Apparent Divergence in Statistical and Process-Based Flood Hydrology
Upper Trinity River – Dallas, Fort Worth Area

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Use of Statistical Hydrology to Inform Flood Risk

- Less costly
- Quick, maybe
- Significant influence from:
  - Development of storage
  - Non-homogeneity of watershed
  - Climate variability
- Requires a record length consistent with the frequency or return interval to be estimated
- Requires greater expertise than is commonly understood
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- Apparent agreement between modeling and statistical hydrology up through early 1990’s
- Divergence of modeling and statistical hydrology mid 1990’s – current period
- Is modeling over estimating flood risk?
- Is statistical hydrology under estimating flood risk?
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- **Statistical Hydrology Investigation**
  - **Study area**
    - Upper Trinity Watershed DA = 8,538 sq. mi.
    - 35 USGS stream gages: length of record (20 years – 58 years, average 30 years of modern)
  - **Methods**
    - Log Pearson Type III
    - Other 3 parameter and higher distributions explored
    - Generalized Skew is important but influence diminishes with increasing record length
    - Importance of the generalized skew can be difficult to discern but it impacts curvature of the fitted distribution and its importance really lays beyond the 25- to 50-year event.
    - Low- and high-outlier treatment is needed
  - **Scope**
    - Investigation into statistics of annual peak data for “modern times.”
    - Modern times are defined as from present (2013 water year) back to an approximate beginning of a static period of flood-storage volume from the National Inventory of Dams

Study Area
Influence of Storage Development

Courtesy of William Asquith (USGS).
Influence of Storage Development on Statistical Hydrology

- **Regulation**
  - 4,478 sq. mi. or 52% controlled by USACE dams
  - 1,970 sq. mi. or 23% TRWD reservoirs
  - 450 NRCS dams influencing about 982 sq. mi. or 12%
  - This regulation or development of storage limits the applicability of statistical hydrology

![Graph of peak streamflow vs. recurrence interval](image)

**DFW17X: 08045850 Clear Fork Trinity River near Weatherford, Tex.**

The seemingly sudden break up and then a “level region” is often a strong indicator of flood control throttling of flood risk. Hence far into the tail using statistics does not represent flood-risk potential.

Courtesy of William Asquith (USGS).
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Challenge to flood-risk estimation and regionalization of statistics for the study area are a mixture of water-sheds classified as “natural” (unregulated and undeveloped), “regulated”, and “urbanized”.

Population mixing of site-specific data for many stations is present.

Courtesy of William Asquith (USGS).
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- **Urbanization**
  - 48% Urbanized
  - 32% Impervious area

- **Highly regulated**
  - 6 major flood control reservoirs
  - 4 major water supply reservoirs

Comparison of Urbanization in DFW Metroplex 1992-2006 (Melinda Luna)
Mixed Population Impacts (A primer)

- Standard methods acknowledge mixing (low outliers) but general lack of practical guidance on how to accommodate more complicated annual peak data

Substantial low-end mixing (conditionally removed by lower quartile) but arguably the lower half of the values could be conditionally removed. But even then, how to interpret the largest value.

At least two populations being mixed together. Less steeply plotted data suggests central tendency. The green lines are stylized to show possible hinge points.

Some minor low end mixing (conditionally removed by lower quartile), LPIII dist. In central part of distribution is close enough, substantial underestimation at the upper end. Does available storage become overwhelmed at about the 10-year event?
PREVIEW: CLIMATE VARIABILITY
UPPER TRINITY RIVER – DALLAS, FORT WORTH AREA

- Region of significant climate variability
- Observations show loss rates vary from 15% to 85%
Trinity River Basin Projects: CY2014
Reservoir Inflow & Basin Average Precip
CY2014 Monthly Avg PDSI = -1.78 (Max = -1.13  Min = -2.56)

Resv Inflow  Basin Avg Precip  1 Jan 2014 Cons. Storage  31 Dec 2014 Cons. Storage
Summary of Projects Averages for CY2014
Reservoir Inflow & Basin Average Precipitation

Reservoir Inflow  Basin Avg Precip  1 Jan 14 Cons Storage  31 Dec 14 Cons Storage

Percent of Normal

Red  Neches  Trinity  Brazos  Colorado  Guadalupe
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Tropical Storm Hermine
(7-9 Sept. 2010)

- Climate and loss rate variability
  - Drought of record based on duration
  - Extremely dry antecedent conditions
  - 24-hr 100-yr point rainfalls, 25-yr basin average produced 10-yr runoff
  - Observed flow = 44,200 cfs
  - Flow (1989-1991 storm reproduction loss rates) = 66,000 cfs
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70% variation in loss rates
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- Why
  - General drying of surface strata
  - Changes in vegetation
  - Changes in groundwater
  - Development of storage
    - Small stock ponds
    - NRCS dams
    - Large impoundments
Climatic Influence on Flood-Risk Potential

Courtesy of William Asquith

Investigation of population mixing by the Palmer Drought Severity Index (PDSI) for the month of the annual peak.

A threshold of PDSI = 1.75 was heuristically determined to about split record into two classifications: dry and wet.

Many streamgages show substantial log-cycle offsets and hints of convergence base on dry/wet. Two examples shown.

Western 2/3 of study area perhaps more strongly impacted by climatic influences than eastern 1/3. Possible that developed (urbanized to substantial degree) watersheds do not show dry/wet impact.

PDSI thought to capture antecedent moisture conditions. If wet, then smaller rains produce larger peaks than during dry conditions.
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USGS streamgage no. 08047000 and low-threshold = 703
Spatial Patterns of Climatic Influence

Available annual peak streamflow data do not suggest substantial wet/dry climatic influences but their quantiles presently remain in the generalized wet/dry adjustment procedure (6 streamgages).

Curiously there is a reversal in climatic influence: annual peak streamflows classified as “wet” seemingly are less than those classified as “dry” by the Palmer Drought Severity Index (PDSI) with a threshold of PDSI < 1.75.

Regardless of having a substantial wet/dry climatic influence, station not included in wet/dry climatic adjustment because more than 50 percent of watershed is developed or has more than 1,500 square miles of drainage area.

EXPLANATION

- Study area boundary
- U.S. Geological Survey streamflow-gaging station and number
- Annual peak streamflow data show substantial wet/dry climatic impact based on Palmer Drought Severity Index for a threshold of 1.75
- Annual peak streamflow data only show substantial wet/dry climatic influence for peaks less than the median (2-year event)

Courtesy of William Asquith (USGS).
We are not saying across the board that **all** statistical methods for flood-risk assessment are inapplicable---observational data remains critical---but there are some justifiable and serious concerns about applicability of the most well-known “17B+” framework.

Courtesy of William Asquith (USGS).
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- **Recommendations and Conclusions**
  - **Statistical hydrology**
    - Log Pearson Type III distribution is applicable
    - Skew in 17B as well as in USGS WRIR 96-4117 coefficients are outdated
    - Regulation or development of storage upstream of a gage site may limit frequency curves derived through statistical methods
    - Urbanization may limit frequency curves derived through statistical methods
    - Climate variability –
      - Significant impact on annual peak series during drought cycles
      - Significant influence on gages with relatively short periods of record
      - With many years of record and no climate change, may not be significant
  - Use caution when utilizing statistical hydrology to determine flood risk
  - **Modeling**
    - Methods developed in other regions should be regionalized and calibrated before use in this region (Clark, SCS Curve Number, etc.) including a review of Asquith and Roussel (2007) unit hydrographs and losses for central and north-central Texas.
    - Adopted loss rates should:
      - Consider wet cycle loss observations
      - Place a higher weighting on wet cycle losses rather than dry cycle losses
NOAA Atlas 14
Precipitation Frequency Estimates

- NOAA - Office of Hydrologic Development – Sanja Perica PhD
- UCAR
  - Technical Paper 40 & 49 (1961 & 1964)
  - USGS/TXDOT (Asquith)
  - 10 volumes completed
  - Improved techniques
  - Additional durations (urban studies, 5-min)
  - Additional frequencies (1000-yr)
  - Aerial reduction factors
  - Increased granularity
    - Denser network
    - Improved spatial interpolation
    - PRISM techniques
  - Longer records
  - Connectivity to USACE software (MetVue)
  - Cost – $1.6 mil, $500k/yr for 3 years
  - $170k in hand plus pledged support from TxDOT ($740k)
NOAA Atlas 14 Min. Record Length

- NA14 – Completion year 2017 (54 years additional data from 1961 TP 40)
- NA14 – Completion year 2017 (24 years additional data from USGS)
- NA14 – Min. record length 30-50 yrs (duration and density) vs. shorter periods used in previous updates
NOAA Atlas 14

Server and Data inquiry Locations and Monthly Statistics

http://hdsc.nws.noaa.gov/hdsc/pfds/index.html
## NOAA Atlas 14 Volume for Texas

#### NOAA Atlas 14 for Texas Funding FY15-FY18

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**USACE Contributed Funds**

**TXDOT Contributed Funds**
QUESTIONS?

US Army Corps of Engineers
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