Lecture 23
Manifold Hydraulic Design

I. Introduction

- Manifolds in trickle irrigation systems often have multiple pipe sizes to:

  1. reduce pipe costs
  2. reduce pressure variations

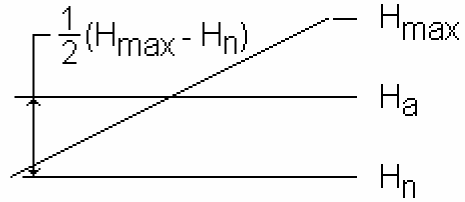
- In small irrigation systems the reduction in pipe cost may not be significant, not to mention that it is also easier to install a system with fewer pipe sizes
- Manifold design is normally subsequent to lateral design, but it can be part of an iterative process (i.e. design the laterals, design the manifold, adjust the lateral design, etc.)
- The allowable head variation in the manifold, for manifolds as subunits, is given by the allowable subunit head variation (Eq. 20.14) and the calculated lateral head variation, ΔH_l
- This simple relationship is given in Eq. 23.1:

$$(\Delta H_m)_a = \Delta H_s - \Delta H_l \qquad (437)$$

- Eq. 23.1 simply says that the allowable subunit head variation is shared by the laterals and manifold
- Recall that a starting design point can be to have $\Delta H_l = \frac{1}{2}\Delta H_s$, and $\Delta H_m = \frac{1}{2}\Delta H_s$, but this *half and half* proportion can be adjusted during the design iterations
- The lateral pressure variation, ΔH_l, is equal to the maximum pressure minus the minimum pressure, which is true for single-direction laterals and uphill+downhill pairs, if H_n' is the same both uphill and downhill

II. Allowable Head Variation

- Equation 20.14 (page 502 in the textbook) gives the allowable pressure head variation in a "subunit"
- This equation is an approximation of the true allowable head variation, because this equation is applied before the laterals and manifold are designed
- After designing the laterals and manifold, the actual head variation and expected EU can be recalculated



- Consider a linear friction loss gradient (no multiple outlets) on flat ground:

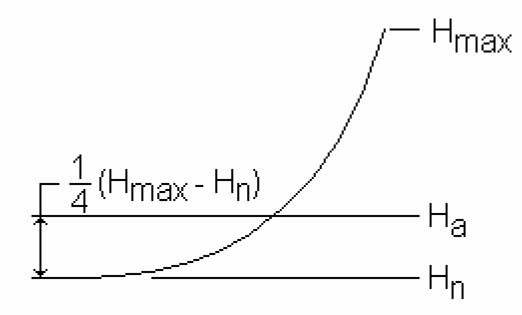
  In this case, the average head is

equal to H_n plus half the difference in the maximum and minimum heads:

$$H_{max} - H_n = 2\left(H_a - H_n\right) \tag{438}$$

- Consider a sloping friction loss gradient (multiple outlets) on flat ground:

  In this case, the average head occurs after about ¾ of the total head loss (due to friction) occurs, beginning from the lateral inlet. Then,



$$H_{max} - H_n = 4\left(H_a - H_n\right) \tag{439}$$

- For a sloping friction loss gradient (multiple outlets) on flat ground with dual pipe sizes, about 63% of the friction head loss occurs from the lateral inlet to the location of average pressure. Then 100/(100-63) = 2.7 and,

$$H_{max} - H_n = 2.7\left(H_a - H_n\right) \tag{440}$$

- In summary, an averaging is performed to skew the coefficient toward the minimum value of 2, recognizing that the maximum is about 4, and that for dual-size laterals (or manifolds), the coefficient might be approximately 2.7
- The value of 2.5 used in Eq. 20.14 is such a weighted average
- With three or four pipe sizes the friction loss gradient in the manifold will approach the slope of the ground, which may be linear
- Thus, as an initial estimate for determining allowable subunit pressure variation for a given design value of EU, Eq. 20.14 is written as follows:

$$\Delta H_s = 2.5\left(H_a - H_n\right) \tag{441}$$

- After the design process, the final value of ΔH_s may be different, but if it is much different the deviation should be somehow justified

III. Pipe Sizing in Manifolds

- Ideally, a manifold design considers all of the following criteria:

  1. economic balance between pipe cost (present) and pumping costs (future)
  2. allowable pressure variation in the manifold and subunit
  3. pipe flow velocity limits (about 1.5 - 2.0 m/s)

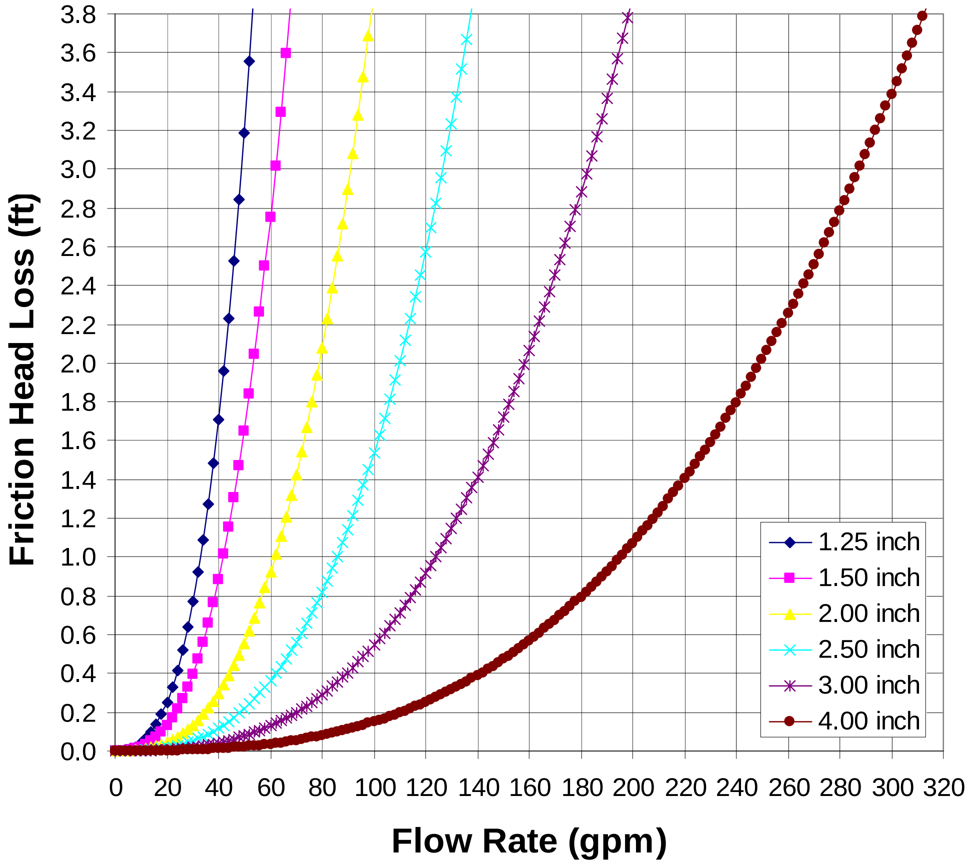
- From sprinkler system design, we already know of various pipe sizing methods
- These methods can also be applied to the design of manifolds
- However, the difference with trickle manifolds is that instead of one or two pipe sizes, we may be using three or four sizes
- The manifold design procedures described in the textbook are:

  1. Semi-graphical
  2. Hydraulic grade line (HGL)
  3. Economic pipe sizing (as in Chapter 8 of the textbook)

Semi-Graphical Design Procedure

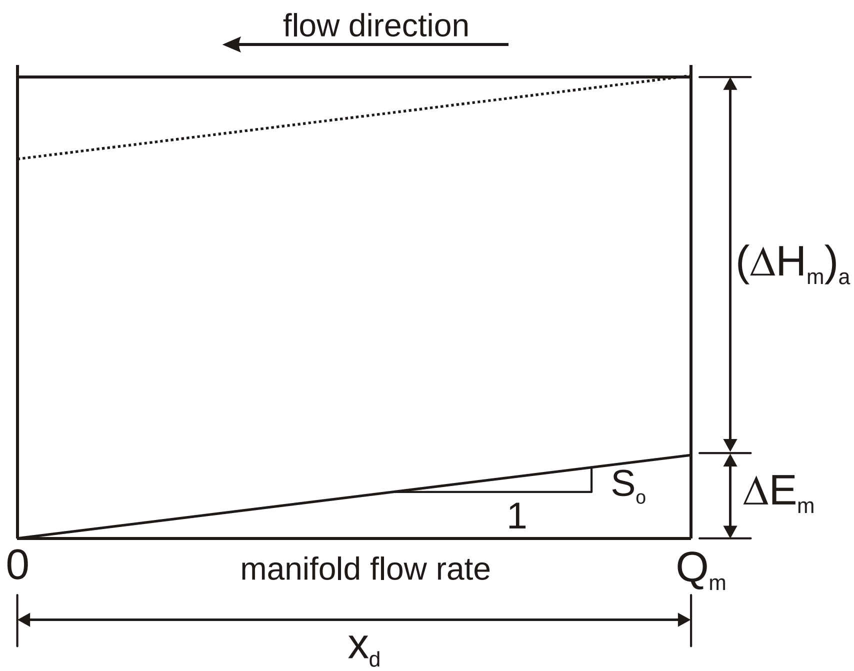
- The graphical method uses "standard" head loss curves for different pipe sizes and different flow rates with equally-spaced multiple outlets, each outlet with the same discharge
- The curves all intersect at the origin (corresponding to the downstream closed end of a pipe)
- Below is a sample of the kind of curves given in Fig. 23.2 of the textbook

- Instead of the standard curves, specific curves for each design case could be custom developed and plotted as necessary in spreadsheets
- The steps to complete a graphical design are outlined in the textbook
- The graphical procedure is helpful in understanding the hydraulic design of multiple pipe size manifolds, but may not be as expedient as fully numerical procedures

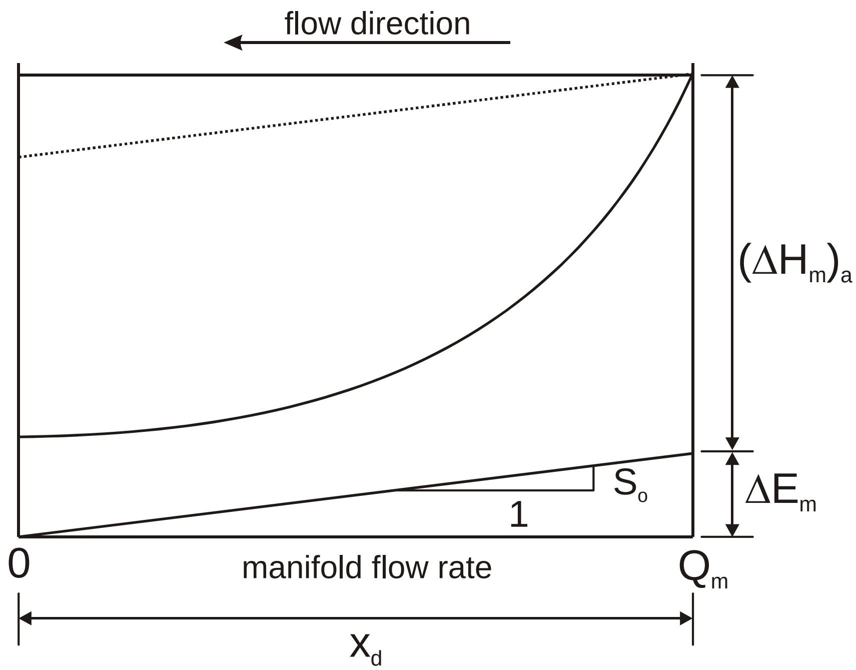


- The following steps illustrate the graphical design procedure:

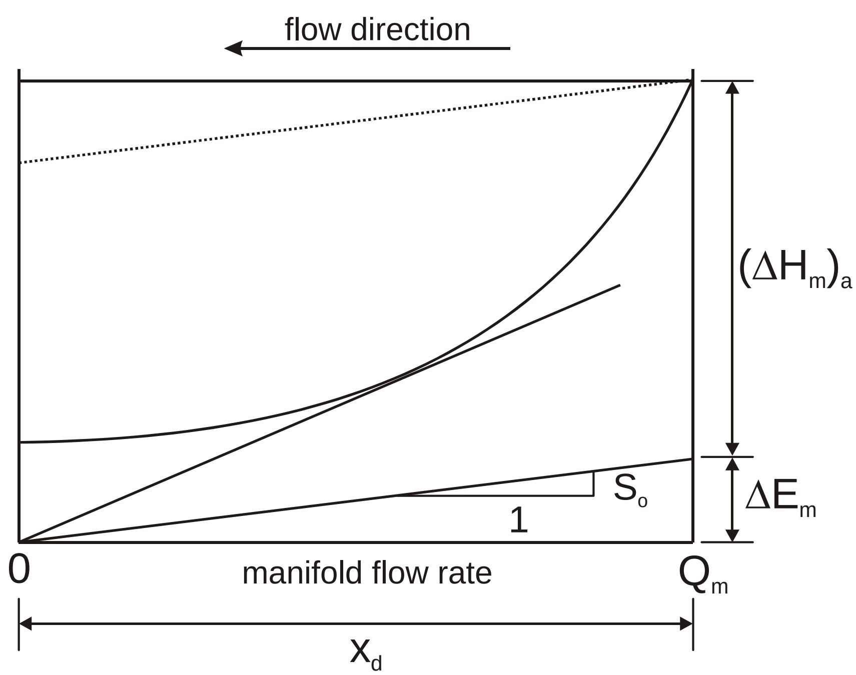
Step 1:



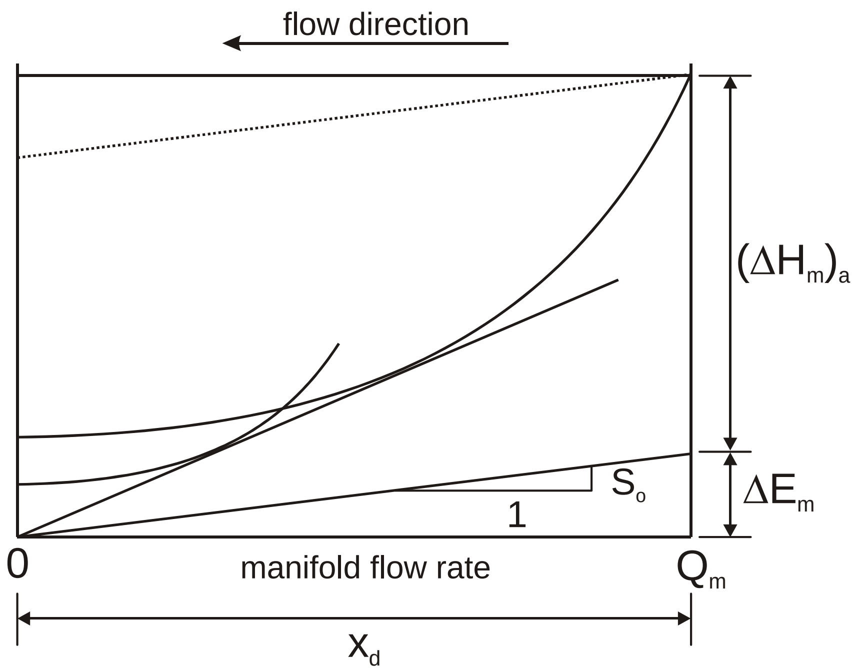
Step 2:


flow direction
(ΔHm)a
ΔEm
So
1
0
manifold flow rate
Qm
xd

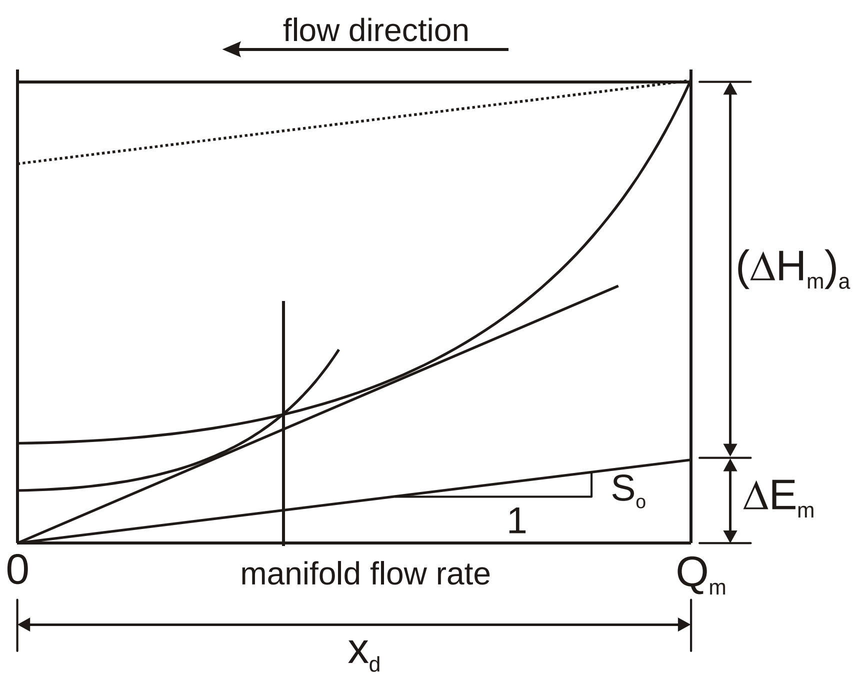
Step 3:


flow direction
(ΔHm)a
ΔEm
So
1
0
manifold flow rate
Qm
xd

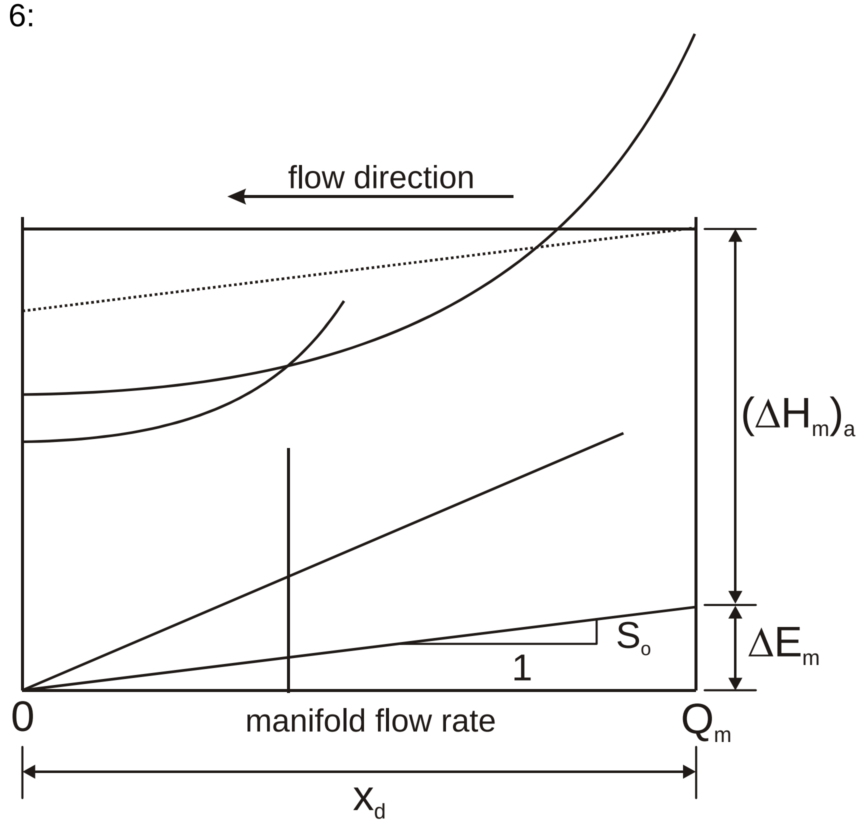
Step 4:


flow direction
$(\Delta H_m)_a$
S_o
1
ΔE_m
0
manifold flow rate
Q_m
x_d

Step 5:


flow direction
$(\Delta H_m)_a$
S_o
1
ΔE_m
0
manifold flow rate
Q_m
x_d

Step 6:



HGL Design Procedure

- The HGL procedure is very similar to the graphical procedure, except that it is applied numerically, without the need for graphs
- Nevertheless, it is useful to graph the resulting hydraulic curves to check for errors or infeasibilities
- The first (upstream) head loss curve starts from a fixed point: maximum discharge in the manifold and upper limit on head variation
- Equations for friction loss curves of different pipe diameters are known (e.g. Darcy-Weisbach, Hazen-Williams), and these can be equated to each other to determine intersection points, that is, points at which the pipe size would change in the manifold design
- But, before equating head loss equations, the curves must be vertically shifted so they just intersect with the ground slope curve (or the tangent to the first, upstream, curve, emanating from the origin)
- The vertical shifting can be done graphically or numerically

Economic Design Procedure

- The economic design procedure is essentially the same as that given in Chapter 8 of the textbook

- The manifold has multiple outlets (laterals or headers), and the "section flow rate" changes between each outlet
- The "system flow rate" would be the flow rate entering the manifold

IV. Manifold Inlet Pressure Head

- After completing the manifold pipe sizing, the required manifold inlet pressure head can be determined (Eq. 23.4):

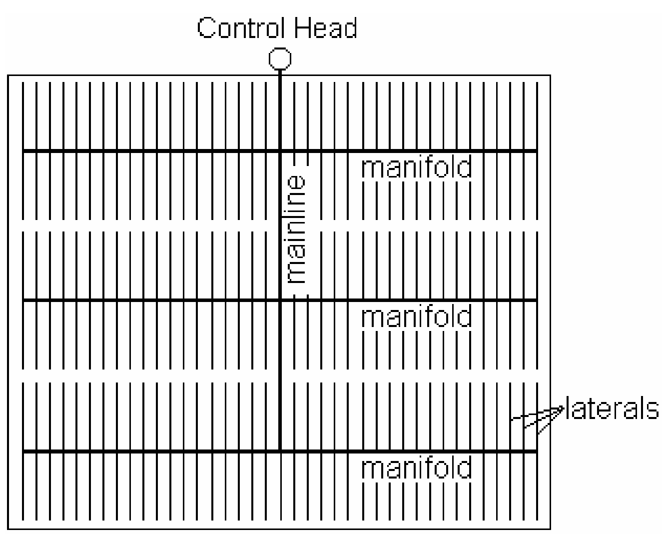
$$H_m = H_l + k\,h_f + 0.5\Delta E_m \qquad (442)$$

where k = 0.75 for single-diameter manifolds; k = 0.63 for dual pipe size laterals; or k ≈ 0.5 for three or more pipe sizes (tapered manifolds); and ΔE_l is negative for downward-sloping manifolds

- As with lateral design, the friction loss curves must be shifted up to provide for the required average pressure
- In the case of manifolds, we would like the average pressure to be equal to the calculated lateral inlet head, H_l
- The parameter ΔE_l is the elevation difference along one portion of the manifold (either uphill or downhill), with positive values for uphill slopes and negative values for downhill slopes

V. Manifold Design

- Manifolds should usually extend both ways from the mainline to reduce the system cost, provided that the ground slope in the direction of the manifolds is less than about 3% (same as for laterals, as in the previous lectures)
- As shown in the sample layout (plan view) below, manifolds are typically orthogonal to the mainline, and laterals are orthogonal to the manifolds



- Manifolds usually are made up of 2 to 4 pipe diameters, tapered (telescoping) down toward the downstream end
- For tapered manifolds, the smallest of the pipe diameters (at the downstream end) should be greater than about ½ the largest diameter (at the upstream end) to help avoid clogging during flushing of the manifold

- The maximum average flow velocity in each pipe segment should be less than about 2 m/s
- Water hammer is not much of a concern, primarily because the manifold has multiple outlets (which rapidly attenuates a high- or low-pressure wave), but the friction loss increases exponentially with flow velocity

VI. Trickle Mainline Location

- The objective is the same as for pairs of laterals: make $(H_n)_{uphill}$ equal to $(H_n)_{downhill}$
- If average friction loss slopes are equal for both uphill and downhill manifold branches (assuming similar diameters will carry similar flow rates):

Downhill side:

$$\left(\Delta H_m\right)_a = h_{fd} - \Delta E\left(\frac{x}{L}\right) = h_{fd} - Y\Delta E \tag{443}$$

Uphill side:

$$\left(\Delta H_m\right)_a = h_{fu} + \Delta E\left(\frac{L-x}{L}\right) = h_{fu} + (1-Y)\Delta E \tag{444}$$

where x is the length of downhill manifold (m or ft); L is the total length of the manifold (m or ft); Y equals x/L; and ΔE is the absolute elevation difference of the uphill and downhill portions of the manifold (m or ft)

- Note that in the above, ΔE is an absolute value (always positive)
- Then, the average uphill and downhill friction loss slopes are equal:

$$\bar{J}_{uphill} = \bar{J}_{downhill}$$
$$\frac{h_{fu}}{L-x} = \frac{h_{fd}}{x} \tag{445}$$

where J-bar is the average friction loss gradient from the mainline to the end of the manifold (J-bar is essentially the same as JF)

Then,

$$h_{fd} = \bar{J}x$$
$$h_{fu} = \bar{J}(L - x) \tag{446}$$

and,

$$\left(\Delta H_m\right)_a = \bar{J}x - Y\Delta E$$
$$\left(\Delta H_m\right)_a = \bar{J}(L - x) + (1 - Y)\Delta E \tag{447}$$

then,

$$\frac{\left(\Delta H_m\right)_a + Y\Delta E}{x} = \bar{J}$$
$$\frac{\left(\Delta H_m\right)_a - (1 - Y)\Delta E}{L - x} = \bar{J} \tag{448}$$

- Equating both J-bar values,

$$\frac{\left(\Delta H_m\right)_a + Y\Delta E}{x} = \frac{\left(\Delta H_m\right)_a - (1 - Y)\Delta E}{L - x} \tag{449}$$

- Dividing by L and rearranging (to get Eq. 23.3),

$$\frac{\left(\Delta H_m\right)_a + Y\Delta E}{Y} = \frac{\left(\Delta H_m\right)_a - (1 - Y)\Delta E}{1 - Y} \tag{450}$$

or,

$$\frac{\Delta E}{\left(\Delta H_m\right)_a} = \frac{2Y - 1}{2Y(1 - Y)} \tag{451}$$

- Equation 23.3 is used to determine the lengths of the uphill and downhill portions of the manifold
- You can solve for Y (and x), given ΔE and $(\Delta H_m)_a = \Delta H_s - \Delta H_l$
- Remember that $\Delta H_s \approx 2.5(H_a - H_n)$, where H_a is for the average emitter and H_n is for the desired EU and ν_s
- Equation 23.3 can be solved by isolating one of the values for Y on the left hand side, such that:

$$Y = 1 - \left(\frac{2Y - 1}{2Y}\right)\left(\frac{\left(\Delta H_m\right)_a}{\Delta E}\right) \tag{452}$$

and assuming an initial value for Y (e.g. Y = 0.6), plugging it into the right side of the equation, then iterating to arrive at a solution

- Note that $0 \leq Y \leq 1$, so the solution is already well-bracketed
- Note that in the trivial case where $\Delta E = 0$, then $Y = 0.5$ (don't apply the above equation, just use your intuition!)
- A numerical method (e.g. Newton-Raphson) can also be used to solve the equation for Y

VII. Selection of Manifold Pipe Sizes

The selection of manifold pipe sizes is a function of:

1. Economics, where pipe costs are balanced with energy costs
2. Balancing h_f, ΔE, and $(\Delta H_m)_a$ to obtain the desired EU
3. Velocity constraints

VIII. Manifold Pipe Sizing by Economic Selection Method

- This method is similar to that used for mainlines of sprinkler systems
- Given the manifold spacing, S_m, and the manifold length, do the following:

(a) Construct an economic pipe size table where $Q_s = Q_m$
(b) Select appropriate pipe diameters and corresponding Q values at locations where the diameters will change
(c) Determine the lengths of each diameter of pipe (where the Q in the manifold section equals a breakeven Q from the *Economic Pipe Size Table* (EPST)

$$L_D = L\left(\frac{Q_{beg} - Q_{end}}{Q_m}\right) \tag{453}$$

where Q_{beg} is the flow rate at the beginning of diameter "D" in the EPST (lps or gpm); Q_{end} is the flow rate at the end of diameter "D" in the EPST, which is the breakeven flow rate of the next larger pipe size) (lps or gpm); L is the total length of the manifold (m or ft); and Q_m is the manifold inflow rate (lps or gpm). (see Eq. 23.7)

(d) Determine the total friction loss along the manifold (see Eq. 23.8a):

$$h_f = \frac{FLK}{100\,Q_m}\left(\frac{Q_1^a}{D_1^c} + \frac{Q_2^a - Q_1^a}{D_2^c} + \frac{Q_3^a - Q_2^a}{D_3^c} + \frac{Q_4^a - Q_3^a}{D_4^c}\right) \tag{454}$$

where,

a = b+1 (for the Blasius equation, a = 2.75)
c = 4.75 for the Blasius equation (as seen previously)

Q_1 = Q at the beginning of the smallest pipe diameter
Q_2 = Q at the beginning of the next larger pipe diameter
Q_3 = Q at the beginning of the third largest pipe diameter in the manifold
Q_4 = Q at the beginning of the largest pipe diameter in the manifold
F = multiple outlet pipe loss factor

- For the Hazen-Williams equation, F equals 1/(1.852+1) = 0.35
- For the Darcy-Weisbach equation, F equals 1/(2+1) = 0.33

L = the total length of the manifold
D = inside diameter of the pipe
K = $7.89(10)^7$ for D in mm, Q in lps, and length in m
K = 0.133 for D in inches, Q in gpm, and length in ft
h_f = friction head loss

- The above equation is for four pipe sizes; if there are less than four sizes, the extra terms are eliminated from the equation
- An alternative would be to use Eq. 23.8b (for known pipe lengths), or evaluate the friction loss using a computer program or a spreadsheet to calculate the losses section by section along the manifold
- Eq. 23.8b is written for manifold design as follows:

$$h_f = \frac{FKQ_m^{a-1}}{100L^{a-1}}\left(\frac{x_1^a}{D_1^c} + \frac{x_2^a - x_1^a}{D_2^c} + \frac{x_3^a - x_2^a}{D_3^c} + \frac{x_4^a - x_3^a}{D_4^c}\right) \quad (455)$$

where, x_1 = length of the smallest pipe size
x_2 = length of the next smaller pipe size
x_3 = length of the third largest pipe size
x_4 = length of the largest pipe size

- Again, there may be up to four different pipe sizes in the manifold, but in many cases there will be less than four sizes

(e) For s ≥ 0 (uphill branch of the manifold),

$$\Delta H_m = h_f + S x_u \quad (456)$$

For s < 0 (downhill branch of the manifold),

$$\Delta H_m = h_f + S\left(1 - \frac{0.36}{n}\right)x_d \quad (457)$$

where n is the number of different pipe sizes used in the branch; and S is the ground slope in the direction of the manifold (m/m)

- The above equation estimates the location of minimum pressure in the downhill part of the manifold

(f) if $\Delta H_m < 1.1\ (\Delta H_m)_a$, then the pipe sizing is all right. Go to step (g) of this procedure. Otherwise, do one or more of the following eight adjustments:

(1) Increase the pipe diameters selected for the manifold

- Do this proportionately by reselecting diameters from the EPST using a larger Q_s (to increase the energy “penalty” and recompute a new EPST). This will artificially increase the break-even flow rates in the table (chart).
- The new flow rates to use in re-doing the EPST can be estimated for s > 0 as follows:

$$Q_s^{new} = Q_s^{old}\left(\frac{h_f}{(\Delta H_m)_a - \Delta E_m}\right)^{1/b} \tag{458}$$

and for s < 0 as:

$$Q_s^{new} = Q_s^{old}\left(\frac{h_f}{(\Delta H_m)_a - \Delta E_l\left(1 - \frac{0.36}{n}\right)}\right)^{1/b} \tag{459}$$

- The above two equations are used to change the flow rates to compute the EPST
- The value of Q_m remains the same
- The elevation change along each manifold (uphill or downhill branches) is $\Delta El = sL/100$

(2) Decrease S_m

- This will make the laterals shorter, Q_m will decrease, and ΔH_l may decrease
- This alternative may or may not help in the design process

(3) Reduce the target EU

- This will increase ΔH_s

(4) Decrease ΔH_l (use larger pipe sizes)
- This will increase the cost of the pipes

(5) Increase H_a
- This will increase ΔH_s
- This alternative will cost money and or energy

(6) Reduce the manufacturer's coefficient of variation
- This will require more expensive emitters and raise the system cost

(7) Increase the number of emitters per tree (N_p)
- This will reduce the value of ν_s

(8) If $N_s > 1$, increase T_a per station
- Try operating two or more stations simultaneously

- Now go back to Step (b) and repeat the process.

(g) Compute the manifold inlet head,

$$H_m = H_l + k h_f + 0.5\Delta E_m \quad (460)$$

where, k = 0.75 for a single size of manifold pipe
k = 0.63 for two pipe sizes
k = 0.50 for three or more sizes

- For non-critical manifolds, or where $\Delta H_m < (\Delta H_m)_a$, decrease Q_s (or just design using another sizing method) in the Economic Pipe Selection Table to dissipate excess head
- For non-rectangular subunits, adjust F using a shape factor:

$$F_s = 0.38 S_f^{1.25} + 0.62 \quad (461)$$

where $S_f = Q_{lc}/Q_{la}$; Q_{lc} is the lateral discharge at the end of the manifold and Q_{la} is the average lateral discharge along the manifold. Then,

$$h_f = F_s F\left(\frac{JL}{100}\right) \quad (462)$$

IX. Manifold Pipe Sizing by the "HGL" Method

- This is the "Hydraulic Grade Line" method
- Same as the semi-graphical method, but performed numerically

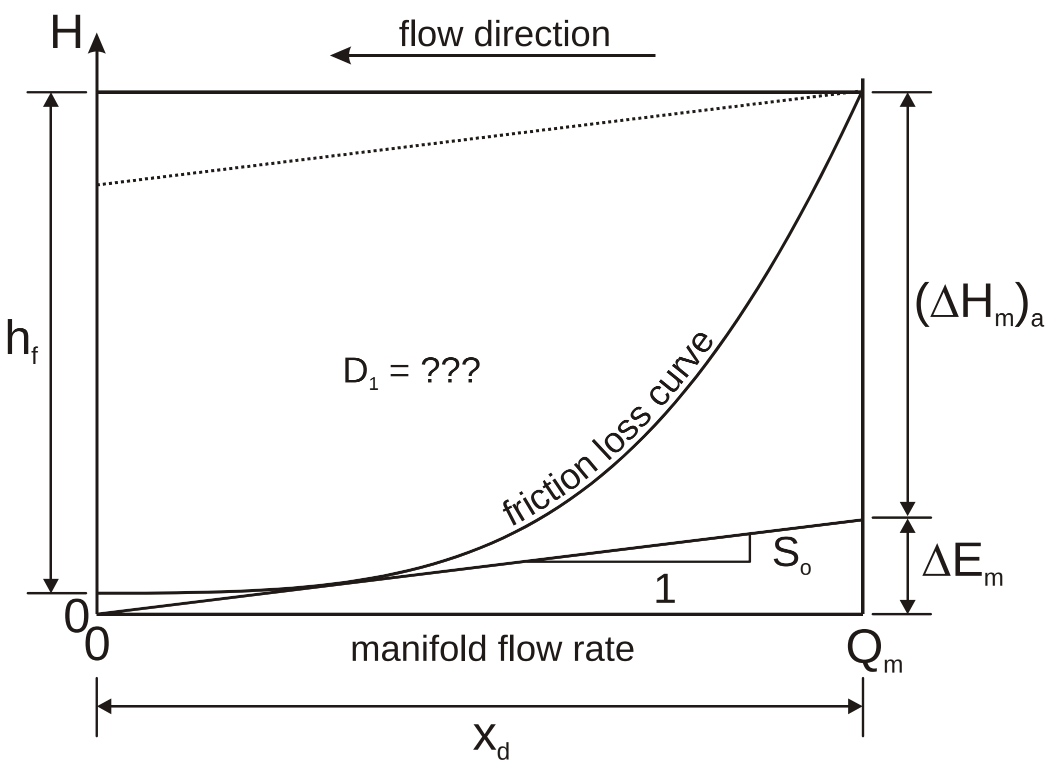
(a) Uphill Side of the Manifold

- Get the smallest allowable pipe diameter and use only the one diameter for this part of the manifold

(b) Downhill Side of the Manifold

Largest Pipe Size, D_1

- First, determine the minimum pipe diameter for the first pipe in the downhill side of the manifold, which of course will be the largest of the pipe sizes that will be used
- This can be accomplished by finding the inside pipe diameter, D, that will give a friction loss curve tangent to the ground slope
- To do this, it is necessary to: (1) have the slope of the friction loss curve equal to S_o; and, (2) have the H values equal at this location (make them just touch at a point)
- These two requirements can be satisfied by applying two equations, whereby the two unknowns will be Q and D_1
- Assume that Q_l is constant along the manifold…
- See the following figure, based on the length of the downstream part of the manifold, x_d
- Some manifolds will only have a downhill part – others will have both uphill and downhill parts



- For the above figure, where the right side is the mainline location and the left side is the downstream closed end of the manifold, the friction loss curve is defined as:

$$H = \left(\Delta H_m\right)_a + \Delta E_m - h_f + \frac{JFL}{100} \tag{463}$$

where, using the Hazen-Williams equation,

$$J = K\left(\frac{Q}{C}\right)^{1.852} D^{-4.87} \quad \text{for} \quad 0 \le Q \le Q_m \tag{464}$$

$$F = \frac{1}{2.852} + \frac{1}{2N} + \frac{\sqrt{0.852}}{6N^2} \tag{465}$$

$$N = \left(\frac{x_d}{S_l}\right)\left(\frac{Q}{Q_m}\right) \quad \text{for} \quad N > 0 \tag{466}$$

where N is the number of outlets (laterals) from the location of "Q" in the manifold to the closed end

$$L = x_d\left(\frac{Q}{Q_m}\right) \tag{467}$$

For Q in lps and D in cm, K = $16.42(10)^6$

- The total head loss in the downhill side of the manifold is:

$$h_f = \frac{J_{hf} F_{hf} x_d}{100} = 0.01K\left(\frac{Q_m}{C}\right)^{1.852} D^{-4.87} F_{hf} x_d \tag{468}$$

where F_{hf} is defined as F above, except with $N = x_d/S_l$.

- The slope of the friction loss curve is:

$$\frac{dH}{dQ} = \frac{1}{100}\left(FL\frac{dJ}{dQ} + JL\frac{dF}{dQ} + JF\frac{dL}{dQ}\right) \tag{469}$$

where,

$$\frac{dJ}{dQ} = \frac{1.852KQ^{0.852}}{C^{1.852}D^{4.87}} \tag{470}$$

$$\frac{dF}{dQ} = -\frac{x_d}{S_l Q_m N^2}\left(\frac{1}{2} + \frac{\sqrt{0.852}}{3N}\right) \tag{471}$$

$$\frac{dL}{dQ} = \frac{x_d}{Q_m} \tag{472}$$

- Note that dH/dQ $\neq$ J
- The ground surface (assuming a constant slope, S_o) is defined by:

$$H = S_o L = S_o x_d\left(\frac{Q}{Q_m}\right) \tag{473}$$

and,

$$\frac{dH}{dQ} = \frac{S_o x_d}{Q_m} \tag{474}$$

- Combine the two equations defining H (this makes the friction loss curve just touch the ground surface):

$$S_o x_d\left(\frac{Q}{Q_m}\right) = \left(\Delta H_m\right)_a + \Delta E_m - h_f + \frac{JFL}{100} \tag{475}$$

- Solve the above equation for the inside diameter, D:

$$D = \left[\frac{100\,C^{1.852}\left(\frac{S_o x_d Q}{Q_m} - \left(\Delta H_m\right)_a - \Delta E_m\right)}{K\left(Q^{1.852}FL - Q_m^{1.852}F_{hf}x_d\right)}\right]^{-0.205} \tag{476}$$

- Set the slope of the friction loss curve equal to $S_o x_d/Q_m$,

$$\frac{S_o x_d}{Q_m} = \frac{1}{100}\left(FL\frac{dJ}{dQ} + JL\frac{dF}{dQ} + JF\frac{dL}{dQ}\right) \tag{477}$$

- Combine the above two equations so that the only unknown is Q (note: D appears in the J & dJ/dQ terms of the above equation)
- Solve for Q by iteration; the pipe inside diameter, D, will be known as part of the solution for Q
- The calculated value of D is the minimum inside pipe diameter, so find the nearest available pipe size that is larger than or equal to D:

$$D_1 \geq D \quad \& \quad \text{minimize}(D_1 - D) \tag{478}$$

Slope of the Tangent Line

- Now calculate the equation of the line through the origin and tangent to the friction loss curve for D_1
- Let S_t be the slope of the tangent line

$$H = S_t L = S_t x_d \left(\frac{Q}{Q_m} \right) \tag{479}$$

then,

$$S_t x_d \left(\frac{Q}{Q_m} \right) = \left(\Delta H_m \right)_a + \Delta E_l - h_f + \frac{JFL}{100} \tag{480}$$

- Set the slope of the friction loss curve equal to $S_t x_d / Q_m$,

$$\frac{S_t x_d}{Q_m} = \frac{1}{100} \left(FL \frac{dJ}{dQ} + JL \frac{dF}{dQ} + JF \frac{dL}{dQ} \right) \tag{481}$$

- Combine the above two equations to eliminate S_t, and solve for Q (which is different than the Q in Eq. 476)
- Calculate the slope, S_t, directly

Smaller (Downstream) Pipe Sizes

- Then take the next smaller pipe size, D_2, and make its friction loss curve tangent to the same line (slope = S_t);

$$H = H_0 + \frac{JFL}{100} \tag{482}$$

where H_0 is a vertical offset to make the friction loss curve tangent to the S_t line, emanating from the origin

- Equating heads and solving for H_0,

$$H_0 = S_t x_d \left(\frac{Q}{Q_m}\right) - \frac{JFL}{100} \tag{483}$$

- Again, set the slope of the friction loss curve equal to S_t,

$$\frac{S_t x_d}{Q_m} = \frac{1}{100}\left(FL\frac{dJ}{dQ} + JL\frac{dF}{dQ} + JF\frac{dL}{dQ}\right) \tag{484}$$

- Solve the above equation for Q, then solve directly for H_0
- Now you have the equation for the next friction loss curve
- Determine the intersection with the D_1 friction loss curve to set the length for size D_1; this is done by equating the H values for the respective equations and solving for Q at the intersection:

$$H_{big} - H_{small} + \frac{FLK}{100}\left(\frac{Q}{C}\right)^{1.852}\left(D_{big}^{-4.87} - D_{small}^{-4.87}\right) = 0 \tag{485}$$

where, for the first pipe size (D_1):

$$H_{big} = \left(\Delta H_m\right)_a + \Delta E_l - h_f \tag{486}$$

and for the second pipe size (D_2):

$$H_{small} = H_0 \tag{487}$$

and F & L are as defined in Eqs. 437 to 439.

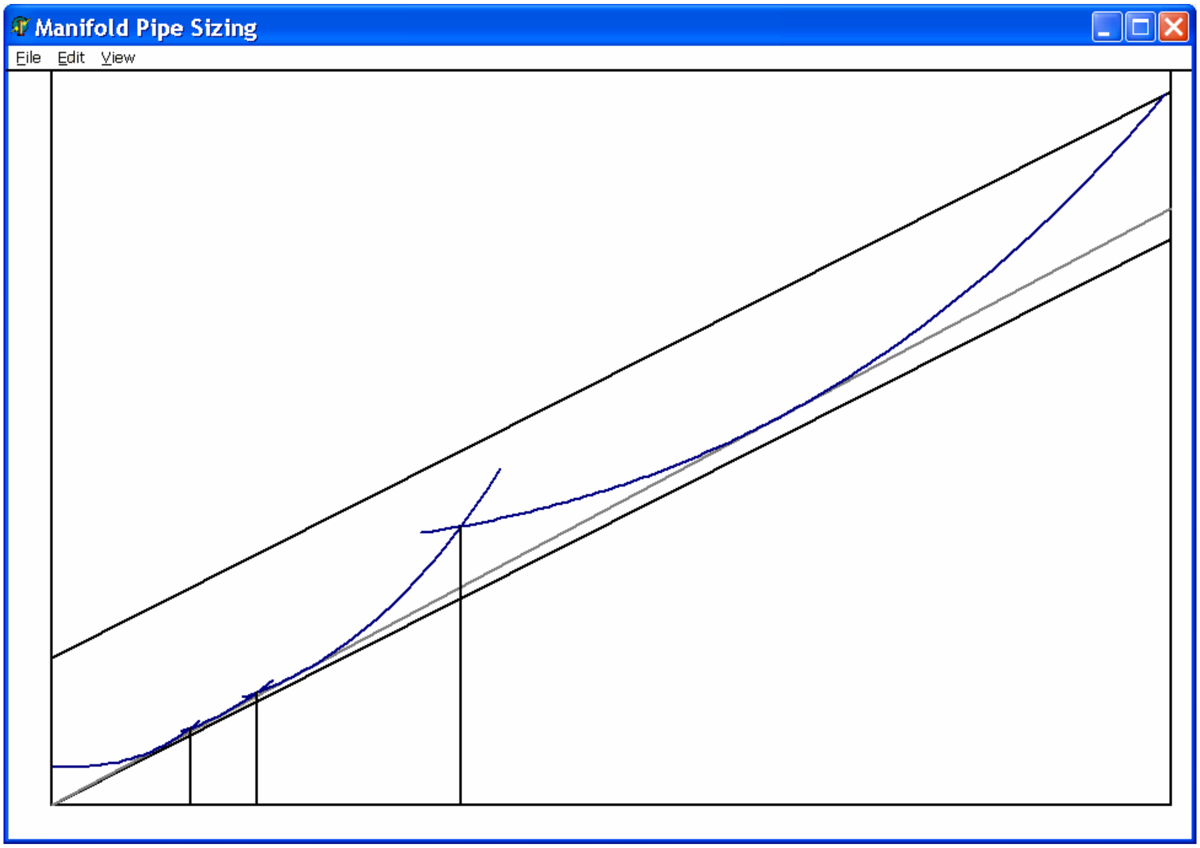
- Then, the length of pipe D_1 is equal to:

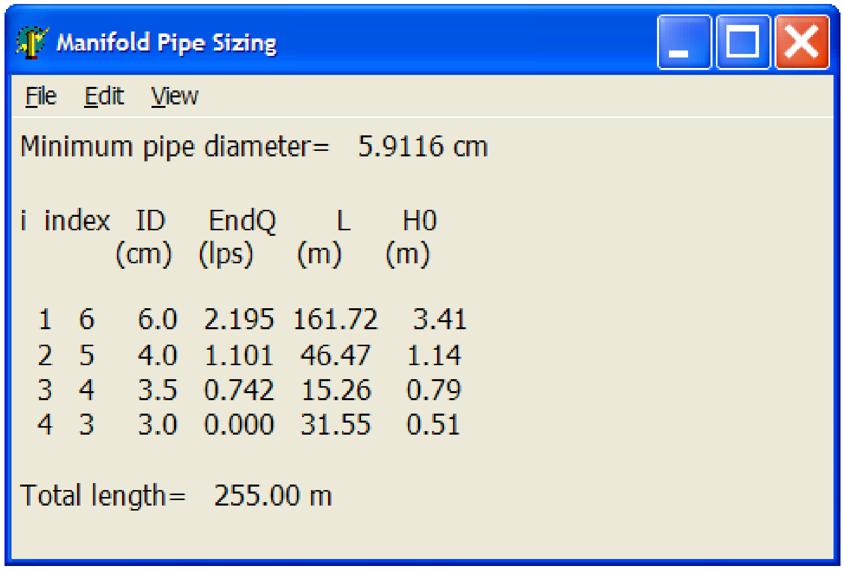
$$L_{D1} = x_d\left(1 - \frac{Q}{Q_m}\right) \tag{488}$$

- Continue this process until you have three or four pipe sizes, or until you get to a pipe size that has $D < ½D_1$

Comments about the HGL Method

- The above equation development could also be done using the Darcy-Weisbach equation
- Specify a minimum length for each pipe size in the manifold so that the design is not something ridiculous (i.e. don't just blindly perform calculations, but look at what you have)
- For example, the minimum allowable pipe length might be something like $5S_l$
- Note that the friction loss curves must be shifted vertically upward to provide the correct average (or minimum, if pressure regulators are used) pressure head in the manifold; this shifting process determines the required manifold inlet pressure head, H_m
- Below is a screen shot from a computer program that uses the HGL method for manifold pipe sizing




Manifold Pipe Sizing

File Edit View

Minimum pipe diameter= 5.9116 cm

i	index	ID (cm)	EndQ (lps)	L (m)	H0 (m)
1	6	6.0	2.195	161.72	3.41
2	5	4.0	1.101	46.47	1.14
3	4	3.5	0.742	15.26	0.79
4	3	3.0	0.000	31.55	0.51

Total length= 255.00 m