Improving efficiency of water utilities: practical examples

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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

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Improving Quality of Life

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

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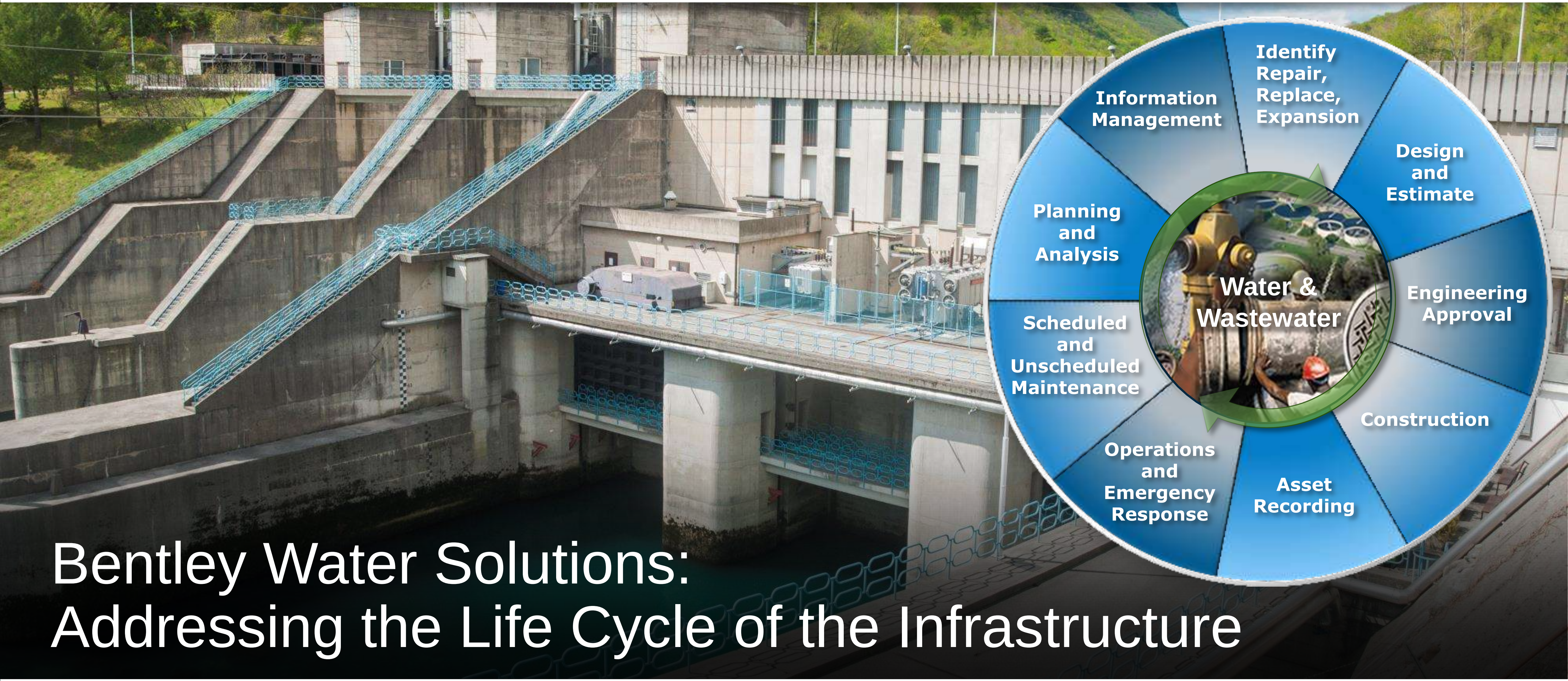
Wastewater / Stormwater

- 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

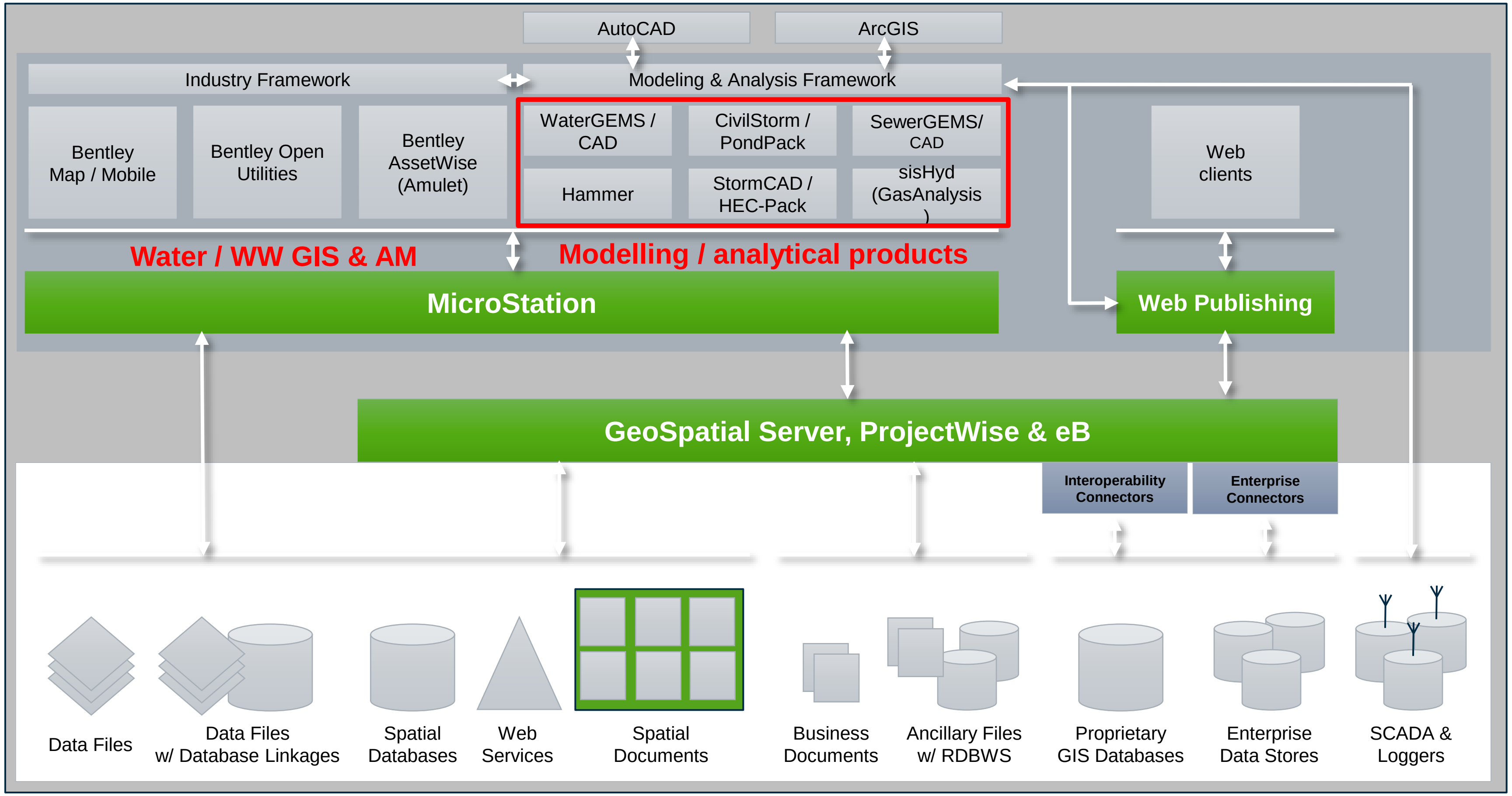
Save Water, Money, Time, Energy, Environment



Bentley Water Solutions: Addressing the Life Cycle of the Infrastructure

Bentley Advancing Infrastructure

Water Industry Solutions Offerings



Bentley Haestad Product Line

HAESTAD METHODS
WATER SOLUTIONS

30 years

130,000 users

170 countries

Acquired by Bentley in 2004

WATER	WaterGEMS. Water distribution modeling with geospatial integration
	WaterCAD. Water distribution modeling and design
	— Darwin Designer. Network design automation
	— Darwin Calibrator. Model calibration optimization
	— Darwin Scheduler. Energy efficiency optimizer
	— Pipe Renewal Planner. Asset investment planning tool
	HAMMER. Transient flow analysis and modeling
	SCADAConnect. Supervisory and control data integration
SEWER	SewerGEMS. Urban sewer modeling with GIS integration
	SewerCAD. Sanitary sewer design and modeling
STORM (flood)	CivilStorm. Stormwater management and dynamic modeling
	StormCAD. Storm sewer design and modeling
	PondPack. Detention pond design and analysis
	HEC-Pack. River basin modeling, reservoir optimization
	CulvertMaster. Culvert design and analysis
	FlowMaster. Hydraulics calculator
Other…	Amulet. Real-time forecasts and dashboards platform
	WaterObjects. *.Net* development environment
	Mohid. 2D / 3D Catchment and costal modelling solution

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

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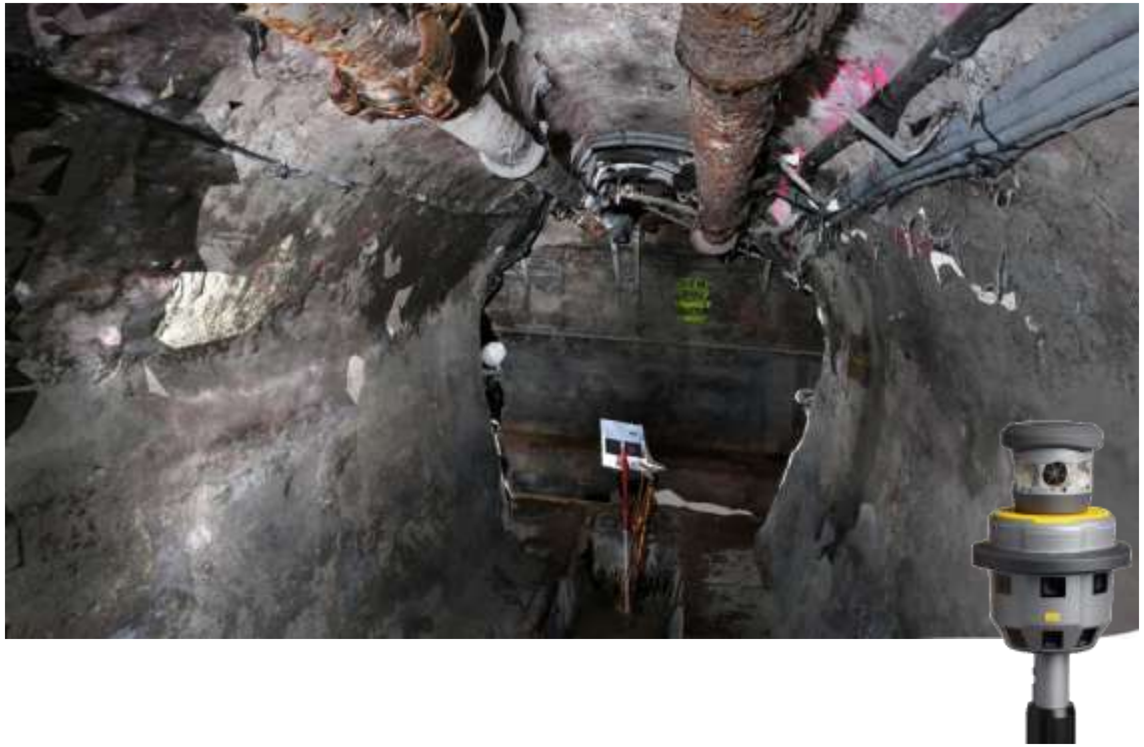
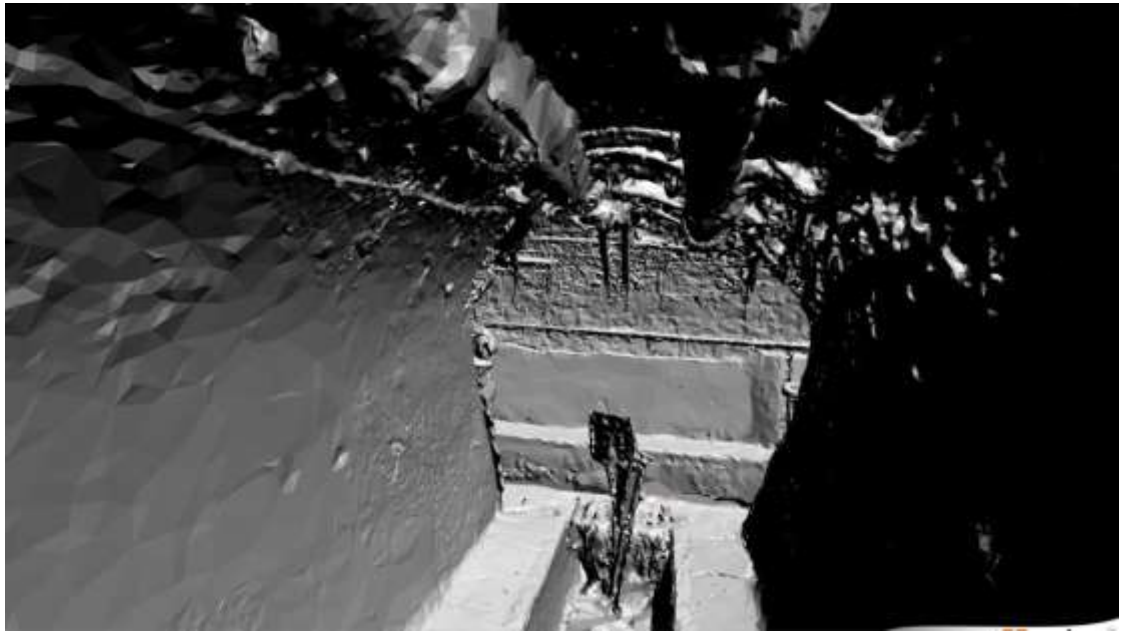
Example: Paris 500 km of sewers mains





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

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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

(Courtesy Dr. Thomas Walski)

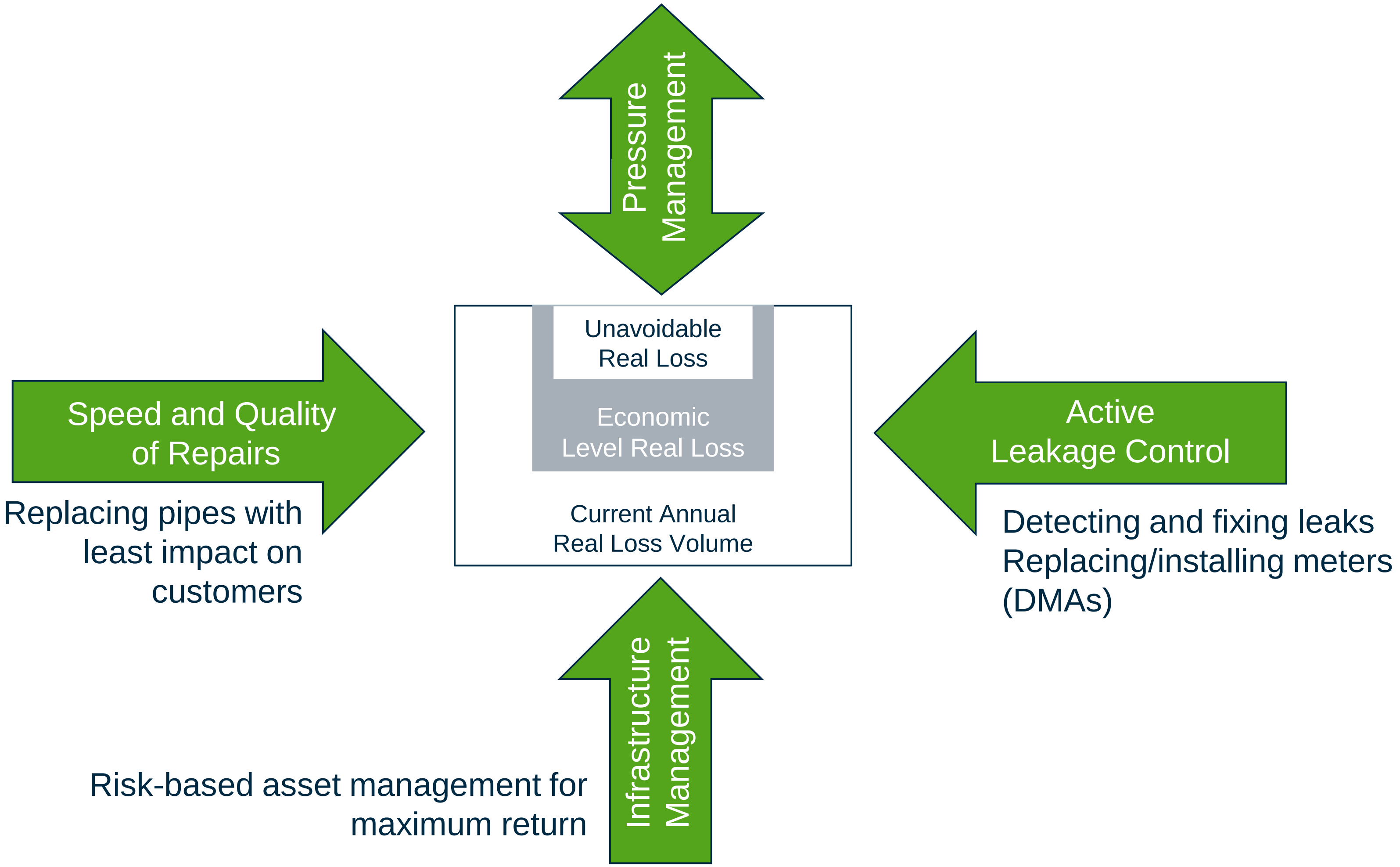
"Many practitioners make common mistakes- they may have the false impression that each time a leak is repaired, physical loss is reduced by the volume saved…"

Vermersch and Rizzo

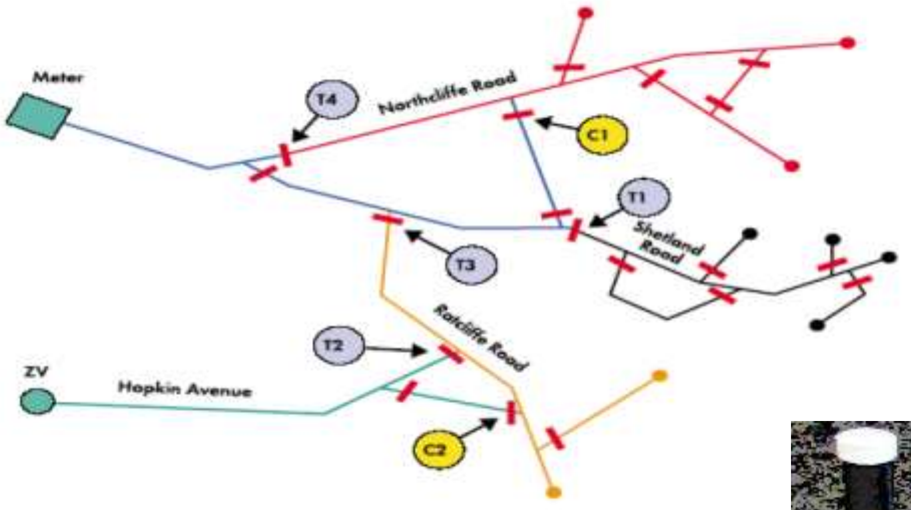
Source: IWA's Water21 Magazine, April 2014

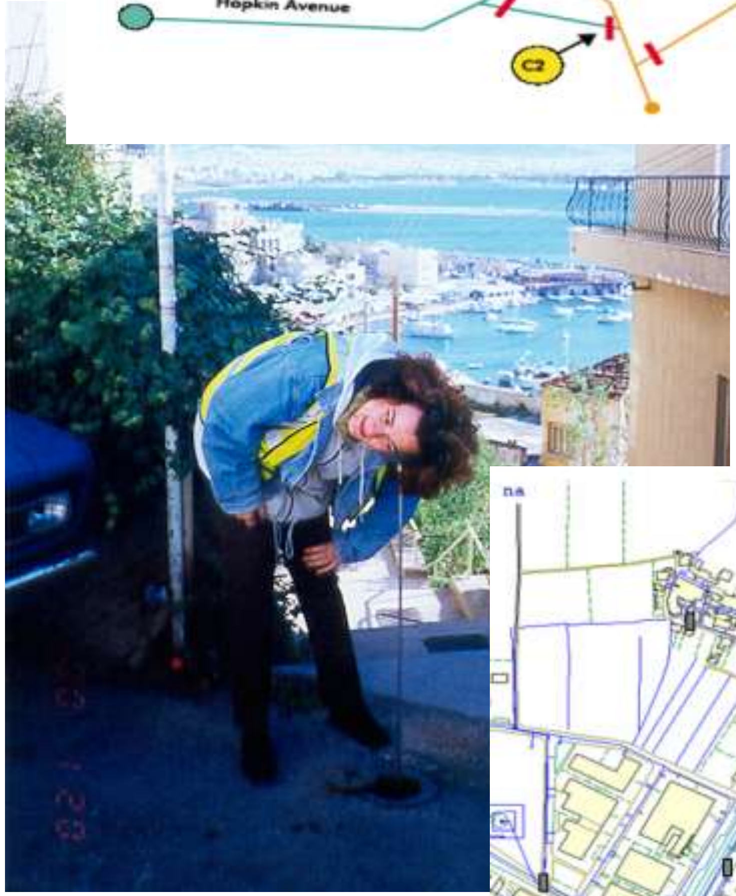
Strategy: A Long-term Approach with Immediate [short-term] Benefits

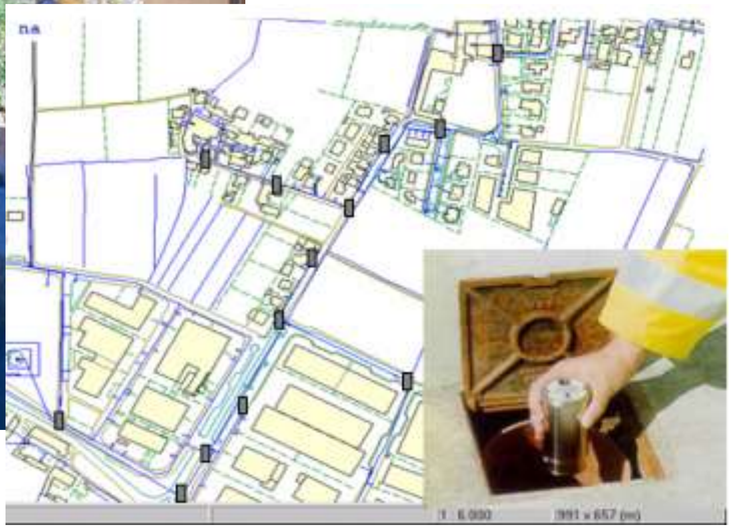
Implement IWA best / good practices



Current Practice

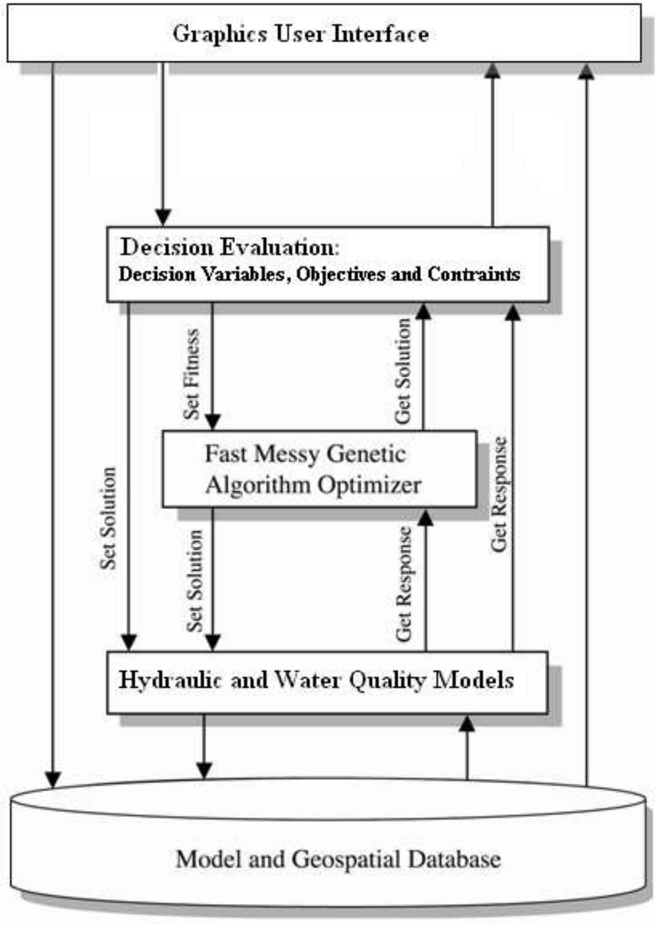




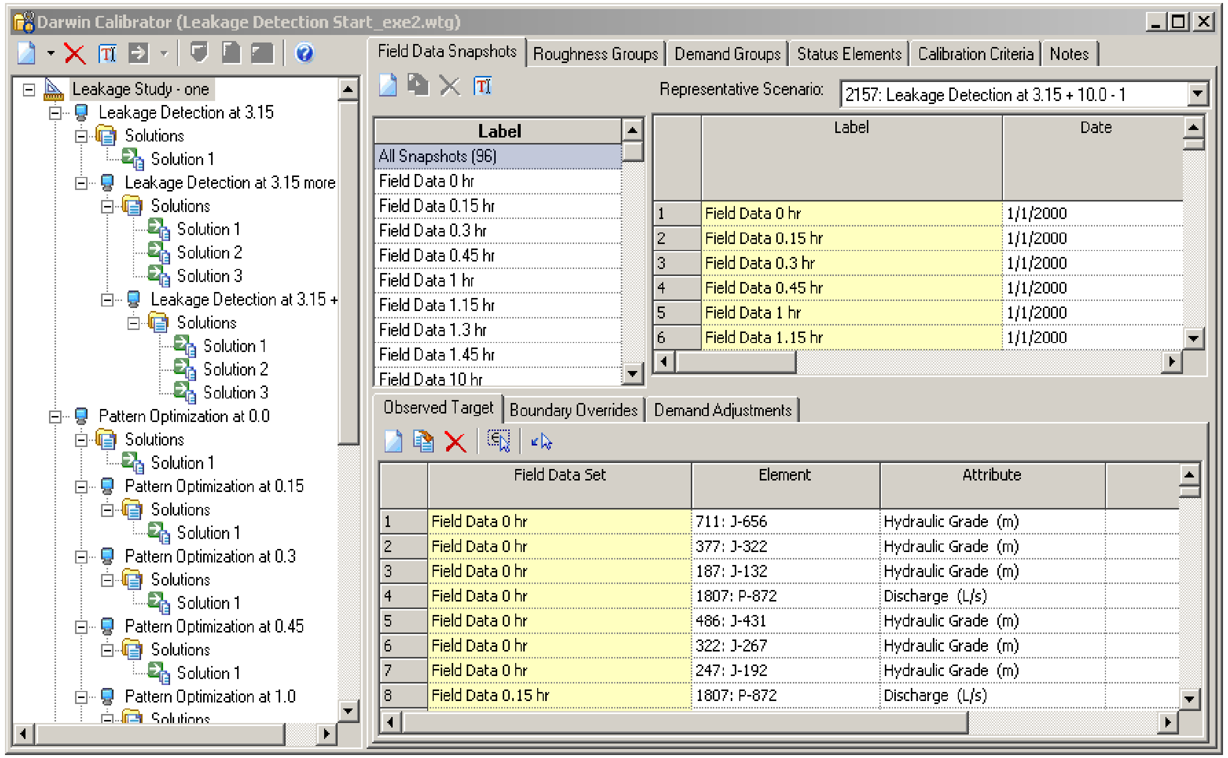


1. Assessment
   - water balance or water auditing based upon water infrastructures’ physical data and some statistics
2. Pressure Management
   - Divide the network in Pressure Zones and DMAs (how detailed)
   - Use hydraulic model for PRVs including pumps optimisation
   - Install PRVs to manage MNF
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

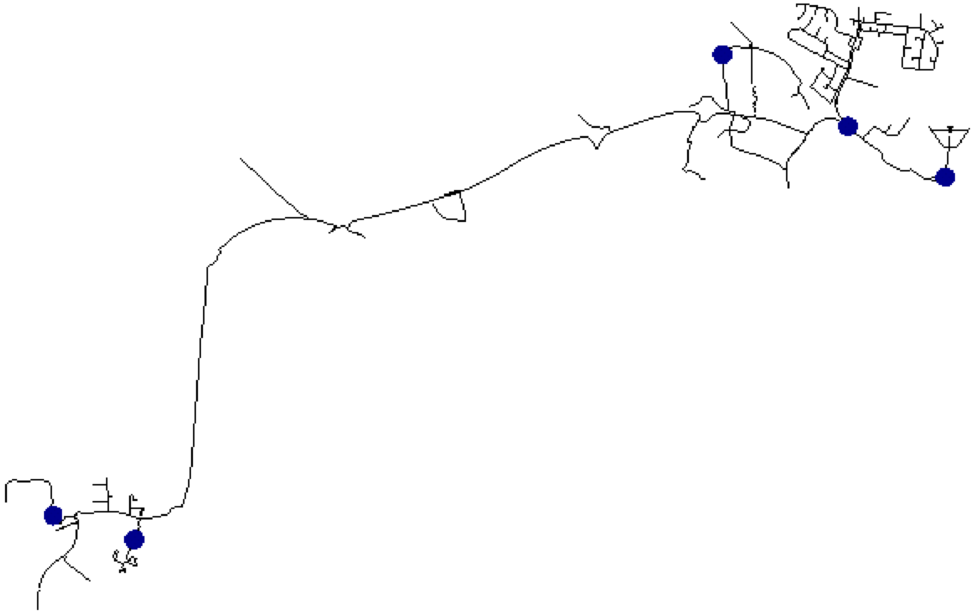


WaterGEMS (Darwin Calibrator)

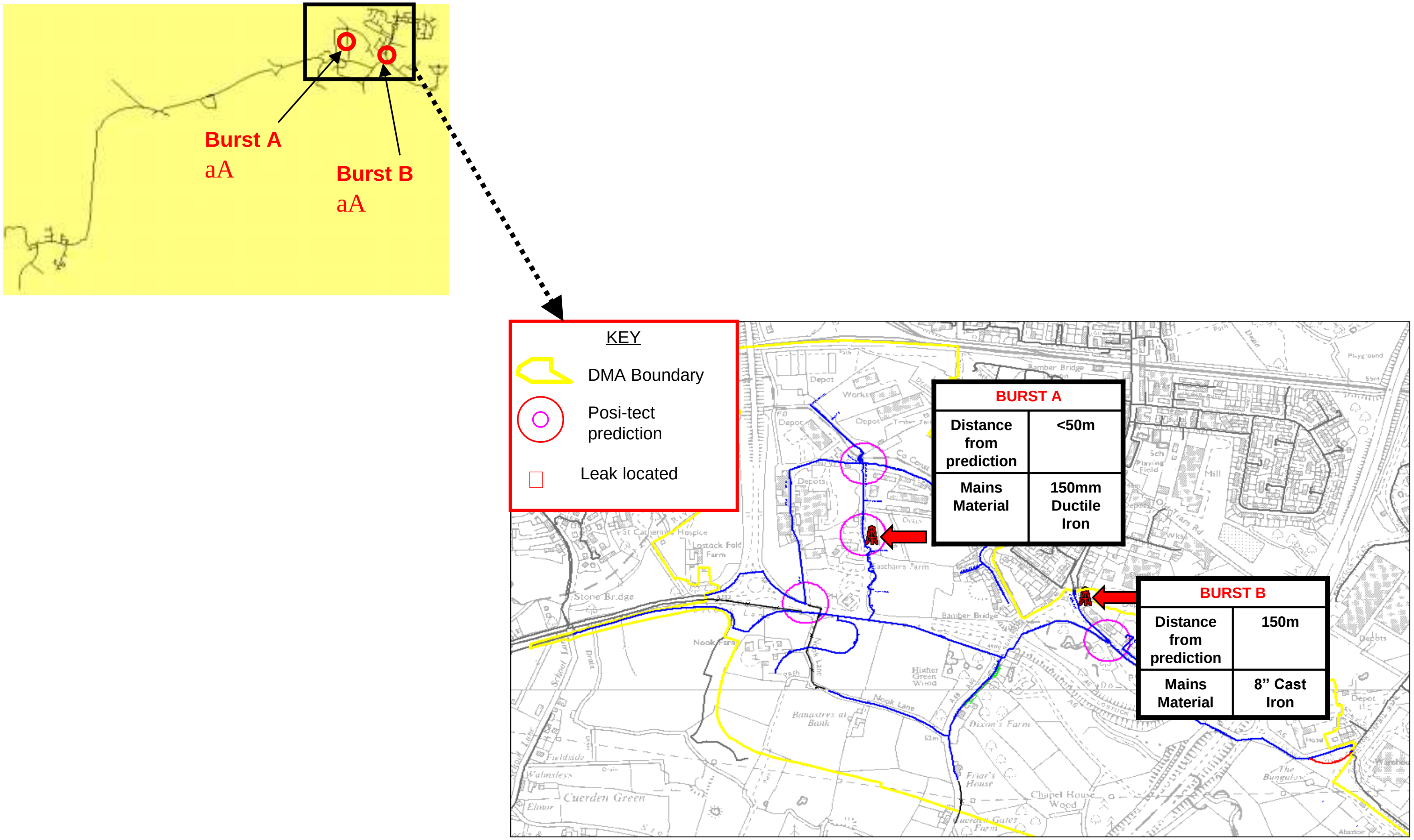


Example Case: system conditions

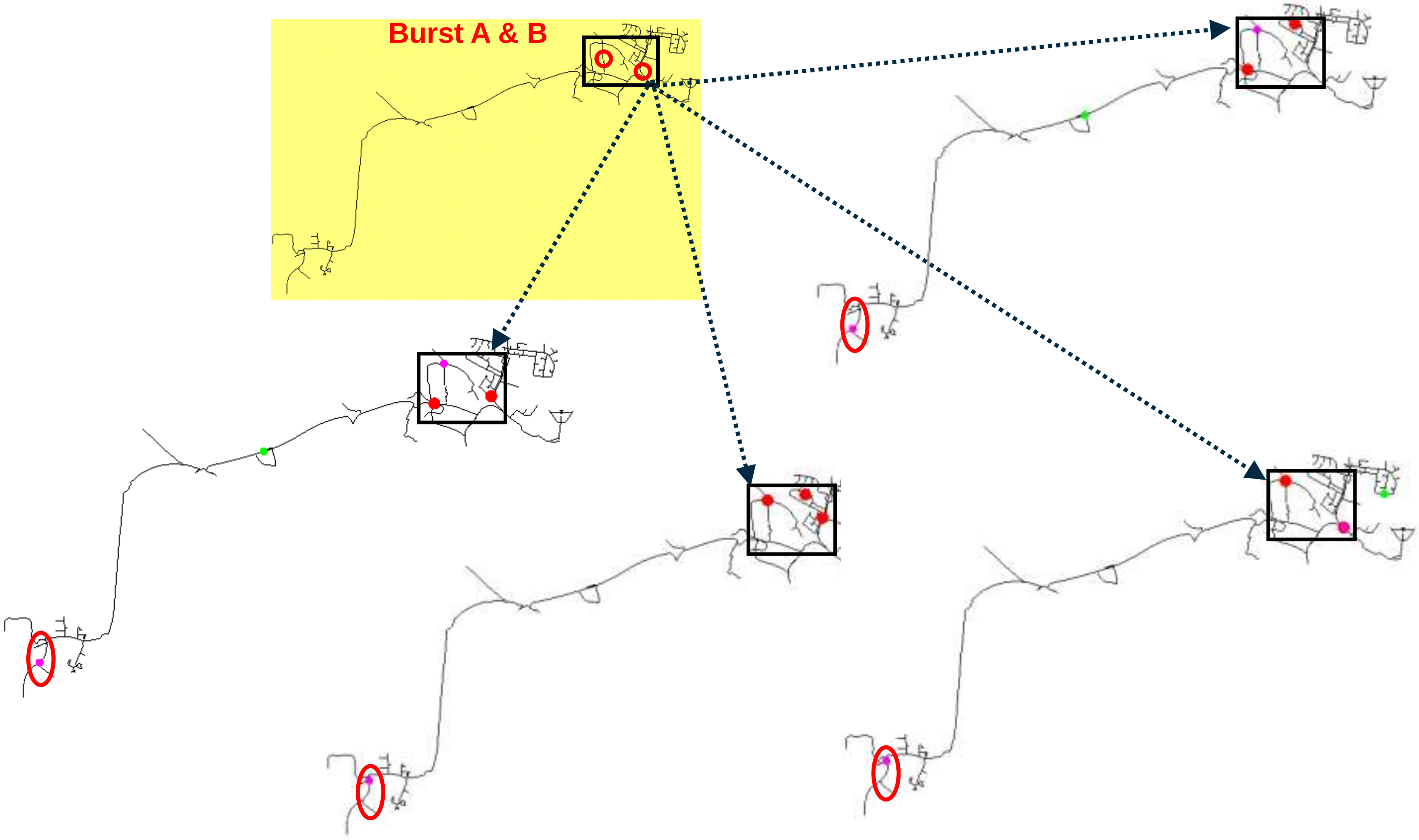
- DMA system model owned by UUW
- 20 km pipelines
- 400 properties
- 5 pressure loggers and one flow meter



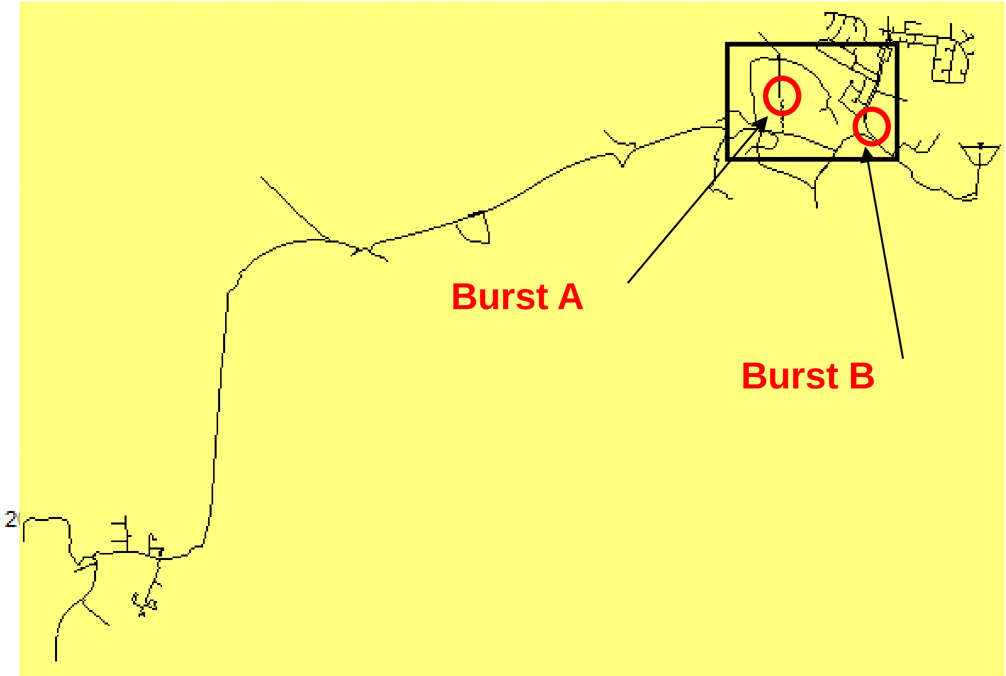
Example: previously detected pipe bursts



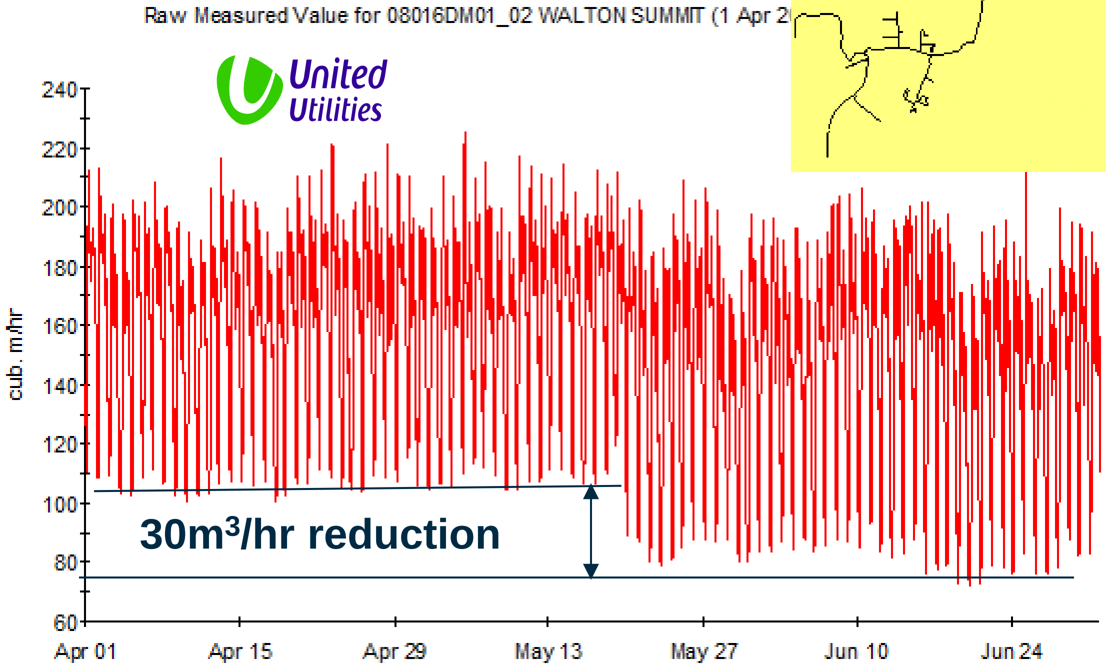
Example Case: results comparison (sensitivity)



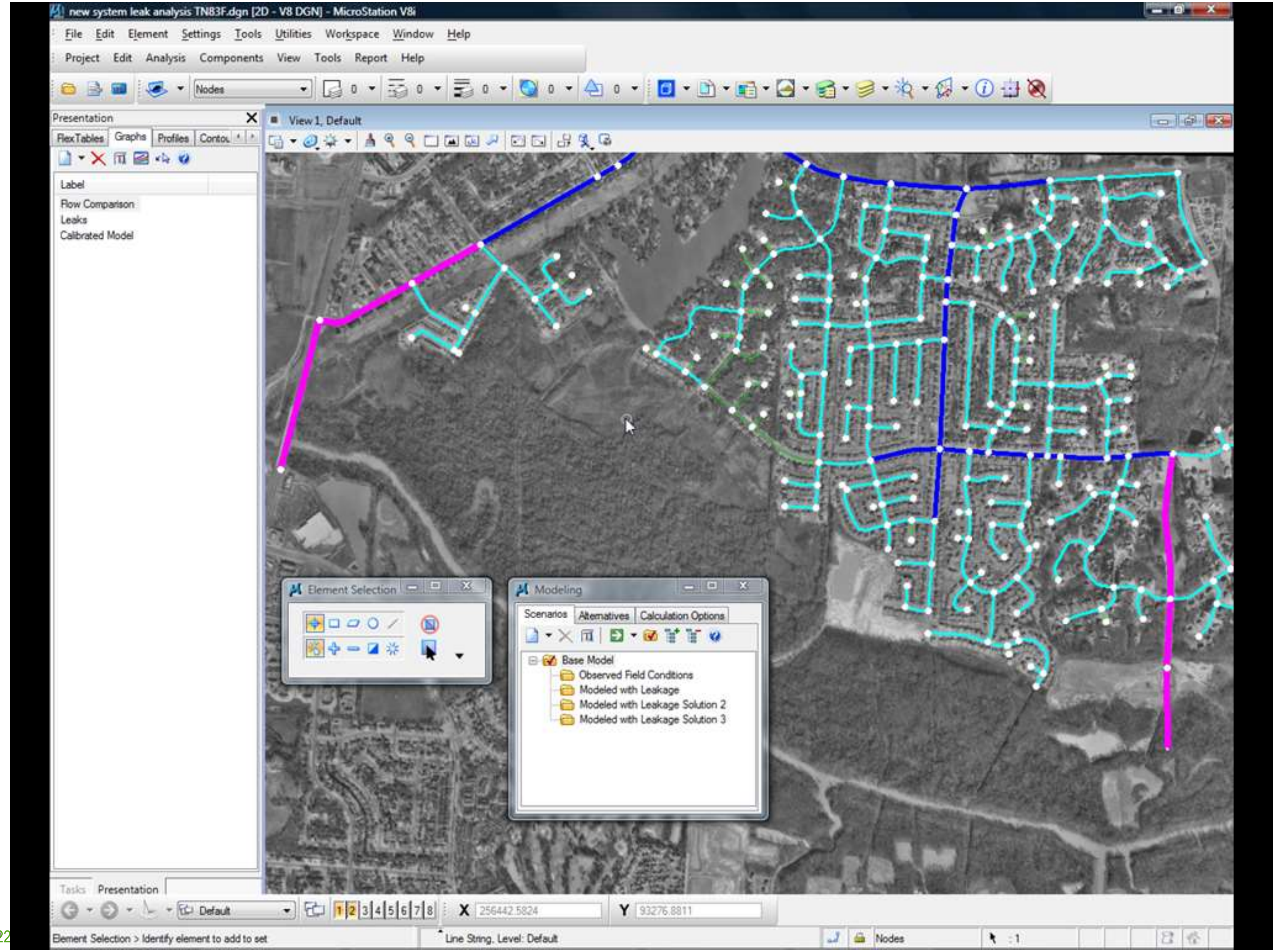
Example Case : ROI savings



Saving > 210,000 Euro / year



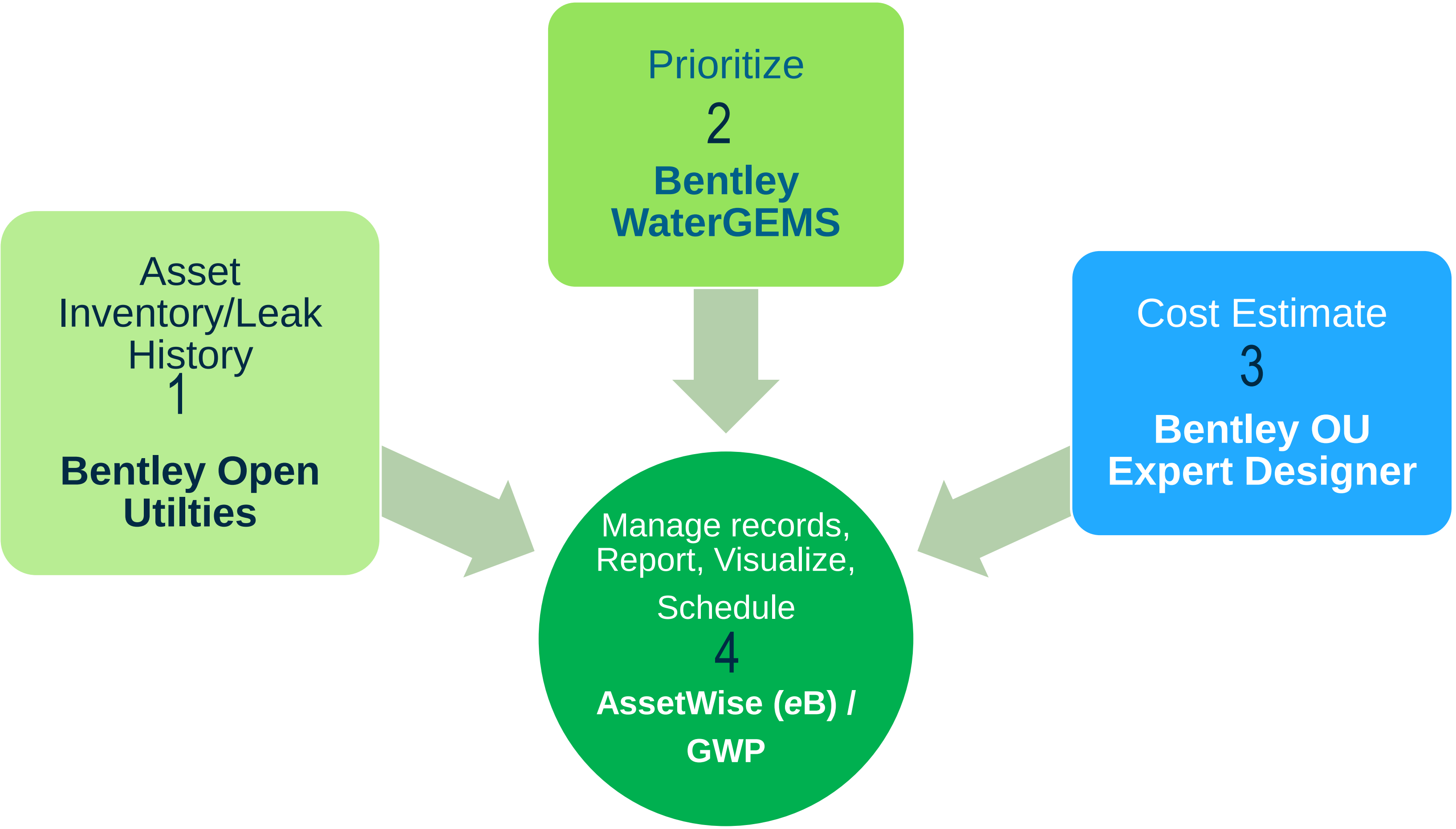
Video: WaterGEMS leakage detection



2) Capital Investment Planning (pipe renewals)

Water Mains Asset Management -
leakage and break records geospatial risk analysis

Example: Pipe Assets Renewal Planning



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)


BHC

FIELD DATA FOR MAIN BREAK EVALUATION

DATE OF BREAK: ______ TIME: ______ A.M. ______ P.M.

TYPE OF MAIN: ______ SIZE: ______ JOINT: ______ COVER: ______ FT ______ IN

THICKNESS AT POINT OF FAILURE: ______ IN.

NATURE OF BREAK: ☐ Circumferential ☐ Longitudinal ☐ Circumferential & Longitudinal ☐ Blowout ☐ Joint ☐ Split at Corporation ☐ Sleeve ☐ Miscellaneous: ______

APPARENT CAUSE OF BREAK: ☐ Water Hammer (surge) ☐ Defective Pipe ☐ Corrosion ☐ Deterioration ☐ Improper Bedding ☐ Excessive Operating Pressure ☐ Differential Settlement ☐ Temperature Change ☐ Contractor ☐ Miscellaneous: ______

SIDE OF STREET: ______ ☐ N ☐ S ☐ E ☐ W

TYPE OF SOIL: ______

ELECTROLYSIS INDICATED: ☐ Yes ☐ No CORROSION: ☐ Outside ☐ Inside

DEPTH FROST: ______ IN. DEPTH OF SNOW: ______ IN.

MAIN BREAK EVALUATION

WEATHER CONDITIONS / TEMPERATURE: ______

WATER TEMPERATURE (by office): Temp. ______ °F

TYPE OF MAIN: ______ CLASS OR THICKNESS: ______ LAYING LENGTH: ______ FT.

DATE LAID: ______ OPERATING PRESSURE: ______

BACKFILL: ☐ Native Material DESCRIBE: ______

☐ Bank Run Sand & Gravel ☐ Gravel ☐ Sand ☐ Crushed Rock ☐ Other: ______

TOWN: ______

STREET: ______

CROSS STREET NO.1: ______

CROSS STREET NO.2: ______

MSLINK #: ______ (to be completed in office)

LENGTH OF SHUTDOWN (HRS.): ______

NUMBER OF CUSTOMERS WITHOUT SERVICE: ______

REPORTED BY: ______

DAMAGE TO PAVING AND/OR PRIVATE PROPERTY: ______

REPAIR MADE (Materials, Labor, Equipment): ______

REPAIR DIFFICULTIES (if any): ______

REPAIR CONTRACTOR: ______

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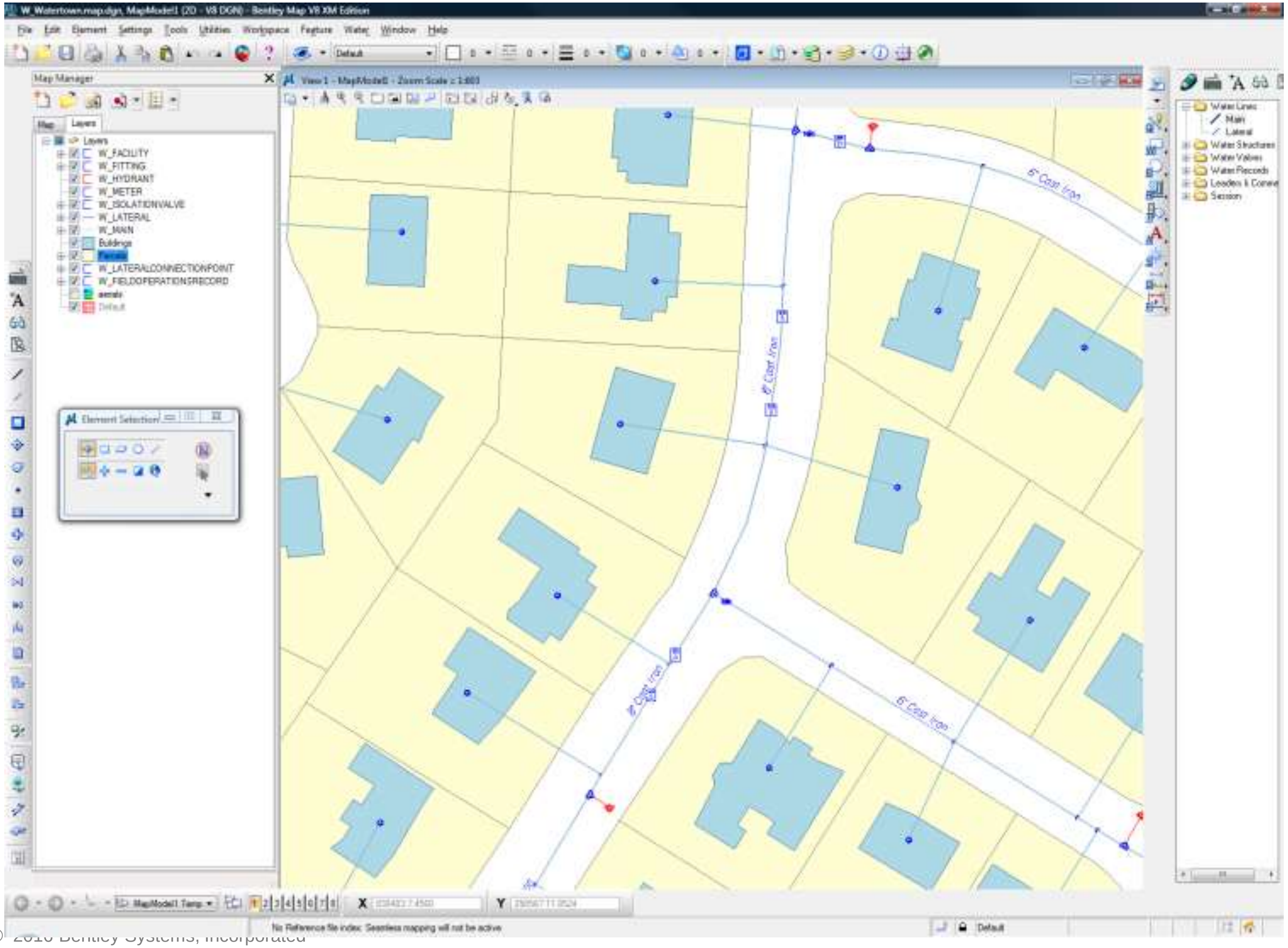
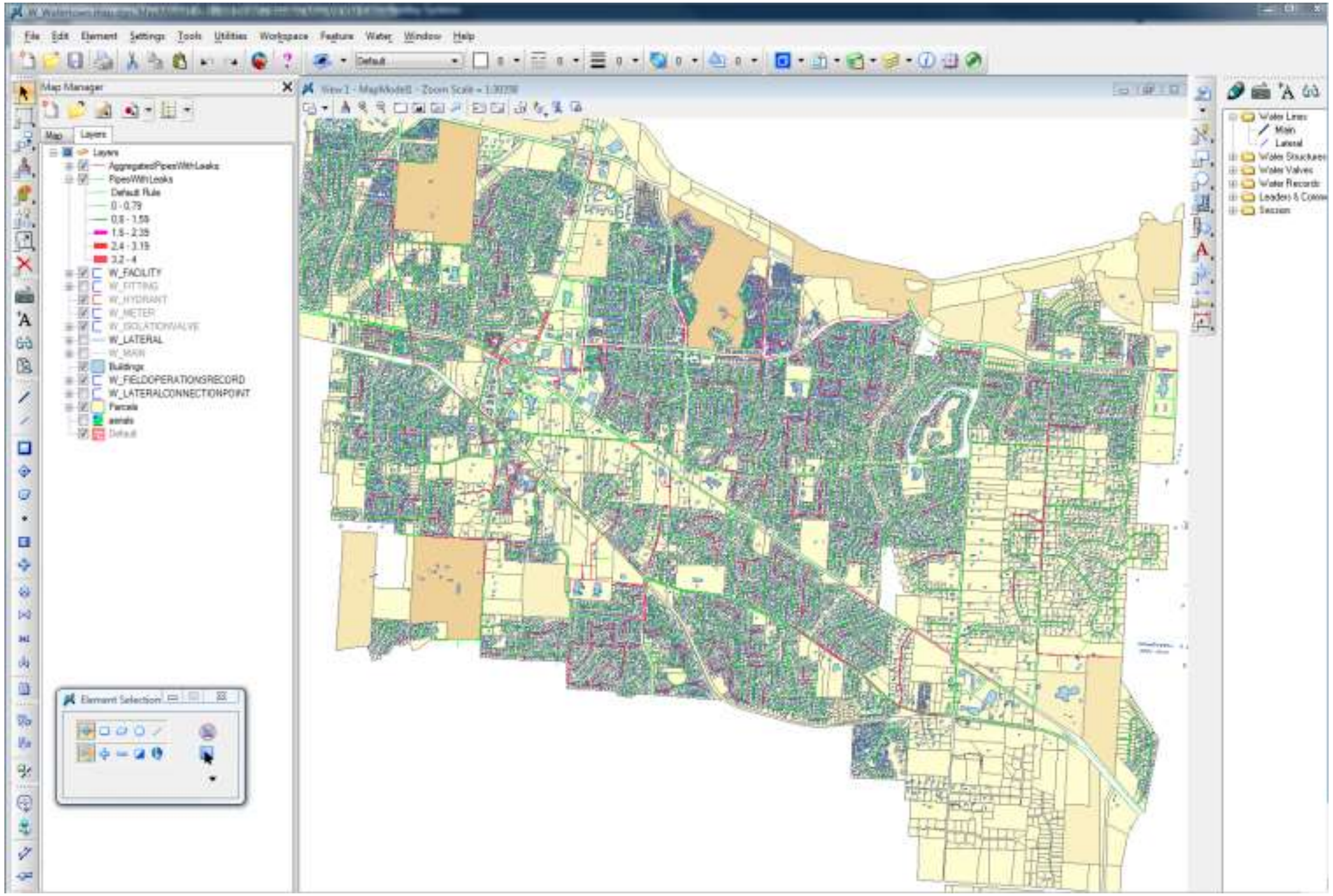
Spatially View Leak Locations



Cluster Thematically Bad Pipes



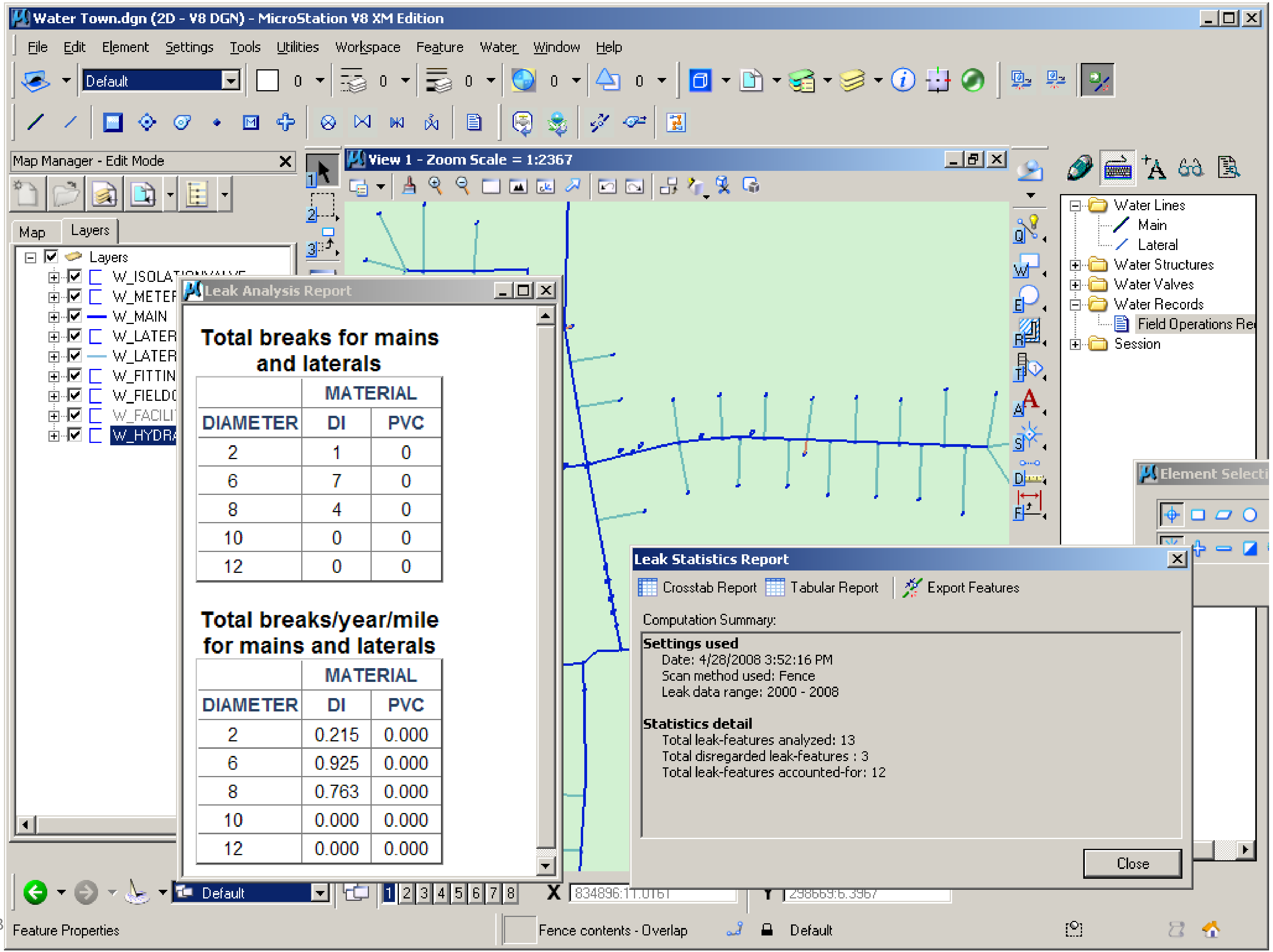
Analyze Patterns

Diameter, in.	Breaks	Break Rate, break/yr/km
6	25	0.105
8	15	0.082
12	8	0.062
16	2	0.041
24	3	0.056

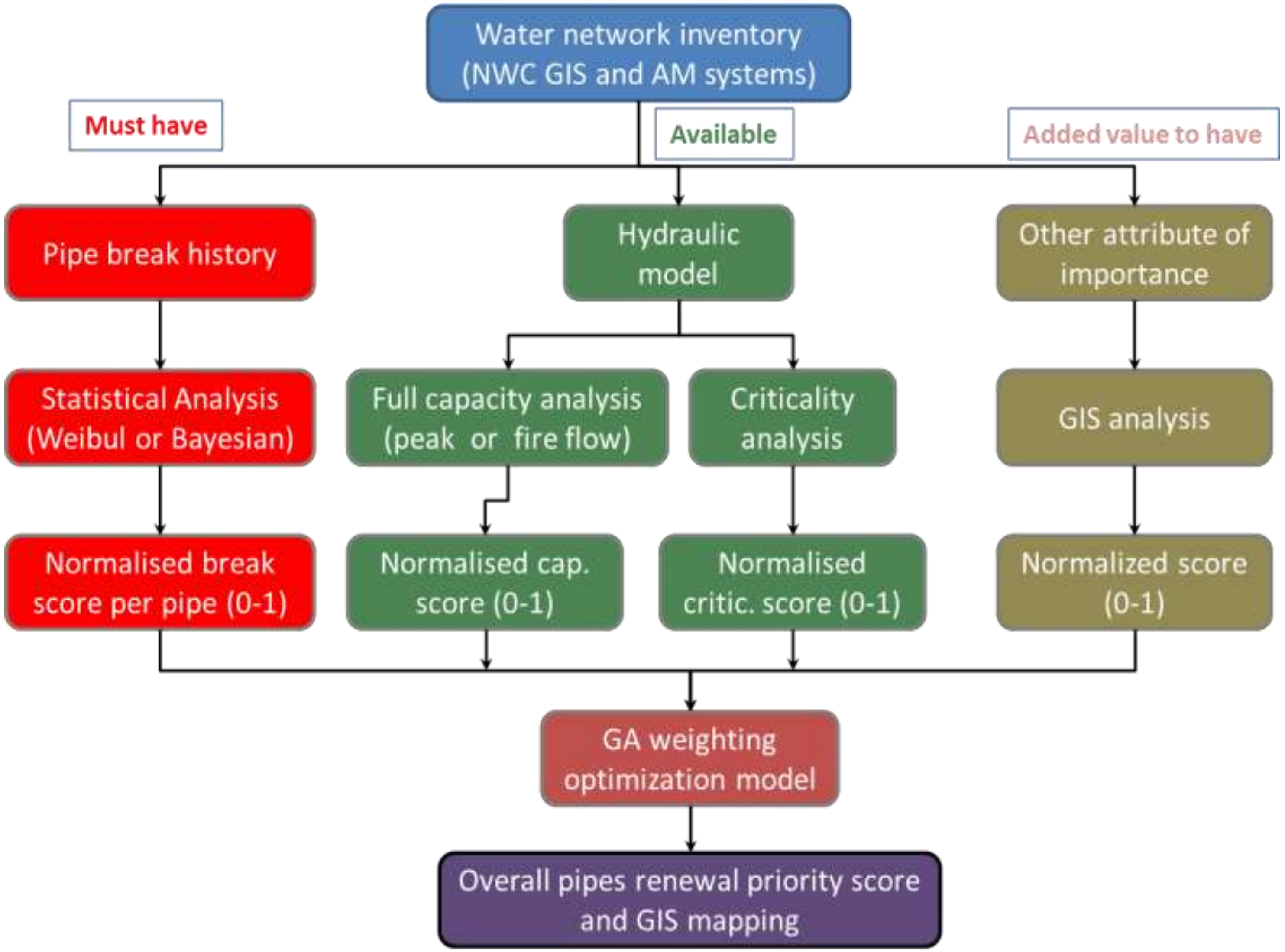
Look for Relationships

	Circumferential breaks	Longitudinal breaks	Corrosion holes
Cast Iron	73	7	4
Ductile iron	12	2	5
PVC	23	17	0
Steel	2	1	12

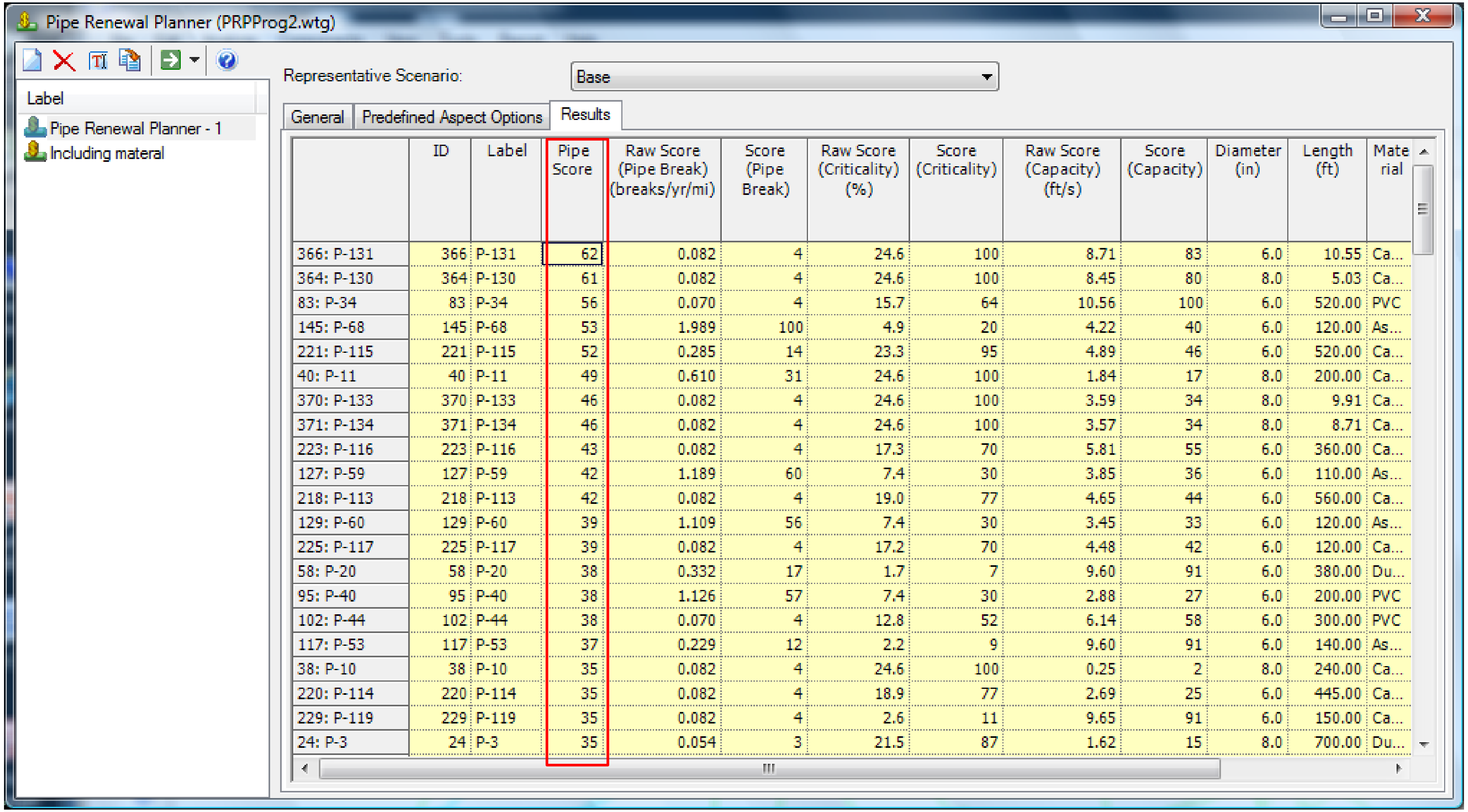
Thematic Maps & Reports



WaterGEMS: Pipe Renewal Planner Tool workflow



Pipe Renewal Planner Results



	ID	Label	Pipe Score	Raw Score (Pipe Break) (breaks/yr/mi)	Score (Pipe Break)	Raw Score (Criticality) (%)	Score (Criticality)	Raw Score (Capacity) (ft/s)	Score (Capacity)	Diameter (in)	Length (ft)	Material
366: P-131	366	P-131	62	0.082	4	24.6	100	8.71	83	6.0	10.55	Ca...
364: P-130	364	P-130	61	0.082	4	24.6	100	8.45	80	8.0	5.03	Ca...
83: P-34	83	P-34	56	0.070	4	15.7	64	10.56	100	6.0	520.00	PVC
145: P-68	145	P-68	53	1.989	100	4.9	20	4.22	40	6.0	120.00	As...
221: P-115	221	P-115	52	0.285	14	23.3	95	4.89	46	6.0	520.00	Ca...
40: P-11	40	P-11	49	0.610	31	24.6	100	1.84	17	8.0	200.00	Ca...
370: P-133	370	P-133	46	0.082	4	24.6	100	3.59	34	8.0	9.91	Ca...
371: P-134	371	P-134	46	0.082	4	24.6	100	3.57	34	8.0	8.71	Ca...
223: P-116	223	P-116	43	0.082	4	17.3	70	5.81	55	6.0	360.00	Ca...
127: P-59	127	P-59	42	1.189	60	7.4	30	3.85	36	6.0	110.00	As...
218: P-113	218	P-113	42	0.082	4	19.0	77	4.65	44	6.0	560.00	Ca...
129: P-60	129	P-60	39	1.109	56	7.4	30	3.45	33	6.0	120.00	As...
225: P-117	225	P-117	39	0.082	4	17.2	70	4.48	42	6.0	120.00	Ca...
58: P-20	58	P-20	38	0.332	17	1.7	7	9.60	91	6.0	380.00	Du...
95: P-40	95	P-40	38	1.126	57	7.4	30	2.88	27	6.0	200.00	PVC
102: P-44	102	P-44	38	0.070	4	12.8	52	6.14	58	6.0	300.00	PVC
117: P-53	117	P-53	37	0.229	12	2.2	9	9.60	91	6.0	140.00	As...
38: P-10	38	P-10	35	0.082	4	24.6	100	0.25	2	8.0	240.00	Ca...
220: P-114	220	P-114	35	0.082	4	18.9	77	2.69	25	6.0	445.00	Ca...
229: P-119	229	P-119	35	0.082	4	2.6	11	9.65	91	6.0	150.00	Ca...
24: P-3	24	P-3	35	0.054	3	21.5	87	1.62	15	8.0	700.00	Du...

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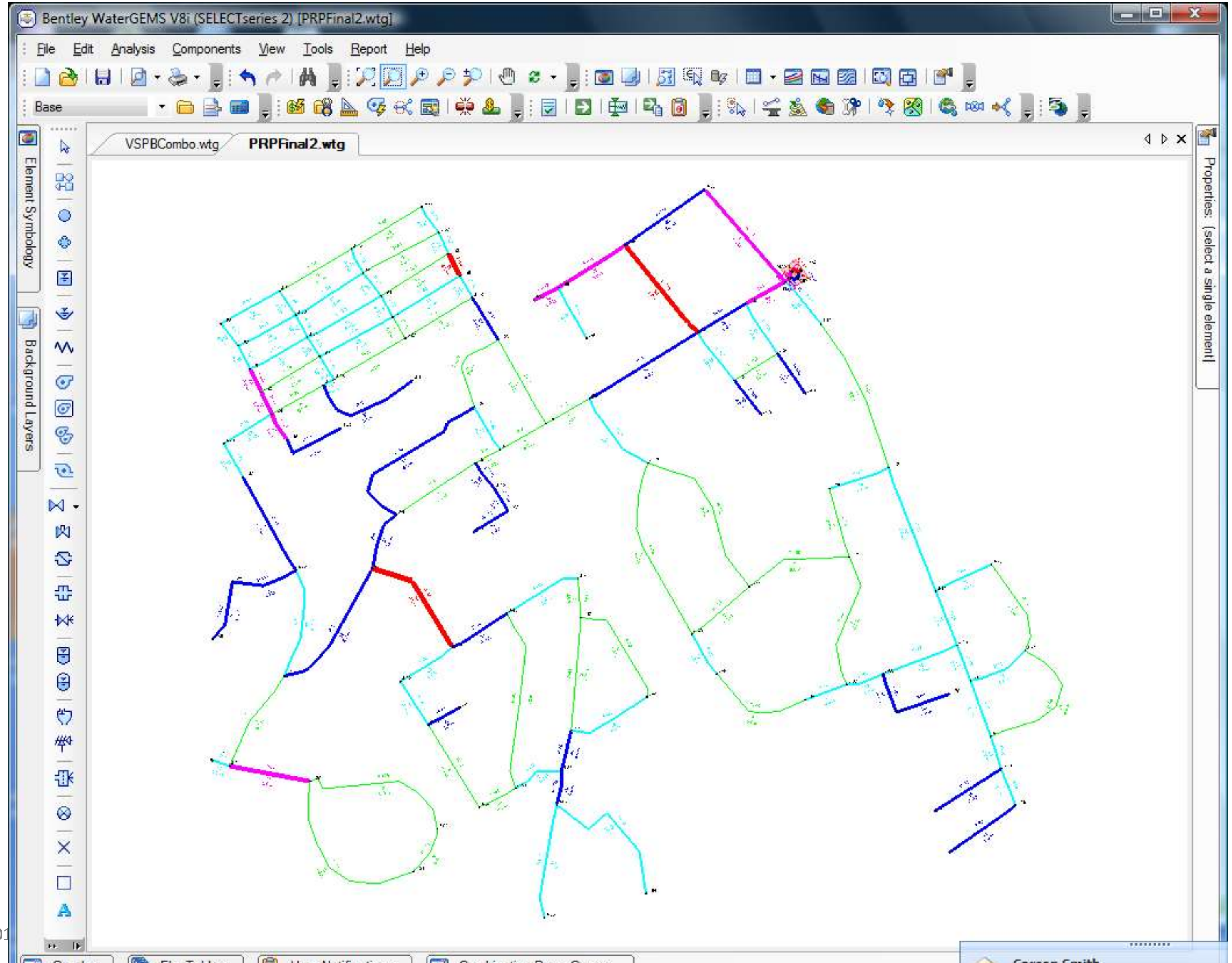
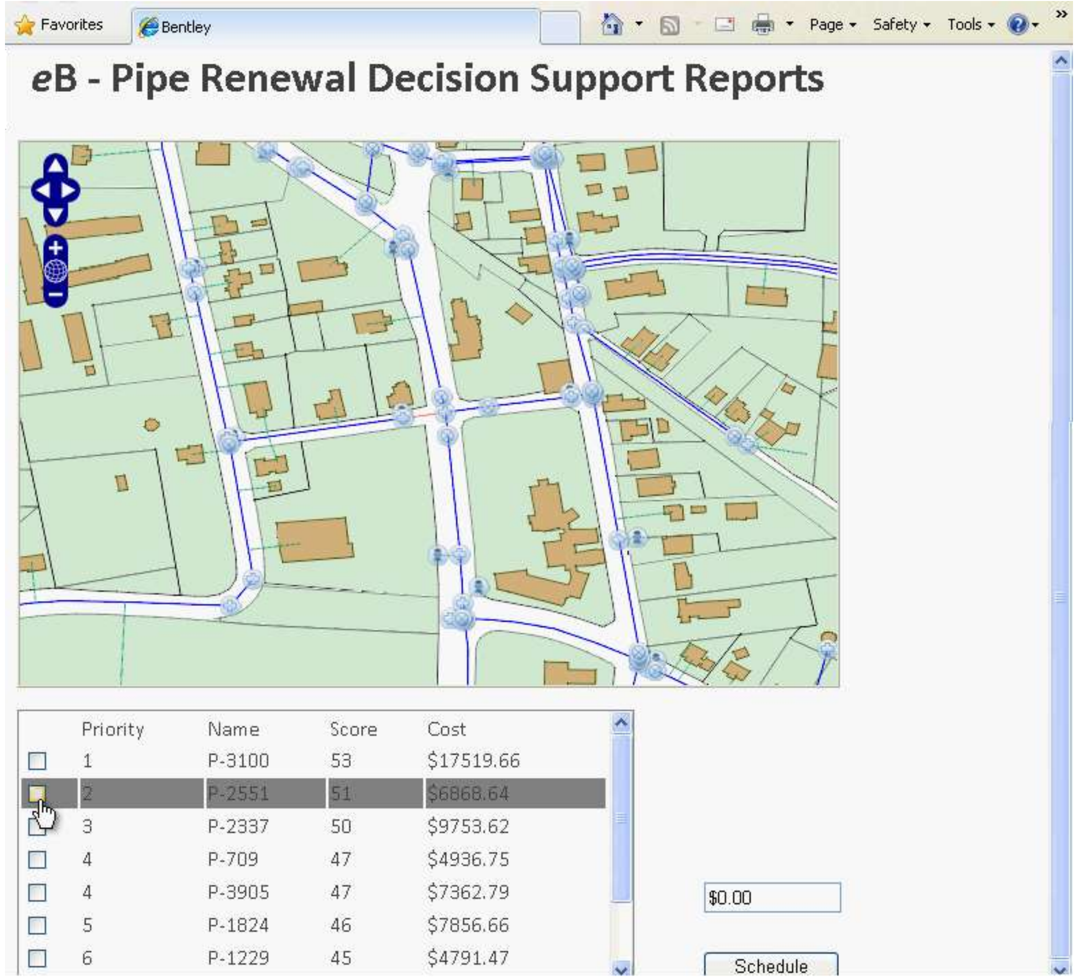
Risk Map: Prioritization of Pipe Replacements

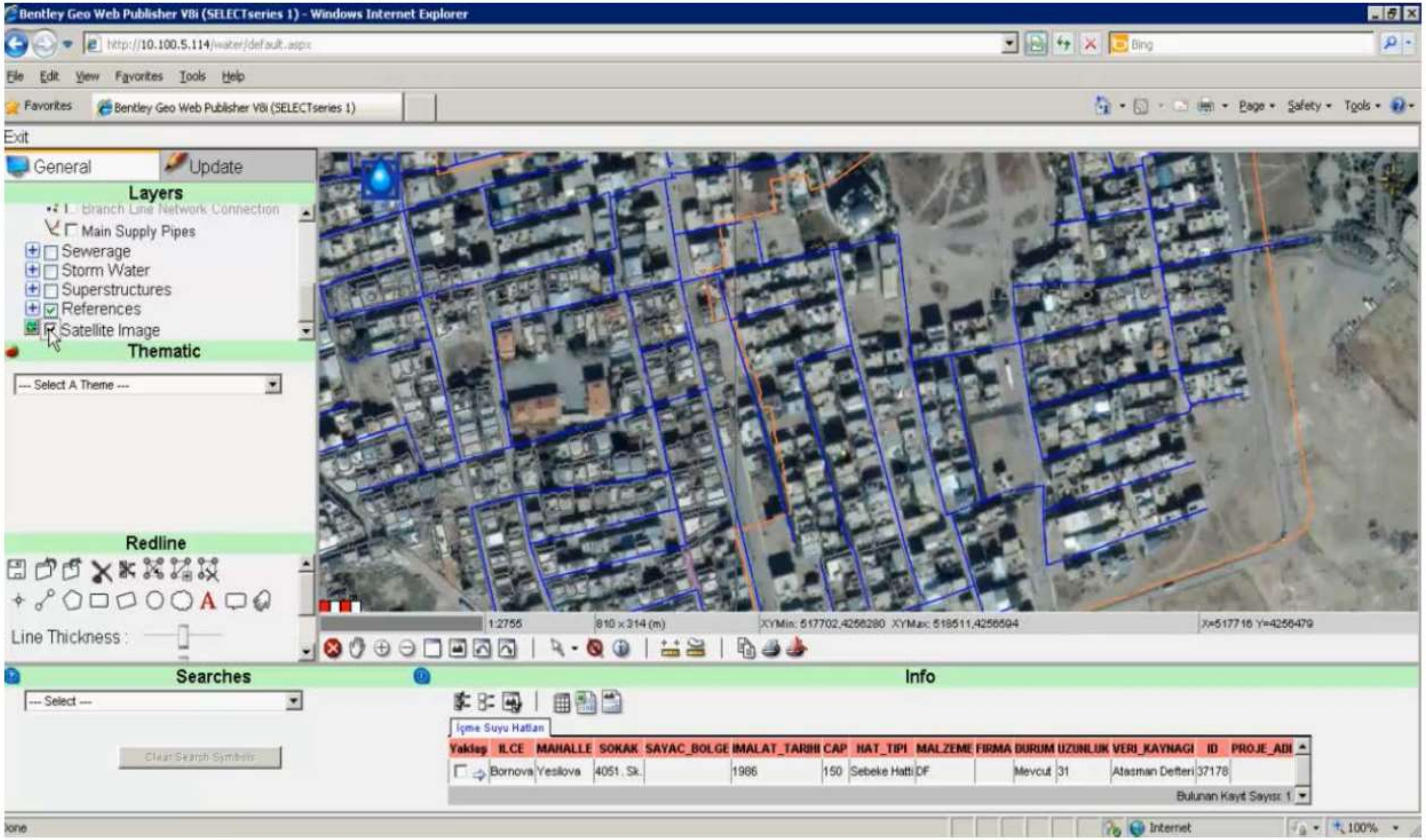


eB – Report, Visualize, Schedule Renewals



- 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)

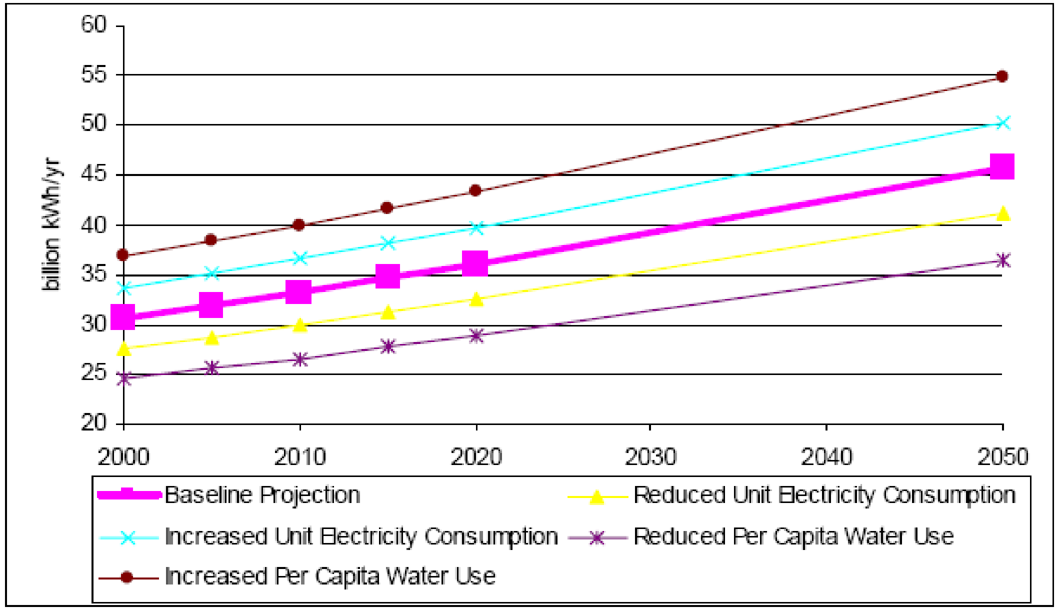


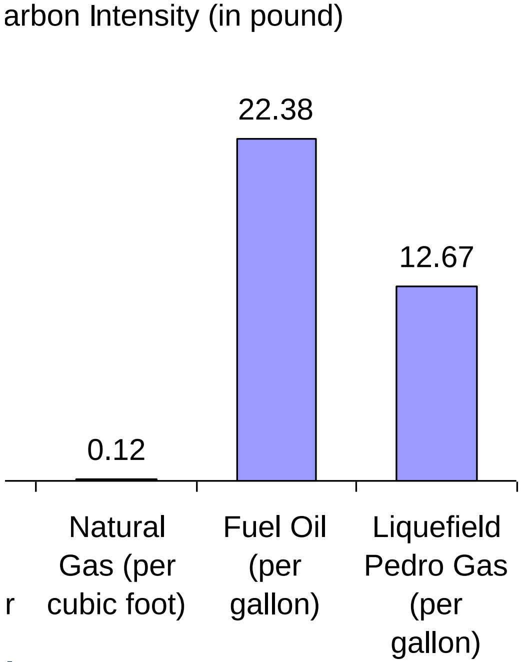
3) Pumping Scheduling

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

Energy Consumption

- Water is pumped throughout system
- Adequate pressure is maintained by pumping
- Pumping results in high energy consumption
- $CO_2 = ExC_{intensity}$





National Energy Consumption Projections for Public Water Supply

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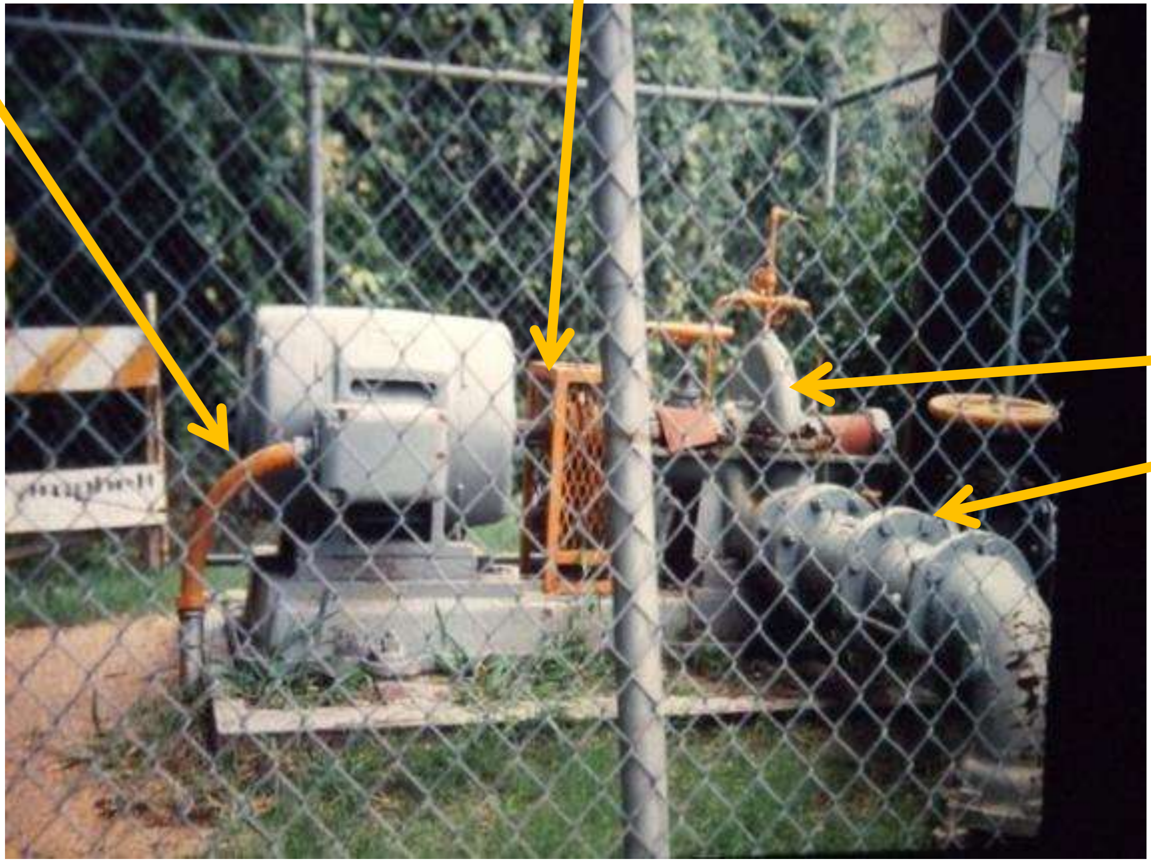
Which pump is wasting energy?

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: $\vec{H} = \left(h_{i,t}\right) \quad i = 1,2,\ldots,N_{ps}, \quad t = 1,\ldots,T$
- Minimize: $C = \sum_{p=1}^{N_p} C_p$
- Subject to:

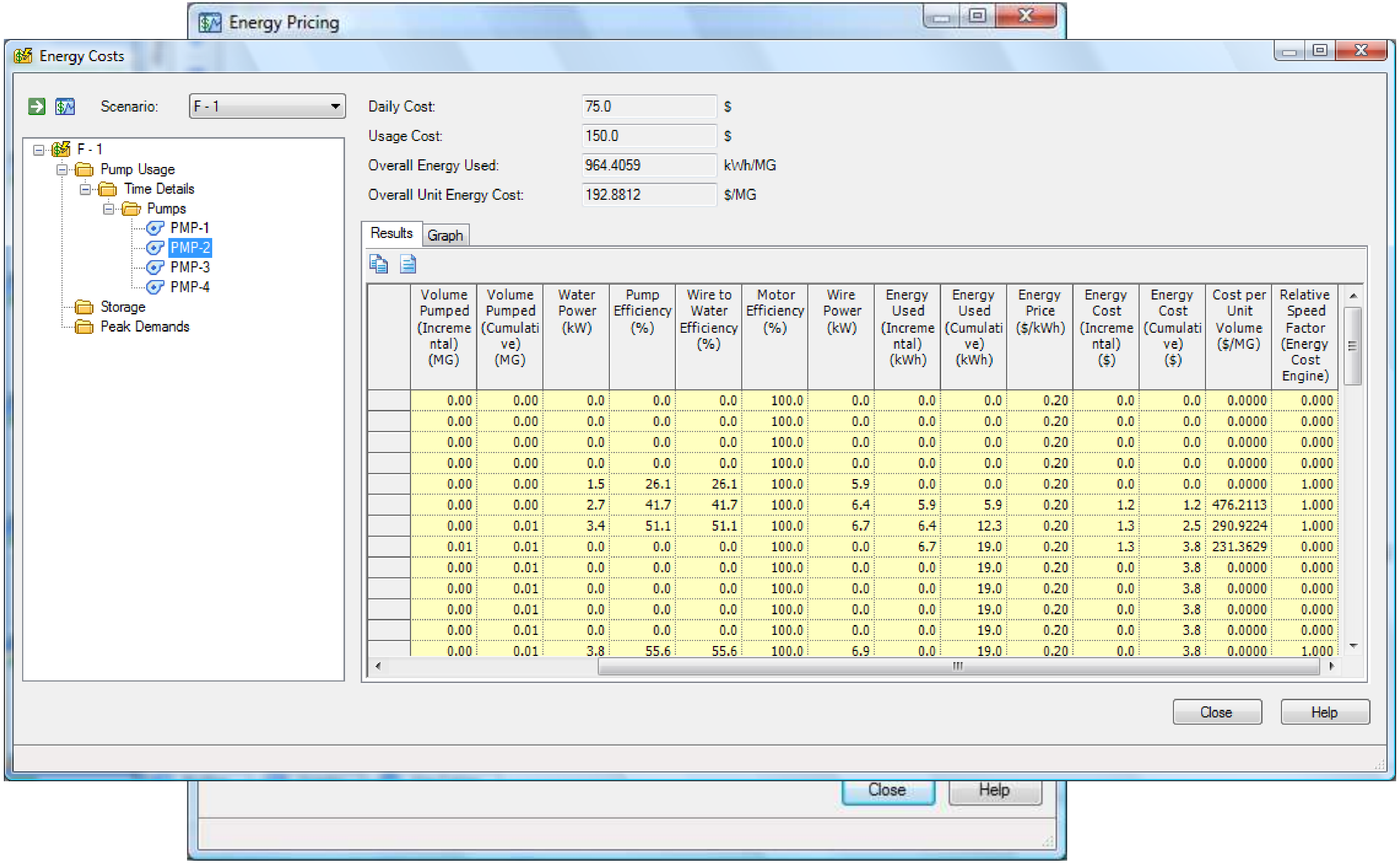
$$h_{\min} \leq h_{i,t} \leq h_{\max}$$

$$v_{\min} \leq v_{j,t} \leq v_{\max}$$

$$\omega_{\min} \leq \omega_p \leq \omega_{\max}$$

Where $h_{i,t}$ is the target hydraulic head of pump station *i* at time *t*
$v_{j,t}$ is the flow veolcity of pipe *j* at time *t*
ω_p is the relative speed factor for pump *p*,
N_{ps} is the number of pump stations,
C_p is the energy cost of pump *p,*
N_p is the number of pumps,
C is the total energy cost of the pumps,
h_{min} and h_{max} are the minimum required and maximum allowed hydraulic head,
v_{min} and v_{max} are the minimum required and maximum allowed flow velocities

Energy Cost Analysis Tool



Volume Pumped (Incremental) (MG)	Volume Pumped (Cumulative) (MG)	Water Power (kW)	Pump Efficiency (%)	Wire to Water Efficiency (%)	Motor Efficiency (%)	Wire Power (kW)	Energy Used (Incremental) (kWh)	Energy Used (Cumulative) (kWh)	Energy Price ($/kWh)	Energy Cost (Incremental) ($)	Energy Cost (Cumulative) ($)	Cost per Unit Volume ($/MG)	Relative Speed Factor (Energy Cost Engine)
0.00	0.00	0.0	0.0	0.0	100.0	0.0	0.0	0.0	0.20	0.0	0.0	0.0000	0.000
0.00	0.00	0.0	0.0	0.0	100.0	0.0	0.0	0.0	0.20	0.0	0.0	0.0000	0.000
0.00	0.00	0.0	0.0	0.0	100.0	0.0	0.0	0.0	0.20	0.0	0.0	0.0000	0.000
0.00	0.00	0.0	0.0	0.0	100.0	0.0	0.0	0.0	0.20	0.0	0.0	0.0000	0.000
0.00	0.00	1.5	26.1	26.1	100.0	5.9	0.0	0.0	0.20	0.0	0.0	0.0000	1.000
0.00	0.00	2.7	41.7	41.7	100.0	6.4	5.9	5.9	0.20	1.2	1.2	476.2113	1.000
0.00	0.01	3.4	51.1	51.1	100.0	6.7	6.4	12.3	0.20	1.3	2.5	290.9224	1.000
0.01	0.01	0.0	0.0	0.0	100.0	0.0	6.7	19.0	0.20	1.3	3.8	231.3629	0.000
0.00	0.01	0.0	0.0	0.0	100.0	0.0	0.0	19.0	0.20	0.0	3.8	0.0000	0.000
0.00	0.01	0.0	0.0	0.0	100.0	0.0	0.0	19.0	0.20	0.0	3.8	0.0000	0.000
0.00	0.01	0.0	0.0	0.0	100.0	0.0	0.0	19.0	0.20	0.0	3.8	0.0000	0.000
0.00	0.01	0.0	0.0	0.0	100.0	0.0	0.0	19.0	0.20	0.0	3.8	0.0000	0.000
0.00	0.01	3.8	55.6	55.6	100.0	6.9	0.0	19.0	0.20	0.0	3.8	0.0000	1.000

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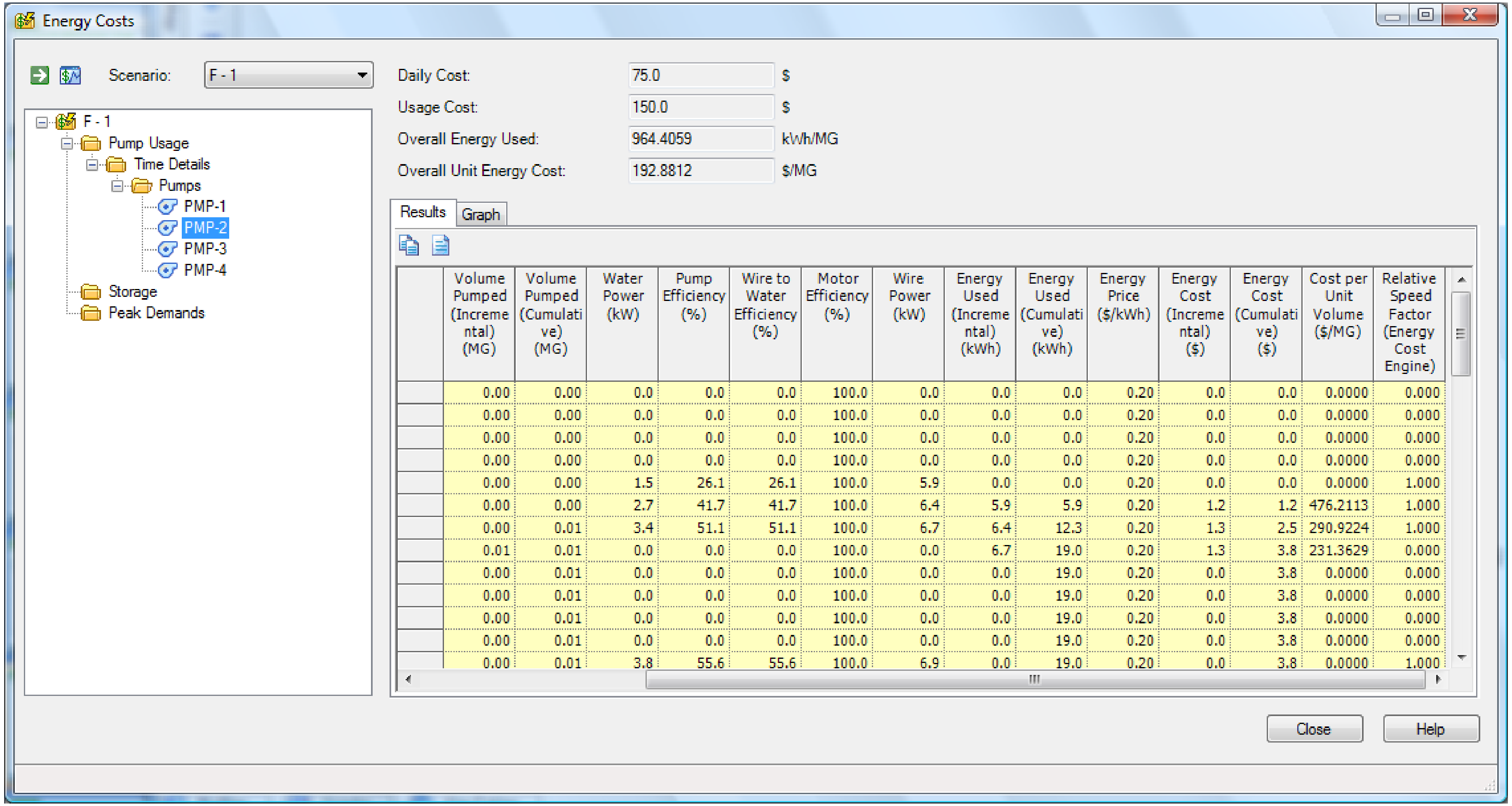
Darwin Scheduler



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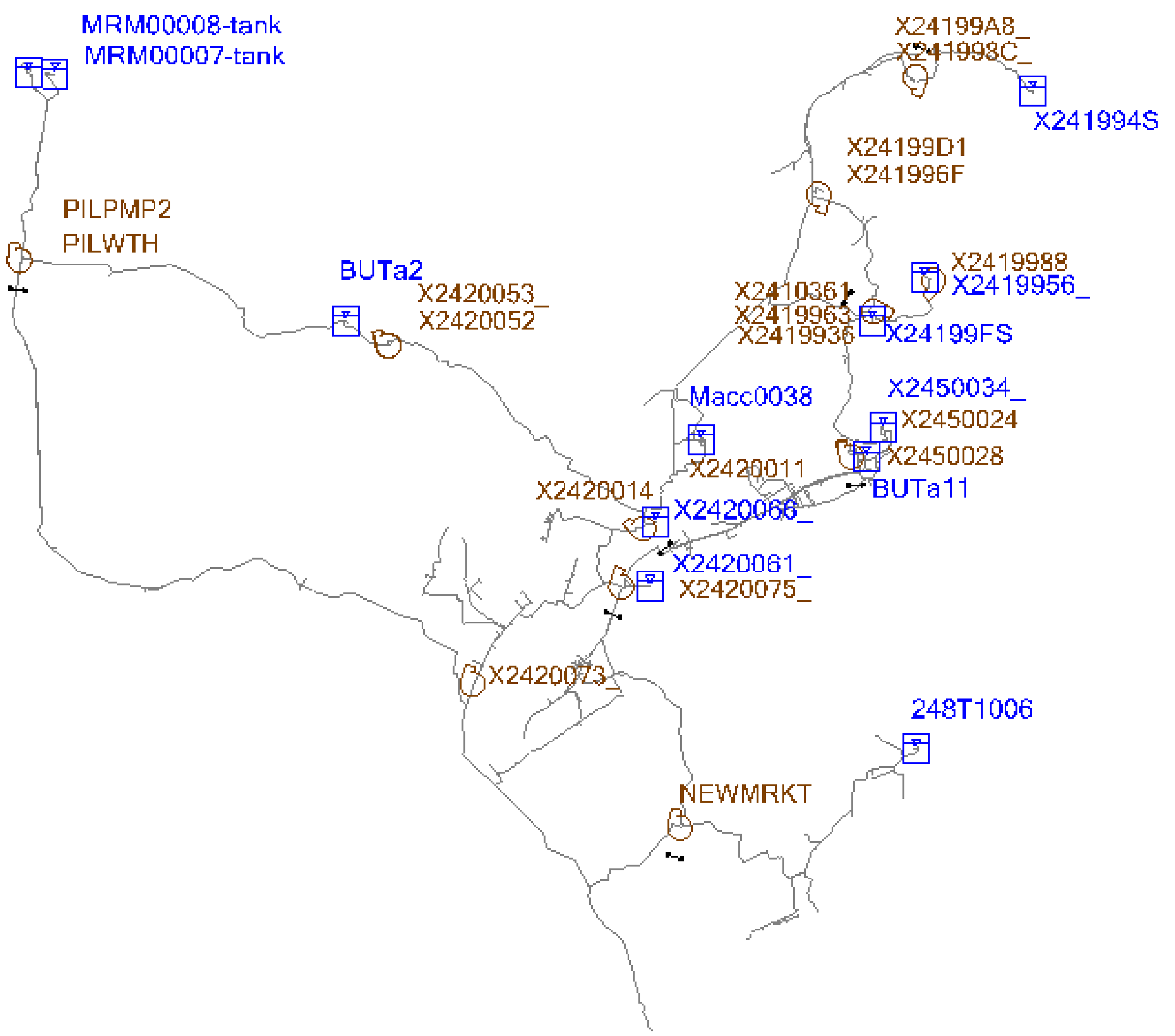
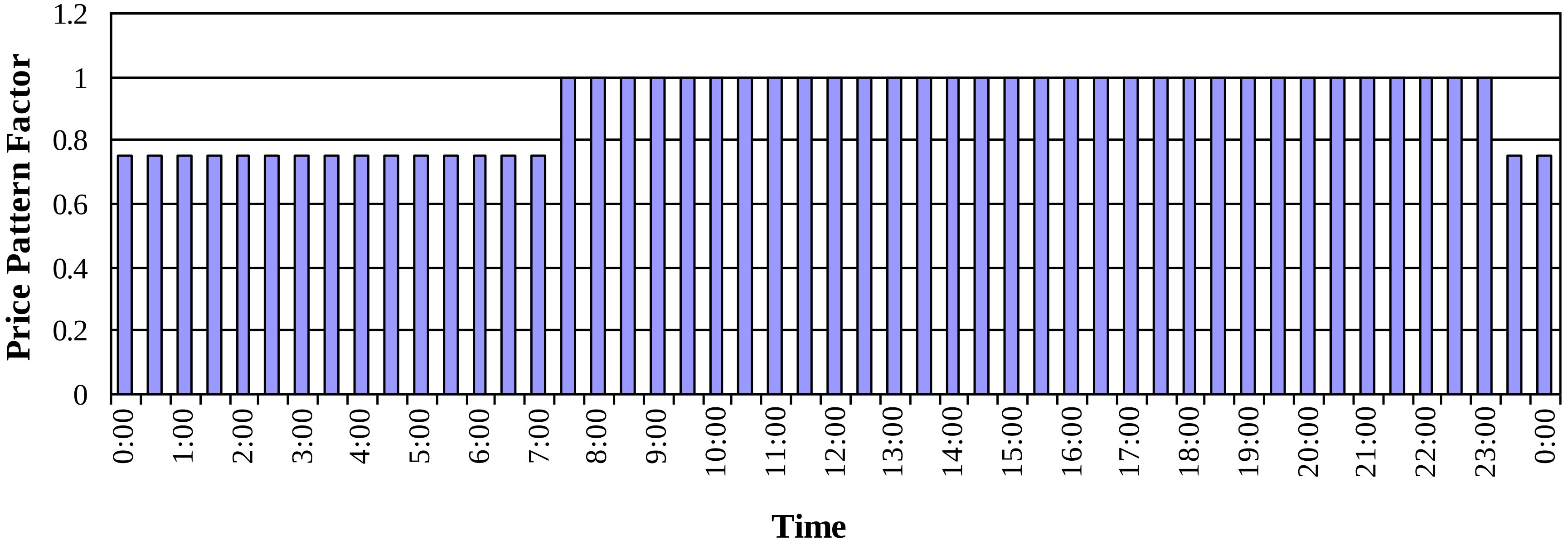
0.00	0.00	0.0	0.0	0.0	100.0	0.0	0.0	0.0	0.20	0.0	0.0	0.0000	0.000
0.00	0.00	0.0	0.0	0.0	100.0	0.0	0.0	0.0	0.20	0.0	0.0	0.0000	0.000
0.00	0.00	0.0	0.0	0.0	100.0	0.0	0.0	0.0	0.20	0.0	0.0	0.0000	0.000
0.00	0.00	0.0	0.0	0.0	100.0	0.0	0.0	0.0	0.20	0.0	0.0	0.0000	0.000
0.00	0.00	1.5	26.1	26.1	100.0	5.9	0.0	0.0	0.20	0.0	0.0	0.0000	1.000
0.00	0.00	2.7	41.7	41.7	100.0	6.4	5.9	5.9	0.20	1.2	1.2	476.2113	1.000
0.00	0.01	3.4	51.1	51.1	100.0	6.7	6.4	12.3	0.20	1.3	2.5	290.9224	1.000
0.01	0.01	0.0	0.0	0.0	100.0	0.0	6.7	19.0	0.20	1.3	3.8	231.3629	0.000
0.00	0.01	0.0	0.0	0.0	100.0	0.0	0.0	19.0	0.20	0.0	3.8	0.0000	0.000
0.00	0.01	0.0	0.0	0.0	100.0	0.0	0.0	19.0	0.20	0.0	3.8	0.0000	0.000
0.00	0.01	0.0	0.0	0.0	100.0	0.0	0.0	19.0	0.20	0.0	3.8	0.0000	0.000
0.00	0.01	0.0	0.0	0.0	100.0	0.0	0.0	19.0	0.20	0.0	3.8	0.0000	0.000
0.00	0.01	3.8	55.6	55.6	100.0	6.9	0.0	19.0	0.20	0.0	3.8	0.0000	1.000

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

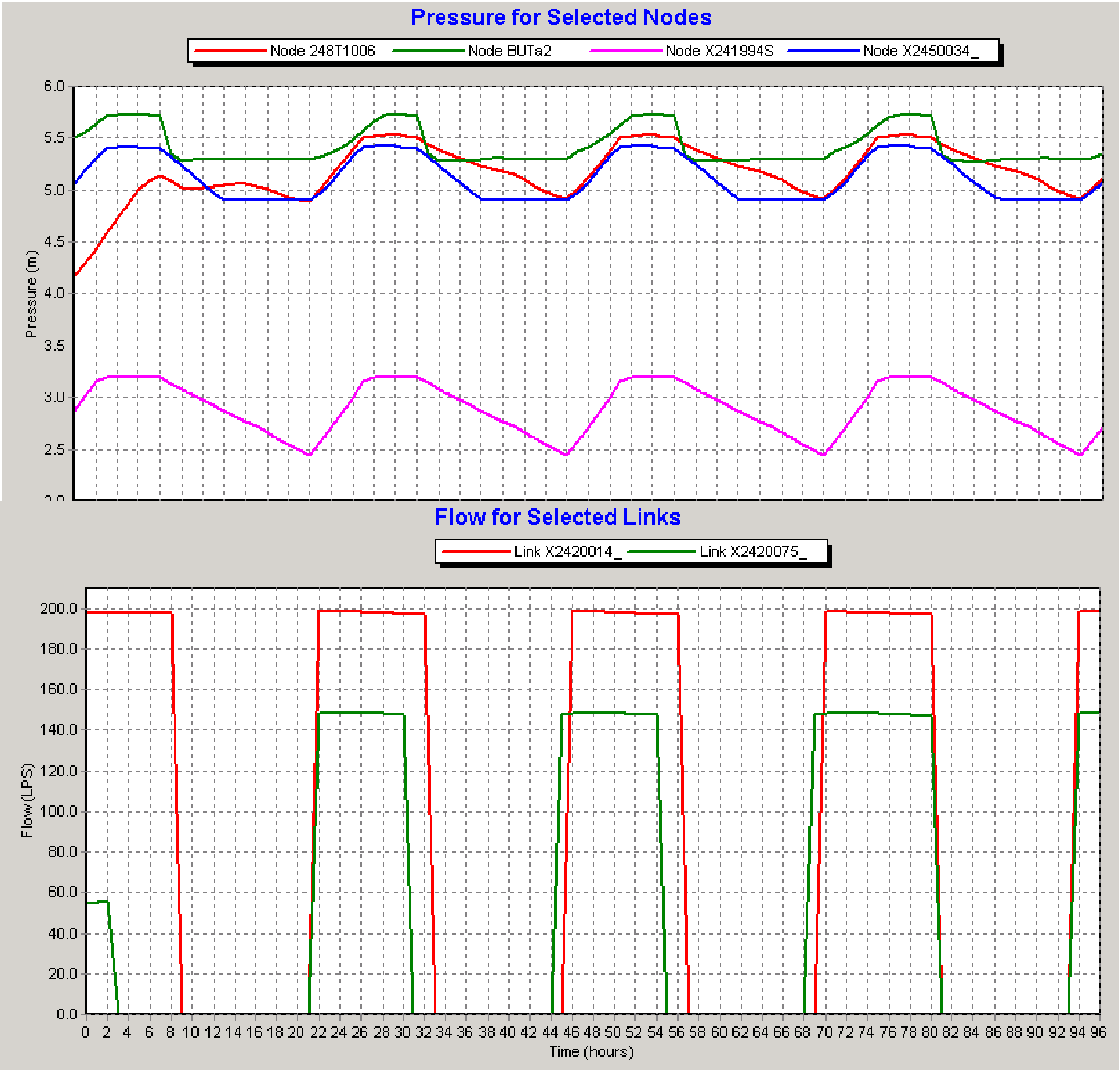
IF	SYSTEM CLOCKTIME		<=	8:00	AM
OR	SYSTEM CLOCKTIME		>=	10:00	PM
AND	TANK	BUTa2	LEVEL BELOW	5.73	
THEN	PUMP	PILWTH	STATUS IS	OPEN	
ELSE	PUMP	PILWTH	STATUS IS	CLOSED	

Energy Cost Comparison

Pump ID	Existing controls		Optimized controls	
	Pump utilization (%)	Daily cost (£)	Pump utilization (%)	Daily cost (£)
X2420052_	100	181.99	100	181.73
X2420014_	40	142.11	41	120.51
X2420075_	42	201.95	37	141.19
X2410361_	50	31.99	42	22.65
X2419963_	50	31.99	42	22.65
X241998C_	26	7.92	31	5.18
X2450024_	40	37.35	21	13.87
PILWTH	82	236.19	40	98.33
NEWMRKT	23	111.63	22	88.98
Total cost(£)		983.12		695.10

- 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

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