HELP HANDBOOK FOR **PRESUD** (PREssurized SUBunit Design) PROGRAM APPLIED TO SUBUNIT OF SPRINKLER IRRIGATION

In order to work with PRESUD it will be necessary, first **to download and install the 32 or 64 bit MATLAB compiler** depending on the type of computer available. The download can be done at http://crea.uclm.es/crea/descargas/matlab.php?s=aspersionygoteo

Also it is possible download and install the compiler for Windows MCR_R2016a (9.0.1) (not the most recent) in the link https://es.mathworks.com/products/compiler/matlab-runtime.html

The first step is to activate the **"start"** button and then the **"default values"** button, which will load a set of typical values for the variables.

After entering all data, activate the "**Calculate**" button.

PRESUD calculates the solution that makes the average application rate of the irrigation subunit equal to the desired value, defined as data

To visualize the graphic representation of the sprinklers discharges and pressures distribution on of the subunit, activate the "**Figures**" button

Additional clarifications:

1. It is necessary to select if paired lateral or manifold pipe is used (Fig. 1) or is fed by one end

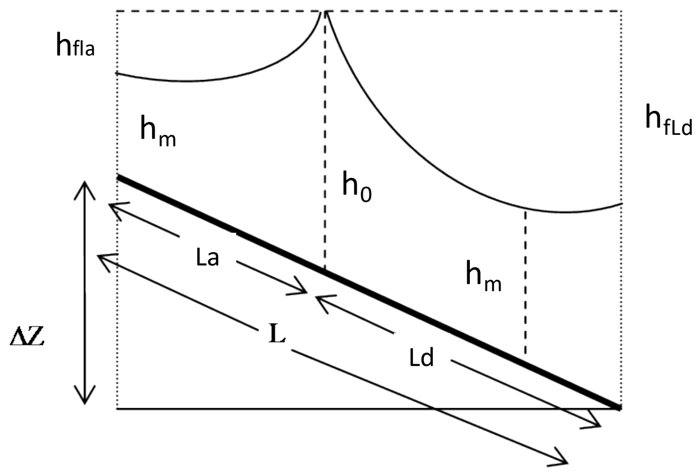

Fig. 1 Diagram of a paired lateral pipe.

Both the feeding of paired **lateral or manifold pipe** could be done: a) by an equidistant point between two sprinklers or two laterals, b) next to one of the sprinklers or laterals, c) by the exact point (" theoretical point ") that makes the pressure difference (h_o - h_m) equal in the ascending and descending part; d) for another distance set by the user, that is not equidistant between two sprinklers or laterals.

2. The general sprinkler equation is expressed as

$$qa = K\ Hx$$

where qa = average sprinkler discharge (L h^{-1}); K = emission coefficient; H inlet pressure head of the sprinkler (m); x= emission exponent (x≈0.5 for sprinklers).

The average application rate is expressed as

$$P_{ms} = qa\ (Ss\ Sl)^{-1} = qa\ Asp^{-1}$$

where P_{ms} = average application rate of the irrigation system (mm h^{-1}); Ss = sprinklers spacing in the lateral (m); Sl = the lateral spacing in the manifold (m); Asp =area irrigated by one sprinkler (m^2) (Asp = Ss Sl).

Known the values of H, x and P_{ms}, PRESUD calculates the value of q and K.

3. The head losses relative to minor singularities (h_s) are considered between 10 and 20% (usually 15%) of friction head losses (h_f) in lateral or manifold pipes
4. Lo y So are the distances from the origin of the lateral or the manifold to the first sprinkler or lateral (m) respectively. Necessary data only when the pipe is fed from one end
5. Annual gross crop irrigation requirement (N_b) are calculated as

$$Nb = Nn/\ Ea$$

Where, Nn is the annual net irrigation requirement (in m^3/ha); Ea the general application efficiency in the subplot, calculated as

$$Ea=EDa\ Pef$$

EDa=(100+(606-24.9*a + 0.349*a2-0.00186*a3)*(1-CUs/100))/100;

where EDa= distribution efficiency (Keller and Bliesner 1990); Pef = effective proportion of water from the sprinklers that reaches the soil surface due to evaporation and drift losses for the set of irrigation during the season; a = percentage of adequately irrigated area; CUs = water uniformity in the soil, that can be estimated as the cumulative CUa of water application in the set of irrigation events during the irrigation season.

Usually, the values of CUs, a, EDa, Pef and Ea of Table 1 can be considered for the different spacings, working pressure (h_a) and climatic conditions of Castilla-La Mancha region (Spain). The selected values of CUs are obtained from different references (Keller and Bliesner 1990, Tarjuelo et al. 1999b, Tarjuelo et al. 2000, Montero et al. 2001, Playán et al 2005, Ortiz et al. 2010)

Table 1. Values of the different parameter related with the sprinkler that can be considered for Castilla-La Mancha (Spain) conditions.

Spacing of sprinklers (m x m)	h_a (kPa)	CU_s (%)	*a* (%)	ED_a (dimension-less)	P_{ef} (dimension-less)	E_a (dimension-less)	AR_a (mm h^{-1})	Diameter of Nozzles (mm)
18 x 18	300	85	80	0.84	0.92	0.77	5.90	4,8+2.4
	350	87	80	0.86	0.92	0.79	6.33	4,8+2.4
	350	87	80	0.86	0.92	0.79	7.30	5.2+2.4
15 x 15	300	86	80	0.85	0.92	0.78	6.33	4.0+2.4
	300	87	80	0.86	0.92	0.79	7.30	4,4+2.4
	350	90	80	0.89	0.92	0.82	8.00	4,4+2.4

h_a = average of the working pressures of the sprinkler assembly in the subunit.

The Christiansen's Uniformity Coefficient CUa of water application by the irrigation system (CUa) con be calculated as

$$CUs = CUa = \left(1 - \frac{\sum_{i=1}^{n} | v_i - v_a |}{v_a \, n} \right) 100$$

Where vi = individual depth of catch observations from uniformity test; va= mean depth of observations; n= number of catch observations

6. Pump efficiency corresponding to the overall performance of the pump + engine + variable speed driver. The recommended real value after the energy audits carried out at more than 30 pumping stations in Castilla-La Mancha is between 65 and 70%

7. It is necessary to make a previous selection of the pipe diameters for the lateral (including emitters) and manifold. Lateral and manifold prices will appear when the pipe diameter is selected. This data (Table 2) may be modified by the user, in which case the "Recalc" button must be activated.

Table 2. Average prices of different manufacturers and distributors in Spain

Concept	External (inner) diameter (mm)	**Price (€ m^{-1})** [1]
Sprinkler		10 €/unid
Riser pipe		0.30
Lateral pipe PVC 0.6 MPa	50 (46.4)	0.65
	63 (59.2)	0.97
	75 (70.6)	1.34
Manifold pipe PVC 0.6 MPa	140 (131.8)	3.52
	160 (150.6)	4.45
	180 (168.4)	5.63
	200 (188.2)	6.78
Riser coupler		0.6 €/unit

[1]The pipe price includes the opening and closing of ditches and assembly costs.

8. In the block called "**Regulation**", it is possible to select the option where the program calculate the necessary pressure at the subunit inlet ("**pre-dimensioned or Predim**.") or the user can enter a specific inlet pressure data at ("**Yes**")

Once all the data has been entered, the **results are shown in a data table**

9. The emission uniformity in the irrigation subunit can also be estimated with the **Christiansen Uniformity Coefficient** CU (Christiansen 1942) defined as

$$CUd = \left(1 - \frac{\sum_{i=1}^{n} |q_i - q_a|}{q_a\, n}\right)100$$

Where q_i is the flow rate of each sprinkler and n the number of sprinklers in the irrigation subunit

10. The **Discharge Uniformity** (UD) of the sprinklers in the subunit is calculated as

$$UD = 100\, q_{25}/q_a$$

where: q_{25} = average sprinklers discharge that constitute 25% of lowest discharge in the irrigation subunit; q_a = average flow discharged by all sprinklers in the irrigation subunit

11. The **emission uniformity** (EU) in the subunit can be estimated as

$$EU = \left(1 - \frac{1{,}27 CV_{qmf}}{\sqrt{e}}\right)\frac{q_m}{q_a}100$$

Where: CV_{qmf} = Coefficient of variation of sprinkler manufacturer; q_m = minimum sprinkler discharge in the subunit due to the pressure; q_a = mean of all sprinkler discharge values in the subunit due to variations in pressure; e = number of sprinklers per plant. This can be considered equal to 2 being normally a point of the soil watered by two sprinklers

12. The **coefficient of variation of flow rate** CVq) in the subunit defined as

$$CV_q \cong \sqrt{CV_{qmf}^{\ 2} + x^2\, CV_h^{\ 2}}$$

Where: CV_{qmf}= manufacturer coefficient of variation of the sprinkler; CV_h= coefficient of variation of sprinkler discharge due to pressure variation ($CV_h = D_h\, h_a^{-1}$), where D_p= standard deviation of the sprinkler discharge due to the variation in pressure, h_a= average sprinkler pressure in the subunit; x emission exponent.

13. **Maximum pressure difference** between two sprinklers of the irrigation subunit (Δh, as % of the average pressure)
14. **Maximum difference in discharge** between two sprinklers of the irrigation subunit (Δq, as % of average flow)
15. **Graphs** of pressures and flows distribution in the sprinklers of the subunit

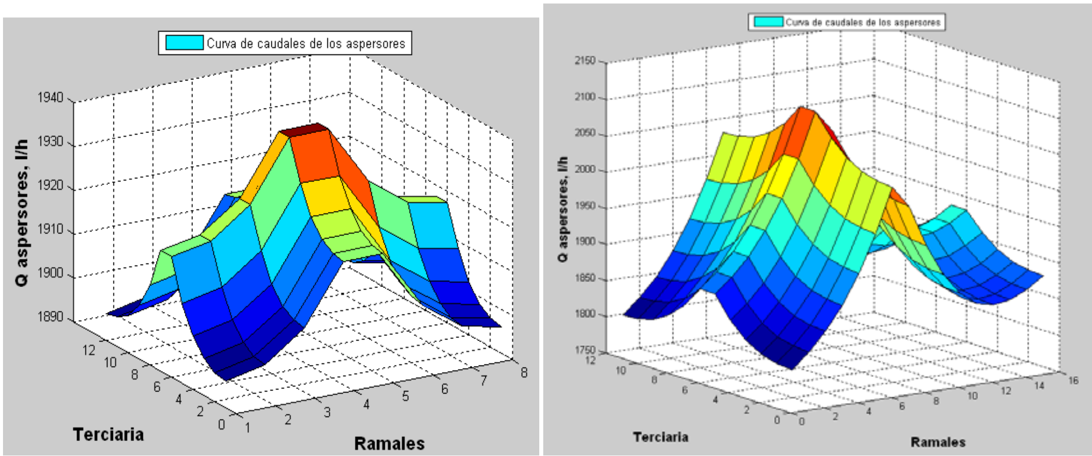

Fig. 2 Discharge of sprinklers distribution for 18x18 m spacing and pressure at the subunit inlet Ho = 350 kPa, with (a) a subunit area of 3.1 ha (12 laterals with 8 sprinklers each), and (b) 6.2 ha (12 laterals with 16 sprinklers each)

Example of PRESUD tool for subunit sprinkler irrigation design

Example of 4.54 ha of onion (252 m x 180 m, corresponding to 10 laterals and 14 sprinkler in the lateral , with spacing 18m x 18m), using sprinklers whit nozzles 4,8+2.4 mm, working to a pressure of 35 m, ARa = 6.5 mm h^{-1}, slope in lateral 3% and 0% in manifold.

DATOS usados

Pendiente terciaria	0 %	Distancia entre ramales	18 m	Adequately irrigated area (a)	80 %
Pendiente	3%	Nº de ramales	10	Nº of sprinkler per plant	2
Terciaria	Alimentada por punto intermedio	Distancia desde la entrada hasta el 1º ramal	0	Pumping efficiency	65 %
Ramal	Alimentado por punto intermedio	Distancia desde la entrada hasta el 1º aspersor	0	Water price	0.1 € m-3
Exponente del aspersor (X) y CV_{qmf}	X= 0.5 CV_{qmf} = 3 %	Spacing between sprinklers	18 m	Lateral price	0.65 € m-1
Presión de trabajo	35 m	Sprinkler height	2 m	Manifold price	2.74 € m-1
Pluviometría media	6.5 mm h-1	Nº sprinkler in lateral	14	Energy rate	0.1 € kWh-1
Entrada en terciaria	Entre 2 ramales	Net crop irrigation water requirement	5500 m3 ha-1 year -1	Sprinkler price	10 € ud-1
Entrada en ramal	Entre 2 aspersores	Application uniformity CUa	87	Riser and coupler	1.2 € ud-1

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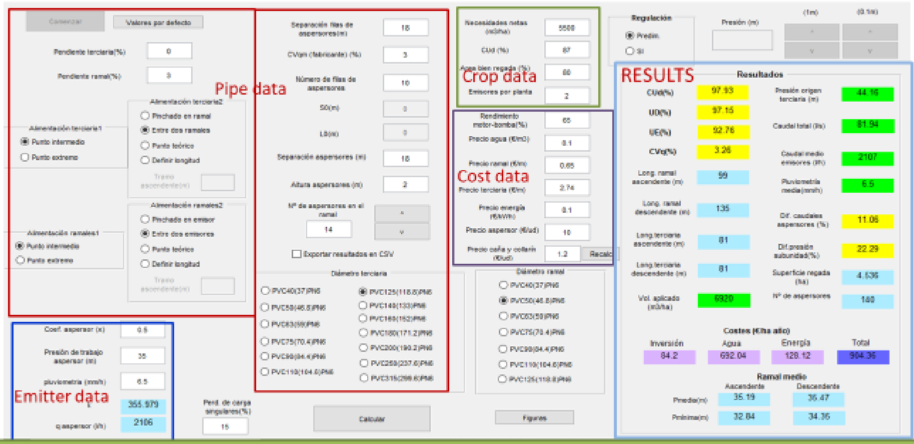

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SUPREMED PRIMA

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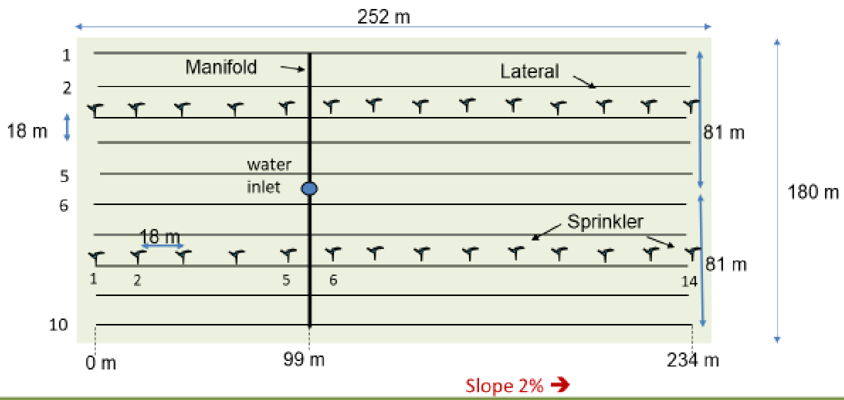
RESULTS



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RESULTS

CUd	97.93 %	Pressure in subunit inlet	44.16 m
UD	97.15%	Total inlet flow rate	81.94 L s^{-1}
EU	92.76	Average emitter discharge	2107 L h^{-1}
CV_q	3.26 %	Average application rate	6.6 mm h^{-1}
Ascending lateral length	99 m	Maximum discharge variation between sprinklers	11.06 %
Descending lateral length	135 m	Maximum pressure variation in the subunit	22.29 %
Ascending manifold length	81 m	Irrigated area	4.54 ha
Descending manifold length	81 m	Nº Sprinklers	140
Applied volumen	6900	Total cost (CT)	904.36 € $ha^{-1}y^{-1}$

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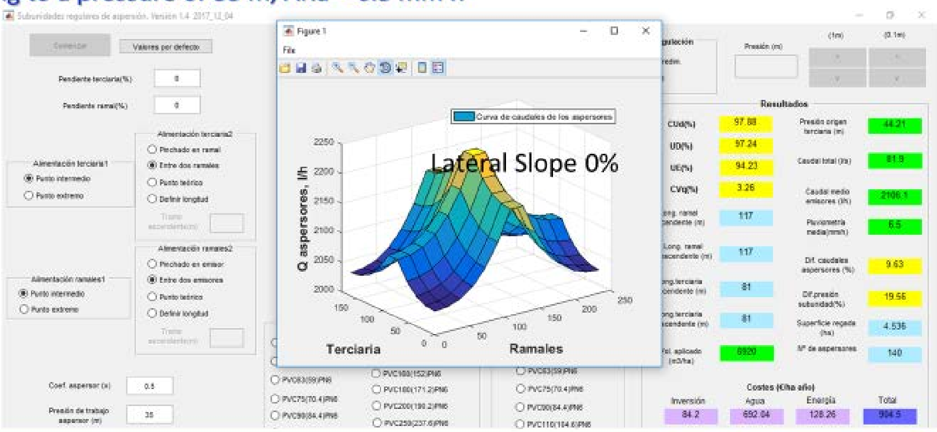

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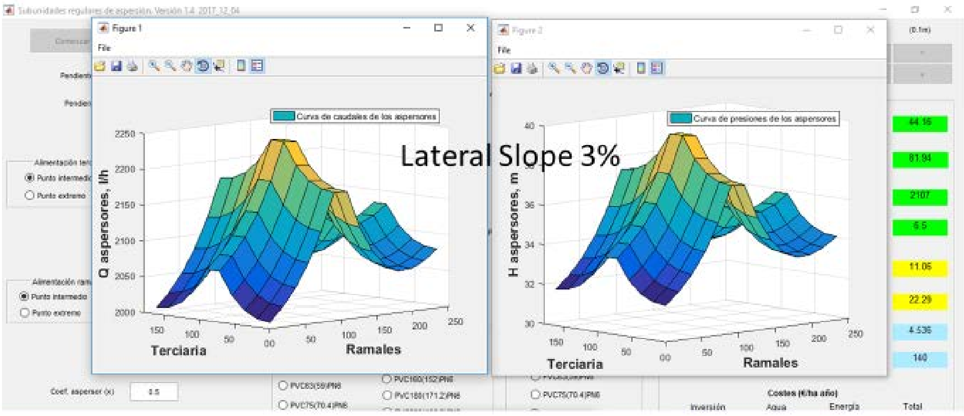

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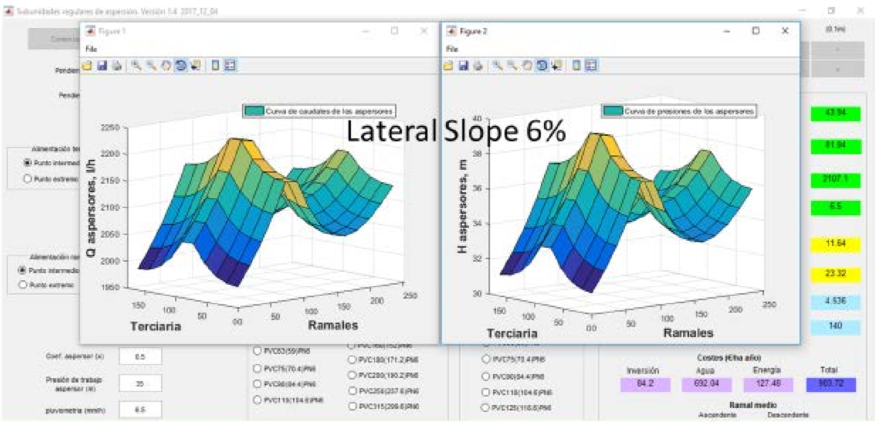

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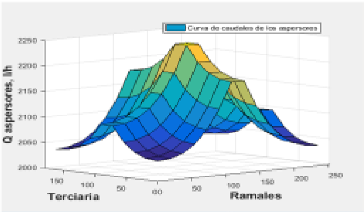
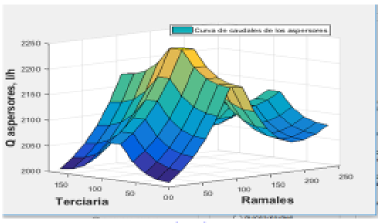
Discharge distribution



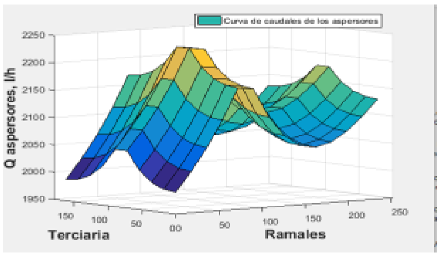
Lateral slope 0%

CU %	97.9
UE %	94.2
CV_q %	3.3
C_T (€ ha^{-1} $year^{-1}$)	904.5



Lateral slope 3%

CU %	97.9
UE %	92.8
CV_q %	3.3
C_T (€ ha^{-1} $year^{-1}$)	904.4



Lateral slope 6%

CU %	97.9
UE %	91.9
CV_q %	3.3
C_T (€ ha^{-1} $year^{-1}$)	903.7