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A real time monitoring and leakage detection and reduction system in water distribution networks

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University of Nis

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Strengthening of master curricula in water resources management for the Western Balkans HEIs and stakeholders

Project number: 597888-EPP-1-2018-1-RS-EPPKA2-CBHE-JP

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A brief description of the project

- **Programme:** Interreg IPA CBC Greece- Republic of North Macedonia
- **Beneficiaries:**
  Lead beneficiary (PB1): Municipality of Prespes
  PB2: Aristotle University of Thessaloniki – Department of Civil Engineering
  PB3: Public Communal Enterprise "Proleter" – Resen
  PB4: Faculty of Electrical Engineering and Information Technologies of Ss. Cyril and Methodius University in Skopje
- **Duration:** July 2018 – July 2021

A brief description of the project

- **Study area:** 5 villages in the Municipality of Prespes + 17 villages in the Municipality of Resen + Resen city

- **Main objectives:**
  - ✓ Introduce an ***innovative technical methodology*** based on the idea of a Supervisory Control and Data Acquisition (***SCADA***) system using real-time flow and pressure monitoring sensors
  - ✓ Promote a ***cost-effective approach*** for achieving a ***significant reduction in water leakage***.

A theoretical approach

The main purpose of water distribution networks is to provide consumers with water of adequate quantity and quality that meets the requirements of the **European Directive 98/83/EC**, with its latest amendments including **European Directive 2015/1787**.

According to the **Special Management Plan for the Sub-basin of Prespa in the River Basin of Prespa** (2014), basic Measures within the 2000/60/EC Directive are:

- «**Actions to enhance the operation of water supply networks of large agglomerations of the River Basin District – Leakage control**» (Measure code: 0M02-01)
- «**Projects for the rehabilitation/enhancement of existing water supply networks**» (Measure code: 0M02-03).

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Work Packages of the project

WP 1: Project Management & Coordination

D1.1: Preparation activities
D1.2: Project coordination meetings
D1.3: Project management
D1.4: Verification of expenditure

WP 2: Communication & Dissemination

D2.1: Multilingual project communication package (logo, slogan, brochure, signs)
D2.2: Information activities (project's website)
D2.3: Transboundary seminar
D2.4: Meetings and Workshops

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Work Packages of the project

WP 3: Mapping and modeling of the water distribution networks

D3.1: Mapping the water distribution networks
- Digitization of all collected data and studies
- Georeferencing all network components
- Mapping & visualizing all processed data into GIS

D3.2: Hydraulic modeling of the water distribution networks
- Introduction of all mapped information in a hydraulic simulation model
- Development of water demand scenarios
- Model calibration using measured hydraulic data
- Detection of leakage problems

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Work Packages of the project

WP 4: Flow and pressure monitoring and management

D4.1: Installation of pressure and flow monitoring system

- Identification & design of DMAs
- Installation of pressure, flow and water level measuring equipment

D4.2: Development of pressure management strategies

- Development of 3 management strategies by changing the inlet pressure of the networks
- Statistical analysis of the acquired measurements for each management strategy
- Estimation of water quantity reduction for each management strategy

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Main steps of the project

WP 4: Flow and pressure monitoring and management

D4.3: Investigation of the relationship between inlet pressure and leakages

- Non-linear regression between the leakage and pressure measurements at each DMA's inlet and at the locations of the remaining pressure gauges for all pressure management strategies

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Work Packages of the project

WP 5: Associated environmental benefits

D5.1: Calculation of saving in energy consumption

D5.2: Calculation of saving in greenhouse gas emissions

- Assessment of the new Water Footprint (WF) indicator (ISO 14046: 2014) to quantify the impacts associated with proposed interventions in the networks
- Establishment of a comprehensive WF indicator based on life cycle assessment

WP 6: Reconstruction of the water networks

D6.1: Hydraulic study for reconstructuring the most water consuming networks

D6.2: Reconstruction works.

Data on population and water consumption

Description	Value
PERMANENT POPULATION (CENSUS 2011)	1560
POPULATION OF TOURISTS	960 (16X60)
POPULATION OF SEASONAL LABOURERS	960 (16X60)
POPULATION OF LARGE ANIMALS	1500 (16X25)
POPULATION OF SMALL ANIMALS	18000
CONSUMPTION PER CAPITA FOR PERMANENT POPULATION (lt/cap/sec)	200
CONSUMPTION PER CAPITA FOR TOURISTS (lt/cap/sec)	250
CONSUMPTION PER CAPITA FOR SEASONAL LABOURERS (lt/cap/sec)	150
CONSUMPTION PER CAPITA FOR LARGE ANIMALS (lt/cap/sec)	80
CONSUMPTION PER CAPITA FOR SMALL ANIMALS (lt/cap/sec)	30
MEAN DISCHARGE FOR PERMANENT POPULATION (lt/sec)	3,64
MEAN DISCHARGE FOR TOURISTS (lt/sec)	2,72
MEAN DISHARGE FOR SEASONAL WORKERS (lt/sec)	1,60
MEAN DISCHARGE FOR LARGE ANIMALS (lt/sec)	1,20
MEAN DISCHARGE FOR SMALL ANIMALS (lt/sec)	6,22
TOTAL MEAN DISCHARGE (lt/sec)	15,38
MAXIMUM DAILY DISCHARGE (lt/sec)	23,02
MAXIMUM HOURLY DISCHARGE (lt/sec)	69,16
FIRE DISCHARGE (lt/sec)	5

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Projection of population

Municipalities	Annual growth rate (%)	Population 2041
Laimos	3,5	525
Agios Achileios	3	266
Agios Germanos	4	590
Antartiko	4	366
Vrontero	3,5	218
Kalithea	4	379
Karies	3	165
Leykonas	4,5	434
Mikrolimni	2,5	97
Pisoderi	1,5	11
Platy	3	178
Prasino	2,5	44
Psarades	3,5	233
Vatochori	3	56
Kristalopigi	4	1017
Kotas	2	40
	Total	**4.619**

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Estimation of water losses in water distribution networks

Municipalities	Losses (%)
Laimos	~ 54 %
Agios Achileios	~ 57 %
Agios Germanos	~ 62 %
Antartiko	~ 68 %
Vrontero	~ 54 %
Kalithea	~ 64 %
Karies	~ 72 %
Leykonas	~ 60 %
Mikrolimni	~ 59 %
Pisoderi	~ 60 %
Platy	~ 61 %
Prasino	~ 69 %
Psarades	~ 55 %
Vatochori	~ 52 %
Kristalopigi	~ 53 %
Kotas	~ 68 %
Total	**~ 58,9 %**

- The value is judged very high
- The tolerable level of water losses in similar water distribution networks is 25-30%

Leakage problems need to be confronted

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Existing infrastructure (selected settlements)

Agios Germanos settlement

- ❑ 1 tank supplied by nearby springs

Antartiko settlement

- ❑ 1 tank supplied by nearby springs

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Existing infrastructure (selected settlements)

Trigono settlement

- ❑ 1 tank supplied by nearby springs (also supplying Antartiko settlement)

Karies settlement

- ❑ 1 tank in Karies supplied by nearby springs

Pisoderi settlement

- ❑ 1 tank supplied by nearby springs
- ❑ 1 water supply borehole

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Water distribution networks mapping methodology

Step 1 — Collection and Digitization of all previous studies and works

Step 2 — Collection and Georeferencing of all the features and systems of the water networks

Step 3 — Mapping the water distribution networks through a survey

Step 4 — Development of a geodatabase in a Geographic Information System software

Step 5 — Digitization of all the processed data in a design software

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Mapping the water distribution networks

Equipment:

Pipe location device (UT 830 by SEWERIN):

Figure. UT 830 pack contents.

Accurately mapping the water distribution networks as well as locate any possible illegal connections to the network

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Mapping the water distribution networks

Water leak detection system (AQUAPHON by SEWERIN):

Figure. AQUAPHON pack contents.

- Detecting leaks in water pipes by electro-acoustic means

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Mapping the water distribution networks

GPS device (GPSMAP 276Cx):

Figure. GPSMAP 276Cx device.

- Georeferencing components of the water distribution networks with high accuracy

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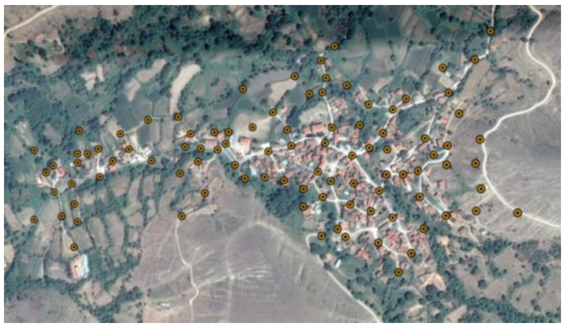
Mapping the water distribution networks

Local community of Agios Germanos:



96 measurement locations

- min= 956.62 m
- max= 1,094.24 m
- average= 1,017.29 m
- range= 137.62 m
- st. dev.= 31.33 m

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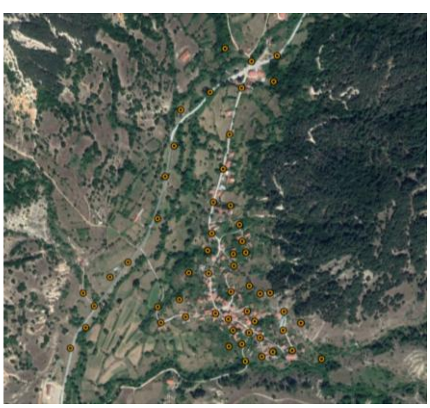
Mapping the water distribution networks

Local community of Antartiko:



54 measurement locations

- min= 1,010.97 m
- max= 1,095.60 m
- average= 1,054.39 m
- range= 84.63 m
- st. dev.= 19.46 m

Mapping the water distribution networks

Local community of Karies:

58 measurement locations

- min= 917.91 m
- max= 972.48 m
- average= 940.15 m
- range= 54.57 m
- st. dev.= 14.55 m

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Mapping the water distribution networks

Local community of Pisoderi:

65 measurement locations

- min= 1,387.21 m
- max= 1,462.53 m
- average= 1,425.33 m
- range= 75.32 m
- st. dev.= 18.24 m

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Mapping the water distribution networks

Local community of Trigono:

60 measurement locations

- min= 972.23 m
- max= 1,029.18 m
- average= 996.12 m
- range= 56.95 m
- st. dev.= 13.25 m

Development of a Geodatabase

The acquired information was inserted in ArcGIS, allowing their spatial analysis. The main layers of the geodatabase are:

- **Tanks**: Depicts the tanks and includes a description of all their features.
- **Network pipes**: Depicts the pipes of the networks. The layer includes information on exact location, pipe length, pipe material and pipe diameter.
- **Background layers**: Refers to the background layers including cadastral maps, Digital Elevation maps, road network, building blocks etc.
- **Consumer meters**: Includes the location and consumer number of water meters.

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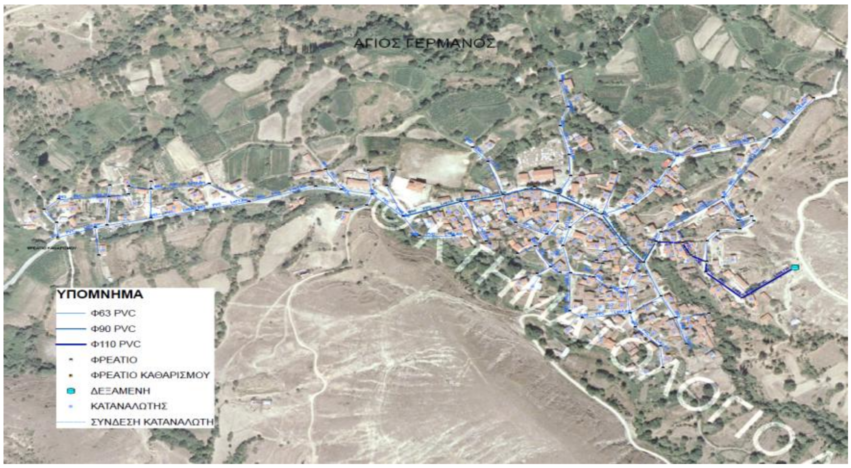
Development of a Geodatabase

Local community of Agios Germanos:



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Development of a Geodatabase

Local community of Antartiko:

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Development of a Geodatabase

Local community of Karies:

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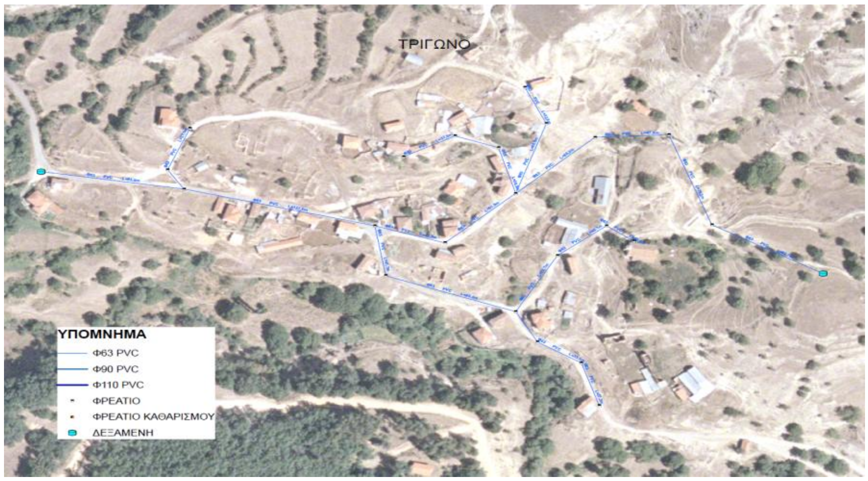
Development of a Geodatabase

Local community of Pisoderi:

Development of a Geodatabase

Local community of Trigono:



Spatial interpolation of elevation measurements

- Creating a continuous surface model requires measurements at each single point of a study area.

The accurate performance of the procedure can significantly improve the utility and purpose of hydraulic modeling of the water distribution networks

- Use ***kriging geostatistical interpolation method*** taking advantage of the spatial autocorrelation feature of the geographical variables

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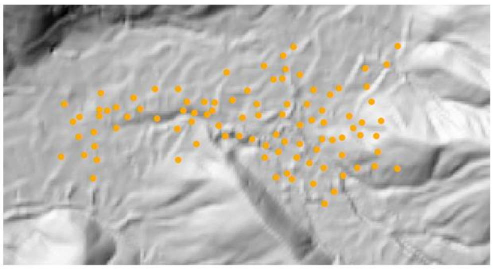
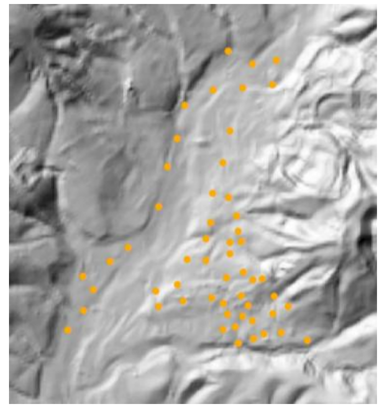
Spatial interpolation of elevation measurements

Agios Germanos

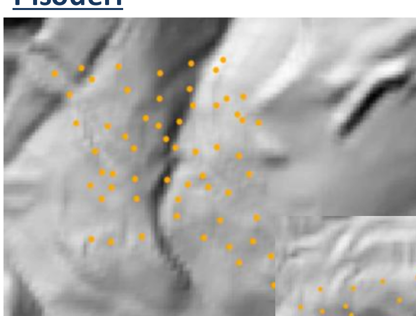


Antartiko

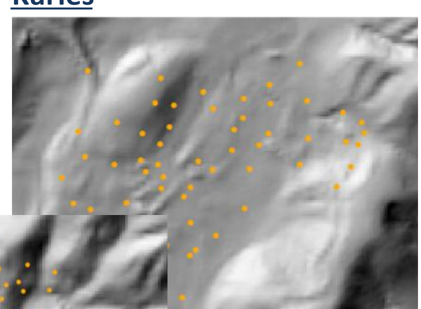


Spatial interpolation of elevation measurements

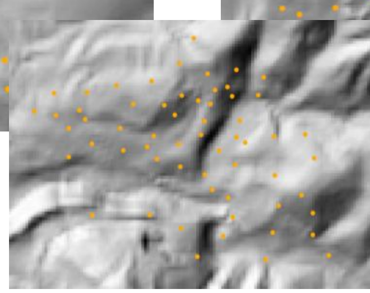
Pisoderi



Karies



Trigono



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Simulation of water distribution networks

Aims – Objectives:

Assessment of the hydraulic behaviour of existing infrastructure of the water distribution network in the Municipality of Prespes in ***their current state of operation*** and of their ***response to different pressure management strategies*** contributing:

- ✓ To **better understanding the operation** of the water distribution networks under normal conditions
- ✓ To estimate the **total non-revenue water quantity** in the studied settlements of Prespes Municipality
- ✓ To **identify** locations of **significant water losses due to leakages or illegal water connections**

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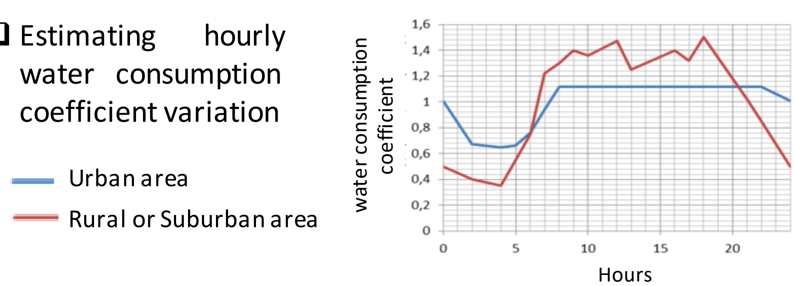
Simulation of water distribution networks

Boundary conditions – Estimating water demand:

- ❑ Assessing **daily water consumption** using data on **population** and **consumption per capita** ⇨ **Estimation of theoretical water demand**
- ❑ Collecting water demand data from account records
- ❑ Estimating hourly water consumption coefficient variation



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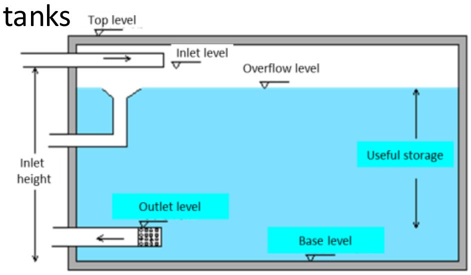
Simulation of water distribution networks

Tank geometry and water elevation data:

- ❑ Surface area (cross-section) of tanks
- ❑ Base elevation of the tank
- ❑ Elevation of tank's outlet pipe
  - → minimum water level
- ❑ Elevation of tank's inlet pipe
  - → maximum water level



Topology and geometry of the network pipes:

- ❑ Use data from constructed GIS

Node elevations in the study area:

- ❑ Elevations recorded by GPS or from created DEMs

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Simulation using Bentley OpenFlows WaterGEMs

Advantages of using WaterGEMs:

- ✓ Includes state-of-the-art genetic algorithm optimisation techniques for automatic calibration, design of new elements and adjustment of pump operations
- ✓ Darwin Calibrator evaluates millions of possible solutions and offers the best possible calibration alternative based on pressures and discharges measured at critical points of the network
- ✓ Darwin Designer automatically finds the maximum benefit or introduces strategic plans that minimise the total cost of the network (economic or energy cost)

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Simulation using Bentley OpenFlows WaterGEMs

- Build the hydraulic model using data from created GIS
- Use water demand data from account records
- Model calibration using SCADA measurements of flows and pressures at the network
- Creation of leakage scenarios, perform leakage detection runs and analyse results of the analyses
- Look for consistent predicted leakage hotspots
- Field measurements to accurately determine leakage locations
- Select a strategy that minimises the cost of operations

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Thank you

for your attention !

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