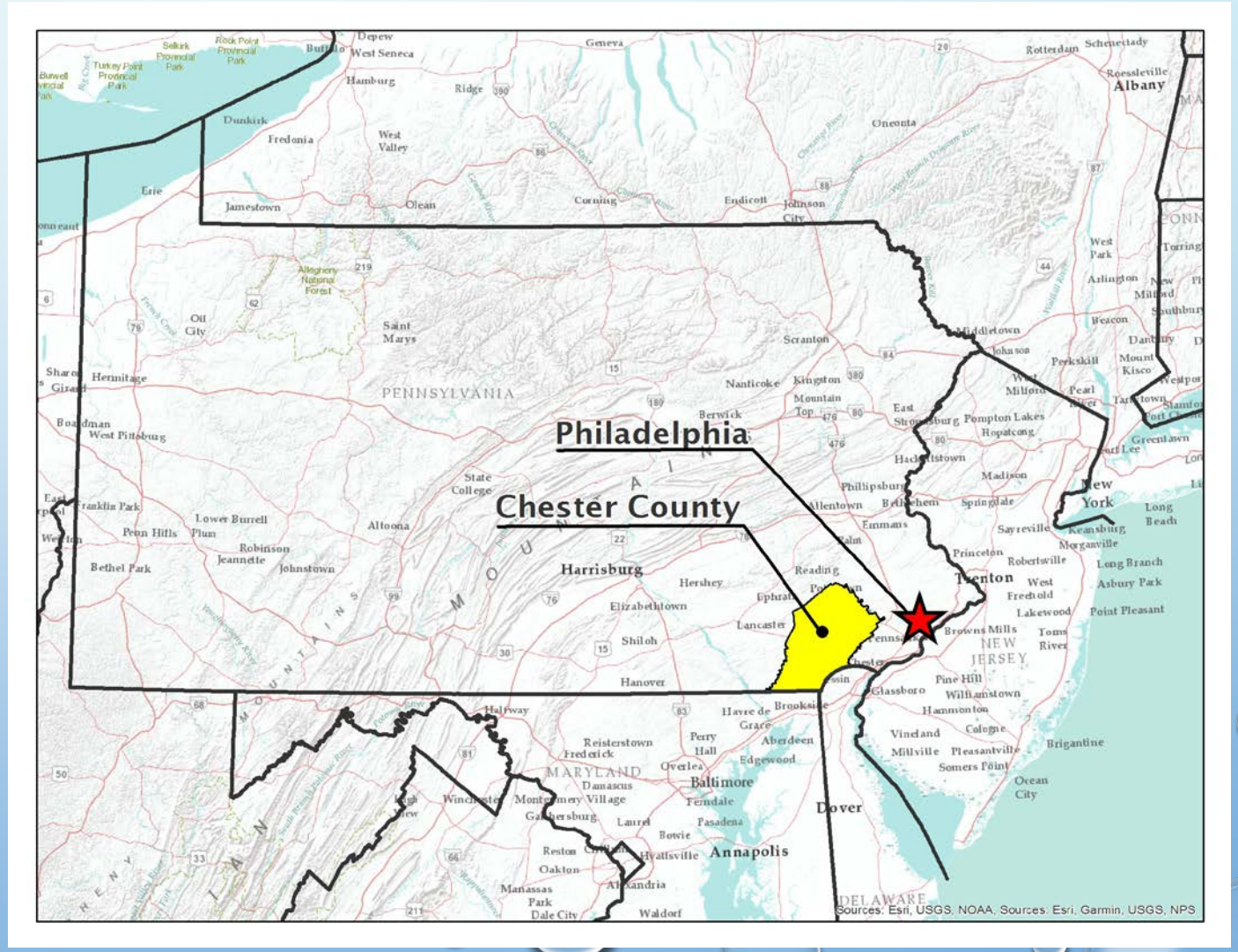
Flood Impact Forecasting Using the National Water Model

Dave Sekkes, GISP

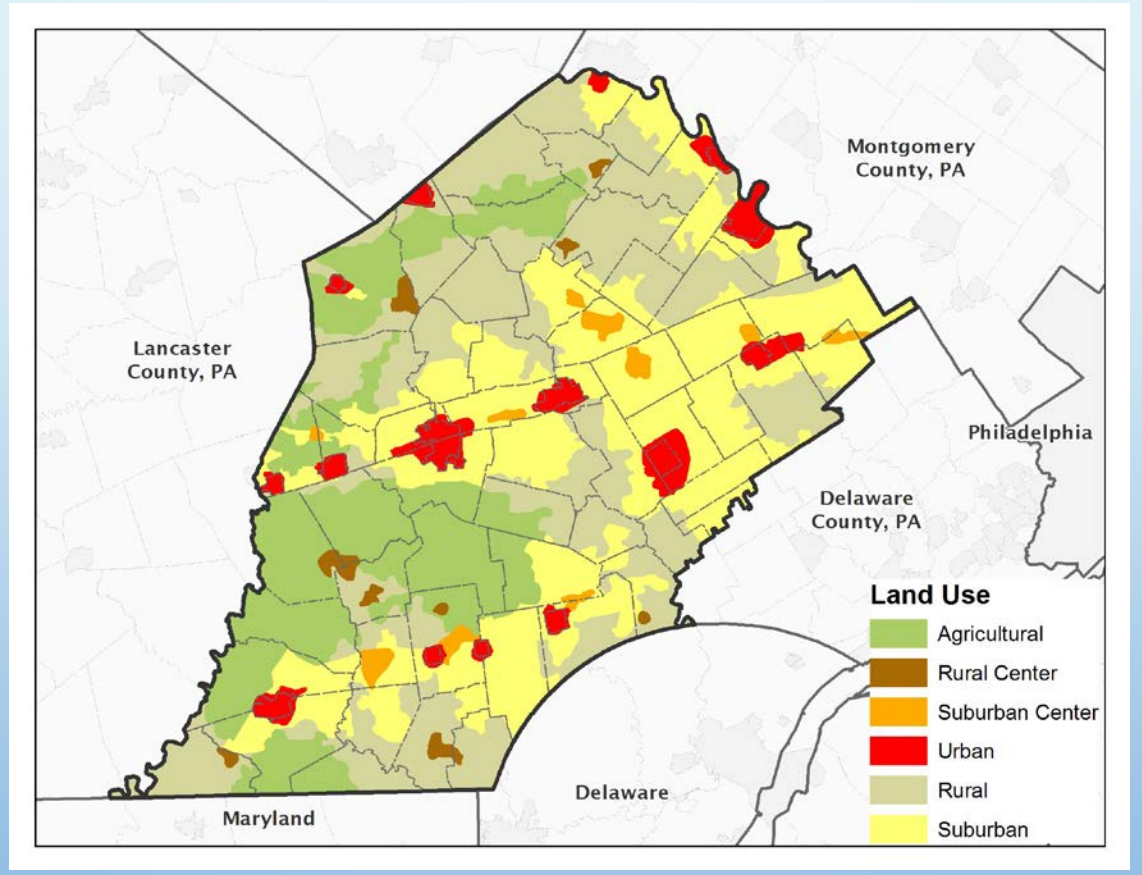
Chester County Department of Emergency Services

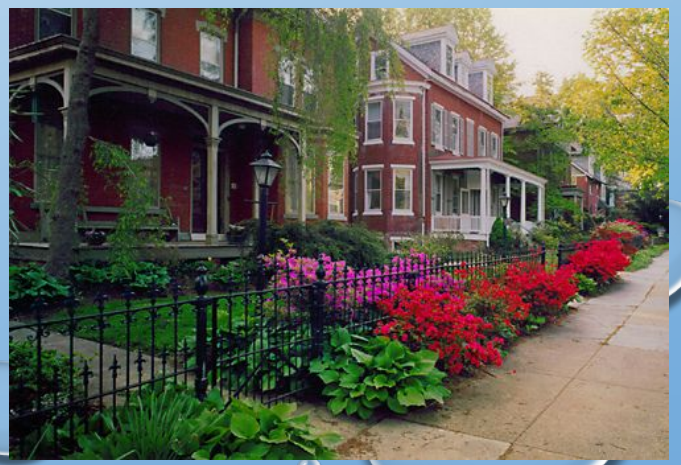
Chester County, Pennsylvania

- Suburban county of Philadelphia
- 517,000 Residents
- 73 Municipalities: 1 City, 15 Boroughs, and 57 Townships
- Southeastern PA Regional Taskforce
- Many small and medium sized creeks with rolling hills and valleys of the Piedmont Plateau

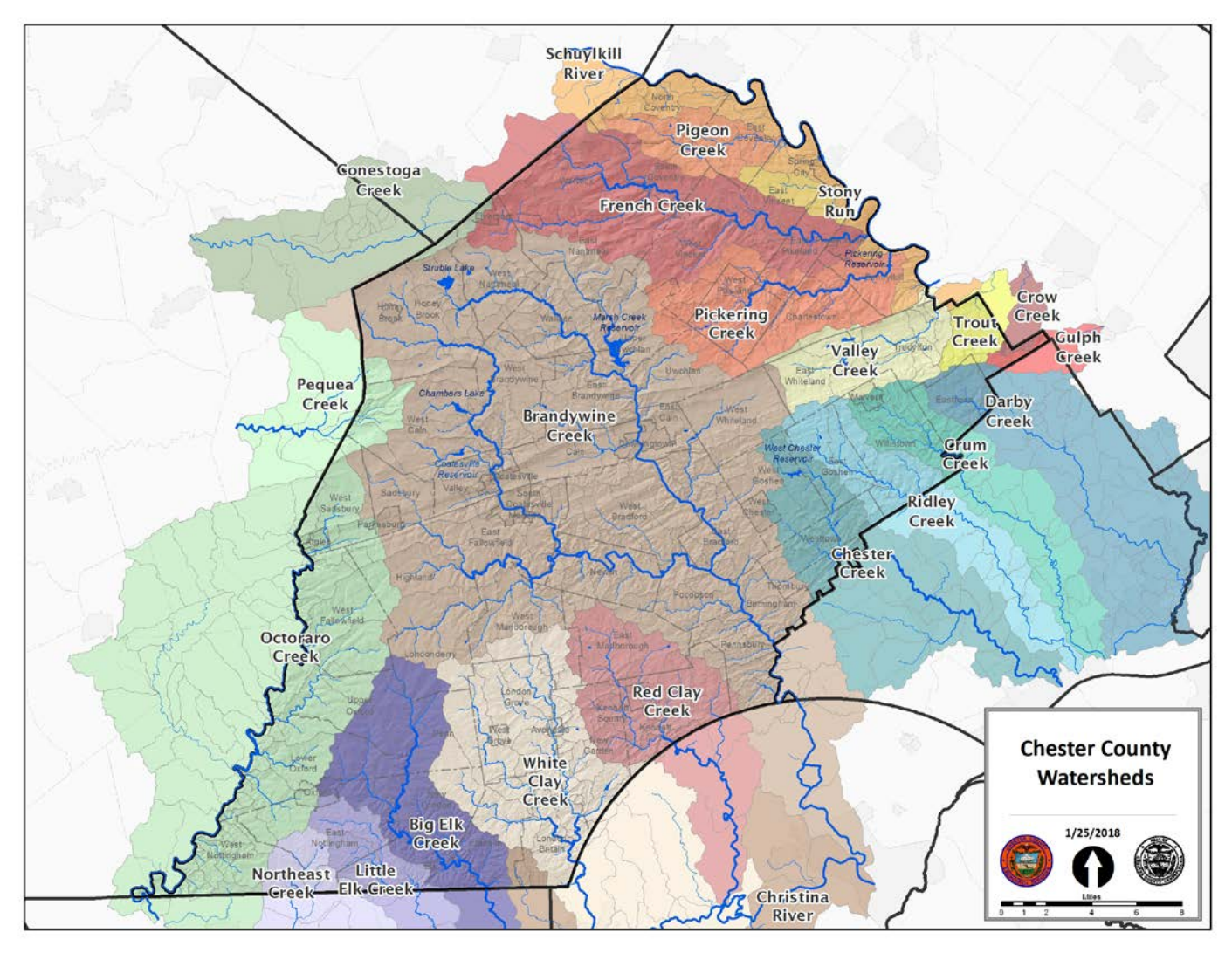


Chester County Landscape

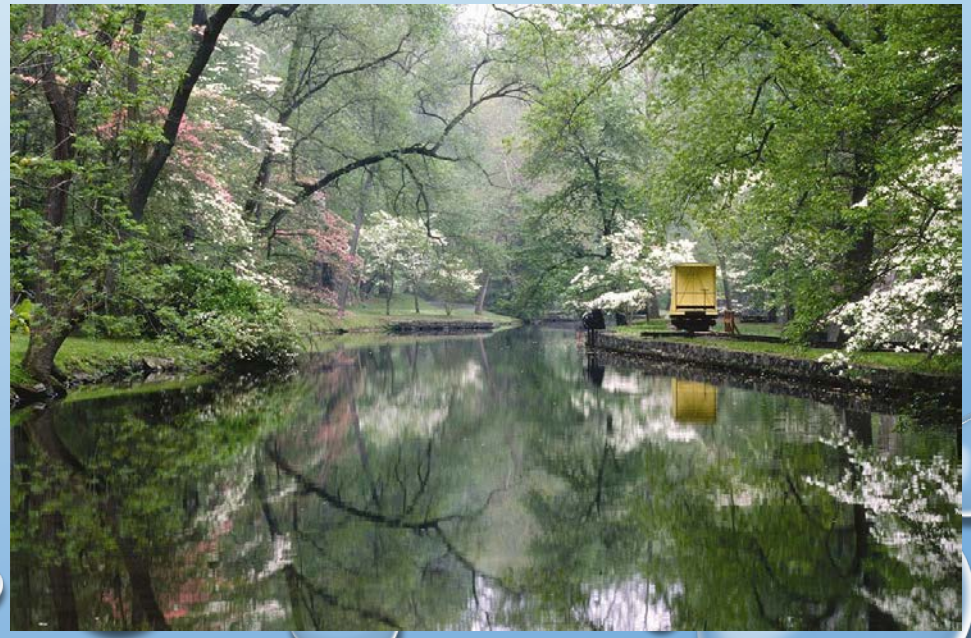




Chester County, PA Watersheds and Waterways



- Brandywine Creek is the dominant watershed in the county and has historically experienced the most severe flooding
- Brandywine Creek splits the county in two during severe flood events
- Schuylkill River to the north has a large upstream watershed that creates severe flooding

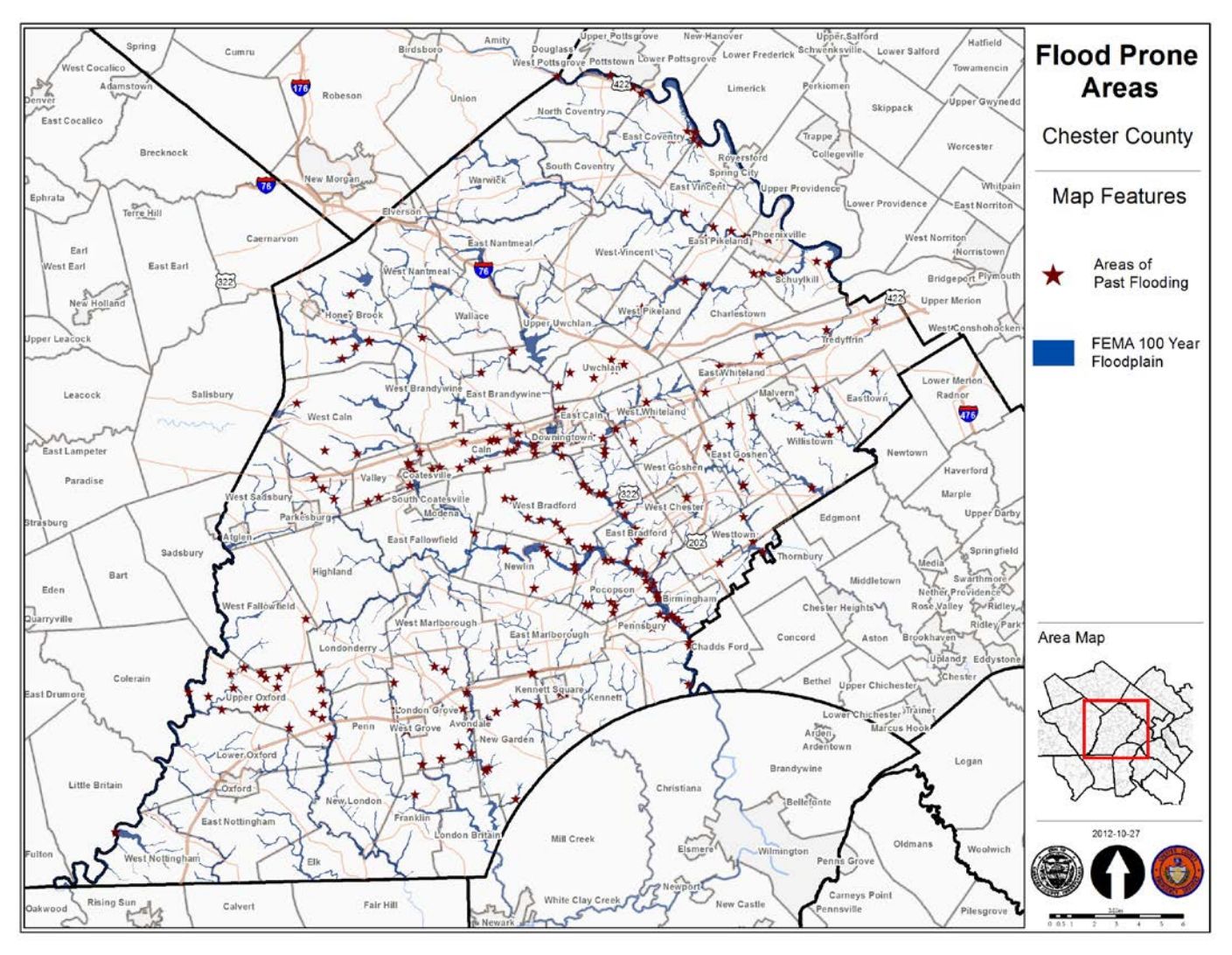


Emergency Operations Center

- The Chester County Emergency Operations Center (EOC) acts as an information portal to provide situational awareness and a common operational picture for responders and key partners
- Acts coordination center between agencies
- The County operates very few deployable resources

Early Situational Awareness Products

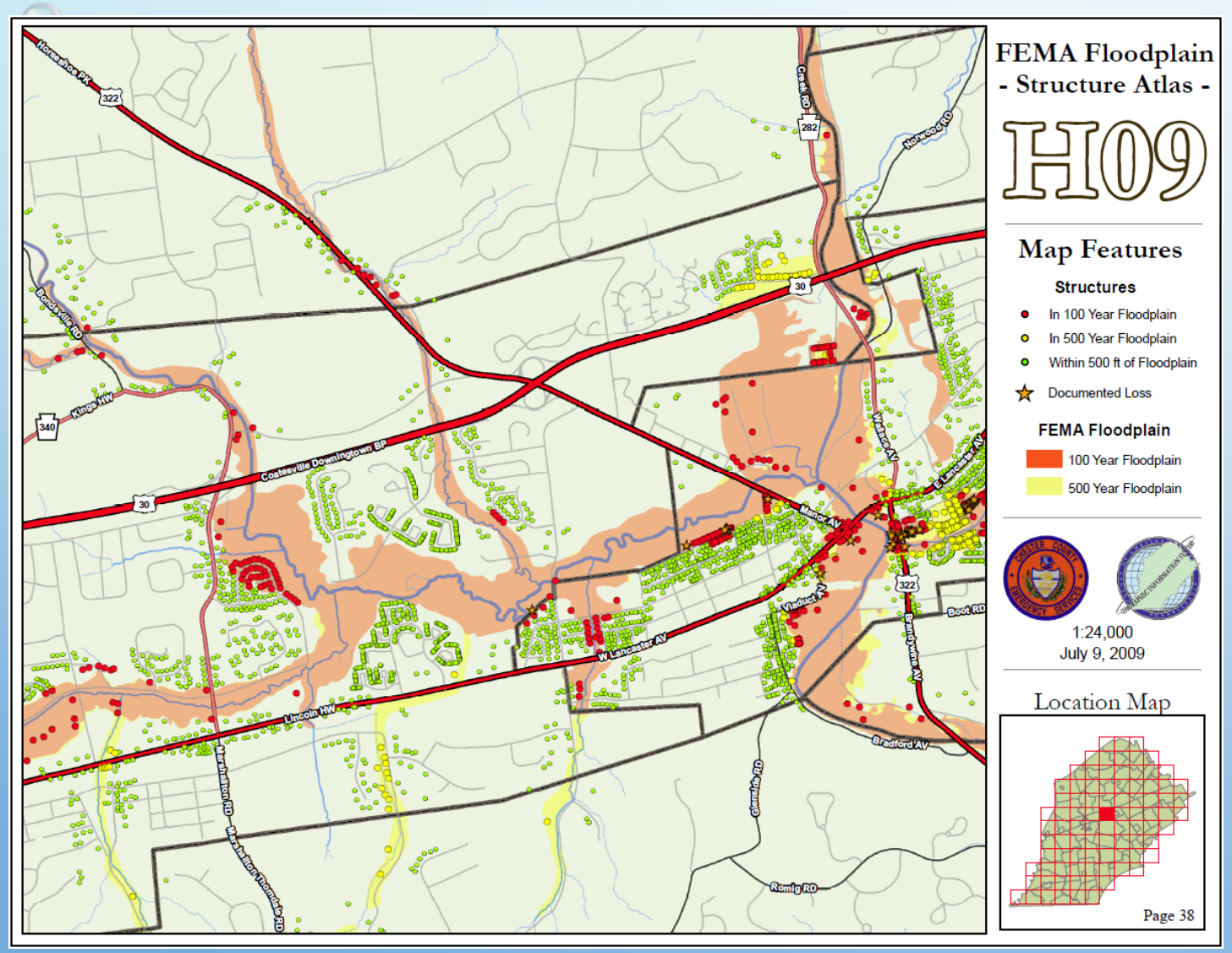
Mapping Historic Flood Damage Locations



The first attempt to quantify the flooding problem was to map historic flood locations from:

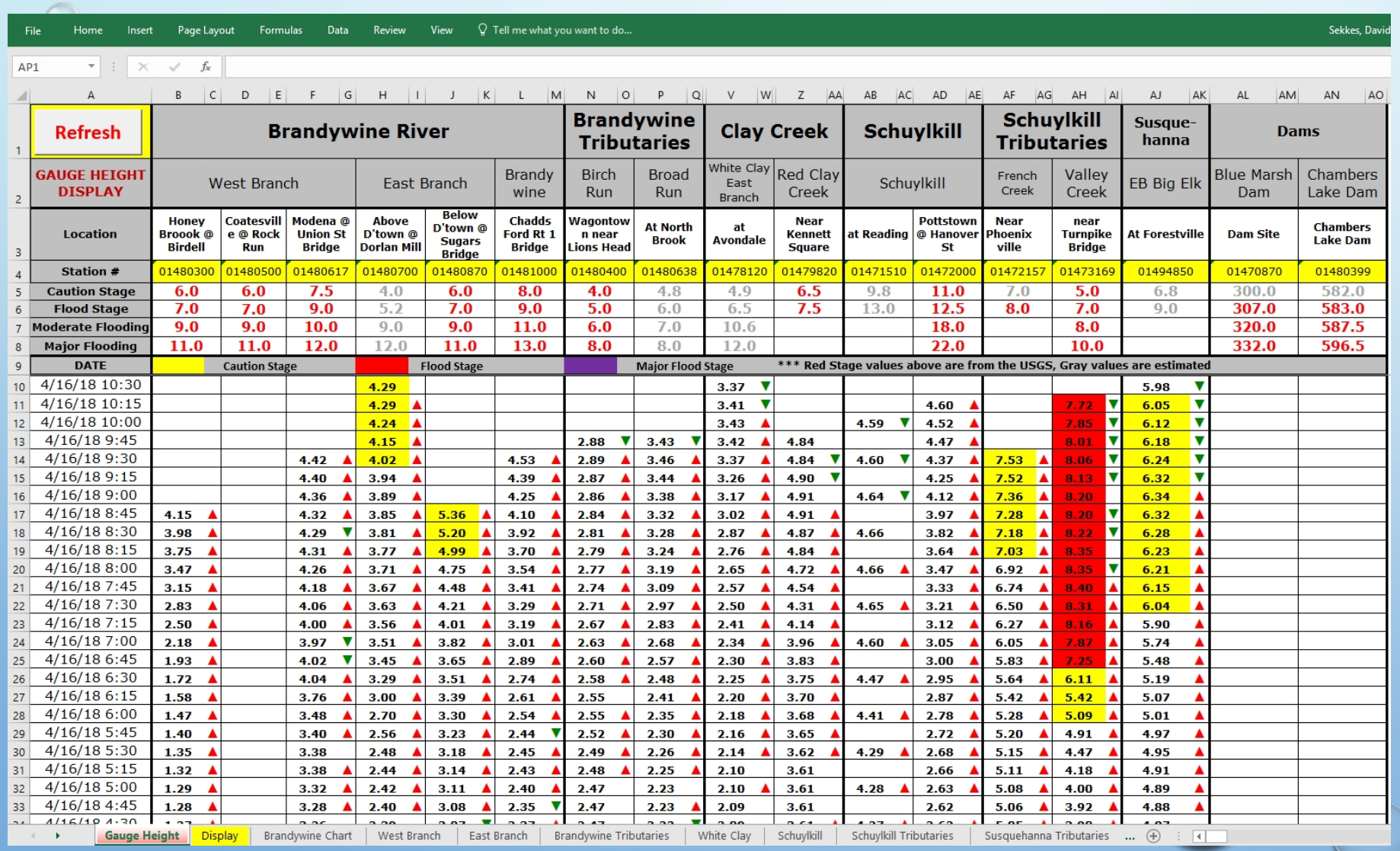
- Damage assessment reports
- Available newspaper articles
- Photos
- Firsthand accounts from the community

Floodplain Structure Atlas



- In 2009 every structure within 500 feet of the floodplain was mapped.
- This atlas was provided to local Emergency Management Coordinators and included in the Emergency Operations Plan Flood Annex.
- Most comprehensive assessment of the flood hazard vulnerability to date.

Stream Gauge Monitoring in Excel



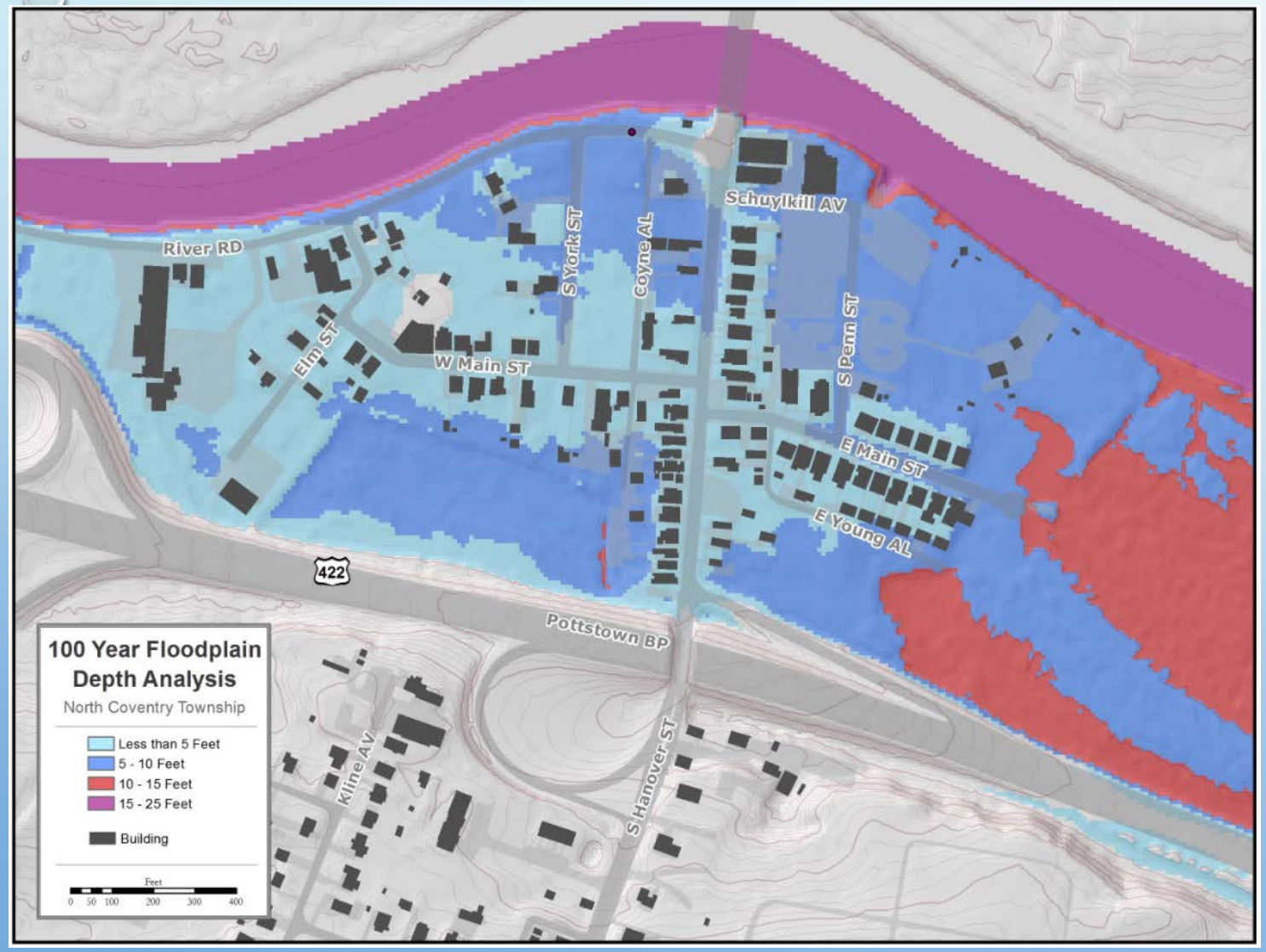
Refresh	Brandywine River						Brandywine Tributaries		Clay Creek		Schuylkill		Schuylkill Tributaries		Susque-hanna	Dams	
GAUGE HEIGHT DISPLAY	West Branch			East Branch		Brandy wine	Birch Run	Broad Run	White Clay East Branch	Red Clay Creek	Schuylkill		French Creek	Valley Creek	EB Big Elk	Blue Marsh Dam	Chambers Lake Dam
Location	Honey Brook @ Birdell	Coatesville @ Rock Run	Modena @ Union St Bridge	Above D'town @ Dorlan Mill	Below D'town @ Sugars Bridge	Chadds Ford Rt 1 Bridge	Wagontown near Lions Head	At North Brook	at Avondale	Near Kennett Square	at Reading	Pottstown @ Hanover St	Near Phoenixville	near Turnpike Bridge	At Forestville	Dam Site	Chambers Lake Dam
Station #	01480300	01480500	01480617	01480700	01480870	01481000	01480400	01480638	01478120	01479820	01471510	01472000	01472157	01473169	01494850	01470870	01480399
Caution Stage	6.0	6.0	7.5	4.0	6.0	8.0	4.0	4.8	4.9	6.5	9.8	11.0	7.0	5.0	6.8	300.0	582.0
Flood Stage	7.0	7.0	9.0	5.2	7.0	9.0	5.0	6.0	6.5	7.5	13.0	12.5	8.0	7.0	9.0	307.0	583.0
Moderate Flooding	9.0	9.0	10.0	9.0	9.0	11.0	6.0	7.0	10.6			18.0		8.0		320.0	587.5
Major Flooding	11.0	11.0	12.0	12.0	11.0	13.0	8.0	8.0	12.0			22.0		10.0		332.0	596.5
DATE	Caution Stage			Flood Stage			Major Flood Stage		*** Red Stage values above are from the USGS, Gray values are estimated								
4/16/18 10:30				4.29					3.37 ▼						5.98 ▼		
4/16/18 10:15				4.29 ▲					3.41 ▼			4.60 ▲		7.72 ▼	6.05 ▼		
4/16/18 10:00				4.24 ▲					3.43 ▲		4.59 ▼	4.52 ▲		7.85 ▼	6.12 ▼		
4/16/18 9:45				4.15 ▲			2.88 ▼	3.43 ▼	3.42 ▲	4.84		4.47 ▲		8.01 ▼	6.18 ▼		
4/16/18 9:30			4.42 ▲	4.02 ▲		4.53 ▲	2.89 ▲	3.46 ▲	3.37 ▲	4.84 ▼	4.60 ▼	4.37 ▲	7.53 ▲	8.06 ▼	6.24 ▼		
4/16/18 9:15			4.40 ▲	3.94 ▲		4.39 ▲	2.87 ▲	3.44 ▲	3.26 ▲	4.90 ▼		4.25 ▲	7.52 ▲	8.13 ▼	6.32 ▼		
4/16/18 9:00			4.36 ▲	3.89 ▲		4.25 ▲	2.86 ▲	3.38 ▲	3.17 ▲	4.91	4.64 ▼	4.12 ▲	7.36 ▲	8.20	6.34 ▲		
4/16/18 8:45	4.15 ▲		4.32 ▲	3.85 ▲	5.36 ▲	4.10 ▲	2.84 ▲	3.32 ▲	3.02 ▲	4.91 ▲		3.97 ▲	7.28 ▲	8.20 ▼	6.32 ▲		
4/16/18 8:30	3.98 ▲		4.29 ▼	3.81 ▲	5.20 ▲	3.92 ▲	2.81 ▲	3.28 ▲	2.87 ▲	4.87 ▲	4.66	3.82 ▲	7.18 ▲	8.22 ▼	6.28 ▲		
4/16/18 8:15	3.75 ▲		4.31 ▲	3.77 ▲	4.99 ▲	3.70 ▲	2.79 ▲	3.24 ▲	2.76 ▲	4.84 ▲		3.64 ▲	7.03 ▲	8.35	6.23 ▲		
4/16/18 8:00	3.47 ▲		4.26 ▲	3.71 ▲	4.75 ▲	3.54 ▲	2.77 ▲	3.19 ▲	2.65 ▲	4.72 ▲	4.66 ▲	3.47 ▲	6.92 ▲	8.35 ▼	6.21 ▲		
4/16/18 7:45	3.15 ▲		4.18 ▲	3.67 ▲	4.48 ▲	3.41 ▲	2.74 ▲	3.09 ▲	2.57 ▲	4.54 ▲		3.33 ▲	6.74 ▲	8.40 ▲	6.15 ▲		
4/16/18 7:30	2.83 ▲		4.06 ▲	3.63 ▲	4.21 ▲	3.29 ▲	2.71 ▲	2.97 ▲	2.50 ▲	4.31 ▲	4.65 ▲	3.21 ▲	6.50 ▲	8.31 ▲	6.04 ▲		
4/16/18 7:15	2.50 ▲		4.00 ▲	3.56 ▲	4.01 ▲	3.19 ▲	2.67 ▲	2.83 ▲	2.41 ▲	4.14 ▲		3.12 ▲	6.27 ▲	8.16 ▲	5.90 ▲		
4/16/18 7:00	2.18 ▲		3.97 ▼	3.51 ▲	3.82 ▲	3.01 ▲	2.63 ▲	2.68 ▲	2.34 ▲	3.96 ▲	4.60 ▲	3.05 ▲	6.05 ▲	7.87 ▲	5.74 ▲		
4/16/18 6:45	1.93 ▲		4.02 ▼	3.45 ▲	3.65 ▲	2.89 ▲	2.60 ▲	2.57 ▲	2.30 ▲	3.83 ▲		3.00 ▲	5.83 ▲	7.25 ▲	5.48 ▲		
4/16/18 6:30	1.72 ▲		4.04 ▲	3.29 ▲	3.51 ▲	2.74 ▲	2.58 ▲	2.48 ▲	2.25 ▲	3.75 ▲	4.47 ▲	2.95 ▲	5.64 ▲	6.11 ▲	5.19 ▲		
4/16/18 6:15	1.58 ▲		3.76 ▲	3.00 ▲	3.39 ▲	2.61 ▲	2.55	2.41 ▲	2.20 ▲	3.70 ▲		2.87 ▲	5.42 ▲	5.42 ▲	5.07 ▲		
4/16/18 6:00	1.47 ▲		3.48 ▲	2.70 ▲	3.30 ▲	2.54 ▲	2.55 ▲	2.35 ▲	2.18 ▲	3.68 ▲	4.41 ▲	2.78 ▲	5.28 ▲	5.09 ▲	5.01 ▲		
4/16/18 5:45	1.40 ▲		3.40 ▲	2.56 ▲	3.23 ▲	2.44 ▼	2.52 ▲	2.30 ▲	2.16 ▲	3.65 ▲		2.72 ▲	5.20 ▲	4.91 ▲	4.97 ▲		
4/16/18 5:30	1.35 ▲		3.38	2.48 ▲	3.18 ▲	2.45 ▲	2.49 ▲	2.26 ▲	2.14 ▲	3.62 ▲	4.29 ▲	2.68 ▲	5.15 ▲	4.47 ▲	4.95 ▲		
4/16/18 5:15	1.32 ▲		3.38 ▲	2.44 ▲	3.14 ▲	2.43 ▲	2.48 ▲	2.25 ▲	2.10	3.61		2.66 ▲	5.11 ▲	4.18 ▲	4.91 ▲		
4/16/18 5:00	1.29 ▲		3.32 ▲	2.42 ▲	3.11 ▲	2.40 ▲	2.47	2.23	2.10 ▲	3.61	4.28 ▲	2.63 ▲	5.08 ▲	4.00 ▲	4.89 ▲		
4/16/18 4:45	1.28 ▲		3.28 ▲	2.40 ▲	3.08 ▲	2.35 ▼	2.47	2.23 ▲	2.09	3.61		2.62	5.06 ▲	3.92 ▲	4.88 ▲		

Gauge Height | Display | Brandywine Chart | West Branch | East Branch | Brandywine Tributaries | White Clay | Schuylkill | Schuylkill Tributaries | Susquehanna Tributaries

Excel Spreadsheet with VBA code to read and visualize the most recent stream gauge data on problem streams

- This still runs in the EOC today
- XML feed that updates the values every 10 minutes
- Caution, Flood, and Major Flood stages are highlighted
- Red and green arrows show trends from the last value

Early Flood Severity Analysis



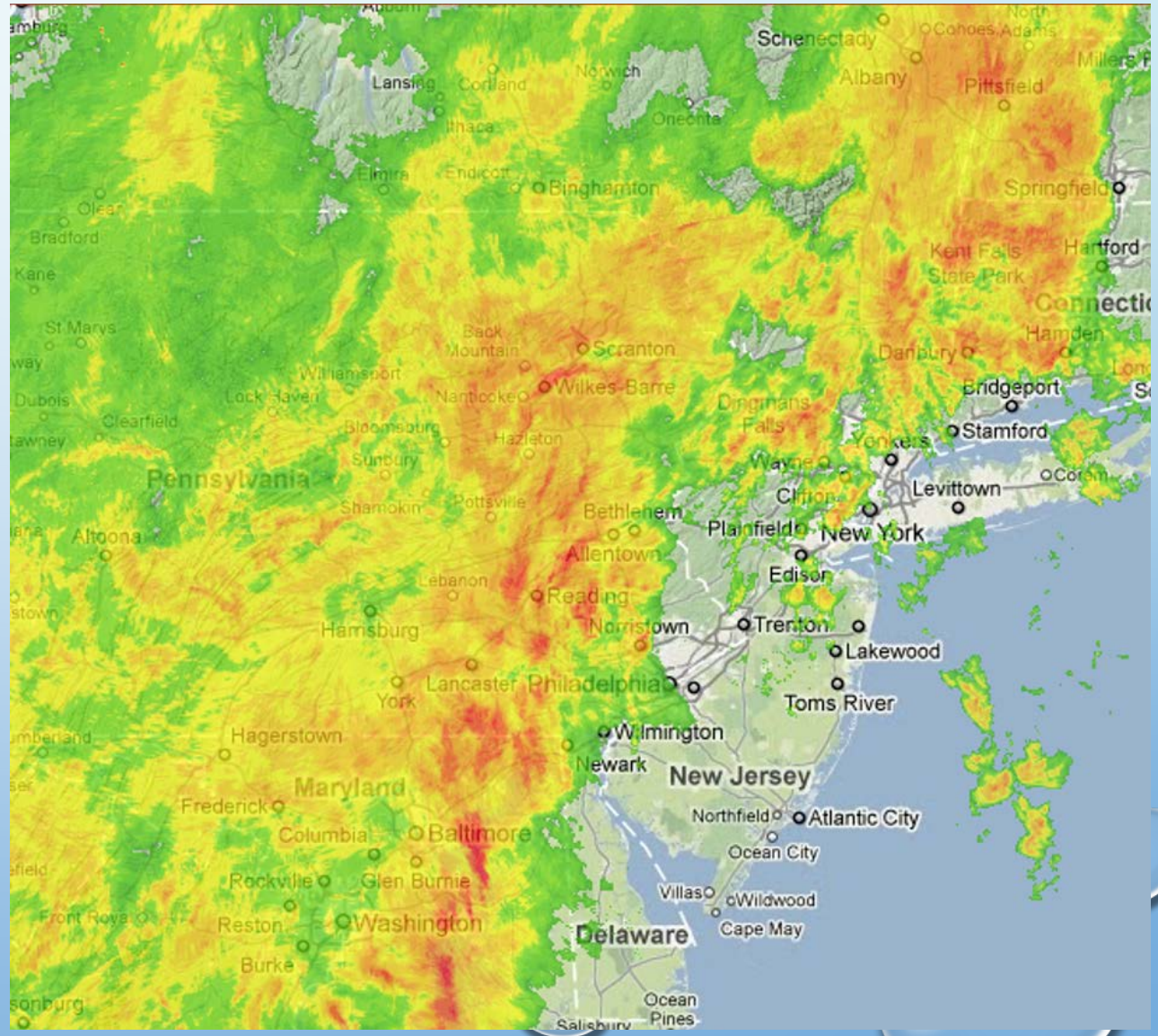
- In preparation for an anticipated flood event, the 100 year floodplain was used as a base level flood extent.
- Used a new DEM and building footprints to locate who would be most impacted by the anticipated flooding for known problem areas.

Recent History of Flooding in Chester County

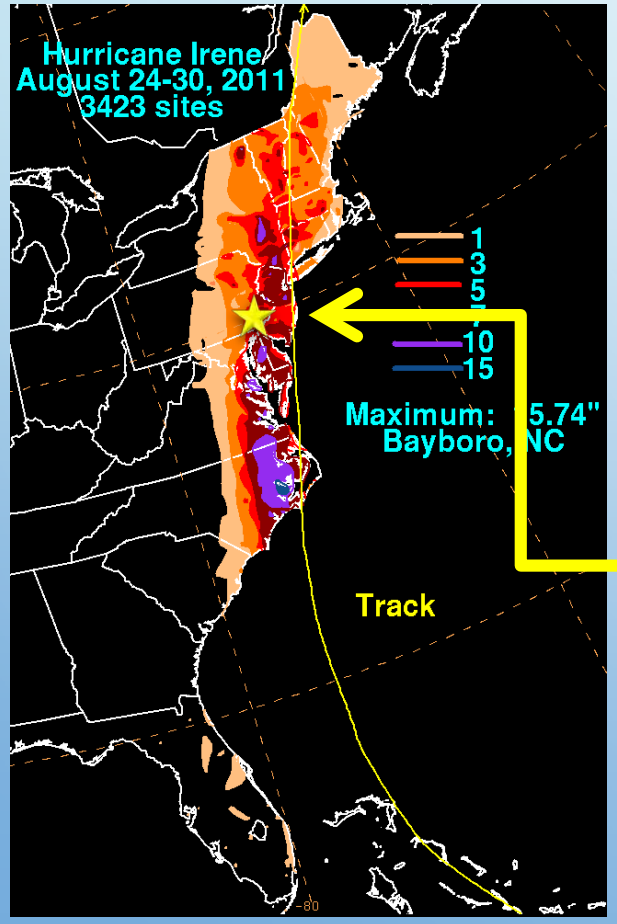
Recent Major Countywide Flooding Events

- June 1972 Hurricane Agnes (The “Big One”)
- June 2001 Hurricane Allison
- Sept 2003 Hurricane Isabel
- Sept 2004 Hurricane Ivan
- June 2007 Hurricane Barry
- Sept 2008 Tropical Storm Hanna
- September 2010 Tropical Storm Nicole
- August 2011 Hurricane Irene
- September 2011 Tropical Storm Lee (The other “Big One”)
- October 2012 Hurricane Sandy
- April 2014 Long Term Rain Event

…Chester County is overdue!



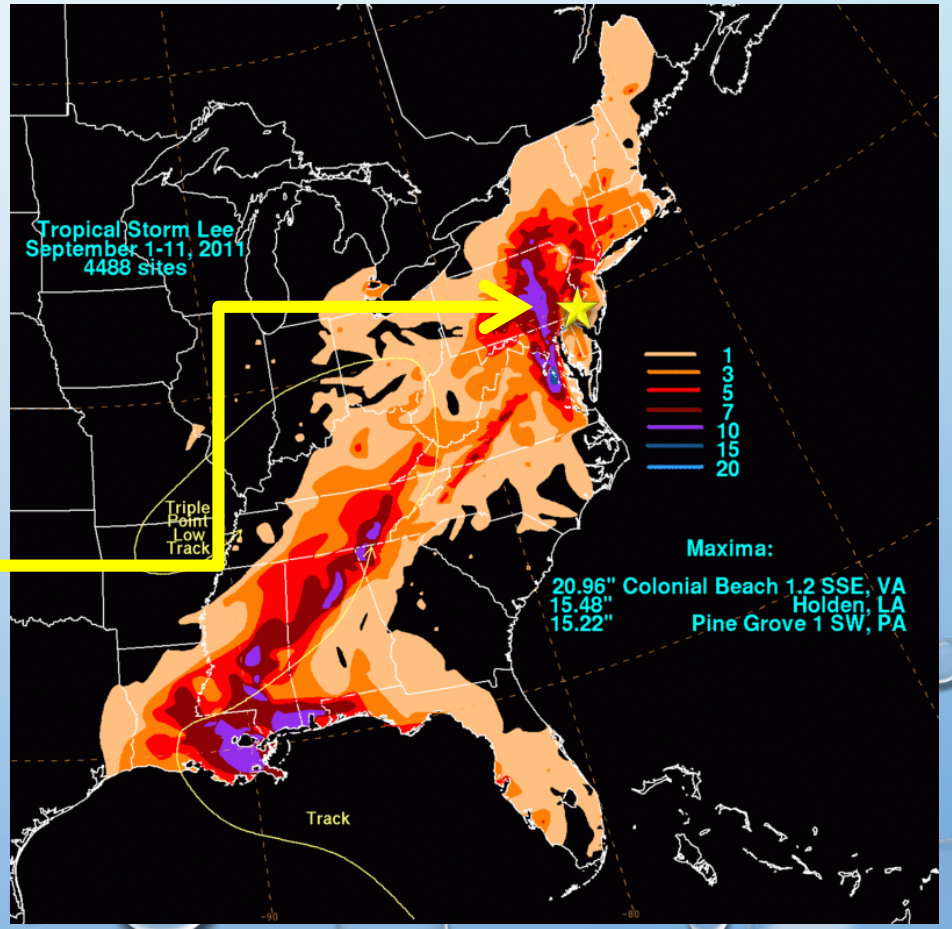
Hurricane Irene & Tropical Storm Lee
Aug-Sept 2011



Two major storms impacted Chester County about a week apart.

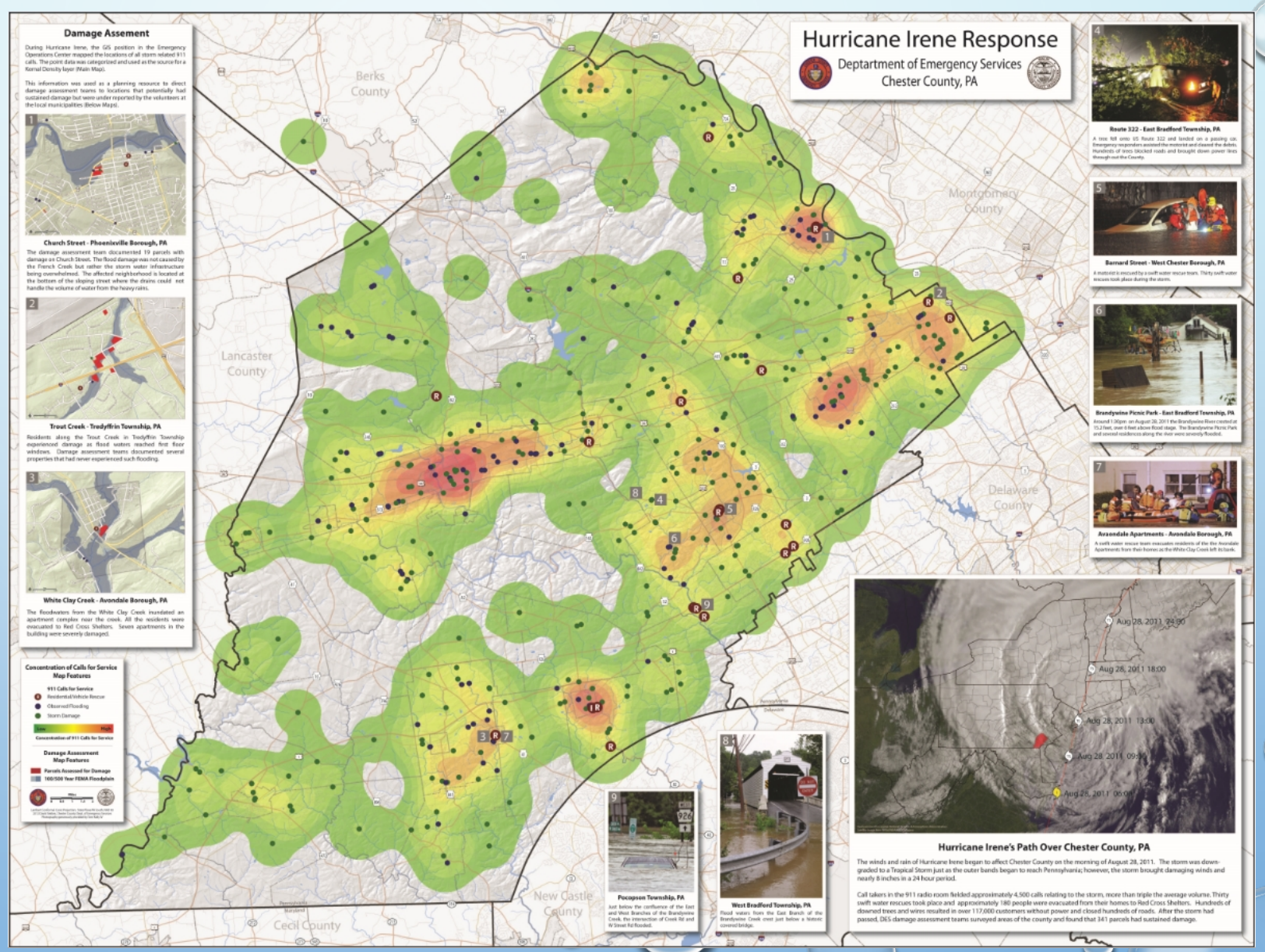
This lead to widespread flooding that effectively cut the county in two.

Chester County, PA

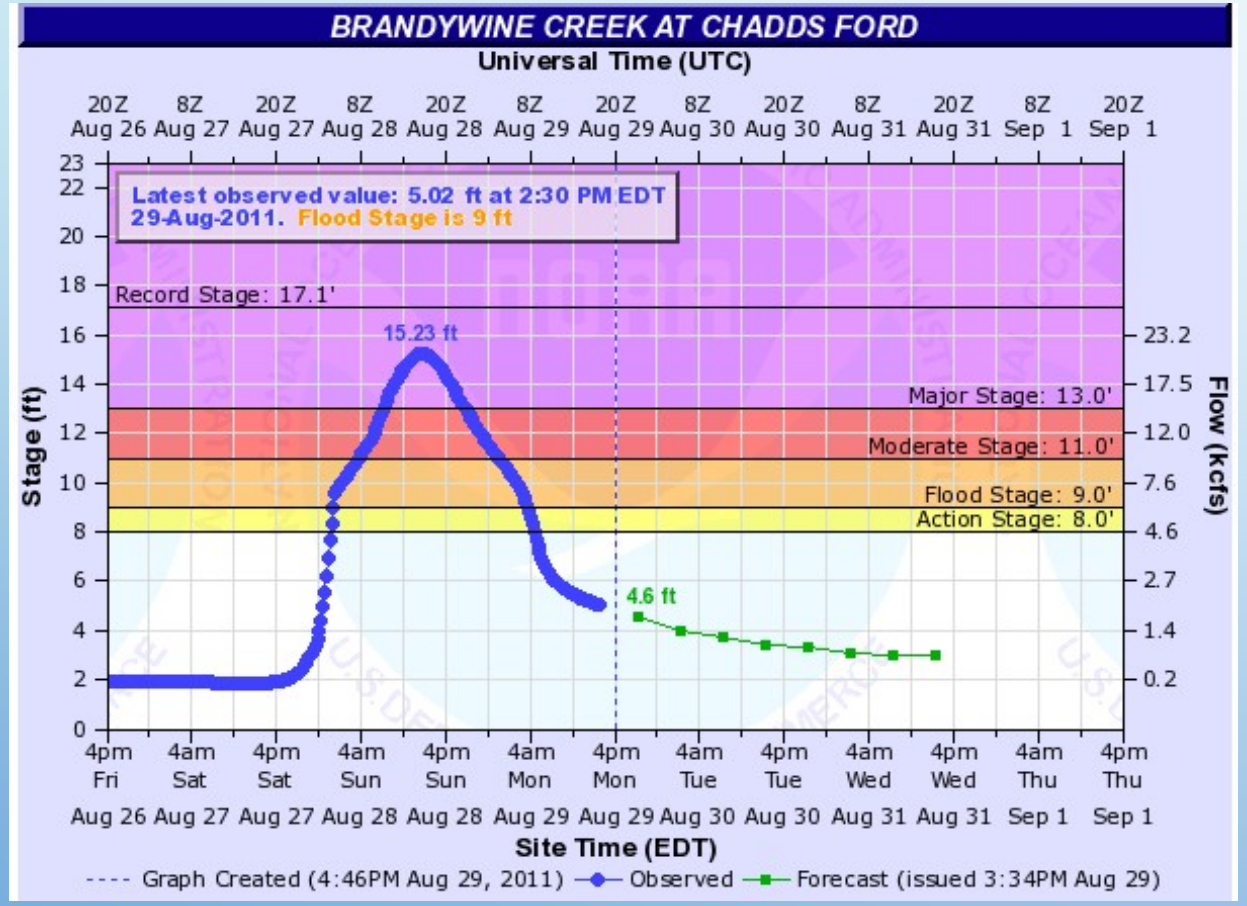


Hurricane Irene Response

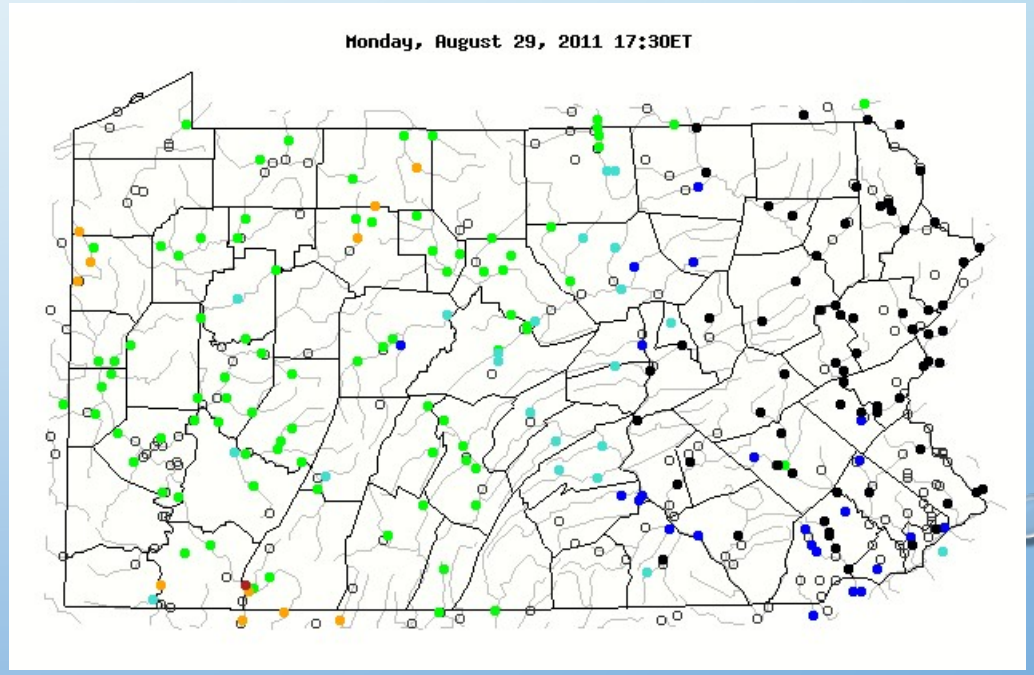
- 4,500 calls for service relating to the storm – triple the daily average
- 30 swift water rescues
- 180 residents evacuated from their homes to shelters
- 117,000 customers without power, about 50% of the entire County
- 341 buildings with significant damage



Near Record Flooding



- Brandywine Creek crested at 15.2 feet, less than 2 feet under the all-time record
- Eastern half of PA experienced widespread flooding



Hurricane Irene & Tropical Storm Lee
Aug-Sept 2011

Bobby's White Whale

This event led to Bobby Kagel, the Emergency Management Deputy Director in 2011, to search for his "White Whale":

Predictive Flood Impact Forecasting!

Emergency Planning for Flood Events

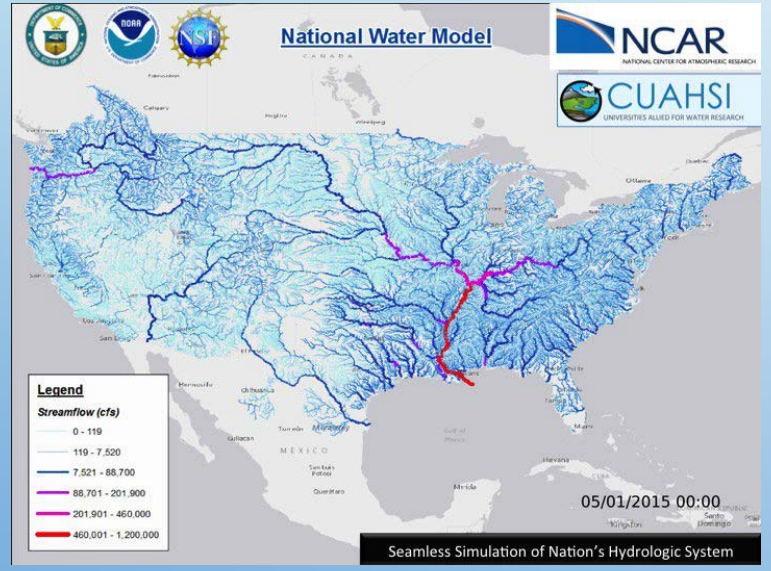
Emergency Management needs to answer three fundamental questions to plan for major flood events:

WHEN will flooding occur
WHERE will flooding occur
WHO will be impacted by flooding

Flood Impact Forecasting

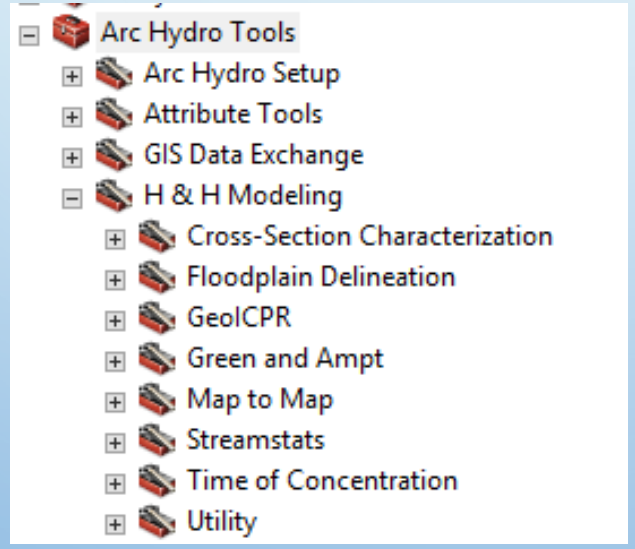
WHEN:

National Water Model



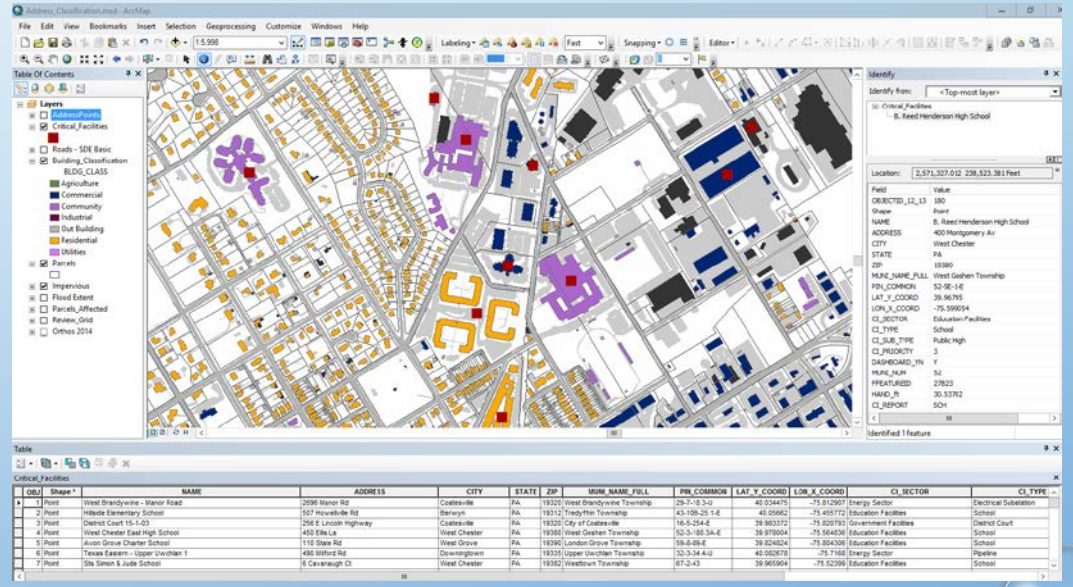
WHERE:

Arc Hydro Tools

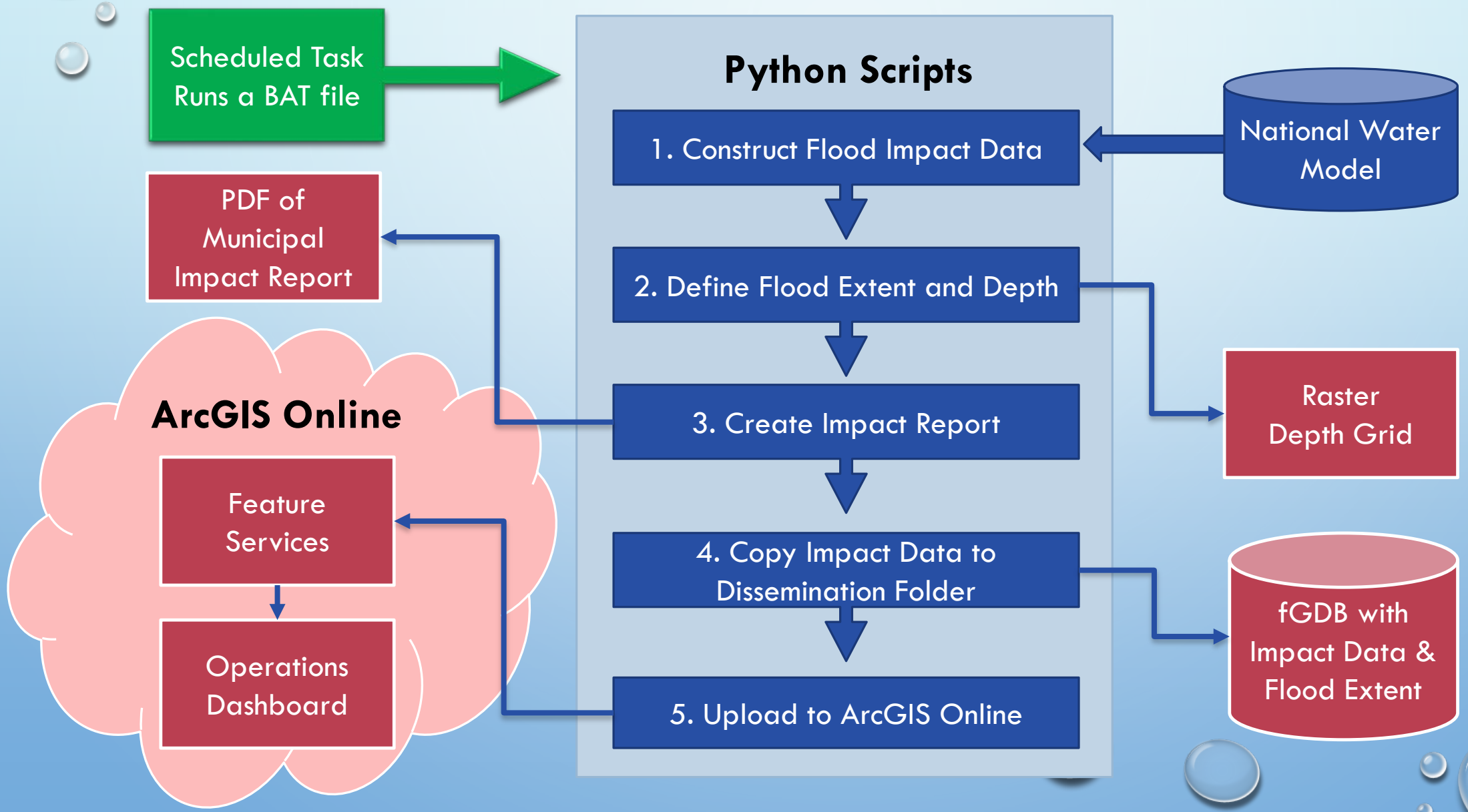


WHO:

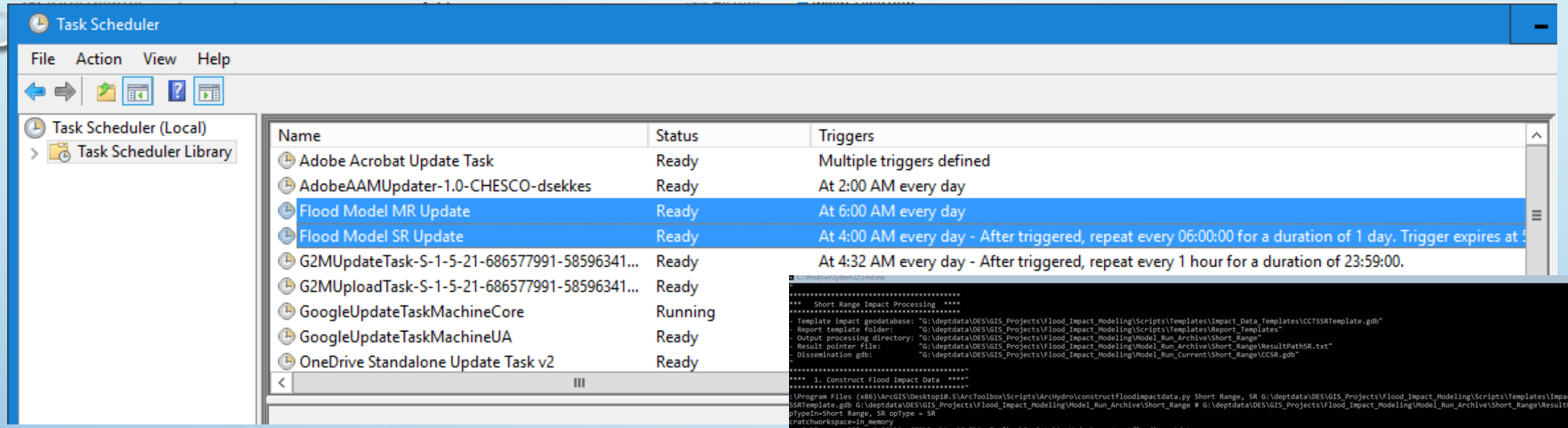
Local County GIS Data

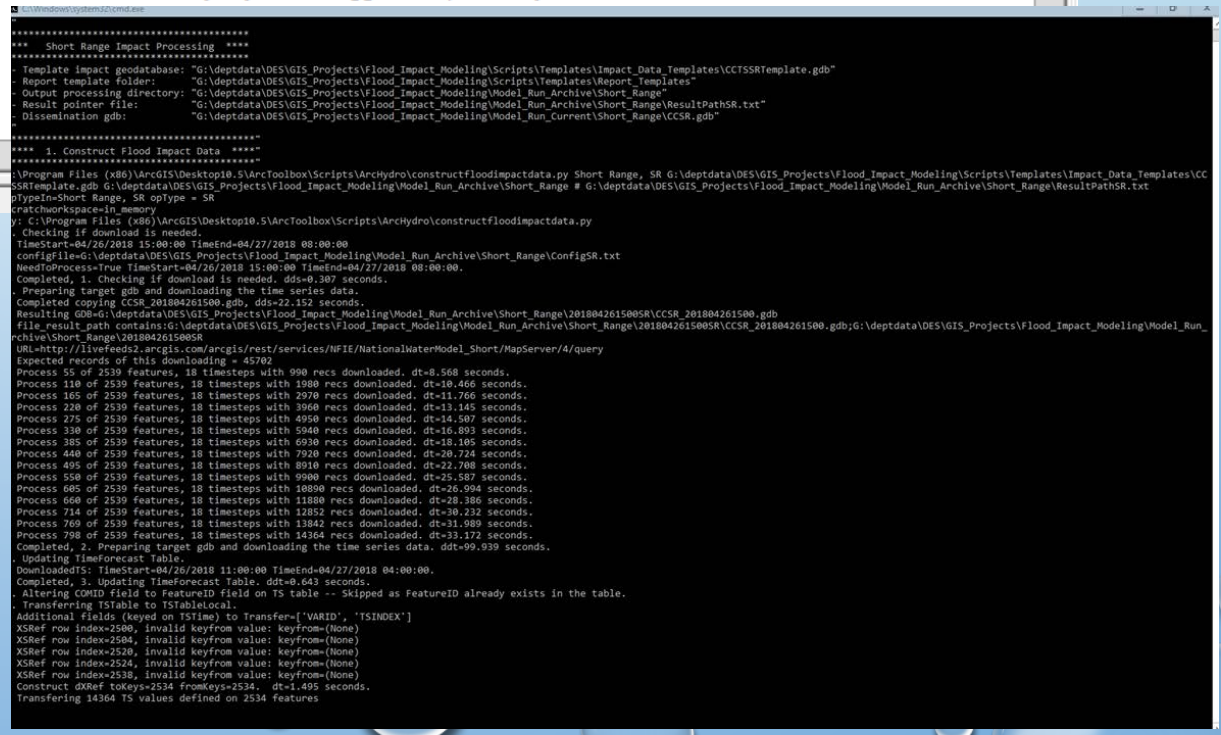


Flood Impact Forecasting Process



Scheduled Task





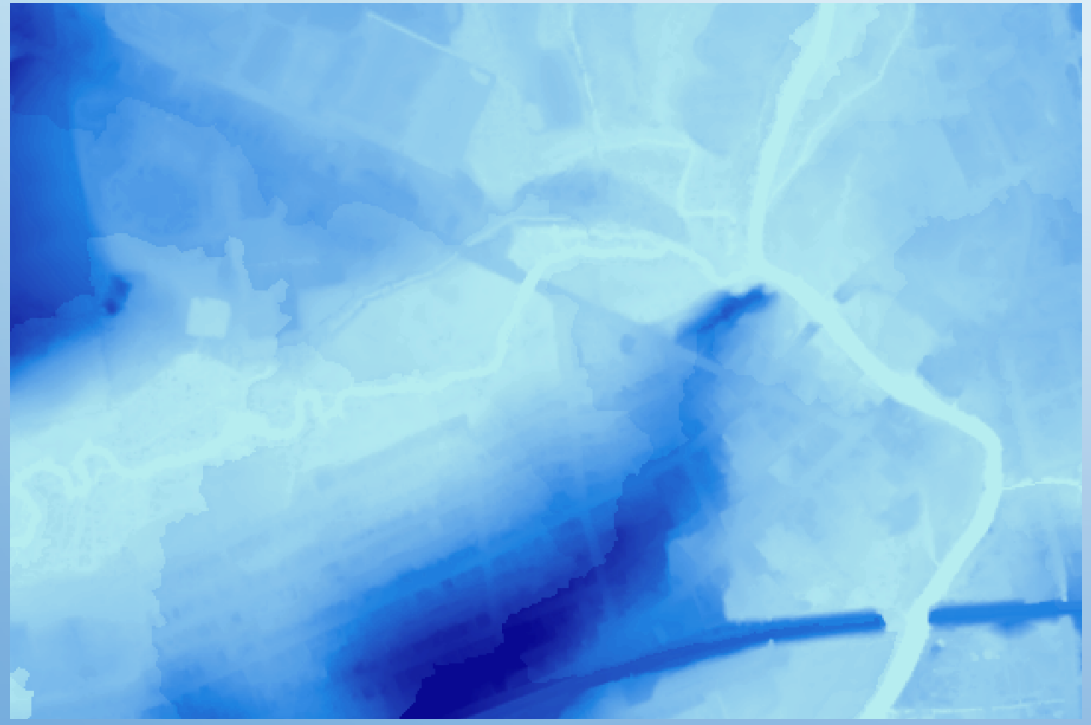
- Runs off local PC. No high-end hardware requirements
- Short Range Model runs 4 times a day beginning at 6am
- Mid Range Model runs once a day at 4am

WHEN: National Water Model Forecast

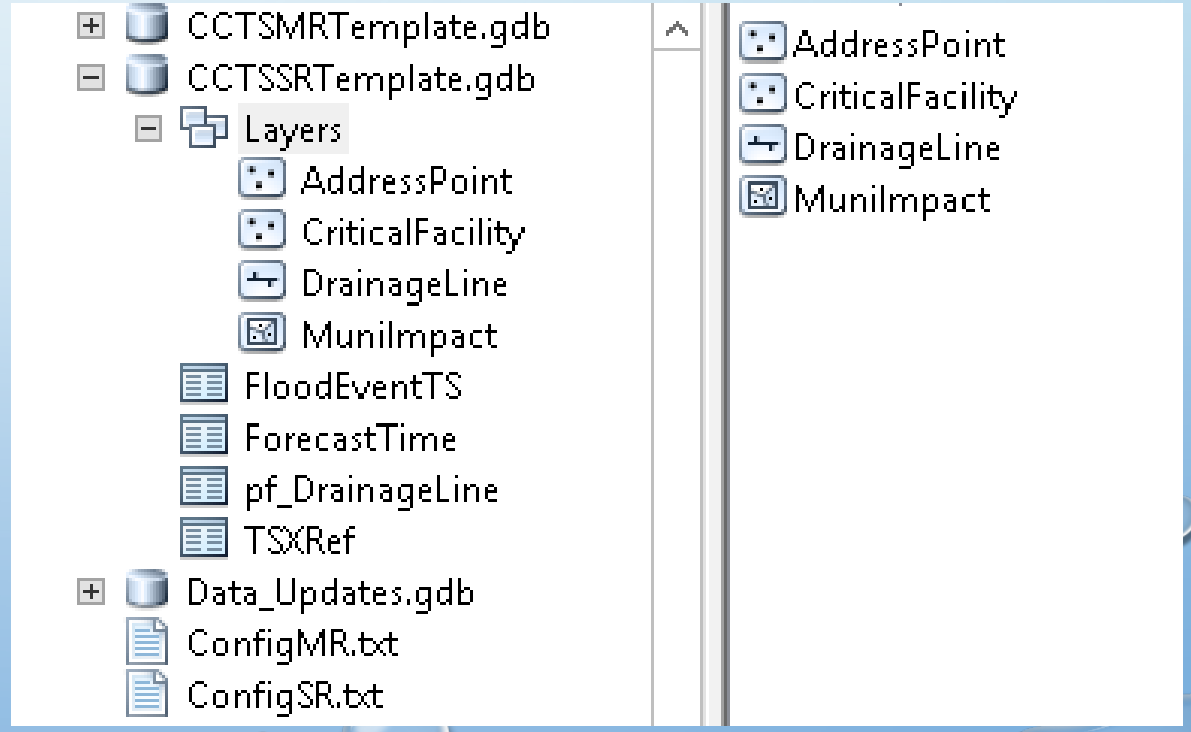
WHERE: Pre-processed Data

Chester County Department of Emergency Services partnered with Esri to create the automation scripts and data preprocessing.

HAND and Catchment Rasters



Template Data



WHERE & WHO: Forecasted Impacts

Arc Hydro tools combine the NWM data and the pre-processed data to output:

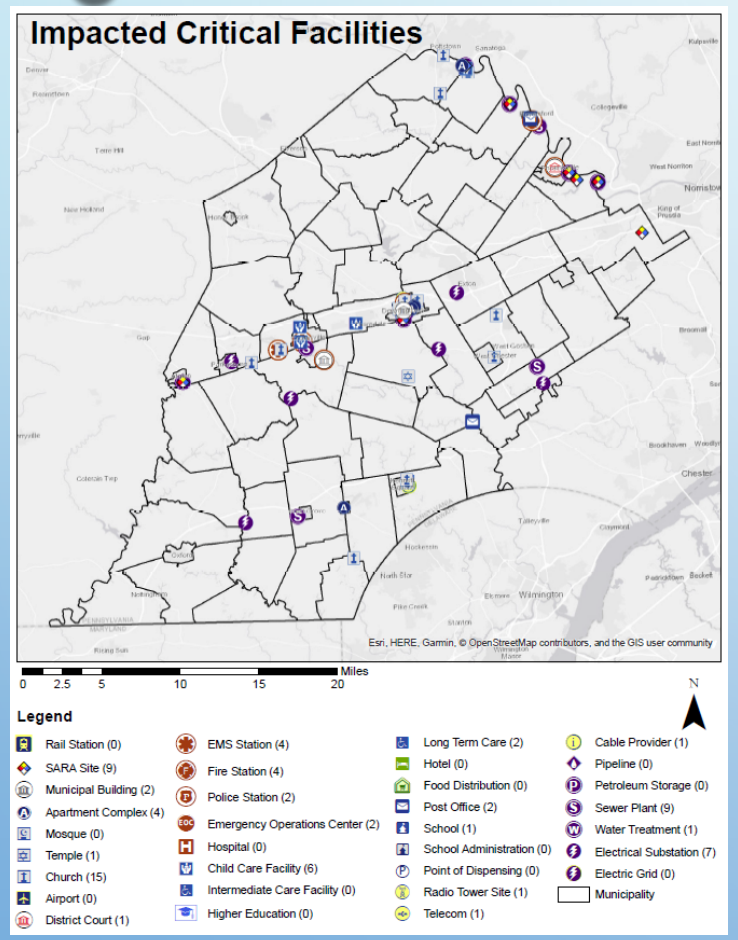
WHERE:

- Flood extent polygons
- Depth raster

WHO:

- Affected addresses
- Affected critical facilities

WHO: Printable PDF Impact Report



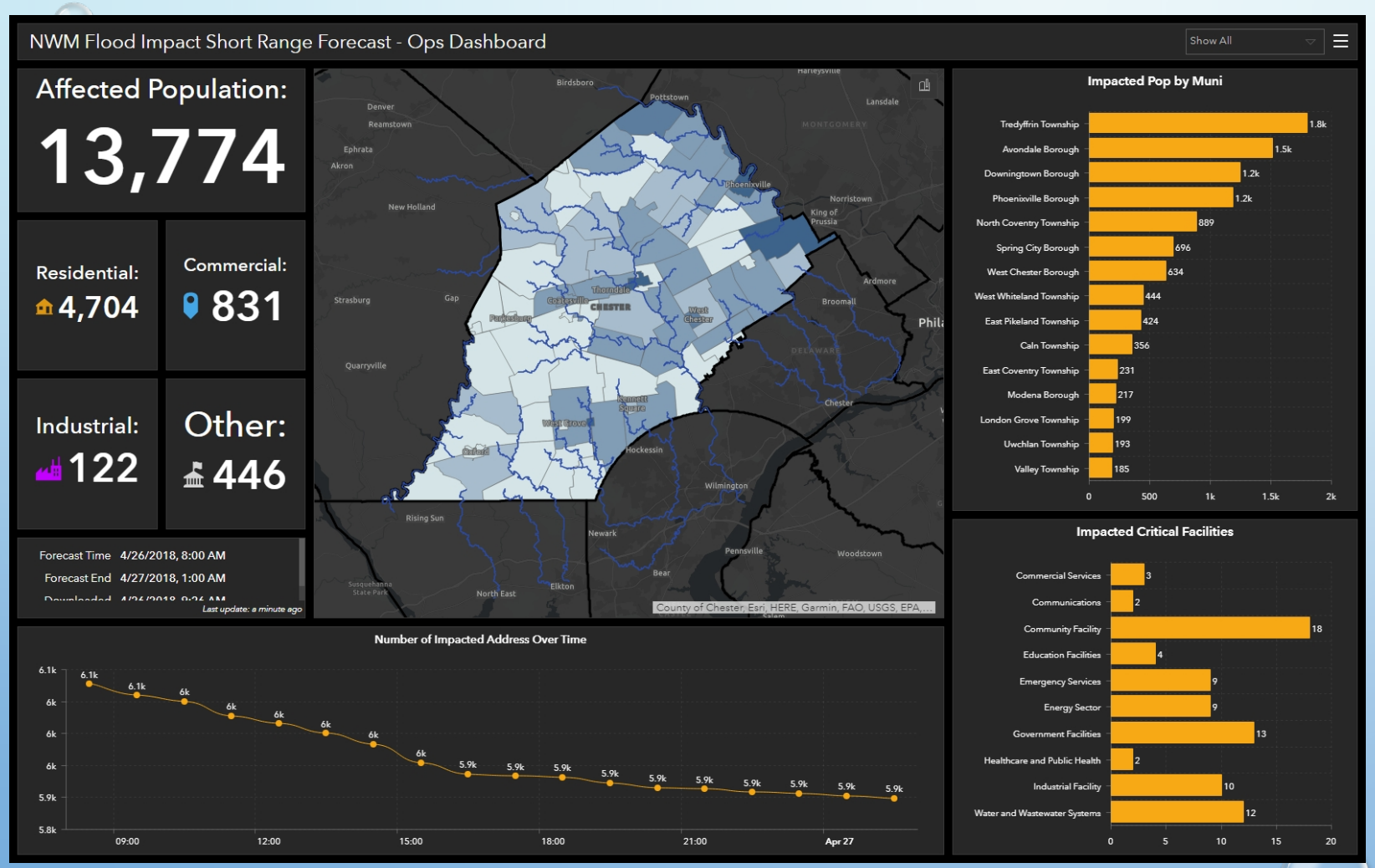
Municipality Impact

Nb	Municipality	Estimated Affected Population	Fire Station	EMS Station	Police Station	EOC	SARA Facility	Water/Sewer Treatment Plant	Hospital	Long-Term Care Facility	School	Child Care Facility	Place of Worship	Apartment Complex
7	Atglen Borough	26					1	1						
4	Avondale Borough	1383												1
65	Birmingham Township	11												
39	Caln Township	477										1		
35	Charlestown Township	33												
16	City of Coatesville	182	1	1								1		
11	Downingtown Borough	1903	1	1	1	1	1				1	1	4	2
51	East Bradford Township	95												
30	East Brandywine	87												
40	East Caln Township	55					1	1					1	
18	East Coventry Township	234								2		1	1	
47	East Fallowfield Township	27												
53	East Goshen Township	126												
61	East Marlborough	10												
24	East Nantmeal Township	37												
69	East Nottingham	122												
26	East Pikeland Township	191												
21	East Vincent Township	119					1	1						
42	East Whiteland Township	134												
55	Easttown Township	73												
70	Elk Township	16												
13	Elverson Borough	0												
72	Franklin Township	15												
45	Highland Township	11												
22	Honey Brook Township	37												
12	Honey Brook Borough	0												
62	Kennett Township	171												
3	Kennett Square Borough	71										1	2	
73	London Britain Township	27												

- Included in situation reports
- Distributed to local emergency managers and key partners

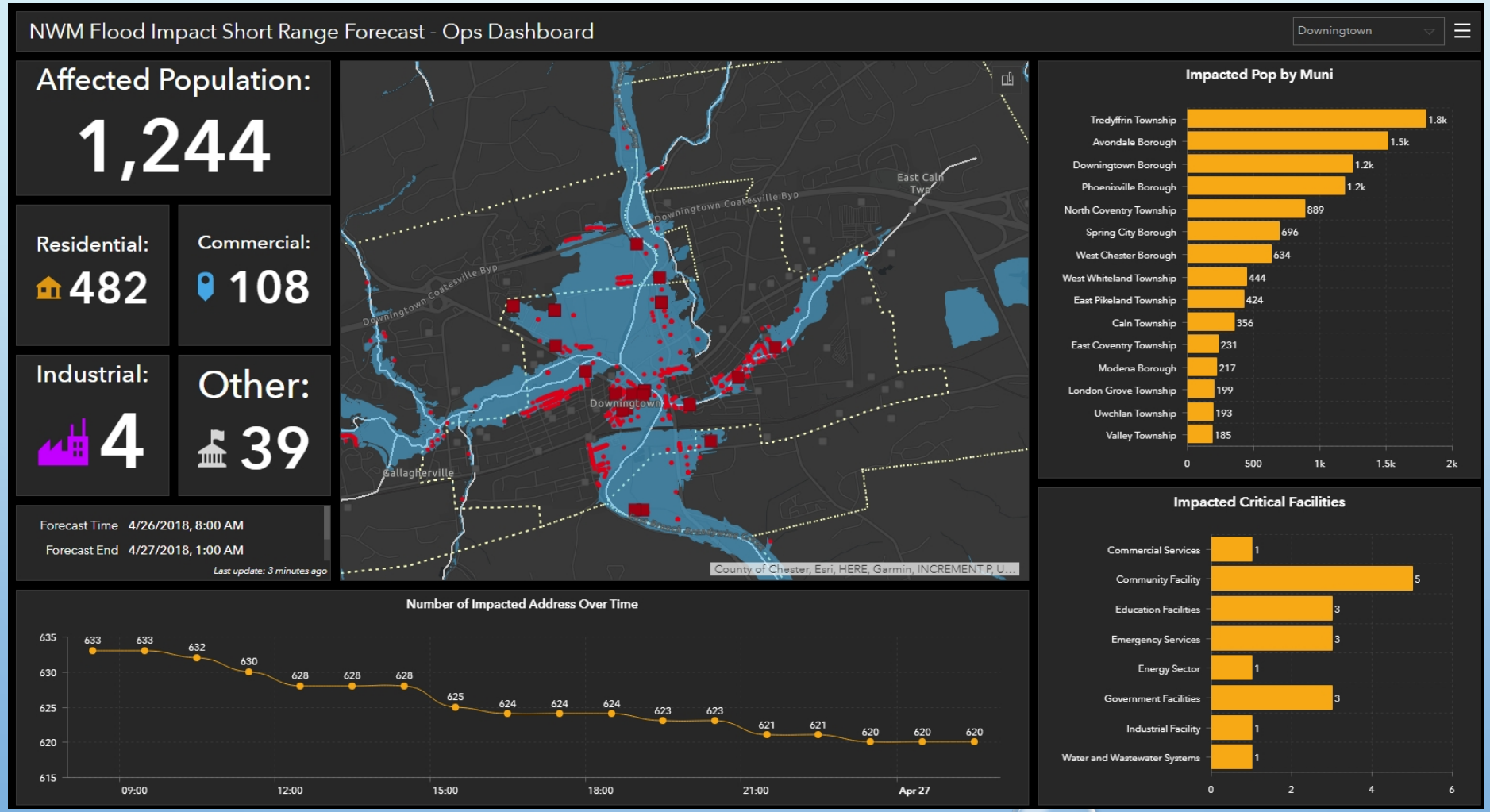
MUNICIPALITY	Downingtown Borough			16
CI SECTOR	Commercial Services			1
CI TYPE	*Child Care Facility*			*1*
Child Care Center	Teach And Learn Day School	66 W Lancaster Av	Downingtown	19335
CI SECTOR	Communications			1
CI TYPE	*Telecom*			*1*
Phone Exchange	Verizon Downingtown Co (PA21017)	201 Whiteland Av	Downingtown	19335
CI SECTOR	Community Facility			6
CI TYPE	*Apartment Complex*			*2*
Apartment Complex	Chestnut Village Apts	238 Chestnut St	Downingtown	19335
Apartment Complex	Downingtown Arms Apts	227 Whiteland Av	Downingtown	19335
CI TYPE	*Church*			*4*
Protestant	Downingtown Friends Meeting	800 E Lancaster Av	Downingtown	19335
Protestant	Messiah Evangelical Lutheran Church	46 W Lancaster Av	Downingtown	19335
Protestant	Mount Raymond Church	220 Manor Av	Downingtown	19335
Protestant	New Beginnings Fellowship	39 W Lancaster Av	Downingtown	19335
CI SECTOR	Education Facilities			1
CI TYPE	*School*			*1*
Private School	Regina Luminis Academy	40 W Pennsylvania Av	Downingtown	19335
CI SECTOR	Emergency Services			3
CI TYPE	*EMS Station*			*1*
ALS/BLS	Minquas Ambulance	141 Wallace Av	Downingtown	19335
CI TYPE	*Fire Station*			*1*
Fire Station	Minquas FC	141 Wallace Av	Downingtown	19335
CI TYPE	*Police Station*			*1*
Municipal Police Station	Downingtown Boro PD	10 W Lancaster Av	Downingtown	19335
CI SECTOR	Energy Sector			1
CI TYPE	*Electrical Substation*			*1*
Electrical Substation	Downingtown - Jefferson Ave	120 Jefferson Av	Downingtown	19335

WHO: Flood Impact Short Range Forecast Ops Dashboard

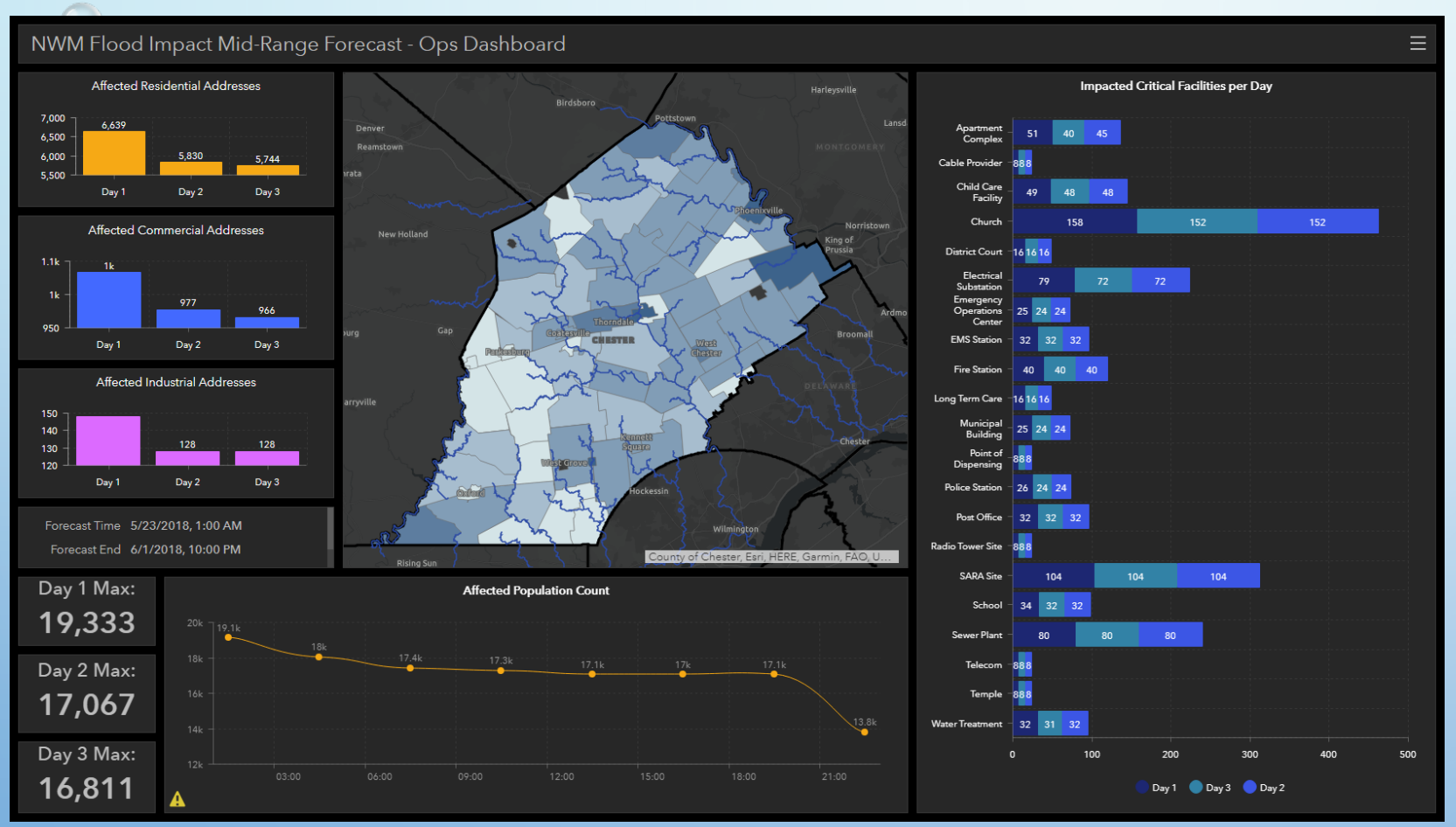


- Total affected population
- Count of addresses affected by type
- Timeline of the number of affected addresses within the next 24 hours
- Top 15 most impacted jurisdictions
- Impacted critical facilities count by sector

WHO: Flood Impact Short Range Forecast Ops Dashboard



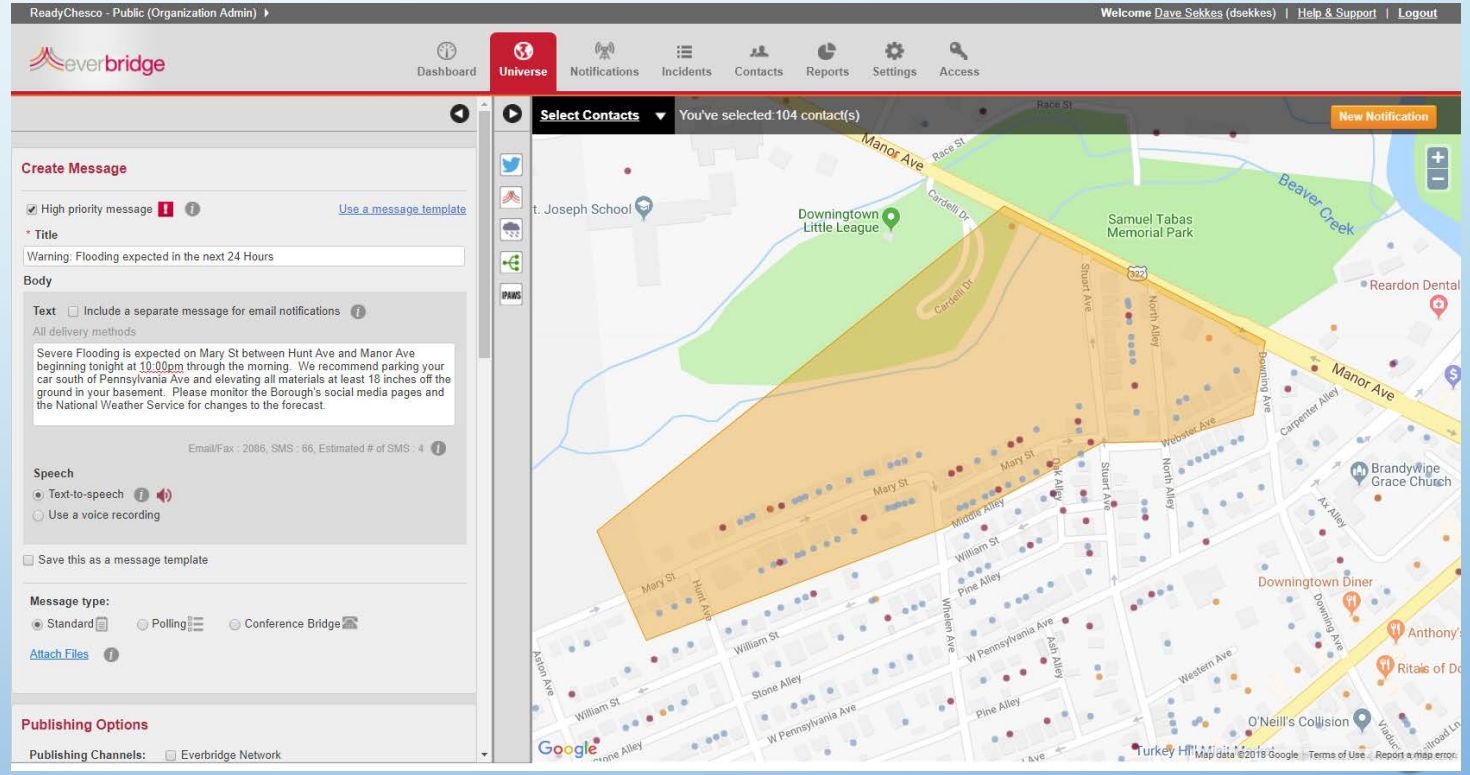
WHO: Flood Impact Mid-Range Forecast Ops Dashboard



- Total affected population for the next 3 day
- Count of addresses affected by type for the next 3 days
- Timeline of the number of affected addresses within the next 3 days
- Impacted critical facilities count by type

Emergency Management Coordinator

- Municipal Public Works can:
  - Target areas to clear drains and culverts before the rain begins
  - Stage barricades for roads
  - Open secondary emergency exits/entrances to neighborhoods that will be isolated
- Notify Emergency Services chiefs to plan for staffing and resource needs for swift water rescue and basement pumping
- Notify neighborhoods that will be directly impacted
- Check up on individuals with lack of transportation or have mobility issues who may not be able to evacuate on their own

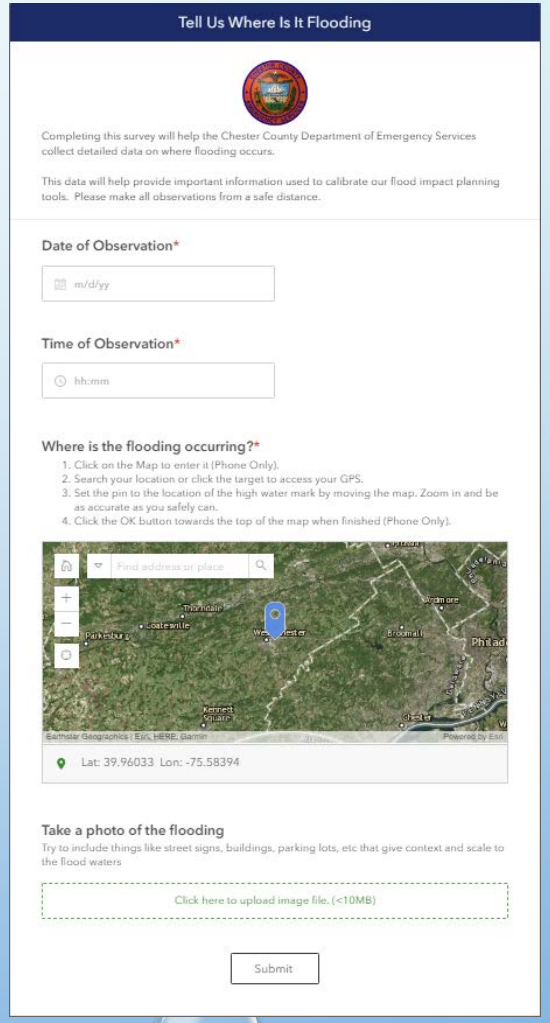


Next Steps to Improving the Model

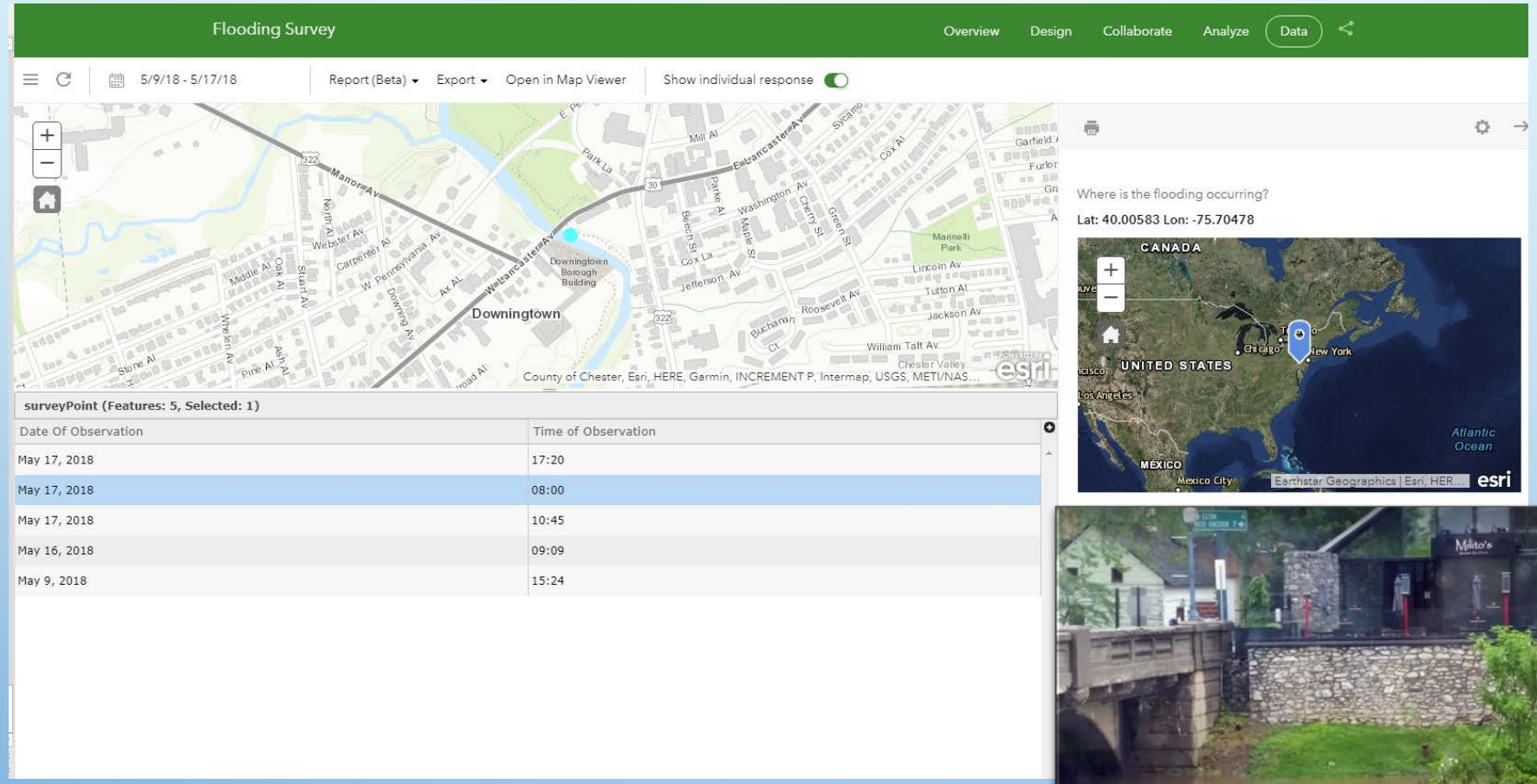
Real World Observations

Simple Survey123 to collect data during flood events:

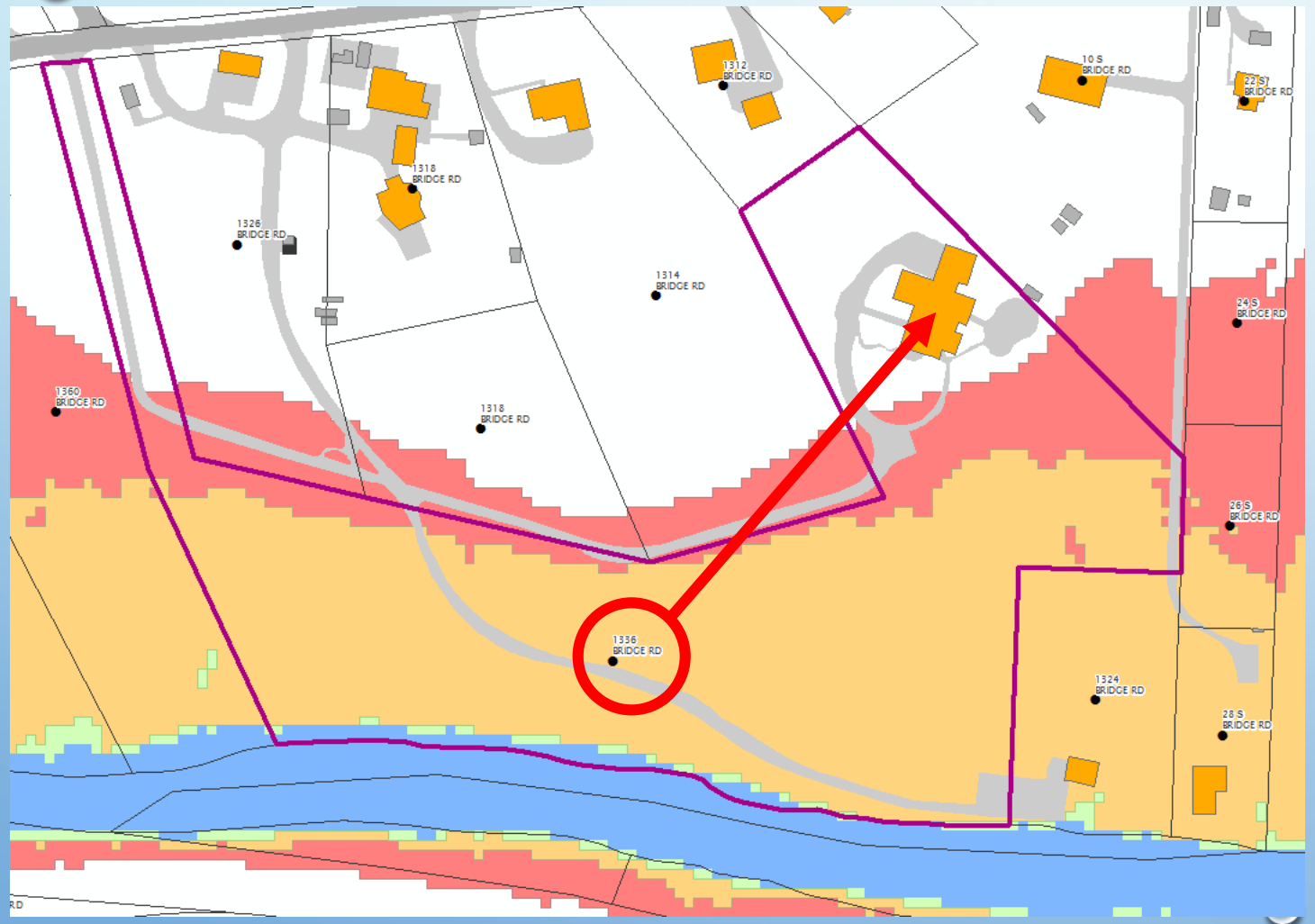
- When the flooding occurred
- Where it occurred
- And a photo (picture is better than a description)



Survey123 Flood Observations



Address Point Clean Up



- Building footprints are spatially accurate but are unattributed
- Address points have great assessment, land use, and address data but are mapped to the parcel centroid
- Centroid is in the flood extent but the actual building is not in danger of flooding

First Floor Elevation Values

Pictometry Explorer

- Measure first floor elevations remotely
- Labor intensive

Questions?

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