[2] Cyprus University of Technology,
Department of Civil Engineering
and Geomatics, Remote Sensing &
Geo-Environment Lab,
ERATOSTHENIS Research Centre

SafeChania 2015
The Knowledge Triangle Serving Civil Protection

Guidelines concerning the improvement of the operation of water supply networks in Cyprus using the 'HYDROGIS' Infrastructure: Local energy losses in T-Junctions

[1] Department of Water
Resources and Environmental
Engineering National
Technical University of Athens

Dimitriadis P.[1], Chazapi A.[1], Papanicolaou P.N.[1], Evlogimenos P.[2], Hadjimitsis D.G.[2]

1. Introduction and innovation

Local energy losses caused by local changes in junctions, are considered to have minor effects in flow rates, if compared to other pipe network uncertainties (e.g. capital flow demand). However, there are cases (e.g. when the ratio of discharges approaching a junction is very small compared to unity) where neglecting them can lead to errors (cf. [1]). Local losses may be estimated as a fraction of the velocity head (else known as K-factor), which is usually obtained experimentally.

Here, we present a methodology for pipe network design including the local losses in each junction (cross or T-shaped of various angles) and flow conditions (dividing or combining flow). Moreover, we apply it to an 'experimental' network of public water supply. The wider aim of this analysis is the establishment of guidelines concerning the simulation of water supply networks and filling the huge gap between basic and applied research in the area of fluid engineering and fluid machinery.

2. T-junction

Tee junctions are frequently used in water distribution networks to divide or combine the flows and they usually account for large energy losses (cf. [2]). The most common type is the 90o T-junction which includes two K-factors, one related to the branch and one to the straight pipe (denoted K31 and K32, respectively). Empirical equations relating the local losses to the discharge ratio are shown below [2].

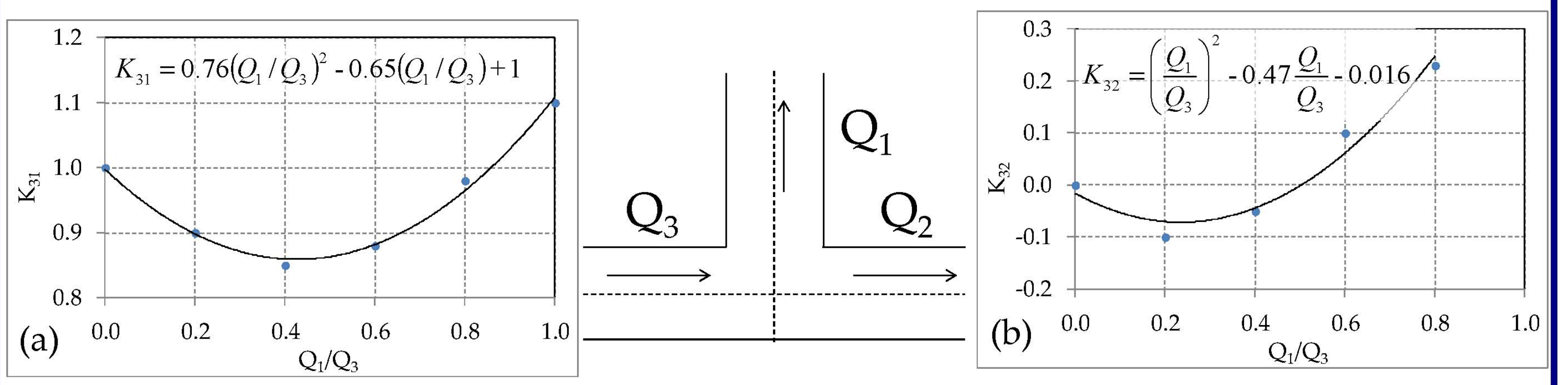
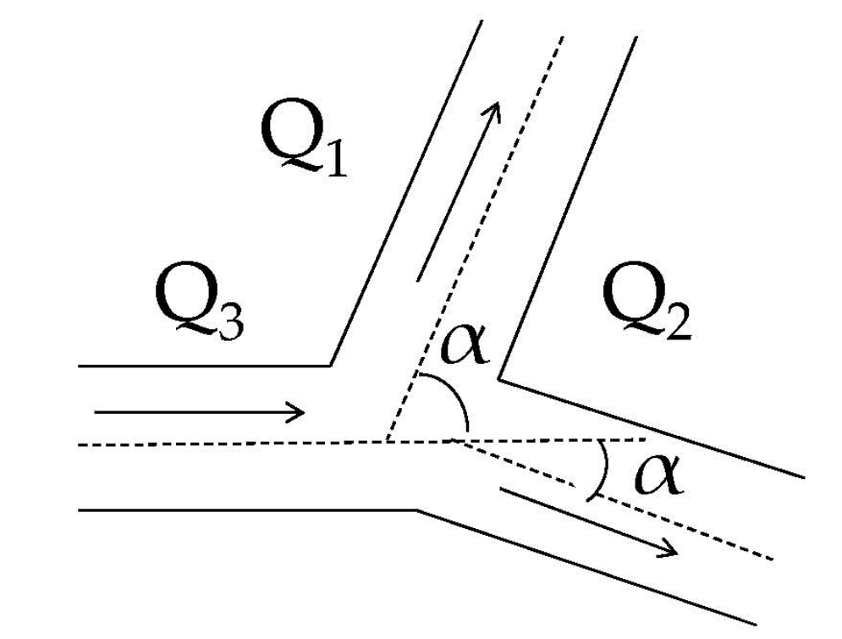


Figure 1: expression and variation of the local loss coefficient (a) K_{31} and (b) K_{32} for a typical sharp edge 90o T-junction.

3. T-junction of arbitrary angle

For angles between branches smaller different from 90o we distinguish two cases, one for dividing flow (where the flow from one branch is divided into the remaining two) and one for combining flow. Empirical equations relating the local losses to the discharge ratio for the dividing flow condition, are shown below [3].



$$K_{31} = \lambda_1 + (2\lambda_2 - \lambda_1)(V_1/V_3)^2 - 2(V_1/V_3)\cos(a')$$

$$K_{32} = \lambda_1 + (2\lambda_2 - \lambda_1)(V_2/V_3)^2 - 2(V_2/V_3)\cos(a')$$

For $a < 22.5^o : \lambda_1 = 0.0712a^{0.7141} + 0.37$

and $\lambda_2 = 0.0592a^{0.7029} + 0.37$

For $a > 22.5^o : \lambda_1 = 1$ and $\lambda_2 = 0.9$

where $a' = 1.41a - 0.00594a^2$

Figure 2: expressions for K_{31} and K_{32} related to a typical T-junction for dividing flow conditions.

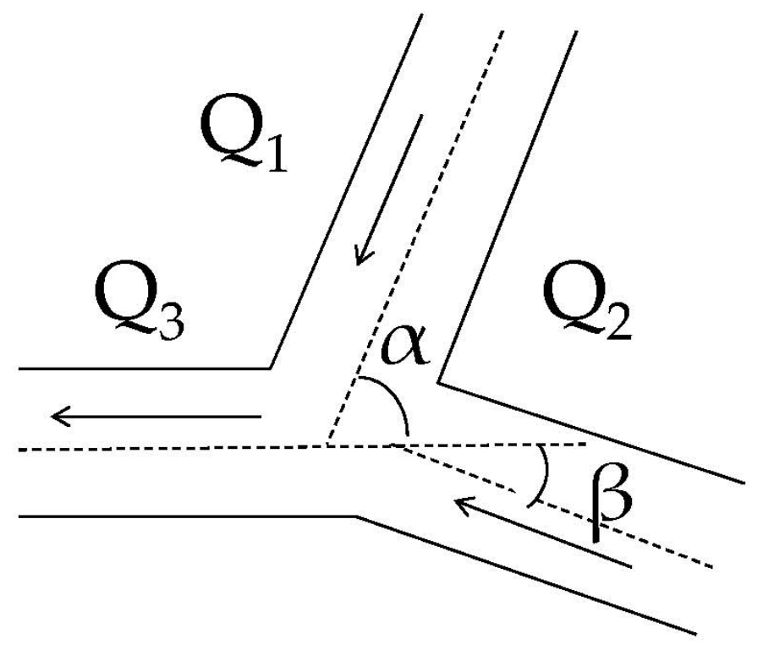
4. T-junction of arbitrary angle (cont.)

Empirical equations relating the local losses to the discharge ratio for the combining flow condition, are shown below [3].

$$K_{31} = \lambda_3(V_1/V_3)^2 + 1 - 2\begin{pmatrix}(V_1/V_3)(Q_1/Q_3)\cos(\alpha') \\ +(V_2/V_3)(Q_2/Q_3)\cos(\beta')\end{pmatrix}$$

$$K_{32} = \lambda_3(V_2/V_3)^2 + 1 - 2\begin{pmatrix}(V_1/V_3)(Q_1/Q_3)\cos(\alpha') \\ +(V_2/V_3)(Q_2/Q_3)\cos(\beta')\end{pmatrix}$$

where $a' = 1.41a - 0.00594a^2$ and $\beta' = 1.41\beta - 0.00594\beta^2$



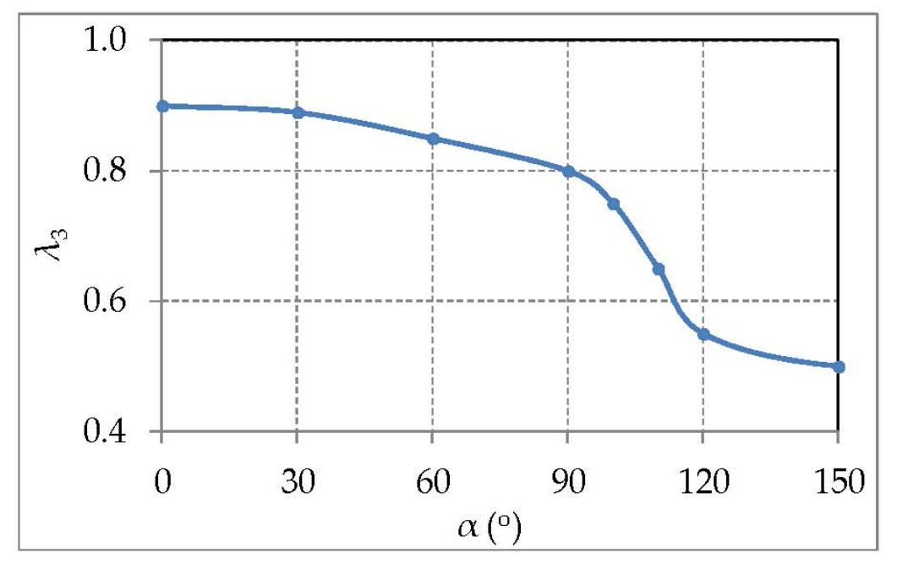
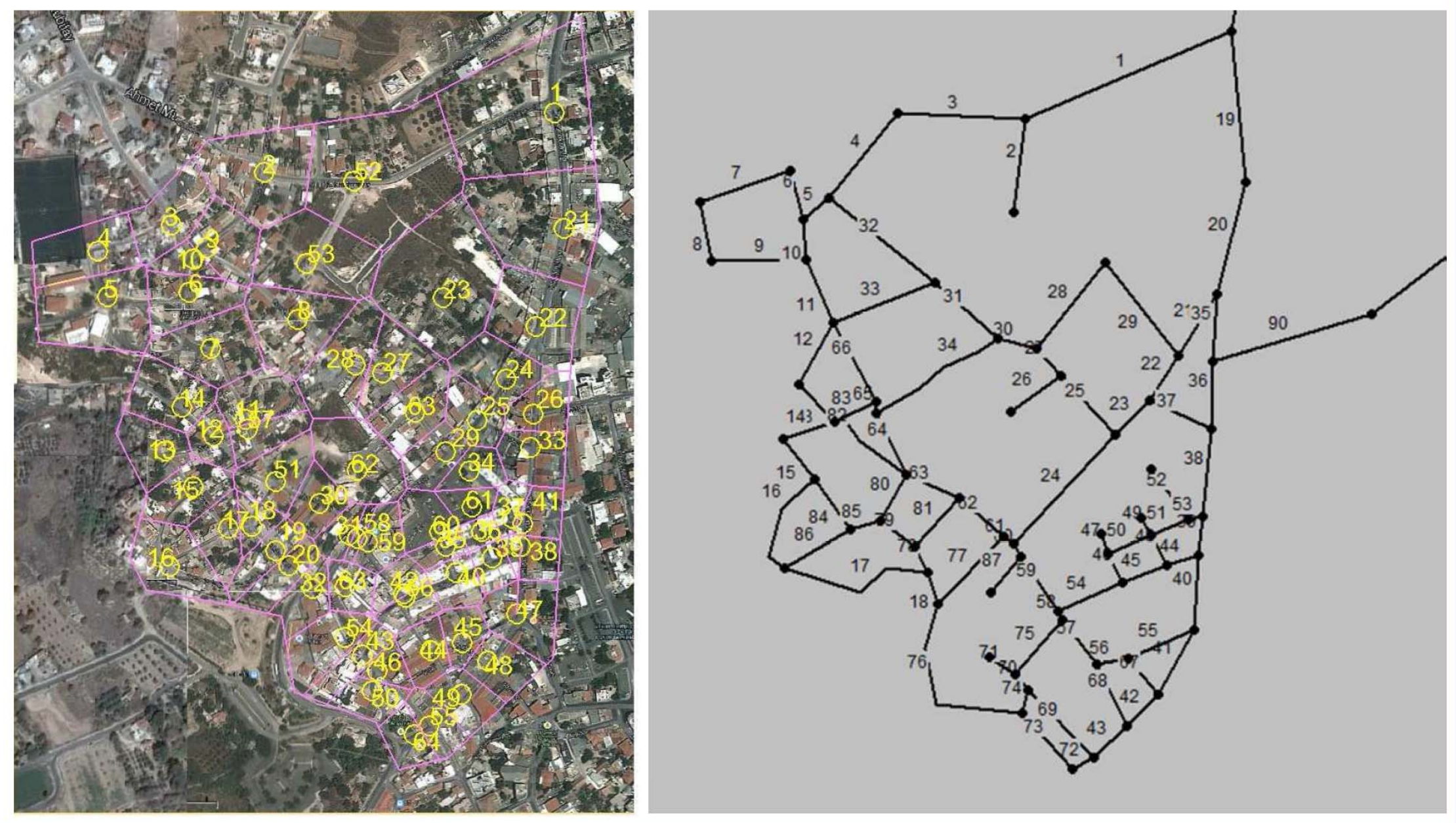


Figure 3: expressions for K_{31} and K_{32} related to a typical T-junction for combining flow conditions.

5. Experimental network

The previous methodologies are applied to an existing distribution network at Mutallos, Paphos in Cyprus. Initially the network was modeled in Epanet2 and checked for various loading conditions showing that for current consumption conditions the network is sufficient [4].

Figure 4: Thiessen polygons for area of influence of Mutallos network (left) and the network design in Epanet2.



6. Experimental network (cont.)

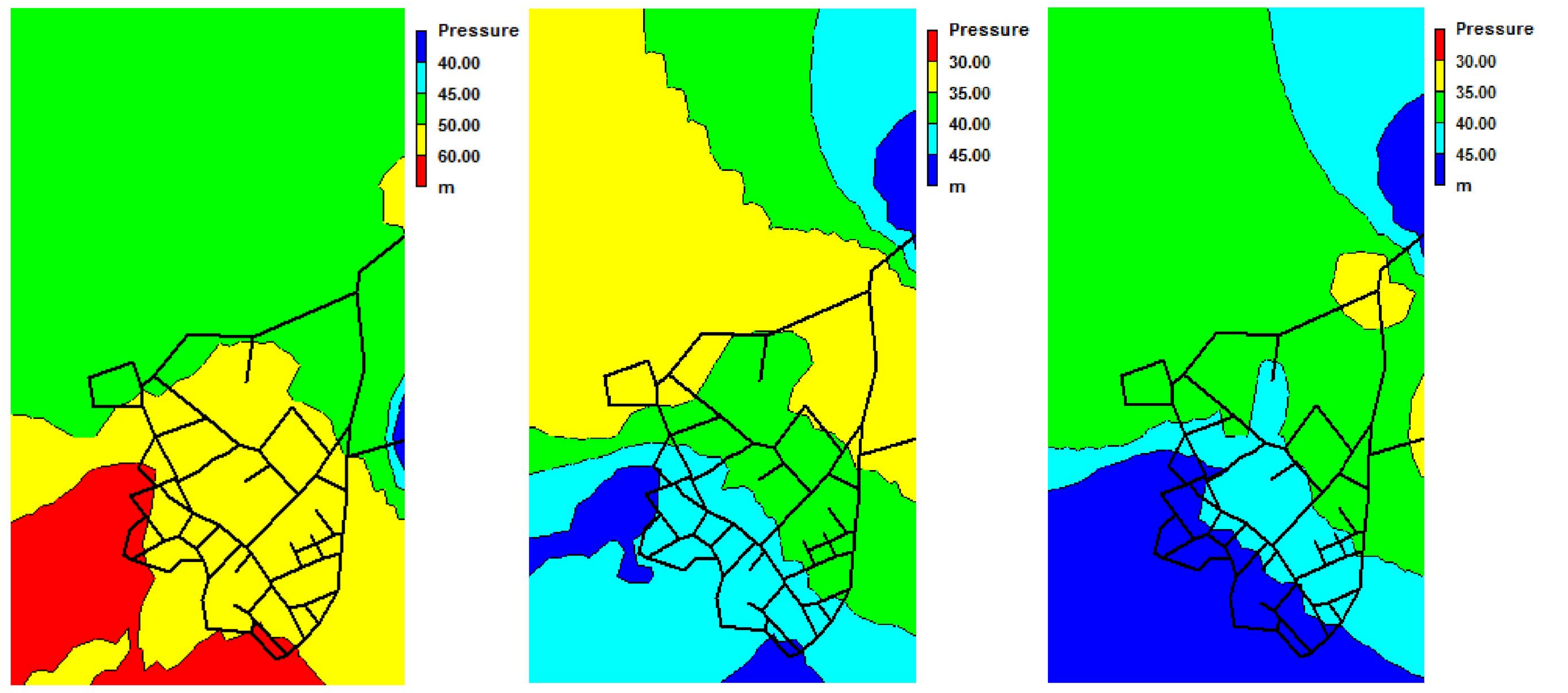


Figure 5: Pressure distribution in Mutallos network (from Epanet2) for (a) the daily average, (b) fire and (c) maximum hourly demand scenarios [4].

7. Modelling local losses

For the estimation of both local losses and flow rates in each T-junction of the network we run the model in a loop (using the Epanet Matlab Toolkit, [5]) until each flow rate and corresponding local coefficient converge to a single value.

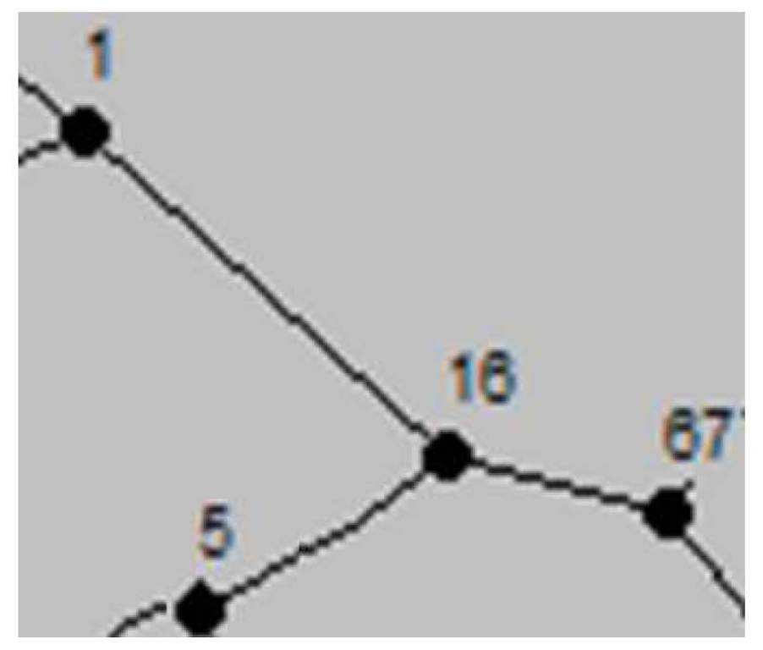


Figure 6: An example of a T-junction with arbitrary angles from the Mutallos network.

For example, the 16th junction is a T-junction with three branches. We set the pipe 5-16 as the 1st branch (Q_1), the pipe 1-16 as the 2nd (Q_2) and the 67-16 as the 3rd one (Q_3). From the initial simulation (assuming zero local losses) we see that this is has combining flow conditions. Thus, we use the expressions in sect. 3 to calculate the new K-factors and then we re-run the model to estimate the new flow rates etc.

8. Results

Table 1: Results from the application of the previous methodologies. Note that the rest junctions are simulated for zero local losses.

Junction	Type	K31	K32	Q1	Q1 (%)	Q3	Q3 (%)
1	dividing	0.223	6.423	-0.151	151.5	1.055	0.2
28	dividing	0.397	0.543	3.005	6.7	4.095	7.3
29	dividing	0.339	0.177	1.728	8.2	5.787	4.3
16	combining	-1.443	-1.443	0.922	-2.6	0.922	-2.6
65	combining	0.356	0.356	2.505	8.5	2.505	8.5
10	T	0.867	0.000	6.002	-11.8	16.322	-0.6
17	T	0.875	0.050	1.237	-3.5	2.583	-8.0
14	T	1.100	0.250	-1.750	-33.8	4.663	-15.7
30	T	0.884	0.000	1.534	3.6	5.787	4.3
69	T	1.100	0.250	-1.656	7.6	3.005	6.7

9. Conclusions

- ➢Mutallos pipe network has been modeled including local energy losses.
- ➢Significant changes of the flow rate due to local losses was found only on the small discharges.
- ➢Measurements are needed for more accurate design.
- ➢Laboratory data regarding local or friction losses for different types of pipes (if available), can be applied to future pipe network modeling.

Acknowledgement

HYDROGIS' is funded under the Framework Programme for Research, Technological Development and Innovation of the Research Promotion Foundation in Cyprus (DESMI 2009-2010).

References

1) Sharp, Z.B., Energy Losses in Cross Junctions, Master Thesis, Utah State University, 2009.
2) Costa N.P, Maia R. Pinho P.T, Proença M.F. Edge effects on the flow characteristics in a 90º tee junction. Trans. ASME, J. of Fluid Engineering 2006, vol. 128, Nº 6, pp. 1204-1217.
3) Vasava, P.R., Fluid Flow in T-Junction of Pipes, Master Thesis, Lappeenranta University of Technology, Department of Information Technology, Laboratory of Applied Mathematics, 2007.
4) Chazapi, A., Probabilistic analysis of water supply network in Mutallos, Pafos (in Greek), Diploma Thesis, Water Resources and Environmental Engineering, Department, School of Civil Engineering, NTUA, 2014.
5) Eliades, G.D., Calling EPANET from Matlab, https://eldemet.wordpress.com/2008/08/14/epanet-and-matlab, 2013.