Using GIS to Assess Risk and Prioritize Storm Sewer Maintenance, Repair and Replacement

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Agenda

• History of storm sewer management
• Objectives of the project
• Project approach
• Next steps
History of storm sewer management

• Where we started – Mapping:
History of storm sewer management

• Next step—Electronic mapping
  – Clearer and easier to read but not much more helpful
History of storm sewer management

- Mapping update into GIS - Goals
- Asset Management
- MS4 requirements
- Updated stormwater modeling
History of storm sewer management

• Field Data Collection
  • Pipes:
    • size, type, invert elevations, outlet and inlet type
  • Structures:
    • Diameter, type, depth, condition

• We had a lot of data...
History of storm sewer management

• Met the city’s primary goals:
  – Asset management
    • Now using a software called CityWorks for work orders and maintenance records
  – MS4 Requirements
    • System is mapped and spill vectors to receiving waters are known
  – H&H modeling
    • Flood areas have been mapped and pipe upgrades have been identified
History of Storm Sewer Management

• Maintenance
  – Reactive: When there was a catastrophic pipe failure creating a public nuisance, flooding or a sink-hole
History of storm sewer management

We had a lot of data...BUT

What we didn’t have:
– Televising data for storm sewer
– Field inspections and conditions of our pipes
Objectives of this project

Use *existing* data to create a simple, cost effective analysis

- Target areas for inspections
- Target critical areas for replacement/lining
- Create a logical CIP program
- Minimize emergency maintenance
Simplified approach to evaluating storm sewer failure risk

Storm Sewer Failure Risk = Likelihood of Failure \times Consequences of Failure
Simplified approach to evaluating storm sewer failure risk

Storm Sewer Failure Risk = Likelihood of Failure \times Consequences of Failure
Key factors affecting the likelihood of pipe failure

- Pipe age
- Pipe material
- Susceptibility to corrosion
- Susceptibility to abrasion
- Joint separation
Pipe age and material can affect failure likelihood

- Pipe age - not historically tracked by City
- Pipe material
  - Vitrified Clay Pipe (VCP)
  - Metal (CMP, CIP, CSP, DIP)
  - Plastic
  - Reinforced Concrete
Storm sewer materials in Minnetonka

- Concrete: 81.75%, 73%
- Plastic: 5%, 68.5%
- VCP: 6%, 0%
- Metal: 1%, 10%
- Unidentified: 12, 0.95
Soil properties affect failure likelihood

- Soil properties - from NRCS web soil survey
  - Corrosive soils - steel, concrete
  - Load supporting capacity
Example: risk of steel corrosion (from NRCS web soil survey)
Ground slope can also affect failure likelihood

- Steep slopes identified
  - Somewhat steep (4:1 to 2:1 slopes)
  - Steep (2:1 to 1:1 slopes)
  - Very Steep (>1:1 slopes)
Failure likelihood rating system

Factors used in Minnetonka rating system equation:

• Pipe material
• Corrosion risk
• Soil structural support capacity
• Ground slope
Distribution of failure likelihood ratings

- Most pipes in top 10% are metal or vitrified clay
- Some RCP pipes with steep slopes are in top 10%
- All pipes in top 2% are metal or vitrified clay
Top 10% Failure Likelihood
- CMP
- Soils w/high corrosivity

Top 2% Failure Likelihood
- CMP
- Soils w/high corrosivity
- Steep Slope
Simplified approach to evaluating storm sewer failure risk

Storm Sewer Failure Risk = Likelihood of Failure \times \text{Consequences of Failure}
Potential consequences of pipe failure

• Four “consequence” scenarios considered:

  1. Failure that results in significant pooling/inundation

  1. Failure at road crossing- potential road washout
Potential consequences of pipe failure

- Four “consequence” scenarios considered:

  3. Failures at steep slopes—potential landslide/washout

  3. Failures that impact critical structures
Failure causing significant pooling/inundation
Example: Holiday-Wing-Rose Chain of Lakes
Step 1 - determine trunk storm sewer
Step 1 - determine trunk storm sewer
Step 2 - map potential inundation areas
Step 3- determine # of potentially impacted structures
Step 3 - determine # of potentially impacted structures
Failure causing significant pooling/inundation
• Factors considered in scoring system
  – Trunk storm sewer identified
  – Inundation areas mapped
  – # of structures within inundation areas identified
  – Scoring based on number of potentially inundated structures
Failure at road crossing

www.dewattoport.com
Failure at road crossing - potential road wash-out

- Step 1: Identify pipes that cross a roadway or railway (3500 of 11,000)
Failure at road crossing - potential road wash-out

• Are these pipes part of the trunk storm sewer system?
• Are these pipes large (high flow capacity)?
Failure at road crossing - potential road wash-out

- Crossings under “critical” roadways (major roads or evacuation routes)?

- Crossings under railways?
Failure at road crossing - potential road wash-out

- Does the crossing have a high likelihood of overtopping based on flood elevations?
• Does the crossing embankment have steep side slopes, increasing potential for wash-out?
Failure at road crossing - potential road wash-out

Top 2% Failure Consequences
- Road crossing
- Trunk system
- Critical roadway
- Somewhat steep
- Overtopping likely
Consequences of pipe failure on steep slopes (increased slope failure risk)

• Steep slopes identified
  – Somewhat steep (4:1 to 2:1 slopes)
  – Steep (2:1 to 1:1 slopes)
  – Very Steep (>1:1 slopes)

• Scoring based on steepness and pipe size
Consequences of pipe failure on steep slopes (increased slope failure risk)
Failure near critical infrastructure

Identified storm sewer located near:
– critical roadways and emergency routes
– critical structures
What are the consequences of pipe failure?

- Maximum rating of four primary “consequence” scenarios used as consequence rating
  - Failure at road crossing
  - Failure that results in significant pooling/inundation
  - Failure at steep slope
  - Failure that impacts critical structures
Distribution of failure consequence ratings

Top 10%

Top 2%
Combined storm sewer failure risk

- Rating scales normalized to compute combined risk
GIS maps identify locations with highest failure risk

- **Combined Risk Score**
  - Top 10% Combined Failure Risk Pipe
  - Top 2% Combined Failure Risk Pipe
GIS data includes attributes used for failure risk rating system:

- Top 10% Combined Failure Risk Pipe
- Top 2% Combined Failure Risk Pipe

Attributes:
- Ground_Slope: Steep
- Trunk_Y_N: Yes
- Road_Cross_Y_N: Yes
- Railway_Crossing_Y_N: No
- Pipe_Size_Consequence: >42"
- Innundation_Bldg_Count: 101
- Join_ID: 6975
- Critical_Infrastructure: Major
  - Road or
  - Evacuation
  - Route
- Critical_Structures
- Road_Overtop_Class
Outcomes of storm sewer failure risk analysis

Pipes with highest combined risk rating have high failure likelihood AND high consequences

- these pipes should be prioritized for inspection and/or replacement

Some pipes with high failure consequences do not have high overall risk

- primarily concrete or plastic material (lower failure likelihood)
- City should consider inspecting these pipes periodically
Project deliverables assist City with inspection program development

• Failure **likelihood** map with top 2% and top 10% flagged
• Failure **consequence** map with top 2% and top 10% flagged
• **Combined** failure risk map with top 2% and top 10% flagged
• Storm sewer database with scoring system
• GIS layers
Next steps

1. Fill in details on unidentified pipe types
2. Pipes rated in top 2% - utilize existing staff to evaluate actual pipe condition in the field.
3. Establish dedicated funding on an annual basis to line or replace failing or deteriorating pipes.
4. Use data in conjunction with pavement management data and water and sewer replacement schedule to coordinate replacements with road reconstructions.
Questions?

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