Use of Handheld Computers for Hydraulic Calculations of Microirrigation Subunits

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Abstract

Software for handheld computers is presented for the hydraulic analysis of sloping irrigation laterals and tapered sloping irrigation manifolds. To obtain the pipe diameters of a sloping tapered multiple outlet pipe analytical expressions are presented. These are based on the assumption that outflow from a multiple outlet pipe is continuous and constant along the pipe, and that the friction coefficient is constant. An intermediate correction factor was developed that allows computation of head losses between any two points of a multiple outlet line.

Key words: Pocket PC, Handheld computer, microirrigation, drip irrigation, trickle irrigation.

1 Introduction

Advances in technology have led to substantial computing power in small portable devices that are rapidly becoming essential tools (Dominick, 2002). Handheld computer have been used in extension for work in agricultural production (Zazueta, Vergot, Beck, & Xin, 2002) and in extension program record keeping (Vergot et al., 2004). The main benefit of the portability of these devices is that they are unobtrusive and make ubiquitous computing capabilities possible. This is particularly useful for the practicing field engineer.

2 Head Losses in Multiple Outlet Pipes

The head loss in a multiple outlet pipe may be computed as the summation of the head losses occurring in each pipe section between contiguous outlets. Christiansen (1942) derived an equation for the total head loss in a multiple outlet pipe. This equation was given by:

$$H_f^m = F H_f$$

Where F is the ratio of the head loss that occurs in the multiple outlet pipe to the head loss that occurs in a pipe of the same geometry, with only one outlet at the end. $H_f^m$ is the head loss from the entrance to the end of the multiple outlet pipe, and $H_f$ is the head loss in the pipe if only a single outlet occurred at the end of the pipe.

Several modifications to the original Christiansen equation have been presented in the literature (Jensen and Fratini, 1957; De Tar, 1982). The concept of an intermediate multiple outlet coefficient was presented by Zazueta and Treviño (1978). This coefficient was based on the observation that the Christiansen factor is obtained by summing the head losses occurring in each section of pipe from the beginning to the end of a multiple outlet pipe.
\[ F_{n,j} = \frac{S_i}{n S_e} + \frac{1}{n^{\beta}} \left( \sum_{i=2}^{n} (n - i + 1)^{3/\beta} \right) \]

(2)

Where \( F_{n,j} \) is the multiple outlet correction factor for a pipe with \( n \) outlets, that is used as a multiplier to obtain the head loss to outlet \( j \), \( S_i \) is the distance from the first outlet to the entrance of the pipe, \( S_e \) is the spacing between the outlets and \( \beta \) is a coefficient that depends on the hydraulic equation used to estimate head losses. For the Hazen-Williams equation \( \beta \) is equal to 0.148. The Christiansen coefficient can be generalized to obtain the head loss between any two points in the pipe to obtain the expression:

\[ H_{f}^{i,j} = F_{i,j} H_f \]

(3)

Where \( H_{f}^{i,j} \) is the head loss occurring between points \( i \) and \( j \) in the multiple outlet pipe, and \( F_{i,j} \) is the intermediate multiple outlet pipe coefficient. Then \( F_{i,j} \) can be obtained from:

\[ F_{i,j} = F_{n,j} - F_{n,i} \]

(4)

For example, consider a 100 m pipe with five outlets. The head loss occurring between 30 m and 70 m is given by:

\[ H_f(0.7,0.3) = [F_{3.0,7} - F_{5.0,3}] H_f \]

\[ = (0.428 - 0.261) H_f \]

\[ = 0.167 H_f \]

(5)

Where \( H_f \) is the head loss in the pipe without outlets. Applications of this equation for manifold design and determining pressure distributions in micro irrigation systems with uneven topography were presented by Zazueta and Treviso (1978).

When the number of outlets in a multiple outlet pipe is large (\( N > 20 \)) (Chu, 1979), or in pipes in which water exits through a porous pipe wall, the outflow may be assumed to be continuous along the pipe. Several researchers have shown the distribution of head losses in a quasicontinuous discharge multiple outlet pipe (Wu and Gitlin, 1975; Keller and Karmeli, 1974, Zazueta and Treviso, 1978).

Analytical attempts have been made to account for unequal emitter discharge (Wu and Yue, 1993; Scaloppi and Allen, 1993). Under the assumption of constant discharge, the head loss distribution along the pipe can be presented as (Zazueta et al., 1984):

\[ \frac{H_{f}^{y,x}}{H_f} = \frac{1}{3 - \beta} \left[ 1 - \left( 1 - \frac{x}{L \beta} \right)^{3/\beta} \right] \]

(6)

Where \( x \) is the distance from the entrance of the pipe to a point along the pipe, \( L \) is the length of the pipe, \( H_{f}^{y,x} \) is the head loss from the entrance of the pipe to point \( x \).

Also, for the head loss between any two points along the multiple outlet pipe:

\[ \frac{H_{f}^{x_1,x_2}}{H_f} = \frac{1}{3 - \beta} \left[ \left( 1 - \frac{x_1}{L} \right)^{3/\beta} - \left( 1 - \frac{x_2}{L} \right)^{3/\beta} \right] \]

(7)

Where \( x_1 \) and \( x_2 \) are the locations of two points along the multiple outlet pipes. Equation 7 can be used as an extremely simple algorithm in software development for hydraulic computations and tapered pipe design for trickle irrigation systems (Zazueta et al. 1984).
3 Pipe Diameters of Sloping Tapered Manifolds and Laterals

From equation 7, the Hazen-Williams equation and the modified Bernoulli equation, the theoretical diameter required to obtain a specified head difference between the beginning and end of a pipe section in a tapered manifold is given by (Zazueta and Smastrla, 1995):

\[
D = \left[ \left( \frac{L/2.852}{H(x_1)} \right)^{1.852} - \left( \frac{L/x}{H(x)} \right)^{1.852} \right] \left( \frac{Q}{0.279 CH} \right)^{1.852} \quad (8)
\]

Where \( D \) is the internal pipe diameter (m), \( x \) and \( L \) are defined before (m), \( s \) is the slope given as a decimal fraction, \( Q \) is the pipe flow (m³/s), and \( CH \) is the Hazen-Williams hydraulic constant.

Equation 10 can be rearranged to compute the theoretical diameter that would be required to generate a desired pressure difference between locations \( x_1 \) and \( x_2 \). Furthermore, if the length of all sections in the tapered pipe are the same, and the fraction of allowable head loss (\( H_a \)) in each section of equal diameter are made the same (Fig. 1), the following equation is obtained:

\[
D_i = \left( \frac{n \left( \frac{Q}{0.279 CH} \right)^{0.2053}}{F_{i-1,i} H_a} + s \right)^{0.2053} \quad (9)
\]

Where \( D_i \) is the diameter of pipe section \( i \) of the tapered manifold, \( F_{i-1,i} \) was defined by equation 4, \( n \) is the number of sections in the tapered manifold and \( H_a \) is the total allowable pressure variation along the manifold.

Because eqn. 9 provides a theoretical diameter, it must be rounded to the diameter of a commercially available pipe, and the head variation in each section verified using the equation below:

\[
\Delta H_i = \frac{LF_{i-1,i} \left( \frac{Q}{0.279 CH} \right)^{1.852}}{D^{0.87}} - \frac{s L}{n} \quad (10)
\]

Where \( \Delta H_i \) is the difference in head between the ends of the pipe section.

Thus, theoretical diameters easily be calculated using eqn. 9. Once these are calculated, real diameters can be substituted into eqn. 10 to obtain the head distribution over the pipes.

4 Software Description

The methodology described here was implemented using for a Pocket PC Platform using the Microsoft Embedded Visual Tools (Microsoft, 2005). This software can be downloaded from http://fsz.ifas.ufl.edu. The software described here supports metric and English units as well as multilingual support for English and Spanish languages.

4.1 Irrigation Lateral Hydraulics

The Irrigation Lateral Hydraulics program allows the computation of head distribution in a single diameter lateral at five equally spaced points along a lateral of constant slope. Executing the program will show a display as in Figure 2a. Data required for the computation are the number of emitters, length of the lateral, pipe diameter, slope of the lateral, average emitter discharge, pressure head at the inlet and the Hazen-Williams coefficient for the pipe. Once these data are entered, head losses and head distribution are calculated (button labeled <<>> and displayed as shown in Figure 2b.)
4.2 Irrigation Manifold Hydraulics

The Irrigation Manifold Hydraulics program allows the computation of head distribution in a manifold with up to four equally spaced tapers along a constant slope. Executing the program will show a display as in Figure 3a. Data required for the computation are desired average head along the manifold, flow rate at the entrance, the allowable head variation, length of the manifold, slope and Hazen-Williams hydraulic constant. Once these data are entered, theoretical diameters and head distribution are calculated (button labeled <D>) and displayed as shown in Figure 3b. After entering user selected commercial diameters and pressing the button labeled <H> the head distribution is calculated as shown in Figure 3c.

5 Conclusion

Handheld computers with the software described here provide a useful tool for rapid calculations of tapered sloping manifold and lateral diameters and heads. Computations can be carried out conveniently virtually at every location without much effort, making the tool especially useful for field engineers and rapid prototyping of design alternatives of microirrigation subunits.

6 References


Figure 1: Tapered Sloping Manifold conditions for the Analysis.

Figure 2: Irrigation Lateral Computations. Data are entered as shown in (a). Pressing the = button will result in calculation of the head distribution along the lateral as shown in (b).
Figure 3: Sloping tapered manifold computations. Data are entered as shown in (a). Pressing the D button will compute the theoretical diameters as shown in (b). After entering user selected commercial diameters and pressing H the head distribution is calculated as shown in (c).