Observed Flood Extent

New Urban Flood Risk – DHS Science & Technology Research Study

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Study Objective

• The New Urban Flood Risk study was in response to a need from DHS to update flood zones and document flooding prior to construction.

• This study focused on using the frequencies of the detected water in OFE to identify flood prone areas.

• OBJECTIVE:
  • To use OFE to identify urban outside the SFHA that was built on land that flooded pre development and to calculate the economic impact on these areas using NFIP flood insurance claims.
    1. Mapping historical flood extents, Observed Flood Extent (OFE)
    2. Identifying New Construction at Risk of Flooding (NCRF)
    3. Identifying Flood Post New Construction (FPNC)
    4. Detecting dates of flood events
Capturing Water Extents

1989, highest extent

Water Index
Lake Razzaza has changed significantly over the past 33 years:

1984

Present

.700+ images
Approx. 800 scenes per path row downloaded. Converted to surface reflectance and cloud masked.

Terrain Normalization/C-Correction applied to each SR image.

Using each TNSR image and other ancillary data, our model utilizes multiple spectral indices that are used to identify water.

Based on the number of indices that collaborate, each pixel is established as standing water or non-water.

Using the TNSR imagery, a snow/ice model is applied to incorporate areas of snow or ice to the water layer.

Result: A layer identifying areas of standing water for the respective image.
Radiant’s water detection algorithm analyzes 30m Landsat imagery and processes up to 800 scenes per path row:

- The water detection model processes approx. 4.2 GB of data per scene.
- All scenes are layer stacked.
- The water frequency is produced from analyzing the layer stack.

OFE uses python scripts, Imagine models, and manual editing and are processed in the Cloud.
Methodology Workflow – New Urban Flood Risk

1. USGS open source Landsat satellite imagery, 1984 to present
2. 300+ Surface Reflectance images
3. Water Detection Algorithm
4. Watermasks
5. Layerstack
6. Observed Flood Extent
7. New Construction at Risk of Flooding
8. Flood Post New Construction
9. Open source flood extents, flood insurance claims, etc.
10. Economic Analysis
Spatial and Economic Priority

1. Austin, TX
2. Charleston, SC
3. Houston, TX
4. Jacksonville, FL
5. Phoenix, AZ
6. Shreveport, LA
7. St. Louis, MO
8. Tuscaloosa, AL
Demos

- https://www.youtube.com/watch?v=2aOH0C7YDXM&feature=youtu.be
Flood Risk on Undeveloped Land in Houston, TX

- Observed Flood Extent on undeveloped land
- Observed Flood Extent prior to urbanization
- Special Flood Hazard Area
- Urban

Detailed Example
In Katy, Texas flooding occurs on undeveloped land in January 1992. Flood waters collect in areas of slight depression and can be seen on Landsat satellite imagery in blues and dark purples. The land is normally dry, as seen in May 2006.
New Construction on Flood Prone Land

Observed Flood Extent (blue) detected flooding in the area prior to development.

OFE detected pluvial flooding outside the SFHA prior to development.
Flooding on Recent Construction

- Neighborhood built in 2012
- Flooded in April 2016 from torrential rains
- Flooded again in Hurricane Harvey, August 2017
St Louis – Flooding Outside the SFHA
Shreveport – Pluvial Flooding
Validation

- Random-stratified point sample in low water frequency zones
  - Avoid validating permanent water bodies
  - Better test for overcall

OFE validation results. The results showed that OFE has an average of 99% accuracy

<table>
<thead>
<tr>
<th>AOI</th>
<th>Accuracy</th>
</tr>
</thead>
<tbody>
<tr>
<td>Austin</td>
<td>93%</td>
</tr>
<tr>
<td>Charleston</td>
<td>99%</td>
</tr>
<tr>
<td>Houston</td>
<td>100%</td>
</tr>
<tr>
<td>Jacksonville</td>
<td>100%</td>
</tr>
<tr>
<td>Phoenix</td>
<td>97%</td>
</tr>
<tr>
<td>Shreveport</td>
<td>100%</td>
</tr>
<tr>
<td>St. Louis</td>
<td>100%</td>
</tr>
<tr>
<td>Tuscaloosa</td>
<td>99%</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>99%</strong></td>
</tr>
</tbody>
</table>
Economic Study Objective

• OUTPUT:
  • Identify structures that are considered to be **New Construction at Risk of Flooding** and estimate the potentially preventable economic risk associated with these areas.
    • To support the need for more documentation of the history of flooding outside the SFHA prior to construction.
    • Supporting dataset for the RiskMAP Discovery process.
Economic Analysis

• Workflow:

\[
\sum_{y=1987}^{2017} \left( \frac{X_c(y)}{X_t} \right) \sum_{y=j+1}^{2017} C(y) \]

\[
\text{Economic Value}
\]
## Economic Analysis

- Primary Input Datasets for the Economic Risk Analysis:

<table>
<thead>
<tr>
<th>Data</th>
<th>Source</th>
<th>Date/Time-span</th>
</tr>
</thead>
<tbody>
<tr>
<td>NCRF</td>
<td>Radiant Solutions</td>
<td>1987-2017</td>
</tr>
<tr>
<td>Block Groups</td>
<td>U.S. Census Bureau</td>
<td>2017</td>
</tr>
<tr>
<td>Parcel Points</td>
<td>Core Logic</td>
<td>2017</td>
</tr>
<tr>
<td>Statewide NFHL</td>
<td>FEMA Flood Map Service Center</td>
<td>2015/16/17 (varies by state)</td>
</tr>
<tr>
<td>Flood Insurance Claims</td>
<td>FEMA</td>
<td>1973 - 2017</td>
</tr>
</tbody>
</table>
500m from NCRF - Multi-block neighborhood analysis:

- Because the exact location of a flood insurance claim was provided at the Census block group level, it is therefore assumed that flooding generally occurs where it has occurred historically.

- To maintain a conservative estimate of loss potential for the economic analysis, the estimate takes the fraction of structures (parcel points) in a block group that are identified as “within 500m of NCRF” vs the total # of structures in that block group.

  ➢ This fraction is ten multiplied by the sum of all claims recorded after that earliest-identified NCRF/structure year (for each structure intersected).

- The calculations are performed on each block group.
- The economic value in an AOI is based on the total for the block groups in that AOI.
- The calculations do not account for inflation.
500m from NCRF - Multi-block neighborhood analysis:

\[ \sum_{y=1987}^{2017} \left( \frac{X_r(y)}{X_t} \right) \sum_{y'=y+1}^{2017} C(y') \]

\( X_r(y) \) is the number of NCRF structures in year \( y \)
\( X_t \) is the total number of structures in a block group
\( C \) is the total claims in year \( y \)
### Vulnerable Structures Identified

<table>
<thead>
<tr>
<th>AOI</th>
<th>Total # structures analyzed</th>
<th>NCRF Structures</th>
<th>% of the total structures that were identified as NCRF</th>
<th>NCRF Structures Outside SFHA</th>
<th>% of the NCRF structures that were outside the SFHA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Austin</td>
<td>725,994</td>
<td>129,097</td>
<td>17.80%</td>
<td>86,505</td>
<td>67.00%</td>
</tr>
<tr>
<td>Charleston</td>
<td>414,948</td>
<td>121,306</td>
<td>29.20%</td>
<td>67,646</td>
<td>55.80%</td>
</tr>
<tr>
<td>Houston</td>
<td>1,746,060</td>
<td>435,372</td>
<td>24.90%</td>
<td>360,674</td>
<td>82.80%</td>
</tr>
<tr>
<td>Jacksonville</td>
<td>481,300</td>
<td>158,284</td>
<td>32.90%</td>
<td>117,360</td>
<td>74.10%</td>
</tr>
<tr>
<td>Phoenix</td>
<td>417,265</td>
<td>14,635</td>
<td>3.50%</td>
<td>6,822</td>
<td>46.60%</td>
</tr>
<tr>
<td>Shreveport</td>
<td>183,247</td>
<td>35,219</td>
<td>19.20%</td>
<td>17,050</td>
<td>48.40%</td>
</tr>
<tr>
<td>St. Louis</td>
<td>778,099</td>
<td>169,374</td>
<td>21.80%</td>
<td>129,359</td>
<td>76.40%</td>
</tr>
<tr>
<td>Tuscaloosa</td>
<td>92,299</td>
<td>11,107</td>
<td>12.00%</td>
<td>7,674</td>
<td>69.10%</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>4,839,212</strong></td>
<td><strong>1,074,394</strong></td>
<td><strong>22%</strong></td>
<td><strong>793,090</strong></td>
<td><strong>74%</strong></td>
</tr>
</tbody>
</table>
### Economic Analysis - Results

#### Potentially Preventable Economic Risk Estimates

<table>
<thead>
<tr>
<th>AOI</th>
<th>ALL NCRF</th>
<th>Only NCRF Outside NFHL</th>
</tr>
</thead>
<tbody>
<tr>
<td>Austin</td>
<td>$29,656,000</td>
<td>$15,120,000</td>
</tr>
<tr>
<td>Charleston</td>
<td>$49,525,000</td>
<td>$24,766,000</td>
</tr>
<tr>
<td>Houston (pre-Harvey)</td>
<td>$387,819,000</td>
<td>$202,472,000</td>
</tr>
<tr>
<td>Jacksonville</td>
<td>$40,866,000</td>
<td>$21,757,000</td>
</tr>
<tr>
<td>Phoenix</td>
<td>$111,000</td>
<td>$66,000</td>
</tr>
<tr>
<td>Shreveport</td>
<td>$12,413,000</td>
<td>$5,675,000</td>
</tr>
<tr>
<td>St. Louis</td>
<td>$70,347,000</td>
<td>$29,492,000</td>
</tr>
<tr>
<td>Tuscaloosa</td>
<td>$725,000</td>
<td>$320,000</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>$591,462,000</td>
<td>$299,668,000</td>
</tr>
</tbody>
</table>
Economic Analysis - Results

• Vulnerable Structures Identified - Hurricane Harvey

The estimated total loss that the 500m neighborhood buffer of NCRF outside the SFHA could have prevented for Hurricane Harvey – for the 21,338 structures intersecting the Hurricane Harvey Flood Extent - amounts to more than $609 million.

• Emphasizes how conservative the base economic analysis method is
• Constricting claims to this known event allows for a more direct loss impact analysis with more precise claims location assumption
• Applying average dollars instead of fraction of the NFIP claims provides larger economic estimate $609,989,000.00 of preventable Hurricane Harvey flood damage.
Economic Analysis - Results

Vulnerable Structures Identified - Hurricane Harvey

29°39'38.83"N 95°44'20.63"W
Items to Improve

• Flood Post New Construction
  • Dropped → Very difficult to detect water in urban areas
    • 30 meter pixel of Landsat
    • Cloud cover
    • Still used reports and FEMA issued flood extents

• Incorporate Sentinel 2 and RADARSAT
  • Higher resolution
  • Can capture during flood event → Don’t have to worry about cloud cover
Summary:

• Documenting previously unknown flood prone areas prior to new construction will prevent $ billions in future NFIP claims.

• 10,000’s of new homes are being built each year outside the SFHA on undeveloped land with a previously unknown history of pluvial flooding.

• If previously undocumented flood events were known by FEMA/FIMA, communities, developers, banks, insurers, etc., subsequent pre-development hydrologic/mitigation efforts may have prevented most of these NFIP claims.

• The Observed Flood Extent (OFE) product identifies additional flood risk through direct observations of previously unknown flood events using 33 years of satellite imagery for the entire US.
Thank You

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