Analyzing and Mapping Upstream Embankment Risk Using Modified Natural Valley Analysis and 2-D Overland Flow Modeling

Part 1
Agenda

1. Overview
2. Study Methodology
3. Modification for Unsteady Flow
4. Results
Location

Joliet, Will County, Illinois

Chicago
Background

- Updated Countywide Study in Progress
- Contracted FEMA to review an area called out by USACE as “weak link” in flood protection system
- There are non-levee embankments along the Des Plaines River and I&M Canal
- Asked to identify risk to Joliet due to potential for embankment failure and define the regulatory floodplain
I&M Canal/ Des Plaines R. Embankments

- Historic Canal – Built in 1848
What is a Non-Levee Embankment?

Levee

“A manmade structure, usually an earthen embankment, designed and constructed in accordance with sound engineering practice to contain, control, or divert the flow of water so as to reduce risk from temporary flooding”
(Source – PM 43, FEMA)

Non-Levee Embankment

Typically highways or railroads built on fill in low lying areas that impose lateral constraints on flood flows.
(Source – Floodplain Mapping of Non-Levee & Non-Dam Embankments, ASPFM)
Are the I&M Canal Embankments Levees?

A structure is a levee and subject to FEMA’s LAMP procedure if it meets the following conditions:

- It was designed as a levee
- An owner has been identified for it
- It is operated and maintained as a levee
- It is hydraulically significant
Are the I&M Canal Embankments Levees?

A structure is a levee and subject to FEMA’s LAMP procedure if it meets the following conditions:

- It was designed as a levee - NO
- An owner has been identified for it
- It is operated and maintained as a levee
- It is hydraulically significant
Are the I&M Canal Embankments Levees?

A structure is a levee and subject to FEMA’s LAMP procedure if it meets the following conditions:

- It was designed as a levee - NO
- An owner has been identified for it - NO
- It is operated and maintained as a levee
- It is hydraulically significant
Are the I&M Canal Embankments Levees?

A structure is a levee and subject to FEMA’s LAMP procedure if it meets the following conditions:

- It was designed as a levee - NO
- An owner has been identified for it - NO
- It is operated and maintained as a levee - NO
- It is hydraulically significant
Are the I&M Canal Embankments Levees?

A structure is a levee and subject to FEMA’s LAMP procedure if it meets the following conditions:

- It was designed as a levee - NO
- An owner has been identified for it - NO
- It is operated and maintained as a levee - NO
- It is hydraulically significant - YES

->Follow Guidance for Non-Levee Embankments
How do we analyze risk to a community from a non-levee embankment upstream?
1 Overview

2 Study Methodology

3 Modification for Unsteady Flow

4 Results
Natural Valley

- Criteria: Levee Doesn't Meet 65.10 and Doesn’t Impact the Flood Elevation
- Mapping Approach: Natural Valley Floodplain Analysis Only to Map Special Flood Hazard Area
Natural Valley

- Only provides flood elevations adjacent to the embankment
- Does not compute discharge into downstream areas
Approach

- Disregard hydraulic impacts of embankment
- Assume landward side of embankments acts as a "bathtub"
- Compute WSEL and flows at each outlet (neglect small conduits)
- Account for constrictions that would reduce flow
Hydraulics Features/ Flow Paths

LEGEND

- Normal Flow Direction
- Potential Flow Reversal
- Hydraulic Feature
- Embankment Crest
### Hydraulic Features

<table>
<thead>
<tr>
<th>Feature Number</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Power Plant Culvert</td>
</tr>
<tr>
<td>2</td>
<td>Railroad Culvert</td>
</tr>
<tr>
<td>3</td>
<td>Lateral Box Culvert</td>
</tr>
<tr>
<td>4</td>
<td>Main Culvert (conveys flow from ditch to storm sewer)</td>
</tr>
<tr>
<td>5</td>
<td>Storm Sewer Inlet</td>
</tr>
<tr>
<td>6</td>
<td>Overland Flow into City at Columbia Street</td>
</tr>
</tbody>
</table>
I&M Canal Outlet to Des Plaines River

The I&M Canal Channel Is Not a Major Constriction (neglected)
1 The Power Plant Culvert is a major constriction (Flow from upstream embankments were neglected)
2 Railroad Double Box Culvert
(Rating Curves were developed to analyze flow through this culvert)
Hydraulic Features

3 Lateral Box Culvert (6’X7’)
(Rating Curves were Developed to analyze flow through this culvert)
Hydraulic Features

4 Main Culvert
(Rating Curves were Developed to analyze flow through this culvert)
Hydraulic Features

5 Storm Sewer Inlet
(Neglected due to small opening)
Main Culvert Plan/Profile

Plan

Profile

NON-LEVEE EMBANKMENT

Impact of weir was neglected

Existing Storm Sewer

Main Culvert

Main Culvert Pipe

STARR II

Stantec
Storm Sewer in Concrete Lock Wall

Slope for Existing Storm Sewer Culvert Obtain From This Profile

Note: Stationing from Right to Left
PROFILE OF SEWER
### Railroad Rating Curve

**Inputs for Low Elevation Box**
- **Span** = 12 ft (Approximate, measured from drawings)
- **DS Invert** = 532.76 ft (Taken from drawing)
- **Rise** = 22 ft (Estimated based on invert and survey elevations at top of culvert)
- **Length** = 70 ft (Estimated based on GIS data)
- **Slope** = 0.042 ft/ft (Assumed and adjusted to compute a logical upstream invert)
- **US Invert** = 535.7 ft (Calculated)

**Inputs for High Elevation Box**
- **Span** = 14 ft (Approximate, measured from drawings)
- **DS Invert** = 543 ft (Estimated from drawings)
- **Rise** = 12 ft (Estimated based on invert and survey elevations at top of culvert)
- **Length** = 70 ft (Estimated based on GIS data)
- **Slope** = 0.042 ft/ft (Assumed the same as the low elevation box)
- **US Invert** = 545.94 ft (Calculated)

<table>
<thead>
<tr>
<th>Discharge (cfs)</th>
<th>Headwater Elevation (ft) for Tailwater = 0 ft</th>
<th>Headwater Elevation (ft) for Tailwater = 1 ft</th>
<th>Headwater Elevation (ft) for Tailwater = 2 ft</th>
</tr>
</thead>
<tbody>
<tr>
<td>50</td>
<td>536.94</td>
<td>536.99</td>
<td>537.77</td>
</tr>
<tr>
<td>100</td>
<td>537.66</td>
<td>537.66</td>
<td>537.99</td>
</tr>
<tr>
<td>150</td>
<td>538.27</td>
<td>538.27</td>
<td>538.34</td>
</tr>
<tr>
<td>200</td>
<td>538.81</td>
<td>538.81</td>
<td>538.81</td>
</tr>
<tr>
<td>210</td>
<td>538.92</td>
<td>538.92</td>
<td>538.92</td>
</tr>
<tr>
<td>220</td>
<td>539.02</td>
<td>539.02</td>
<td>539.02</td>
</tr>
<tr>
<td>230</td>
<td>539.12</td>
<td>539.12</td>
<td>539.12</td>
</tr>
<tr>
<td>240</td>
<td>539.22</td>
<td>539.22</td>
<td>539.22</td>
</tr>
<tr>
<td>250</td>
<td>539.31</td>
<td>539.31</td>
<td>539.31</td>
</tr>
<tr>
<td>260</td>
<td>539.41</td>
<td>539.41</td>
<td>539.41</td>
</tr>
<tr>
<td>270</td>
<td>539.51</td>
<td>539.51</td>
<td>539.51</td>
</tr>
<tr>
<td>280</td>
<td>539.60</td>
<td>539.60</td>
<td>539.60</td>
</tr>
<tr>
<td>285</td>
<td>539.65</td>
<td>539.65</td>
<td>539.65</td>
</tr>
<tr>
<td>290</td>
<td>539.69</td>
<td>539.69</td>
<td>539.69</td>
</tr>
<tr>
<td>295</td>
<td>539.74</td>
<td>539.74</td>
<td>539.74</td>
</tr>
<tr>
<td>300</td>
<td>539.78</td>
<td>539.78</td>
<td>539.78</td>
</tr>
<tr>
<td>305</td>
<td>539.83</td>
<td>539.83</td>
<td>539.83</td>
</tr>
<tr>
<td>310</td>
<td>539.87</td>
<td>539.87</td>
<td>539.87</td>
</tr>
<tr>
<td>315</td>
<td>539.92</td>
<td>539.92</td>
<td>539.92</td>
</tr>
<tr>
<td>320</td>
<td>539.96</td>
<td>539.96</td>
<td>539.96</td>
</tr>
<tr>
<td>330</td>
<td>540.05</td>
<td>540.05</td>
<td>540.05</td>
</tr>
<tr>
<td>340</td>
<td>540.14</td>
<td>540.14</td>
<td>540.14</td>
</tr>
<tr>
<td>350</td>
<td>540.23</td>
<td>540.23</td>
<td>540.23</td>
</tr>
<tr>
<td>400</td>
<td>540.65</td>
<td>540.65</td>
<td>540.65</td>
</tr>
<tr>
<td>500</td>
<td>541.44</td>
<td>541.44</td>
<td>541.44</td>
</tr>
<tr>
<td>600</td>
<td>542.19</td>
<td>542.19</td>
<td>542.19</td>
</tr>
<tr>
<td>700</td>
<td>542.91</td>
<td>542.91</td>
<td>542.91</td>
</tr>
<tr>
<td>800</td>
<td>543.60</td>
<td>543.60</td>
<td>543.60</td>
</tr>
<tr>
<td>900</td>
<td>544.27</td>
<td>544.27</td>
<td>544.27</td>
</tr>
<tr>
<td>1000</td>
<td>544.94</td>
<td>544.94</td>
<td>544.94</td>
</tr>
</tbody>
</table>
Procedure

1. Identify hydraulic structures

2. Compute rating curves for a range of tailwater elevations

3. Iterative process – Compute Q at each structure based on tailwater from previous iteration
Step 1
• Compute River Elevation in HEC-RAS

Step 2
• Compute Flow into Each Outlet based on tailwater

Step 3
• Recompute River Flow

Iterative Process
<table>
<thead>
<tr>
<th>Iteration</th>
<th>River (NAVD 88)</th>
<th>Main Culvert TW/Flow</th>
<th>Lateral Culvert TW/Flow</th>
<th>Railroad Culvert TW/Flow</th>
<th>Sum Outflow</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>543.42</td>
<td>0/287</td>
<td>0/326</td>
<td>0/773</td>
<td>1,386</td>
</tr>
<tr>
<td>2</td>
<td>543.16</td>
<td>5.3/275</td>
<td>4.0/310</td>
<td>4.3/735</td>
<td>1,321</td>
</tr>
<tr>
<td>3</td>
<td>543.17</td>
<td>5.1/278</td>
<td>3.9/311</td>
<td>4.2/737</td>
<td>1,328</td>
</tr>
</tbody>
</table>
## RESULTS

<table>
<thead>
<tr>
<th>Feature Number</th>
<th>Flow Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Power Plant Culvert (NEGLECTED)</td>
</tr>
<tr>
<td>2</td>
<td>Railroad Culvert (740 cfs)</td>
</tr>
<tr>
<td>3</td>
<td>Lateral Box Culvert (310 cfs)</td>
</tr>
<tr>
<td>4</td>
<td>Main Culvert (280 cfs)</td>
</tr>
<tr>
<td>5</td>
<td>Storm Sewer Inlet (NEGLECTED)</td>
</tr>
<tr>
<td>6</td>
<td>Overland Flow into City at Columbia Street (1,050 cfs)</td>
</tr>
</tbody>
</table>
Is there enough volume to fill the low lying areas in the City?

Steady-State flow may overestimate inundation area
Options for Incorporating Flow in 2D Model

1. Use Steady-State Flows

2. Use Gage Data (Gage #05537980)

3. Use 2004 UNET Model by USACE
Options for Incorporating Flow in 2D Model

1. Use Steady-State Flows

   Eliminated due to concern of storage affects not being accounted for
Options for Incorporating Flow in 2D Model

1. Use Steady State Flows

2. Use Gage Data
   (Gage #05537980)

   • Considered September 14, 2008 and April 18, 2013 event.

   • Concluded that regulation and operation of Brandon Road L&D does not allow for a reliable stage-discharge relationship at the gage.
Options for Incorporating Flow in 2D Model

1. Use Steady-State Flows

2. Use Gage Data
   (Gage #05537980)
   - Considered September 14, 2008 and April 18, 2013 event.
   - September 14, 2008 Event
   - Concluded that regulation and operation of Brandon Road L&D does not allow for a reliable stage-discharge relationship at the gage.
Options for Incorporating Flow in 2D Model

1. Use Steady State Flows
2. Use Gage Data (Gage #05537980)
3. Use 2004 UNET Model by USACE
Step 1 - Hydrograph Applied at 288.78
Step 2 - Extract Inflection Points

100 YR Computed Stage @ XS 288.78 in 2004 UNET Model

Time (hours)

Stage (feet, NAVD 88)

Time (Days)
Last Step – Apply Iterative Process

Step 1
- Compute River Elevation in HEC-RAS

Step 2
- Compute Flow into Each Outlet based on tailwater

Step 3
- Recompute River Flow

Iterative Process
Results

\[ Q_{\text{peak}} = 928 \text{ cfs} \]
Questions?