Ag Irrigation

Aqua-TraXX®

Design Manual

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Printing History:

First Edition	**June 1997**
Second Edition	**August 1998**
Third Edition	**October 1999**
Fourth Edition	**August 2000**

TABLE OF CONTENTS

LIST OF FIGURES:

LIST OF TABLES:

LIST OF EQUATIONS:

CHAPTER I

Aqua-TraXX® TAPE

PRINCIPLES OF OPERATION

Aqua-TraXX is a ***seamless, extruded*** drip tape with a ***molded, turbulent flow*** emitter bonded to the inner wall.

Seamless construction eliminates seam failures, and reduces the incidence of root intrusion. ***Extrusion*** technology utilizes high-quality, extrusion-grade engineering polymers renowned for their toughness and flexibility. These polymers were developed specifically for use in harsh industrial and agricultural environments.

The exclusive flowpath ***molding*** process creates crisp, well-formed physical features, resulting in excellent repeatability and high emission uniformity (EU). The ***turbulent*** flowpath design creates a clog-resistant flow channel, and permits longer run lengths and higher uniformity of water application.

As shown in Fig. 1, water enters the flowpath through the filter inlets, and then flows through the turbulent flow channel which accurately regulates the flow rate. Finally, the water flows through the laser-made, slit type outlets to the crop.

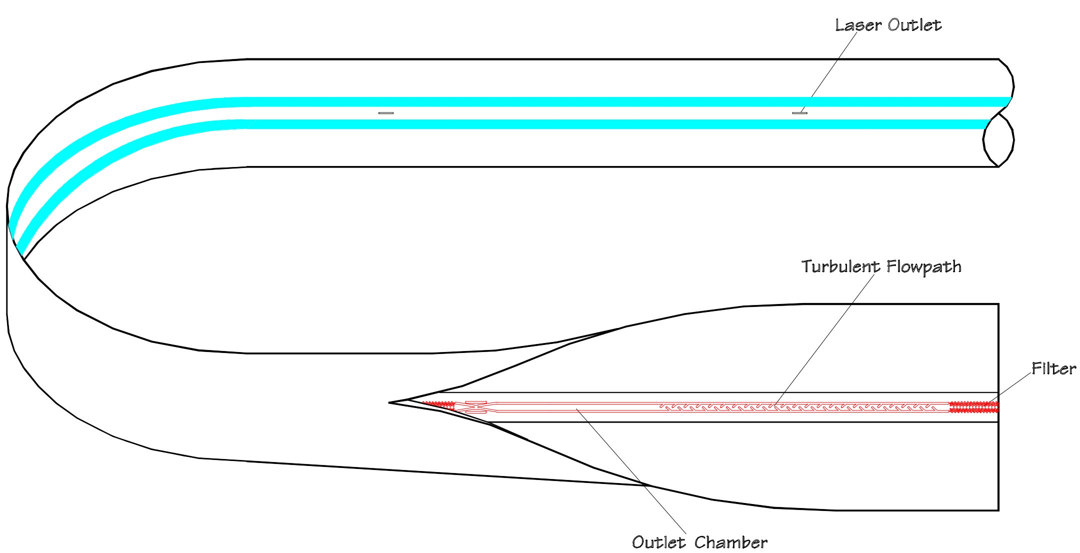


Figure 1: Aqua-TraXX Tape

FEATURES AND ADVANTAGES

- ⇒ Precision molded emitter for high uniformity.
- ⇒ Seamless construction for greater reliability.
- ⇒ Each flowpath has many filter inlets, making it highly resistant to clogging.
- ⇒ Laser slit outlet eliminates startup clogging and impedes root intrusion.
- ⇒ Truly turbulent flowpath provides excellent uniformity with reduced clogging.
- ⇒ Available in a wide range of wall thicknesses, outlet spacings and flow rates.
- ⇒ Highly visible blue stripes for quality recognition and Emitter UP indicator.
- ⇒ Superior tensile and burst strength.
- ⇒ Tough, abrasion-resistant material reduces field damage.
- ⇒ East and West Coast manufacturing for prompt delivery and enhanced availability.

Figure 2: Aqua-TraXX on Lettuce (Murcia, Spain)

SPECIFICATIONS

Aqua-TraXX Diameter & Wall Thickness Dimensions

Diameter	Wall (mils)	Min PSI	Max PSI	Reel Length	Reel Weight
5/8”	4	4	10	13,000’	70 lbs
	6	4	12	10,000’	66 lbs
	8	4	15	7,500’	63 lbs
	10	4	15	6,000’	60 lbs
	12	4	15	5,100’	58 lbs
	15	4	15	4,000’	61 lbs
7/8”	8	4	15	6,000’	68 lbs
	10	4	15	4,400’	65 lbs
	12	4	15	4,000’	61 lbs
1-3/8”	15	4	15	2,700’	74 lbs

Flowpath Specifications & Dimensions

Number of Inlets	8” & 16” spacing	60
Number of Inlets	12” & 24” spacing	200
Inlet Dimensions	(All)	.007 min. x .010 max.
Flowpath Dimensions	(All)	.008 min. x .033 max.
Outlet Dimensions	4 & 6 mil	.140 x .012
Outlet Dimensions	8 - 15 mil	.170 x .012
Coefficient of Variation	(All)	0.03
Flow Coefficient Cd & X	Cane Flow (6 - 12 psi range)	0.11859, 0.50
Flow Coefficient Cd & X	High Flow (6 - 12 psi range)	0.09487, 0.50
Flow Coefficient Cd & X	Med Flow (6 - 12 psi range)	0.07115, 0.50
Flow Coefficient Cd & X	Low Flow (6 – 12 psi range)	0.04743, 0.50
Hazen-Williams C Factor	(Main Tube)	140

Flowpath Design & Nomenclature

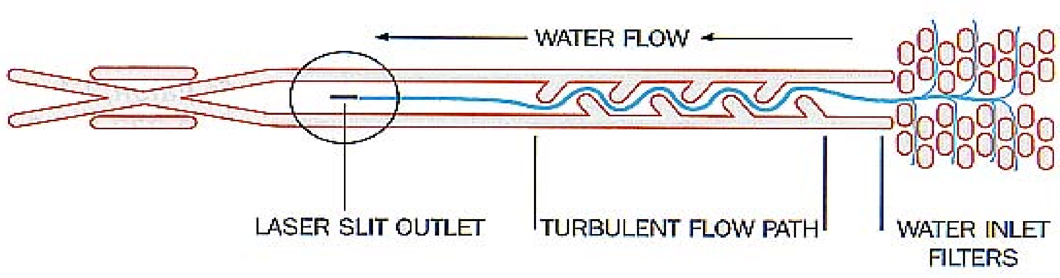


Figure 3: Turbulent Flowpath Design Details

USE AND SELECTION

Wall Thickness

4 mil - Light-walled products used for short season crops, in soils with a minimum of rocks. Recommended for experienced tape users.

6 and 8 mil - Intermediate products for general use in longer-term crops and average soil conditions.

10 -15 mil - Heavy wall designed to be used in rocky soils, where insects and animals may cause damage, or where the tape is to be used for more than one season.

Spacing

8 inch - Used in closely spaced crops, on sandy soils, or where higher flow rates are desired.

12 inch **-** Used on crops in medium soils and average crop spacings.

16 inch **-** Used on wide spaced crops where a longer length of run is desired.

24 inch **-** Used for widely spaced crops, heavy soils, long run lengths.

Flow Rate

Cane Flow **–** Used for sugarcane.

High Flow **-** Normally recommended for most crops and soils.

Medium Flow **-** Recommended for longer runs on most crops and soils.

Low Flow **-** Used in soils with low infiltration rates, where long irrigation times are necessary, or for very long runs.

Diameter

5/8” - Used for average run lengths (0 to 1,000 ft).

7/8” - Used for long run lengths (up to 2,500 ft).

1-3/8” - Used for very long run lengths (up to 5,000 ft).

CHAPTER II

SOIL

SOIL

Soil Water Relationships

A micro-irrigation system is a transportation system that delivers water to a point in or near the root zone. The final link in this transportation system is the soil, an essential bridge between the irrigation system and the plant. The soil's physical and chemical properties determine its ability to transport and store water and nutrients. The characteristics of soils vary widely according to their physical properties, often determining the type of crop that can be grown, and the type of irrigation system that is appropriate. Therefore, a thorough understanding of soil properties and soil-water relationships is important for purposes of irrigation design.

Figure 4: Aqua-TraXX on Tomatoes (Florida sandy soil)

Infiltration Rate

The infiltration rate is the rate at which water enters the soil. A soil's infiltration rate will vary greatly according to its chemistry, structure, tilth, density, porosity, and moisture content. The infiltration rate of a soil may impose a limitation upon the design of an irrigation system, since water application rates in excess of the infiltration rate may result in runoff and erosion.

Soil Water Movement

When water is applied slowly to the soil at a single point, it is acted upon by the forces of gravity (downward) and capillary action (radially outward), producing a wetted pattern characteristic of the soil type and application rate.

Sandy soils are characterized by large voids between soil particles. These large voids exert relatively weak capillary forces, but offer little resistance to gravitational flow, with the result that lateral and upward water movement is limited, while downward water movement is rapid. The wetting pattern for a sandy soil will therefore be deep with little lateral spread, and upward water movement will be minimal. To improve the lateral distribution of water on sandy soils, some Florida tomato growers have installed two Aqua-TraXX rows per bed, as shown in Figure 4.

At the other extreme, a heavy clay soil exerts strong capillary forces, but resists downward water movement by gravity. The wetted pattern in a heavy clay soil will tend to be broad and of moderate depth because of the clay's high capillary forces and relatively low permeability. In clay soils which have undergone compaction, the downward movement of the water is even further restricted, resulting in a wetted zone that is wide and shallow. In clay soils the wetted pattern will depend not only on soil type, but will also vary markedly with the tilth of the soil.

For the majority of soils, wetting patterns will be between the extremes exhibited by light sands and heavy clays. In addition, water movement in soils will be affected by the condition of the topsoil, the permeability of the subsoil, layers of soil with varying properties, and the presence of a plow pan. Figure 5 illustrates the relative shapes of wetting patterns that might be created under a tape outlet in various soil types.

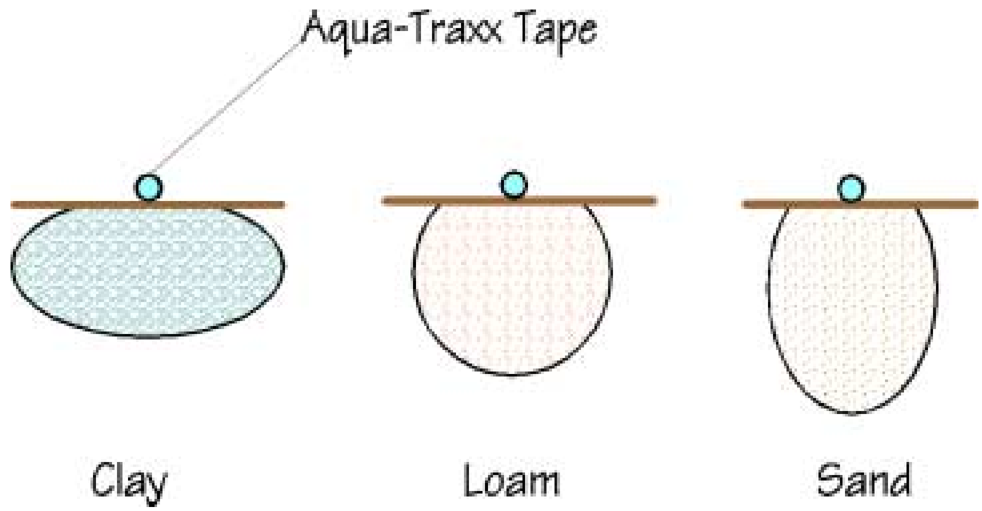


Figure 5: Wetting Patterns For Clay, Loam And Sand

Application Rate

In addition to soil type, the application rate will affect the shape of the wetted pattern. It is possible to alter the shape of the wetted zone by varying the application rate. For example, 10 gallons of water applied to a soil in 1 hour will probably produce a wider, shallower wetted pattern than 10 gallons applied over a 10-hour period. This is because a higher application rate tends to produce a wider zone of saturation under the emitter, assisting horizontal movement.

For increased lateral movement, light sandy soils require water application at higher rates. Heavy clays and clay loams, on the other hand, often benefit from a lower water application rate. This low rate avoids surface ponding and runoff, and promotes deeper water penetration. Table 1 provides data on the approximate size of the wetted area, which can be expected under average conditions.

Table 1: Approximate Size of Wetted Area

SOIL TYPE	WETTED RADIUS (ft)
Coarse Sand	0.5 - 1.5
Fine Sand	1.0 - 3.0
Loam	3.0 - 4.5
Heavy Clay	4.0 - 6.0

Tape Placement In Relation To The Plant

Tape placement is an important factor in the performance of the irrigation system and the health of the crop. The location of the tape in relation to the plant will affect germination and early growth, establishment of the root system, efficient utilization of water and nutrients, and the effects of salinity on the plant.

Germination of seeds or initial growth of seedlings will usually require that the tape be placed in close proximity - 18 inches or less in most soils - to the plant. In sandy soils this distance should be reduced to 12 inches or less.

The outlet spacing, flow rate and location of the tape will establish the wetted zone, and therefore the location of most intensive root development. The root system can be encouraged to extend itself horizontally or vertically, or it can be confined to a relatively small area. The size and shape of the root system is important in terms of the stability and vigor of the plant, and its ability to utilize the naturally occurring water and nutrients in the soil around it. Because water and nutrients applied outside the confines of the root zone are wasted, it is best to locate the tape near the center of the root zone.

Salts present in the soil or in the irrigation water will be concentrated at the perimeter of the wetted zone formed around the tape, as shown in Figure 6. The placement of the tape will determine whether harmful salts are pushed out and away from the root zone, or concentrated within it.

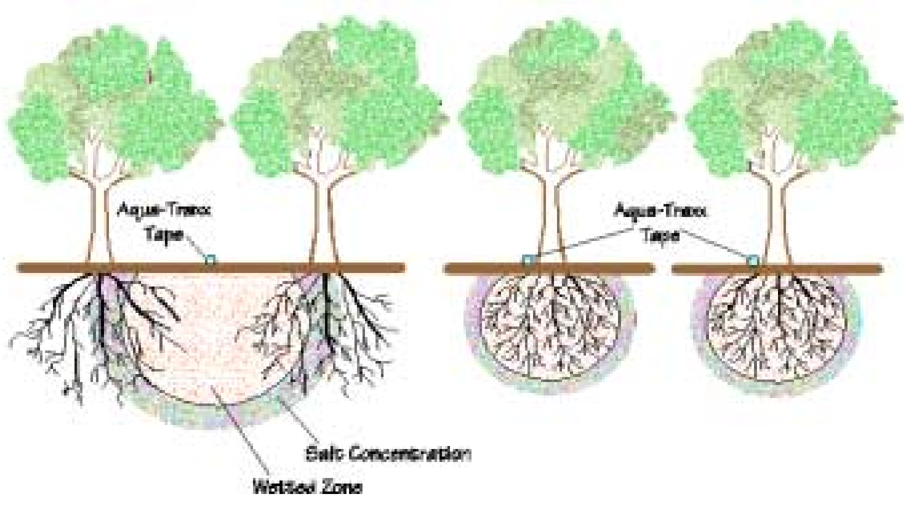


Figure 6: Effect Of Emitter Location On Salts

Determination of Wetting Pattern

The wetting pattern for any given soil is difficult to predict accurately from knowledge of the soil type alone. General principles may be outlined, but for practical purposes, a test of the wetting pattern should be carried out on the proposed site of the irrigation system.

Much can be learned about water movement by applying measured amounts of water to limited areas and observing the lateral and downward movement of water, and the shape of the wetted zone at various time intervals. Provided that the soils tested are representative, the observations will have practical application to the design of the irrigation system. Such experiments can reveal soil layers and compaction zones, and can indicate water retention capacities and the time needed for the soil to reach field capacity at different depths in the soil.

A simple method for determining the wetting pattern in a particular soil consists of installing a tape lateral of the type to be used, and connecting it to a temporary water source such as an elevated 55-gallon drum. The drum is filled with water and the test system is allowed to run for some length of time. Observations of the wetting pattern are made by measuring the wetted surface diameter, and by digging beneath the surface to measure the extent of subsurface water movement. This test will provide extremely valuable information concerning wetting patterns and water movement in the specific soil type of interest.

CHAPTER III

WATER QUALITY AND TREATMENT

WATER QUALITY

Taking A Water Sample For Analysis

The preliminary study for a micro-irrigation system will require a careful analysis of the source water. A micro-irrigation system requires good quality water free of all but the finest suspended solids and free of those dissolved solids, such as iron, which may precipitate out and cause problems in the system. Neglecting to analyze the quality of source water and provide adequate treatment is one of the most common reasons for the failure of micro-irrigation systems to function properly.

Figure 7: Aqua-TraXX on Head Lettuce

It is important that a representative water sample be taken. If the source is a well, the sample should be collected after the pump has run for half an hour or so. For a tap on a domestic supply line, the supply should be run for several minutes before taking the sample. When collecting samples from a surface water source such as a ditch, river, or reservoir, the samples should be taken near the center and below the water surface.

Where surface water sources are subject to seasonal variations in quality, these sources should be sampled and analyzed when the water quality is at its worst.

Glass containers are preferable for sample collection and they should hold about a half-gallon. The containers should be thoroughly cleaned and rinsed before use to avoid contamination of the water sample. Two samples should be collected. The first sample should be used for all tests except iron, and no additives are required. The second sample is used for the iron analysis, and after collecting the water, ten drops of HCl should be added. HCl is commonly available in the form of muriatic acid.

Sample bottles should be filled completely, carefully labeled, and tightly sealed. Samples should be sent immediately to a water-testing laboratory. The following tests should be requested from the laboratory: Salinity, pH, Calcium, Magnesium, Sodium, Potassium, Iron, Manganese, Boron, Bicarbonate, Carbonate, Chloride, Sulfate, Sulfide, the quantity and size of suspended solids and, for city water supplies, the free chlorine level.

The water should also be tested for the presence of oil, especially in areas close to oil fields. Oil will very rapidly block both sand media and screen filters. Oil may also clog tape outlets and may attack plastic pipes, tubing, or other components.

Interpretation Of Water Quality Analysis

Suspended Solids

Suspended solids in the water supply include soil particles ranging in size from coarse sands to fine clays, living organisms including algae and bacteria, and a wide variety of miscellaneous waterborne matter. Suspended solids loads will often vary considerably over time and seasonally, particularly when the water source is a river, lake, or reservoir.

Calcium

Calcium (Ca) is found to some extent in all natural waters. A soil saturated with calcium is friable and easily worked, permits water to penetrate easily and does not puddle or run together when wet. Calcium, in the form of gypsum, is often applied to soils to improve their physical properties. Generally, irrigation water high in dissolved calcium is desirable, although under certain conditions, calcium can precipitate out and cause clogging.

Iron

Iron (Fe) may be present in soluble form, and may create clogging problems at concentrations as low as 0.1 ppm. Dissolved iron may precipitate out of the water due to changes in temperature, in response to a rise in pH, or through the action of bacteria. The result is an ocher sludge or slime mass capable of clogging the entire irrigation system.

Manganese

Manganese (Mn) occurs in groundwater less commonly than iron, and generally in smaller amounts. Like iron, manganese in solution may precipitate out because of chemical or biological activity, forming sediment, which will clog tape emitters. The color of the deposits ranges from dark brown, if there is a mixture of iron, to black if the manganese oxide is pure. Caution should be exercised when chlorination is practiced with waters containing manganese, due to the fact that there is a time delay between chlorination and the development of a precipitate.

Sulfides

If the irrigation water contains more than 0.1 ppm of total sulfides, sulfur bacteria may grow within the irrigation system, forming masses of slime, which may clog filters and tape outlets.

Interpreting The Water Analysis

Table 2 provides a guideline for interpretation of water analysis results.

Table 2: Water Quality Interpretation Chart

WATER QUALITY PARAMETER	DEGREE OF PROBLEM		
	NONE	INCREASING	SEVERE
1. Salinity			
EC (mmho/cm)	0.0 - 0.8	0.8 - 3.0	3.0 +
TDS (ppm)	0.0 – 500	500 - 2,000	2,000 +
2. Permeability			
- *Caused by Low Salt*			
EC (mmho/cm)	0.5 +	0.5 - 0.2	0.2 - 0.0
TDS (ppm)	320 +	320 - 0.0	
- *Caused by Sodium*			
SAR_a	0.0 - 6.0	6.0 - 9.0	9.0 +
3. Toxicity			
Sodium (SAR_a)	0.0 - 3.0	3.0 - 9.0	9.0 +
Chloride (me/L)	0.0 - 4.0	4.0 - 10.0	10.0 +
(ppm)	0.0 – 140	140 – 350	350 +
Boron (ppm)	0.0 - 0.5	0.5 - 2.0	2.0 +
4. Clogging			

Iron (ppm)	**0.0 - 0.1**	**0.1 - 0.4**	**0.4 +**
Manganese (ppm)	**0.0 - 0.2**	**0.2 - 0.4**	**0.4 +**
Sulfides (ppm)	**0.0 - 0.1**	**0.1 - 0.2**	**0.2 +**
Calcium Carbonate (ppm)	**No levels established**		

WATER TREATMENT

Micro-irrigation systems are characterized by large numbers of emitters having fairly small flow paths. Because these small flow paths are easily clogged by foreign material, many water sources require some treatment to ensure the successful long-term operation of the system. Nearly all water sources can be made suitable for micro-irrigation by means of appropriate physical and/or chemical treatment.

The various water quality problems encountered in operating micro-irrigation systems are outlined below. In some situations, two or more of these problems may be present, giving rise to more complex treatment procedures.

1. Presence of large particulate matter in the water supply.

2. Presence of high silt and clay loads in the water supply.

3. Growth of bacterial slime in the system.

4. Growth of algae within the water supply or the system.

5. Precipitation of iron, sulfur, or calcium carbonates.

Presence Of Large Particulate Matter

Large particles present in the water supply will usually be either inorganic sands or silts, scale from pipe walls or well casings, or organic materials such as weed seeds, small fish, eggs, algae, and so forth. Inorganic particles are usually heavy and can easily be removed by a settling basin or a centrifugal sand separator. Organic materials, on the other hand, are lighter and must be removed by a sand or screen filter of some type. Floating materials may be skimmed from the water surface with a simple skim board.

Presence Of High Silt and Clay Loads

A media filter may remove sand in water supplies down to a particle size of 70 microns (0.003 inch). However, high silt and clay loads (greater than 200 ppm) will quickly block a media filter, resulting in inefficient operation and increased backwashing frequency.
Rather than using filtration alone to remove heavy silt and clay loads from the water, it is often preferable to build a settling basin for preliminary treatment prior to

filtration. The size of the settling basin will be determined by the system flow rate and the settling velocity of the particles to be removed. This settling velocity, in turn, is determined by the particle size, shape, and density.

Figure 8: Aqua-TraXX on Broccoli (Santa Maria, CA)

Very fine silts and colloidal clay particles are too small to be economically removed by means of a settling basin, because they settle so slowly that a prohibitively large settling basin would be required. Fortunately, these clay particles are of a sufficiently small size to pass completely through the system without any adverse effects if the proper precautions are followed. Silt and clay particles which pass through the settling basin and/or the filter may settle out of the water in the tape lines, where they may become cemented together by the action of bacteria to form large and potentially troublesome masses of slime. In order to combat this tendency, chlorination is often practiced to curb the growth of any biological organisms, and submains and lateral lines are regularly flushed to remove sediments.

Growth Of Bacterial Slime In The System

Bacteria can grow within the system in the absence of light. They may produce a mass of slime or they may cause iron or sulfur to precipitate out of the water. The slime may clog emitters, or it may act as an adhesive to bind fine silt or clay particles together to form aggregated particles large enough to cause clogging. The usual treatment to control bacterial slime growth is chlorination on a continuous basis to achieve a residual concentration of 1 to 2 ppm, or on an intermittent basis at a concentration of 10 to 20 ppm for between 30 and 60 minutes.

Growth Of Algae Within The Water Supply Or The System

Algae may grow profusely in surface waters and may become very dense, particularly if the water contains the plant nutrients nitrogen and phosphorus. When conditions are right, algae can rapidly reproduce and cover streams, lakes, and reservoirs in large floating colonies called blooms. In many cases, algae may cause difficulty with primary screening or filtration systems, because of a tendency for algae to become entangled within the screen.

Algae can effectively be controlled in reservoirs by adding copper sulfate. The copper sulfate may be placed in bags equipped with floats and anchored at various points in the reservoir, or it can be broadcast over the water surface. Chelated copper products may be more effective, particularly if there is a heavy silt load in the water, but they are considerably more expensive. Copper sulfate should not be used in any system with aluminum pipe.

The recommended concentration of copper sulfate for algae control varies from a low of 0.05 to a high of 2.0 ppm, depending upon the species of algae involved. The dosage required can be based upon a treatment of the top 6 feet of water, since algal growth tends to occur primarily where sunlight is most intense.

Green algae can only grow in the presence of light. Algae will not grow in buried pipelines or in black polyethylene laterals or emitters. However, enough light may enter through exposed white PVC pipes or fittings to permit growth in some parts of the system. These algae can cause clogging problems when washed into tape laterals. Chlorination is the recommended treatment to kill algae growing within the irrigation system. The chlorine concentration should be 10 to 20 ppm for between 30 and 60 minutes. Where practical, exposed PVC pipe and fittings should be painted with a PVC-compatible paint to reduce the possibility of algal growth within the system.

Filtration

Settling Basins

Settling basins serve to remove the larger inorganic suspended solids from surface water supplies. Often used for turbulent surface water sources such as streams or ditches, settling basins frequently function as economical primary treatment facilities and can greatly reduce the sediment load of the water. Settling basins are also used in conjunction with aeration to remove iron and other dissolved solids.

Centrifugal Sand Separators

Centrifugal sand separators are used to remove sand, scale, and other particulates that are appreciably heavier than water. Centrifugal sand separators will remove particles down to a size of 74 microns (200 mesh) under normal operation. Centrifugal sand separators are often installed on the suction side of pumping stations to reduce pump wear. They are self-cleaning and require a minimum of maintenance. Centrifugal sand separators will not remove organic materials, and they suffer from the drawback that the head loss across them is higher (8 to 12 psi) than with other types of filters. It is important that sand separators be sized correctly. The operation of a separator depends upon centrifugal forces within a vortex created by the incoming flow, thus separator size must be carefully matched to the design flow rate.

Pressure Screen Filters

Pressure screen filters serve to remove inorganic contaminants such as silts, sand, and scale. Pressure screen filters are available in a variety of types and flow rate capacities, with screen sizes ranging from 20 mesh to 200 mesh. In addition to primary filtration of water sources, screen filters often act as backup filters to catch sand or scale which may have accidentally entered the system through pipeline breaks, media filter failures, or other unforeseen circumstances. Figure 8 illustrates the relative sizes of screen mesh openings in comparison to an orifice having a diameter of 0.020 inches. Pressure screen filters require regular cleaning of the screen element.

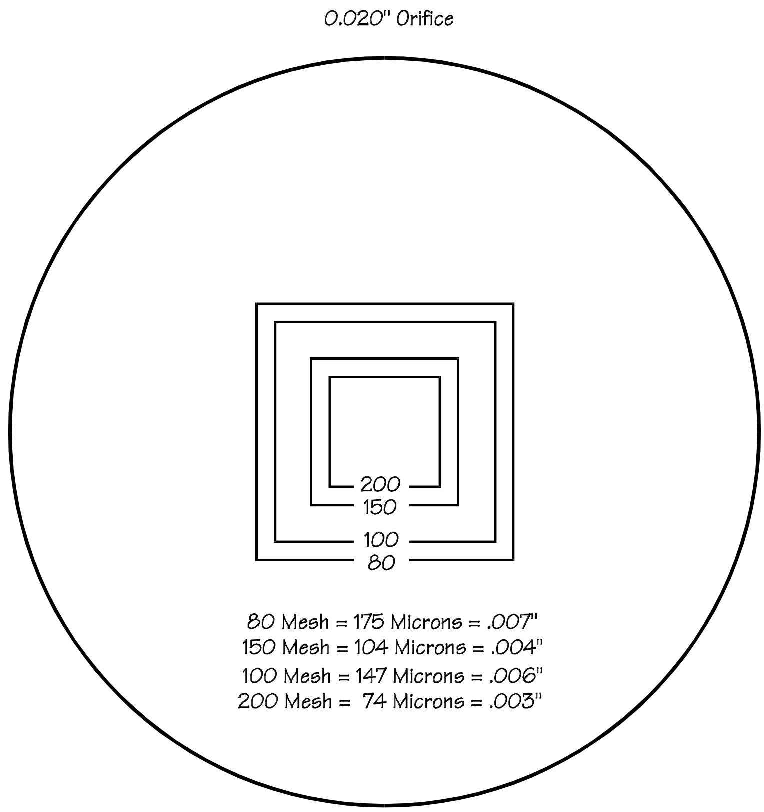


Figure 9: Screen Mesh Sizes Compared To 0.020-Inch Orifice

Gravity Screen Filters

Gravity screen filters rely upon gravity instead of water pressure to move water through the screen. Most gravity screens consist of 2 chambers separated by a fine mesh screen. Pressure losses across gravity screens are in most cases negligible, rarely exceeding one psi, and for this reason gravity screens find applications in systems where pressure losses must be minimized. Gravity screen filters are useful where an elevated water source is available. Gravity screens are very effective on most surface water sources, including canal and reservoir waters.

Media Filters

Media filters are especially suitable for micro-irrigation systems because they are a three dimensional filter, trapping contaminants both at the surface and deeper down in the media bed. Media filters serve to remove fine suspended solids such as algae, soil particles, and organic detritus. They are frequently necessary where surface water sources such as streams or reservoirs are used for irrigation. The quality of effluent produced by a media filter depends upon the flow rate through the filter, and on the type of sand used. In general, the lower the flow rate and the finer the sand, the better the filtration will be.

Media filters are cleaned by backwashing. During this process, the normal downward direction of water flow is reversed, passing back upwards through the media, fluidizing the media bed and removing trapped contaminants. The velocity of the backwash is carefully regulated so that contaminants are removed and the sand media remains in the filter. A media filter should be followed by a screen filter to protect against the possibility of the filter sand finding its way into the irrigation system.

CHLORINATION

Prior to any discussion of adding chemicals to irrigation water, it must be pointed out that there are two potential hazards involved:

1. The first possible hazard associated with chemical injection is the direct use of irrigation water by people or animals. Field workers accustomed to drinking or washing with irrigation water must be re-educated, and the designer should recognize that chemically treated water may be toxic.

2. The second possible hazard is backflow. Backflow is a reversal of direction of normal flow caused by siphonage or backpressure. Backflow may result in contamination of potable water supplies, such as reservoirs, wells, municipal pipe-lines, and so forth, unless the designer has incorporated a suitable backflow prevention device into the system.

The practice of chlorination, which is the addition of chlorine to a water source, has been used for many decades as a means of purifying drinking water supplies. Chlorine, when dissolved in water, acts as a powerful oxidizing agent and vigorously attacks microorganisms such as algae, fungi, and bacteria. Chlorination is an effective, economical solution to the problem of orifice and emitter clogging where such clogging is due to micro-organic growths.

When chlorine is dissolved in water, it combines with water in a reaction called hydrolysis. The hydrolysis reaction produces hypochlorous acid (HOCl), as

$$H_2O + Cl_2 = HOCl + H^+ + Cl^-$$

Following this reaction, hypochlorous acid then undergoes an ionization reaction, as

$$HOCl = H^+ + OCl^-$$

Hypochlorous acid (HOCl) and hypochlorite (OCl^-), which are together referred to as free available chlorine, coexist in an equilibrium relationship that is influenced by temperature and pH. Where water is acidic (low pH) the above equilibrium shifts to the left and results in a high percentage of the free available chlorine being in the form of HOCl. Where the water is basic (high pH), a high percentage of the free available chlorine is in the form of hypochlorite.

Since the microorganism killing efficiency of HOCl is about 40 to 80 times greater than that of OCl^-, the effectiveness of chlorination is highly dependent upon the pH of the source water. Thus, water having a low pH will result in a high concentration of HOCl, which is the more potent biocide.

Chlorine is highly reactive with many compounds. Free available chlorine reacts strongly with readily oxidizable substances such as iron, manganese, and hydrogen sulfide, often producing insoluble compounds, which may precipitate out of solution. These precipitates may cause clogging problems in a micro-irrigation system. Chlorine also reacts with ammonia, producing compounds called chloramines, and thus, where nitrogen fertilizer is to be applied via the system, steps should be taken to ensure that the nitrogen and chlorine are applied at different times.

The most common chlorine compounds used in micro-irrigation systems are calcium hypochlorite, sodium hypochlorite and chlorine gas.

CALCIUM HYPOCHLORITE

Calcium hypochlorite is available commercially in a dry form as a powder or as granules, tablets, or pellets. Calcium hypochlorite is readily soluble in water, and under proper storage conditions, is relatively stable. Calcium hypochlorite should be stored in a cool, dry location in corrosion-resistant containers.

SODIUM HYPOCHLORITE

Sodium hypochlorite, familiar to most people as laundry bleach, is available in solution in strengths up to 15 percent. Sodium hypochlorite decomposes readily at high concentrations and is affected by light and heat, and must be stored in a cool location in corrosion-resistant tanks.

CHLORINE GAS

Chlorine gas is supplied as a liquefied gas under high pressure in containers varying in size from 100-lb cylinders to one-ton containers. Chlorine gas is both very poisonous and very corrosive, and because it is heavier than air, adequate exhaust ventilation must be provided at the floor level of storage rooms.

INJECTION OF CHLORINE

Chlorine may be introduced into the system in a number of ways. Sodium hypochlorite (liquid) or calcium hypochlorite (solid) may be metered into the system, or chlorine gas may be dissolved directly into the supply line with the use of a metering device called a chlorinator. Where chlorination of larger systems is required, a gas system may be most economical, but for smaller systems, the solid or liquid forms may be more appropriate. Gas chlorination, while potentially hazardous under certain circumstances, is widely used because it is generally the least expensive method. The use of gas is also preferable in areas where the addition of sodium or calcium to the soil is to be avoided.

Chlorine is a strong oxidizing agent and in concentrated liquid or gaseous form can be hazardous if used without following the manufacturer's instructions. Pressure relief valves should be installed on any tanks holding solutions of chlorine to guard against a buildup of pressure.

Chlorination of a system may be either continuous or intermittent, depending upon the intended results. Where the goal is to control biological growth in laterals or other parts of the system, intermittent treatment has generally proved to be satisfactory. Continuous treatment will be necessary in those instances where the goal is to treat the water itself, as in the case where chlorine is injected to precipitate dissolved iron. General recommendations for injection of chlorine follow:

1. Inject chlorine at a point upstream of the filter. This prevents growth of bacteria or algae in the filter, which would reduce filtration efficiency. It also permits the removal of any precipitates caused by the injection of chlorine, and eliminates the filter as a potential incubator for organic growth.

2. Calculate the amount of chlorine to inject. The following information is necessary: volume of water to be treated, active ingredient of chlorine chemical being used, and desired concentration in treated water.

3. Injection should be started with the system operating.

4. Sample the water output of an emitter on the nearest lateral and determine the level of free chlorine using a chlorine test kit. Allow sufficient time to achieve a steady reading.

5. Adjust the injection rate.

6. Repeat steps 4 and 5 until the desired concentration is obtained.

7. Sample the water output from an emitter at the end of the most distant lateral and determine the free chlorine level. If there is a marked decrease in the concentration, increase the injection rate to compensate for the chlorine absorption in the system.

RECOMMENDED CHLORINE CONCENTRATION

The following are guidelines for the concentrations, which may be required. These concentrations are sampled at the end of the furthest lateral.

1. Continuous treatment to prevent growth of algae or bacteria: 1 to 2 ppm.

2. Intermittent treatment to kill a buildup of algae or bacteria: 10 to 20 ppm for 30 to 60 minutes. In most cases where control of micro-organic slimes or growths is desired, intermittent treatment is recommended. The frequency of intermittent treatment will depend upon the level of contamination in the water supply. Begin treatments on a frequent basis, and then gradually space the treatments farther apart if conditions permit it.

HOW TO CALCULATE THE AMOUNT OF CHLORINE TO INJECT

LIQUID FORM SODIUM HYPOCHLORITE NaOCl

General Formula: IR = Q x C x 0.006 / S (Eq. 1)

Where IR = Chlorine Injection Rate (gallons/hour)
Q = System Flow Rate (gpm)
C = Desired Chlorine Concentration (ppm)
S = Strength of NaOCl Solution (percent)

EXAMPLE #1:

A grower wishes to use household bleach (NaOCl @ 5.25% active chlorine) to achieve a 2 ppm chlorine level at the injection point. His system flow rate is 155 gpm. At what rate should he inject the bleach?

SOLUTION:

IR = 155 gpm x 2 ppm x 0.006 / 5.25

= 0.35 gallons per hour.

EXAMPLE #2:

A grower wishes to use 10.0% NaOCl to achieve a 10 ppm chlorine level. His system flow rate is 620 gpm. At what rate should he inject the NaOCl?

SOLUTION:

IR = 620 gpm x 10 ppm x 0.006 / 10.0

= 3.72 gallons per hour.

SOLID FORM CALCIUM HYPOCHLORITE $Ca(OCl)_2$

Calcium hypochlorite is normally dissolved in water to form a solution, which is then injected into the system. Calcium hypochlorite is 65% chlorine (hypochlorite) by weight. Therefore, a 1 percent chlorine solution would require the addition of 8.34/0.65 = 12.8 pounds of calcium hypochlorite per hundred gallons of water. Using this fact, a stock solution of the desired strength may be mixed and used in the same manner as sodium hypochlorite solutions.

GASEOUS FORM Cl_2

General Formula : $IR = Q \times C \times 0.012$ Eq. 2

Where IR = Chlorine Injection Rate (lb/day)
Q = System Flow Rate (gpm)
C = Desired Chlorine Concentration (ppm)

EXAMPLE:

A grower wants to inject gas chlorine into his system to achieve a 15 ppm chlorine concentration at the mainline injection point. If the mainline flow rate is 2250 gpm, what should the gas injection rate be?

SOLUTION:

$$IR = 2{,}250 \times 15 \times 0.012 = 405.0 \text{ pounds per day}$$

Table 3 provides further guidelines for the computation of dosage levels for chlorination.

TABLE 3: CHLORINE EQUIVALENTS FOR COMMERCIAL SOURCES

CHLORINE FORM	1-lb EQUIVALENT	Q PER ACRE-FT*
Chlorine Gas 100 % available Cl_2	1.0 lb	2.7 lb
Calcium Hypochlorite 65-70 % available Cl_2	1.5 lb	4.0 lb
Sodium Hypochlorite		

15 % available Cl_2	0.8 gal	2.2 gal
10 % available Cl_2	1.2 gal	3.3 gal
5 % available Cl_2	2.4 gal	6.5 gal

* This is the quantity required to treat one acre-foot of water to attain 1 ppm chlorine at the injection point.

CAUTION:

1. ***Never mix chlorine directly with any other chemicals.***
2. ***Store chlorine apart from other chemicals.***
3. ***Inject chlorine and acid into the system using separate injection points.***

INJECTION OF ACID

The injection of acid is generally done to lower the pH as a control mechanism for various water quality problems. Acid treatment is often used to prevent precipitation of dissolved solids such as carbonates and iron. Acid may also be used to discourage micro-organic growth in the system, and may be used in conjunction with chlorine to increase the concentration of HOCl, which enhances chlorine's biocidal action. The injection of acid is generally done on an intermittent basis and will not affect the growth of most perennial plants. Caution should be exercised when handling acids, because many system components and injection pumps are not resistant to acid. Care should be taken that only pumps with acid resistant materials are used.

Among the various acids commonly used are Phosphoric acid (which also adds phosphate to the root zone), Hydrochloric acid (muriatic acid), and Sulfuric acid (sulfur dioxide). All acids are hazardous if used incorrectly.

The procedure to use is as follows:

1. Calculate the amount of acid to inject. You will need to know the volume of water to be treated, concentration and type of acid being used, pH of water and desired pH after treatment.

2. Injection should be started with the system operating.

3. Proceed to an emitter on the nearest lateral and determine the pH using a pH test kit or pH indicator paper. Allow sufficient time to obtain a steady reading.

4. Adjust the injection rate.

5. Repeat steps 3 and 4 until the desired concentration is obtained.

HOW TO CALCULATE AMOUNT OF ACID TO INJECT

In order to calculate the amount of acid to add to irrigation water to achieve the desired pH, a titration curve is necessary, and this requires a laboratory with the proper equipment. In the field it is easiest to take a 55-gallon drum and fill it with irrigation water. Then slowly add the type of acid you wish to inject to the drum and stir the water to ensure complete mixing. Measure the pH of the water and repeat until the desired pH is obtained. The quantity of acid required may be quite small and, using sulfuric acid, as little as 0.7 fluid ounces may be required to reduce the pH from 7 to 4.

When the quantity of acid required to correct the pH of the water has been measured, it is a simple operation to calculate the amount of acid to inject into the system, assuming the system flow rate is known.

CAUTION:

1. ***Never add water to acid: Always add acid to water.***
2. ***Never mix acid directly with chlorine or chlorine compounds: This will release toxic chlorine gas.***
3. ***Inject acid downstream of filters and other metal components.***

CHAPTER IV

DESIGN CRITERIA

EMISSION UNIFORMITY (EU)

The goal of irrigation design is the efficient distribution of water and nutrients to the crop. One important measure of efficient distribution is the uniformity of water application. Emission Uniformity is a measure of the uniformity of water application, and is used in both the design and operation of a micro-irrigation system. Emission uniformity may apply to a single lateral line, a submain block, or an entire irrigation system.

Emission uniformity EU is defined (ASAE EP405), as

$$EU = (1-1.27Cv/\sqrt{n})\,(Qm/Qa) \qquad \text{Eq. 3}$$

Where EU = Emission Uniformity, expressed as a decimal.

n = For a point-source emitter on a permanent crop, the number of emitters per plant. For a line source emitter on an annual crop, either the spacing between plants divided by the same unit length of lateral line used to calculate Cv, or 1, whichever is greater.

Cv = The manufacturer's coefficient of variation for point or line source emitters, expressed as a decimal.

Qm = The minimum emitter flow rate for the minimum pressure Hm in the system in gph.

Qa = The average, or design, emitter flow rate for the average or design pressure Ha in gph.

Equation 3 incorporates two distinct and independent factors into an expression of emission uniformity. The first factor, $(1-1.27Cv/\sqrt{n})$ expresses the flow rate variation resulting from manufacturing variation Cv, which is computed for a sample population of emission devices as the standard deviation divided by the mean. For Aqua-TraXX tape systems (Cv = .03 and n = 1), this factor is equal to 0.96. The second factor, (Qm/Qa), expresses the flow rate variation caused by pressure variations within the field and is a function of irrigation design. Therefore, for a typical Aqua-TraXX system, EU is equal to 0.96 (Qm/Qa).

Figure 10: Aqua-TraXX on Celery (Santa Maria, CA)

DESIGN CAPACITY

Design capacity is the maximum rate of irrigation water that the system can apply. Design capacity is based upon the anticipated Peak Evapotranspiration (PET) of the crop. This maximum water requirement will be a function of the following factors:

1. Climate. The peak water use period for the crop occurs during the hottest period of the growing season. For a summer crop, July and August are often the peak use months. Other factors that will affect the peak use period are relative humidity, day length, wind patterns, and the intensity of sunlight.

2. Crop maturity. On annual crops, the water requirement will increase with the growth of the plant and the plant leaf coverage. For tree crops, the system design capacity must be based upon the irrigation needs of the mature plant.

3. Rainfall patterns. During periods of rainfall, the crop's evapo-transpiration rate will be low, and the irrigation requirement will be reduced in proportion to the amount of effective rainfall the crop receives.

4. Effective soil water storage. The effective soil water storage is the volume of water stored in the soil, which is available for use, by the plant. It is a function of the soil's ability to store a water reserve, and the ability of the plant to draw upon that reserve. Small, shallow rooted, drought-sensitive plants in a sandy soil will require frequent irrigation, whereas drought-resistant plants with extensive root systems growing in a loamy soil will require less frequent irrigation.

5. Where effective soil water storage is low, the design capacity must be based upon the peak water requirement over a short period of time. On the other hand, where the effective soil water storage is relatively large, it will serve as a water storage reservoir, allowing the designer to base his design capacity upon average water requirements over a longer period of time.

6. Crop type. Crop type has a major influence in determining the design capacity of the system. The water requirements of different crops vary markedly because of several factors, including the amount of leaf area on the plant and the type of leaf surface. A wheat or sugar cane plant with vertically oriented leaves has a far greater leaf area per unit ground area than a sunflower plant with horizontally oriented leaves. A plant with soft fleshy leaves such as tomato loses more water through evapotranspiration than a waxy leafed plant such as jojoba.

7. Application efficiency. Once the peak ET rate has been determined, it can be expressed in terms of a required system flow rate. The actual design capacity is then computed by dividing the required system flow rate by the application efficiency.

8. Leaching requirement. Where saline water sources are used, particularly in arid regions lacking heavy seasonal rains, or wherever salinity may become a problem, it may be necessary to provide for leaching in the design of the irrigation system.

   The amount of water that must be applied for leaching depends upon the soil characteristics and on the amount of salts present in the soil. Generally, about 80 percent of the soluble salts present in a soil profile will be removed by leaching with a depth of water equivalent to the soil depth to be leached. Therefore, if a soil rooting zone of two feet is to be leached of 80 percent of its soluble salts, a water application of two feet must be applied. Further water applications will produce little further leaching of salts.

Computing System Design Capacity

Once the peak evapotranspiration requirement of the crop is known, the system design capacity may be computed. Assuming that PET is expressed in inches per day, and that this water application is to be applied over the entire cultivated area, the system design capacity may be computed by the formula,

$$Q = 452.5 \frac{PET \times A}{T \times EU} \qquad \text{Eq. 4}$$

Where Q = System Design Capacity (gpm)
PET = Peak Evapotranspiration (inches per day)
A = Area to be Irrigated (acres)
T = Irrigation Time (hours per day)
EU = Emission Uniformity (decimal)

EXAMPLE:

A farmer wishes to irrigate an 80-acre field planted in Kiwi fruit. He plans to irrigate a ***maximum*** of 12 hours per day, and the PET for the mature crop will be 0.30 inches of water per day. For an Emission Uniformity of 85%, compute the system design capacity.

SOLUTION:

$$Q = 452.5 \times \frac{0.30 \times 80}{12 \times 0.85} = 1{,}064.7 \text{ gpm}$$

CHAPTER V

Aqua-TraXX SYSTEM DESIGN

SELECTING Aqua-TraXX PRODUCTS

Aqua-TraXX is manufactured in a wide range of diameters, wall thicknesses, outlet spacings, and flow rates to meet the specific requirements of various crops. Designers should consider the following when selecting Aqua-TraXX products.

1. **Diameter** - Aqua-TraXX is available in three diameters: 5/8” (0.625” I.D.), 7/8” (0.875” I.D.) and 1-3/8” (1.375” I.D.) and will fit standard fittings. The standard 5/8” diameter is used in applications calling for standard run lengths of up to 1,000 feet. The 7/8” diameter is used on long run lengths of up to 2,500 feet, and the 1-3/8” diameter is used on very long run lengths of up to 5,000 feet.

Figure 11: Aqua-TraXX on Strawberries (Dover, Florida)

2. **Wall Thickness** determines how rugged and durable the product will be. For short-term vegetable crops, the experienced grower will generally be able to use the lightest weight tubing. For longer-term crops a heavier wall thickness will be more

resistant to mechanical damage. Aqua-TraXX is manufactured in a range of wall thicknesses: 4 mil, 6 mil, 8 mil, 10 mil, 12 mil, and 15 mil (one mil is 0.001 inch).

3. **Flow Rate** selection will depend upon water quality, the availability of water, the desired length of the tape, and the crop water requirement. Aqua-TraXX is available in four emitter flow rates. These four flow rates are designated as Low Flow, Medium Flow, High Flow, and Cane Flow. It is advantageous to choose the lowest flow rate that will do the job, because low flow rates minimize friction loss and allow for longer runs and better uniformity. However, low flow rates may require a higher level of filtration.

For the initial selection of a tape product, it is often helpful to refer to the standard flow rate table. The standard flow rate is the flow per 100 feet of tubing in gpm, neglecting friction losses. Table 4 provides standard flow rate data for the various Aqua-TraXX flow rates and outlet spacings.

AQUA-TRAXX FLOW RATES: Q100 (GPM PER 100 FEET.)

PART NUMBER	SPACING (Inches)	4 PSI	5 PSI	6 PSI	7 PSI	8 PSI	9 PSI	10 PSI	11 PSI	12 PSI	13 PSI	14 PSI	15 PSI
CANE FLOW													
EAXxx0884	8	0.59	0.66	0.73	0.78	0.84	0.89	0.94	0.98	1.03	1.07	1.11	1.15
EAXxx1256	12	0.40	0.44	0.48	0.52	0.56	0.59	0.63	0.66	0.68	0.71	0.74	0.77
EAXxx1642	16	0.30	0.33	0.36	0.39	0.42	0.44	0.47	0.49	0.51	0.53	0.55	0.57
EAXxx2428	24	0.20	0.22	0.24	0.26	0.28	0.30	0.31	0.33	0.34	0.36	0.37	0.38
HIGH FLOW													
EAXxx04134	4	0.95	1.06	1.16	1.25	1.34	1.42	1.50	1.57	1.64	1.71	1.77	1.84
EAXxx0867	8	0.47	0.53	0.58	0.63	0.67	0.71	0.75	0.79	0.82	0.86	0.89	0.92
EAXxx1245	12	0.32	0.35	0.39	0.42	0.45	0.47	0.50	0.52	0.55	0.57	0.59	0.61
EAXxx1634	16	0.24	0.27	0.29	0.31	0.34	0.36	0.38	0.39	0.41	0.43	0.44	0.46
EAXxx2422	24	0.16	0.18	0.19	0.21	0.22	0.24	0.25	0.26	0.27	0.29	0.30	0.31
MED FLOW													
EAXxx0850	8	0.36	0.40	0.44	0.47	0.50	0.53	0.56	0.59	0.62	0.64	0.67	0.69
EAXxx1234	12	0.24	0.27	0.29	0.31	0.34	0.36	0.38	0.39	0.41	0.43	0.44	0.46
EAXxx1625	16	0.18	0.20	0.22	0.24	0.25	0.27	0.28	0.29	0.31	0.32	0.33	0.34
EAXxx2417	24	0.12	0.13	0.15	0.16	0.17	0.18	0.19	0.20	0.21	0.21	0.22	0.23
LOW FLOW													
EAXxx0834	8	0.24	0.27	0.29	0.31	0.34	0.36	0.38	0.39	0.41	0.43	0.44	0.46
EAXxx1222	12	0.16	0.18	0.19	0.21	0.22	0.24	0.25	0.26	0.27	0.29	0.30	0.31
EAXxx1617	16	0.12	0.13	0.15	0.16	0.17	0.18	0.19	0.20	0.21	0.21	0.22	0.23
EAXxx2411	24	0.08	0.09	0.10	0.10	0.11	0.12	0.13	0.13	0.14	0.14	0.15	0.15

Table 4: Standard Flow Rates For Aqua-TraXX

4. **Outlet Spacing** selection is often based upon the initial germination or growth needs of the crop. For seeds or seedlings that are planted in a closely spaced pattern, it is advantageous to use a tape product with closely spaced outlets. Soil type plays a major role in the determination of outlet spacing, since the soil texture and condition determines water movement and the shape of the wetted profile.

COMPUTER PROGRAM AquaFlow

AquaFlow provides designers with the information they need to design an Aqua-TraXX tape system for optimum performance. AquaFlow provides system operators with the information necessary to operate the system, efficiently applying the desired amount of water and nutrients to the crop.

AquaFlow will help you to design a complete Aqua-TraXX system, including the selection of the Aqua-TraXX tape and the sizing of submains and mainlines. The AquaFlow program includes both metric and U.S. measurement units in the graphic screens for pressure profile and flow profile curves. Metric units are given in kPa and meters. U.S. units are given in psi and feet. The following design example will familiarize the designer with the use of the AquaFlow program.

Design Example

A designer is planning an Aqua-TraXX tape system for tomatoes. The plant rows run downhill at a 2% slope, they are 400 feet long, and they are spaced 36 inches apart. There will be one Aqua-TraXX line per plant row. There will be four submains, each 100 feet long. The submains will each feed 34 tape lines, and they will run downhill at a 1-% slope. The mainline runs parallel to the submains. The designer has selected Aqua-TraXX tape part number EA5060867 (**5**/8-inch diameter, **6** mil, **8**-inch spacing, 0.**67** gpm/100 feet). He will run the system at an operating pressure of 10 psi. He wants to achieve an overall EU of 90% within each submain block.

Figure 10 below illustrates the various elements of the submain block. To begin, the user clicks on the Red TORO icon on the computer desktop. When the Main Menu is displayed, the user clicks on the word "Design" on the upper menu bar. Four sub-menu selections appear. We will use these sub-menus in sequence to complete the design example.

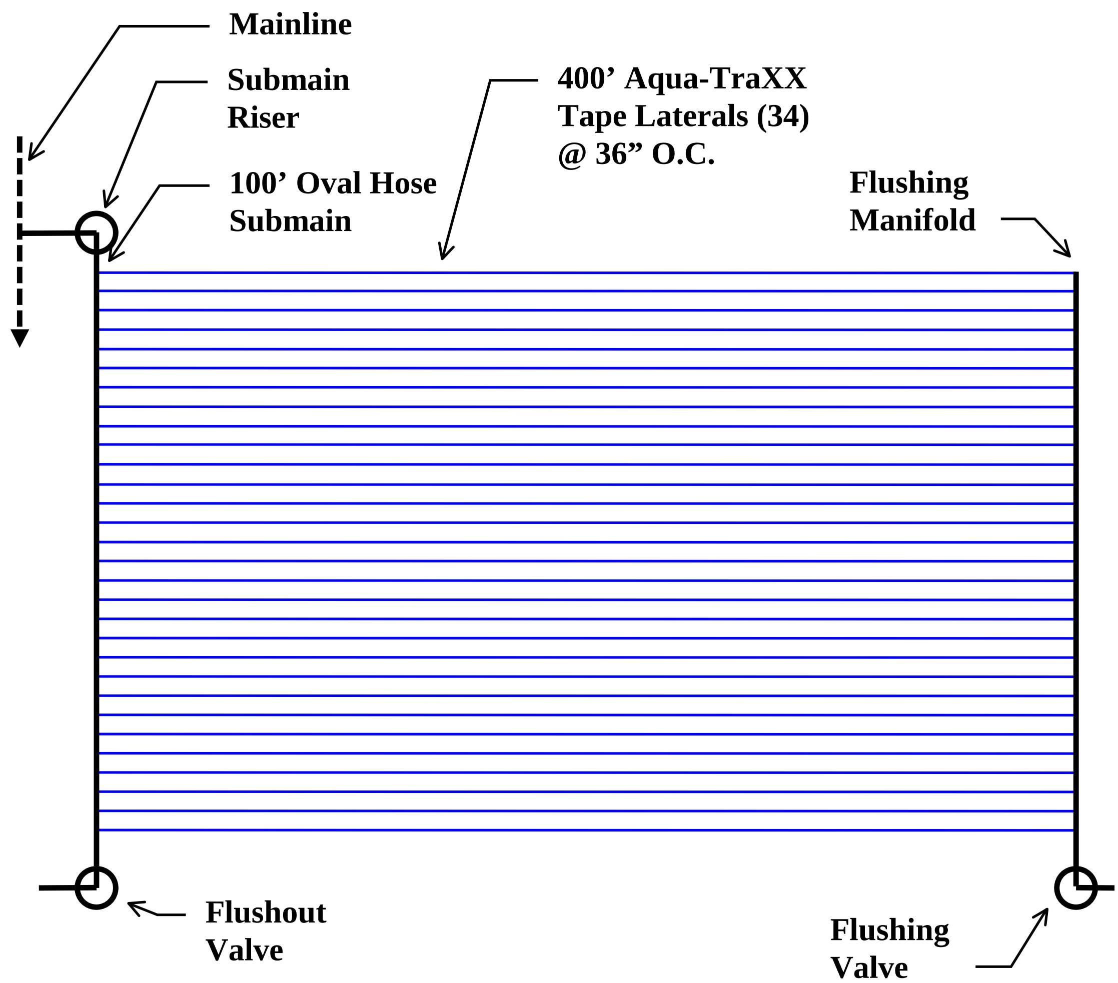
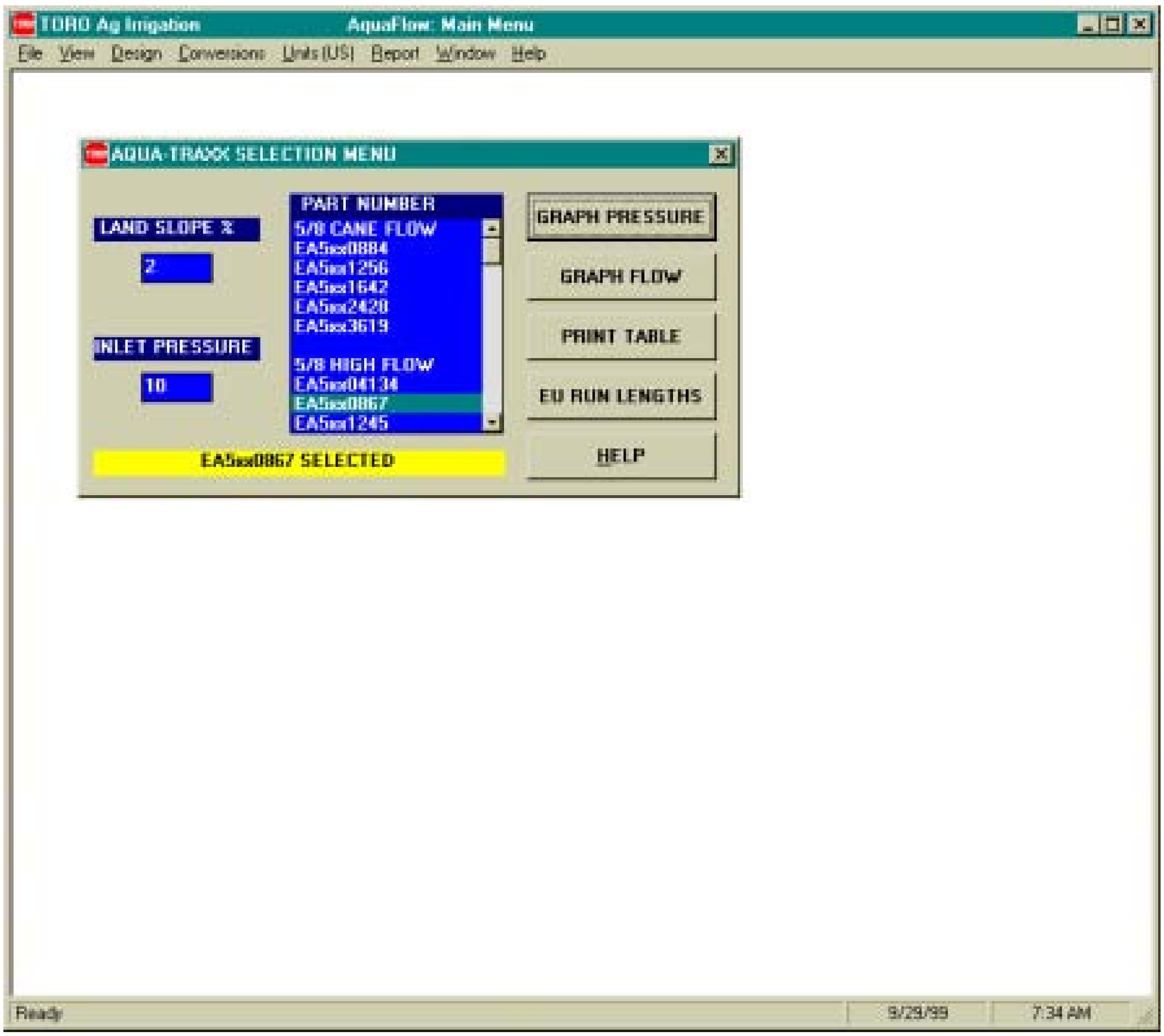


Figure 12: Example Submain Block.

Aqua-TraXX SELECTION MENU

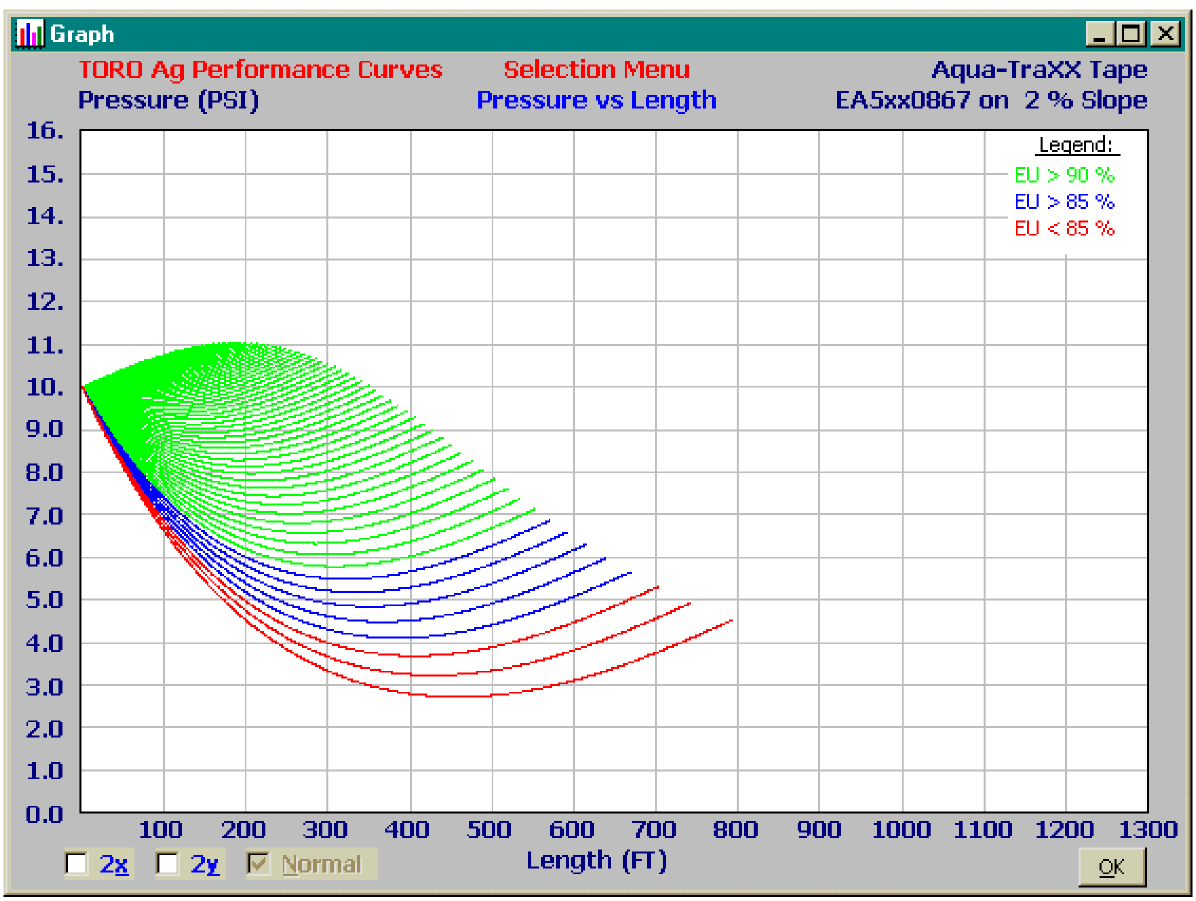
From the AquaFlow Main Menu, click on Design, and then click on Aqua-TraXX Selection Menu. Choose an **INLET PRESSURE** of 10 PSI, a **LAND SLOPE** of 2%, and **Aqua-TraXX PART NUMBER** EA5xx0867. Click the "Graph Pressure" button.

Note: The "xx" in the part number designates the wall thickness in mils (thousandths of an inch). Since wall thickness does not affect hydraulic design, the many wall thicknesses available are not listed individually.



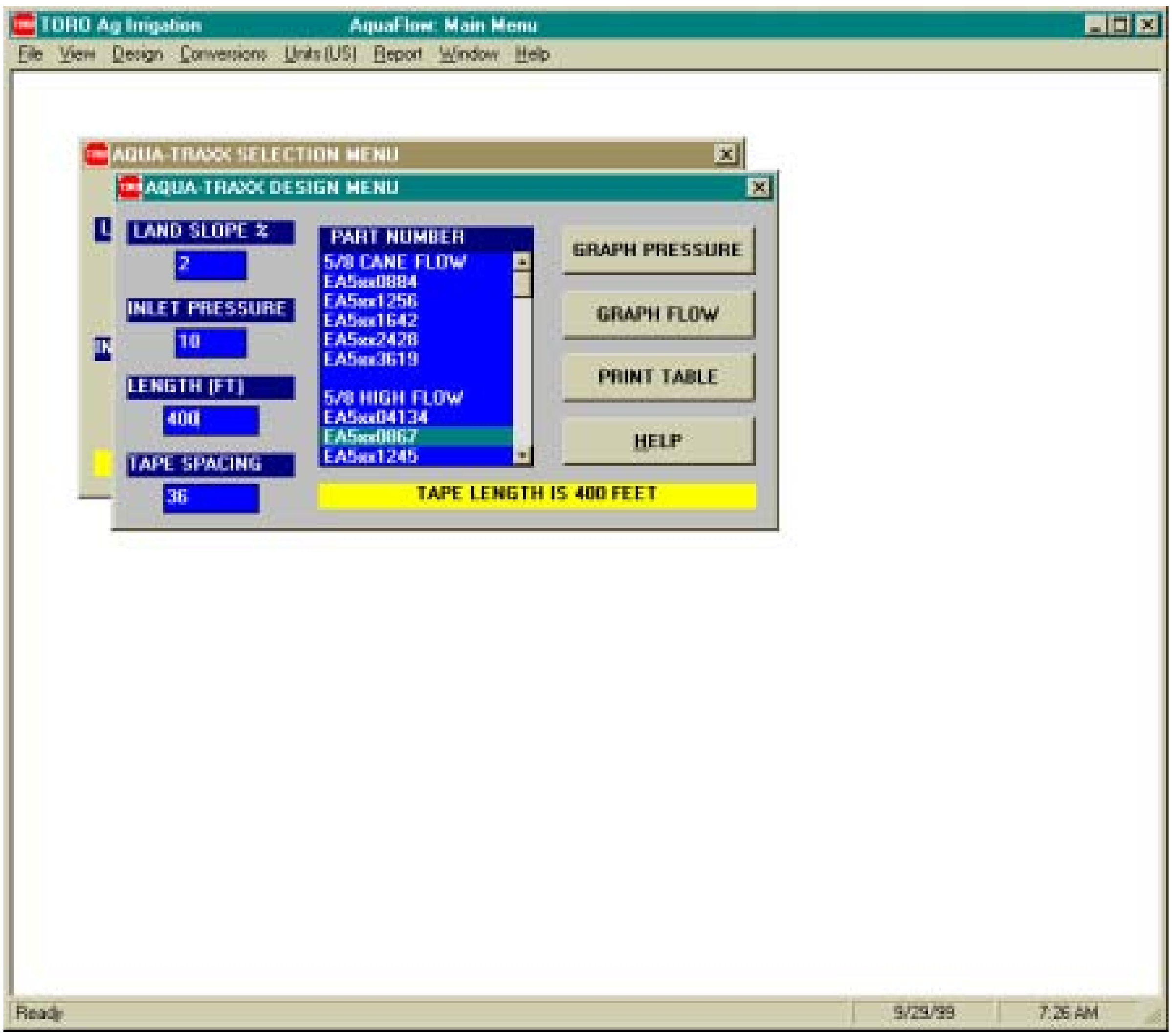
Aqua-TraXX SELECTION MENU: GRAPH PRESSURE

When the GRAPH PRESSURE button is clicked, AquaFlow computes and plots a family of pressure profile curves representing tape lengths out to an EU (Emission Uniformity) value of 80%. The pressure profile curves are color-coded to indicate the EU value ranges for each line length. The graph below indicates that the selected Aqua-TraXX product EA5xx0867 is suitable for run lengths as long as 550 feet at 10 psi inlet pressure and 2% slope.



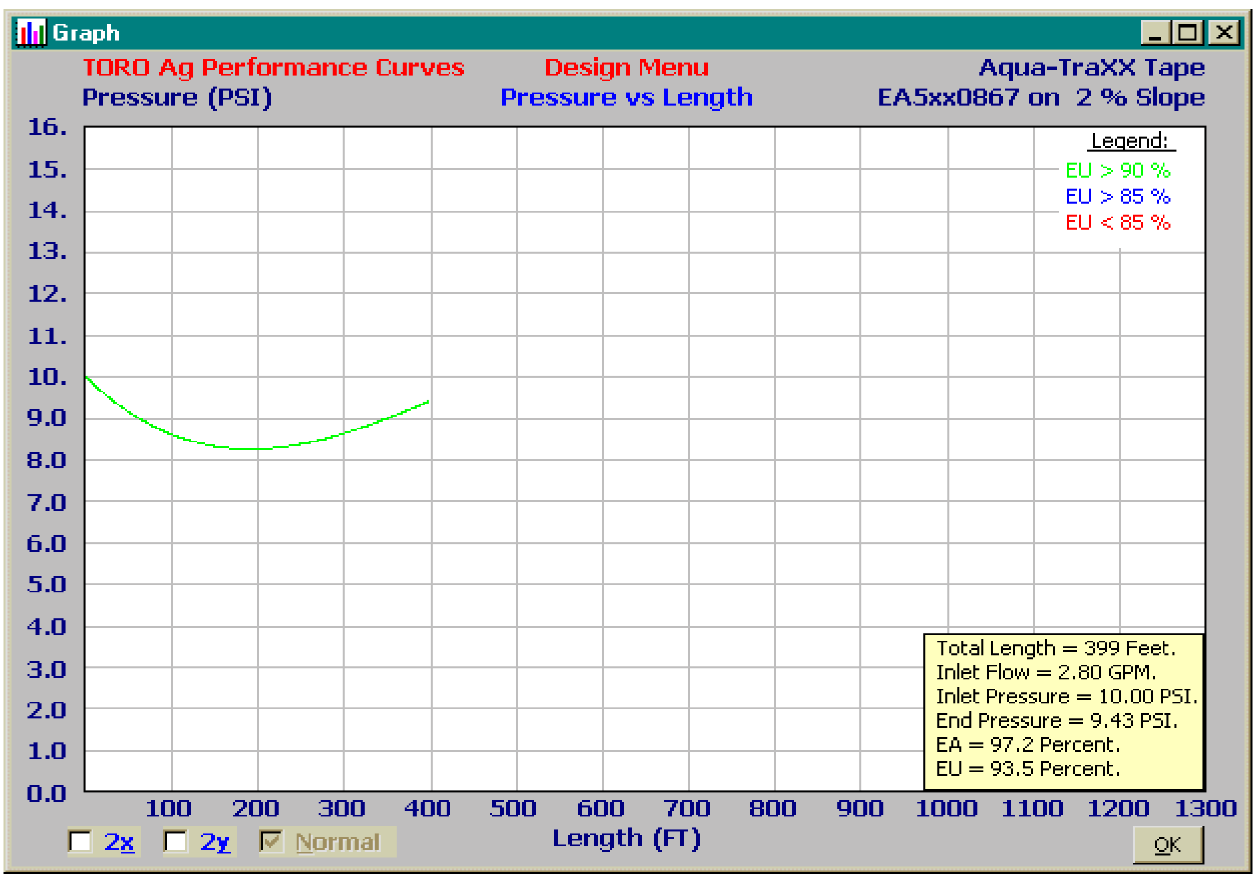
Aqua-TraXX DESIGN MENU

With the initial selection of EA5xx0867 made, the next step is to go to the Design Menu. AquaFlow preserves the previously entered inlet pressure, land slope, and Aqua-TraXX part number for you. You must now enter a specific tape **LENGTH** and **SPACING** - this is the spacing in inches from tape-to-tape across the field - and click the GRAPH PRESSURE button. AquaFlow then computes and plots a pressure profile curve representing the selected tape length.



DESIGN MENU: GRAPH PRESSURE

AquaFlow computes and plots the individual pressure profile curve representing the tape length selected. The graph below shows the pressure profile for a 400-foot long run, and provides design data including the inlet flow rate and the Emission Uniformity value for the single line.



SUBMAIN DESIGN

Submains provide water to individual field blocks, distributing water at a uniform pressure to the Aqua-TraXX lateral lines. Submains may be constructed of PVC pipe, PVC layflat hose, or Oval Hose™.

Oval Hose is a popular and widely used choice for submains because it is economical, rugged, and easy to handle and install. Oval Hose can be retrieved from the field and used again year after year. Oval Hose is manufactured in a round configuration, and subsequently flattened and wound on reels or in coils for ease of handling and compact shipment. After it is installed in the field and pressurized, Oval Hose returns to its round configuration. Aqua-TraXX tape may be connected to Oval Hose submains using barbed connectors (FCA0798) or leader tubing.

Good submain design incorporates a flushout valve at the end of the submain, and a flushing manifold, which is used to flush the entire block of lateral lines simultaneously.

Submain Riser Design

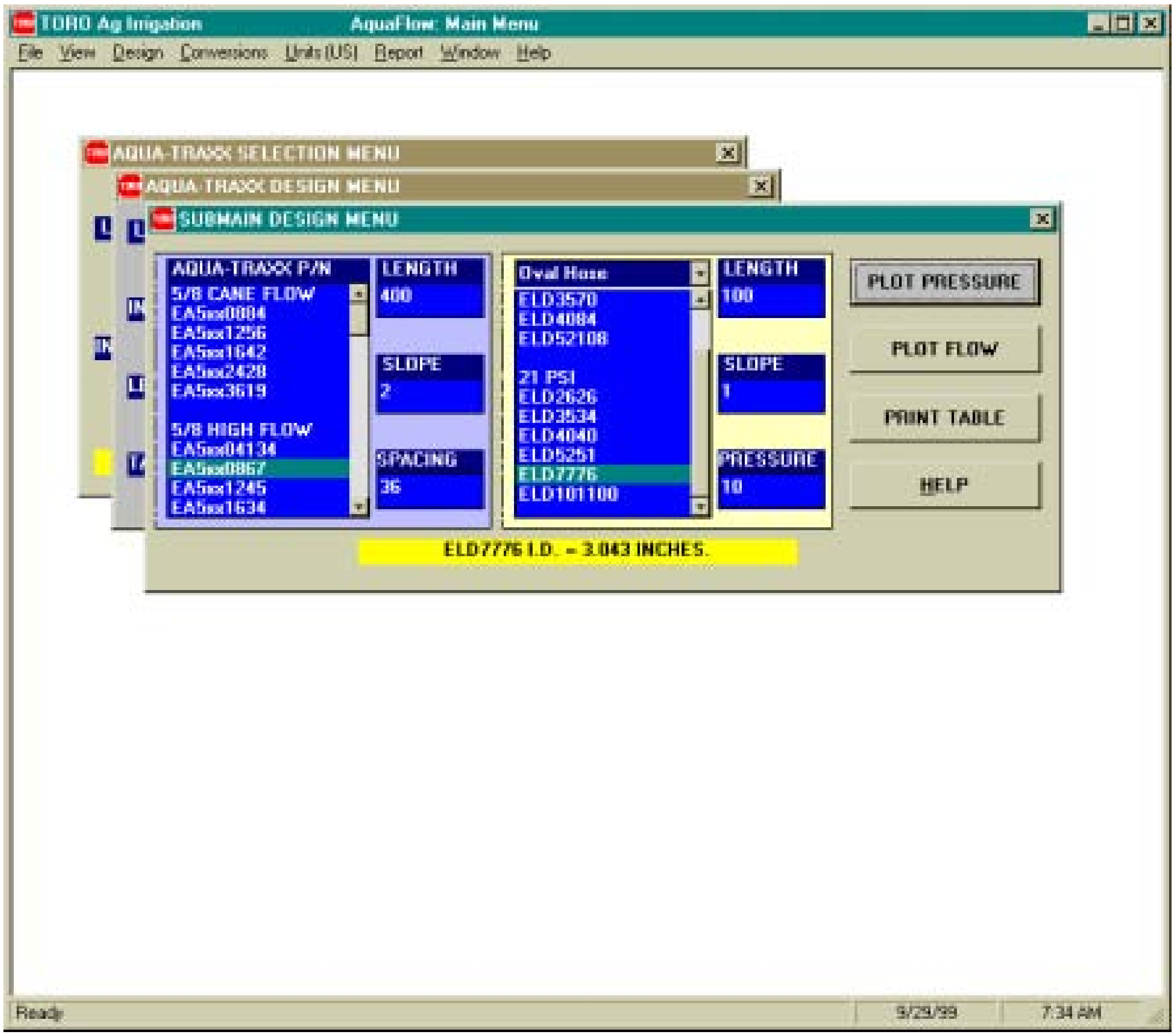
A submain riser serves to regulate water flow from the mainline to the submain. A typical submain riser assembly will normally consist of:

1. A screen filter to prevent debris from entering the tape lines.
2. A manual or pressure regulating valve to control the flow rate.
3. A vacuum relief valve to prevent suction in the submain and tape lines.
4. A Schrader valve to be used as a pressure test point.

SUBMAIN DESIGN MENU

With the Aqua-TraXX selection and design completed, the next step is to go to the Submain Design Menu. As before, AquaFlow preserves the previously entered design parameters for you. You must now select a submain material (Oval Hose or PVC), select a pipe size, enter a submain **LENGTH, SLOPE,** and **PRESSURE,** and click the Plot Pressure button.

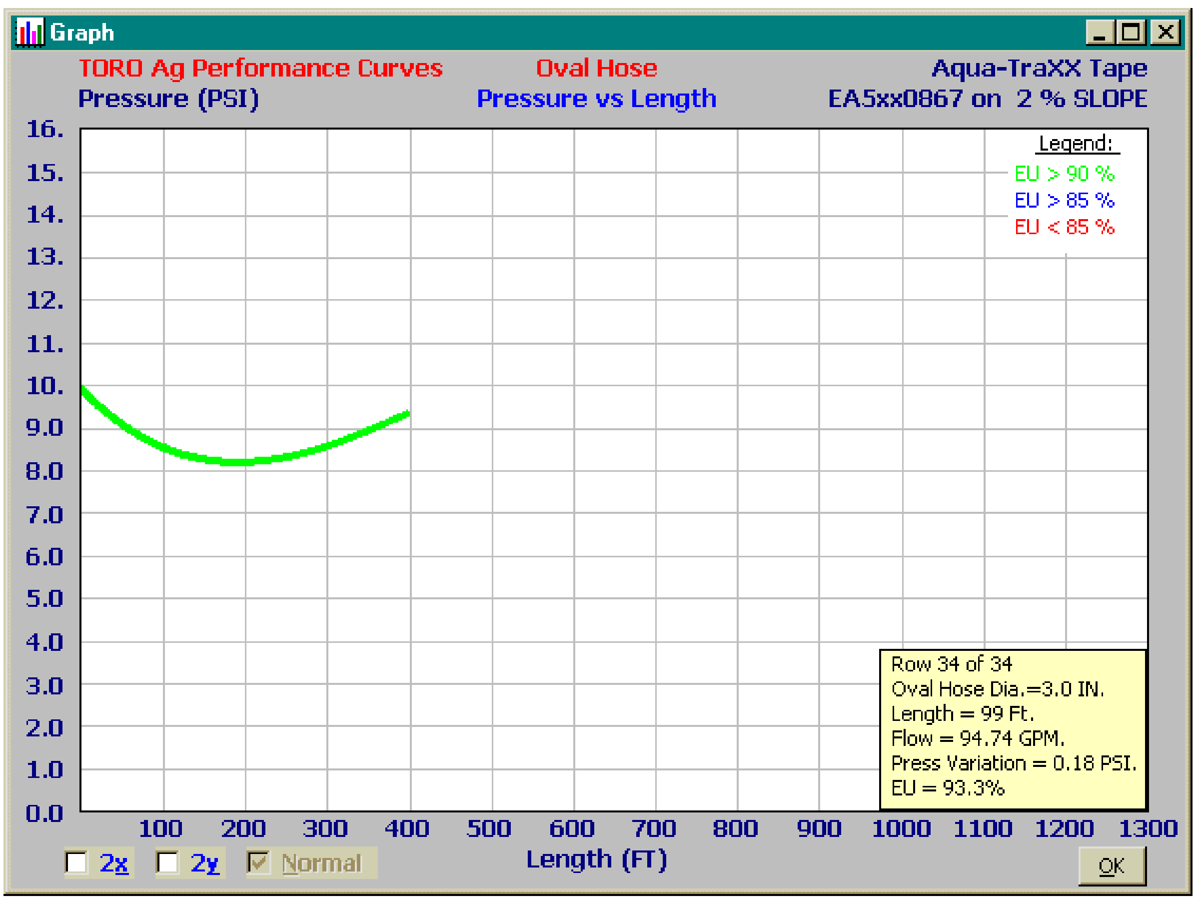
Hint: To see the full list of available submain pipe selections, click on the down arrow to the right of the Oval Hose label box.



SUBMAIN DESIGN MENU: PLOT PRESSURE

The Plot Pressure function plots pressure profiles of all the Aqua-TraXX lines on the submain, superimposed on one another. These pressure profiles will vary vertically on the graph due to the pressure variation within the submain.

Note: The submain pressure calculations begin at the downstream end of the submain and proceed to the upstream end. Therefore, the last curve plotted is at the submain inlet.



MAINLINE DESIGN

The initial stage of mainline design consists of determining its location. Laying out the route for the mainline to follow is often a trial-and-error procedure, involving analysis of the costs and benefits of a number of alternative routes. Once the mainline route has been chosen, the proper pipe sizes must be specified.

For small systems the mainline can often be designed without an elevation drawing. However, for large or complex systems it is best to prepare an elevation drawing of the topography that the mainline will traverse. The required submain pressure in feet is superimposed on the drawing to indicate the minimum allowable pressure at any point. Then, the proposed hydraulic grade line may be drawn in, from the inlet of the mainline to the end.

Once the proposed hydraulic grade line has been drawn and the required flow rates calculated, individual sections of the mainline are sized, each section being designed to most closely adhere to the specified hydraulic grade line. The designer must also compute static pressures in the pipelines, and check each section to ensure that the average water velocity does not exceed a specified limit, usually 5 to 10 feet per second. This is done to minimize the damaging effects of waterhammer.

AquaFlow will help you to size the mainline once the maximum velocity, hydraulic grade line and flow rates are specified. AquaFlow utilizes the Hazen-Williams equation to compute friction losses, which is recalled here for PVC pipe (C=150) as,

$$Hf = 0.000977 \{Q^{1.852} / D^{4.871}\} L \qquad \text{Eq. 5}$$

Where Hf = Friction Loss (feet of water)
Q = Flow Rate (gpm)
D = Actual Pipe I.D. (inches)
L = Length of Pipe (feet)

Velocity of flow in a pipeline may be computed as follows,

$$V = 0.4085 \; Q/D^2$$

Eq. 6

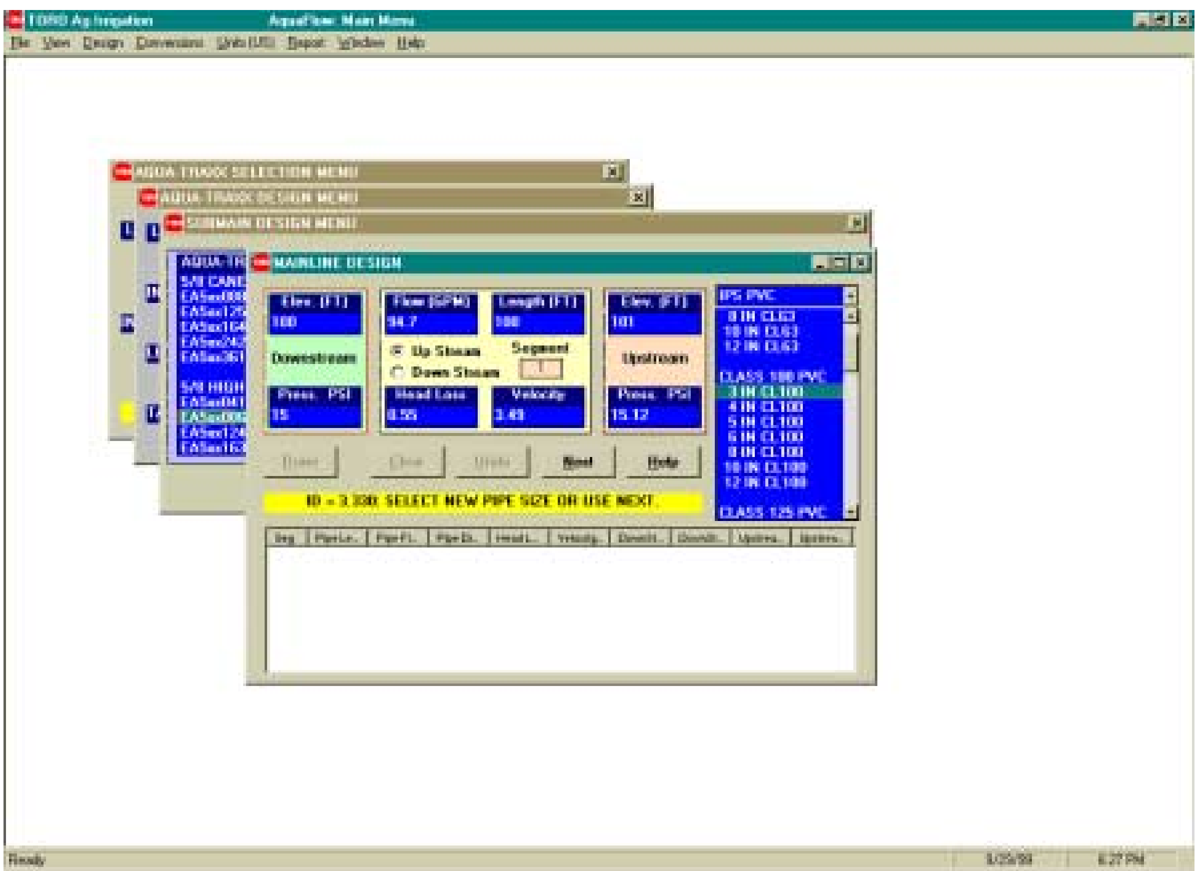
Where V = Velocity (ft per second)
Q = Flow Rate (gpm)
D = Actual Pipe I.D. (inches)

Mainline Design Menu

The final step in the design process is to size the mainline. For this example we will design a mainline which feeds four of the above submain blocks simultaneously. Click on the Mainline Design Menu. This menu will enable you to size the mainline one segment at a time.

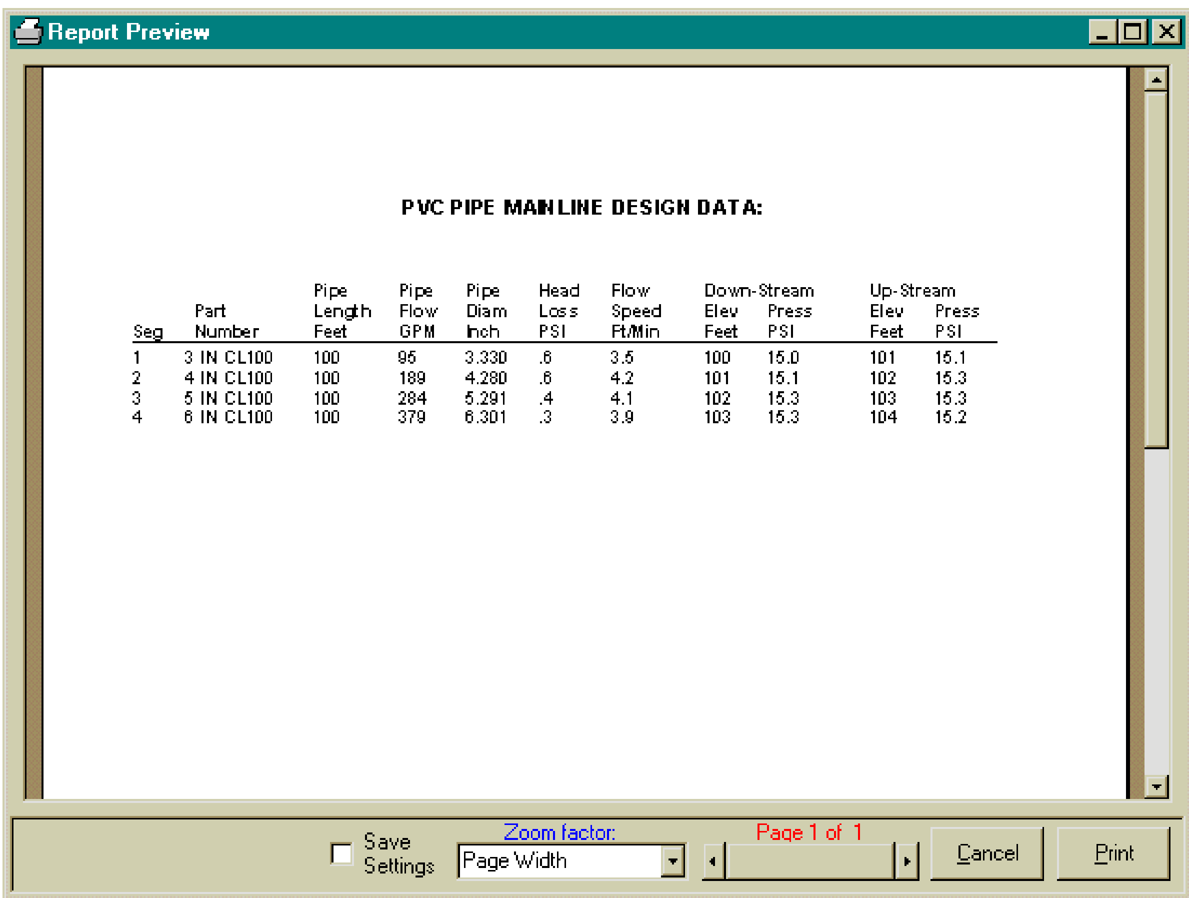
To start, enter the land elevations upstream and downstream, enter the downstream flow rate (feeding the last submain) and the downstream pressure (in this case we allow for a 5 psi pressure loss through the submain riser assembly). Select a pipe type and click on a pipe size. Values of head loss, velocity, and upstream pressure will appear in the appropriate boxes. You may experiment with a number of different pipe sizes until you select the one you want: note that the Velocity box turns yellow (warning) for velocities over 5 feet per second.

When you are satisfied, click “Next”. The program will store the design values for the first segment and advance to the next segment, where all the steps above are repeated. When the last segment has been completed, click “Done”.



Mainline Design Summary

When you click the Done box, the program displays the Mainline Design Data summary for you on the screen as shown below.

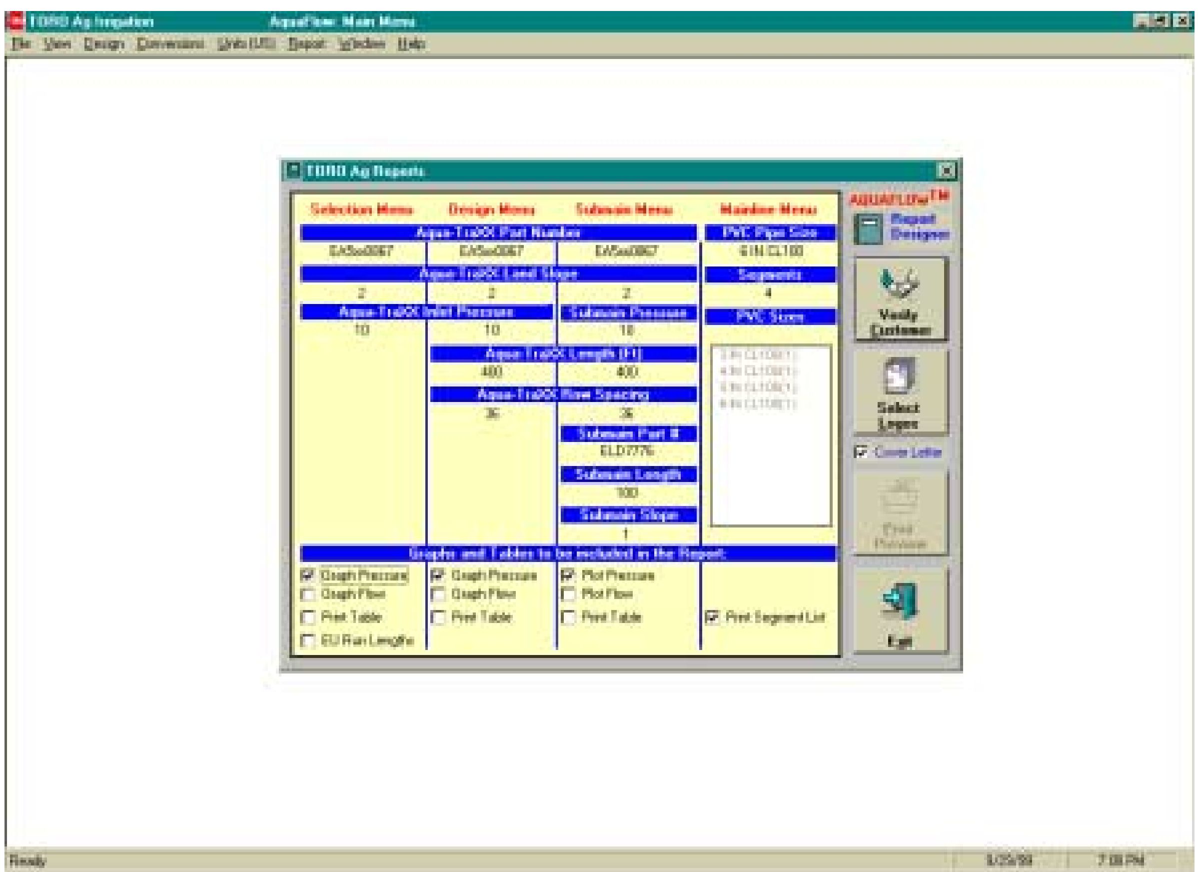


Seg	Part Number	Pipe Length Feet	Pipe Flow GPM	Pipe Diam Inch	Head Loss PSI	Flow Speed Ft/Min	Down-Stream Elev Feet	Down-Stream Press PSI	Up-Stream Elev Feet	Up-Stream Press PSI
1	3 IN CL100	100	95	3.330	.6	3.5	100	15.0	101	15.1
2	4 IN CL100	100	189	4.280	.6	4.2	101	15.1	102	15.3
3	5 IN CL100	100	284	5.291	.4	4.1	102	15.3	103	15.3
4	6 IN CL100	100	379	6.301	.3	3.9	103	15.3	104	15.2

Design Report

AquaFlow will produce a design report that can be printed out for your customer, and will store the report on your hard drive for future reference. In order to produce the Design Report, click Report on the main menu.

To generate the report, first verify the data presented in the Report Menu. Then select the graphs and tables you want to include. Click the Verify Customer button to enter or verify customer information. Click the Select Logos button to put the Toro Ag logo, the Aqua-TraXX logo, and your company Logo on the front page of the report. Click “Print Preview” and AquaFlow will preview the report for you on your screen. Finally, click “Print” and AquaFlow will print the report to your printer.



CHAPTER VI

INSTALLATION PROCEDURES

INSTALLATION

The following recommendations apply to the installation of Aqua-TraXX tape:

1. Store tape reels in a covered area, protected from sunlight and rain.

2. Install tape with the blue stripes and outlets facing upwards. Fine soil particles in the incoming water will normally settle to the bottom of the tape. Installation of tape upside down may result in clogging if there is any contamination in the incoming water.

3. An air/vacuum relief valve should always be installed at the submain riser to prevent suction from occurring in the tape when the system is shut down. Suction in buried tape will tend to draw muddy water back into the tubing through the outlets, causing contamination.

4. Tape may be laid on the surface or buried. Burial is preferred where possible, since it protects the tubing from accidents and animal damage, reduces clogging, maintains tape location and alignment, reduces surface evaporation, and insures that water is applied at the desired location.

5. Tape must be buried when used under clear plastic mulch. Condensed water droplets on the underside of clear plastic will focus sunlight like a magnifying glass, burning holes in the tape.

6. Care should be taken during installation to prevent soil, insects, and other contaminants from getting into the tape. Ends should be closed off by kinking or knotting until the tape can be hooked up to the system.

7. Tape must be monitored as it is injected into the soil. Someone should be watching to insure that the tape maintains its blue stripes upwards orientation, to assist in case the tape becomes tangled in the injector, and to signal the tractor driver when the tape reel is empty and must be replaced.

CONNECTIONS

Figure 13: Aqua-TraXX Connection to Oval Hose

Aqua-TraXX tape is connected to Oval Hose submains using either a plastic fitting or a length of leader tubing, as shown in Fig. 10. Fittings are popular because they are quickly and easily installed, they provide a strong and rugged connection, and they can be re-used for many years.

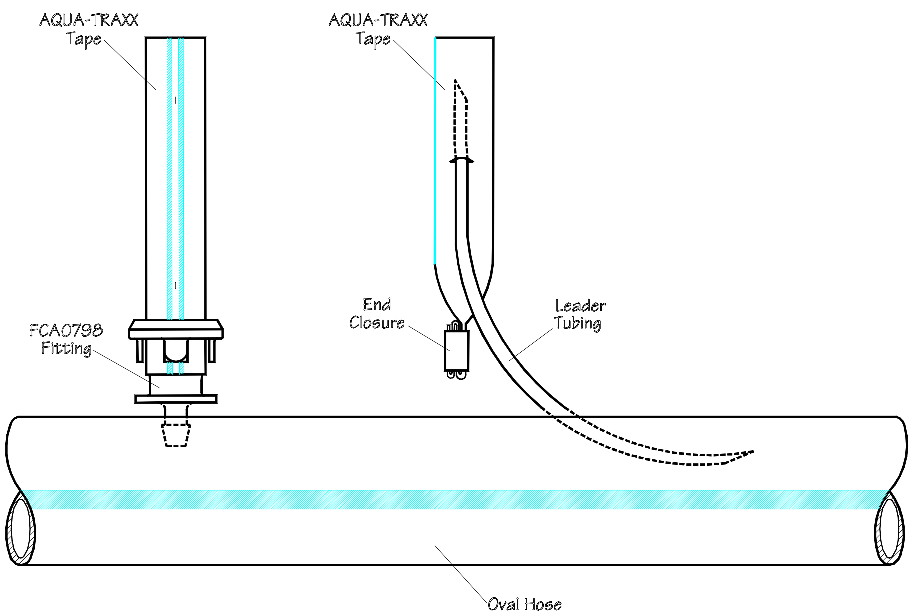


Figure 14: Methods of Aqua-TraXX Tape Connections

TABLE 5: Friction Losses in PSI through Tape Connections.

Flow Rate (GPM)	FCA0798
1	0.23
1.5	0.49
2	0.83
2.5	1.25
3	1.74
3.5	2.31
4	2.95

INJECTION EQUIPMENT

Figure 15: Injecting Aqua-TraXX (Casa Grande, Arizona)

Aqua-TraXX tape may be installed above or below ground with a tractor-mounted injector tool similar to the one shown in Figure 16. This type of injector may be fabricated on the farm or purchased from a number of manufacturers. Typically, from two to six reels of tape may be installed simultaneously with tractor-mounted injectors of this type.

The design of tape injection equipment should take the following into account:

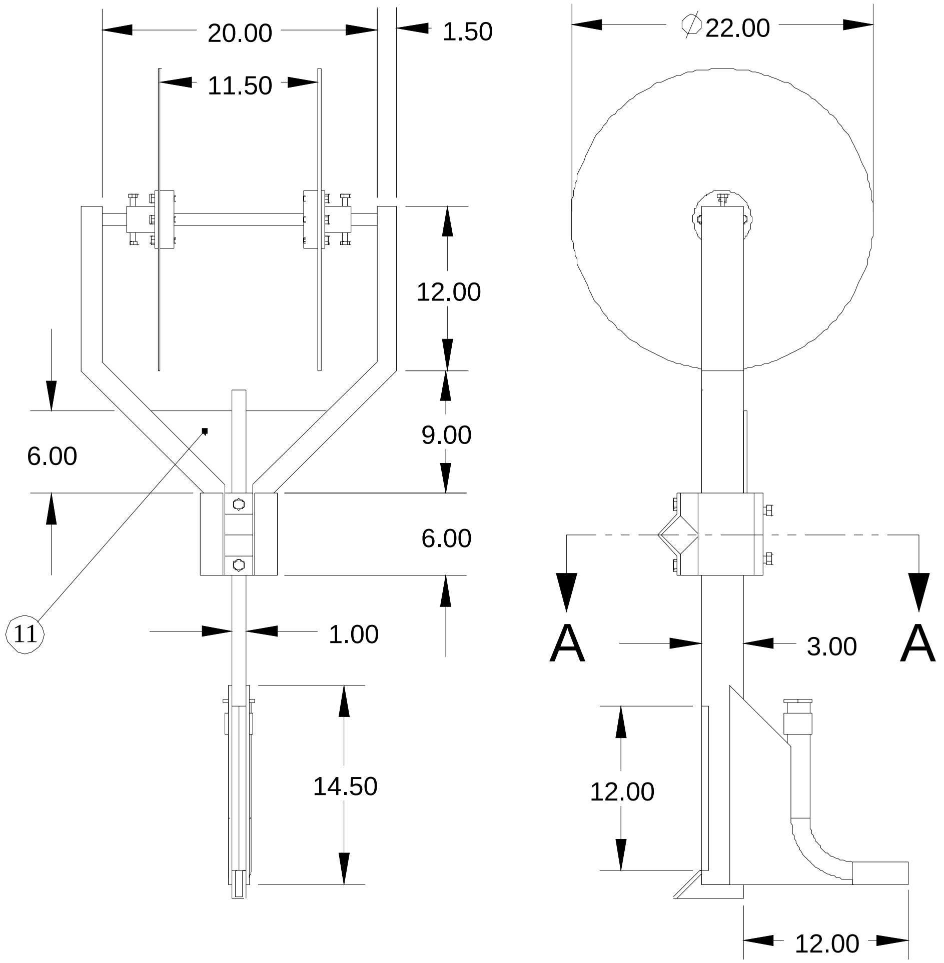
1. Each tape reel should have a braking mechanism to maintain a slight tension and to prevent reel overrunning when the tractor slows or stops. A simple and effective braking system can be made from an 11-inch-wide strip of canvas draped over the tape reel and fastened at one end to the injector frame. The other end of the canvas strip is folded over and sewn, forming a pocket for weights.

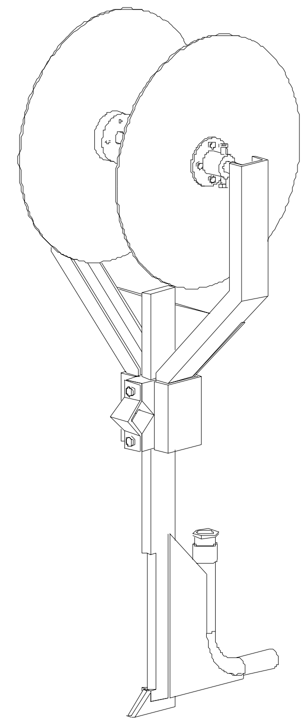
2. The reels must be monitored continuously during injection to insure a quality installation.

3. Reels are heavy – approximately 70 pounds – and procedures for mounting them onto the tractor must take their weight into account.

4. The tractor should carry spare reels that can be mounted when a reel runs out in mid-field.

5. Injection equipment used to install tape should be free of sharp edges, burrs, and areas where the tubing could be damaged. Bends, rollers, and other points of contact with the tape should be kept to a minimum to reduce both the possibilities for damage and the tension on the tape as it is injected.





ITEM NO.	QTY.	Material
1	2	3" X 1.498" X .247" Channel
2	2	4" X 1.647" X .258" Channel
3	1	Tool Bar Clamp
4	1	1" X 3" Tool Steel
5	1	1" CF Steel
6	2	3/16" Aluminum Plate
7	1	1 1/4" Sweep Elbow
8	1	1 1/4" FPT Coupling
9	1	1 1/4" MPT Hex Bushing
10	2	1/4" Steel Plate
11	1	1/4" Steel Plate

FIGURE 16: Aqua-TraXX INJECTION TOOL

CHAPTER VII

OPERATION AND MAINTENANCE

COMPUTING IRRIGATION TIME

Once ET has been determined, the irrigation time T may be computed. In order to perform the calculation, it is necessary to know the average Q100 flow rate (gpm per 100 feet) and the system Emission Uniformity EU.

For row crops on Aqua-TraXX tape, the irrigation time T may be computed from the following formula:

$$T = 1.04 \times \frac{S \times ET}{Q\text{-}100 \times EU} \qquad \text{Eq. 7}$$

Where T	=	Irrigation Time (hours)
S	=	Average Tube Spacing (feet)
ET	=	Evapotranspiration (inches)
Q-100	=	Average Q100 Flow Rate (gpm per 100 feet)
EU	=	System Emission Uniformity (decimal)

Figure 17: Aqua-TraXX on Peppers (Florida sandy soil)

EXAMPLE:

In a field of Pima cotton growing in Arizona, the previous day's ET value was found to be 0.221 inches. The cotton rows are spaced 40 inches (3.33 feet) apart with Aqua-TraXX tape buried under each row. The average flow rate is 0.30 gpm per 100 feet, and the system emission uniformity is 90 percent. Find T:

SOLUTION:

$$T = 1.04 \times \frac{3.33 \times 0.221}{0.30 \times 0.90} = 2.8 \text{ hours}$$

On newly planted acreage, the computed ET, and therefore the irrigation time T, may be quite low. Nevertheless, because the young plants are not likely to have extensive root systems, it is best to apply this small amount on a frequent basis rather than attempting to apply more water less frequently. On established crops, however, it is usually best to have a minimum irrigation period of one hour or longer. This minimizes uneven distribution due to mainline fill and drain times and establishes a larger wetting pattern under each tape outlet. For example, if the irrigation time is determined to be 35 minutes for a given day, it would probably be better to accumulate the time for two days and irrigate 70 minutes every other day.

MONITORING SYSTEM PERFORMANCE

The well-designed micro-irrigation system will have built-in diagnostic tools that will allow the operator to monitor the performance of the system, and to detect possible problems in the early stages. Included in this category are flow meters, pressure gauges, and submain riser filters.

Flow Meters

System flow meters should be installed on the main supply lines, and should provide readings of both instantaneous and cumulative flow. These meters should be read regularly and the readings kept in a logbook. Variations in the system flow rate may indicate that something in the system is amiss.

For example, a gradual decline in system flow rate as measured by the flow meters may indicate a problem with the pumping station or a clogging problem in the field. On the other hand, an unexpected increase in the system flow rate might be an indication of a pipeline break or the presence of leakage in the system. Measurements of cumulative flow will serve to verify water application schedules.

Pressure Test Points

The system should have sufficient pressure testing points so that an overall check of the system pressures can be made. Widely differing pressures in different sections of the system may indicate that some blockage, leakage, or other problem has arisen in some section of the system. Pressure checks should be regularly made, and the pressures recorded.

Submain Riser Filters

Submain riser filters are small, in-line or “wye” strainers installed at each submain riser. Under normal conditions these filters, which are usually 80 - 120 mesh, will collect few if any contaminants because the main filtration system will normally have removed this material. Periodic examination of these riser filters can be a valuable indication that the system is contaminated. In the case of a pipeline break or a failure of the main filter station, riser filters will help to prevent foreign material from entering the tape lines.

MAINTENANCE PROCEDURES FOR Aqua-TraXX TAPE

Flushing

In many micro-irrigation systems it has been found that provisions must be made to flush submain lines and lateral lines to remove settled sediments, and flushing constitutes an important maintenance routine. Research has shown that most settled sediments can be flushed from pipe or tubing with a flow velocity of one foot per second, which is referred to as the "scour velocity". In standard half-inch lateral lines, the 1 ft/sec scour velocity is equivalent to a flow rate of 1 gpm at the downstream end.

Mainlines, submains and lateral lines should be flushed thoroughly prior to system startup, and tape lines should be regularly flushed during the season. Open the ends of the lateral lines while the system is running and allow water to run into a container until it runs clear. Collect some of the dirty water in a glass jar, and examine it carefully. Take note of the nature of the impurities in the water. If there is a significant amount of contaminant in the flush water, find out what it is. Does it appear to be a bacterial slime? Are large aggregated particles present? Is there evidence of iron precipitation? Is there any material which could be sand from the media filter?

Examine the contaminant under a microscope. Put samples of the dirty water into two small jars or test tubes. Treat one with a few drops of chlorine bleach and the other with a few drops of hydrochloric acid. Note any changes: chlorine will attack organic matter, while acid will dissolve many inorganic precipitates. Acid or chlorine will not affect soil and sand particles.

Prevention of Clogging

The biggest potential problem facing the operator of a micro-irrigation system is clogging. Because the water passages in most tape emitters are very small, they easily become clogged by particles of mineral or organic matter. This can reduce emission rates, cause non-uniformity of water distribution, and thereby cause stress and damage to the crop.

Growers sometimes inadvertently cause clogging by injecting inappropriate chemicals or other substances into their systems.

In some cases, contaminants are present in irrigation water delivered to the user and are not adequately filtered out. These contaminants may include soil particles, living or dead organic materials, and scale from rusty pipes. In other cases, contaminants enter the system during the installation phase, and are not adequately flushed out of the system. Included in this category are insects, Teflon tape, PVC pipe shavings, and soil particles. Pipeline breaks often result in system contamination with soil, causing subsequent clogging problems.

In buried systems, soil particles may enter, or be sucked into, tape outlets. Roots may grow into these buried outlets to plug them.

Finally, contaminants may grow, aggregate, or precipitate in water as it stands in the lines or evaporates from tape outlets between irrigations. Iron oxide, manganese dioxide, calcium carbonate, algae, and bacterial slimes can form in micro-irrigation systems under certain circumstances.

The solution to a particular clogging problem must be based upon the nature of the problem. Acid treatment has been used successfully to dissolve calcium precipitates, and chlorine is frequently used to decompose organic materials.

Once a system is badly clogged, there is usually little that can be done to fix it. Therefore, the wisest course is to prevent clogging in the first place. Experience has shown that most clogging problems can be avoided by following a few simple rules:

1. Analyze the source water for suspended and dissolved solids, and design the irrigation, chemical injection, and filter systems accordingly.

2. Install secondary filters on submain risers to protect the system from pipeline breaks or filter system failures.

3. Install vacuum breakers on submain risers to prevent suction in lateral lines.

4. Take care during installation to minimize contamination by soil, insects, pipe dope, PVC pipe shavings, and the like.

5. Thoroughly flush the system before connecting tape to submains.

6. Practice regular chemical treatment (acid or chlorine).

7. Flush tape lines on a regular basis.

Prevention of Insect Damage

Ants, wireworms, and other insects may cause damage to tape. Insect damage typically takes the form of holes chewed through the sides of tape. Researchers have noted that insect damage is most severe in tape having wall thicknesses of less than 10 mils (0.010 inches).

Insect damage has been successfully controlled with insecticides. However, these chemicals are highly toxic and persist in the environment. For this reason, growers are advised to select a tape with sufficient wall thickness to prevent insects from making holes through the wall of the tubing.

Prevention of Root Intrusion

In micro-irrigation systems utilizing buried tape, plant roots may grow into tape outlets, effectively clogging them. This so-called “root intrusion” into tape outlets may be widespread throughout the field, severely compromising the effectiveness of the irrigation system. In advanced cases, there is no alternative but to replace the tape.

The tendency for root intrusion to occur varies widely according to crop type, the type of system components selected, depth and placement of the drip tape, and irrigation scheduling practices. It is known that moisture stress encourages plant root structures to expand more aggressively, seeking water. It is also known that roots will find and follow a seam on buried drip tape, and grow into outlets if they are placed along this seam.

Two of the most effective preventive measures against root intrusion are to schedule irrigation in such a way as to avoid moisture stress, and to select tape types which do not have a seam. Drip tapes employing slit type outlets are considerably less susceptible to root intrusion than are those with hole type outlets.

Other measures employed against root intrusion are chemical treatments with acid, acidic fertilizers, chlorine, or chemicals, which retard root growth. It must be noted that this type of chemical treatment, because it is used to retard the roots of the crop, may lead to serious crop damage if done incorrectly. Growers are strongly encouraged to seek expert advice before attempting chemical treatments to discourage root intrusion.

APPENDIX A
CONVERSION FACTORS

TO CONVERT	INTO	MULTIPLY BY
acres	hectares	0.4047
acres	sq feet	43,560
acres	sq meters	4,047
acres	sq miles	1.562x10-3
acres	sq yards	4,840
acre-feet	cu feet	43,560
acre-feet	gallons	3.259x10+5
atmospheres	ft of water	33.90
atmospheres	in of mercury	29.92
atmospheres	kg/sq cm	1.0333
atmospheres	kg/sq meter	10,332
atmospheres	pounds/sq in	14.70
bars	atmospheres	0.9869
bars	dynes/sq cm	1.0x10+6
bars	kg/sq meter	1.020x10+4
bars	pounds/sq ft	2,089
bars	pounds/sq in	14.50
BTU	kilowatt-hrs	2.928x10-4
Centigrade	Fahrenheit	(C x 1.8)+32
centimeters	feet	3.281x10-2
centimeters	inches	0.3937
centimeters	millimeters	10
cubic centimeters	cu inches	0.06102
cubic centimeters	gallons (U.S.)	2.642x10-4
cubic centimeters	liters	0.001
cubic centimeters	pints (U.S.)	2.113x10-3
cubic centimeters	quarts (U.S.)	1.057x10-3
cubic feet	cu cm	28,320
cubic feet	cu inches	1,728
cubic feet	cu meters	0.02832
cubic feet	cu yards	0.03704
cubic feet	gallons (U.S.)	7.48052
cubic feet	liters	28.32
cubic feet	pints (U.S.)	59.84
cubic feet	quarts (U.S.)	29.92
cubic feet/sec	million gals/day	0.646317
cubic feet/sec	gallons/min	448.831
cubic inches	cu cm	16.39
cubic inches	gallons	4.329x10-3
cubic inches	liters	0.01639
cubic meters	cu yards	1.308
cubic meters	gallons (U.S.)	264.2
cubic meters	liters	1,000
TO CONVERT	**INTO**	**MULTIPLY BY**

Dynes/sq cm	atmospheres	9.869x10-7
Dynes/sq cm	in of mercury at 0° C	2.953x10-5
Dynes/sq cm	in of water at 4° C	4.015x10-4
Dynes/sq cm	bars	1.0x10-4
feet	centimeters	30.48
feet	kilometers	3.048x10-4
feet	meters	0.3048
feet of water	atmospheres	0.02950
feet of water	in of mercury	0.8826
feet of water	kg/sq meter	304.8
feet of water	pounds/sq in	0.4335
gallons	cu cm	3,785
gallons	cu feet	0.1337
gallons	cu inches	231
gallons	cu meters	3.785x10-3
gallons	cu yards	4.951x10-3
gallons	liters	3.785
gallons (Imp.)	gallons (U.S.)	1.20095
gallons (U.S.)	gallons (Imp.)	0.83267
gallons of water	pounds of water	8.3453
gallons/min	cu ft/sec	2.228x10-3
gallons/min	liters/sec	0.06308
gallons/min	cu ft/hr	8.0208
hectares	acres	2.471
hectares	sq feet	1.076x10+5
horsepower	Btu/min	42.44
horsepower	foot-lbs./min	33,000
horsepower	foot-lbs./sec	550
horsepower (metric)	horsepower (British)	0.9863
horsepower (British)	horsepower (metric)	1.014
horsepower	kg-calories/min	10.68
horsepower	kilowatts	0.7457
horsepower	watts	745.7
inches	centimeters	2.54
inches	meters	2.54x10-2
inches	miles	1.578x10-5
inches	millimeters	25.4
inches	mils	1,000
inches	yards	2.778x10-2
in of mercury	atmospheres	0.03342
in of mercury	feet of water	1.133
in of mercury	kg/sq cm	0.03453
in of mercury	kg/sq meter	345.3
in of mercury	pounds/sq ft	70.73
in of mercury	pounds/sq in	0.4912
in of water	atmospheres	2.458x10-3
in of water	inches of mercury	0.07355
in of water	kg/sq cm	2.540x10-3
in of water	ounces/sq in	0.5781
TO CONVERT	**INTO**	**MULTIPLY BY**
in of water	pounds/sq ft	5.204

in of water	pounds/sq in	0.03613
kilograms	pounds	2.205
kilograms/cu meter	pounds/cu ft	0.06243
kilograms/hectare	pounds/acre	0.8924
kilograms/sq cm	dynes	980,665
kilograms/sq cm	atmospheres	0.9678
kilograms/sq cm	feet of water	32.81
kilograms/sq cm	in of mercury	28.96
kilograms/sq cm	pounds/sq ft	2,048
kilograms/sq cm	pounds/sq in	14.22
kilograms/sq meter	atmospheres	9.678x10-5
kilograms/sq meter	bars	98.07x10-6
kilograms/sq meter	ft of water	3.281x10-3
kilograms/sq meter	in of mercury	2.896x10-3
kilograms/sq meter	pounds/sq ft	0.2048
kilograms/sq meter	pounds/sq in	1.422x10-3
kilometers	feet	3,281
kilometers	meters	1,000
kilometers	miles	0.6214
kilometers	yards	1,094
kilometers/hr	feet/min	54.68
kilometers/hr	feet/sec	0.9113
kiloPascals (kPa)	pounds/sq in	0.14503
kilowatts	BTU/min	56.92
kilowatts	horsepower	1.341
kilowatt-hrs	BTU	3,413
kilowatt-hrs	horsepower-hrs	1.341
liters	cu cm	1,000
liters	cu feet	0.03501
liters	cu inches	61.02
liters	cu meters	0.001
liters	cu yards	1.308x10-3
liters	gallons (U.S.)	0.2642
liters	pints (U.S.)	2.113
liters	quarts (U.S.)	1.057
liters/min	cu ft/sec	5.886x10-4
liters/min	gals/sec	4.403x10-3
liters/sec	gallons/min	15.852
liters/sec-sq meter	gallons/min-sq ft	1.4726
meters	centimeters	100
meters	feet	3.281
meters	inches	39.37
meters	kilometers	0.001
meters	miles (naut.)	5.396x10+4
meters	miles (stat.)	6.214x10+4
meters	millimeters	1,000
meters	yards	1.094
meters/min	miles/hr	0.03728
meters/sec	feet/min	196.8
TO CONVERT	**INTO**	**MULTIPLY BY**
meters/sec	feet/sec	3.281
meters/sec	kilometers/hr	3.6

meters/sec	kilometers/min	0.06
meters/sec	miles/hr	2.237
meters/sec	miles/min	0.03728
miles (statute)	feet	5,280
miles (statute)	inches	6.336x10+4
miles (statute)	kilometers	1.609
miles (statute)	meters	1,609
miles/hr	cm/sec	44.70
miles/hr	feet/min	88
miles/hr	feet/sec	1.467
milligrams/liter	parts/million	1
milliliters	liters	0.001
millimeters	centimeters	0.1
millimeters	inches	0.03937
millimeters	mils	39.37
million gals/day	cu ft/sec	1.54723
mils	centimeters	2.540x10-3
mils	inches	0.001
parts/million	pounds/million gal	8.345
pounds	dynes	44.4823x10+4
pounds	grams	453.5924
pounds	kilograms	0.4536
pounds	ounces	16
pounds of water	gallons	0.1198
pounds/cu ft	grams/cu cm	0.01602
pounds/cu ft	kg/cu meter	16.02
pounds/sq in	atmospheres	0.06804
pounds/sq in	bars	0.0689
pounds/sq in	ft of water	2.307
pounds/sq in	in of mercury	2.036
pounds/sq in	kPa	6.895
pounds/sq in	kg/sq meter	703.1
pounds/sq in	pounds/sq ft	144
quarts (liq.)	liters	0.9463
square miles	acres	640
square meters	square feet	10.7639
square meters	square inches	1,550
tonnes (metric)	kilograms	1,000
tonnes (metric)	pounds	2,205
tons (short)	kilograms	907.1848
tons (short)	pounds	2,000
tons (short)	tonnes (metric)	0.9078
yards	meters	0.9144

APPENDIX B

REFERENCE TABLES OF SELECTED DATA

TABLE B-1: ROUGHNESS COEFFICIENT C VALUES FOR HAZEN-WILLIAMS EQUATION

VALUES OF C TYPE OF PIPE	RANGE	NEW PIPE	DESIGN C
PVC	160 - 145	150	150
Polyethylene	150 - 130	140	140
Asbestos-Cement	160 - 140	150	140
Cement-Lined Steel	160 - 140	150	140
Welded Steel	150 - 80	140	100
Riveted Steel	140 - 90	110	100
Concrete	150 - 85	120	100
Cast Iron	150 - 80	130	100
Copper, Brass	150 - 120	140	130
Wood Stave	145 - 110	120	110
Vitrified Clay		110	100
Corrugated Steel		60	60

Above values of C for use with Hazen-Williams Equation, friction head losses in feet per foot of pipe length for fresh water at 50 degrees Fahrenheit.

$$Hf = \frac{10.472}{C^{1.852}} \times \frac{Q^{1.852}}{D^{4.871}} \times L$$

Where Hf = Friction Head Loss (ft)
C = Roughness Coefficient
Q = Flow Rate (gpm)
L = Pipe Length (ft)
D = Pipe Inner Diameter (inches)

TABLE B-2: FRICTION LOSS IN POLYETHYLENE (PE) SDR RATED TUBE

LOSSES IN PSI PER 100 FEET OF TUBE (PSI/100 FT) C = 140						
SIZE ID GPM	**0.50** (0.622)	**0.75** (0.824)	**1.00** (1.049)	**1.25** (1.380)	**1.50** (1.610)	**2.00** (2.067)
1	0.49	0.12	0.04	0.01	0.00	0.00
2	1.76	0.45	0.14	0.04	0.02	0.01
3	3.73	0.95	0.29	0.08	0.04	0.01
4	6.35	1.62	0.50	0.13	0.06	0.02
5	9.60	2.44	0.76	0.20	0.09	0.03
6	13.46	3.43	1.06	0.28	0.13	0.04
7		4.56	1.41	0.37	0.18	0.05
8	**2.50**	5.84	1.80	0.47	0.22	0.07
9	(2.469)	7.26	2.24	0.59	0.28	0.08
10		8.82	2.73	0.72	0.34	0.10
12	0.06	12.37	3.82	1.01	0.48	0.14
14	0.08		5.08	1.34	0.63	0.19
16	0.10	**3.00**	6.51	1.71	0.81	0.24
18	0.13	(3.068)	8.10	2.13	1.01	0.30
20	0.15		9.84	2.59	1.22	0.36
22	0.18	0.05	11.74	3.09	1.46	0.43
24	0.21	0.07	13.79	3.63	1.72	0.51
26	0.25	0.09	16.00	4.21	1.99	0.59
28	0.29	0.10	18.35	4.83	2.28	0.68
30	0.32	0.11		5.49	2.59	0.77
35	0.43	0.15	**4.00**	7.31	3.45	1.02
40	0.55	0.19	(4.026)	9.36	4.42	1.31
45	0.69	0.24		11.64	5.50	1.63
50	0.83	0.29	0.08	14.14	6.68	1.98
55	1.00	0.35	0.09	16.87	7.97	2.36
60	1.17	0.41	0.11		9.36	2.78
65	1.36	0.47	0.13	**6.00**	10.86	3.22
70	1.56	0.54	0.14	(6.065)	12.46	3.69
75	1.77	0.61	0.16		14.16	4.20
80	1.99	0.69	0.18	0.03	15.95	4.73
85	2.23	0.77	0.21	0.03	17.85	5.29
90	2.48	0.86	0.23	0.03		5.88
95	2.74	0.95	0.25	0.03		6.50
100	3.01	1.05	0.28	0.04		7.15
110	3.59	1.25	0.33	0.05		8.53
120	4.22	1.47	0.39	0.05		10.02
130	4.90	1.70	0.45	0.06		11.62
140	5.62	1.95	0.52	0.07		13.33
150	6.38	2.22	0.59	0.08		15.15
160	7.19	2.50	0.67	0.09		17.08
170	8.05	2.80	0.75	0.10		
180	8.95	3.11	0.83	0.11		
190	9.89	3.44	0.92	0.12		
200	10.87	3.78	1.01	0.14		
225	13.52	4.70	1.25	0.17		
250	16.44	5.71	1.52	0.21		
275	19.61	6.82	1.82	0.25		
300		8.01	2.13	0.29		
325		9.29	2.48	0.34		
350		10.65	2.84	0.39		
375		12.10	3.23	0.44		
400		13.64	3.64	0.50		
425		15.26	4.07	0.55		
450		16.97	4.52	0.62		
475			5.00	0.68		
500			5.50	0.75		
550			6.56	0.89		
600			7.70	1.05		

TABLE B-3: FRICTION LOSS TABLES FOR LAYFLAT HOSE

LOSSES IN PSI PER 100 FEET OF TUBE (PSI/100 FT) C = 140

SIZE ID GPM	<u>**0.50**</u>	<u>**0.63**</u>	<u>**0.75**</u>	<u>**1.00**</u>	<u>**1.25**</u>	<u>**1.50**</u>
1	1.41	0.48	0.20	0.05	0.02	0.01
2	5.09	1.72	0.71	0.18	0.06	0.02
3	10.77	3.64	1.50	0.37	0.13	0.05
4	18.34	6.19	2.55	0.63	0.21	0.09
5		9.36	3.85	0.95	0.32	0.13
6	<u>**2.00**</u>	13.11	5.40	1.33	0.45	0.19
7		17.44	7.18	1.77	0.60	0.15
8	0.08		9.19	2.27	0.77	0.32
9	0.10		11.43	2.82	0.95	0.39
10	0.12		13.89	3.43	1.16	0.48
11	0.14		16.57	4.09	1.38	0.57
12	0.17		19.47	4.80	1.62	0.67
13	0.19			5.57	1.88	0.77
14	0.22			6.39	2.16	0.89
15	0.25			7.26	2.45	1.01
16	0.28			8.18	2.76	1.14
17	0.31			9.15	3.09	1.27
18	0.35	<u>**2.50**</u>		10.15	3.43	1.41
19	0.39			11.24	3.79	1.56
20	0.42	0.14		12.35	4.17	1.72
22	0.51	0.17		14.74	4.98	2.05
24	0.59	0.20		17.31	5.85	2.41
26	0.69	0.23			6.78	2.79
28	0.79	0.27			7.77	3.20
30	0.90	0.30			8.83	3.64
32	1.01	0.34			9.95	4.10
34	1.13	0.38			11.13	4.59
36	1.26	0.43	<u>**3.00**</u>		12.38	5.10
38	1.39	0.47			13.68	5.63
40	1.53	0.52	0.21		15.04	6.19
42	1.67	0.57	0.23		16.46	6.78
44	1.82	0.62	0.25		17.94	7.39
46	1.98	0.67	0.28		19.48	8.02
48	2.14	0.72	0.30			8.68
50	2.31	0.78	0.32			9.36
52	2.48	0.84	0.35			10.06
54	2.66	0.90	0.37			10.79
56	2.85	0.96	0.40	<u>**4.00**</u>		11.54
58	3.04	1.03	0.42			12.32
60	3.23	1.09	0.45	0.11		13.11
62	3.44	1.16	0.48	0.12		13.93
64	3.65	1.23	0.51	0.13		14.78
66	3.86	1.30	0.54	0.13		15.64
68	4.08	1.38	0.57	0.14		16.53
70	4.30	1.45	0.60	0.15		17.44
75	4.89	1.65	0.68	0.17		19.82
80	5.51	1.86	0.77	0.19		
85	6.16	2.08	0.86	0.21		
90	6.85	2.31	0.95	0.24		
95	7.57	2.56	1.05	0.26	<u>**6.00**</u>	
100	8.32	2.81	1.16	0.29		
105	9.11	3.08	1.27	0.31	0.04	
110	9.93	3.35	1.38	0.34	0.05	
115	10.78	3.64	1.50	0.37	0.05	
120	11.66	3.94	1.62	0.40	0.06	
125	12.58	4.25	1.75	0.43	0.06	
130	13.52	4.57	1.88	0.46	0.07	
135	14.50	4.90	2.02	0.50	0.07	
140	15.51	5.24	2.16	0.53	0.07	
145	16.55	5.59	2.30	0.57	0.08	
150		5.95	2.45	0.60	0.08	
160		6.70	2.76	0.68	0.10	
170		7.50	3.09	0.76	0.11	
SIZE ID GPM	<u>**2.00**</u>	<u>**2.50**</u>	<u>**3.00**</u>	<u>**4.00**</u>	<u>**6.00**</u>	<u>**8.00**</u>

180		8.34	3.43	0.85	0.12	
190		9.21	3.79	0.94	0.13	
200		10.13	4.17	1.03	0.14	0.03
210		11.09	4.57	1.13	0.16	0.04
220		12.08	4.98	1.23	0.17	0.04
230		13.12	5.40	1.33	0.19	0.05
240			5.85	1.44	0.20	0.05
250			6.30	1.56	0.22	0.05
260			6.78	1.67	0.23	0.06
270			7.27	1.79	0.25	0.06
280			7.78	1.92	0.27	0.07
290			8.30	2.05	0.29	0.07
300			8.83	2.18	0.30	0.08
325			10.24	2.53	0.35	0.09
350				2.90	0.40	0.10
375				3.29	0.46	0.11
400				3.71	0.52	0.13
425				4.15	0.58	0.14
450				4.61	0.64	0.16
475				5.10	0.71	0.18
500				5.61	0.78	0.19
550				6.69	0.93	0.23
600					1.09	0.27
650					1.27	0.31
700					1.45	0.36
800					1.86	0.46
900					2.31	0.57
1,000					2.81	0.69
1,100					3.35	0.83
1,200					3.94	0.97
1,300					4.57	1.13
1,400						1.29
1,500						1.47
2,000						2.50
2,500						3.78