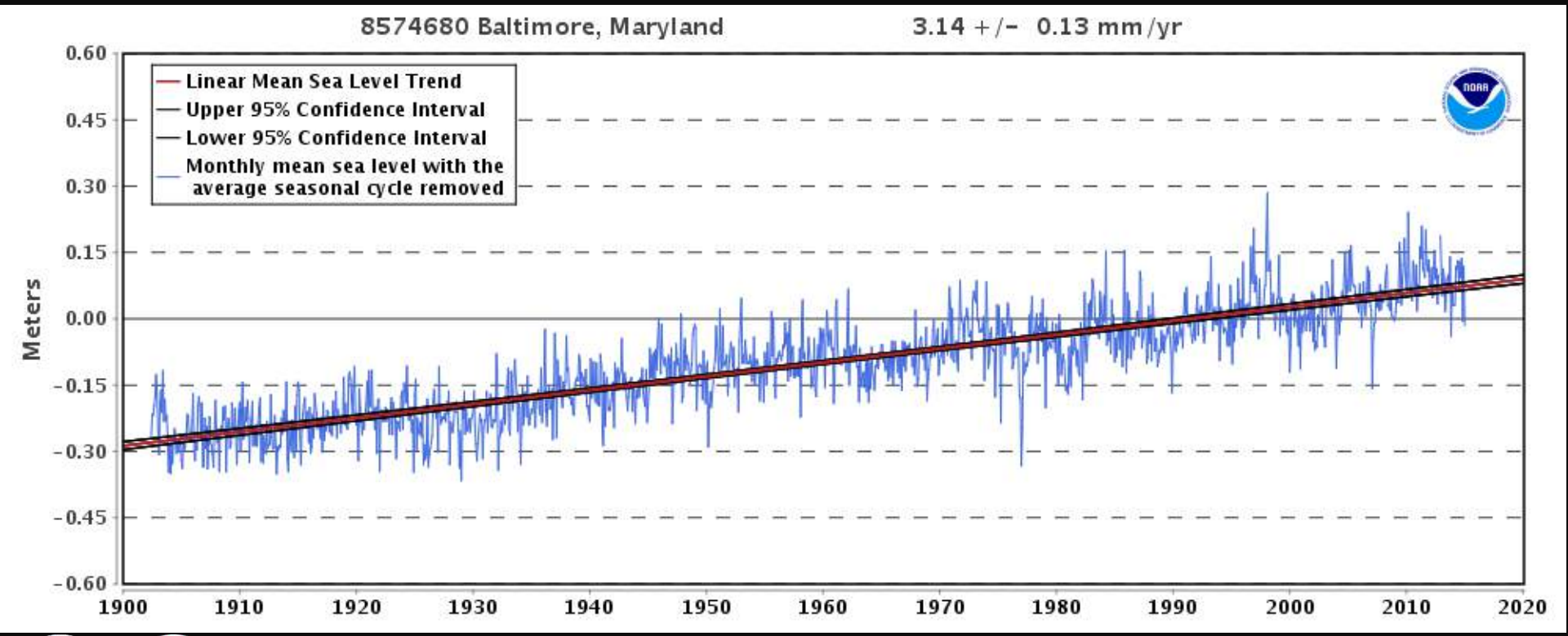
Coastal Flooding

- Two distinct peaks for positive departures
  April/May & September/October
- September stands out due to tropical systems

Minor Coastal Flooding at the US Naval Academy June 2005

On the Rise

- Mean Sea Level (MSL) is steadily rising…
  (average rate ~1 foot/century)



More of a Nuisance

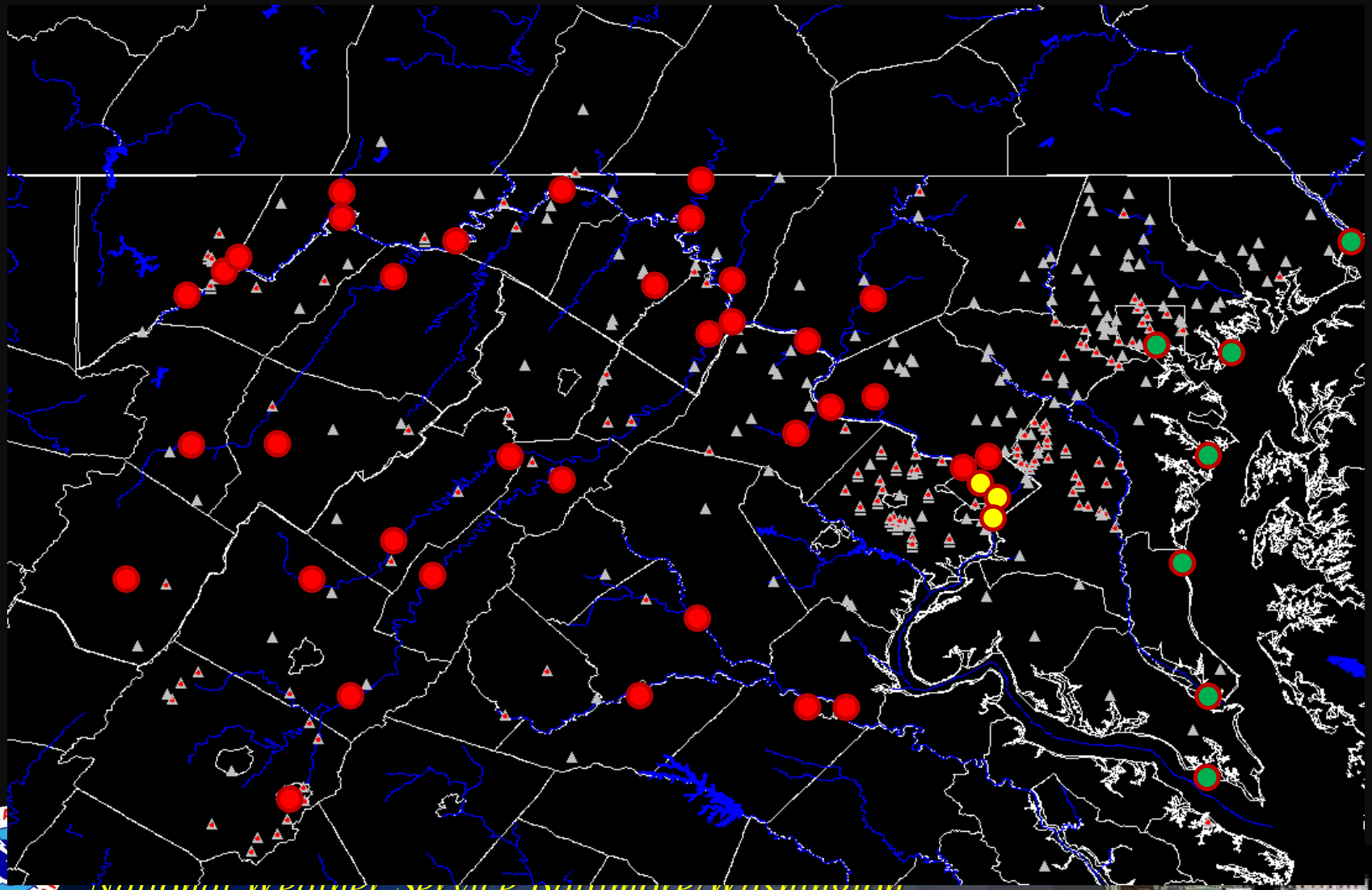
- A NOAA study finds that nuisance flooding (defined as reaching our NWS 'minor flood' level) has substantially increased in the last 50 years.
  - This is due to a rise in the base water level, not due to increased storms.

City	Average nuisance flood days (1957-63)	Average nuisance flood days (2007-13)	Percent increase
Annapolis	3.8	39.3	**925%**
Baltimore	1.3	13.1	**922%**
Washington	6.3	29.7	**373%**

Weather Plays a Role

- During strong El Niño patterns, there was a much higher incidence of days with storm surge > 1 foot, and higher mean sea level along the Mid-Atlantic Coast.
  - *Sweet and Zervas (2011)*
- Recent years with stronger El Niño:
  - **2015-2016 (2.3)**
  - Late 2009 – Early 2010 (1.6)
  - 1997 – Early 1998 (2.3)
  - 1991 – 1992 (1.6)
  - 1982 – 1983 (2.1)
  - 1972 – Early 1973 (2.0)

Flood Forecast Points



Flood Type Summary

- In a single event, we must consider:
  - Flash Flooding
  - Areal Flooding
  - Nuisance Flooding
  - Tidal Flooding
- …often all at the same time…and at the same time as severe weather or other hazardous weather…
- …and ensure the public is properly notified of any/all of these threats that may affect them!

As a spotter…

- Don’t worry about characterizing the type of flooding. Just give the facts, as specifically as possible, and we can do the characterization.
  - More on that in a little bit!

Flood History

- **Did you know?**

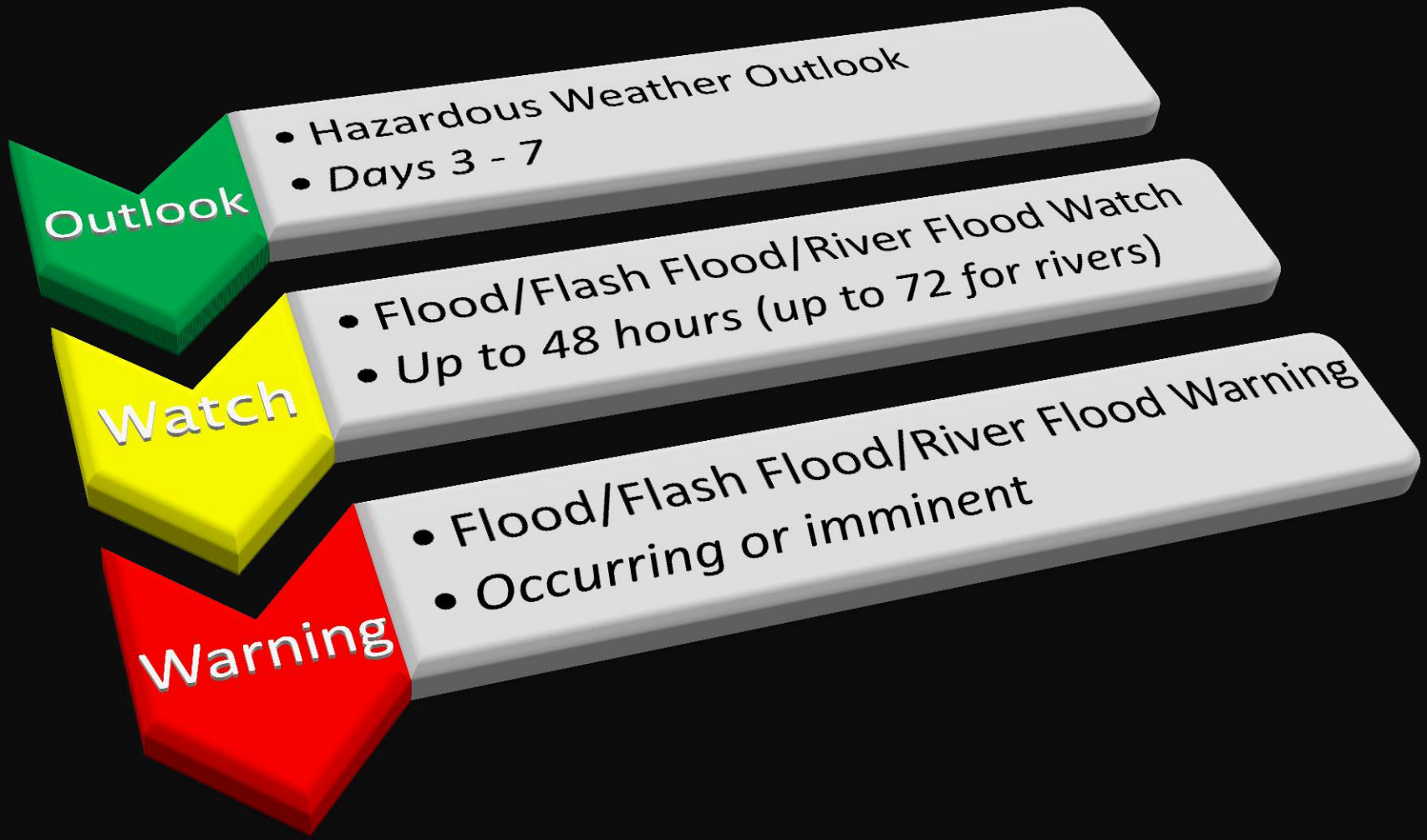
Five of the seven biggest floods in the Potomac region have decadal anniversaries within a one year period (Nov 2015 – Oct 2016):

October 1896	120 years ago
March 1936	80 years ago
November 1985	30 years ago
January 1996	20 years ago
September 1996	20 years ago
June 2006 (flash flood)	10 years ago

Break time!

Please return in 5 minutes

Our Products



Watch vs. Warning

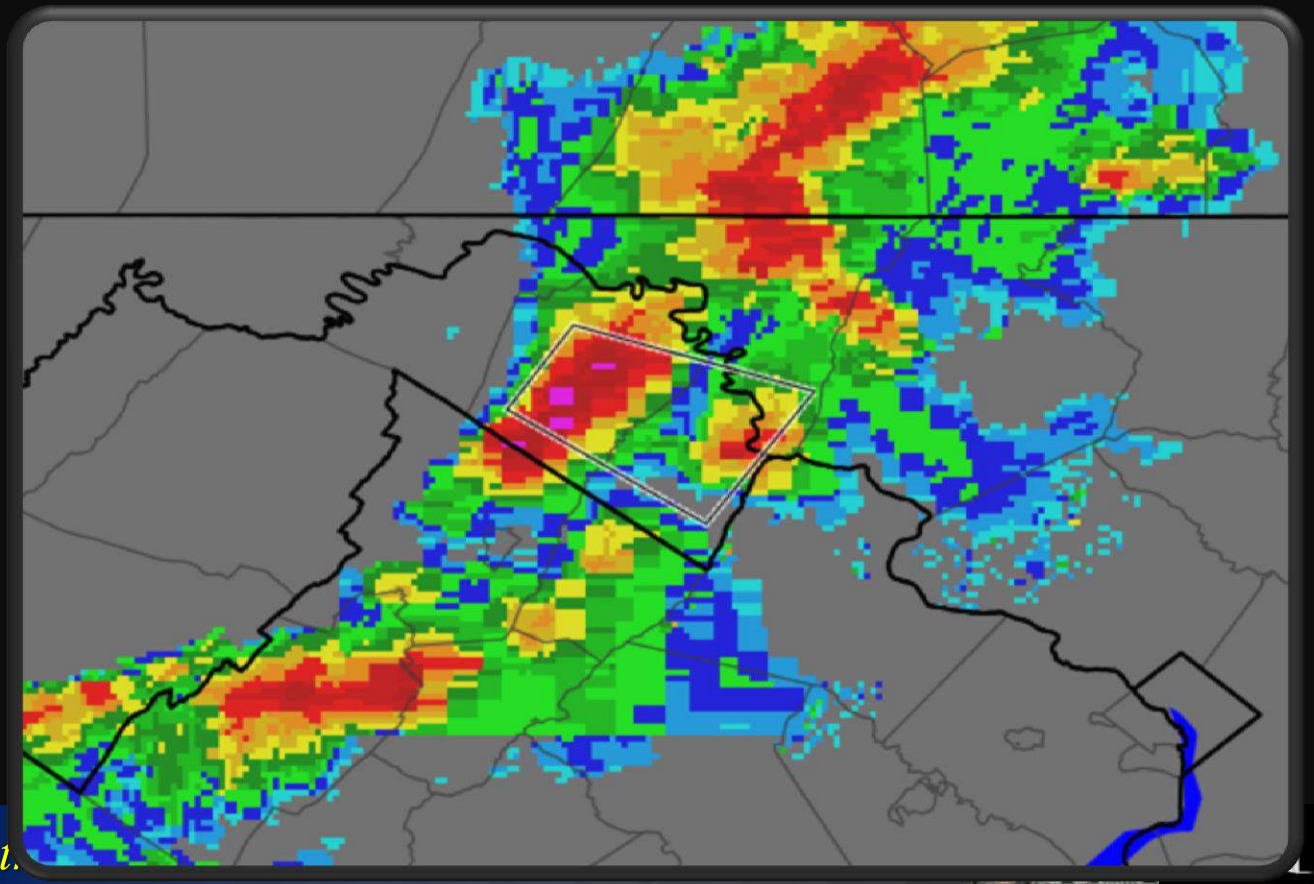
- WATCH: Conditions are favorable for flooding to occur (>50% chance). Be alert for possible flooding during the watch period.

- WARNING: Flooding is occurring or is extremely likely to occur (>75% chance). Stay out of low areas and seek higher ground if necessary!

- Note: A watch does not necessarily precede a warning, especially for river flooding.

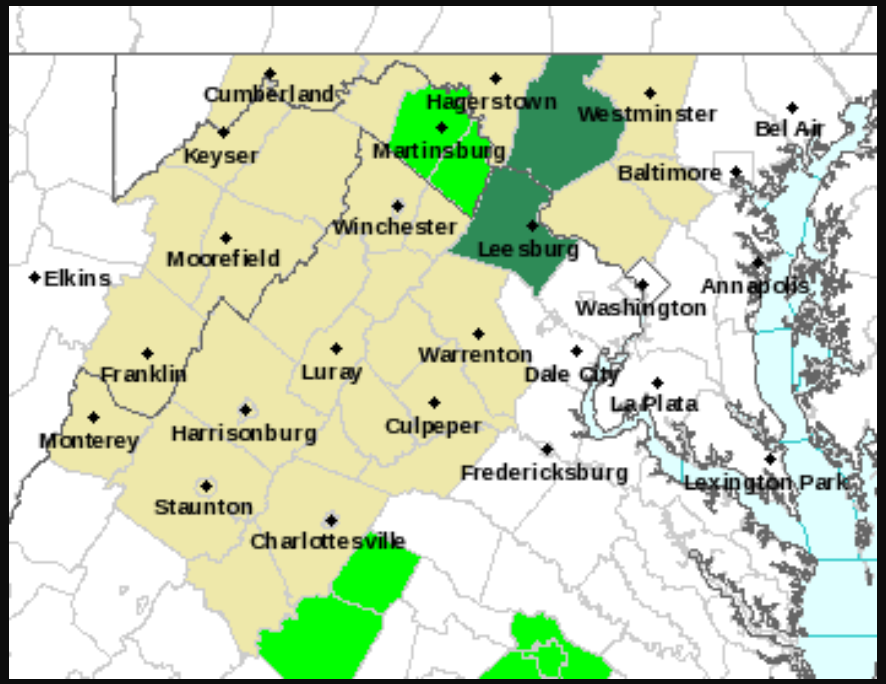
Basin-Based Warnings

- Our goal is to warn for:
  - Where the rain is going to go
  - Where the water is going to flow
- This means we may warn for places where it will not even rain!



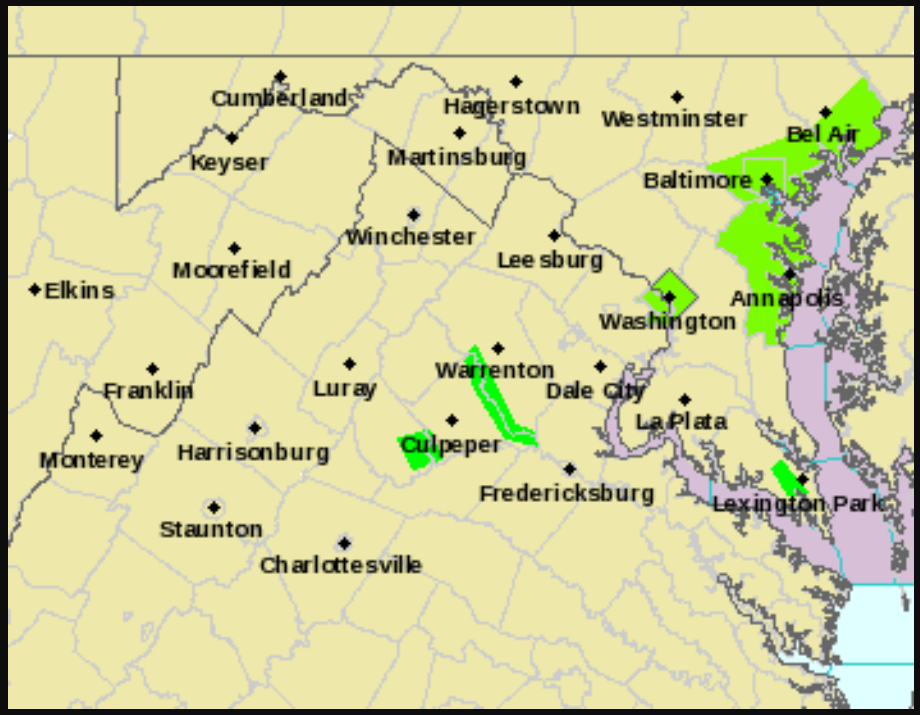
River Flood Watch/Warnings

- In 2011, we began issuing river flood watches for our designated forecast points
  - Issued when:
  - River Forecast reaches flood stage, but there is uncertainty about that forecast
  - River Forecast does not reach flood stage, but is close and a little more rain could put the river over
  - >50% confidence of reaching flood
  - Successful in lessening unnecessary warnings



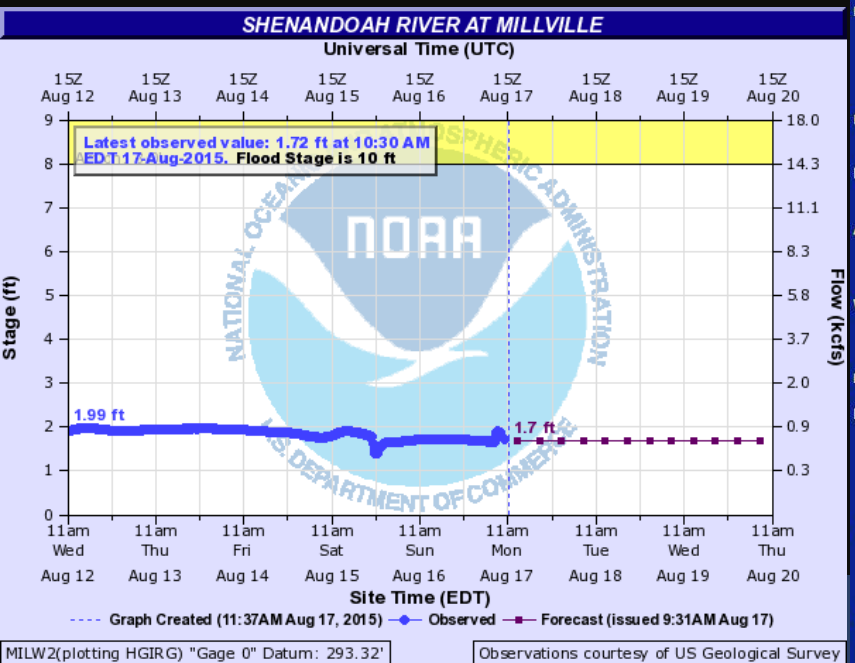
River Flood Watch/Warnings

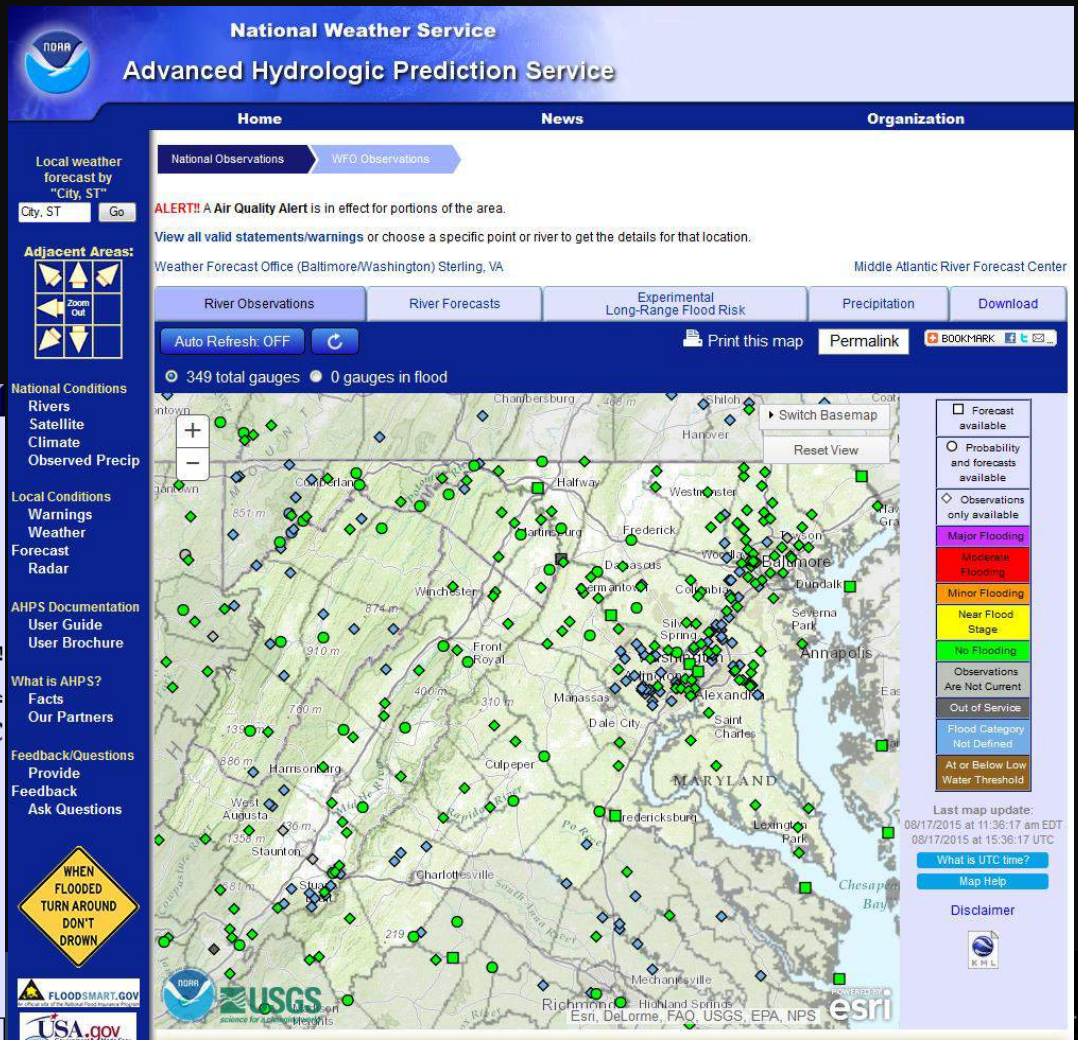
- In 2014, we began issuing river flood watches and warnings via polygons for designated forecast points
  - Limits the area covered by a watch or warning
  - Matches flash flood warnings and areal flood warnings which are already issued by polygon



Advanced Hydrologic Prediction Service (AHPS)

http://water.weather.gov





Observations during heavy rain

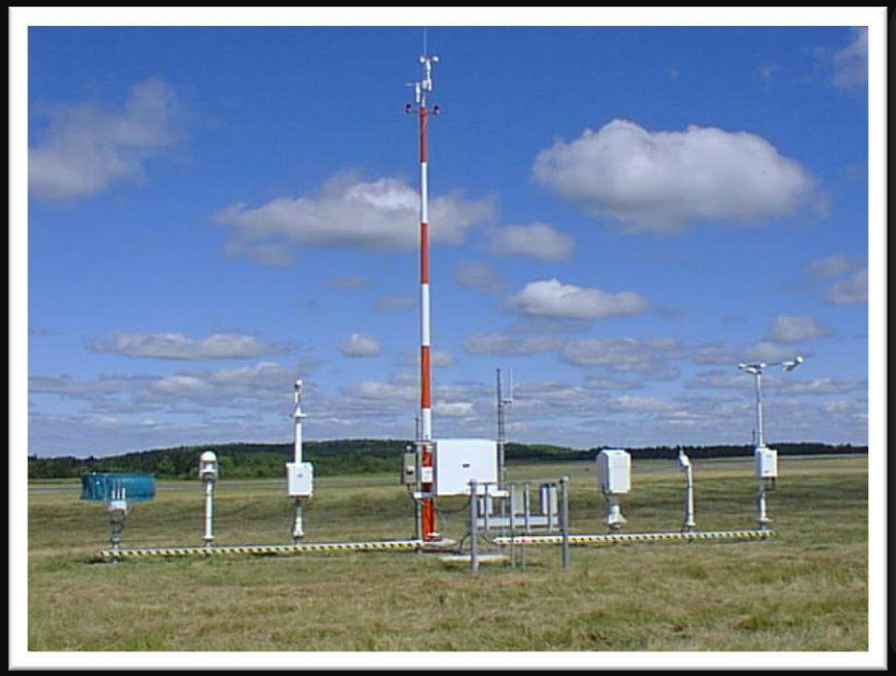
- Ground truth
  - Nothing ever beats an eye in the field!
  - Rainfall measurement / flood report / stream measurement
    - Safety is always key!

Photo courtesy Prince George's County EMS

US 301 / MD 4
Prince George's Co., MD

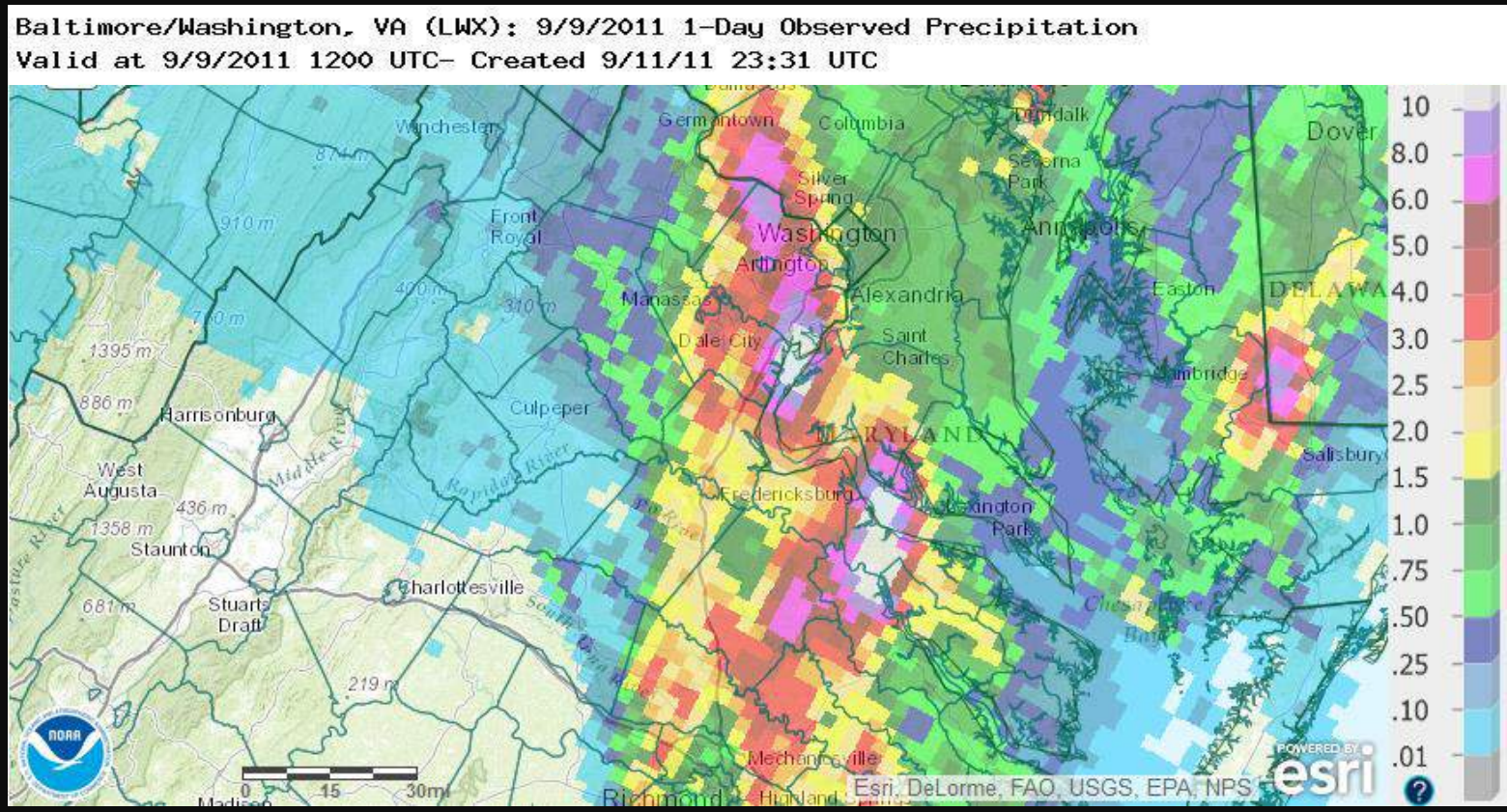
Observations during heavy rain

- Automated observations
  - Near-real time, but…
    - Subject to error/clogging/freezing
    - No measurement of how much of the fallen rain is being soaked into the ground, and how much is running into streams



Precipitation Estimates

- Remote Sensing
  - Radar
  - Satellite



The "Ultimate Combo"

- Ground truth observations
- Radar & satellite estimates skewed by ground truth
- Gaps filled in by radar & satellite

- Spotter reports are <u>vital</u>!
  - Rain amounts
  - River level status
  - Is there water over the road?
    - (We'll talk more about this later…)

Ellicott City, MD

Photos by Craig Coyne

Why Do We Need Spotters?

- All one team!
  - Emergency Managers
  - Other Government Agencies
  - Broadcast and Print Media
  - SKYWARN Spotters
  - Amateur Radio Operators
  - Cooperative Observers

Spotter Reports

- **Answer the 4 Ws:**
  - Who are you?
  - What is your report?
  - When did this happen?
  - Where did this happen?

Tips:

Give us your spotter number & name

Be descriptive about what you see

(pictures are great, but be safe!)

Be as specific about location as possible

Why Specificity Matters

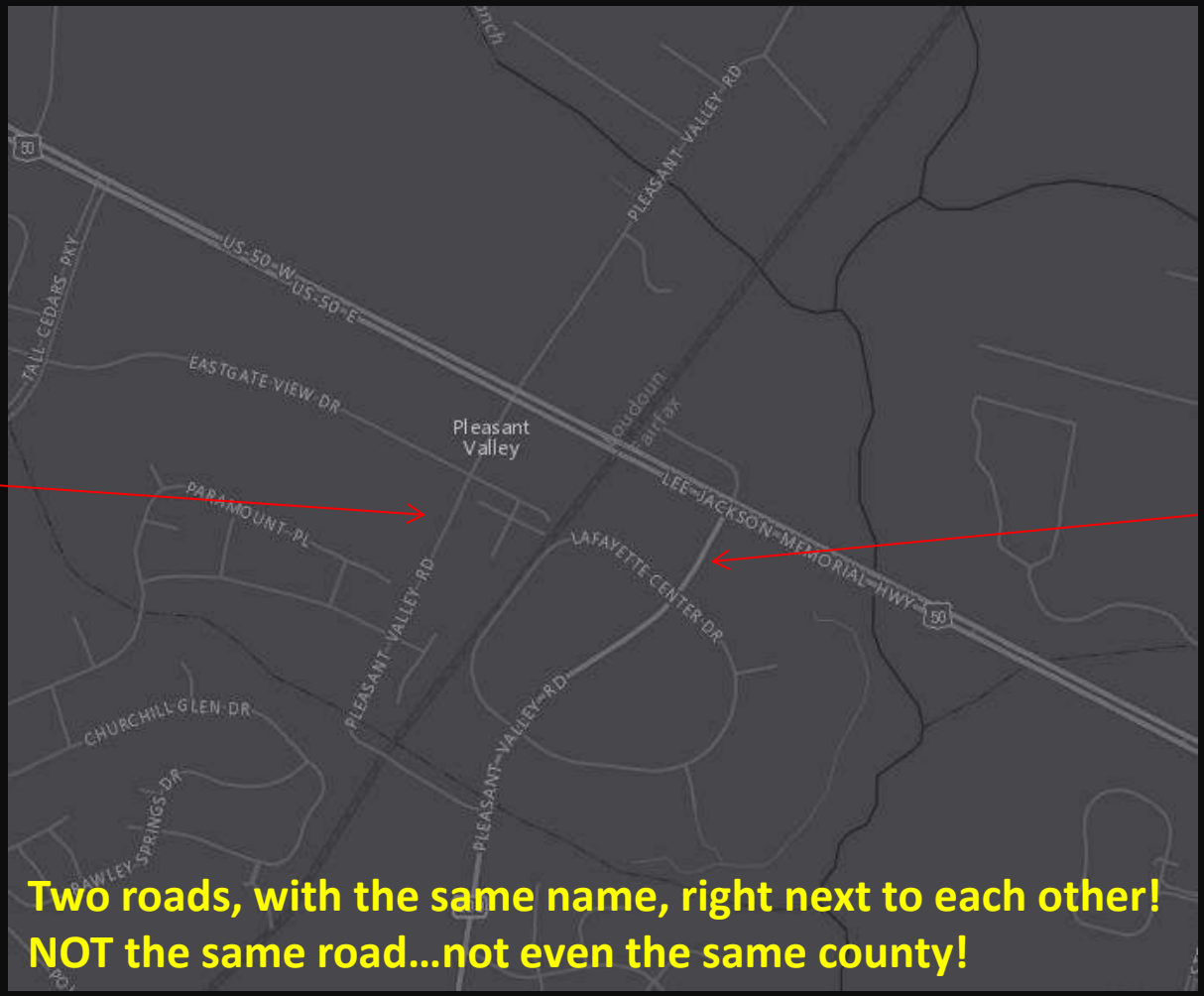
- **Floods are not created equal!**

VS.

Why Specificity Matters

- **Location…location…location!**

Pleasant Valley Rd (Loudoun Co.)



Pleasant Valley Rd (Fairfax Co.)

What to Report

- **Heavy Rain** – measured 1" or more (we like getting periodic reports & a storm total at end)
- **Flooding & Flash Flooding** – Streams, creeks or rivers out of banks or flooding of roads from poor drainage

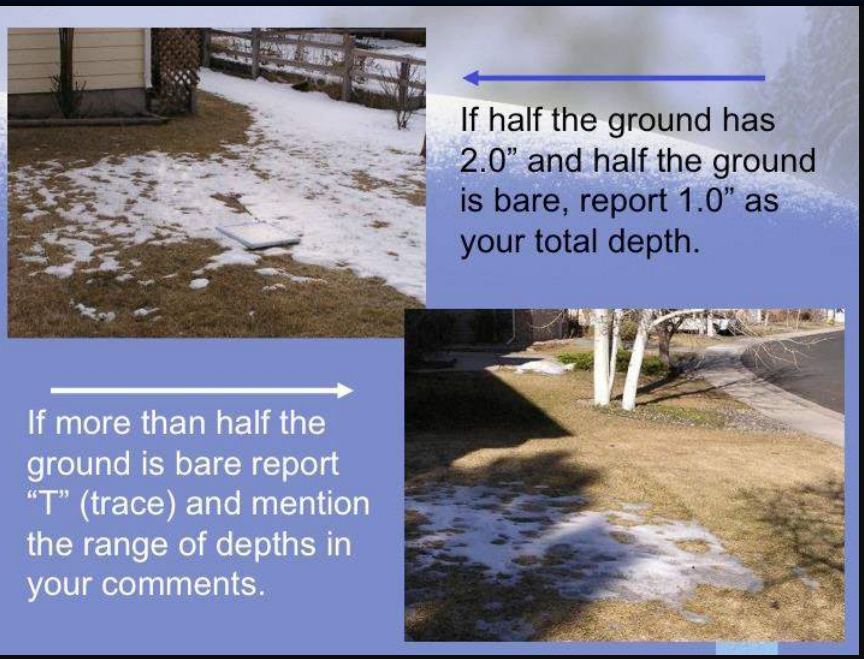
Terminology:

* Water over banks but not affecting anything – "bankfull/just over bankfull"
* Water affecting farmland, roads, property out of floodplain – "flooding"

***** *If it is a low water bridge, please say so!*

What to report

- **Ice Accumulation** – Any glaze on surfaces (or more)
- **Snow Accumulation** – Every 2” and a storm total, or any accumulation not reflected in the forecast



Non-hydro spotter reports

- Although we don't go into severe reports here, if you're already a spotter by having taken our Basic course, you certainly should report that too!

How to report

- Call NWS Sterling as soon as you see something:
  (800) 253-7091 or (703) 996-2201
- You can email delayed reports or pictures to:
  LWX-Report@noaa.gov
- Contact local Emergency Management
- Amateur Radio (when activated)

- If you see storm damage after the event, let us know!
  Immediate reports are best; but no report is too late!
- If a report is second-hand (not directly from you), please let us know that.

Best way to report

VERY IMPORTANT INFORMATION:

- Please DO NOT send flooding reports by email, unless you see it after the fact or can't get to a phone!
- This is very time critical information that needs to be relayed to forecasters immediately.
- Best means to get information to the NWS quickly is via the telephone or Amateur Radio.
- Rainfall/snowfall observations via email are fine unless you think we need to know more urgently.

PLEASE DON'T WAIT FOR US TO CALL YOU! (we will…)

Additional Reports

If you have a rain gauge or automated weather station:

- We would love to have your reports routinely!
- Rain gauge or automated weather station must be well-sited (not attached to side of house, not under trees, etc.)

CoCoRaHS
Community Collaborative Rain, Hail & Snow Network

How can I join?

Five easy steps

Simply sign-up on the CoCoRaHS web page: www.cocorahs.org

Obtain a 4” plastic rain gauge

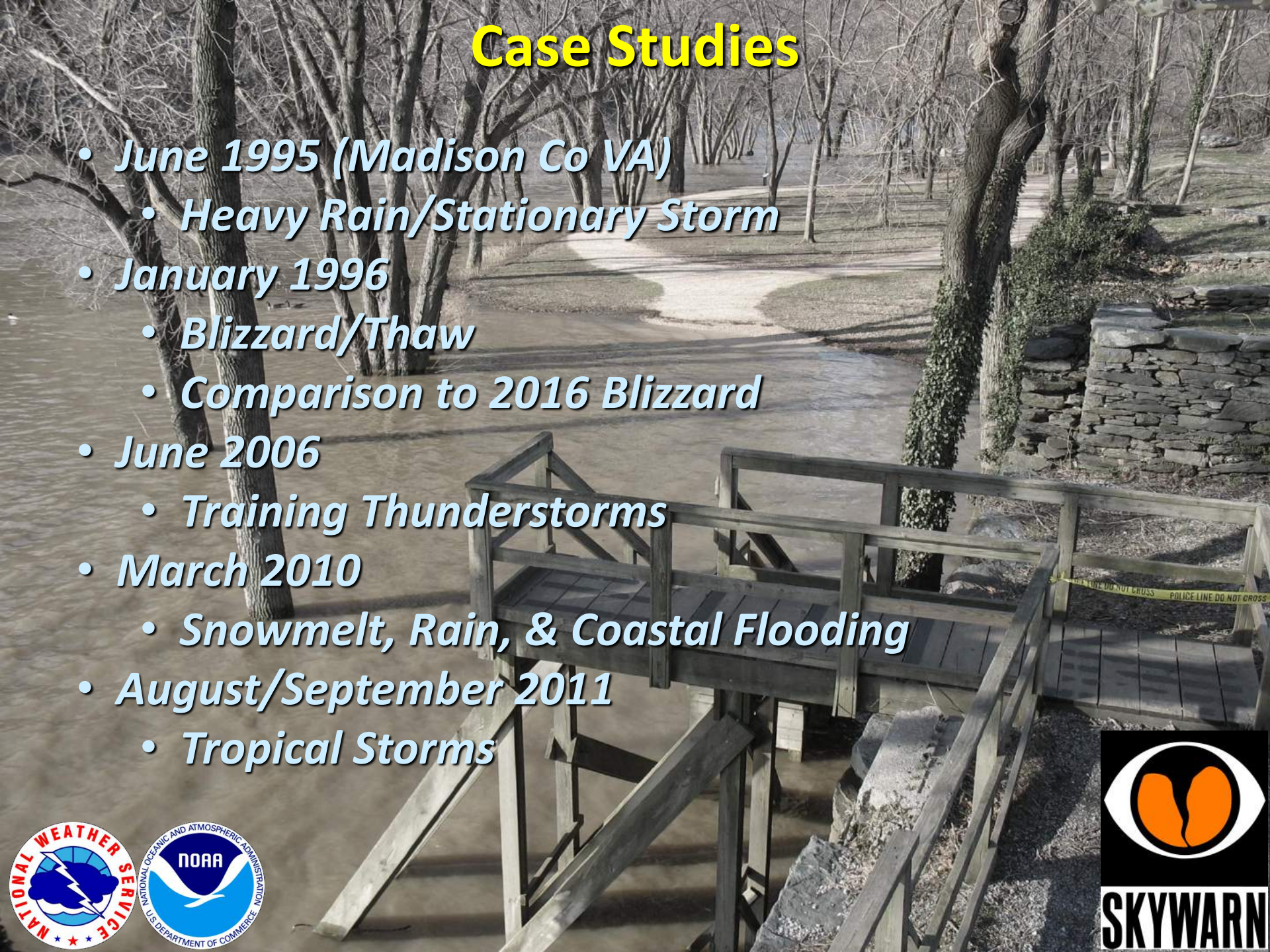
View the on-line “training slide show”

Set-up the gauge in a “good” location in your yard

Start observing precipitation and report on-line daily

Case Studies

- June 1995 (Madison Co VA)
  - Heavy Rain/Stationary Storm
- January 1996
  - Blizzard/Thaw
  - Comparison to 2016 Blizzard
- June 2006
  - Training Thunderstorms
- March 2010
  - Snowmelt, Rain, & Coastal Flooding
- August/September 2011
  - Tropical Storms



NATIONAL WEATHER SERVICE

NOAA

U.S. DEPARTMENT OF COMMERCE · NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION

SKYWARN

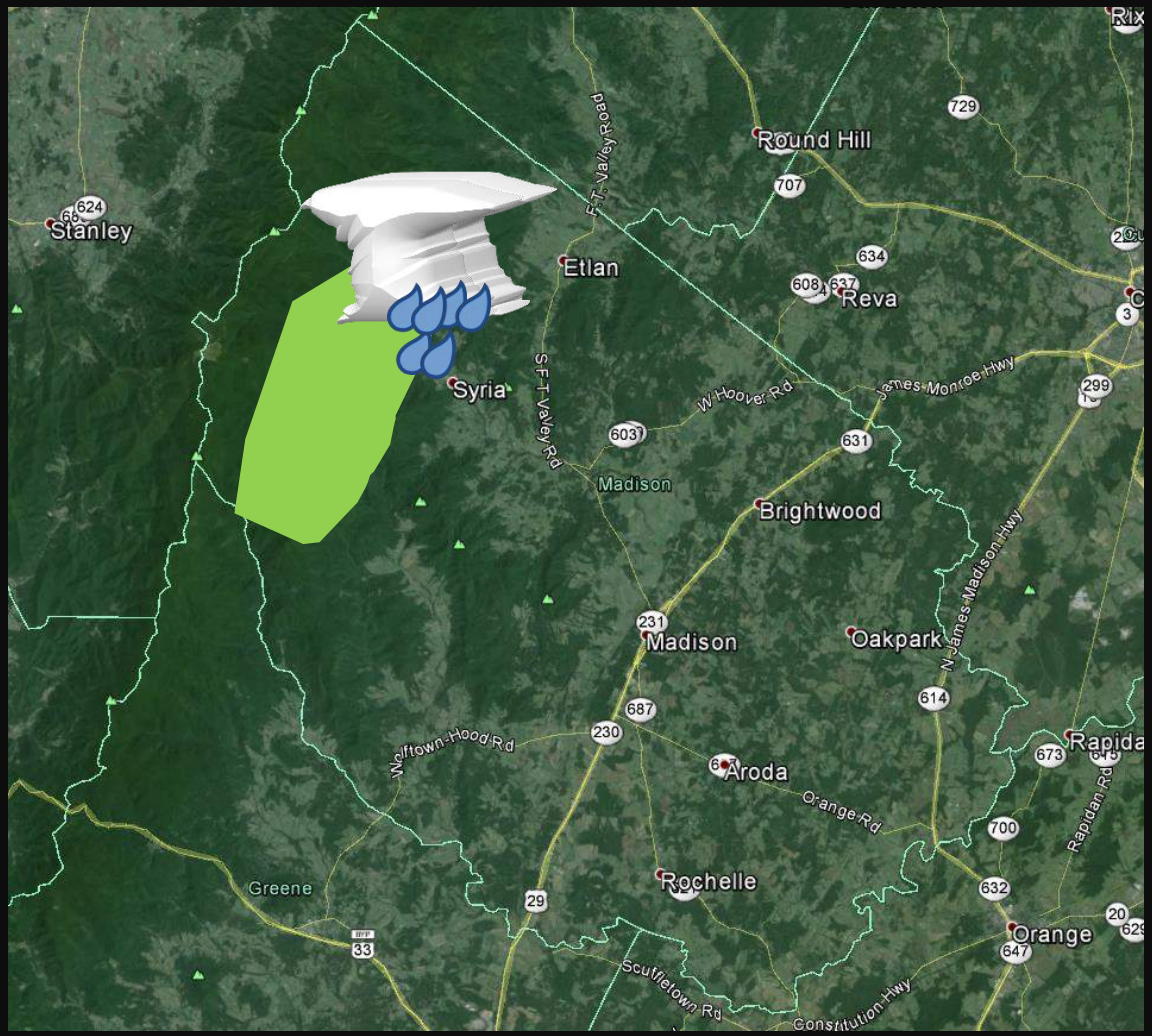
June 27, 1995

- Affected foothills of central Virginia
- 24” rain within 24 hours
- 3 fatalities
- Mud/Debris slides
- All bridges in and out of Madison County were washed out or damaged except for U.S. Route 29 South.

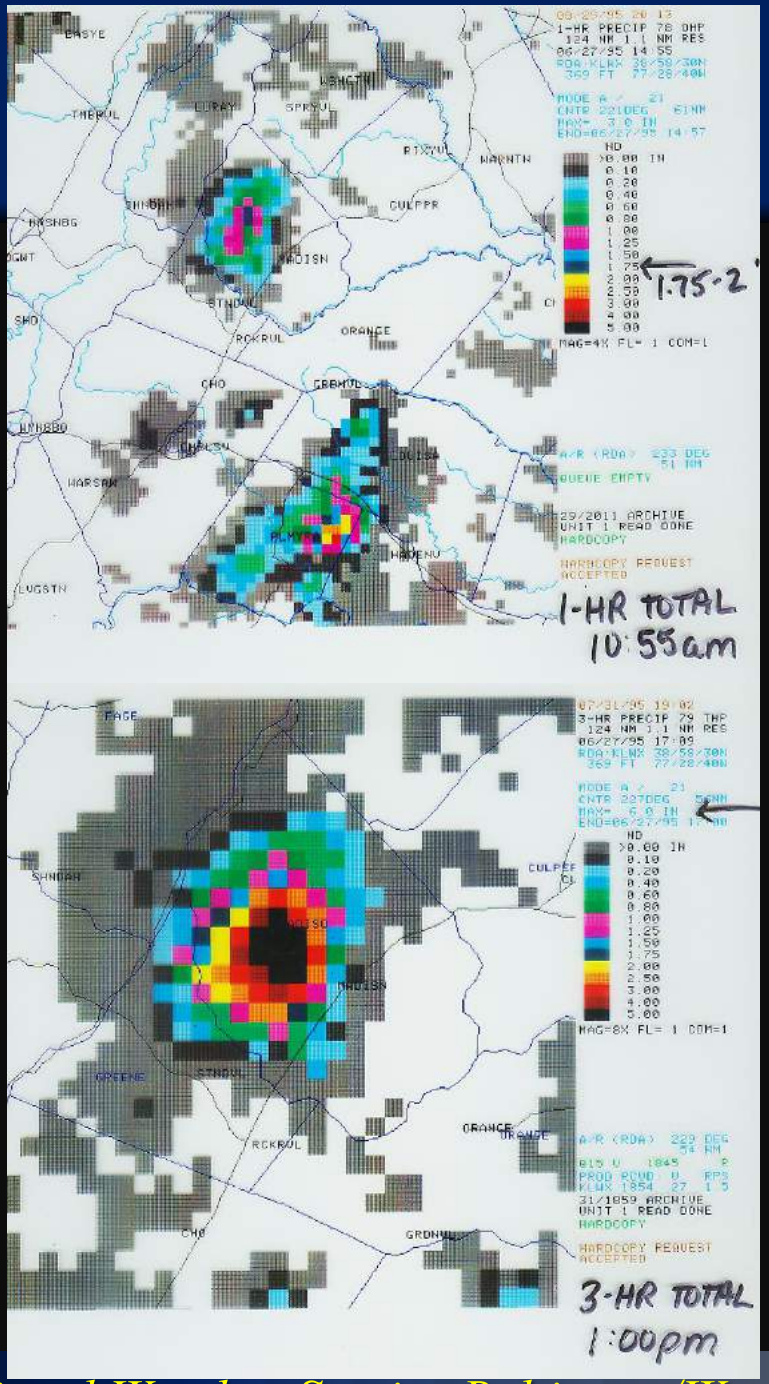
Rt. 29 @ Madison/Greene County Line

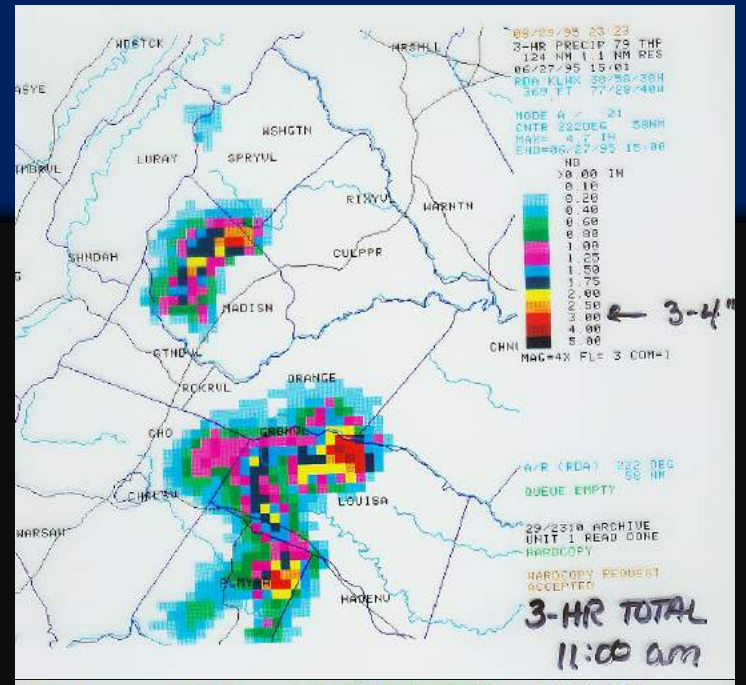
Rapidan River poured over U.S. Rt 29 at the border of Madison & Greene counties

How it Happened

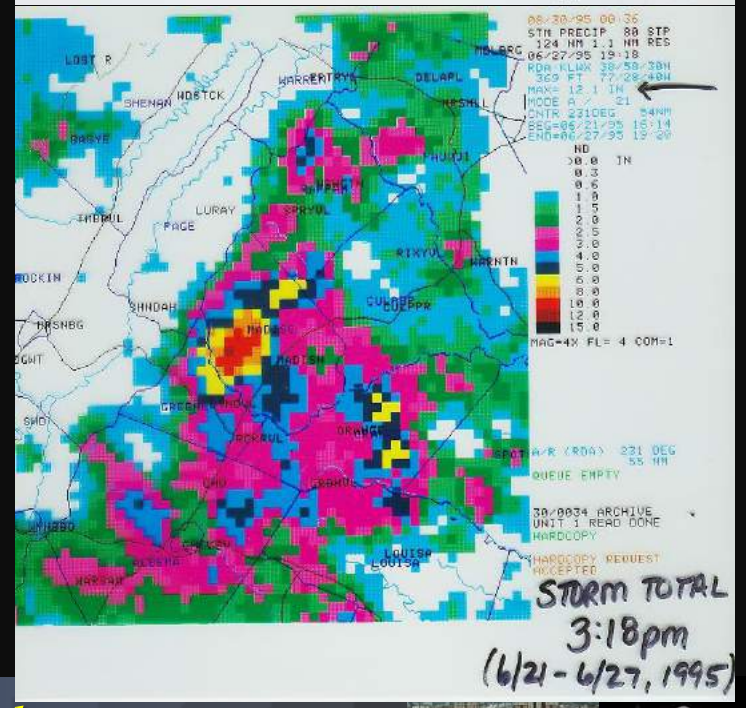


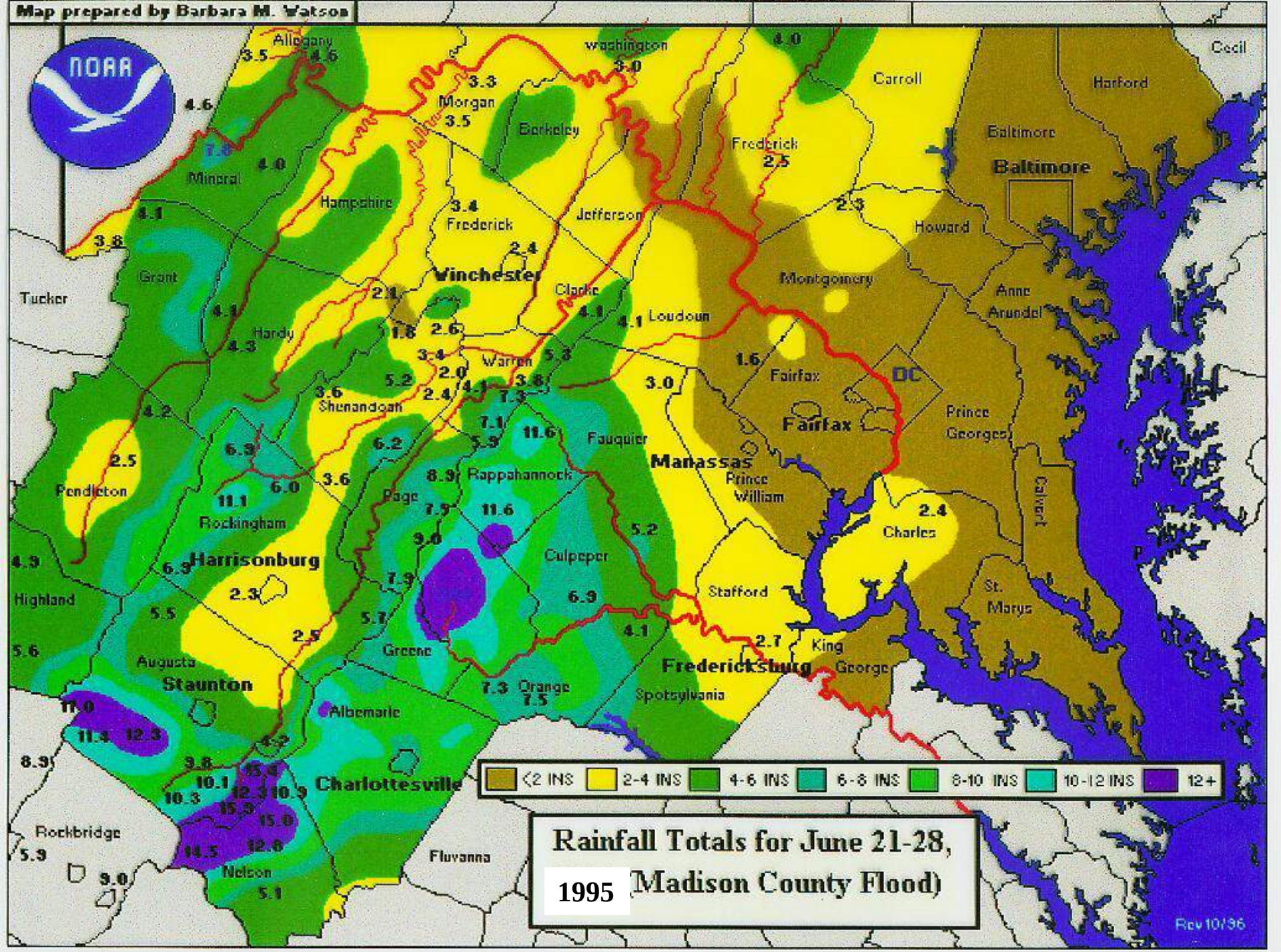
Rain


1-HR TOTAL
10:55am


3-HR TOTAL
11:00 am

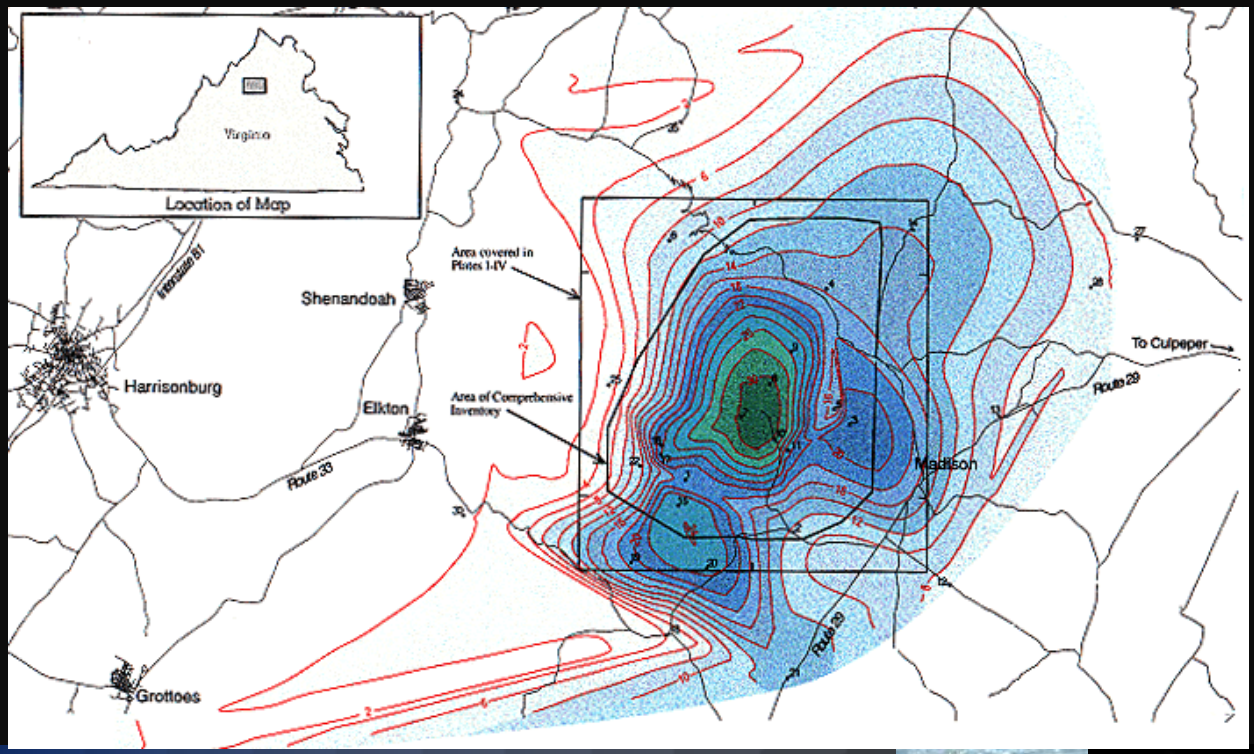
3-HR TOTAL
1:00pm


STORM TOTAL
3:18pm
(6/21 - 6/27, 1995)


Map prepared by Barbara M. Watson
NOAA
Allegany
Washington
Carroll
Harford
Cecil
Morgan
Berkeley
Frederick
Baltimore
Baltimore
Mineral
Hampshire
Jefferson
Howard
Grant
Winchester
Montgomery
Tucker
Clarke
Anne Arundel
Loudoun
Hardy
Warren
Fairfax
DC
Shenandoah
Fairfax
Prince Georges
Fauquier
Manassas
Rappahannock
Prince William
Pendleton
Page
Calvert
Rockingham
Charles
Harrisonburg
Culpeper
Highland
Stafford
St. Marys
Augusta
Greene
King George
Staunton
Fredericksburg
Orange
Spotsylvania
Albemarle
Charlottesville
Rockbridge
Fluvanna
Nelson
<2 INS
2-4 INS
4-6 INS
6-8 INS
8-10 INS
10-12 INS
12+
Rainfall Totals for June 21-28,
1995 (Madison County Flood)
Rev 10/96

Madison County (VA) Flash Flood

- Precipitable water before the event from the Dulles sounding was 1.97”, near record high for the date.
- The Rapidan River was flowing at 125 times its normal rate – 37 *billion* gallons per hour!
- Rainfall of 20 to 30 inches over quite a large area

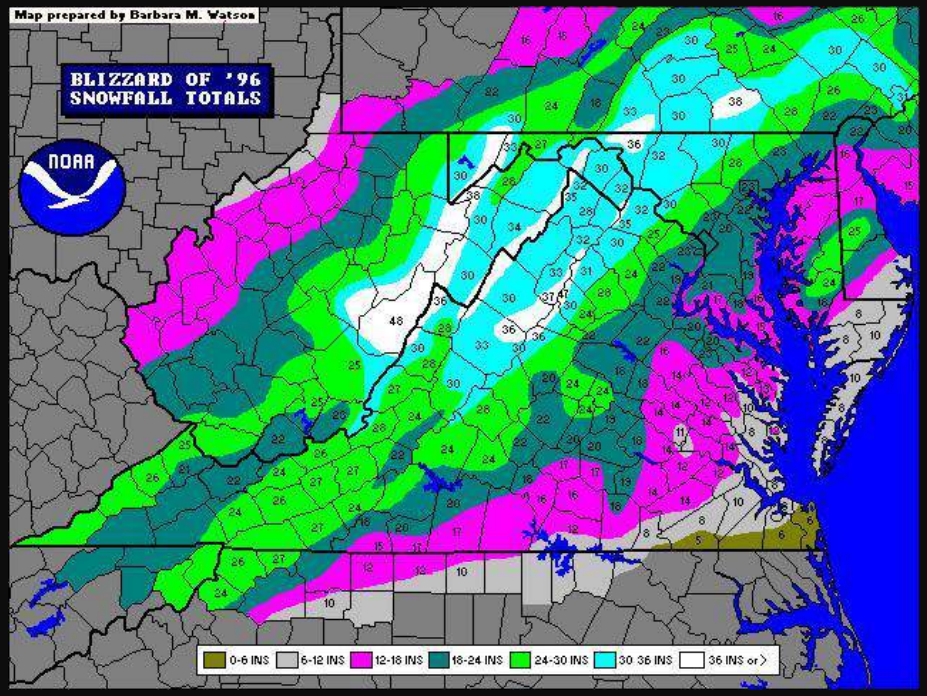


Madison County (VA) Flash Flood

- Radar was underestimating rainfall - ratio of ground truth to radar estimates was 1.8 : 1.
- As flooding became more severe, communications were lost.
- Skywarn amateur radio spotters provided the first ground-truth report from Madison County.
- At 2PM, Etlan reported 10”, with 5” falling between 10AM & 2PM.
- Record Flooding along the Rapidan River near Ruckersville and Culpeper

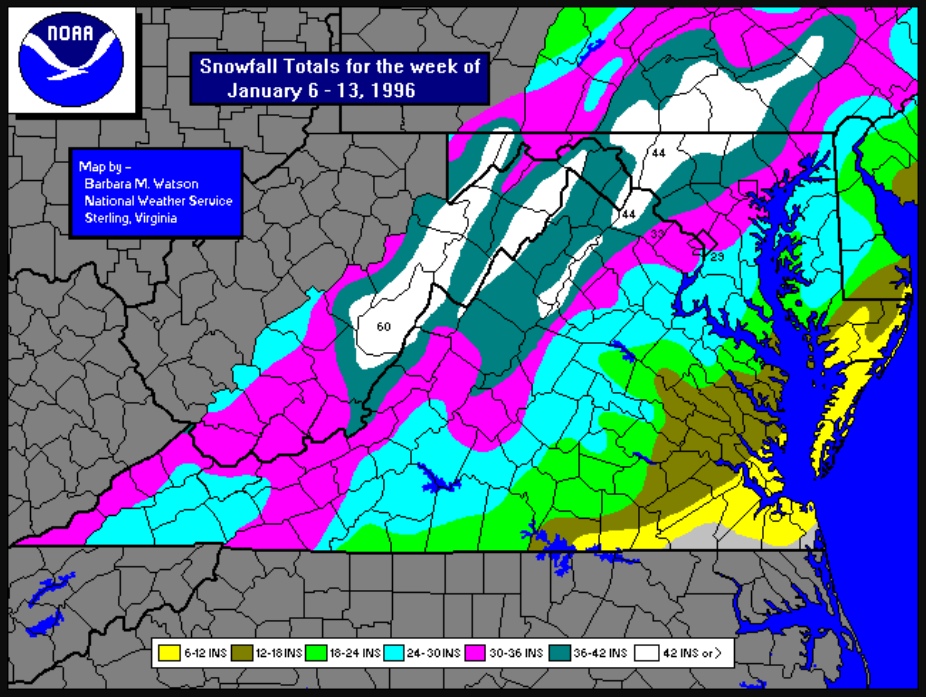
Debris Flow from Madison County flood

January 6-13, 1996



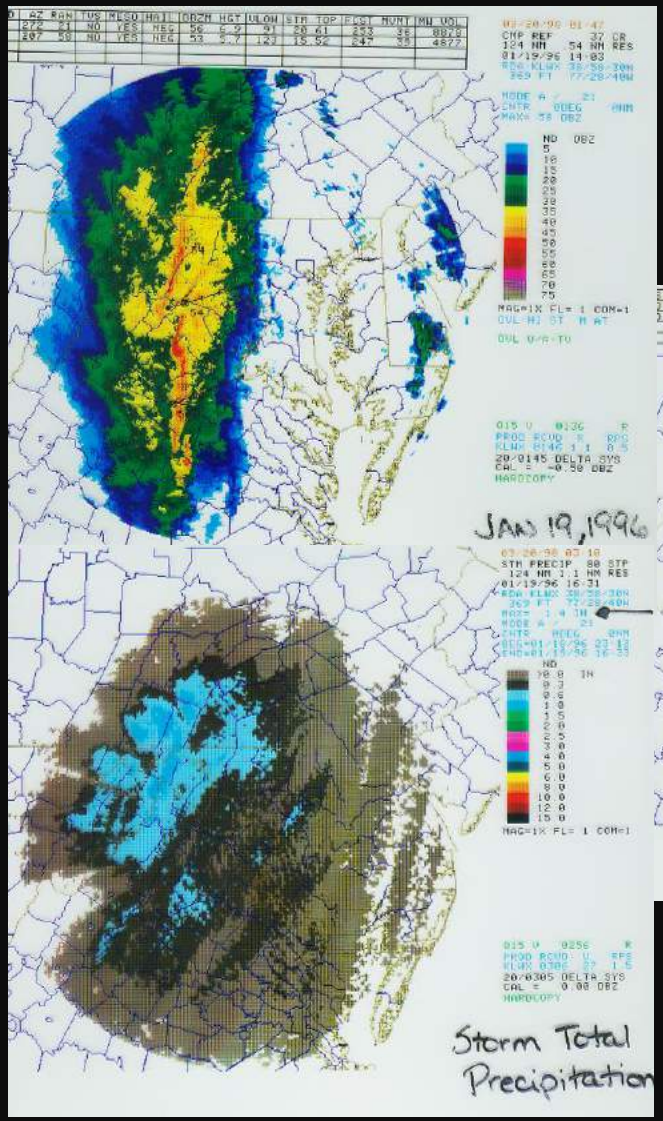
Snowfall from January 6-8, 1996 Blizzard

Additional snow fell January 12th. Snowfall totals for the week January 6-13, 1996

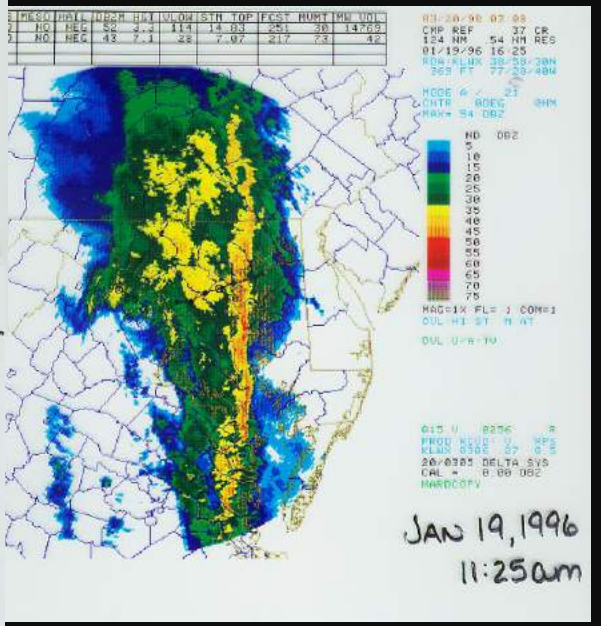


January 19, 1996

Snowfall at Dulles Int'l Airport (IAD)		
Date	New Snow	Snow on ground (7 am)
6	1.4	0
7	19.8	7
8	3.4	24
9	0.2	24
10	T	21
11	0	18
12	6.1	19
13	0	23
14	0	20
15	0	14
16	0	12
17	0	11
18	0	9
19	0	T
20	0	T
21	T	T



Radar images on Jan 19th…
-9:03 am (left)
-11:25 am (below)



Radar estimated total rainfall – max 1.4 inches

January 1996 event

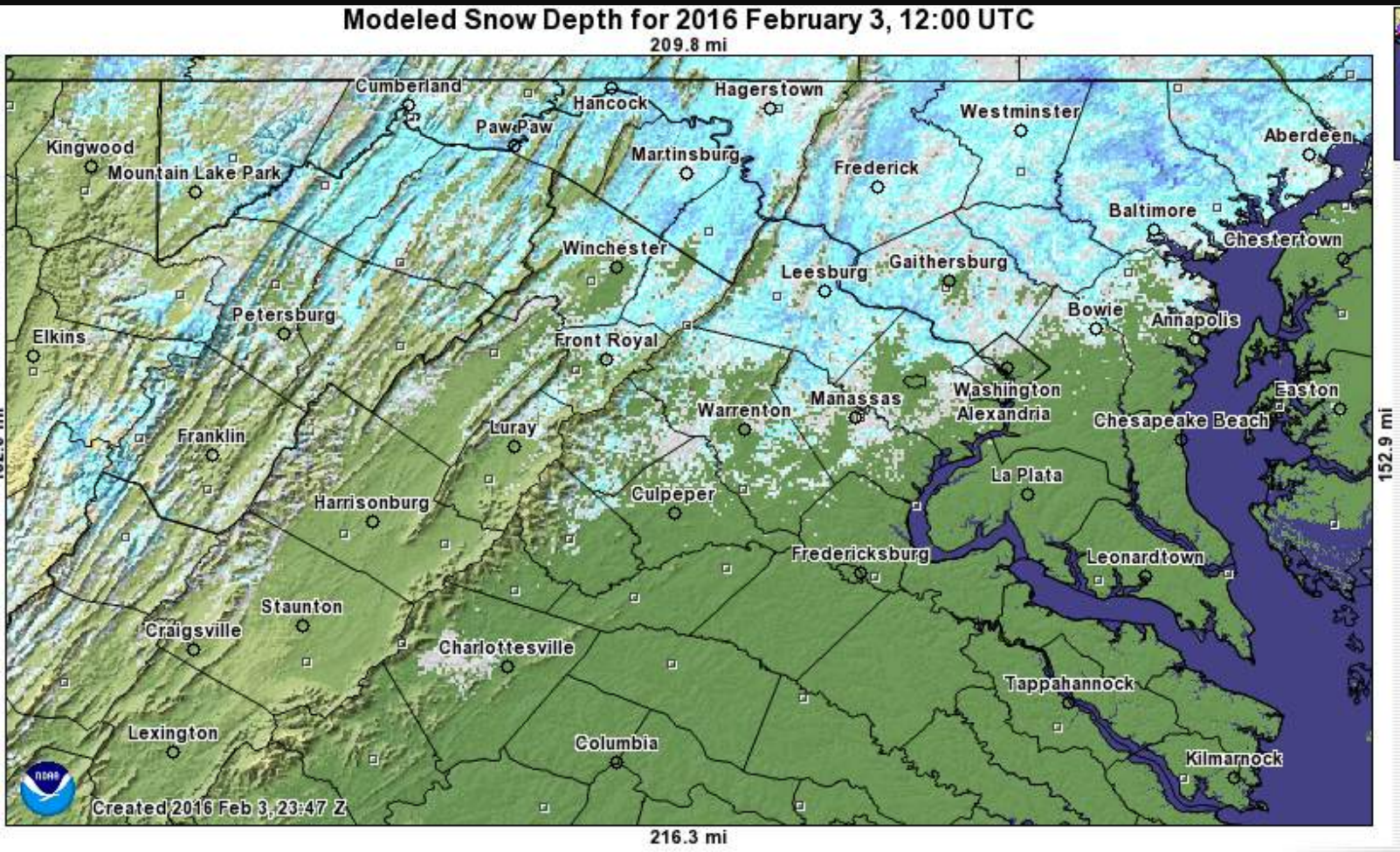
- 2 – 3 feet snowfall early
- Additional snow a week later (less than 1’ East & 3’ West)
- Water equivalent of snow pack 2-3” (17th & 18th)
- Additional 1 – 3” rain, locally up to 5”

Above: Shenandoah Street in Harpers Ferry flooded in January 1996

Left: Flood Markers on Whites Ferry General Store include the January 1996 flood

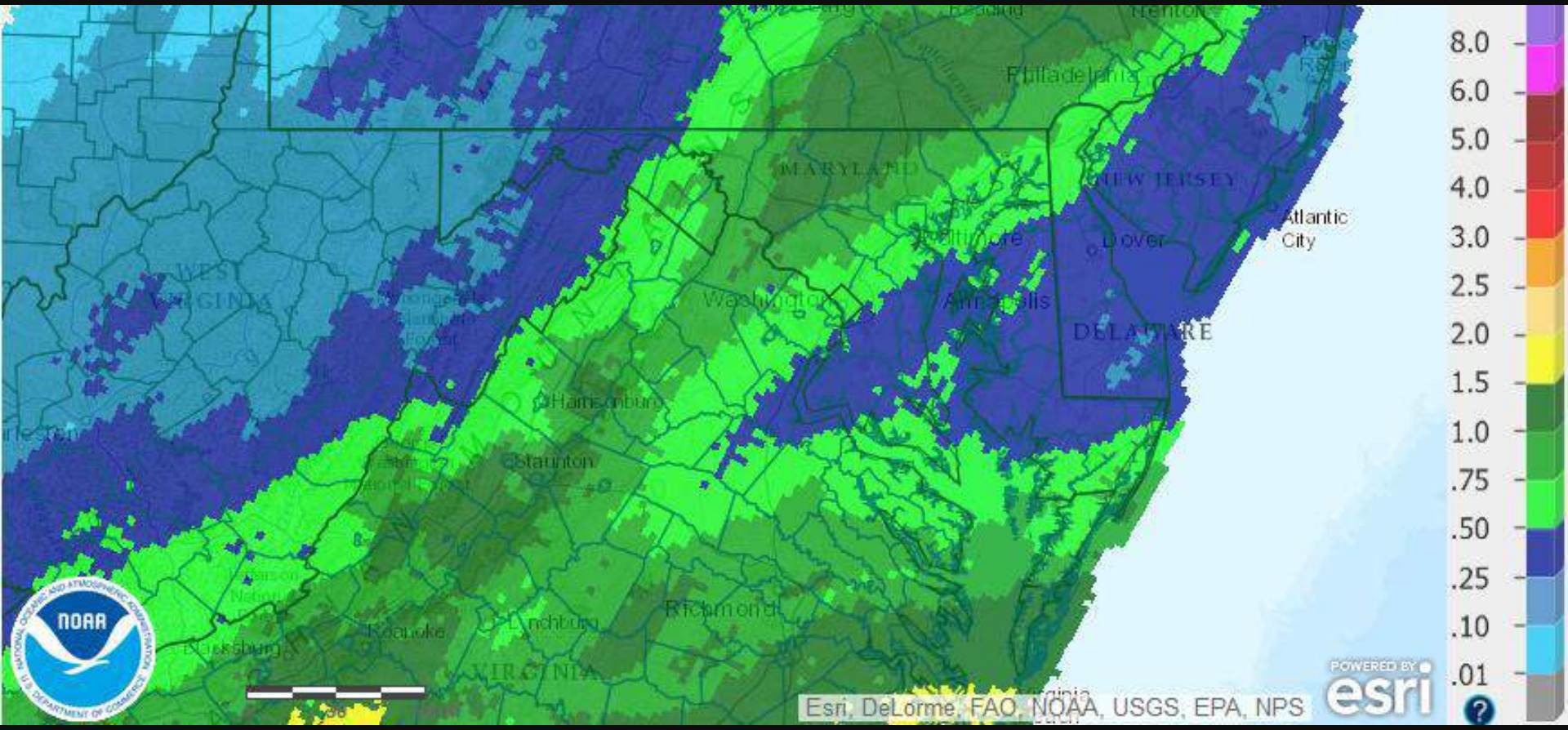
1996 Blizzard vs. 2016 Blizzard

Why no flood this time??



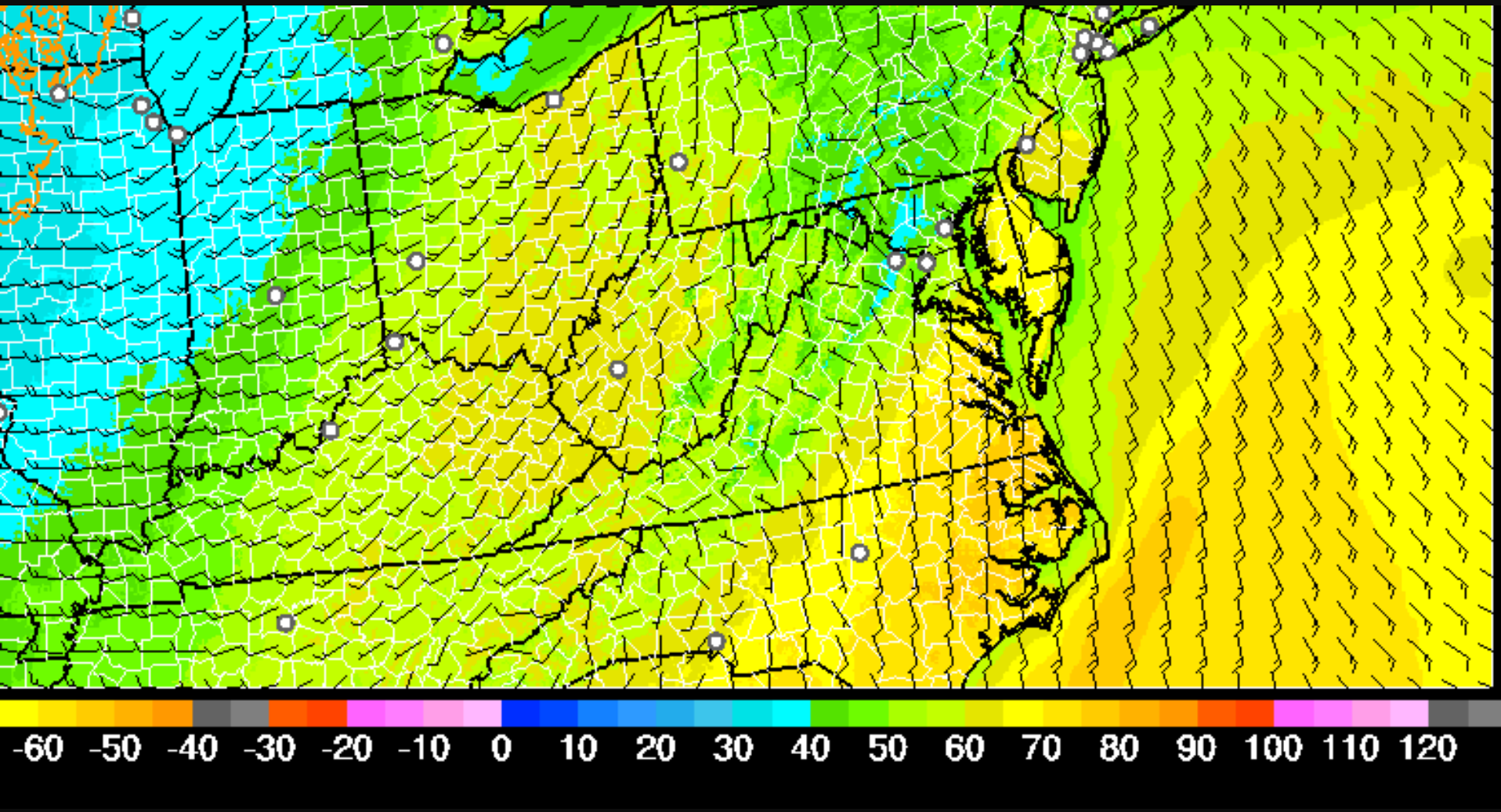
1996 Blizzard vs. 2016 Blizzard

Why no flood this time??



1996 Blizzard vs. 2016 Blizzard

Why no flood this time??



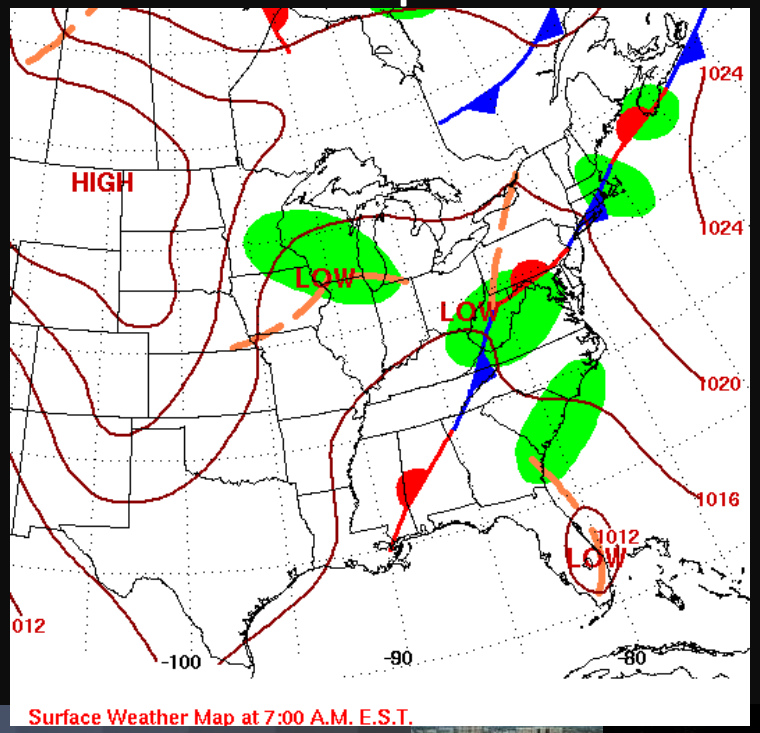
But wait…there's more…

- Cleanup from the January 1996 event had just ended when Hurricane Fran slammed into the area in September, causing nearly the same flooding across the Potomac basin.
- However…
  There hasn't been a major flood of the Potomac since. (There have been lots of minor & moderate floods)
- Flood frequency studies indicate a major flood happens, on average, every 7-10 years on the Potomac.

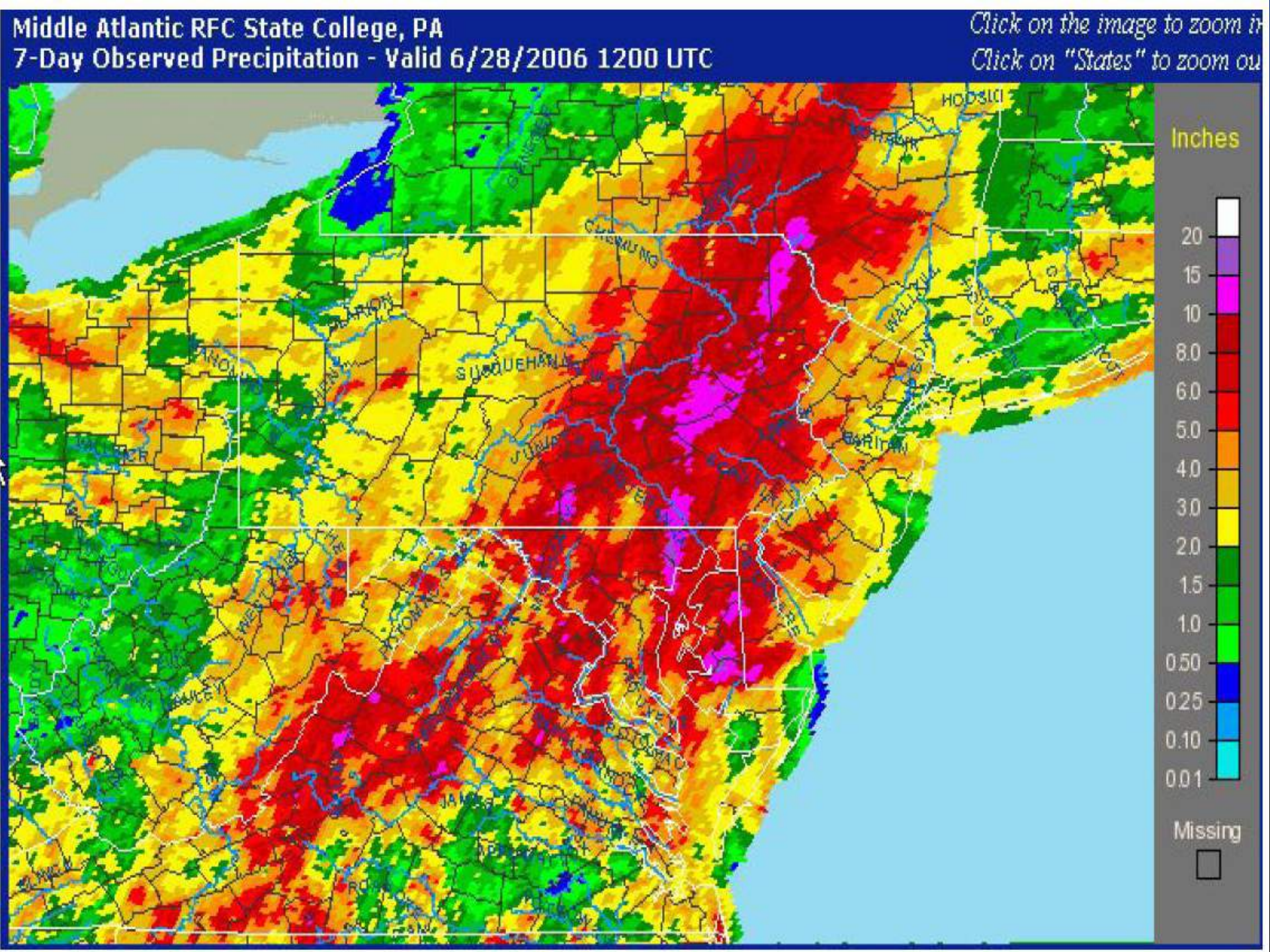
Are we overdue?

June 2006 Heavy Rain Event

- Waves of low pressure rode northeast along a stationary front from June 22 until June 27.
- Flow in the atmosphere was parallel to the boundary, producing several rounds of training echoes.
- As a result, double digit rainfall totals affected parts of the region through the five days.
- Scattered instances of flash flooding began late on June 22 and continued into June 24. Then, flooding began to take on a more serious nature since the ground had become saturated in so many spots.



Surface Weather Map at 7:00 A.M. E.S.T.


Middle Atlantic RFC State College, PA
7-Day Observed Precipitation - Valid 6/28/2006 1200 UTC
Click on the image to zoom in
Click on "States" to zoom out
Inches
20
15
10
8.0
6.0
5.0
4.0
3.0
2.0
1.5
1.0
0.50
0.25
0.10
0.01
Missing

A record setting day!

- At Reagan National Airport (DCA)…

24-hour rainfall record…	7.94” (6/25-26)
Daily rainfall record…	5.19” (6/25)
Daily rainfall record…	4.22” (6/26)
2-day rainfall record…	9.41” (6/25-26)
7-day rainfall record…	11.37” (6/22-28)
June rainfall record…	14.02”

2006 Impacts – Lake Needwood

- Nearly 2400 people in Montgomery County, MD were evacuated when engineers on site determined that the Lake Needwood Dam may fail.
- Water levels behind the dam rose 23 feet, resulting in uncontrolled seepage.

2006 Impacts – Rock Creek

- 5 deaths in Frederick (MD) & Carroll Counties
- In Huntington VA, 158 homes were declared uninhabitable, two homes and one business were condemned. ($11M)
- Flooding and mudslides closed portions of Capital Beltway
- Rock Creek flooded, and threw several vehicles up against trees due to the fast flowing high water.

Flood damage along Rock Creek.

2006 Impacts – Washington DC

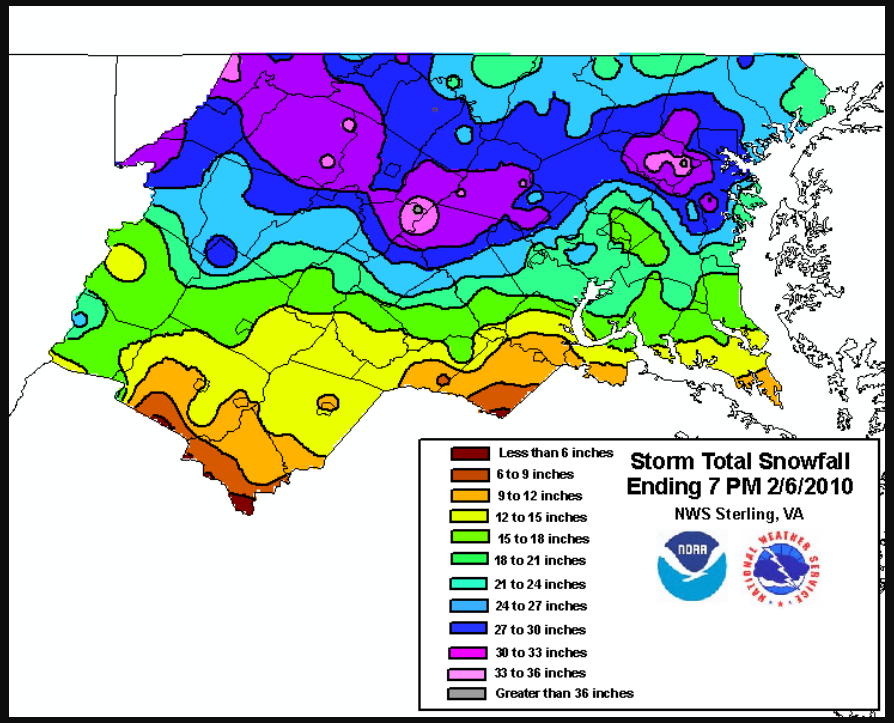
- Significant flooding in the Monumental Core

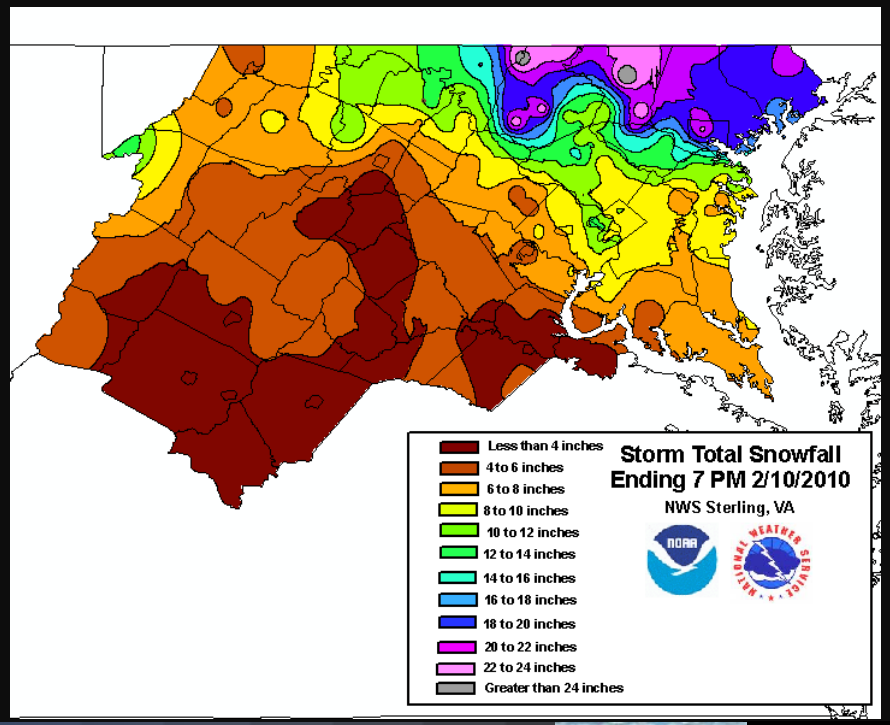
Photos courtesy GSA & National Archives

March 2010

- Believe it or not, this event really began a month before:

Two rounds of heavy snow: February 5-6, and again 9-10





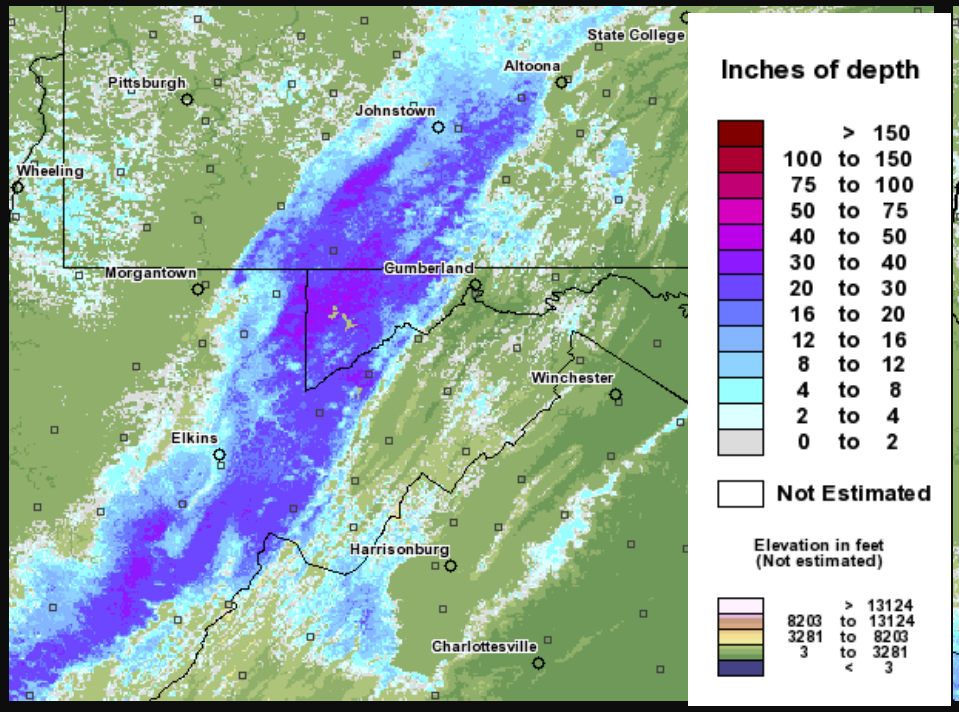
A slow melt…

- Next 30 days had below normal temperatures
- Max temperatures above freezing allowed for controlled melting
- Min temperatures below freezing at first, then gradually above freezing
- By early March, snowpack only in the mountains
- Rain March 12-15th

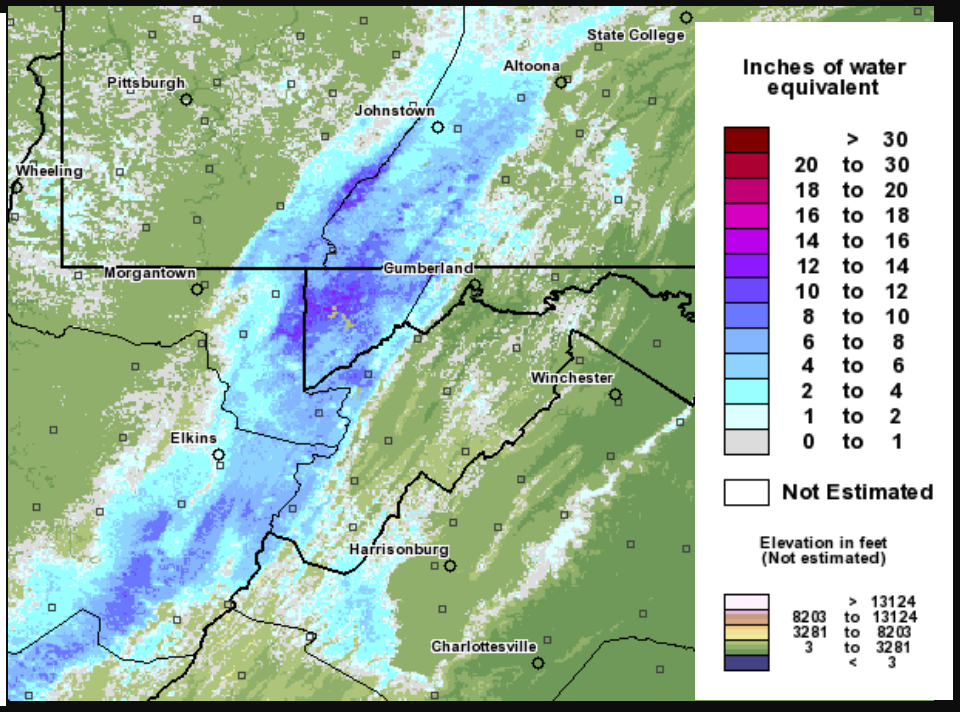
Feb 2010 data – National Airport				
Date	Liquid pcpn	Snowfall	Snow on Ground	High temp.
5	0.77	8.7	0	37
6	0.73	9.1	13	32
7	0	0	18	32
8	0	0	14	34
9	0.38	3.7	13	36
10	0.25	7.1	14	31
11	0	0	21	40
12	0	0	17	38
13	0	0	15	34
14	0	0	14	41
15	0.04	0.1	13	39
16	T	T	12	37
17	0	0	10	37
18	0	0	9	43
19	0	0	7	45
20	0	0	6	44
21	0	0	4	50
22	0.27	0	1	43

What remains…

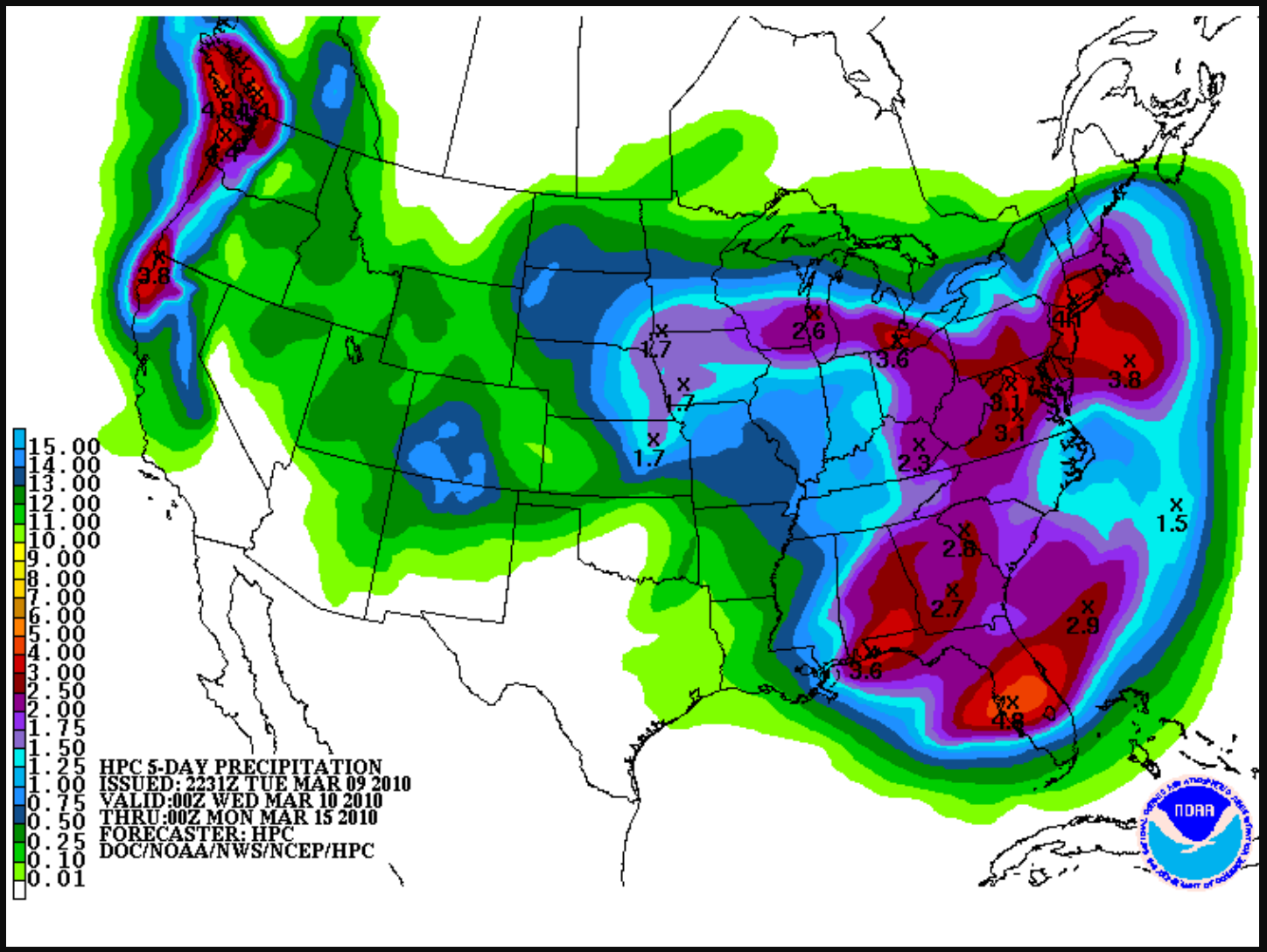
March 11th Snow Depth



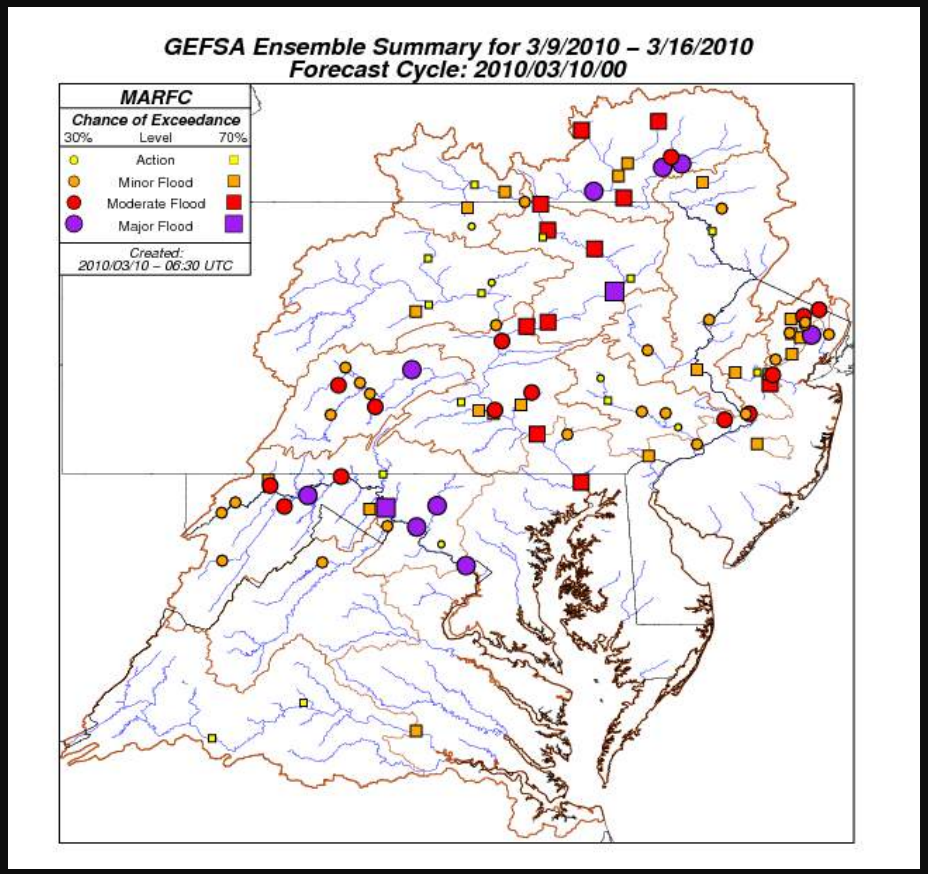
March 11th Snow Equivalent

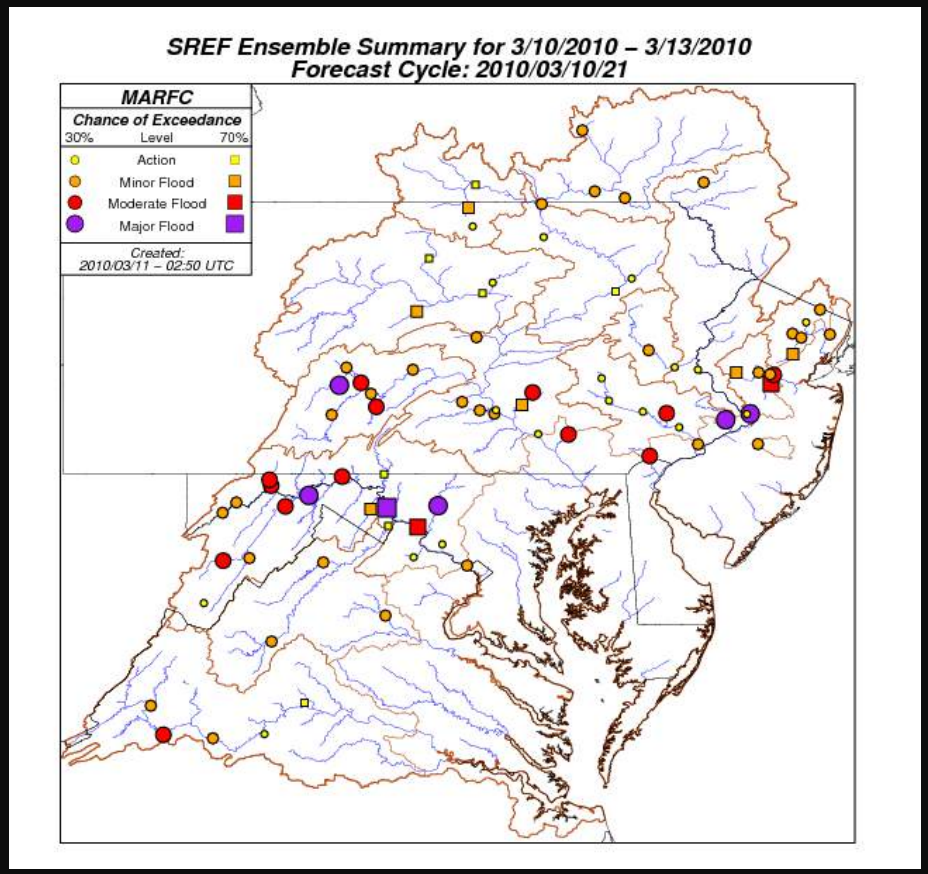


This could be trouble…

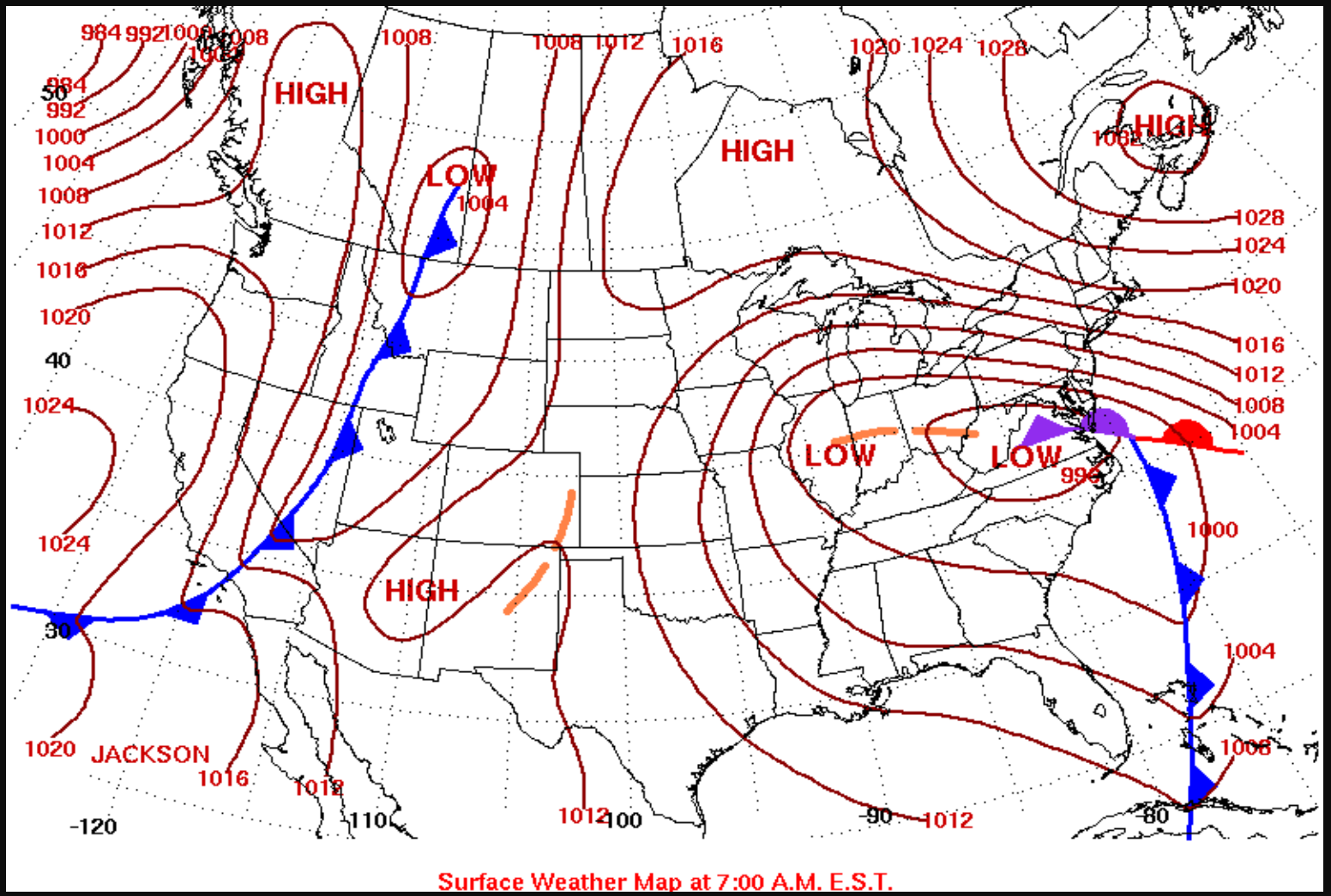


Ensemble Forecasts





Coastal Flood Concern



Surface Weather Map at 7:00 A.M. E.S.T.

Ground Truth

WASHINGTON, DC	
WASHINGTON 4.0 WNW	5.65

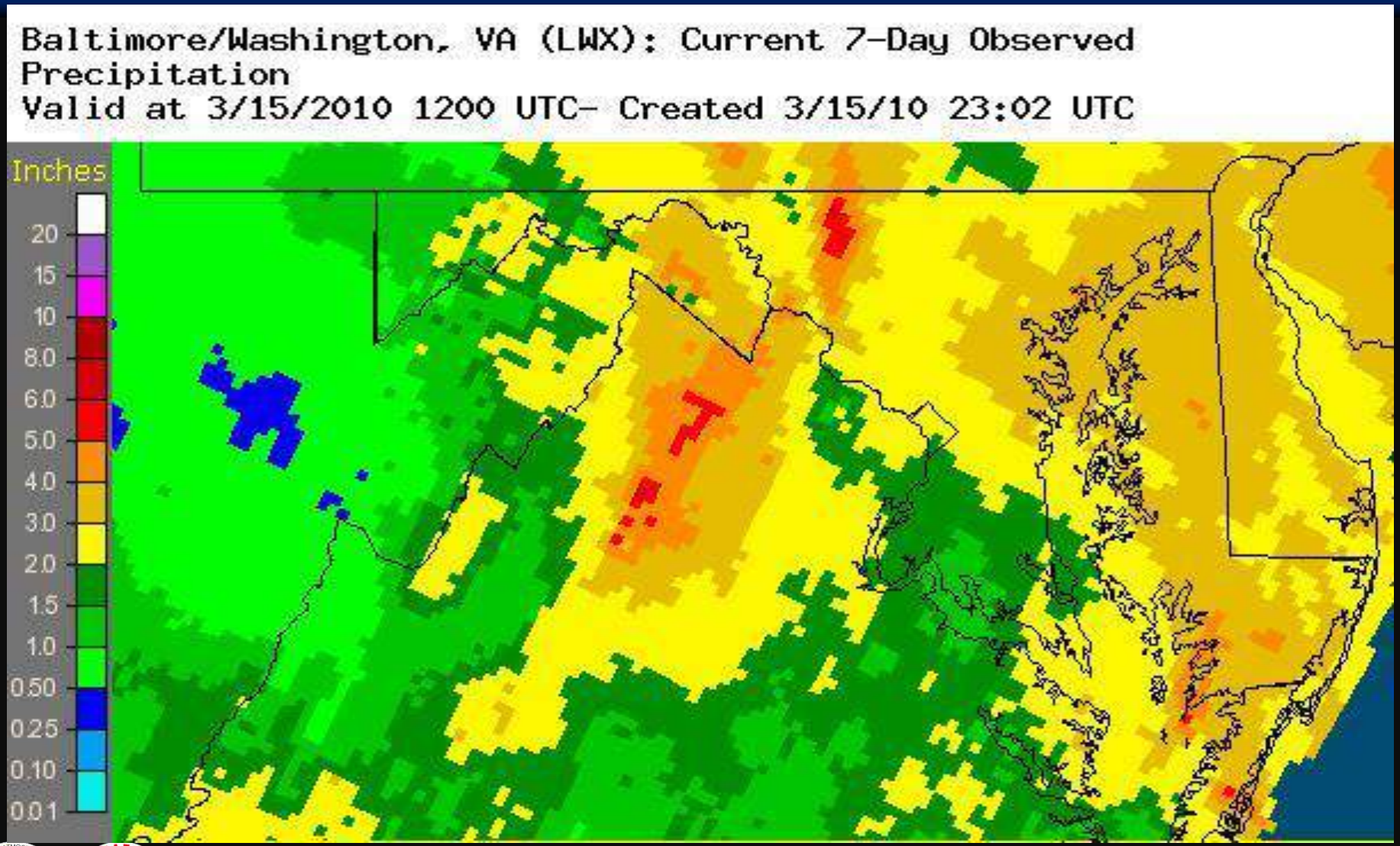
MARYLAND	
ELKRIDGE 1.8 W	4.79
THURMONT 0.8 SSE	3.96
SEVERN 2.0 W	3.93
SMITHSBURG 3.1 NNE	3.88
PERRY HALL 0.9 E	3.85
TOWSON 2.3 NE	3.83
SOUTH GATE 1.0 SW	3.81
FREDERICK 3.1 NW	3.77
BWI AIRPORT	3.77
CROFTON 1.5 NNE	3.56

VIRGINIA	
WASHINGTON 3.2 W	4.36
WINCHESTER 9.4 NW	3.98
LEESBURG 8.0 N	3.85
RIXEYVILLE 6.1 N	3.57
STEPHENS CITY 2.2 E	3.57
ROUND HILL 2.7 WSW	3.42
WARRENTON 3.5 SE	3.28

VIRGINIA (CONTINUED)	
STRASBURG 3.7 N	3.11
BARBOURSVILLE 1.1 NW	2.94
REMINGTON 4.0 ENE	2.71
LAKE RIDGE 1.7 SW	2.62
STAFFORD 2.0 NNW	2.59
STANARDSVILLE 2.1 WNW	2.59
FREDERICKSBURG 5.2 SSW	2.39
ALEXANDRIA 1.8 S	2.00
NATIONAL AIRPORT	1.57
DULLES AIRPORT	1.37

WEST VIRGINIA	
BUNKER HILL 0.8 WNW	4.21
CHARLES TOWN 2.5 NE	2.60
FALLING WATERS 2.4 NW	2.49
SHENANDOAH JUNCTION	2.44
MARTINSBURG 8.0 ENE	2.34

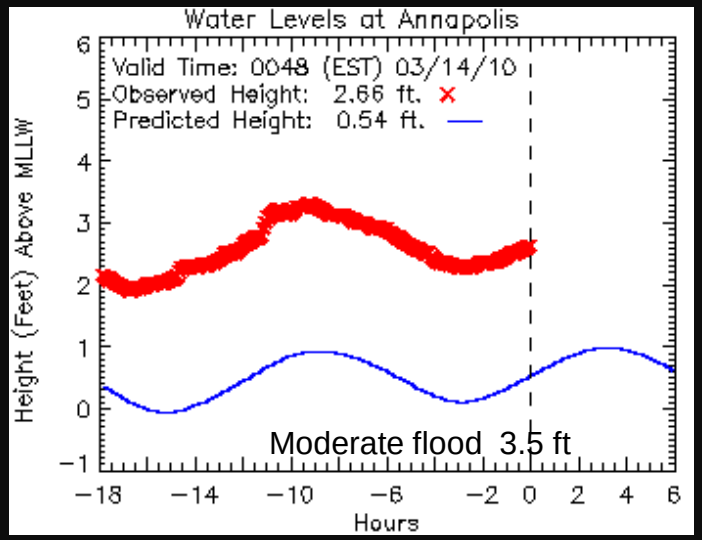
Estimated Rainfall

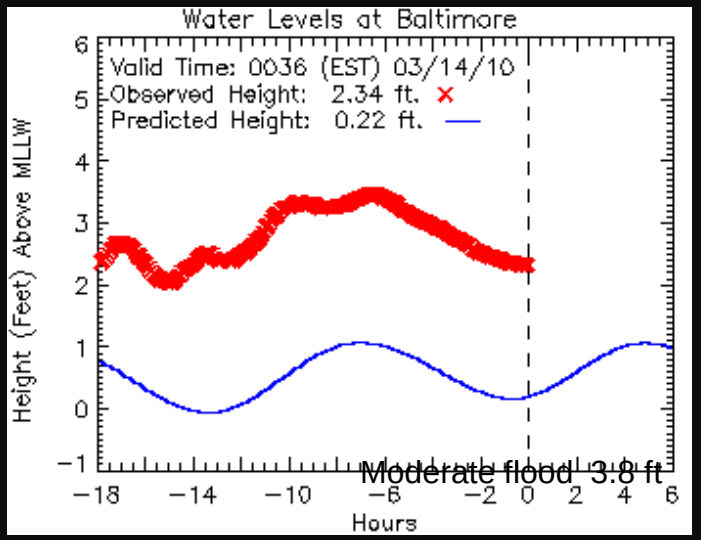


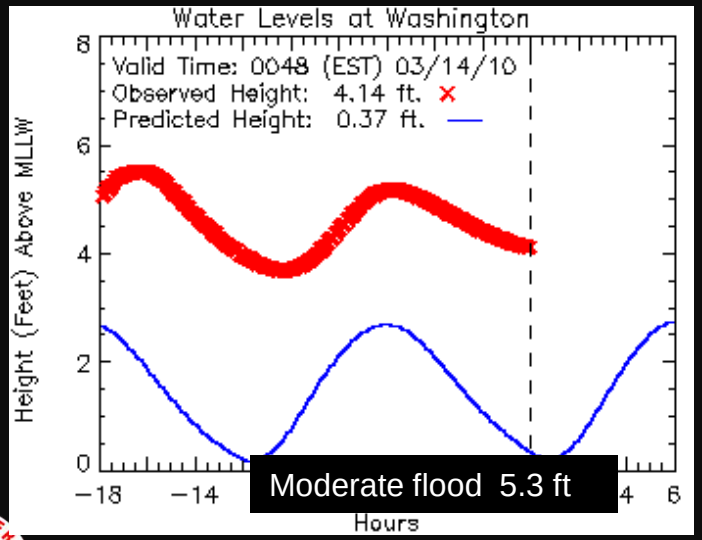
Areal Flooding

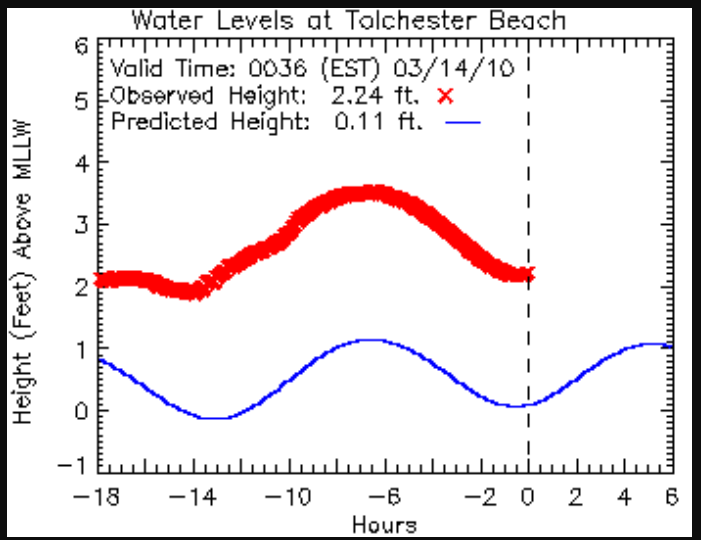
- Numerous reports of urban and stream flooding, mainly on March 13. The flooding was concentrated in Shenandoah Valley/northern foothills of Virginia, and in metro Baltimore areas.
- Additional flooding was reported the morning of the 14th, as another band of rain crossed the area.

Tidal Flooding

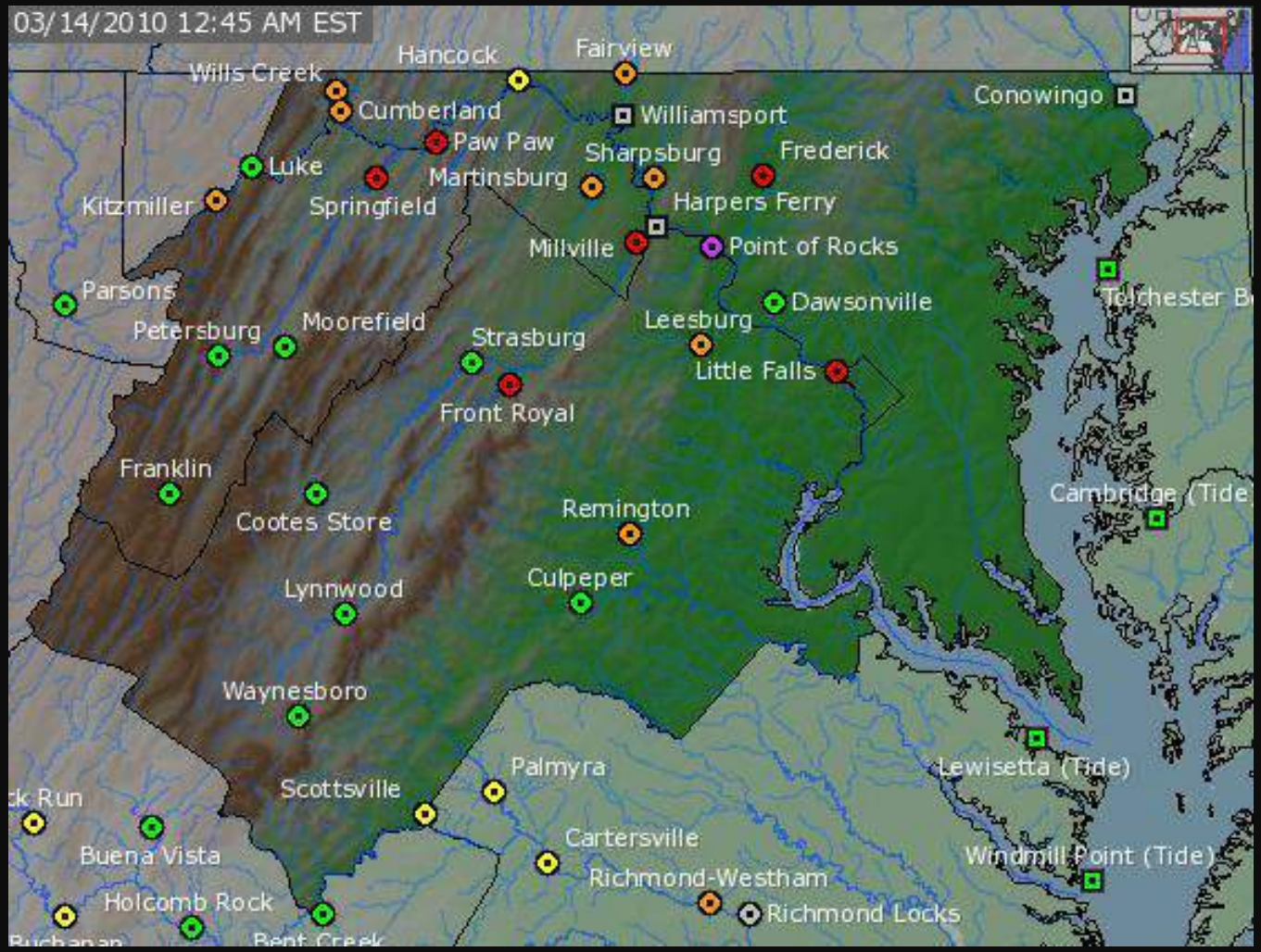




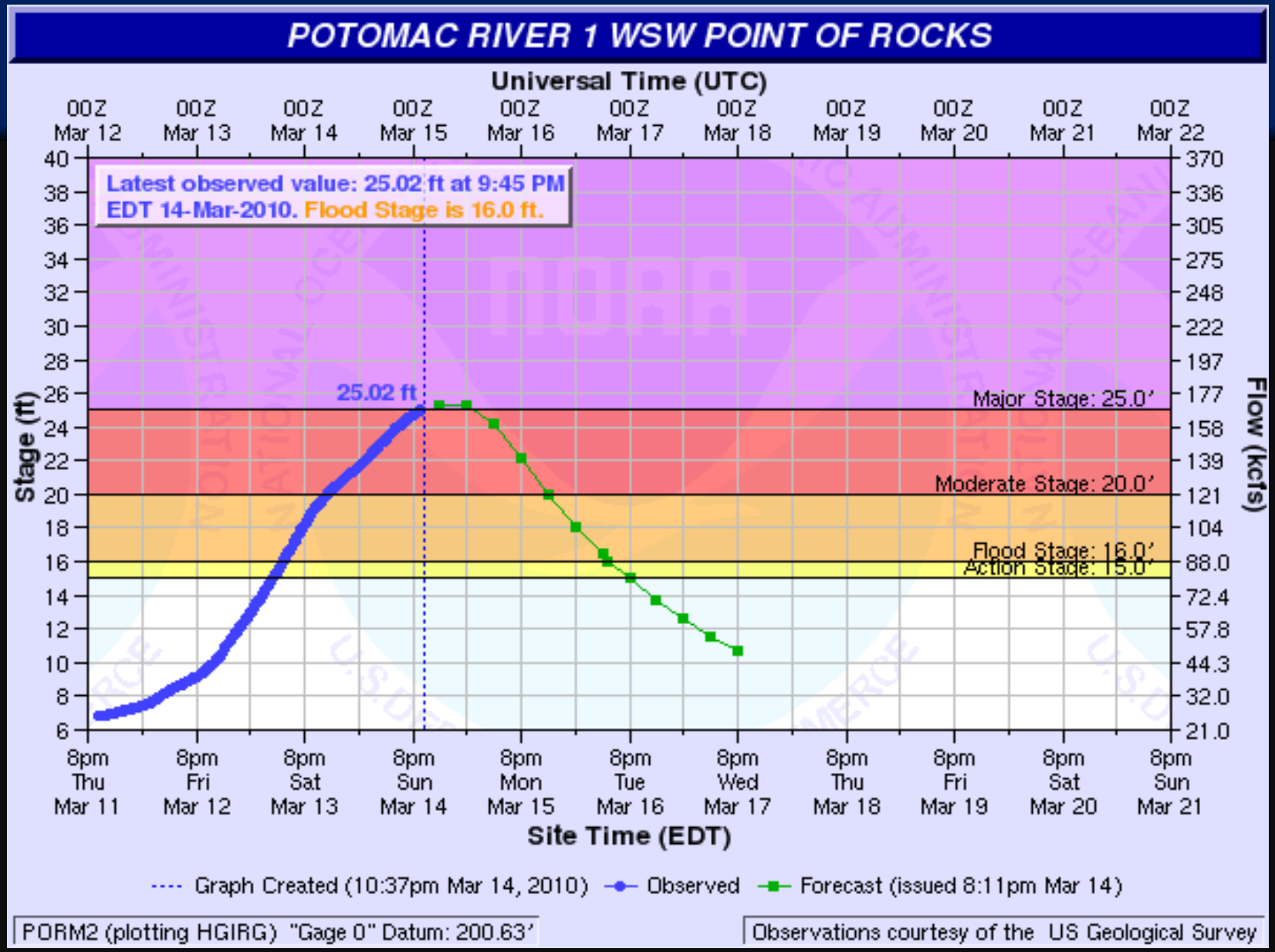




River Flooding



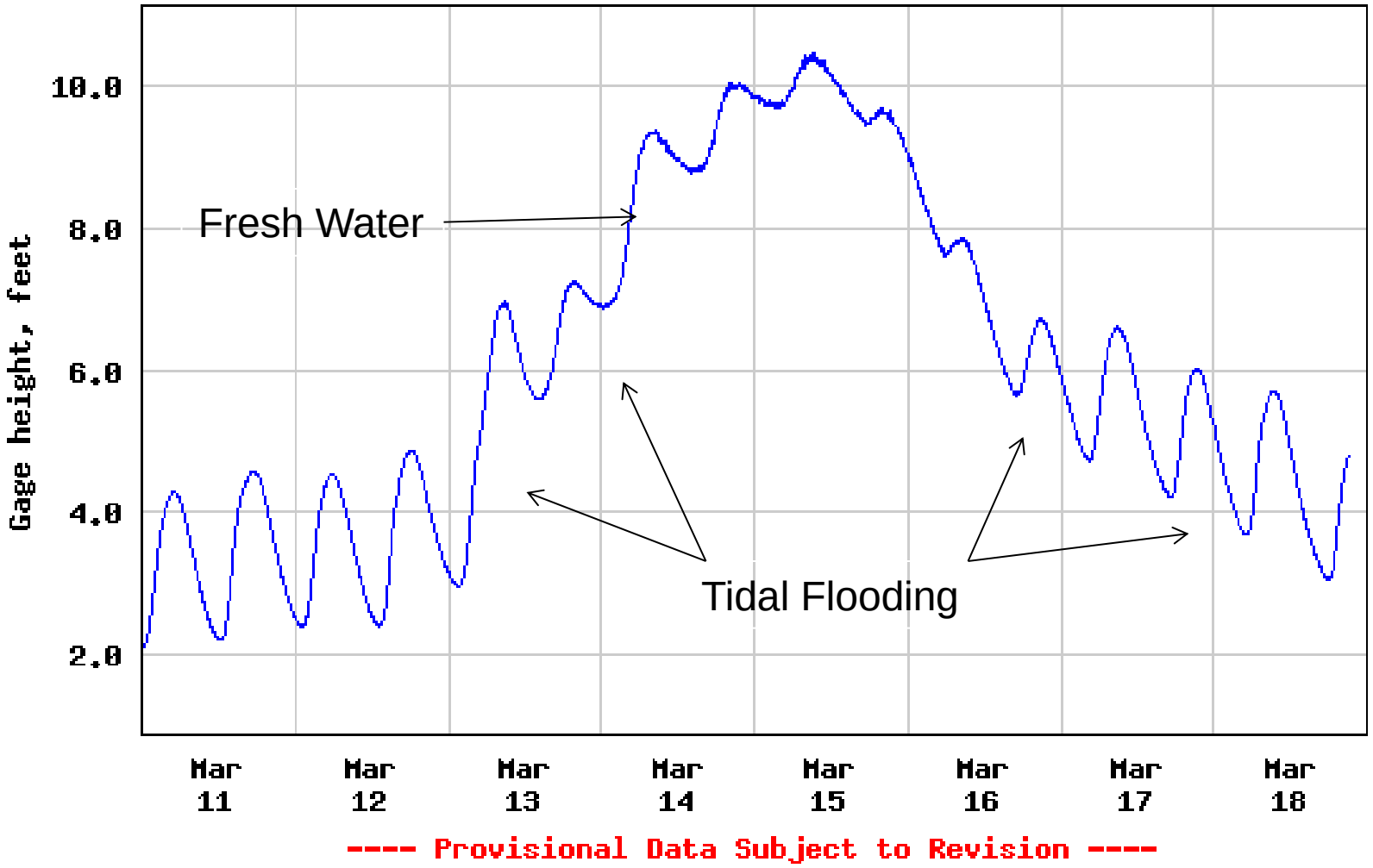
Legend:
Minor
Moderate
Major


POTOMAC RIVER 1 WSW POINT OF ROCKS
Universal Time (UTC)
00Z Mar 12
00Z Mar 13
00Z Mar 14
00Z Mar 15
00Z Mar 16
00Z Mar 17
00Z Mar 18
00Z Mar 19
00Z Mar 20
00Z Mar 21
00Z Mar 22
Latest observed value: 25.02 ft at 9:45 PM EDT 14-Mar-2010. Flood Stage is 16.0 ft.
25.02 ft
Major Stage: 25.0'
Moderate Stage: 20.0'
Flood Stage: 16.0'
Action Stage: 15.0'
Stage (ft)
Flow (kcfs)
40 38 36 34 32 30 28 26 24 22 20 18 16 14 12 10 8 6
370 336 305 275 248 222 197 177 158 139 121 104 88.0 72.4 57.8 44.3 32.0 21.0
8pm Thu Mar 11
8pm Fri Mar 12
8pm Sat Mar 13
8pm Sun Mar 14
8pm Mon Mar 15
8pm Tue Mar 16
8pm Wed Mar 17
8pm Thu Mar 18
8pm Fri Mar 19
8pm Sat Mar 20
8pm Sun Mar 21
Site Time (EDT)
Graph Created (10:37pm Mar 14, 2010)
Observed
Forecast (issued 8:11pm Mar 14)
PORM2 (plotting HGIRG) "Gage 0" Datum: 200.63'
Observations courtesy of the US Geological Survey

Millville, Martinsburg, Frederick

USGS

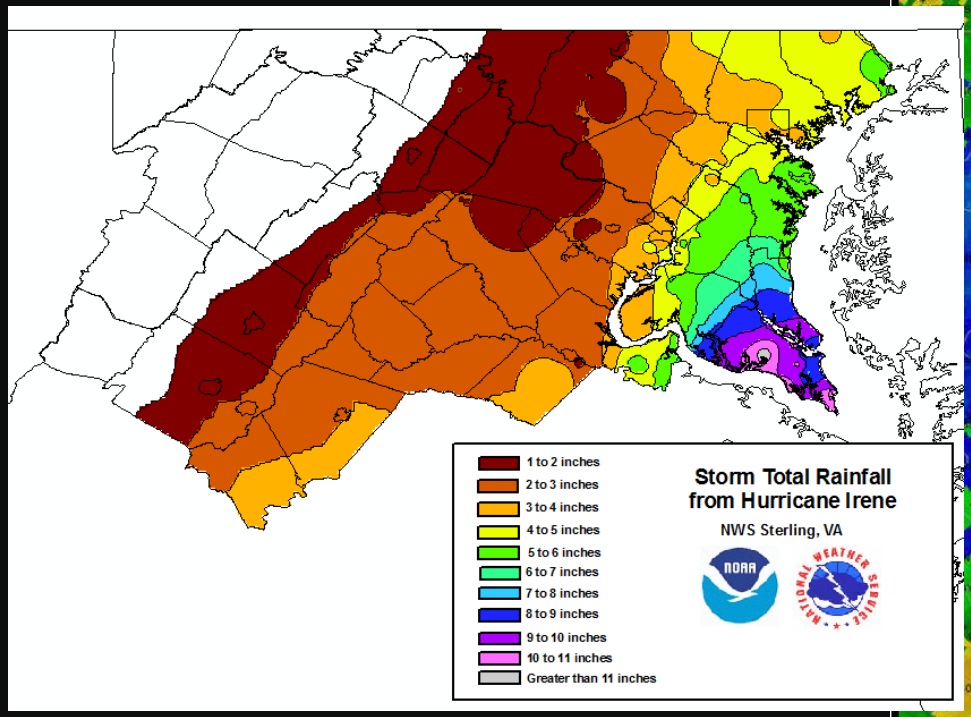
USGS 01647600 POTOMAC RIVER AT WISCONSIN AVE, WASHINGTON, DC

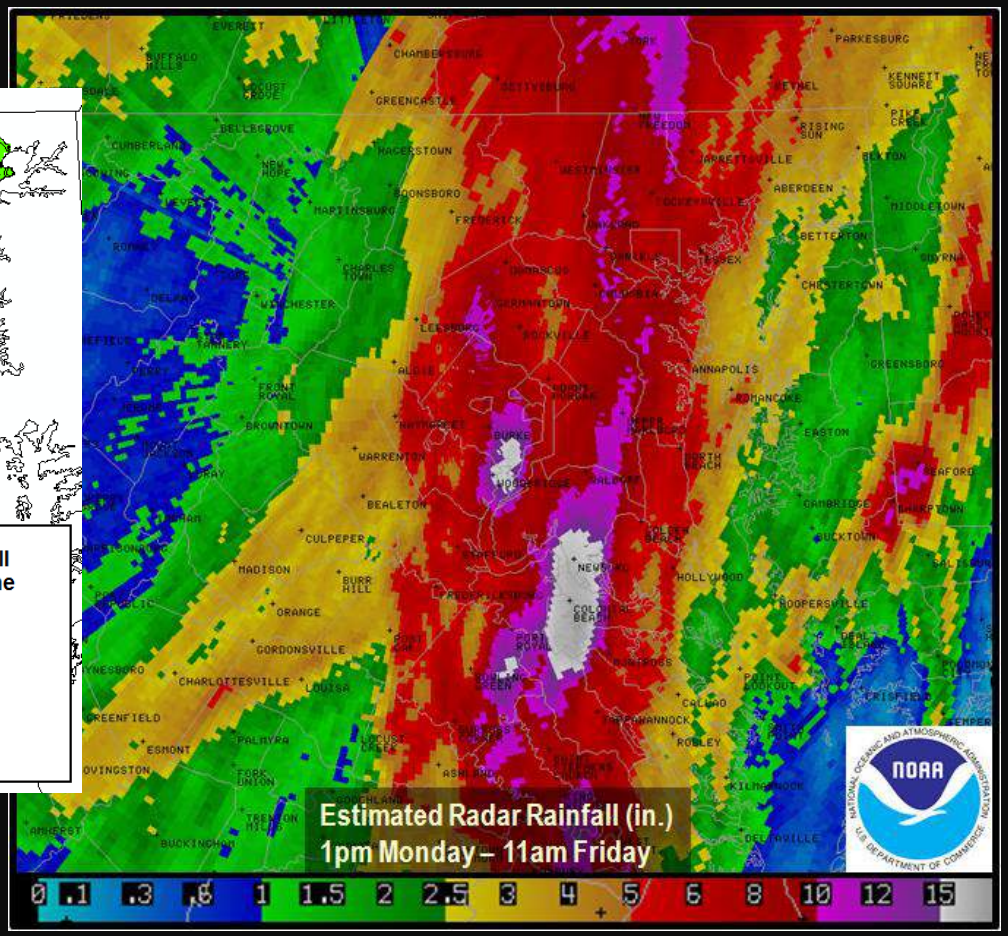


Alexandria & Washington DC

2011 Tropical Systems

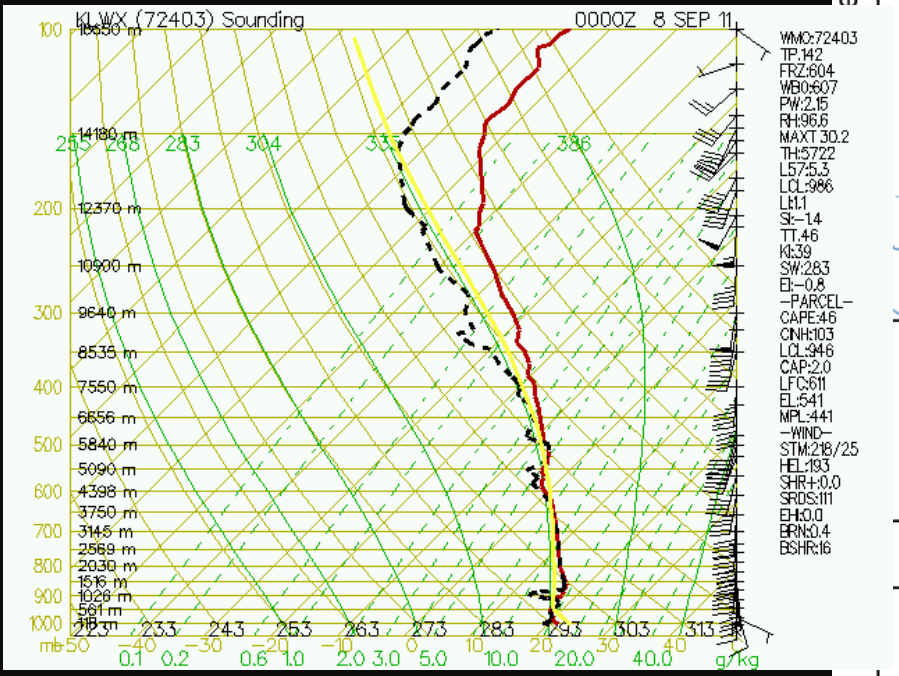
- Below: Irene
  Right: Lee

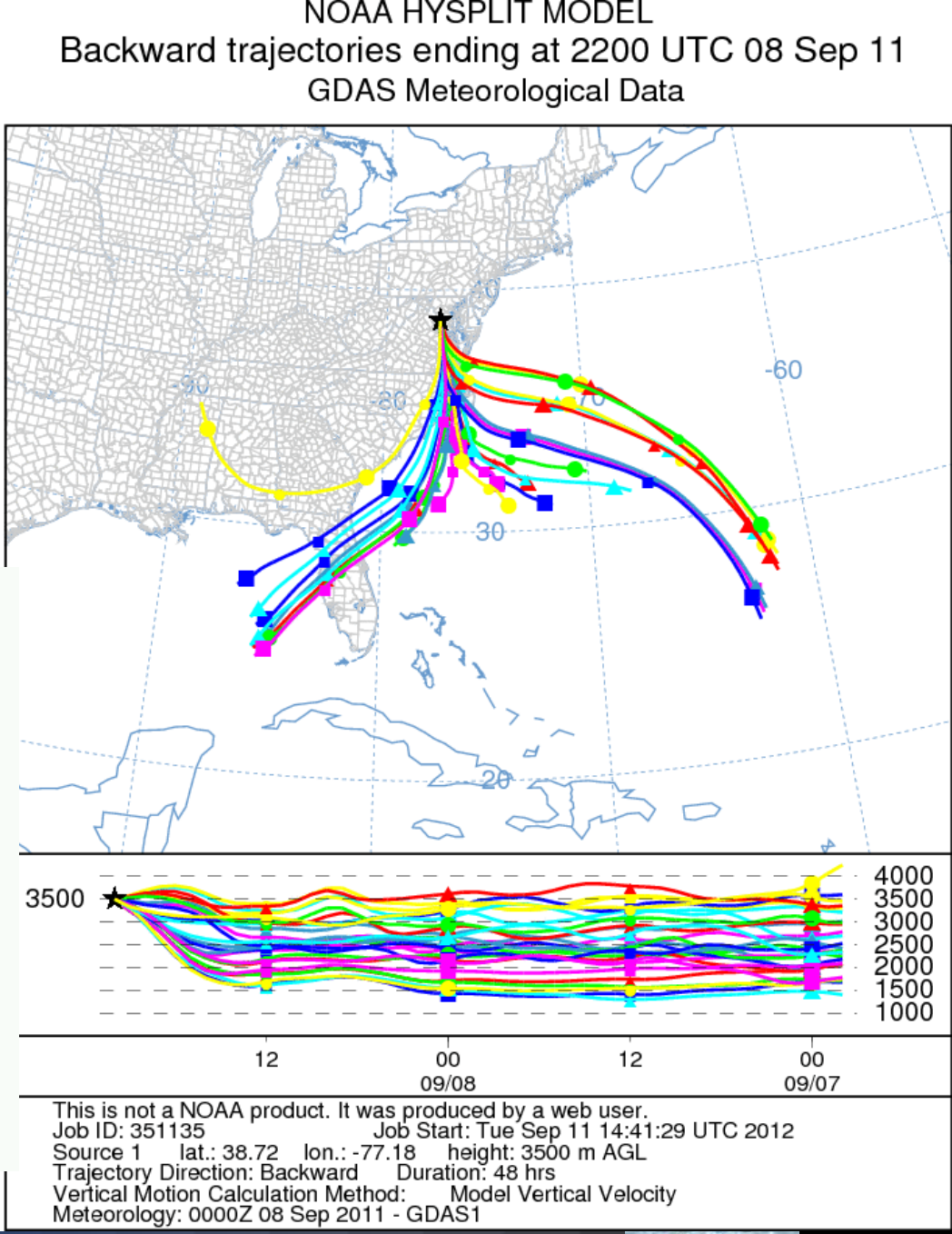




The Cause

- Combination of airmasses from the Tropical Atlantic and Gulf of Mexico





“Lee” Rainfall Totals

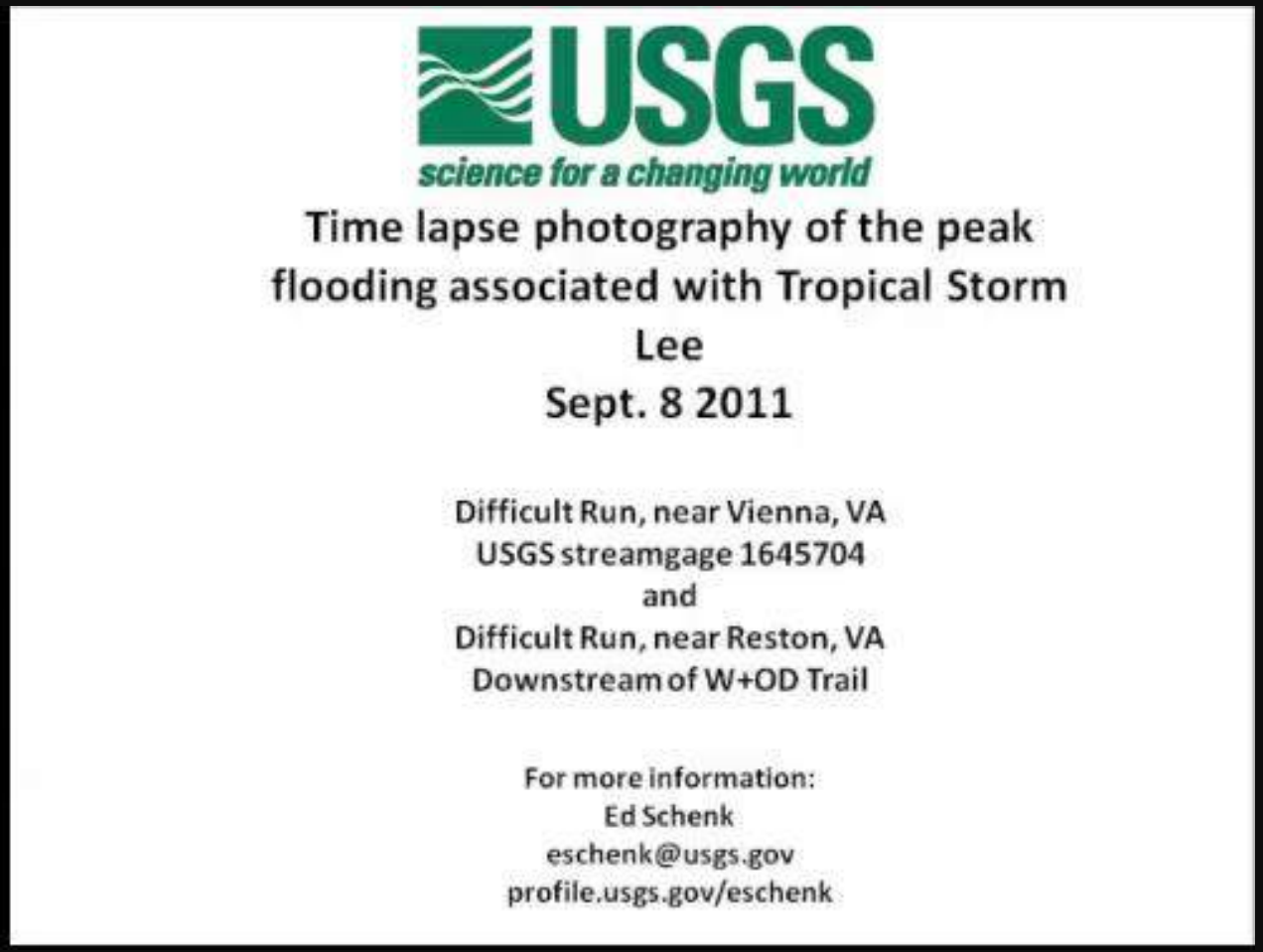
Fort Belvoir, VA	13.52”
Newington, VA	13.48”
Franconia, VA	12.56”
Reston, VA	11.97”
Waldorf, MD	11.66”
Ellicott City, MD	11.36”
Crofton, MD	10.21”
Quantico, VA	9.39”
Andrews AFB, MD	9.20”
Oakton, VA	7.21”

September 2011 flooding – Fairfax Co.

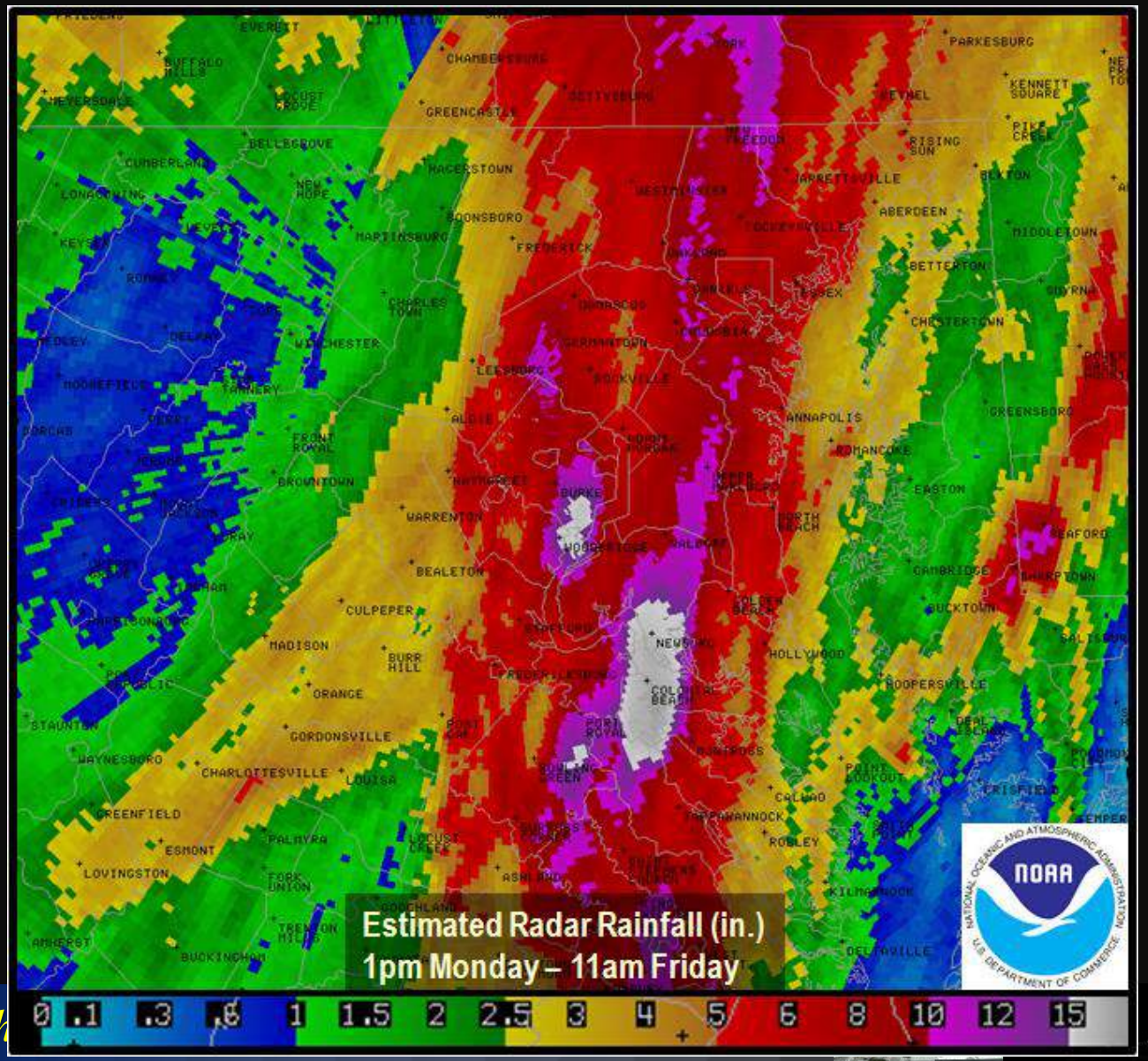
- Giles Run at Lorton Road

- Reston Park & Ride →

Lee Time Lapse



What if…


Estimated Radar Rainfall (in.)
1pm Monday – 11am Friday
0 .1 .3 .6 1 1.5 2 2.5 3 4 5 6 8 10 12 15
EVERETT
PARKESBURG
CHAMBERSBURG
GETTYSBURG
KENNETT SQUARE
GREENCASTLE
NEWARK
RISING SUN
BELLEBROVE
CUMBERLAND
HAGERSTOWN
JARRETTSVILLE
ABERDEEN
MIDDLETOWN
BOONSBORO
MARTINSBURG
FREDERICK
BETTERTON
CHESTERTOWN
CHARLES TOWN
WINCHESTER
LEESBURG
ROCKVILLE
ANNAPOLIS
GREENSBORO
FRONT ROYAL
EASTON
BROWNTOWN
WARRENTON
BURKE
BEALETON
CULPEPER
CAMBRIDGE
BUCKTOWN
MADISON
BURR HILL
HOLLYWOOD
ORANGE
GORDONSVILLE
CHARLOTTESVILLE
LOUISA
GREENFIELD
ESMONT
PALMYRA
LOVINGSTON
FORK UNION
ROBLEY
AMHERST
BUCKINGHAM
NOAA
NATIONAL WEATHER SERVICE
National Weath

Review

- Stay informed via the NWS website.

weather.gov/washington

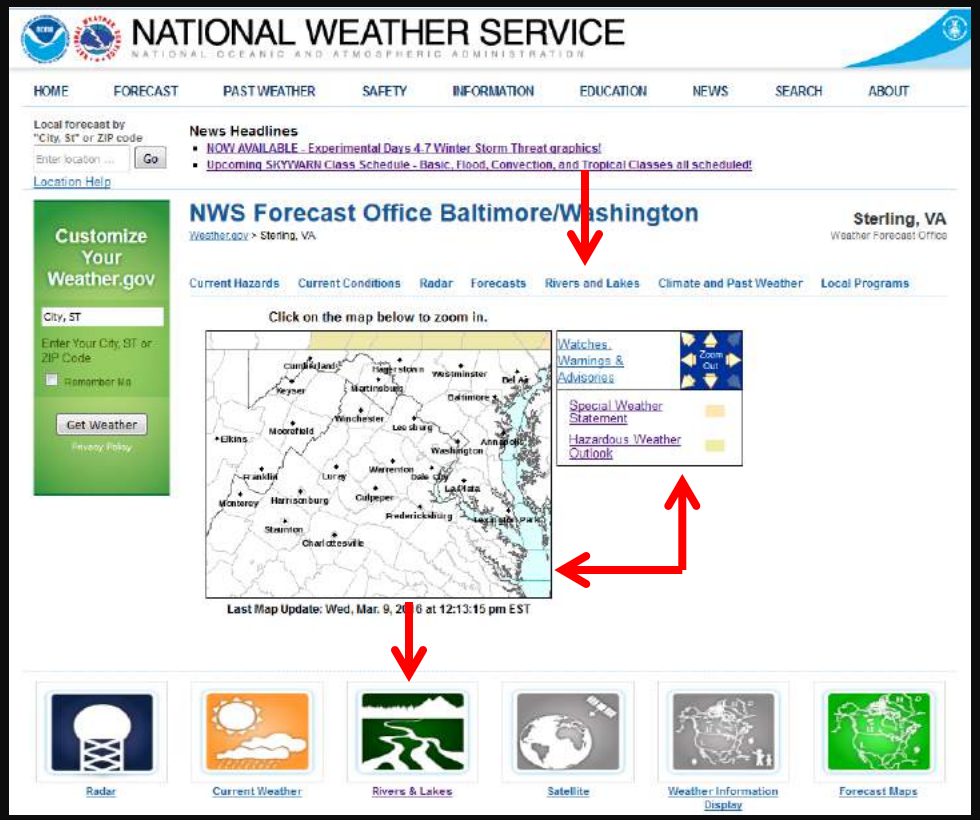
or

weather.gov/baltimore

Or use…

mobile.weather.gov

for cell phone display



Watch & Warning Review

- Hazardous Weather Outlook
  - Detail on flooding potential through day seven.
- Flood Watch
  - Conditions are favorable for flooding. Check the product for threat details (river/flash/areal)
- Flood Warning
  - Flooding is imminent or nearly certain to occur. Take action immediately!!!

Review

- Remember…FLOODING KILLS!
- When a warning has been issued for your area, or you observe signs of imminent flooding, YOU must make the decision to leave flood prone areas and seek higher ground.
- If you are driving and come to a flooded roadway, STOP! TURN AROUND AND GO ANOTHER WAY.

Review – What to Report

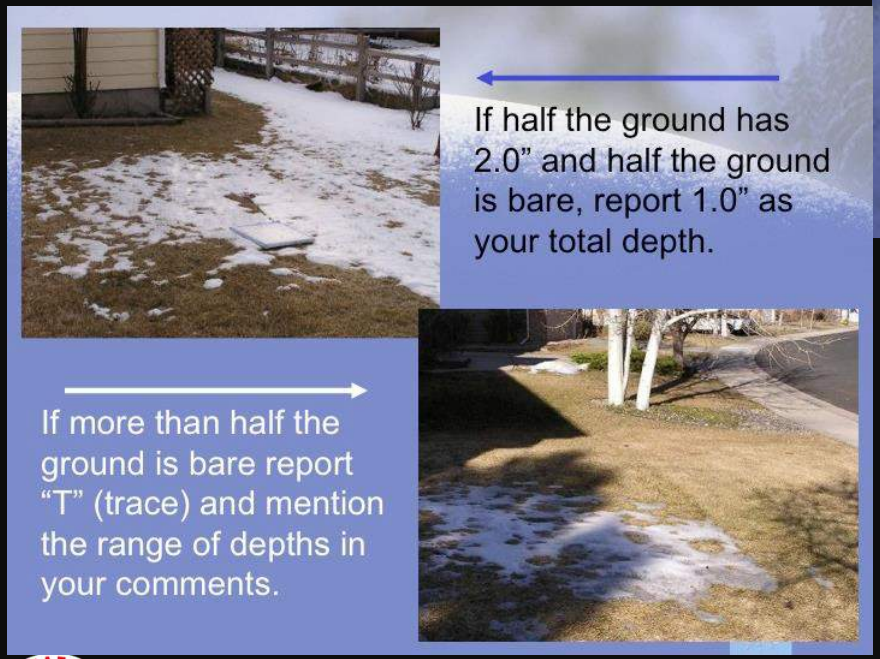
- **Heavy Rain** – measured 1” or more (we like getting periodic reports & a storm total at end)
- **Flooding & Flash Flooding** – Streams, creeks or rivers out of banks or flooding of roads from poor drainage

Terminology:

* Water over banks but not affecting anything – “bankfull/just over bankfull”
* Water affecting farmland, roads, property out of floodplain – “flooding”

Review – What to report

- **Ice Accumulation** – Any glaze on surfaces (or more)
- **Snow Accumulation** – Every 2” and a storm total, or any accumulation not reflected in the forecast



Review – How to report

- Call NWS Sterling as soon as you see something:
  (800) 253-7091 or (703) 996-2201
- You can email delayed reports or pictures to:
  LWX-Report@noaa.gov
- Contact local Emergency Management
- Amateur Radio (when activated)

- If you see storm damage after the event, let us know!
  Immediate reports are best; but no report is too late!