Michael Baker
INTERNATIONAL
We Make a Difference

Estimating Peak flows for Ungaged Streams Using Trail Camera Images

By Mark Hoskins

Introduction

- Indiana DNR eFARA Mapping and Hydrology
- Baker builds an HMS model **Trail Camera Calibration**
- Issues with Calibration
- Inputting **Synthetic rainfall** into HMS model
- **Comparison** of Indiana DNR and Baker Flows
- Get out the Popcorn !

Michael Baker
INTERNATIONAL

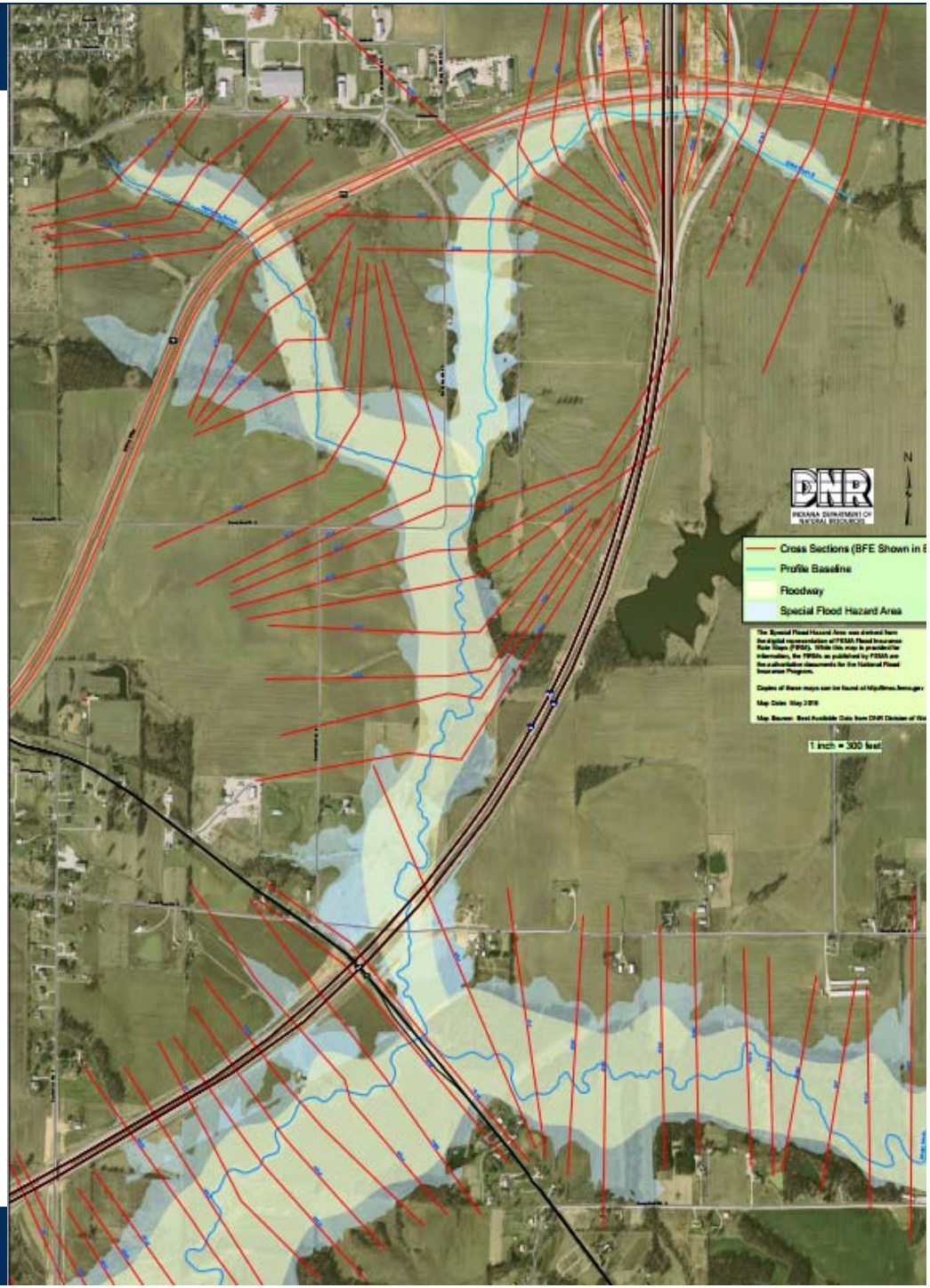
A developer asks…

Is this IDNR Flood Study too Conservative?

IDNR Flood Map merged:

1) Regression Equations
2) No structures (“Approximate”)
3) LiDAR channel and overbank

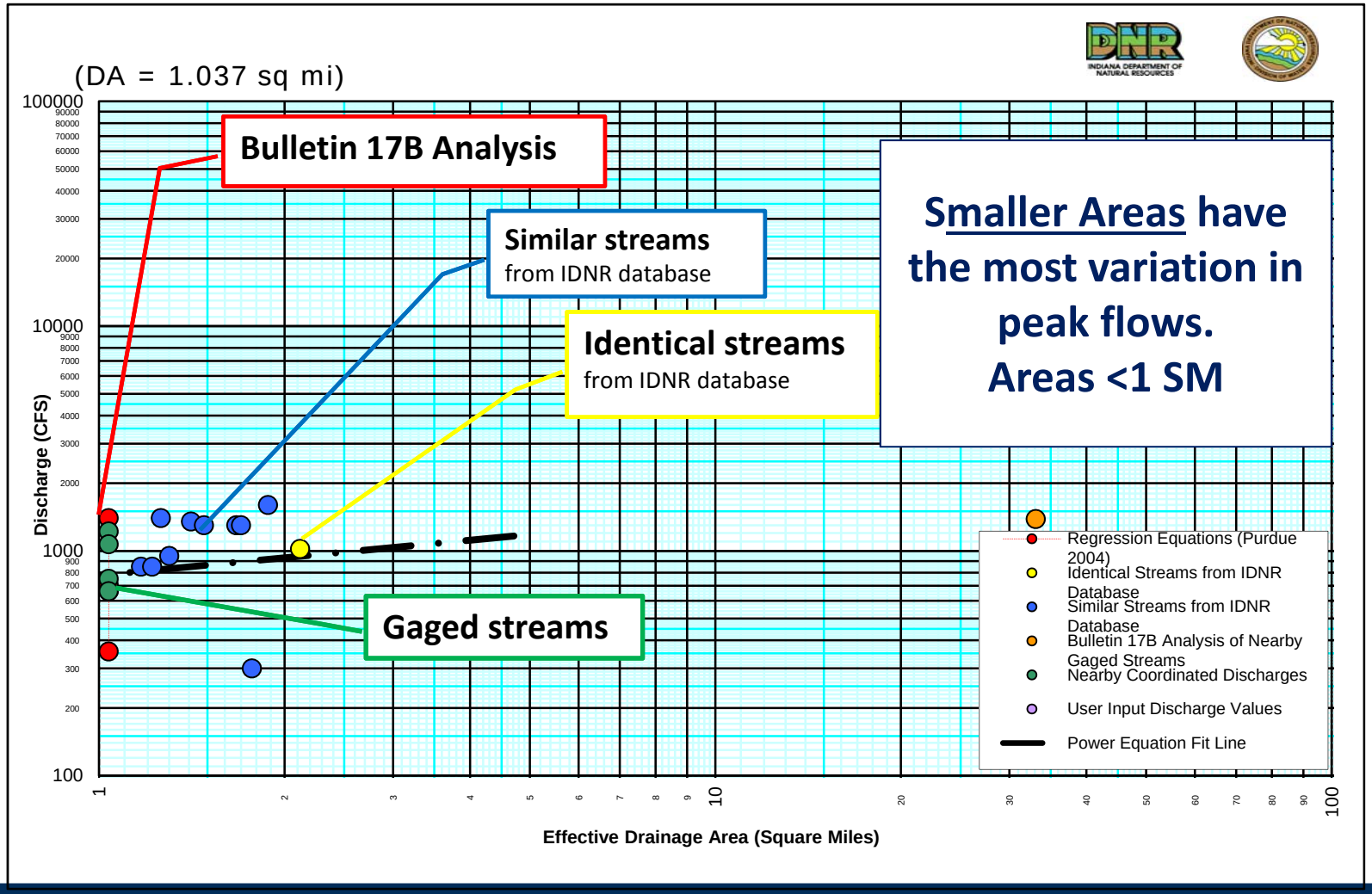
More details on how was this model constructed?



Indiana DNR Hydrology (Peak Flows)

- Currently unmapped FEMA floodplain
- Indiana maps approximate studies upon request
  - **Under the eFARA Program**
- IDNR hydrology, uses several estimates:
  - **Regression equations + one standard deviation**
  - **Use Bulletin 17B**
  - **Nearby gaged streams**
  - **Similar Stream Discharges**
- Approximate with no bridges or channel survey

Existing IDNR Hydrology



Baker Hydrology HMS Model

- Compare HMS model to IDNR hydrology
  - Bulletin 71 storms 1,3,6,12,14 Hour (Huff Quartiles)
  - Add TOC, CN of the watershed
  - Modified-Puls Channel Routing

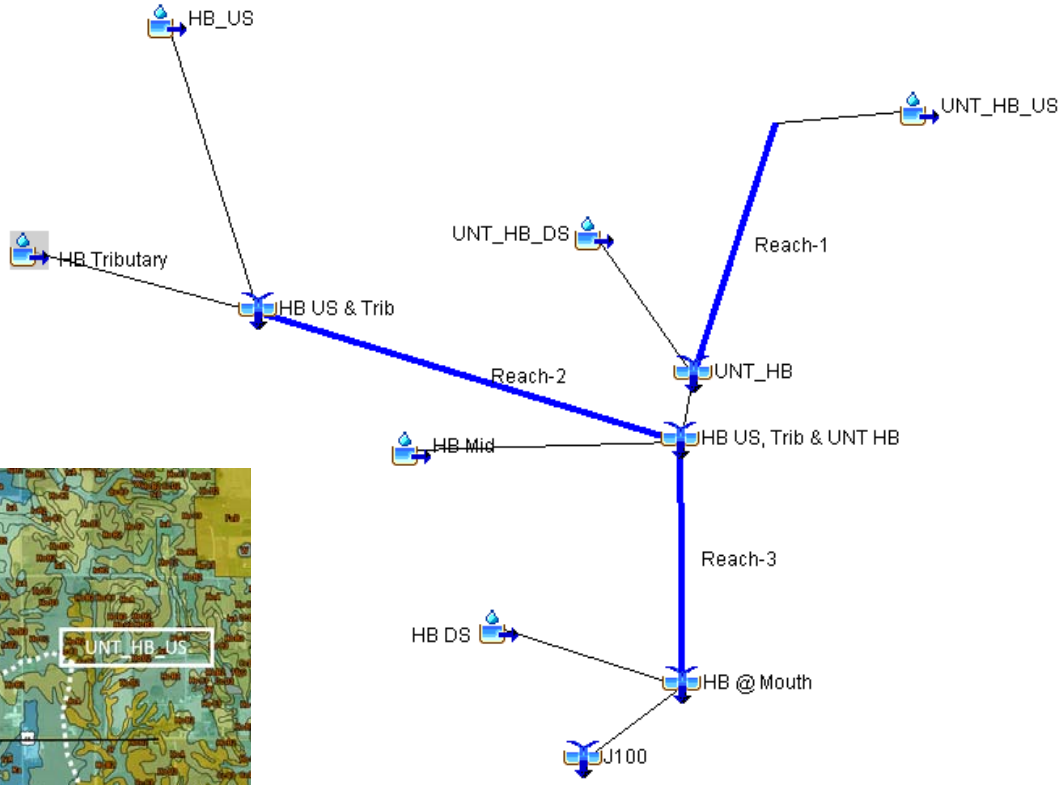
- Detailed HEC-RAS model based on field survey and including bridges

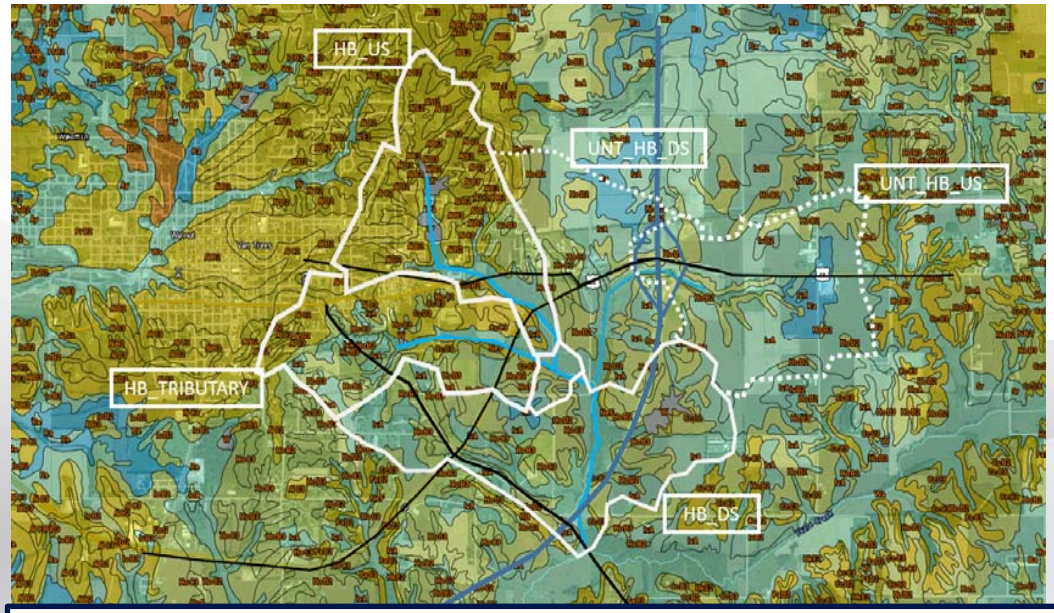
Michael Baker INTERNATIONAL
We Make a Difference

Baker HMS Model Parameters

Watershed parameters:

Time of Concentration
CN value
Modified Puls channel routing
Used Bulletin 71 rainfall
Ran 1,3,6,12,and 24 hour storms





NRCS Soils and Color-Coded Hydrologic Soils map

Need Calibration…

Michael Baker INTERNATIONAL
We Make a Difference

Trail Camera Calibration

In 2 months…calibrate with a 100 year storm?

Decided to TRY USING a trail camera

Baker Hydrology Calibration/Verification

Modeling Challenge	Modeling Answer
1) Rainfall spatial variability	Daily/Hourly NOAA Radar
2) Rainfall depth	NOAA and CoCoRAS
3) Delta Channel water levels	Trail Camera
4) Backwater effects	HEC-RAS Model
5) Pre-storm moisture	AMC 1,2 or 3 ?
6) Does 100 yr. rain = 100 yr. runoff	Almost Never

Michael Baker
INTERNATIONAL
We Make a Difference

Trail Camera Specifications

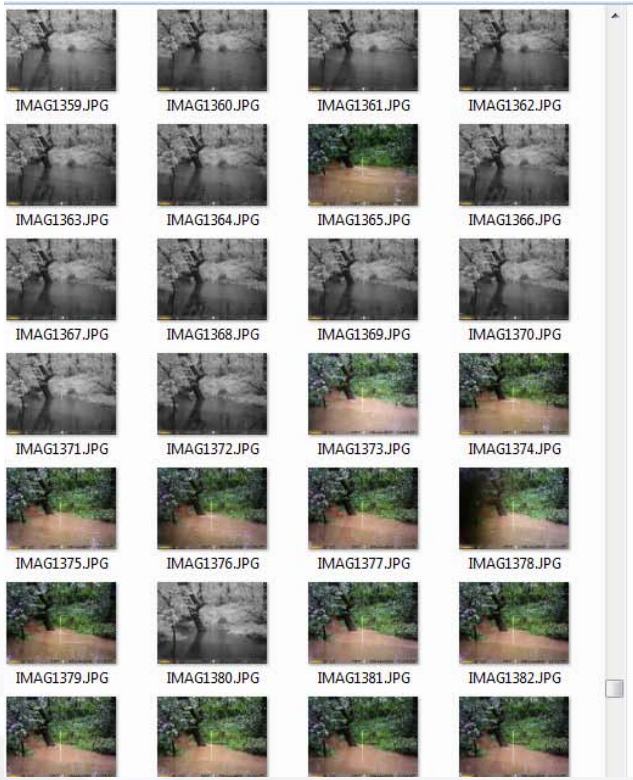
$145 trail camera capable of taking 5 minute interval

Day and night pictures for 3 months (IR lens)

Need 32 GB SD card

Michael Baker
INTERNATIONAL

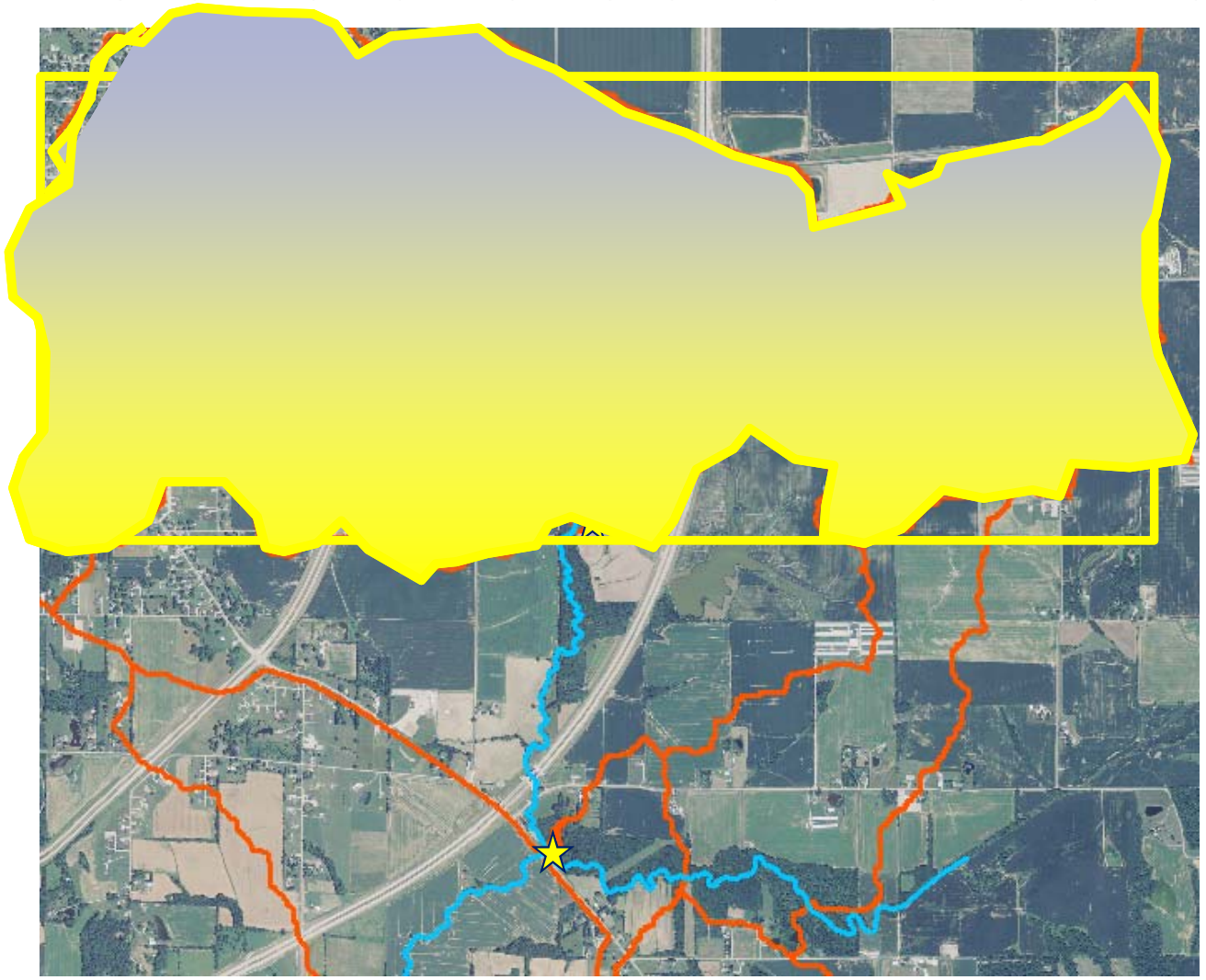
We Make a Difference

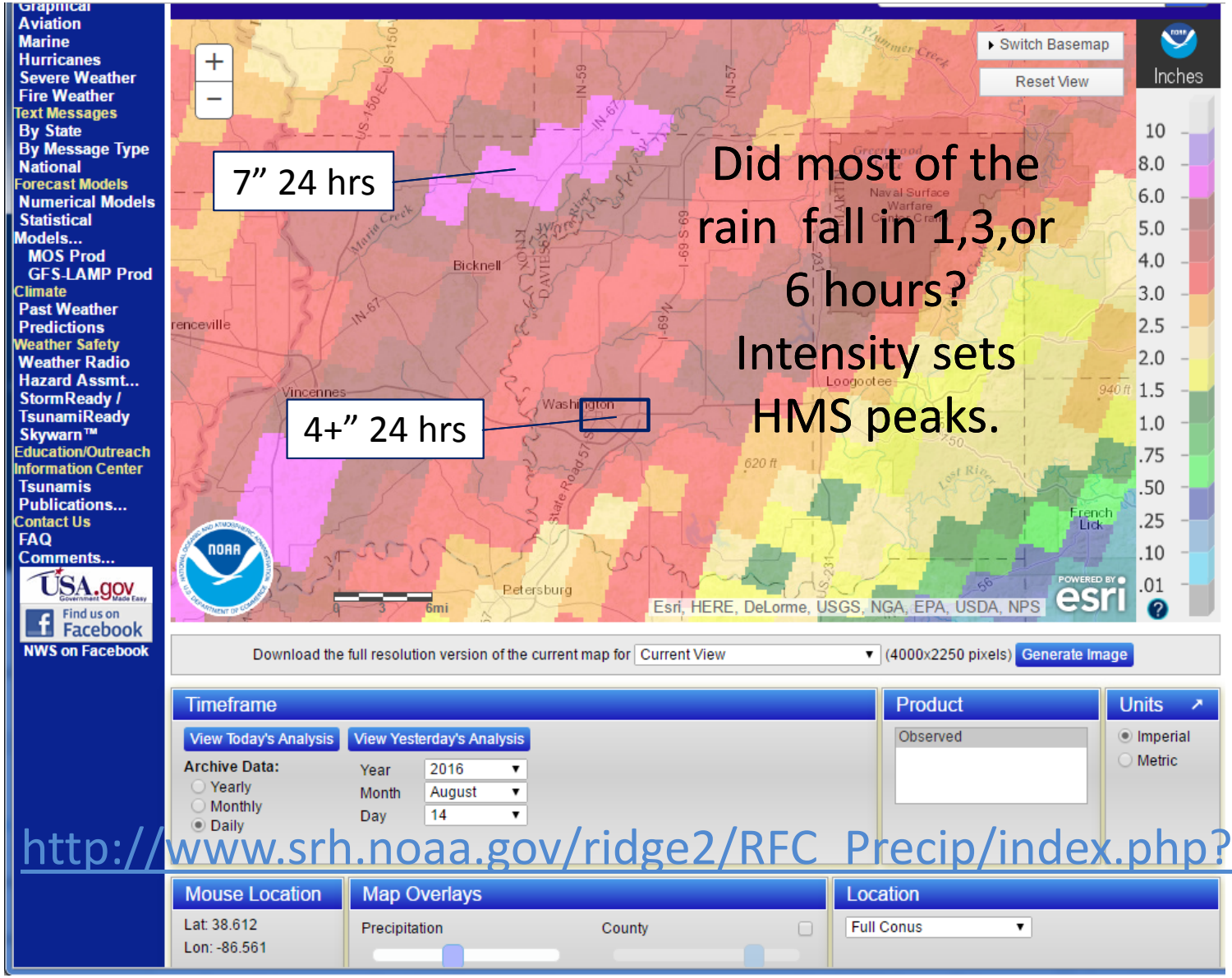


Camera pictures every 5 minutes… lots of images! See staff markings

For this study… it rained hard… on August 13 and 14th
Documented Dramatic pictures, a 6 foot rise in water level

Camera Locations and Watersheds





http://www.srh.noaa.gov/ridge2/RFC_Precip/index.php?site=ind

NOAA Atlas 14, Volume 2, Version 3
Location name: Washington, Indiana, US*
Latitude: 38.6414°, Longitude: -87.1106°
Elevation: 490 ft*
* source: Google Maps

POINT PRECIPITATION FREQUENCY ESTIMATES

G.M. Bonnin, D. Martin, B. Lin, T. Parzybok, M.Yekta, and D. Riley

NOAA, National Weather Service, Silver Spring, Maryland

PF_tabular | PF_graphical | Maps_&_aerials

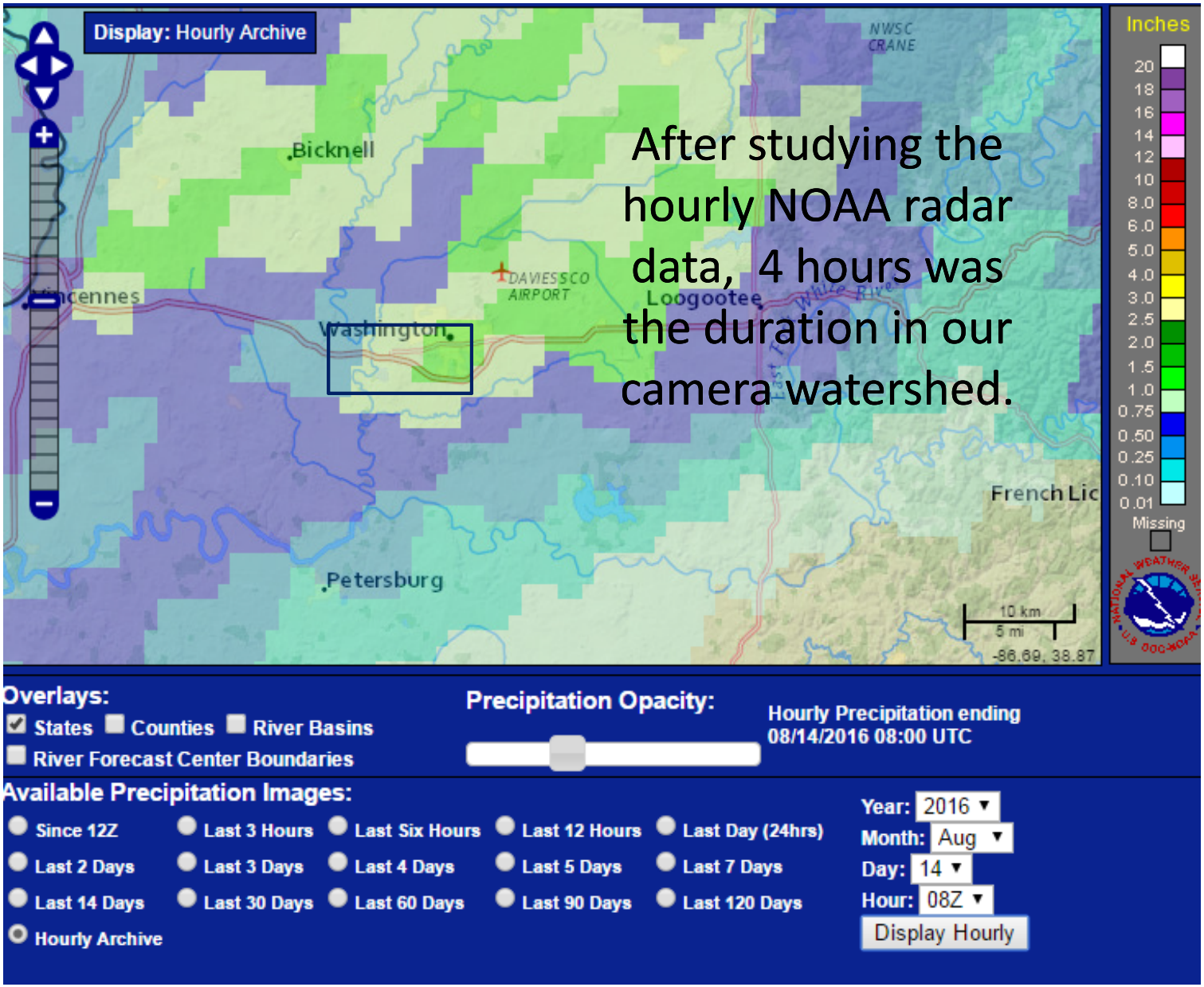
Rain Depth	Storm Duration 1	6	24
2 inches	7yr	1 yr	<1yr
4 inches	500yr	25yr	5yr
6 inches	2000yr	400yr	50yr

PF tabular

PDS-based point precipitation frequency estimates with 90% confidence intervals (in inches)[1]

Duration	Average recurrence interval (years)									
	1	2	5	10	25	50	100	200	500	1000
5-min	0.395 (0.364–0.431)	0.469 (0.431–0.512)	0.556 (0.511–0.607)	0.626 (0.573–0.682)	0.715 (0.652–0.778)	0.785 (0.713–0.854)	0.853 (0.770–0.928)	0.925 (0.830–1.01)	1.02 (0.908–1.11)	1.09 (0.964–1.19)
10-min	0.614 (0.565–0.670)	0.732 (0.672–0.799)	0.864 (0.794–0.943)	0.966 (0.885–1.05)	1.09 (0.997–1.19)	1.19 (1.08–1.29)	1.28 (1.16–1.40)	1.38 (1.24–1.50)	1.50 (1.33–1.63)	1.59 (1.40–1.73)
15-min	0.753 (0.693–0.821)	0.895 (0.822–0.977)	1.06 (0.975–1.16)	1.19 (1.09–1.29)	1.35 (1.23–1.47)	1.47 (1.34–1.60)	1.60 (1.44–1.74)	1.72 (1.54–1.87)	1.87 (1.67–2.04)	1.99 (1.76–2.17)
30-min	0.996 (0.916–1.09)	1.20 (1.10–1.31)	1.45 (1.34–1.59)	1.65 (1.51–1.80)	1.91 (1.74–2.08)	2.11 (1.91–2.29)	2.30 (2.08–2.51)	2.51 (2.25–2.73)	2.77 (2.47–3.02)	2.98 (2.63–3.25)
60-min	1.22 (1.12–1.33)	1.47 (1.35–1.61)	1.82 (1.68–1.99)	2.10 (1.92–2.29)	2.47 (2.26–2.69)	2.77 (2.52–3.02)	3.08 (2.78–3.35)	3.40 (3.05–3.70)	3.84 (3.41–4.18)	4.18 (3.70–4.56)
2-hr	1.45 (1.33–1.58)	1.75 (1.61–1.92)	2.20 (2.01–2.39)	2.55 (2.33–2.78)	3.03 (2.75–3.30)	3.43 (3.10–3.73)	3.84 (3.45–4.17)	4.27 (3.82–4.64)	4.87 (4.31–5.30)	5.35 (4.70–5.83)
3-hr	1.55 (1.42–1.69)	1.87 (1.72–2.04)	2.35 (2.15–2.56)	2.73 (2.49–2.97)	3.27 (2.97–3.56)	3.71 (3.36–4.04)	4.18 (3.76–4.54)	4.68 (4.18–5.08)	5.38 (4.75–5.84)	5.95 (5.20–6.46)
6-hr	1.87 (1.72–2.05)	2.26 (2.08–2.48)	2.82 (2.59–3.09)	3.29 (3.01–3.60)	3.94 (3.58–4.30)	4.48 (4.04–4.88)	5.05 (4.53–5.49)	5.65 (5.04–6.14)	6.50 (5.72–7.07)	7.19 (6.27–7.83)
12-hr	2.22 (2.05–2.42)	2.68 (2.47–2.93)	3.32 (3.06–3.62)	3.84 (3.52–4.18)	4.57 (4.18–4.97)	5.17 (4.70–5.61)	5.79 (5.24–6.29)	6.45 (5.80–7.00)	7.37 (6.56–8.01)	8.11 (7.16–8.82)
24-hr	2.68 (2.51–2.87)	3.21 (3.00–3.44)	3.96 (3.71–4.25)	4.56 (4.26–4.89)	5.41 (5.02–5.80)	6.09 (5.62–6.55)	6.80 (6.24–7.34)	7.54 (6.86–8.17)	8.57 (7.71–9.36)	9.40 (8.35–10.3)

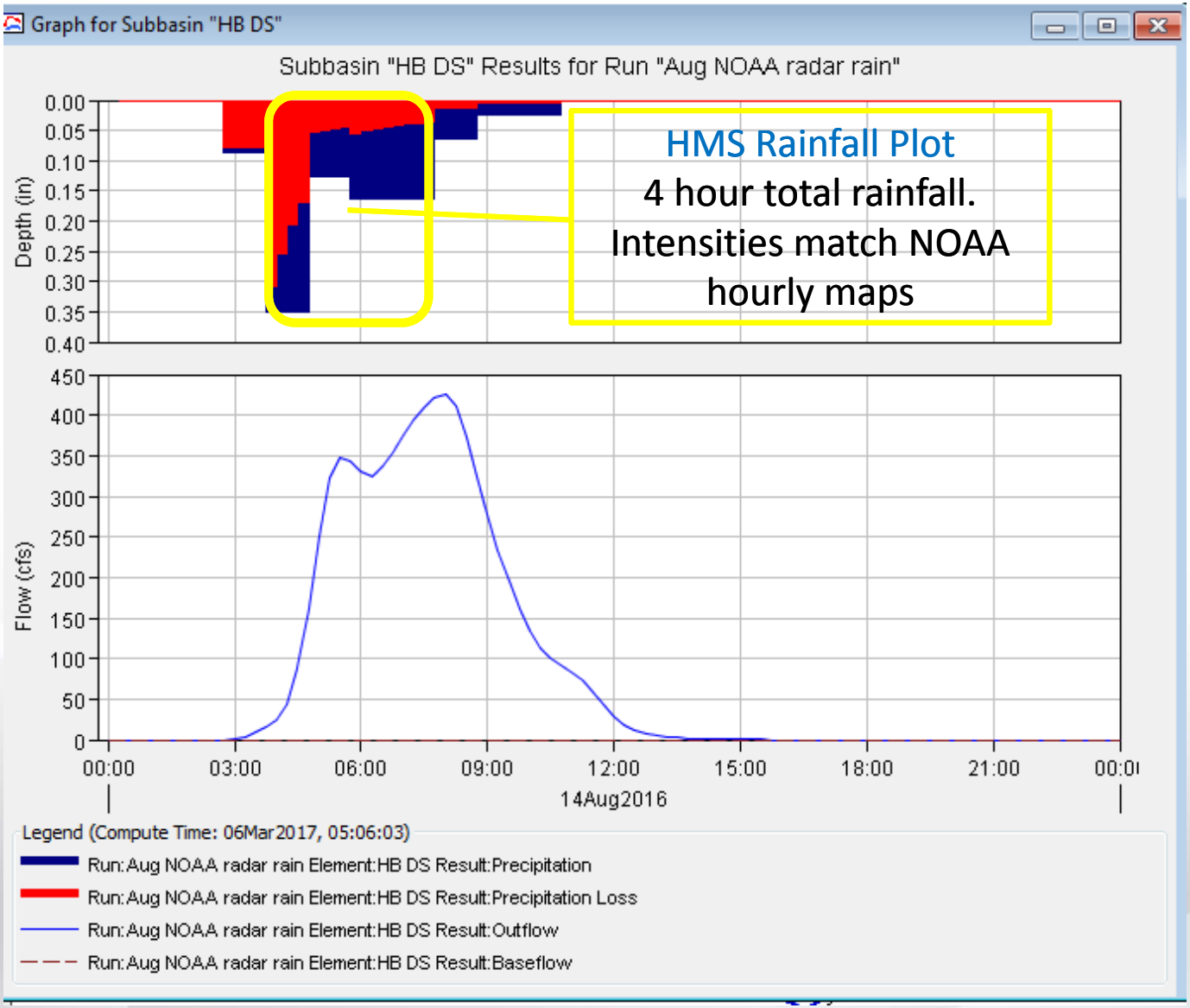
Aug 14th Storm appears to be about here.



After studying the hourly NOAA radar data, 4 hours was the duration in our camera watershed.

Michael Baker
INTERNATIONAL

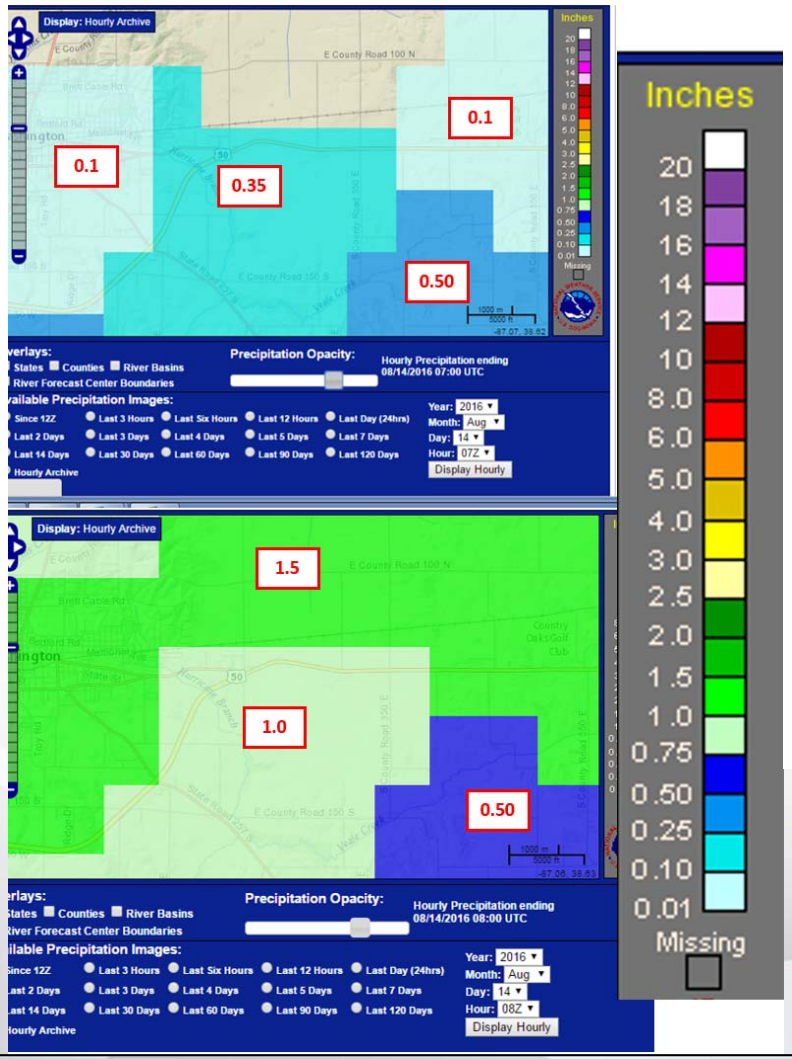
We Make a Difference

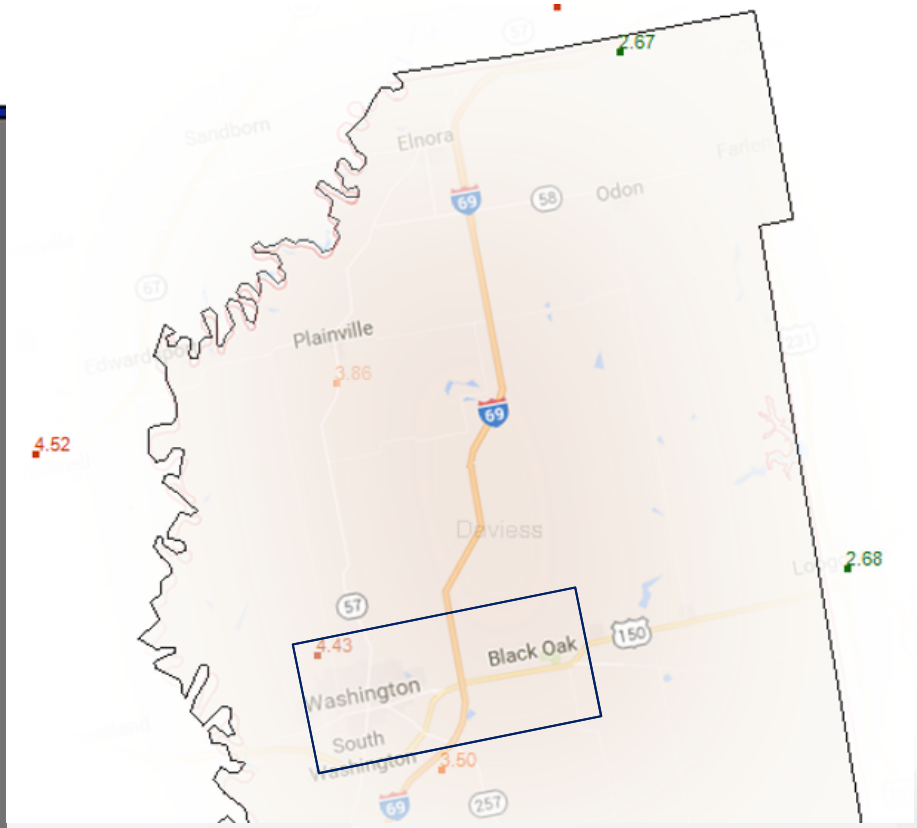


Michael Baker INTERNATIONAL

We Make a Difference

NOAA Intensities CoCoRAHS Daily





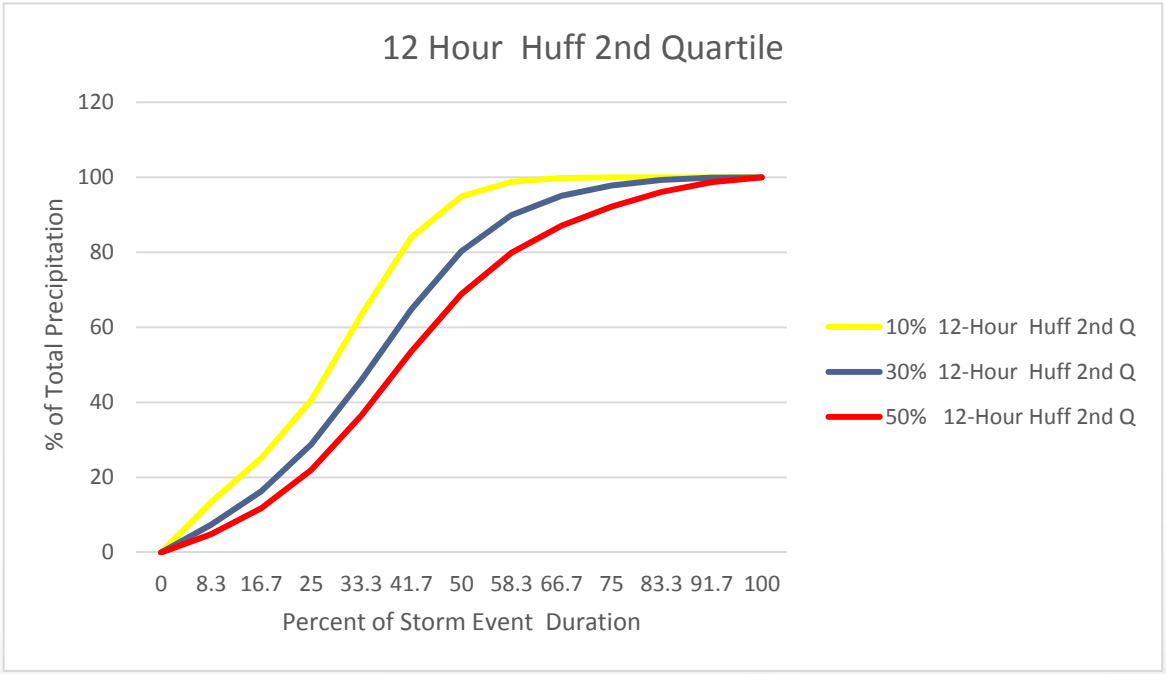
NOAA Hourly Aug 14 rain totals (During Peaks)

CoCoRAHS Aug 14 rain totals

Michael Baker INTERNATIONAL

We Make a Difference

Inputting Huff Quartiles or ANY Synthetic Rainfall Distribution



Exact synthetic rainfall varies:

1) # increments (5 min or 15 min)

2) total rainfall amount (5.4”)

Huff Rainfall Quartiles

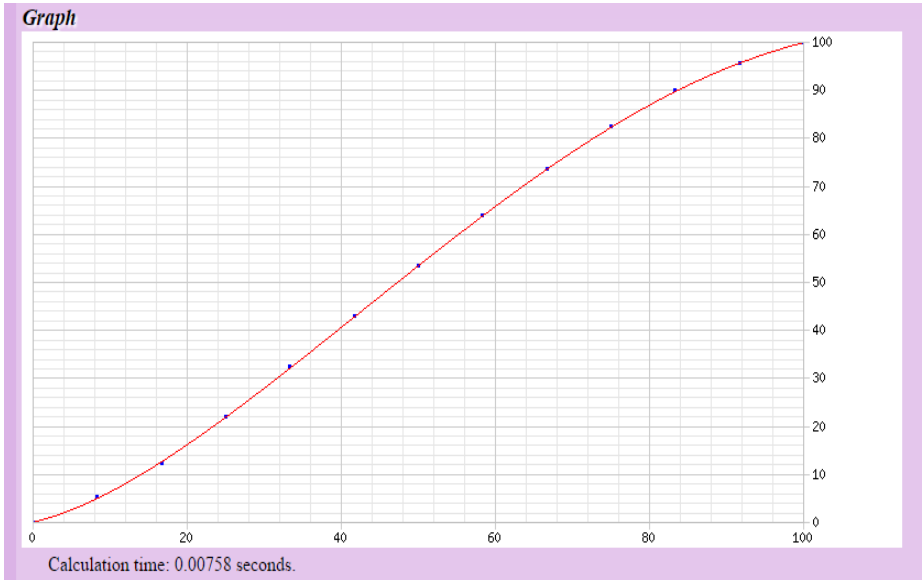
Synthetic Regulatory rainfall

	Percent Rain		
% Time	HUFF 1	HUFF 2	HUFF 3
5	8	3	3
10	17	8	6
15	34	12	9
20	50	16	12
25	63	22	15
30	71	29	19
35	76	39	23
40	80	51	27
45	83	62	32
50	86	70	38
55	88	76	45
60	90	81	57
65	92	85	70
70	93	88	79
75	95	91	85
80	96	93	89
85	97	95	92
90	98	97	95
95	99	98	97
100	100	100	100

	Cumulative Rainfall				
Total (Min)	60	180	360	720	1440
100 Year	1 HR	3 HR	6 HR	12 HR	24 HR
Rain Total	3.6	4.7	5.8	6.3	7.4
Increm MIN	3	9	18	36	72
% Time	HUFF 1	HUFF 1	HUFF 1	HUFF 2	HUFF 3
5	0.29	0.38	0.46	0.19	0.22
10	0.61	0.80	0.99	0.50	0.44
15	1.22	1.60	1.97	0.76	0.67
20	1.80	2.35	2.90	1.01	0.89
25	2.27	2.96	3.65	1.39	1.11
30	2.56	3.34	4.12	1.83	1.41
35	2.74	3.57	4.41	2.46	1.70
40	2.88	3.76	4.64	3.21	2.00
45	2.99	3.90	4.81	3.91	2.37
50	3.10	4.04	4.99	4.41	2.81
55	3.17	4.14	5.10	4.79	3.33
60	3.24	4.23	5.22	5.10	4.22
65	3.31	4.32	5.34	5.36	5.18
70	3.35	4.37	5.39	5.54	5.85
75	3.42	4.47	5.51	5.73	6.29
80	3.46	4.51	5.57	5.86	6.59
85	3.49	4.56	5.63	5.99	6.81
90	3.53	4.61	5.68	6.11	7.03
95	3.56	4.65	5.74	6.17	7.18
100	3.60	4.70	5.80	6.30	7.40
	Cumulative Rainfall				
	3.60	4.70	5.80	6.30	7.40

	Incremental Rainfall				
Total (Min)	60	180	360	720	1440
100 Year	1 HR	3 HR	6 HR	12 HR	24 HR
Rain Total	3.6	4.7	5.8	6.3	7.4
Increm MIN	3	9	18	36	72
% Time	HUFF 1	HUFF 1	HUFF 1	HUFF 2	HUFF 3
5	0.29	0.38	0.46	0.19	0.22
10	0.32	0.42	0.52	0.32	0.22
15	0.61	0.80	0.99	0.25	0.22
20	0.58	0.75	0.93	0.25	0.22
25	0.47	0.61	0.75	0.38	0.22
30	0.29	0.38	0.46	0.44	0.30
35	0.18	0.24	0.29	0.63	0.30
40	0.14	0.19	0.23	0.76	0.30
45	0.11	0.14	0.17	0.69	0.37
50	0.11	0.14	0.17	0.50	0.44
55	0.07	0.09	0.12	0.38	0.52
60	0.07	0.09	0.12	0.32	0.89
65	0.07	0.09	0.12	0.25	0.96
70	0.04	0.05	0.06	0.19	0.67
75	0.07	0.09	0.12	0.19	0.44
80	0.04	0.05	0.06	0.13	0.30
85	0.04	0.05	0.06	0.13	0.22
90	0.04	0.05	0.06	0.13	0.22
95	0.04	0.05	0.06	0.06	0.15
100	0.04	0.05	0.06	0.13	0.22
	Incremental Rainfall				
	3.60	4.70	5.80	6.30	7.40

Website for Polynomial functions



WEBSITE

http://polynomialregression.drque.net/online.php

A function allows you to quickly input SYNTHETIC storm durations and total rainfall amounts.

$(x) = 0.06397664537591213 + 0.23518034487206948x + 0.05389097577613207x^2 - 0.002716097844729224x^3 + 0.0000498856680944414x^4 - 1.5015740940882e\text{-}7x^5 - 3.3147040978e\text{-}9x^6 + 2.081404341e\text{-}11x^7$

7^{th} order polynomial equation that approximates

All the Quartiles (Above is the Huff 2^{nd} Quartile 50% curve).

Left Col= Actual Storm % (time)

Right Col= Huff Distribution of Actual Storm %

Polynomial Regression

A PHP regression class

Data entry

0	0
8.3	5.3
16.7	12.3
25	22
33.3	32.3
41.7	42.8
50	53.4
58.3	63.8
66.7	73.5
75	82.3

Actual Storm %

Huff Distribution of Actual Storm

\t Column separator (NOTE: \t for tab). \n Row separator (NOTE: \n means a new line).

☑ Show equation. ☑ Show coefficients. ☑ Show graph. ☑ Show R^2 (Coefficient of determination).

☐ Show examples. ☐ Use weighting. ☐ Force coefficients.

7 coefficients, Sextic/hexic regression ▾

Submit

F(x) =Huff distribution of actual storm %
X=Actual storm %

Function

$f(x) = 0.06868188461417553 + 0.3821290309035111x + 0.029495854038151127x^2 - 0.0005059033177976044x^3 + 0.00000545822280320876x^4 - 3.877489782502e\text{-}8x^5 + 1.1454468985e\text{-}10x^6$

Synthetic Rainfall by Polynomials

USE the Polynomial website to get equation

Edit out all spaces in equation pasted
Substitute "x" for cell reference
Place Percentage of storm left
Place Huff Quartile polynomial to Right
Copy polynomial cells with total rainfall %

Will provide excel sample spreadsheet

TOTAL RAIN=	4.18
3 Hr Storm	
5 Min time step	
36 Intervals	
0	0.000
2.778	0.285
5.556	0.597
8.334	0.917
11.112	1.234
13.89	1.538
16.668	1.823
19.446	2.084
22.224	2.319
25.002	2.529
27.78	2.712

Polynomial Accuracy

		Actual NOAA	
% Storm	% Rain	% Rain	
X-val	From Equation	Y-Val	% accurate
0	0	0.00	1.00%
8.3	5.21%	4.90	1.063%
16.7	11.31%	11.80	0.959%
25	22.07%	22.00	1.003%
33.3	36.96%	36.50	1.013%
41.7	53.53%	53.60	0.999%
50	68.44%	68.90	0.993%
58.3	79.90%	79.90	1.000%
66.7	87.54%	87.10	1.005%
75	92.20%	92.20	1.000%
83.3	95.68%	96.10	0.996%
91.7	98.98%	98.70	1.003%
100	99.94%	100.00	0.999%
Huff 2nd Quartile		50% Percentile curve	

7^{th} order polynomial equation accuracy is excellent.

IDNR Flows very Conservative

100 Year PEAK FLOWS BAKER HMS MODELING SIMULATION RESULTS (Atlas 14 + Huff Quartiles)								
Watershed and Reaches	Watershed SM	SIM= 1 HR	SIM= 3 HR	SIM= 6 HR	SIM= 12 HR	SIM= 24 HR	IDNR Flows	Percent Drop
HB_US	1.24	689	783	703	511	390	1320	59%
HB Tributary	1.04	819	813	668	454	335		
HB US & Trib	2.28	1375	1495	1329	954	722		
Reach-2	2.28	918	1158	1125	894	706	1810	64%
UNT_HB_US	1.24	528	659	621	484	382	1030	64%
Reach-1	1.24	314	460	479	424	361		
UNT_HB_DS	0.97	461	552	508	386	301		
UNT_HB	2.21	684	888	897	774	651	1380	65%
HB Mid	0.09	126	96	70	43	30		
HB US, Trib & UNT HB	4.58	1602	2071	2041	1694	1384		
Reach-3	4.58	953	1488	1616	1488	1312		
HB DS	1.42	951	1012	868	611	456		
HB @ Mouth	6.00	1278	1802	1997	1903	1709	2840	70%
J100	6.00	1278	1802	1997	1903	1709		
Peak Flows are in Red Font Shape Factor = 484 on all Basins.								


Cabela's BOLY
73°F
08-13-2016 06:55:57

Michael Baker
INTERNATIONAL
We Make a Difference

Questions?