Rainfall Short Duration Analysis in Arid/Semi Arid Regions

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Objectives

- Generate IDF, for each Rainfall Station for 5, 10, 20, 25, and 100 Years Return Periods in KSA and Sinai.
- Weighted Design Storm for Relative 2.0 hours and 24 hours depths of Each Rainfall Stations in KSA and Sinai for 5, 10, 20, 25, and 100 Years.
- Weighted Design Storm Relative 2.0 hours and 24 hours depths for All Rainfall Stations in KSA, as well as Sinai.
- Comparing Relative 2.0 hours and 24 hours depths of All Rainfall Stations verses Bell's and SCS storm type II respectively for both KSA and Sinai.
- Evaluate adopting Bell's ratios and SCS Storm type II in KSA and Sinai.
- Generate Representative 24 hours Design Storm for KSA and Sinai as Arid Regions.
- Check the relation between the Return Period and Relative 24 hours Depths for KSA and Sinai.

INTRODUCTION

Arid and Semi-Arid Regions

- **Arid Regions**: These in which the rainfall on a given piece of land is not adequate for regular crop production.
- **Semi-Arid Regions**: Those in which the rainfall is sufficient for short season crop and where grass is an important element in natural vegetation.
Rainfall Types

- **Frontal**: Produced in conjunction with movement of large air masses (hot and cold fronts). Precipitation produced by juxtaposition of warm, moist air, and cold air.
- **Cyclonic**: A cyclone is a large low pressure region with circular wind motion. Strong winds can reach 200 km/hr and might produce excessive precipitation over very large areas for several days.
- **Convective**: Due to intense heating of air at ground surface, air mass expands and rises.
- **Orographic**: Air mass is mechanically lifted over an elevated land mass. Results in high precipitation on western slopes (BC temperate rain forest) and the shadow effect on eastern slopes of mountain ranges.

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Hydrological Cycle Introduction:

**Rainfall - Runoff**
Factors Affecting Runoff

- Soil and land Use
- Drainage Characteristics
- Rainfall Distribution Pattern

Rainfall - Runoff

Use Design Storm OR IDF point on IDF

- Design Storm Concept
  A precipitation pattern defined for use in a hydrologic system, i.e., a hypothetical worst case hyetograph for a storm of predetermined duration and recurrence frequency (e.g. 6 hour, 50 year storm).

- Developed from IDF curves for a location.
  IDF curve does not represent a storm. It describes recurrence intervals for periods of rainfall of various intensities.

Intensity-Duration-Frequency (IDF) Curves

- Intensity
  Rate at which precipitation falls. This is generally expressed as depth of rainfall per unit of time (cm/hr)
- Duration:
  The length of time over which a precipitation event occurs
- Frequency:
  The “repeat” time interval for an event having the same volume and duration.
- Intensity and Duration combine to yield volume
  The amount of precipitation in total and as a function of time per unit area

Intensity-Duration-Frequency (IDF) Curves

![Intensity-Duration-Frequency (IDF) Curves](image)
Alternating Block Method

- This method positions the block of maximum incremental depth at the middle of the required duration.
- The remaining blocks are arranged then in descending order, alternating before and after the central block.

Rational Formula

\[ Q = \frac{CIA}{3.6} \]

Rainfall Intensity (mm/hr)
Basin Area (km²)
Frequency Adjustment Coefficient (dimensionless)

Runoff Estimation (a type of regression equations)

- Drainage Area (ha)
  - 1.0-400
  - 2.400 to 1258
  - 3.1258 to 35,944
  - 4. over 35,944

- 25 year Frequency Rain Storm
  \[ Q_{50} = 1.2 \times Q_{25} \]
  \[ Q_{100} = 1.4 \times Q_{25} \]

Loss method

\[ S = 25.4 \times \left( \frac{1000}{CN} - 10 \right) \]

Rainfall Excess

- CN: is the Curve Number.
- S: is the maximum storage depth (in mm).
- P: is the accumulated depth of daily storm rainfall (mm).
Runoff Applications

- Engineering:
  - Design of Dams, Culverts, Bridges...
  - Hill slope stability

- Natural Hazards:
  - Flood mitigation
  - Slope failure

- Environmental Protection:
  - Soil contamination
  - Surface and groundwater pollution
  - Wetlands

- Water Resource Management for water supply purposes or for agriculture

Rainfall - Runoff

- Historical rainfall events: the way in which the precipitation is distributed in time over the duration of the storm.
  - This can be described using a rainfall hyetograph of real storms as well as synthetic hyetograph.
  - The time distribution of the design hyetograph will significantly affect the timing and magnitude of the peak runoff.
  - Therefore, care should be taken in selecting a design storm to ensure that it is representative of the rainfall patterns in the area under study.

Synthetic Hyetographs

No Short Duration Record?

- Bell Ratios!
- SCS type II
- Arid zone hydrology 1st graph
- Arid zone hydrology 2nd graph
  or similar distributions
Bell’s Ratios used in IDF Development

<table>
<thead>
<tr>
<th>Country</th>
<th>5 min</th>
<th>6 min</th>
<th>12 min</th>
<th>15 min</th>
<th>18 min</th>
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Synthetic Hyetographs

“Arid zone hydrology” proposes the following 1st graph:
“Arid zone hydrology” proposes this 2nd graph:

Data Availability

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<tr>
<th>No.</th>
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A fourteen (14) rainfall stations located in Sinai (Egypt) with total 181 years records with average 13 years for each station maximum 20 years, and minimum 5 years.

Data Availability & Accuracy

A fourteen (14) rainfall stations located in Sinai (Egypt) with total 181 years records with average 13 years for each station maximum 20 years, and minimum 5 years.
Data Availability

<table>
<thead>
<tr>
<th>No.</th>
<th>No.</th>
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A sixteen (16) rainfall stations located in Saudi Arabia with total 422 years records with average 26.4 years for each station maximum 40 years, and minimum 8 years.
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<td>APR</td>
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Why to Use Distribution Fitting?

- To extrapolate
- To assume a population with known characteristics based on a small sample
Statistical Analysis

- Lack of High Quality Data for Rainfall Short Duration Record
- No Specific Techniques
- What statistical distribution should be used? No Specifically Recommended Probability Distribution.
- Find best estimate of design quantiles and hydrologic risk
- Outliers
- The Problem of Zeros

Typical Distributions

- Characteristics:
  - Type of Phenomenon
  - Number of Distribution Parameters
  - Range of Variable
- Types:
  - Normal Family (Normal (Gaussian), Lognormal)
  - Extreme Value Family (Gumbel)
  - Pearson Family (Log Pearson type III)

Choice between Distribution

- Visual Comparison with Empirical Probability Plot
- Moment Diagrams
- Chi-Square Comparison as a Fitting Test
- Akaike Information Criterion and Bayesian Information Criterion
- Procedure of HYFRAN+

HYFRAN+ DSS
Choice between Distribution

Distribution fitting criteria:

- **Choice criterion:**
  - **AIC**
  - **BIC**

**Bayesian Information Criterion (BIC):**

\[
BIC = -2 \log(L) + k \log(n)
\]

**Akaike Information Criterion (AIC):**

\[
AIC = -2 \log(L) + 2k
\]

where \( L \) is the likelihood, \( k \) is the number of parameters and \( n \) is the sample size.

Visual Comparison

- **Comparison of the distributions:**
  - **Rivière Harricana à Amos**

AIC and BIC Comparison Criteria

- **Bayesian Information Criterion (BIC):**
  - \( BIC = -2 \log(L) + k \log(n) \)
- **Akaike Information Criterion (AIC):**
  - \( AIC = -2 \log(L) + 2k \)

where \( L \) is the likelihood, \( k \) is the number of parameters and \( n \) is the sample size.
Outliers

- Outliers are measurements that are extremely large or small relative to the rest of the data and, therefore, are suspected of misrepresenting the population from which they were collected.
- Outliers may result from transcription errors, data coding errors, or measurement system problems such as instrument breakdown.
- However, outliers may also represent true extreme values of a distribution (for instance, hot spots) and indicate more variability in the population than was expected.
- Not removing true outliers and removing false outliers both lead to a distortion of estimates of population parameters.
- Statistical outlier tests give the analyst probabilistic evidence that an extreme value (potential outlier) does not "fit" with the distribution of the remainder of the data and is therefore a statistical outlier.
- These tests should only be used to identify data points that require further investigation.

KSA Design Storm

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Conclusion

- Most of rainfall stations short duration rainfall ratios are greater than Bell's and SCS's type II.
- The peak rainfall ratios are higher than SCS's type II for the weighted average of all stations of KSA and Sinai for each return period.
- The peak rainfall ratios are higher than SCS's type II for the average of weighted average of all stations of KSA and Sinai for all return period.
- The weighted average/average of this ratios are in the upper limits of Bell's ratios, while the upper limit of average is much greater than Bell's ratios.
- Applying Bell's / SCS's type II ratios may be not safe.
- Rainfall stations of KSA show increase in the rainfall depth ratio with return period increase, while this trend was not shown in Sinai stations.

Recommendations

- Further study using more short duration rainfall data by establishing new stations, and gathering data from the old stations in the arid regions, continuous update of the design storms to get a reliable design storms with adequate rainfall records.
- Zoning and grouping of the arid regions avoiding generalizing errors.
- Generate Iso-Line maps the arid regions for different return periods.

Thank You