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

Part 1

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Stantec/STARR
March 8, 2017

Agenda

1 **Overview**

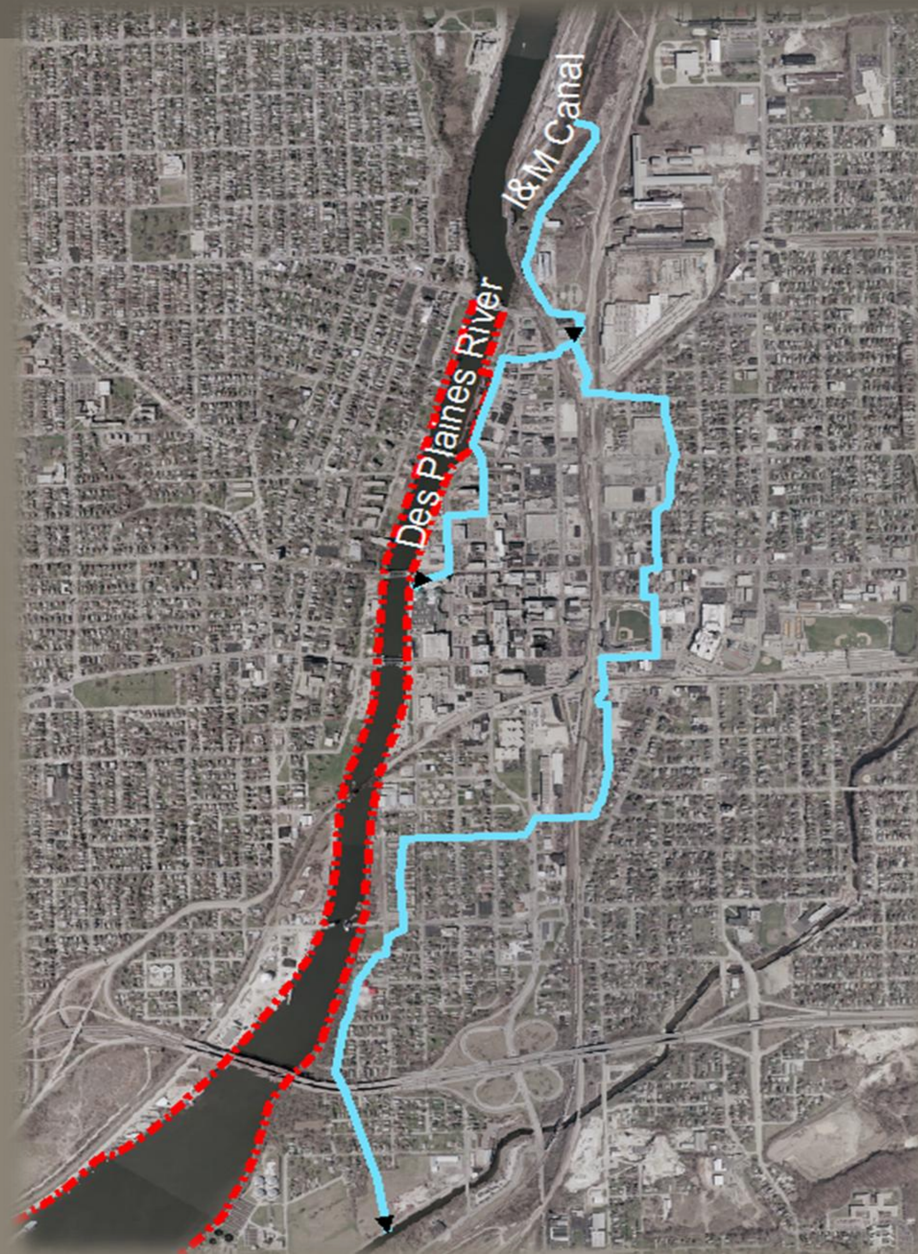
2 **Study Methodology**

3 **Modification for Unsteady Flow**

4 **Results**

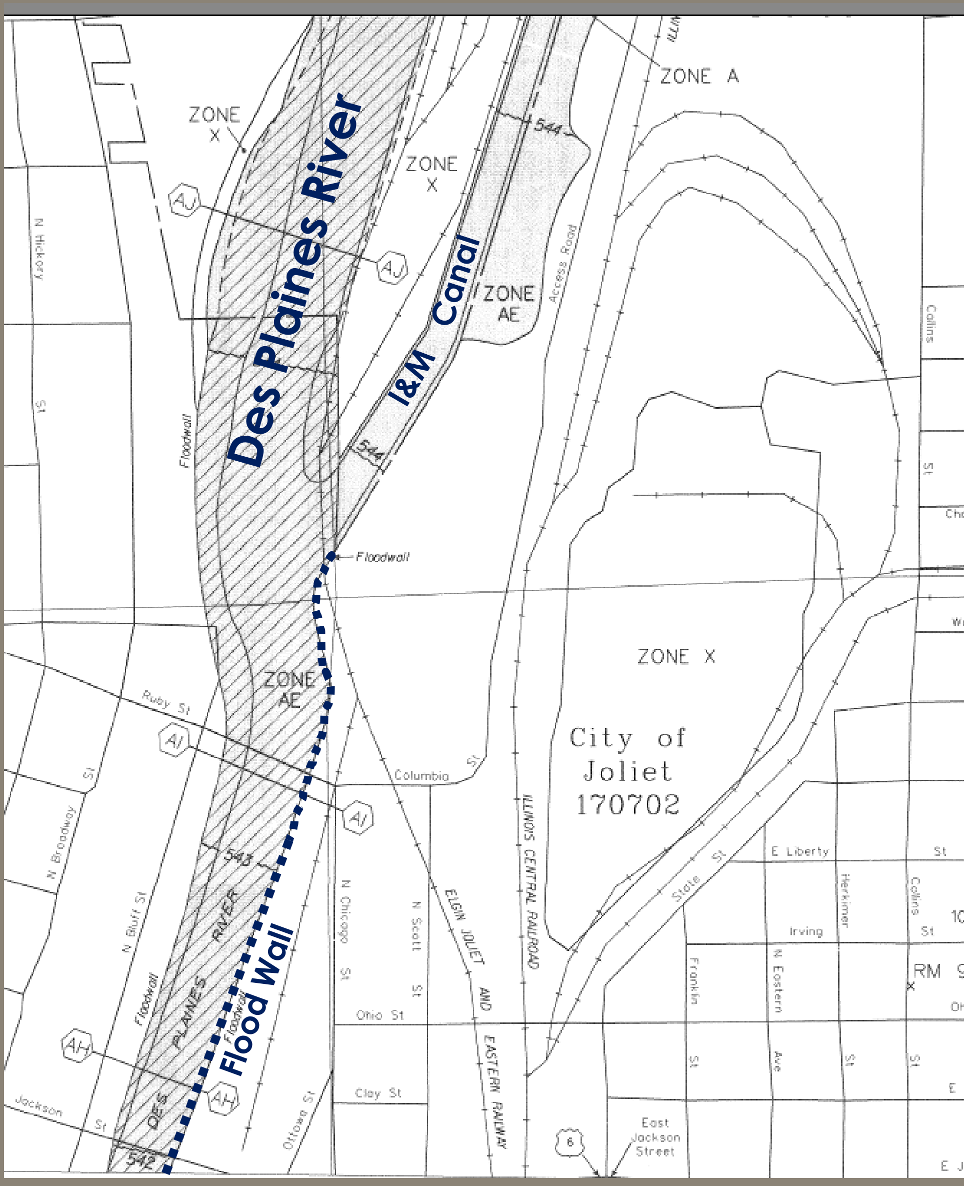
Location


Joliet, Will County, Illinois
Chicago


I&M Canal
Des Plaines River

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

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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)

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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

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->Follow Guidance for Non-Levee Embankments

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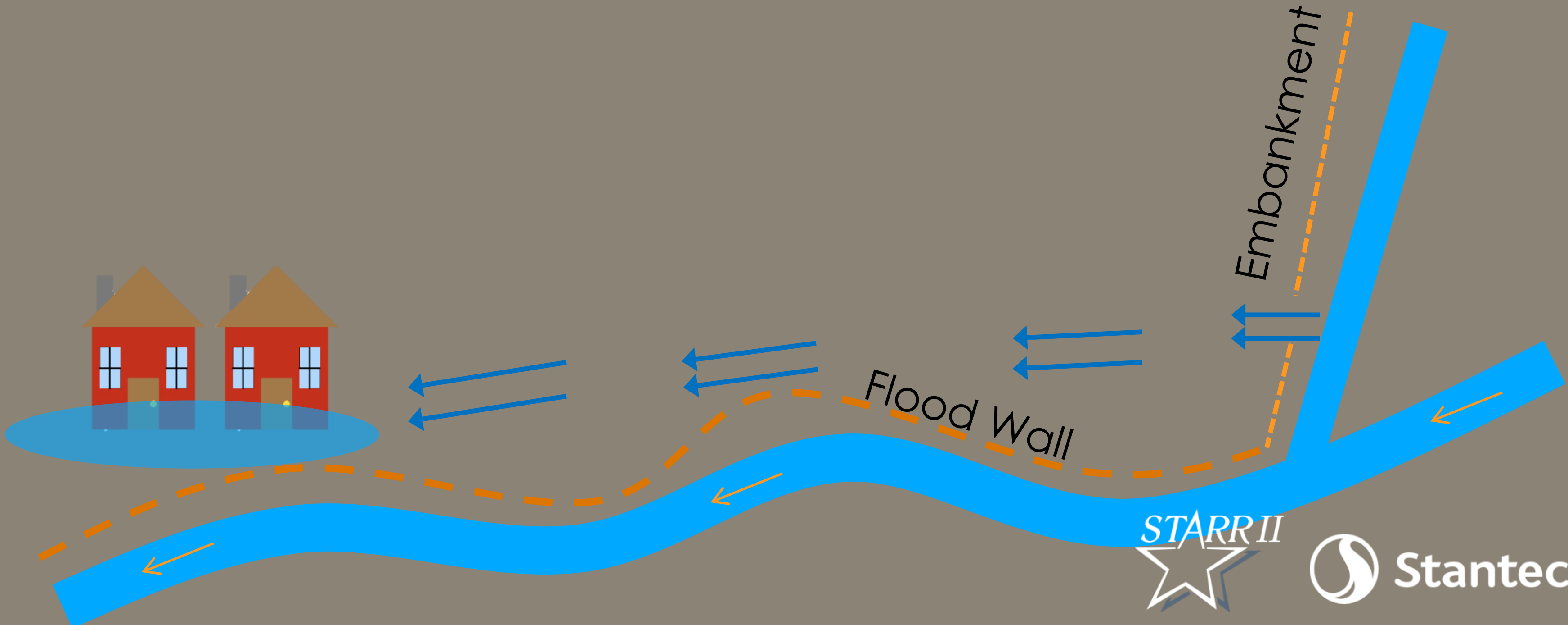
How do we analyze risk to a community from a non-levee embankment upstream?.



1 Overview

2 Study Methodology

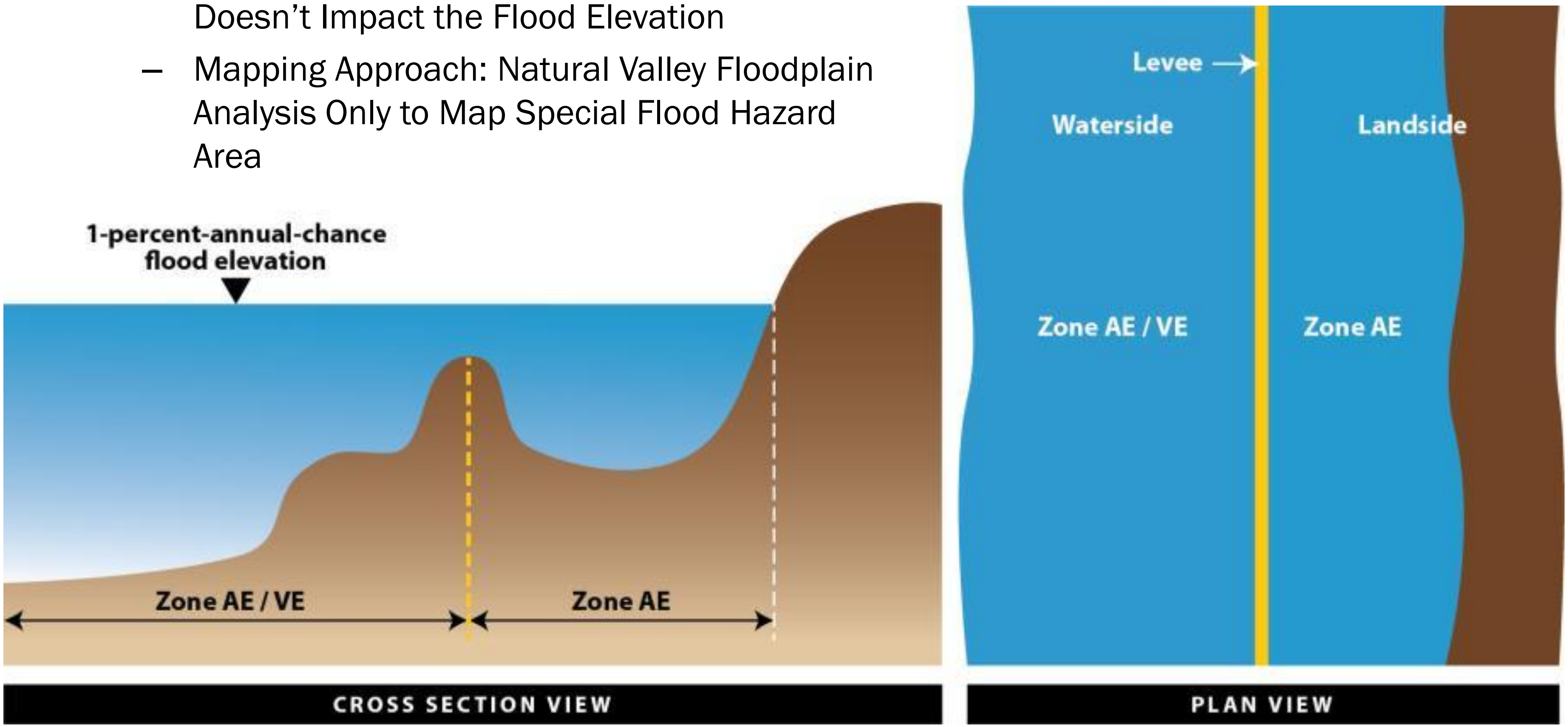
3 Modification for Unsteady Flow

4 Results

Natural Valley

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



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Natural Valley

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

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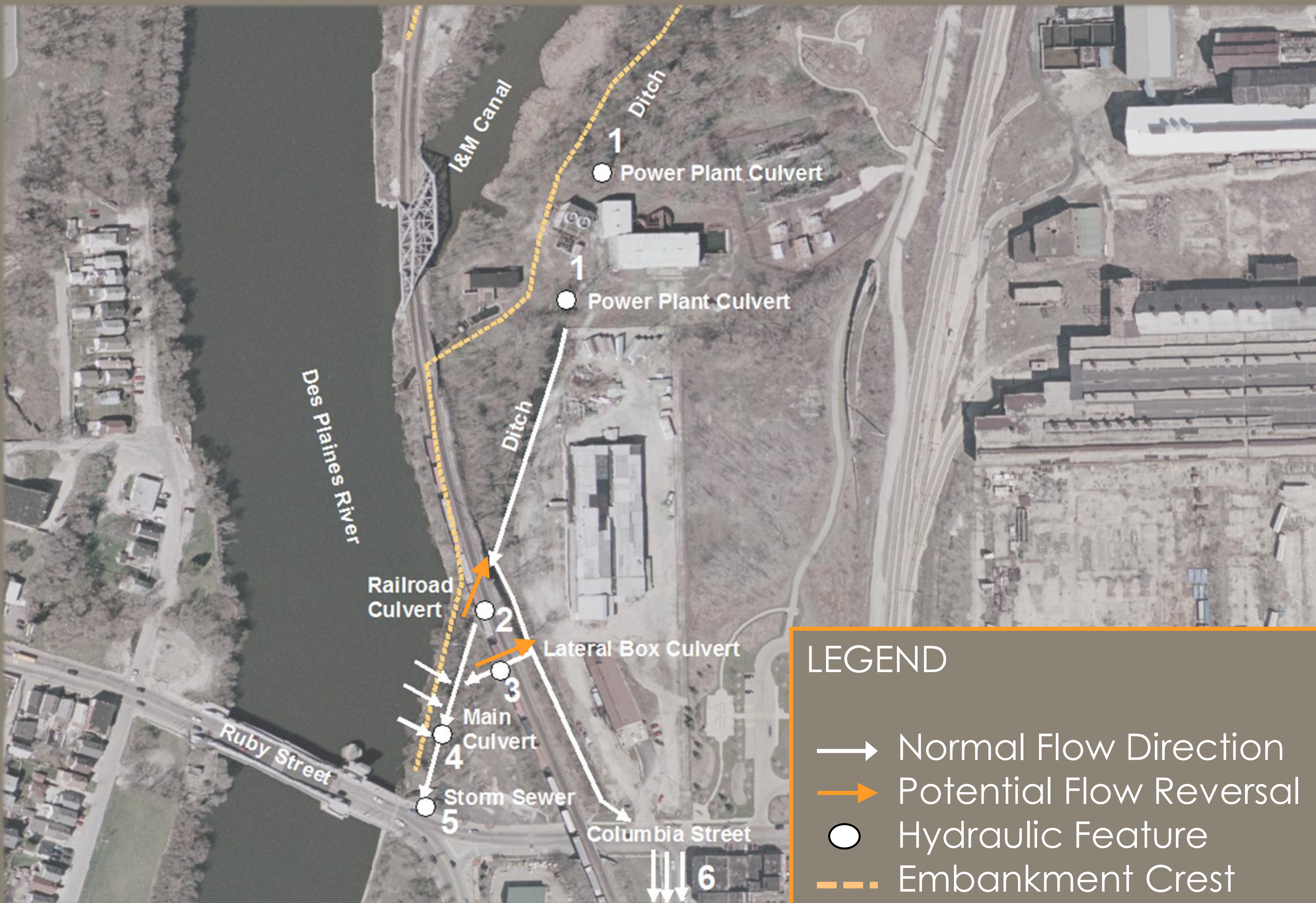
Approach

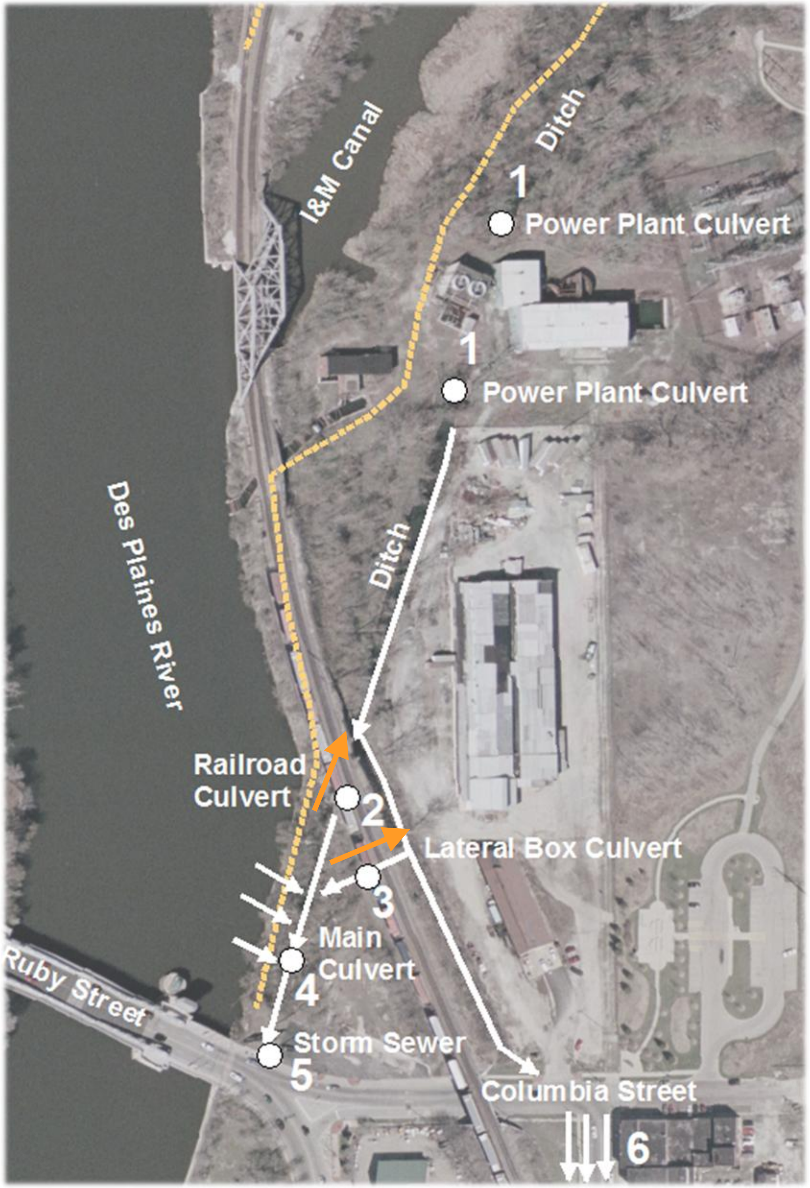
- Disregard hydraulic impacts of embankment
- Assume landward side of embankments acts as a "bathtub"
- Compute WSEL and flows at each outlet (neglect small conduits)
- Account for constrictions that would reduce flow

Hydraulics Features/ Flow Paths

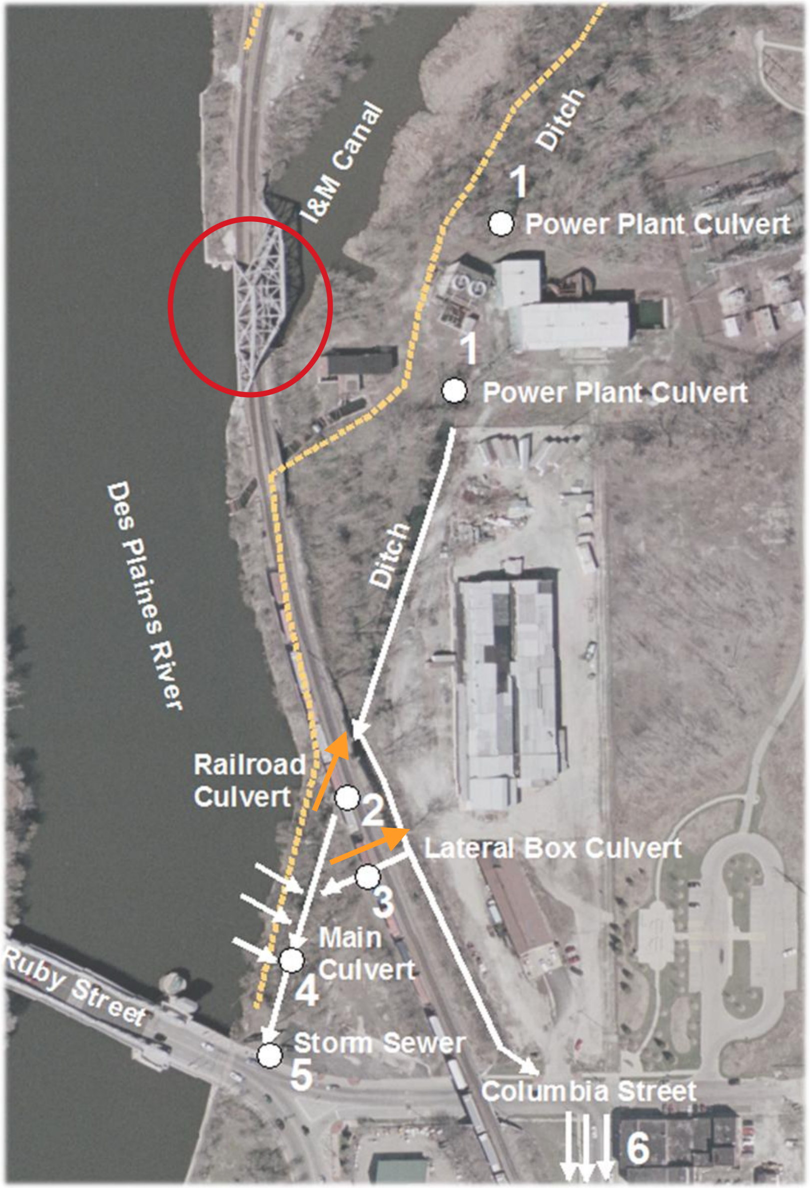


Hydraulic Features

Feature Number	Description
1	Power Plant Culvert
2	Railroad Culvert
3	Lateral Box Culvert
4	Main Culvert (conveys flow from ditch to storm sewer)
5	Storm Sewer Inlet
6	Overland Flow into City at Columbia Street

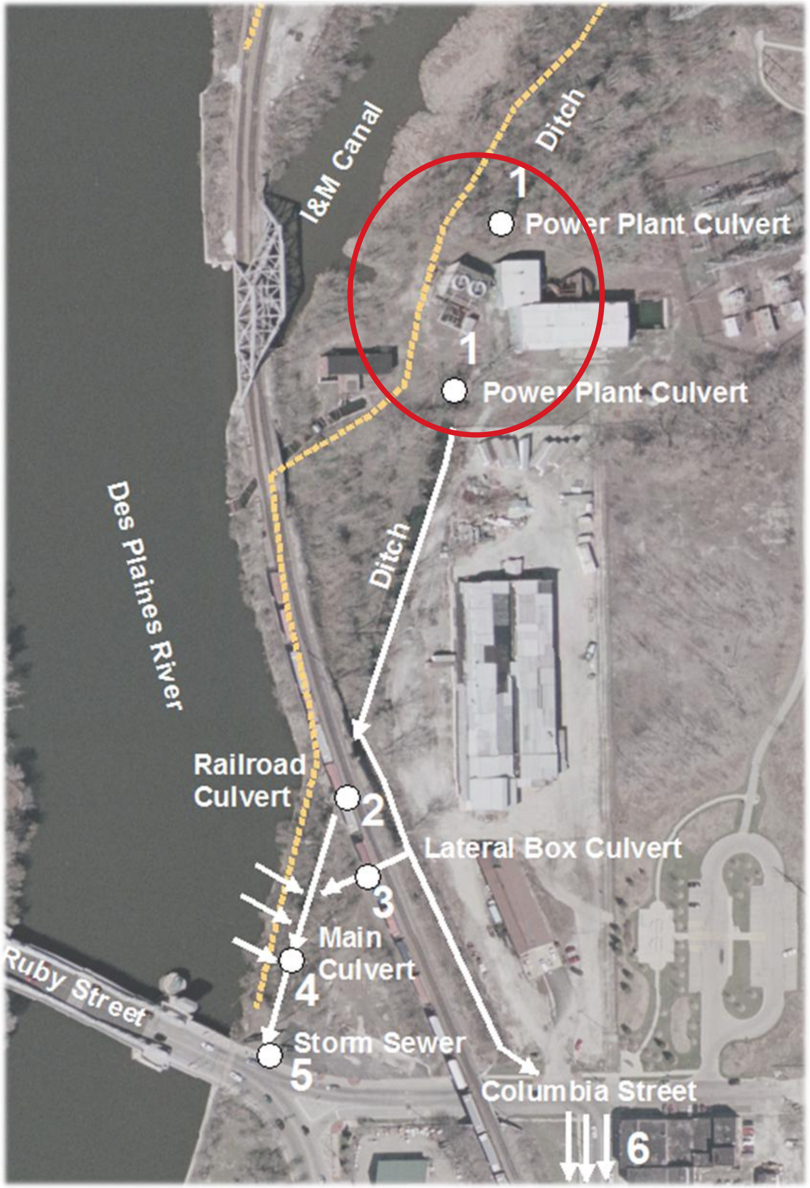


I&M Canal Outlet to Des Plaines River



The I&M Canal Channel Is Not a Major Constriction (neglected)

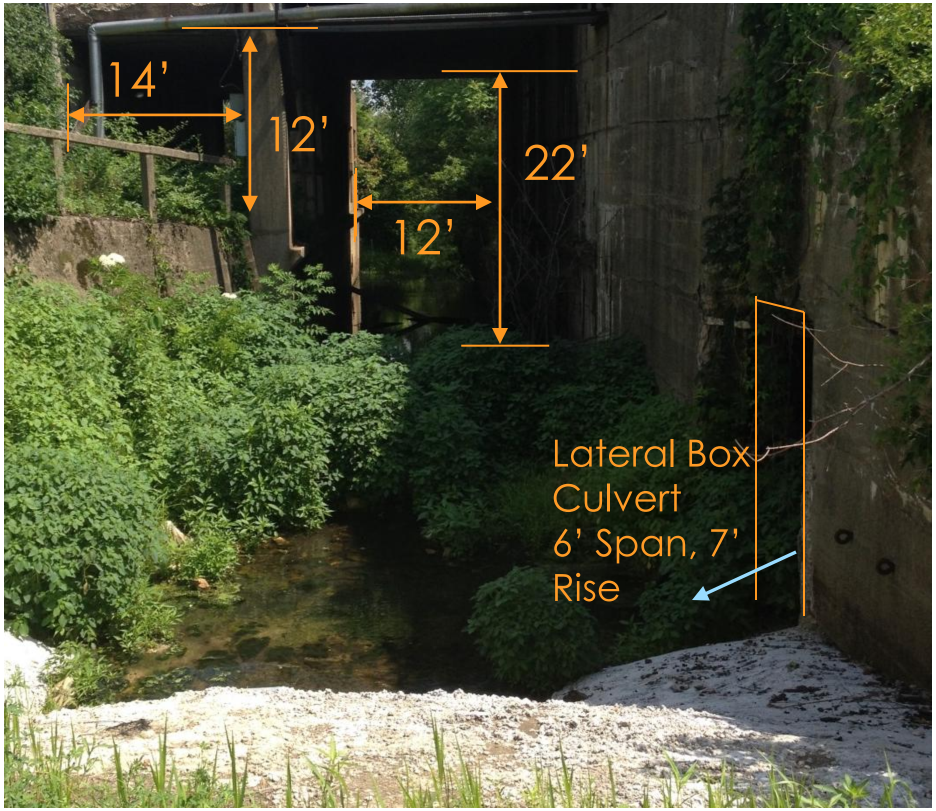
Hydraulic Features

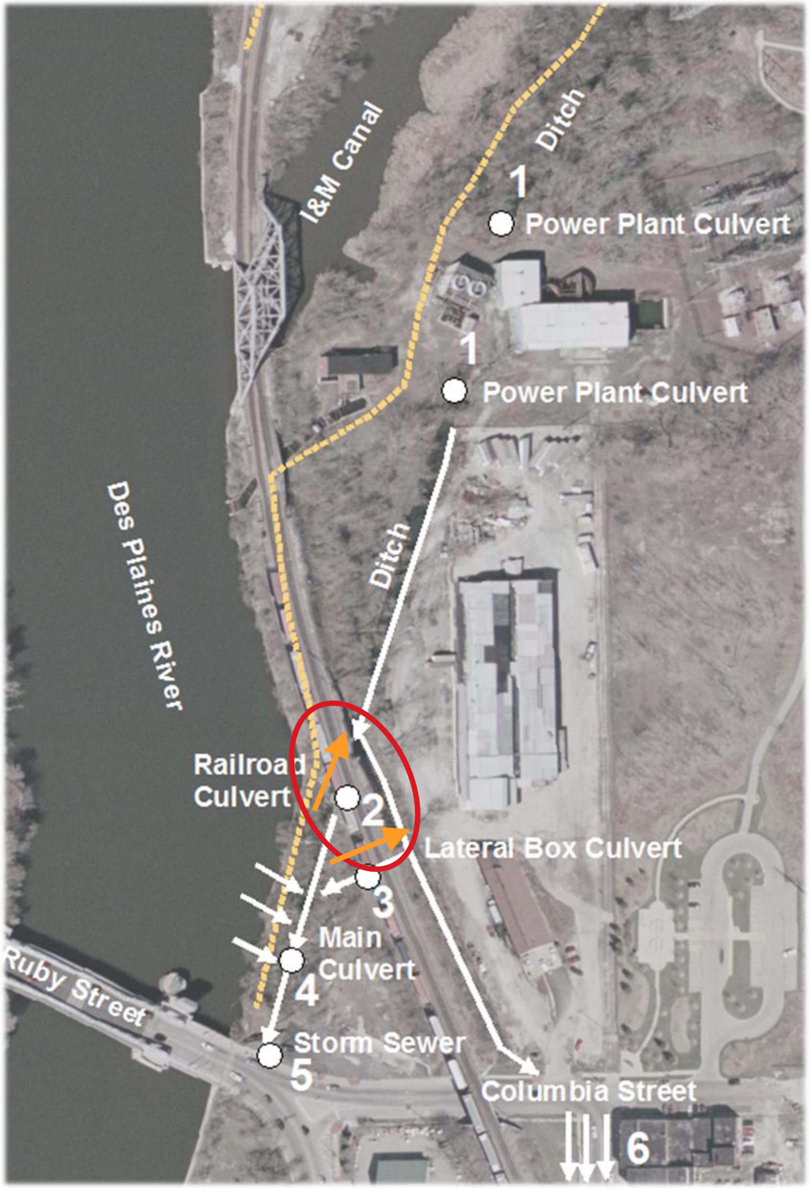


1 The Power Plant Culvert is a major constriction

(Flow from upstream embankments were neglected)

Hydraulic Features

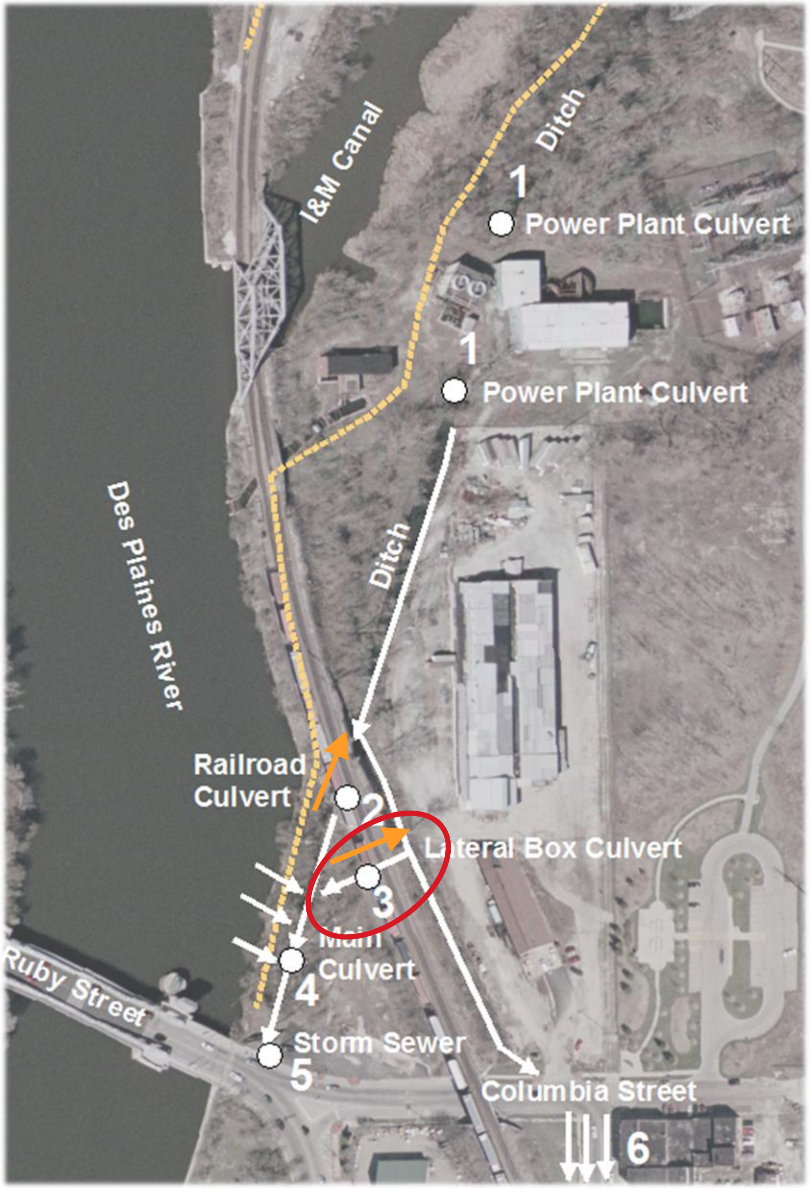




2 Railroad Double Box Culvert

(Rating Curves were developed to analyze flow through this culvert)

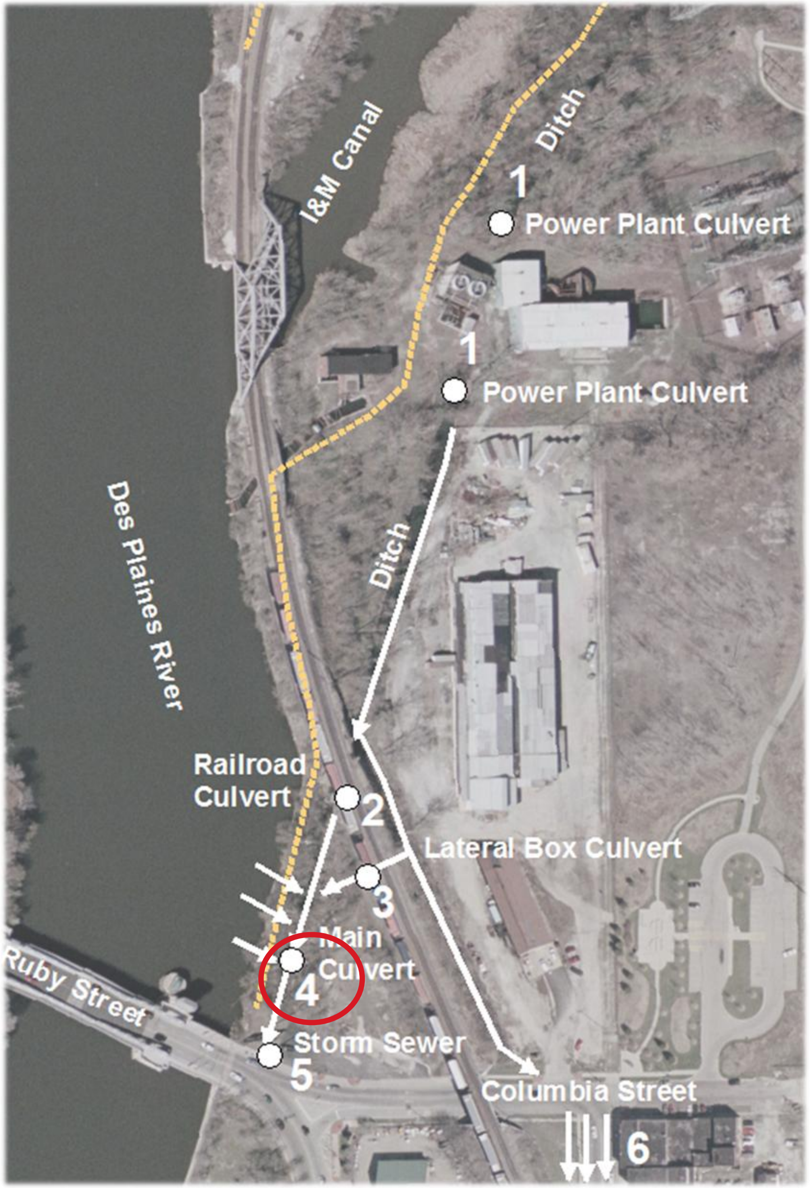
Hydraulic Features



3 Lateral Box Culvert (6'X7')

(Rating Curves were Developed to analyze flow through this culvert)

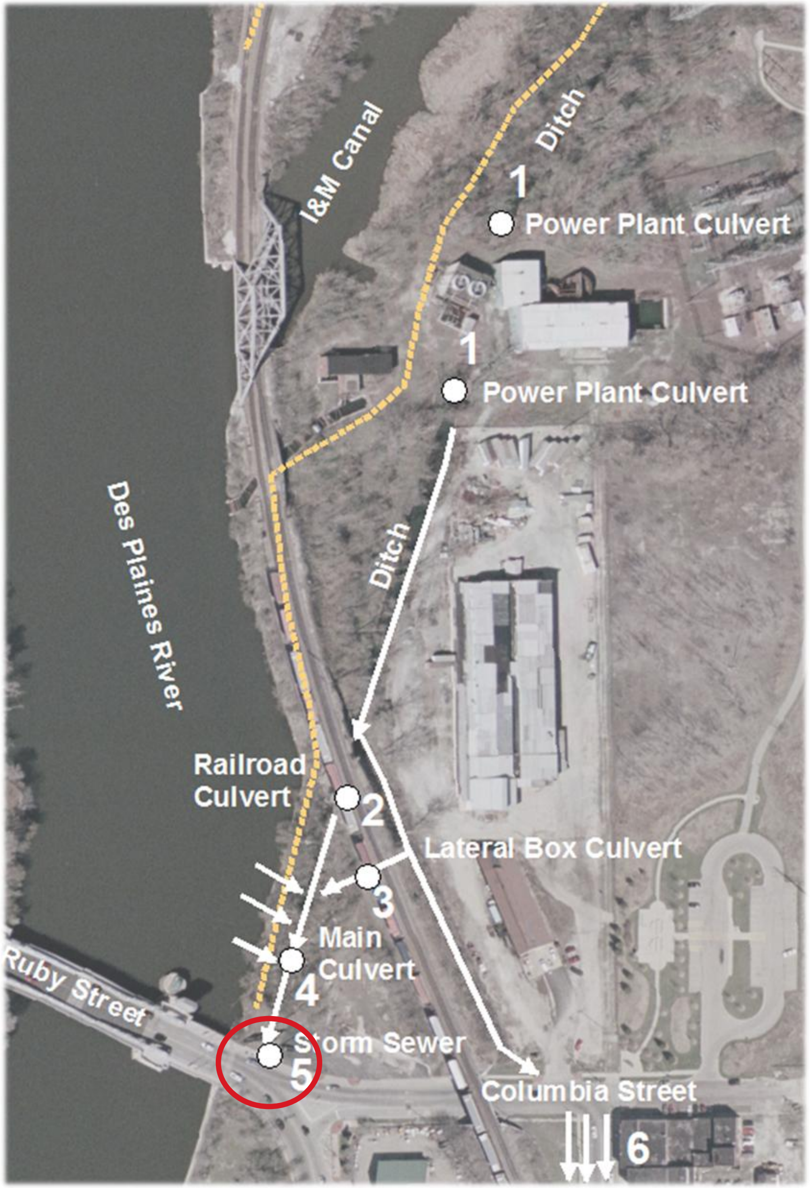
Hydraulic Features



4 Main Culvert

(Rating Curves were Developed to analyze flow through this culvert)

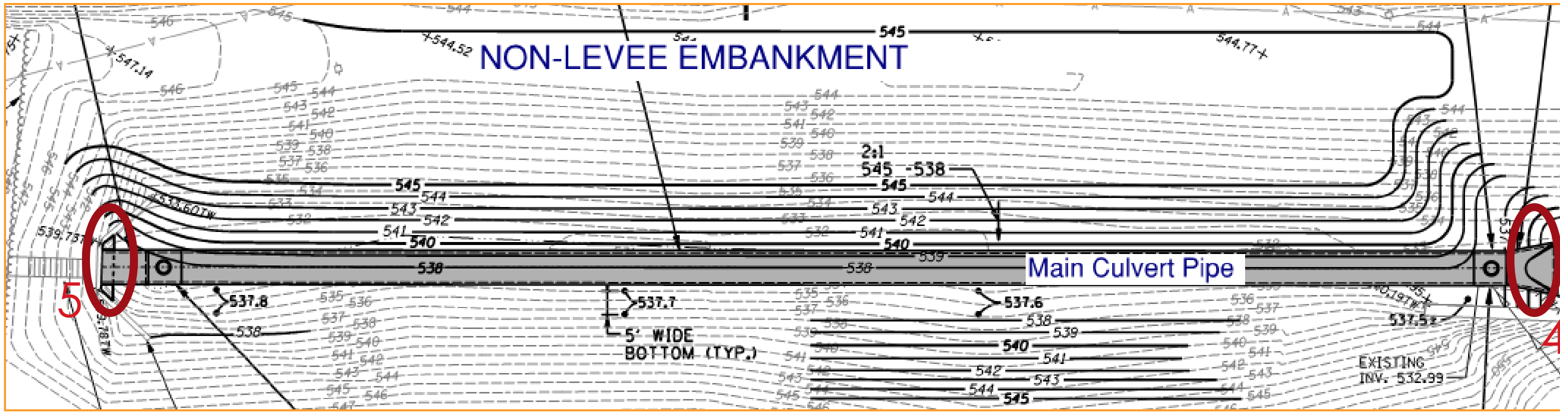
Hydraulic Features



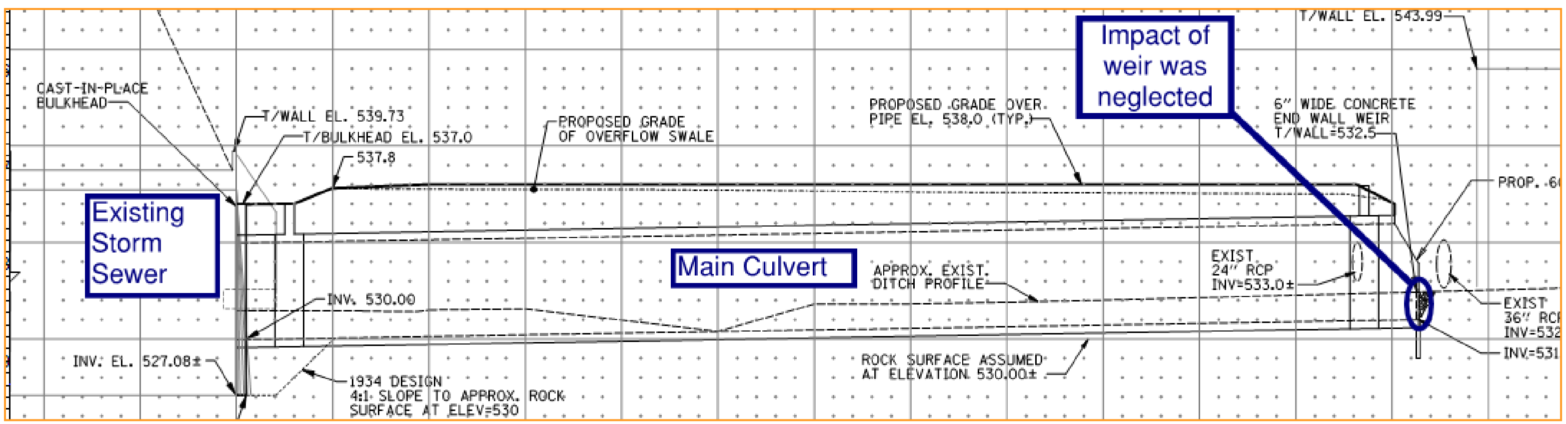
5 Storm Sewer Inlet

(Neglected due to small opening)

Main Culvert Plan/Profile

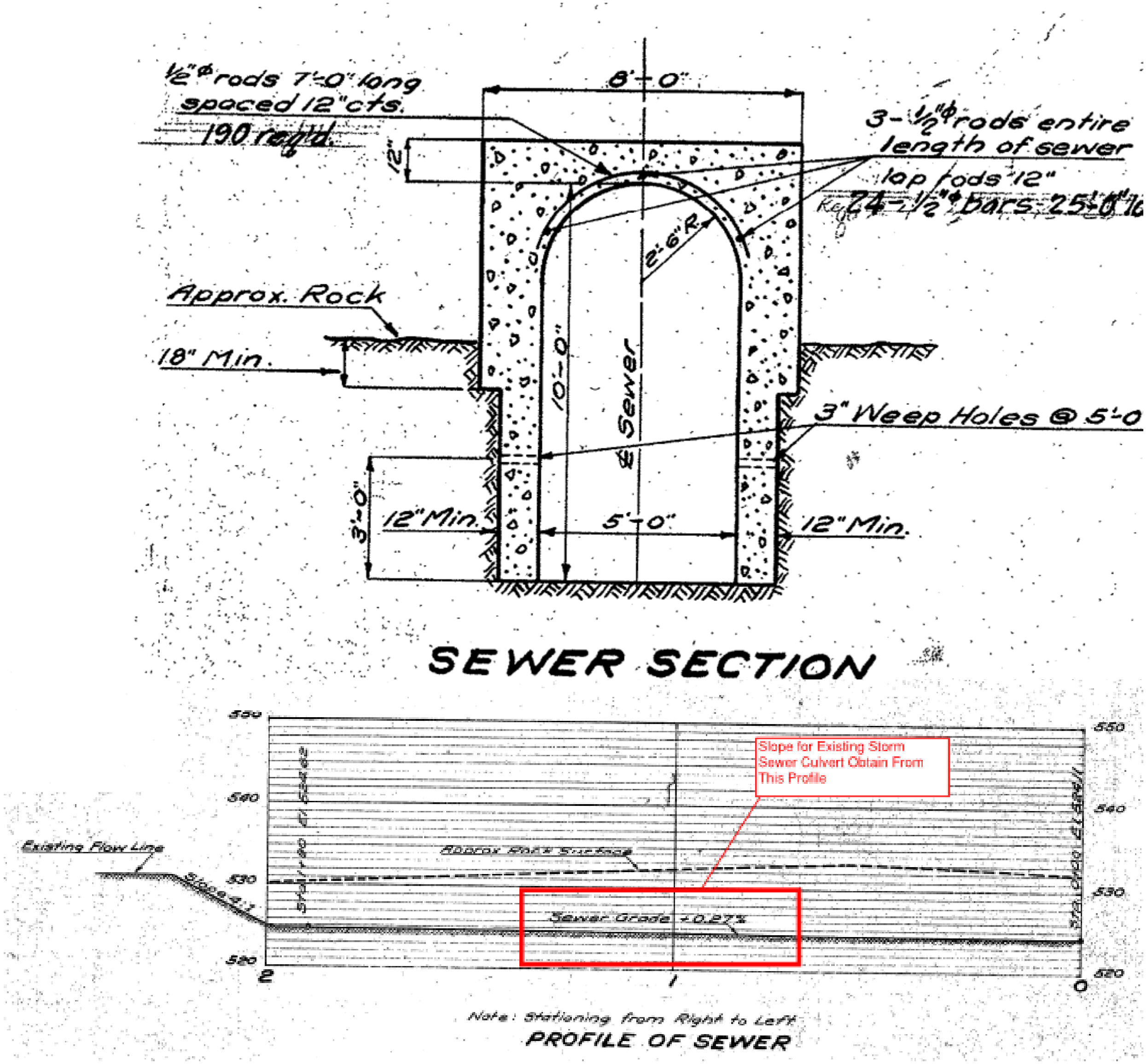


Plan



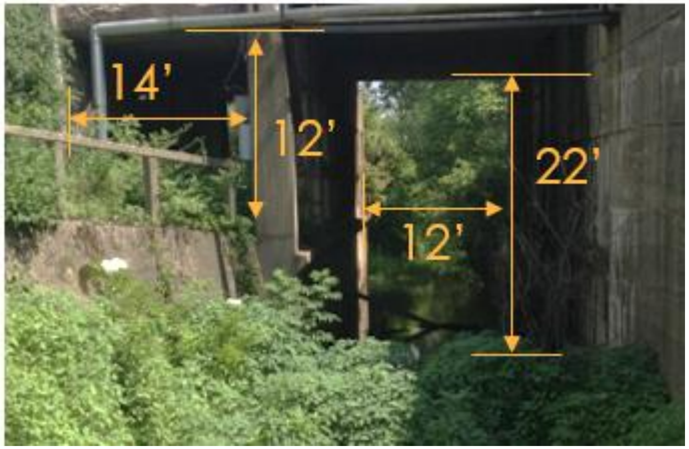
Profile

Storm Sewer in Concrete Lock Wall



Railroad Rating Curve

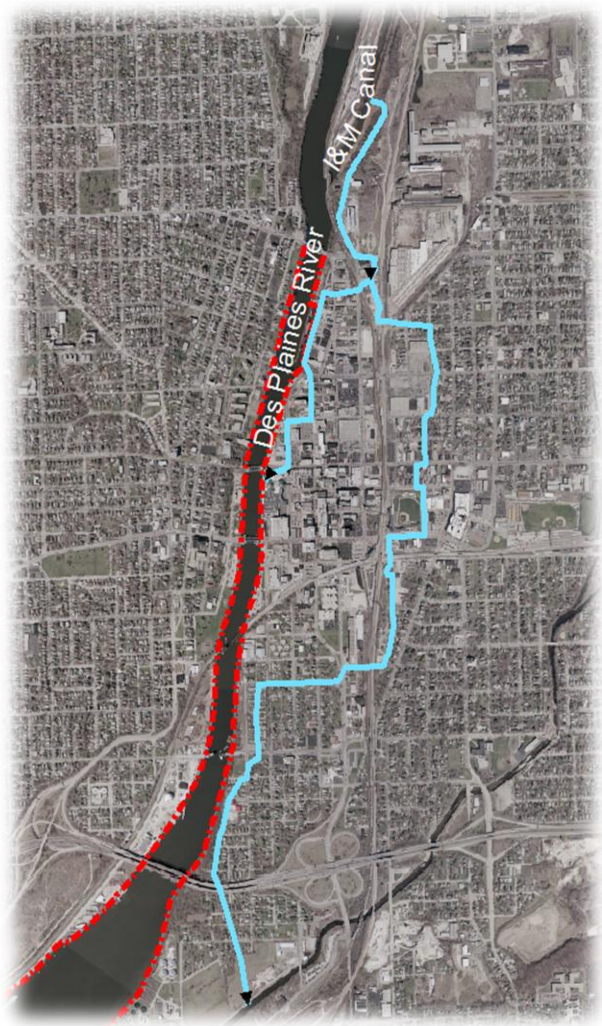
INPUTS FOR LOW ELEVATION BOX			
Span =	12	ft	(Approximate, measured from drawings)
DS Invert =	532.76	ft	(Taken from drawing)
Rise=	22	ft	(Estimated based on invert and survey elevations at top of culvert
Length=	70	ft	(Estimated based on GIS data)
Slope	0.042	ft/ft	Assumed and adjusted to compute a 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



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

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**



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Step 1

- Compute River Elevation in HEC-RAS

Step 2

- Compute Flow into Each Outlet based on tailwater

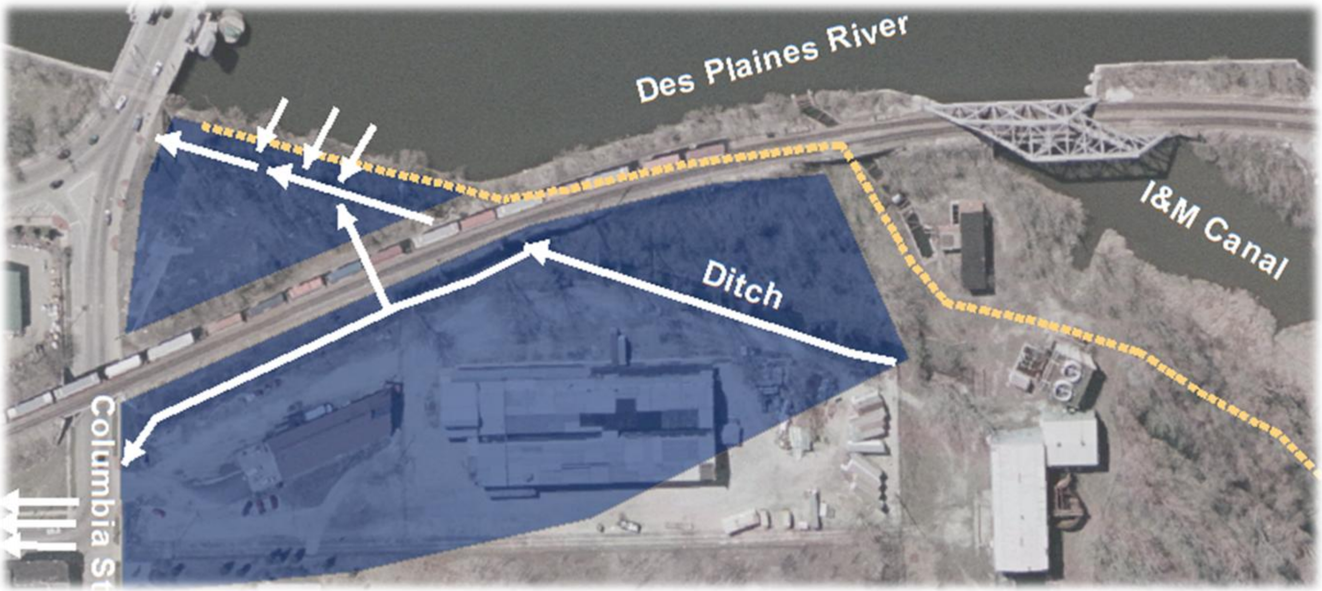
Step 3

- Recompute River Flow

Iterative Process

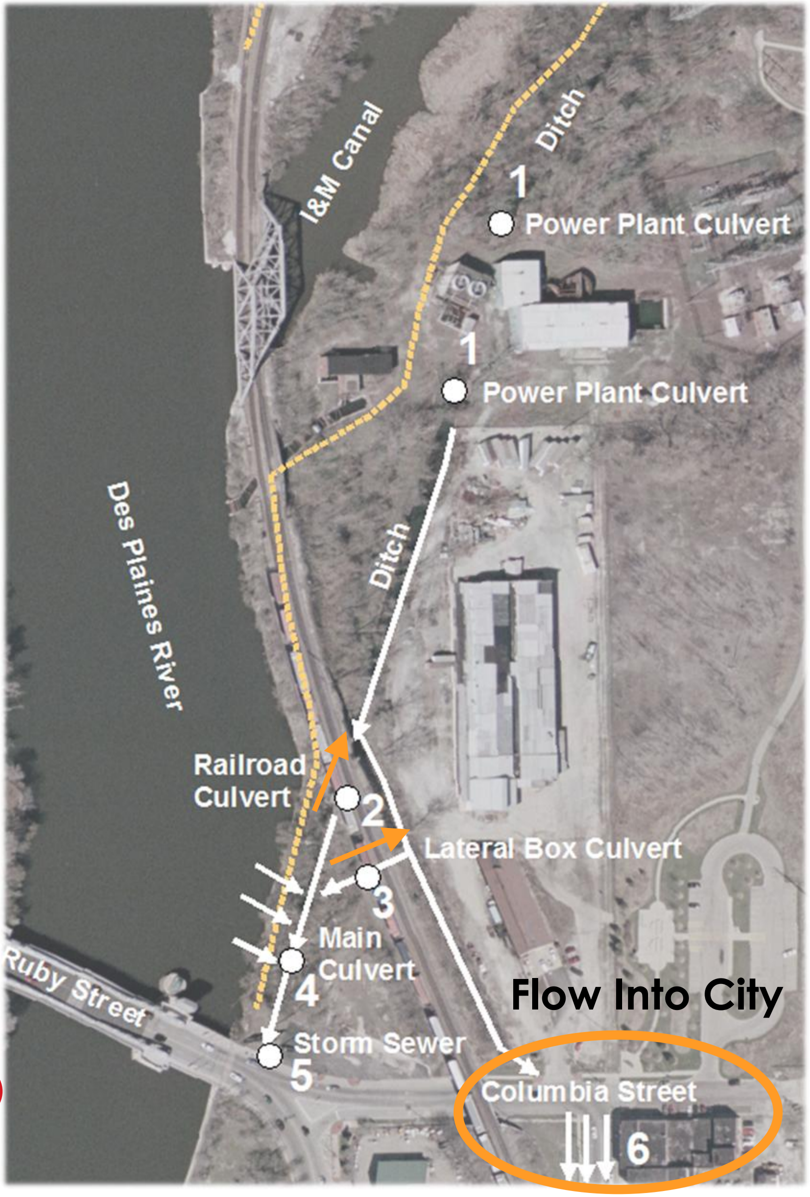
ITERATIONS

Iteration	River (NAVD 88)	Main Culvert TW/ Flow	Lateral Culvert TW/ Flow	Railroad Culvert TW/ Flow	Sum Outflow
1	543.42	0/287	0/326	0/773	1,386
2	543.16	5.3/275	4.0/310	4.3/735	1,321
3	543.17	5.1/278	3.9/311	4.2/737	1,328



RESULTS

Feature Number	Flow
1	Power Plant Culvert (NEGLECTED)
2	Railroad Culvert (740 cfs)
3	Lateral Box Culvert (310 cfs)
4	Main Culvert (280 cfs)
5	Storm Sewer Inlet (NEGLECTED)
6	Overland Flow into City at Columbia Street **(1,050 cfs)**



Steady versus Unsteady Flow

- ❖ 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

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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.

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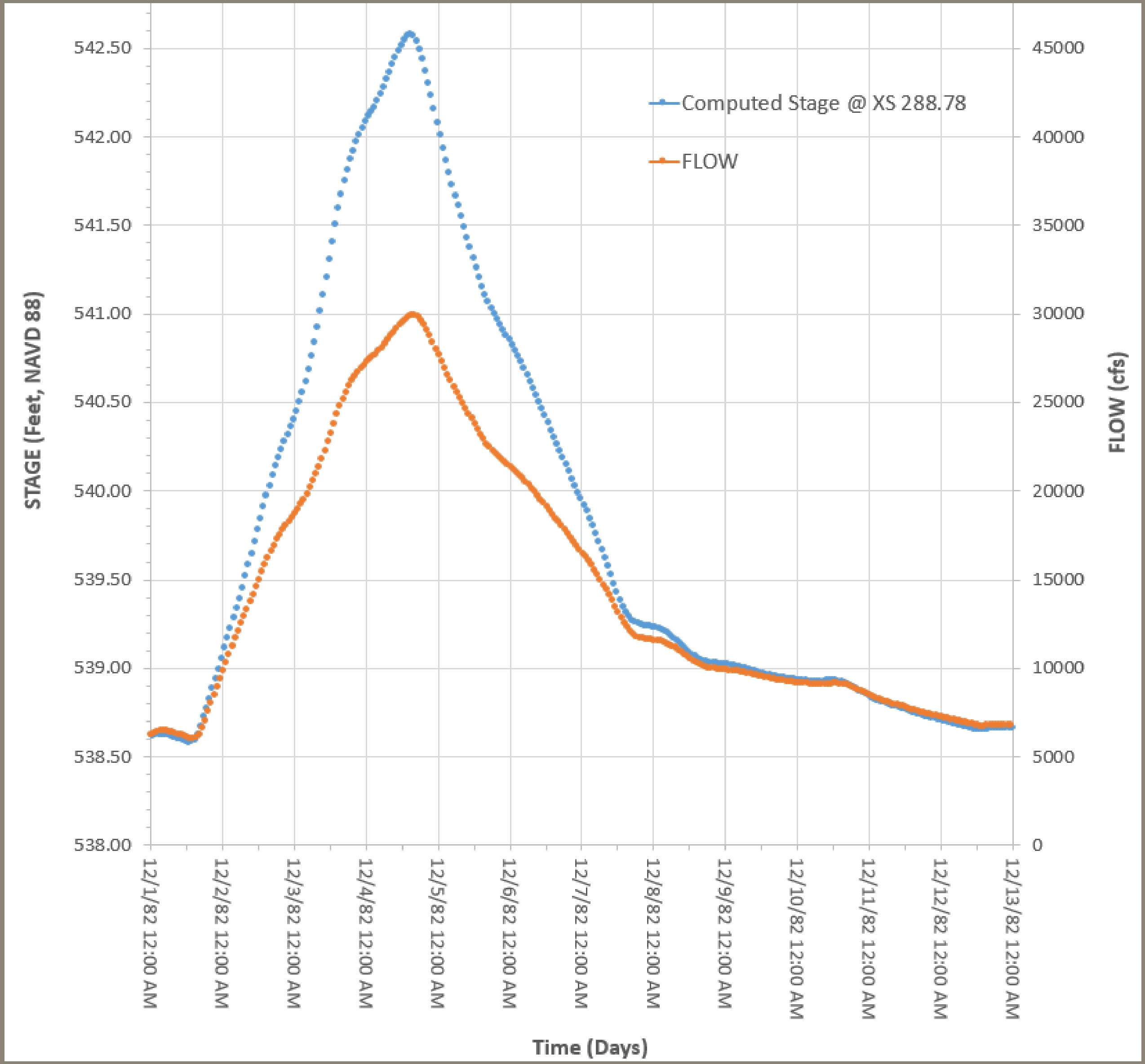
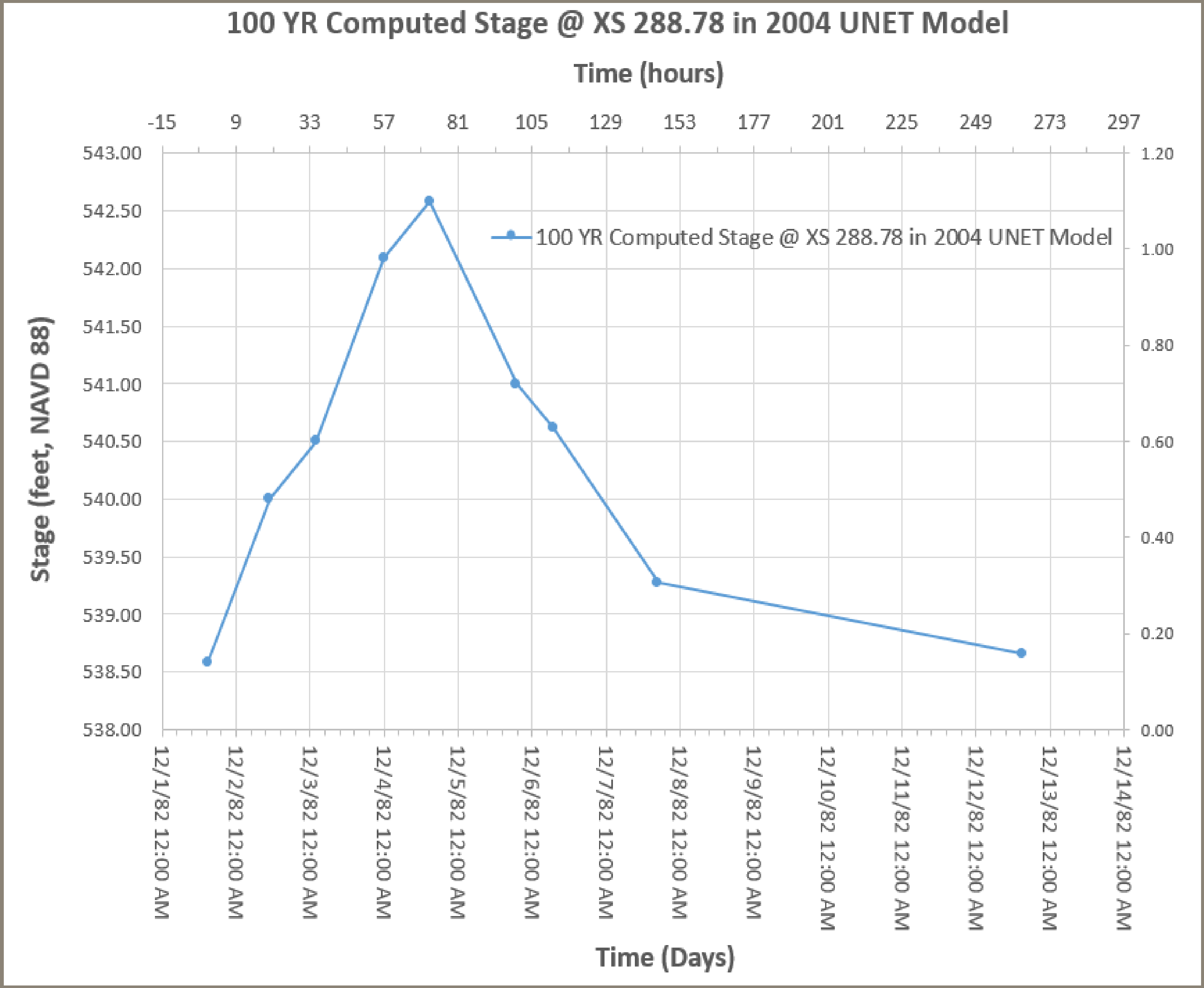
Step 1 -Hydrograph Applied at 288.78



Step 2 - Extract Inflection Points



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

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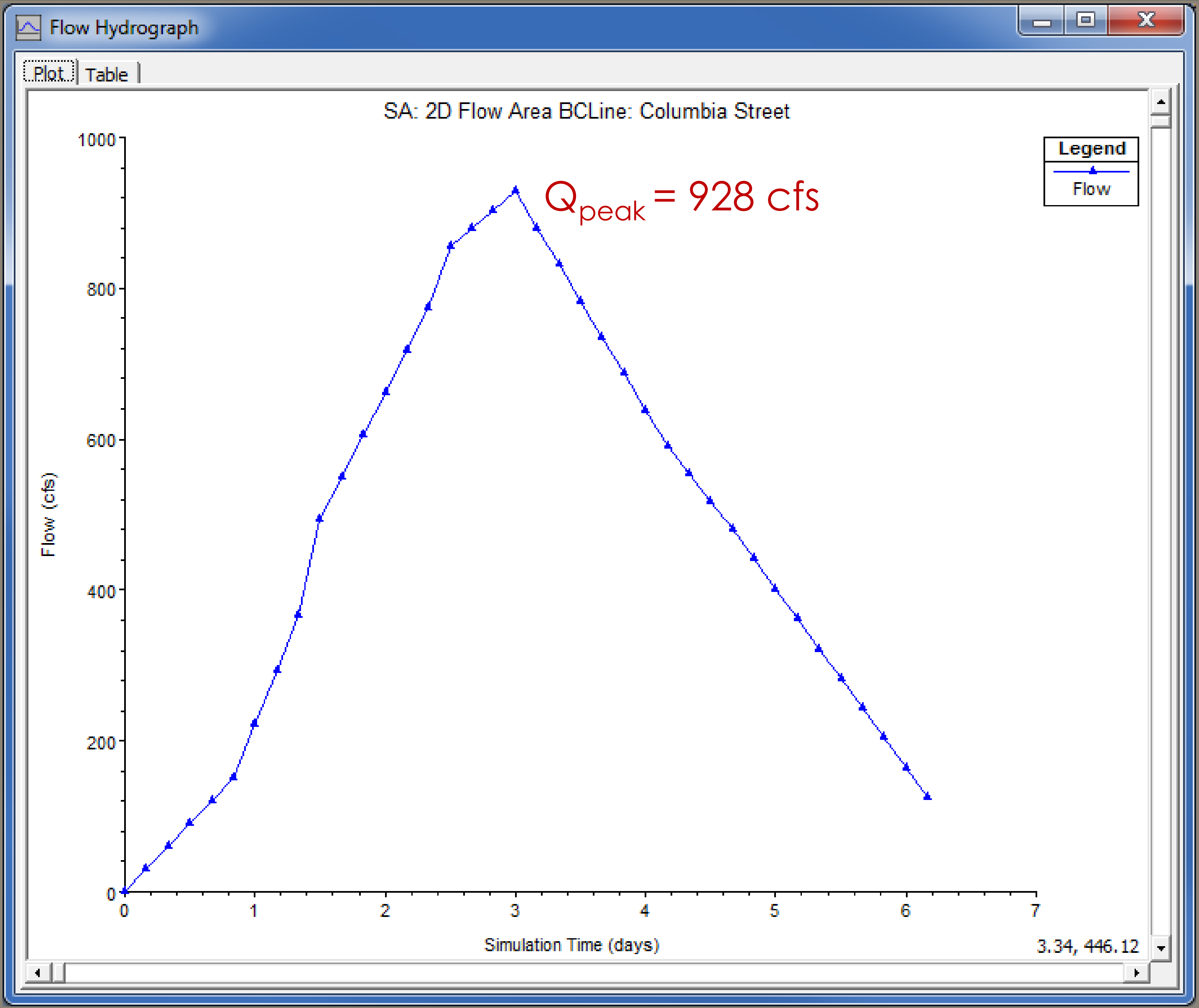
Results



Flow Hydrograph
Plot
Table
SA: 2D Flow Area BCLine: Columbia Street
Q_{peak} = 928 cfs
Legend
Flow
Flow (cfs)
1000
800
600
400
200
0
0
1
2
3
4
5
6
7
Simulation Time (days)
3.34, 446.12

Questions?

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