Improving efficiency of water utilities: practical examples

Slavco Velickov, PhD - Water Industry Director EMEA
Geospatial Forum, Rotterdam, 23-26 May 2016
Agenda

1. Bentley at a glance
2. Business drivers (trends) in the Water Industry
3. Water solutions overview
4. Improving efficiency, examples:
   1. Active Leakage Management (finding leakage hot-spots)
   2. Geospatially enabled Asset Management (leakage and break records analysis)
   3. Pumping scheduling and pressure optimization (saving water and energy)
5. Take away message
6. Contact information
Improving Quality of Life

Sustaining Infrastructure
Bentley’s Solutions

- MicroStation
- ProjectWise
- AssetWise
- Navigator
Water and Wastewater Business Drivers
Water Utilities Drivers

• Leakage Reductions
• Energy Efficiency
• Pressure Control
• Water Safety (Quality)
• Pipe Renewal Planning
• Master Planning
• Real-time Operations
• Emergency Response
• Staff Capacity Development and Resources
Wastewater / Stormwater

• Similar Drivers as for Clean Water
  – Prevent CSO / SSO with Models
  – Master Planning
  – Water Quality Analysis
  – Efficiency & Skills
• Inspection/Condition Assessment
• Implement BIM / ISO 55000
• WWT Plant Operation and Efficiency
Everyone’s Drivers

Save Water, Money, Time, Energy, Environment
Bentley Water Solutions: Addressing the Life Cycle of the Infrastructure
Water Industry Solutions Offerings

Water / WW GIS & AM

Modelling / analytical products

MicroStation

GeoSpatial Server, ProjectWise & eB

Data Files

Spatial Databases

Web Services

Spatial Documents

Business Documents

Ancillary Files w/ RDBWS

Proprietary GIS Databases

Enterprise Data Stores

SCADA & Loggers

Interoperability Connectors

Enterprise Connectors

Web clients

Web Publishing
Bentley Haestad Product Line

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<td>WaterObjects. .Net development environment</td>
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<td>Mohid. 2D / 3D Catchment and costal modeling solution</td>
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30 years
130,000 users
170 countries
Acquired by Bentley in 2004

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130,000 users
170 countries
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Bentley Reality Modelling for Water Industry

**ContexCapture**
Photos to 3D models | Buildings, Plants
Ground Infrastructure (asset conditions)

**LumenRT**
Visualize and Communicate | Infrastructure Models, Designs, Model Results
Example: Paris 500 km of sewers mains

**REQUIREMENT**
- Model and refresh a sewer infrastructure (500km long) including pipes, cables and other equipment

**SOLUTION**
- Multi-directional camera system (like Trimble v10) + specific lighting system + Smart3DCapture Ultimate

**RESULT**
- Photorealistic 3D model, helping users to detect and extract structure components from the mesh and point cloud
1) Water Loss

Leakage Reduction by pressure management, hydraulic modelling, measured data and optimization techniques
Remediating Water Loss is Complex

- It’s impossible to find and fix all leaks (economic level of leakage)
- Partial implementation of a water loss plan is highly likely to fail
- Coordination between all components of a water loss program is required

"Many practitioners make common mistakes- they may have the false impression that each time a leak is repaired, physical loss is reduced by the volume saved...”

Vermersch and Rizzo
Source: IWA's Water21 Magazine, April 2014

(Courtesy Dr. Thomas Walski)

Implement IWA best / good practices

Speed and Quality of Repairs
Replacing pipes with least impact on customers

Pressure Management

Unavoidable Real Loss

Economic Level Real Loss
Current Annual Real Loss Volume

Active Leakage Control
Detecting and fixing leaks
Replacing/installing meters (DMAs)

Risk-based asset management for maximum return

Infrastructure Management
Current Practice

1. **Assessment**
   - water balance or water auditing based upon water infrastructures’ physical data and some statistics

2. **Pressure Management**
   - Divide the network in Pressure Zones and DMAs (how detailed)
   - Use hydraulic model for PRVs including pumps optimisation
   - Install PRVs to manage MNF

3. **Active Leakage Detection**
   - Sounding for leaks
   - Step-testing
   - Acoustic loggers (noise correlators)
   - Smart balls
   - Use hydraulic model and measured (Scada) data
Bentley Integrated Framework: Leakage Detection & Model Calibration

WaterGEMS (Darwin Calibrator)
Example Case: system conditions

- DMA system model owned by UUW
- 20 km pipelines
- 400 properties
- 5 pressure loggers and one flow meter
Example: previously detected pipe bursts

**Burst A**
- Distance from prediction: <50m
- Mains Material: 150mm Ductile Iron

**Burst B**
- Distance from prediction: 150m
- Mains Material: 8" Cast Iron

**KEY**
- DMA Boundary
- Posi-tect prediction
- Leak located
Example Case: results comparison (sensitivity)
Example Case: ROI savings

Saving > 210,000 Euro / year

30m³/hr reduction
Video: WaterGEMS leakage detection
2) Capital Investment Planning (pipe renewals)

Water Mains Asset Management - leakage and break records geospatial risk analysis
Example: Pipe Assets Renewal Planning

1 Asset Inventory/Leak History

Bentley Open Utilities

Prioritize

2 Bentley WaterGEMS

Cost Estimate

3 Bentley OU Expert Designer

Manage records, Report, Visualize, Schedule

4 AssetWise (eB) / GWP
Manage Leak Records

• Most utilities keep leak records
• Many forms
  – Paper records
  – Databases
  – Spreadsheets
  – Shapefiles
  – Work orders
• Import to Bentley Water
• Need x-y coordinates (georeference)
Spatially View Leak Locations
Cluster Thematically Bad Pipes
## Analyze Patterns

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<th>Breaks</th>
<th>Break Rate, break/yr/km</th>
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## Look for Relationships

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<th>Circumferential breaks</th>
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Thematic Maps & Reports
WaterGEMS: Pipe Renewal Planner Tool workflow

Water network inventory (NWC GIS and AM systems)

**Must have**
- Pipe break history
- Statistical Analysis (Weibul or Bayesian)
- Normalised break score per pipe (0-1)

**Available**
- Hydraulic model
- Full capacity analysis (peak or fire flow)
- Criticality analysis
- Normalised cap. score (0-1)
- Normalised critic. score (0-1)

**Added value to have**
- Other attribute of importance
- GIS analysis
- Normalized score (0-1)

GA weighting optimization model

Overall pipes renewal priority score and GIS mapping
Pipe Renewal Planner Results

<table>
<thead>
<tr>
<th>ID</th>
<th>Label</th>
<th>Pipe Score</th>
<th>Raw Score (Pipe Break) (break)/y/ml</th>
<th>Score (Pipe Break) (%)</th>
<th>Raw Score (Criticality) (%/y/ml)</th>
<th>Score (Criticality) (%)</th>
<th>Raw Score (Capacity) (Cu.)</th>
<th>Score (Capacity) (%)</th>
<th>Diameter (in)</th>
<th>Length (ft)</th>
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Risk Map: Prioritization of Pipe Replacements
eB – Report, Visualize, Schedule Renewals

- Customizable Dashboard
- None Technical Presentation
- Easy to read, easy to use
- Integrated Spatial Map
- Integrate with Enterprise Workflows
- Visualize and Approve
Or Publish with Geo Web Publisher (mobile as well)
3) Pumping Scheduling

Optimizing Pumps Operation for Minimum Energy Usage in Water / Wastewater / Stormwater Systems
Energy Consumption

- Water is pumped throughout the system
- Adequate pressure is maintained by pumping
- Pumping results in high energy consumption
- \( \text{CO}_2 = \text{ExC}_{\text{intensity}} \)

The diagram shows national energy consumption projections for public water supply, with bars indicating energy consumption intensity in pounds for different energy sources.
Which pump is wasting energy?
Wire Power In

Brake (Motor) Power

Water Power

Added

Overall (wire-to-water) Efficiency = Water Power/Input Power

Pump Efficiency = Water Power/Motor Power
Pump Power and Efficiency

Water Power (hp) = Q * h * S / efficiency

Wire-to-Water Efficiency = Pump x Motor x Drive Efficiency
Reduce Energy by Optimal Pump Scheduling

• **What to schedule**
  - Which pump is on duty
  - When pump is on duty
  - What speed is on duty
  - Which Tanks to utilise

• **Goal**
  - Minimize energy consumption
  - Minimize total energy cost

• **Supply requirements**
  - Water demand and hydraulics
  - Manage pressure constrains (water loss)
  - Deliver water quality
Formulation (mathematical optimization)

- Search for: 
  \[ \vec{H} = (h_{i,t}) \quad i = 1,2,\ldots,N_{ps}, \quad t = 1,\ldots,T \]

- Minimize: 
  \[ C = \sum_{p=1}^{N_p} C_p \]

- Subject to: 
  \[ h_{\min} \leq h_{i,t} \leq h_{\max} \]
  \[ v_{\min} \leq v_{j,t} \leq v_{\max} \]
  \[ \omega_{\min} \leq \omega_p \leq \omega_{\max} \]

Where 
- \( h_{i,t} \) is the target hydraulic head of pump station \( i \) at time \( t \)
- \( v_{j,t} \) is the flow velocity of pipe \( j \) at time \( t \)
- \( \omega_p \) is the relative speed factor for pump \( p \)
- \( N_{ps} \) is the number of pump stations,
- \( N_p \) is the number of pumps,
- \( C \) is the total energy cost of the pumps,
- \( h_{\min} \text{ and } h_{\max} \) are the minimum required and maximum allowed hydraulic head,
- \( v_{\min} \text{ and } v_{\max} \) are the minimum required and maximum allowed flow velocities
Energy Cost Analysis Tool
Darwin Scheduler
Case Study (Water Utility in UK)

- DMZ system
- 57 Ml/day
- 11 pump stations and 9 tanks
- Energy cost: £330K/year
- Recorded daily energy cost: £912
- Modeled daily energy cost: £923
Electricity Tariff Pattern
Pump Scheduling Optimization

• Optimization criteria
  – One hour control interval
  – Tank minimum level is set to 20% of depth
  – Tank maximum level is set to 90% of depth
  – Meet minimum pressure requirements at PRVs and critical points

• Results converted to control rules, e.g.

Rule 100
IF SYSTEM CLOCKTIME <= 8:00 AM
OR SYSTEM CLOCKTIME >= 10:00 PM
AND TANK BUTa2 LEVEL BELOW 5.73
THEN PUMP PILWTH STATUS IS OPEN
ELSE PUMP PILWTH STATUS IS CLOSED
## Energy Cost Comparison

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<th>Pump ID</th>
<th>Existing controls</th>
<th>Optimized controls</th>
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<tbody>
<tr>
<td></td>
<td>Pump utilization (%)</td>
<td>Daily cost (£)</td>
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<tr>
<td>X2420052_</td>
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<td>NEWMRKT</td>
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<tr>
<td><strong>Total cost (£)</strong></td>
<td><strong>983.12</strong></td>
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</table>

- Immediate saving is 100,000 £ (29% of original energy cost)
- By optimizing pumping hours and better supply from storage sources
Optimized Pump Controls

- Pressure points and Tank levels
- Pump flows and controls
Take Away Message

- Improving Efficiency is a part of a lifecycle asset management practice in Water Utilities and Consulting Ecosystem

- Integrated Geospatial, Hydraulic Modeling and Optimization technology can help:
  - Detecting leakage hotspots
  - Pipe renewal planning process
  - Pumping scheduling and optimal pressure and energy management (including CO2 footprint)

- From ‘dull pipes’ towards Smart Water Networks for real-time modelling, decision making and emergency response
Contact Information and Resources

Email: Slavco.Velickov@bentley.com

www.bentley.com/water
www.bentley.com/waterstories
www.bentley.com/systemefficiency
communities.bentley.com