Saskatchewan
Ministry of
Agriculture

IRRIGATION

Saskatchewan Trickle Irrigation Manual

The efficient, productive and sustainable use of water

Acknowledgments

June 1997 – The publication of the original "Prairie Provinces Trickle Irrigation Manual" was funded through the Canada-Saskatchewan Green Plan Agreement. The publication was researched and written by K. Kelk-Whenham, Kel-tech Irrigation and edited by W.J. King, PAg, Saskatchewan Water Corporation (Sask Water).

April 1999 – Edited and updated. Revisions to the design example were added in 1999 by Lloyd Barteski, P.Eng., Sask Water.

March 2005 – Edited and updated. Funded by the Canada-Saskatchewan Agriculture Green Plan Agreement.

May 2011 – Edited and updated

August 2011 – Edited and revised to be the "Saskatchewan Trickle Irrigation Manual" by the staff of the Irrigation Branch, Saskatchewan Ministry of Agriculture, notably Avery Nerbas A.Sc.T., Morley Sinclair A.Sc.T. and Lloyd Barteski, P.Eng. The revised manual is published by the Irrigation Branch and posted on the Irrigation Branch's internet website: http://www.irrigationsaskatchewan.com.

Cover photographs are from WJ Market Gardens and the Canada-Saskatchewan Irrigation Diversification Centre.

Units

Measurement units: the working units for this manual are United States and Imperial Units. A listing of equivalent metric units and conversion factors are provided in Appendix 3.

Gallons: all references to gallons in the manual indicate US gallons. There are 1.2 US gallons in 1.0 Imperial gallons.

Pipe size: typically pipe size refers to the nominal pipe diameter (Ø) for the indicated pipe. Irrigators and designers need to be familiar with the conventions used for referring to pipe size, notably the standard dimension ratio (SDR), nominal diameter (N.D.), inside diameter (I.D.), outside diameter (O.D.) and others. These conversions will be different for pipe materials, for instance: polyethylene (PE), polyvinyl chloride (PVC), aluminum, steel, cast iron, etc.

Saskatchewan Trickle Irrigation Manual

Table of contents

List of figures

List of tables

What is trickle irrigation?

Trickle irrigation, often called drip irrigation, falls under the broader heading of micro-irrigation. Micro-irrigation is the accepted term used to describe the frequent and low-volume application of water by small devices, commonly called emitters. Emitters are devices used to regulate the flow of water to the plants. The idea of trickle irrigation is to provide optimum growing conditions by applying water and nutrients directly to the plant. Quantities of applied water should approach the consumptive use of the plant, while maintaining a proper air-water balance in the soil for healthy root development. In Saskatchewan, producers can obtain assistance with engineering design, irrigation soil and water evaluations as well as irrigation cropping from the Ministry of Agriculture, Irrigation Branch, at www.agriculture.gov.sk.ca.

A trickle irrigation system is made up of various components: a pump or pressurized water source, filtration unit, main line, sub-mail line, manifold (also called header line), valves, fittings and lateral lines where the emitter devices are located (Figure 1). Additional equipment often used with trickle irrigation systems include pressure controllers, backflow prevention devices, chemical injectors for water treatment, fertilizer injectors, automatic timers, soil moisture monitoring devices and system failure alarms.

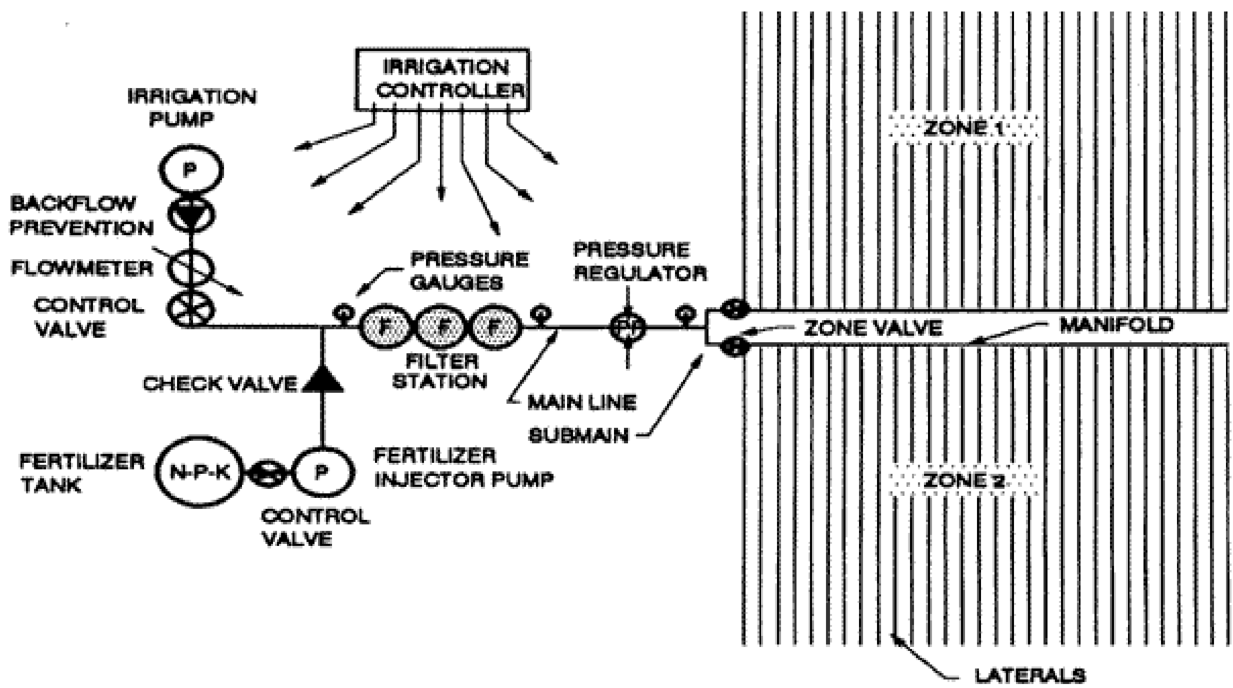


Figure 1: Typical layout and various components of trickle irrigation system

Advantages of trickle irrigation

- Lower volumes of water used – crops can be grown with a limited water supply.
- Better use of available water – this is especially important as competition for water resources between users becomes greater.
- Energy savings – lower water volumes and pressures reduce the energy needed for pumping.
- Reduced weed growth – only the targeted root zone of crops receive water.
- Optimum plant growth – water and fertilizer target the crop, reducing crop stress and creating ideal growing conditions without competition from weeds and other plants.
- Reduced chemical and labour costs – watering of crop rows means poor growing conditions for weeds between rows. Also, mulching and garden cloth work well with trickle systems.
- Soil temperature, air and water content stay relatively constant – the slow application of water to the crop over an extended period of time is less of a shock to crops than other methods of irrigation.
- Reduced risk of disease – diseases of foliage commonly spread by water are reduced since only the crop root zone is watered.
- Automation – trickle systems are readily automated.
- Less soil erosion – water applications can be managed to match soil infiltration, crop needs, and topography without runoff.

Disadvantages of trickle irrigation

- Plugging – since trickle irrigation emitters and other equipment are small, plugging can occur from algae, soil, foreign particles and hard water deposits. These problems are mostly avoided with proper filters and water treatment.
- Higher management requirement – the soil moisture must be monitored to a greater degree in order to avoid crop stress since only part of the crop's root zone is watered.
- Cost – the initial investment may be greater depending on the type of system required for particular crops, the equipment needed for water treatment, and the degree of automation.
- Control of the microenvironment – with only the roots being watered, misting of plants with water for cooling or frost protection is not possible. A dual system with both sprays and point source emitters can alleviate this problem, but may be cost-prohibitive.

SYSTEM COMPONENTS

Water source

The water source for trickle irrigation can be a well, rural pipeline, dugout, irrigation canal, reservoir, river, lake, holding tank or municipal water connection. The quantity and quality of the water source needs to be determined for the initial design. The use of water for irrigation requires approvals from the Saskatchewan Watershed Authority (SWA). Irrigation Certification of irrigation projects using more than 10 acre-ft annually of water (typically 10 acres or more in size) is required prior to development. The Saskatchewan Ministry of Agriculture, Irrigation Branch needs to be contacted in order to meet this requirement. The Irrigation Branch's "Irrigation Development Process" (see Appendix 4) can assist with the evaluation, system design and government approvals.

Power source

Electric power is preferred for trickle irrigation systems because of low maintenance and quiet pump operation. Electric power can be either single-phase (120-240v, 240-480v) or three-phase (480v). Most common is single-phase power that can handle up to a ten-horsepower motor. When three-phase power is not readily available, the capital cost to obtain power is high (up to $25,000 per mile) and may make the project not economical. A recent innovation is the development of the variable-speed motors that start at a low speed, then gradually increase in speed and horsepower. This avoids the sudden large power demand of conventional motor and allows higher horsepower motors to be used on single phase power lines.

Pumps

The type of pump selected for the trickle irrigation system depends on the water source, amount of lift from the intake to the pump, and requirements for pressure and volume. Centrifugal pumps, vertical turbine pumps and submersible pumps are commonly used for trickle systems. The motors of these pumps can be submersible, or non-submersible.

Centrifugal pumps are most commonly used when pumping water from shallow lakes, rivers, reservoirs, canals, very shallow wells, dugouts and holding tanks. Generally, centrifugal pumps are used only when the height from the water level to the pump intake is less that 20 feet.

Submersible and turbine pumps are commonly used in wells or high lift situations. Submersibles are often used in small wells.

Pump intakes often need a screen installed on their intake pipe to prevent large debris from entering the pump. The screen should be located at least two feet below water surface, but held up from the bottom of the water source. (Figure 2).

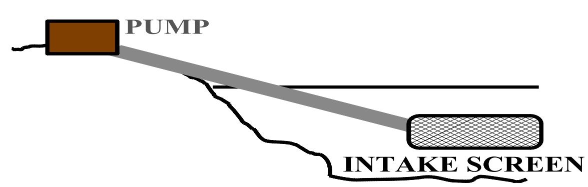


Figure 2: Pump intake pipe and screen

Backflow prevention valves, check valves and vacuum breakers

Backflow prevention valves and check valves are safety devices installed downstream from the pump or pressurized water supply. Backflow prevention valves are needed when low pressures can develop and allow contaminated water from the irrigation system to flow back into the water source and when dirty water can be sucked back into lateral lines thereby causing plugging of the emitters. Often considered optional equipment with trickle irrigation systems, they are standard equipment on public water supplies. They are also necessary when chemicals or fertilizers are being injected into the system.

Vacuum breakers or air release valves are another type of safety device that allow air into the header lines when the system is shut down. This prevents damage to the pipelines and prevents soil particles from being drawn back into the emitters. They are required for underground installation of dripper lines and are recommended for all trickle irrigation systems.

Chemical injectors

Chemical injectors are installed after the backflow prevention valves. They often use two independent injection ports: one before the filter for non-corrosive chemicals, and one after the filter for chemicals which are corrosive to the filter and do not need filtering. Chemicals for water treatment (chlorine or acids), fertilizers, herbicides, nematicides, or insecticides are injected into the system as a concentrated liquid which is then diluted with irrigation water.

Venturi injectors do not require a power source, are inexpensive and require little maintenance since there are no moving parts. These injectors use pressurized water diverted from the irrigation system to create a pressure drop. In order to ensure a large enough pressure drop, the injector should be installed on each side of a flow restrictor such as a valve. The mechanics of the venturi are very simple (Figure 3): water flows through the injector and increases speed at a constriction point thus creating a suction that draws chemical through a small hole located in the constricted portion of the injection device.

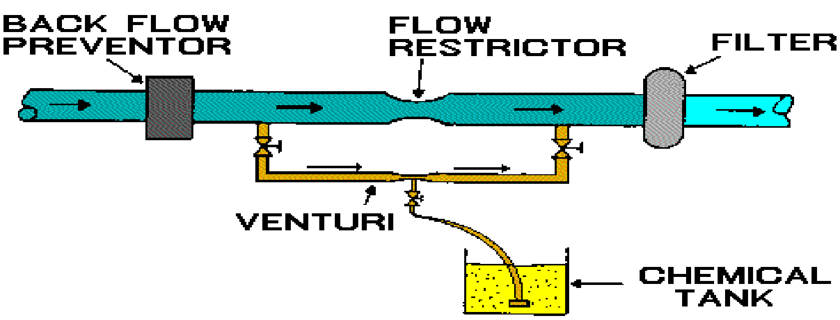


Figure 3: Typical layout of a venturi injector

Injector pumps are electric or water-driven. They are designed to inject under-pressure chemicals at a constant rate into the irrigation system. Metering injector pumps is recommended when it is crucial for a constant rate of chemical to be injected into the system. These pumps should have safety devices to prevent undiluted chemical from pumping into the system if water stops flowing.

Filters

Water quality can be greatly affected by physical, chemical and biological contaminants that may cause emitter plugging. Therefore, a properly designed, reliable filter is one of the most important parts in the irrigation system. There are several types of filters used alone or in combination with one another for effective filtration of contaminants. Selection of a filter depends on the size of the emitter's opening (emitter manufacturers have specific filter size recommendations), on the flow rate of the irrigation system and on the amount and type of contaminant to be filtered from the water source. Filters should be sized to remove particles $1/10^{th}$ the diameter of the smallest opening in the emitter flow path.

Cyclone filters or centrifugal separators are used as a primary filter in cases of very dirty water or high silt or sand load, followed by one of the filters described below for secondary filtering. Cyclone filters use centrifugal force to remove contaminants (Figure 4). Water enters the filter in a spinning motion which sends contaminants to the wall of the filter. These contaminants settle to the bottom of the filter in a collection chamber, while clean water is drawn from the center. The collection chamber may have a manual or an automatic flush valve at the bottom to clean the filter. Cyclone filters need a constant flow of water for efficient operation.

Media filters are commonly used for trickle irrigation systems because of their versatility and ability to trap large amounts of physical and biological contaminants in the filter bed. The filter media consists of a thin layer of coarse gravel and a thick layer of sand placed in pressurized tanks (Figure 5). The finer the sand, the smaller the particle removed by the filter will be.

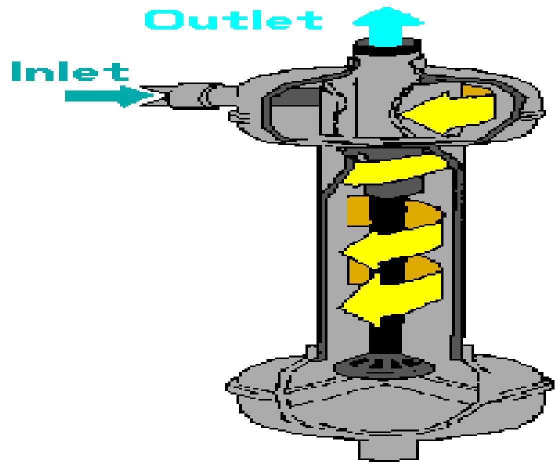


Figure 4: Cyclone filter

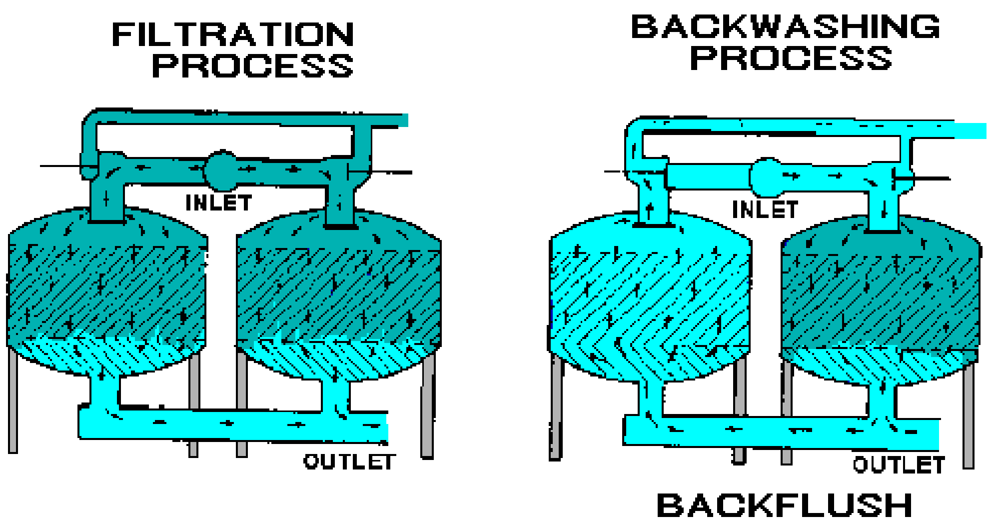


Figure 5: Media filters showing filtration and backflush process

Various sand sizes and shapes can be compared to screen mesh equivalents (Table 1). The size of media filter is determined by flow rate of the system and is measured by the surface area of the filter. Manufacturers provide recommendations, but in general, for every 20 USgpm (US gallons per minute) of flow there should be a minimum of one square foot of top surface area.

Media filters are cleaned by reversing the flow of water. This can be done manually or automatically by timers or pressure drop across the filter. Proper backwashing is necessary to avoid compaction and to clean the sand of contaminants. A screen filter of 200 mesh should be installed after the sand filter in case sand gets into the system during backwashing. At least two filters are required to allow for backwashing with filtered water.

Table 1: Equivalent screen mesh size to media size number

Media number	Screen mesh size
#8 Crushed granite	100-140
#11 Crushed granite	140-200
#12 Crushed silica	130-140
#16 Crushed silica	150-200
#20 Crushed silica	200-250

Disc filters are commonly used in place of screen filters if the water source is borderline-filled with organic contaminants. They consist of lightweight, compact stacks of grooved, washer-like discs (Figure 6) that provide more filter surface area than screen filters of the same size. The discs are compressed in a moulded plastic or stainless steel filter body by a screw-on cap and by water pressure when the irrigation system is operating.

The discs of the filters are stacked in opposing directions creating an interface of cross (X) shapes. Water flows from the outside through the discs. Debris is caught and held on and between the discs, while the clean water is dispersed from the centre. Discs are rated as mesh equivalents to screen sizes (see manufacturers' specifications). To backflush, run clean water backwards throughout the discs. Some disc filters have an automatic backwash feature.

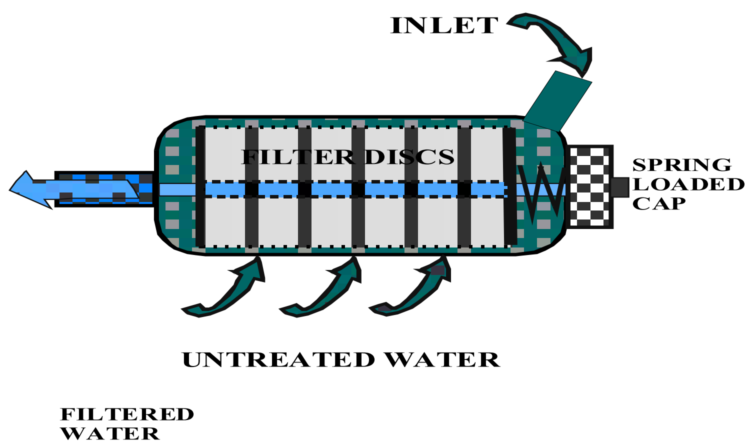


Figure 6: Disc filter

Screen filters are simple and inexpensive but only remove small amounts of physical and biological contaminants. These filters are used in combination with other filters as backup filters. They can be used alone when the water source is very clean and free from algae (which can squeeze through the screen and cause plugging). They come in a variety of shapes and sizes from in-line to y-shape (see Figure 7). The filtering screen is made of plastic or steel mesh. The mesh size is determined by the number of openings per linear inch (the more openings, the finer the filter). Most trickle systems require filters of 140 mesh or finer. Some screen filters are designed with a valve on the bottom which can be opened to clean the filter or partially left open to clean continuously while

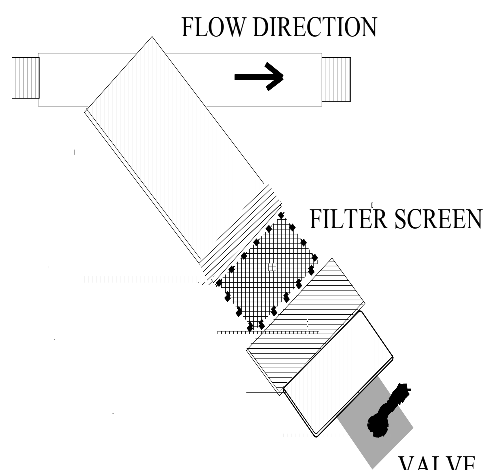


Figure 7: Screen filter

the system is operating. Self-cleaning screen filters with various innovations such as internal brushes which clean the filter screen are available.

Monitoring and control equipment

Valves are used in trickle systems to control and direct the flow of water. They include gate valves, ball valves and solenoid valves (for automatic operation).

Pressure regulators are used to maintain a desired pressure and flow rate for non pressure compensating emitters and drip tape. There are preset (non-adjustable) and adjustable pressure regulators. Pressure regulators are often used throughout (usually at the start of sub-main pipelines) the trickle system to stabilize pressure due to elevation differences or high water pressure.

Flow meters are often installed to monitor system flow rate. It is important to keep track of operating flow rates to find problems before they become serious. A reduction in flow may indicate plugging problems and an increase in flow may indicate a line break.

Pressure gauges are used as a visual aid to monitor pressure throughout the system. Gauges are generally placed at the pump discharge: one on each side of the filter to indicate when cleaning is necessary, and one in each sub-main throughout the system. Pressure gauges provide a quick reference as to whether or not the system is operating at the correct pressure. Reduction in pressure indicates plugging of filters, while an increase in pressure may indicate a faulty pressure regulator.

Irrigation controllers are devices that use timer clocks to automatically turn irrigation equipment off and on at preset times. The type of controller selected depends on the number of devices it must control. Applications which are commonly automated include starting and stopping the pump and chemical injector, soil moisture sensors, backwashing filters, and sequencing watering times for zones in the trickle system.

Distribution pipelines

Distribution pipelines for a trickle system include the mainline, sub-mains, manifold and laterals (see Figure 8). Plastic pipe is preferred because it has a higher resistance to corrosion, and its good friction loss characteristics (due to the smooth inner surface). Friction loss is the loss of pressure caused by friction between water flowing through the system and the pipe walls. The rougher the inside of the pipe, the higher the pressure loss due to friction will be. Friction loss is determined by the flow, length of pipe, and size of the pipe's internal diameter, and the type of pipe. See Appendix 1 for a sample Friction loss table (psi loss per 100 ft) for polyethylene pipe.

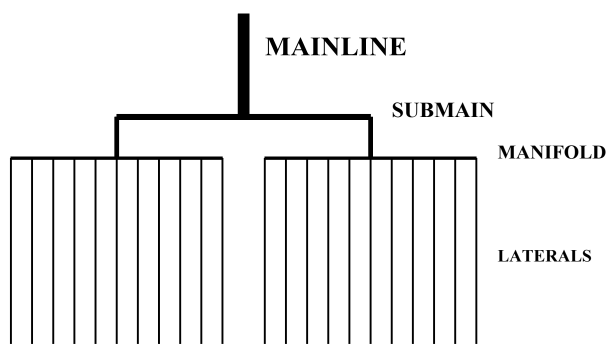


Figure 8: Trickle distribution line layout

It is important to use the correct friction loss tables for the chosen pipe. Use the manufacturers' friction loss data if possible. Flow velocities of more than five feet per second (fps) should be avoided when selecting the size of pipe. When there are multiple evenly-spaced outlets along a supply pipeline, as often is the case in trickle irrigation, the friction loss is a fraction of the friction loss in the same pipeline with only one outlet. This fraction is the multiple outlet factor "F" (Table 2) and depends on the number of outlets. Multiple outlet factor "F" is elaborated in the following example.

Table 2: Pipe friction loss factors "F" for multiple outlets

#OUTLETS	"F"	# OUTLETS	"F"	# OUTLETS	"F"
1	1.000	9	0.391	22	0.357
2	.0625	10	0.385	24	0.355
3	0.518	11	0.380	26	0.353
4	0.469	12	0.376	28	0.351
5	0.440	14	.0370	30	.0350
6	0.421	16	.0365	40	.0345
7	0.408	18	0.361	50	0.343
8	0.398	20	0.359	100	0.338

Data for Table 2 taken from Hardie Design Manual

Example using the multiple outlet factor "F"

Select the proper pipe size for 300 ft. manifold of polyethylene tubing with a 40 USgpm flow and 22 outlets.

Step 1
Select the appropriate friction loss chart for polyethylene pipe (use Appendix 1).
Look on the left-hand column for the 40 USgpm flow rate, look across chart and find the velocity (fps) less than 5 fps and friction loss (psi) which are just above the bolded lettered values (3.81 fps and 1.31 psi loss per 100 ft). Now look to the top of the chart to see which pipe size to select: namely 2 " N.D. (Nominal Diameter).
For 300 ft of 2" N.D. pipe the psi loss $H_{L'} =$ 1.31 psi /100 ft x 300 ft = 3.93 psi loss.

Step 2:
Friction loss decreases each time the water passes an outlet. This must be taken into account for the final friction loss calculation. Refer to Table 2 for multiple outlet factors "F".
"F" = 0.357 for 22 outlets extrapolated from Table 2.
The actual friction loss for the 2"Ø = $H_L = H_{L'}$ x F = 3.93 psi x 0.357 = 1.40 psi loss.

PVC pipe is a ridged plastic pipe which joins together by gluing or gasket lock. It can be affected by the sun's ultraviolet light and should be buried to avoid damage. PVC pipe is often used for mainline and sub-mains pipelines.

Polyethylene pipe can be high density or low density. High density polyethylene pipe is a stiffer, more durable tubing which can be used instead of PVC for mainlines or sub-mains in larger installations. It joins together with a special machine which welds the joints and fittings. Low density polyethylene pipe is flexible tubing which joins together by insert or compression fittings. Polyethylene pipe has some resistance to ultraviolet light but should also be buried. Polyethylene pipe is often used for mainline, sub-mains and manifolds pipelines. Note: always use stainless steel clamps for insert fittings, especially if the pipe is buried.

Trickle/drip tubing is thin-walled, polyethylene pipe which is very flexible, has good resistance to ultraviolet light (high in carbon black) and is used for lateral pipelines. This tubing is specially designed for trickle laterals and may have emitters already placed into the tube (in-line emitters) or emitters inserted on the outside. This type of tubing should have a lifespan of 20 to 25 years.

Linear drip tape is a very thin-walled plastic tape which has small holes throughout its entire length at specific intervals (see specific area drip in Figure 10). It is commonly used as a disposable type of watering system for annual row crops. The thickness of tape is directly related to lifespan and price (commonly sold by the pound). Common types of tape and their estimated life spans are: 4 MIL (four one-thousand inches wall thickness) lasting one to two years, 8 MIL lasting three to four years, and 12 MIL lasting five to seven years.

Emitters

There are several basic types of water delivery devices unique to micro-irrigation. They are designed to discharge water at low flow rates through small openings. The application rate of water is very small and slow, thus the name trickle or drip. The discharge rate per emitter is usually given in US gallons per hour or litres per hour (ranging from 0.5 to 25 gph or from 1.0 to 4.0 lph). Operating pressure ranges between two and 60 psi depending on the type of emitter (see manufacturers' specifications). Emitters can also be pressure-compensating, which means discharge rates remain relatively constant over a range of pressures.

Point source emitters are small devices inserted or moulded into plastic pipe which apply water from a discrete point. This allows pinpoint watering to the root area of the plant (see Figure 9). Some emitters are designed to self-flush at low pressure.

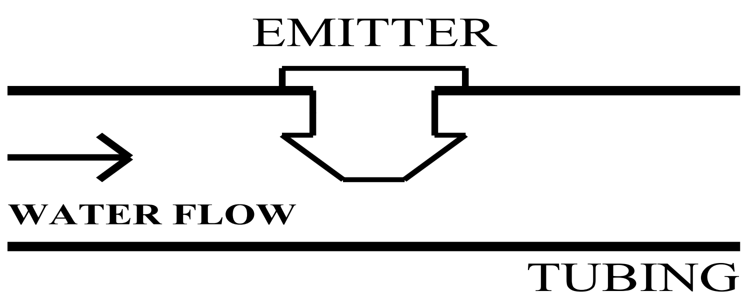


Figure 9: Inserted point source emitter

Specific area drip, also known as porous or weeping wall linear tape, is a small porous pipe commonly made from rubber, tyvac, paper, or plastic. Depending on soil texture, water spreads from the porous pipe to cover a specific planted area (see Figure 10). Porous wall pipe is not typically recommended for commercial agricultural operations since their application uniformity is highly variable.

Porous pipe or tape

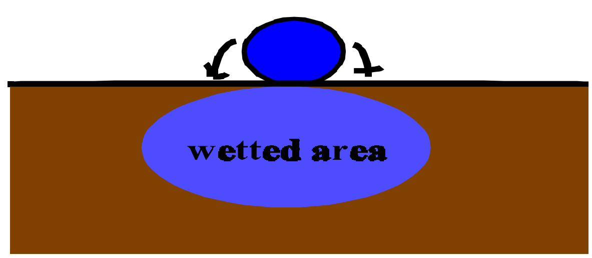


Figure 10: Specific area drip (porous pipe)

Spray emitter, or mini sprinklers, are devices that imitate larger spray heads, but on a smaller scale (see Figure 11). The wetted area is often larger due to higher flow rates than point source emitters. They are commonly used where a wash-down or syringing (cooling off) effects on plants is desired and for frost protection.

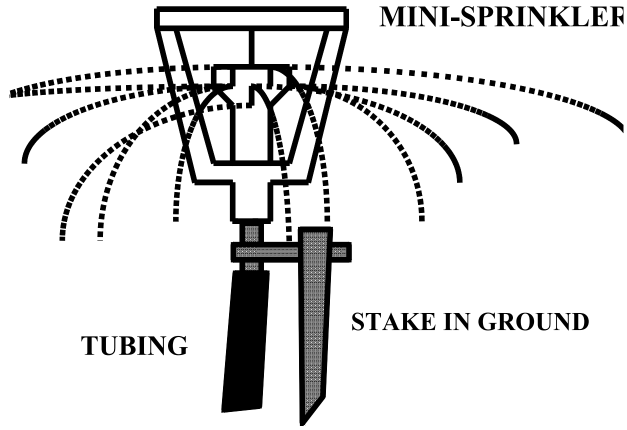


Figure 11: Mini-sprinkler

Bubblers have higher discharge rates (around one gallon per minute) than other common drip devices. They apply water as a small fountain or stream. Micro-bubblers are smaller versions of the traditional bubbler and have discharge rates around five to nine gallons per hour. These devices are ideal for larger trees or flower beds, but should have a small basin to contain water as the infiltration rate of the soil will probably be lower than the water application rate.

Sub-surface drip involves burying the dripper line. Often point-source emitter lines or specific area drip lines (porous pipe) are buried. There will be some movement of water upward due to capillary action which will be governed by soil texture. There could be problems for germination of shallow seeded crops in coarse soils or if the drip line is too deep. The advantages of burying the drip line include reduced damage by tillage equipment and longer pipe life due to protection from ultraviolet light. The problems with sub-surface drip are root-intrusion and difficulty evaluating whether drippers are plugged. One way to know if drippers are plugged is to place a micro-spray emitter at the end of each lateral as it comes out of the ground. When the micro-spray is working, it indicates that the lateral line is working.

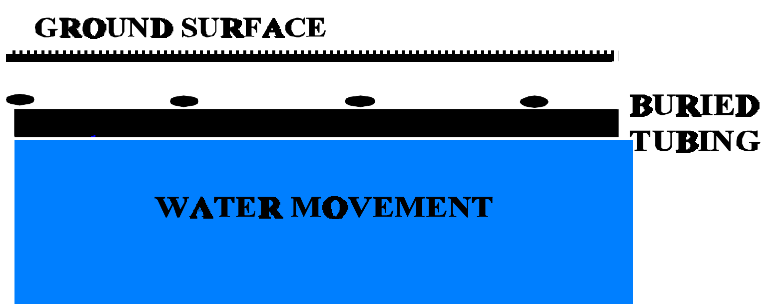


Figure 12: Sub-surface drip (point source emitters)

Trickle systems design

Design factors

Design of a trickle irrigation system begins with gathering information required for proper hydraulic design of the system. This information includes crop type and spacing; soil texture; climate factors; field size, shape and topography; and water source, quality and supply. Crop type determines plant and row spacing (See Table 3).

Table 3: Recommended plant and row spacing of various crop types

Crop type and height	Plant spacing	Row spacing
Fruit shrubs and trees (2-5 feet)		
Raspberries		
* Low bush blueberries	1 – 5 feet	4 – 12 feet
Haskap		
Grapes		
Fruit shrubs and trees (5-9 feet)		
Saskatoon berries		
Choke cherries	3 - 5 feet	16 - 20 feet
Sour cherries		
Buffalo berries		
Sea buckthorn		
Shelterbelt trees		
Poplar	10 -15 feet	10 -15 feet
Evergreen		
Fruit trees (9-20 feet)		
Pin cherries		
Apple trees	10 -15 feet	10-15 feet
Plum trees		
Low fruits and vegetables		
• Wide spacing •		
Rhubarb	3 feet	6 feet
Tomatoes	1.5 - 2 feet	4 feet
Cucumbers	1 - 1.5 feet	4 - 6 feet
• Close spacing •		
Strawberries	0.5 - 1.5 feet	4 feet
Corn	0.6 - 0.8 feet	3 - 4 feet
Garden vegetables		
Lettuce	Solid row	2 feet
Carrots	Solid row	2 feet

*Low bush blueberries must be burned every two to three years to enhance fruit development. Emitter laterals of the trickle system must therefore be buried to avoid damage (See sub-surface irrigation).

Field size, shape and topography

A detailed sketch of the trickle irrigation project should include: field size, shape, topography (elevation changes), water supply, power source and soil type (see Figure 15). Draw a sketch of the field to scale and in relationship to the north direction. The elevation changes of the field and the location of the water source will dictate the best direction to run laterals. For example, if the elevation changes in Figure 15 were greater, laterals should be run east-west to reduce pressure variability. Try to group laterals with similar elevation changes together for even flow distribution. Emitter placement on slopes is also important. If the emitter is placed below the plant on a downhill slope, there is a good chance the wetted area of the emitter will miss the plant. In such cases emitters should be placed above the plant (see Figure 13).

Soil texture will determine the number, discharge rate, and spacing of emitters. Water infiltrates different soil types at different rates and creates a different wetting pattern. In coarse, sandy soil, water moves down with little outward movement (Figure 14). Therefore, to wet a large enough volume of the plant root zone, select emitters with higher discharge or choose a closer spacing. In fine, clay soil, water moves outward and downward at much the same rate. (Figure 14). To avoid puddling and runoff when watering finer soils, use emitters with a lower discharge rate or increase the spacing of emitters (Table 4).

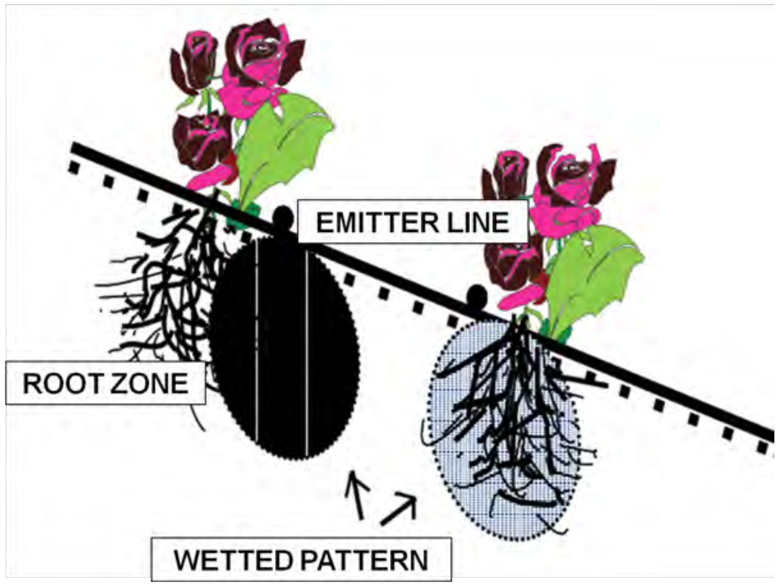


Figure 13: Emitter placement on slopes

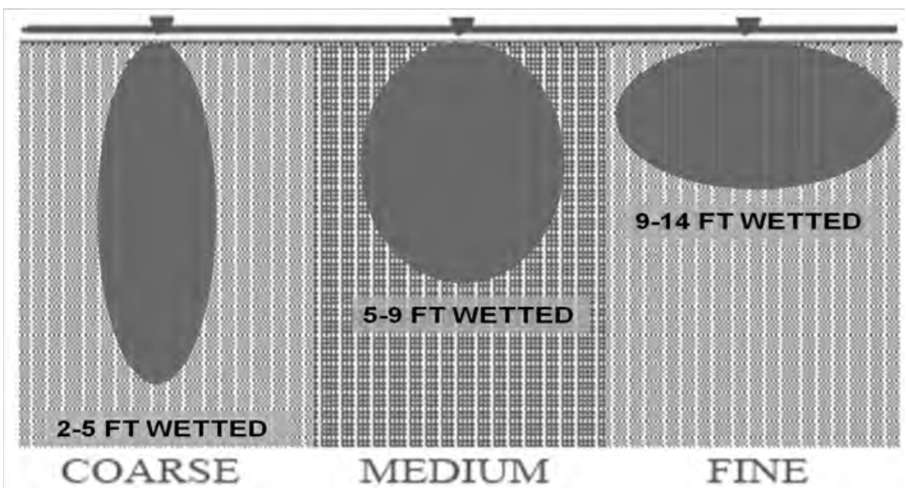


Figure 14: Wetting pattern in coarse, medium and fine texture soil.

Water requirement of plants and emitter selection

The following table has been developed to aid in general design of a trickle irrigation system. For larger acreages, it is recommended that more detailed design factors such as potential evapotranspiration rate, crop factor and irrigation efficiency be more precisely calculated by a professional irrigation designer. The Irrigation Branch, Saskatchewan Ministry of Agriculture, provides irrigation project design and irrigation soil and water assessment services as part of their Irrigation Development Process, as described at www. irrigationsaskatchewan.com.

Table 4: Recommendations for plant water required, emitter flow, type and spacing

Crop type and height	Soil type	Water required gallons/day/plant	Emitter flow and type gallons/hour		Emitter spacing
Fruit, shrubs and trees (2-5 ‘)	Coarse Medium Fine	1.5 gpd	1 gph 1-0.5 gph 0.5 gph	Point source Point source Point source	2-3 feet 2-3 feet 2-3 feet
Fruit, shrubs and trees (5-9’)	Coarse Medium Fine	4.0 gpd	1 gph 1-0.5 gph 0.5 gph	Point source Point source Point source	2-3 feet 2-3 feet 2-3 feet
*Shelter-belt trees	Coarse Medium Fine	10 gpd	1 gph 0.5-1 gph 0.5 gph	Point source Point source Point source	3 - 4 feet
Fruit, shrubs and trees (9-20’)	Coarse Medium Fine	22 gpd	17-25 gpd	**Micro-sprays	In row half way between trees
Low fruits and vegetables **Wide spacing**	Coarse Medium Fine	0.5 gpd	1.0 gph 0.5 gph 0.5 gph	Point source Point source Point source	At plant At plant At Plant
Close spacing	Coarse Medium Fine		0.5 gph	Point source, Drip tape or Micro-sprays	1- 1.5 feet
Garden vegetables **Solid spacing**	Coarse Medium Fine	0.3 to 0.5 gpd per foot of row	0.2-0.5 gph	Point source, Drip tape or Micro-sprays	1-1.5 feet

* Watering of shelterbelts for establishment and maintenance only.
**Micro-sprays are used because of high gallonage required for fruit trees of this size.

Example trickle irrigation design - saskatoon berries

Step 1
Determine the water source along with the location, size, soil type and topography of the field:

- Water source - well (pump tests at 20 gpm), depth to water = 55 feet
- Field location - SW-13-26-7-W3M.
- Field topography - see survey map of area (Figure 15).
- Soil texture - sandy (coarse).
- Field size - 240 feet x 250 feet.

Note: in example, all “gallons are US gallons.

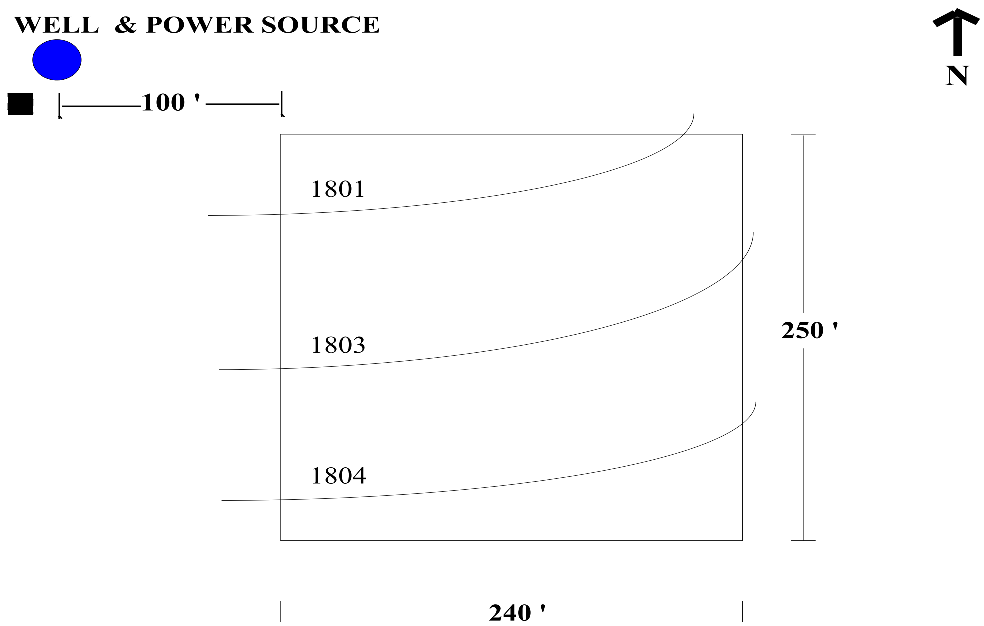


Figure 15: Preliminary sketch of field

Step 2
Contact Saskatchewan Ministry of Agriculture, Irrigation Branch for information on certification and licensing approvals for your project.

Step 3
Determine recommended plant spacing and row spacing for Saskatoon berry (see Table 3) and design field layout of irrigation system (see Figure 16):

- Plant spacing = 3 ft.
- Row spacing = 20 ft.

Step 4
Determine water required, emitter type, flow and spacing for Saskatoon berry fruit shrubs 5-9' in height (Table 4):

- Water required = 4.0 gallons per plant per day.
- Emitter type - point source, pressure compensating emitter: between 15 psi to 50 psi (as per manufacturer specifications).
- Emitter flow and spacing - one gallon per hour at two-foot spacing.

Step 5

Calculate number of laterals and total system flow when all emitters are running:

- Field width / row spacing = number of laterals.
- 240 feet/20 feet = 12 laterals.
- Row length = 250 ft.
- Emitter spacing = 2 ft.
- Emitter discharge rate = 1 gallon per hour.
- Total system flow (gallons per minute) = number of laterals x (row length/emitter spacing) x emitter discharge rate x 60 min/hr.
- 12 x 250 feet/2feet x 1 gph/60 min per hour = 25 gpm.

Step 6

Calculate system operating time:

- Water required = 4 gallons per day per plant.
- Plant spacing = 3 feet.
- Emitter flow = 1 gallon per hour.
- Emitter spacing = 2 feet.
- 4 gpd per plant x 3 feet/2 ft x 1 gallon per hour = 6.0 hours.

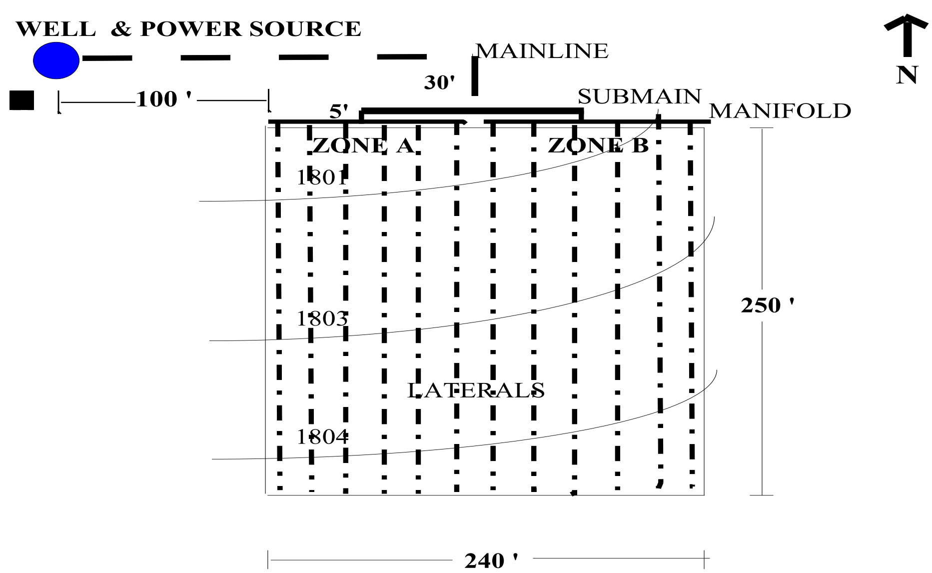


Figure 16: System layout of field

Step 7

Calculate number of zones required to irrigate field:

- Water source =20 gpm.
- Total system gpm = 25 gpm.
- #Z = 25/20 = 1.25 zones (round up to 2 zones).

Step 8

Calculate flow requirements per zone:

- Total system gpm = 25 gpm.
- Number of zones = 2.
- Q_z = 25/2 = 12.5 gpm per zone.

Step 9
Calculate flow requirements per lateral:
- Number of laterals per zone = 12/2 = 6 laterals.
- Flow per lateral = gpm per zone/ number of laterals per zone.
- Q_{Lat} = 12.5/6 = 2.08 gpm per lateral.

Step 10
Determine pipe size and pressure loss of lateral:
- Lateral length = gpm per lateral/flow per emitter (gph) x 60 min/hr x emitter spacing
  = 2.08/1at x 60 x 2 = 250 feet.
- Lateral length = 250 ft and flow per lateral = 2.08 gpm.

Manufacturers' recommendations are required for sizing of laterals because of the unique friction loss characteristics of the emitter barbs and roughness coefficients of different pipes. Basically, manufacturers will supply information for the longest length of run for a certain size of pipe with a specific spacing of their emitters. A method of making a preliminary estimate of pressure losses is shown in Step 11 and in the design supplement included in this document.

Step 11
Determine pipe size and pressure loss of manifold:
- Flow per zone = 12.5 gpm.
- Manifold length = field width/2 zones = 240 feet/2 = 120 feet per zone.

Note: Since we are center-feeding laterals with a sub-main connected at the centre of the manifold, we can size manifold pipe for half of flow per zone or three outlets in this case. The manifold length to use is 120 ft/2 = 60 feet and flow will therefore be three laterals x lateral flow of 2.08 gpm = 6.24 gpm.

From the friction-loss characteristics for polyethylene pipe (Appendix 1), we can use ¾" N.D. pipe in order for the flow velocity to be less than 5 fps. The pipe pressure loss will thus be just over 3.43 psi per 100 feet.

- Total psi loss in manifold = manifold length (feet)/100 feet x psi loss per 100 feet.
- Total loss in manifold = 60/100 x 3.43 = 2.06 psi loss for each side of manifold.
- The friction factor "F" (see Table 2) for three outlets is 0.518.
- The true friction loss will be 2.06 x 0.518 = 1.06 psi loss.

Step 12
Determine pipe size and pressure loss of sub-main and mainline:
- Total zone flow = 12.5 gpm (gallons per minute).
- Total sub-main and mainline length = 315 feet.

From Appendix 1 we find that a pipe size of 1½ inches with a pressure loss of just over 0.52 per 100 feet is needed in order for the flow velocity to be less than 5 fps. The total pressure loss will therefore be 315 feet/100 x 0.52 = 1.64 psi loss in the sub-main and mainline. The sub-main and mainline do not have multiple outlets so no F factor is applied.

Step 13
Determine filter requirements:
- Flow per zone = 12.5 gpm.
- Water source is a well that is low in biological and physical contaminants.
- Select a screen filter sized for 12.5 gpm or higher according to manufacturers' specifications.

Step 14
Determine required fittings:

Fittings are determined by the type of material being used and according to where there has to be a connection (valve, filter, injector, etc.), direction change, reduction in pipe size, or a closure to a pipe end. See irrigation suppliers for help in selecting the proper fittings for the job.

Step 15:
Pump sizing - Information required for proper pump selection:

- System operating pressure is based on pressure required for emitters to operate properly. This information is obtained from manufacturer specifications.
- Total system pressure loss is based on pressure loss due to friction of water flowing in system. Friction loss information for filters, valves and fittings can be obtained from manufacturers' specifications. Friction loss for mainline, sub-main and laterals can be calculated using charts in Appendix 1. Elevation loss or gain is calculated from a topographical map which is necessary if there are significant changes in elevation at the irrigated site.
- Suction lift is based on the vertical distance from pump impeller to water level.
- Miscellaneous loss includes 10-15 per cent pressure loss due to pump wear and unknown losses.
- Power source is electric, gas or diesel.
- Required flow in gallons per minute for largest zone in system.

This information can be taken to irrigation or pump suppliers who will determine the best pump suited for your system as every pump is individually rated.

Supplement: Example of detailed pump selection calculations

The methodology for determining the pressure losses for the example trickle irrigation system described in the manual is shown here in more detail. Calculation of the flow requirements and pressure losses allow the pumping unit size to be determined. These calculations are preliminary, but give a reasonable idea of the final system characteristics. A final design would use the results from field tests, surveys, and actual performance characteristics of the particular equipment that will be installed for the project.

Pressure losses in the lateral

Given: Pressure compensating emitters capable of supplying 1 gph over an operating pressure range of 15 psi to 50 psi.

- Average lateral length = 250 feet.
- Flow per lateral = 2.08 gpm.
- Number of emitters per lateral = 250/2 = 125 emitters per lateral.

Calculation of lateral inlet and end pressures

Assigned average pressure in lateral = 20 psi.

For a one-pipe-size lateral, the average pressure is related to lateral inlet pressure and the end of lateral pressure as follows:

- $H_I = P_{average} + 0.75\ H_L \pm 0.5\ \Delta Elev + H_M$
- $H_o = P_{average} - 0.25\ H_L \pm 0.5\ \Delta Elev - H_M$
- $H_I = H_o + H_L \pm \Delta Elev + H_M$

H_I = inlet pressure.
H_o = end of lateral pressure.
ΔElev = elevation difference along lateral.
H_L = lateral friction loss (calculated as $H_{L'}$ (from Appendix 1) x “F”, if required).
$P_{average}$ = average emitter pressure.
H_M = minor losses.

Note: Minor pressure losses due to emitter barbs can be estimated at 30 per cent of pipe friction losses. Losses due to barbs, filters, pressure regulators, injectors or chlorination equipment are calculated along with pipeline friction losses. Minor losses in the manifold, sub main, mainline and suction pipe due to connectors, valves, etc. are estimated as 10 per cent of total losses when determining total dynamic head (TDH) and pump size.

Given: Average lateral length (average for zone) = 250 feet.
Lateral hose diameter 0.622 inches I.D. (½ inch PE pipe N.D., a common size, see Appendix 1).
Average pressure = $P_{average}$ = 20 psi (assigned by designer).
Number of emitters per lateral = 125.
Lateral flow = 2.08 gpm.

1. Elevation difference along lateral (as per Figures 15 and 16):
- Zone A = 1,805 - 1,800 = 5 feet uphill ΔElev = 2.2 psi.
- Zone B = 1,806 - 1,800 = 6 feet uphill ΔElev = 2.6 psi.

Pipe friction loss H_L (calculated as $H_{L'}$ (from Appendix 1) x “F”, if required)
- $H_{L'}$ at 2.08 US gpm for ½” tubing N.D. = 1.76 psi per 100 feet.
- $H_{L'}$ = (1.76/100) (250) = 4.4 psi for pipeline without multiple outlets.
- $H_{L'}$ is pipe friction loss without outlets, consider each emitter an outlet and refer to Table 2.

2. Note: when the only outlet is at the end of the pipe then $H_{L'} = H_L$:
- Number of outlets = 125 so F = 0.338 (Table 2)
- $H_L = F \times H_{L'} = 0.338 \times 4.4 = 1.5$ psi

3. Minor losses (due to barbs, connectors, etc. in lateral)
- H_M = 30% of 1.5 psi = 0.5 psi.
- Assume half of the barb losses occur upstream and downstream of the emitter with the average pressure. Thus half of the barb losses are accounted for by the average pressure.

4. Lateral inlet and end pressure:
- H_I = 20.0 + 0.75 (1.5) + 0.5 (2.6) + 0.25 = 22.7 psi.
- H_o = 20.0 - 0.25 (1.5) - 0.5 (2.6) - 0.25 = 18.1 psi.

Both inlet and end pressures are within the operating range of the pressure compensating emitters. In a more detailed design, an evaluation of pressure and flow variation along the lateral and an evaluation of water distribution uniformity across the zone would be recommended.

Calculation of manifold (or header) pressure losses

Given: Manifold length = 120 feet.
Manifold length from junction with sub main to manifold end = 60 feet.
Number of outlets from sub main to manifold end = 3 so F = 0.518 (Table 2).
Manifold flow = Q = 3 x 2.08 = 6.24 gpm.
Manifold pipe size = ¾ inch N.D. = 0.824 inches I.D. in order for the flow velocity to be less than 5 fps.

1. Elevation difference along manifold:
- Zone A = $\Delta Elev_{Z1}$ = 1,800 - 1,800 = 0 feet (0 psi).
- Zone B = $\Delta Elev_{Z2}$ = 1,800 - 1,800 = 0 feet (0 psi).

Manifold pipe friction loss (as per Appendix 1 and Table 2):
- $H_L = F \times H_{L'}$ = 0.518 x 3.43/100 x 60 = 1.1 psi.

Minor friction losses and secondary filter losses:
Minor losses in the manifold are calculated as the pressure drop across the secondary filter, as is recommended by the filter manufacturer (assumed to be 5 psi in this example).
- H_M = 5.0 psi.

4. Manifold inlet pressures and flow
Manifold outlet pressure equals the lateral inlet pressure (Appendix 4.b):
- H_I = 22.7 psi.
- H_{M0} = 22.7 psi.
- $H_{MI} = H_1 + H_L + \Delta Elev_Z + H_M$ = 22.7 + 1.1 + 0.0 + 5.0 = 28.8 psi.

Flow into each zone to supply all laterals in the zone:
- Q_{ZA} = 6 x 2.08 = 12.48 gpm.

Upstream of each zone's filter the flow and pressure is 12.5 gpm at 28.8 psi.

Calculation of sub main and main pipeline pressure losses

The pipeline from the manifold to the main pipeline is called the sub main. In this example the sub mains for both Zone A and Zone B are the same size since the flow to each zone is the same. Since only one zone operates at a time, the size of the main equals the size of the sub main in this example.

Given: Main and sub main length = 315 feet.
Total flow in sub main and main line = 12.5 gpm.
Pipe size = 1½ inches N.D. (I.D. = 1.610 inches, from Appendix 1).

1. Elevation difference along sub main and main line:
- Zone A & Zone B elevation = $Elev_{A\&B}$ = 1,800 feet.
- Pump elevation = $Elev_P$ = 1,800 feet.
- Δ Elev = $Elev_P - Elev_{A\&B}$ = 1,800 - 1,800 = 0 feet (0 psi).

2. Elevation difference of pump and water in well is 55 ft at 20 gpm (pump test):
- Draw down in well at 12.5 US gpm discharge = $Elev_W$ = 1,745 feet.
- $\Delta Elev_D = Elev_P - Elev_W$ = 1,800 - 1,745 = 55 feet (23.8 psi).

Note: Irrigation from a groundwater source needs approval from the Saskatchewan Watershed Authority (SWA). A ground water investigation is needed to ensure that the ground water source can sustain the proposed trickle development without adversely impacting on the source and the existing ground water users.

Pipe friction losses in 1½ inches N.D main and sub main pipelines.
The zones will be supplied separately so at 12.5 US gpm:

- H_f = 0.52 psi per 100 feet.
- H_L = (0.52/100) (315) = 1.6 psi.

4. Minor friction losses along sub main and main pipelines

The primary filter is assumed to be a sand or media filter. The actual pressure drop across the filter is recommended by the specific filter manufacturer (for this example it is assumed to be 10 psi):

- $H_M = H_{filter}$ = 10.0 psi.

5. Total pressure losses in sub mains and main pipelines:

- $H_T = \Delta Elev + H_L + H_M$ = 0 + 1.6 + 10.0 = 11.6 psi.

Pump unit calculation of TDH (Total Dynamic Head)

- Maximum capacity required (Q): 12.5 US gpm.
- Pressure required at zone(H_{MI}): 28.8 psi.
- Head loss in main pipelines (H_T): 11.6 psi.
- Static lift (draw down) ($\Delta\ Elev_D$): 23.8 psi.
- Miscellaneous losses (10 per cent of total losses): 6.4 psi.
- Total Dynamic Head (TDH): 70.6 psi (163 feet).

- Pump efficiency (Eff. per cent): 50%.

- Horsepower required = $\frac{\text{TDA (ft) x Q (gpm)}}{\text{3,960 x Eff.\%}} = \frac{163 \times 12.5}{3{,}960 \times 50\%}$ = 1.03 BHP Continuous

The pumping unit requirements are identified as:

- Flow = 12.5 USgpm at a TDH = 163 ft at an efficiency of at least 50 per cent.

The estimated power (electric) needed is 1 BHP continuous.

If the pump will be driven by an engine, then the engine efficiency needs to be considered in order for the engine to be properly sized.

Step 16
List of Materials:
Make a list and price all the materials needed for the project. Prices have not been included in the following table since they will change over time.

Table 5: List of materials required for sample design

Description	Size	Amount	Unit price	Total price
Low density polyethylene pipe - mainline, sub-main	1½”	375 ft		
Low density polyethylene pipe - manifold	¾”	240 ft		
Drip tubing - laterals (manufacturers’ specs)	½”	3000 ft		
Pressure compensating emitters	1.0 gph	1500		
Emitter insertion tool (each manufacturer’s emitter may have a different size barb)	for specific emitter	1		
Figure 8’s (for lateral end closure)	½”	12		
Combination nylon or polyethylene insert tees (manifold to lateral connection)	¾” x ¾” x ½”	8		
Combination nylon or polyethylene insert elbows (manifold to lateral connection-ends)	¾” x ½”	4		
Combination nylon or polyethylene insert tee (sub-main to manifold connection)	1½” x ¾” x ¾”	2		
Nylon or polyethylene insert elbow (mainline-sub-main)	1½”	3		
Nylon or polyethylene insert tee (mainline-sub-main)	1½”	1		
Screen filter (150 mesh, max flow rate 28 gpm from manufacturer specs)	1”	1		
Vacuum flow breaker	1½”	1		
Stainless steel clamps	1- 1½ “	28		
Stainless steel clamps	½- ¾”	38		
Unions (filter to polyethylene for easy removal)	1”	2		
Male adapter polyethylene or nylon (union to poly)	1” male x 1½” insert	2		
Valves (mainline and on each side of sub-main)	l½ “	3		
Male adapter polyethylene or nylon (valve connection)	1½”	6		
Valve boxes and filter box	medium	4		
Pump and required fittings as suggested by pump supplier from Step 15				

Assembly, operation and maintenance

Assembly

Start assembly at the water source and continue to the laterals.

IMPORTANT NOTE: At each step of assembly flush the system until water runs clean. This removes any dirt, plastic pieces or small animals which may have contaminated the pipes or components during system installation.

Always wrap threaded connections with Teflon tape (clockwise) to prevent leaky connections.

Many components have "direction of flow" arrows (filters, back flow prevention valves, pressure regulators and check valves). Keep this in mind when installing these components.

Lateral tubing may be connected to the manifold in different ways. An insert or compression fitting is used if manifold is 1"Ø or less. A head connector, which has an insert fitting on one end and barb fitting on the other for insertion into pre drilled or punched holes in manifold pipe can be used on manifold 1"Ø or greater. If tubing is to be inserted into PVC pipe, then a gasket must be used. Spaghetti tubing is often used to connect low-pressure drip tape to the manifold by inserting a two-way barb emitter into manifold line by connecting the spaghetti tubing into a small hole in drip tape.

Lateral lines must be flushed throughout the growing season to keep the irrigation system clean and minimize emitter plugging. There are several methods used to close off the ends of laterals and the method chosen depends on the cost and how often lines will be flushed. Some of these methods include the "figure 8" closure which is most common and inexpensive, (slip bottom of "figure 8" fitting over the end of the tubing, bend tubing over and through top of a "figure 8" fitting). Wire or clamps are sometimes used, but are more time consuming for opening lateral ends to flush. Small valves are a more expensive type of closure for lateral ends, but are very handy for flushing laterals which need more frequent cleaning.

Lateral lines should be immediately staked after being installed to prevent movement from contraction and expansion which occurs from temperature changes (day to night).

When the system is completely installed, leave lateral lines open, flush again and then close off while system is running.

Walk the system, check for leaks and replace any emitters not working or missing.

Adjust pressure regulators and control valves for proper flow and operation.

Operation

The operation of the trickle system involves estimating when to irrigate and for how long. This is determined by crop demand which is dependant upon the crop's stage of growth, weather conditions, the water-holding capacity of the soil, and irrigation capacity to deliver water. It is important to gather information and learn as much as possible about the crop you are growing. The Saskatchewan Ministry of Agriculture, Irrigation Branch, horticulture groups and other experienced growers are good sources of information.

Many experienced growers learn to read a crop or probe the soil and know whether the crop needs watering. If you do not have this experience, there are many methods and tools available for monitoring soil moisture which can be used to help determine the need for watering. These methods include something as simple as taking a soil sample with a shovel or soil probe and feeling and smelling the soil for moisture. Other more automated devices can be used to turn the irrigation system off and on as required based on the moisture status of the soil. Tools used to monitor soil moisture include: tensiometers, evaporation pans, soil-moisture blocks, watermark sensors, automated atnometers, and time domain reflectometry. For more information on these devices, contact the Saskatchewan Ministry of Agriculture, Irrigation Branch.

Trickle irrigation offers the ability to maintain moisture in the root zone very near the optimum level for maximum crop growth. Automated systems can be set to irrigate any time soil moisture drops to a pre-set level, perhaps as often as several times per day. This is impractical for manually operated systems due to the labour necessary to determine if irrigation is needed and to operate the system. Trickle systems are usually designed to operate once per day, replacing the water used by the crop the previous day. Actual operation of most systems in Saskatchewan are more likely to be two or three times per week during hot weather in the summer months and less frequently when conditions are not as extreme.

Finer-textured soils such as clay loam are able to absorb and hold greater amounts of water than sandy loam or sand. However, they also have a tendancy to retain more water. For most soils and situations we can estimate available soil water in saturated soil as one inch of water per foot of soil. With sprinkler irrigation growers determine the rooting depth of the crop, calculate the available water held in the soil to that routing depth and schedule irrigation when cumulative crop use since the last irrigation reaches that amount.

Because trickle irrigation only replenishes the moisture in part of the root zone (usually only six to ten inches to either side of the tubing) and to make use of its ability to maintain uniform water availability, trickle irrigation should occur more frequently than sprinkler irrigation and should be based on crop water use. Growers deciding to use soil moisture capacity as a guideline should limit soil moisture depletion to 25 per cent of the available water.

Crop water use depends on temperature, humidity, wind speed, the age or size of the plants being irrigated and the stage of plant growth. High temperature, low humidity and high wind speed increase water use. Large plants and rapidly-growing young plants use more water than small or mature plants that have finished their physical growth. Widely-spaced plants will use less water per acre than closely-spaced plants but not less on a per plant basis. A good example of that difference is the water use of Saskatoon berry plants on a three by twenty foot spacing. If the inter-row area is kept cultivated and free of weeds the per tree and the per acre water use during the first few years of growth is very small: Less than 0.1 gallons per tree per day or about 73 gallons per acre per day. Mature Saskatoon bushes will use up to 10 gallons per tree per day or 7,300 gallons per acre per day.

Daily average water use during the May to September growing season will be between 0.2 and 0.25 inches for most areas of Saskatchewan. Maximum daily water use can exceed 0.3 inches. Row crops will have water use similar to solid seeded crops except where the row spacing is very wide. While no firm numbers are available, some work by Ministry irrigation agrologists suggests water use per acre will stay roughly the same until row spacing exceeds twice the height of the crop. At that point, it will begin to decrease.

Fertigation is the application of fertilizer through the irrigation system during irrigation. Trickle irrigation works very well with fertigation because of its very accurate delivery of water and fertilizer to the plant. A fertilizer is injected into the trickle system with an injector pump (see section on chemical injectors) preferably before the filter. The fertilizer used can either be liquid fertilizer or soluble fertilizer mixed with water. Commercial granular fertilizer does not dissolve well enough to use in this manner.

The amount and analysis of the fertilizer used will depend on the crop being grown.

Maintenance

A maintenance schedule for the trickle irrigation system should be set up immediately. Records of maintenance and performance should be kept on a daily or weekly basis to alert the operator of potential problems before they become costly. The following is a list of what to monitor on a trickle irrigation system:

- Lubricate and check oil-fill reservoir on pump.
- Check any electrical wires for damage. Rodents can chew on wires that are unprotected. It is a good idea to have traps or poison in the pump house to deter this damage or have wires installed in a sealed housing (such as another pipe) for protection from moisture, rodents and vandalism.
- Listen to the pump for any unusual noises and check for vibrations or leaks.
- Check pressure gauges to ensure normal operating pressure is maintained.
- Check pressure regulators and control valves if pressure gauges are indicating unusual pressure readings.
- Check all filter equipment and back flush or clean as necessary.
- Flush drip laterals periodically. Two to three times a year is recommended.

It may be necessary to treat the water for organic growth or hard water buildup. Generally, chlorine is the most common chemical used to prevent the growth of algae, bacteria and fungi in trickle systems. These microorganisms can multiply rapidly due to the slow flow of water and can easily plug emitters if not controlled. Often chlorine is injected at the end of an irrigation cycle to provide residual treatment while the system is shut down.

The amount of chlorine injected into the system depends on the concentration of the chlorine as well as the flow rate of the irrigation system. The most common form of chlorine used is liquid sodium hypochlorite (household bleach) with stock concentrations of 5.25, 10 and 15 per cent available chlorine. Chlorine treatment levels are given in parts per million (ppm) per gallons per hour (gph) of chlorine solution.

Sulfuric and phosphoric acids are commonly used to combat problems of hard water scale build-up that is caused from calcium and magnesium carbonate precipitates. When the pH of water is lowered to about 6.5 (7 being neutral) precipitation is prevented. The injection point should be downstream from metal connections and filters to avoid damage. **Remember, always pour acid into water. Never pour water into acid.**

Winterizing the irrigation system involves draining and blowing air into the lines. Replace all compnents to avoid mice, etc. from getting into the system over winter. Be sure to leave valves part-way open so they do no crack. Drain and lubricate pump, drain the filters and chemical injector or remove them for winter storage if outside. Be sure to plug any openings left in the system.

Appendix 1: Friction loss characteristics for polyethylene pipe

POLYETHYLENE (PE) SDR-PRESSURE RATED TUBE
(2306, 3206, 3306) SDR 7, 9, 11.5, 15 at c=140
PSI LOSS PER 100 FEET OF TUBE (PSI/100 FT)
Sizes ½" thru 4"; Flow GPM 1 thru 325

Size	½"		¾"		1"		1 ¼"		1 ½"		2"		2 ½"		3"		3 ½"	
ID	0.622		0.824		1.049		1.380		1.610		2.067		2.469		3.068		4.026	
Flow GPM	Velocity FPS	PSI Loss	Velocity FPS	PSI Loss	Velocity FPS	PSI Loss	Velocity FPS	PSI Loss	Velocity FPS	PSI Loss	Velocity FPS	PSI Loss	Velocity FPS	PSI Loss	Velocity FPS	PSI Loss	Velocity FPS	PSI Loss
1	1.05	0.49	0.60	0.12	0.37	0.04	0.21	0.01	0.15	0.00	0.09	0.00						
2	2.10	1.76	1.20	.045	0.74	0.14	0.42	0.04	0.31	0.02	0.19	0.01						
3	3.16	3.73	1.80	0.95	1.11	0.29	0.64	0.08	0.47	0.04	0.28	0.01	0.20	0.00				
4	4.21	6.35	2.40	1.62	1.48	0.50	0.85	0.13	0.62	0.06	0.38	0.02	0.26	0.01				
5	**5.27**	**9.60**	3.00	2.44	1.85	0.76	1.07	0.20	0.78	0.09	0.47	0.03	0.33	0.01	0.21	0.00		
6	**6.32**	**13.46**	3.60	3.43	2.22	1.06	1.28	0.28	0.94	0.13	0.57	0.04	0.40	0.02	0.26	0.01		
7	**7.38**	**17.91**	4.20	4.56	2.59	1.41	1.49	0.37	1.10	0.18	0.66	0.05	0.46	0.02	0.30	0.01		
8	**8.43**	**22.93**	4.80	5.84	2.96	1.80	1.71	0.47	1.25	0.22	0.76	0.07	0.53	0.03	0.34	0.01		
9	**9.49**	**28.52**	**5.40**	**7.36**	3.33	2.24	1.92	0.59	1.41	0.28	0.85	0.08	0.60	0.03	0.39	0.01		
10	**10.54**	**34.67**	**6.00**	**8.82**	3.70	2.73	2.14	0.72	1.57	0.34	0.95	0.10	0.66	0.04	0.43	0.01		
11	**11.60**	**41.36**	**6.00**	**10.53**	4.07	3.25	2.35	0.86	1.73	0.40	1.05	0.12	0.73	0.05	0.47	0.02	0.27	0.00
12	**12.65**	**48.60**	**7.21**	**12.37**	4.44	3.82	2.57	1.01	1.88	0.48	1.14	0.14	0.80	0.06	0.52	0.02	0.30	0.01
14	**14.76**	**64.65**	**8.41**	**16.46**	**5.19**	**5.08**	2.99	1.34	2.20	0.63	1.33	0.16	0.93	0.08	0.60	0.03	0.35	0.01
16	**16.87**	**82.79**	**9.61**	**21.07**	**5.93**	**6.51**	3.42	1.71	2.51	0.81	1.52	0.24	1.07	0.10	0.69	0.04	0.40	0.01
18	**18.98**	**102.97**	**10.81**	**26.21**	**6.67**	**8.10**	3.85	2.13	2.83	1.01	1.71	0.30	1.20	0.13	0.78	0.04	0.45	0.01
20			**12.01**	**31.86**	**7.41**	**9.84**	4.28	2.59	3.14	1.22	1.90	0.36	1.33	0.15	0.86	0.05	0.50	0.01
22			**31.21**	**38.01**	**8.15**	**11.74**	4.71	3.09	3.46	1.46	2.10	0.43	1.47	0.18	.095	0.06	0.55	0.02
24			**14.42**	**44.65**	**8.89**	**13.79**	**5.14**	**3.63**	3.77	1.72	2.29	0.51	1.60	0.21	1.04	0.07	0.60	0.02
26			**15.62**	**51.76**	**9.66**	**16.00**	**5.57**	**4.21**	4.09	1.99	2.48	0.59	1.74	0.25	1.12	0.09	0.65	0.02
28			**16.82**	**59.41**	**10.38**	**18.35**	**5.99**	**4.83**	4.40	2.28	2.67	0.68	1.87	0.29	1.21	0.10	0.70	0.03
30			**18.02**	**67.50**	**11.12**	**20.85**	**6.42**	**5.49**	4.72	2.59	2.86	0.77	2.00	0.32	1.30	0.11	0.75	0.03
35					**12.97**	**27.74**	**7.49**	**7.31**	**5.50**	**3.45**	3.34	1.02	2.34	0.43	1.51	0.15	0.88	0.04
40					**14.83**	**35.53**	**8.56**	**9.36**	**6.29**	**4.42**	3.81	1.31	2.67	0.55	1.73	0.19	1.00	0.05
45					**16.68**	**44.19**	**9.64**	**11.64**	**7.08**	**5.50**	4.29	1.63	3.01	0.69	1.95	0.24	1.13	0.06
50					**18.53**	**53.71**	**10.71**	**14.14**	**7.87**	**6.68**	4.77	1.98	3.34	0.83	2.16	0.29	1.25	0.08
55							**11.78**	**16.87**	**8.65**	**7.97**	**5.25**	**2.36**	3.68	1.00	2.38	0.35	1.38	0.09
60							**12.85**	**19.82**	**9.44**	**9.36**	**5.72**	**2.78**	4.01	1.17	2.60	0.41	1.51	0.11
65							**13.92**	**22.99**	**10.23**	**10.86**	**6.20**	**3.22**	4.35	1.36	2.81	0.47	1.63	0.13
70							**14.99**	**26.37**	**11.01**	**12.46**	**6.68**	**3.69**	4.68	1.56	3.03	0.54	1.76	0.14
75							**16.06**	**29.97**	**11.80**	**14.16**	**7.16**	**4.20**	**5.01**	**1.77**	3.25	0.61	1.88	0.16
80							**17.13**	**33.77**	**12.59**	**15.95**	**7.63**	**4.73**	**5.35**	**1.99**	3.46	0.69	2.01	0.18
85							**18.21**	**37.79**	**13.37**	**17.85**	**8.11**	**5.29**	**5.68**	**2.23**	3.68	0.77	2.13	0.21
90							**19.28**	**42.01**	**14.16**	**19.84**	**8.59**	**5.88**	**6.02**	**2.48**	3.90	0.86	2.26	0.23
95									**14.95**	**21.93**	**9.07**	**6.50**	**6.35**	**2.74**	4.11	0.95	2.39	0.25
100									**15.74**	**24.12**	**9.54**	**7.15**	**6.69**	**3.01**	4.33	1.05	2.51	0.28
110									**17.31**	**28.77**	**10.50**	**8.53**	**7.36**	**3.59**	4.76	1.25	2.76	0.33
120									**18.88**	**33.80**	**11.45**	**10.02**	**8.03**	**4.22**	**5.20**	**1.47**	3.02	0.39
130											**12.41**	**11.62**	**8.70**	**4.90**	**5.63**	**1.70**	3.27	0.45
140											**13.36**	**13.33**	**9.37**	**5.62**	**6.06**	**1.95**	3.52	0.52
150											**14.32**	**15.15**	**10.03**	**6.38**	**6.50**	**2.22**	3.77	0.59
160											**15.27**	**17.08**	**10.70**	**7.19**	**6.93**	**2.50**	4.02	0.67
170											**16.23**	**19.11**	**11.37**	**8.05**	**7.36**	**2.80**	4.27	0.75
180											**17.18**	**21.24**	**12.04**	**8.95**	**7.80**	**3.11**	4.53	0.83
190											**18.14**	**23.48**	**12.71**	**9.89**	**8.23**	**3.44**	4.78	0.92
200											**19.09**	**25.81**	**13.38**	**10.87**	**8.66**	**3.78**	**5.03**	**1.01**
225													**15.05**	**13.52**	**9.75**	**4.70**	**5.66**	**1.25**
250													**16.73**	**16.44**	**10.83**	**5.71**	**6.29**	**1.52**
275													**18.40**	**19.61**	**11.92**	**6.82**	**6.92**	**1.82**
300															**13.00**	**8.01**	**7.55**	**2.13**
325															**14.08**	**9.29**	**8.18**	**248**

Note: Bolded numbers on chart indicate velocities over five feet per second. Use with Caution.
Courtesy: Rain Bird Corporation.

Appendix 2: Irrigation service agencies in Saskatchewan

In Saskatchewan, the provision of irrigation services, management and certification is provided by:

Saskatchewan Ministry of Agriculture
Irrigation Branch
Box 609, 410 Saskatchewan Avenue West
OUTLOOK SK S0L 2N0
Phone: (306) 867-5500
Fax: (306) 867-9868
Website: www.agriculture.gov.sk.ca

Irrigation research and demonstration is provided by:

Canada Saskatchewan Irrigation Diversification Centre (CSIDC)
Box 700, 901 McKenzie Street South
OUTLOOK SK S0L 2N0
Phone: (306) 867-5400
Fax: (306) 867-9656
E-mail address: CSIDC@agr.gc.ca

Saskatchewan Ministry of Agriculture
Irrigation Branch
Box 609, 410 Saskatchewan Avenue West
OUTLOOK SK S0L 2N0
Phone: (306) 867-5500
Fax: (306) 867-9868
Website: www.agriculture.gov.sk.ca

Irrigation Crop Diversification Corporation (ICDC)
Website: www.irrigationsaskatchewan.com

Direct questions about water rights, ground water, water allocation and licensing can be referred to the Saskatchewan Watershed Authority (SWA) at:

SWA head office
111 Fairford Street East
MOOSE JAW SK S6H 7X9
Phone: (306) 694-3900
Fax: (306) 694-3465
E-mail address: comm@swa.ca
Website: www.swa.ca

SWA regional offices

Northeast (Nipawin)
Box 2133, 201-1st Avenue East
NIPAWIN SK S0E 1E0
Phone: (306) 862-1750
Fax: (306) 862-1771

SWA regional offices (cont.)

Northwest (North Battleford)
402 Royal Bank Tower
1101-101st Street
NORTH BATTLEFORD SK S9A 0Z5
Phone: (306) 446-7450
Fax: (306) 446-7461

Southwest (Swift Current)
Box 5000, 350 Cheadle Street West
SWIFT CURRENT SK S9H 4G3
Phone: (306) 778-8257
Fax: (306) 778-8271

Southeast (Weyburn)
Box 2003, 110 Souris Avenue
WEYBURN SK S4H 2Z9
Phone: (306) 848-2345
Fax: (306) 848-2356

East central (Yorkton)
120 Smith Street East
YORKTON SK S3N 3V3
Phone: (306) 786-1490
Fax: (306) 786-1495

Appendix 3: Equivalent unit conversion factors

1 inch = 25.4 millimetres (mm)
1 MIL = 1/1000 inch = 0.025 mm
1 foot = 0.3048 metres (m)
1 pound (mass) = 0.445 kilograms (kg)
1 pound = 4.448 Newtons (N)
1 psi = 2.31 feet of pressure head = 6.895 KPa
1 US gallon (USg) = 0.833 Imperial Gallon (Impg)
1 cubic foot (ft^3) = 7.48 US gallons (US g) = = 0.0283 cubic metres (m^3)
1 acre-foot (ac-ft) = 12 acre-inches (ac-in) = 43,560 cubic-feet (ft^3) = 325,851 US gallons (US g) = 1,233 cubic metres (m^3)
1 acre = 43,560 square feet (ft^2) = 0.4047 hectare = 4,047 square metres (m^2)

Appendix 4: Irrigation development process and request for technical assistance

Saskatchewan

Saskatchewan Ministry of Agriculture

Irrigation Development Process

A. PURPOSE

This process and fee schedule is intended to assist clients with irrigation development.

NOTE:

To qualify for technical assistance, the proposed project should be at least four hectare (10 acres) in area with sufficient water for a minimum 30 cm. (12-inch) annual allocation based on availability seven years in 10 for intensive projects and a 20 cm. (8-inch) annual allocation based on availability five years in 10 for non-intensive projects as determined by a water supply study undertaken by the Saskatchewan Watershed Authority (SWA).

B. INQUIRY AND APPLICATION

Upon receiving an inquiry Saskatchewan Agriculture will discuss the proposal and the irrigation development process with the client. Further services will be provided upon receipt of a Request for Technical Assistance (RFTA) and the appropriate fees. For district irrigation proposals, the RFTA must be approved by the appropriate Irrigation District and forward to Saskatchewan Agriculture.

C. WATER SUPPLY

The available water supply for non-district projects will determine the eligibility for any future assistance.

1. Surface Water
   The Saskatchewan Watershed Authority will determine the amount of water that is available for allocation to the proposed project.

2. Groundwater
   The Saskatchewan Watershed Authority will provide comments on water availability based on existing aquifer information. The client will be responsible for the cost of undertaking a hydrogeology study, if necessary, to determine whether or not sufficient groundwater is available for the project. The Saskatchewan Watershed Authority can assist the client in developing terms of reference for the study.

D. SITE INSPECTION AND PRELIMINARY ENGINEERING

Saskatchewan Agriculture will do an on-site inspection, GPS survey; discuss the irrigation development process and special development concerns and assess project feasibility. If a project appears feasible, a sketch plan and cost estimate for various alternatives will be prepared by Saskatchewan Agriculture.

E. IRRIGATION CROPPING AND ECONOMICS

Saskatchewan Agriculture Irrigation Agrologists can provide agro-economic information and publications to help clients understand the economic and agronomic impact of irrigation development on their farm.

...2

F. **IRRIGATION CERTIFICATION**

An Irrigation Certificate is required under *The Irrigation Act, 1996* for all new projects allocated more than 12,300 cubic metres (10 acre feet) of water, excluding effluent utilization projects. To ensure environmental and economic sustainability all proponents, regardless of project size and water source, are encouraged to have their soil and water tested. An Irrigation Certificate will be issued for each irrigation project that meets soil and water compatibility standards. A copy of the Irrigation Certificate (or soil/water investigation report for effluent utilization projects) will be provided to the client when all fees have been paid. Saskatchewan Environment may require soil and water investigations for effluent irrigation projects as part of their approval process.

Client Cost for Irrigation Certification:
First Parcel up to 64.8 hectares (160 acres) or portion thereof - $1,365.00 (GST included)
Each additional parcel up to 64.8 hectares (160 acres) or portion thereof - $1,155.00 (GST included)

G. **IRRIGATION PLAN**

A plan showing the general layout and recommended irrigation equipment for the proposed development will be prepared by Saskatchewan Agriculture. The plan is required by SWA for the issuance of the Approval to Construct and Water Rights Licence. It may also be used for approvals issued by Saskatchewan Environment and Department of Fisheries and Oceans.

H. **APPROVAL TO CONSTRUCT WORKS**

If a plan has been approved, an Irrigation Certificate has been issued, recognized standards are met, and other clearances are in order, the Saskatchewan Watershed Authority will issue an Approval to Construct Works to the non-district client. For effluent utilization, Saskatchewan Environment will issue the appropriate approvals.

I. **IRRIGATION SYSTEM INSTALLATION**

Additional field surveying for equipment installation or confirmation of the preliminary design can be provided upon request of the client.

J. **APPROVAL TO OPERATE**

Upon confirmation that the project is constructed and all approvals are in place, either Saskatchewan Watershed Authority will issue a Water Rights License for the use of surface or groundwater or Saskatchewan Environment will issue an approval for effluent irrigation. District irrigators will be required to enter into a Water Supply Contract with the irrigation district providing services.

For more information contact:

SASKATCHEWAN MINISTRY OF AGRICULTURE
Box 609, 410 Saskatchewan Avenue West
OUTLOOK SK S0L 2N0
Phone: (306) 867-5500 Fax: (306) 867-9868

Saskatchewan

Saskatchewan
Ministry of
Agriculture

Request for Technical Assistance

CLIENT INFORMATION:

Applicant's Name (please print) ____
(Hereinafter referred to as the Client)

☐ Individual ☐ Incorporated Farm ☐ Municipality ☐ Other

Address ____

____ Postal Code ____________

Home Land Location: Quarter ________ Township _________ Range ________ W _____

E-mail ______________________________________ Fax __________________

Telephone ______________________ Cell ______________________

PROJECT INFORMATION:

☐ Irrigation District (Name) ____________; ☐ Non-District________; ☐ Non-Agricultural ________

Project Land Location ___________________________________ R.M. No. __________

Landowner's Name ____

Proposed Size _______________ Acres/Hectares Water Source ________________

Proposed Method of Irrigation: ☐ Sprinkler ☐ Flood ☐ Trickle ☐ Other ________________

Anticipated Date of Development: _____/_____/_____ Please allow sufficient lead time for investigations.
Day / Month / Year

The project is: ☐ new irrigation development ☐ re-development of old irrigation ☐ combination of old and new

TECHNICAL ASSISTANCE AND FEE SCHEDULE ***(All fees include GST)***

The Client hereby requests Saskatchewan Ministry of Agriculture to provide the following technical services:

☐ **Preliminary Engineering:**
Project feasibility assessment (on-site inspection, client consultation, preliminary water availability study, sketch plan & preliminary cost estimate) $0.00

☐ **Irrigation Certificate/Soil Water Investigation:**
Soils Investigation: First parcel up to 64.8 hectares (160 acres) or portion thereof .... $ 1365.00
Each additional parcel up to 64.8 hectares (160 acres) or portion thereof $1155.00
Note: Soil and water analytical costs are included in the soil investigation fee.

☐ **Other Services:**
Engineering services such as pivot point staking, drainage surveys and design, etc $0.00

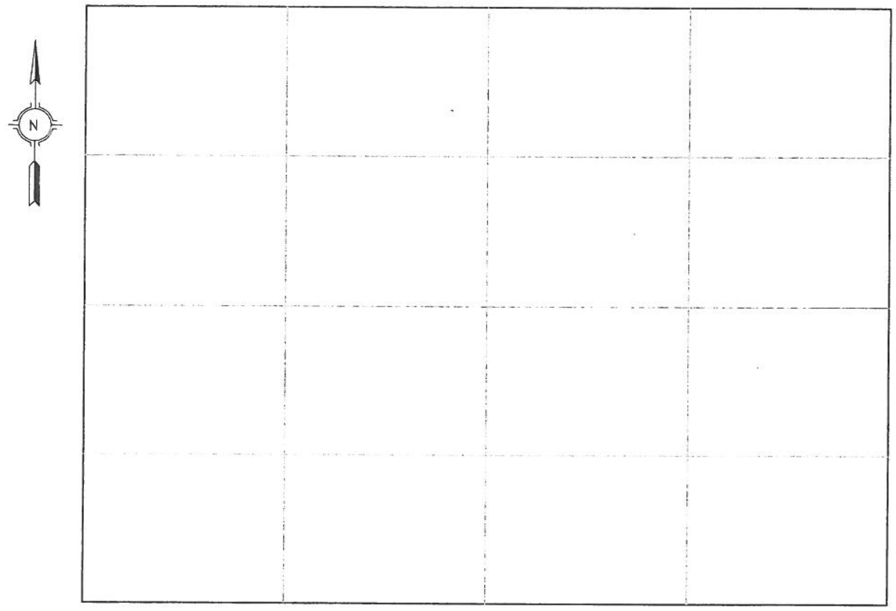
Payments should be payable to the "Minister of Finance"

☐ Additional Material Attached

OFFICE USE ONLY		
Receipt # ________	Amount $________	Date ____/____/____ (d/m/y)
Project #		

April 1, 2010

SKETCH: Show locations of the legal boundaries of affected parcels, proposed irrigable area, source of supply and the location of all underground utilities present.



______ Quarter of Section ______ Township ______ Range ______ West of _____ Meridian

Information provided will be used for future program delivery/development/evaluation and statistical purposes by Saskatchewan Agriculture staff. The information may be shared with provincial and federal agencies, research scientists and agri-business. It may also be used to provide you with information on future programs from which you may benefit.

I (We) hereby make application for services and assistance in accordance with the provisions of the current Irrigation Development Process, and I (we) acknowledge responsibility for providing or obtaining right of entry for all areas affected by the proposed project and for obtaining approvals, agreements, licences, etc. under the appropriate provincial and federal legislation prior to development. I (We) authorize Saskatchewan Agriculture, its employees and agents, to enter upon the lands to conduct all necessary field inspections, tests and surveys required to determine the feasibility of irrigating the lands listed in this application and for post construction monitoring. I (We) also agree to pay Saskatchewan Agriculture for the technical services provided according to the listed fee schedule and/or estimate of costs. I (We) acknowledge these charges as a debt due Saskatchewan Agriculture and may be recovered from the client. I (We) further agree to contact utility companies to have all underground lines marked when requested to do so.

The client hereby requests the services indicated and agrees to pay the fee identified for each service provided.

______________________________ ________/________/________

Signature of Client (Day/Month/Year)

______________________________ ________/________/________

Signature of Owner (Day/Month/Year)

______________________________ ________/________/________

Field Officer's Signature (Day/Month/Year)

SASKATCHEWAN MINISTRY OF AGRICULTURE
Box 609, 410 Saskatchewan Avenue West
OUTLOOK SK S0L 2N0
Phone: (306) 867-5500 Fax: (306) 867-9868

Saskatchewan
Ministry of
Agriculture