Multiple design tools enhanced the design of underground hydraulic structures for a new relief sewer system in an urban environment

This presentation focuses on Computational Fluid Dynamics (CFD) and enhanced field reconnaissance using a detailed Subsurface Utility Engineering (SUE) program.
Agenda

- Project Overview
- Design
  - Diversion Structure R1-D1
  - Hydraulic Analysis & CFD
  - SUE
  - Diversion Structure R6-D1
  - SUE
  - Utility Owner Coordination
- Construction
- Conclusions

Project Context

NEORSD Sewer District Service Area

Serves:
- 62 municipalities
- >1M residents

Maintains & Operates:
- Interceptor Sewers
- 3 WWTPs

Consent decree
- 25-yr, $3.6B program
- 4B gallons/yr CSO reduction
- Tunnels
- Plant improvements
- Increased system conveyance capacity
Project Overview

- London Road Relief Sewers Project (LNDN)
  - Control CSOs
  - Reduce Surcharging

- 6 PROJECT REACHES
- 10,700 FT OF NEW 24-72 IN RELIEF SEWERS (TRENCHLESS)
- 870 FT OF NEW 12- TO 72-INCH-RELIEF SEWERS (OPEN-CUT)
- 6 HYDRAULIC DROP/TUNNELING SHAFTS STRUCTURES
- 8 DIVERSION STRUCTURES
- MISCELLANEOUS JUNCTION STRUCTURES AND MANHOLES
- 6 REGULATOR MODIFICATIONS
Project Schedule & Current Status

• Design
  • Started: December 2016
  • Completed: March 2018

• Construction
  • Started: July 2018
  • Scheduled Completion: July 2020
  • $40M CV

Overall Design Process

• Establish alignment and locate near surface hydraulic structures
  • Hydraulic analysis
  • Anticipated construction methods
  • Geotechnical considerations
  • Existing underground utility impacts
  • Community impacts

• Balance hydraulic performance with construction risk

• Selectively deploy CFD and SUE design enhancement tools
  • When to use?
  • In which order?
  • Why use them at all?
Diversion Structure R1-D1

Structure Purpose:
• Relieve flow from existing interceptor

How achieved:
• Utilize the full conveyance capacity of the existing combined sewer
• Divert excess wet weather flows to relief sewer
• Dissipate energy due to elevation difference
R1-D1 Location Evaluation

- Hydraulic analysis
- Anticipated construction methods
- Geotechnical conditions
- Existing underground utility impacts
- Community impacts

R1-D1 Site - Location #1 Utilities

- 20” water main
- Electric ductbank
- Telephone ductbank
- Gas lines
R1-D1 Site - Location #2 Utilities

- 6” water main
- Telephone ductbank
- Gas lines

R1-D1 Location Evaluation

1. Optimal hydraulics
   - Most utility conflicts
2. Acceptable hydraulics
   - Manageable utility conflicts
3. Least hydraulic benefit
   - Least utility conflicts
Diversion Structure R1-D1

Advance design to 60%, then use additional tools to refine

- CFD modeling
- SUE

CFD Modeling Workflow

- Develop 3D model representing structure geometry
  - Autodesk REVIT
- Export 3D model as Stereolithography (STL) file for import into FLOW-3D
- Develop coarse mesh model, define boundary and initial conditions
- Evaluate the sensitivity of the numerical methods
- Refine mesh for additional accuracy and verification of solution convergence
Diversion Structure R1-D1 Refinement Through CFD

Alt 1 - Large chamber with side spill weir (60% design)
- Stagnant area after drop due to momentum over weir
- Large footprint

Alt 2 - Decreased chamber length with intermediate step
- High turbulence on step, unsteady flow
- Improved energy dissipation and outlet hydraulics
Diversion Structure R1-D1 Refinement Through CFD

Alt 3 - Decreased chamber length, stepped with dividing walls
- Steady flow through structure
- Improved energy dissipation and outlet hydraulics

SUE Approach

- ASCE Standard 38-02 “Standard Guideline for the Collection and Depiction of Existing Subsurface Utility Data”
- Progression of detail:
  - Level D: records research
  - Level C: above ground survey
  - Level B: utility designation
  - Level A: test hole/ pot holing
Diversion Structure R1-D1 SUE

- 5 Level A test holes performed
  - Located top and sides of existing sewers
  - Confirmed underground utility locations
  - Coordinated with utility companies

Results:
- Unknown gas line was confirmed as abandoned, remove during construction
- Telephone ductbank located, different than record drawings
  - Lowered structure roof
  - Relocated structure riser
R1-D1 Structure Final Configuration

Compact shape
Refined hydraulics
Minimized utility conflicts

Diversion Structure R6-D1
Design Refinement

- SUE
- Utility Owner Coordination
Diversion Structure R6-D1

Structure purpose:
• Reduce CSO overflows to Nine Mile Creek

How achieved:
• Divert excess wet weather flows to new relief sewer
• Use conveyance capacity of nearby existing combined system (HHI)

No. 4 egg shaped sewer (39"H x 30"W)
Diversion Structure R6-D1 SUE

- 12 Level A test holes performed in two rounds
  - Located top and sides of existing sewers
  - Confirmed underground utility locations
- Coordinated with utility companies
  - Electric Company - CEI

Diversion Structure R6-D1 SUE

- Round 1: 7 test holes
  - Horizontal and vertical conflicts with electric ductbanks
- Round 2: 5 test holes
  - Reduced vertical conflict
Diversion Structure R6-D1 Electric Utility Coordination

- 12 Duct system
  - Can be relocated horizontally
- 9 duct system
  - Top 3 ducts are vacant, can relocate vertically

R6-D1 Electric Ductbank Locations
R6-D1 Results of SUE and Utility Coordination

SUE
- Confirmed horizontal and vertical locations of utilities
  - 1st round – revise layout
  - 2nd round – viable

Utility coordination
- Corroborated SUE information
  (from MH inspections & records)
- Confirmed vacant ducts
- Allowed R6-D1 Structure to be cast against existing Electric Vault
- Estimated relocation costs

R6-D1 Final Configuration
Construction?
Pipe Installation & Duct Bank Relocation
Conclusions

- Designs can be enhanced by selectively using targeted tools

- Use tools at appropriate times
  - Collection system modeling
  - CFD modeling
  - SUE
  - Coordination with utility owner(s)

- Additional cost during design yields reduced risk and cost during construction

Thank you!

Questions?
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R1-D1 Site – Location #3 Utilities

- 6” water main
- Telephone ductbank
- Gas lines

Diversion Structure R6-D1

- Purpose of Structure
- Sewer Alignment/Connectivity
- SUE
- Utility Owner Coordination
Diversion Structure R6-D1
Exiting R6-D1 and conveying WWF down Hillsboro

Hobas (R6-D1 to R6-M1)  RCP (downstream of R6-M1)