

Agriculture Water Demand Model (AWDM)
Fraser Valley Regional District (FVRD)

Executive Summary

The Agriculture Water Demand Model (AWDM) is a water management planning tool to estimate current and future agriculture water demands. The AWDM calculates water use on a property-by-property basis, and can sum all properties to obtain a total for sub-basin, aquifer, water purveyor, local government, electoral area, or the entire region. Crop type, irrigation system type, soil type and climate data are used to calculate the water demand. Since the AWDM can calculate future water demands based on climate change scenarios, it can help with watershed planning processes to make informed decisions on water use and land use planning. The AWDM was started in the Okanagan basin in 2006, and since then it has been expanded to over 10 regions in the Province. The AWDM can be used for any regions provided with the appropriate land use and climate information.

Agricultural Land Use Inventory (ALUI) was conducted in the Fraser Valley Regional District (FVRD) through the summers of 2011 to 2013. Based on the land use data, the outdoor irrigated acreage in the Fraser Valley Regional District is 15,283 hectares (ha) including 221 ha in golf courses.

In the AWDM report, climate data from 1997 and 2003 were chosen as they represent a relatively wet year and dry year respectively. This report is primarily based on the 2003 data as the maximum irrigation demand can be presented. The total annual irrigation demand was 67,388,512 m³ in 2003 (a dry year), and dropped to 35,559,136 m³ in 1997 (a wet year). During a wet year like 1997, the demand was only 52% of a hot dry year like 2003. The actual water demand supplied by an irrigation system may be less than these numbers because the AWDM does not have an adjustment for water supplied to crops grown in low lying areas with a high water table. In portions of the FVRD, farms located in the lowland regions have high water tables during portions of the growing season. Some water may also be supplied by sub-irrigation to the crops through the drainage and irrigation ditch infrastructure. The high water tables will reduce irrigation demand which is not accounted for in the AWDM outputs. The AWDM numbers should therefore be considered the higher estimate of demand.

As shown in Table 1, the predominant irrigated agricultural crop in the Fraser Valley is forage, followed by blueberries, nursery, and then vegetables and raspberries. The average irrigation requirements for golf course, pasture/grass and turf are expected to be high as the roots are shallow and water storage is limited; therefore, require more water. Greenhouses often have a high demand as rainfall is not factored into irrigation demand. Depending on the crop grown (floriculture) these numbers may be reduced slightly, i.e., around 1,100 mm. Blueberries and raspberries have much lower requirements because of deeper rooting depths and more efficient irrigation systems are typically used.

Table 1. Current Irrigated Area and Average Water Requirement by Crop Type.

Crop Type	Irrigation Area (ha)	Average Irrigation Requirement (mm)
Apple	19	430
Berry	321	325
Blueberry	3,754	333
Cranberry	165	568
Forage	5,818	534
Fruit	8	306
Golf	221	580
Grape	34	179
Greenhouse	58	1,129
Nursery	1,498	417
Pasture/Grass	178	562
Raspberry	1,160	311
Recreational Turf	67	533
Strawberry	8	299
Sweetcorn	231	265
Turf Farm	377	590
Vegetable	1,362	472
TOTAL	15,283	441

The total area that is currently irrigated by efficient systems such as drip, microsprinkler or microspray is 3,790 ha or 11% of all areas irrigated. If irrigation system type were to become more efficient in the future, e.g., sprinkler systems were converted to drip and good management practices were implemented, the water demand for 2003 would reduce from 67,388,512 m³ to 59,041,117 m³ (12% reduction).

According to climate change research done by the Agriculture and Agri-Food Canada, future years 2053, 2056 and 2059 generate the highest annual evapotranspiration and lowest annual precipitation. Therefore, these three years were used in this report for climate change scenarios. With current land use and future climate change, the AWDM estimates for water demand can be as high as 130,408,838 m³ in extreme years. It can be expected that seasons like 2003 will likely happen more often, possibly 3 or 4 out of 10 years.

An agricultural buildout scenario was also developed to estimate potential agricultural lands that could be irrigated in the future. The criteria for the buildout scenario includes predicted changes in crop and irrigation system types, predetermined distances from water sources, elevation, Agricultural Capability Class, and Agricultural Land Reserve status. The AWDM estimated an additional 18,650 ha of agricultural land could be irrigated in the future (122% increase), and the water demand would be about 132 million m³ (96% increase) using current climate data and assuming efficient irrigation systems and good management practices. Table 2 below shows the current and buildout irrigated area and water demands

by electoral areas. The same comparison was done based on surface water and groundwater sources, and is illustrated in Table 3.

Table 2. Current and Buildout Irrigated Area and Water Demand by Electoral Areas.

	Current		Buildout	
	Irrigated Area (ha)	Irrigation Demand (m ³)	Irrigated Area (ha)	Irrigation Demand (m ³)
Abbotsford	10,679	46,225,283	10,685	45,118,453
Chilliwack	2,334	10,372,941	10,451	39,028,546
District of Hope	6	49,724	130	592,751
District of Kent	1,077	5,367,996	4,025	16,053,710
Electoral Area A	55	566,117	352	2,530,713
Electoral Area B	81	483,699	640	2,849,505
Electoral Area C	12	75,658	182	648,542
Electoral Area D	48	300,770	244	1,012,102
Electoral Area E	77	362,007	976	3,428,540
Electoral Area F	117	382,973	1,595	4,759,772
Electoral Area G	762	3,040,337	3,769	13,193,033
Mission	31	161,006	850	2,717,944
Village of Harrison	-	-	21	105,643
TOTAL	15,283	67,388,512	33,933 (122% increase)	132,087,388 (96% increase)

Table 3. Current and Buildout Irrigated Area and Water Demand by Water Sources.

	Current		Buildout	
	Irrigated Area (ha)	Irrigation Demand (m ³)	Irrigated Area (ha)	Irrigation Demand (m ³)
Surface Water	6,161	28,673,054	12,996	51,379,449
Groundwater	9,122	38,715,458	20,937	80,707,939
TOTAL	15,283	67,388,512	33,933 (122% increase)	132,087,388 (96% increase)

A combination of buildout area and increase in water demand due to climate change has not been run at this time. Planning teams with FVRD can request specific scenarios that they may be interested in and these scenarios can then be prepared by the AWDM model developer at a cost.

An aerial photograph of a rural landscape in the Fraser Valley. The scene shows rolling green hills, scattered trees, and a small cluster of buildings in the middle ground. A faint rainbow is visible in the sky above the valley. The foreground is dominated by the dark green foliage of trees, with some houses and roofs visible through the branches.

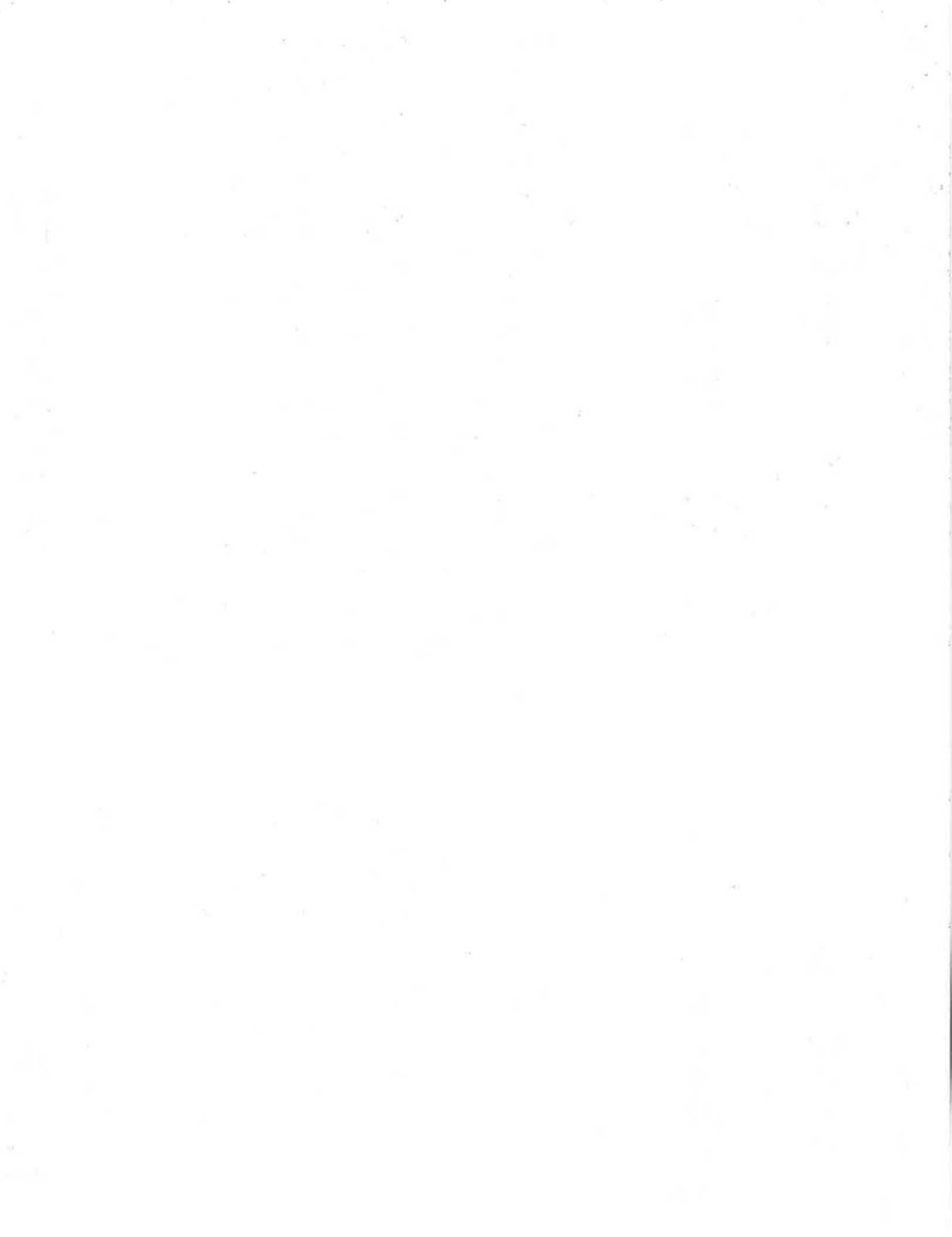
AGRICULTURE WATER DEMAND MODEL

Report for Fraser Valley

February 2015



Canada



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Report for Fraser Valley Regional District

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February 2015

ACKNOWLEDGEMENT

This project was funded by the Fraser Valley Regional District, the BC Ministry of Agriculture and Growing Forward 2, a federal-provincial-territorial initiative.

DISCLAIMER

The data that presented in this report provides the best estimates for agriculture water demand that can be generated at this time. While every effort has been made to ensure the accuracy and completeness of the information, the information should not be considered as final. The Government of Canada, the BC Ministry of Agriculture, the BC Agriculture Council, and the Fraser Valley Regional District, or its directors, agents, employees, or contractors will not be liable for any claims, damages, or losses of any kind whatsoever arising out of the use of, or reliance upon, this information.

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Acknowledgements

There are many people who have been involved with the preparation and collection of data used in the development of the Water Demand Model for the Fraser Valley Region. The authors wish to express appreciation to the following for their efforts and/or in-kind contribution for the tasks noted.

Alex Cannon	Environment Canada	Climate data downscaling
Sam Lee	Ministry of Agriculture	GIS Coordination and report preparation
Corrine Roesler	Ministry of Agriculture	GIS Coordination
Kathleen Zimmerman	Ministry of Agriculture	Land Use Survey
Chris Zabek	Ministry of Agriculture	Land Use Survey
Linda Hokanson	Ministry of Agriculture	Publication formatting
Julie Mundy	Ministry of Agriculture	Land Use Survey
Kelsey Lang	Ministry of Agriculture	Land Use Inventory
Kelsey MacKenney	Ministry of Agriculture	Land Use Inventory
Michael Dykes	Ministry of Agriculture	Land Use Inventory
Catherine Overgaard	Fraser Valley Regional District	Land Use Survey
Adam Loughheed	Fraser Valley Regional District	Land Use Survey
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Julia Healy	Fraser Valley Regional District	Land Use Survey
Jessica Dick	Fraser Valley Regional District	Land Use Survey
Mike Wallis	Contractor	Land Use Survey
Bob Drinkwater	Contractor	Land Use Survey

Background

The Agriculture Water Demand Model (AWDM) was developed in the Okanagan Watershed. It was developed in response to rapid population growth, drought conditions from climate change, and the overall increased demand for water. Many of the watersheds in British Columbia (BC) are fully allocated or will be in the next 15 to 20 years. The AWDM helps to understand current agricultural water use and helps to fulfil the Province’s commitment under the “*Living Water Smart – BC Water Plan*” to reserve water for agricultural lands. The Model can be used to establish agricultural water reserves throughout the various watersheds in BC by providing current and future agricultural water use data.

Climate change scenarios developed by the University of British Columbia (UBC) and the Pacific Agri-Food Research Centre (PARC) in Summerland predict an increase in agricultural water demand due to warmer and longer summers and lower precipitation during summer months in the future.

The Model was developed to provide current and future agricultural water demands. The Model calculates water use on a property-by-property basis, and sums each property to obtain a total water demand for the entire basin or each sub-basin. Crop, irrigation system type, soil texture and climate data are used to calculate the water demand. Climate data from 2003 was used to present information on one of the hottest and driest years on record, and 1997 data was used to represent a wet year. Lands within the Agriculture Land Reserve (ALR), depicted in green in Figure 1, were included in the project for the Fraser Valley.

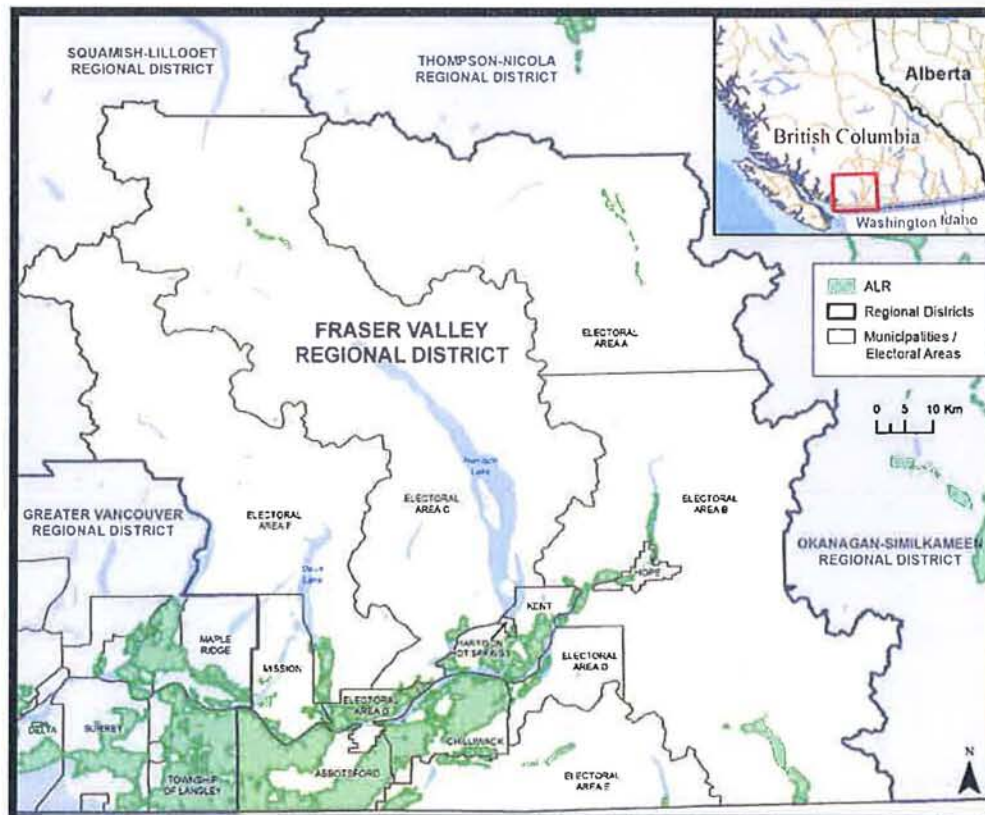


Figure 1 Map of ALR in Fraser Valley

Methodology

The Model is based on a Geographic Information System (GIS) database that contains information on cropping, irrigation system type, soil texture and climate. An explanation of how the information was compiled for each is given below. The survey area included all properties within the ALR and areas that were zoned for agriculture by the local governments. The inventory was undertaken by Ministry of Agriculture (AGRI) staff, hired professional contractors and summer students.

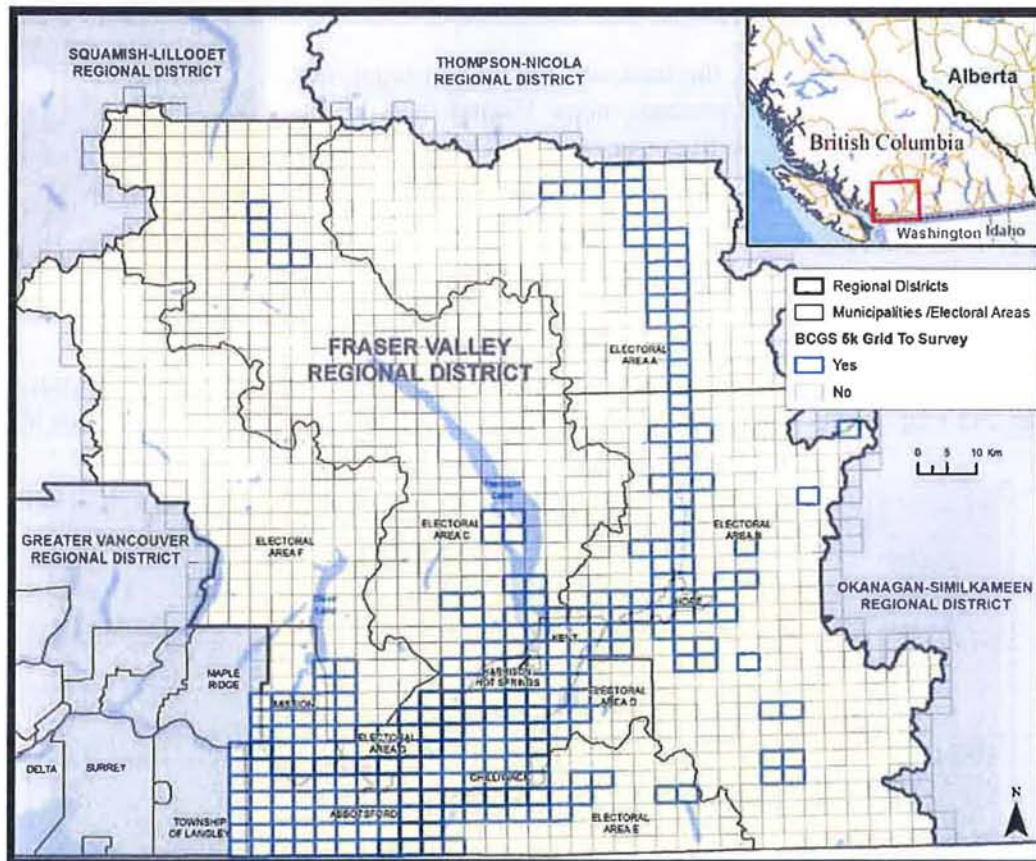


Figure 2 Overlaid Survey Map Sheets, Fraser Valley

Cadastre

Cadastre information was provided by Fraser Valley Regional District and local governments. The entire Fraser Valley Regional District is covered in one dataset which allows the Model to report out on each sub-basin, local government, water purveyor or groundwater aquifer. A GIS technician used aerial photographs to conduct an initial review of cropping information by cadastre, and divided the cadastre into polygons that separate farmstead and driveways from cropping areas. Different crops were also separated into different polygons if the difference could be identified on the aerial photographs. This data was entered into the database that was used by the field teams to conduct and complete the land use survey.

Land Use Survey

The survey maps and database were created by AGRI for the survey crew to enter data about each property. Surveys were done through the summers of 2011 to 2013. The survey crew drove by each property where the team checked the database for accuracy using visual observation and the aerial photographs on the survey maps. A Professional Agrologist verified what was on the site, and a GIS technician altered the codes in the database as necessary (Figure 3). Corrections were handwritten on the maps during. The maps were then brought back to the office to have the hand-drawn lines digitized into the GIS system and have the additional polygons entered into the database.

Once acquired through the survey, the land use data was brought into the GIS to facilitate analysis and produce maps. Digital data, in the form of a database and GIS shape files (for maps), is available upon request through a data sharing agreement with the Ministry of Agriculture.

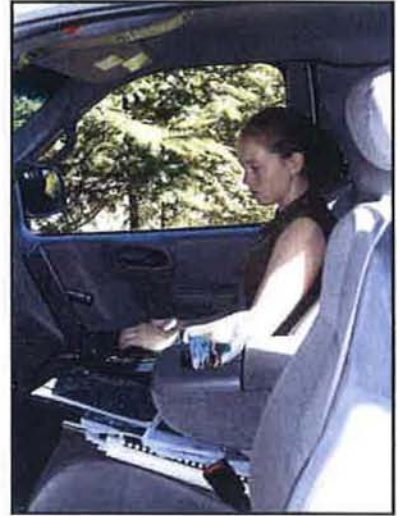


Figure 3 Land Use Survey

Figure 4 provides an example of a map sheet from Abbotsford. The Fraser Valley Regional District was divided into 245 map sheets. Each map sheet also had a key map to indicate where it was located in the region.

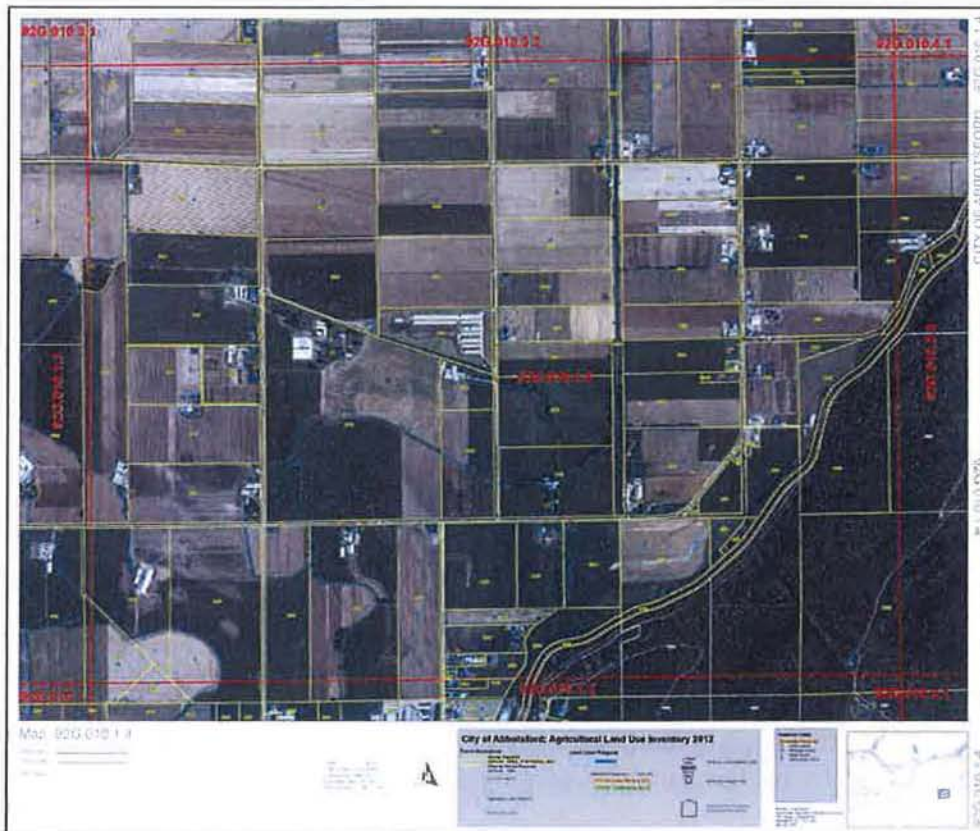


Figure 4 GIS Map Sheet

The smallest unit for which water use is calculated are the polygons within each cadastre. A polygon is determined by a change in land use or irrigation system within a cadastre. Polygons are designated as blue lines within each cadastre as shown in Figures 4 and 5. The dataset for Fraser Valley encompasses 13,310 land parcels that are in or partially in the ALR. There are a total of 52,662 polygons generated within these land parcels. Figure 5 provides an enhanced view of a cadastre containing three polygons. Each cadastre has a unique identifier as does each polygon. The polygon identifier is acknowledged by PolygonID. This allows the survey team to call up the cadastre in the database, review the number of polygons within the cadastre and ensure the land use is coded accurately for each polygon.



Figure 5 Cadastre with Polygons

Soil Information

Soil information was obtained digitally from the Ministry of Environment's Terrain and Soils Information System. The Computer Assisted Planning and Map Production application (CAPAMP) provided detailed (1:20,000 scale) soil surveys that were conducted in the Lower Mainland, on Southeast Vancouver Island, and in the Okanagan-Similkameen areas during the early 1980s. Products developed include soil survey reports, maps, agriculture capability and other related themes. Soil information required for this project was the soil texture (loam, etc.), the available water storage capacity and the peak infiltration rate for each texture type.

The intersection of soil boundaries with the cadastre and land use polygons creates additional polygons that the Model uses to calculate water demand. Figure 6 shows how the land use information is divided into additional polygons using the soil boundaries. The Model calculates water demand using every different combination of crop, soil and irrigation system as identified by each polygon.

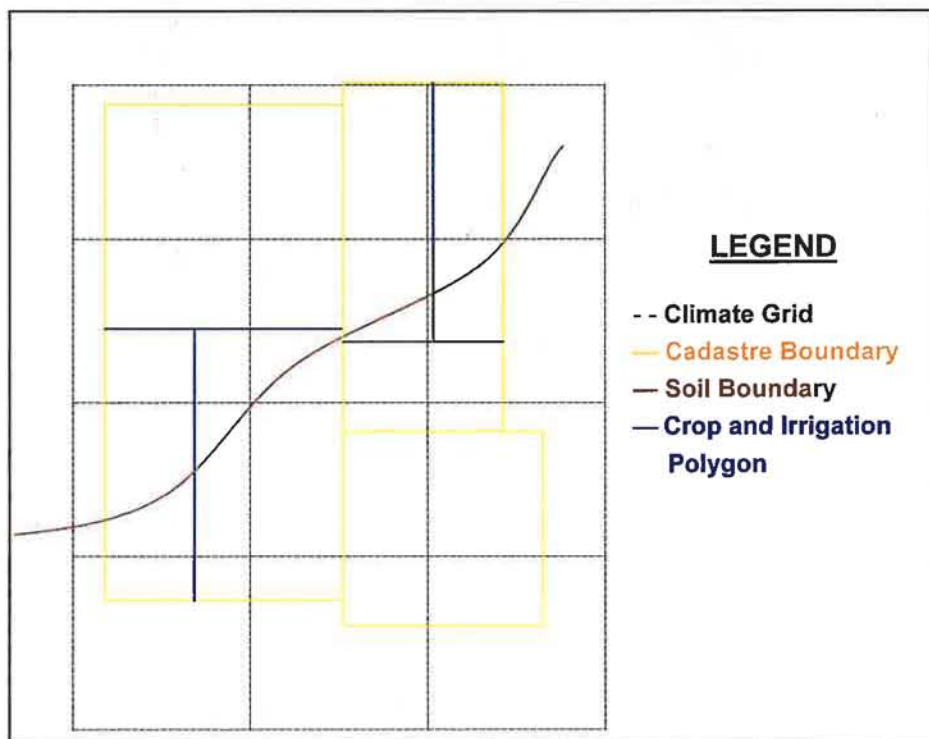


Figure 6 GIS Model Graphic

Climate Information

The agricultural water demand is calculated using climate, crop, irrigation system and soil information data. To incorporate the climatic diversity, climate layers were developed for the entire region on a 500 m x 500 m grid. Each grid cell contains daily climate data, minimum and maximum temperature (T_{min} and T_{max}), and precipitation which allows the Model to calculate a daily reference evapotranspiration rate (ET_o) value. A range of agro-climatic indices such as growing degree days (GDD), corn heat units (CHU), frost free days and temperature sum (T_{sum}) can also be calculated for each grid cell based on temperature data. These values are used to determine seeding dates and the length of the growing season in the Model.

The climate dataset has been developed by using existing data from climate stations in and around Fraser Valley from 1961 to 2003. This climate data set was then interpolated to provide a climate data layer for the entire watershed on the 500 m x 500 m grid. A detailed description of the Model can be obtained by contacting the authors.

Some of the existing climate stations that were used to determine the climate coverage are shown in Figure 7. The attributes attached to each climate grid cell include:

- Latitude
- Longitude
- Elevation
- Aspect
- Slope
- Daily Precipitation
- Daily T_{min} and T_{max}

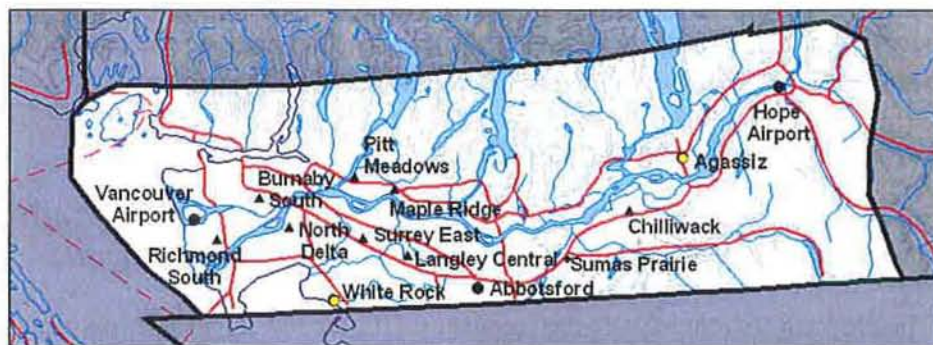


Figure 7 Fraser Valley Climate Stations

The climate database generated contains T_{min} , T_{max} , T_{mean} and Precipitation for each day of the year from 1961 to 2003. The parameters that need to be selected, calculated and stored within the Model are evapotranspiration (ET_o), T_{sum} of 1,000 (for the Fraser Valley), effective precipitation (EP), frost free days, GDD with base temperatures of 5 °C and 10 °C, CHU, and first frost date. These climate and crop parameters are used to determine the growing season length as well as the beginning and end of the growing season in Julian day.

Model Calculations

The Model calculates the water demand for each polygon by using crop, irrigation, soil and climate parameters as explained below. Each polygon has been assigned an ID number as mentioned previously.

It should be noted that in Fraser Valley, many low-lying areas have high water tables which will reduce the overall irrigation demand. Agricultural water demand results from the Model will therefore be higher than what may actually be used as water tables have not been incorporated in the equation.

Crop

The CropID is an attribute of the PolygonID as each polygon will contain a single crop. The crop information (observed during the land use survey) has been collected and stored with PolygonID as part of the land use survey. CropID will provide cropping attributes to the Model for calculating water use for each polygon. CropID along with the climate data will also be used to calculate the growing season length and the beginning and end of the growing season. The attributes for CropID include rooting depth, availability coefficient, crop coefficient and a drip factor.

Rooting depth is the rooting depth for a mature crop in a deep soil.

An availability coefficient is assigned to each crop. The availability coefficient is used with the IrrigID to determine the soil moisture available to the crop for each PolygonID.

The crop coefficient adjusts the calculated ET_0 for the stages of crop growth during the growing season. Crop coefficient curves have been developed for every crop. The crop coefficient curve allows the Model to calculate water demand with an adjusted daily ET_0 value throughout the growing season.

The drip factor is used in the water use calculation for polygons where drip irrigation systems are used. Since the Model calculates water use by area, the drip factor adjusts the percentage of area irrigated by the drip system for that crop.

Irrigation

The IrrigID is an attribute of the PolygonID as each polygon will have a single irrigation system type operating. The irrigation information has been collected and stored (as observed during the land use survey) with the land use data. The land use survey determined if a polygon had an irrigation system operating, what the system type was, and if the system was being used. The IrrigID has an irrigation efficiency listed as an attribute.

Two of the IrrigID's, Overtreedrip and Overtreemicro are polygons that have two systems in place. Two irrigation ID's occur when an overhead irrigation system has been retained to provide crop cooling or frost protection. In this case, the efficiencies used in the Model are the drip and microsprinkler efficiencies.

Soil

The soil layer came from CAPAMP at the Ministry of Environment. In addition, soil data provided by Agriculture and Agri-Food Canada (AAFC) was also used to generate multiple soil layers within each polygon. Each parcel was assigned the most predominant soil polygon, and then for each crop field within that soil polygon, the most predominant texture within the crop's rooting depth was determined and assigned to the crop field.

Note that textures could repeat at different depths – the combined total of the thicknesses determined the most predominant texture. For example, a layer of 20 cm sand, followed by 40 cm clay and then 30 cm of sand would have sand be designated at the predominant soil texture.

The attributes attached to the SoilID is the Available Water Storage Capacity (AWSC) which is calculated using the soil texture and crop rooting depth.

The Maximum Soil Water Deficit (MSWD) is calculated to decide the parameters for the algorithm that is used to determine the Irrigation Requirement (IR). The Soil Moisture Deficit at the beginning of the season is calculated using the same terms as the MSWD.

Climate

The climate data in the Model is used to calculate a daily reference evapotranspiration rate (ET_0) for each climate grid cell. The data that is required to calculate this value are:

- Elevation, metres (m)
- Latitude, degrees ($^{\circ}$)
- Minimum Temperature, degree Celsius ($^{\circ}C$)
- Maximum Temperature, degree Celsius ($^{\circ}C$)
- Classification as Coastal or Interior
- Classification as Arid or Humid
- Julian Day

Data that is assumed or are constants in this calculation are:

- Wind speed 2 m/s
- Albedo or canopy reflection coefficient, 0.23
- Solar constant, G_{sc} 0.082 MJ $^{-2}$ min $^{-1}$
- Interior and Coastal coefficients, K_{RS} 0.16 for interior locations
0.19 for coastal locations
- Humid and arid region coefficients, K_o 0 $^{\circ}C$ for humid/sub-humid climates
2 $^{\circ}C$ for arid/semi-arid climates

Agricultural Water Demand Equation

The Model calculates the Agriculture Water Demand (AWD) for each polygon, as a unique crop, irrigation system, soil and climate data is recorded on a polygon basis. The polygons are then summed to determine the AWD for each cadastre. The cadastre water demand values are then summed to determine AWD for the basin, sub-basin, water purveyor or local government. The following steps provide the process used by the Model to calculate Agricultural Water Demand. Detailed information is available on request.

1. *Pre-Season Soil Moisture Content*

Prior to the start of each crop's growing season, the soil's stored moisture content is modelled using the soil and crop evaporation and transpiration characteristics and the daily precipitation values. Precipitation increases the soil moisture content and evaporation (modelled using the reference potential evapotranspiration) depletes it. In general, during the pre-season, the soil moisture depth cannot be reduced beyond the maximum evaporation depth; grass crops in wet climates, however, can also remove moisture through crop transpiration.

The process used to model the pre-season soil moisture content is:

1. Determine whether the modelling area is considered to be in a *wet* or *dry* climate (see *Wet/Dry Climate Assessment*), and retrieve the early season evaporation factor in the modelling area
2. For each crop type, determine the start of the growing season (see *Growing Season Boundaries*)
3. For each crop and soil combination, determine the *maximum soil water deficit* (MSWD) and *maximum evaporation factor* (maxEvaporation)
4. Start the initial storedMoisture depth on January 1 at the MSWD level
5. For each day between the beginning of the calendar year and the crop's growing season start, calculate a new storedMoisture from:
 - a. the potential evapotranspiration (ET_o)
 - b. the early season evaporation factor (earlyEvaporationFactor)
 - c. the effective precipitation (EP) = actual precipitation \times earlyEvaporationFactor
 - d. daily Climate Moisture Deficit (CMD) = $ET_o - EP$
 - e. storedMoisture = previous day's storedMoisture - CMD

A negative daily CMD (precipitation in excess of the day's potential evapotranspiration) adds to the stored moisture level while a positive climate moisture deficit reduces the amount in the stored moisture reservoir. The stored moisture cannot exceed the maximum soil moisture deficit; any precipitation that would take the stored moisture level above the MSWD gets ignored.

For all crops and conditions except for grass in wet climates, the stored moisture content cannot drop below the maximum soil water deficit minus the maximum evaporation depth; without any crop transpiration in play, only a certain amount of water can be removed from the soil through evaporative processes alone. Grass in wet climates does grow and remove moisture from the soil prior to the start of the irrigation season however. In those cases, the stored moisture level can drop beyond the maximum evaporation depth, theoretically to 0.

Greenhouses and mushroom barns have no stored soil moisture content.

2. *In-Season Precipitation*

During the growing season, the amount of precipitation considered effective (EP) depends on the overall wetness of the modelling area's climate (see *Wet/Dry Climate Assessment*). In dry climates, the first 5 mm of precipitation is ignored, and the EP is calculated as 75% of the remainder:

$$EP = (\text{Precip} - 5) \times 0.75$$

In wet climates, the first 5 mm is included in the EP. The EP is 75% of the actual precipitation:

$$EP = \text{Precip} \times 0.75$$

Greenhouses and mushroom barns automatically have an EP value of 0.

3. *Crop Cover Coefficient (K_c)*

As the crops grow, the amount of water they lose due to transpiration changes. Each crop has a pair of polynomial equations that provide the crop coefficient for any day during the crop's growing season. It was found that two curves, one for modelling time periods up to the present and one for extending the modelling into the future, provided a better sequence of crop coefficients than using a single curve for all years (currently 1961 to 2100). The application automatically selects the current or future curve as modelling moves across the *crop Curve Changeover Year*.

For alfalfa crops, there are different sets of equations corresponding to different cuttings throughout the growing season.

4. *Crop Evapotranspiration (ET_c)*

The evapotranspiration for each crop is calculated as the general ET_o multiplied by the crop coefficient (K_c):

$$ET_c = ET_o \times K_c$$

5. *Climate Moisture Deficit (CMD)*

During the growing season, the daily Climate Moisture Deficit (CMD) is calculated as the crop evapotranspiration (ET_c) less the Effective Precipitation (EP):

$$CMD = ET_c - EP$$

During each crop's growing season, a stored moisture reservoir methodology is used that is similar to the soil moisture content calculation in the pre-season. On a daily basis, the stored moisture level is used towards satisfying the climate moisture deficit to produce an *adjusted Climate Moisture Deficit (CMD_a)*:

$$CMD_a = CMD - \text{storedMoisture}$$

If the storedMoisture level exceeds the day's CMD, then the CMD_a is 0 and the stored moisture level is reduced by the CMD amount. If the CMD is greater than the stored moisture, then all of the stored moisture is used (storedMoisture is set to 0) and the adjusted CMD creates an irrigation requirement.

The upper limit for the storedMoisture level during the growing season is the maximum soil water deficit (MSWD) setting.

6. Crop Water Requirement (CWR)

The Crop Water Requirement is calculated as the adjusted Climate Moisture Deficit (CMD_a) multiplied by the soil water factor (swFactor) and any stress factor (used primarily for grass crops):

$$CWR = CMD_a \times swFactor \times stressFactor$$

7. Irrigation Requirement (IR)

The Irrigation Requirement is the Crop Water Requirement (CWR) after taking into account the irrigation efficiency (I_e) and, for drip systems, the drip factor (D_f):

$$IR = CWR \times \frac{D_f}{I_e}$$

For irrigation systems other than drip, the drip factor is 1.

8. Irrigation Water Demand (IWD_{perc} and IWD)

The portion of the Irrigation Water Demand lost to deep percolation is the Irrigation Requirement (IR) multiplied by the percolation factor (soilPercFactor):

$$IWD_{perc} = IR \times soilPercFactor$$

The final Irrigation Water Demand (IWD) is then the Irrigation Requirement (IR) plus the loss to percolation (IWD_{perc}):

$$IWD = IR + IWD_{perc}$$

9. Frost Protection

For some crops (e.g. cranberries), an application of water is often used under certain climatic conditions to provide protection against frost damage. For cranberries, the rule is: when the temperature drops to 0 °C or below between March 16 and May 20 or between October 1 and November 15, a frost event will be calculated. The calculated value is an application of 2.5 mm per hour for 10 hours. In addition, 60% of the water is recirculated and reused, accounting for evaporation and seepage losses.

This amounts to a modelled water demand of 10 mm over the cranberry crop's area for each day that a frost event occurs between the specified dates.

10. Annual Soil Moisture Deficit

Prior to each crop's growing season, the Model calculates the soil's moisture content by starting it at full (maximum soil water deficit level) on January 1, and adjusting it daily according to precipitation and evaporation. During the growing season, simple evaporation is replaced by the

crop's evapotranspiration as it progresses through its growth stages. At the completion of each crop's growing season, an annual soil moisture deficit (SMD) is calculated as the difference between the soil moisture content at that point and the maximum soil water deficit (MSWD):

$$\text{SMD} = \text{MSWD} - \text{storedMoisture}$$

In dry/cold climates, this amount represents water that the farmer would add to the soil in order to prevent it from freezing. Wet climates are assumed to have sufficient precipitation and warm enough temperatures to avoid the risk of freezing without this extra application of water; the SMD demand is therefore recorded only for dry areas.

There is no fixed date associated with irrigation to compensate for the annual soil moisture deficit. The farmer may choose to do it any time after the end of the growing season and before the freeze up. In the Model's summary reports, the water demand associated with the annual soil moisture deficit shows as occurring at time 0 (week 0, month 0, etc.) simply to differentiate it from other demands that do have a date of occurrence during the crop's growing season.

Greenhouses and mushroom barns do not have an annual soil moisture deficit.

11. *Flood Harvesting*

Cranberry crops are generally harvested using flood techniques. The Model calculates the flood harvesting demand as 250 mm of depth for 10% of the cranberry farmed area. For modelling purposes, it is assumed that 250 mm of water gets applied to the total cranberry crop area, 10% at a time. The water is reused for subsequent portions, but by the time the entire crop is harvested, all of the water is assumed to have been used and either depleted through losses or released from the farm.

The water demand is therefore calculated as a fixed 25 mm over the entire cranberry crop area. The harvesting generally takes place between mid-October and mid-November where the Model treats it as occurring on the fixed date of November 16.

Livestock Water Use

The Model calculates an estimated livestock water demand using agricultural census data and an estimate of the water use per animal. Water use for each animal type is calculated a bit differently depending on requirements. For example, for a dairy milking cow, the water demand for each animal includes, drinking, preparation for milking, pen and barn cleaning, milking system washout, bulk tank washout and milking parlor washing. However, for a dry dairy cow, the demand only includes drinking and pen and barn cleaning.

The water use is estimated on a daily basis per animal even though the facility is not cleaned daily. For example, for a broiler operation, the water use for cleaning a barn is calculated as 4 hours of pressure washing per cycle at a 10 gpm flow rate, multiplied by 6 cycles per barn with each barn holding 50,000 birds. On a daily basis, this is quite small with a value of 0.01 litres per day per bird applied.

For all cases, the daily livestock demand is applied to the farm location. However, in the case of beef, the livestock spend quite a bit of the year on the range. Since the actual location of the animals cannot be ascertained, the water demand is applied to the home farm location, even though most of the demand will not be from this location. Therefore, the animal water demand on a watershed scale will work fine but not when the demand is segregated into sub-watersheds or groundwater areas.

The estimates used for each livestock are shown in Table 1.

Table 1 Livestock Water Demand (Litres/day)				
Animal Type	Drinking	Milking Preparation	Barn Component	Total
Milking Dairy Cow	65	5	15	85
Dry Cow	45		5	50
Swine	12		0.5	12.5
Poultry – Broiler	0.16		0.01	0.17
Poultry – Layer	0.08		0.01	0.09
Turkeys	0.35		0.01	0.36
Goats	8			8
Sheep	8			8
Beef – range, steer, bull, heifer	50			50
Horses	50			50

Definition and Calculation of Individual Terms used in the Irrigation Water Demand Equation

Growing Season Boundaries

There are three sets of considerations used in calculating the start and end of the irrigation season for each crop:

- temperature-based growing season derivations, generally using Temperature Sum (Tsum) or Growing Degree Day (GDD) accumulations
- the growing season overrides table
- the irrigation season overrides table

These form an order of precedence with later considerations potentially overriding the dates established for the previous rules. For example, the temperature-based rules might yield a growing season start date of day 90 for a given crop in a mild year. To avoid unrealistic irrigation starts, the season overrides table might enforce a minimum start day of 100 for that crop; at that point, the season start would be set to day 100. At the same time, a Water Purveyor might not turn on the water supply until day 105; specifying that as the minimum start day in the irrigation season overrides table would prevent any irrigation water demands until day 105.

This section describes the rules used to establish growing season boundaries based on the internal calculations of the Model. The GDD and Tsum Day calculations are described in separate sections. The *standard end of season* specified for several crops is the earlier of the end date of Growing Degree Day with base temperature of 5 °C (GDD₅) or the first frost.

1. *Corn (silage corn)*

- uses the corn_start date for the season start
- season end: earlier of the killing frost or the day that the CHU2700 (2700 Corn Heat Units) threshold is reached

2. *Sweetcorn, Potato, Tomato, Pepper, Strawberry, Vegetable, Pea*

- corn_start date for the season start
- corn start plus 110 days for the season end

3. *Cereal*

- GDD₅ start for the season start
- GDD₅ start plus 130 days for the season end

4. *AppleHD, AppleMD, AppleLD, Asparagus, Berry, Blueberry, Ginseng, Nuts, Raspberry, Sourcherry, Treefruit, Vineberry*

- season start: $(0.8447 \times \text{tsum600_day}) + 18.877$
- standard end of season

5. *Pumpkin*

- corn_start date
- standard end of season

6. ***Apricot***
 - season start: $(0.9153 \times \text{tsum400_day}) + 5.5809$
 - standard end of season
7. ***CherryHD, CherryMD, CherryLD***
 - season start: $(0.7992 \times \text{tsum450_day}) + 24.878$
 - standard end of season
8. ***Grape, Kiwi***
 - season start: $(0.7992 \times \text{tsum450_day}) + 24.878$
 - standard end of season
9. ***Peach, Nectarine***
 - season start: $(0.8438 \times \text{tsum450_day}) + 19.68$
 - standard end of season
10. ***Plum***
 - season start: $(0.7982 \times \text{tsum500_day}) + 25.417$
 - standard end of season
11. ***Pear***
 - season start: $(0.8249 \times \text{tsum600_day}) + 17.14$
 - standard end of season
12. ***Golf, TurfFarm***
 - season start: later of the GDD₅ start and the tsum300_day
 - standard end of season
13. ***Domestic, Yard, TurfPark***
 - season start: later of the GDD₅ start and the tsum400_day
 - standard end of season
14. ***Greenhouse (interior greenhouses)***
 - fixed season of April 1 – October 30
15. ***GH Tomato, GH Pepper, GH Cucumber***
 - fixed season of January 15 – November 30
16. ***GH Flower***
 - fixed season of March 1 – October 30
17. ***GH Nursery***
 - fixed season of April 1 – October 30
18. ***Mushroom***
 - all year: January 1 – December 31

19. Shrubs/Trees, Fstock, NurseryPOT

- season start: tsum500_day
- end: Julian day 275

20. Floriculture

- season start: tsum500_day
- end: Julian day 225

21. Cranberry

- season start: tsum500_day
- end: Julian day 275

22. Grass, Forage, Alfalfa, Pasture

- season start: later of the GDD₅ and the tsum600_day
- standard end of season

23. Nursery

- season start: tsum400_day
- standard end of season

Evapotranspiration (ET_o)

The ET_o calculation follows the FAO Penman-Montieth equation. Two modifications were made to the equation:

- Step 6 – Inverse Relative Distance Earth-Sun (d_r)
Instead of a fixed 365 days as a divisor, the actual number of days for each year (365 or 366) was used.
- Step 19 – Evapotranspiration (ET_o)
For consistency, a temperature conversion factor of 273.16 was used instead of the rounded 273 listed.

Availability Coefficient (AC)

The availability coefficient is a factor representing the percentage of the soil's total water storage that the crop can readily extract. The factor is taken directly from the crop factors table (crop_factors) based on the cropId value.

Rooting Depth (RD)

The rooting depth represents the crop's maximum rooting depth and thus the depth of soil over which the plant interacts with the soil in terms of moisture extraction. The value is read directly from the crop factors table.

Stress Factor (stressFactor)

Some crops, such as *grasses*, are often irrigated to a less degree than their full theoretical requirement for optimal growth. The *stress factor (crop_groups_and_factors)* reduces the calculated demand for these crops.

Available Water Storage Capacity (AWSC)

The available water storage capacity is a factor representing the amount of water that a particular soil texture can hold without the water dropping through and being lost to deep percolation. The factor is taken directly from the soil factors table (*soil_factors*).

Maximum Soil Water Deficit (MSWD)

The maximum soil water deficit is the product of the crop's availability coefficient, rooting depth, and the available water storage capacity of the soil:

$$MSWD = RD \times AWSC \times AC$$

Deep Percolation Factor (soilPercFactor)

The soil percolation factor is used to calculate the amount of water lost to deep percolation under different management practices.

For greenhouse crops, the *greenhouse leaching factor* is used as the basic soil percolation factor. This is then multiplied by a greenhouse recirculation factor, if present, to reflect the percentage of water re-captured and re-used in greenhouse operations.

$$soilPercFactor = soilPercFactor \times (1 - recirculationFactor)$$

For Nursery Pot (Nursery POT) and Forestry Stock (Fstock) crops, the soil percolation factor is fixed at 35%. For other crops, the factor depends on the soil texture, the MSWD, the irrigation system, and the Irrigation Management Practices code. The percolation factors table (*soil_percolation_factors*) is read to find the first row with the correct management practices, soil texture and irrigation system, and a MSWD value that matches or exceeds the value calculated for the current land use polygon.

If the calculated MSWD value is greater than the index value for all rows in the percolation factors table, then the highest MSWD factor is used. If there is no match based on the passed parameters, then a default value of 0.25 is applied.

For example, a calculated MSWD value of 82.5 mm, a soil texture of sandy loam (SL) and an irrigation system of solid set overtree (Ssovertree) would retrieve the percolation factor associated with the MSWD index value of 75 mm in the current table (presently, there are rows for MSWD 50 mm and 75 mm for SL and Ssovertree).

Maximum Evaporation Factor (maxEvaporation)

Just as different soil textures can hold different amounts of water, they also have different depths that can be affected by evaporation. The factor is taken directly from the soil factors table.

Irrigation Efficiency (I_e)

Each irrigation system type has an associated efficiency factor (inefficient systems require the application of more water in order to satisfy the same crop water demand). The factor is read directly from the irrigation factors table (*irrigation_factors*).

Soil Water Factor (swFactor)

For the greenhouse “crop”, the soil water factor is set to 1. For other crops, it is interpolated from a table (*soil_water_factors*) based on the MSWD. For Nurseries, the highest soil water factor (lowest MSWD index) in the table is used; otherwise, the two rows whose MSWD values bound the calculated MSWD are located and a soil water factor interpolated according to where the passed MSDW value lies between those bounds.

For example, using the current table with rows giving soil water factors of 0.95 and 0.9 for MSWD index values of 75 mm and 100 mm respectively, a calculated MSWD value of 82.5 mm would return a soil water factor of:

$$0.95 + \left[\frac{82.5 - 75}{100 - 75} \times (0.9 - 0.95) \right]$$
$$= 0.935$$

If the calculated MSWD value is higher or lower than the index values for all of the rows in the table, then the factor associated with the highest or lowest MSWD index is used.

Early Season Evaporation Factor (earlyEvaporationFactor)

The effective precipitation (precipitation that adds to the stored soil moisture content) can be different in the cooler pre-season than in the growing season. The early season evaporation factor is used to determine what percentage of the precipitation is considered effective prior to the growing season.

Crop Coefficient (K_c)

The crop coefficient is calculated from a set of fourth degree polynomial equations representing the crop’s ground coverage throughout its growing season. The coefficients for each term are read from the crop factors table based on the crop type, with the variable equalling the number of days since the start of the crop’s growing season. For example, the crop coefficient for Grape on day 35 of the growing season would be calculated as:

$$K_c = \frac{[0.0000000031 \times (35)^4] + [-0.0000013775 \times (35)^3] + (0.0001634536 \times (35)^2) + (-0.0011179845 \times 35) + 0.2399004137}{0.346593241}$$

Alfalfa crops have an additional consideration. More than one cutting of alfalfa can be harvested over the course of the growing season, and the terms used for the crop coefficient equation changes for the different cuttings. For alfalfa, the alfalfa cuttings table is first used to determine which cutting period the day belongs to (first, intermediate or last), and after that the associated record in the crop factors table is accessed to determine the terms.

There are two sets of polynomial coefficients used to calculate the crop coefficient; the first set is used for modelling time periods up to the year specified as the *crop curve changeover year*; and the second for modelling into the future. The changeover year will be modified as time goes on and new historical climate observations become available.

Growing Degree Days (GDD)

The Growing Degree Day calculations generate the start and end of GDD accumulation.

1. *Start of GDD Accumulation*

For each base temperature (bases 5 and 10 are always calculated, other base temperature can be derived), the start of the accumulation is defined as occurring after 5 consecutive days of T_{mean} matching or exceeding the base temperature (BaseT). The search for the start day gets reset if a killing frost (< -2 °C) occurs, even after the accumulation has started. The search also restarts if there are 2 or more consecutive days of $T_{\text{min}} \leq 0$ °C. The GDD start is limited to Julian days 1 to 210; if the accumulation has not started by that point, then it is unlikely to produce a reasonable starting point for any crop.

2. *End of GDD accumulation*

The search for the end of the GDD accumulation begins 50 days after its start. The accumulation ends on the earlier of 5 consecutive days where T_{mean} fails to reach BaseT (strictly *less than*) or the first killing frost (-2 °C).

During the GDD accumulation period, the daily contribution is the difference between T_{mean} and BaseT, as long as T_{mean} is not less than BaseT:

$$\text{GDD} = T_{\text{mean}} - \text{BaseT}; 0 \text{ if negative}$$

Frost Indices

Three frost indices are tracked for each year:

- the last spring frost is the latest day in the first 180 days of the year with a $T_{\text{min}} \leq 0$ °C
- the first fall frost is the first day between days 240 and the end of the year where $T_{\text{min}} \leq 0$ °C
- the killing frost is the first day on or after the first fall frost where $T_{\text{min}} \leq -2$ °C

Corn Heat Unit (CHU)

The Corn Heat Unit is the average of two terms using T_{min} and T_{max} . Prior to averaging, each term is set to 0 individually if it is negative.

$$\begin{aligned} \text{term1} &= [3.33 \times (T_{\max} - 10)] - [0.084 \times (T_{\max} - 10) \times (T_{\max} - 10)]; 0 \text{ if negative} \\ \text{term2} &= 1.8 \times (T_{\min} - 4.44); 0 \text{ if negative} \\ \text{CHU} &= \frac{(\text{term1} + \text{term2})}{2} \end{aligned}$$

Corn Season Start and End

The corn season boundary derivations are similar to the GDD determinations. The start day is established by 3 consecutive days where $T_{\text{mean}} \geq 11.2$ °C. As in the case of the GDD calculations, the search for the corn season start day gets reset if $T_{\text{min}} \leq -2$ °C, or if there are 2 or more consecutive days of -2 °C $\leq T_{\text{min}} \leq 0$ °C.

The search for the silage corn season end begins 50 days after the start. The season ends on the earlier of a mean temperature dropping below 10.1 or a killing frost.

The end of the sweet corn season is defined as 110 days after the season start.

Tsum Indices

The Tsum day for a given number is defined as the day that the sum of the positive daily T_{mean} reaches that number. For example, the Tsum400 day is the day where the sum of the positive T_{mean} starting on January 1 sum to 400 units or greater.

Days where T_{mean} falls below 0 °C are simply not counted; therefore, the Model does not restart the accumulation sequence.

Wet/Dry Climate Assessment

Starting with the Lower Mainland, some of the modelling calculations depend on an assessment of the general climatic environment as *wet* or *dry*. For example, when modelling the soil moisture content prior to the start of the crop's growing season, the reservoir can only be drawn down by evaporation except for *grass* crops in *wet* climates which can pull additional moisture out of the soil.

The assessment of wet or dry uses the total precipitation between May 1 and September 30. If the total is more than 125 mm during that period, the climate is considered to be *wet* and otherwise *dry*.

Groundwater Use

The Model generates water sources for irrigation systems. This is done by first determining which farms are supplied by a water purveyor, and then coding those farms as such. Most water purveyors use surface water but where groundwater is used, the farms are coded as groundwater use. The second step is to check all water licences and assign the water licences to properties in the database. The remaining farms that are irrigating will therefore not have a water licence or be supplied by a water purveyor. The assumption is made that these farms are irrigated by groundwater sources.

Land Use Results

A summary of the land area and the inventoried area of Fraser Valley is shown in Table 2. The inventoried area includes parcels that are in and partially in the Agricultural Land Reserve (ALR). The primary agricultural use of the ARL area is shown in Table 3.

The Model also reports out on groundwater aquifers and local governments. Figure 8 provides a schematic of the higher yielding aquifer areas in the Fraser Valley Regional District based on the information from B.C. Ministry of Environment.

Table 2 Overview of Fraser Valley's Land and Inventoried Area	
Area Type	Area (ha)
Fraser Valley	
Total Area	1,389,740
Area of Water Feature	58,221
Area of Land (excluding water features)	1,331,519
ALR Area	71,706
Area of First Nations Reserve	12,156
Inventoried Area	
Total Inventoried Area	73,989
Area of First Nations Reserve in ALR	7,437

Table 3 Summary of Primary Agricultural Activities within the Inventoried Area where Primary Land Use is Agriculture in Fraser Valley	
Primary Agriculture Activity	Total Land Cover (ha)
Berries	5,779
Cultivated land, crop transition, fallow land	365
Floriculture	175
Forage, pasture	26,598
Glass greenhouse	113
Grains, cereals, oilseeds	106
Nursery and tree plantations	2,061
Poly greenhouse	124
Specialty, turf and nut trees	696
Tree fruits	42
Vegetables	2,078
Vines	55
Others	28
Total	38,220

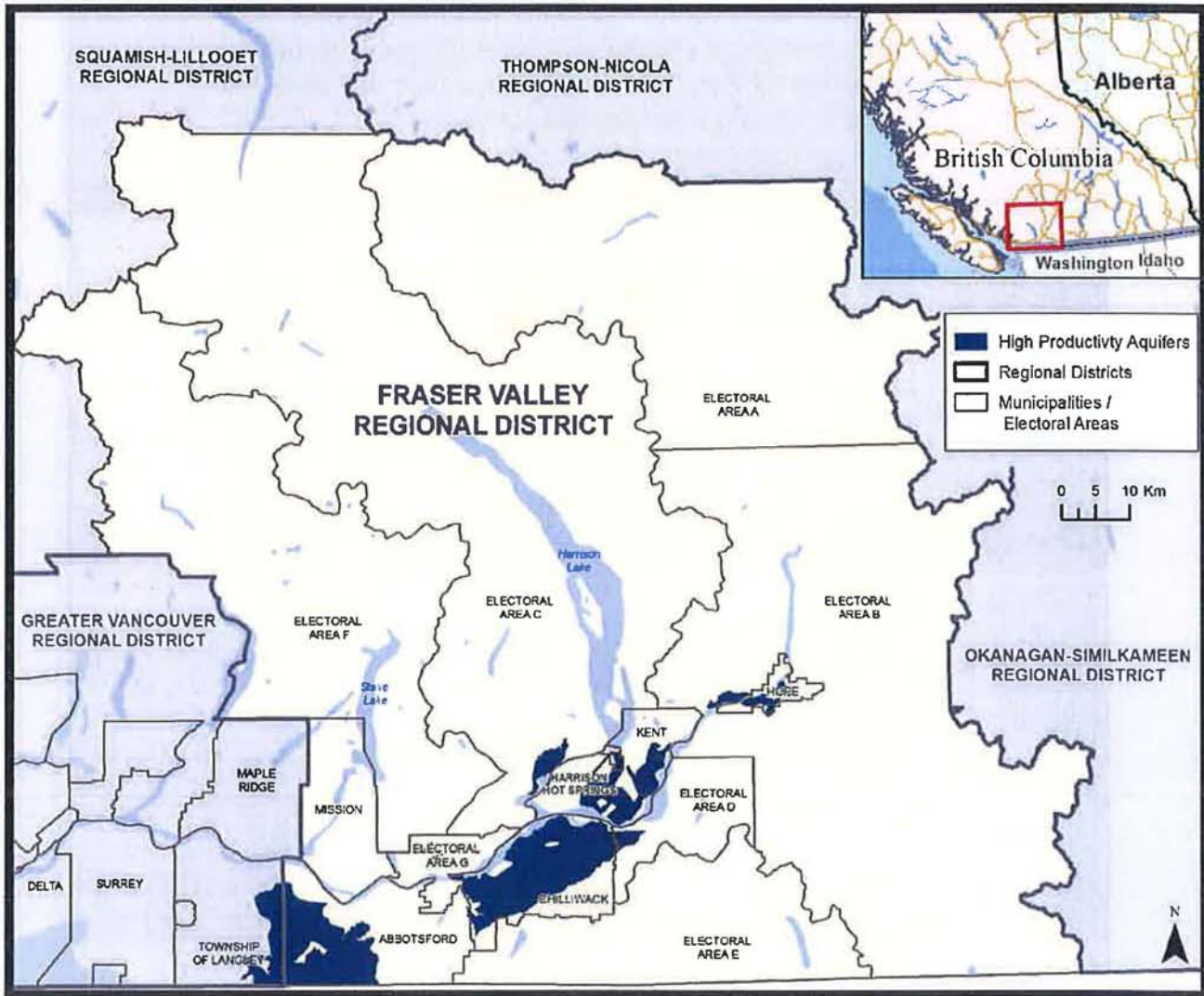


Figure 8 Higher Productive Groundwater Aquifers in Fraser Valley

Agricultural Water Demand Model Results

The Model has a reporting feature that can save and generate reports for many different scenarios that have been pre-developed. This report will provide a summary of the reported data in the Appendices. Climate data from 1997 and 2003 were chosen as they represent a relatively wet year and dry year respectively. Most reports are based on the 2003 data since the maximum current demand can then be presented.

Annual Crop Water Demand – Tables A and B

The Model can use three different irrigation management factors, good, average and poor. Unless otherwise noted, average management were used in the tables. Table A provides the annual irrigation water demand for current crop and irrigation systems for the year 2003 using average irrigation management, and Table B provides the same data for 1997.

The outdoor irrigated acreage in Fraser Valley is 15,283 hectares (ha) including 221 ha in golf courses. The total annual irrigation demand for this area was 67,388,512 m³ in 2003 (a dry year), and dropped to 35,559,136 m³ in 1997 (a wet year).

Of interest is that during a wet year like 1997, the demand was only 52% of a hot dry year like 2003. Another point to consider is that the actual water demand supplied by an irrigation system may be less than the numbers shown above. The reason is that the Model does not have an adjustment for water supplied to crops grown in low lying areas with a high water table. In portions of the Fraser Valley Regional District, farms located in the lowland regions have high water tables during portions of the growing season. Some water may also be supplied by sub-irrigation to the crops through the drainage and irrigation ditch infrastructure. The high water tables will reduce irrigation demand which is not accounted for in the Model outputs. The Model numbers should therefore be considered the higher estimate of demand.

In addition, the Model also calculates demand based on relatively good practices. As such, actual use may actually be higher or lower than what is calculated by the Model.

The predominant irrigated agriculture crop in Fraser Valley is forage, followed by blueberries, nursery, and then vegetables and raspberries. The average irrigation requirements for golf course, pasture/grass and turf are expected to be high as the roots are shallow and water storage is limited; therefore, require more water. Greenhouses often have a high demand as rainfall is not factored into irrigation demand. Depending on the crop grown (e.g., floriculture), these numbers may be reduced slightly, i.e., around 1,100 mm. Blueberries and raspberries have much lower requirements because of deeper rooting depths and more efficient irrigation systems are typically used.

Annual Water Demand Reported by Irrigation System – Table C

The crop irrigation demand can also be reported by irrigation system type as shown in Tables C. The total area irrigated includes indoor irrigation, such as greenhouses and mushroom farms. The total area that is currently irrigated by efficient systems such as drip, microsprinkler or microspray is 3,790 ha or 11% of all areas irrigated.

Annual Water Demand by Soil Texture – Table D

Table D provides the annual water demand by soil texture. Where soil texture data is missing, the soil texture has been defaulted to sandy loam. The defaults are shown in the Table D.

Water Demand by Local Government – Table E

Many of the local governments in Fraser Valley supply water to agricultural areas through a network of pumps and drainage channels. Table E in the appendix provides a breakdown of the water supplied by local governments.

Water Demand by Electoral Area – Table F

Table F shows the water demands by electoral areas. Figure 9 shows the electoral areas boundaries in the Fraser Valley Regional District.

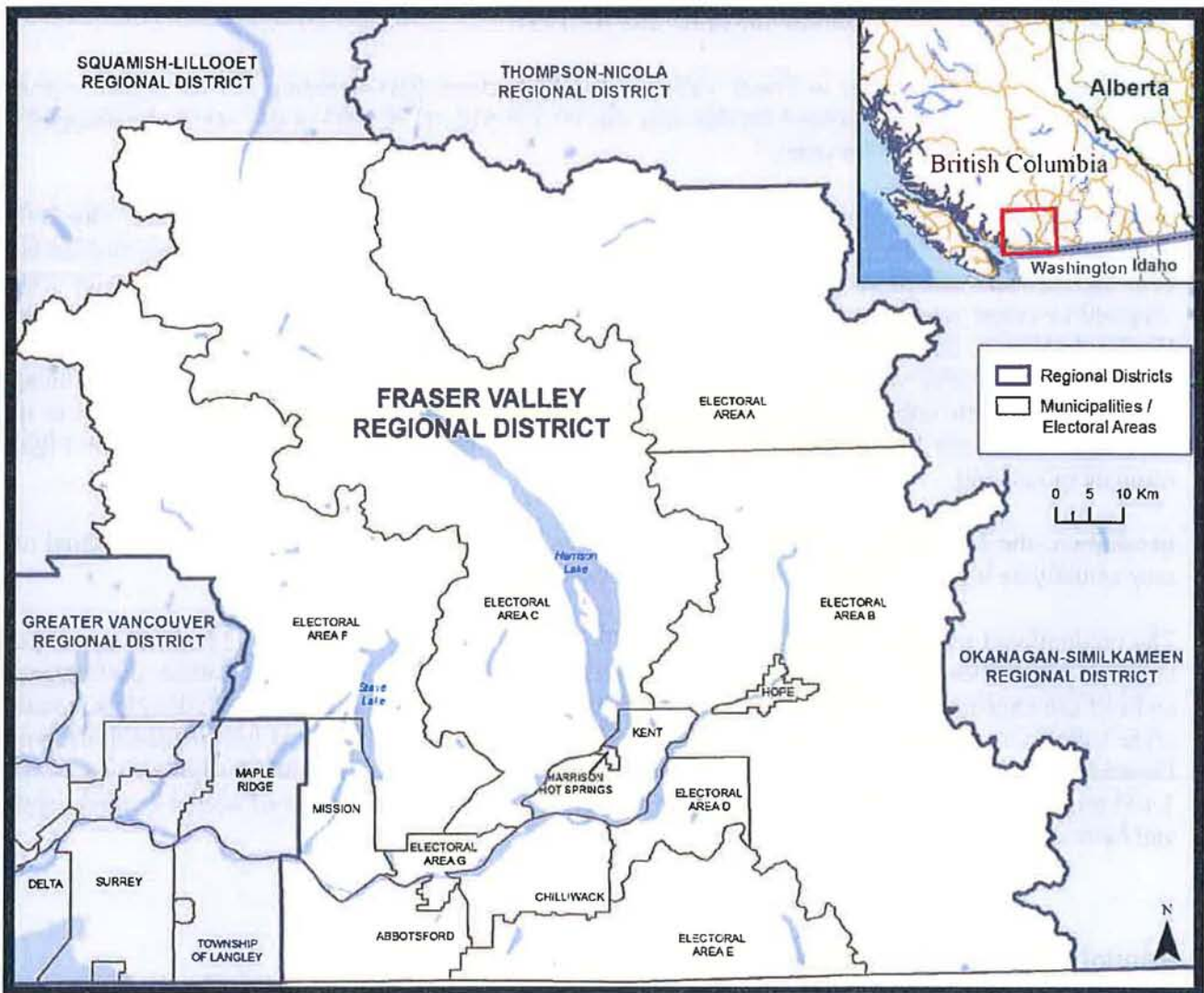


Figure 9 Electoral Areas in Fraser Valley Regional District

Irrigation Management Factors – Table G

The Model can estimate water demand based on poor, average and good irrigation management factors. This is accomplished by developing an irrigation management factor for each crop, soil and irrigation system combination based on subjective decision and percolation rates. The Maximum Soil Water Deficit (MSWD) is the maximum amount of water that can be stored in the soil within the crop rooting zone. An irrigation system applying more water than what can be stored will result in percolation beyond the crop's rooting depth. Irrigation systems with high application rates will have a probability of higher percolation rates, a stationary gun for instance.

For each soil class, a range of four MSWD are provided, which reflect a range of crop rooting depths. An irrigation management factor, which determines the amount of leaching, is established for each of the MSWD values for the soil types (Table 5). The management factor is based on irrigation expertise as to how the various irrigation systems are able to operate. For example, Table 4 indicates that for a loam soil and a MSWD of 38 mm, a solid set overtree system has a management factor of 0.10 for good management while the drip system has a management factor of 0.05. This indicates that it is easier to prevent percolation with a drip system than it is with a solid set sprinkler system. For poor management, the factors are higher.

There are a total of 1,344 irrigation management factors established for the 16 different soil textures, MSWD and 21 different irrigation system combinations used in the Model.

Table 4 Irrigation Management Factors							
Soil Texture	MSWD	Solid Set Overtree			Drip		
		Good	Average	Poor	Good	Average	Poor
Loam	38	0.10	0.15	0.20	0.05	0.10	0.15
	50	0.05	0.10	0.15	0.05	0.075	0.10
	75	0.05	0.10	0.15	0.05	0.075	0.10
	100	0.05	0.075	0.10	0.05	0.075	0.10
Sandy loam	25	0.20	0.225	0.25	0.10	0.15	0.20
	38	0.10	0.15	0.20	0.10	0.125	0.15
	50	0.05	0.10	0.15	0.05	0.10	0.10
	75	0.05	0.10	0.15	0.05	0.075	0.10

The management factors increase as the MSWD decreases because there is less soil storage potential in the crop rooting depth. For irrigation systems such as guns, operating on a pasture which has a shallow rooting depth, on a sandy soil which cannot store much water, the poor irrigation management factor may be as high as 0.50.

The management factor used in the Model assumes all losses are deep percolation while it is likely that some losses will occur as runoff as well.

Table G provides an overview of the impacts on the management factors and irrigation systems used. Since a large portion of the crops in the region are irrigated with drip systems, the impacts of improved management are not that significant. An improvement of 5% in total water use reduction could be

achieved by improved management. A further reduction could be achieved by improving irrigation efficiencies as shown in Table I.

Table G also provides percolation rates based on good, average and poor management using 2003 climate data. In summary, good management is 5,813,444 m³, average is 7,492,942 m³ and poor management is 9,172,440 m³. Percolation rates for poor management are 37% higher than for good management.

Deep Percolation – Table H

The percolation rates vary by crop, irrigation system type, soil and the management factor used. Table H shows the deep percolation amounts by irrigation system type for average management. The last column provides a good indication of the average percolation per hectare for the various irrigation system types. Landscape systems have a high percolation rate predominantly because application rates are high and the crop rooting depth is quite shallow. Flood irrigation and gun systems are expected to have high percolation rate due to high application rates.

Improved Irrigation Efficiency and Good Management – Table I

There is an opportunity to reduce water use by converting irrigation systems to a higher efficiency for some crops. For example, drip systems could be used for all berry crops, vegetable crops and some of the other horticultural crops, but not forage crops. In addition, using better management such as irrigation scheduling techniques will also reduce water use, especially for forage where drip conversion is not possible. Table I provides a scenario of water demand if all sprinkler systems are converted to drip systems for horticultural crops in Fraser Valley, using good irrigation management. The water demand for 2003 would reduce from 67,388,512 m³ to 59,041,117 m³ if sprinkler systems were converted to drip and good management practices were implemented. Since many of the horticultural crops are already using drip systems, (e.g., blueberries) the reduction achieved is 14%. If forage fields of over 10 to 20 ha can have their irrigation systems converted to more efficient ones, e.g., low-pressure centre pivots, water demand can potentially be further reduced.

Water Demand for Frost Protection, Greenhouse and Crop Harvesting – Table J

Greenhouse water use is calculated with separate algorithms as the water demand may not be directly related to ET_o during times of the year when the greenhouse is heated. The estimated water demand is therefore shown separately from other crops in Table J. Other crops that fall in this category are potted nursery plants, forestry stock found inside plastic shelters and mushroom house water use.

Irrigation systems are also used for frost protection for crops such as cranberries. An estimate of frost protection is also provided. The Model calculates a water demand for frost protection whenever the temperature drops to 0°C in the spring. In 1997, only about 10% of the cranberry area had one or more frost events. In 2003, no frost events were indicated. In reality, growers would have applied more water than what is indicated by the Model, as frost protection systems are often started prior to a frost to eliminate any risk.

Cranberries also use water for harvesting purposes. An estimate of the cranberry harvesting water requirements are provided in Table J.

Livestock Water Use – Table K

The Model provides an estimate of water use for livestock. The estimate is based on the number of animals in Fraser Valley as determined by the latest census, the drinking water required for each animal per day and the barn or milking parlour wash water. Values used are shown in Table K. For Fraser Valley, the amount of livestock water is estimated at 3.3 million m³.

Climate Change Water Demand for 2050 – Table L

The Model also has access to climate change information until the year 2100. While data can be run for each year, three driest years in the 2050's were selected to give a representation of climate change. Figure 10 shows the climate data results which indicate that 2053, 2056, and 2059 generate the highest annual ET_o and lowest annual precipitation. These three years were used in this report.

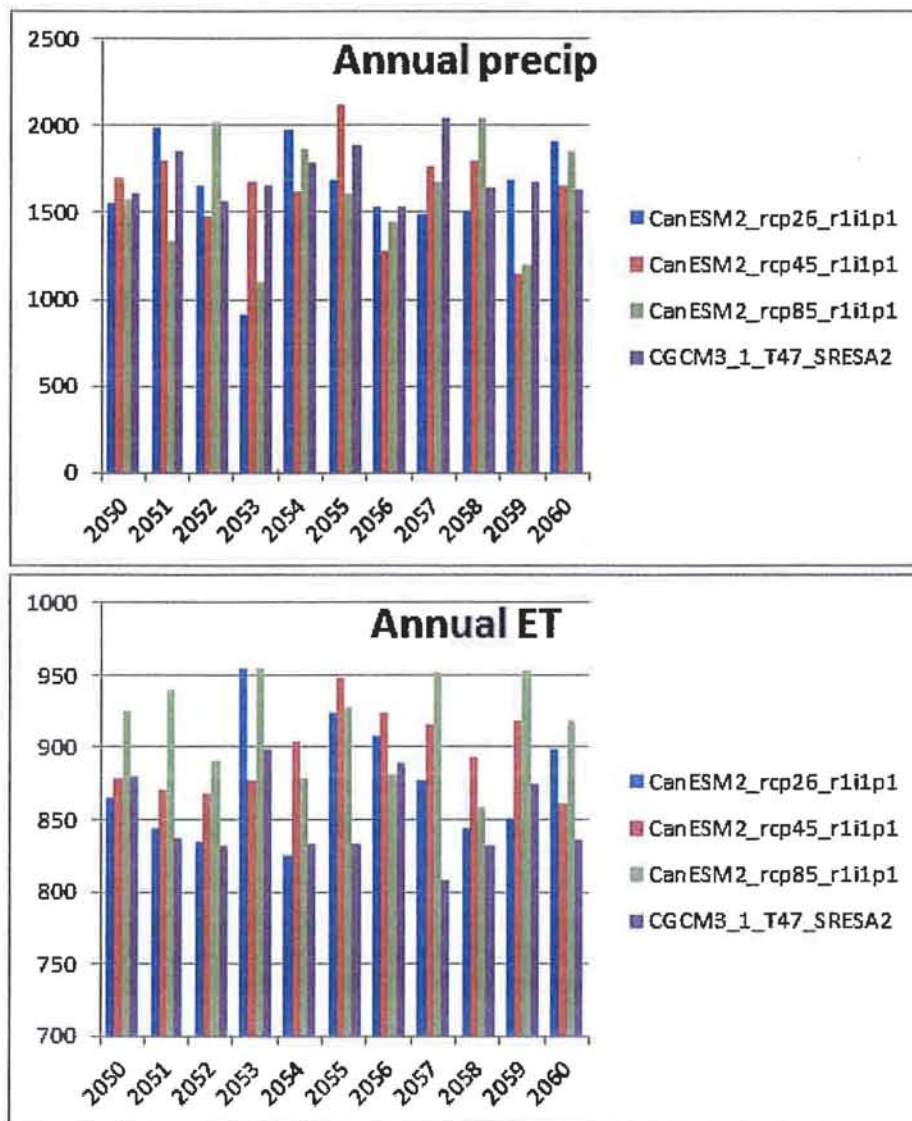


Figure 10 Annual ET and Effective Precipitation in 2050's

Table L provides the results of climate change on irrigation demand for the three years selected using current crops and irrigation systems. Current crops and irrigation systems are used to show the increase due to climate change only, with no other changes taking place.

The climate change scenario used in this report is RCP85. The data is shown from each Model for all three years. Without running many years of data, it is difficult to get a reliable trend. However, the preliminary data indicates that without changing crops and irrigation systems, climate change may have a significant impact in drier years. These results show a possible increase of 94% in extreme years like 2053.

Figure 11 shows all of the climate change scenario runs for the Okanagan using 12 climate models from 1960 to 2100. This work was compiled by Denise Neilsen at the Agriculture and Agri-Food Canada – Summerland Research Station. There is a lot of scatter in this figure, but it is obvious that there is a trend of increasing water demand.

The climate change model used in this report is RCP85. Running only one climate change model on three selected future years is not sufficient to provide a trend like in Figure 11. What the results do show is that in an extreme climate scenario, it is possible to have an annual water demand that is 94% higher than what was experienced in 2003. More runs of the climate change models will be required to better estimate a climate change trend for the Fraser Valley Regional District.

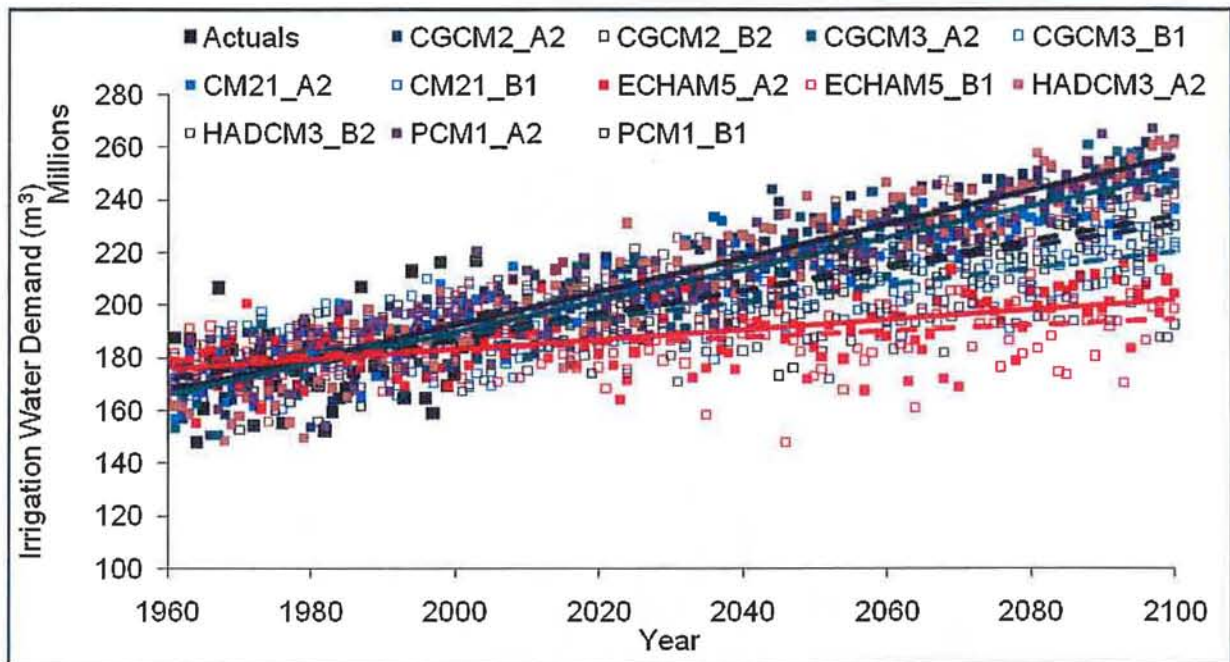


Figure 11 Future Irrigation Demand for All Outdoor Uses in the Okanagan in Response to Observed Climate Data (Actuals) and Future Climate Data Projected from a Range of Global Climate Models

Agricultural Buildout Crop Water Demand Using 2003 Climate Data – Table M

An agricultural buildout scenario was developed that looked at potential agricultural lands that could be irrigated in the future. The rules used to establish where potential additional agricultural lands were located are as follows:

For Fraser Valley

- within 1,000 m of water supply (lake)
- within 1,000 m of water supply (water course)
- within 1,000 m of water supply (wetland)
- within 1,000 m of high productivity aquifer
- within 1,000 m of water purveyor
- with Ag Capability class 1-4 only where available
- must be within the ALR
- below 750 m average elevation
- for surface water sources, the maximum elevation from water source to the property is 125 m

For the areas that are determined to be eligible for future buildout, a crop and irrigation system need to be applied. Where a crop already existed in the land use inventory, that crop would remain and an irrigation system assigned. If no crop existed, then a crop and irrigation system are assigned as per the criteria below:

- **Forage (grass/legume):** 25% of the buildout are with centre pivot irrigation
- **Corn:** 20% of the buildout area with centre pivot irrigation
- **Blueberry:** 20% of the buildout area with drip irrigation
- **Raspberry:** 10% of the buildout area with drip irrigation
- **Vegetable:** 10% of the buildout area with drip irrigation
- **Nursery:** 10% of the buildout area with drip irrigation
- **Pasture (grass):** 5% of the buildout area with centre pivot irrigation

Figure 12 indicates the location of agricultural land that is currently irrigated (blue) and the land that can be potentially irrigated (red). Based on the scenario provided for Fraser Valley, the additional agricultural land that could be irrigated is 18,650 ha. The water demand for a year like 2003 is about 132 million m³ assuming efficient irrigation systems and good management.

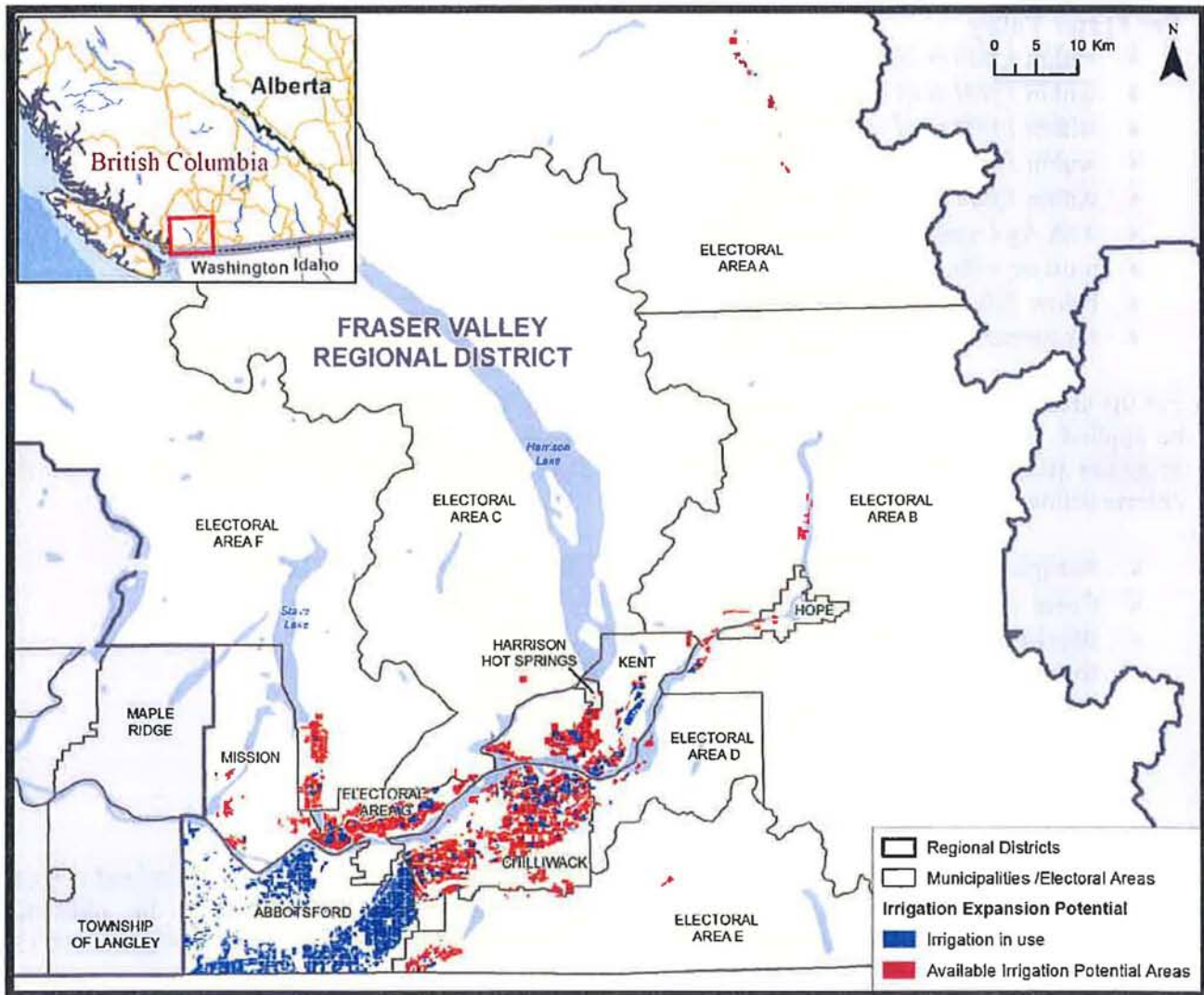


Figure 12 Fraser Valley Irrigation Expansion Potential

Agricultural Buildout Crop Water Demand for 2050 – Table N

The same irrigation expansion and cropping scenario used to generate the values in Table M were used to generate the climate change water demand shown in Table N. The climate change model was used. See discussion under Table L section. When climate change is added to the buildout scenario, the water demand increases from 132 million m³ to 246 million m³.

Irrigation Systems Used for the Buildout Scenario for 2003 – Table O

Table O provides an account of the irrigation systems used by area for the buildout scenario in the previous two examples. Note that drip irrigation is one of the predominant system types.

Water Demand for the Buildout Area by Local Government 2003 Climate Data – Table P

Table P provides the water demand by local governments for the buildout scenario used in this report. Comparing these values with the result in Table E will provide information on the possible increased water demand.

Water Demand for the Buildout Area by Electoral Area 2003 Climate Data – Table Q

Table Q provides the future water demand within electoral area boundaries using previous scenarios. Comparing these values with the result in Table F will provide information on the possible increased water demand within electoral areas if the buildout scenarios actually occurred in the future.

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Appendix Tables

Appendix Table A	2003 Water Demand by Crop with Average Management
Appendix Table B	1997 Water Demand by Crop with Average Management
Appendix Table C	2003 Water Demand by Irrigation System with Average Management
Appendix Table D	2003 Water Demand by Soil Texture with Average Management
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Appendix Table A 2003 Water Demand by Crop with Average Management

Water Source	Surface Water			Reclaimed Water			Groundwater			Total		
	Irrigated Area (ha)	Irrigation Demand (m ³)	Avg. Req. (mm)	Irrigated Area (ha)	Irrigation Demand (m ³)	Avg. Req. (mm)	Irrigated Area (ha)	Irrigation Demand (m ³)	Avg. Req. (mm)	Irrigated Area (ha)	Irrigation Demand (m ³)	Avg. Req. (mm)
Apple	0.8	4,577	563	-	-	-	18.7	79,358	424	19.5	83,935	430
Berry	74.1	355,075	479	-	-	-	247.1	689,677	279	321.2	1,044,752	325
Blueberry	1,595.2	5,121,094	321	-	-	-	2,159.0	7,396,401	343	3,754.2	12,517,496	333
Cranberry	65.3	377,667	554	-	-	-	100.0	601,548	577	165.3	979,215	568
Forage	2,410.8	13,351,564	554	-	-	-	3,408.0	17,693,785	519	5,818.7	31,045,349	534
Fruit	-	-	-	-	-	-	7.9	24,232	306	7.9	24,232	306
Golf	104.6	585,098	560	-	-	-	116.8	698,976	599	221.3	1,284,074	580
Grape	0.3	790	266	-	-	-	33.7	60,062	178	34.0	60,852	179
Greenhouse	11.9	142,232	1,110	-	-	-	46.5	538,971	1,138	58.4	681,203	1,129
Nursery	301.5	1,104,691	411	-	-	-	1,196.9	4,478,449	405	1,498.5	5,583,140	417
Pasture/Grass	48.3	262,832	544	-	-	-	130.2	739,992	569	178.4	1,002,824	562
Raspberry	62.9	188,813	300	-	-	-	1,097.3	3,417,232	311	1,160.3	3,606,045	311
Recreational Turf	10.0	49,652	496	-	-	-	57.2	308,859	540	67.2	368,511	533
Strawberry	0.4	1,311	368	-	-	-	7.9	23,424	296	8.3	24,735	299
Sweetcorn	192.2	534,315	278	-	-	-	39.4	80,384	204	231.6	614,700	285
Turf Farm	268.5	1,642,013	612	-	-	-	108.6	580,798	535	377.1	2,222,811	590
Vegetable	1,015.3	4,969,105	492	-	-	-	346.9	1,335,243	409	1,362.0	6,304,348	472
TOTALS	6,161.8	28,673,054	465	-	-	-	9,122.1	38,715,458	424	15,283.9	67,388,512	441

Appendix Table B 1997 Water Demand by Crop with Average Management

Water Source	Surface Water			Reclaimed Water			Groundwater			Total		
	Irrigated Area (ha)	Irrigation Demand (m ³)	Avg. Req. (mm)	Irrigated Area (ha)	Irrigation Demand (m ³)	Avg. Req. (mm)	Irrigated Area (ha)	Irrigation Demand (m ³)	Avg. Req. (mm)	Irrigated Area (ha)	Irrigation Demand (m ³)	Avg. Req. (mm)
Apple	0.8	2,856	351	-	-	-	18.7	43,341	231	19.5	46,197	236
Berry	74.1	202,562	273	-	-	-	247.1	362,913	147	321.2	565,476	176
Blueberry	1,595.2	2,986,403	187	-	-	-	2,159.0	4,212,638	195	3,754.2	7,199,041	192
Cranberry	65.3	274,899	396	-	-	-	100.0	424,691	400	165.3	699,590	398
Forage	2,410.8	6,257,166	260	-	-	-	3,408.0	7,818,599	229	5,818.7	14,075,766	242
Fruit	-	-	-	-	-	-	7.9	11,017	139	7.9	11,017	139
Golf	104.6	416,624	398	-	-	-	116.8	504,704	432	221.3	921,327	416
Grape	0.3	422	142	-	-	-	33.7	28,501	85	34.0	28,923	85
Greenhouse	11.9	136,035	1,054	-	-	-	46.5	506,330	1,069	58.4	642,365	1,065
Nursery	301.5	744,122	396	-	-	-	1,196.9	2,213,441	341	1,498.5	2,957,562	389
Pasture/Grass	48.3	154,550	320	-	-	-	130.2	423,624	325	178.4	578,175	324
Raspberry	62.9	103,650	165	-	-	-	1,097.3	1,803,211	164	1,160.3	1,906,861	164
Recreational Turf	10.0	35,592	355	-	-	-	57.2	220,248	385	67.2	255,841	381
Strawberry	0.4	805	226	-	-	-	7.9	13,030	165	8.3	13,835	168
Sweetcorn	192.2	175,790	91	-	-	-	39.4	19,076	48	231.6	194,866	84
Turf Farm	268.5	1,276,685	475	-	-	-	108.6	416,575	384	377.1	1,693,259	449
Vegetable	1,015.3	3,177,892	315	-	-	-	346.9	640,854	195	1,362.0	3,818,746	286
TOTALS	6,161.6	15,928,279	258	-	-	-	9,122.1	19,630,858	215	15,283.9	35,559,136	233

Appendix Table C 2003 Water Demand by Irrigation System with Average Management

Water Source	Surface Water			Reclaimed Water			Groundwater			Total		
	Irrigated Area (ha)	Irrigation Demand (m ³)	Avg. Req. (mm)	Irrigated Area (ha)	Irrigation Demand (m ³)	Avg. Req. (mm)	Irrigated Area (ha)	Irrigation Demand (m ³)	Avg. Req. (mm)	Irrigated Area (ha)	Irrigation Demand (m ³)	Avg. Req. (mm)
Drip	590.1	1,707,229	289	-	-	-	1,114.3	3,044,873	273	1,704.3	4,752,102	279
Flood	0.2	1,367	564	-	-	-	25.4	251,946	993	25.6	263,313	988
Golfsprinkler	60.0	334,334	557	-	-	-	96.8	560,951	579	156.8	895,285	571
Gun	53.3	426,752	800	-	-	-	70.5	471,200	668	123.8	897,951	725
Handline	133.1	516,724	388	-	-	-	127.9	586,368	458	261.0	1,103,092	423
Landscapesprinkler	14.3	83,638	585	-	-	-	56.1	336,709	600	70.4	420,347	587
Microspray	17.7	60,698	343	-	-	-	14.2	46,660	327	32.0	107,358	336
Microsprinkler	0.1	1,119	872	-	-	-	10.1	89,521	888	10.2	90,640	888
Overtreedrip	986.9	3,322,358	337	-	-	-	1,615.7	5,621,977	348	2,602.6	8,944,335	344
Pivot	32.7	186,040	569	-	-	-	-	-	-	32.7	186,040	569
PivotLP	14.5	77,815	535	-	-	-	-	-	-	14.5	77,815	535
SDI	30.3	86,874	286	-	-	-	426.6	1,435,877	337	456.9	1,522,751	333
Sprinkler	486.5	2,216,651	456	-	-	-	561.2	2,476,627	441	1,047.6	4,693,278	448
Ssovertree	170.3	767,659	451	-	-	-	995.7	3,961,005	398	1,166.0	4,728,664	406
Sssprinkler	60.6	335,440	554	-	-	-	68.3	365,926	536	128.9	701,366	544
Ssundertree	8.0	21,582	270	-	-	-	2.6	8,740	338	10.6	30,322	287
Travgun	3,230.0	16,917,056	524	-	-	-	3,644.0	17,895,774	491	6,873.9	34,812,830	506
Wheeline	266.9	1,609,720	603	-	-	-	270.9	1,561,303	576	537.8	3,171,022	590
TOTALS	6,161.8	28,673,064	465	-	-	-	9,122.1	38,716,458	424	15,283.9	67,388,512	441

Appendix Table D 2003 Water Demand by Soil Texture with Average Management

Water Source	Surface Water			Reclaimed Water			Groundwater			Total		
	Irrigated Area (ha)	Irrigation Demand (m ³)	Avg. Req. (mm)	Irrigated Area (ha)	Irrigation Demand (m ³)	Avg. Req. (mm)	Irrigated Area (ha)	Irrigation Demand (m ³)	Avg. Req. (mm)	Irrigated Area (ha)	Irrigation Demand (m ³)	Avg. Req. (mm)
Clay	12.8	66,586	521	-	-	-	-	-	-	12.8	66,586	521
Cultured Medium	48.9	340,455	696	-	-	-	185.3	1,321,132	713	234.3	1,661,587	709
Fine Sandy Loam	98.5	569,148	578	-	-	-	85.7	487,630	569	184.2	1,056,778	574
Loam	-	-	-	-	-	-	9.2	32,325	352	9.2	32,325	352
Loamy Sand	2,047.1	11,160,717	545	-	-	-	389.3	2,297,153	590	2,436.4	13,457,870	552
Peat	65.3	361,352	554	-	-	-	100.0	576,549	577	165.3	937,901	566
Sand	345.4	2,377,519	688	-	-	-	1,021.6	4,534,512	444	1,367.1	6,912,031	506
Sandy Loam	-	-	-	-	-	-	63.1	384,051	609	63.1	384,051	609
Sandy Loam (defaulted)	250.9	900,071	359	-	-	-	237.7	1,279,663	538	488.6	2,179,734	446
Silt Loam	1,408.1	5,924,090	421	-	-	-	5,308.5	20,591,548	388	6,716.6	26,515,638	395
Silty Clay	414.4	1,397,509	337	-	-	-	101.5	414,398	408	516.0	1,811,907	351
Silty Clay Loam	1,470.5	5,575,607	379	-	-	-	1,620.1	6,796,497	420	3,090.6	12,372,104	400
TOTALS	6,161.8	28,673,054	465	-	-	-	9,122.1	38,715,458	424	15,283.9	67,388,512	441

Appendix Table E 2003 Water Demand by Local Government with Average Management

Water Source	Surface Water			Reclaimed Water			Groundwater			Total		
	Irrigated Area (ha)	Irrigation Demand (m ³)	Avg. Req. (mm)	Irrigated Area (ha)	Irrigation Demand (m ³)	Avg. Req. (mm)	Irrigated Area (ha)	Irrigation Demand (m ³)	Avg. Req. (mm)	Irrigated Area (ha)	Irrigation Demand (m ³)	Avg. Req. (mm)
Abbotsford	5,596.1	26,100,986	466	-	-	-	5,000.0	19,752,483	395	10,596.0	45,853,469	433
Cheam First Nation	-	-	-	-	-	-	37.6	175,322	466	37.6	175,322	466
Chilliwack	232.2	1,150,997	496	-	-	-	2,053.4	9,016,055	439	2,285.7	10,167,052	445
Fraser Valley	208.8	795,844	381	-	-	-	910.9	4,206,045	462	1,119.7	5,001,888	447
Hope	-	-	-	-	-	-	6.6	49,724	751	6.6	49,724	751
Kent	80.7	418,477	519	-	-	-	641.4	3,233,354	504	722.0	3,651,831	506
Legamel First Nation	-	-	-	-	-	-	0.8	2,777	356	0.8	2,777	356
Matsqui First Nation	-	-	-	-	-	-	-	68	228	-	68	228
Mission	17.5	100,540	576	-	-	-	13.8	60,467	438	31.3	161,006	515
Popkum First Nation	-	-	-	-	-	-	17.7	124,015	702	17.7	124,015	702
Seabird Island First Nation	-	-	-	-	-	-	334.0	1,622,634	486	334.0	1,622,634	486
Shxwhtay Village First Nation	-	-	-	-	-	-	20.3	82,914	406	20.3	82,914	406
Skawahlook First Nation	-	-	-	-	-	-	0.2	1,089	532	0.2	1,089	532
Skowkale First Nation	-	-	-	-	-	-	13.9	59,654	430	13.9	59,654	430
Skwah First Nation	-	-	-	-	-	-	9.5	32,395	341	9.5	32,395	341
Sumas First Nation	26.6	106,210	399	-	-	-	57.0	265,536	466	83.6	371,746	444
Tzeachten First Nation	-	-	-	-	-	-	4.9	30,926	625	4.9	30,926	625
TOTALS	6,161.8	28,673,054	465	-	-	-	9,122.1	38,715,458	424	15,283.9	67,388,512	441

Appendix Table F 2003 Water Demand by Electoral Area with Average Management

Water Source	Surface Water			Reclaimed Water			Groundwater			Total		
	Irrigated Area (ha)	Irrigation Demand (m ³)	Avg. Req. (mm)	Irrigated Area (ha)	Irrigation Demand (m ³)	Avg. Req. (mm)	Irrigated Area (ha)	Irrigation Demand (m ³)	Avg. Req. (mm)	Irrigated Area (ha)	Irrigation Demand (m ³)	Avg. Req. (mm)
Agriculture Local Government												
Abbotsford	5,622.7	26,207,196	466	-	-	-	5,057.0	20,018,086	396	10,679.7	46,225,283	433
Chilliwack	232.2	1,150,997	496	-	-	-	2,102.1	9,221,945	439	2,334.3	10,372,941	444
District of Hope	-	-	-	-	-	-	6.6	49,724	751	6.6	49,724	751
District of Kent	80.7	418,477	519	-	-	-	997.1	4,949,519	496	1,077.8	5,367,996	498
Electoral Area A	-	-	-	-	-	-	55.1	566,117	1,027	55.1	566,117	1,027
Electoral Area B	-	-	-	-	-	-	81.7	483,699	592	81.7	483,699	592
Electoral Area C	-	-	-	-	-	-	12.2	75,658	623	12.2	75,658	623
Electoral Area D	-	-	-	-	-	-	48.2	300,770	624	48.2	300,770	624
Electoral Area E	-	-	-	-	-	-	77.7	362,007	466	77.7	362,007	466
Electoral Area F	51.3	156,101	308	-	-	-	65.9	224,872	341	117.2	382,973	327
Electoral Area G	157.5	637,743	405	-	-	-	604.6	2,402,594	397	762.1	3,040,337	399
Mission	17.5	100,540	576	-	-	-	13.8	60,467	438	31.3	161,008	515
TOTALS	6,161.8	28,673,054	465	-	-	-	9,122.1	38,715,458	424	15,283.9	67,388,512	441

Appendix Table G 2003 Management Comparison on Irrigation Demand and Percolation Volumes

Water Source	Surface Water				Reclaimed Water				Groundwater				Total				
	Irrigated Area (ha)	Irrigation Demand (m ³)	Avg. Req. (mm)	Deep Percolation (m ³)	Irrigated Area (ha)	Irrigation Demand (m ³)	Avg. Req. (mm)	Deep Percolation (m ³)	Irrigated Area (ha)	Irrigation Demand (m ³)	Avg. Req. (mm)	Deep Percolation (m ³)	Irrigated Area (ha)	Irrigation Demand (m ³)	Avg. Req. (mm)	Deep Percolation (m ³)	Percolation (m ³ /ha)
Agriculture Management																	
Poor	6,161.8	29,389,470	477	4,387,102	-	-	-	-	9,122.1	39,728,249	436	4,785,338	15,283.9	69,117,719	452	9,172,440	600
Avg	6,161.8	28,690,829	466	3,688,461	-	-	-	-	9,122.1	38,747,392	425	3,804,481	15,283.9	67,438,221	441	7,492,942	460
Good	6,161.8	27,992,188	454	2,989,820	-	-	-	-	9,122.1	37,766,535	414	2,823,624	15,283.9	65,758,723	430	5,813,444	360

Appendix Table H 2003 Percolation Volumes by Irrigation System with Average Management

Water Source	Surface Water			Reclaimed Water			Groundwater			Total			
	Irrigated Area (ha)	Irrigation Demand (m ³)	Deep Percolation (m ³)	Irrigated Area (ha)	Irrigation Demand (m ³)	Deep Percolation (m ³)	Irrigated Area (ha)	Irrigation Demand (m ³)	Deep Percolation (m ³)	Irrigated Area (ha)	Irrigation Demand (m ³)	Deep Percolation (m ³)	Percolation (m ³ /ha)
Drip	590.1	1,707,229	166,964	-	-	-	1,114.3	3,044,873	307,453	1,704.3	4,762,102	474,417	278
Flood	0.2	1,367	316	-	-	-	25.4	251,946	52,362	25.6	253,313	52,677	2,058
Golfsprinkler	60.0	334,334	37,148	-	-	-	96.8	560,951	79,237	156.8	895,285	116,385	742
Gun	53.3	426,752	93,570	-	-	-	70.5	471,200	83,000	123.8	897,951	176,570	1,426
Handline	133.1	516,724	86,007	-	-	-	127.9	586,368	53,927	261.0	1,103,092	139,934	536
Landscapesprinkler	14.3	83,638	9,293	-	-	-	56.1	336,709	55,102	70.4	420,347	64,395	915
Microspray	17.7	60,698	8,311	-	-	-	14.2	46,660	4,623	32.0	107,358	12,934	404
Microsprinkler	0.1	1,119	271	-	-	-	10.1	89,521	21,702	10.2	90,640	21,973	254
Overfreedrip	986.9	3,322,358	284,935	-	-	-	1,615.7	5,621,977	474,284	2,602.6	8,944,335	769,219	292
Pivot	32.7	186,040	20,671	-	-	-	-	-	-	32.7	186,040	20,671	632
PivotLP	14.5	77,815	11,589	-	-	-	-	-	-	14.5	77,815	11,589	799
SDI	30.3	86,874	6,061	-	-	-	426.6	1,435,877	147,373	456.9	1,522,751	153,434	336
Sprinkler	486.5	2,216,651	292,021	-	-	-	561.2	2,476,627	286,927	1,047.6	4,693,278	578,948	553
Ssovertree	170.3	767,659	117,970	-	-	-	995.7	3,961,005	513,869	1,166.0	4,728,664	631,838	542
Sssprinkler	60.6	335,440	30,495	-	-	-	68.3	365,926	33,266	128.9	701,366	83,761	495
Ssundertree	8.0	21,582	1,962	-	-	-	2.6	8,740	889	10.6	30,322	2,851	269
Travgun	3,230.0	16,917,056	2,235,011	-	-	-	3,644.0	17,895,774	1,538,665	6,873.9	34,812,830	3,773,676	549
Wheeline	266.9	1,609,720	285,866	-	-	-	270.9	1,561,303	151,804	537.8	3,171,022	437,670	814
TOTALS	6,161.8	28,673,054	3,688,461	-	-	-	9,122.1	38,715,458	3,804,481	15,283.9	67,388,512	7,492,942	490

Appendix Table I 2003 Crop Water Demand for Improved Irrigation System Efficiency and Good Management

Water Source	Surface Water			Reclaimed Water			Groundwater			Total		
	Irrigated Area (ha)	Irrigation Demand (m ³)	Avg. Req. (mm)	Irrigated Area (ha)	Irrigation Demand (m ³)	Avg. Req. (mm)	Irrigated Area (ha)	Irrigation Demand (m ³)	Avg. Req. (mm)	Irrigated Area (ha)	Irrigation Demand (m ³)	Avg. Req. (mm)
Agriculture Crop Group												
Apple	0.8	2,948	362	-	-	-	18.7	61,502	328	19.5	64,450	330
Berry	74.1	185,013	250	-	-	-	247.1	510,431	207	321.2	695,444	217
Blueberry	1,595.2	4,203,576	264	-	-	-	2,159.0	5,891,950	273	3,754.2	10,095,526	269
Cranberry	65.3	361,242	529	-	-	-	100.0	581,043	556	165.3	942,285	545
Forage	2,410.8	13,013,261	540	-	-	-	3,408.0	17,276,447	507	5,816.7	30,289,708	521
Fruit	-	-	-	-	-	-	7.9	23,866	302	7.9	23,866	302
Golf	104.6	572,191	547	-	-	-	116.8	686,253	588	221.3	1,258,444	569
Grape	0.3	414	140	-	-	-	33.7	43,801	130	34.0	44,215	130
Greenhouse	11.9	142,232	1,110	-	-	-	46.5	538,971	1,138	58.4	681,203	1,129
Nursery	301.5	1,073,937	402	-	-	-	1,196.9	4,312,705	396	1,495.5	5,386,641	407
Pasture/Grass	48.3	256,701	532	-	-	-	130.2	724,038	556	178.4	980,739	550
Raspberry	62.9	145,218	231	-	-	-	1,097.3	2,325,596	212	1,160.3	2,470,814	213
Recreational Turf	10.0	48,548	485	-	-	-	57.2	302,930	530	67.2	351,478	523
Strawberry	0.4	720	202	-	-	-	7.9	13,782	174	8.3	14,502	176
Sweetcom	192.2	522,102	272	-	-	-	39.4	78,351	199	231.6	600,453	259
Turf Farm	268.5	1,605,198	598	-	-	-	108.6	567,891	523	377.1	2,173,089	576
Vegetable	1,015.3	2,328,761	231	-	-	-	346.9	689,207	210	1,362.0	3,017,968	226
TOTALS	6,161.6	24,444,287	397	-	-	-	9,122.1	34,596,830	379	15,283.9	59,041,117	386

Appendix Table J 2003 Water Demand for Frost Protection, Harvesting and Other Use with Average Management

Water Source	Surface Water			Reclaimed Water			Groundwater			Total		
	Irrigated Area (ha)	Irrigation Demand (m ³)	Avg. Req. (mm)	Irrigated Area (ha)	Irrigation Demand (m ³)	Avg. Req. (mm)	Irrigated Area (ha)	Irrigation Demand (m ³)	Avg. Req. (mm)	Irrigated Area (ha)	Irrigation Demand (m ³)	Avg. Req. (mm)
Cranberry Harvesting	65.3	16,315	25	-	-	-	100.0	24,999	25	165.3	41,314	25
Forestry Stock	-	-	-	-	-	-	0.3	1,790	641	0.3	1,790	641
Greenhouse Cucumber	4.2	46,143	1,111	-	-	-	4.4	51,222	1,159	8.6	97,365	1,136
Greenhouse Flower	0.1	1,119	872	-	-	-	10.1	89,521	888	10.2	90,640	888
Greenhouse Pepper	2.8	30,825	1,109	-	-	-	17.1	188,850	1,103	19.9	219,675	1,104
Greenhouse Tomato	4.8	64,145	1,348	-	-	-	14.9	209,378	1,403	19.7	273,523	1,389
Mushroom	6.3	1,460	23	-	-	-	21.8	6,935	32	28.0	8,395	30
Nursery Pot	30.8	198,224	643	-	-	-	116.7	780,371	668	147.6	978,594	663
TOTALS	114.2	358,230	314	-	-	-	285.3	1,353,066	474	399.5	1,711,297	428

Appendix Table K 2003 Water Demand by Animal Type

Animal Type	Demand (m ³)
Beef	145,963
Dairy - dry	776,492
Dairy - milking	1,320,036
Goats	9,937
Horses	47,194
Llama/Alpaca	2,067
Poultry - broiler	431,216
Poultry - laying	228,291
Sheep	13,928
Swine	329,777
TOTALS	3,304,902

Appendix Table L Climate Change Water Demand Circa 2050 for High Demand Year with Good Management Using Current Crops and Irrigation Systems

Water Source	Surface Water			Reclaimed Water			Groundwater			Total		
	Irrigated Area (ha)	Irrigation Demand (m ³)	Avg. Req. (mm)	Irrigated Area (ha)	Irrigation Demand (m ³)	Avg. Req. (mm)	Irrigated Area (ha)	Irrigation Demand (m ³)	Avg. Req. (mm)	Irrigated Area (ha)	Irrigation Demand (m ³)	Avg. Req. (mm)
2053	6,161.8	54,185,162	879	-	-	-	9,122.1	76,223,676	836	15,283.9	130,408,838	853
2056	6,161.8	20,259,415	329	-	-	-	9,122.1	30,626,981	336	15,283.9	50,886,396	333
2059	6,161.8	52,141,801	846	-	-	-	9,122.1	74,095,902	812	15,283.9	126,237,703	828

Appendix Table M Buildout Crop Water Demand for 2003 Climate Data with Good Management

Water Source	Surface Water			Reclaimed Water			Groundwater			Total		
Agriculture Crop Group	Irrigated Area (ha)	Irrigation Demand (m ³)	Avg. Req. (mm)	Irrigated Area (ha)	Irrigation Demand (m ³)	Avg. Req. (mm)	Irrigated Area (ha)	Irrigation Demand (m ³)	Avg. Req. (mm)	Irrigated Area (ha)	Irrigation Demand (m ³)	Avg. Req. (mm)
Apple	3.8	11,846	310	-	-	-	23.3	89,448	384	27.1	101,294	374
Berry	74.2	345,797	466	-	-	-	263.8	723,128	274	338.0	1,068,926	316
Blueberry	2,817.3	8,369,880	297	-	-	-	4,295.5	13,188,799	307	7,112.8	21,558,679	303
Corn	1,186.4	4,643,938	391	-	-	-	2,037.6	7,433,692	365	3,224.0	12,077,631	375
Cranberry	65.3	361,242	529	-	-	-	100.0	581,043	556	165.3	942,285	545
Forage	4,551.9	23,036,851	506	-	-	-	7,647.9	38,784,209	507	12,199.8	61,821,060	507
Fruit	-	-	-	-	-	-	7.9	23,866	302	7.9	23,866	302
Golf	104.6	572,191	547	-	-	-	116.8	686,253	588	221.3	1,258,444	589
Grape	1.2	1,937	164	-	-	-	39.3	68,244	174	40.5	70,181	173
Greenhouse	11.9	142,232	1,110	-	-	-	46.5	538,971	1,138	58.4	681,203	1,129
Nursery	1,562.4	3,703,796	354	-	-	-	3,104.5	8,216,403	357	4,667.0	11,920,197	364
Pasture/Grass	354.5	1,713,208	483	-	-	-	594.3	3,021,827	509	948.7	4,735,036	498
Raspberry	774.7	1,446,308	187	-	-	-	2,098.6	5,106,618	243	2,873.3	6,552,926	228
Recreational Turf	10.0	48,548	485	-	-	-	57.2	302,930	530	67.2	351,478	523
Strawberry	2.9	5,286	182	-	-	-	9.0	24,320	269	11.9	29,606	248
Sweetcorn	192.2	522,102	272	-	-	-	39.4	78,351	199	231.6	600,453	259
Turf Farm	268.5	1,605,198	598	-	-	-	108.6	567,891	523	377.1	2,173,089	576
Vegetable	1,015.3	4,866,863	482	-	-	-	346.9	1,303,879	399	1,362.0	6,170,742	482
TOTALS	12,996.8	51,379,449	395	-	-	-	20,937.0	80,707,939	385	33,933.8	132,087,388	389

Appendix Table N Buildout Crop Water Demand for Climate Change Circa 2050 and Good Management

Water Source	Surface Water			Reclaimed Water			Groundwater			Total		
	Irrigated Area (ha)	Irrigation Demand (m ³)	Avg. Req. (mm)	Irrigated Area (ha)	Irrigation Demand (m ³)	Avg. Req. (mm)	Irrigated Area (ha)	Irrigation Demand (m ³)	Avg. Req. (mm)	Irrigated Area (ha)	Irrigation Demand (m ³)	Avg. Req. (mm)
2053	12,996.8	94,175,682	725	-	-	-	20,937.0	152,112,665	727	33,933.8	246,288,347	726
2056	12,996.8	36,916,321	284	-	-	-	20,937.0	60,738,270	290	33,933.8	97,654,591	288
2059	12,860.2	89,025,533	692	-	-	-	20,804.4	143,032,825	688	33,664.6	232,058,358	689

Appendix Table O Buildout Irrigation System Demand for 2003 Climate Data and Good Management

Water Source	Surface Water			Reclaimed Water			Groundwater			Total		
	Irrigated Area (ha)	Irrigation Demand (m ³)	Avg. Req. (mm)	Irrigated Area (ha)	Irrigation Demand (m ³)	Avg. Req. (mm)	Irrigated Area (ha)	Irrigation Demand (m ³)	Avg. Req. (mm)	Irrigated Area (ha)	Irrigation Demand (m ³)	Avg. Req. (mm)
Drip	3,768.6	8,872,055	235	-	-	-	6,184.0	14,706,279	238	9,952.5	23,578,334	237
Flood	0.2	1,367	564	-	-	-	25.4	251,946	993	25.6	263,313	989
Golfsprinkler	60.0	326,905	545	-	-	-	96.8	550,945	569	156.8	877,850	580
Gun	53.3	402,878	756	-	-	-	70.5	448,261	636	123.8	851,140	687
Handline	133.1	505,453	380	-	-	-	130.8	583,420	446	263.9	1,088,873	413
Landscapesprinkler	14.3	81,779	572	-	-	-	56.1	330,550	589	70.4	412,329	585
Microspray	17.7	58,340	329	-	-	-	14.2	45,707	321	32.0	104,047	326
Microsprinkler	0.1	1,119	872	-	-	-	10.1	89,521	888	10.2	90,640	888
Overtreedrip	1,007.3	3,315,954	329	-	-	-	1,618.2	5,490,132	339	2,625.6	8,806,086	335
Pivot	32.7	181,906	556	-	-	-	-	-	-	32.7	181,906	556
PivotLP	1,711.5	6,894,830	403	-	-	-	2,616.9	11,006,772	421	4,328.4	17,901,602	414
SDI	30.3	86,482	285	-	-	-	426.6	1,405,165	329	456.9	1,491,647	326
Sprinkler	2,425.6	11,380,961	469	-	-	-	4,674.2	21,955,482	470	7,099.7	33,336,444	470
Ssovertree	170.3	742,418	436	-	-	-	995.9	3,825,833	384	1,166.2	4,568,252	392
Sssprinkler	60.6	320,193	529	-	-	-	68.3	349,293	511	128.9	669,486	519
Ssunderfree	8.0	20,601	258	-	-	-	2.6	8,382	324	10.6	28,983	274
Travgun	3,230.0	16,607,368	514	-	-	-	3,653.6	18,113,829	496	6,883.6	34,721,197	504
Wheeline	266.9	1,578,839	592	-	-	-	270.9	1,546,420	571	537.8	3,125,259	581
TOTALS	12,996.8	61,379,449	395	-	-	-	20,937.0	80,707,939	385	33,933.8	132,087,388	389

Appendix Table P Buildout Water Demand by Local Government for 2003 Climate Data and Good Management

Water Source	Surface Water			Reclaimed Water			Groundwater			Total		
	Irrigated Area (ha)	Irrigation Demand (m ³)	Avg. Req. (mm)	Irrigated Area (ha)	Irrigation Demand (m ³)	Avg. Req. (mm)	Irrigated Area (ha)	Irrigation Demand (m ³)	Avg. Req. (mm)	Irrigated Area (ha)	Irrigation Demand (m ³)	Avg. Req. (mm)
Agriculture Local Government												
Abbotsford	5,599.7	25,472,410	455	-	-	-	5,002.2	19,283,886	386	10,601.9	44,756,295	422
Cheam First Nation	-	-	-	-	-	-	37.6	172,260	458	37.6	172,260	458
Chilliwack	2,708.4	9,589,558	354	-	-	-	7,694.9	29,237,738	380	10,403.3	38,827,297	373
Fraser Valley	3,770.6	13,144,887	349	-	-	-	3,966.8	15,134,565	382	7,737.4	28,279,452	365
Harrison Hot Springs	4.1	9,725	237	-	-	-	17.4	95,918	553	21.5	105,643	492
Hope	65.1	266,033	409	-	-	-	65.2	326,718	501	130.3	592,751	455
Kent	200.4	819,955	409	-	-	-	3,465.2	13,552,105	391	3,665.6	14,372,060	392
Legamel First Nation	1.4	3,549	263	-	-	-	0.8	2,715	348	2.1	6,264	294
Matsqui First Nation	-	-	-	-	-	-	-	67	222	-	67	222
Mission	620.6	1,959,483	317	-	-	-	229.3	748,461	326	850.0	2,717,944	320
Popkum First Nation	-	-	-	-	-	-	17.7	121,259	687	17.7	121,259	687
Seabird Island First Nation	-	-	-	-	-	-	334.0	1,571,691	471	334.0	1,571,691	471
Shxwhay Village First Nation	-	-	-	-	-	-	20.3	81,071	399	20.3	81,071	399
Skawahlook First Nation	-	-	-	-	-	-	0.2	1,065	520	0.2	1,065	520
Skowkale First Nation	-	-	-	-	-	-	13.9	58,329	421	13.9	58,329	421
Skwah First Nation	-	-	-	-	-	-	9.5	30,923	326	9.5	30,923	326
Sumas First Nation	26.6	103,850	390	-	-	-	57.0	258,241	453	83.6	362,091	433
Tzeachten First Nation	-	-	-	-	-	-	4.9	30,926	625	4.9	30,926	625
TOTALS	12,996.8	51,379,449	395	-	-	-	20,937.0	80,707,939	385	33,933.8	132,087,388	389

Appendix Table Q Buildout Water Demand by Electoral Area for 2003 Climate Data and Good Management

Water Source	Surface Water			Reclaimed Water			Groundwater			Total		
	Irrigated Area (ha)	Irrigation Demand (m ³)	Avg. Req. (mm)	Irrigated Area (ha)	Irrigation Demand (m ³)	Avg. Req. (mm)	Irrigated Area (ha)	Irrigation Demand (m ³)	Avg. Req. (mm)	Irrigated Area (ha)	Irrigation Demand (m ³)	Avg. Req. (mm)
Agriculture Local Government												
Abbotsford	5,626.3	25,576,259	455	-	-	-	5,059.3	19,542,194	386	10,685.6	45,118,453	422
Chillwack	2,708.4	9,589,558	354	-	-	-	7,743.5	29,438,987	380	10,451.9	39,028,546	373
District of Hope	65.1	266,033	409	-	-	-	65.2	326,718	501	130.3	692,751	455
District of Kent	200.4	819,955	409	-	-	-	3,825.1	15,233,755	398	4,025.6	16,053,710	399
Electoral Area A	192.2	1,300,701	677	-	-	-	160.0	1,230,011	769	352.1	2,530,713	719
Electoral Area B	272.3	1,114,906	409	-	-	-	368.4	1,734,599	471	640.7	2,849,505	445
Electoral Area C	81.5	258,303	317	-	-	-	100.6	390,239	386	182.2	648,542	356
Electoral Area D	131.0	446,700	341	-	-	-	113.6	565,402	498	244.6	1,012,102	414
Electoral Area E	606.2	2,053,235	339	-	-	-	369.9	1,375,305	372	976.1	3,428,540	351
Electoral Area F	585.7	1,664,575	284	-	-	-	1,010.1	3,095,198	306	1,595.9	4,759,772	298
Electoral Area G	1,903.0	6,310,016	332	-	-	-	1,866.2	6,883,017	369	3,769.2	13,193,033	350
Mission	620.6	1,969,483	317	-	-	-	229.3	748,461	326	850.0	2,717,944	320
Village of Harrison	4.1	9,725	237	-	-	-	17.4	95,918	553	21.5	105,643	492
TOTALS	12,996.8	51,379,449	395	-	-	-	20,937.0	80,707,939	385	33,933.8	132,087,388	389