Improved Network Operations
Through Computer Modeling and Support System

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www.uky.edu/WaterSecurity
Workshop Agenda

• 1. Project Overview (UK) – 15 minutes
• 2. Overview of Project Website (UK) – 15 minutes
• 3. Overview of Visualization Models (UK) – 30 minutes
  – Graphical Flow Model
  – Pipe Break Model
• 4. Off-line network modeling (UK) – 10 minutes
• 5. Overview of SCADA (UK) – 25 minutes
• 6. Overview of Sensor Placement (UK) – 25 minutes
  – Sensor Placement Model
• 9. Wrap up discussion – 30 minutes
Workshop Agenda

- **1. Project Overview/Objectives**
- 2. Overview of Project Website
- 3. Overview of Visualization Models
  - Graphical Flow Model
  - Pipe Break Model
- 4. Off-line network modeling
- 5. Overview of SCADA
- 6. Overview of Sensor Placement
  - Sensor Placement Model
- 7. On-line network modeling
  - Real-time predictive analytics: process and benefits
  - Real-time network modeling: NKWD field study
- 8. Overview of Toolkit
- 9. Wrap up discussion
Project Goal

• To assist water utilities in improving the operation of their water distribution systems through a better understanding of the impact of water distribution system hydraulics and flow dynamics on operational decision making:
  – Normal operations
  – Emergency operations
    • Natural events
    • Man made events
Water Distribution System Operations Hierarchy

- Real Time Operations
- On-Line Water Quality Model
- On-Line Hydraulic Model
- Supervisory Control and Data Acquisition (SCADA)
- Off-Line Water Quality Model
- Off-Line Hydraulic Model
- Spatial Visualization Model
- Telemetry/Communication Systems
- Water Quality Sensors
- Hydraulic Sensors

SCADA Database
Project Objectives

- Develop knowledge and tools to support water distribution system operations
- Develop a decision support system
  - Operational guidance
  - Operational toolkit
WDS Operational Objectives

• Maintain Adequate Pressures
• Minimize Water Quality Problems
• Minimize Operational Cost
• Schedule Maintenance
• Emergency Response
Operational Questions

• How long will it take to fill or drain my tanks under:
  – Normal conditions?
  – Emergency conditions?

• When and how long should I run my pumps to minimize cost?

• Can I improve my water quality by changing my operations?

• How will my system perform if I have to close several pipes?

• Which valves do I need to close to isolate a pipe break? What are the impacts on pressures and flows?
Operational Support

• Supervisory Control and Data Acquisition System
• Computer Models
Need for SCADA

• Why do we need a monitoring/ control system?
  – Normal Operations
  – Pipe Breaks/Leaks
  – Pump/Tank Failures
  – Contamination Events
  – Maintain Energy Efficiency
  – Minimize Operational Costs
Need for Models

• Graphical representation of system
  – Network schematic
  – Background map
• Infrastructure database
• Customer database
• Computer analyses
Workshop Agenda

• 1. Project Overview

• **2. Overview of Project Website**

• 3. Overview of Visualization Models
  – Graphical Flow Model
  – Pipe Break Model

• 4. Off-line network modeling

• 5. Overview of SCADA

• 6. Overview of Sensor Placement
  – Sensor Placement Model

• 9. Wrap up discussion
THE WATER DISTRIBUTION SYSTEM OPERATIONAL DECISION SUPPORT WEBSITE

The Water Distribution System Operational Decision Support Website has been developed to assist water utilities in designing a monitoring/control system for their water distribution system that will provide water distribution system data (WDSD) for use in support of various operational needs. Such data could include either general operational data as determined from either real-time telemetry or off-line computer models, or on-line data (including data from both hydraulic and water quality sensors). Operational applications could include 1) normal operations, 2) emergency response management, 3) water quality management, 4) energy management and 5) event detection.

Operational support for water distribution systems can be obtained by utilizing a series of different hardware and software components. These can arrange in an operational hierarchy that can be linearly visualized in a ladder of components, in which each rung on the ladder will be dependent upon the previous rung. Four basic rungs can be envisioned as illustrated below. These include 1) a Supervisory Control and Data Acquisition System (SCADA), 2) spatial visualization of network components, 3) an off-line computer model of the water distribution system, 4) an on-line computer model of the water distribution system.

- Supervisory Control and Data Acquisition (SCADA)
- Spatial Visualization of Network Components

Hierarchy of Operational Components for a Water Distribution System

Technical information and support for each of these operational functions can be obtained using the self-directed operational guidance or the expert system driven operational toolkit with the links on top in blue.

www.uky.edu/WaterSecurity
WDS Operational Decision Support Tool

[Diagram showing the decision-making process involving User, Question, Model Results, Data & Facts, User Defined Decisional Process, User Assisted Decisional Process, Responses/Recommendations, Fact Sheets, Reports, and WebLinks]
User Defined Decisional Process (Guidance)

User Defined Decisional Process

- Question
- Model Results
- Data & Facts

User Assisted Decisional Process

- Model Results

Responses/Recommendations

- Fact Sheets
- Reports
- WebLinks
OPERATIONAL GUIDANCE

SUPERVISORY CONTROL AND DATA ACQUISITION (SCADA)

SPATIAL Visualization OF NETWORK COMPONENTS

OFF-LINE COMPUTER MODELS

ON-LINE COMPUTER MODELS
User Assisted Decisional Process (toolkit)
WDS Toolkit

This is the Water Distribution System Module of Water Wizard.

WDS Wizard provides recommendations for optimizing water distribution system operations.

Through the following interview, you will be asked a series of questions regarding your system, from which you will be provided recommendations for recovery operations.

Please choose an option to continue:
Workshop Agenda

• 1. Project Overview
• 2. Overview of Project Website
• 5. Overview of SCADA

• 3. Overview of Visualization Models
  – Graphical Flow Model
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SCADA

On-Line Computer Models

Off-Line Computer Models

Spatial Visualization of Network Components

Supervisory Control and Data Acquisition (SCADA)
SCADA

Water Distribution System Operations

SCADA SYSTEMS

A water distribution system is made up of many different operational components, including sensors, meters, pumps, and control valves. Such components can be monitored or controlled onsite or from a central location. In the past these operations were normally accomplished through the use of onsite instrument and control panels. These panels typically consist of a series of electro mechanical devices such as indicators, push buttons, lights switches, relays and analog control instrument. In recent years many utilities have made the transition to computerized supervisory control and data acquisition SCADA systems in which commands are entered through a keyboard, mouse, or touch screen instead of through the use of switches or push buttons.

Supervisory Control Schemes

SCADA systems are usually built around a central computer and operator’s station, which communicate with intelligent Remote Terminal Units (RTUs) or Programmable Logic Controllers (PLCs) via an integrated communication network. The exact composition of the system will be dependent upon the selected control scheme. Two different control schemes are available: hierarchical control or distributed control (Gingell and Rice, 1990).

Hierarchical Control

In a hierarchical control environment there is normally a single control computer which is linked to several remote control units via the communication network. RTUs are normally used for the remote control units. Each RTU contains a point database for all field I/O points and calculated values like flow totals, tank volumes, etc. The central computer contains a mirror image database which includes points for all RTUs in the system. Under normal operation the RTU continuously scans all input points and updates the calculated values. The central computer is then used to poll each RTU to update the central database. Any control decisions are then sent back to the selected RTU for control of a particular network component (Riddle, 1989).

Distributed Control

In a distributed control environment more of the control is distributed to the remote stations. Although a distributed control system can also contain a central host computer, it is typically used more to manage and monitor the control units as opposed to controlling the actual field instrumentation. PLCs are normally used as the control units for this type of system. Since the PLCs are connected to a central host computer, the computer can still be used to monitor all the control data. However, in this case the central computer can be used to change selected set points of the associated remote control units or even download complete control schemes (Christie, 1989).
<table>
<thead>
<tr>
<th>SCADA SYSTEMS GUIDANCE</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Potential SCADA Uses</td>
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<tr>
<td>• SCADA Functions</td>
</tr>
<tr>
<td>• SCADA Survey</td>
</tr>
<tr>
<td>• SCADA Components</td>
</tr>
<tr>
<td>• Supervisory Control Schemes</td>
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<tr>
<td>• SCADA Implementation Process</td>
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<tr>
<td>• SCADA Sensor Location</td>
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<td>• SCADA Sensor Placement Decision-Making Sequence</td>
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<td>• SCADA CWS Sensor Placement Optimization Program Inputs</td>
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<tr>
<td>• SCADA Sensor Placement Guidance</td>
</tr>
<tr>
<td>• SCADA Sensor Placement Software</td>
</tr>
</tbody>
</table>
SCADA Functions

• Data Acquisition (Collection)
• Data Communication (Monitoring)
• Data Presentation
• Equipment Control
SCADA Components

- Sensors and Controllers
- SCADA Interface Units
- Communications Network
- SCADA Master

Figure 1: Illustration of four SCADA Equipment Categories
Hydraulic Sensors

• Types of Hydraulic Sensors
  – Pressure Sensors
  – Flow Sensors
Hydraulic Sensors

- Sources of Hydraulic Sensors:
  - ABB, abb.com
  - Ashcroft, ashcroft.com
  - Holykell, holykell.com
  - Honeywell, honeywell.com
  - Keyence, keyence.com
  - Truck, truck-usa.com
Water Quality Sensors

• Types of Water Quality Sensors
  – Chlorine Residual Sensor
  – TOC Sensor
  – Turbidity Sensor
  – Conductivity Sensor
  – pH Sensor
  – ORP Sensor

www2.emersonprocess.com
www.directindustry.com
Water Quality Sensors

• Sources of Water Quality Sensors
  – ABB, abb.com
  – GE, ge.com
  – Hach, hach.com
  – Siemens, siemens.com
  – Emerson, emersonprocess.com
  – Yokogawa, yokogawa.com/us
Picture of Water Quality Control Station
Control Equipment (Pumps)
Control Equipment (PRVs)
Control Equipment (Control Valves)
SCADA Interface Units

- Remote Telemetry Units (RTU1s)
- Remote Terminal Units (RTU2s)
- Programmable Logic Controllers (PLCs)
RTU: Remote Telemetry Unit

- Field interface unit compatible with the SCADA system language
- Convert electronic signals received from field sensors (i.e. pressure sensors, tank level sensors, etc.) into protocol and transmit data to the SCADA Master
- Typically consist of a box which contains a microprocessor and a database

Simplified Illustration of RTU Function in a SCADA System
RTU: Remote Terminal Unit

- Field interface unit compatible with the SCADA system language
- Convert electronic signals received from field sensors (i.e. pressure sensors, tank level sensors, etc.) into protocol and transmit data to the SCADA Master
- Typically consist of a box which contains a microprocessor and a database
PLC: Programmable Logic Controller

- Basic alternative to RTU; higher cost
- Typical components include
  - CPU
  - Memory
  - Control Software
  - Power Supply
  - Input/Output Modules
- A digital computer used to monitor and control certain aspects of equipment such as motor speed, valve actuation, and other functions

![Diagram of PLC components and data flow](image)
SCADA
“Supervisory Control and Data Acquisition”

2 Supervisory Control Schemes

Hierarchical Control

Distributed Control
Control Schemes: Advantages/Disadvantages

Hierarchical Control

ADVANTAGES:
• Low cost (RTUs vs. PLCs)

DISADVANTAGES:
• Inability to operate in case of communication failure
• Potential problems from data transmission rates and computer scan rates

Distributed Control

ADVANTAGES:
• Normal operations maintained despite communications failure
• Potential differences are minimized for scan and transmission rates

DISADVANTAGES:
• High cost (PLCs vs. RTUs)
Need for SCADA

- Why do we need a monitoring/ control system?
  - Normal Operations
  - Pipe Breaks/Leaks
  - Pump/Tank Failures
  - **Contamination Events**
  - Maintain Energy Efficiency
  - Minimize Operational Costs
EPA Water Security Initiative

- The Water Security (WS) initiative is a U.S. Environmental Protection Agency (EPA) program that addresses the risk of contamination of drinking water systems.
- EPA established this initiative in response to Homeland Security Presidential Directive 9, under which the Agency must "develop robust, comprehensive, and fully coordinated surveillance and monitoring systems, including international information, for...water quality that provides early detection and awareness of disease, pest or poisonous agents."
EPA Water Security Operational Phases

**Phase I. Routine Monitoring & Surveillance**
- Online Water Quality
- Public Health
- Sampling and Analysis
- Enhanced Security
- Customer Complaints

**Possible Determination**
- Event Detection
- Initial Trigger Validation

**Phase II. Consequence Management**

**Credibility Determination Actions**
- Site characterization
- Outside data sources
- Laboratory confirmation

**Response Actions**
- Protect public health during the investigation process and may include:
  - Isolation
  - Flushing
  - Public alerts/notifications

**Remediation and Recovery**
- Restores a system to normal operations and may include:
  - System characterization
  - Remedial action
  - Post-remediation activities
## EPA Water Security Initiative

<table>
<thead>
<tr>
<th>Phase</th>
<th>I. DESIGN</th>
<th>II. DEMONSTRATE</th>
<th>III. EXPAND</th>
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<tr>
<td></td>
<td>System Architecture</td>
<td>Initial Pilot</td>
<td>Additional Pilots</td>
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<tr>
<td>Approach</td>
<td>Conceptual Design</td>
<td>Apply to single pilot utility</td>
<td>Evaluate</td>
</tr>
<tr>
<td>Scope</td>
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<td>Cincinnati</td>
<td>Philadelphia</td>
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</tbody>
</table>
SPATIAL VISUALIZATION OF NETWORK COMPONENTS

SUPERVISORY CONTROL AND DATA ACQUISITION (SCADA)

OFF-LINE COMPUTER MODELS

ON-LINE COMPUTER MODELS

Computer Models
Computer Models

- Computer models for network modeling have been around since the late 1950s.
Potential Model Uses

• Static hydraulic analyses
  – Flows and pressures in the system
  – Fire flow tests
  – Valve closure

• Dynamic hydraulic analyses
  – Tank turnover
  – Pump operations
  – Emergency response

• Water Quality analyses
  – Age analysis
  – Chlorine residual analysis
  – Tracer analysis

• Real Time Analysis
  – Real Time Operations
  – Emergency Response
The hydraulic model gets applied most frequently for:

- Planning scenarios, 28%
- Operational what-ifs, 21%
- Asset management, 7%
- Water quality, 10%
- Energy, 4%
- Flushing, 5%
- Other, 1%
The Most Technically challenging Aspects of the Hydraulic Model

- Calibrating the model, 42%
- Developing & analyzing planning & operational scenarios, 15%
- Water quality analysis, 9%
- Integration with GIS, 9%
- Building/updating the model, 18%
- Other, 5%
- Reporting & results presentation, 2%
The Hydraulic Model Was Last Calibrated

- Never Calibrated, 5%
- <1 year ago, 34%
- 1-2 years ago, 23%
- 2-4 years ago, 13%
- >5 years ago, 25%
The frequency of hydraulic model calibration is

- >5 years ago, 42%
- 1-2 years ago, 29%
- 2-4 years ago, 21%
- <1 year ago, 8%
Utility information systems that will benefit the hydraulic models

- GIS, 51%
- SCADA, 37%
- AMI/AMR, 9%
- Work order management systems, 1%
- Other, 2%
Water Distribution System Model
Water Distribution System Model

Topologic Information

Network Layout
Water Distribution System Model

Maps

Topologic Information

Network Layout
Water Distribution System Model

- Maps
- Topologic Information
- Network Layout

KIA GIS Data
Water Distribution System Model
Water Distribution System Model

Maps

Elevation Information

Elevations

[Map Image]
Water Distribution System Model

KY GIS DEM Data → Elevation Information → Elevations → Maps
Water Distribution System Model

- Maps
- Topologic Information
- Elevation Information
- KIA GIS Data
- KIA DEM Data
- Pipe Information
- L, D
Water Distribution System Model

Maps
Topologic Information
KIA GIS Data
KIA DEM Data
Elevation Information
Historical Records
Pipe Information

L, D
Water Distribution System Model
Water Distribution System Model

- Maps
- Topologic Information
- Elevation Information
- Historical Records
- Pipe Information
- Pipe Roughness
- KIA GIS Data
- KIA DEM Data
- C

Water Distribution System Model

Maps

KIA GIS Data

Topologic Information

Elevation Information

Historical Records

Pipe Information

Pipe Roughness

C

KIA GIS Data

KIA DEM Data
Water Distribution System Model

- KIA GIS Data
- Topologic Information
- Elevation Information
- Historical Records
- KIA DEM Data
- Pipe Information
- Literature C Values
- Pipe Roughness

<table>
<thead>
<tr>
<th>Pipe Material</th>
<th>Age (yrs)</th>
<th>Diameter (in)</th>
<th>C Factor</th>
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<tr>
<td>Cast Iron</td>
<td>New</td>
<td>All sizes</td>
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<tr>
<td></td>
<td>5 years</td>
<td>&gt; 15 inches</td>
<td>120</td>
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<tr>
<td></td>
<td></td>
<td>&gt; 4 inches</td>
<td>118</td>
</tr>
<tr>
<td></td>
<td>10 years</td>
<td>&gt; 24 inches</td>
<td>113</td>
</tr>
<tr>
<td></td>
<td></td>
<td>&gt; 12 inches</td>
<td>111</td>
</tr>
<tr>
<td></td>
<td></td>
<td>&gt; 4 inches</td>
<td>107</td>
</tr>
<tr>
<td></td>
<td>20 years</td>
<td>&gt; 24 inches</td>
<td>100</td>
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<tr>
<td></td>
<td></td>
<td>&gt; 12 inches</td>
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<tr>
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<td>&gt; 4 inches</td>
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<td>30 years</td>
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<td></td>
<td>&gt; 16 inches</td>
<td>87</td>
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<tr>
<td></td>
<td></td>
<td>&gt; 4 inches</td>
<td>75</td>
</tr>
<tr>
<td></td>
<td>40 years</td>
<td>&gt; 30 inches</td>
<td>83</td>
</tr>
<tr>
<td></td>
<td></td>
<td>&gt; 16 inches</td>
<td>80</td>
</tr>
<tr>
<td></td>
<td></td>
<td>&gt; 4 inches</td>
<td>64</td>
</tr>
<tr>
<td>Ductile Iron</td>
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<td>140</td>
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<tr>
<td>Plastic PVC</td>
<td>Average</td>
<td></td>
<td>140</td>
</tr>
<tr>
<td>Asbestos Cement</td>
<td>Average</td>
<td></td>
<td>140</td>
</tr>
<tr>
<td>Wood Stave</td>
<td>Average</td>
<td></td>
<td>120</td>
</tr>
</tbody>
</table>
Water Distribution System Model

C = 4.73 Q L^{0.54} \over H_f^{0.54} D^{2.63}

Maps

KIA GIS Data

Topologic Information

KIA DEM Data

Elevation Information

Historical Records

Pipe Information

Literature C Values

Pipe Roughness

C-Factor Tests

PRESSURE HYDRANT 1

PRESSURE HYDRANT 2

FLOW HYDRANT

FLOW DIRECTION

VALVE

PIPE LENGTH
Water Distribution System Model

- Maps
- KIA GIS Data
- Topologic Information
- KIA DEM Data
- Elevation Information
- Historical Records
- KIA GIS Data
- Pipe Information
- Literature C Values
- C-Factor Tests
- Manufacturer Data
- Component Information
- Tank
- Valve
- Reservoir
- Pump
Water Distribution System Model

- Maps
- Topologic Information
- Pipe Information
- Elevation Information
- Historical Records
- KIA GIS Data
- GIS Data
- DEM Data
- Literature C Values
- C-Factor Tests
- Manufacturer Data
- Component Information

Diagram showing connections and data flows:

- Billing Information
- Production Information
- Nodal Demands
- AGGREGATED DEMANDS
- DISTRIBUTED DEMANDS
- MIDPOINT
- SERVICE CONNECTIONS
Q = 29.8 C D^2 P^{0.5}

where: D (inches), P (psi), Q (gpm)
SPATIAL VISUALIZATION OF NETWORK COMPONENTS

Water Distribution
System Operations

SPATIAL VISUALIZATION OF NETWORK COMPONENTS

It has become possible for many small utilities to develop or utilize hydraulic network models in their day-to-day planning and operational activities. In addition to determining pressures and flows within a particular system, such models can be used to address the issues of fire-flow capacity, system reliability, rehabilitation scheduling, emergency response, and energy management. In most cases, the costs associated with network modeling will be more than offset by better operation and management decisions that will result from a more comprehensive understanding of the network system.

Despite such advantages, many utilities do not feel like they have the technical background, staff or budget to develop and use a water distribution system computer model on a regular basis. As a result, an intermediate tool, called the Graphical Flow Model has been developed for use by such utilities to help them get started up this ladder of improved operational control.

Graphical Flow Model

The Graphical Flow Model (GFM) has been developed for water utility managers as a first step toward utilizing a computer model of their distribution system. The GFM is not a comprehensive water system model, modeling all possible aspects of operations; however, for systems that have little to no computer based representations of their system, the GFM is a great asset. First, it provides a graphical representation of a system within an interactive interface, capable of storing and manipulating data pertaining to many components of the system. Secondly, given certain hydraulic operational control inputs, the GFM is capable of returning output for many important system questions such as flow directions and magnitudes, pressures, hydraulic grade line contours, and more.

The GFM has been designed to allow the use of pre-developed GIS datasets for use in constructing graphical representations of water distribution systems. In particular, the model has been developed to allow use of the Kentucky Infrastructure Authority (KIA) water distribution system database. Finally, the GFM has an option that will allow the user to export any model developed within the GFM graphical user interface (GUI) for possible subsequent use with comprehensively functional water distribution network analysis software (i.e. KYPipe).
SPATIAL VISUALIZATION OF NETWORK COMPONENTS

Downloading and installing the Graphical Flow Model

The Graphical Flow Model and associated users manual can be accessed below. The user should first download the user’s manual and read the appendix that describes how to download the computer program to the user’s computer.

- Graphical Flow User’s Manual
- Graphical Flow Model

Downloading and installing the Network Decontamination Model

In addition to the Graphical Flow Model, a Network Decontamination Model has also been developed for use by water utilities. This model can be used to help determine which valves should be shut to isolate part of the water distribution system in response to a pipe break or a contamination event. The program has been developed to use the same data files generated using the Graphical Flow Model. The user should first download the user’s manual and read the appendix that describes how to download the computer program to the user’s computer.

- Network Decontamination Model User’s Manual
- Network Decontamination Model

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Contact: Christie Oliver, 859-257-8637
Kentucky Water Resources Research Institute copyright ©2014
Graphical Flow Model
User Interface
Program Command Bar

- File
  - New
  - Open...
  - Save
  - Save as...
  - Delete Unnecessary Files
  - Pipe2000 Utilities
  - Print...
  - Reload Current File
  - Exit
Map Function Menu

Map Layout Mode

Fixed Mode 1 – Cannot move or add nodes

Select Multiple Nodes and Pipes

Attach a note to the map

View data tables

Add north arrow to map

Undo last map change

Zoom and pan functions

Shift map window functions

Map Text Mode

Fixed Mode 2 – Cannot move/Can add nodes

Select Nodes/Pipes using a polygon

Clear selections

Refresh map

Views

Redo last map change

Zoom and pan functions

Shift map window functions
Network Data Management
You can also use GFM to manage facilities data.

If you click on the Table icon, the program will take you to a table that contains information about your system.
These are the parameter values that have been read in from the KIA database.

However, you can change them if you want.
These results can also be viewed from the Map menu. In order to “turn on” a particular set of data, first go to the **Map Settings** Tab and then click on the **Labels** tab.

Now you can use the drop down menu to select a particular type of data. Here we have selected diameter data.

To show this data on your map, make sure to click on the box next to the selected parameter (e.g. Diameter as shown)

Now, click on the **Map** tab to take you back to the map viewing area.
Here is the map view with all the pipe diameters (in inches) shown.
Hydraulic Model
Generating a Flow Analysis
Analyze
Error Check
Analysis
Inventory/Costs
Quick Results
Flow analysis options are provided in a menu after the run completes.
Pipe flowrates displayed by yellow boxes.

Nodal system inputs/outputs displayed by blue boxes.
Pressures at System Nodes Displayed by Labels
Result of Screen Capture
Elements of a Flow Analysis Report

1. File name of the network
2. Regulatory valve data and properties
3. Pipeline data and properties
4. Node data and properties
5. Regulatory valve flow analysis results (upstream and downstream pressure and throughflowrate)
6. Pipeline Flow analysis (flowrates)
7. Node flow analysis results (external demand, hydraulic grade, pressure head and node pressure in psi)
8. Summary of system inflows and outflows
<table>
<thead>
<tr>
<th>PIPE NAME</th>
<th>NODE NAME1</th>
<th>NODE NAME2</th>
<th>LENGTH (ft)</th>
<th>DIAMETER (in)</th>
<th>ROUGHNESS COEFF.</th>
<th>MINOR LOSS COEFF.</th>
</tr>
</thead>
<tbody>
<tr>
<td>P-1</td>
<td>J-2</td>
<td>J-18</td>
<td>388.00</td>
<td>6.00</td>
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<td>J-18b</td>
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### Pipeline Results

**Status Code:** XX - CLOSED PIPE  CV - CHECK VALVE

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**Node Results**

- @Pump-2KV
- I-Pump-2
- O-Pump-2
Pipe Break/Contamination Extent Visualization
What will be the final disposition of the flushed water? Where will the water flow?

What is the associated volume of contaminated water? Number of customers? Total demand?

If the system should be flushed, can the “upstream” part of the system be used or does the system need to be isolated and flushing water pumped through a hydrant? If so, which hydrant?

If the system needs to be isolated, using what valve(s)?

What is the associated volume of isolated water? Number of customers? Total demand?

What critical pieces of infrastructure are impacted?

What will be the final disposition of the flushed water? Where will the water flow?
Generate a contamination report by a point

1. Click on “Facilities Management” on the top menu bar
2. Select “Contamination (point)” from the menu
3. Click on a pipe in the network map in the location of the contamination
4. Click on a valve to expand the contamination beyond the valve
5. Go back to the Facilities Management menu and select “Contamination Report”
Contaminated Volume: 1835.695 ft^3
Isolated Volume: 0 ft^3
4. Single-click this valve to see the contamination move north and west in the system. (Note: clicking again on this valve will close it and the contamination will update to the new boundary condition.)
Pipes isolated from the system are highlighted green.

Contaminated Volume: 3028.047 ft$^3$
Isolated Volume: 1339.131 ft$^3$
Contaminated Volume: 3027.698 ft^3
Isolated Volume: 1339.131 ft^3
Elements of a Contamination Report (Point Selection)

1. File name of the network
2. Date that the analysis was performed
3. Name of the pipe that contains the source of the contaminant (this is defined by where the user clicked to insert the point intrusion)
4. Volume of water contained in the contaminated pipes
5. Volume of water contained in pipes that are not contaminated but are isolated from a source
6. List of valve that must be turned off in order to isolate the contamination
7. List of hydrants that are in the contaminated region
8. Name and elevation of the lowest hydrant in the contaminated area (for use in flushing)
9. List of the lengths of all of the types of pipes within the contaminated region; categorized by material, rating, and diameter
Workshop Agenda

• 1. Project Overview
• 2. Overview of Project Website
• 3. Overview of Visualization Models
  – Graphical Flow Model
  – Pipe Break Model

• 4. Off line network modeling

• 5. Overview of SCADA
• 6. Overview of Sensor Placement
  – Sensor Placement Model
• 7. On-line network modeling
  – Real-time predictive analytics: process and benefits
  – Real-time network modeling: NKWD field study
• 8. Overview of Toolkit
• 9. Wrap up discussion
OFF-LINE COMPUTER MODELS

ON-LINE COMPUTER MODELS

SUPERVISORY CONTROL AND DATA ACQUISITION (SCADA)

OFF-LINE COMPUTER MODELS

SPATIAL VISUALIZATION OF NETWORK COMPONENTS
Workshop Agenda

• 1. Project Overview
• 2. Overview of Project Website
• 3. Overview of Visualization Models
  – Graphical Flow Model
  – Pipe Break Model
• 4. Off-line network modeling

5. Overview of SCADA

• 6. Overview of Sensor Placement
  – Sensor Placement Model
• 7. On-line network modeling
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  – Real-time network modeling: NKWD field study
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Workshop Agenda

1. Project Overview
2. Overview of Project Website
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   - Sensor Placement Model
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   - Real-time predictive analytics: process and benefits
   - Real-time network modeling: NKWD field study
8. Overview of Toolkit
9. Wrap up discussion
Water Quality Sensor Placement

• General guidelines
  – Single sensor placement
    • Graphical method
    • Simplified graphical method

• Placement Software
  – TEVA SPOT
  – KYPIPE
Sensor Location Tool

**INPUT**
- Number of sensors to be placed in system
- Mass injection rate of contaminant (1000 mg/min)
- Duration of injection (1 hr)

* Be sure you are using an Extended Period Simulation (EPS)

**OUTPUT**
- Optimal sensor placement locations within system
- Contamination Report
Sensor Location Tool
Sensor Location Tool
Sensor Location Tool

Press "SHIFT + F7"
Sensor Location Tool

[Image of a user interface for a sensor location tool]

- Number of Sensors (max 5): 2
- Simulation Start Time: 
- Process Start Time: 
- Process End Time: 
- Number of Nodes: 
- Number of Pipes: 
- Deadend Nodes: 
- Demand Nodes: 
- Injection Nodes: 
- Sensor Nodes: 
- Mass Inj Rate (mg/min): 
- Injection Start Time (hrs): 
- Injection End Time (hrs): 
- Detection Limit (mg/l): 
- WQ Comp Time (sec): 
- Average Travel Time: 
- View Report
Sensor Location Tool

![Default Parameters](image)

10

Fill in req. fields

- Total Simulation Time (Hours): 24
- WQ Computational Time (sec): 300
- Mass Injection Rate (mg/min): 1000
- Injection Start Time (Hours): 4
- Injection End Time (Hours): 5
- Detection Limit (mg/l): 0.01

Exit
Sensor Location Tool
Sensor Location Tool

2 sensors placed at optimal locations
Sensor Location Tool

Number of Sensors (max 5): 2
Generate INP File
Run
Abort
Exit

Number of Nodes: 189
Number of Pipes: 244
Deadend Nodes: 8
Demand Nodes: 136
Injection Nodes: 148
Sensor Nodes: 151
Mass Inj Rate (mg/min): 1000
Injection Start Time (hrs): 4
Injection End Time (hrs): 5
Detection Limit (mg/l): 0.01
WQ Comp Time (sec): 300

Times
Simulation Start Time: 4:03:52 PM
Process Start Time: 4:04:10 PM
Process End Time: 4:04:14 PM

Hydraulic Simulation Done
WQ Simulation Done
Sensor Node: 148 of 143
Injection Node Name: J-99
Sensor Selection Done
Optimal Sensor Locations
Sensor Node: J-171
Sensor Node: J-204
Average Travel Time (hrs): 3.07

Number of Sensor Nodes: 2
Contaminant Detection Limit: 0.01
Total WQ Simulation Time (hrs): 24
WQ Computational Time (sec): 300
Mass Injection Rate (mg/min): 1000
Injection Start Time (hrs): 4
Injection End Time (hrs): 5
Workshop Agenda

• 1. Project Overview
• 2. Overview of Project Website
• 3. Overview of Visualization Models
  – Graphical Flow Model
  – Pipe Break Model
• 4. Off line network modeling
• 5. Overview of SCADA
• 6. Overview of Sensor Placement
  – Sensor Placement Model

• 7. On-line network modeling
  – Real-time predictive analytics: process and benefits
  – Real-time network modeling: NKWD field study
• 8. Overview of Toolkit
• 9. Wrap up discussion
ON-LINE COMPUTER MODELS

ON-LINE COMPUTER MODELS

SUPERVISORY CONTROL AND DATA ACQUISITION (SCADA)

OFF-LINE COMPUTER MODELS

SPATIAL VISUALIZATION OF NETWORK COMPONENTS
ON-LINE COMPUTER MODELS

Water Distribution System Operations

ON LINE COMPUTER MODELS

Since measurement of hydraulic and water quality dynamics in pipe networks is performed at relatively few locations, network models are important tools for understanding network-wide flow dynamics, and their impact on the evolution of water quality. Many water utilities have developed computer models of water distribution systems as a tool for system design and analysis. Although great effort has been invested in such models, most of them are limited to off line analysis. These models are calibrated with data sampled during certain periods of time (usually several days) and only simulate the hydraulic and water quality conditions under specific water demand and operational scenarios. Despite the relatively wide application of SCADA systems, and the presumably vast amount of data stored within these archives, water distribution system models are not updated frequently, nor compared to historical SCADA records.

Off line models may not accurately represent the hydraulic or water quality behavior of water distribution systems under typical variability in water demands and operational response. Water utility operations will greatly benefit from the development of real-time network models since such models will provide a powerful mechanism to synthesize SCADA data and analyze/predict the network system performance under different operational scenarios. Such analysis will likely lead to better water quality predictions and improved anomaly/event detection, as well as dual-benefits such as improved energy efficiency or disinfectant residual management, because operators would have a consistently reliable tool to determine how system operational changes affect current and forecasted hydraulic and water quality behavior.

While off-line computer models (both hydraulic and water quality) can be used to improve the overall operations of a water distribution system, further improvement may be obtained through the use of models in a real-time or on-line environment. Water distribution systems are designed and operated to satisfy a range of objectives, including hydraulic performance. Metrics of hydraulic performance include pressure levels, fire protection, water quality, and various measures of system reliability. Real-time monitoring can be used to identify the status of a water distribution system at a particular point in time. By archiving such data, subsequent statistical analysis can be performed to identify various performance trends under different conditions. Use of an on-line or (real-time) hydraulic model can be further used to evaluate the future performance of the system under different conditions.

Water utilities are frequently faced with the challenge of having to respond to a range of different emergency situations. Such emergencies can include pipe breaks, component failures (e.g. pumps), low pressure issues, cross connections, and contamination events (either accidental or intentional). Real-time hydraulic models can be used to evaluate the impact of such emergencies on the future status of the system as well as for use in evaluating possible response actions. Water quality management continues to be a significant challenge for water distribution system operators, especially in light of increasing water quality regulations. The use of real-time water quality models provides the opportunity for system operators to improve the water quality of their delivered product by having the capability to model the water quality impacts of different operational changes in the system as well as to explore the impact of the location of regional chlorine booster stations.
ON-LINE COMPUTER MODEL GUIDANCE

• Model / SCADA Integration / Calibration

• Implementation Strategies and Barriers for Real-Time Modeling

• Potential Applications of Real-Time Simulation

• Actual Applications of Real-Time Simulation
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Operational Toolkit for a Water Distribution System

WDS Wizard

A Water Wizard Module

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Joseph L. Gutenson
The Environmental Institute
The University of Alabama

Project Workshop
May 27th 2014
Northern Kentucky Water District
User Assisted Decisional Process (toolkit)
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Survey

- On a scale of 1-9, how important are the following knowledge databases to your operations?
  - Information on sensors and telemetry. [   ]
  - Information on SCADA. [   ]
  - Information on network visualization. [   ]
  - Information on sensor placement. [   ]
  - Information on off-line modeling. [   ]
  - Information on model calibration. [   ]
  - Information on real-time modeling. [   ]
- What additional content would you like to see added?
Survey

• On a scale of 1-9, how likely would you be to use the following models?
  – Graphical flow model [   ]
  – Decon/pipe break model [   ]
  – Sensor placement tool [   ]
  – Real-time operations [   ]
Survey

• How useful was the project presentation?
• What additional information would you like to see?
• What information, if any, do you feel was not necessary?
• What changes could be made to make the presentation more informative or useful to your operations?
Questions?
OFF-LINE COMPUTER MODELS

Computer models for use in the analysis and design of water distribution systems have been available since the mid 1960's. Such models are typically composed of three parts: a database (composed of both graphical and physical data), a computer program (which solves both hydraulic and water quality equations), and a graphical user interface (see Figure 1).

The physical database will contain information that describes the physical infrastructure of the network, system demands, and the operational characteristics of the system. The actual physical characteristics of the network are typically represented in the computer using a node-link representation, where each pipe segment is represented by a line that is joined at both ends by a node (Figure 2). Observed or assumed water demands along the pipe line are normally averaged and then assigned to the nodes (see Figure 3). Additional components, such as tanks, valves and pumps are then represented in the model by treating them either as a special node or pipe element. The graphical database will contain information on the spatial location of the physical components of the system (see Figure 4). The Graphical Flow Model has been especially designed to take advantage of the Kentucky Infrastructure Authority graphical and physical databases for use in building a water distribution system model.
### OFF-LINE COMPUTER MODEL GUIDANCE

- Network Analysis
- Model Development
- Model Calibration
- Model Calibration Literature
- Laboratory Model Calibration Case Study
- Actual System Calibration Case Studies
- Model Application
- Examples of Model Applications
- Model Selection
- EPANET
- KYPipe