B.C. SPRINKLER IRRIGATION MANUAL

Chapter 4

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LIMITATION OF LIABILITY AND USER'S RESPONSIBILITY

The primary purpose of this manual is to provide irrigation professionals and consultants with a methodology to properly design an agricultural irrigation system. This manual is also used as the reference material for the Irrigation Industry Association's agriculture sprinkler irrigation certification program.

While every effort has been made to ensure the accuracy and completeness of these materials, additional materials may be required to complete more advanced design for some systems. Advice of appropriate professionals and experts may assist in completing designs that are not adequately convered in this manual.

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4 CROP, SOIL AND CLIMATE

Designing an efficient irrigation system requires a good understanding of soil texture, soil moisture and crop relationships. The effects of soil type, crop rooting depth, and climate are important when considering irrigation system application rates and set times. Six specific design criteria need to be selected or calculated: 1). Maximum Soil Water Deficit, 2). Maximum Irrigation System Application Rate, 3). Maximum Irrigation Interval, 4). Peak Evapotranspiration Rate, 5). Peak Irrigation System Flow Rate and 6). Annual Irrigation System Demand.

4.1 Maximum Soil Water Deficit

The maximum soil water deficit is the maximum amount of water that can be removed by the crop from the soil before irrigation is required. Maximum soil water deficit is measured in inches or millimeters. It is calculated by determining crop rooting depths, the soil's available water storage capacity and the crop's availability coefficient.

Equation 4.1 Soil Water Storage (SWS)

$$SWS = RD \times AWSC$$

where

SWS = soil water storage (in or mm)
RD = rooting depth (ft or m)
AWSC = available water storage capacity (in/ft or mm/m)

Equation 4.2 Maximum Soil Water Deficit (MSWD)

$$MSWD = SWS \times AC$$

where

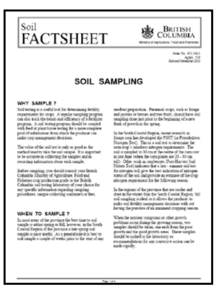
MSWD = maximum soil water deficit (in or mm)
SWS = soil water storage (in or mm)
AC = availability coefficient (decimal)

Effective Rooting Depth (RD)

The effective rooting depth (RD) of a mature crop is that depth of soil from which a crop removes a significant amount of water. The normal effective rooting depths for crops grown in deep, uniformly porous, friable and fertile soils are given in Table 4.1. These depths must be modified for soils which do not permit normal root development. Compaction of the surface soil, excessively coarse subsoil, impervious subsoil, poor soil drainage, high water tables, soil chemistry and fertility problems may inhibit normal root development and reduce the effective rooting depth for irrigation. Irrigation systems must be designed for mature crop requirements. More frequent irrigations at shorter durations will be required for crops that have not reached full rooting depth.

Available Water Storage Capacity (AWSC)

The available water storage capacity (AWSC) of the soil is the depth of water that can be retained between field capacity and the permanent wilting point. The capacity of a soil to store water depends upon the composition of the soil by particle size (texture) and the soil particle arrangement (structure). To obtain an estimate of the water holding capacity of a soil it is necessary to determine soil textures within the effective rooting depth of the crop to be irrigated.


Soil FACTSHEET

BRITISH COLUMBIA

SOIL SAMPLING

WHY SAMPLE ?

WHEN TO SAMPLE ?

The textural characteristics of mineral soils are distinguished by the percent composition of sand, silt and clay, as shown in Figure 4.1. If the soil texture is not known, soil samples should be taken and analyzed. Refer to Soil Sampling factsheet. Table 4.2 can be used to estimate the AWSC of the soil once texture has been determined. The total AWSC of the effective rooting zone is obtained by adding the AWSC of the various textural layers.

Soil Sampling (Factsheet 611.100-1)

Availability Coefficient (AC)

The availability coefficient (AC) is used to determine the amount of water that the crop can extract from the soil. Different crops have varying availability coefficients. Only a portion of the total AWSC is readily available for plant use. The availability coefficient (AC) is the maximum fraction of the total AWSC stored in the root zone that can be removed by the crop before irrigation is required. Allowing depletion of soil moisture to exceed the levels indicated by the availability coefficient may result in crop stress and a reduction in crop yields. Table 4.3 lists the availability coefficient for various crop types.

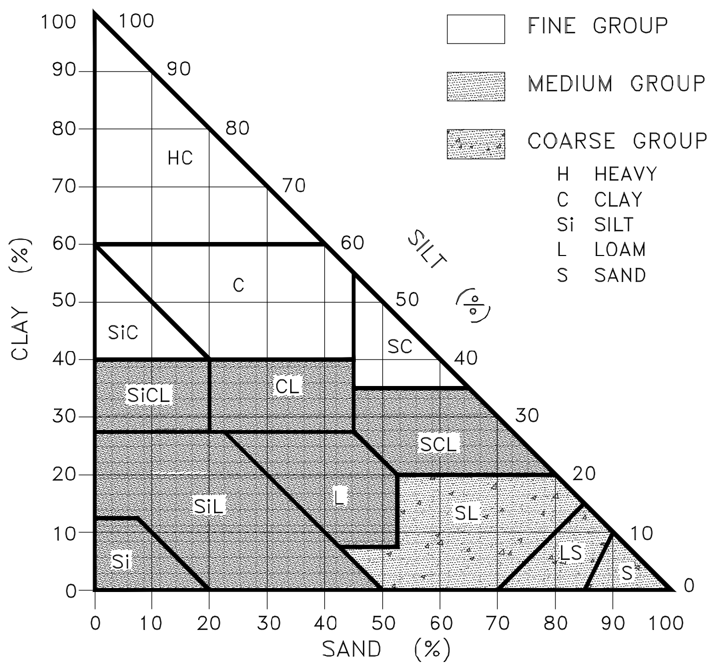


Figure 4.1 Soil Texture Triangle

Table 4.1 Effective Rooting Depth of Mature Crops

Shallow 0.45 m (1.5 ft)	Medium Shallow 0.6 m (2 ft)	Medium Deep 0.9 m (3 ft)	Deep 1.2 m (4 ft)
Cabbages	Beans	Brussels Sprouts	Alfalfa
Cauliflowers	Beets	Cereal	Asparagus
Cucumbers	Blueberries	Clover (red)	Blackberries
Lettuce	Broccoli	Corn (sweet)	Corn (field)
Onions	Carrots	Eggplant	Grapes
Pasture species	Celery	Kiwifruit	Loganberries
Radishes	Peas	Peppers	Raspberries
Turnips	Potatoes	Squash	Sugar beets
	Spinach	Saskatoons	Tree Fruits (12' x 18')
	Strawberries	Tree Fruits (6' x 12')	
	Tomatoes		
	Tree Fruits (3' x 10')		

Table 4.2 Available Water Storage Capacity (AWSC)		
Soil Texture	**AWSC**	
	Inches of Water per Foot of Soil (in/ft)	**Millimetre of Water per Metre of Soil (mm/m)**
Sand (S)	1.0	83
Loamy Sand (LS)	1.2	100
Sandy Loam (SL)	1.5	125
Fine Sandy Loam (Fine SL)	1.7	142
Loam (L)	2.1	167
Silt (Si)	2.0	167
Silty Loam (SiL)	2.5	192
Silty Clay (SiC)	2.5	208
Clay Loam (CL)	2.4	192
Silty Clay Loam (SiCL)	2.4	200
Clay (CL)	2.4	200
Heavy Clay (Heavy C)	2.5	208
Organic Soils (muck)	3.0	250

Table 4.3 Crop Availability Coefficients	
Crop	**Maximum Percent [% expressed as decimal]**
Peas	0.35
Potatoes	0.35
Tree Fruits	0.40
Grapes	0.40
Tomatoes	0.40
Others	0.50

Example 4.1 Maximum Soil Water Deficit in Armstrong

Question: A farmer near Armstrong intends to grow alfalfa on a deep sandy loam soil. What is the Maximum Soil Water Deficit (MSWD)?

Information:

Crop type	*alfalfa*	1	
Effective rooting depth (RD) (Table 4.1)	*4.0 ft*	2	ft or m
Availability coefficient (AC) (Table 4.3)	*0.50*	3	

Soil Depth [ft] or [m]	Soil Texture	RD [ft] or [m]			AWSC [in/ft] or [mm/m] (Table 4.2)			SWS [in] or [mm]	
0 – 1 ft	*Sandy Loam*	*1 ft*	4	x	*1.5 in/ft*	5	=	*1.5 in*	6
1 – 2 ft	*Sandy Loam*	*1 ft*	4	x	*1.5 in/ft*	5	=	*1.5 in*	6
2 – 3 ft	*Sandy Loam*	*1 ft*	4	x	*1.5 in/ft*	5	=	*1.5 in*	6
3 – 4 ft	*Sandy Loam*	*1 ft*	4	x	*1.5 in/ft*	5	=	*1.5 in*	6

Calculation: Determine Total Soil Water Storage (SWS).

Step 1. Calculate SWS for each soil depth interval that can be reached by the crop's roots. Use the first interval as an example.

Equation 4.1

SWS = RD x AWSC

= *1* [4] ft x *1.5* [5] in/ft

= *1.5* [6] in

Step 2. Add all SWS for each soil depth interval to obtain Total SWS.

Total SWS = $SWS_{(0\text{-}1\ ft)} + SWS_{(1\text{-}2\ ft)} + SWS_{(2\text{-}3\ ft)} + SWS_{(3\text{-}4\ ft)}$

= (*1.5* [6] + *1.5* [6] + *1.5* [6] + *1.5* [6]) in

= *6.0* [7] in

Answer:

Equation 4.2

MSWD = Total SWS x AC

= *6.0* [7] ft x *0.50* [3] in

= *3.0* [8] in

Example 4.2 Maximum Soil Water Deficit in Osoyoos

Question: A farmer in Osoyoos is growing apples in a soil that consists of 2 ft of loam, 2 ft of loamy sand. Calculate the maximum soil water deficit (MSWD).

Information:

While tree fruits have a rooting depth of 4 ft (Table 4.1), the rooting depth for dwarf tree fruits is limited to 3 ft.

Crop type	*Apples*	1	
Effective rooting depth (RD) (Table 4.1)	*3 ft*	2	ft or m
Availability coefficient (AC) (Table 4.3)	*0.40*	3	

Soil Depth [ft] or [m]	Soil Texture	RD [ft] or [m]			AWSC [in/ft] or [mm/m] (Table 4.2)			SWS [in] or [mm]	
0 – 1 ft	*Loam*	*1 ft*	4	x	*2.1 in/ft*	5	=	*2.1 in*	6
1 – 2 ft	*Loam*	*1 ft*	4	x	*2.1 in/ft*	5	=	*2.1 in*	6
2 – 3 ft	*Loamy Sand*	*1 ft*	4	x	*1.2 in/ft*	5	=	*1.2 in*	6
3 – 4 ft	*–*	*–*	4	x	*–*	5	=	*–*	6

Calculation: Determine Total Soil Water Storage (SWS).

Step 1. Calculate SWS for each soil depth interval that can be reached by the crop's roots. Use the first interval as an example.

Equation 4.1

SWS = RD x AWSC

= *1* [4] ft x *2* [5] in/ft

= *2* [6] in

Step 2. Add all SWS for each soil depth interval to obtain Total SWS.

Total SWS = $SWS_{(0\text{-}1\ ft)} + SWS_{(1\text{-}2\ ft)} + SWS_{(2\text{-}3\ ft)} + SWS_{(3\text{-}4\ ft)}$

= (*2.1* [6] + *2.1* [6] + *1.2* [6] + *–* [6]) in

= *5.2* [7] in

Answer:

Equation 4.2

MSWD = Total SWS x AC

= *5.2* [7] ft x *0.40* [3] in

= *2.1* [8] in

4.2 Maximum Irrigation System Application Rate

The rate of water infiltration into the soil surface depends on soil texture, structure and type of ground cover. The irrigation system application rate should not exceed the infiltration capability of the soil. The objective of a good irrigation design is to eliminate runoff and puddling of water on the soil surface. Exceeding the maximum soil infiltration rate shown in Table 4.4 may lead to soil degradation by compaction or soil erosion. Soil compaction and erosion can result in lower crop yields if poor irrigation practices are ongoing from year to year. Proper nozzle selection and maintenance is important to ensure that maximum soil infiltration rates are not exceeded.

Table 4.4 provides estimated maximum soil infiltration rates based on various soil textures and ground cover under normal irrigation practices. The rates shown are for irrigation set times of 4 hours or greater. The maximum soil infiltration rate for irrigation set times less than 4 hours may be higher. The values shown in Table 4.4 are for level ground and should be reduced if the irrigated area is on a slope. A general rule is to reduce the maximum application rate by 25% for field slopes exceeding 10% and 50% for field slopes exceeding 20%. If unsure, field tests under actual sprinkler conditions should be conducted to determine an accurate and safe maximum design application rate.

Table 4.4 Maximum Soil Infiltration Rate

Soil Texture	Grass Sod		Cultivated	
	[in/hr]	[mm/hr]	[in/hr]	[mm/hr]
Sand (S)	0.75	19.0	0.40	10.0
Loamy Sand (LS)	0.65	16.5	0.35	9.0
Sandy Loam (SL)	0.45	11.5	0.25	6.0
Fine Sandy Loam (Fine SL)	0.40	10.0	0.25	6.0
Loam (L)	0.35	9.0	0.20	5.0
Silt (Si)	0.35	9.0	0.20	5.0
Silty Loam (SiL)	0.35	9.0	0.20	5.0
Silty Clay (SiC)	0.35	9.0	0.20	5.0
Clay Loam (CL)	0.30	7.5	0.15	4.0
Silty Clay Loam (SiCL)	0.30	7.5	0.15	4.0
Clay (CL)	0.25	6.0	0.10	3.0
Heavy Clay (Heavy C)	0.25	6.0	0.10	3.0
Organic Soils (muck)	0.50	12.5	0.50	13.0

4.3 Maximum Irrigation Interval

The Maximum Irrigation Interval (Max II) is the maximum number of days between irrigations during peak climatic conditions that a crop can sustain optimum growth and production. It is calculated by dividing the MSWD by the peak evapotranspiration rate. The actual irrigation interval may be less than the maximum irrigation interval if the irrigation system applies less than the total amount of water that can be stored in the soil (MSWD).

The maximum irrigation interval is always calculated during peak conditions. Actual irrigation intervals can exceed the calculated maximum irrigation interval during non peak conditions.

Equation 4.3 Maximum Irrigation Interval

$$Max\ II = \frac{MSWD}{Peak\ ET}$$

where

Max II = maximum irrigation interval (day)
MSWD = maximum soil water deficit (in)
Peak ET = peak evapotranspiration (in/day) Table 4.5

4.4 Peak Evapotranspiration Rate

Evapotranspiration (ET) is a measure of the rate at which water is transpired by plants plus the moisture that is evaporated from the plants and soil surface.

For irrigation system design the Peak ET rate used is actually an average of the Peak ET rates determined for each day over the duration of the maximum irrigation interval during the peak of the season. This is referred to as the Peak ET rate and is provided as a daily value. This averaged Peak ET rate will decrease as the irrigation interval increases (larger MSWD values). The reason the values decrease over larger irrigation intervals is that it is less likely that there will be a succession of very hot days over a longer irrigation interval than there would be over a shorter interval.

Since the MSWD determines how much water can be stored within the crop's root zone, a larger MSWD will have a longer irrigation interval if the soil profile is completely filled with water. The Peak ET rate will therefore decrease with an increase in MSWD. Table 4.5 provides an estimate of the Peak ET rates for a range of MSWD values. The Peak ET values are given in inches per day or mm per day for MSWD ranging from 25 to 125 mm (i.e. 1 to 5 inches) of water that can be stored in the soil.

The Peak ET rates shown in the 1 inch or 25mm column should not generally be used for irrigation system design except in extreme conditions. Climate change may impact this however. See section 4.7.

Table 4.5 Peak Evapotranspiration Rates for Various B.C. Locations

Location	Maximum Soil Water Deficit (Depth of Water)									
	1 in★	25 mm★	2 in	50 mm	3 in	75 mm	4 in	100 mm	5 in	125 mm
	in/d	mm/d	in/d	mm/d	in/d	mm/d	in/d	mm/d	in/d	mm/d
100 Mile House	0.26	6.6	0.24	6.1	0.23	5.8	0.22	5.6	0.22	5.6
Abbotsford	0.18	4.6	0.16	4.1	0.15	3.8	0.14	3.6	0.14	3.6
Agassiz	0.18	4.6	0.16	4.1	0.15	3.8	0.14	3.6	0.14	3.6
Alexis Creek	0.18	4.6	0.16	4.1	0.15	3.8	0.14	3.6	0.14	3.6
Armstrong	0.26	6.6	0.23	5.8	0.21	5.3	0.20	5.1	0.19	4.8
Ashcroft	0.36	9.1	0.32	8.1	0.30	7.6	0.29	7.4	0.28	7.1
Aspen Grove	0.27	6.9	0.23	5.8	0.21	5.3	0.20	5.1	0.20	5.1
Barriere	0.24	6.1	0.21	5.3	0.20	5.1	0.19	4.8	0.18	4.6
Baynes Lake	0.28	7.1	0.26	6.6	0.25	6.4	0.24	6.1	0.23	5.8
Campbell River	0.28	7.1	0.22	5.6	0.20	5.1	0.18	4.6	0.17	4.3
Canal Flats	0.30	7.6	0.28	7.1	0.26	6.6	0.25	6.4	0.25	6.4
Castlegar	0.36	9.1	0.33	8.4	0.31	7.9	0.30	7.6	0.29	7.4
Cawston	0.38	9.7	0.34	8.6	0.32	8.1	0.31	7.9	0.30	7.6
Chase	0.24	6.1	0.22	5.6	0.21	5.3	0.20	5.1	0.20	5.1
Cherryville	0.23	5.8	0.22	5.6	0.21	5.3	0.20	5.1	0.20	5.1
Chilliwack	0.21	5.3	0.19	4.8	0.17	4.3	0.16	4.1	0.16	4.1
Clinton	0.26	6.6	0.24	6.1	0.23	5.8	0.22	5.6	0.22	5.6
Cloverdale	0.18	4.6	0.16	4.1	0.14	3.6	0.13	3.3	0.13	3.3
Comox	0.28	7.1	0.22	5.6	0.20	5.1	0.18	4.6	0.16	4.1
Creston	0.20	5.1	0.19	4.8	0.18	4.6	0.18	4.6	0.17	4.3
Dawson Creek	0.21	5.3	0.19	4.8	0.19	4.8	0.18	4.6	0.18	4.6
Donald	0.16	4.1	0.14	3.6	0.14	3.6	0.13	3.3	0.13	3.3
Douglas Lake	0.23	5.8	0.21	5.3	0.21	5.3	0.20	5.1	0.20	5.1
Duncan	0.20	5.1	0.17	4.3	0.16	4.1	0.15	3.8	0.15	3.8
Ellison	0.27	6.9	0.24	6.1	0.23	5.8	0.21	5.3	0.21	5.3
Fort Fraser	0.22	5.6	0.20	5.1	0.19	4.8	0.18	4.6	0.18	4.6
Fort Steele	0.26	6.6	0.23	5.8	0.22	5.6	0.21	5.3	0.20	5.1
Fort St. John	0.21	5.3	0.19	4.8	0.19	4.8	0.18	4.6	0.18	4.6
Golden	0.17	4.3	0.15	3.8	0.15	3.8	0.14	3.6	0.14	3.6
Grand Forks	0.21	5.3	0.19	4.8	0.19	4.8	0.18	4.6	0.18	4.6
Grandview	0.29	7.4	0.27	6.9	0.25	6.4	0.24	6.1	0.24	6.1
Grasmere	0.26	6.6	0.23	5.8	0.22	5.6	0.21	5.3	0.20	5.1
Grindrod	0.19	4.8	0.16	4.1	0.14	3.6	0.14	3.6	0.13	3.3
Hazelton	0.22	5.6	0.19	4.8	0.19	4.8	0.19	4.8	0.19	4.8
Hixon	0.18	4.6	0.16	4.1	0.16	4.1	0.15	3.8	0.15	3.8
Hope	0.28	7.1	0.25	6.4	0.22	5.6	0.21	5.3	0.20	5.1
Invermere	0.27	6.9	0.25	6.4	0.23	5.8	0.22	5.6	0.21	5.3
Joe Rich	0.21	5.3	0.18	4.6	0.16	4.1	0.15	3.8	0.15	3.8
Jura	0.28	7.1	0.24	6.1	0.22	5.6	0.21	5.3	0.20	5.1
Kamloops	0.33	8.4	0.30	7.6	0.28	7.1	0.27	6.9	0.26	6.6

Table 4.5 Peak Evapotranspiration Rates for Various B.C. Locations

Location	Maximum Soil Water Deficit (Depth of Water)									
	1 in★	25 mm★	2 in	50 mm	3 in	75 mm	4 in	100 mm	5 in	125 mm
	in/d	mm/d	in/d	mm/d	in/d	mm/d	in/d	mm/d	in/d	mm/d
Kelowna	0.28	7.1	0.25	6.4	0.24	6.1	0.23	5.8	0.22	5.6
Keremeos	0.31	7.9	0.30	7.6	0.29	7.4	0.28	7.1	0.28	7.1
Kersley	0.24	6.1	0.23	5.8	0.22	5.6	0.22	5.6	0.22	5.6
Kettle Valley	0.29	7.4	0.28	7.1	0.27	6.9	0.26	6.6	0.26	6.6
Kimberley	0.34	8.6	0.32	8.1	0.30	7.6	0.28	7.1	0.27	6.9
Ladner	0.16	4.1	0.14	3.6	0.13	3.3	0.13	3.3	0.12	3.0
Langley	0.17	4.3	0.14	3.6	0.14	3.6	0.13	3.3	0.12	3.0
Lillooet	0.33	8.4	0.30	7.6	0.28	7.1	0.27	6.9	0.26	6.6
Lister	0.23	5.8	0.21	5.3	0.21	5.3	0.20	5.1	0.20	5.1
Lumby	0.27	6.9	0.24	6.1	0.23	5.8	0.22	5.6	0.21	5.3
Lytton	0.36	9.1	0.32	8.1	0.30	7.6	0.28	7.1	0.28	7.1
Malakwa	0.23	5.8	0.20	5.1	0.19	4.8	0.19	4.8	0.18	4.6
Merritt	0.30	7.6	0.28	7.1	0.26	6.6	0.25	6.4	0.25	6.4
Nanaimo	0.26	6.6	0.21	5.3	0.19	4.8	0.17	4.3	0.16	4.1
Natal	0.21	5.3	0.19	4.8	0.18	4.6	0.17	4.3	0.17	4.3
Notch Hill	0.24	6.1	0.21	5.3	0.20	5.1	0.19	4.8	0.18	4.6
Oliver	0.29	7.4	0.26	6.6	0.24	6.1	0.23	5.8	0.23	5.8
Osoyoos	0.33	8.4	0.30	7.6	0.28	7.1	0.27	6.9	0.26	6.6
Oyster River	0.14	3.6	0.13	3.3	0.12	3.0	0.11	2.8	0.11	2.8
Parksville	0.21	5.3	0.17	4.3	0.16	4.1	0.15	3.8	0.14	3.6
Pitt Meadows	0.16	4.1	0.14	3.6	0.13	3.3	0.12	3.0	0.12	3.0
Port Alberni	0.28	7.1	0.23	5.8	0.20	5.1	0.19	4.8	0.18	4.6
Prince George	0.18	4.6	0.16	4.1	0.15	3.8	0.15	3.8	0.14	3.6
Princeton	0.28	7.1	0.26	6.6	0.25	6.4	0.23	5.8	0.23	5.8
Quesnel	0.29	7.4	0.27	6.9	0.26	6.6	0.25	6.4	0.25	6.4
Radium	0.23	5.8	0.21	5.3	0.20	5.1	0.19	4.8	0.19	4.8
Riske Creek	0.31	7.9	0.29	7.4	0.28	7.1	0.27	6.9	0.27	6.9
Saanichton	0.19	4.8	0.17	4.3	0.16	4.1	0.15	3.8	0.15	3.8
Salmon Arm	0.19	4.8	0.17	4.3	0.17	4.3	0.16	4.1	0.16	4.1
Smithers	0.18	4.6	0.16	4.1	0.15	3.8	0.14	3.6	0.14	3.6
Spillimacheen	0.23	5.8	0.20	5.1	0.19	4.8	0.18	4.6	0.18	4.6
Sumas	0.20	5.1	0.18	4.6	0.17	4.3	0.16	4.1	0.15	3.8
Summerland	0.30	7.6	0.28	7.1	0.26	6.6	0.24	6.1	0.24	6.1
Terrace	0.32	8.1	0.31	7.9	0.30	7.6	0.29	7.4	0.28	7.1
Vancouver	0.24	6.1	0.20	5.1	0.18	4.6	0.17	4.3	0.16	4.1
Vanderhoof	0.21	5.3	0.20	5.1	0.20	5.1	0.19	4.8	0.19	4.8
Vavenby	0.19	4.8	0.17	4.3	0.16	4.1	0.15	3.8	0.14	3.6
Vernon	0.26	6.6	0.23	5.8	0.22	5.6	0.21	5.3	0.21	5.3
Walhachin	0.31	7.9	0.30	7.6	0.29	7.4	0.28	7.1	0.27	6.9
Westwold	0.30	7.6	0.28	7.1	0.27	6.9	0.26	6.6	0.25	6.4
Williams Lake	0.30	7.6	0.29	7.4	0.28	7.1	0.27	6.9	0.26	6.6

★ Values in the 1-inch (2.5-cm) column should not be used except for special circumstances. They are shown here for comparison only.

Example 4.3 Maximum Irrigation Interval in Armstrong

Question: What is the maximum irrigation interval for a farmer in Armstrong with a soil and crop that have a maximum soil water deficit of 3 inches?

Information:

Farm location	*Armstrong*	1	
Maximum soil water deficit (MSWD)	*3 in*	2	in or mm
Peak evapotranspiration (ET) (Table 4.5)	*0.21*	3	in/day

Answer:

Equation 4.2

$$\text{Max II} = \frac{\text{MSWD}}{\text{Peak ET}}$$

$$= \frac{3 \text{ [2] in}}{0.21 \text{ [3] in/day}}$$

$$= 14 \text{ [8] days}$$

4.5 Peak Irrigation System Flow Rate

Determining a peak irrigation system flow rate is often required to estimate water source capability and to provide a design check on the flow rate used in an irrigation system design. The peak flow rate can also be used for licencing purposes by determining the maximum withdrawal rate allowed from a surface or groundwater source. A peak irrigation system flow rate is determined by combining crop, soils and climate data with an acceptable risk factor. A risk factor is the number of years out of ten that an irrigation system will be deficient in supplying the crop water requirement. A very low risk factor should be used on fruit or vegetable crops as severe crop loss could result from a water shortage. Forage crops, on the other hand, can sustain higher risk values. In this manual a risk factor of 10% is used in determining the peak flow rate for all crops in the tables provided.

Table 4.6 can be used as a guide in determining the peak water supply flow rate for a field using a 10% risk factor and the Peak ET rate. Field shape, soil type, root depth, irrigation system type and farm management may result in a field requiring a higher flow rate in some instances. Irrigation systems designed at flow rates higher than the values per acre indicated in Table 4.6 should be assessed to determine if improvements can be made.

The peak flow rate is provided in gpm/acre or m3/hr/hectare.

Helpful Tips – Peak Flow Rate and Irrigation System Design

The peak flow rate determined in Table 4.6 and 4.7 of this chapter requires that the irrigation system needs to operate 24 hours per day, 7 days a week. In other words, continuously during peak conditions. The values also assume the irrigation system has an efficiency of 72%. Following this design process will ensure that the irrigation system is taking the lowest peak flow rate possible from surface water sources or groundwater. This will help maintain minimum stream flows for fish and reduce groundwater draw down that could affect other users.

Table 4.6 Estimated Peak Irrigation System Flow Rate Requirements (using 10% risk factor)

ET		Irrigation System Flow Rates	
[in/d]	[mm/d]	[US gpm/acre]	[m^3/hr/ha]
0.16	4.1	4.0	2.24
0.18	4.6	4.5	2.52
0.20	5.1	5.0	2.80
0.22	5.6	5.5	3.10
0.23	5.8	6.0	3.36
0.25	6.4	6.5	3.64
0.27	6.9	7.0	3.92
0.29	7.4	7.5	4.20
0.31	7.9	8.0	4.48

For irrigation system design, use the following guide to determine a peak flow rate for the irrigation system:

1. If an irrigation water licence indicates a peak flow rate, use the flow rate stated on the licence.

2. If water is supplied by a water purveyor, use the flow rate established by the purveyor (Table 4.8).

3. If neither of the first two options are available and the farm is near one of the locations listed in Table 4.5, the following options can then be used:

Option 1 (recommended)

- Follow Example 4.1 or 4.2 to obtain maximum soil water deficits (MSWD)

- Use the closest MSWD value available in Table 4.5 to determine a peak ET rate.

- Locate the flow rate that corresponds to the peak ET rate in Table 4.6. If the flow rate is between two values in Table 4.6, choose the lower one. These flow rate estimates are based on a 10% risk factor, meaning the farm may be short of water once in ten years. Note the comments in section 4.7.

Option 1 is recommended since MSWD is taken into account instead of using an average value; therefore, a more accurate peak flow rate may be obtained.

Option 2

Table 4.7 gives quick estimates of peak irrigation flow rates based on ET rates, an average deep-rooted crop in a medium-textured soil with a 3-inch (average) MSWD for various locations in BC.

Table 4.7 Estimated Peak Irrigation Flow Rate Requirements for B.C. Locations[1,2]

Location	Flow Rate [US gpm/acre][3]	Location	Flow Rate [US gpm/acre][3]	Location	Flow Rate [US gpm/acre][3]
Abbotsford	4.0	Golden	4.0	Oliver	7.0
Agassiz	4.0	Grand Forks	5.0	100 Mile House	5.5
Alexis Creek	4.0	Grandview Flats	5.5	Osoyoos	8.0
Armstrong	5.0	Grasmere	5.5	Oyster River	4.0
Ashcroft	8.0	Grindrod	4.0	Parksville	4.0
Aspen Grove	5.0	Hazelton	5.0	Pitt Meadows	4.0
Barriere	5.0	Hixon	4.0	Port Alberni	5.0
Baynes Lake	6.5	Hope	5.0	Prince George	4.0
Campbell River	5.0	Invermere	6.0	Princeton	6.0
Canal Flats	6.0	Kamloops	6.5	Quesnel	6.0
Castlegar	8.0	Kelowna	6.0	Radium	5.0
Cawston	8.0	Keremeos	7.5	Riske Creek	7.0
Chase	5.0	Kersley	5.5	Saanichton	4.0
Cherryville	5.0	Kettle Valley	7.0	Salmon Arm	4.5
Chilliwack	4.5	Kimberley	7.0	Smithers	4.0
Clinton	6.0	Ladner	4.0	Spillimacheen	5.0
Cloverdale	4.0	Langley	4.0	Sumas	4.5
Comox	5.0	Lillooet	7.5	Summerland	6.5
Creston	4.5	Lister	5.0	Terrace	5.5
Dawson Creek	4.0	Lumby	5.5	Vancouver	4.5
Douglas Lake	5.0	Lytton	8.0	Vanderhoof	5.0
Duncan	4.0	Malakwa	5.0	Vernon	5.0
Ellison	6.0	Merritt	6.5	Walhachin	6.5
Fort Fraser	5.0	Nanaimo	5.0	Westwold	6.5
Fort Steele	5.5	Natal	4.5	Williams Lake	6.0
Fort St. John	4.0	Notch Hill	5.0		

1 Based on peak evapotranspiration rates on an average deep-rooted crop in a medium-textured soil (values in Table 2.1), as well as overall topographic knowledge of each location.
2 Based on 10% risk factor, i.e., water shortage once in 10 years.
3 Multiply values in US gpm/acre by 0.156 to convert to L/s/ha.

Water Purveyor

In the Okanagan Basin and Fraser Valley, irrigation water is often supplied to producers by a water purveyor such as an Irrigation District or a municipality. In these cases, the water purveyor will hold the licensed volume for the withdrawal of water from the source and will also be responsible for the operation and maintenance of the intake works. Water purveyors will usually supply the farm with a peak flow determined by the climate, soil and acreage to be irrigated.

Purveyors may provide pressurized water to the farm gate via the municipal infrastructure or via a ditch system where the farmer is responsible for pumping irrigation water onto the farm. Table 4.8 provides peak flows for a number of water purveyors in British Columbia. For farms located within a water purveyor boundary and receiving irrigation supply from a purveyor, irrigation designs must stay within the peak flow rates established by the water purveyor.

Clarification – Peak Flow Rates Calculated in Manual Examples

The design examples 5.1, 6.2 and 7.1 in the following chapters all use the same farm layout for the wheel move sprinkler, travelling gun and center pivot designs. However the peak flow rates that are determined for each are slightly different. This was done intentionally to show that there are different methods for determining a peak flow rate.

Example 5.1 uses soils and climate information to determine an appropriate irrigation interval which ends up with a flow rate of 693 gpm that is higher than the other two. This methodology does not take into account the10% risk factor as indicated in Table 4.6 using the Peak ET rate to determine peak flow.

Example 6.2 uses the information from Table 4.6 and ends up with a flow rate of 630 gpm. The 10% risk is now applied and therefore the flow rate used is 10% less than example 5.1.

Example 7.1 uses a different formula for determining the peak flow rate for the center pivot system. The pivot without the end gun covers 94 acres. Using the information in Table 4.6 the pivot flow rate would be 494 gpm (5.25 gpm/acre x 94 acres However the formula used for the pivot uses an efficiency value of 80% rather than 72% and the flow rate calculated is therefore less at 466 gpm. If the estimated flow rate of the end gun is added then the total flow rate is 553 gpm. The flow rate for the pivot is less as the system is more efficient and it is not irrigating the entire area as the other two systems do.

Table 4.8 Water Allotments of Water Purveyors in British Columbia

Water Purveyor	Contact Phone Number	Water Allotment	
		[US gpm/acre]	[IMP gpm/acre]
Pressurized Supply			
Black Mountain Irrigation District	250-765-5169	5 to 6.5	–
Cawston Irrigation District	250-499-2562	Based on water licence	–
Chase Irrigation District	250-679-1121	3/8” nozzle/acre at 80 - 120 psi	–
Creston Dyking District	250-428-5724	4.5	–
Fairview Heights Irrigation District	250-499-2386	6.6 and 7.2	–
Glenmore Ellison Irrigation District	250-763-6506	4.5 in Glenmore 5.0 in Ellison	–
Kaleden Irrigation District	250-497-5407	6.25	–
Keremeos Irrigation District	250-499-5651	7 and 7.5	–
Lake Country (District)	250-766-5650	6 except for 6.25 in Oyama	–
Lakeview Irrigation District	250-769-4322	–	6
Langley Groundwater Management Area	604-534-3211	5	
Regional District of Okanagan-Similkameen	250-492-0237	5 in Naramata	–
North Canyon Irrigation District	250-428-4031	3	–
Okanagan Falls Irrigation District	250-497-8541	–	6
Oliver (Town)	250-485-6207	10	–
Osoyoos (Town)	250-495-6515	8.25	–
Osoyoos Irrigation District	250-495-3565	8	–
Peachland (District)	250-767-2647	–	6
Penticton (City)	250-490-2400	5, 6 and 7	–
South East Kelowna Irrigation District	250-861-4200	5, 6 and 6.5	–
St. Mary’s Prairie	250-427-4319	4.5	–
Summerland (District)	250-494-6451	–	6
Vernon (Greater Vernon Services)	250-550-3702	5	–
Westbank Irrigation District	250-768-5154	5 to 6.5	–
Wynndel Irrigation District	250-866-5312	4.45	–
Ditch Supply			
Abbotsford (City)	604-853-2281	4	–
Pitt Meadows (City)	604-465-5454	4	–

Peak flow rate is determined by using Equation 4.4 and the estimated peak flow rate requirement per acre obtained from Table 4.7.

Equation 4.4 System Peak Flow Rate

$$Peak\ Flow\ Rate = Estimated\ Peak\ Flow\ Rate\ Requirement\ per\ Acre \times Irrigated\ Area$$

where

Peak Flow Rate	=	irrigation system peak flow rate [US gpm]
Estimated Peak Flow Rate Requirement per Acre	=	values from Table 4.7 [US gpm/acre]
Irrigated Area	=	entire area covered by irrigation system [acres]

Example 4.4 System Peak Flow Rate in Armstrong

Question: What is the peak flow rate of a wheelmove irrigation system that irrigates 40 acres of alfalfa in Armstrong?

Information:

Farm location	*Armstrong*	1	
Estimated peak flow rate requirement per acre (Table 4.7)	*5.0*	2	US gpm/acre
Irrigated area	*40*	3	acres

Answer:

Equation 4.4

Peak Flow Rate = Estimated Peak Flow Rate Requirement per Acre x Irrigated Area

= *5.0* **2** US gpm/acre x *40* **3** acres

= *200* **4** US gpm

4.6 Annual Irrigation System Demand

Annual irrigation system demand is determined to ensure that the irrigation system does not exceed the water use as stated on a water licence or provided by a water purveyor. Water law in B.C. requires all users extracting water from a surface water source to obtain a water licence from the Ministry of Environment before such usage is authorized.

As of the printing date of this manual, withdrawal from ground water does not require licensing in B.C. but is expected to change in the near future. However, an estimate of the peak irrigation system flow rate is helpful in determining the well casing size and also if the groundwater source is capable of supplying the required flow.

In some cases, peak withdrawal rates are also shown on a surface water licence.

Annual Water Requirement

The maximum annual irrigation requirements shown in Table 4.8 are the best estimates for maximum demand crops such as alfalfa and tree fruits for the locations shown. Crops which are not irrigated for an entire season will be proportionately less. Table 4.9 lists the estimated annual **crop** water requirements based on various MSWD for various BC locations. Irrigation system application efficiencies must be applied to the values in Table 4.9 to determine the annual **irrigation** water requirements (Equation 4.5).

Equation 4.5 Annual Water Requirement

$$Annual\ Water\ Requirement = \frac{Estimated\ Annual\ Crop\ Water\ Requirement}{Application\ Efficiency} \times 100\%$$

where

Annual Water Requirement =	annual water required by irrigation system [in]
Estimated Annual Crop Water Requirement =	values from Table 4.9
Application Efficiency =	values from Table 3.1

Example 4.5 Annual Water Requirement in Armstrong

Question: What is the annual water requirement of alfalfa irrigated by a wheelmove irrigation system in Armstrong with MSWD of 2.5 from Example 4.2?

Information:

Farm location	*Armstrong*	1	
MSWD	*2.5 in*	2	in or mm
Estimated annual crop requirement (Table 4.9)	*12 in*	3	in or mm
Irrigation system	*wheelmove*	4	
Application efficiency (Table 3.1)	*72*	5	%

Answer:

Equation 4.5

$$\textbf{Annual Water Requirement} = \frac{\textbf{Estimated Annual Crop Water Requirement}}{\textbf{Application Efficiency}} \times 100\%$$

$$= \frac{12\ [3]\ \text{in}}{72\ [5]\ \%} \times 100\%$$

$$= 17\ [6]\ \text{in}$$

Table 4.9 Estimated Annual Crop Water Requirements for Various B.C. Locations

Location	Maximum Soil Water Deficit (Depth of Water)									
	1 in★	25 mm★	2 in	50 mm	3 in	75 mm	4 in	100 mm	5 in	125 mm
	in	mm	in	mm	in	mm	in	mm	in	mm
100 Mile House	27	675	20	510	17	435	14	365	12	310
Abbotsford	18	455	12	310	9	220	6	145	4	90
Agassiz	13	325	6	165	4	110	3	70	1	35
Alexis Creek	19	475	14	345	11	270	9	220	6	165
Armstrong	21	530	16	400	12	310	10	255	8	200
Ashcroft	38	965	30	765	25	640	22	565	19	490
Aspen Grove	22	565	17	420	13	325	11	270	9	220
Barriere	22	550	16	400	13	325	10	255	9	220
Baynes Lake	27	695	20	510	17	420	14	345	12	295
Campbell River	18	455	12	310	10	255	8	200	6	165
Canal Flats	24	600	18	455	14	365	12	310	10	255
Castlegar	33	840	25	640	21	530	18	455	15	380
Cawston	38	965	30	765	25	640	22	565	19	490
Chase	26	655	19	490	15	380	13	325	10	255
Cherryville	24	620	17	435	14	345	12	295	10	255
Chilliwack	14	345	6	165	5	125	4	90	2	55
Clinton	27	675	20	510	17	435	14	365	12	310
Cloverdale	15	380	10	255	7	180	5	125	3	70
Comox	19	490	14	365	12	295	9	235	8	200
Creston	24	600	19	475	16	400	13	325	12	290
Dawson Creek	15	380	10	255	7	180	5	125	3	70
Donald	14	345	9	235	6	165	4	110	2	55
Douglas Lake	24	620	19	475	16	400	14	345	12	295
Duncan	15	380	11	270	9	220	7	180	6	145
Ellison	27	675	20	510	17	420	14	365	12	310
Fort Fraser	15	380	11	270	8	200	6	145	4	90
Fort Steele	19	475	13	325	10	255	8	200	6	145
Fort St. John	15	380	10	255	7	180	5	125	3	70
Golden	19	490	14	345	11	270	9	235	8	200
Grand Forks	19	475	14	345	11	270	9	220	7	180
Grandview Flats	29	730	22	550	18	455	16	400	14	345
Grasmere	22	565	17	420	13	325	11	270	9	220
Grindrod	14	365	10	255	7	180	5	125	3	70
Hazelton	7	180	4	110	2	55	1	15	0	0
Hixon	15	380	9	235	6	165	4	90	2	55
Hope	20	510	12	310	9	235	7	180	5	125
Invermere	28	710	21	530	17	435	14	345	12	295
Joe Rich	20	510	14	365	12	295	9	235	7	180
Jura	22	565	15	380	12	295	9	235	7	180
Kamloops	32	820	26	655	23	585	20	510	19	475
Kelowna	30	750	22	570	19	475	17	420	14	365
Keremeos	32	820	26	655	23	585	20	510	19	475
Kersley	17	420	12	310	9	235	7	180	6	145

Table 4.9 Estimated Annual Crop Water Requirements for Various B.C. Locations

Location	Maximum Soil Water Deficit (Depth of Water)									
	1 in★	25 mm★	2 in	50 mm	3 in	75 mm	4 in	100 mm	5 in	125 mm
	in	mm	in	mm	in	mm	in	mm	in	mm
Kettle Valley	30	750	22	570	18	455	15	380	13	325
Kimberley	29	730	22	550	17	435	14	365	12	310
Ladner	15	380	11	270	8	200	6	165	4	110
Langley	14	365	9	220	6	165	5	125	4	90
Lillooet	30	750	23	585	19	490	17	420	14	365
Lister	24	620	19	475	16	400	13	325	11	270
Lumby	24	620	19	475	15	385	13	325	11	270
Lytton	37	930	29	730	25	640	22	565	19	490
Malakwa	16	400	12	295	9	220	6	165	5	125
Merritt	32	805	24	620	21	530	18	455	15	380
Nanaimo	18	455	13	325	10	255	8	200	6	145
Natal	19	490	14	345	10	255	8	200	6	145
Notch Hill	23	585	17	435	14	365	12	295	10	255
Oliver	35	895	27	695	24	620	22	550	19	490
Osoyoos	36	910	29	730	25	640	22	565	20	510
Oyster River	13	325	9	220	6	165	4	110	3	70
Parksville	18	455	13	325	10	255	9	220	7	180
Pitt Meadows	13	325	9	220	6	145	3	70	1	35
Port Alberni	19	490	14	365	12	295	9	235	7	180
Prince George	17	435	13	325	10	255	8	200	6	165
Princeton	30	750	21	530	18	455	16	400	14	365
Quesnel	16	400	12	295	9	235	7	180	6	145
Radium	21	530	15	380	12	310	9	235	7	180
Riske Creek	25	640	19	475	16	400	13	325	11	270
Saanichton	18	455	12	310	10	255	9	215	7	180
Salmon Arm	21	530	16	400	13	325	11	270	9	220
Smithers	16	400	12	295	9	220	6	165	5	125
Spillimacheen	24	600	17	435	14	345	11	270	9	220
Sumas	16	400	10	255	6	165	4	110	3	70
Summerland	30	765	23	585	19	490	17	435	15	380
Terrace	16	400	12	295	9	220	7	180	6	145
Vancouver	18	455	14	345	11	270	9	220	7	180
Vanderhoof	17	420	12	295	8	200	6	145	4	90
Vavenby	21	530	16	400	13	325	11	270	9	220
Vernon	24	620	19	475	16	400	14	345	12	295
Walhachin	31	785	24	600	20	510	17	435	14	365
Westwold	31	785	24	600	20	510	18	455	16	400
Williams Lake	22	565	17	420	13	325	11	270	9	220

Note: The figures are net amounts. Irrigation system efficiencies need to be applied to the figures to obtain gross amounts. The inch figures have been rounded off to the nearest whole number, and the millimetre figures to the nearest 5 mm. The values are derived from a formula; therefore, the conversions between the two may not be exact.

★ Values in the 1-inch (2.5-cm) column should not be used except for special circumstances. They are shown here for comparison only.

4.7 Loss of Stationarity

The methodology provided in this guide determines the peak irrigation water requirement and annual crop water requirement based on historical climate data. However as climate change starts to take hold this data may no longer be reliable and an increased water demand may result. The changes being brought on by climate change is the loss of stationarity. Historical data, being considered reliable and consistent, may no longer be reliable or consistent in determining what future water demands may be.

To take this into account the following steps should be considered in the design process:

- What is the expected life of the current irrigation system and will it likely be replaced before significant climatic changes occur?
- Is there any flexibility in the current irrigation system design?
- Can efficiency improvements be implemented over time that may reduce the impacts of climate change?