**Hydrologic Methods for Scaling 2D BLE to Probabilistic Datasets:**

**Date: May 13, 2020**

Overview:

This memorandum provides a procedure for preparing the hydrologic input required to scale 2D BLE to a probabilistic dataset. The information within serves as the basis for the hydrologic data development prepared for the FEMA Innovations: Scaling 2D BLE to PFRA Standard Operations 5 project.

Minimum criteria and data development protocols are outlined for each level of hydrology being employed, ranging from a base level engineering to a probabilistic analysis of hydrologic parameters. A summary of each Hydrology level (1-4) is listed below. Information about the original hydrologic methodology used for the BLE model is included in the project area assessment forms and is referred to as Hydrology 0.

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| **Hydrology 1** | **Hydrology 2** | **Hydrology 3** | **Hydrology 4** |
| -5 rainfall events from base BLE model (10, 25, 50, 100, 500 yr events)  -NRCS nested hyetograph  -5 simulations | -uses mean precipitation curve  -12 rainfall events sampled between 2yr and PMP)  -NRCS nested hyetograph  - 12 simulations | -uses mean precipitation curve  -12 rainfall events sampled between 2yr and PMP)  -2 infiltration conditions sampled  -24 runoff events sampled  - NRCS nested hyetograph - 24 simulations | -uses mean precipitation curve  -12 rainfall events sampled between 2yr and PMP)  -2 infiltration conditions sampled  -24 runoff events sampled  - 4 Atlas 14 quartile hyetographs sampled  ~100 simulations |

Hydrology 1:

**Data Required**

* Rainfall data:
  + NOAA Atlas 14 basin-area weighted 24-hour precipitation totals for the 10-, 4-, 2-, 1-, 0.2-percent-annual-chance events (24-hour storm)
  + NOAA Atlas 14 basin centroid precipitation totals for the 5-min, 10-min, 15-min, 30-min, 60-min, 2-hr, 3-hr, 6-hr, 12-hr, 24-hr duration events are required for nested hyetograph creation
* Infiltration factors
  + SCS Curve Number per model domain
  + Areal Reduction factor (area-depth duration curves from the Technical Paper No. 29, *U.S. Weather Bureau, 1960* (see resources folder)
* Rainfall temporal distribution
  + NRCS nested hyetograph (see resources folder)

**Procedures:**

**Derive excess precipitation estimates (median precipitation)**

1. Obtain basin-area weighted cumulative 24-hour precipitation totals for the 10-, 4-, 2-, 1-, 0.2-percent-annual-chance events if not already prepared for the model <https://hdsc.nws.noaa.gov/hdsc/pfds/pfds_gis.html> (note units are in inches\*1000)
2. Apply areal reduction factor to model domains greater than 100 sq miles.

**Develop Nested Hyetograph**

1. Prepare nested hyetograph utilizing the Nested Rainfall Distribution Spreadsheet template in the Hydrology2 resources folder
   * Input the basin centroid cumulative precipitation total from the 5-min through 24-hour events to obtain the temporal distribution for the nested hyetograph.
2. Confirm that model can run in HEC-RAS 5.0.7 without error

Hydrology 2:

**Data Required**

* Rainfall Data
  + NOAA Atlas 14 basin-area weighted 24-hour precipitation totals for the 10-, 4-, 2-, 1-, 0.2-percent-annual-chance events (24-hour storm)
    - need median, 10% and 90% confidence precipitation
  + NOAA Atlas 14 basin centroid precipitation totals for the 5-min, 10-min, 15-min, 30-min, 60-min, 2-hr, 3-hr, 6-hr, 12-hr, 24-hr duration events are required for nested hyetograph creation
  + Preparation of GEV fitted mean precipitation curve.
* Infiltration factors
  + SCS Curve Number per model domain
  + Areal Reduction factor (area-depth duration curves from the Technical Paper No. 29, *U.S. Weather Bureau, 1960* (see resources folder)
* Rainfall temporal distribution
  + NRCS nested hyetograph (see resources folder)

**Procedures:**

**Derive excess precipitation estimates (mean precipitation)**

1. Obtain the Atlas 14 cumulative precipitation frequency grids (including 10% and 90% confidence bounds) for the 50-, 20-,10-,4-, 2-, 1-, 0.5-, 0.2-, 0.1-percent-annual-chance events <https://hdsc.nws.noaa.gov/hdsc/pfds/pfds_gis.html> (note units are in inches\*1000)
2. Calculate a basin weighted average cumulative value for the 10 published recurrence intervals (50-, 20-,10-,4-, 2-, 1-, 0.5-, 0.2-, 0.1-, 0.05-percent-annual-chance events) and 3 confidence intervals (10%, median, 90%).
3. Utilize the mean precipitation curve workbook or python code to obtain 10 mean precipitation totals for the published 50-, 20-,10-,4-, 2-, 1-, 0.5-, 0.2-, 0.1-, 0.05-percent-annual-chance events.
4. Utilize a GEV fitted curve to obtain the 11th (0.033-percent-annual-chance event) and 12th event (a representative event found by integrating the GEV from the 0.033-percent-annual-chance event to the PMP)
5. Apply areal reduction factor to model domains greater than 100 sq miles.

**Develop Nested Hyetograph**

1. Same as Hydrology 1
2. Confirm that model can run in HEC-RAS 5.0.7 without error

Hydrology 3:

**Data Required**

* Rainfall Data
  + Same as Hydrology 2
* Infiltration factors
  + An SCS Curve Number per model domain
  + Maximum potential retention distributions (from NRCS 10% and 90% quantile values) (see resources folder)
  + Areal Reduction factor (area-depth duration curves from the Technical Paper No. 29, *U.S. Weather Bureau, 1960* (see resources folder)
  + Python code for deriving distribution and sampling routine for runoff (see resources folder)
* Rainfall temporal distribution
  + NRCS nested hyetograph (see resources folder)

**Procedures:**

**Derive excess precipitation estimates (mean precipitation)**

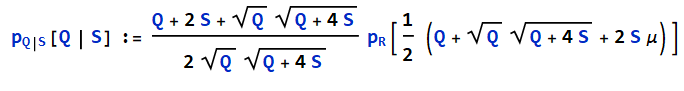
1. Same as Hydrology 2

**Derive Distribution of Maximum Potential Retention**

1. Utilizing selected CN for model domain, obtain distribution of maximum potential retention (S) (from NRCS 10% and 90% quantile values)

**Derive Distribution of Runoff**

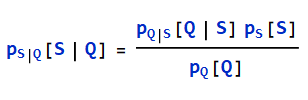
1. Assume the distribution of rainfall using the mean precipitation curve (numerical form of the probability density function)
2. Obtain the probability distribution of runoff (Q) by integrating numerically over the distribution of S (several methods to do this, pilot test included 40 parts equal in probability (python code available)).
3. For each partition, calculate average mid-point values of S.
4. Insert midpoint value of S into the conditional formula below and weight by the partition cumulative probability.



1. Obtain the probability distribution function for Q (via python)
2. Integrate to find the cumulative distribution function for Q (via python)
3. Calculate the inverse cumulative distribution function for Q (in terms of exceedance probability)

**Sampling of Runoff and Maximum Potential Retention**

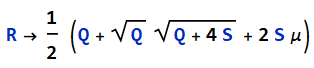
1. Sample 8 exceedance probabilities (50-, 20-,10-,4-, 2-, 1-, 0.5-, 0.2-percent-annual-chance events) to obtain Runoff (Q).
2. Calculate distribution of S conditional on Q (utilizing formula below)



1. Obtain the values of S for a given value of Q by partitioning the distribution of S into 2 equal partitions of probability.
   1. For each partition, calculate the midpoint value of S

**Develop Nested Hyetograph**

1. For each sampled Q, use the two midpoint values of S to calculate the corresponding values of R (see equation below).



1. Given a 24-hour value of R, utilize the temporal distribution prepared in Hydrology 3 that most closely matched the cumulative precipitation estimate.
2. Obtain the excess runoff hyetograph utilizing the cumulative excess precipitation value obtained in step 1 and temporal distribution obtained in step 2.
3. Confirm that model can run in HEC-RAS 5.0.7 without error

Hydrology 4

**Data Required**

* Rainfall Data
  + Same as Hydrology 2
* Infiltration factors
  + An SCS Curve Number per model domain
  + Maximum potential retention distributions (from NRCS 10% and 90% quantile values) (see resources folder)
  + Areal Reduction factor (area-depth duration curves from the Technical Paper No. 29, *U.S. Weather Bureau, 1960* (see resources folder)
* Rainfall temporal distribution
  + NOAA Atlas 14 temporal distributions

**Procedures:**

**Excess Precipitation**

1. Utilize same methodology as Hydrology 3

**Derive Distribution of Maximum Potential Retention**

1. Utilize same methodology as Hydrology 3

**Derive Distribution of Runoff**

1. Utilize same methodology as Hydrology 3

**Sampling of Runoff and Maximum Potential Retention**

1. Utilize same methodology as Hydrology 3

**Hyetograph development**

1. Obtain the Atlas 14 quartile temporal distributions for the 24-hour storm utilizing the centroid of the basin. <https://hdsc.nws.noaa.gov/hdsc/pfds/pfds_temporal.html>
2. Utilize the excess distribution and 4 median hyetographs (50% decile from each quartile) representing the temporal distribution expressed as probability terms as cumulative percentages of precipitation totals between 0 and 24 hours.
3. Enter the excess runoff values over time utilizing the excess precipitation and hyetograph prepared.
4. Retain the value of the percentage of cases that fell within each quartile for later analysis.
5. Confirm that model can run in HEC-RAS 5.0.7 without error