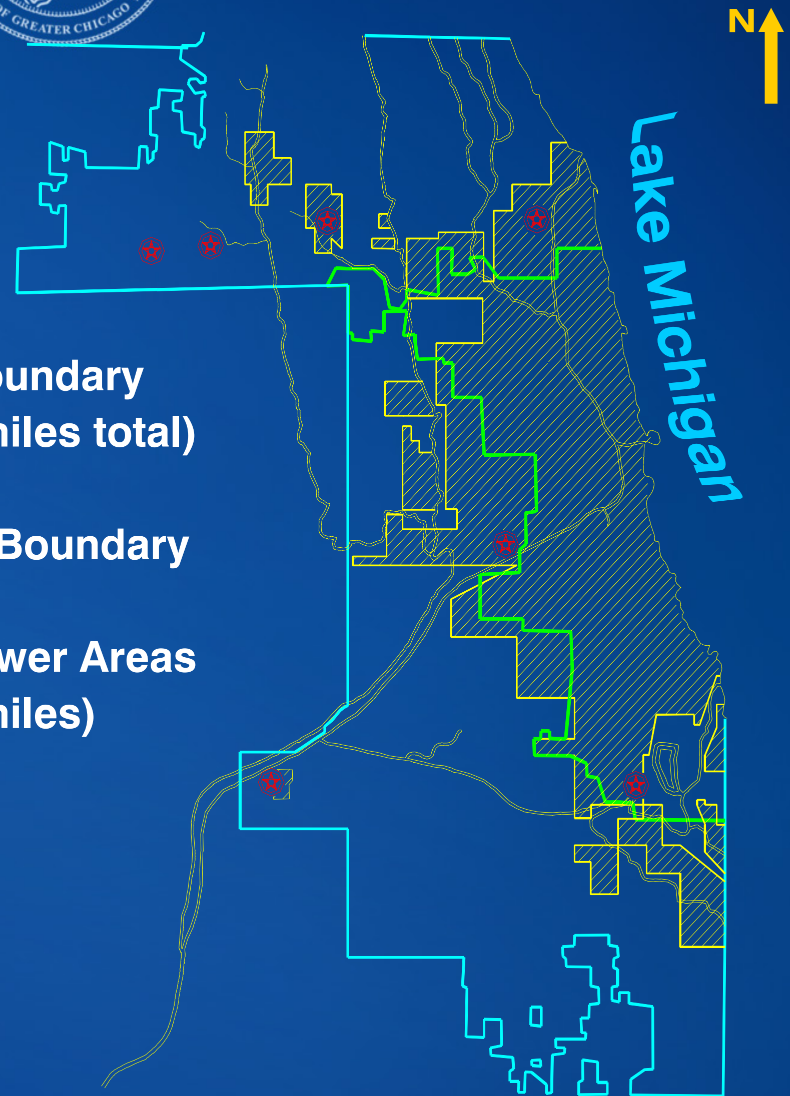
Development and Utilization of a Customized Model for Evaluating Performance of the Calumet, Mainstream and Des Plaines Tunnel and Reservoir Systems

Ann Gray, P.E.
Associate Civil Engineer

Areas Served by Combined Sewers



MWRDGC Boundary (872 square miles total)

Chicago City Boundary

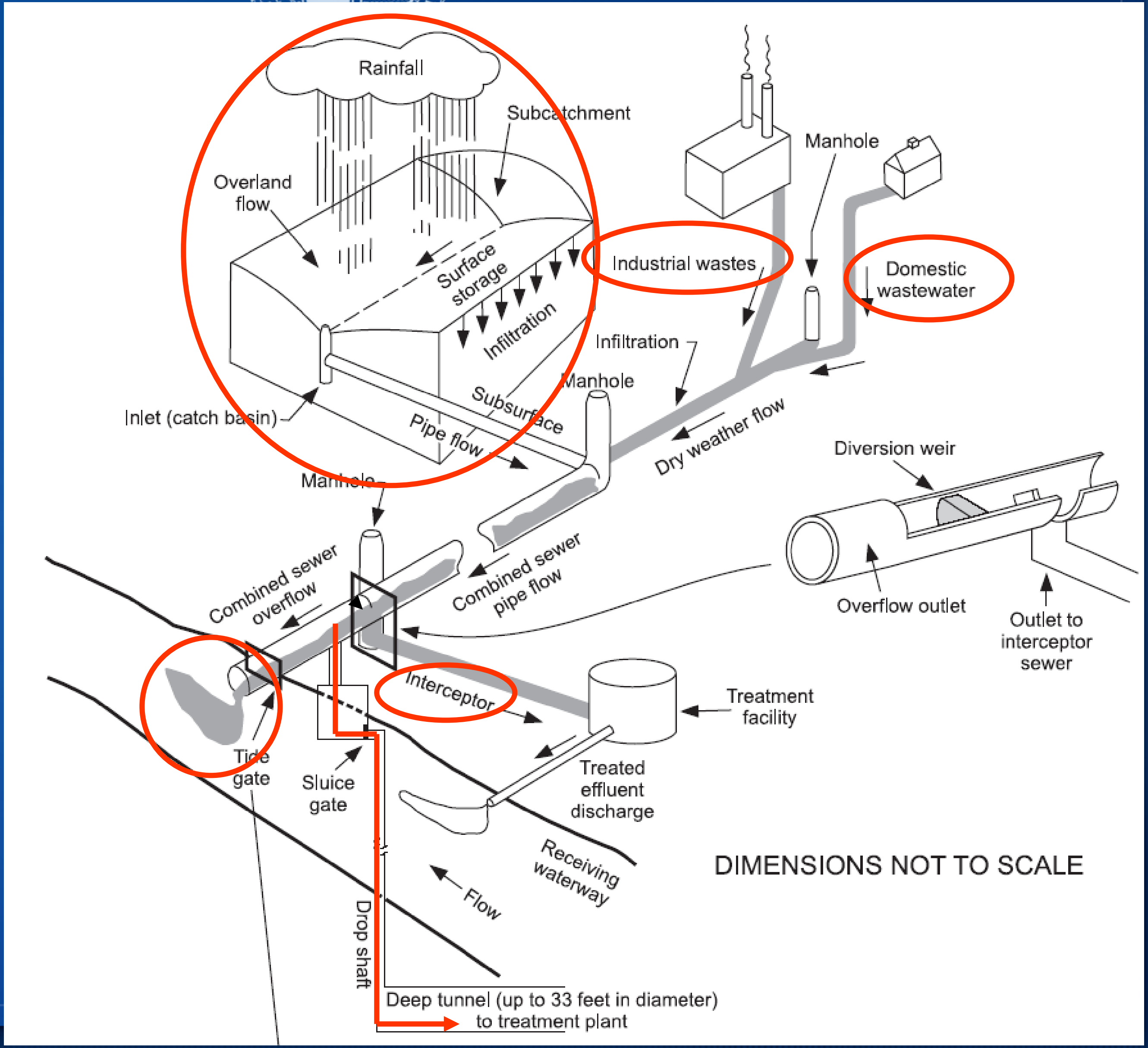
Combined Sewer Areas (375 square miles)

WRP's - 7

Tunnel and Reservoir Plan (TARP)

Purpose:

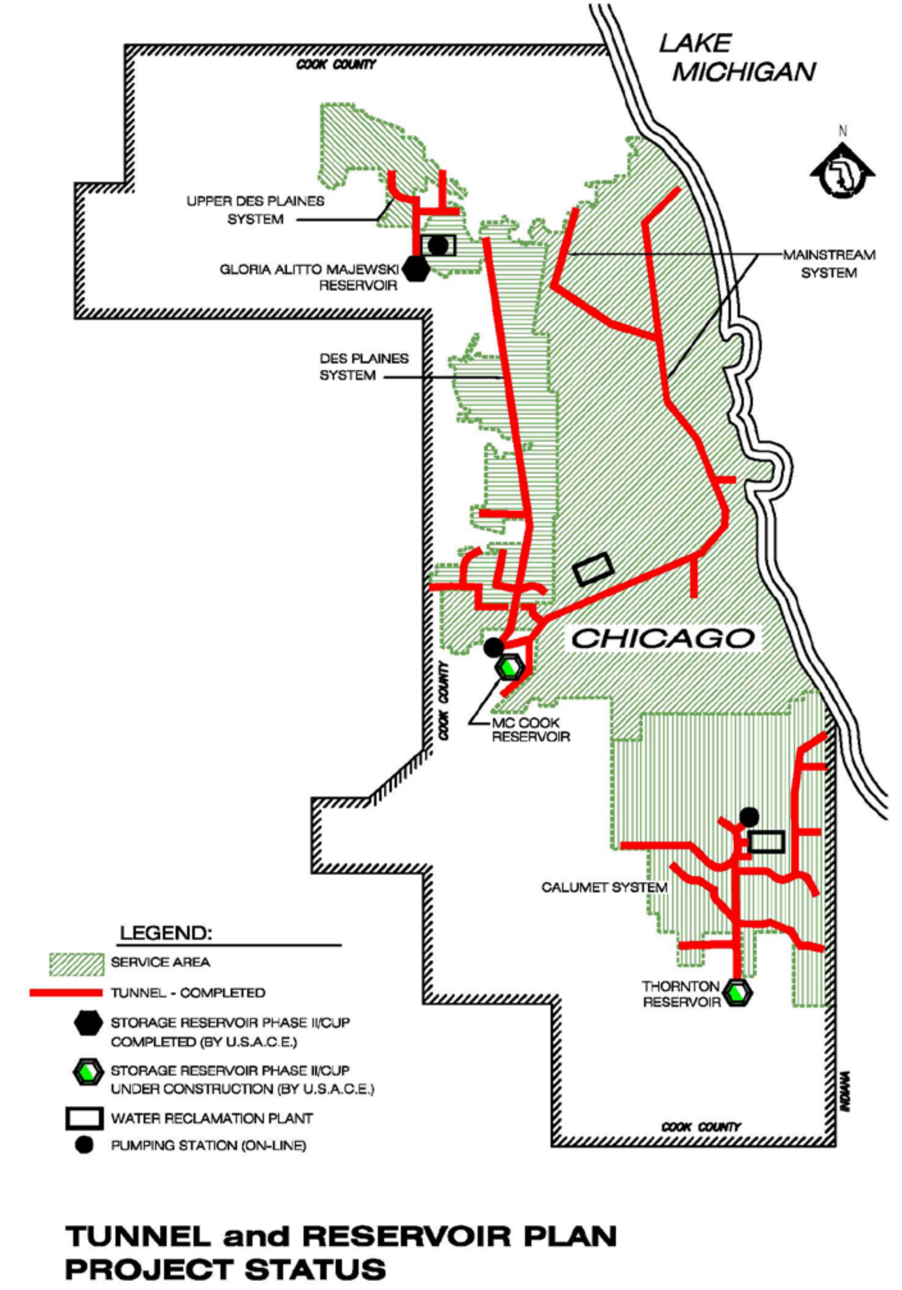
- Intercept
- Convey
- Store
- Reduce

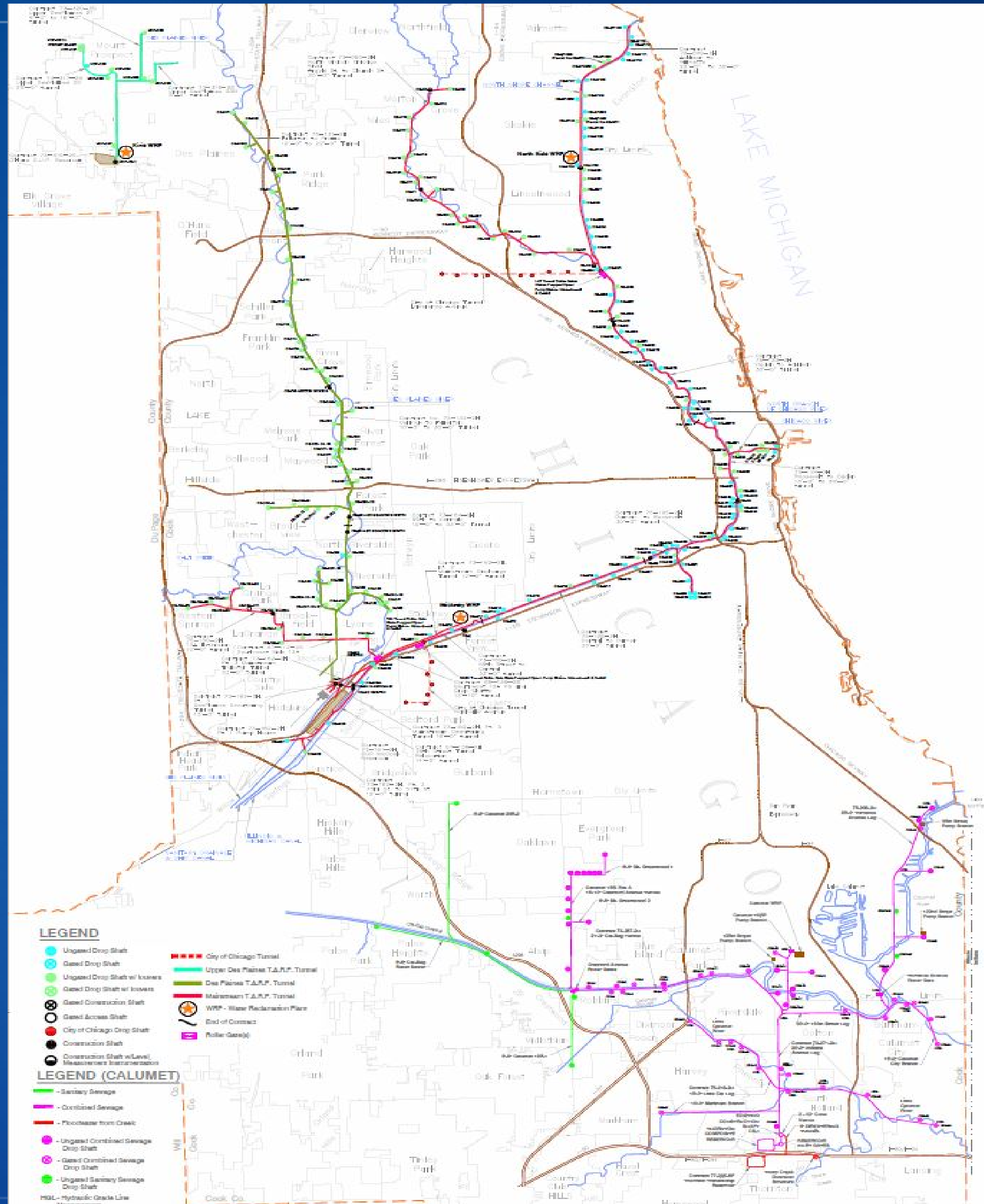


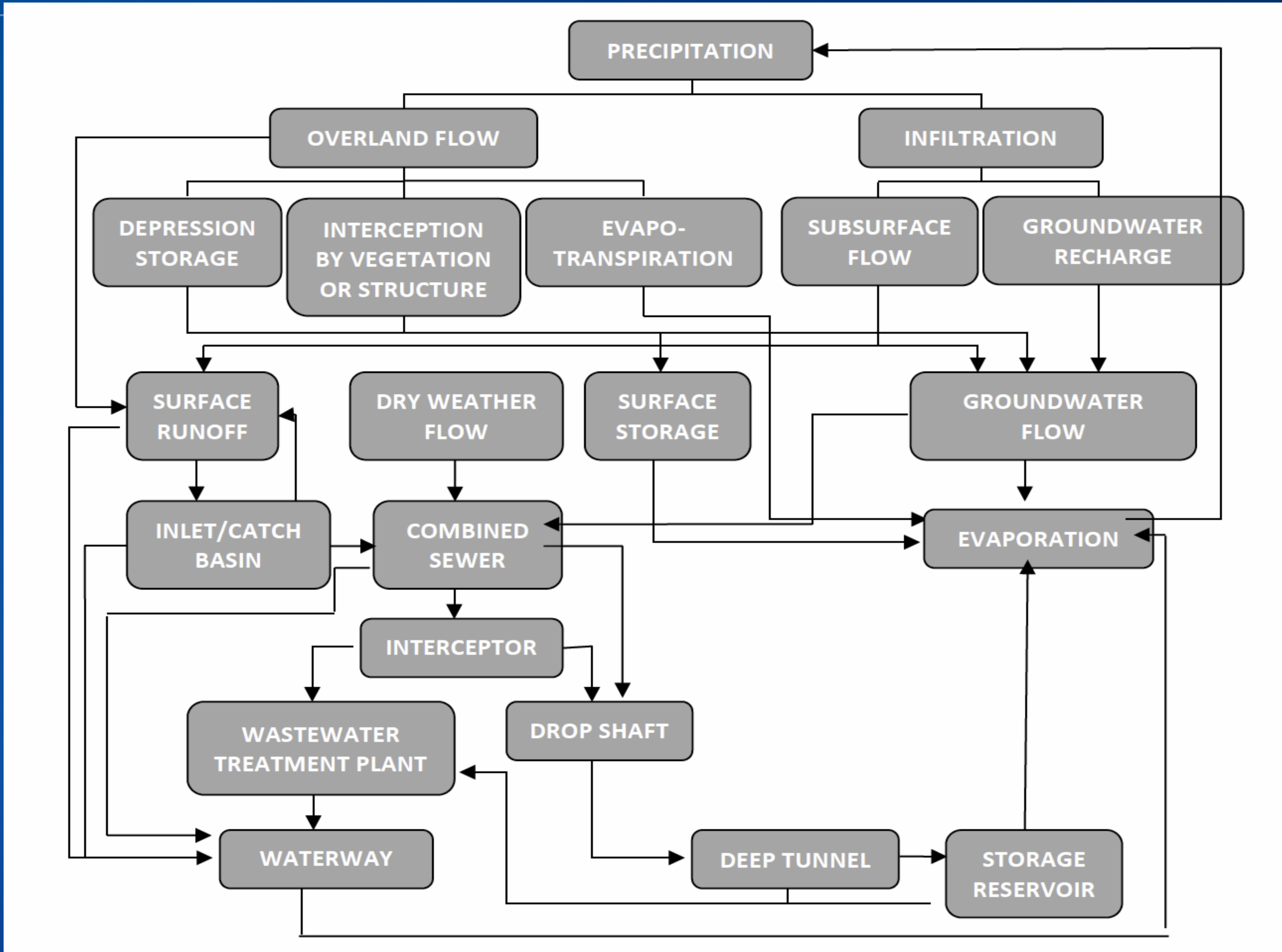
TARP

- Phase I
  (Pollution Control)
  109 miles of deep tunnels
  250 drop shafts
  600 Surface Connecting Structures
  Completed in March 2006

- Phase II
  (Flood Control)
  3 large reservoirs
  - *Gloria Alitto Majewski*
  - *Thornton Composite*
  - *McCook*




LAKE MICHIGAN
CHICAGO
LEGEND
Ungaged Drop Shaft
Gated Drop Shaft
Ungaged Drop Shaft w/ louvers
Gated Drop Shaft w/ louvers
Gated Construction Shaft
Gated Access Shaft
City of Chicago Drop Shaft
Construction Shaft
Construction Shaft w/Level Measurement Instrumentation
City of Chicago Tunnel
Upper Des Plaines T.A.R.P. Tunnel
Des Plaines T.A.R.P. Tunnel
Mainstream T.A.R.P. Tunnel
WRP - Water Reclamation Plant
End of Contract
Roller Gate(s)
LEGEND (CALUMET)
- Sanitary Sewage
- Combined Sewage
- Floodwater from Creek
- Ungaged Combined Sewage Drop Shaft
- Gated Combined Sewage Drop Shaft
- Ungaged Sanitary Sewage Drop Shaft
HGL - Hydraulic Grade Line Measurement


PRECIPITATION
OVERLAND FLOW
INFILTRATION
DEPRESSION STORAGE
INTERCEPTION BY VEGETATION OR STRUCTURE
EVAPO-TRANSPIRATION
SUBSURFACE FLOW
GROUNDWATER RECHARGE
SURFACE RUNOFF
DRY WEATHER FLOW
SURFACE STORAGE
GROUNDWATER FLOW
INLET/CATCH BASIN
COMBINED SEWER
EVAPORATION
INTERCEPTOR
WASTEWATER TREATMENT PLANT
DROP SHAFT
WATERWAY
DEEP TUNNEL
STORAGE RESERVOIR

What is needed?

- Simulate TARP as-built system:
  - Overcome limitations of widely used commercial models
  - Determine constraints within the system
  - Identify physical changes needed
  - Allow “what-if” analyses for potential storm scenarios
  - Optimize operation of system (revised operation rules)

Role of University of Illinois Urbana-Champaign

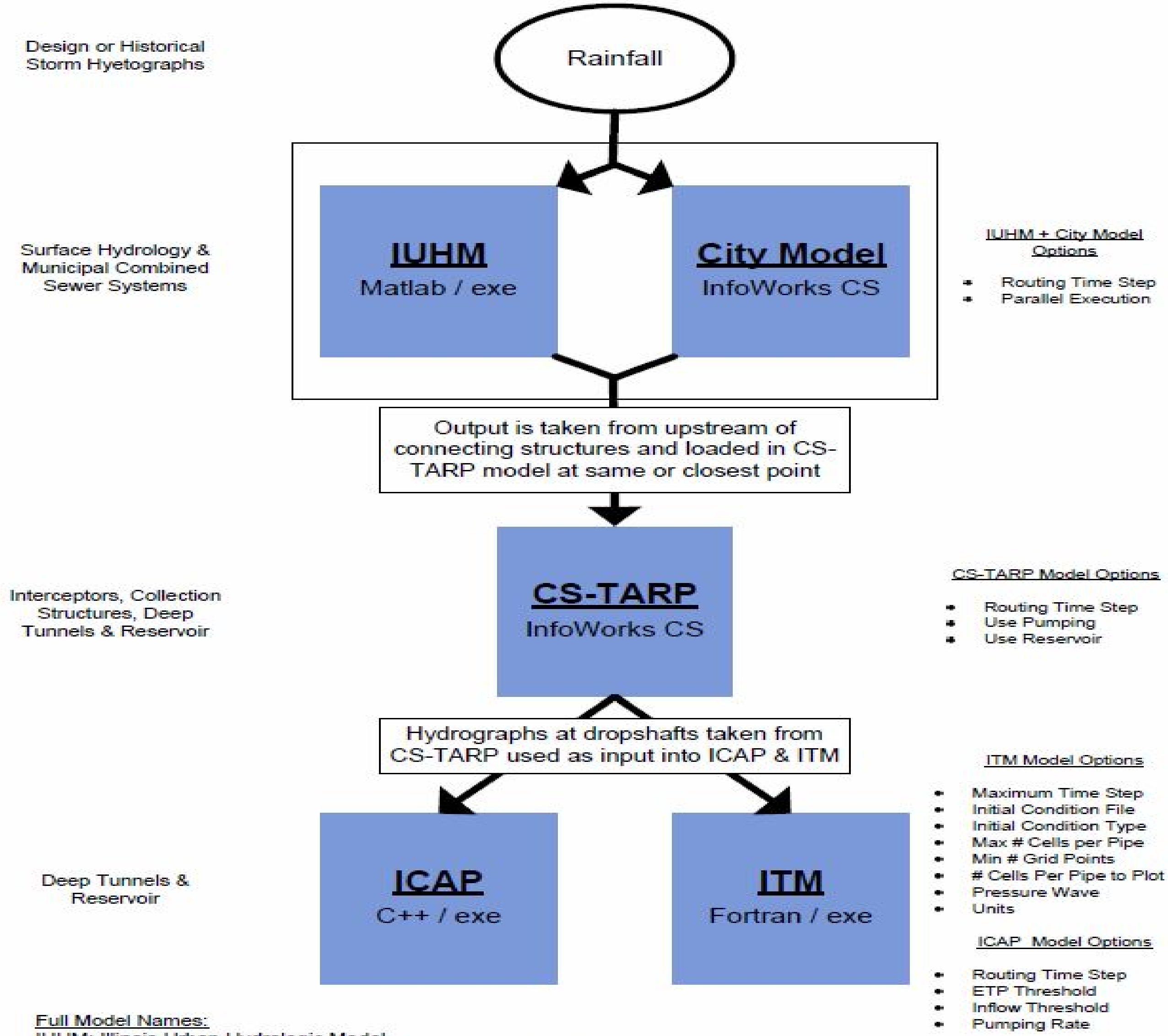
- Develop a model interface that includes hydrologic and hydraulic models to simulate TARP systems
  - Capable of simulating design storms, historical storms or extended continuous simulations (water years)
  - Provide tools to facilitate interpretation of simulation results
- Provide a framework so that different models, which reflect different purposes, scales, and levels of complexity, can be consolidated into a single system

TARP Model

Metroflow - User Friendly Model Interface

- Developed by University of Illinois Urbana-Champaign (U of I)
- Provides framework that allows different models to be consolidated into a single system
- Includes both hydrologic and hydraulic models

MetroFlow v1.7 MSDP Model Interaction



Full Model Names:
IUHM: Illinois Urban Hydrologic Model
CS-TARP: InfoWorks CS-TARP Model (CS = Collection Structures)
ICAP: Illinois Conveyance Analysis Program
ITM: Illinois Transient Model

Hydrologic Models

- Illinois Urban Hydrologic Model (IUHM)

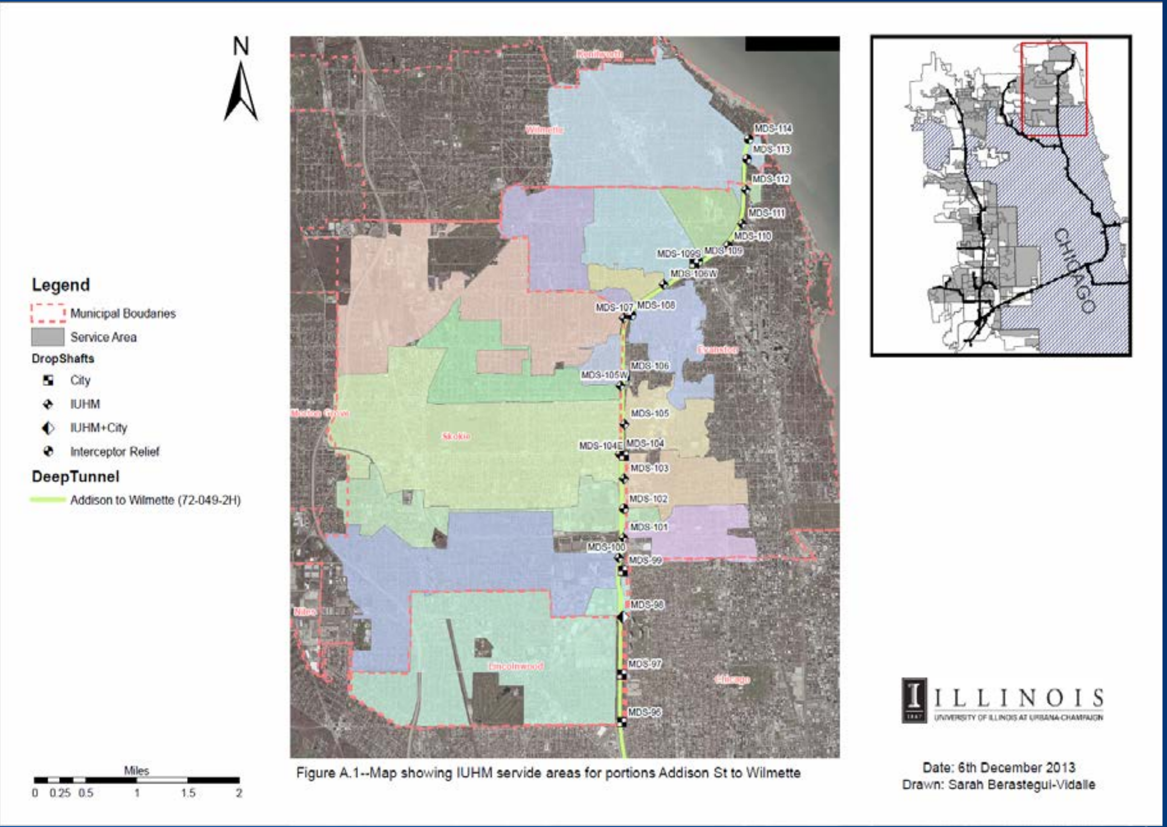
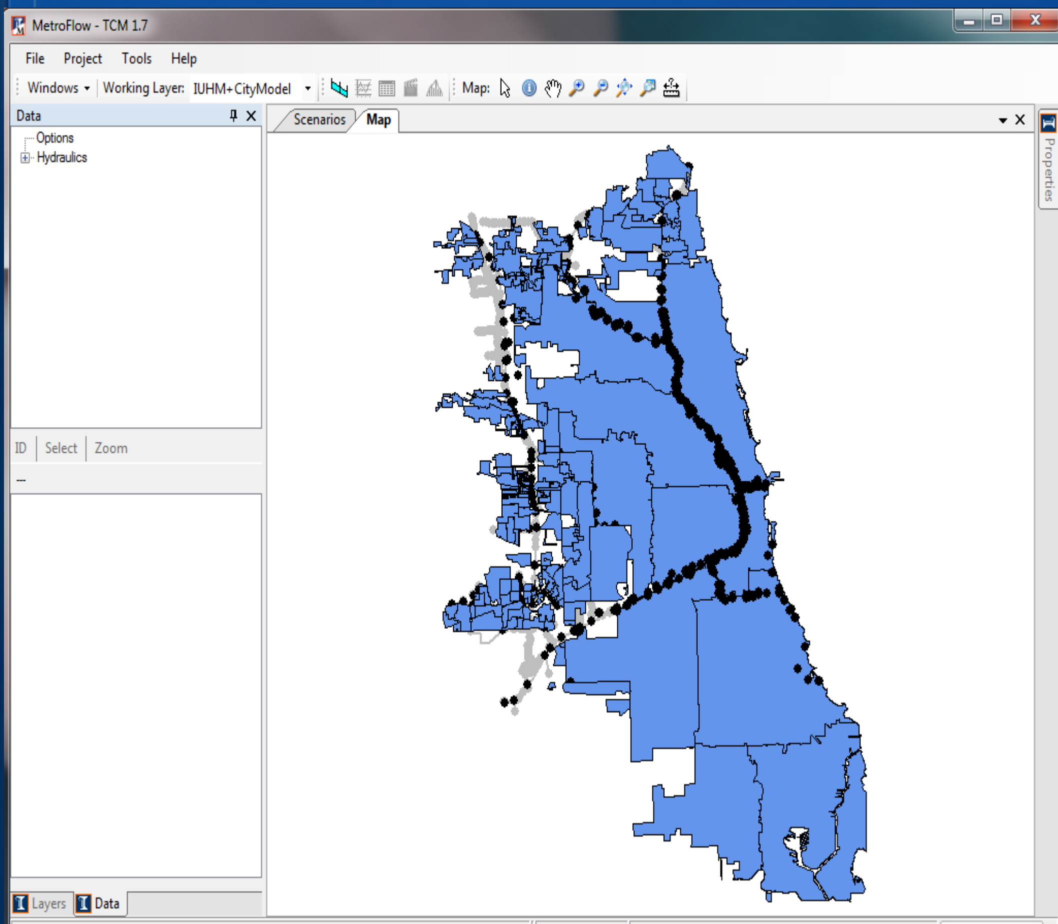


Figure A.1--Map showing IUHM servide areas for portions Addison St to Wilmette

- Developed by U of I for each service area outside of the city contributing to drop shafts in TARP
- Designed to simulate the transformation of rainfall to runoff, and the capture and conveyance through combined sewer systems that eventually contributes flow to TARP

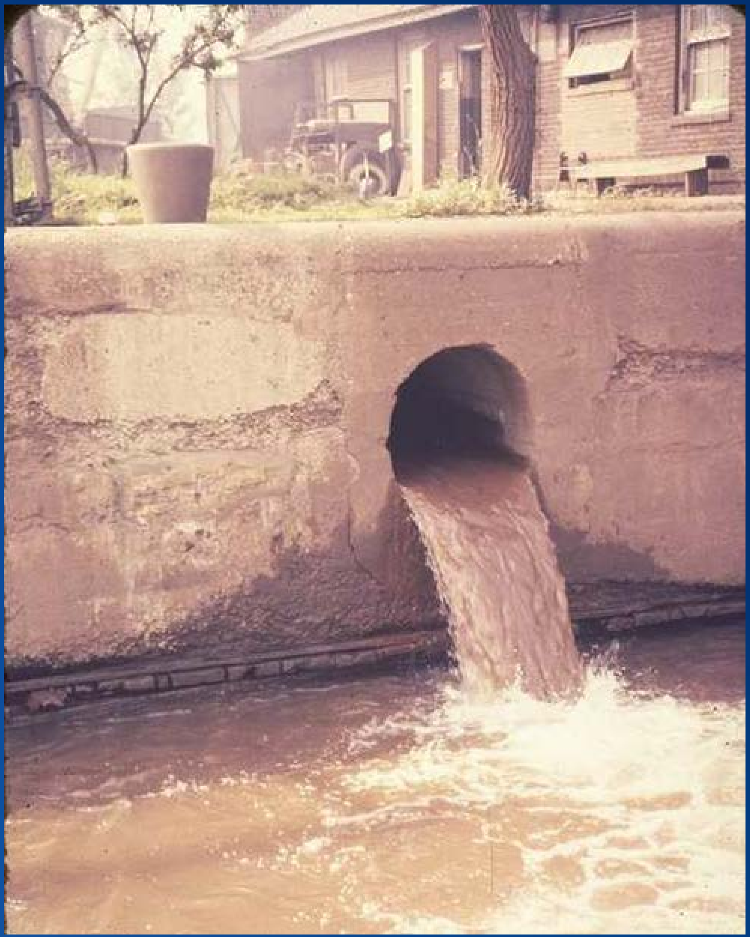
Hydrologic Models



- City Model
  - Utilizes InfoWorks CS
  - IUHM could not be used within city limits
  - Also simulates the transformation of rainfall to runoff, and conveyance through combined sewers to TARP

Hydraulic Models

- InfoWorks CS-TARP
  - Incorporates TARP tunnels and McCook Reservoir
  - Simulates unsteady flow and identifies bottlenecks in the TARP system.
  - Determines the distribution of flow between TARP drop shafts and combined sewer overflow locations
  - Determines volume, duration and frequency of CSO’s



Hydraulic Models

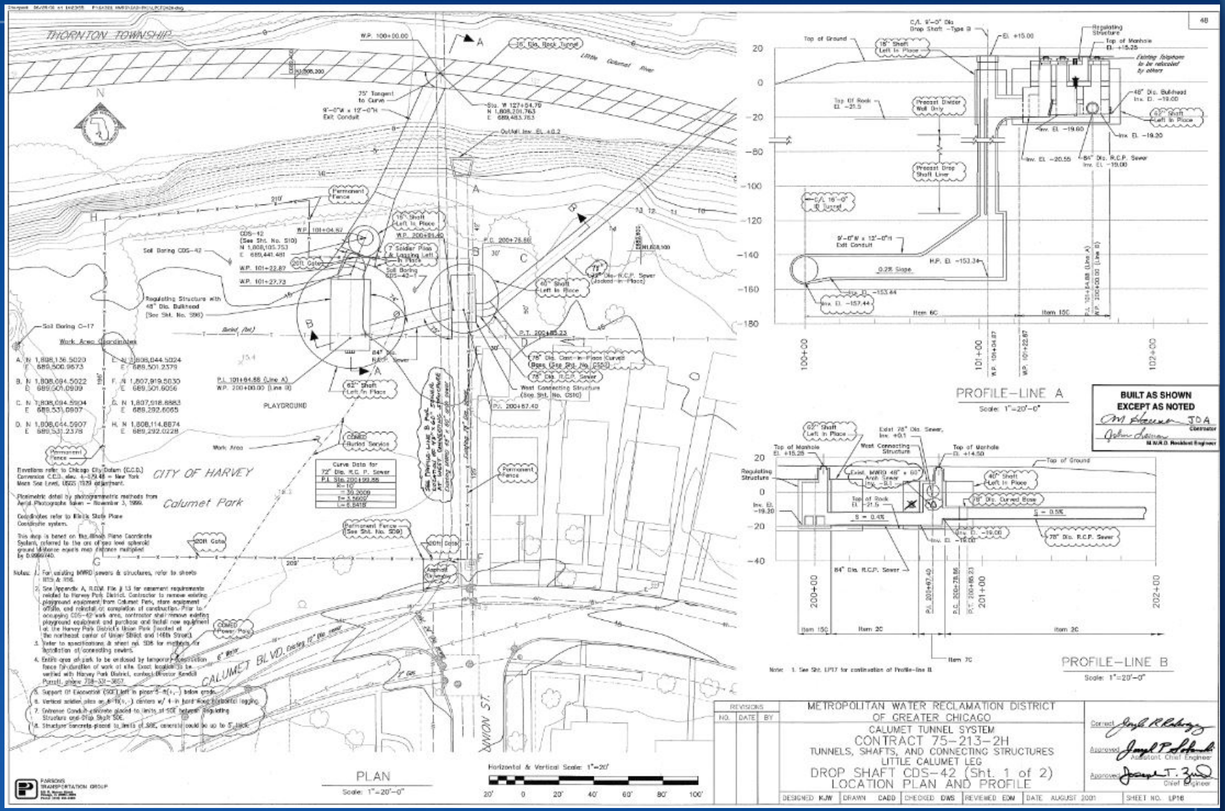
- Illinois Conveyance Analysis Program (ICAP)
  - Developed by U of I for analysis of the conveyance capacity of the tunnels and reservoirs
  - Allows for filling and dewatering of the tunnels and reservoirs to be simulated over extended periods (water year simulations)
  - Designed to identify bottlenecks in the system
  - Unable to accurately predict CSO volumes or simulate transient behavior

Hydraulic Models

- Illinois Transient Model (ITM)
  - Developed by U of I to simulate transient behavior that may be observed in the TARP system
  - Capable of predicting the formation of hydraulic transients and shocks and tracking them through the system
  - Not a model used for extended period simulations

Model Development

Physical Inventory



- Foundation for hydraulic models
- Based on construction “as-built” drawings
- Provided a digital description of the physical geometry and hydraulic performance of the systems

Data Collection

- TARP Tunnels
- TARP Drop Shafts
- Connecting Structures
- Control Structures
- Combined Sewer Outfalls
- Thornton Reservoir – Calumet
- McCook Reservoir – Mainstream and Des Plaines

Model Calibration

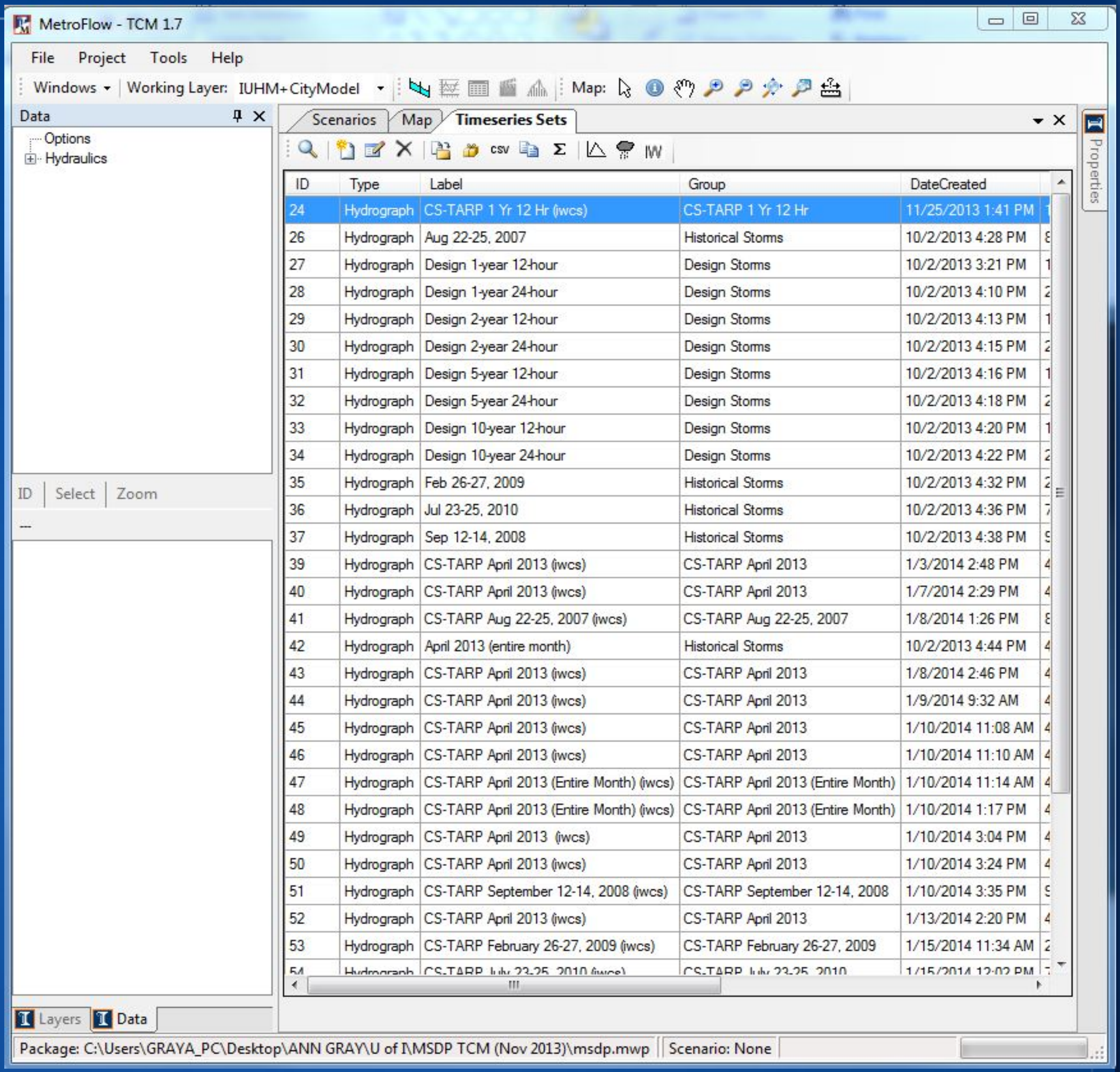
- USGS conducted flow monitoring at several drop shafts to allow for validation of hydrologic modeling
- U of I compared model run results from specific storm events to the actual flow metering results

Model Assumptions

- Interceptor flowing at capacity at time of the storm
- Uses existing District control rules for each TARP System
  - Ex: TARP Sluice Gates
- Ability to run models using reservoir or no reservoir scenarios

Model Runs

- Design Storms
  - 1 Year, 12 Hour
  - 5 Year, 12 Hour
  - 10 Year, 24 Hour
- Historical Storms
  - August 2007
  - September 2008
  - February 2009
  - July 2010
- Water Years
  - WY 2009
  - WY 2010
  - WY 2011



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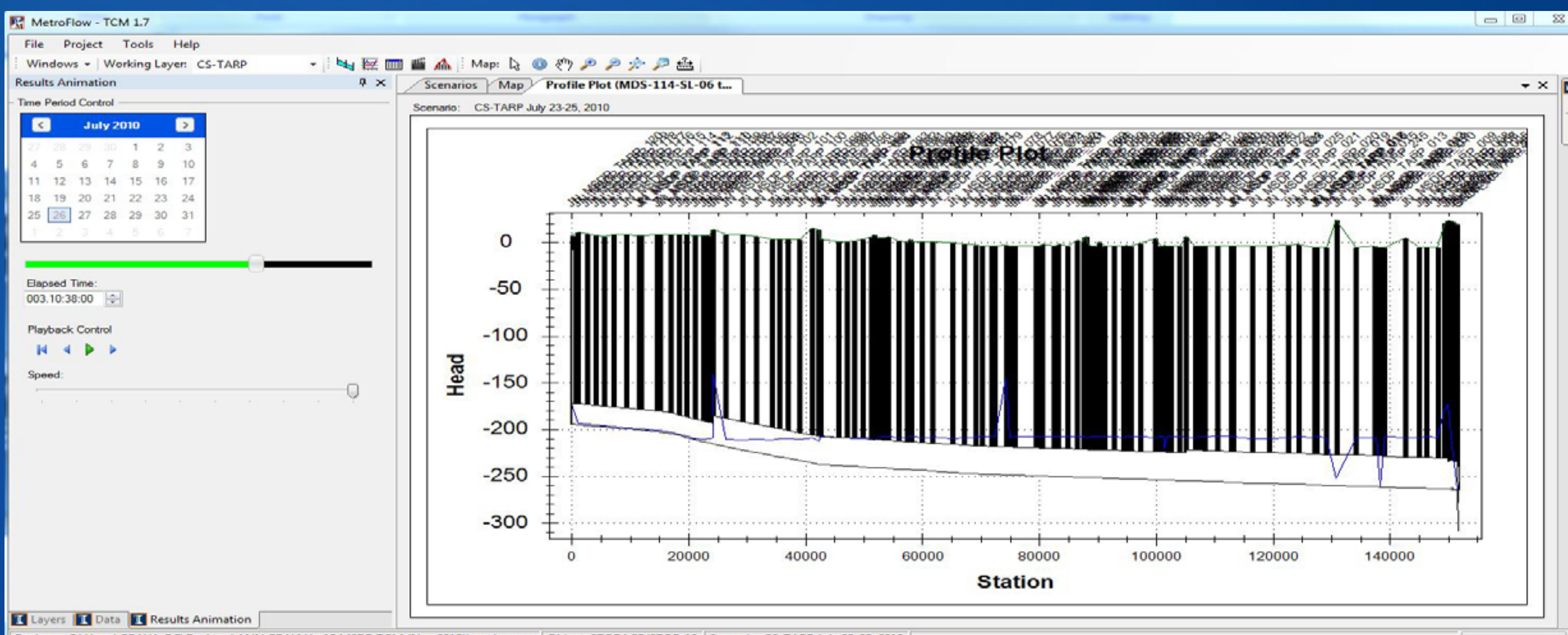
26	Hydrograph	Aug 22-25, 2007	Historical Storms	10/2/2013 4:28 PM
27	Hydrograph	Design 1-year 12-hour	Design Storms	10/2/2013 3:21 PM
28	Hydrograph	Design 1-year 24-hour	Design Storms	10/2/2013 4:10 PM
29	Hydrograph	Design 2-year 12-hour	Design Storms	10/2/2013 4:13 PM
30	Hydrograph	Design 2-year 24-hour	Design Storms	10/2/2013 4:15 PM
31	Hydrograph	Design 5-year 12-hour	Design Storms	10/2/2013 4:16 PM
32	Hydrograph	Design 5-year 24-hour	Design Storms	10/2/2013 4:18 PM
33	Hydrograph	Design 10-year 12-hour	Design Storms	10/2/2013 4:20 PM
34	Hydrograph	Design 10-year 24-hour	Design Storms	10/2/2013 4:22 PM
35	Hydrograph	Feb 26-27, 2009	Historical Storms	10/2/2013 4:32 PM
36	Hydrograph	Jul 23-25, 2010	Historical Storms	10/2/2013 4:36 PM
37	Hydrograph	Sep 12-14, 2008	Historical Storms	10/2/2013 4:38 PM
39	Hydrograph	CS-TARP April 2013 (iwcs)	CS-TARP April 2013	1/3/2014 2:48 PM
40	Hydrograph	CS-TARP April 2013 (iwcs)	CS-TARP April 2013	1/7/2014 2:29 PM
41	Hydrograph	CS-TARP Aug 22-25, 2007 (iwcs)	CS-TARP Aug 22-25, 2007	1/8/2014 1:26 PM
42	Hydrograph	April 2013 (entire month)	Historical Storms	10/2/2013 4:44 PM
43	Hydrograph	CS-TARP April 2013 (iwcs)	CS-TARP April 2013	1/8/2014 2:46 PM
44	Hydrograph	CS-TARP April 2013 (iwcs)	CS-TARP April 2013	1/9/2014 9:32 AM
45	Hydrograph	CS-TARP April 2013 (iwcs)	CS-TARP April 2013	1/10/2014 11:08 AM
46	Hydrograph	CS-TARP April 2013 (iwcs)	CS-TARP April 2013	1/10/2014 11:10 AM
47	Hydrograph	CS-TARP April 2013 (Entire Month) (iwcs)	CS-TARP April 2013 (Entire Month)	1/10/2014 11:14 AM
48	Hydrograph	CS-TARP April 2013 (Entire Month) (iwcs)	CS-TARP April 2013 (Entire Month)	1/10/2014 1:17 PM
49	Hydrograph	CS-TARP April 2013 (iwcs)	CS-TARP April 2013	1/10/2014 3:04 PM
50	Hydrograph	CS-TARP April 2013 (iwcs)	CS-TARP April 2013	1/10/2014 3:24 PM
51	Hydrograph	CS-TARP September 12-14, 2008 (iwcs)	CS-TARP September 12-14, 2008	1/10/2014 3:35 PM
52	Hydrograph	CS-TARP April 2013 (iwcs)	CS-TARP April 2013	1/13/2014 2:20 PM
53	Hydrograph	CS-TARP February 26-27, 2009 (iwcs)	CS-TARP February 26-27, 2009	1/15/2014 11:34 AM

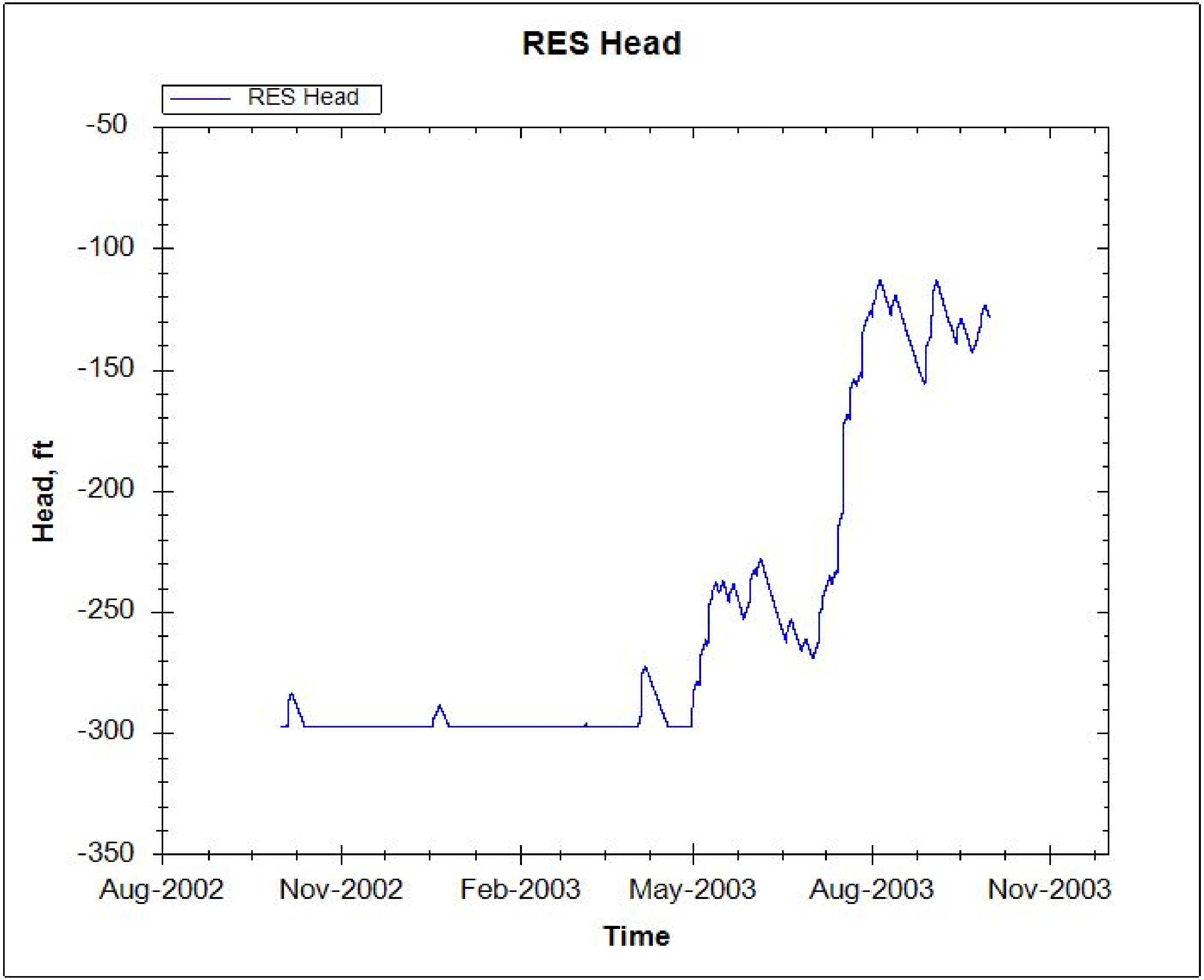
How Long Does it Take to Perform Model Runs?

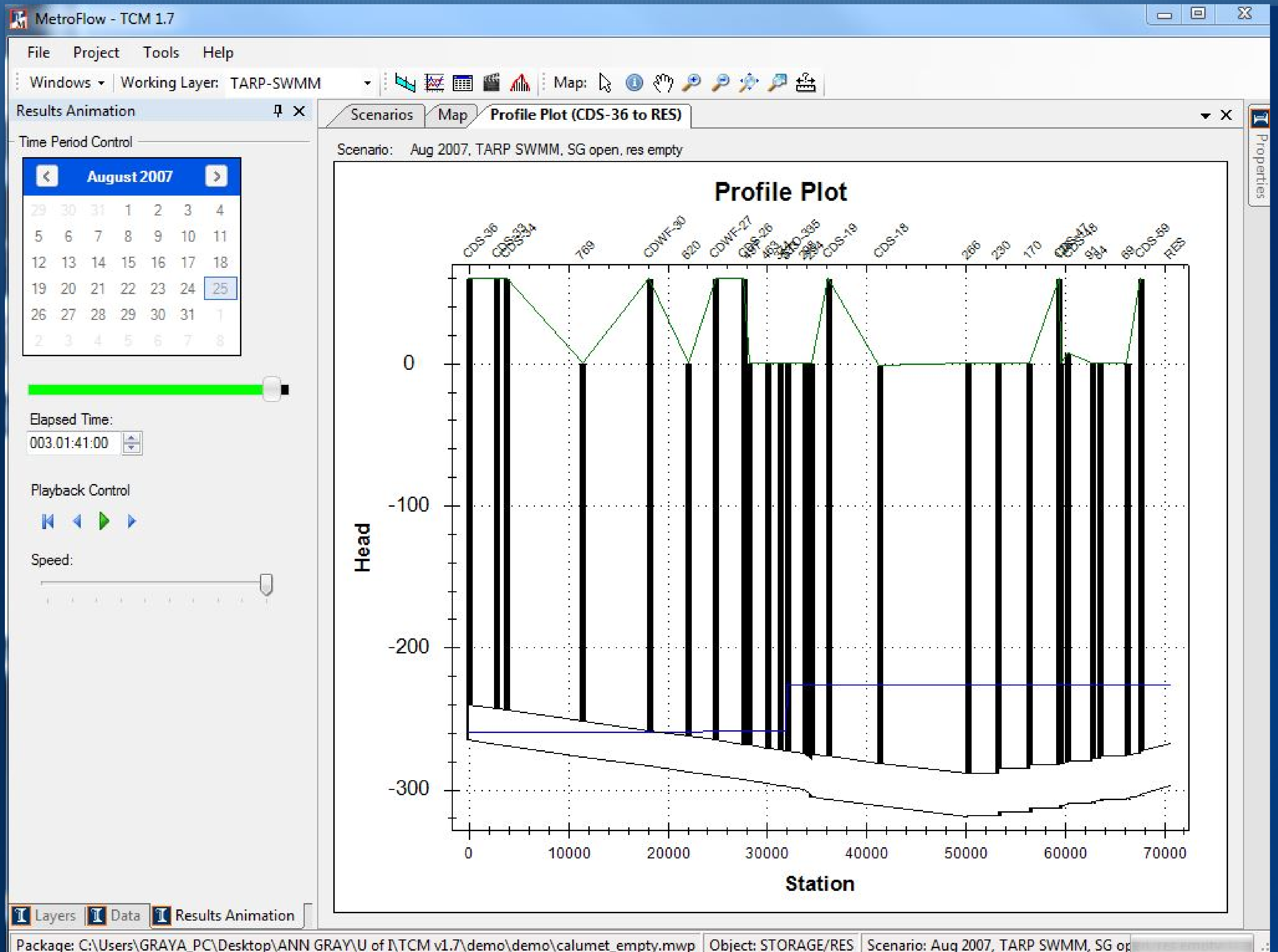
- IUHM + City Model: 20 Minutes
- CS-TARP: 10 Minutes
- ICAP: 2 Minutes
- ITM: Hours

Model Outputs

- Map Displays to indicate frequency and duration of combined sewer overflows
- Time-Animated Profile Plots of water elevations
- Graphs and Tables showing flows and water elevations




RES Head
RES Head
-50
-100
-150
-200
-250
-300
-350
Head, ft
Aug-2002
Nov-2002
Feb-2003
May-2003
Aug-2003
Nov-2003
Time


MetroFlow - TCM 1.7
File
Project
Tools
Help
Windows
Working Layer:
TARP-SWMM
Map:
Results Animation
Time Period Control
August 2007
29 30 31 1 2 3 4
5 6 7 8 9 10 11
12 13 14 15 16 17 18
19 20 21 22 23 24 25
26 27 28 29 30 31 1
2 3 4 5 6 7 8
Elapsed Time:
003.01:41:00
Playback Control
Speed:
Layers
Data
Results Animation
Scenarios
Map
Profile Plot (CDS-36 to RES)
Scenario: Aug 2007, TARP SWMM, SG open, res empty
Profile Plot
CDS-36
769
CDWF-30
620
CDWF-27
CDS-26
CDS-19
CDS-18
266
230
170
CDS-59
RES
Head
0
-100
-200
-300
0
10000
20000
30000
40000
50000
60000
70000
Station
Properties
Package: C:\Users\GRAYA_PC\Desktop\ANN GRAY\U of I\TCM v1.7\demo\demo\calumet_empty.mwp
Object: STORAGE/RES
Scenario: Aug 2007, TARP SWMM, SG op

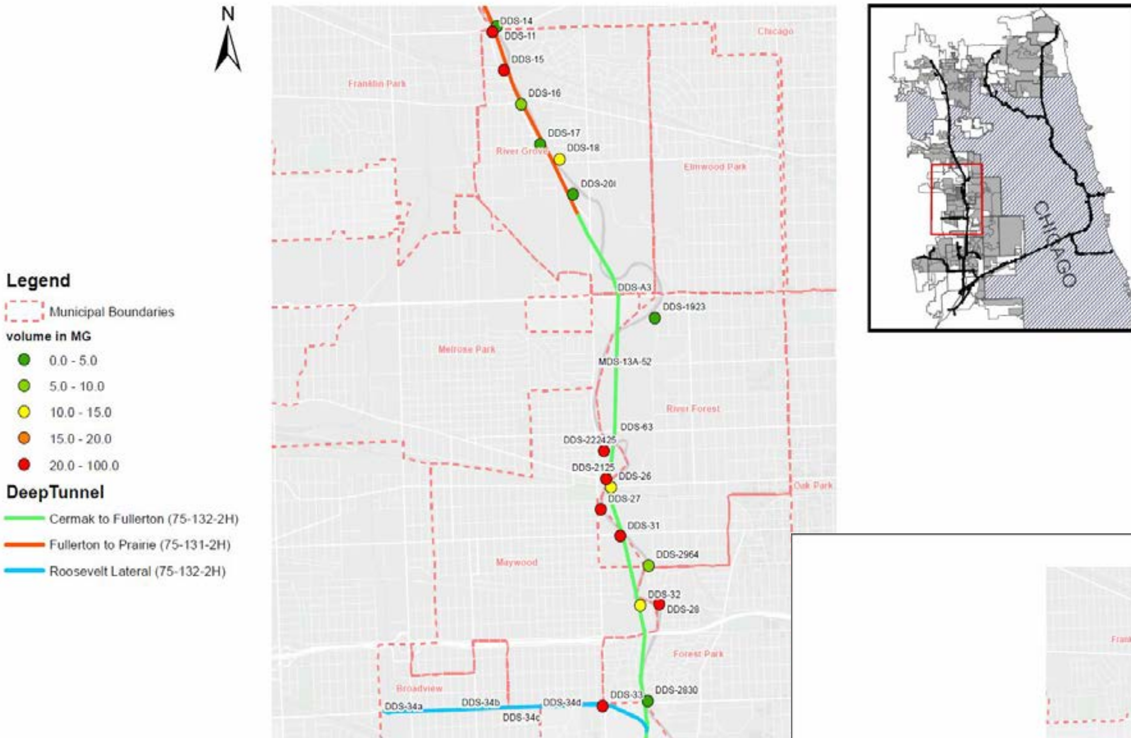


Figure B.10.210--Map showing CSO volumes for September 2008 storm with No Rese
for portions of Cermak Rd. to Fulleton Ave. and Roosevelt Rd. Lateral

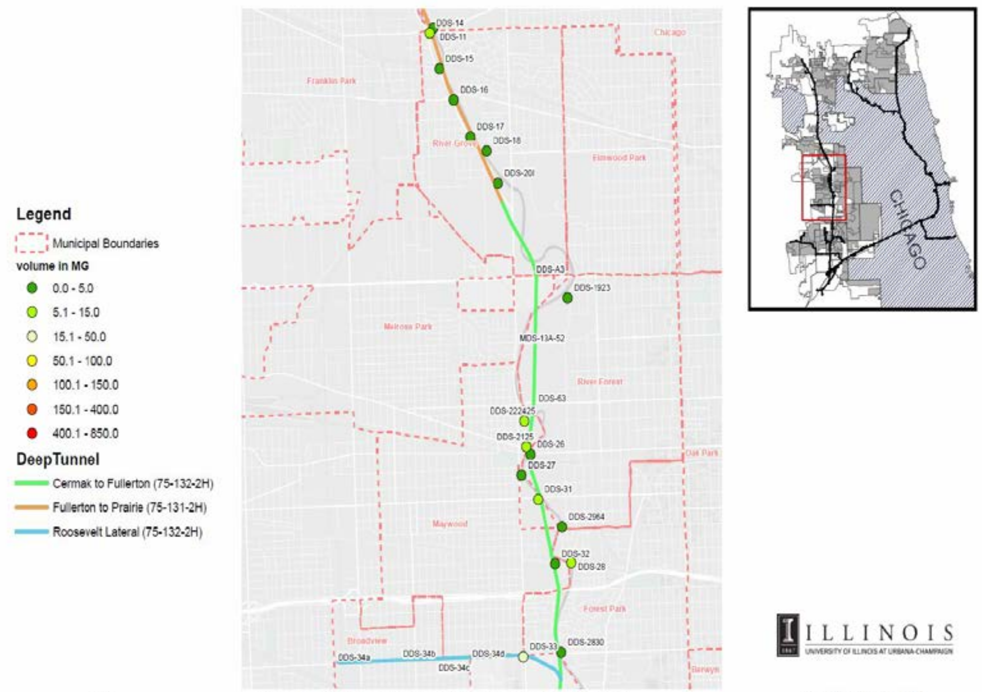


Figure B.10.10--Map showing CSO volumes for september 2008 storm
for portions of Cermak Rd. to Fulleton Ave. and Roosevelt Rd. Lateral

ILLINOIS
UNIVERSITY OF ILLINOIS AT URBANA-CHAMPAIGN

Date: 6th December 2013
Drawn: Sarah Berastegui-Vidalle

Total CSO Volume With and Without McCook Reservoir Online

Storm	CSO Volume (MG)	
	No Reservoir	Reservoir
1 YR/12 HR	1350	18
1 YR/24 HR	1220	25
5 YR/12 HR	3050	271
5 YR/24 HR	2630	39
10 YR/12 HR	4100	271
10 YR/24 HR	3530	39
Aug 2007	1950	30
Sept 2008	5000	2060
Feb 2009	1050	37
July 2010	7050	3550

Mainstream & Des Plaines System Deep Tunnel Modeling

Patrick Jensen
Associate Civil Engineer, P.E.

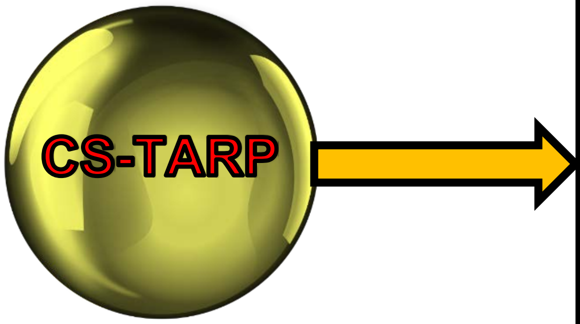
Outline:

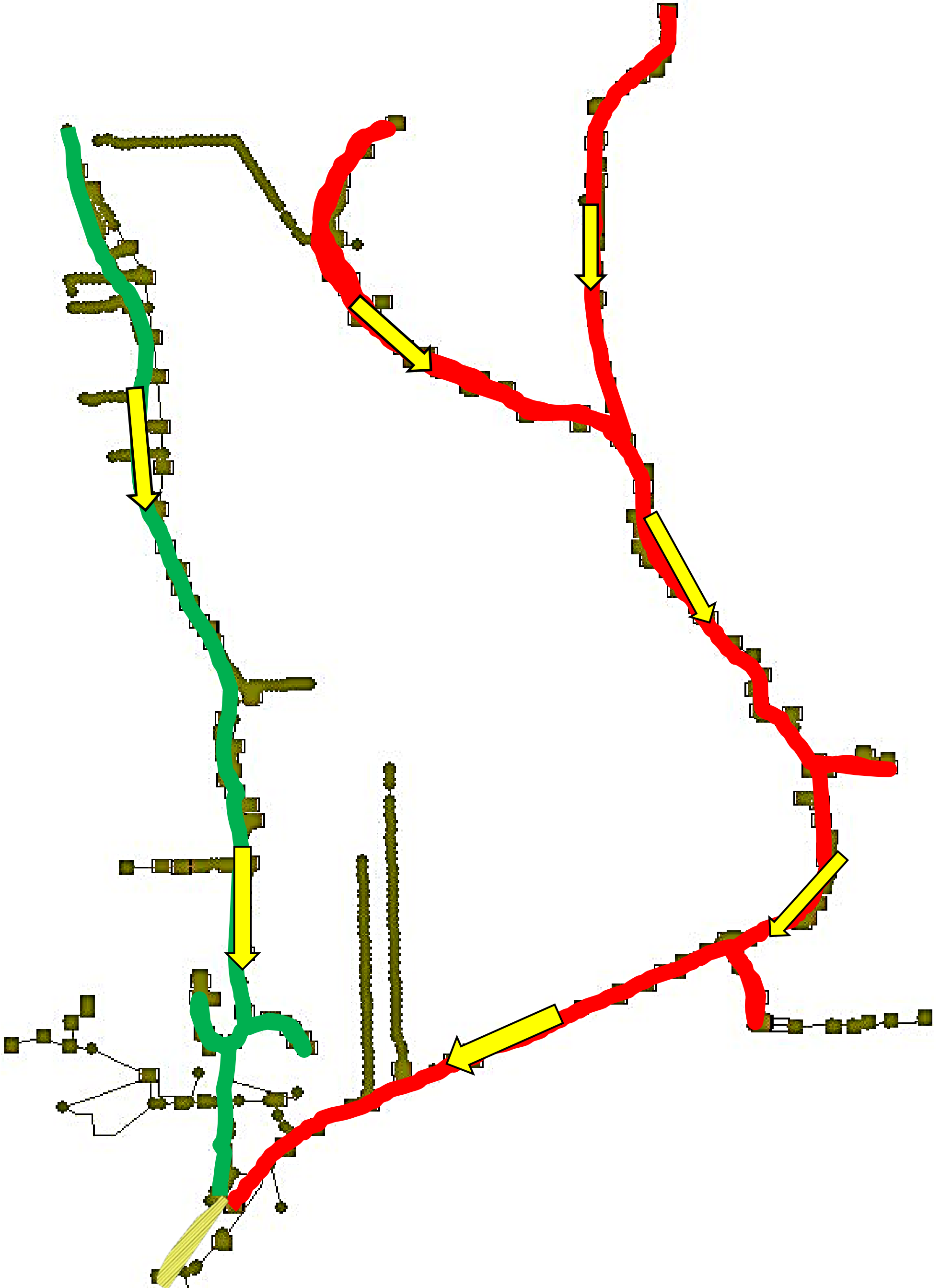
- Purpose
- Background on IUHM model
- Development of revised model
- Results
- Project Alternatives
- Questions

Purpose: To enhance MWRD'S existing hydrologic model to provide results related to CSO & flood reduction alternatives.

CS-TARP

MODEL





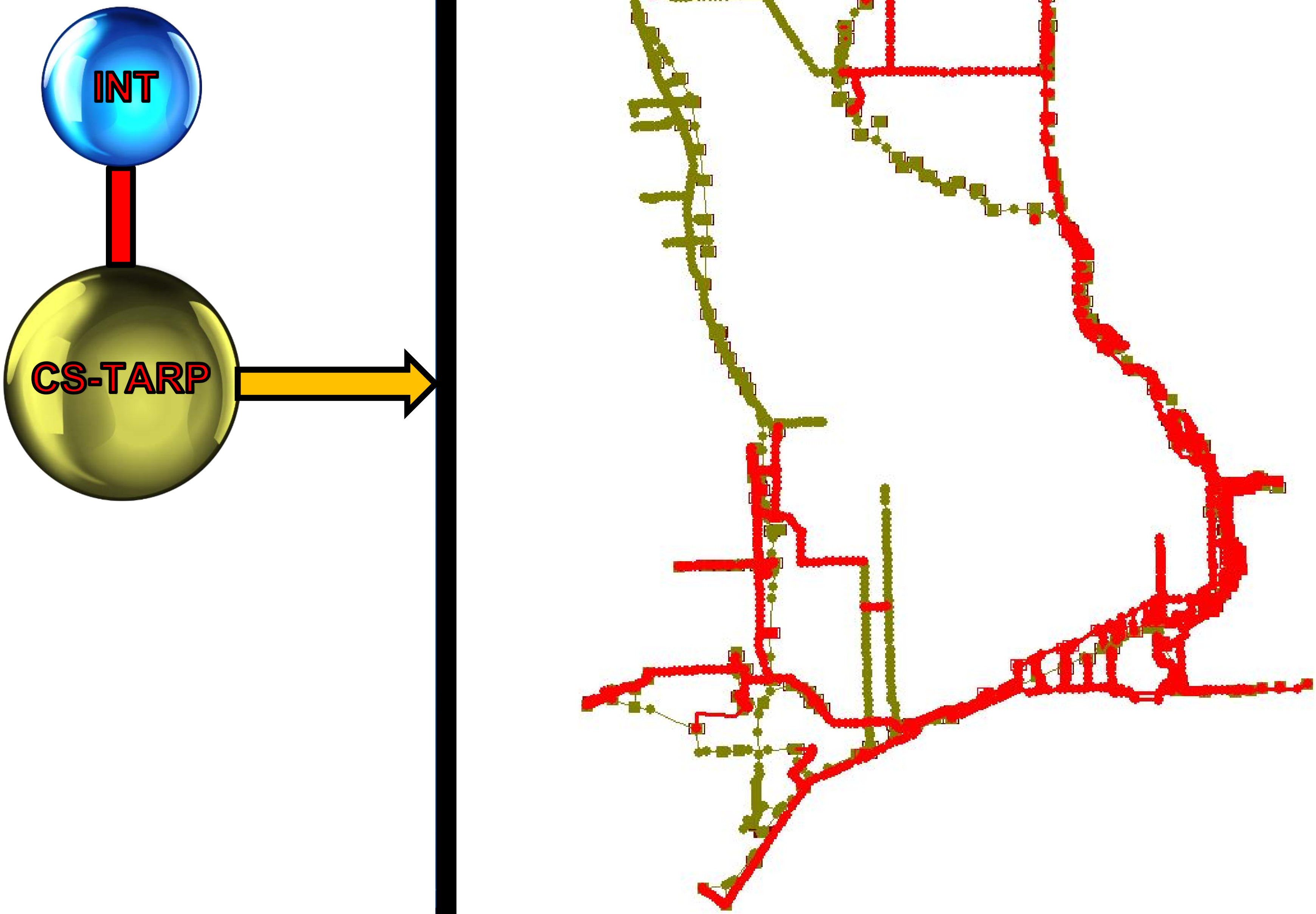
Adding Interceptors Improves Model By :

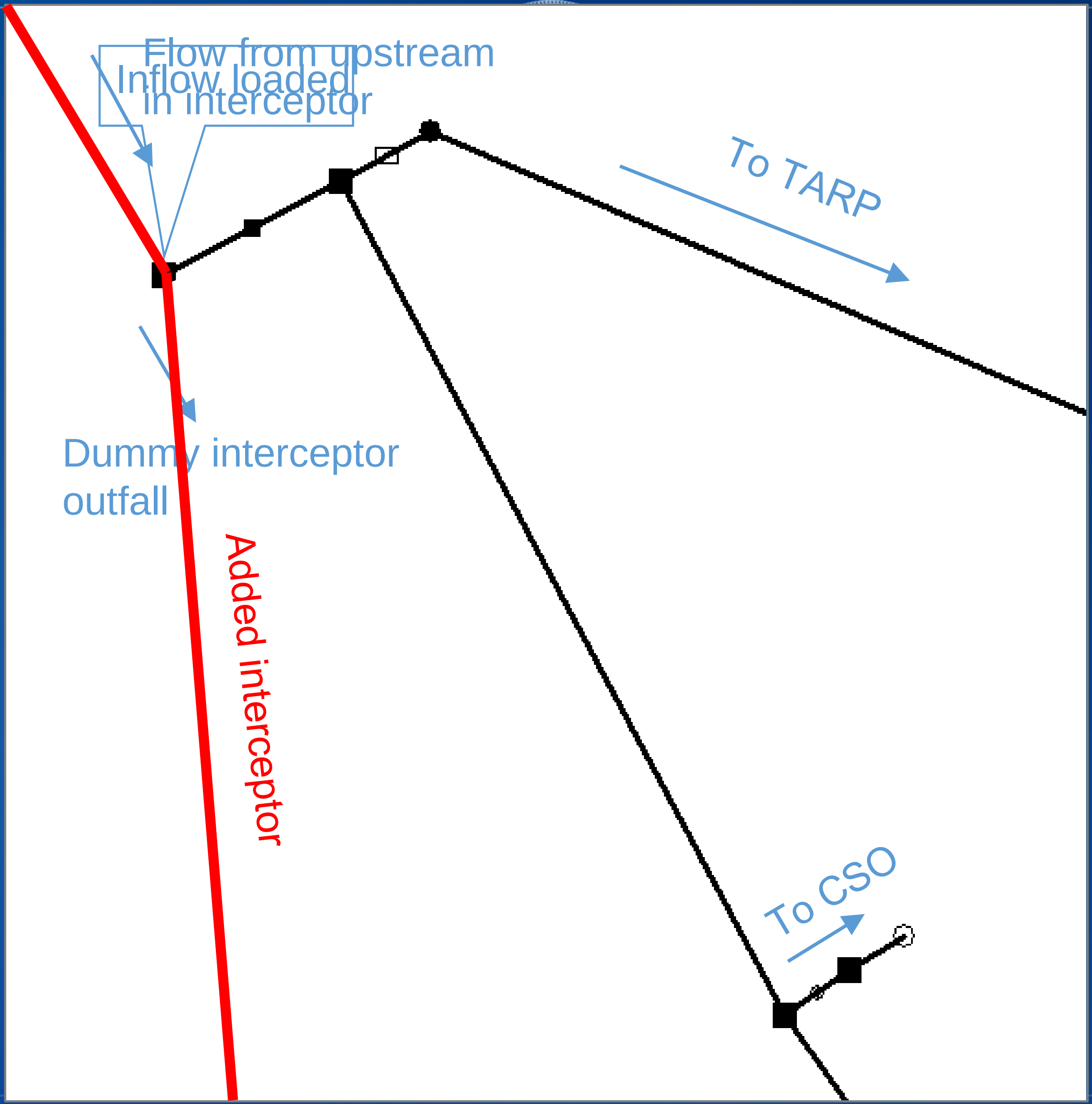
- Links local sewer performance, CSO overflow volume & TARP availability

- Increase confidence in CSO volume & peak flow values

- Better represents flows to WRPs

MODEL





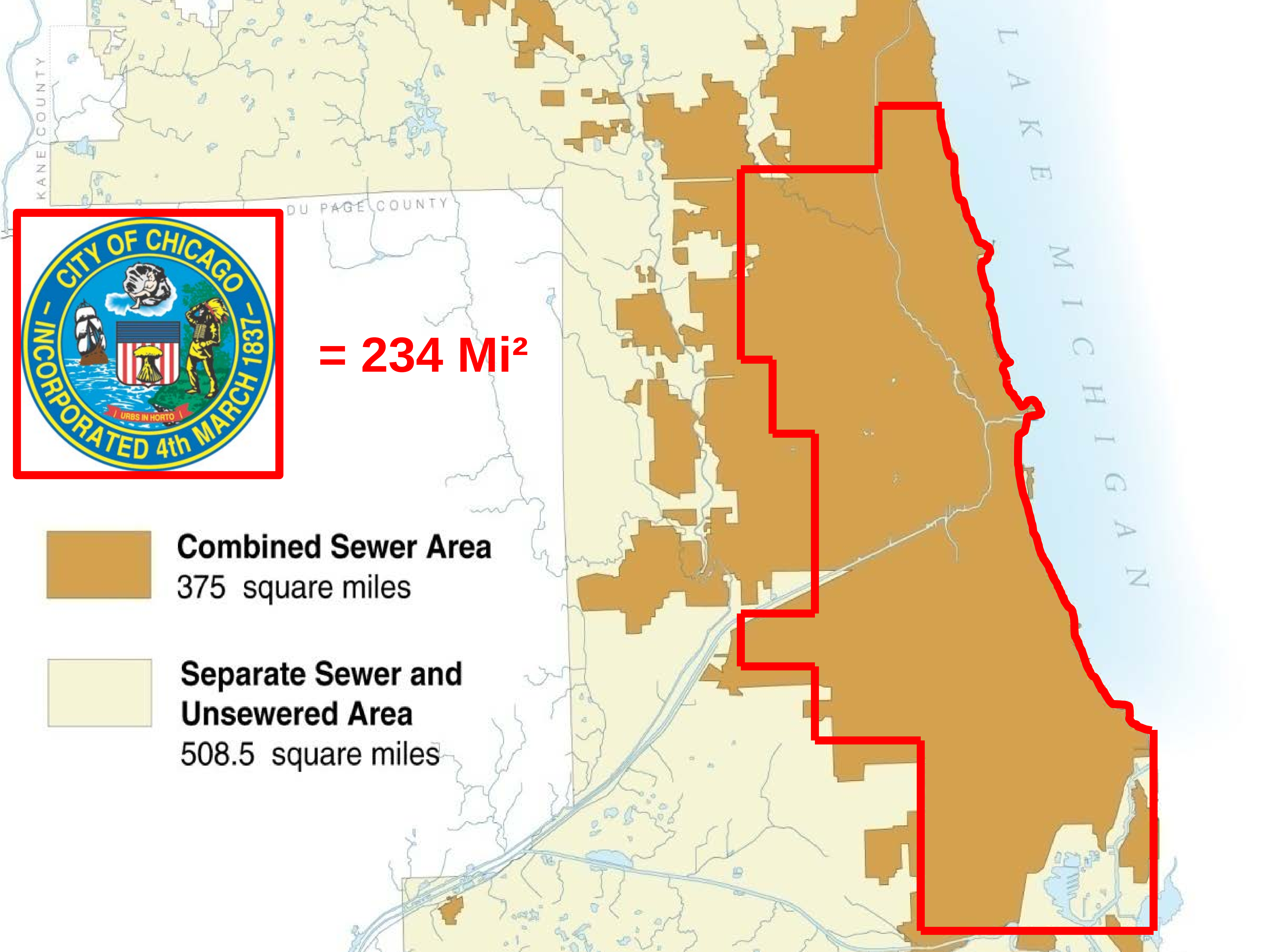
Flow from upstream
Inflow loaded
in interceptor
To TARP
Dummy interceptor
outfall
Added interceptor
To CSO

Stickney WRP

Max
1.26 BGD

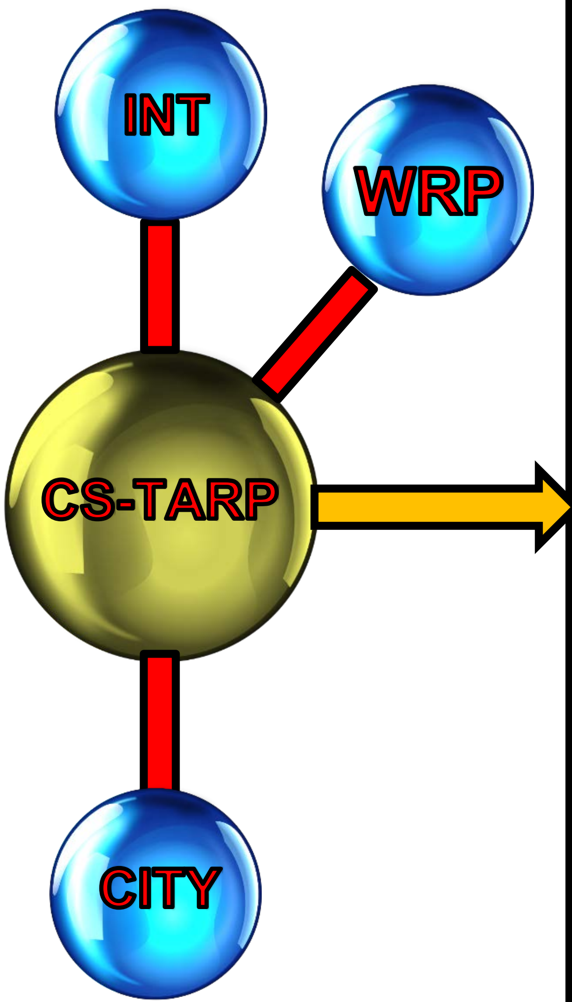
O'Brien WRP

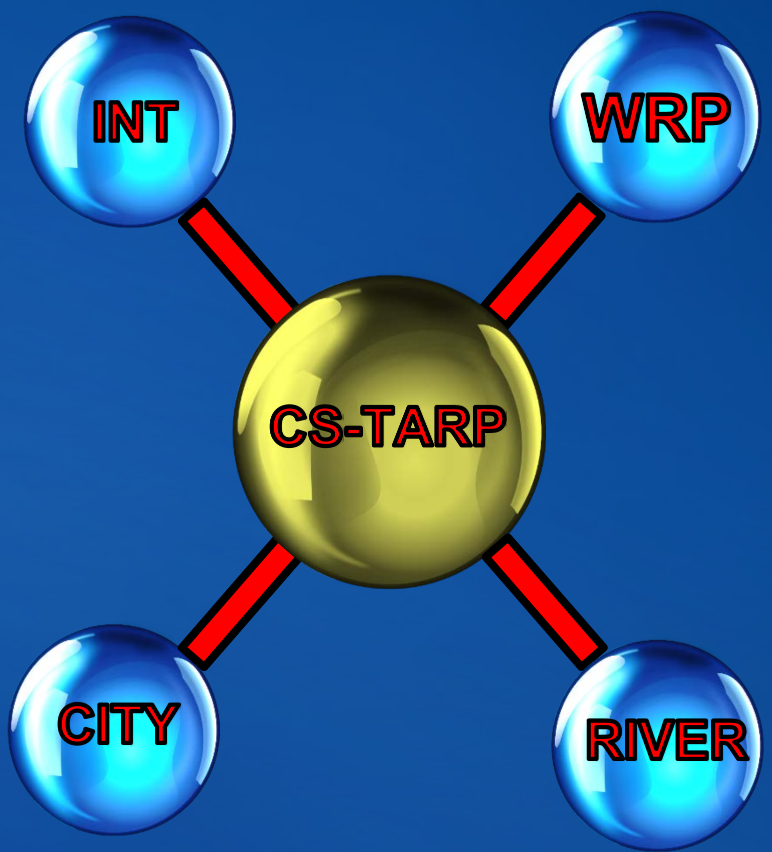
Max
0.30 BGD

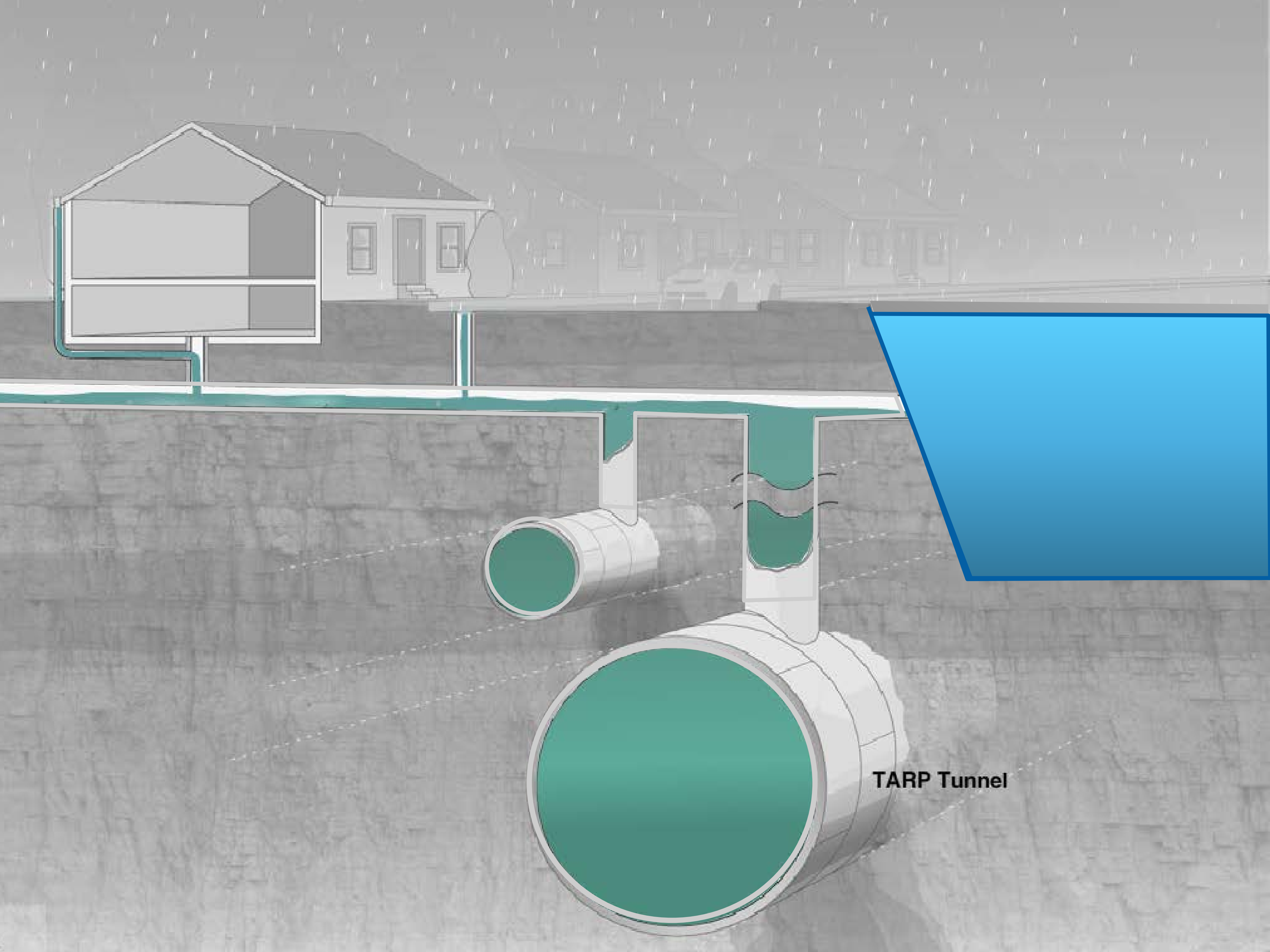


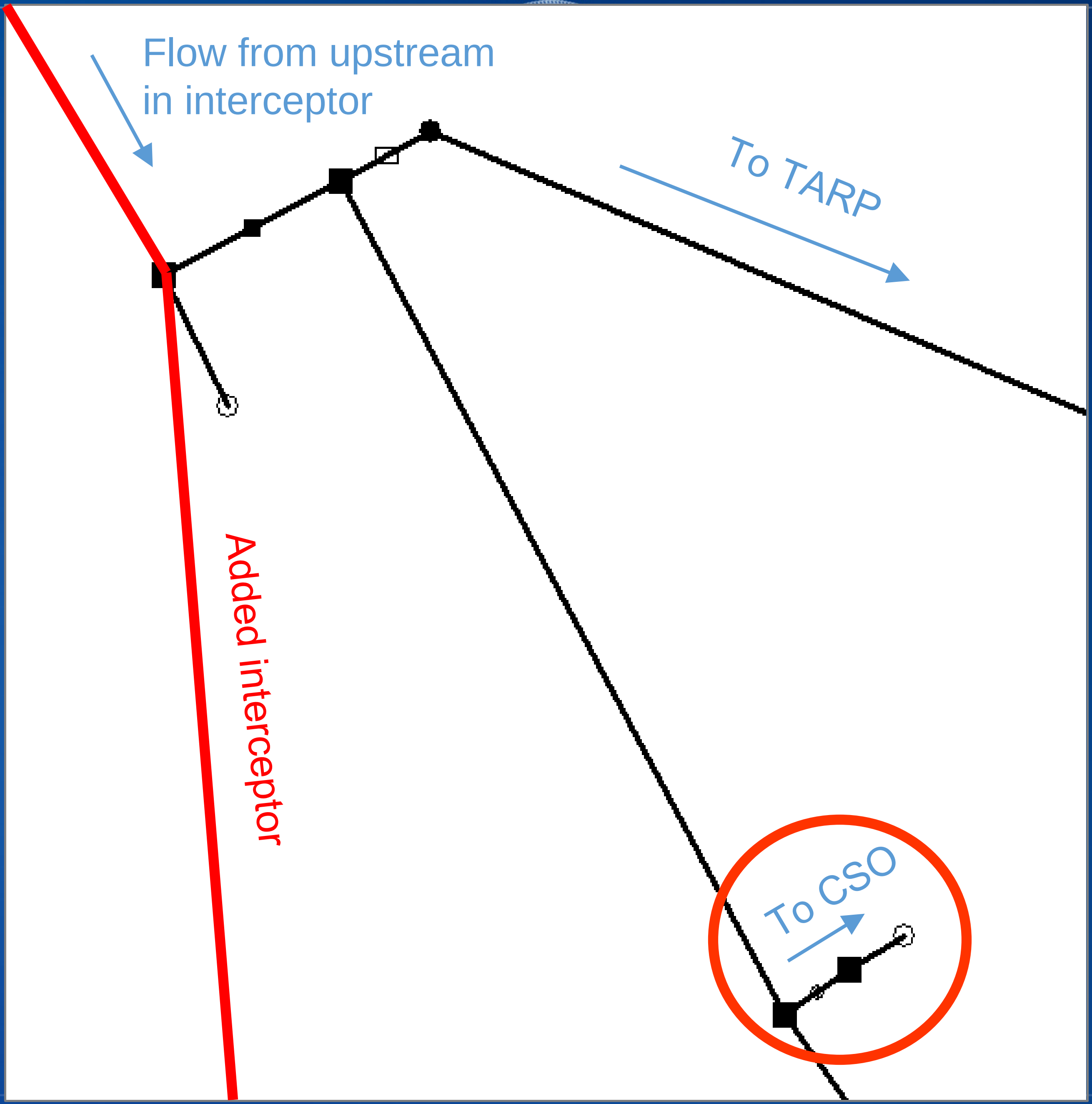
KANE COUNTY
DU PAGE COUNTY
LAKE MICHIGAN
CITY OF CHICAGO
INCORPORATED 4th MARCH 1837
URBS IN HORTO
= 234 Mi²
Combined Sewer Area
375 square miles
Separate Sewer and Unsewered Area
508.5 square miles

MODEL




INT
WRP
CS-TARP
CITY
RIVER


TARP Tunnel



Flow from upstream
in interceptor
To TARP
Added interceptor
To CSO

River Level Representation

- River level source: U.S. Army of Engineer's Great Lakes & Mississippi River Interbasin Study (GLMRIS) for a 3-hour duration storm event.

- River level hydrographs applied to all CSOs along Mainstream TARP system.

- No river data available for North Branch or Des Plaines river

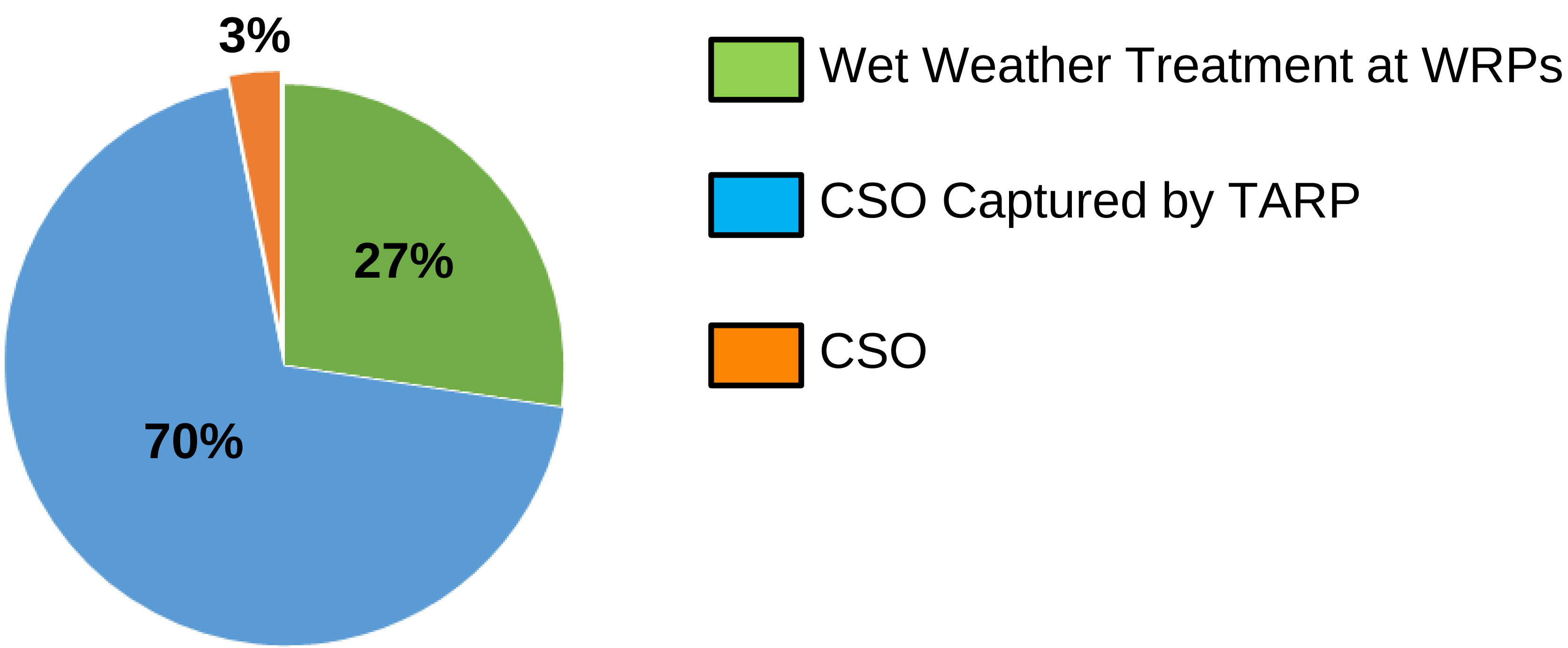
Why??

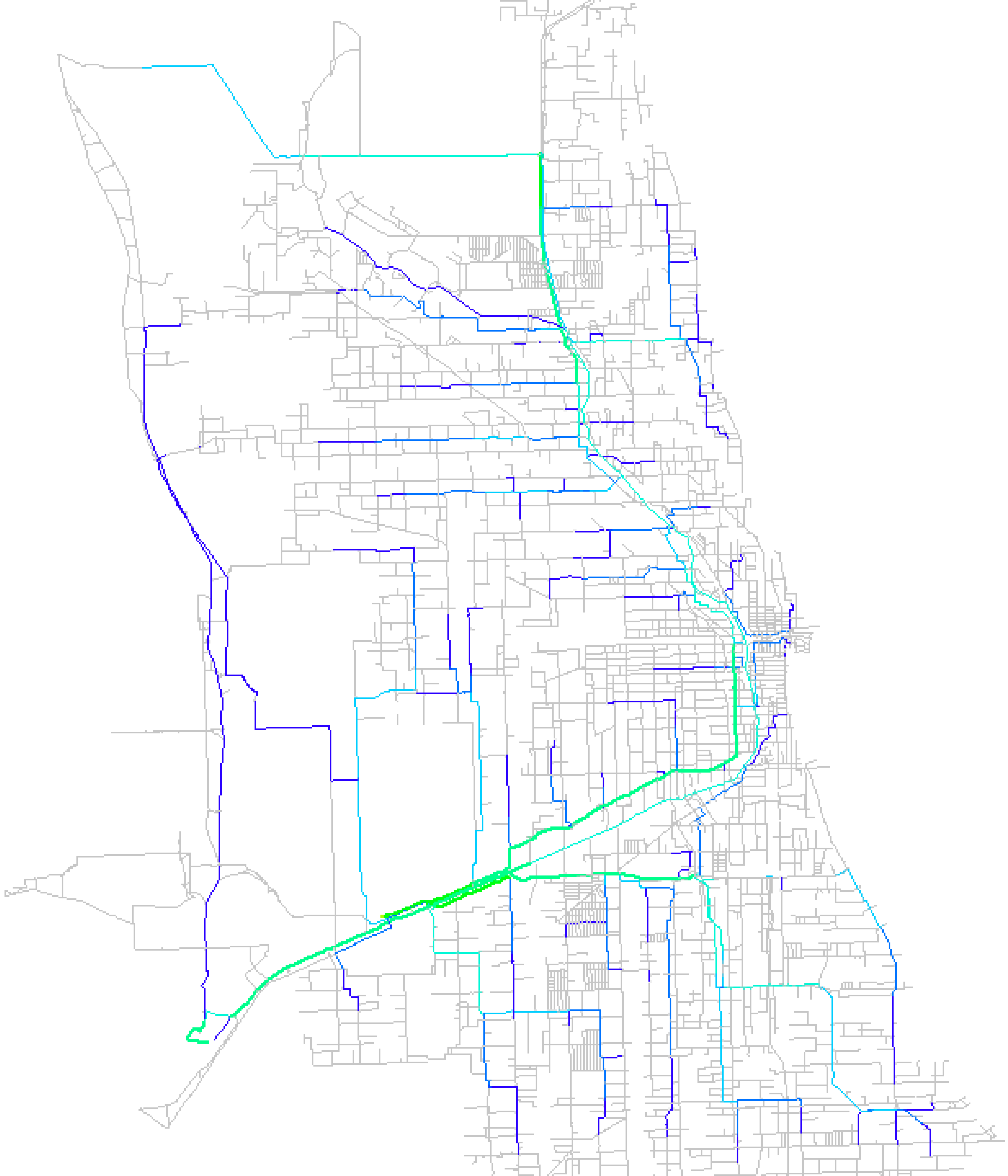
- Interceptor conveyance limitations
- WRP treatment capacity limitations

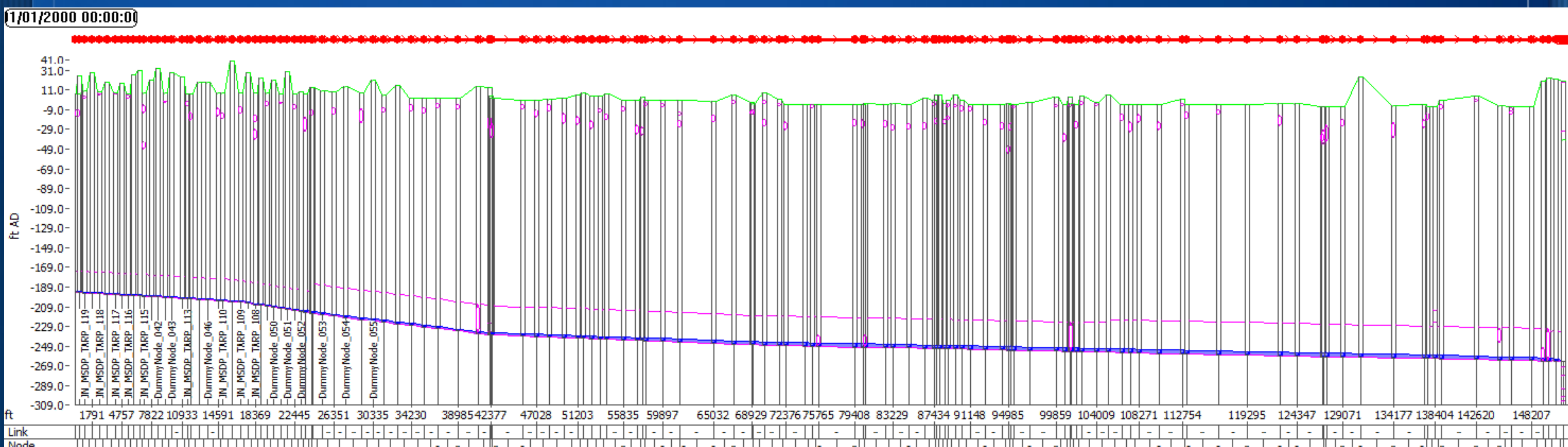
Model Version	5-year 2-hour Storm CSO (mgal)
CS-TARP	85.3
CS-TARP + INT + CITY	303.0
CS-TARP + INT + CITY + RIVER	193.9

CSO Captured by TARP
2029 Baseline Conditions with McCook Reservoir

- Typical Year Rainfall: 35.07 in
- MSDP Service Area: 254.7 mi^2
- Runoff Produced: 74 BGal
- ~ 7 full reservoirs of runoff produced annually



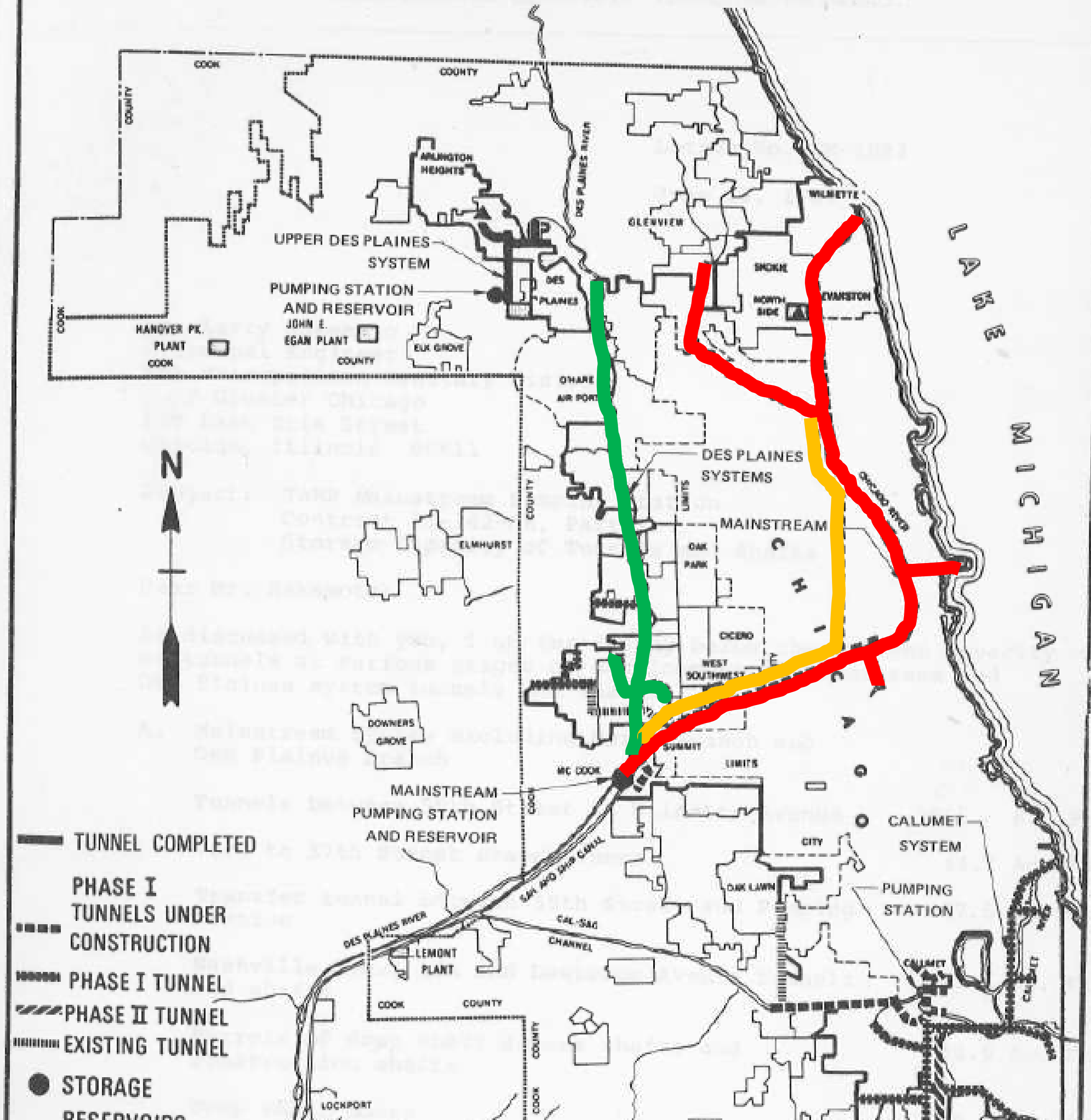


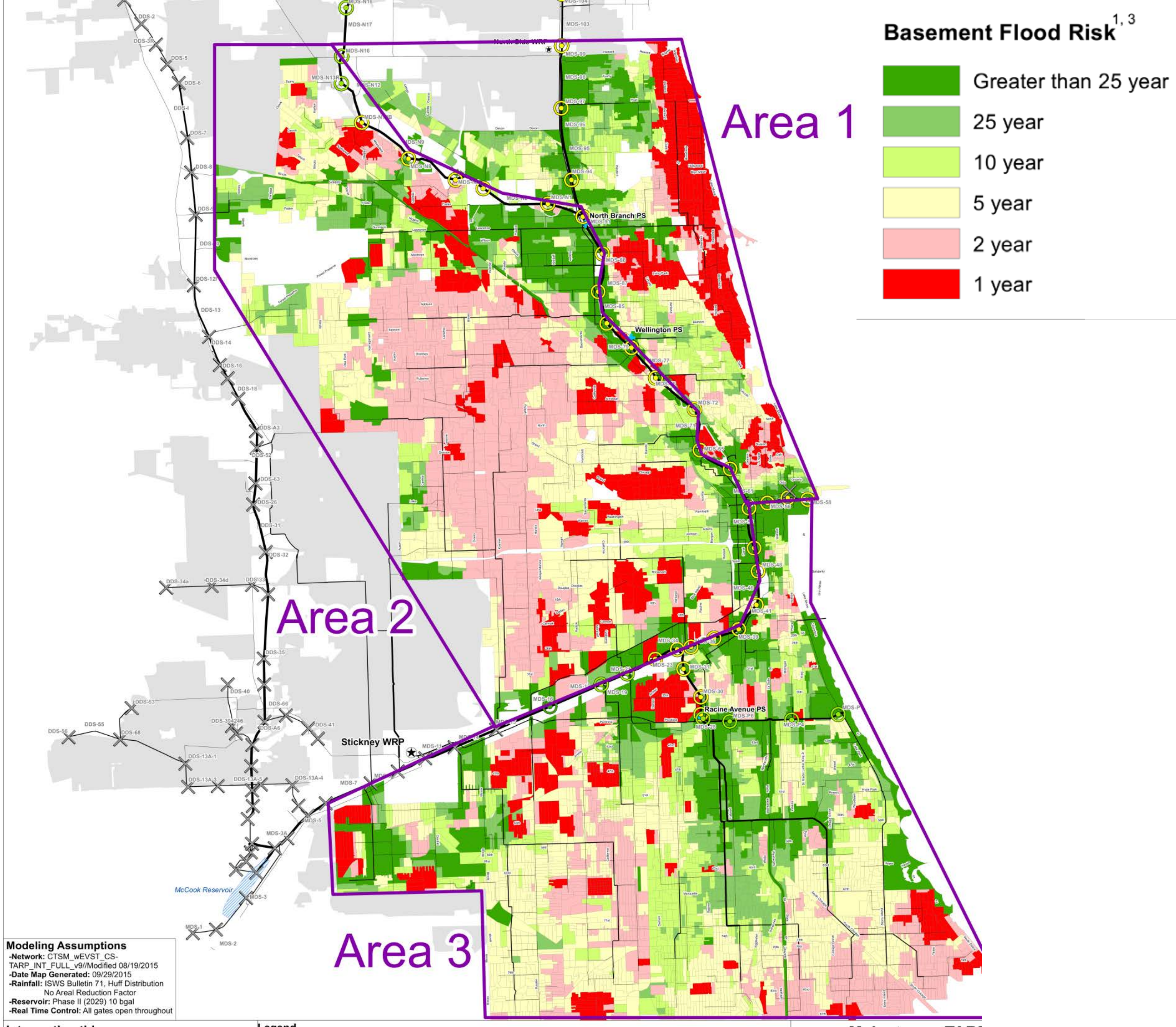


1/01/2000 00:00:0
ft AD
41.0
31.0
11.0
-9.0
-29.0
-49.0
-69.0
-89.0
-109.0
-129.0
-149.0
-169.0
-189.0
-209.0
-229.0
-249.0
-269.0
-289.0
-309.0
ft
1791 4757 7822 10933 14591 18369 22445 26351 30335 34230 38985 42377 47028 51203 55835 59897 65032 68929 72376 75765 79408 83229 87434 91148 94985 99859 104009 108271 112754 119295 124347 129071 134177 138404 142620 148207
Link
Node

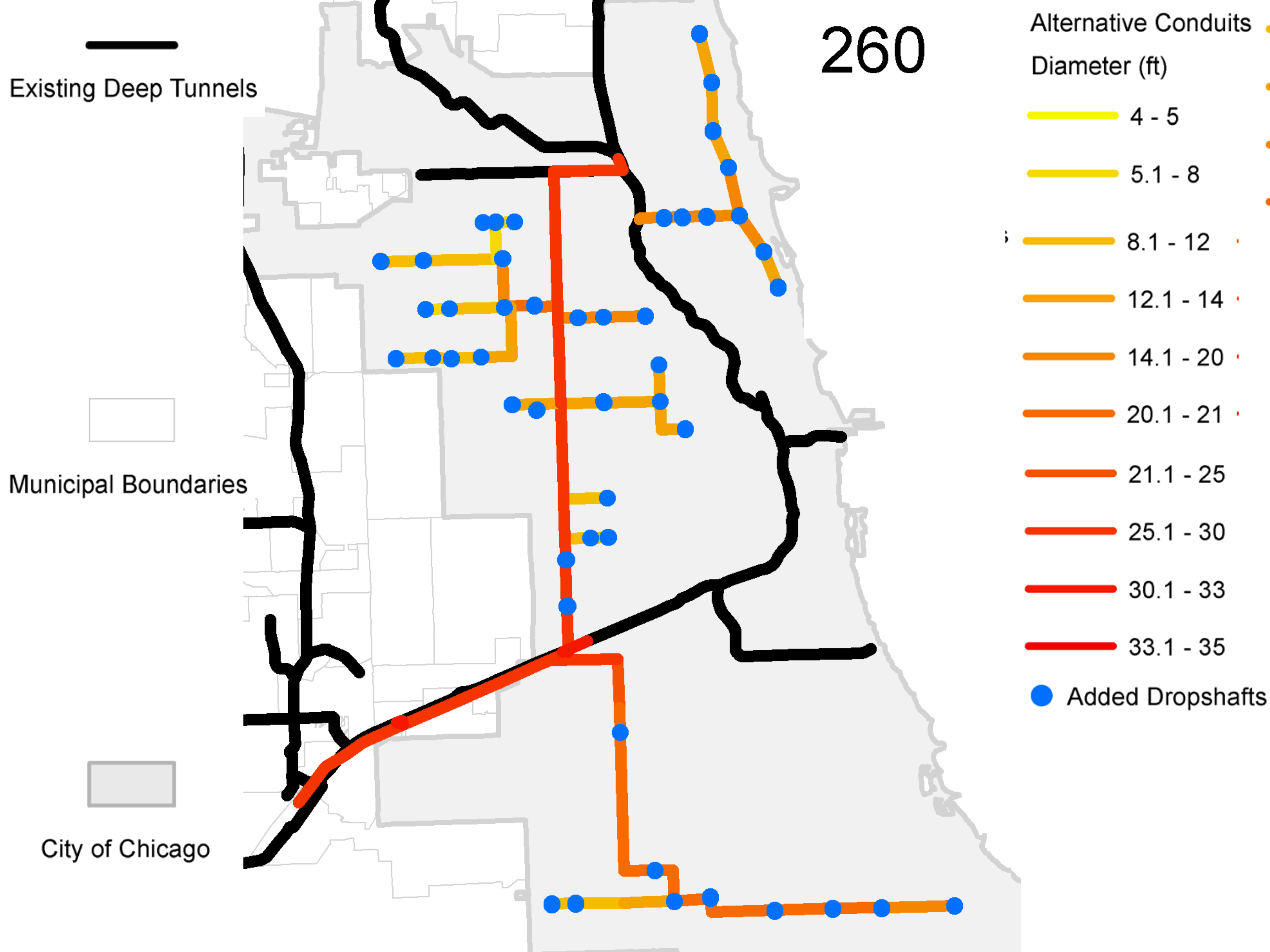
TUNNEL AND RESERVOIR PLAN

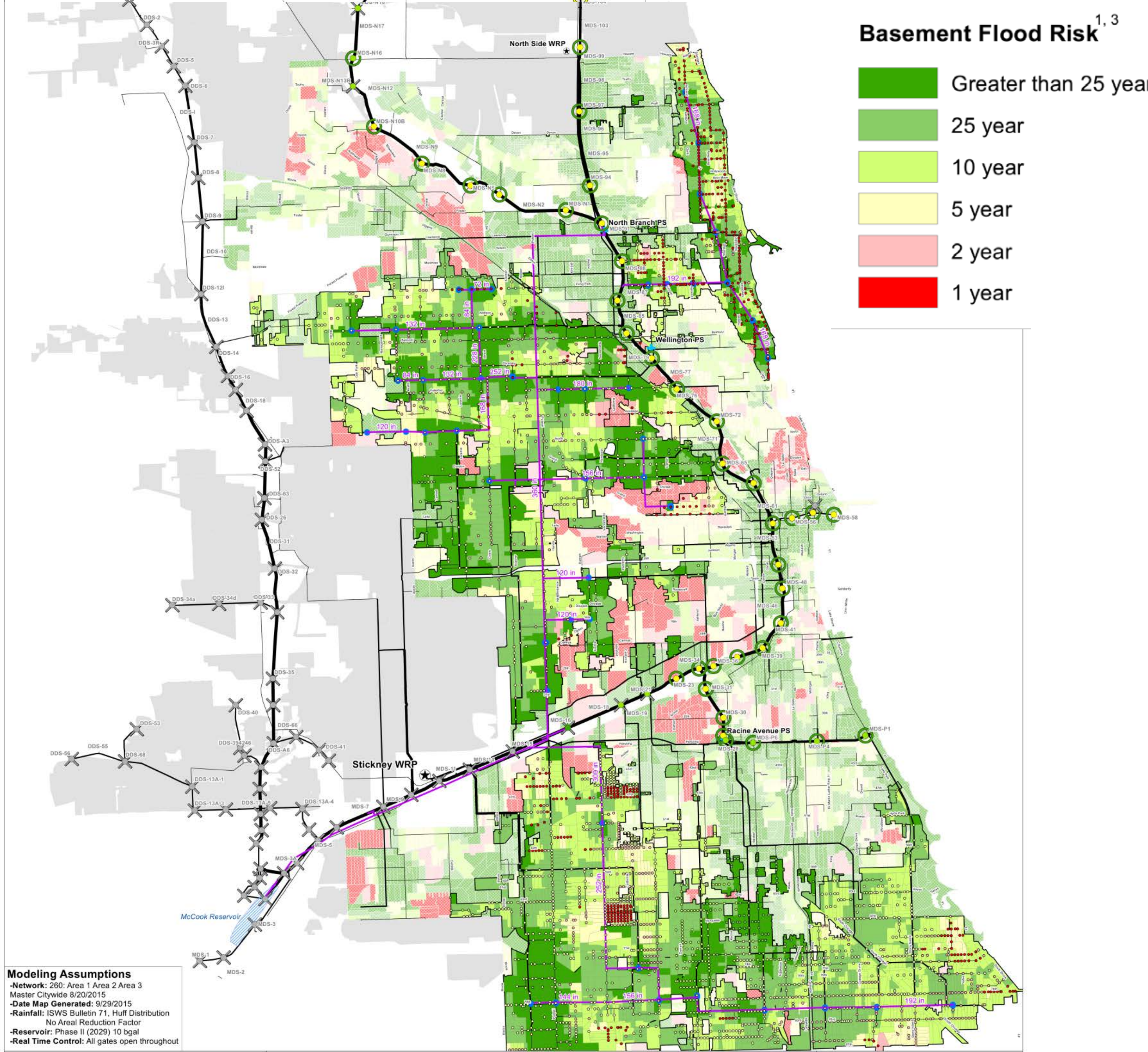
EXHIBIT I–1





Basement Flood Risk 1, 3
Greater than 25 year
25 year
10 year
5 year
2 year
1 year
Area 1
Area 2
Area 3
North Side WRP
North Branch PS
Wellington PS
Racine Avenue PS
Stickney WRP
McCook Reservoir
Modeling Assumptions
-Network: CTSM_wEVST_CS-TARP_INT_FULL_v9//Modified 08/19/2015
-Date Map Generated: 09/29/2015
-Rainfall: ISWS Bulletin 71, Huff Distribution
No Areal Reduction Factor
-Reservoir: Phase II (2029) 10 bgal
-Real Time Control: All gates open throughout


260
Existing Deep Tunnels
Municipal Boundaries
City of Chicago
Alternative Conduits
Diameter (ft)
4 - 5
5.1 - 8
8.1 - 12
12.1 - 14
14.1 - 20
20.1 - 21
21.1 - 25
25.1 - 30
30.1 - 33
33.1 - 35
Added Dropshafts


Basement Flood Risk[1, 3]
Greater than 25 year
25 year
10 year
5 year
2 year
1 year
North Side WRP
North Branch PS
Wellington PS
Racine Avenue PS
Stickney WRP
McCook Reservoir
Modeling Assumptions
-Network: 260: Area 1 Area 2 Area 3
Master Citywide 8/20/2015
-Date Map Generated: 9/29/2015
-Rainfall: ISWS Bulletin 71, Huff Distribution
No Areal Reduction Factor
-Reservoir: Phase II (2029) 10 bgal
-Real Time Control: All gates open throughout

So What?

Comprehensive Model

- City of Chicago Sewers
- Intercepting Sewers
- WRP's
- River Level Boundaries
- Connecting Structures
- Drop Shafts
- Mainstream & Des Plaines Deep Tunnels
- McCook Reservoir

- TARP system performance
- Quantify
  - CSO Frequency
  - CSO Volume
  - Flood Risk
- Evaluate potential flood reduction projects

QUESTIONS?