OPTIMUM DESIGN AND ANALYSIS TOOLS FOR DRIP IRRIGATION HYDRAULICS IN COMPLEX CONFIGURATIONS

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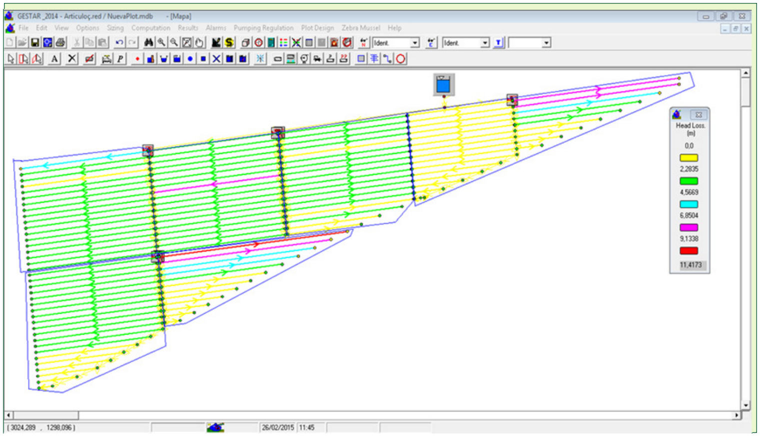
1 Requirements for pressure dependent emission modelling in drip irrigation networks

To take advantage of pressurised irrigation, drip irrigation is being introduced in extensive crops formerly irrigated by surface or sprinkler irrigation, looking to minimise pressure requirements and thus the energy costs of pumping. Turbulent flow emitters (with pressure dependent emission) rather than self compensating drippers are frequently found in these applications to minimise the coverage cost.
Turbulent flow emitters are also often preferred for long drip lines in irregular plots with uneven altitudes. In these conditions, good hydraulic design is critical. The local emitter pressure - dependent flow rate, working at the lowest pressure limits, must be considered, regardless of plot complexity
The traditional Christiansen formulae based on nearly constant emission for limited pressure differences are not applicable or valid in this context. Therefore, a more powerful general approach is required to make designs accurate enough

GESTAR (www.gestarcad.com), in continuous development at the University of Zaragoza (Spain) since 1995 with funding from the Regional Government of Aragon, is a complete software package for engineering pressurised irrigation systems (collective distribution networks and plot irrigation). Its tools and modules, specifically designed for pressurised irrigation and tested over the long term, enable optimum design, execution and management, integrating a wide range of resources, many of them available exclusively in this programme, and a long history of innovations and application to large and small systems. The GESTAR 2014 platform has recently added advanced tools for the optimum hydraulic design and simulation of drip irrigation.

Figure 1. *GESTAR 2014 Home Screen, Drip Irrigation Module for optimum plot design & hydraulic*



2 GESTAR 2014 Advanced drip line modelling in arbitrary pipe networks.

The advance hydraulic modelling of drip irrigation networks in GESTAR 2014 combine general nodal analysis (Estrada et al, 2009) with an improved generalised integral-differential approach (Warrick & Yitayew, 1988).

As the number of drip emitters is usually quite large, trickle tubing can be better modelled as continuous-like emission when dealing with large systems with tens of thousands of drippers. The strategy used for dealing with drip lines in a general water network distribution consists of introducing the drip lines flow rates at the end nodes as additional unknowns in the nodal continuity equations, and calculate them with a continuous emission (pressure dependent) constitutive model. The local emission of flow rate per unit length, q, along the position x of a trickle tube, of constant section A and diameter D, with emitters spacing e , at a point $_p$, where the pressure is p and the velocity is v, can be expressed as: $A\left.\frac{dv_p}{dx}\right|_p = -q_p$ where the pressure dependent emission for turbulent emitters is: $q_p = \left(\frac{c}{e}\right)p_p^y$

Being the friction factor on the Darcy-Weisbach equation expressed as $f = f_0 v^{m-2}$, and denoting s the drip line slope, the energy equation is formulated:

$$\frac{d}{dx}\left(p_p + \frac{v_p^2}{2g}\right) + \frac{fv_p^2}{2gD} + s = 0$$

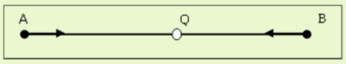
After recombining, transformed energy and continuity nonlinear implicit eqs (Fig. 2) are found for every dripline, and solved together with NN nodal equations (one nodal eq. for each network node).
The model capabilities were further expanded to consider the more general situation where the tube is fed by both ends A and B (Fig. 2) with a null velocity (equilibrium) intermediate point, Q. In this case a much more complex system of five nonlinear fully coupled equations appears for each dripline.

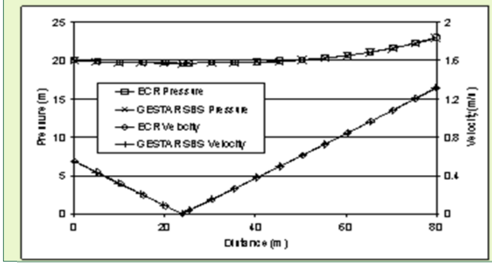
Figure 2 *Transformed continuity and energy eqs for each drip line:*

$$\frac{vA}{x_0\left((1+y)\cdot\left(\frac{V_p^{m+1}}{m+1}+S\cdot V_p\right)+C\right)^{-\frac{y}{y+1}}} - \left(\frac{c}{e}\right)p_p^y = 0$$

$$\int_{V_t}^{1}\left((1+y)\cdot\left(\frac{V^{m+1}}{m+1}+S\cdot V\right)+C\right)^{-\frac{y}{y+1}} dV - \frac{L}{x_0} = 0$$

Extensions for drip lines fed by both ends (looped connections)





$$X_p = \frac{x_p}{x_0}$$

$$V_p = \frac{v_p}{v}$$

$$S_p = \frac{2gDs}{f_0 v^m}$$

$$x_0^{1+\frac{1}{y}} = \frac{2^{1-\frac{2}{y}}\pi^{\frac{1}{y}}gD^{1+\frac{2}{y}}e^{\frac{1}{y}}}{c^{\frac{1}{y}}f_0 v^{m-\frac{1}{y}}}$$

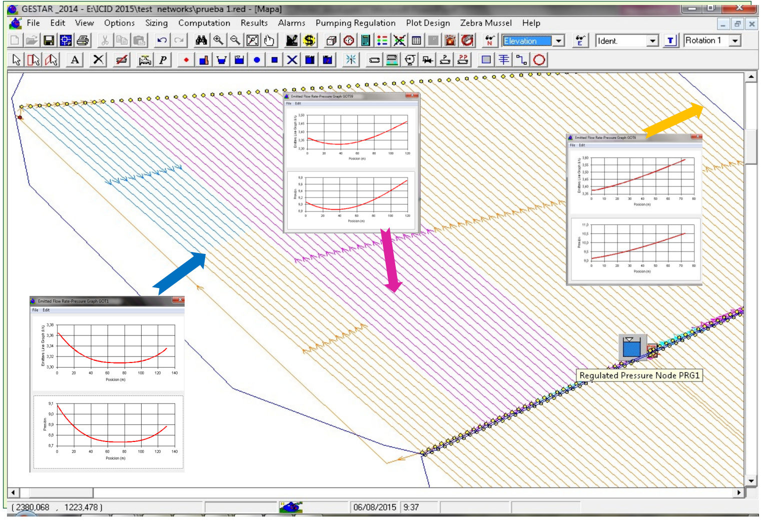
3 Results.

The model is being debugged and validated using an extensive set of test cases based on real conditions. Figure 3 shows an example of results obtained: an irregular drip irrigation sector presenting drip lines fed by one side and both sides. Apart from overall emission uniformity coefficients (calculated based on true local emissions), detailed profiles of pressure, velocity and local emitted flow rate by unit length are obtained. Despite the complexity of the case where the terrain presents different slopes, line lengths and trickle tube feeds, the algorithms provide a detailed simulation.

Figure 3 shows the profiles for pressure and emitted flow rate along 3 drip lines at different locations. Even though the driplines have the same diameter, emitters and emitter spacing, the different combinations of length, slope in the terrain and connections to secondary tubing lead to quite different results and emission profiles.

The hydraulic modelling of individual or distributed emitters, with emitted flow rate depending on pressure, gives precise, interactive and context-sensitive results in response to the challenge of low cost, low pressure drip irrigation.

Figure 3 *Calculated pressure and emitted flow rates profiles along 3 different drip lines*



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References

Estrada, C., González, C., Aliod, R. & Paño, J. (2009). Improved Pressurized Pipe Network Hydraulic Solver for Applications in Irrigation Systems. Journal of Irrigation and Drainage Engineering, Vol. 135, No. 4, August 1, 2009.

Warrick, A. W. & Yitayew, M. (1988). Trickle Lateral Hydraulics. I: Analytical Solution. Journal of Irrigation and Drainage Engineering, Vol. 114, No. 2, Paper No. 22438, pp. 281-288.