Pump and Valve Scheduling for Improved Leakage and Energy Management

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TRANSITIONS TO THE URBAN WATER SERVICES OFTOMORROW

Outline

- Introduction
- Optimization Methodology
- Implementation Details
- Case Study
- Conclusions

TRUST Task T42.3 Introduction

Aims

Develop a new methodology for integrated pressure and energy management in a water distribution system (WDS) with the aim to save both water and energy:

- With the pressure-dependent nature of much leakage in the distribution system, it is imperative to practice reduction in pressures whenever and wherever possible, throughout the network, without impacting on minimum supply standards.
- Given variable electricity tariffs, where prices are lower during periods of low overall consumption – e.g. overnight – pumps should be scheduled so that as much of the necessary pumping as possible takes place during the lowest energy-cost regimes.

METHODOLOGY

Leakage Modelling

Leakage is modelled as a pressure-driven component over and above the demands associated with each node in the network using the standard emitter components of EPANET.

A pressure-driven extension to EPANET is employed to calculate any deficit in the water supplied to each node as a measure of relative fitness for infeasible solutions.

This extension also permits the specification of exponents for individual nodes – allowing the representation of leakage from differing materials of pipe.

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Optimization Methodology

Methodology is implemented as a multiple objective Genetic Algorithm based on NSGA-II, considering:

- Objectives:
  - Minimize pumping cost
  - Minimize water lost through leakage
- Decision variables:
  - Pump status (on/off) for each timestep; *and/or*
  - Valve status (setting) – for PRVs; *and/or*
  - Initial levels for each tank in the system

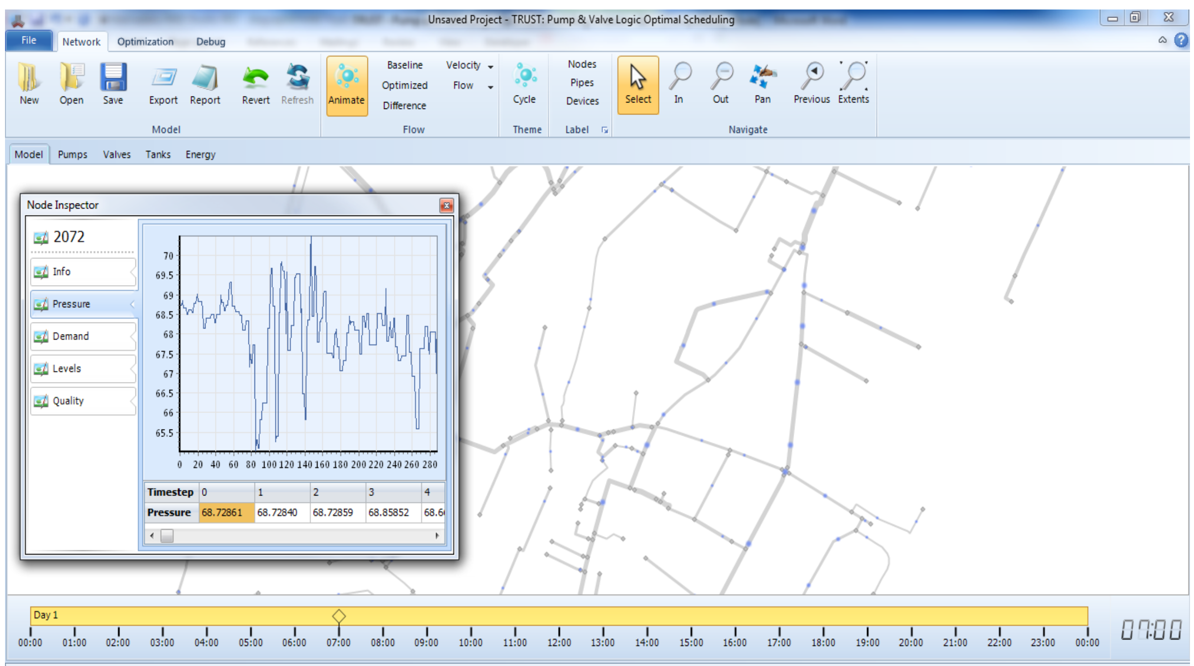
Optimization Methodology *(continued)*

- Constraints:
  - Solution must be hydraulically feasible – i.e. the mass and energy-balance should be respected and no demand nodes in the system should exhibit negative pressures.
  - A user-specified minimum pressure requirement for each node in the network with a demand associated with it.
  - Ensure tank levels return to *at least* their initial level at the end* of the time-horizon being optimized.

SOFTWARE IMPLEMENTATION

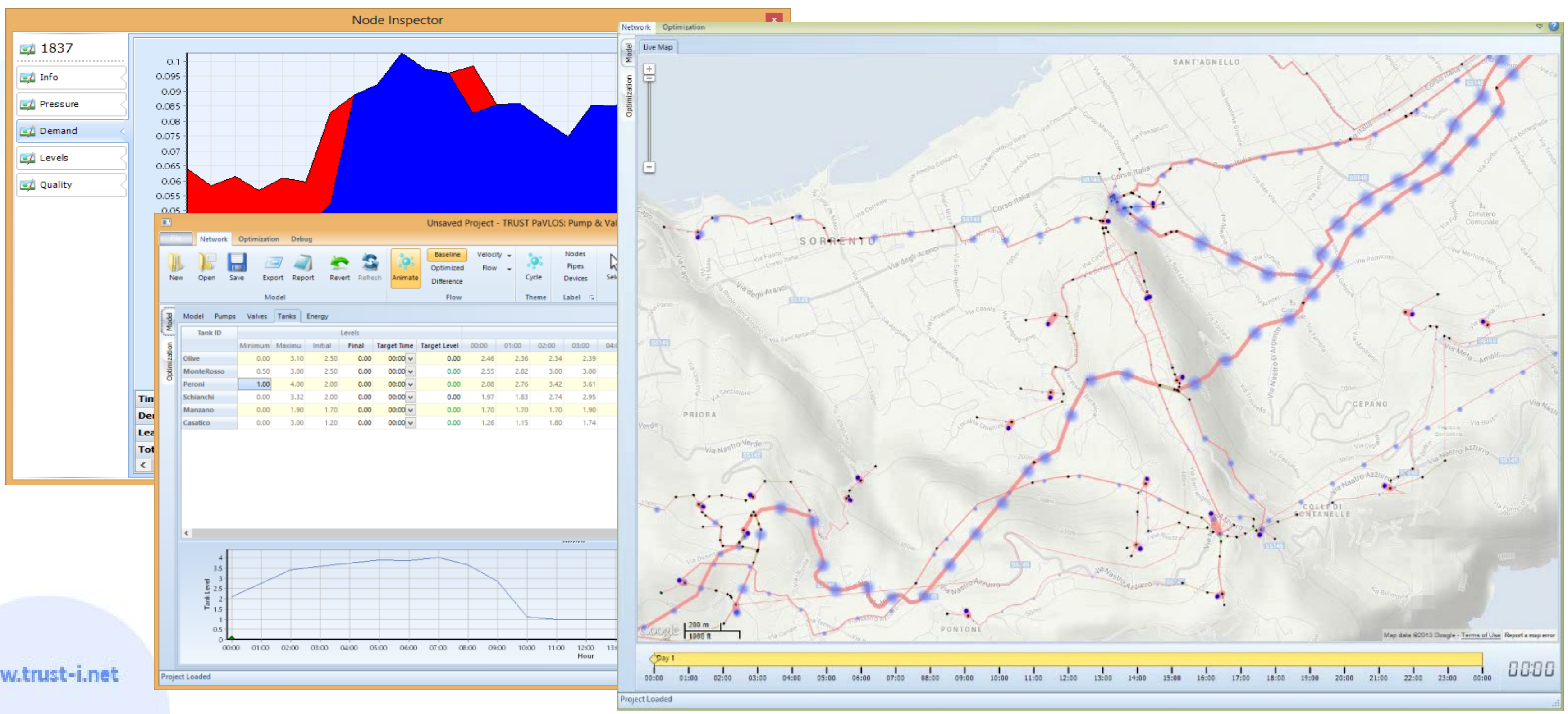
Software Implementation

Methodology is implemented as a standalone application which embodies a pressure-driven version of EPANET. A distributed-computing approach is employed to accelerate the performance of the Genetic Algorithm used for the optimization reducing ypical runtimes for the optimization < 1 hour on a single quad-core computer.



trust Software Implementation *(continued)*

A Graphical User Interface to the optimization model is provided which, as well as permitting the configuration of the optimization problem, allows the user to interactively compare the performance of individuals from the non-dominated set of solutions obtained from the multi-objective optimization.

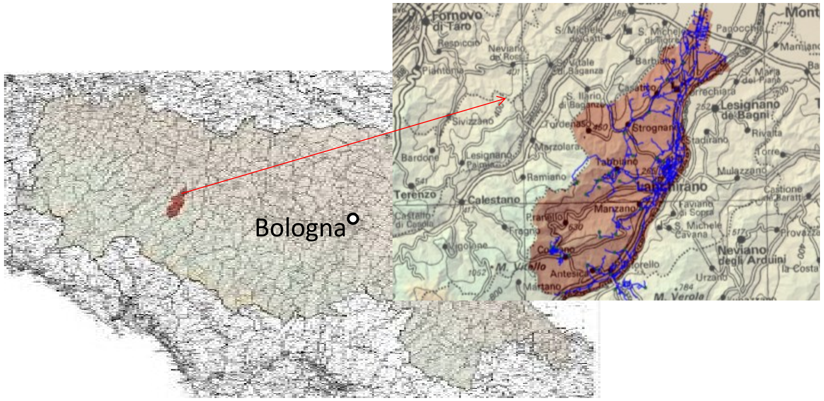


CASE STUDY

Langhirano Case Study: Overview

Case study network of a small municipal network (10,000 inhabitants) in northern Italy modelled by the University of Bologna, comprising:

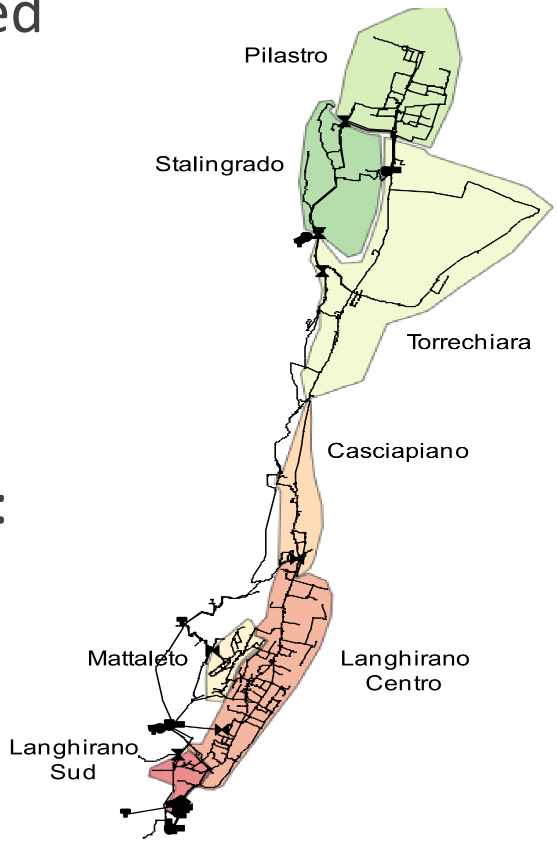
- 1007 Pipes
- 6 Tanks
- 11 Pumps
- 6 PRVs



The network is characterized by significant variation in topography with three principal tanks feeding the network from elevated positions. This arrangement contributes to excessive pressures in the system.

Langhirano Case Study: Overview *(continued)*

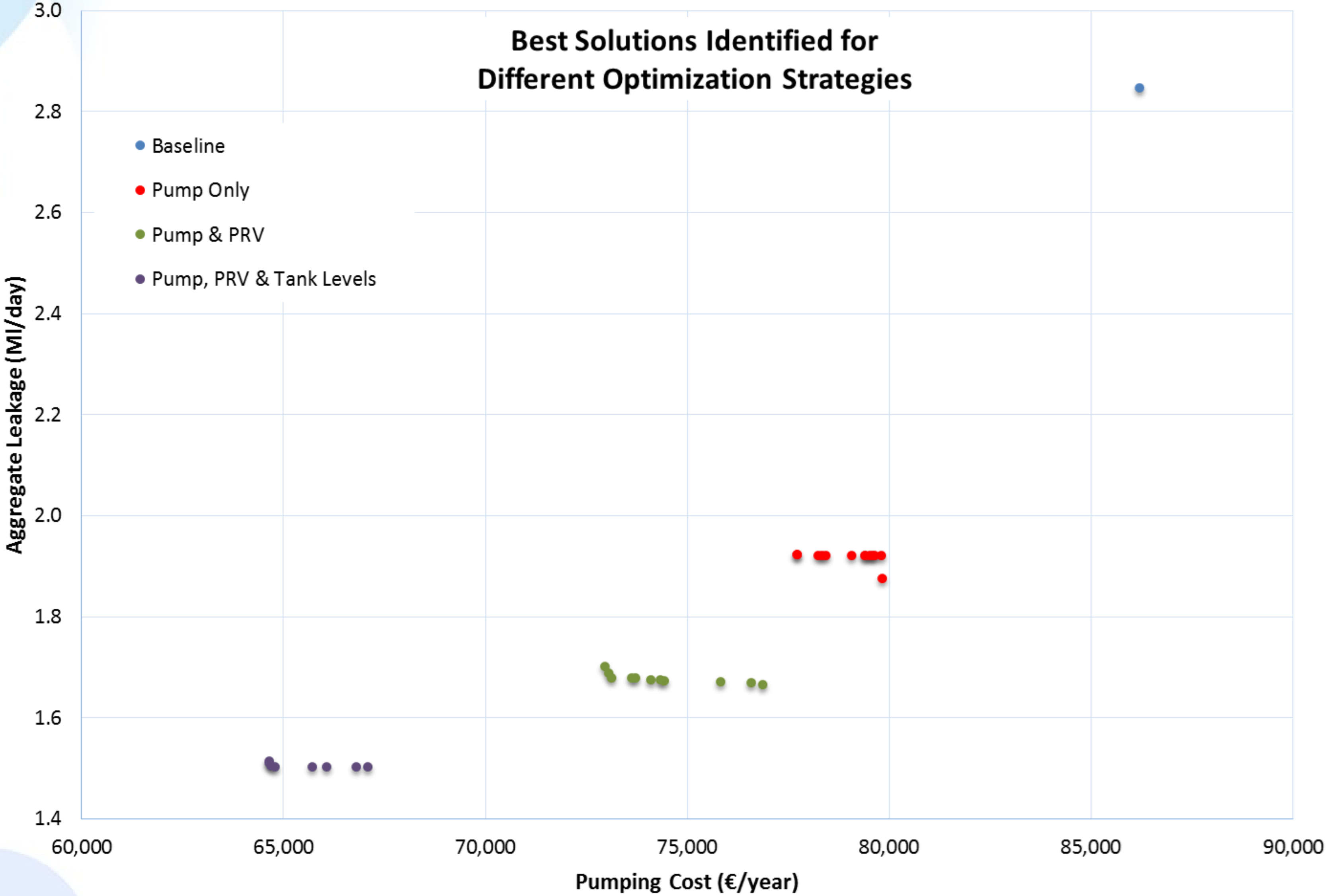
The existing Langhirano network is divided into 7 pressure management zones. Owing to the excessive pressures noted previously, the system has non-revenue water of approximately 35%.



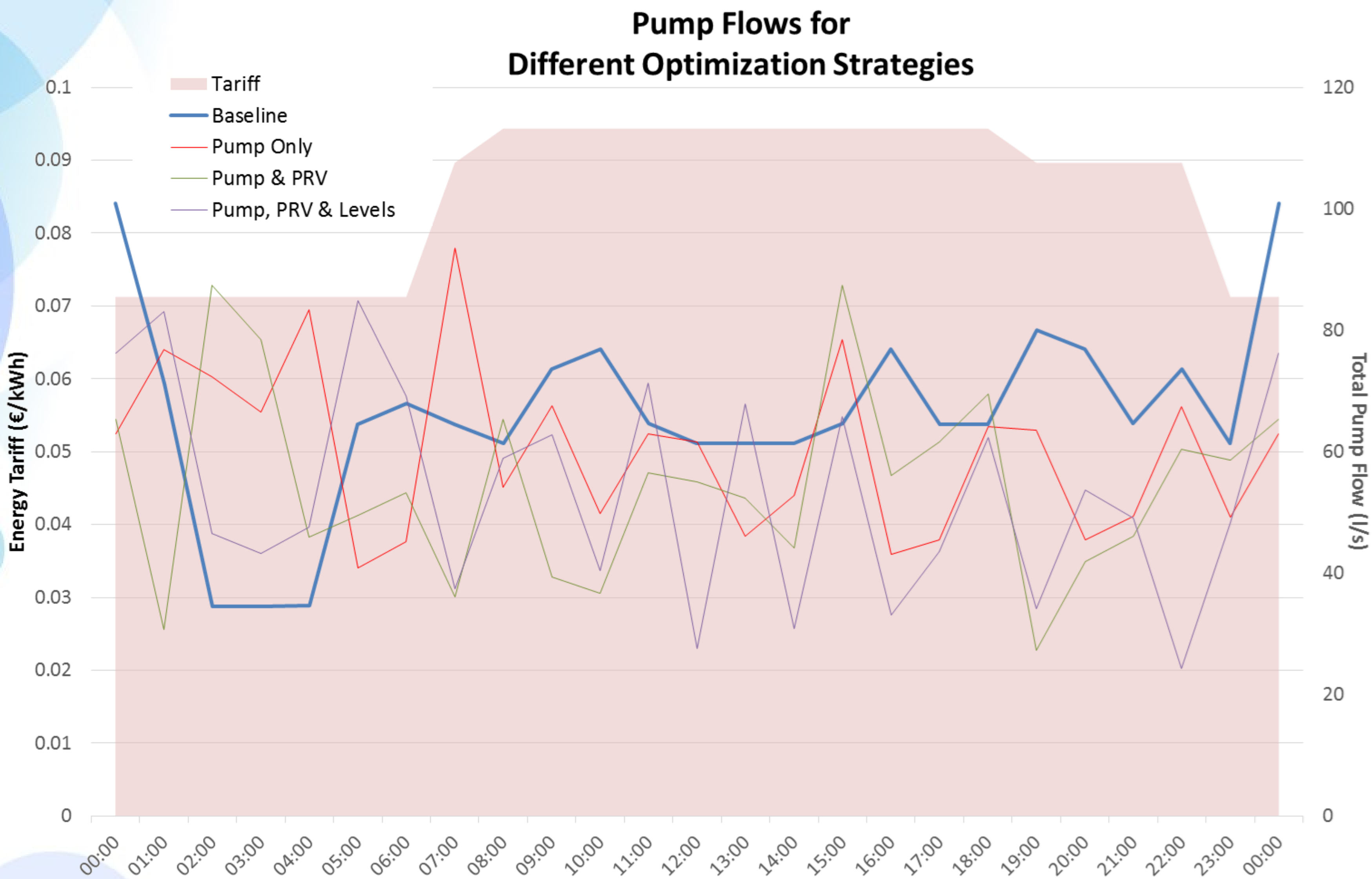
Three optimization scenarios considered:

- Hourly scheduling of pumps only.
- Hourly scheduling of pumps and PRV settings.
- Hourly scheduling of pumps, PRV settings and setting of initial levels for the three principal tanks

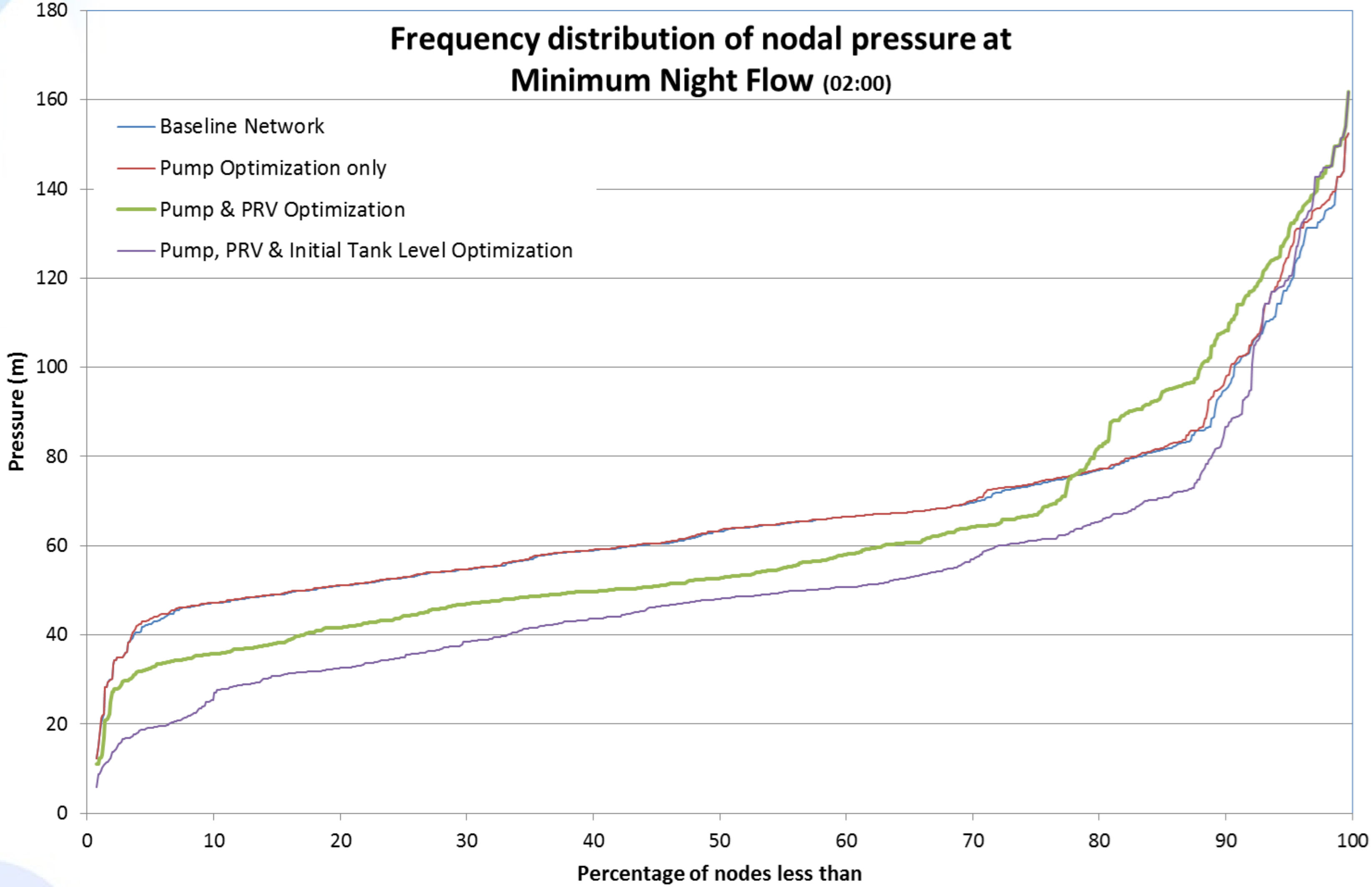
Langhirano Case Study: Results



Langhirano Case Study: Energy Management Results



Langhirano Case Study: Pressure Management Results



Conclusions

Software implementing a new methodology for optimizing leakage through integrated energy and pressure management has been presented. Application of the software to a real-life case study demonstrated:

- Joint optimization of pump schedules and PRV settings can lead to a substantial reduction in both system leakage and energy costs, over and above those achievable by pump scheduling or pressure-management alone, yielding savings of ~43% in leakage and ~24% in energy costs over the baseline state.
- A further improvement of 4% and 10% in leakage and energy costs, respectively, were able to be realised through the selection of appropriate tank operation strategies – i.e. selecting appropriate initial levels.

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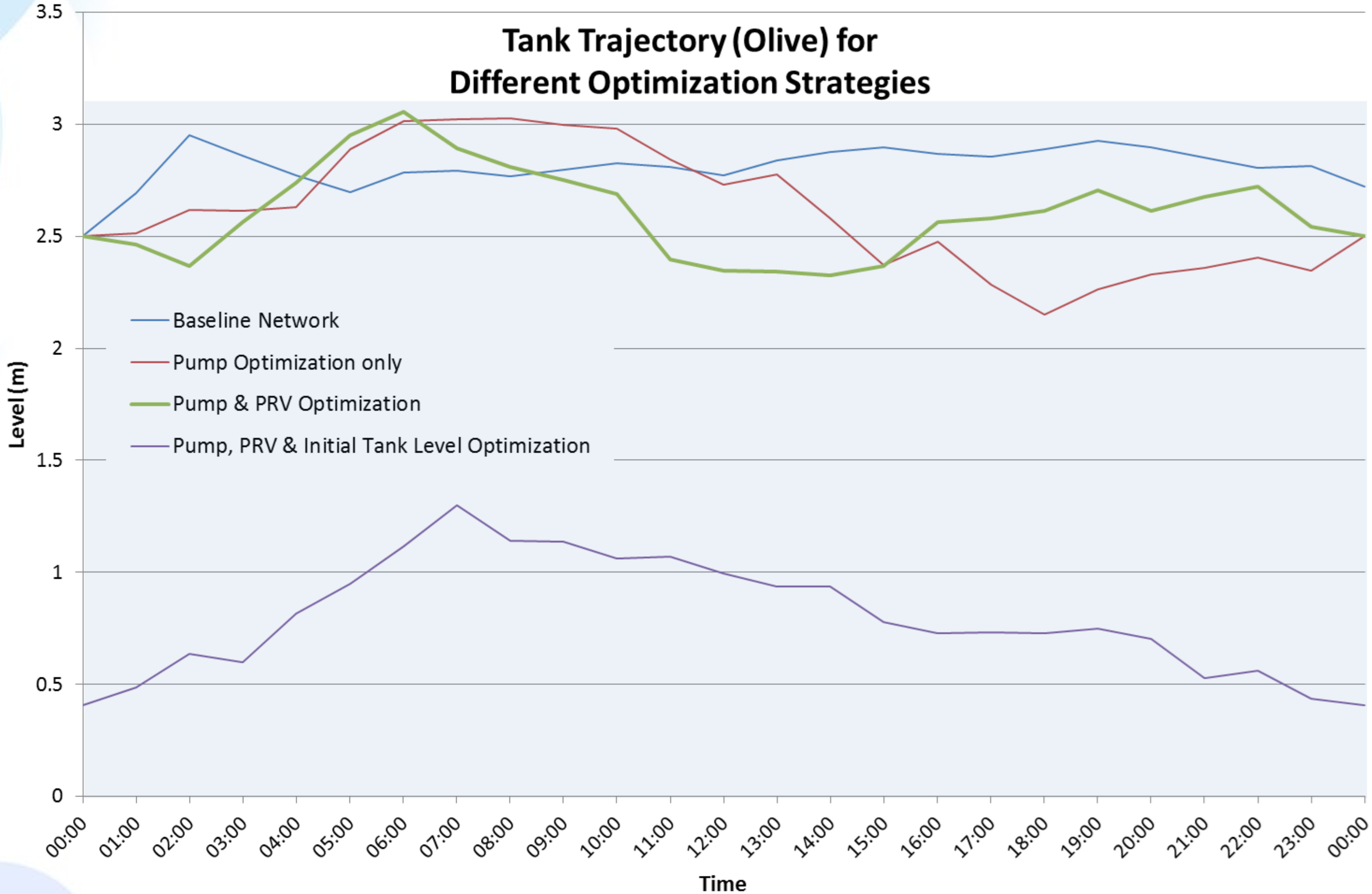
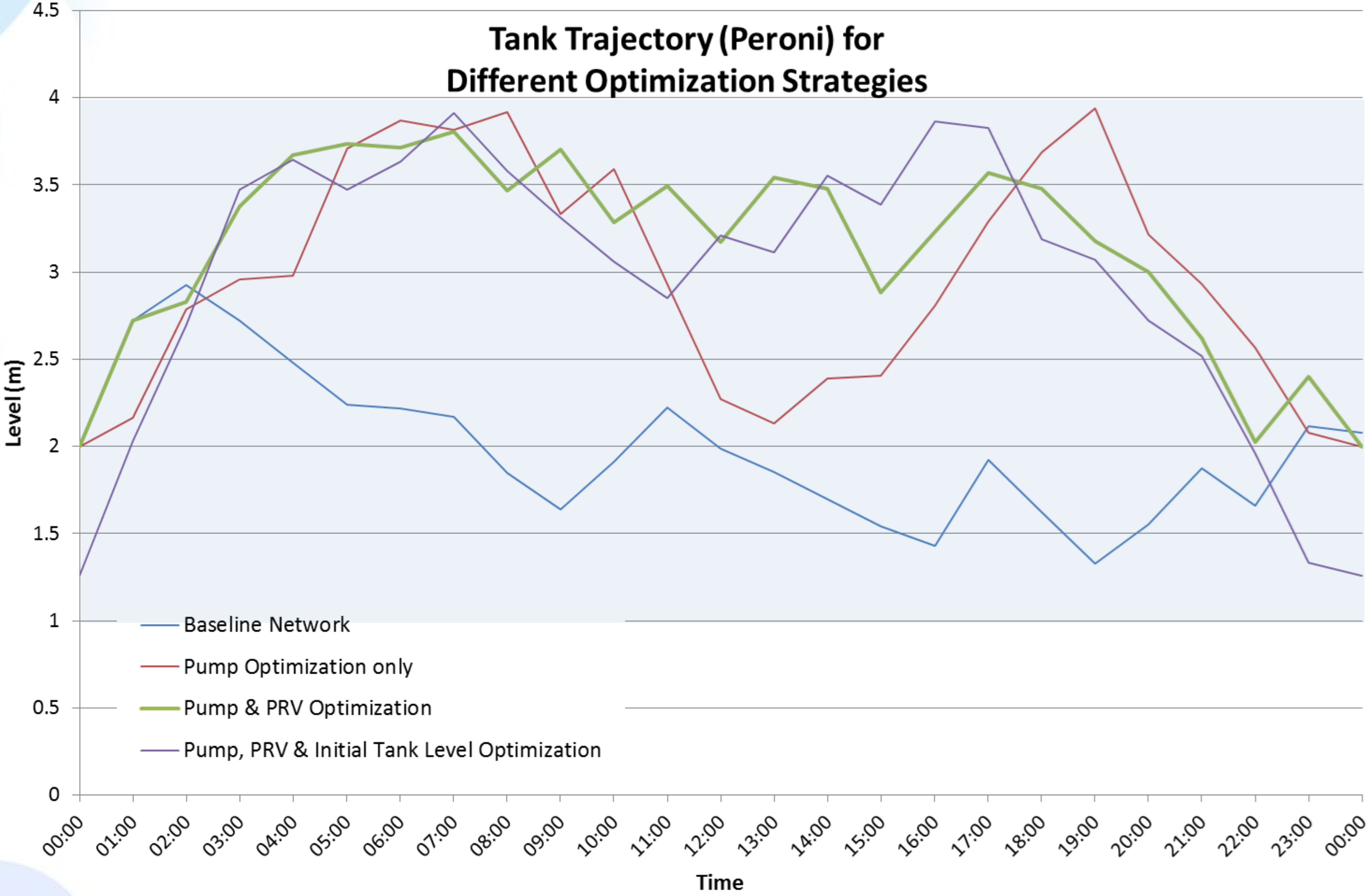
The European Commission is acknowledged for funding TRUST in the 7th Framework Programme under Grant Agreement No. 265122

SEVENTH FRAMEWORK PROGRAMME

Langhirano Case Study: Pressure Management Results



Langhirano Case Study: Pressure Management Results



Outputs/References

Outputs

- MORLEY, M.S., BELLO-DAMBATTA, A. & KAPELAN, Z. 2013. Integrated Energy and Pressure Management Optimization for Water Distribution Systems. *Asset management for enhancing energy efficiency in water and wastewater systems*, International Water Association, Marbella - Spain, 24-26 April 2013.
- MORLEY, M.S., BELLO-DAMBATTA, A., KAPELAN, Z., BOLOGNESI, A. & BRAGALLI, C. 2013. *Task 42.3 – New Technique for Leakage Reduction via Integrated Energy and Pressure Management*. TRUST Report.
- Journal paper in preparation.

References

- MORLEY, M.S., TRICARICO, C., KAPELAN, Z., SAVIĆ, D.A. & DE MARINIS, G. 2006. deEPANET: A Distributed Hydraulic Solver Architecture for Accelerating Optimization Applications Working With Conditions of Uncertainty. In: GOURBESVILLE, P., CUNGE, J., GUINOT, V. & LIONG, S-Y. (eds.) *Proceedings 7th International Conference on Hydroinformatics, Nice, France.* pp2465-2472.
- MORLEY, M.S. & TRICARICO, C. 2008. *Pressure Driven Demand Extension for EPANET (EPANETpdd) – Technical Report 2008-02.* Centre for Water Systems, University of Exeter, UK. 10pp.