LOWER BRAZOS RIVER FLOODPLAIN PROTECTION PLANNING STUDY

Rosenberg, Texas

November 19, 2015

Reasons for the Study

* One of the fastest growing areas in the country
* Hydrologic and hydraulic models/data are dated outside of Fort Bend County
* Need for consistent modeling methodology across county boundaries
* Need to assess lower Brazos watershed from a comprehensive basinwide perspective (existing conditions and alternatives)
* 10,000 square miles of uncontrolled drainage area

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Goals of the Study

* Quantify existing flooding issues and flood damage reduction alternatives
* Update hydrologic and hydraulic data for the lower Brazos River (Hempstead gauge to mouth across 5 counties)
* Calibrate new models to historical events and provide flood volumes, flood depths, and flood durations
* Facilitate land use planning, emergency response, and sound floodplain management

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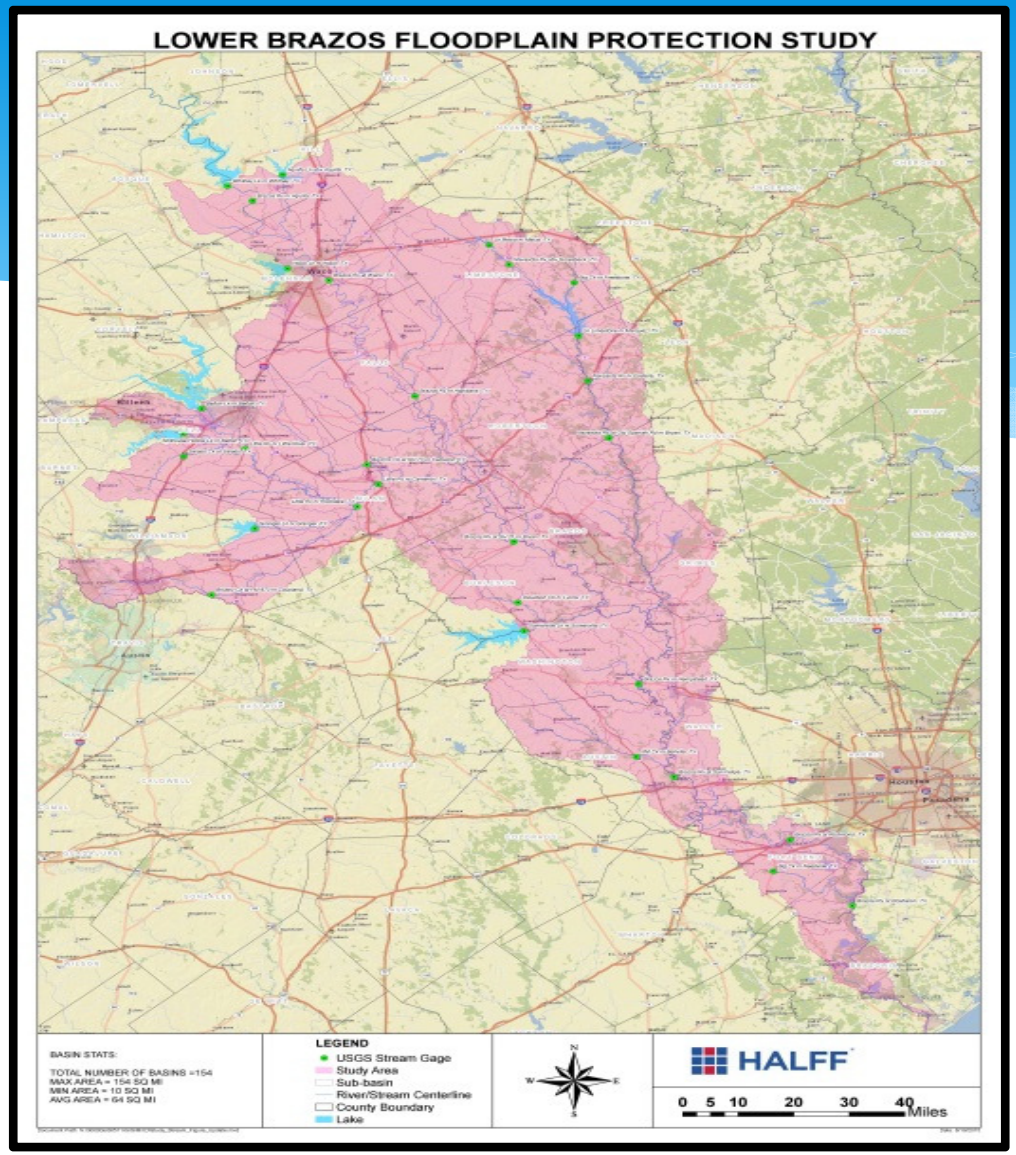

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May-June 2015






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Schedule

Phase 1

* Terrain Development – March 2015
* Data Collection – February 2015
* Hydrology – September 2015
* Field Surveys – June 2015
* Hydraulics – February 2016
* Alternatives Formulation – June 2016
* Flood Damage Analysis – June 2016
* Environmental Constraints Analysis – April 2016
* Draft Report – October 2016
* Final Report – April 2017

Phase 2

* Begin Work – January 2016
* Terrain Development – July 2016
* Data Collection – March 2016
* Field Surveys – June 2016
* Hydraulics – November 2016
* Alternatives Formulation – June 2017
* Flood Damage Analysis – June 2017
* Environmental Constraints Analysis – April 2017
* Draft Report – October 2017
* Final Report – March 2018

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Hydrologic Modeling Update

Hydrology Topics

A. Where We Left Off

B. Where We Are Going

C. Hydrologic Model

D. Flood Frequency Analysis

E. Design Storm Analysis

F. Discharge Comparison

G. Conclusions

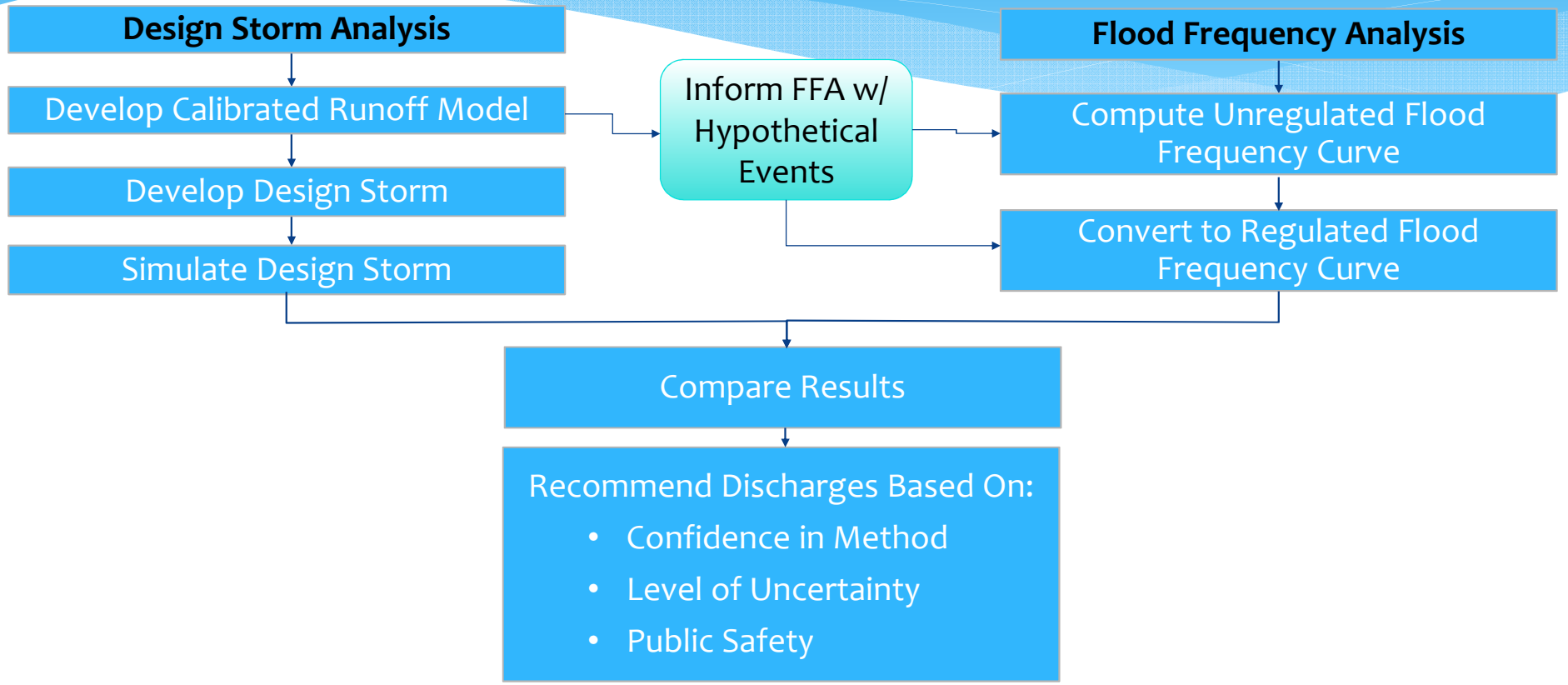
Where We Left Off

* Hydrology
  * Sub-basin delineation
  * Data Collection
  * HEC-HMS Skeleton Model
* Flood Frequency Analysis
  * Preliminary Flood Frequency Analysis at Hempstead and Richmond
  * Seeing signs of reduced discharges

Hydrology Topics

A. Where We Left off
B. Where We Are Going
C. Hydrologic Model
D. Flood Frequency Analysis
E. Design Storm Analysis
F. Discharge Comparison
G. Conclusions

Where We Are Going

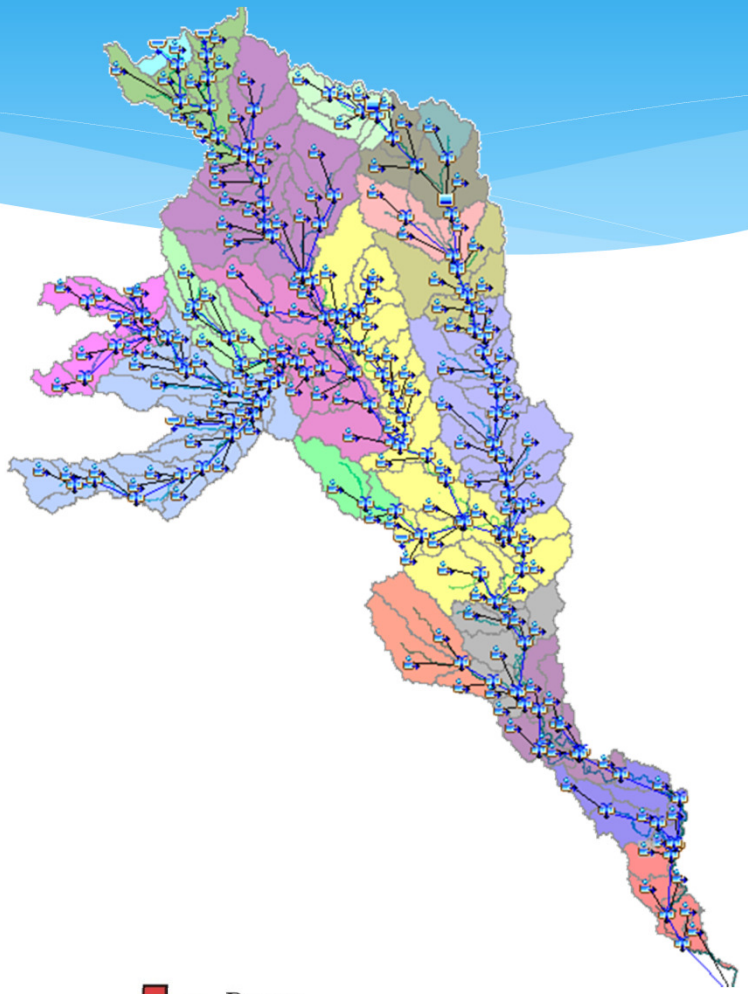


Hydrology Topics

A. Where We Left Off
B. Where We Are Going
C. Hydrologic Model
D. Flood Frequency Analysis
E. Design Storm Analysis
F. Discharge Comparison
G. Conclusions

Hydrologic Model

* Lower Brazos HMS Model
  * 9,766 sq. mi. below 7 USACE reservoirs
  * 154 sub-basins (63 sq. mi. avg. size)
  * 114 routing reaches (over 1,240 river miles modeled)
  * Reach Routing
    * Muskingum – Brazos & Navasota
    * Modified Puls - Elsewhere
  * Above Hempstead Gauge
    * Initial and Constant Loss Method
    * Snyder Unit Hydrograph Method
  * Below Hempstead Gauge
    * Exponential Loss Method
    * Clark Unit Hydrograph Method



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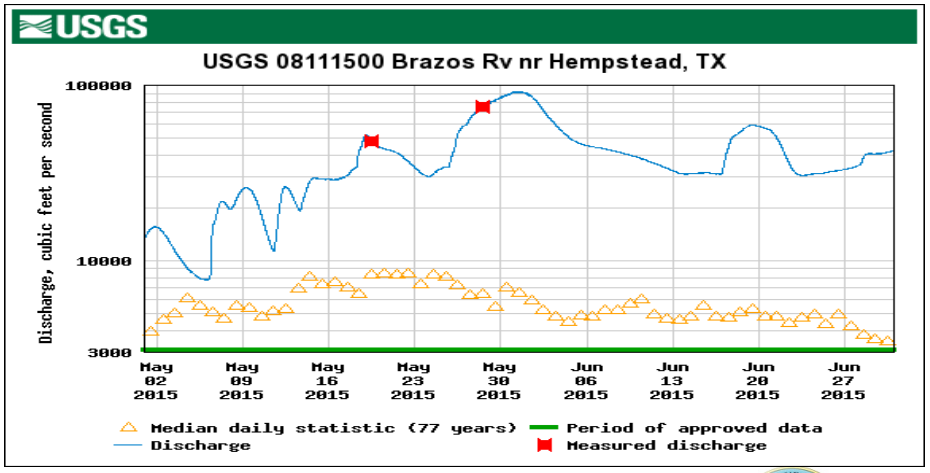
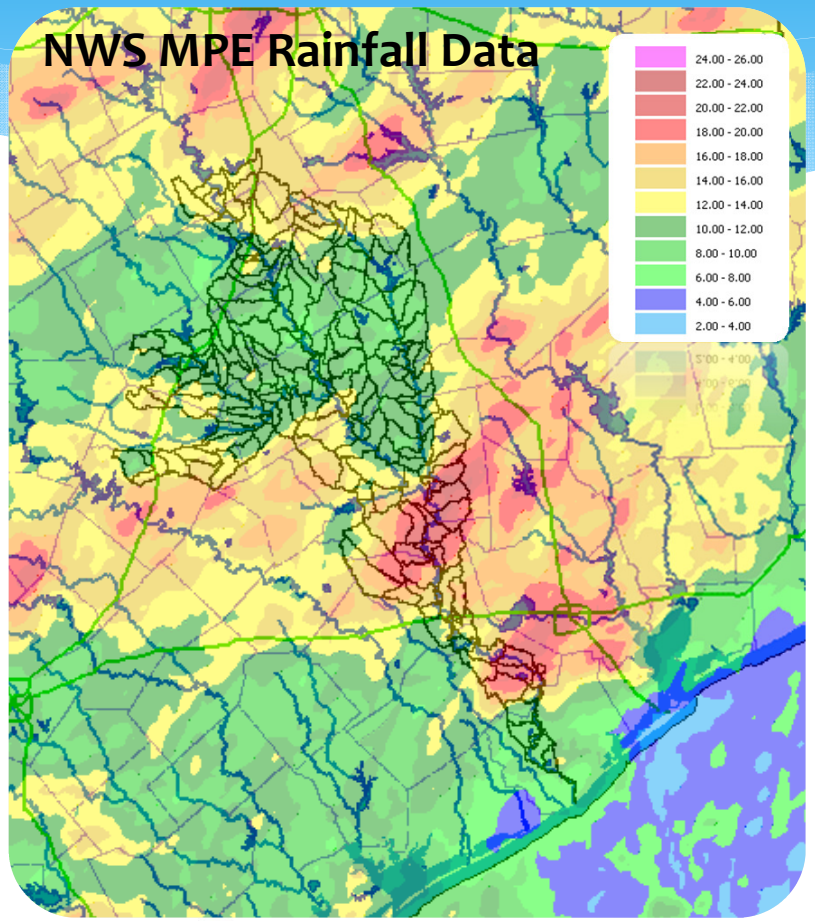
Hydrologic Model

- Calibration Methodology
  - Data Collection
    - Stream Flow
    - Reservoir Releases
    - Rainfall – Gridded & Gauged





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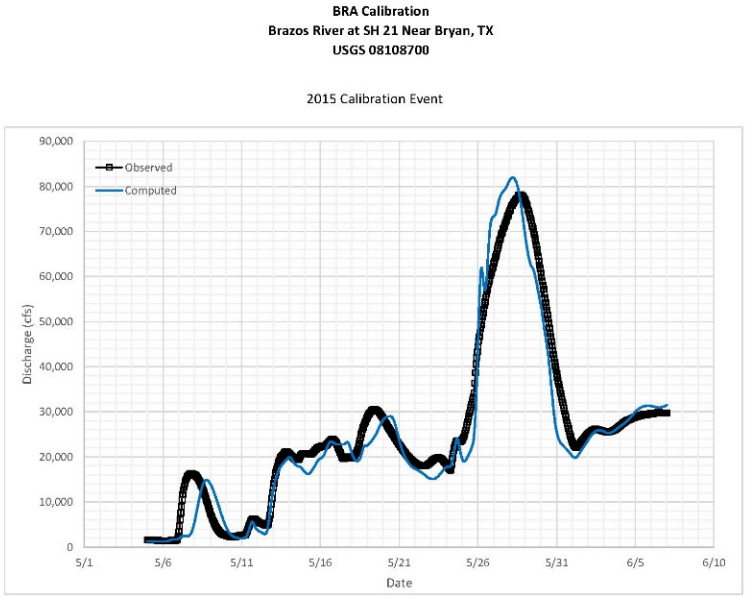
Hydrologic Model

- Calibration Methodology Cont.
  - 17 calibration zones
  - 8 calibration storms
    - 7 from MPE era
    - 1 from ground gauges
  - Reset using observed data
  - Parameter Adjustment
    - Loss and Unit Hydrograph Parameters
    - Routing
    - 10% Rule and eyeball test



Parameter Summary				
Initial Loss	Constant Loss	Percent Impervious	Snyder Ct	Snyder Cp
(in)	(iph)	(%)		
2.9	0.14	6.0	2.00	0.80

Results Summary		
	Peak (cfs)	Volume (acre-ft)
Observed	78,200	1,693,257
Computed	81,979	1,609,639
Residual	3,779	-83,618
Error	5%	-5%

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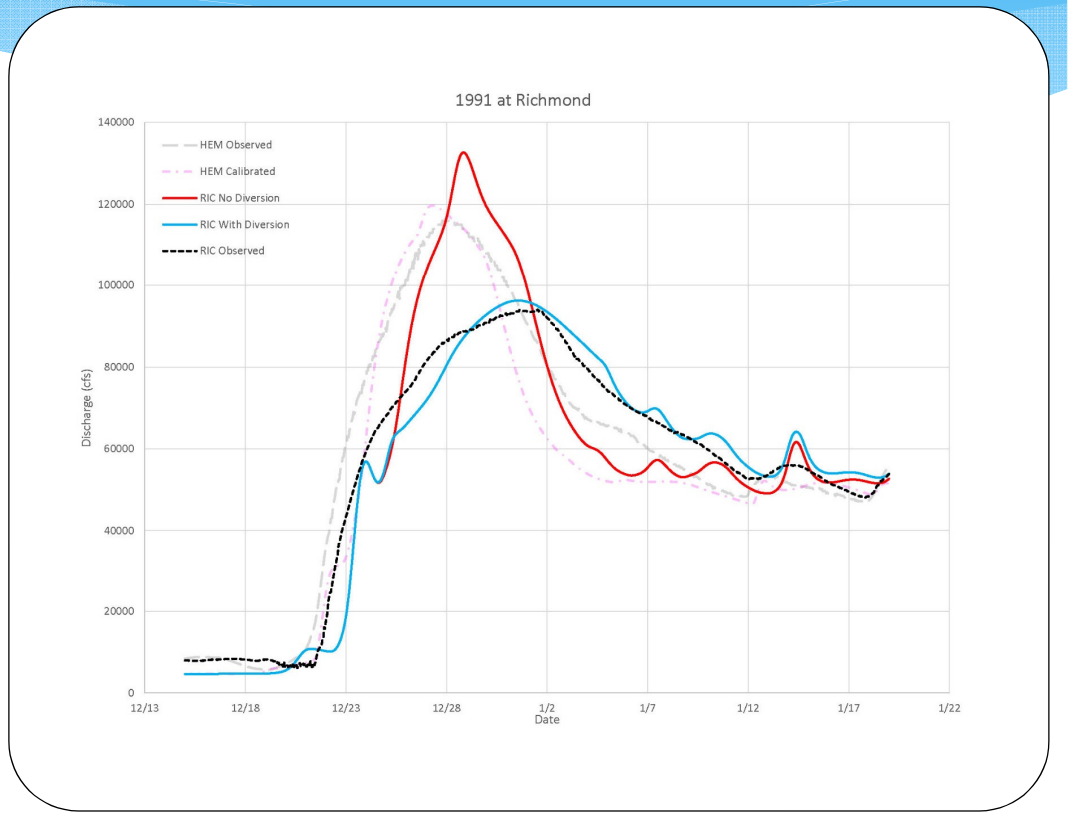
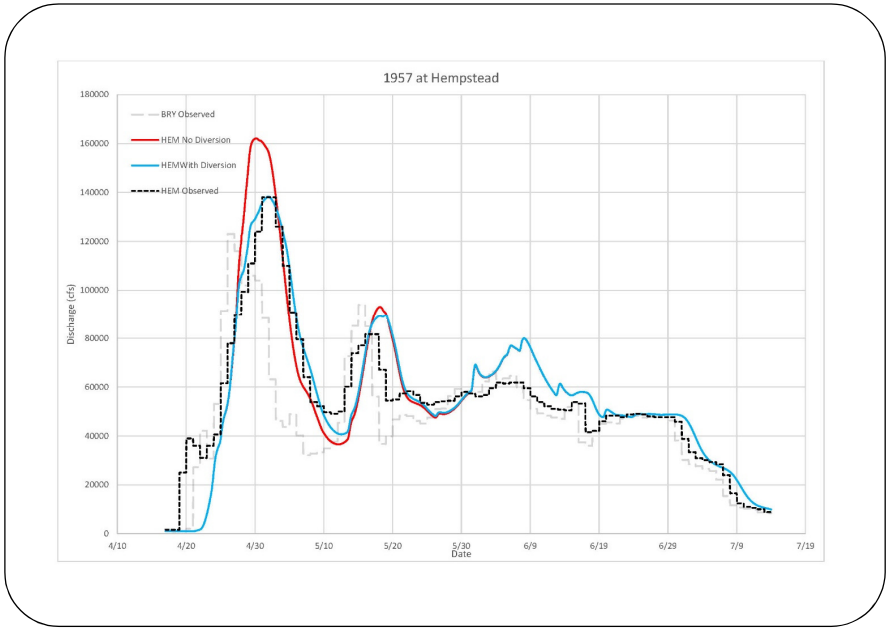
Hydrologic Model

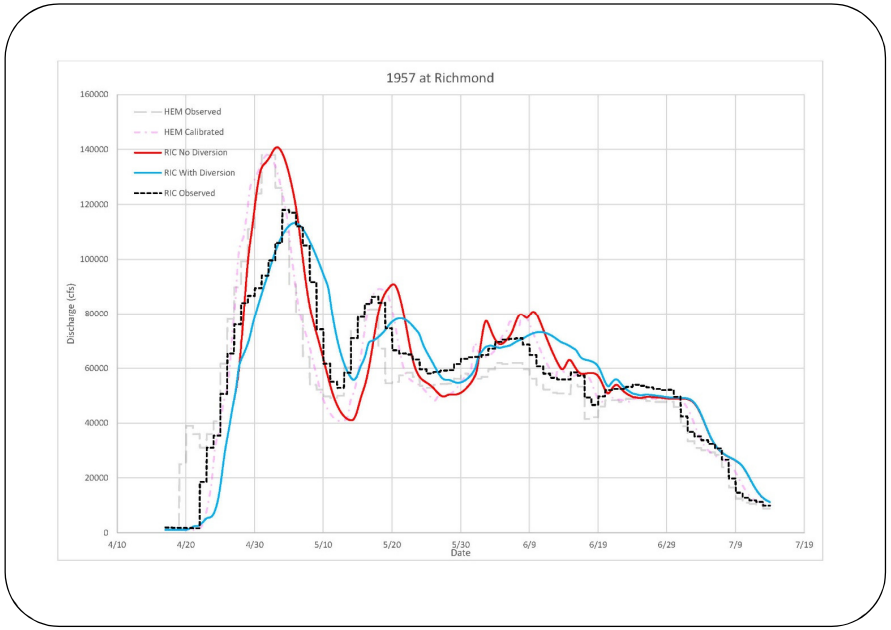
- Calibration Methodology Cont.
  - Brazos River Routing
    - Muskingum
    - Ideal for less than bank full conditions
    - Diversion reach (floodplain storage)
    - Validation



Hydrologic Model

* Calibration Methodology Cont.
  * Brazos River Routing Validation Event - 1957





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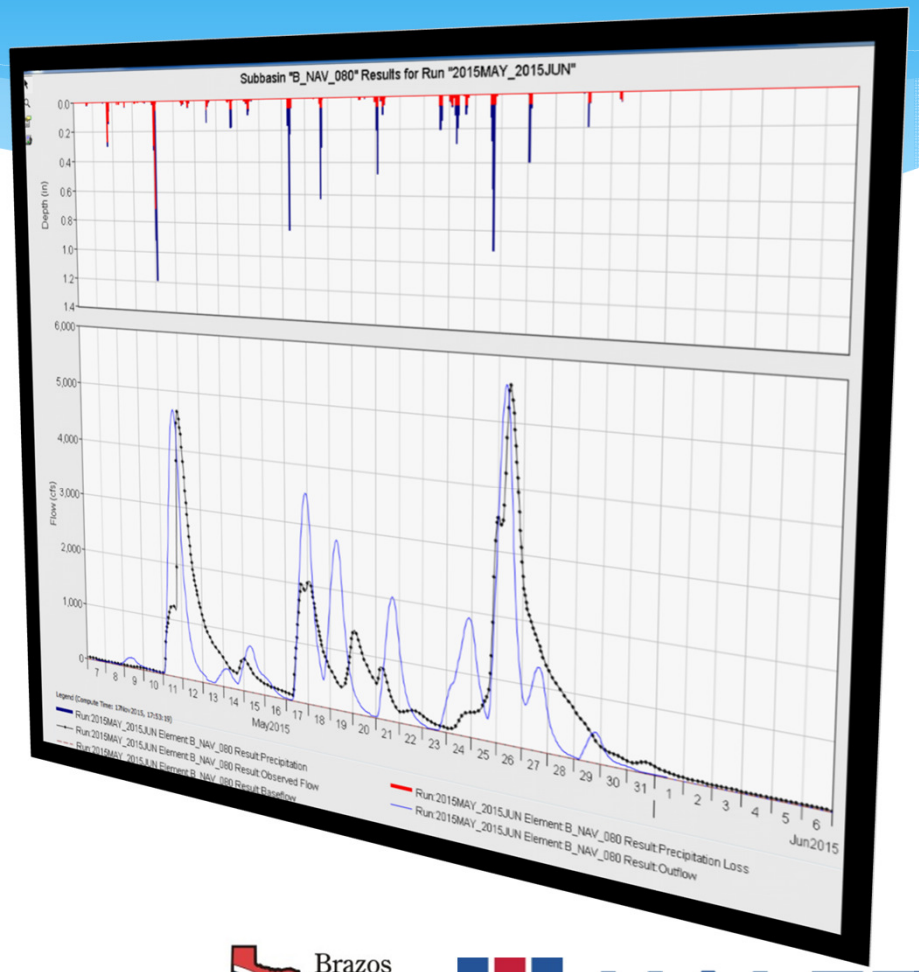
Hydrologic Model

- Calibration Results
  - Single set of unit-hydrograph parameters
  - Single set of reach routing parameters
  - Losses vary by storm and antecedent moisture conditions
  - Training wheels off validation
    - 1991
    - 2015



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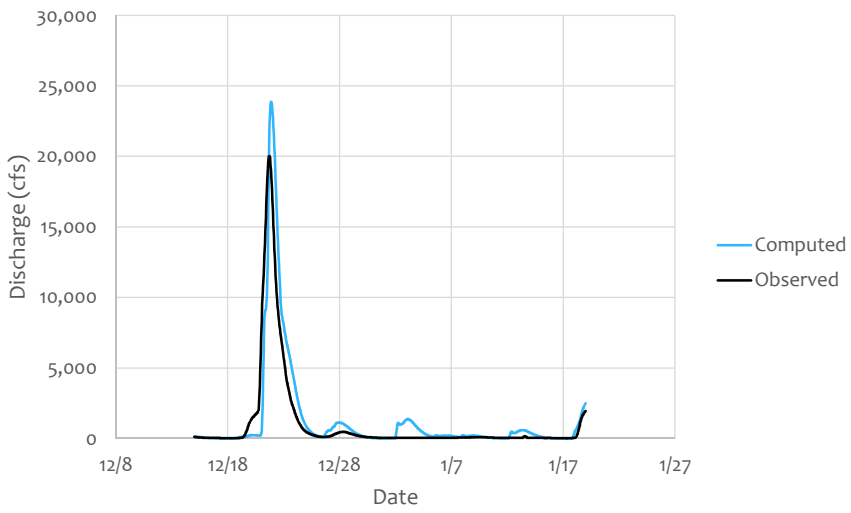
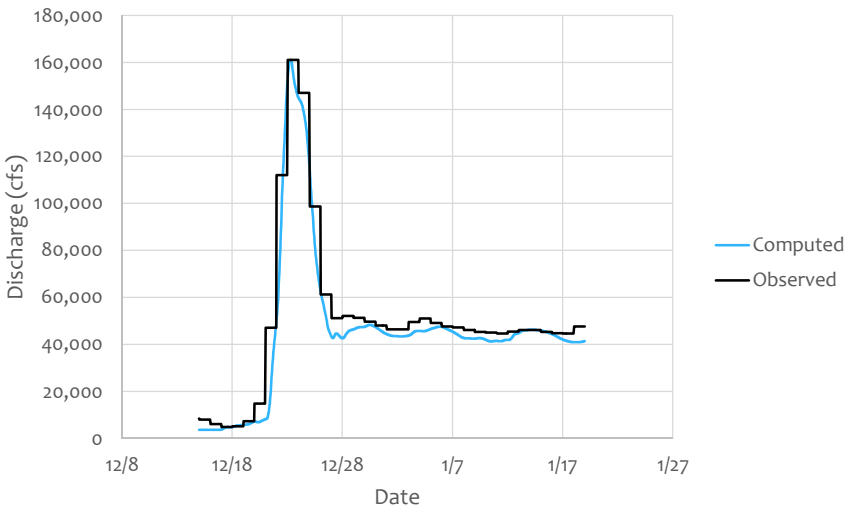
Hydrologic Model

* Calibration Results Cont.

1991-Navasota River @ Groesbeck



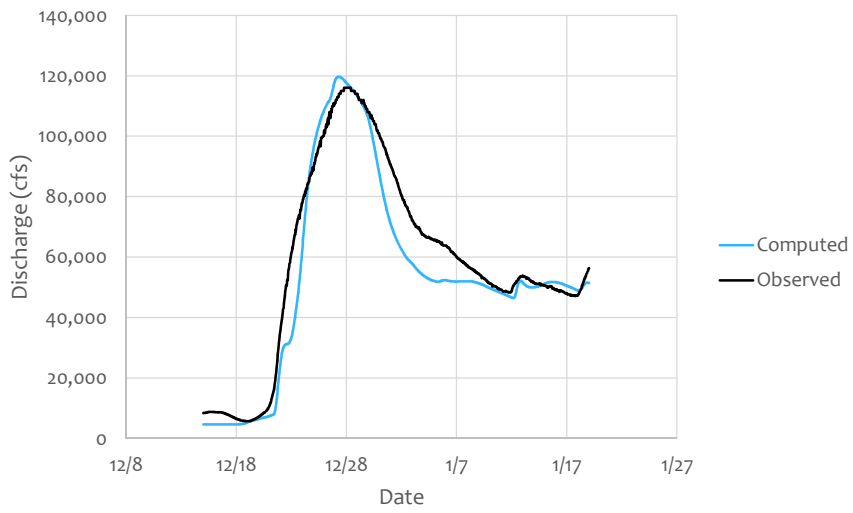
1991-Brazos River @ Bryan



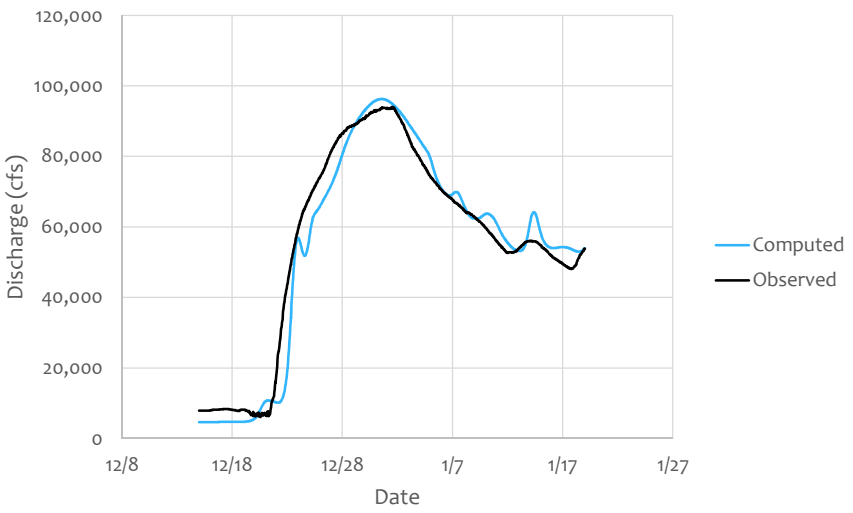
Hydrologic Model

* Calibration Results Cont.

1991-Brazos River @ Hempstead



1991-Brazos River @ Richmond



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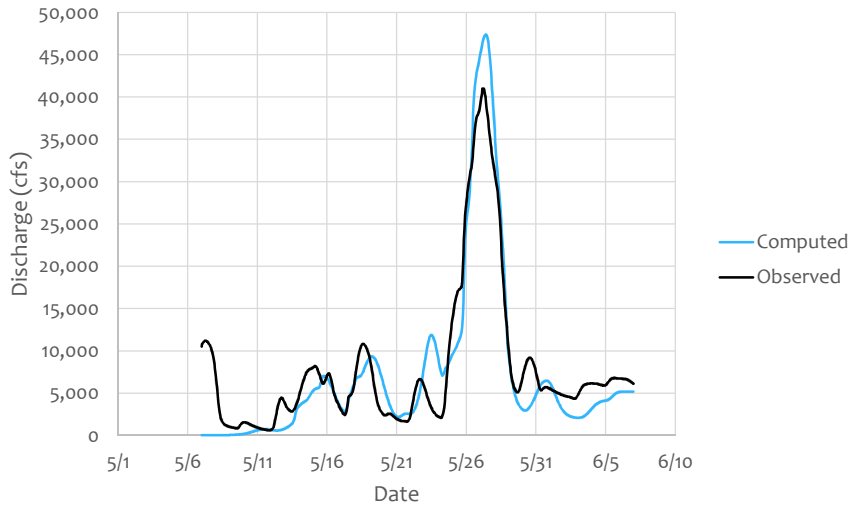
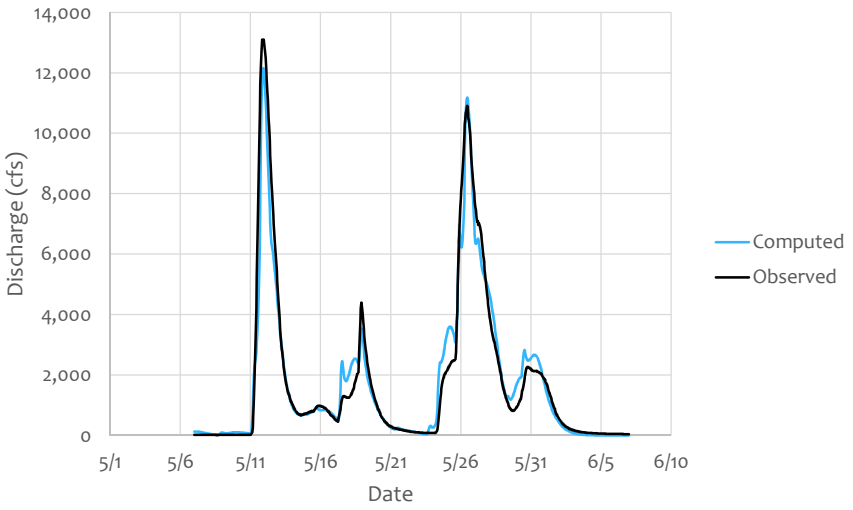
Hydrologic Model

* Calibration Results Cont.

2015-Little River @ Cameron



2015-Navasota River @ Groesbeck



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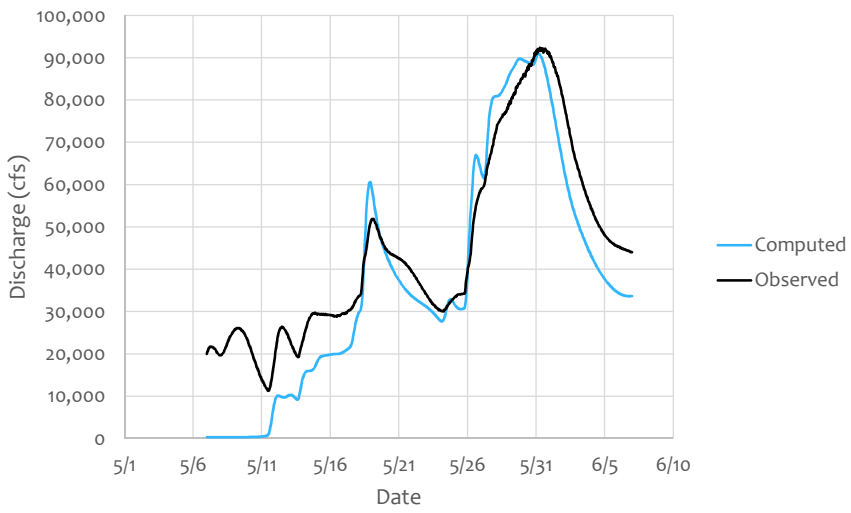
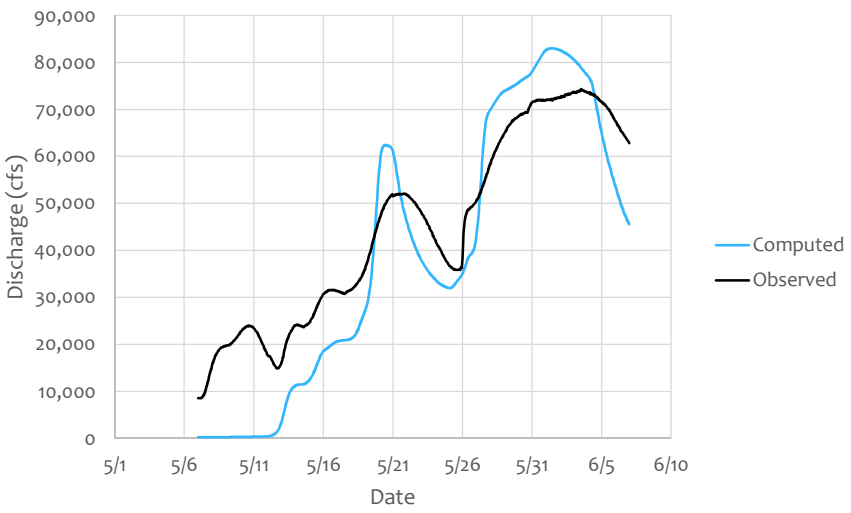
Hydrologic Model

* Calibration Results Cont.

2015-Brazos River @ Hempstead



2015-Brazos River @ Richmond



Hydrologic Model

- Hypothetical Storms
  - Lower Basin Only
    - No contribution from area above USACE reservoirs
    - 1991 and 2015 – small reduction compared to computed
    - 1913 "Regulated"
  - Unregulated
    - Simulated with unregulated reservoir discharges from USACE Riverware Model
    - 1991 and 1957

Regulated vs Lower Basin Only Discharges (cfs)

Site	Observed	Computed	No Reservoirs
1991-Hempstead	116,000	119,700	116,200
2015-Hempstead	92,500	91,000	84,800
1991-Richmond	94,000	96,300	90,500
2015-Richmond	74,300	83,000	76,500

- 1913 "Regulated"
  - Hempstead – 155,500 cfs
  - Richmond – 115,200 cfs

Hypothetical Unregulated Discharges (cfs)

Site	Observed	Unregulated
1957-Hempstead	143,000	189,000
1991-Hempstead	116,000	204,000
1957-Richmond	119,000	161,000
1991-Richmond	94,000	160,000

Hydrology Topics

A. Where We Left Off
B. Where We Are Going
C. Hydrologic Model
D. Flood Frequency Analysis
E. Design Storm Analysis
F. Discharge Comparison
G. Conclusions

Flood Frequency Analysis

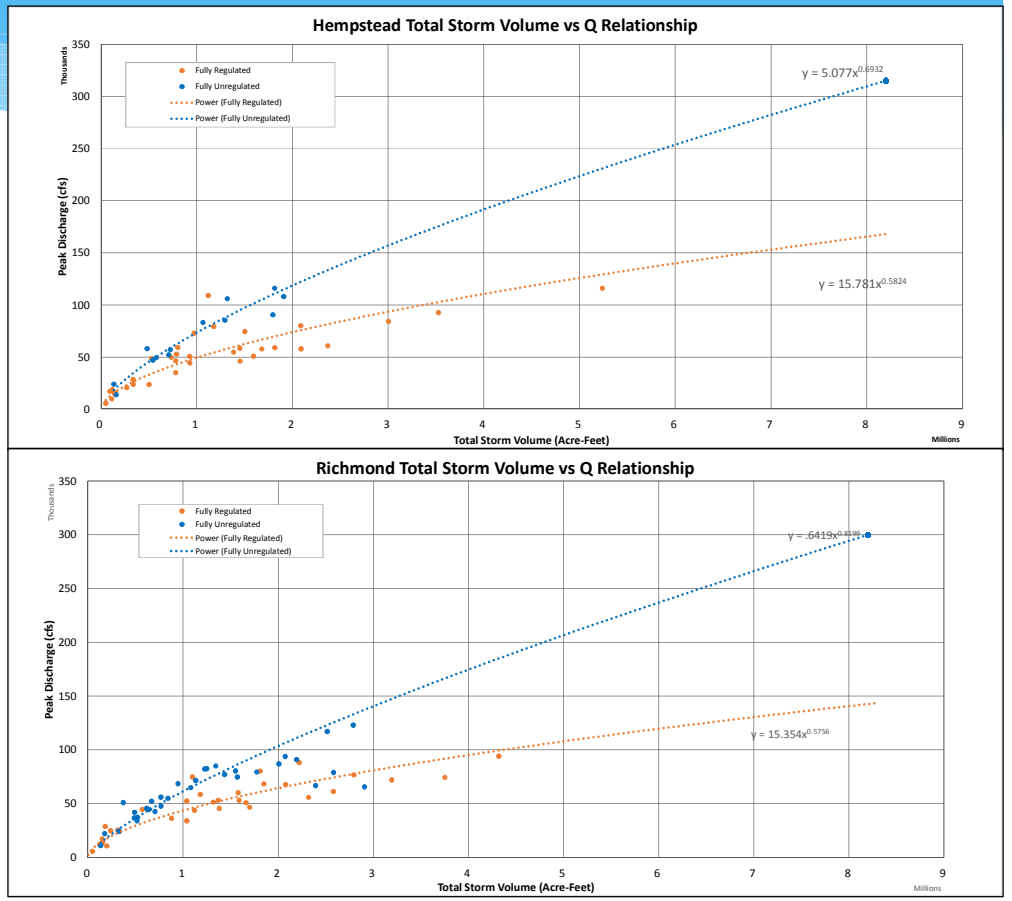
* Effective FIS Discharge Sources
  * Brazos River at Hempstead
    * 2009 Waller Co. FIS
    * Methodology – 1979 Espey, Huston & Associates, Inc. (EHA), Determination of the 100-Year Flood Discharge of the Brazos River at Richmond
    * 1979 report updated in 1984 for Richmond but not for Hempstead
  * Brazos River at Richmond
    * 2014 Fort Bend Co. FIS
    * Methodology – 2006 LJA Engineering and Surveying, Inc. , Brazos River within Fort Bend County, Texas – Flood Frequency Analysis
    * Retains portions of 1984 EHA, Reassessment of 100-year Peak Flow, Brazos River at Richmond,

Flood Frequency Analysis

* Methodology
  * Homogeneous Record
  * Log Pearson Type III Analysis
  * Unregulated to Regulated Transform

Flood Frequency Analysis

- Homogeneous Record
  - LJA Method
    - Described in 2006 report by LJA for Ft. Bend Co. FIS
    - Extend record at Richmond
    - Develop new record at Hempstead
    - Estimate total runoff volume for each annual peak event
    - Best-fit through Vol. vs Q
    - Adjust post-1952 observed annual peak Q's to unregulated
    - Additional adjustment for partially regulated period



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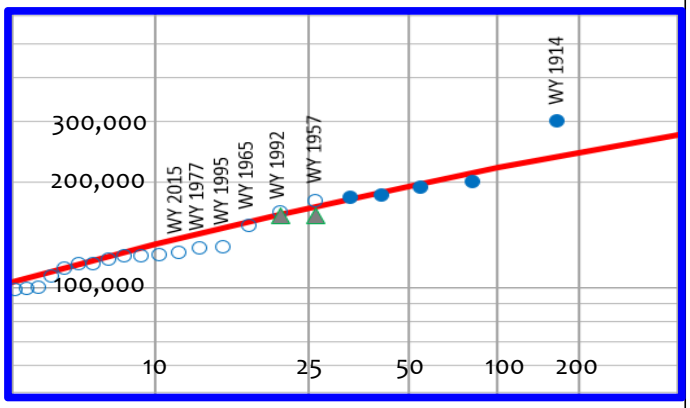
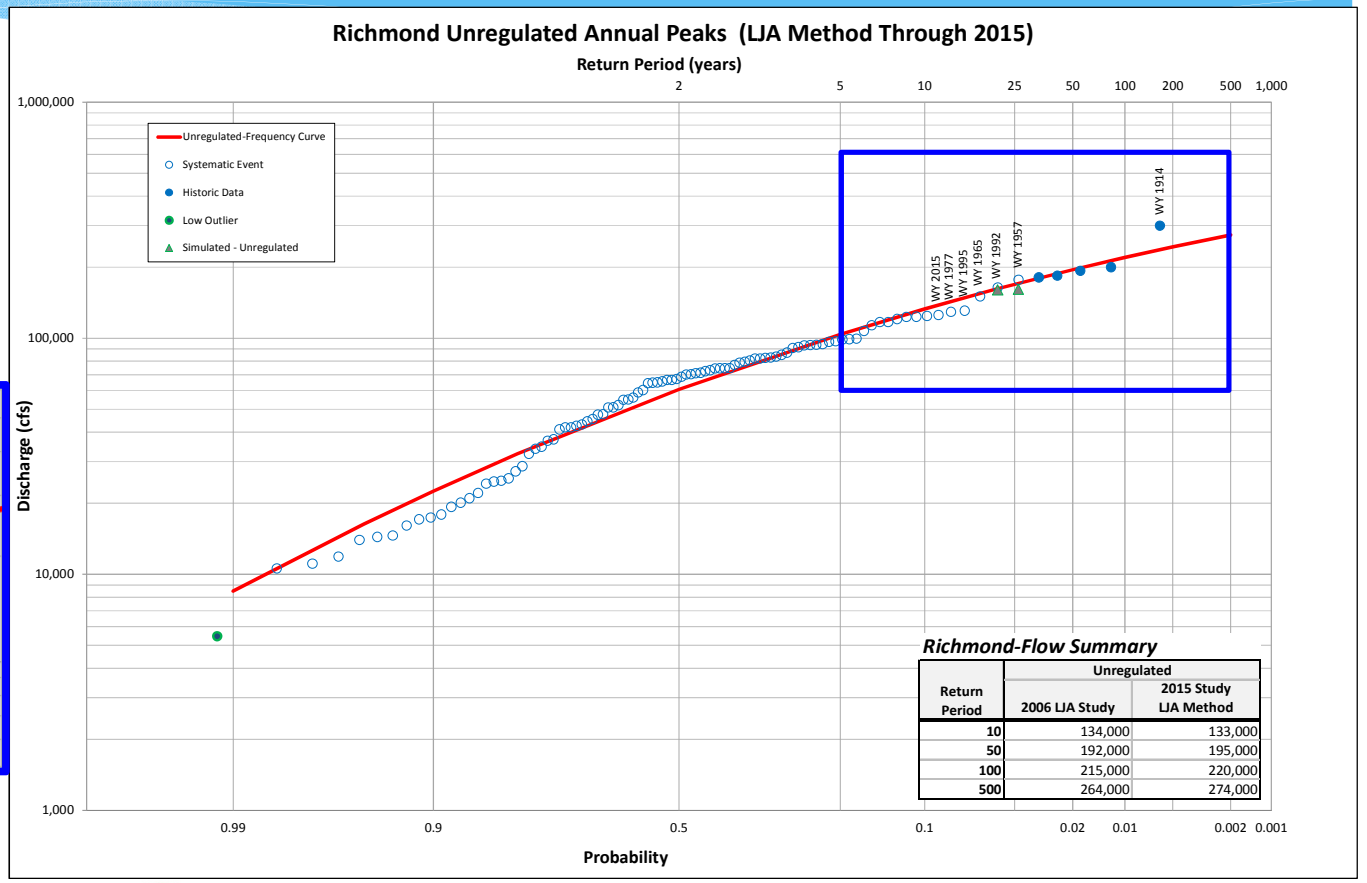
Flood Frequency Analysis

* Homogeneous Record cont.
  * USACE Riverware
    * Riverware data provided by USACE
    * Estimated daily flows for regulated and unregulated conditions
    * Data set supplemented by observed flows prior to 1952
* Log Pearson Type III Analysis
  * Historical Data
    * Used 1884, 1885, 1899, 1913, and 1915 discharge estimates
    * Historical record begins in 1852, based on news articles
  * Skew
    * Generalized (Map) skew not used
    * Watershed is too large

Flood Frequency Analysis

* Log Pearson Type III Analysis cont.
  * LJA Method at Richmond





Richmond-Flow Summary

Return Period	Unregulated	
	2006 LJA Study	2015 Study LJA Method
10	134,000	133,000
50	192,000	195,000
100	215,000	220,000
500	264,000	274,000

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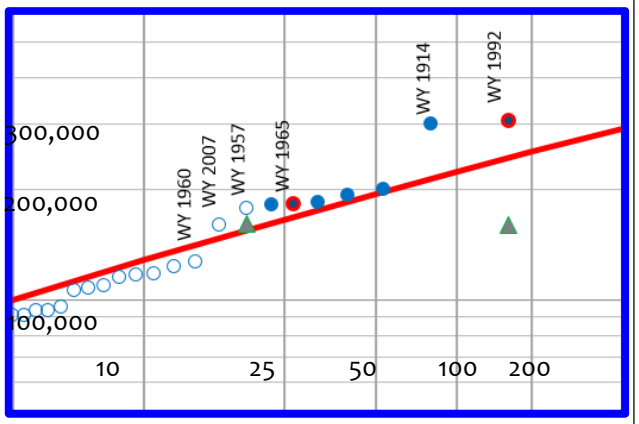
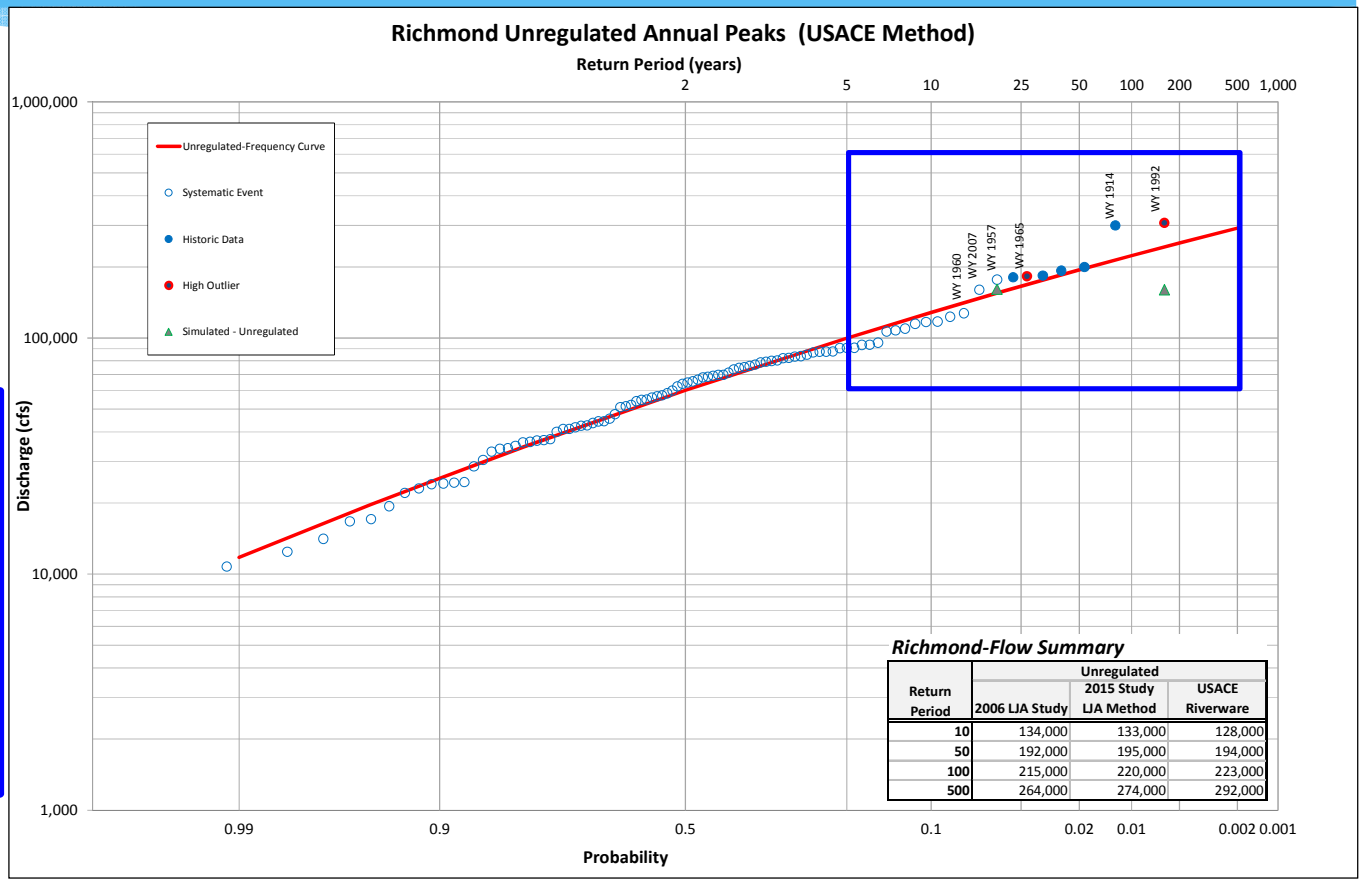
Flood Frequency Analysis

* Log Pearson Type III Analysis cont.
  * USACE Method at Richmond





Richmond-Flow Summary

Return Period	Unregulated		
	2006 LJA Study	2015 Study LJA Method	USACE Riverware
10	134,000	133,000	128,000
50	192,000	195,000	194,000
100	215,000	220,000	223,000
500	264,000	274,000	292,000

Flood Frequency Analysis

- Log Pearson Type III Analysis cont.
  - Historical Data?
    - Reduces discharges
    - Estimates may be inaccurate, but something happened and shouldn't be ignored
    - Included in analysis
  - Final Answer (Unregulated Conditions)
    - LJA Method described in 2006 Fort Bend County FIS
    - At Richmond
      - Extended Record from 2004 to 2015
      - Little Change
    - At Hempstead
      - New Analysis
      - Inferred historic discharges from Richmond

Unregulated Discharges at Hempstead

Return Period	2015 Study LJA Method	USACE Riverware	2015 Study LJA Method w/o Hist.
10-yr	**148,000**	138,000	141,000
50-yr	**222,000**	222,000	204,000
100-yr	**252,000**	262,000	229,000
500-yr	**318,000**	364,000	282,000

Unregulated Discharges at Richmond

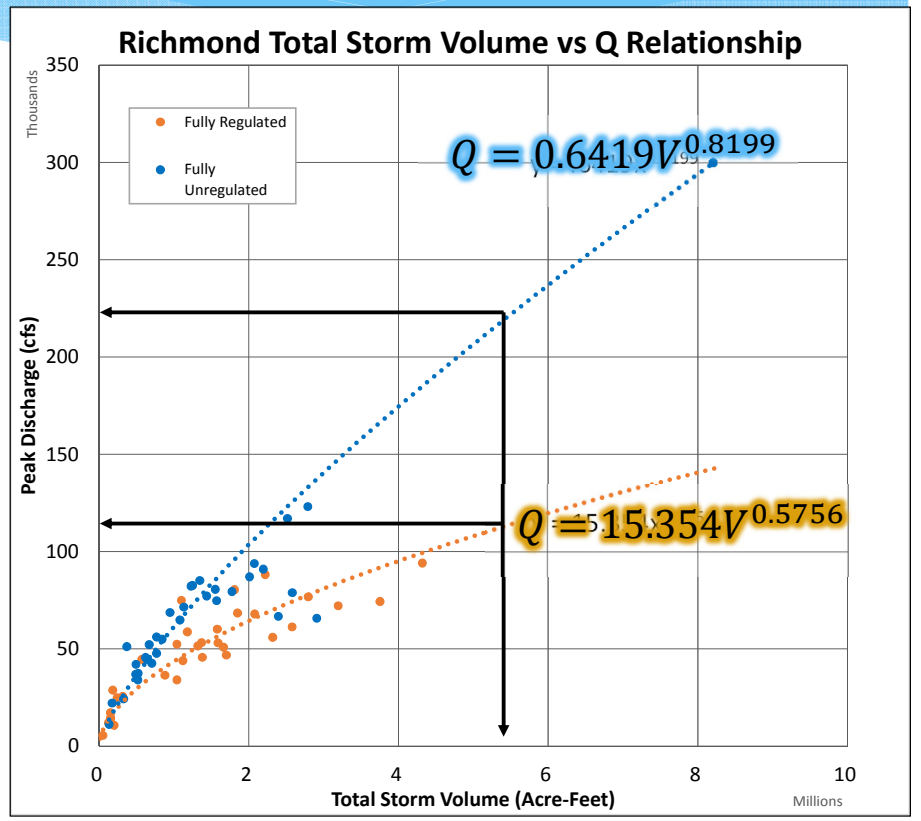
Return Period	2015 Study LJA Method	USACE Riverware	2015 Study LJA Method w/o Hist.
10-yr	**133,000**	128,000	120,000
50-yr	**195,000**	194,000	159,000
100-yr	**220,000**	223,000	172,000
500-yr	**274,000**	292,000	198,000

Flood Frequency Analysis

* Unregulated to Regulated Transform EHA Method
  * Developed in 1979 EHA Brazos River study
  * Updated in 1984 EHA Brazos River Reassessment study
  * Comparison of unregulated and regulated discharges for frequency storms
  * Resulted in $Q_{Regulated}$ = 76% of $Q_{Unregulated}$ for all frequencies
  * 2006 LJA report for Ft. Bend Co. FIS uses this multiplier
  * Concerns
    * Uses Muskingum routing throughout, i.e. very little attenuation along the Brazos
    * Unrealistic design storm, approximately 3" rainfall in 24-hours on entire watershed for 100-year event

Flood Frequency Analysis

- Unregulated to Regulated Transform
  - Volume vs. Q Adjustment
    - Used relationship developed for creating unregulated flow record
    - $Q_{reg} = c_{reg} V^{b_{reg}}$,
    - $Q_{unreg} = c_{unreg} V^{b_{unreg}}$
    - Solve for V and substitute
    - $Q_{reg} = c_{Reg} \left[\frac{Q_{unreg}}{c_{unreg}}\right]^{\left(\frac{b_{reg}}{b_{unreg}}\right)}$
    - Plot curve on unregulated frequency plot
    - Plot observed regulated events
    - Compare to hypothetical storms



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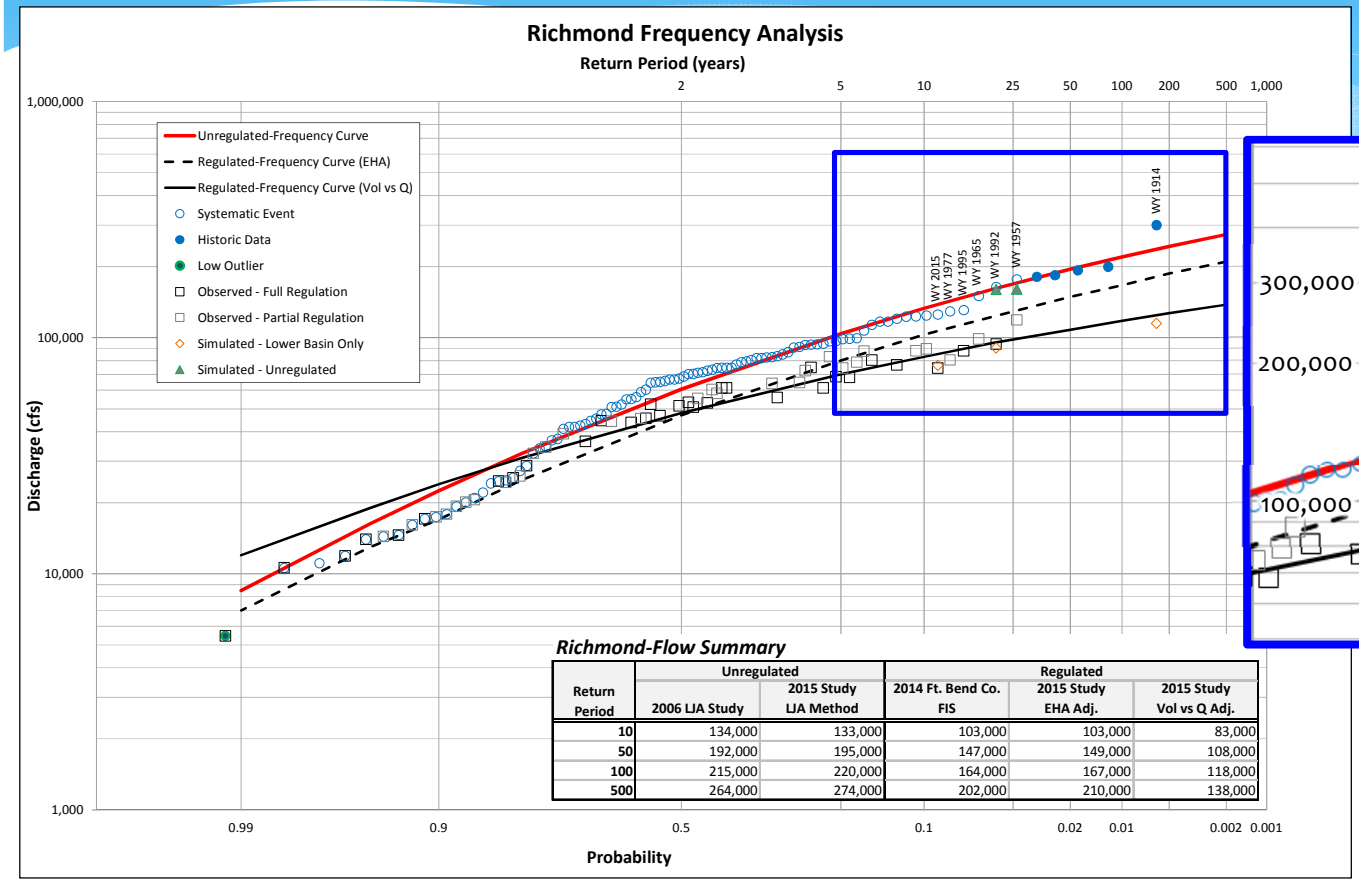
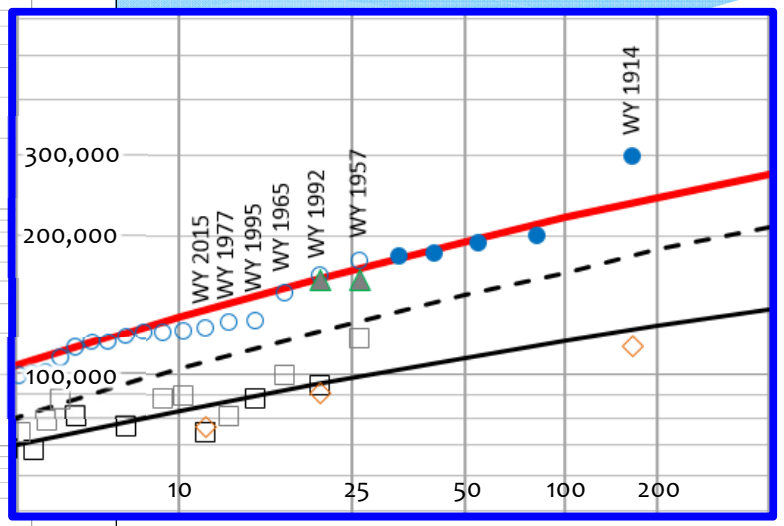
Flood Frequency Analysis

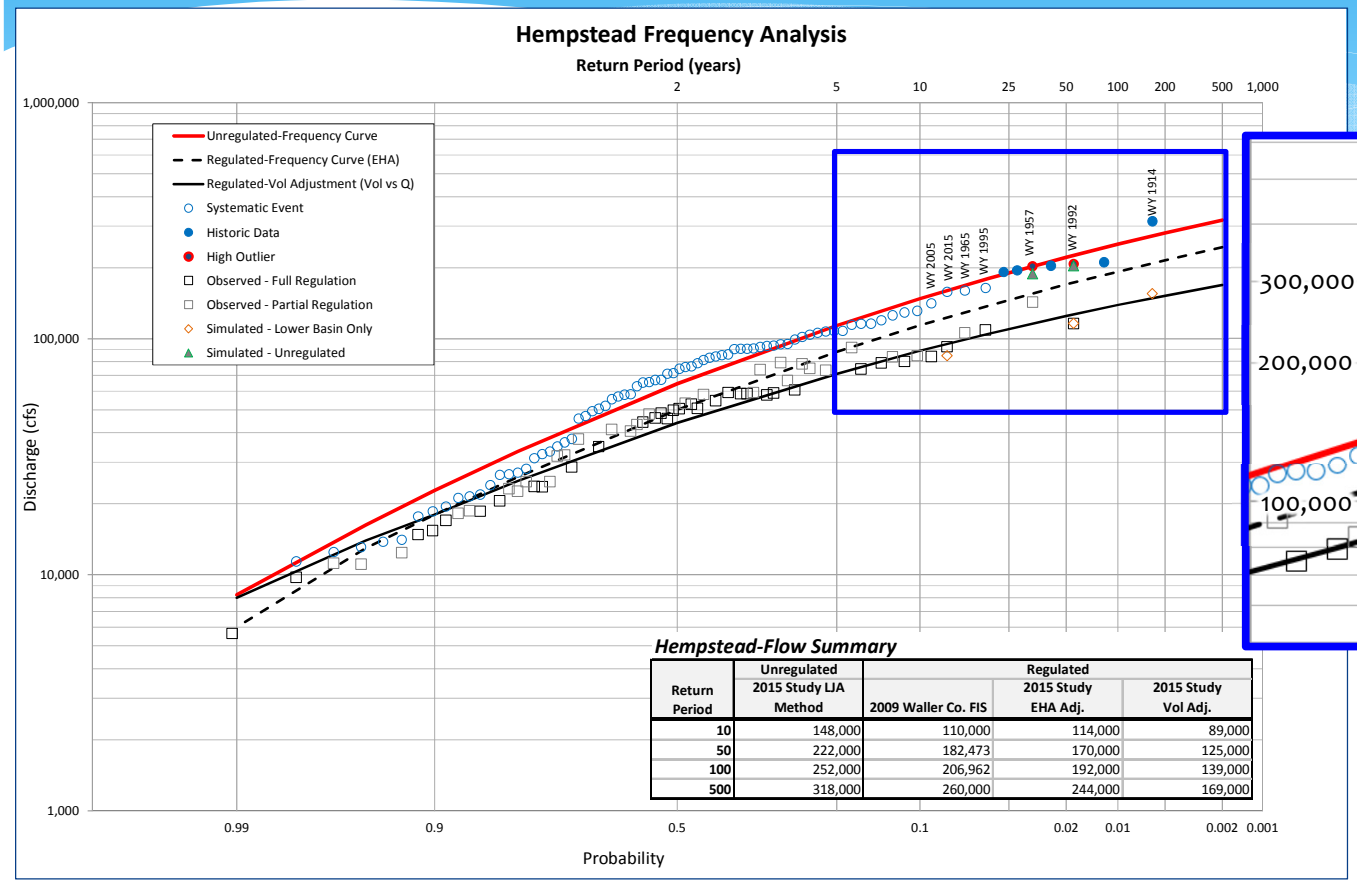


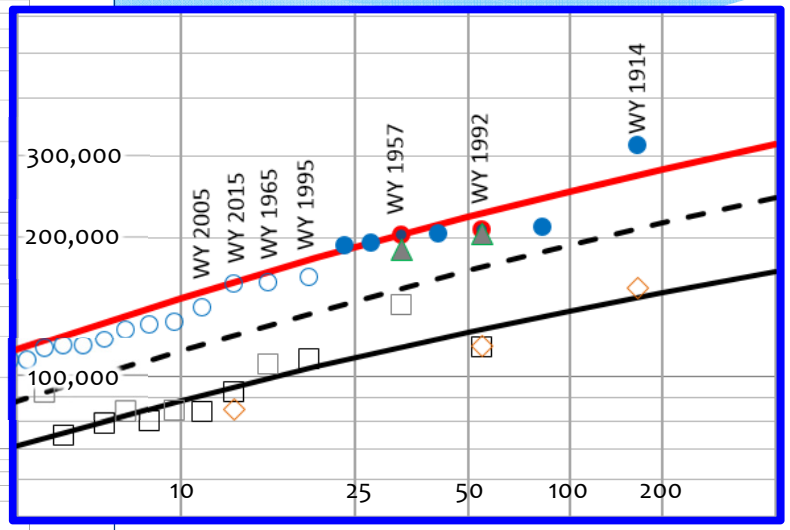


Richmond-Flow Summary

Return Period	Unregulated		Regulated		
	2006 LJA Study	2015 Study LJA Method	2014 Ft. Bend Co. FIS	2015 Study EHA Adj.	2015 Study Vol vs Q Adj.
10	134,000	133,000	103,000	103,000	83,000
50	192,000	195,000	147,000	149,000	108,000
100	215,000	220,000	164,000	167,000	118,000
500	264,000	274,000	202,000	210,000	138,000

Flood Frequency Analysis





Hempstead-Flow Summary

Return Period	Unregulated 2015 Study LJA Method	Regulated 2009 Waller Co. FIS	Regulated 2015 Study EHA Adj.	Regulated 2015 Study Vol Adj.
10	148,000	110,000	114,000	89,000
50	222,000	182,473	170,000	125,000
100	252,000	206,962	192,000	139,000
500	318,000	260,000	244,000	169,000

Hydrology Topics

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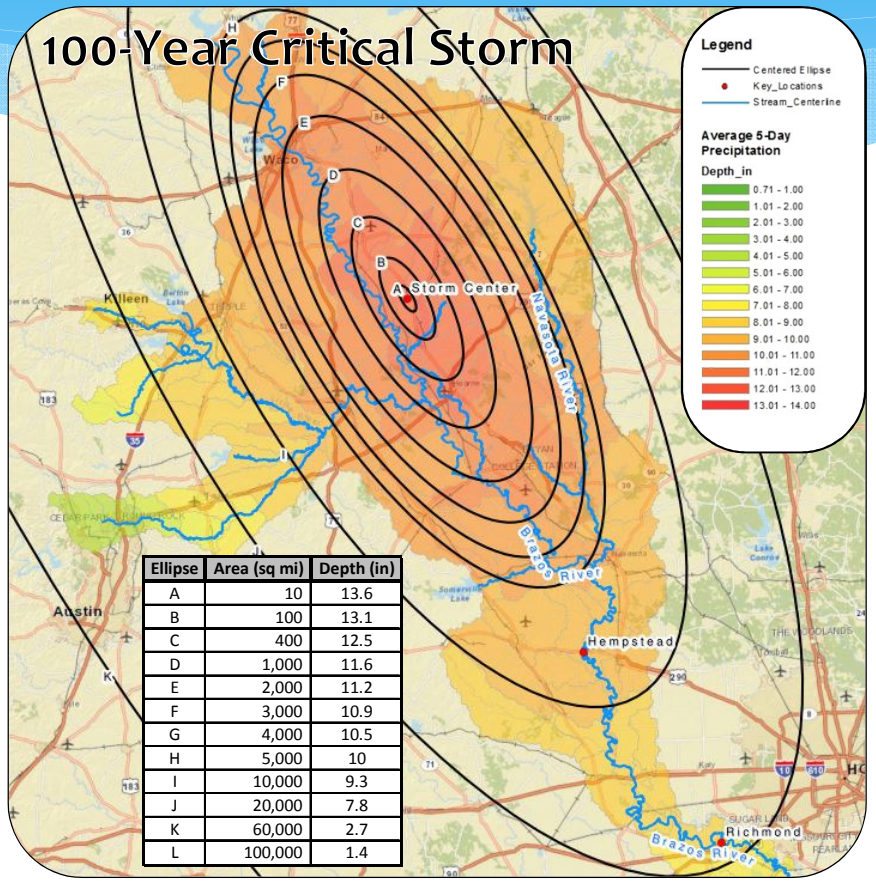
Design Storm Analysis

* Loss Rates
  * Initial Loss – 1.5” for 10-year and adjust values by frequency event per USACE guidance
  * Constant Loss – Use 2015 values for 10-yr event and adjust values by frequency event per USACE guidance
* Design Storm
  * Elliptical Shape
  * 5-day duration
  * Alternating block temporal distribution
  * Precipitation Data Source – Atlas of Depth-Duration-Frequency of Precipitation Annual Maxima for Texas, USGS 2004
  * Areal Reduction Curve
    * USACE SWF Curve used in Upper Trinity Model
    * Developed from storm data across the state
    * Extended past 10,000 sq. mi. based on 1899 Hearne Event
  * Critical location and orientation determined to produce maximum discharge

Design Storm Analysis

- Lower Brazos Critical Storm
  - Located near Hwy. 6 and 14
  - Near Bremond
  - Orientated 330° CW from N
  - Location and Orientation used for all frequencies
  - Maximum 5-Day Depths
    - 10-yr = 8.4” 50-yr = 12.0”
    - 100-yr = 13.6” 500-yr = 17.7”



Ellipse	Area (sq mi)	Depth (in)
A	10	13.6
B	100	13.1
C	400	12.5
D	1,000	11.6
E	2,000	11.2
F	3,000	10.9
G	4,000	10.5
H	5,000	10
I	10,000	9.3
J	20,000	7.8
K	60,000	2.7
L	100,000	1.4

Design Storm Analysis

* Antecedent Reservoir Releases
  * Conversations with USACE suggest that a realistic scenario is a storm occurs below reservoirs while the reservoirs are making releases from a previous event in the upper basin.
  * How much release?
    * USACE controls holds releases up to 60,000 cfs at Richmond and Hempstead
    * 60,000 cfs release would be worst case and unlikely
    * Selected the upper 10th percentile flood release from each reservoir based on historical release data
    * Equal to approximately 25,000 cfs combined from all reservoirs
    * In HEC-HMS, the release is shutoff when 60,000 cfs threshold is exceeded at downstream control points

Design Storm Analysis

* Results

Return Period	Hempstead Discharge w/o Release (cfs)	Hempstead Discharge w/ Release (cfs)	Richmond Discharge w/o Release (cfs)	Richmond Discharge w/ Release (cfs)
10-Year	100,000	107,000	78,000	86,000
50-Year	140,000	148,000	113,000	122,000
100-Year	161,000	170,000	131,000	139,000
500-Year	217,000	223,000	169,000	178,000

Hydrology Topics

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Discharge Comparison

Hempstead

Return Period	2009 Waller Co. FIS	2015 Study w/ EHA Adj.	2015 Study w/ Vol vs Q Adj.	Freq. Storm Analysis
10-Year	110,000	114,000	89,000	107,000
50-Year	182,473	170,000	125,000	148,000
100-Year	206,962	192,000	139,000	170,000
500-Year	260,000	244,000	169,000	223,000

Richmond

Return Period	2014 Ft. Bend Co. FIS	2015 Study w/ EHA Adj.	2015 Study w/ Vol vs Q Adj.	Freq. Storm Analysis
10-Year	103,000	103,000	83,000	86,000
50-Year	147,000	149,000	108,000	122,000
100-Year	164,000	167,000	118,000	139,000
500-Year	202,000	210,000	138,000	178,000

Hydrology Topics

A. Where We Left Off
B. Where We Are Going
C. Hydrologic Model
D. Flood Frequency Analysis
E. Design Storm Analysis
F. Discharge Comparison
G. Conclusions

Conclusions

* A well calibrated hydrologic model was developed
* A flood frequency analysis, informed by observed and hypothetical storms was performed
* A realistic design storm and reservoir release scheme was developed
* The design storm was modeled with the calibrated hydrologic model
* Results are lower than effective FIS discharges, but higher than flood frequency analysis

Conclusions

Return Period	2009 Waller Co. FIS Hempstead Discharge (cfs)	2015 Study Hempstead Discharge (cfs)	2014 Ft. Bend Co. FIS Richmond Discharge (cfs)	2015 Study Richmond Discharge (cfs)
10-year	110,000	**107,000** (-3,000, -3%)	103,000	**86,000** (-17,000, -17%)
50-year	182,473	**148,000** (-34,473, -19%)	147,000	**122,000** (-25,000, -17%)
100-year	206,962	**170,000** (-36,962, -18%)	164,000	**139,000** (-25,000, -15%)
500-year	260,000	**223,000** (-37,000, -14%)	202,000	**178,000** (-24,000, -12%)

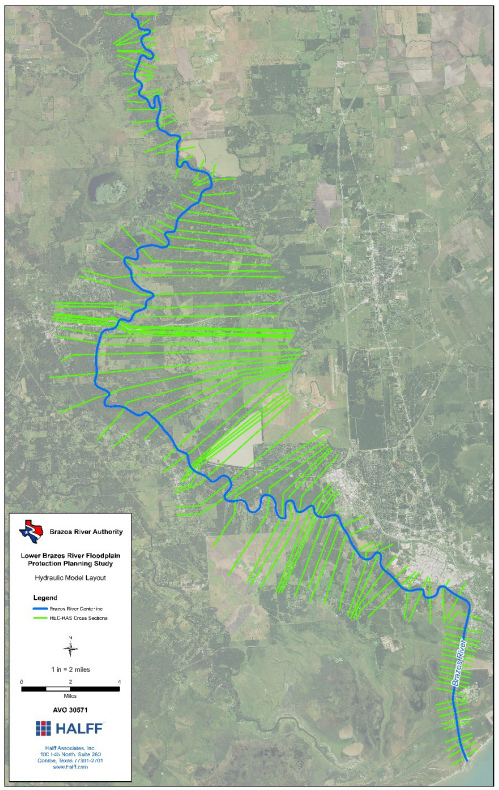
Hydraulic Modeling Update

Fort Bend Unsteady HEC-RAS

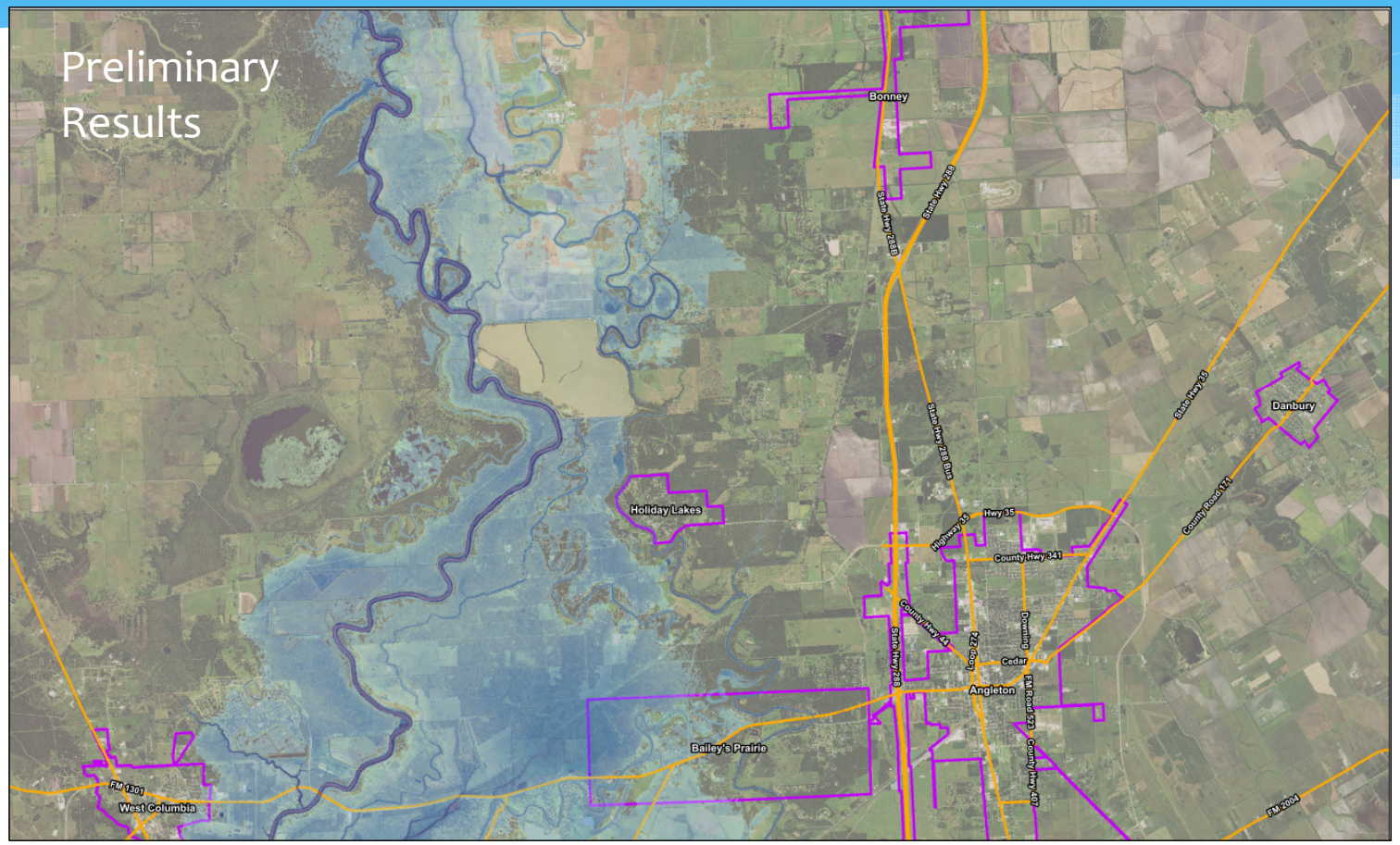
* Incorporate the Fort Bend 2015 HEC-RAS FIS Model
  * Briefly reviewed the steady state model
  * Stationing revised to align with new Brazoria County HEC-RAS Model
  * Converting from steady state to unsteady model
  * Add 2015 updated discharges
  * Updated floodplain mapping and water surface elevation profiles will be developed

Brazoria Unsteady HEC-RAS

* Develop the Hydraulic Model
  * Model Cross Sections
  * Updated terrain data with survey data
  * Develop simulations with 2015 updated discharges
  * Updated floodplain mapping and water surface elevation profiles will be developed



Brazoria Unsteady HEC-RAS



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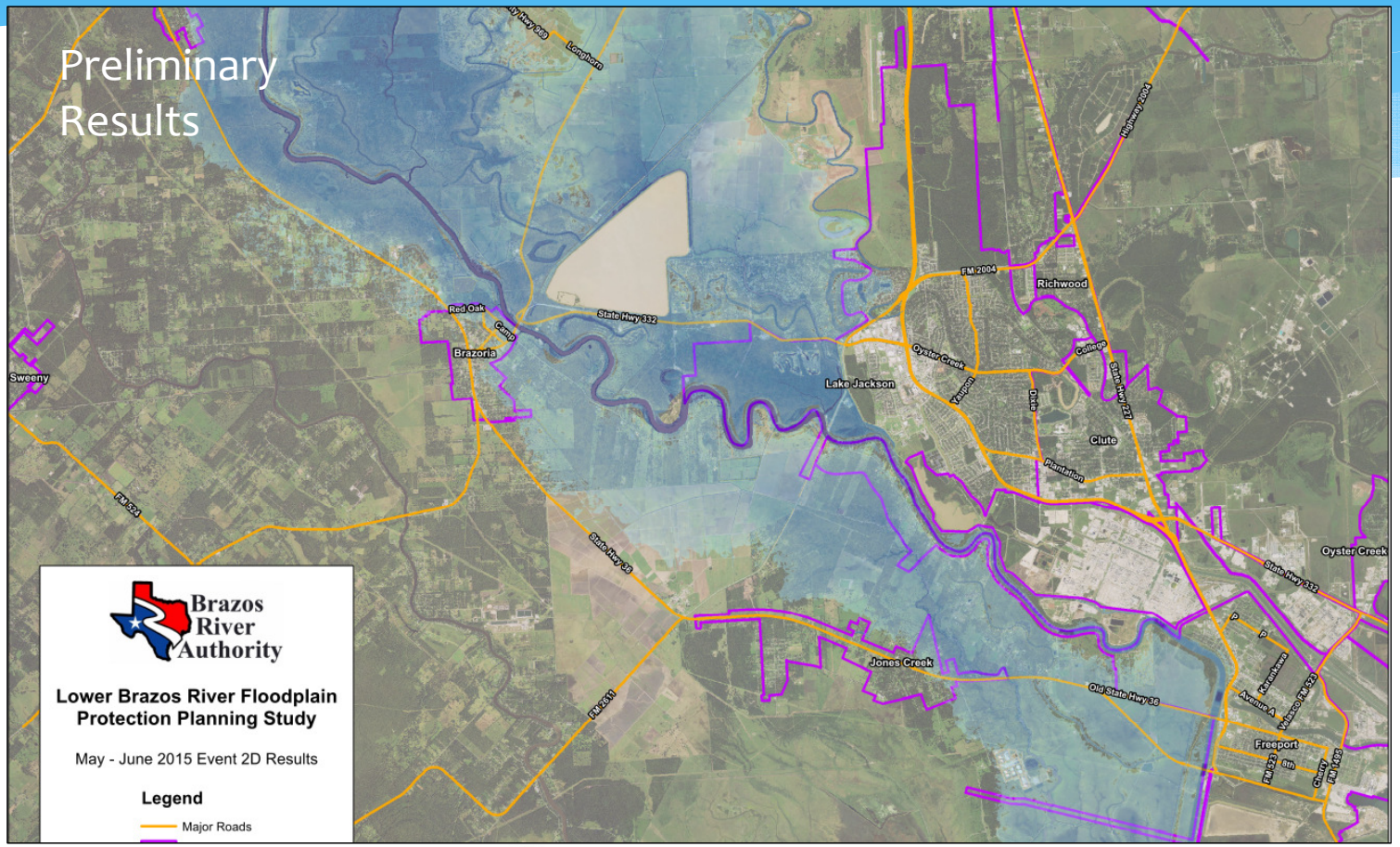
Brazoria Unsteady HEC-RAS



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Questions?