3.0 Irrigation Demands

3.1 PEAK DEMANDS PER ACRE

3.1.1 General

The water requirement of a planted area, or potential evapotranspiration, changes during the season depending on the stage of growth of the crop and the weather conditions. The irrigation supply and distribution facilities are sized based on the peak irrigation demand of the serviced areas. This demand includes the peak potential evapotranspiration of the irrigated land plus allowance for water losses. The water losses are usually taken into account by applying an irrigation efficiency factor to the peak evapotranspiration of the service area. The result is the peak demand per unit area.

This section aims to arrive at preliminary estimates for the peak demands of the major irrigated crops in the target areas.

3.1.2 Peak Demand for Tender Fruits and Grapes Based on Existing Irrigation Practices

Interviews with a number of tender fruit and grape growers throughout the study area indicated that they generally do not irrigate before July. Also, they consistently stated that they irrigated after there was a period of no rain for about two weeks, and then every two weeks or so after that, unless there was sufficient effective rainfall.

The farmers in the area were also very consistent in terms of the quantity of irrigation water they apply each time they irrigate. The general rule of irrigation in the area seems to be approximately 38 to 51 mm of water column (1.5 to 2 inches of water) as measured by rain gauges; although quantities as low as 26 mm (1 inch) and as high as 77 to 102 mm (3 to 4 inches) depending on the crop and the degree of dryness, were mentioned by some farmers. Grapes generally receive less irrigation, as low as 26 mm (1 inch) of water, and often no more than one application per year.

From these discussions, it appears that the first irrigation in July is the seasonal peak. For the purpose of this study, we will assume that during this period the tender fruits will receive 51 mm (2 inches) of water column and the grapes will receive 38 mm (1.5 inches) of water column.

3.1.3 Theoretical Peak Demands for Tender Fruits and Grapes

Table 3-1 shows the average daily water use for grapes and peaches/pears throughout the growing season. The substantial difference between the daily demands of different crops with and without ground cover should be noted.

Table 3-1: Average Daily Water Use for Tender Fruits and Grapes

Month	Date	Grapes	Peaches, Pears	
			Clean Cultivated	Ground Cover
		Average Daily Water use (mm)		
May	1 – 7	1.2	1.2	1.7
	8 - 14	1.9	1.9	2.6
	15 - 21	2.0	2.0	2.8
	22 - 31	2.2	2.2	3.0
June	1 – 7	2.7	2.9	4.1
	8 - 14	2.8	3.0	4.1
	15 - 21	2.8	3.1	4.2
	22 - 30	3.0	3.2	4.5
July	1 – 7	3.6	3.9	5.2
	8 - 14	**3.7**	**4.0**	**5.3**
	15 - 21	3.5	3.8	5.0
	22 - 31	3.4	3.6	4.8
August	1 – 7	3.4	3.6	4.8
	8 - 14	2.8	3.0	4.0
	15 - 21	2.6	2.8	3.7
	22 - 31	2.3	2.5	3.3
September	1 – 7	2.0	2.3	3.1
	8 - 14	1.8	2.1	2.9

Source: Tan & Layne, 2002

The average daily demands are converted into average monthly demands in Table 3-2 [8]. In addition to the monthly crop demands, average monthly rainfalls for Vineland Station are shown in Table 3-2. The difference between "effective rainfall" and crop water use provides a good indication of the water deficit to be alleviated by irrigation. Effective rainfall is the rainfall that is infiltrated into the root zone, and is generally rainfall minus surface runoff. It is assumed that during the irrigation season, the effective rainfall is close to the actual rainfall. This assumption makes the calculated water deficit an underestimation of the actual water deficit. Table 3-3 shows the calculated average water deficit for different irrigated crops in the Niagara Region based on the above assumption. The average water deficits in Table 3-3 are calculated by subtracting the average monthly plant water use rates (figures in the second to fourth columns of Table 3-2) from the average monthly rainfall (figures in the fifth column of Table 3-2).

[8] Note that the figures for September are for the first two weeks of September only.

Table 3-2: Average Monthly Water Use and Rainfalls for Tender Fruits and Grapes

Month	Grapes	Peaches/Pears		Avg. Monthly Rainfall (mm) [1]	Drought Monthly Rainfall (mm) [2]	Drought Accumulated Rainfall (mm) [3]
		Clean Cultivated	Ground Cover			
	Average Monthly Water use (mm)					
May	57.7	57.7	79.7	64.9	26.6	26.6
June	85.1	91.8	127.3	76.8	27.3	68.5
July	109.6	117.9	156.5	67.8	15.0	135.2
August	84.6	90.8	120.5	85.8	23.3	222.6
September [4]	26.6	30.8	42.0	33.3	0.0	228.6

Notes:

(1) Thirty-Year Average rainfall for Vineland Station 1959 to 1988, Source: http://climate.weatheroffice.ec.gc.ca/prods_servs/cdcd_iso_e.html

(2) Ten-year return minimum rainfalls for each month, calculated as Average Month Rainfall minus 1.645 times Standard Deviation of month rainfalls between 1959 and 1988.

(3) Ten-year return minimum accumulated seasonal rainfalls, calculated as Average Accumulated Rainfalls for the season minus 1.645 times Standard Deviation of Accumulated Rainfalls between 1959 and 1988.

(4) Only up to September 14.

Table 3-3: Average Calculated Water Deficit for Tender Fruits and Grapes

Month	Grapes	Peaches, Pears	
		Clean Cultivated	Ground Cover
	Monthly Water Deficit (mm)*		
May	-7	-7	15
June	8	15	50
July	42	50	89
August	-1	5	35
September **	-7	-2	9
	End of Month Cumulative Water Deficit (mm)*		
May	0	0	15
June	8	15	65
July	**50**	65	154
August	49	**70**	189
September **	42	68	**197**

*: Assumes effective precipitation equal to actual precipitation

**: Only up to September 14

In southern Ontario, soils are at maximum practical soil water content (field capacity) at the beginning of the growing season; therefore, the initial stages of water deficit will not require irrigation. As the daily water deficit continues, the soil water content drops, until it reaches a

point where it would be impossible for plants to draw water (wilting point). The difference between the field capacity and the wilting point is referred to as soil water storage capacity. At field capacity, soil water storage is considered to be at full capacity. As the soil moisture drops, it becomes increasingly difficult for plants to draw moisture from the soil. Tender fruit and grapes are generally allowed a soil water depletion of 40% of the soil water storage capacity. Soil water storage capacities of different soil textures are shown in Table 3-4. The active root zone of the tender fruits and grapes in the Niagara Region is assumed to be 1.2 meters deep. Table 3-4 also shows the total calculated water storage capacity of different soils, together with the allowable depletions based on the assumptions made for the Niagara tender fruit and grape areas (depth of root zone of 1.2 m and allowable depletion of 40% of the soil storage capacity).

Table 3-4: Ranges in Available Water Capacity and Intake Rate for Various Soil Textures

Soil Textures	Available Water Capacity (mm of water / cm of soil)		Intake Rate (mm / hr)		Water Storage Capacity (mm of water / 1.2 m of soil)		Allow. Water Depletion * (mm of water)	
	Range	Avg	Range	Avg	Range	Avg	Range	Avg
Sands	0.5 - 0.8	0.65	12 - 20	16	60 - 96	78	24 - 38	31
Loamy Sand	0.7 - 1.0	0.85	7 - 12	9.5	84 - 120	102	34 - 48	41
Sandy Loam	0.9 - 1.2	1.05	7 - 12	9.5	108 - 144	126	43 - 58	50
Loam	1.3 - 1.7	1.5	7 - 12	9.5	156 - 204	180	62 - 82	72
Silt Loam	1.4 - 1.7	1.55	4 - 7	5.5	168 - 204	186	67 - 82	74
Silty Clay Loam	1.5 - 2.0	1.75	4 - 7	5.5	180 - 240	210	72 - 96	84
Clay Loam	1.5 - 1.8	1.65	4 - 7	5.5	180 - 216	198	72 - 86	79
Clay	1.5 - 1.7	1.6	2 - 5	3.5	180 - 204	192	72 - 82	77

Source for soil Available Water Capacities and Intake Rates:
http://www.gov.on.ca/OMAFRA/english/crops/facts/90-069.htm
*: Allowable Water Depletion for Grapes and Tender Fruits is assumed to be 40% of the Water Storage Capacity.

Table 3-4 indicates that most crops in the Niagara Region will need irrigation once 40 to 80 mm of accumulated water deficit is experienced during the season. Table 3-3 shows that during a normal year this level of soil water depletion will occur sometime in July if the land is clean cultivated (if ground cover is not removed, the need for irrigation is generally advanced to June). The existing practice of providing 38 to 51 mm (1.5 to 2 inches) of water column at this time is acceptable for most soils in the Region, as it replenishes the soil water content sufficiently without causing excessive leaching. The need for another irrigation set will not arise for another 10 to 12 days according to the daily consumptions in Table 3-1.

Our calculation therefore endorses the timing and quantity of the first irrigation as currently practiced in the Region.

In order to determine the irrigation demand at the farm gate, we will need to consider the efficiency of the irrigation systems. Irrigation system efficiency is defined as the volume of water stored in the root zone divided by the volume of water extracted from supply (i.e. crop consumptive use divided by crop consumptive use plus losses). Sprinkler systems can have irrigation efficiencies of above 80%, and dripper systems can reach efficiencies of above 90%. We propose the use of an on-farm **irrigation efficiency of 80%** for the purpose of this feasibility study. Applying an average irrigation system efficiency of 80% to the peak average daily water use for mid July (from Table 3-1), the peak irrigation demands at the farm gate will be **4.6 mm/day** for grapes and **5.0 mm/day** for tender fruits. These demands exclude distribution system losses (from the source to the farm gate); therefore, the supply quantities should be higher due to leaks, seepage and evaporation losses, depending on the type of water distribution system.

3.1.4 Peak Demand for Greenhouses

The majority of the greenhouses in the Niagara Region produce flowers. The annual water consumptions of these greenhouses range from 700 mm to 1500 mm of water column over the active production areas[9]. The average water consumption of the greenhouses is therefore 1.9 to 4.1 mm/day. The peak water demand of greenhouse flowers is **7.0 mm/day** in July[10].

3.1.5 Peak Demands for Nurseries[11]

The region of Niagara has 43 nursery operations with a total area of 897 hectares (2217 acres). Approximately 35% of the operations are container production which receive intensive irrigation. The peak demand of container nursery production can be as high as **14.8 mm/day**.

3.1.6 Summary of Unit Irrigation Demands

Table 3-5 summarizes the proposed peak irrigation demands at the farm gates in the Niagara Region.

[9] Source: Personal communication with Mr. W. Brown, Ontario Ministry of Agriculture Food and Rural Affairs.
[10] Source: Email from OMAF (R. Shortt) to Stantec (S. Soltani), April 18, 2005
[11] This section is based on the information from OMAF as per email from OMAF (R. Shortt) to Stantec (S. Soltani), April 18, 2005.

Table 3-5: Peak Day Demands (mm/d)

Crop	Demand
Tender Fruits	5.0
Grapes	4.6
Greenhouses	7.0
Nurseries	14.8

3.2 SEASONAL DEMANDS

The total demand of an irrigated area during a growing season is of interest for the protection of water resources in the long-term and for designing seasonal water storage reservoirs. The seasonal irrigation demand changes from year-to-year. The average seasonal demand is of interest for the long-term protection of water resources. Storage reservoirs for irrigation supply should be sized for seasonal demand during a predefined drought (e.g. a ten-year return drought).

Table 3-3 indicates the cumulative seasonal water deficit for different crops for the average year according to our assumptions. Using the clean cultivated figures, the average seasonal irrigation requirements for Grapes and Peaches/Pears are 50 mm (2.0 inches), and 70 mm (2.8 inches) of water column, respectively. It should be noted that these calculations are based on the assumption of the effective rainfall being equal to the actual rainfall (no runoff); therefore, these seasonal quantities are underestimates.

In Table 3-2, the rainfalls associated with a ten-year return drought for the Niagara Region are shown. Table 3-6 presents the monthly and accumulated water deficit for various fruits based on this drought. Using the clean cultivated figures, the seasonal irrigation requirements for Grapes and Peaches/Pears during this drought would be 135 mm (5.3 inches) and 160 mm (6.3 inches) of water column, respectively.

Table 3-6: Drought Calculated Water Deficit for Fruits and Grapes in Niagara Region

Month	Grapes	Peaches, Pears	
		Clean Cultivated	Ground Cover
	Monthly Water Deficit (mm)*		
May	31.1	31.1	53.1
June	57.8	64.5	100.0
July	94.6	102.9	141.5
August	61.3	67.5	97.2
September **	26.6	30.8	42.0
	End of Month Cumulative Water Deficit (mm)*		
May	31.1	31.1	53.1
June	74.3	81.0	138.5
July	117.2	132.2	228.3
August	114.4	135.6	261.4
September **	**135.0**	**160.4**	**297.4**

*: Assumes effective precipitation equal to actual precipitation
**: Only up to September 14

The potential sources of significant inaccuracy for the calculated average year water deficits (50 mm for grapes and 70 mm for tender fruits from Table 3-3) and the calculated drought year water deficits (135 mm for grapes and 160 mm for tender fruits from Table 3-6) are the following:

- Effective rainfall may be substantially different from actual rainfall due to large surface and subsurface drainage
- Daily water use for tender fruits and grapes in Niagara Region may be somewhat different from the quantities in Table 3-1.

Tan and Reynolds (2003) studied the trends in the climate conditions in Southwestern Ontario. According to their report, the average annual crop water deficit for Southwestern Ontario is 150 mm (6 inches). For the purpose of this preliminary report, we shall assume that the difference between the calculated average year water deficits for grapes and tender fruits is mainly due to the drainage of approximately 90 mm per year[12]. The estimated average year water deficit for grapes and tender fruits would therefore be **140 mm** and **160 mm**, respectively.

Similarly, we shall assume that 90 mm of rain is lost to drainage during a ten-year return drought, increasing the drought water deficits for grapes and tender fruits to **225 mm** and **250 mm**, respectively.

[12] It is recommended that the average and drought water deficits be studied in more detail at the subsequent phase of this project.

The annual demands for greenhouse water ranges between 700 and 1500 mm, as stated in the previous section. Taking the average of this range and assuming that 50% of the rooftop precipitation is beneficially used toward this requirement, the demand for imported water would be **700 mm/yr**.

The average annual water requirement of container nurseries is **893 mm**[13]. At this preliminary stage, we shall use this gross requirement in our calculation.

The figures in the above discussion have been summarized in Table 3-7. Allowable Water Depletions for various soils from Table 3-4 were considered. Given that Tender Fruits are generally produced on sandy soils and grapes are generally grown on heavier soils, Allowable Water Depletions of 70 mm and 40 mm for grapes and tender fruits, respectively, were used in calculating the gross seasonal demands. Furthermore, the gross demands were increased by 25% to account for an estimated 80% on-farm irrigation efficiency. It should be noted that the gross demands shown in Table 3-7 may need to be increased to allow for possible water losses (such as leaks, evaporation, seepage) in the regional water supply system, by applying a supply system efficiency to the calculated volumes.

Table 3-7: Annual Irrigation Demands (mm/year)

Crop	Net Seasonal Water Deficits (mm)(1)		Allowable Water Depletion (mm)	Efficiency	Gross Annual Water Demands (mm) (2)	
	Average Year	Ten-Year Return Drought			Average Year	Ten-Year Return Drought
Grapes	140	225	70	80%	88	194
Peaches/Pears	160	250	40	80%	150	263
Greenhouses (3)					700	900
Nurseries (4)					893	893

Notes:

(1) These are estimated water deficits at crop root zone.

(2) These are overall farm water requirements, including on-farm losses.

(3) These demands are in addition to the rooftop water used in irrigation of greenhouses.

(4) Rainfall contributions has not been included in these demands, therefore there is no difference between drought demand and average demand. The actual demands are likely to be less than these demands due to the contribution of rainfall.

[13] Source: Email from OMAF (R. Shortt) to Stantec (S. Soltani), April 18, 2005.

3.3 REGIONAL IRRIGATION DEMANDS

3.3.1 Proposed Irrigation Districts

Irrigation "districts" are areas of irrigated lands that due to their geographical, political, or other characteristics can be irrigated by a common supply system. In the Niagara Region, we propose the following irrigation districts as illustrated in Figure 3-1:

- East Irrigation District - to service the existing and potential irrigated lands of Niagara-on-the-Lake including a small fruit area west of St. Catharines and a small fruit area north of Niagara Falls.

- West Irrigation District - to service the existing and potential irrigated lands of Grimsby, Lincoln, east of St. Catharines and a small grape area north of Pelham. Due to substantial elevation differences within this area, this district may be further subdivided into two zones:

    - Zone A: lowlands (below the Escarpment); and
    - Zone B: highlands (above the Escarpment).

  Depending on the final choice of infrastructure, it may be decided to separate these two zones into two separate districts.

- South District - to service the existing and potential irrigated lands in Pelham south of the escarpment.

The estimated potential irrigated areas of these districts – based on the areas under tender fruits, grapes, greenhouse and nursery production in 2001 – are shown in Table 3-8. The good grape and tender fruit areas are also shown in this table. It is interesting to note that the areas reported under tender fruits and grapes are approximated 40% of the total designated good tender fruits and grape lands in the Niagara Region. Therefore there is potential for significant increase in the tender fruits and grape areas of the Niagara Region. According to OMAF, the tender fruit acreage is stable at the present time, while grape acreage is undergoing a growth of three to five percent per year[14]. The availability of irrigation water will likely result in the growth of tender fruit acreage, especially in the West District Zone A and the South District. However, not all the tender fruits and grapes will be irrigated.

For the purpose of this study, we will assume that all the existing tender fruits and grape areas are irrigated. Although at the present time this is a very conservative assumption, it reflects potential expansion of the irrigated areas due to the existing growth in the grape areas and the predicted growth in irrigated tender fruit areas due to the ready availability of irrigation water. A subsequent study should investigate the existing and potential irrigated areas.

[14] Source: Email from OMAF (R. Shortt) to Stantec (S. Soltani), April 18, 2005.

Table 3-8: Areas of Potential Irrigation District Lands in the Niagara Region (acres)

District	Grapes (1)	Tender Fruits (1)	Green-houses (2)	Nurseries (3)	Estimated Total Current Areas	Good Grape Areas (5)	Good Tender Fruit Areas (5)	Total Potential Areas
East	5,999	4031	57	354	10,441	7,763	10,767	18,530
West - Zone A	4,219	3,674	163	281	8,337	11,834	9,374	21,208
West - Zone B (4)	2,812			97	2,909	9,276	0	9,276
South	348	899	29	44	1,320	0	6,163	6,163
Total	13,378	8,604	249	776	23,007	28,874	26,303	55,177

Notes:

(1) General Source: Regional Agricultural Economic Impact Study (Planscape, 2003). Source for Grape area in South District: Email from OMAF (R. Shortt) to Stantec (S. Soltani), April 18, 2005. Breakdown of grapes areas in West District: approximately proportional to good grape lands in Zones A and B.

(2) Source: Greenhouse Growers Directory and Buyers Guide 2004 (Niagara Economic and Tourism Corporation, 2004)

(3) Source for total Nursery area: Email from OMAF (R. Shortt) to Stantec (S. Soltani), April 18, 2005. Preliminary breakdown between districts and zones: based on proportion of total target agricultural areas.

(4) Preliminary breakdown of current Grape areas between Zone A and Zone B is estimated based on the approximate proportion of good grape lands below and above the Escarpment. Tender fruits and greenhouses are assumed to be generally in Zone A for the purpose of this report.

(5) Source: Digital maps provided by the Regional Municipality of Niagara

3.3.2 Peak Regional Demand

The probable peak regional demands based on the calculated peak day demands for the different crops and the estimated areas of the different crops are shown in Table 3-9.

Table 3-9: Estimated Regional and District Peak Day Demands

District	Grapes	Tender Fruits	Green-houses	Nurseries	Total		
Units>	m^3/day	m^3/day	m^3/day	m^3/day	m^3/day	USGPM	acre-in/day
East	111,675	81,564	1,615	21,202	216,056	39,636	2,102
West - Zone A	78,532	74,341	4,617	16,830	174,320	31,979	1,696
West - Zone B	52,354	0	0	5,810	58,164	10,670	566
South	6,478	18,191	822	2,635	28,126	5,160	274
Total	249,039	174,096	7,054	46,477	476,665	87,446	4,637

3.3.3 Seasonal Regional Demand

The probable average annual irrigation demands based on the calculated annual irrigation demands for the different crops and the estimated areas of the different crops of the target areas are shown in Table 3-10. It should be noted that during a ten-year return drought, the demand may be 75% to 100% higher that the averages shown in Table 3-10 (as calculated in Table 3-7).

Table 3-10: Estimated Regional and District Average Annual Irrigation Demands

District	Grapes	Tender Fruits	Green-houses	Nurseries	Total		
Units>	m^3/yr	m^3/yr	m^3/yr	m^3/yr	m^3/yr	Million USG/yr	acre-ft/yr
East	2,127,280	2,448,971	161,470	1,279,300	6,017,021	1,590	4,880
West - Zone A	1,495,940	2,232,081	461,746	1,015,490	5,205,257	1,375	4,221
West - Zone B	997,293	0	0	350,543	1,347,836	356	1,093
South	123,403	546,173	82,151	159,009	910,736	241	739
Total	4,743,916	5,227,225	705,367	2,804,342	13,480,851	3,561	10,933