Analysis of Chicago Area CSOs for Initial Identification of Rainfall and Infrastructure Dependencies

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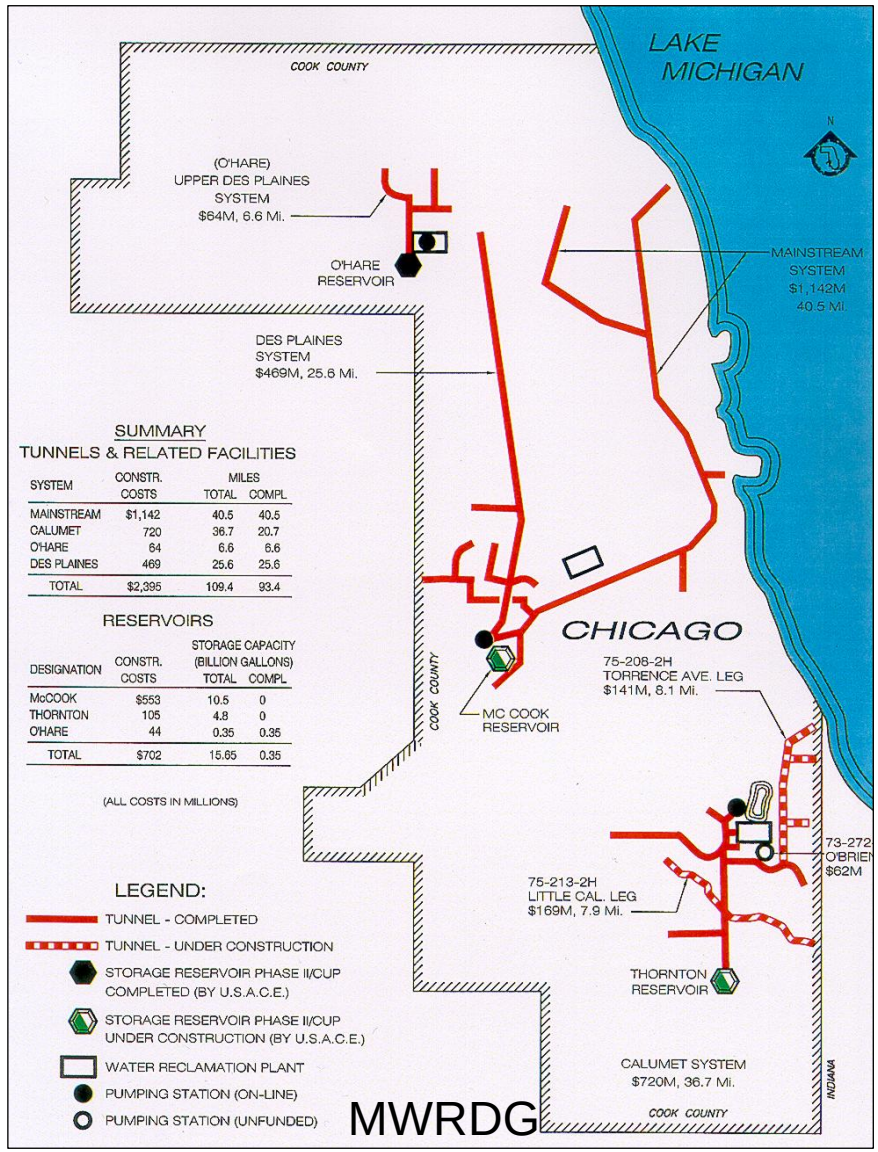
Introduction

- 375 square miles of Chicago and 51 neighboring municipalities are serviced by combined sewers
- Over 300 combined sewer outfall points exist within Metropolitan Water Reclamation District of Greater Chicago (MWRDGC) service area
- Tunnel and Reservoir Plan (TARP) was designed to capture potential CSOs; 109 miles of tunnel up to 35 feet in diameter



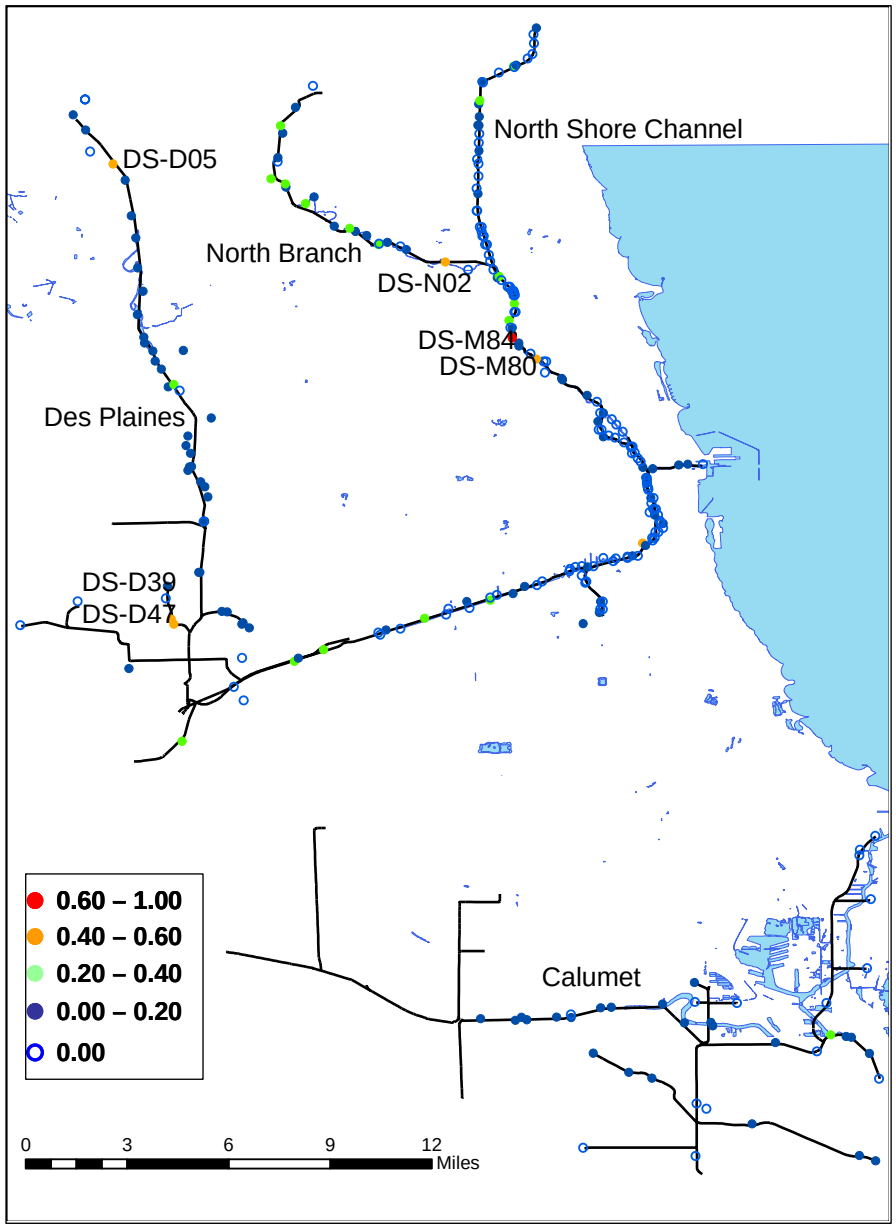
Research Objectives

- Understand the spatial-temporal patterns of CSOs
  - Mainstream and Calumet branches of the deep tunnel network
  - Different years, seasons, and time scales
- Evaluate high-risk overflow points for variables that would be most helpful to CSO modeling
  - Sensitivity to rainfall intensities
  - Proximity to pumping stations
- Minimize number of CSOs into Chicago Waterways
  - Use physics-based and statistical simulation models
  - Generate optimal sequence of management decisions during storm events

Data for Analysis

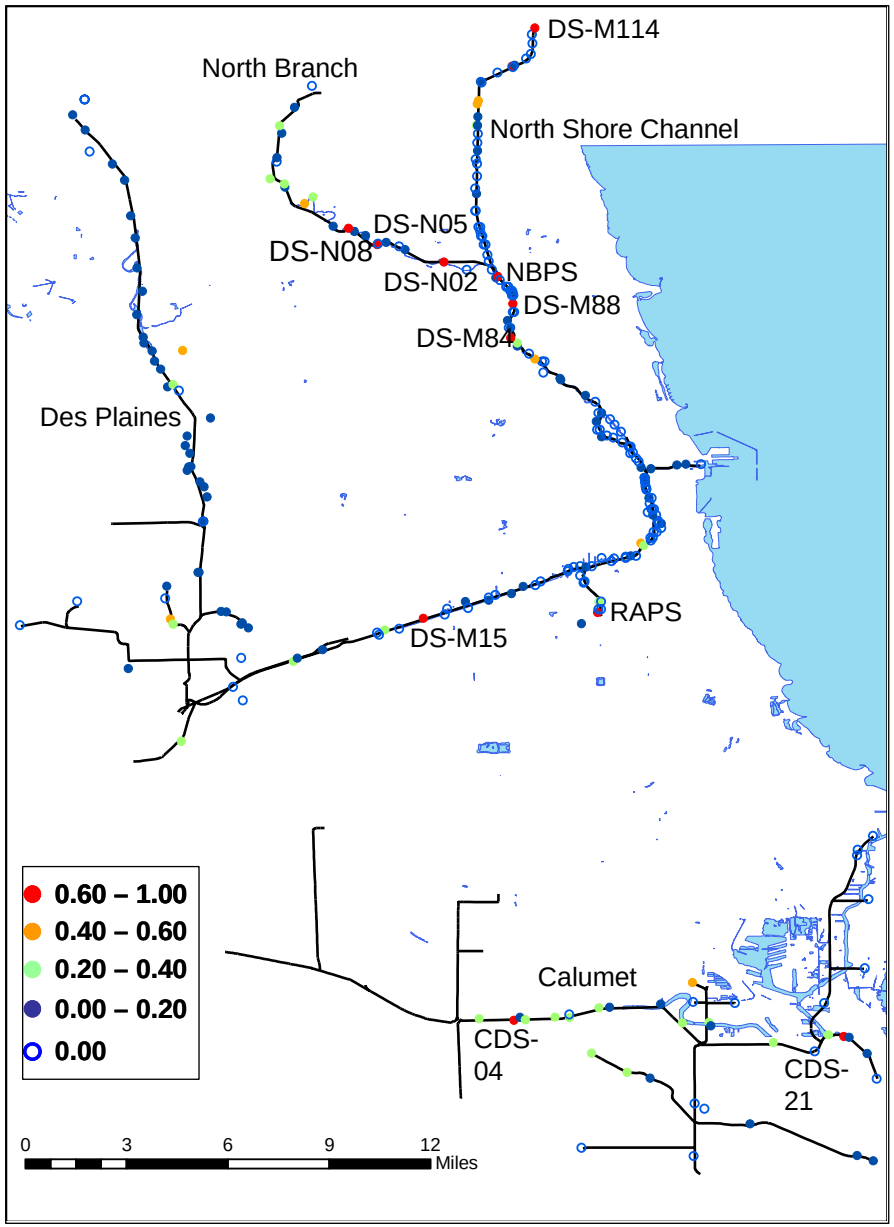
- Outfall inventory compiled by MWRD cross-referenced with City of Chicago inventory
  - 329 outfalls identified by the TARP dropshafts through which they connect to deep tunnel system
  - GPS coordinates for 275 outfalls
- CSO reports compiled by MWRD for the period 10/21/04-12/31/07
  - Duration of reportable events ranges from 15 seconds to 5.2 days
- Time series of CSO activity derived from CSO reports
- NEXRAD precipitation rates

Reportable Overflow Frequency



- Indicates which outfalls were responsible for the most reportable events
- Normalized relative to 189 at DS-M84 (Roscoe WTP)
- Events are considered equivalent regardless of duration
  - May be biased by large number of short events
- Reportable events occur most frequently near the confluence of North Branch of the Chicago River (NBCR) and North Shore Channel (NSC)

Cumulative Overflow Duration



- Indicates which outfalls discharged for the most time (correlates to discharge volume)
- Removes bias caused by short reportable events
- Normalized to longest duration of 32.7 hours at DS-N05
- Longest durations observed near the confluence of NBCR and NSC

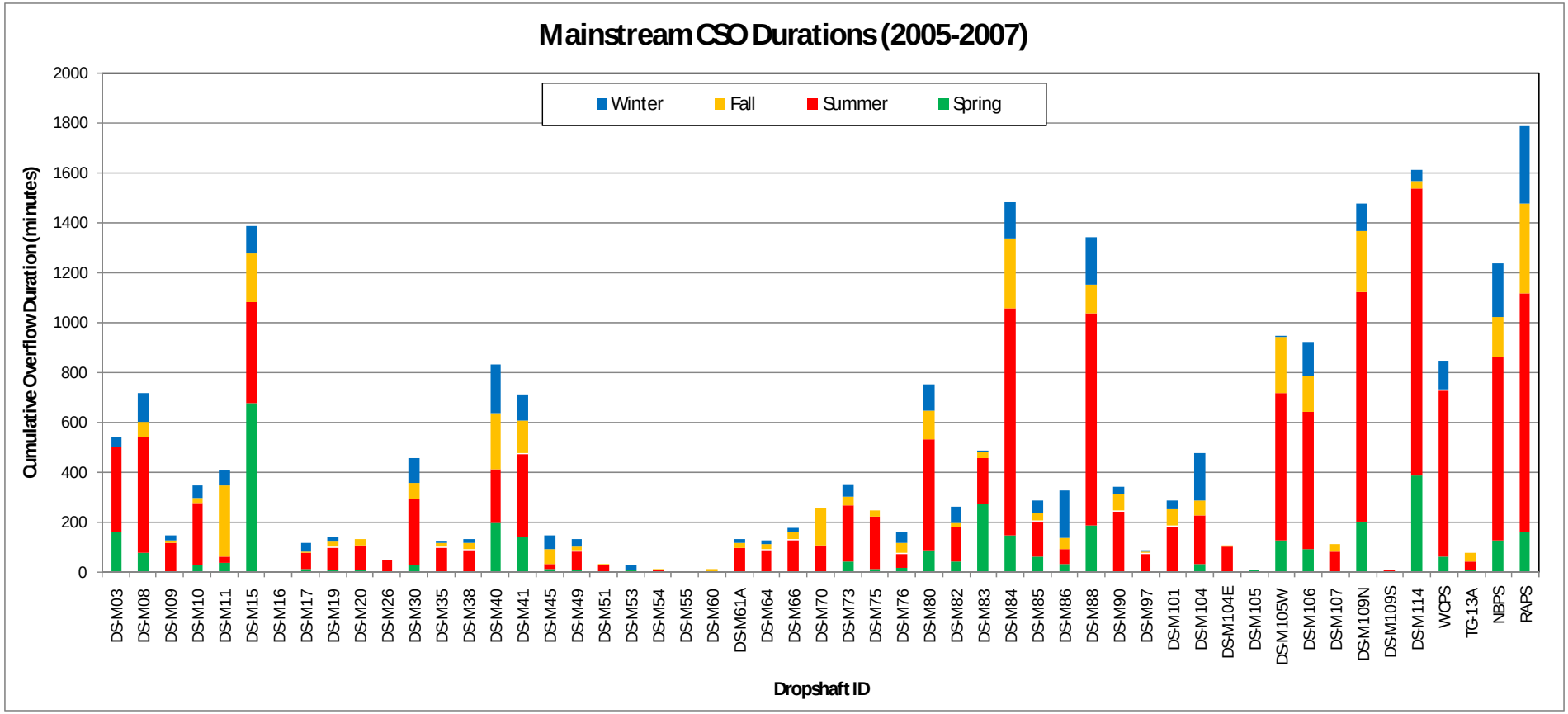
Seasonal Analysis of CSOs

- General seasons during which more reportable overflow events occur along the tunnels
  - Mainstream: Summer
  - North Branch: Summer
  - Des Plaines: Winter
  - Calumet: Winter

- Most reportable events by year
  - Des Plaines: Winter 2005, Fall 2006
  - Mainstream: Fall 2006, Summer 2007
  - North Branch: Summer 2006, Fall 2006, Summer 2007
  - Calumet: Winter 2005, Fall 2006

- Overflow durations
  - 2004 eliminated from analysis to obtain an equal number of all seasons for relative seasonal trends along tunnel branches

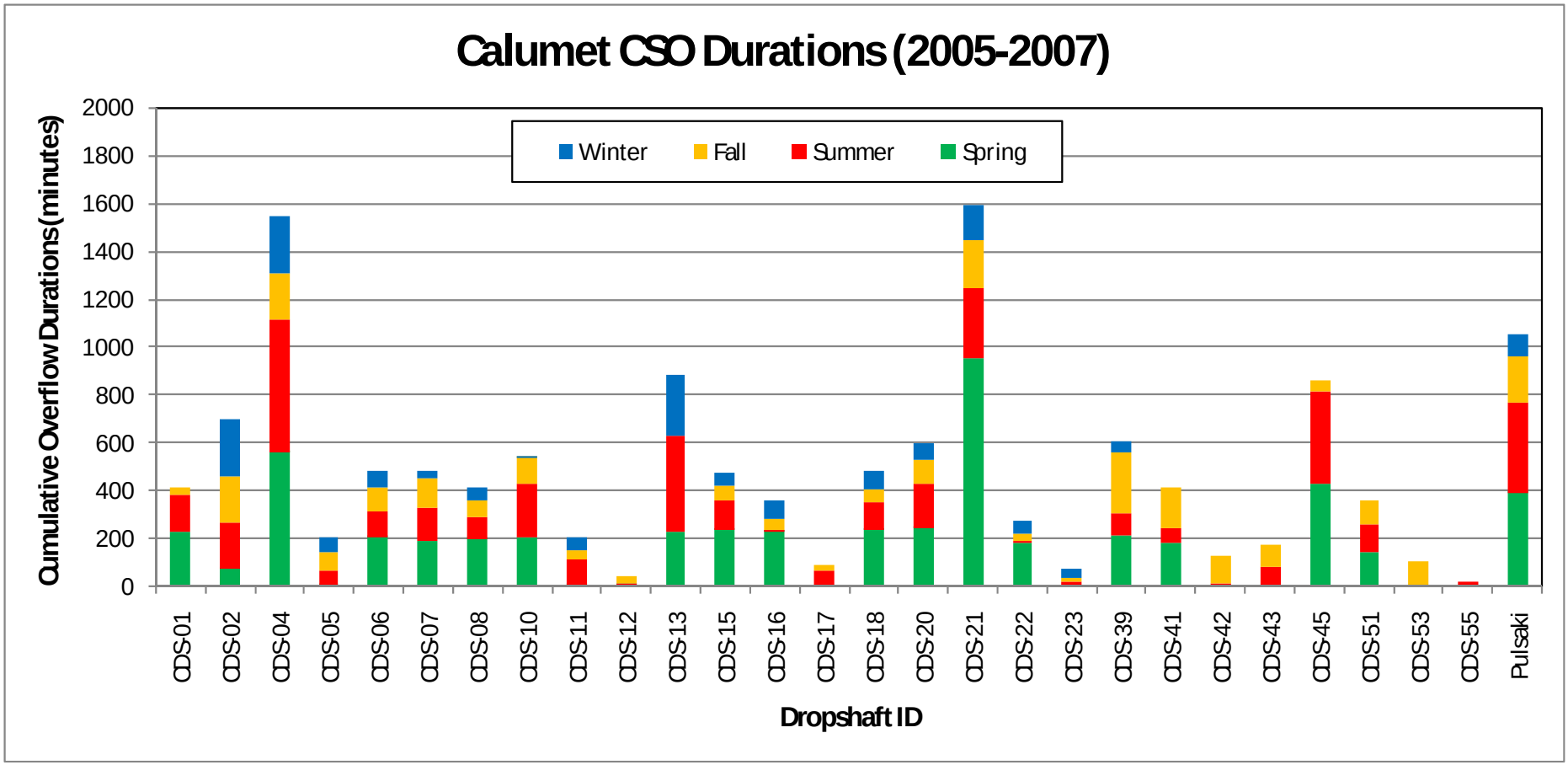
Mainstream Overflows



15.2% in Spring 56.5% in Summer 15.1% in Fall 13.2% in Winter

- Strong summer influence at all dropshafts and pumping stations
- DS-M15 has a strong spring influence(Downstream of Stickney)
- DS-M11 has a strong fall influence (Imhoff tank at Stickney)
- Short winter durations overall
- Longest durations occur at Racine PS (30 hrs) and DS-M114, Wilmette PS, (27 hrs)

Calumet Overflows



39.6% in Spring 29.4% in Summer 18.8% in Fall 12.2% in Winter

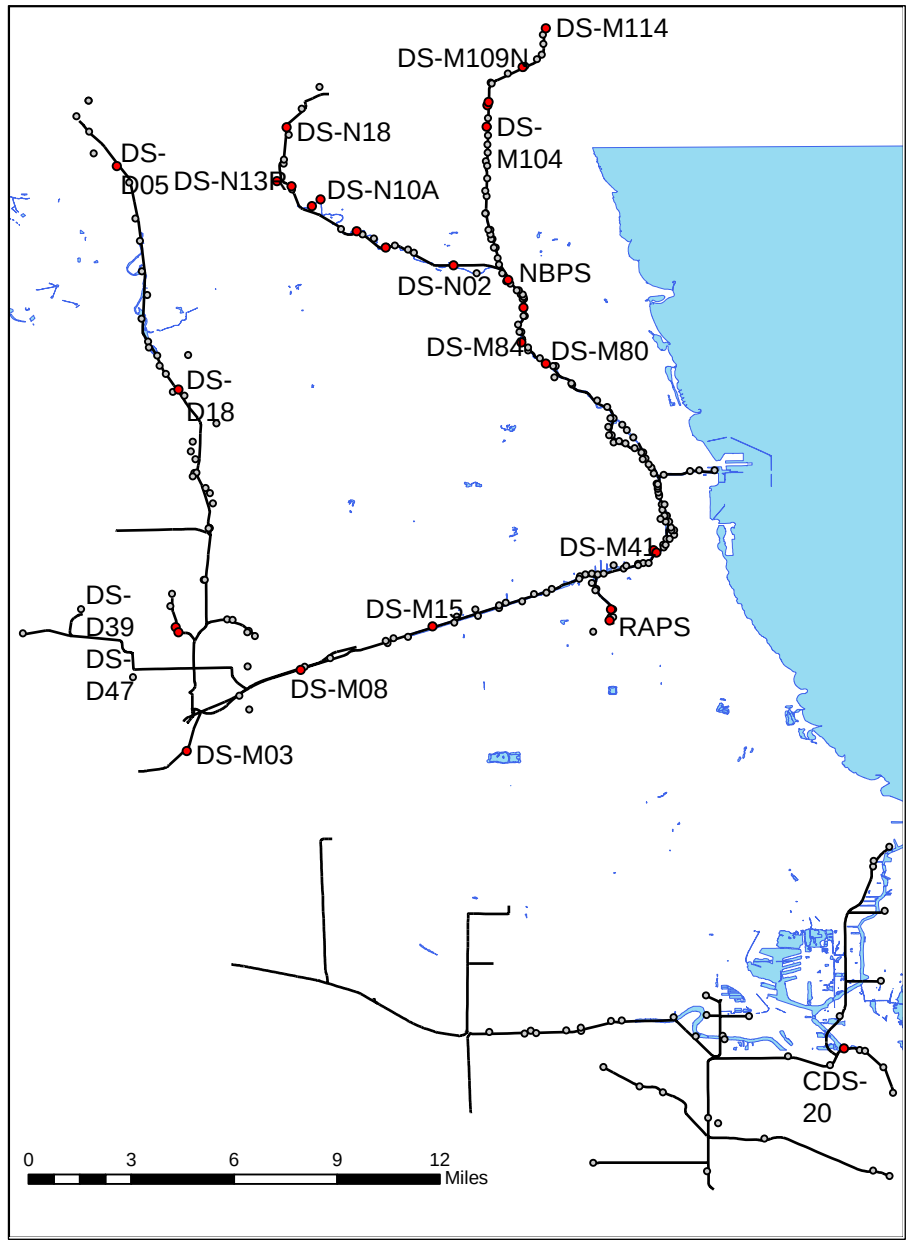
- Longest overall duration in the spring, although summer is not negligible
- CDS-04 has the longest duration in summer
- CDS-13 has a negligible fall duration (125th St. pumping station)
- Longest duration at CDS-21 (27 hrs)

Outfalls with Highest CSO Risk

- Ranking criteria
  - Season
    - CSO in at least 7 of 14 seasons in data record
  - Reportable
    - 24 or more reportable events in data record
  - Duration
    - 377 minutes or more of CSO discharge
  - Correspond to 85th percentile of data in each category

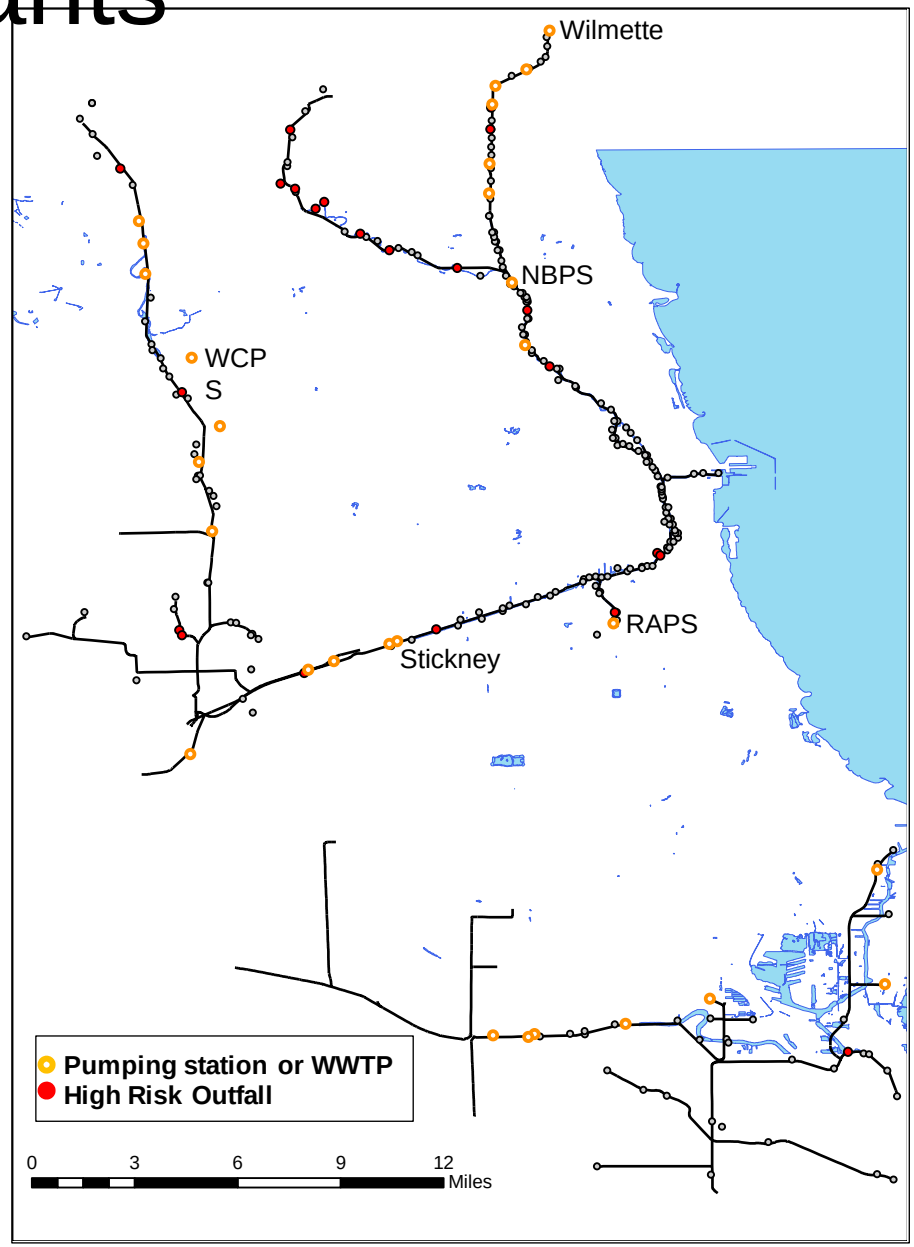
Location of High Risk Outfalls

- 32 are located in Mainstream, 16 for all categories. Occur near ends of tunnel branches
- 12 are located in North Branch, 8 for all categories. High density of high-risk outfalls
- Downstream of confluence of North Branch of the Chicago River and the North Shore Channel
- Pumping stations (RAPS, NBPS, DS-M114)
- 6 are located in Desplaines, 4 for all categories
- 18 are located in Calumet, 1 for all categories



Pumping Stations and Treatment Plants

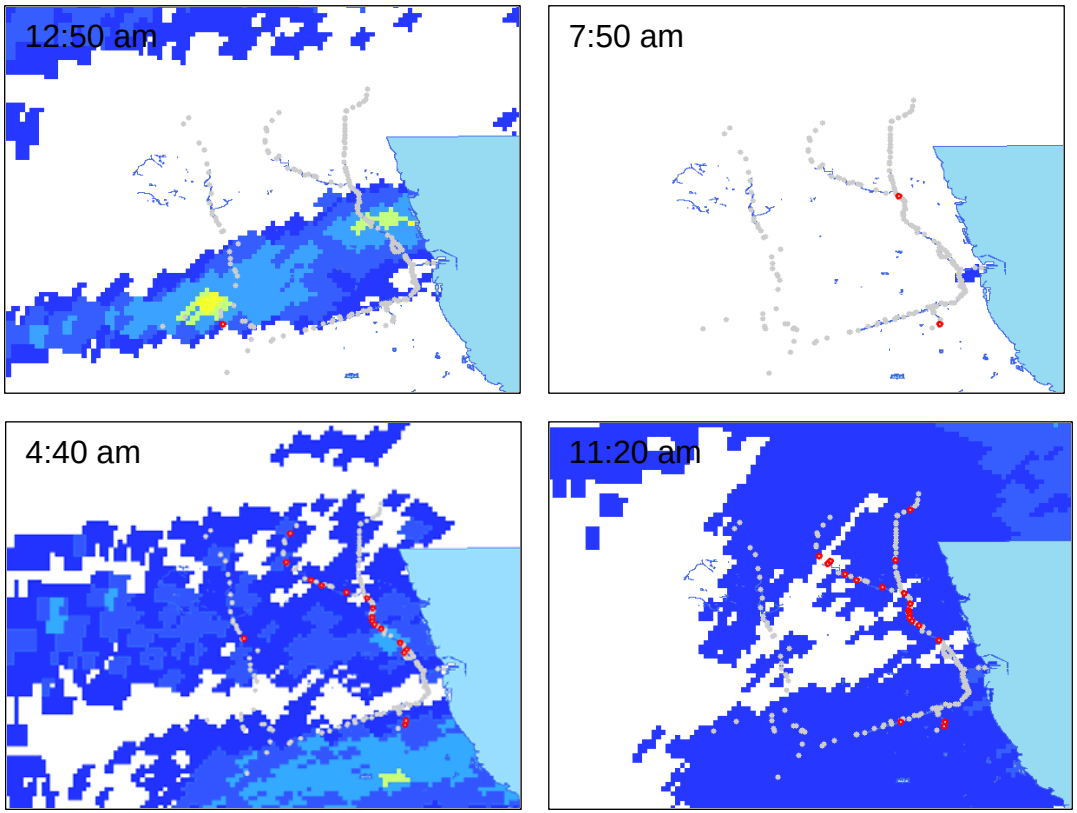
- High risk outfalls that are not pumping stations or treatment plants require further analysis
  - North Branch
  - Lower Desplaines
  - Below NBCR and NSC Confluence
  - Upstream of RAPS
- In Calumet pumping stations are not high risk locations
- Probable correlations between tunnel branches with pump stations and fewer overflows
- Evaluate trends for variables that cause high-risk overflows at basin and interceptor level



Summary of Seasonal Analysis

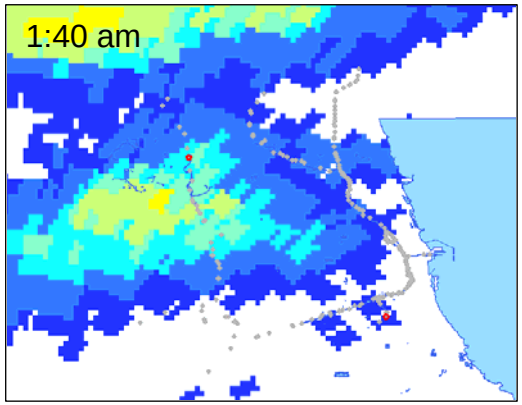
- CSO occurrences along different sections of the tunnel system have different seasonal influences
  - Summer: Mainstream and North Branch
  - Winter: Des Plaines and Calumet
- CSO durations along different sections of the tunnel have different seasonal influences
  - Summer: Mainstream, North Branch, and Des Plaines
  - Spring: Calumet
- CSOs occur more frequently and have longer durations downstream of the confluence of the NBCR and the NSC
  - Structure or design of these outfalls
  - No proximity to pumping stations
- More CSOs occurred in Winter 2005, Summer 2006, Fall 2006, & Summer 2007 than in the other seasons in the record
  - There is a dynamic feature that needs further investigation

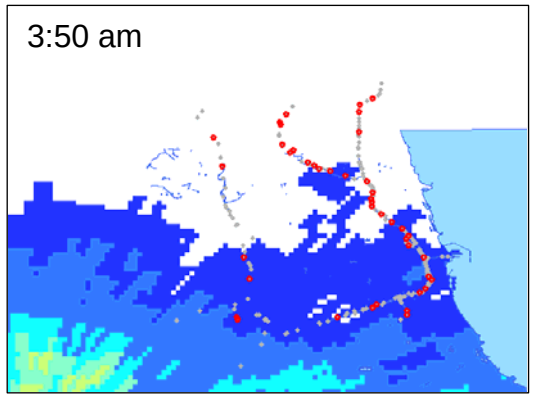
August 3rd, 2006

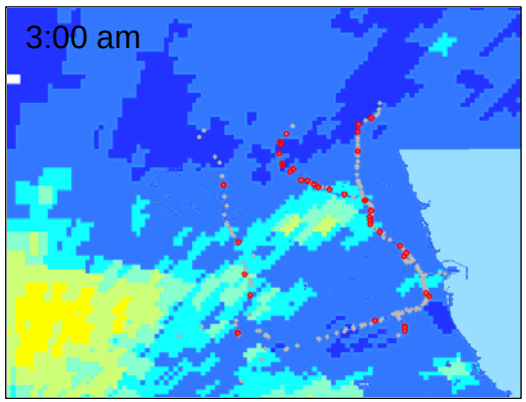


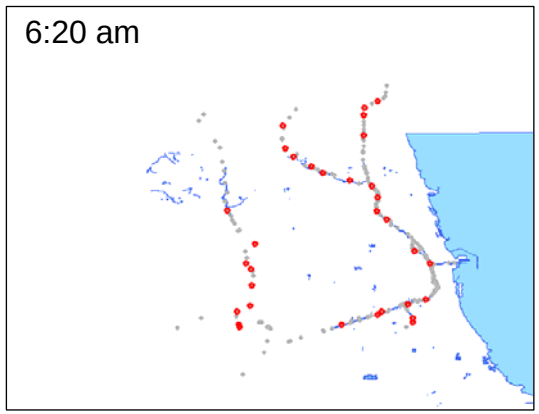
- Rainfall bands form directly over Des Plaines and North Branch
- Only DS-D39 is affected until four hours after heaviest rainfall when other CSOs along the North Branch begin
- Rainfall clears by 8:30, but NBPS and RAPS continue to CSO (decision likely influenced by next band of rainfall)
- A second storm comes in from the west, North Branch CSOs begin in north-to-south order
- RAPS is the last CSO to stop

October 3rd, 2006









Rainfall Intensity (mm/hr)

0	0.9	1.8	2.7
0.15	1.05	1.95	2.85
0.3	1.2	2.1	
0.45	1.35	2.25	
0.6	1.5	2.4	
0.75	1.65	2.55	

- Center of heavy rainfall covers city in arc from northwest to southeast
- RAPS and upper Des Plaines are the first CSOs to begin
- CSOs start in a north-to-south order from upstream in the North Branch to downstream at the confluence
- North Branch CSOs have approximately 6 hours duration (most are off by 9:30 am)

Storm Event-Scale Analysis

- August storm forms over the NBCR, while the October storm moves from northwest to southeast over Chicago
  - Management decisions should be compared between storms
- CSOs for the August event begin more gradually than for the October event
  - The October event produced direct, heavy rainfall immediately on top of North Branch and the CSOs responded instantaneously
  - The August storm was less intense and resulted in slower network responses
  - Need to evaluate effect of storm intensity on CSO response-times
- Following the August event, most of the CSOs end after 2 hours. For the October event, many of the CSOs continue for up to 6 hours
- CSOs respond from north to south in both cases, a direction that would not be expected if overflows are caused by back ups in the TARP system
- Local phenomena are important and the role of drop-shaft and interceptor specific infrastructure should be further examined

Conclusions

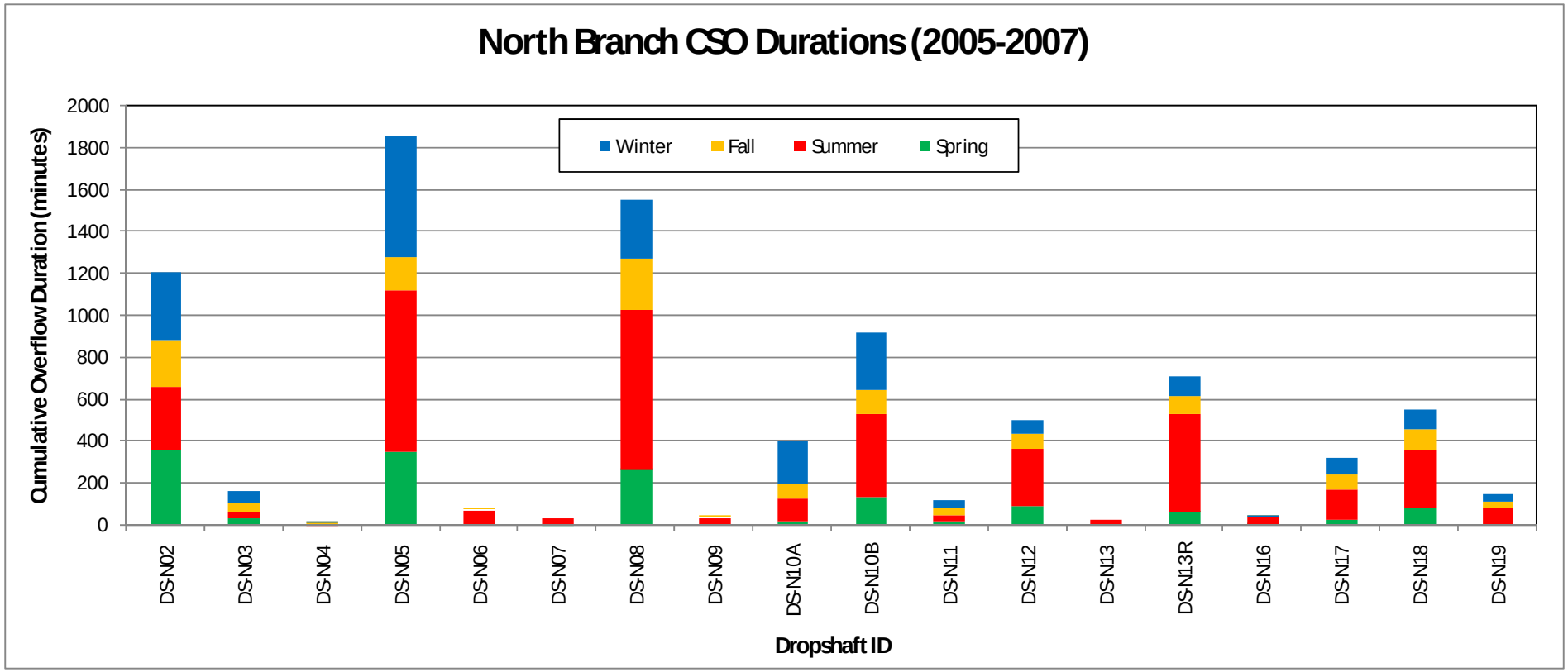
- Initial analysis of CSO patterns helped identify certain system characteristics to be evaluated further
  - High risk CSO locations
  - CSO response times and durations
  - Overflow dependence on rainfall pattern and intensity
- Performing analysis for more storms will help substantiate patterns
  - Overflows along North Branch where there are no pumping stations
  - Decisions made at pumping stations to start or stop overflows

Conclusions

- Identification of important thresholds (rainfall and infrastructure dependencies) will aid in creation of physics-based and statistical models
- Apparent importance of localized effects may require coupling with detailed models in key local areas
- Models will benefit real-time optimization
  - Generalized models will allow quick, accurate decision sequence computation
  - Incorporate real-time rainfall, radar tunnel levels, and waterway stages
  - Enable more informed decision making by allowing decision makers to visualize state of system and evaluate best operations sequence

Backup Slides

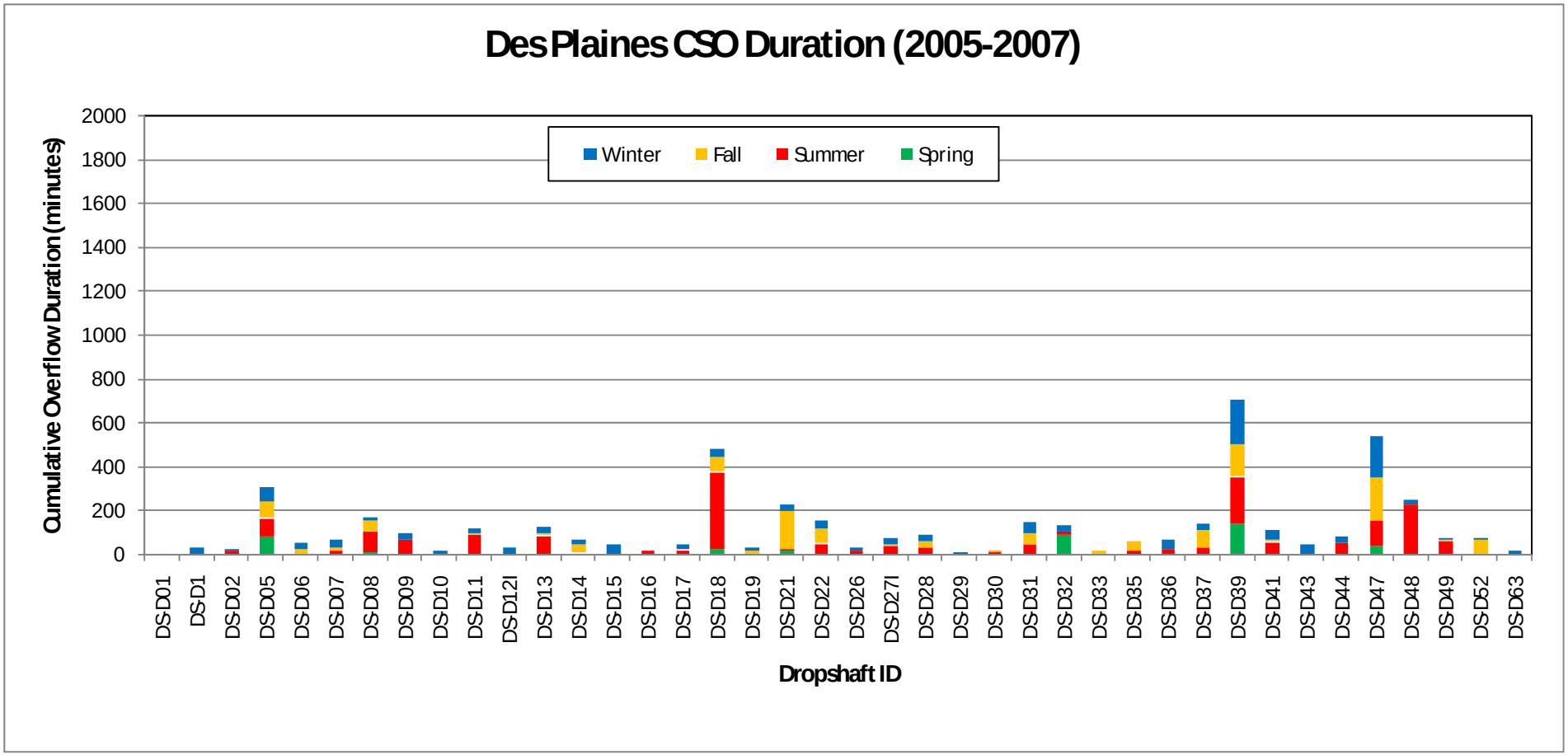
North Branch Overflows



16.4% in Spring 44.3% in Summer 14.9% in Fall 24.4% in Winter

- Strong summer influence
- DS-N02 appears to experience nearly equivalent durations in all seasons
- DS-N10A exhibits longer durations in winter
- Longest duration at DS-N05 (31 hrs)

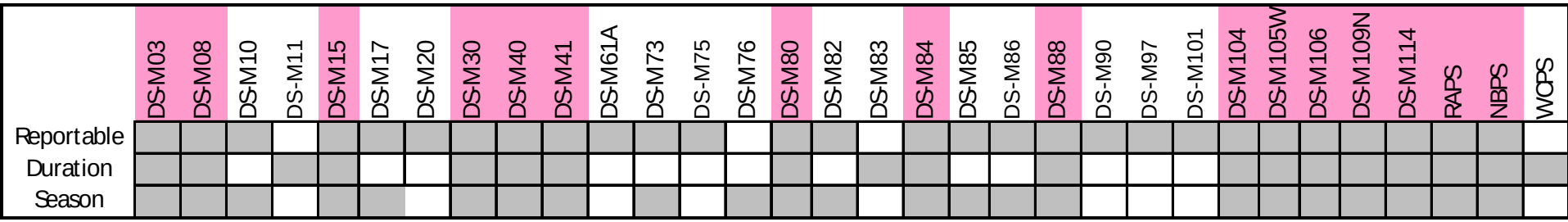
Des Plaines Overflows



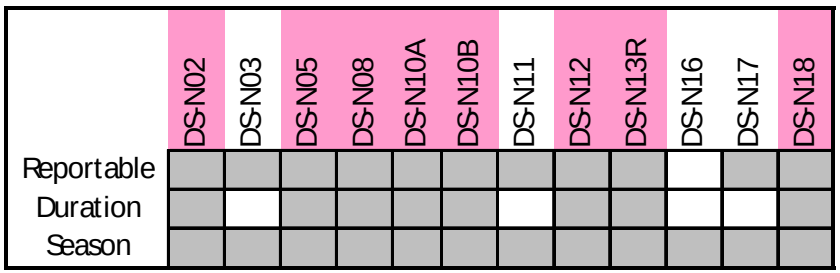
8.5% in Spring 38.3% in Summer 26% in Fall 27.2% in Winter

- Longest durations are predominantly in summer
- Winter and fall are also higher than for other tunnel branches
- Very low overall durations (scale is the same as for all others)
- Longest duration at DS-D39 (12 hrs)

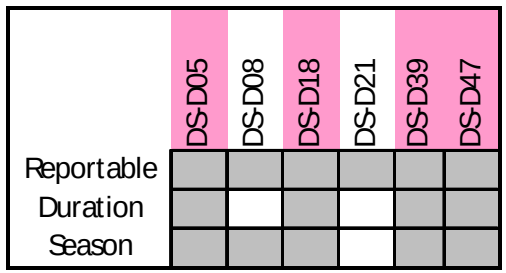
High Risk Outfalls



32 are located in Mainstream, 16 are in the 85th percentile for all categories



12 are located in North Branch, 8 are in the 85th percentile for all categories



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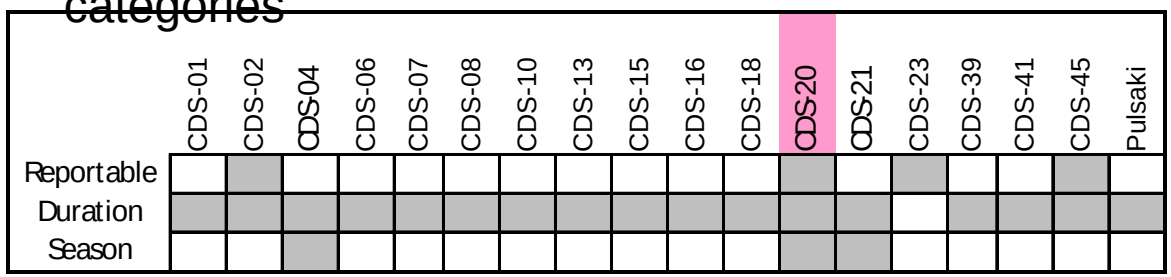

18 are located in Calumet, 1 is in the 85th percentile for all categories

Current CSO Modeling

- Create a physics-based and a statistical model of the Mainstream and Calumet TARP Systems for fast real-time computation
- Input real-time rainfall, radar tunnel levels, and waterway stages into the models at user-specified time intervals
- Generate water levels at TARP dropshafts for these time intervals; forecast water levels and CSO events
- Derive a sequence of optimal actions to minimize CSOs to be taken as a result of the current water levels
- Allow decision maker to make alterations to initial optimal sequence
- Re-run the model with the updated decision sequence