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pennsylvania DEPARTMENT OF ENVIRONMENTAL PROTECTION

Applied Weather Associates

Probable Maximum Precipitation Study for Pennsylvania

Flood Analysis of the July 1942 "Smethport" Extreme Rainfall Event

Aterra Solutions
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Applied Weather Associates
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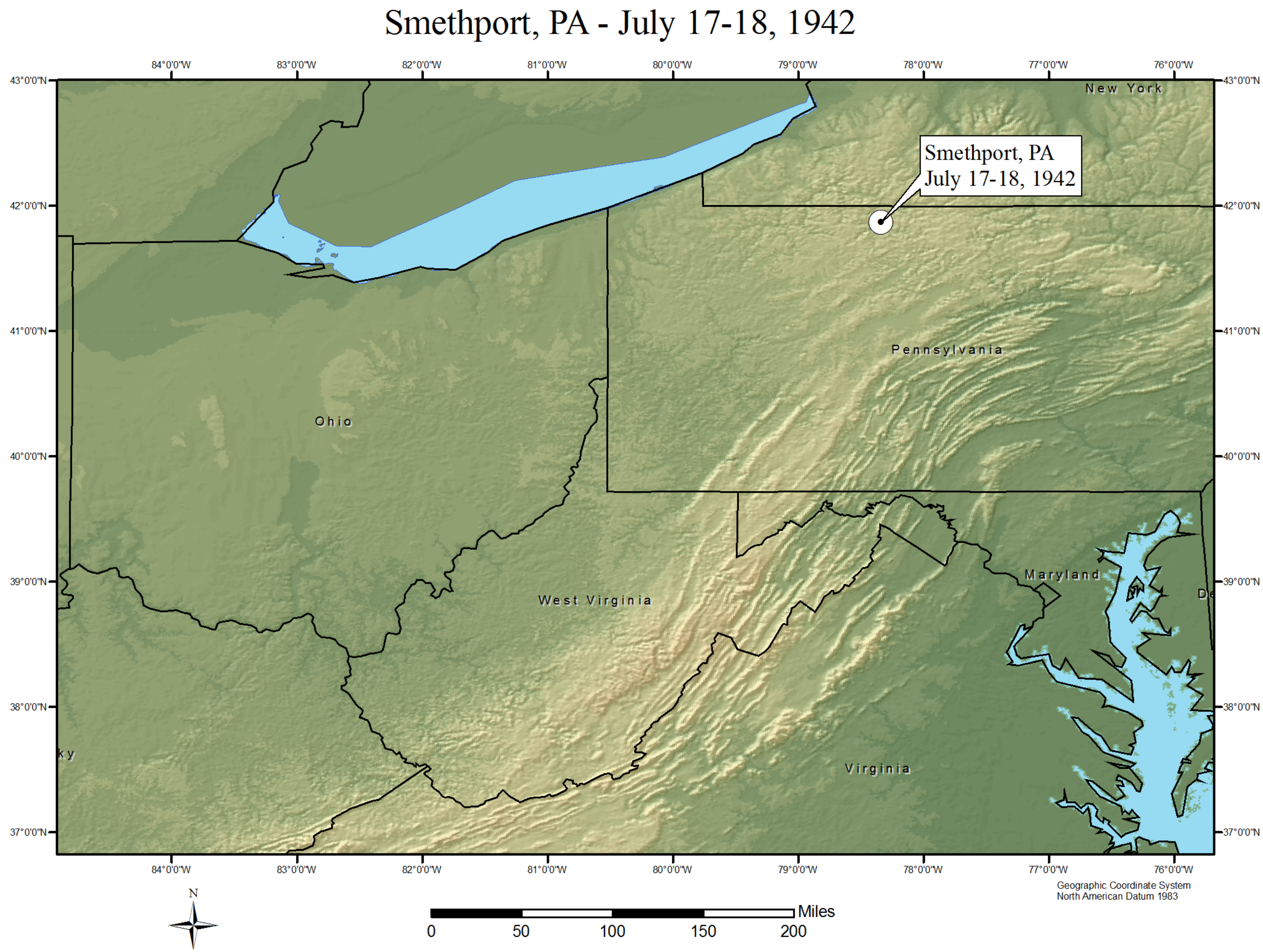
September 11, 2018

Agenda

- Objective
- Overview of the July 1942 Storm and Flood
- Modeling Approach and Calibration
- Review of Available Flood Information
- Lessons Learned regarding Rainfall
- Questions

Location



Smethport, PA - July 17-18, 1942
Smethport, PA
July 17-18, 1942
New York
Pennsylvania
Ohio
West Virginia
Maryland
Virginia
84°0'0"W
83°0'0"W
82°0'0"W
81°0'0"W
80°0'0"W
79°0'0"W
78°0'0"W
77°0'0"W
76°0'0"W
43°0'0"N
42°0'0"N
41°0'0"N
40°0'0"N
39°0'0"N
38°0'0"N
37°0'0"N
Geographic Coordinate System
North American Datum 1983
N
Miles
0
50
100
150
200

Background

- World-record rainfall for the 3- and 4.5-hour durations at 28.5 and 30.8 inches, respectively.
- July 1942 Smethport controlling of PMP depths particularly for shorter durations and small area sizes.
- Reanalysis/verification needed to ensure depths are as accurate as possible

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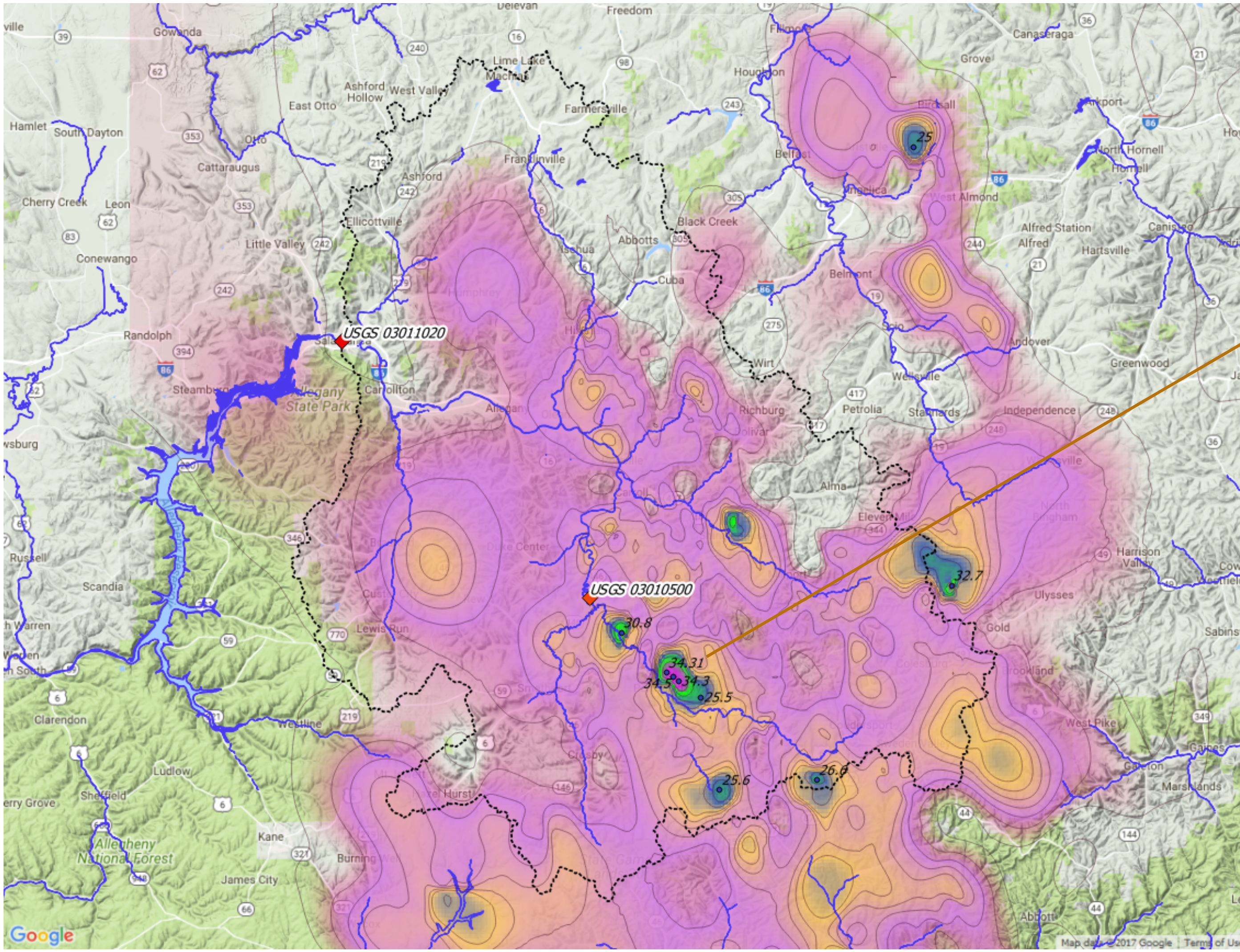
Objective

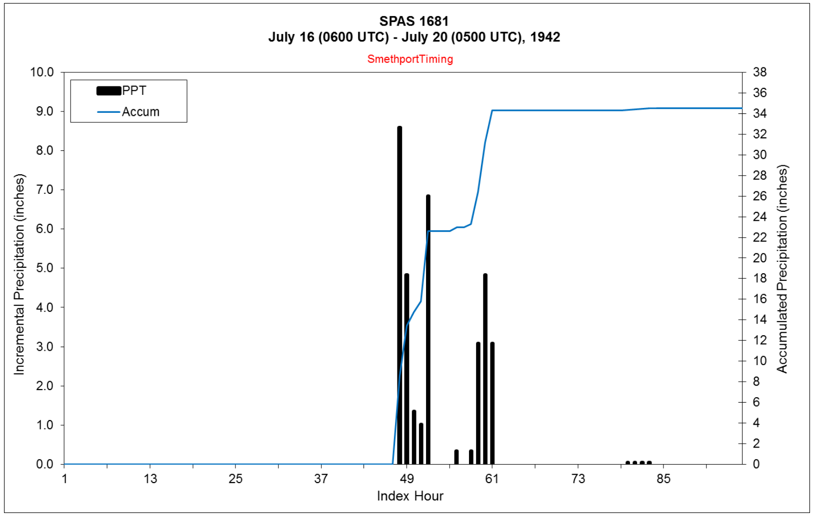
- To validate precipitation data for the July 1942 storm, a hydrologic/hydraulic analysis will be conducted for the headwater portion of the Allegheny River watershed.
- The purpose is to essentially reenact or reproduce the July 1942 flood and corroborate the recorded rainfall or provide explicit evidence that would support updated rainfall accumulation depth, timing, and/or spatial distributions.
- The ultimate objective is to identify, quantify, and isolate areas where the recorded rainfall is inaccurate and resolve discrepancies to produce the most accurate precipitation information possible.

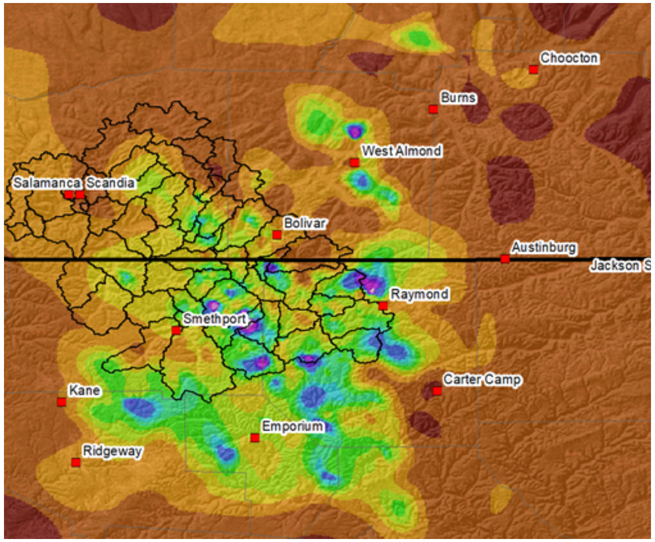
Overview of the July 1942 Storm and Flood

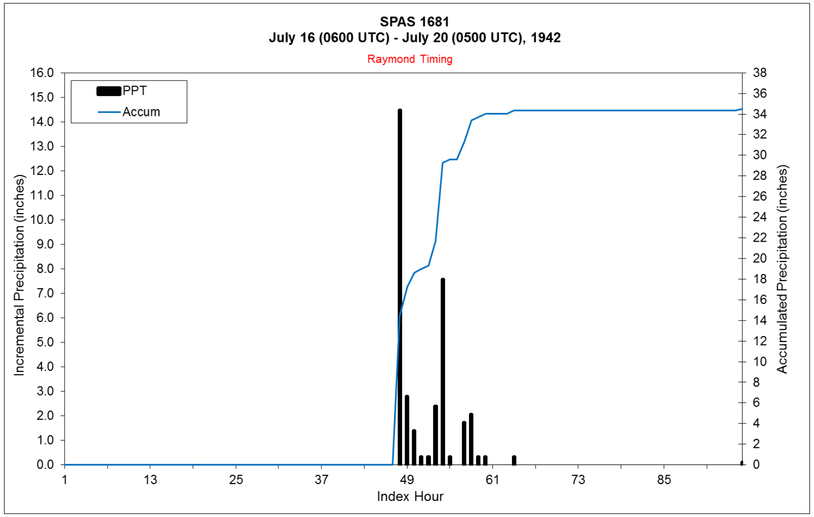


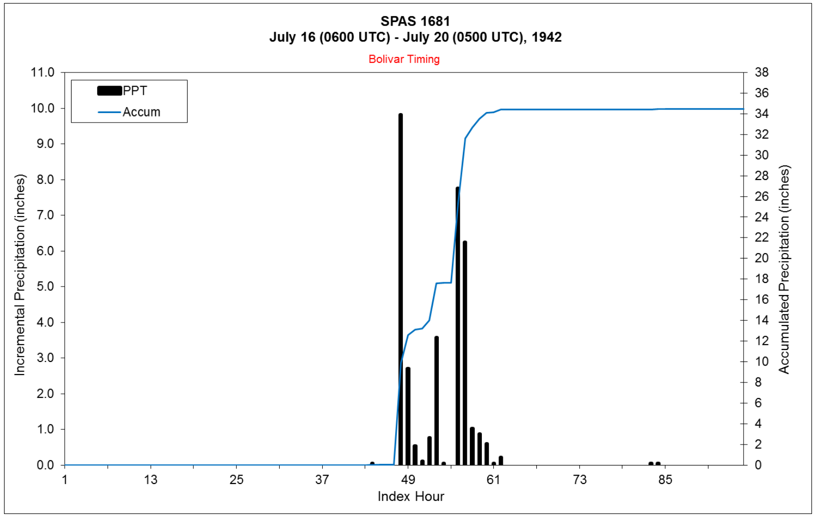
Port Allegany (location of most intense rainfall)

Overview of the July 1942 Storm and Flood









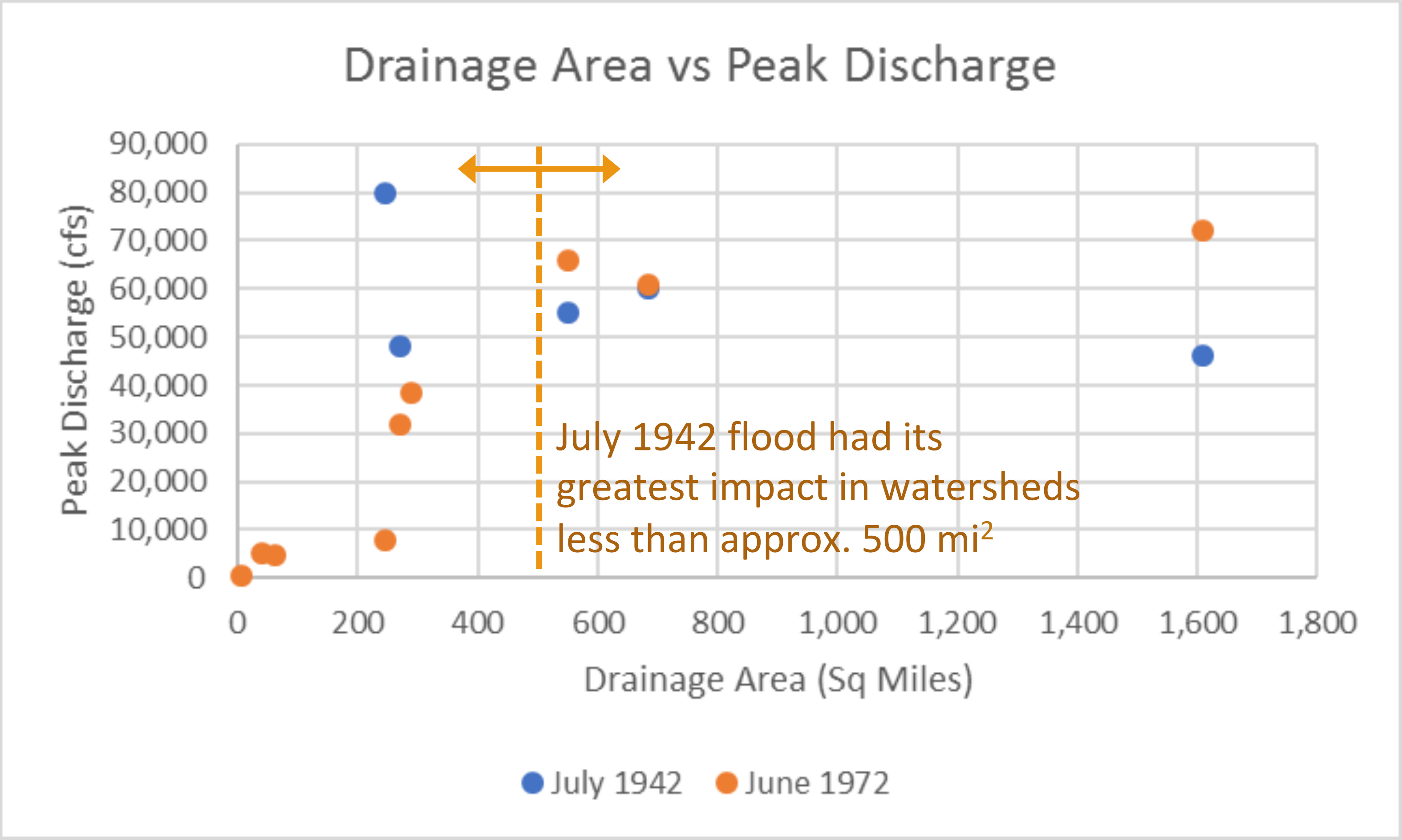
Overview of the July 1942 Storm and Flood

- The record-setting rainfall occurred at Port Allegany. A key observation stated:
  - *This jar was set out about 7:45 a. m. [on July 18, 1942]; it filled with rain for a catch of 30.8 inches, and then overflowed. Considering the unmeasured rainfall prior to 7:45 a. m. and the unknown amount lost by overflow, it would appear that the rainfall at this point was at least 35 inches.*

Overview of the July 1942 Storm and Flood

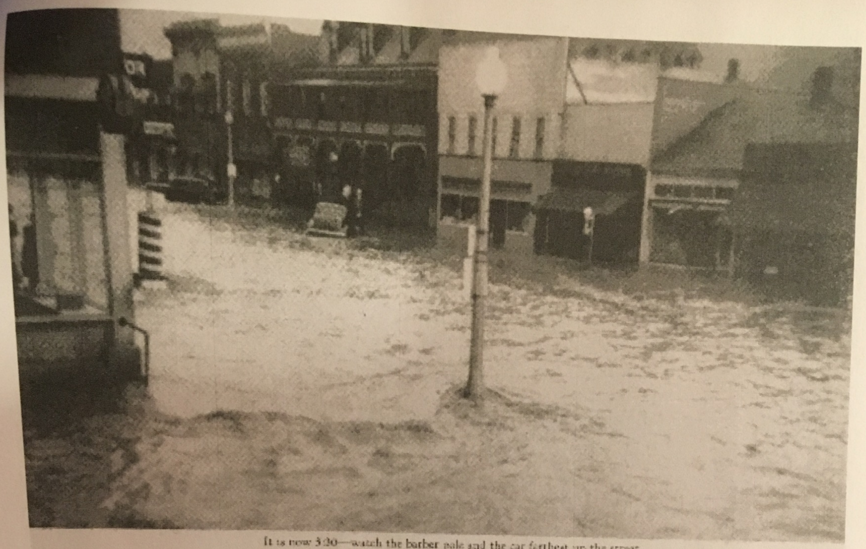
- Greatest flows ever recorded in the:
  - Upper Allegheny River basin
  - Upper part of Clarion River basin
  - Driftwood Branch Sinnemahoning Creek
  - First Fork Sinnemahoning Creek
  - Karr Valley Creek
- Flows diminished in the lower reaches of major streams
- Peak discharge at Port Allegany, PA was 77,000 cfs, at Eldred, PA the peak was 55,000 cfs, and only 45,300 cfs at Red House, NY. The drainage area at Red House is approximately 6 times greater than at Port Allegany.
- Hardest hit areas were Port Allegany, Coudersport, Smethport, Eldred, Portville, and Austin

Overview of the July 1942 Storm and Flood



Overview of the July 1942 Storm & Flood - Port Allegany

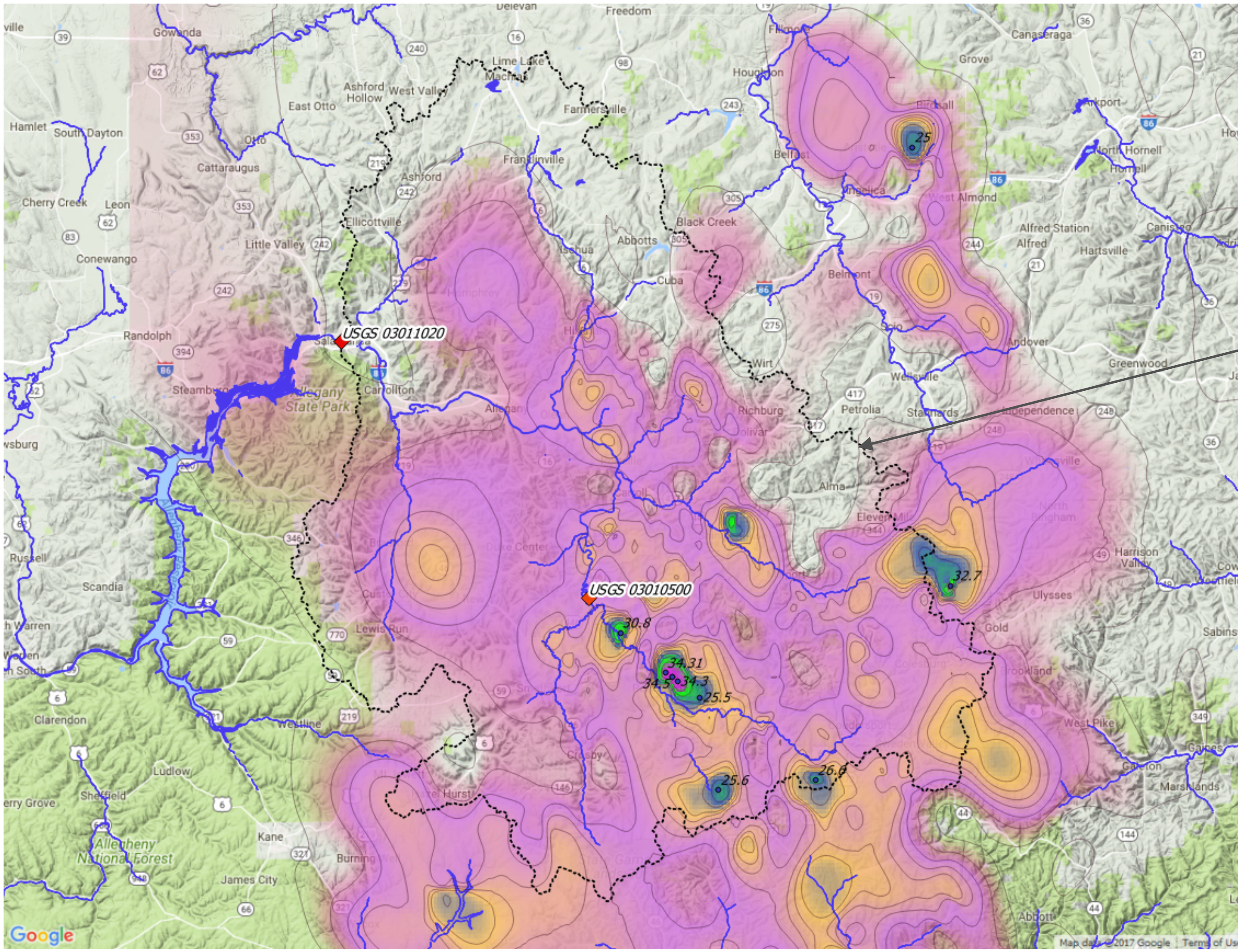
Overview of the July 1942 Storm & Flood - Coudersport



It is now 5:30-watch barber pole and the car farthest up the street.

Now it's 6 o'clock- here's the car-we'll show you the barber pole later.

Flood Model Development

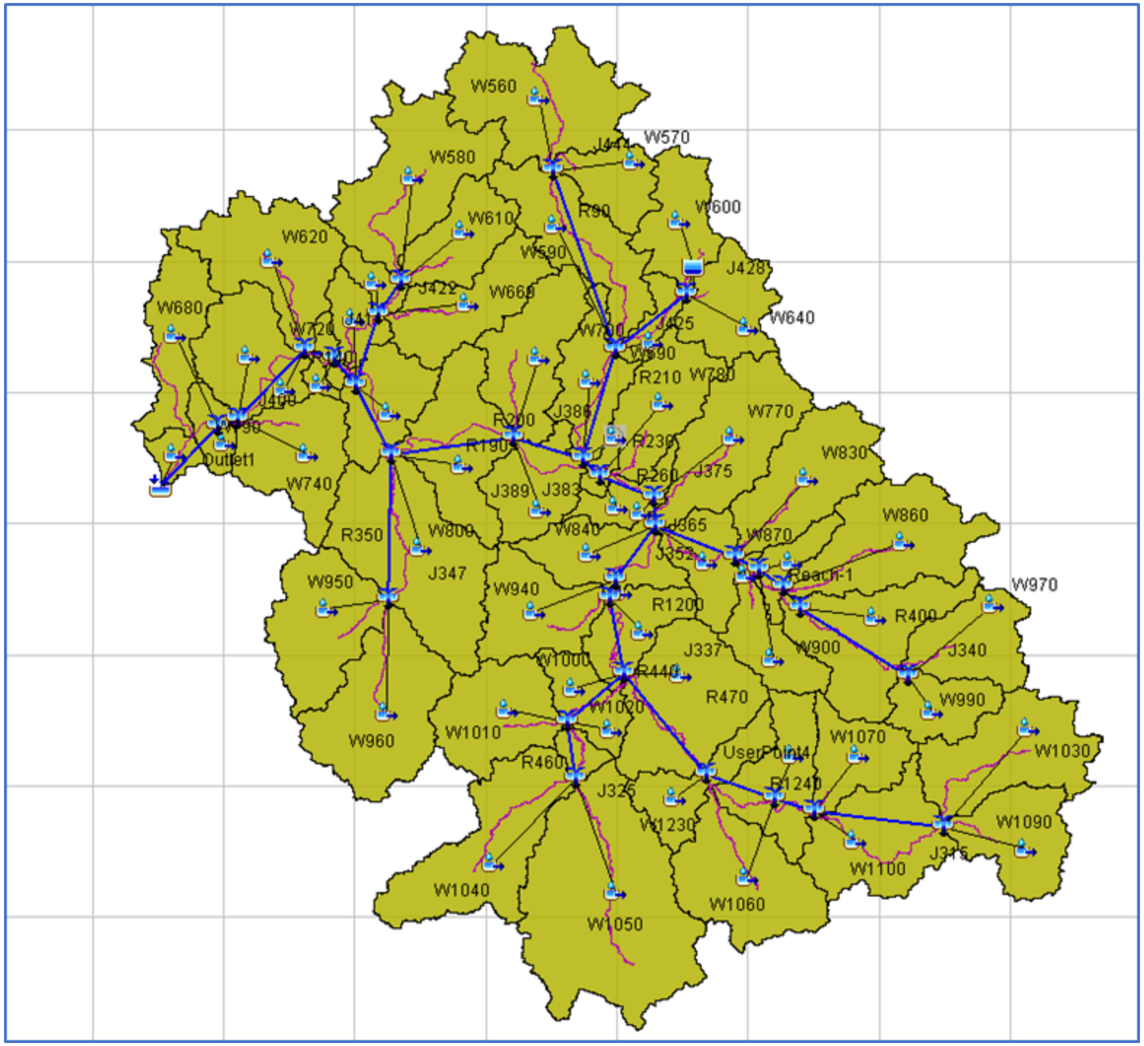


Model Domain

Flood Model Development

- The flooding analysis of the 1,780 mi^2 watershed was accomplished using complementary models designed to make optimal use of current computational capacity.
- The entire study domain was modeled using the USACE's HEC-HMS software.
- As part of the calibration process, the Unit Hydrograph in the HEC-HMS model was adjusted to reconcile the hydrograph from the 2D hydrologic/hydraulic models and account for a non-linear watershed response in the calibration events.

Flood Modeling Development

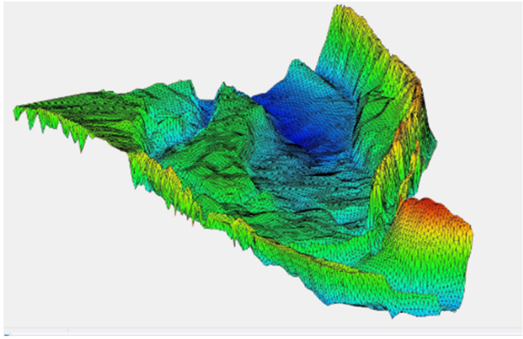


Flood Model Development

- To supplement the HEC-HMS model for the more critical areas, distributed, 2-dimensional (2D) watershed models were developed for three (3) sub-watersheds within the study domain:
  - Upper Allegheny River watershed Port Allegany, PA
  - Oswayo Creek watershed to its confluence with the Allegheny River, and
  - Tunungwant Creek watershed to its confluence with the Allegheny River.
- These are the sub-watersheds, particularly the watershed to Port Allegany, where the most extreme rainfall measurements were recorded.
- A distributed 2D modeling approach has advantages over conventional lumped and semi-distributed hydrologic models (e.g., HEC-HMS). The distributed 2D modeling approach is physically-based, making it flexible in modeling hydrologic and hydraulic responses to rainfall events of various magnitudes, intensities, spatial distributions, and temporal distributions.

Flood Model Development

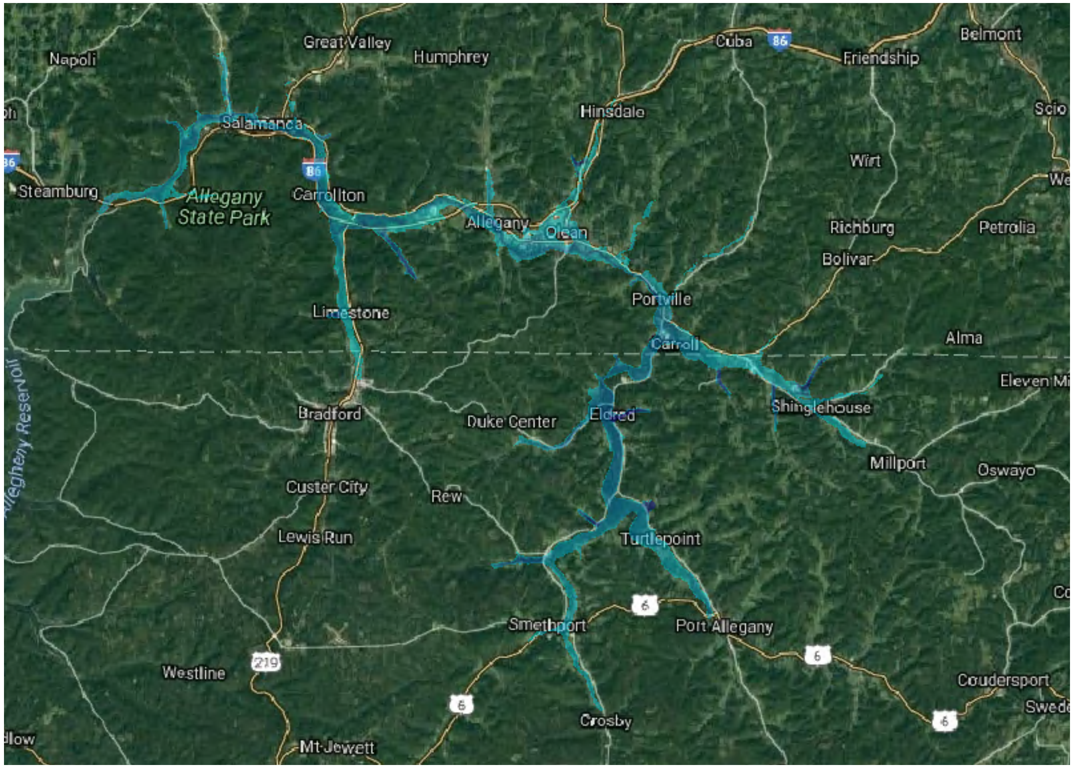
- Another important consideration in using the 2D approach is reducing concerns over the use of generic non-linearity Unit Hydrograph adjustments in a lumped model, which introduces an unknown level of inaccuracy.
- Mesh sizes were kept relatively small (25 ft to 60 ft, with an average distance between the mesh nodes of 46 ft) to maintain accuracy, particularly to limit the artificial retention of runoff in the watershed.
- RiverFlow-2D (Hydronia) was the software chosen for the 3 sub-watersheds.

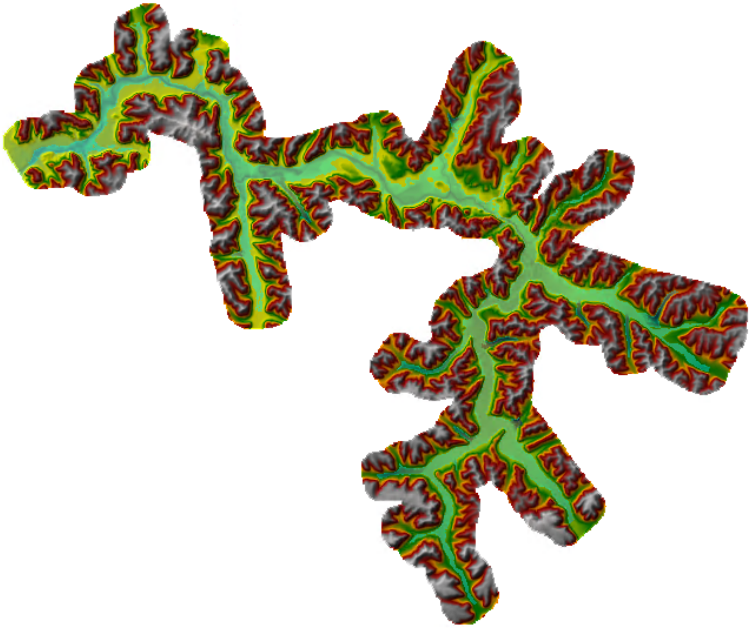


Flood Model Development

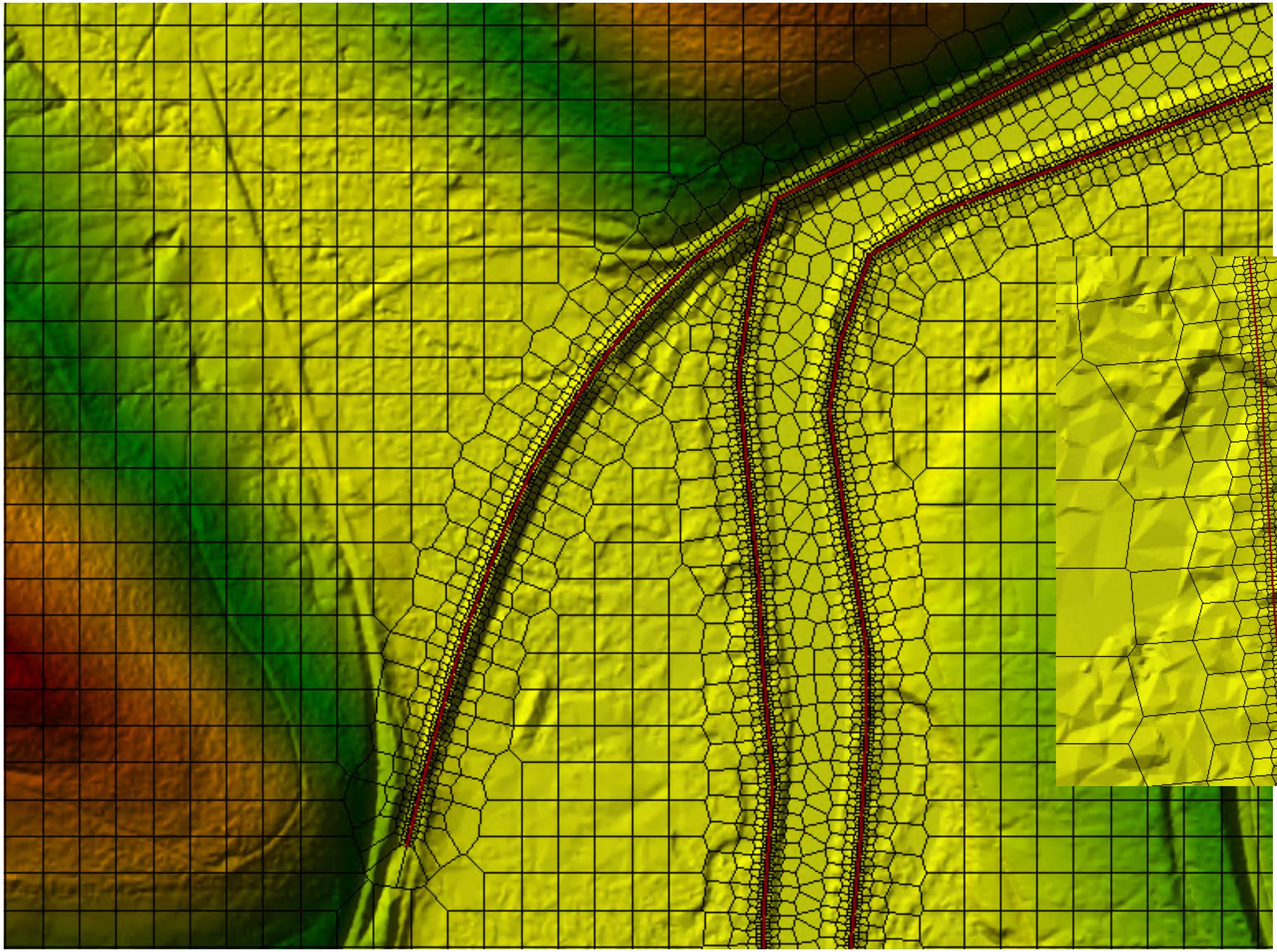
- Downstream of Port Allegany PA, 2D hydraulic modeling was developed using the USACE HEC-RAS-2D (version 5.0.4), with the HEC-HMS and RiverFlow-2D models providing the inflow at the boundaries.
- The HEC-RAS model provided the ability to more accurately account for river and floodplain attenuation, flood data for comparison with high-water observations, and to dynamically link with the numerous inflow locations.

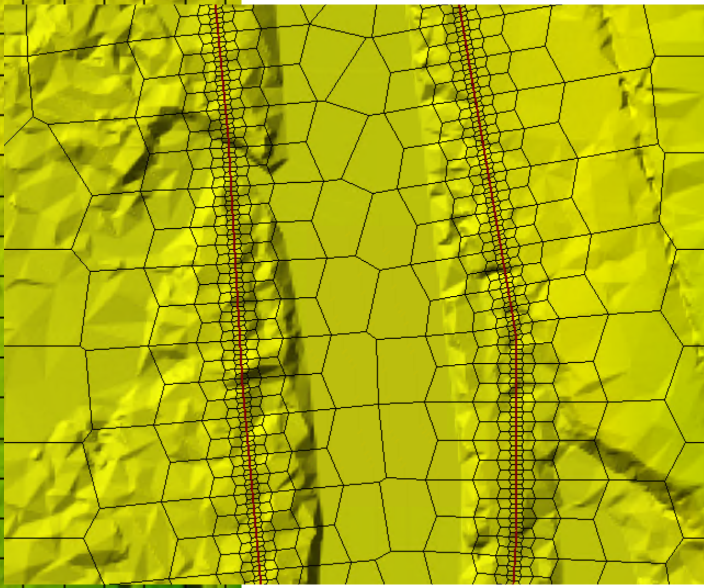
Flood Model Development



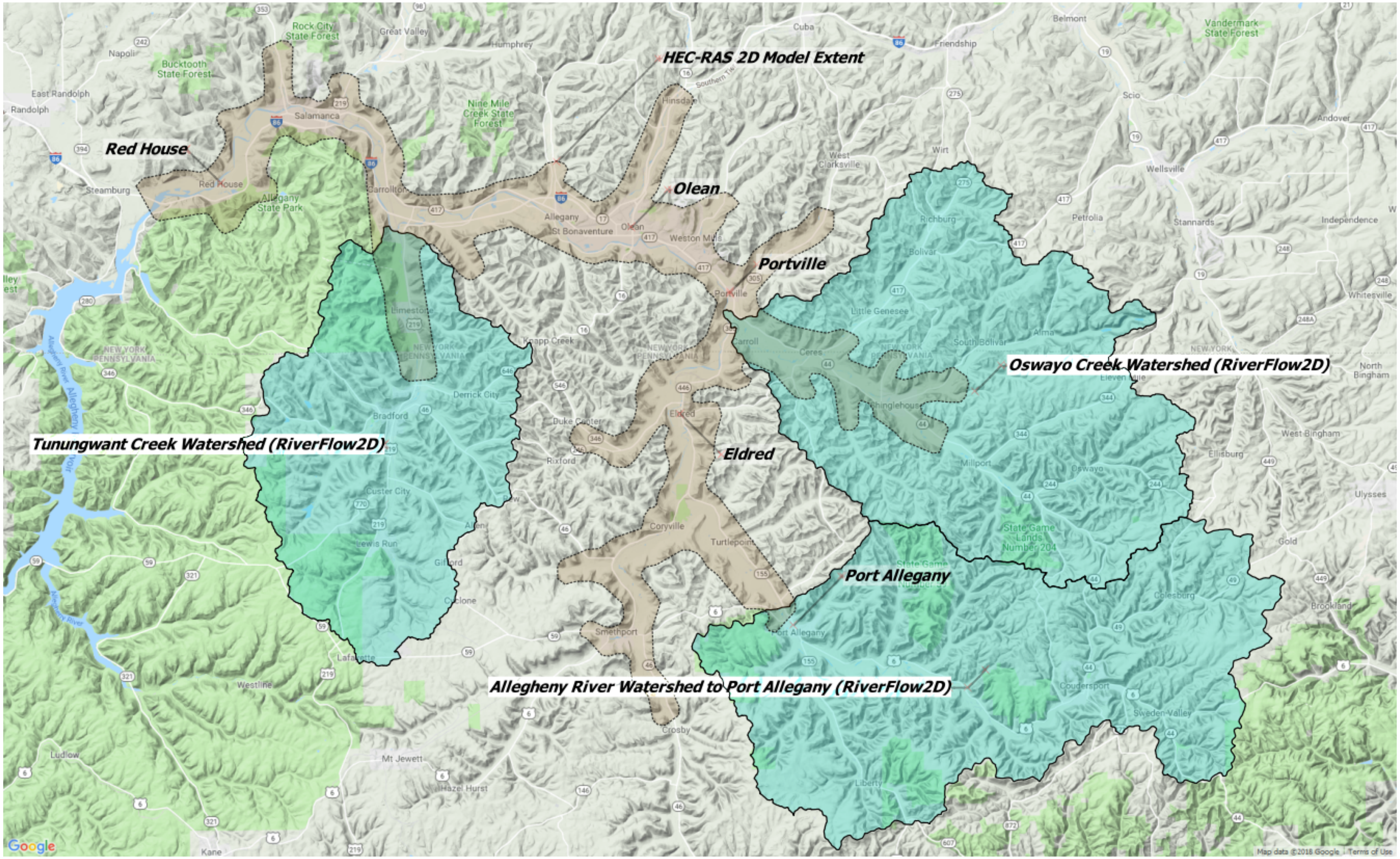


Flood Model Development





Flood Model Development



Flood Modeling – Calibration

- The 1972 “Tropical Storm Agnes” flood was the primary calibration storm due to its significant effect on the region and reliability of precipitation and flood data.
- Two warm-season floods after 1996 (2004 and 2014) were used as verification storms.
- Post-1996 floods allowed the use of the NEXRAD data, providing a more reliable and comprehensive understanding of the spatial and temporal distribution for the calibration storms.

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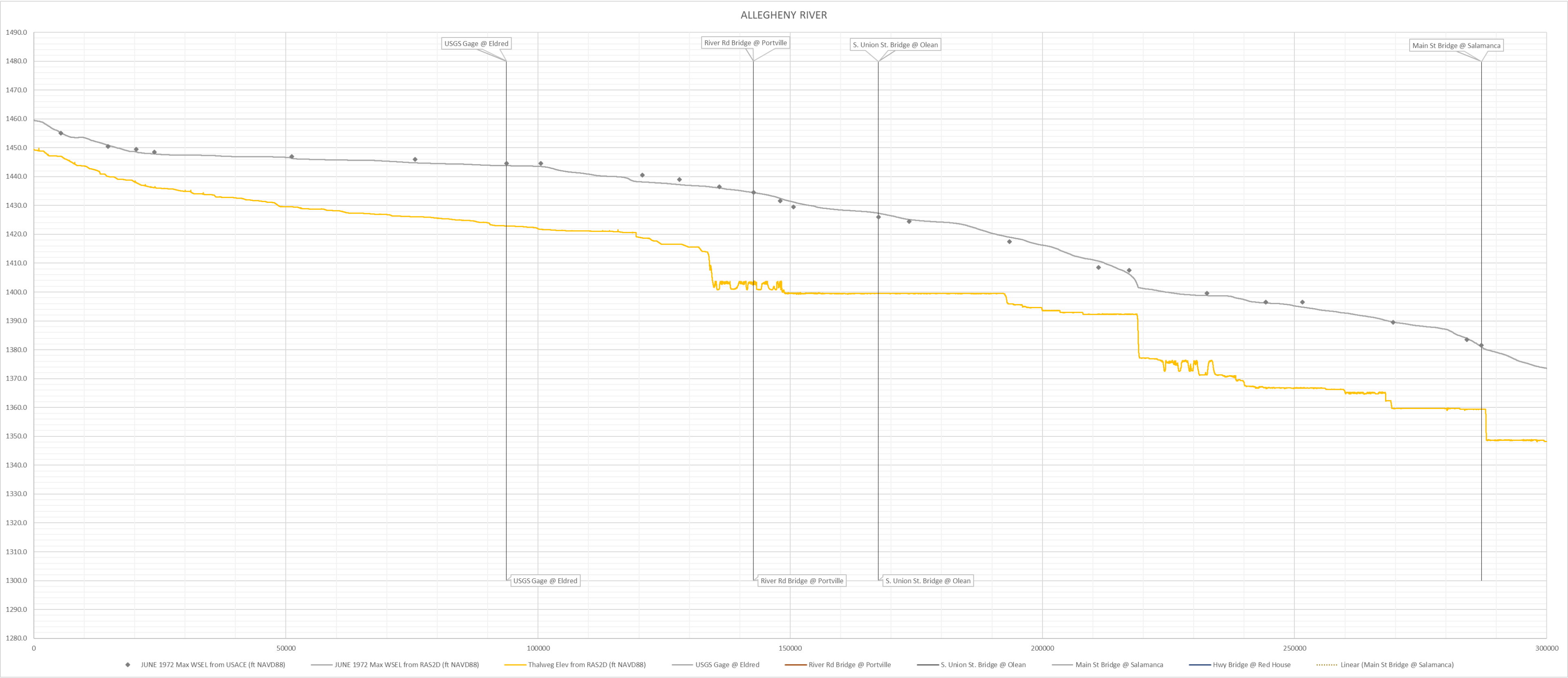
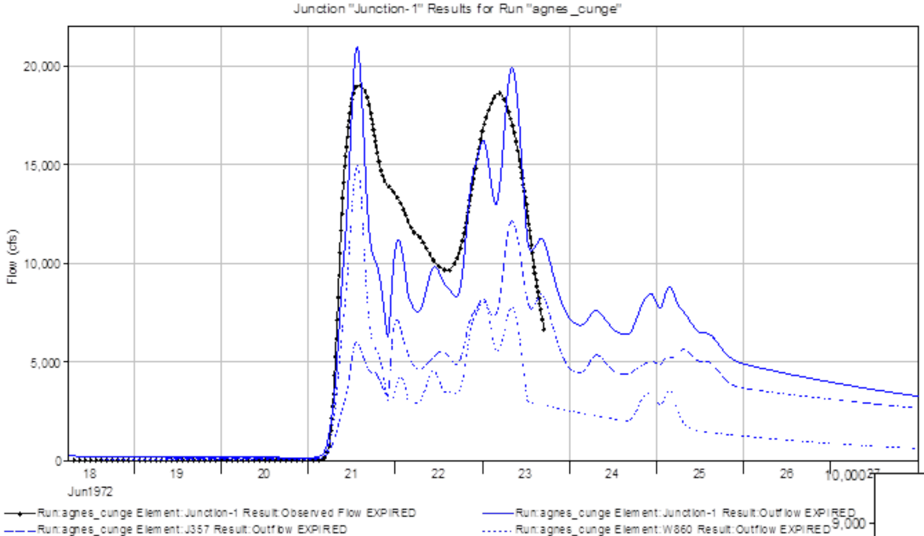
Flood Modeling – Calibration

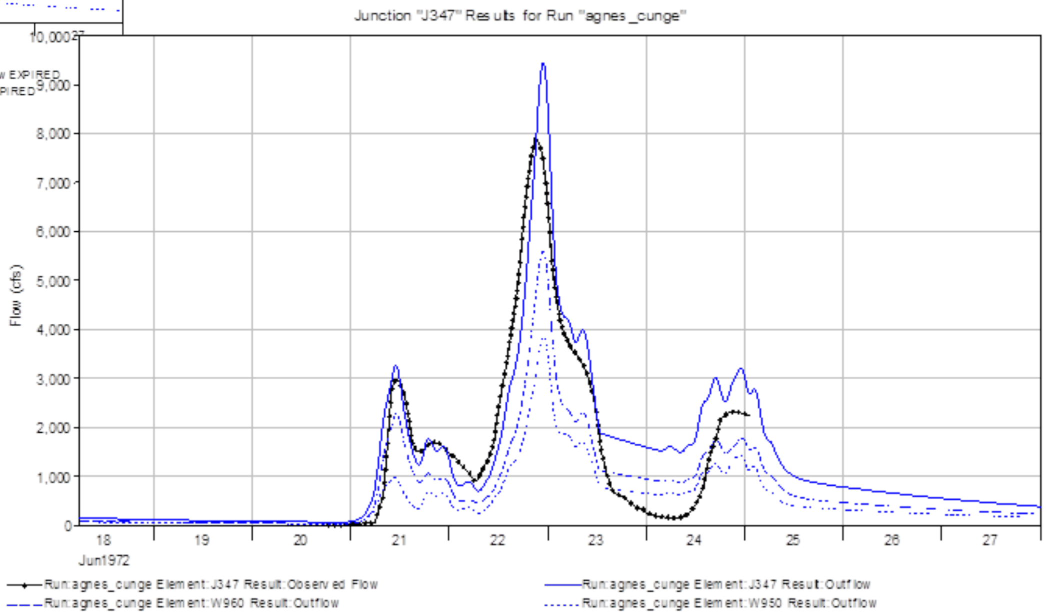


Flood Modeling – Calibration

River Mile[3]	Location	June 1972 (Agnes)						
		Observed			Model			
		Date/Time	Peak Discharge (cfs)	Peak WSEL (ft, NGVD29)	Date/Time	Peak Discharge (cfs)	Peak WSEL (ft, NAVD88)	Peak WSEL (ft, NGVD29)
	Coudersport (US Rt 6 Br)		5,790	1653.1	6/23/72 12:00 AM	6,348	1655.0	1655.4
	Coudersport (Mill Creek)		3,490			2,865		
298.3	Roulette (Fishing Cr Rd Br)			1527.6			1529.2	1529.7
295.1	Burtville PA (Kim Hill Rd Br)			1509.7			1510.7	1511.2
289.6	Port Allegany (Route 155 Bridge)			1478.9			1478.4	1478.9
288.9	Port Allegany (W Mill St Br)[2]	6/22/72 9:00 PM	22,000	1475.2	6/22/72 9:00 PM	21,083	1476.6	1477.1
288.0	Port Allegany (Route 6 Bridge)[2]	6/22/72 9:00 PM		1472.3	6/22/72 9:00 PM	21,325	1473.1	1473.6
	Turtle Point (Champlin Hollow Road Bridge)[2]			1450.0			1448.3	1448.8
	Route 446 Bridge[2]			1448.0			1445.4	1445.9
269.0	Eldred PA (at USGS gage)[1,4]	6/23/72 9:00 PM	35,000	1445.5	6/23/72 8:00 AM	35,540	1443.1	1443.6
	River Road Bridge (at Portville NY)[4]			1434.0			1434.1	1434.6
	Route 16 Bridge (at Olean NY)[4]		59,000	1426.0	6/23/72 9:30 AM	65,143	1427.1	1427.6
255.5	South First Street Bridge (Allegany NY)[1]			1418.0			1418.7	1419.2
	Route 219 Bridge (Carrollton NY just u/s of Tun Cr)[1]			1397.5			1395.3	1395.8
233.7	Main Street Bridge (USGS gage at Salamanca NY)[1]	6/23/72 1:00 PM	73,000	1381.5	6/23/72 12:45 PM	80,797	1379.2	1379.7

Flood Modeling – Calibration

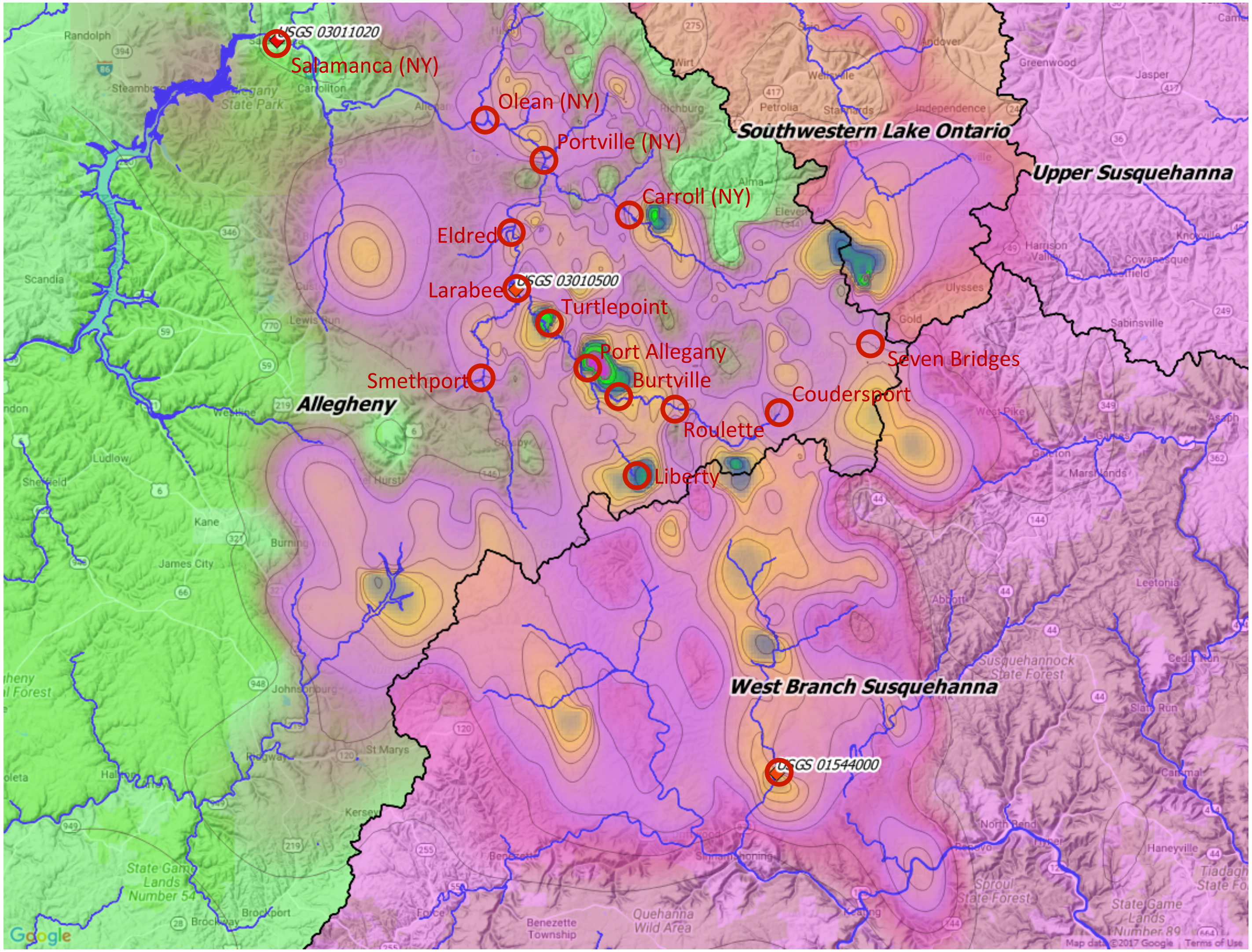




Flood Modeling – Calibration (Key Considerations)

- Effects of dams and levees.
- Understand and account for baseflow contribution.
- Non-linearity Unit Hydrograph adjustments in HEC-HMS.
- Adjusted n-values for the July 1942 model for land use changes.
- Changes in bridge crossings and roadway construction.
- Differences in NED DEM for New York and LiDAR in PA.
- Due to fast-rising nature of the July 1942 flood hydrograph at Port Allegany, HEC-RAS2D runs were done using the “Full Momentum” equations to incorporate the “unsteady, advection, and viscous terms” that are disregarded for the “Diffusion Wave” equations.
- More weight placed on comparing modeled and observed stages rather than flow since the hysteresis effect was probably not accounted for in the stage-discharge rating curve used to convert the observed stage to flow.

Review of Available Flood Information



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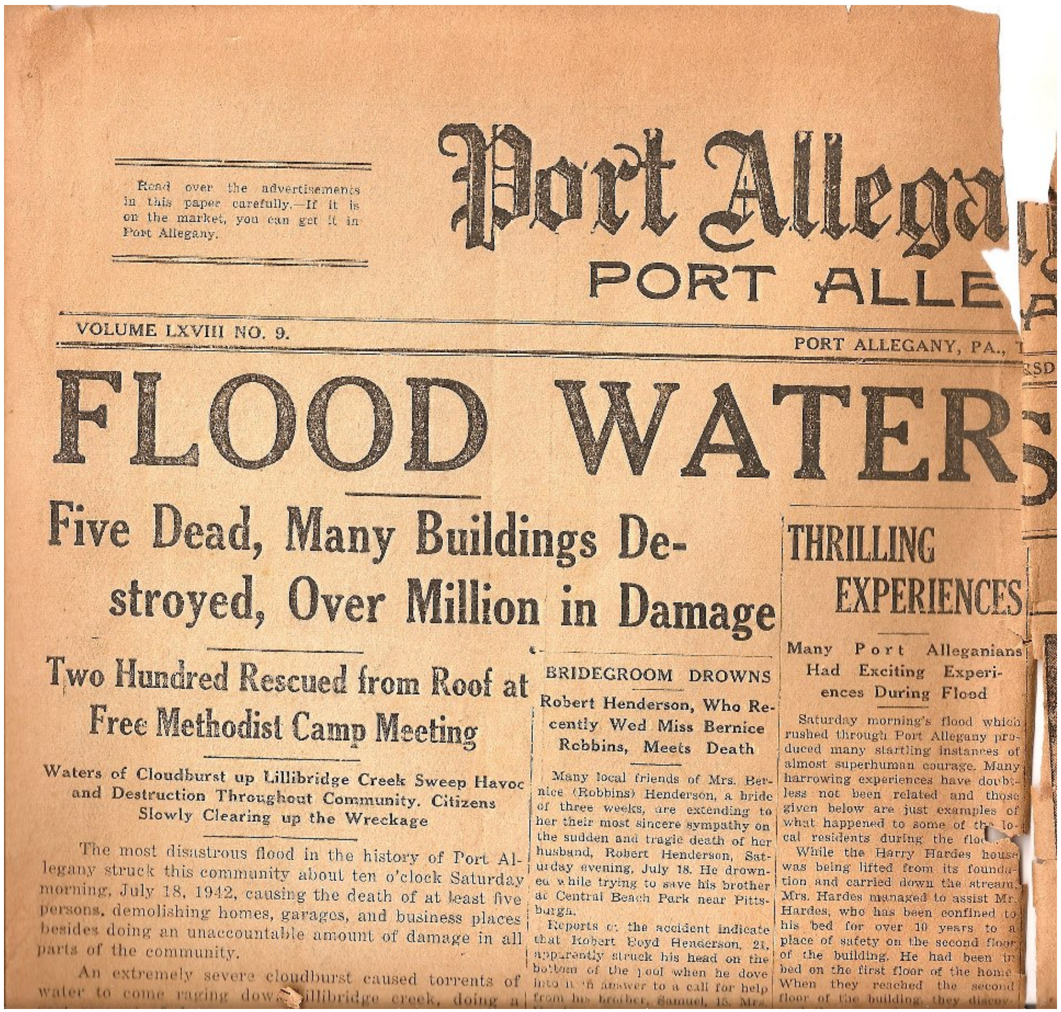
Review of Available Flood Information



Read over the advertisements in this paper carefully.—If it is on the market, you can get it in Port Allegany.

Port Allega

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VOLUME LXVIII NO. 9. PORT ALLEGANY, PA., T

FLOOD WATER

Five Dead, Many Buildings Destroyed, Over Million in Damage

Two Hundred Rescued from Roof at Free Methodist Camp Meeting

Waters of Cloudburst up Lillibridge Creek Sweep Havoc and Destruction Throughout Community. Citizens Slowly Clearing up the Wreckage

The most disastrous flood in the history of Port Allegany struck this community about ten o'clock Saturday morning, July 18, 1942, causing the death of at least five persons, demolishing homes, garages, and business places besides doing an unaccountable amount of damage in all parts of the community.

An extremely severe cloudburst caused torrents of water to come raging dow[n] Lillibridge creek, doing a

BRIDEGROOM DROWNS

Robert Henderson, Who Recently Wed Miss Bernice Robbins, Meets Death

Many local friends of Mrs. Bernice (Robbins) Henderson, a bride of three weeks, are extending to her their most sincere sympathy on the sudden and tragic death of her husband, Robert Henderson, Saturday evening, July 18. He drowned while trying to save his brother at Central Beach Park near Pittsburgh.

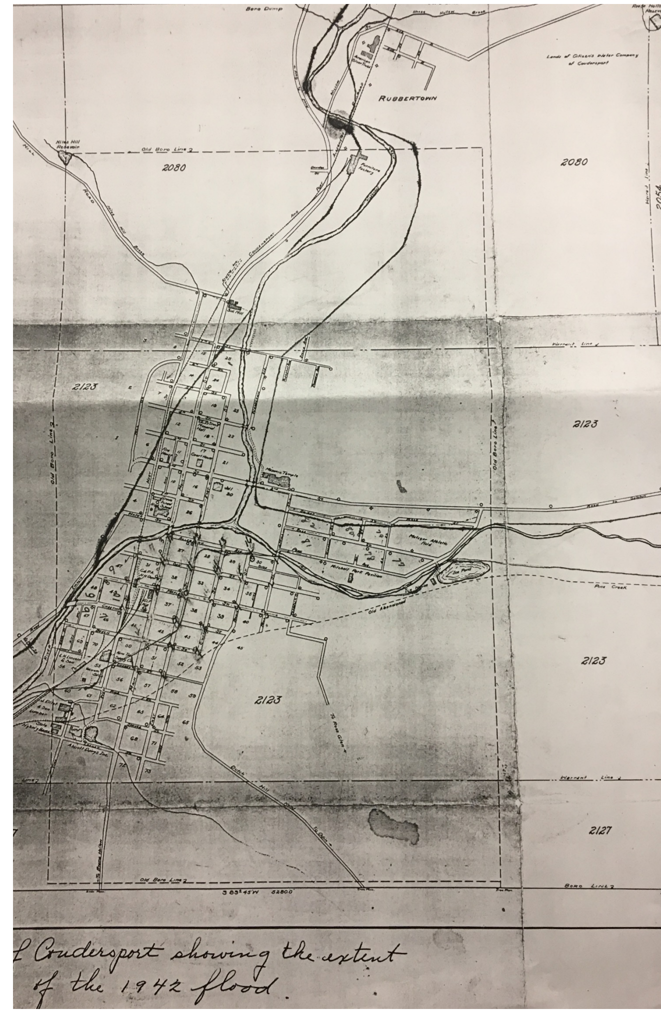
Reports of the accident indicate that Robert Boyd Henderson, 21, apparently struck his head on the bottom of the pool when he dove into it in answer to a call for help from his brother, Samuel, 15. Mrs.

THRILLING EXPERIENCES

Many Port Alleganians Had Exciting Experiences During Flood

Saturday morning's flood which rushed through Port Allegany produced many startling instances of almost superhuman courage. Many harrowing experiences have doubtless not been related and those given below are just examples of what happened to some of the local residents during the flood.

While the Harry Hardes house was being lifted from its foundation and carried down the stream, Mrs. Hardes managed to assist Mr. Hardes, who has been confined to his bed for over 10 years to a place of safety on the second floor of the building. He had been in bed on the first floor of the home. When they reached the second floor of the building they discov-



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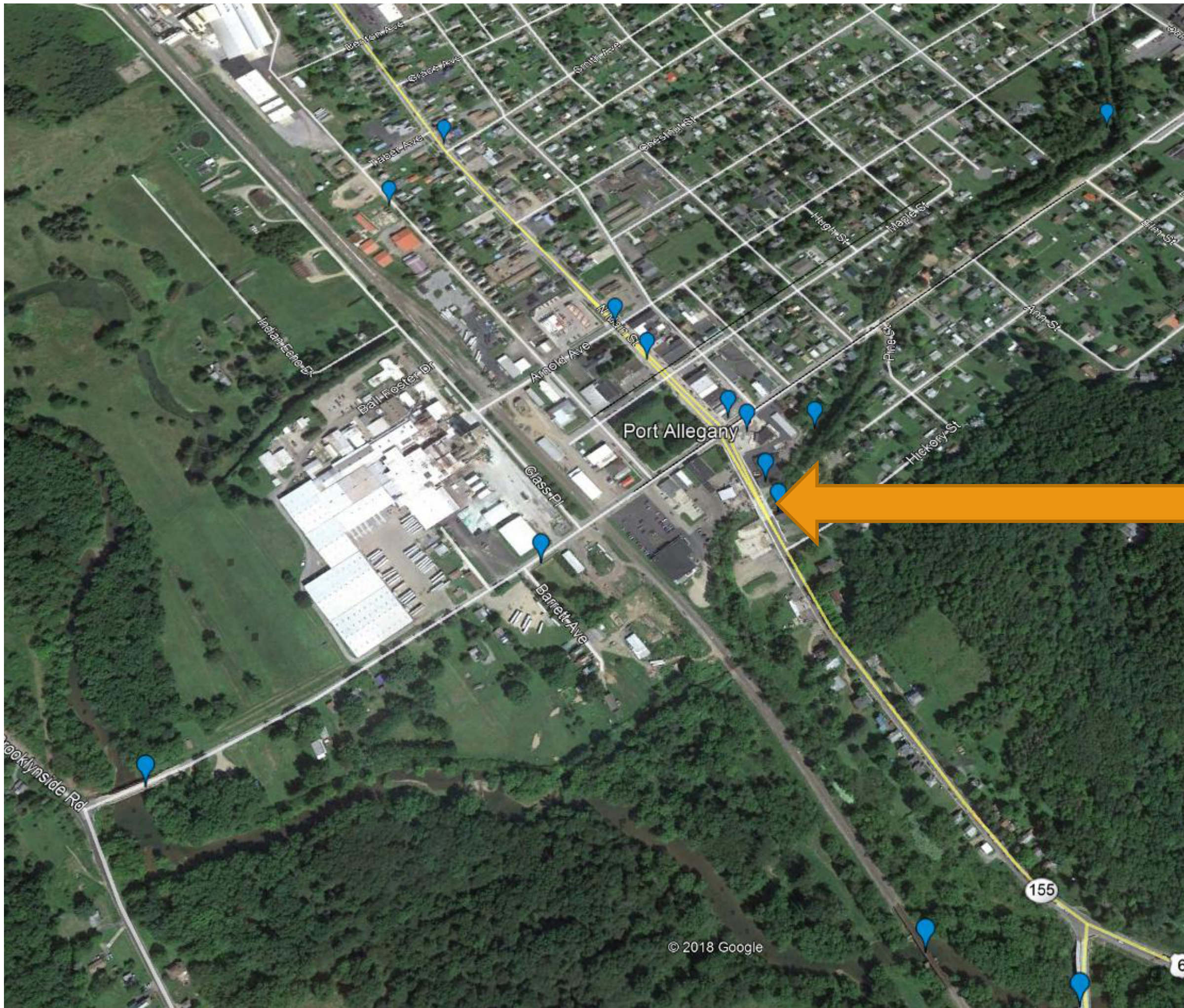
Review of Available Flood Information



Review of Available Flood Information

TABLE 6.—*Flood-crest elevations*—Continued

Stream and location	Miles above month	Day and hour (July)	Elevation (feet)
SUSQUEHANNA RIVER DRAINAGE BASIN—Continued			
First Fork Sinnemahoning Creek:			
Costello, Pa.. mouth of Freeman Run	25.2	18, 1 p. m.	1,195.4
Nelson Run, 0.6 mile below mouth of	21.4		1,132.7
Wharton, Pa., mouth of East Fork	19.7	18, 2 p. m.	1,094.5
Bailey Run, mouth of	17.2		1,063.5
First Fork, Pa	12.0	18, 3 p. m.	
Lushbaugh, Pa., 1.1 miles downstream at mouth of Short Bend Run.	8.1		907.4
Lick Island	4.3	18, 4 p. m.	844.7
Mouth	0	18, 5 p. m.	
Freeman Run:			
Austin, Pa., above, at dam that failed	5.6	18, 11 a. m.	
Austin, Pa., Ford garage	3.3	18, 11:30 a. m.	1,353.5
Highway bridge	.6		1,223.4
East Fork Sinnemahoning Creek: Highway bridge	2.5		1,172.8
ALLEGHENY RIVER DRAINAGE BASIN			
Allegheny River: [1]			
Seven Bridges, Pa., Dunn farm	317.9	18, 7:30 a. m.	1,930.9
Coudersport, Pa., highway bridge	308.6	18, 1:30 p. m.	1,646.7
Roulette, Pa., highway bridge	298.3	18, 2 p. m.	1,535.1
Burtville, Pa., highway bridge	295.1		1,505.4
Port Allegany, Pa., State Highway 155, bridge	289.6		1,482.1
Port Allegany, Pa., U. S. Highway 6, old bridge	288.9	18, 3:30 p. m.	1,479.0
Port Allegany, Pa., U. S. Highway 6, new bridge (destroyed by flood).	288.0		1,477.4
Turtlepoint, Pa., highway bridge	281.7		1,453.7
Larabee, Pa., highway bridge, USGS gage (discontinued)	276.4	19, 1 a. m.	1,447.4
Eldred, Pa., highway bridge, USGS gage	269.0	19, 9:30 a. m.	1,443.8
Mill Grove, N. Y., highway bridge	262.9		1,434.5
Portville, N. Y., fire department building	261.4	19, 3 p. m.	1,434.5
Olean, N. Y., highway bridge	255.5	19, 6:30 p. m.	1,423.3
North Allegany, N. Y., highway bridge	250.7		1,413.9
Vandalia, N. Y., highway bridge	246.4	19, 11:30 p. m.	1,404.7
Riverside Junction, N. Y., Erie R. R. bridge	242.1		1,393.5
South Carrollton, N. Y., railroad bridge	240.4		1,388.6
Salamanca, N. Y., highway bridge	233.7	20, 5 a. m.	1,374.2
Red House, N. Y., highway bridge, USGS gage	226.0	20, 8:30 a. m.	1,342.2
Quaker Bridge, N. Y., highway bridge	220.4		1,320.2
Onoville, N. Y., highway bridge	214.0		1,290.6
Kinzua, Pa., railroad bridge, USGS gage	200.0	20, 5 p. m.	1,217.7
Clarion River:			
Instanter	109.4	18, 3:30 p. m.	
Johnsonburg, Pa., lower highway bridge	94.0	18, 9 p. m.	1,439.8
Ridgway, Pa., West Penn power station	88.4		1,390.0
Ridgway, Pa., Main Street bridge, USGS gage	87.4	19, 1 a. m.	1,378.0
Carman, Pa., highway bridge	80.1		1,330.4
Bell Town, Pa., highway bridge	62.2		1,225.2
Cooksburg, Pa., dam site gage	49.3		1,170.6
Cooksburg, Pa., highway bridge, USGS gage	47.6	19, 9:30 a. m.	1,161.4
Clarion, Pa., Piney Dam, upper pool	25.1		1,093.1
St. Petersburg, Pa., highway bridge, USGS gage	4.5	19, 2 p. m.	891.0

[1] Data other than for gaging stations furnished by Corps of Engineers.

ADDITIONAL FLOOD CREST ELEVATIONS

JULY 1942

ALLEGHENY RIVER ABOVE KINZUA, PA.

Miles above Mouth	Location	Elevation (feet)
200.0	Kinzua, Pa.; R. R. bridge; gage	1,217.7
214.0	Onoville, N. Y.; highway bridge	1,290.6
220.4	Quaker Bridge, N. Y.; highway bridge	1,320.2
226.0	Red House, N. Y.; highway bridge; gage	1,342.2
233.7	Salamanca, N. Y.; highway bridge	1,374.2
240.4	South Carrollton, N. Y.; R. R. bridge	1,388.6
242.1	Riverside Jct., N. Y.; Erie R. R. bridge	1,393.5
246.4	Vandalia, N. Y.; highway bridge	1,404.7
250.7	North Allegany, N. Y.; highway bridge	1,413.9
255.5	Olean, N. Y.; highway bridge	1,423.3
261.4	Portville, N. Y.; fire department building	1,434.5
262.9	Mill Grove, N. Y.; highway bridge	1,434.5
269.0	Eldred, Pa.; highway bridge; gage	1,443.8
276.4	Larabee, Pa.; highway bridge; gage	1,447.4
281.7	Turtlepoint, Pa.; highway bridge	1,453.7
288.9	Port Allegany, Pa.; highway bridge; Route No. 6	1,479.0
289.6	Port Allegany, Pa.; highway bridge; Route 155	1,482.1
295.1	Burtville, Pa.; highway bridge	1,505.4
298.3	Roulette, Pa.; highway bridge	1,535.1
308.6	Coudersport, Pa.; highway bridge	1,646.7
317.9	Seven Bridges, Pa.; Dunn Farm	1,930.9

Notes.- Elevations, except at gaging stations, furnished by U. S. Engineer Office, Pittsburgh, Pa.

The July 1942 flood crest elevation at Mile 288.0, the location of the new bridge site for Route 6, is 1,477.4 feet.

Review of Available Flood Information

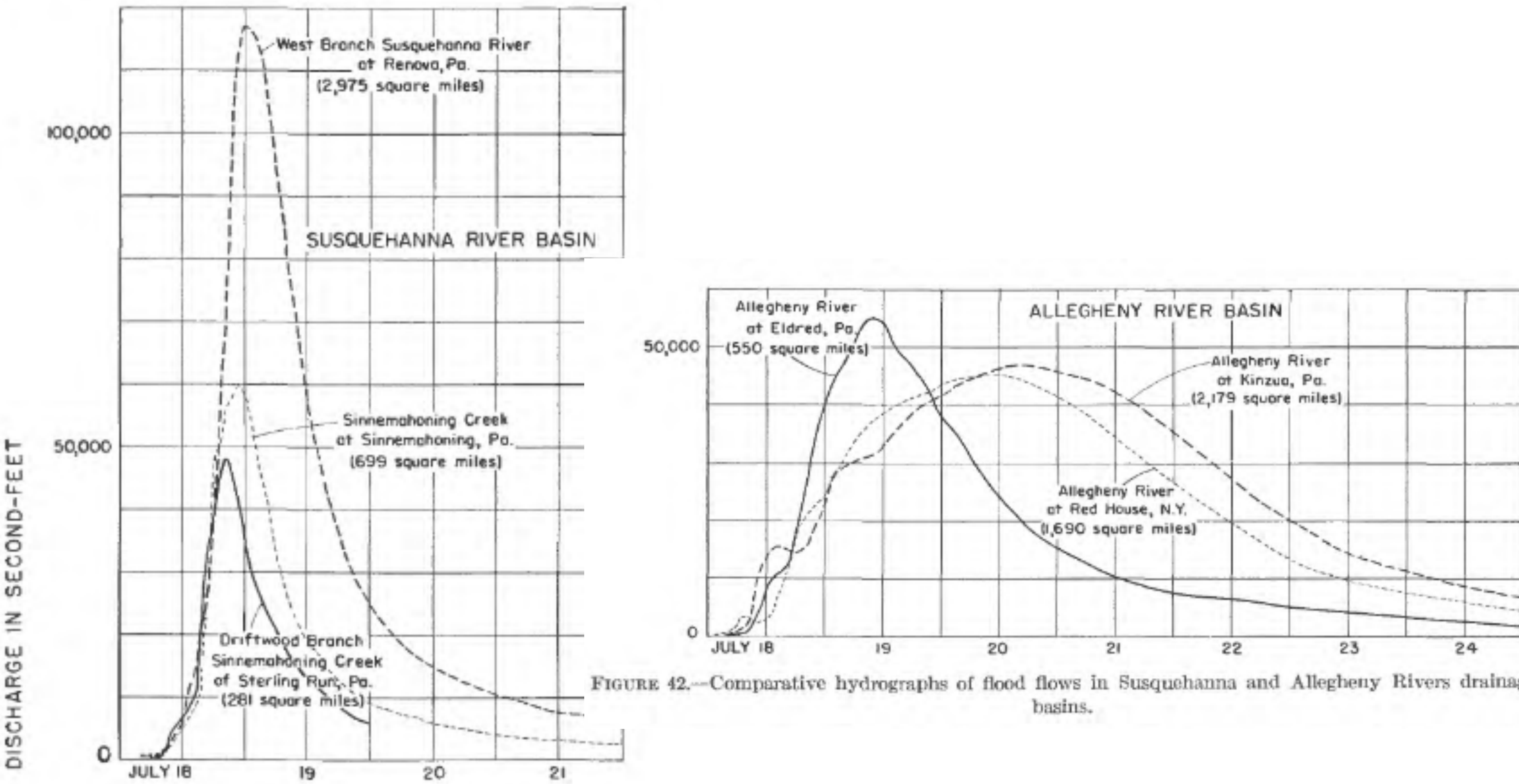
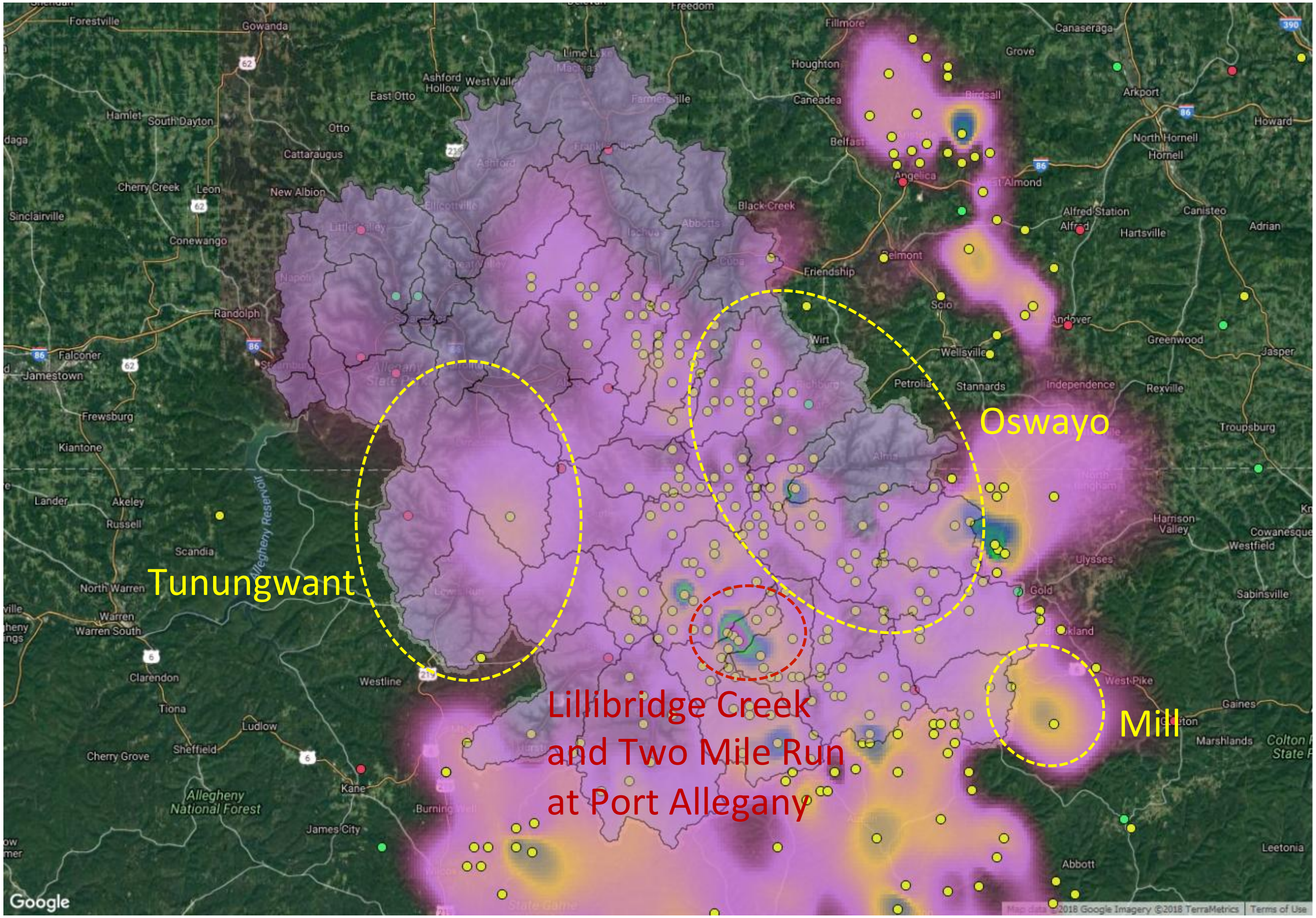


FIGURE 42.—Comparative hydrographs of flood flows in Susquehanna and Allegheny Rivers drainage basins.

July 1942 Rainfall Adjustments and Lessons Learned



July 1942 Rainfall Adjustments and Lessons Learned

- The original rainfall temporal distribution in the tributary sub-watersheds between Coudersport and Port Allegany is front loaded, which lead to a very early peak flow. The temporal pattern revised to better match nearby hourly gages.
- Hydrology does support the record rainfall at Port Allegany but only if it had very localized spatial influence. This is based on flood analysis in the Lillibridge Creek and Two Mile Run watersheds and their unnamed tributaries. See later slides.
- For the Mill Creek sub-watershed (just upstream of Coudersport PA), factors were applied to further adjust rainfall by reducing the 2 peak hourly depths and redistributing to the other hours to maintain the total volume.
- The spatial extent of the "Bradford 2A" gage inn the Tunungwant Creek Watershed was reduced. This gage is located in the Bradford PA area were rainfall collection was sparse.

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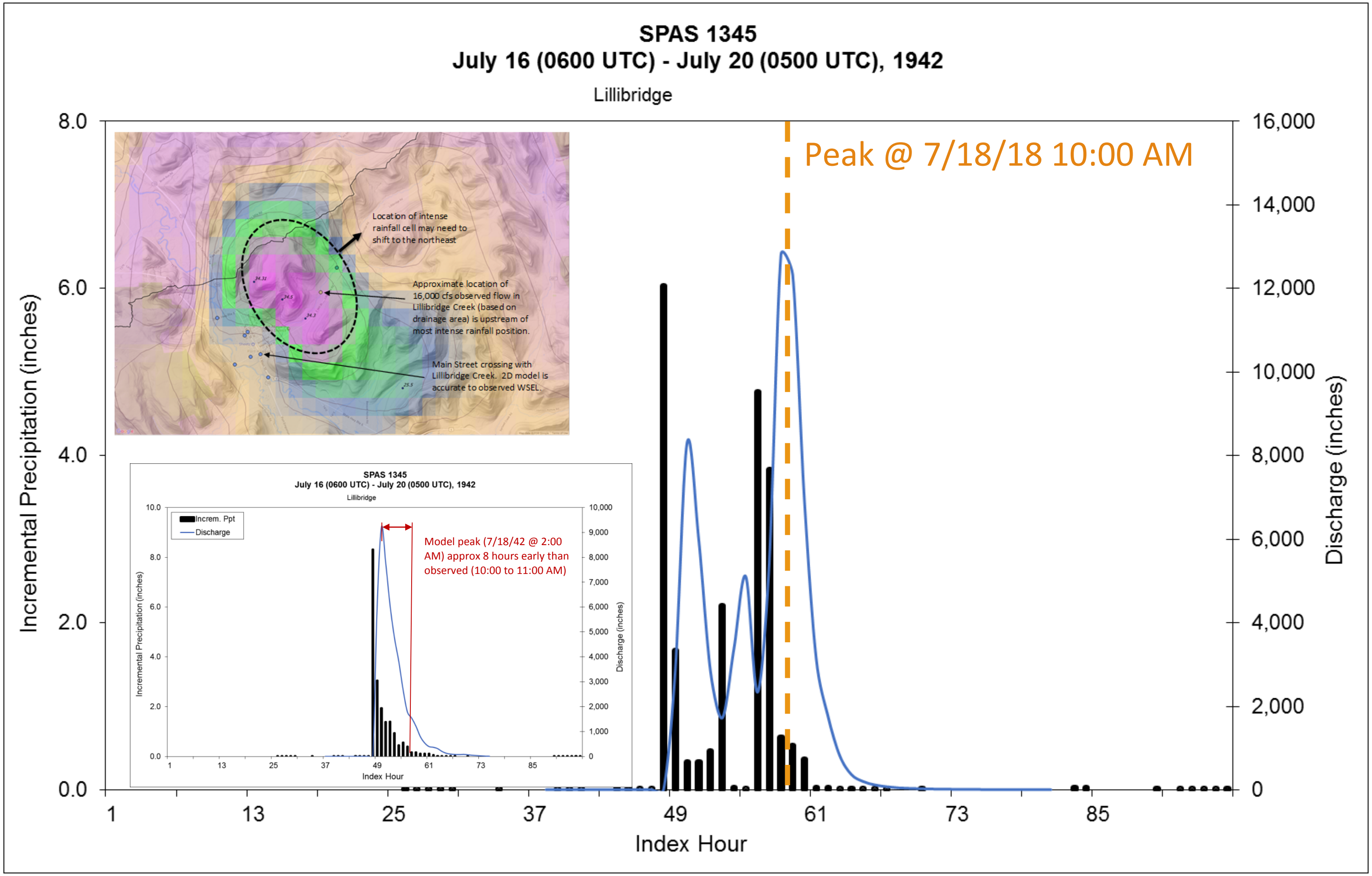
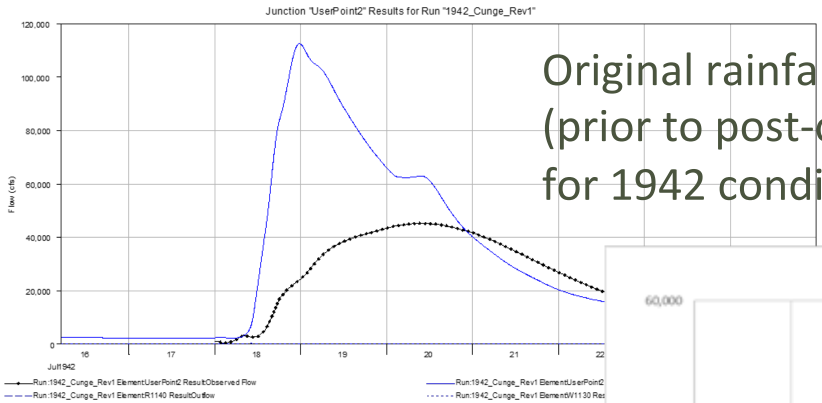
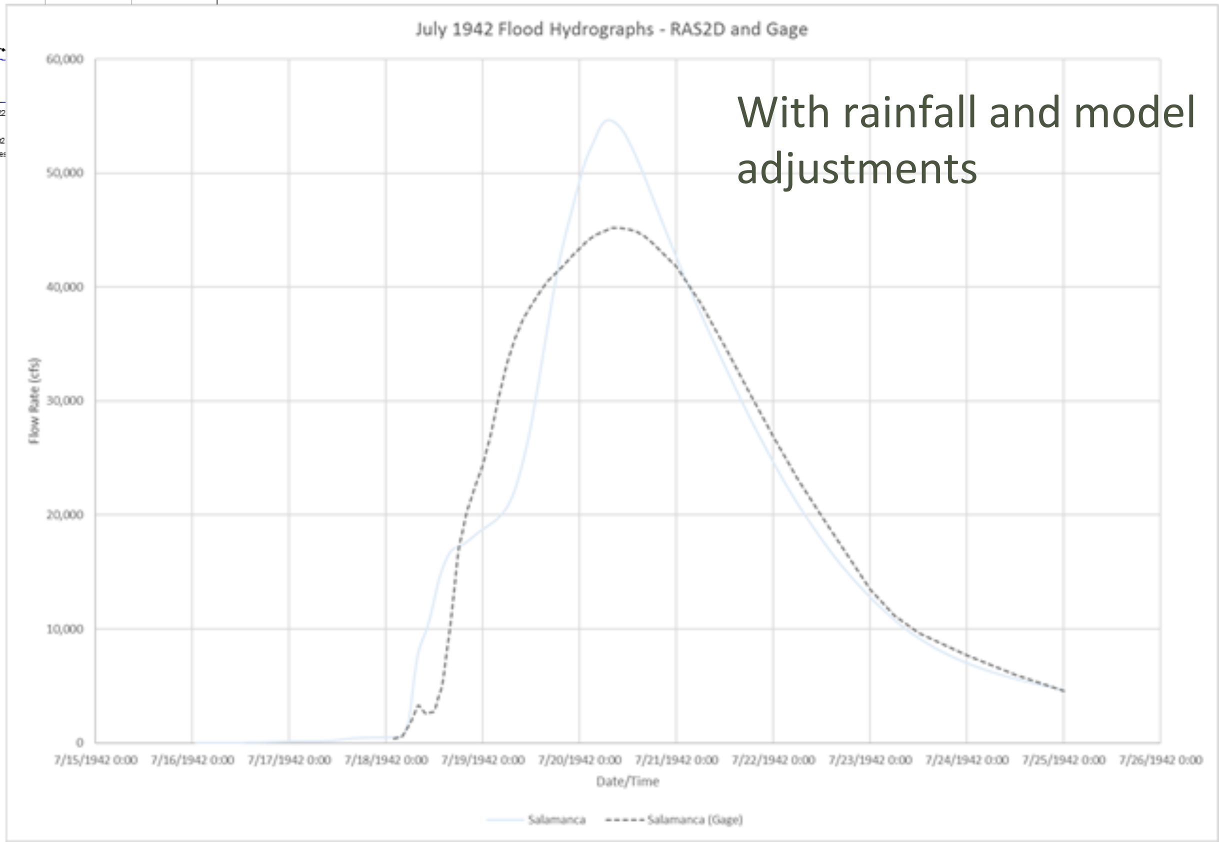
July 1942 Rainfall Adjustments and Lessons Learned



Downstream Results of 1942 Rainfall & Modeling Adjustments



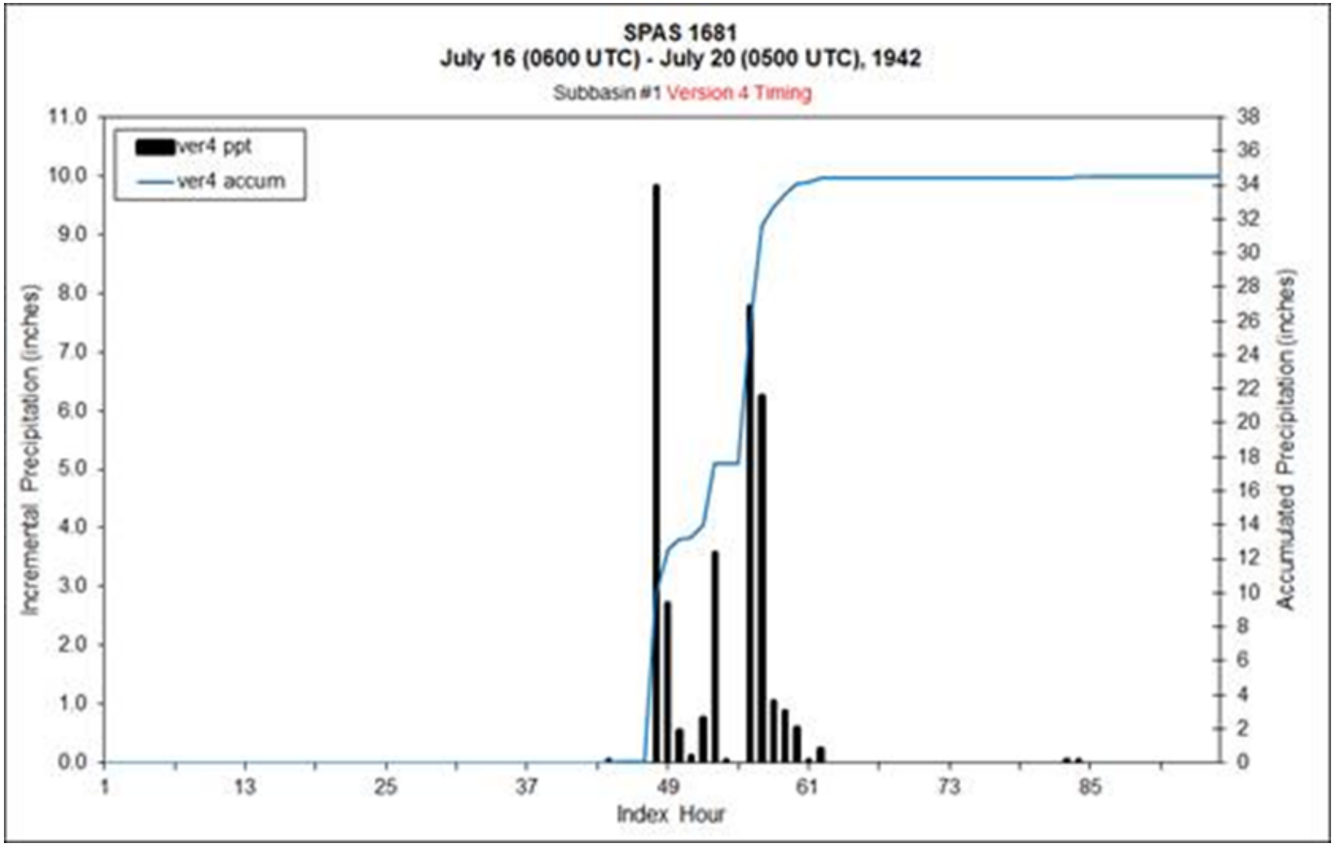
Original rainfall and calibrated models (prior to post-calibration adjustments for 1942 conditions)



With rainfall and model adjustments

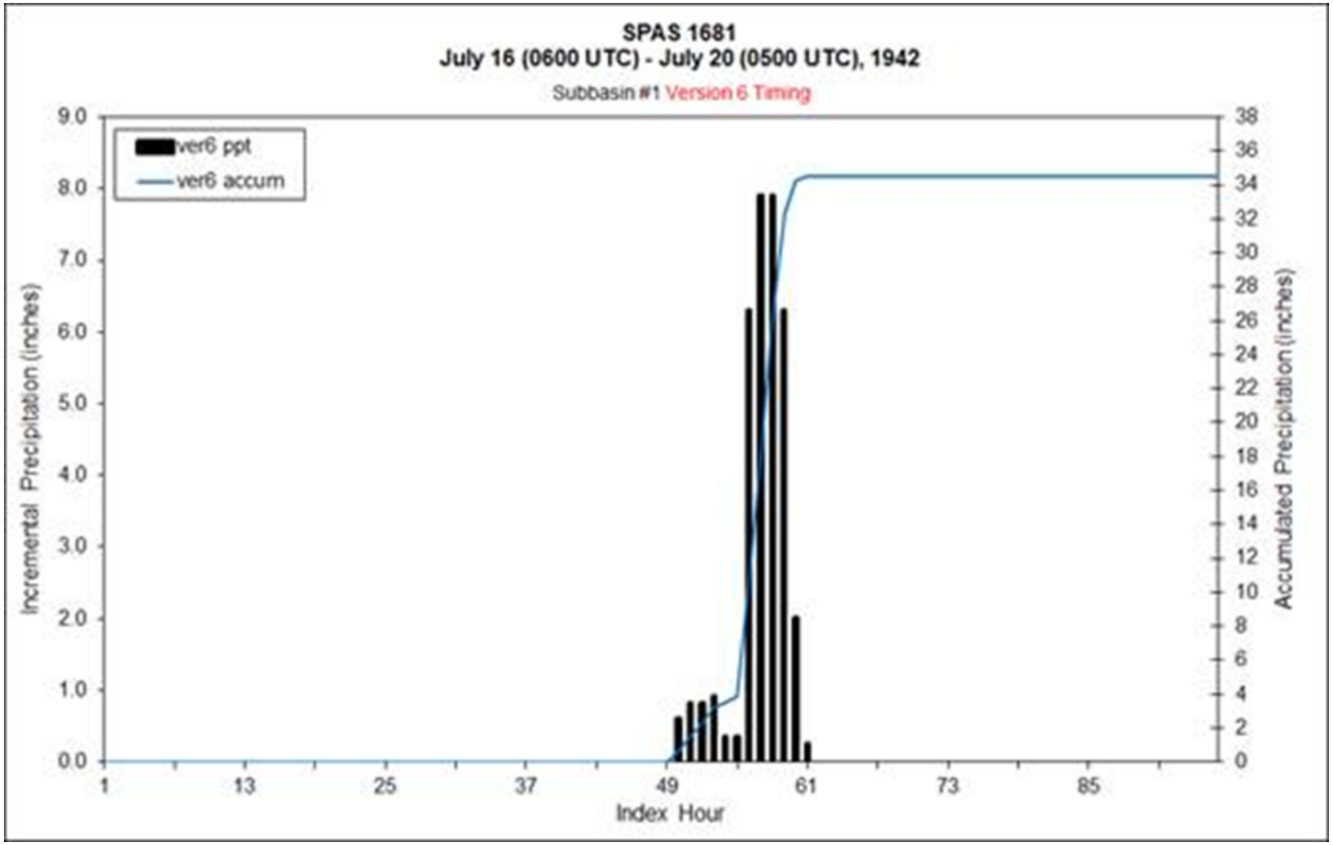
July 1942 Rainfall Adjustments and Lessons Learned

- The adjusted temporal pattern in the Upper Allegheny River watershed provides a good overall hydrologic fit but does not contain the record rainfall at Port Allegany (30.8 inches in 4.5 hours).



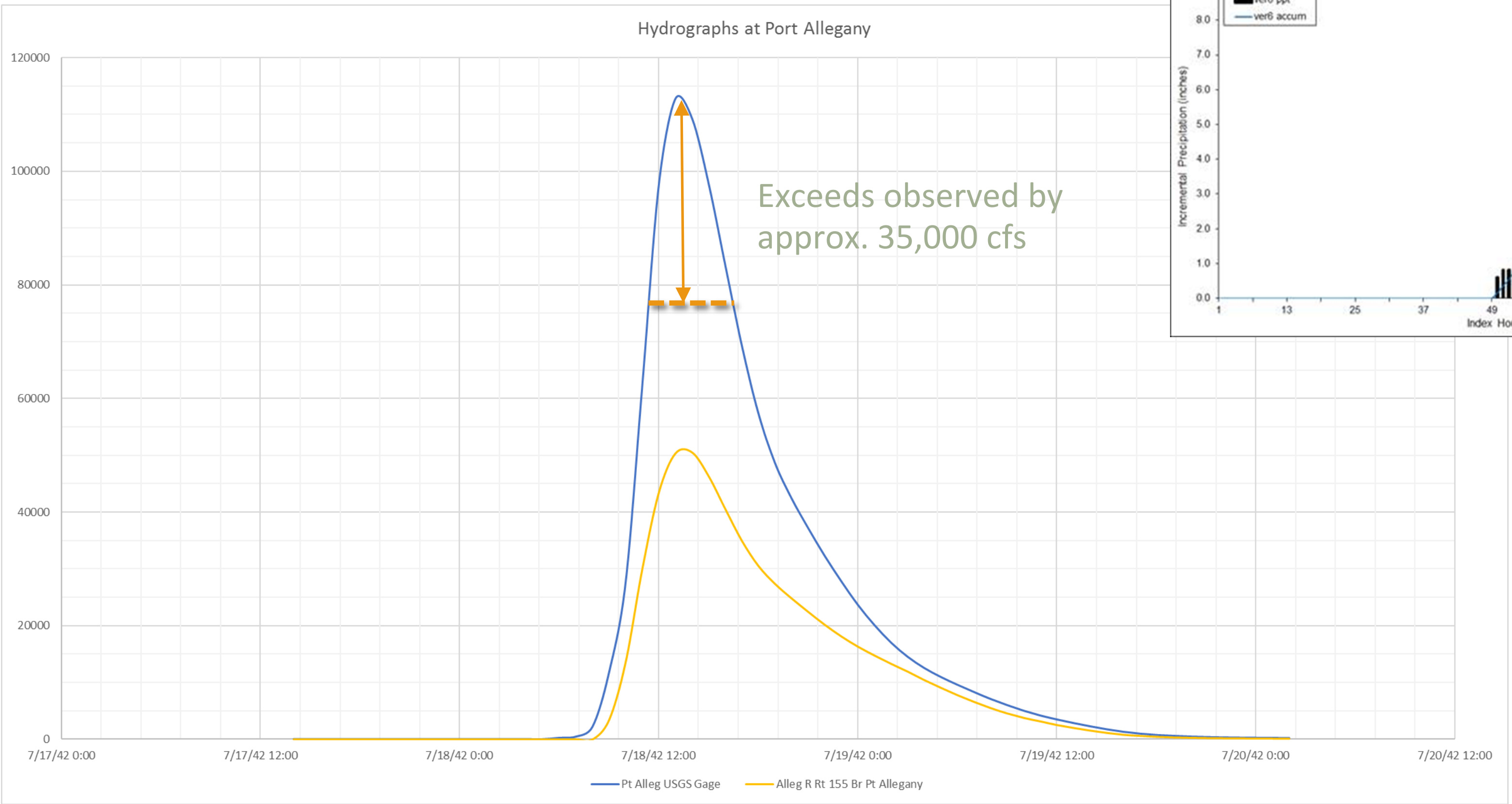
July 1942 Rainfall Adjustments and Lessons Learned

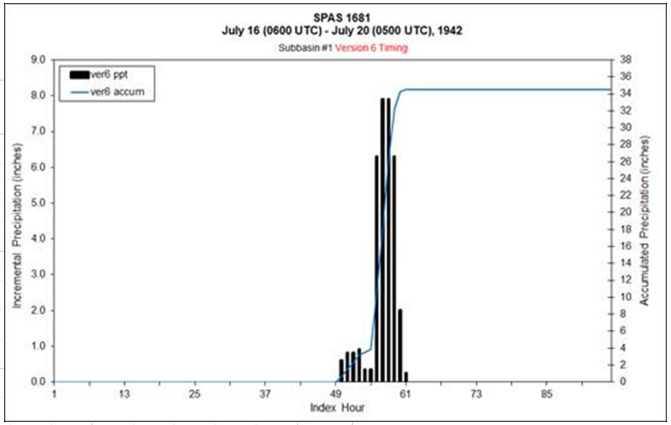
- An alternative temporal pattern was developed (below) that does contain the record 4.5-hour rainfall. This rainfall was applied at Port Allegany (at the storm center) and interpolated in SPAS to the surrounding hourly gages.



July 1942 Rainfall Adjustments and Lessons Learned

- The RiverFlow2D model shows that the alternative rainfall pattern, when permitted to have broad influence between hourly gages, does not produce a good hydrologic match.

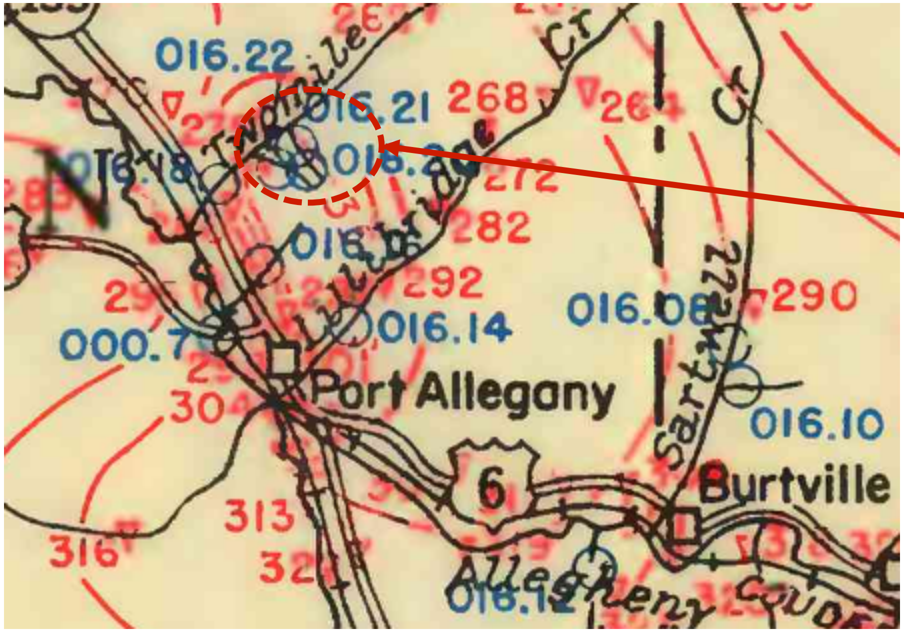




July 1942 Rainfall Adjustments and Lessons Learned

- Does that mean the record rainfall didn't actually happen? Localized hydrology does support the record rainfall but shows that it was very localized and the temporal pattern outside the localized cell would have been more closely patterned after the nearby hourly gages.

- Below is from the Water Supply Paper 1134-B Report, which shows peak flow measurements in blue.



Location of record rainfall observation near flow measurements at points 016.20, 21, and 22.

July 1942 Rainfall Adjustments and Lessons Learned

- The input to RiverFlow2D was gridded hourly rainfall. Therefore, very small watersheds with short time-of-concentrations, would have required sub-hourly data to hydrologically reproduce the peak flows. A simple Rational Equation was applied (with C factors calibrated to the RiverFlow2D model at 6 to 7 mi^2 sub-watersheds) to obtain an estimated rainfall intensity that would have produced observed flows.

Watershed	Point #	Drainage Area (mi^2)	Peak Flow (cfs)	Flow per Sq Mi (cfs/mi^2)	Peak Intensity (in/hr)
Lillibridge Creek	016.14	6.7	16000	2388	10.7
Lillibridge Creek		6.3	15000	2381	10.7
Port Allegany	016.16	0.39	1400	3590	16.1
Two Mile Run	016.18	7.06	15000	2125	9.5
Two Mile Run	016.20	0.032	200	6250	28.0
Two Mile Run	016.21	0.053	640	12075	54.0
Two Mile Run	016.22	0.087	400	4598	21.0
Sartwell Creek	016.08	9.86	11000	1116	5.0
Sartwell Creek	016.10	0.094	310	3298	15.0
Dexter Run	016.12	0.83	840	1012	4.5
Laninger Creek	016.05	0.45	850	1889	8.5
Annin Creek	016.25	11.4	24000	2105	9.4

These high rainfall intensity estimates suggest that the record rainfall observation was plausible but:

1. Very localized; and
2. Occurred with intervals of very short, but very high-intensity bursts over a 2 to 3 hour period that accumulated to the 30.8 inches in 4.5 hours.

Questions

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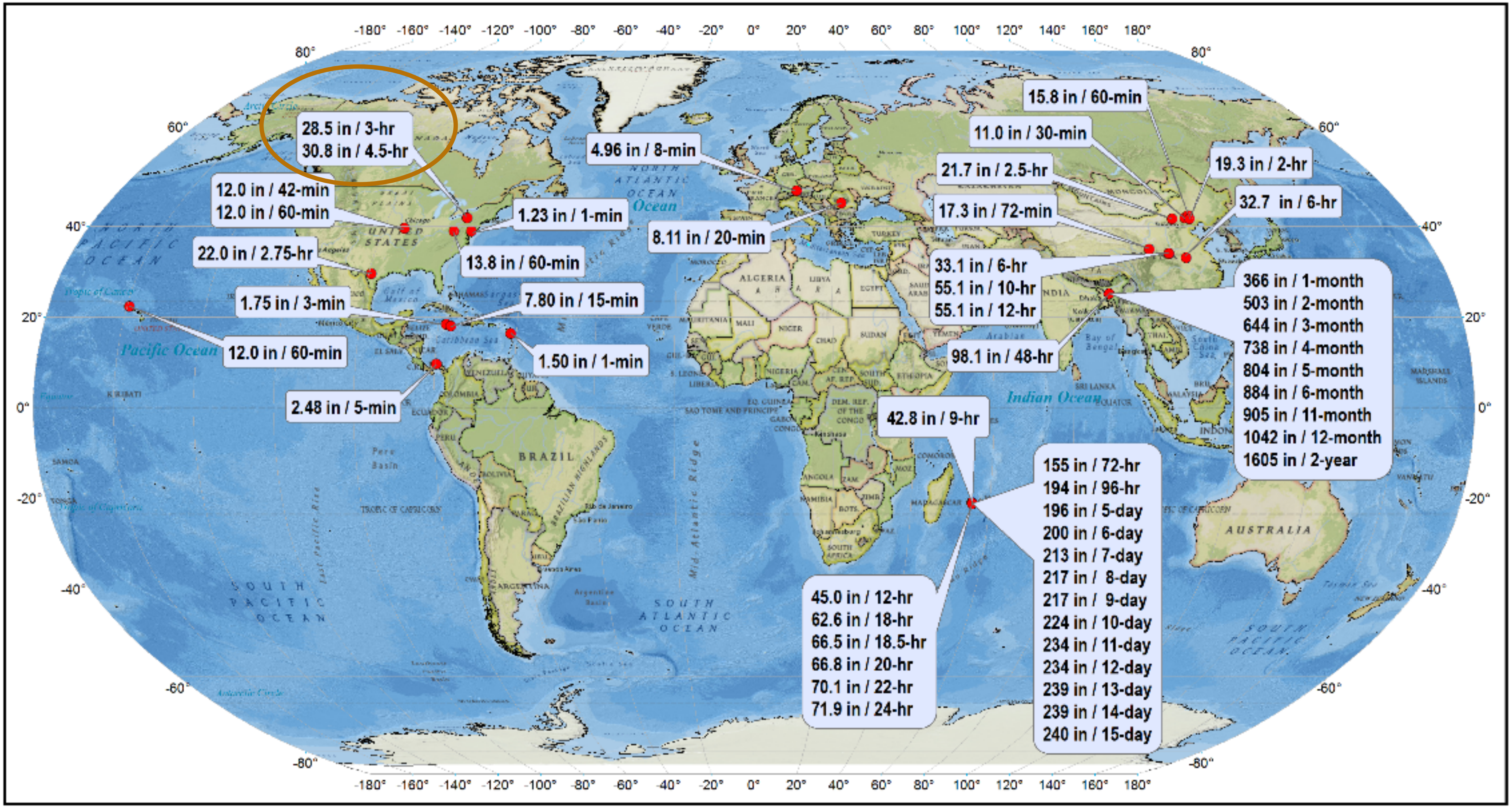
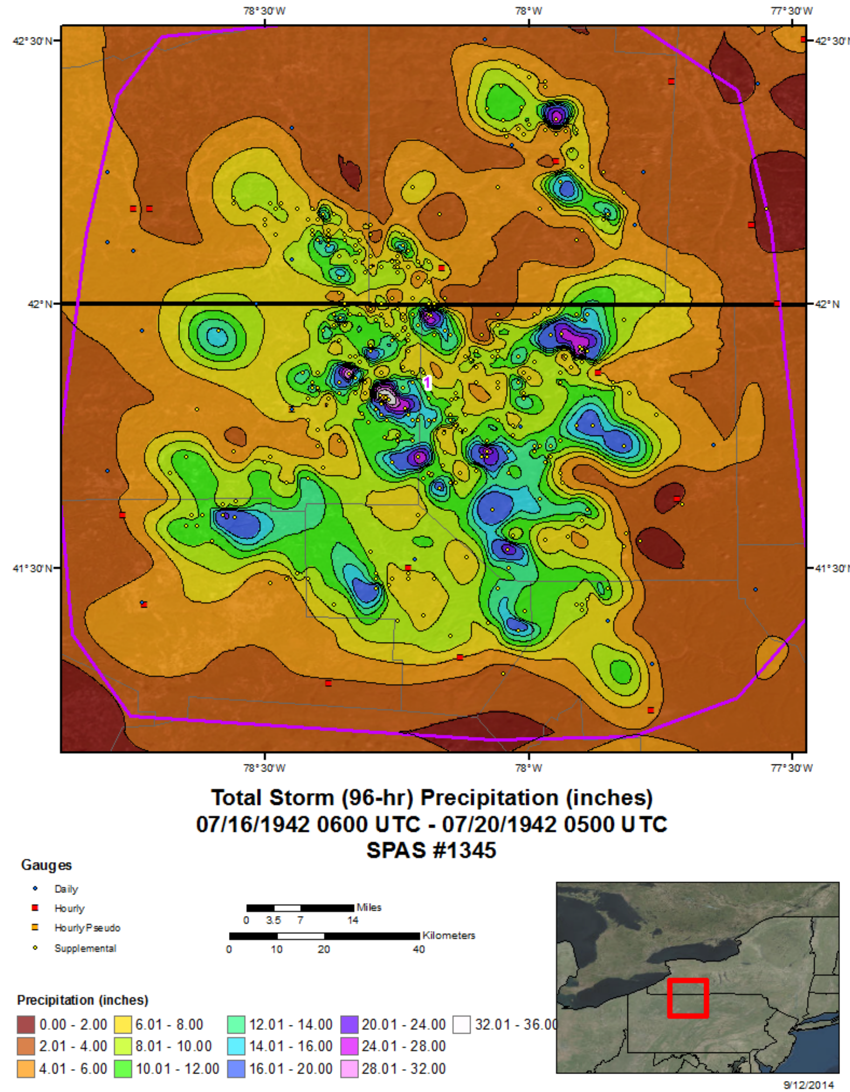
ATERRA SOLUTIONS

Objective



SPAS Total Storm Isohyetal Original Analysis



Overview of the July 1942 Storm and Flood