The Challenge of Urban Flooding

Steven E. Eubanks, P.E., CFM
City of Fort Worth
Urban Flooding Awareness Bill

- Introduced into Congress in 2014 & 2015
- Based on Illinois law passed in 2014
- Study urban flooding, with “primary focus ... on urban areas outside of special flood hazard areas”
- Never got out of committees
Urban Flooding Awareness Bill

• Adequacy of federal flood risk information

• Investigate causes:
  – global climate change;
  – increasing urbanization
  – undersized, deteriorating stormwater infrastructure

• Evaluate funding mechanisms

• Relevance of NFIP & CRS to urban flooding areas outside traditional floodplains
The Challenge of Urban Flooding

WHAT IS URBAN FLOODING?
What Is Urban Flooding?

• Long-term chronic or nuisance flooding
• Typically older parts of town
• Small streams or storm drain system
• Happens fast: often gone in an hour
• Often only brief public attention
• Exacerbated by redevelopment activity
The Challenge of Urban Flooding

• Generally not addressed by NFIP
• Considered local problem only
• No affordable solutions available
• Low grant priority
• Flood risk and BFE’s not mapped
• “Not floodplain”
Typical urban drainage patterns
Typical urban drainage patterns
Typical urban drainage patterns
Typical urban drainage patterns
Main Causes of Urban Flooding

• Pre-1970, small creeks often enclosed in storm drains, usually severely undersized

• Street grid often ignored drainage patterns, leading to mid-block sumps

• Homes and buildings constructed over these creeks and storm drains, with overflow path running through them
Typical Older Neighborhood
The Challenge of Urban Flooding

TRADITIONAL SOLUTIONS ARE NOT FEASIBLE
“I think that you should be more explicit in your explanation of this step.”
7800’ of pipe from worst flooding to the outfall, then across a rail yard
Cross-Section

Buried telephone line to be relocated

Sewer line to be relocated

Gas line to be relocated

Water line to be relocated

Excavation trench

Double 6’x6’ box culvert 32’ deep

People live here!

Street to be reconstructed
The only place for 3 6’x10’ box culverts in this street is...

where the houses are!
Tunneling preserves neighborhood. $30-50 million!
Larger pipesheds likely requires several ponds occupying 150+ homes
Deep Detention with Pumps

DETENTION STORAGE: 320 ACRE-FEET = 104 MILLION GALLONS
Buyouts and Neighborhood Integrity

- Empty lots destroy neighborhood integrity
- Are linear parks, greenways and pocket parks acceptable?
The Challenge of Urban Flooding

DOWNSTREAM CONSIDERATIONS
No Adverse Impact

• “No Adverse Impact floodplain management takes place when the actions of one property owner are not allowed to adversely affect the rights of other property owners.” (ASFPM, 2008)

• Consistent with Texas Water Code §11.086 and similar laws in other states.
Texas Water Code §11.086

a) No person may divert or impound the natural flow of surface waters in this state, or permit a diversion or impounding by him to continue, in a manner that damages the property of another by the overflow of the water diverted or impounded.

b) A person whose property is injured by an overflow of water caused by an unlawful diversion or impounding has remedies at law and in equity and may recover damages occasioned by the overflow.
In other words: LAWSUITS!
Downstream Impacts Factors

• Increased runoff due to more impervious cover
• Increased runoff due to faster travel time in storm drains
• Increased runoff due to loss of valley storage (a/k/a “living room detention”)

➢ Any solution has to consider these
Unit Hydrograph

Precipitation causes the discharge in the river to rise.

Discharge rises quickly due to rapid surface run-off and reaches its peak just 10 hours after peak rainfall.

Discharge falls at a slower rate due to base flow increasing. Base flow is the normal flow of water in the river derived from throughflow and groundwater flow.

Base flow slowly declines as throughflow declines.
Effects of Urbanization

- Total Volume greater due to less infiltration
- Time to peak shorter due to faster flow on paving and in pipes
- Peak flow rate may be doubled or tripled
**Volume Issues**

**Valley Storage:**
Undersized pipes cause floodwater to be stored in neighborhoods, decreasing the peak flows downstream.
System Timing: A Case Study

EASTLAND CREEK
Eastland Creek – Eastern Fort Worth

- 800 acres
- Mostly Residential
- Extensive Storm Drain System in top 3 basins
Storm Drain Flow Paths

- 18,000 Ft
- Average 4 ft/s Velocity
Overland Flow Paths

- 17,000 Ft
- Average 1.5 ft/s Velocity
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<th>Sub-basin</th>
<th>Area (acres)</th>
<th>Tc (min)</th>
<th>Peak Discharge (cfs)</th>
<th>% Difference</th>
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<td>Storm drain</td>
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<td>57</td>
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<td>54</td>
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<td>695</td>
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</table>
Hydrograph Comparison

SUB-BASIN 7a 100-YR HYDROGRAPH COMPARISON

- 50% Longer Time to Peak
- 38% Lower Q
Hyetographs

Sub-basin 7a

Rainfall (inches)

Time (hours)

6:00 6:30 7:00 7:30 8:00 8:30 9:00 9:30 10:00 10:30 11:00 11:30 12:00 12:30 13:00 13:30 14:00 14:30 15:00 15:30 16:00 16:30 17:00 17:30 18:00

100YR - 5YR

5-YR
Combined Hydrograph

- Double peak hydrograph
- 66” pipe capacity = 250 cfs
Hydrograph Comparison

• Similar Time of Peak as Overland
• Q within 1% of overland
• Outfall is an 84” RCP & 36” RCP
Timing Issues: Summary

Conveyance improvements would increase peak at outfall by over 60%!
Increased Flooding Downstream
Downstream Impacts?

• Should FEMA floodplain be mapped based on existing storm drain constraints or potential capacity improvements?

• Should capacity improvements be considered an adverse impact?

• How do you prevent future downstream flooding as a policy?
Downstream Impacts Summary

- Flooding upstream caused by undersized pipes reduces flooding downstream.
- Increased conveyance (larger pipes) is likely to move flooding downstream.
- “Managing flooding in place”
  - Detention and related solutions.
  - Downstream impacts are beneficial.
A DIFFERENT PARADIGM

Issues in Urban (Zone X) Flooding
How do you compete?

- Challenge the conventional wisdom
- The numbers do not lie

New York Yankees
$114,457,768
vs
Oakland Athletics
$39,722,689
Challenging the conventional wisdom

- Baseball teams have traditionally relied upon scouts who assess players based upon observations, biases, and prejudices
- Process never challenged or validated
- A “good ol’ boy” system
- A lot of bad investments
The numbers do not lie

• Sabremetrics – the search for objective knowledge about baseball
• Coined by Bill James, after Society for American Baseball Research
• Statistical measures to:
  – Question traditional measures of baseball evaluation
  – See true value in players (bargains)
  – Example: OBP >> AVG
Moneyball Example – 2002 A’s

• After 2001, lost 3 best players to free agency
• Couldn’t afford to replace with “all star” players
• Signed 3 players whose combined OBP equalled Damon and Giambi
• Won Division in 2002
• 20-game winning streak
What does this have to do with flood mitigation?

- You are the Oakland A’s, not the Yankees!
  - Never enough funding
  - Your fans have high expectations
  - Must compete with higher profile funding expenditures (traffic, police, schools)

- Can we take a “sabremetric” approach to flood mitigation?
- Should we? YES!
Understanding Risk

• Usually public safety not a major threat
• Zone X: nothing hinders rebuilding
• Chronic flooding vs. periodic flooding
• Manage flooding like other risks in life
• Flood risk management:
  – Avoidance: move out
  – Coping: minor prevention and repair
  – Insurance: limit economic losses
The Challenge

• More than just a technical challenge!
• In most situations we must find a bit of compromise in all three elements.
Buy out the Traditional Buy-outs in the neighborhood.

Acceptability

Affordability

Effectiveness
Let’s think about a rain gage

1- hour Storm Duration

System Capacity

- 1” (properties damaged)
- 100-yr (92)
- 50-yr (85)
- 25-yr (70)
- 10-yr (55)
- 5-yr (42)
- 2-yr (29)
- 1-yr (18)
What if it rains more than 1”?

Single-Event Damages

- $5.1M
- $4.7M
- $4.1M
- $3.5M
- $3.0M
- $2.5M
- $1.9M

System Capacity

- 100-yr (92)
- 50-yr (85)
- 25-yr (70)
- 10-yr (55)
- 5-yr (42)
- 2-yr (29)
- 1-yr (18)

1 hour
Damage X Annual Probability

- 100-yr (92)
- 50-yr (85)
- 25-yr (70)
- 10-yr (55)
- 5-yr (42)
- 2-yr (29)
- 1-yr (18)

System Capacity

1 hour
Expected Annual Damage

- Area under the curve equals the expected annual damages ($2.6M)
- Present value of expected annual damages can be computed (Using 50-year cash flow, i=7%)

Net Present Value = $36.5 million
Expected Annual Damage

Net Present Value = $36.5 million

What if we increase capacity to 2 in/hr???
Net Present Value of Damages

Area Under the Curve equals the expected annual damages if capacity improved from 1”/hour to 2”/hour

Existing Damages = $36.5 million
Residual Damages = $7.5 million
Benefit = $29 million
The Challenge of Urban Flooding

MANAGING FLOODING IN PLACE
NOT THIS!

• Historically, detention viewed as fenced-off drainage facility
• Ends up as eyesores and wasted land
Multi-Use Detention

Detention areas can be used for aesthetics and water quality
Multi-Use Detention

Detention areas can be used for recreation and open space
Detention Basin—Neighborhood Park
Integrated with Urban Redevelopment
Daylighting Streams
Storm Drain with Overflow Swale
Linear Parks and Greenways
URBAN FLOODING

• Solutions must be EFFECTIVE, AFFORDABLE & ACCEPTABLE

• NO ADVERSE IMPACT principles require evaluating downstream effects

• INCREMENTAL improvements may be the only cost-effective option

• MANAGING FLOODING IN PLACE is likely to be the most feasible solution
URBAN FLOODING

• It is receiving more attention.
• Handled differently than riverine flooding.
• Hydrodynamic modeling and citizen videos provide a better understanding.

• Major issues:
  – How to map it
  – How to enforce it
  – Who should regulate it
The Challenge of Urban Flooding

QUESTIONS?
City of Fort Worth
TPW Stormwater
Major Capital Projects

Steven E. Eubanks, P.E., CFM
Major Projects

1. Central Arlington Heights
Central Arlington Heights
Proposed Under-Street Detention

- Ashland Under-Street Detention
- Western Under-Street Detention
- Bryce-Hulen Surface Detention
Modeled Flood Reduction
## BCA for Planned Detention Projects

<table>
<thead>
<tr>
<th>Project Description</th>
<th>Damages</th>
<th>Cumulative Benefits</th>
<th>Cumulative Cost</th>
<th>Cumulative BCR</th>
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<tr>
<td>Existing Conditions</td>
<td>$36,503,254</td>
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<td>Ashland Detention</td>
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<td>Ashland Detention + Western Detention</td>
<td>$32,332,898</td>
<td>$4,170,356</td>
<td>$3,177,284</td>
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| Ashland Detention + Western Detention + Hulen/Bryce Detention | $30,759,546  | $5,743,708          | $4,084,284      | 1.41           
Major Projects

1. Central Arlington Heights
2. Eastern Hills
City of Fort Worth
2004 CIP
Watershed Planning Study

Eastern Hills Drainage System

Proposed Multi-Purpose Storm Water Detention Pond

Benefits include:
- Reduced flooding downstream
- Improved storm water quality
- Multi-sport athletic field
CFW-FWISD Master Agreement

- FWISD grants easement at no cost
- City installs basin and some amenities: lighting, planting, irrigation, access, etc.
- City installs water quality features to keep trash from washing into basin
- Routine maintenance by FWISD
- WQ maintenance & major repairs by City
Major Projects

1. Central Arlington Heights
2. Eastern Hills
3. Luella Merrett
Luella Merrett Detention Basin

- Flooding due to small pipe at mid-block sump
- Lots of impervious area in watershed
- Pipe capacity improvements $2 million +
Luella Merrett Detention Basin

- Sloping play field at school suitable for detention
- Principal liked idea because of success of Eastern Hills
Major Projects

1. Central Arlington Heights
2. Eastern Hills
3. Luella Merrett
4. Lebow Channel
Lebow
Low-Water Crossings
PROPERTY ACQUISITION, LINEAR PARK & FLOODPLAIN RESTORATION/PRESERVATION (TYPICAL)

REMOVE HAZARDOUS LOW WATER CROSSING (TYP)

CHANNEL REGRADING/STREAM RESTORATION & ENVIRONMENTAL ENHANCEMENT (TYPICAL)

ENLARGE ROADWAY CROSSING (TYP)

TRAIL DRIVERS PARK

NE 28TH ST

BRENNAN

CONFLUENCE TO DIAMOND AVE ENLARGED EARTHEEN CHANNEL SECTION (TYPICAL)
NE Twenty-Eighth Street Crossing
NE 28th St. Crossing
Major Projects

1. Central Arlington Heights
2. Eastern Hills
3. Luella Merrett
4. Lebow Channel
5. Westcliff
Westcliff Manor Apts., 6/28/04
(31 units flooded)
Surface Flooding

Transfer of Flow

Storm Sewer System Capacity
Hydrograph of Spillover Flow

5 Year 24 Hour

Volume = 1.2 Acre-ft

100 Year 24 Hour

Volume = 7.5 Acre-ft
## Flooded Structures

### Summary of Flooded Structures and Estimated Depth of Flood for the 100 Year and 5 Year 3 Hour Design Events

<table>
<thead>
<tr>
<th>Address</th>
<th>District</th>
<th>Approx. Ground Elevation (NW SD Model)</th>
<th>Approx. FFE</th>
<th>Approx. FFE Above Ground Elev. (ft)</th>
<th>Simulated Max Water Elev. (NW SD Model)</th>
<th>Water Depth Above FFE (ft)</th>
<th>Simulated Max Water Elev. (NW SD Model)</th>
<th>Water Depth Above FFE (ft)</th>
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<tbody>
<tr>
<td>320 W SEMINARY DR</td>
<td>WC South</td>
<td>713.4</td>
<td>0.5</td>
<td>713.9</td>
<td>714.0</td>
<td>0.1</td>
<td>712.3</td>
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<td>712.0</td>
<td>0.5</td>
<td>712.5</td>
<td>713.0</td>
<td>0.5</td>
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</table>

**Impacted Structures:** 15

**Impacted Structures:** 45

**Impacted Structures:** 10
North Storage Structure Conceptual Layout

Underground Storage 550'x200'

North

Relief Sewer

Orifice
North Storage Structure – Potential Construction Method 1

Storm Trap: Contech Engineered Solutions
South 1 Storage Pond Conceptual Layout
South: Capacity Improvements
Fort Worth Stormwater Capital Projects

QUESTIONS?