Near Real-Time Runoff Estimation Using Spatially Distributed Radar Rainfall Data

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Introduction

- Water availability has become a major issue in Texas in the last several years, and the population is expected to double in the next 50 years (Texas Water Development Board, 2000).

- Thus, there is a need for real-time weather data processing and hydrologic modeling which can provide information useful for planning, flood and drought mitigation, reservoir operation, and watershed and water resource management practices.

- Traditionally, hydrologic models have used rain gauge networks which are generally sparse and insufficient to capture the spatial variability across large watersheds, and are unable to provide data in real-time.
Obtaining accurate rainfall data, in particular, is extremely important in hydrologic modeling because rainfall is the driving force in the hydrologic process.

NEXRAD radar can provide data for planning and management with spatial and temporal variability in real-time over large areas.
The objective of this study is to evaluate several variations of the Natural Resource Conservation Service (NRCS – formerly known as the Soil Conservation Service – SCS) curve number (CN) method for estimating near real-time runoff, using high resolution radar rainfall data for watersheds in various agro-climatic regions of Texas.
Issues with CN Assignment

- Hawkins (1998) and Hawkins and Woodward (2002) state that CN tables should be used as guidelines and that actual CNs should be determined based on local and regional data.

- Price (1998) determined that CN could be variable due to seasonal changes.

- Ponce and Hawkins (1996) stated that values for initial abstractions ($I_a$) could be interpreted as a regional parameter to improve runoff estimates.

- According to Hawkins et al. (2002) and Jiang (2001) an $I_a$ value of 0.05 was generally a better fit than a value of 0.2. In 252 of 307 cases, a higher $r^2$ was produced with the 0.05 value.
Datasets

- **LULC**: 1992 USGS National Land Cover Data (NLCD), 30m resolution

- **SOILS**: USDA-NRCS State Soil Geographic (STATSGO) Database, 200m resolution

- **Weather**
  - **NEXRAD** – West Gulf River Forecasting Center (WG RFC) of the National Weather Service (NWS), 1999-2001, 4km resolution
  - **Rain gauge** – National Climatic Data Center (NCDC) of the NWS

- **Stream Flow**: USGS stream flow data will be downloaded and passed through a filter program obtained from the SWAT website
OBJECTIVES

- Select study areas based on the size of the watershed, landuse, soil hydrologic group, rainfall pattern/ agro-climatic region, and stream gauge location; then evaluate several variations of the NRCS curve number method in the selected study areas, with NEXRAD radar and long-term rain gauge rainfall data.
OBJECTIVES

- Run all variations for all study areas with CN grids at several different resolutions to account for spatial variability.
- Compare the modeled runoff for NEXRAD and rain gauge data with observed stream gauge data to determine the most appropriate method for estimating runoff in various regions of Texas.
Size, Stream Gauge Location, & Landuse

1. No existing reservoirs.
2. Stream gauge at watershed outlet.
3. Stream gauge has sufficient historical data (03/01/1956 - 09/30/2001).
4. Drainage is approximately 683 mi$^2$.
5. Subwatershed is delineated according to the 4km x 4km NEXRAD grid.
6. Landuse is determined to be 73% rangeland.
Weather Station Locations

The nearest rain gauge information is used for each 4km x 4km grid cell within the subwatershed boundary. NEXRAD stations are known for each cell.
NRCS CN Method Variations

/* Function: Calculates total runoff for X number of days using the basic SCS CN method with Texas curve numbers and 0.2S, 0.1S, or 0.05S, based on Julian Day. Produces a summary table of runoff and rainfall inputs for further analysis.

&s file1 = c:\research\runs\rnge_%year%.txt
&s file2 = c:\research\runs\rnge_RF_%year%.txt

GRID

SETCELL mgbndry
SETWINDOW mgbndry

initial = 25.4 * ( (1000 / (cn1_con4k)) - 10 )
rainfall = shapegrid (%weather%, %date%, 4000)

if (%julian% <= 115) then
    runoff = con(rainfall > (0.2 * initial), Sqr((rainfall - 0.2 * (initial)) / ((rainfall) + 0.8 * (initial)), 0)
else if (%julian% > 115 && %julian% <= 273) then
    runoff = con(rainfall > (0.1 * initial), Sqr((rainfall - 0.1 * (initial)) / ((rainfall) + 0.9 * (initial)), 0)
else if (%julian% > 273) then
    runoff = con(rainfall > (0.05 * initial), Sqr((rainfall - 0.05 * (initial)) / ((rainfall) + 0.95 * (initial)), 0)
endif

final_runoff = ZONALSUM (mgbndry, runoff)
total_rain = ZONALSUM (mgbndry, rainfall)

Writes runoff and rainfall outputs to text files for each year.

Sets resolution

Generates initial abstraction and rainfall grids

Runs CN method variations based on Julian Day

Summarizes runoff and rainfall by zone
Runoff / Rainfall Outputs

Flow (mm)

Estimated Runoff
NEXRAD Rainfall
Base Flow Filter

The graph shows the flow (cfs) over time, with specific dates marked from January 1, 1970, to May 28, 1970. The chart includes three types of flow data:

- **Stream Flow** (blue line)
- **Filter Pass 2** (green line)
- **Runoff** (yellow line)

The x-axis represents the dates, and the y-axis represents the flow in cubic feet per second (cfs). The data points are plotted for each date, indicating the flow at that time.
Further Analysis

- Repeat this process for 8-10 subwatersheds throughout the state at various resolutions.

- Complete estimation efficiency and regression analysis for each output dataset.

- Make recommendations for CN variation to be used in each agro-climatic region.
Potential Sources of Error / Limitations

- NLCD dataset is from 1992, which may not reflect the true land use for the study periods.

- Point source discharge to streams, especially non-daily or storm water discharge, could increase runoff portion of stream flow unpredictably.

- Runoff data displays characteristics of storm intensity, whereas rainfall data is daily and does not account for intensity.
Potential Solutions

- Remove upper and lower 10% of values to remove influence from outlying data points.

- Plot both natural and ordered pairs for runoff estimates... in ordering the dataset, the P and Q values should have approximately the same return time. In other words, the frequency of these values will be matched.