Computational Fluid Dynamics (CFD) Applications for Wastewater Engineering

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freshwatereng.com
About FreshWater Engineering

- Founded in 2014 by Laura Rozumalski
- Woman-owned small business
- Based in Madison

Hydrodynamic (CFD) Modeling

Ecosystem Restoration

Water Resources Engineering

Hydrographic Surveying
Outline

• CFD modeling background
• Capabilities of FLOW-3D
  • Applications of FLOW-3D to wastewater systems
  • FWE project example
Computational Fluid Dynamics

- Numerical analysis of Navier-Stokes equation to solve fluid flow problems
- Solves 2D/3D transient/unsteady flow problems
- Modeler must weigh accuracy and efficiency
- A powerful design and analysis tool

Applications

- Aerodynamic design
- Biomedical engineering
- Metal casting
- Hydraulic analysis & design
- Environmental modeling
- Municipal & wastewater systems
Applications of CFD to Civil Engineering

- Municipal & Wastewater
  - Conveyance/wet tunnel hydraulics
  - Grit and sediment control
  - Flow control structures
  - Contact tanks
  - Clarifiers and settling tanks
  - Sewer design
  - Aeration dynamics

- Rivers
  - Hydraulic structures
  - Thermal discharge & contaminant modeling
  - Scour & sediment transport

- Dams
  - Spillways and stilling basins
  - Fish passage
  - Dam breaks
Advantages of CFD

- Fewer assumptions and uncertainties than most engineering models
- Clearly view system geometry
- Detailed understanding of flow
- Excellent correlation to physical modeling
- Less expensive than physical modeling
- Realistic simulations
Why use CFD to solve wastewater problems?

- Excellent design optimization tool
- Assess performance of existing systems
- Provide insight into complex interactions of hydraulic, chemical, and physical processes
- Gain understanding of system performance under different:
  - Flow conditions
  - Operation scenarios
  - Design alternatives

CONFIDENCE
FLOW-3D Capabilities

• Versatility
  • Geometry based on CAD designs
  • 27 physics packages
    • Particle transport
    • Chemical reactions
    • Sludge settling
    • Moving objects
  • Excellent visualization options

• Accuracy & Dependability
  • Industry-standard CFD model
  • Well validated
  • Free surface and pressurized flow

• Efficiency
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Circular Contact Tank Design Optimization

- Poor mixing efficiency
- Not hydraulically efficient
- Poor performance

- Fully coupled **hydraulic** and **chemical** models
- Existing system analysis
Circular Contact Tank Design Optimization

- Lowered center inlet
- Introduced center and outer baffles
  - Improved mixing efficiency
  - Even residence time distribution
  - Hydraulically efficient

**Modeling Capabilities**
- Design optimization
- Assess existing systems
- Diagnose problems
Contact Tank Analysis

- Coupled hydraulics, chemical, and micro-organism decay models
  - Hydraulic performance
  - Mixing
  - Chemical/organism decay
- Design optimization
- Assess existing systems
- Simulate regulatory tests (residence time, species concentration, etc.)
Mixing Tank with Airfoil Impellers

- Moving and rotating object simulations
- **Fluid/structure** interactions
  - Impeller design, type, rotational speed
  - Mixing efficiency
  - Hydraulic performance

- Design optimization
- Evaluate current systems
- Diagnose issues
Secondary Clarifier Design

- Customizable sludge settling velocity models
  - Density currents
  - Hydraulic performance
- Design optimization
- Evaluate existing systems
Flux Splitting Grit Separator

- Drift flux and sediment transport models: fluid/particle interactions
  - Hydraulic balance and efficiency
  - Sediment scour / buildup
- Design optimization
- Assess performance for various flow conditions and sediment species
- Address operation and maintenance issues
Complex Pipe System Analysis

- Complex, time-varying, 3D flows
- Air entrainment processes
  - Fluid discharge
  - Hydrostatic and dynamic pressures

- Optimize structure designs
- Analyze current systems
- Diagnose problems
Municipal: Vortex Grit Chamber

- Vortex modeling capabilities
- Fully coupled hydraulics and particle transport models

  - Multiple particle sizes

- Analyze suspended sediment removal efficiency
- Residence time analysis
- Location-specific sediment deposition rate
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Project Example: Grit Chamber Optimization for DMWW

- Existing sedimentation problem in grit chambers
- CFD resulted in a retrofit design to reorient gates for even grit distribution
Project Example: Grit Chamber Baffle Optimization for DMWW

- Existing sedimentation problem in grit chambers
- Design alternatives modeled to determine best gate orientation for improved grit distribution
- Flow conditions of 60-220 MGD
- Simulated movement of 100-, 200-, & 300-micron particles
Project Example: Grit Chamber Baffle Optimization for DMWW

- Flow conditions of 60-220 MGD
- Simulated movement of 100-, 200-, & 300-micron particles
Project Example: Infiltration Gallery Assessment

- Proposed design for an infiltration gallery-type water intake in the Great Lakes
- Located in intermediate water depths
- Modeling investigated scour potential and flow characteristics of the preliminary design
- ‘1-year’ wave conditions simulated
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Is CFD the right choice?

Considerations

• Project objectives
• Budget and timeline
• Regulatory requirements
• Impact of modeling insights
Thank you!

Take-Away Messages

• CFD is a powerful tool that can provide insight to a wide array of wastewater & municipal projects

• Versatile, accurate, and efficient models have enormous value that cannot be overstated

Questions?

Contact Us!
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