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18.0 TIER 2 WATER BUDGET RESULTS

The Tier 2 Water Budget and Water Quantity Stress Assessment reports were completed to increase the understanding of water quantity and availability in the Grand River watershed (AquaResource, 2009a, 2009b).

The Integrated Water Budget was completed using numerical hydrologic and groundwater flow models. A continuous hydrologic model for the Grand River watershed was developed using a GAWSER (Guelph All-Weather Storm-Event Runoff) model to simulate surface water flows and the partitioning of precipitation (Schroeter & Associates, 2004). Groundwater flows were simulated by the development of a regional-scale numerical groundwater flow model using the FEFLOW software package. The regional groundwater flow model was designed to represent average annual groundwater flow conditions, with a particular focus on volumetric flow from one subwatershed to another. When used together, these modelling tools provided a physical means of quantifying flow through the system to determine available water resources in the Grand River watershed.

The results of the Integrated Water Budget were then incorporated into the Tier 2 Water Quantity Stress Assessment (AquaResource, 2009b). The objective of the Tier 2 Water Quantity Stress Assessment was to evaluate the degree of potential water quantity stress throughout an area by comparing the volume of water demand to that which was practically available for use.

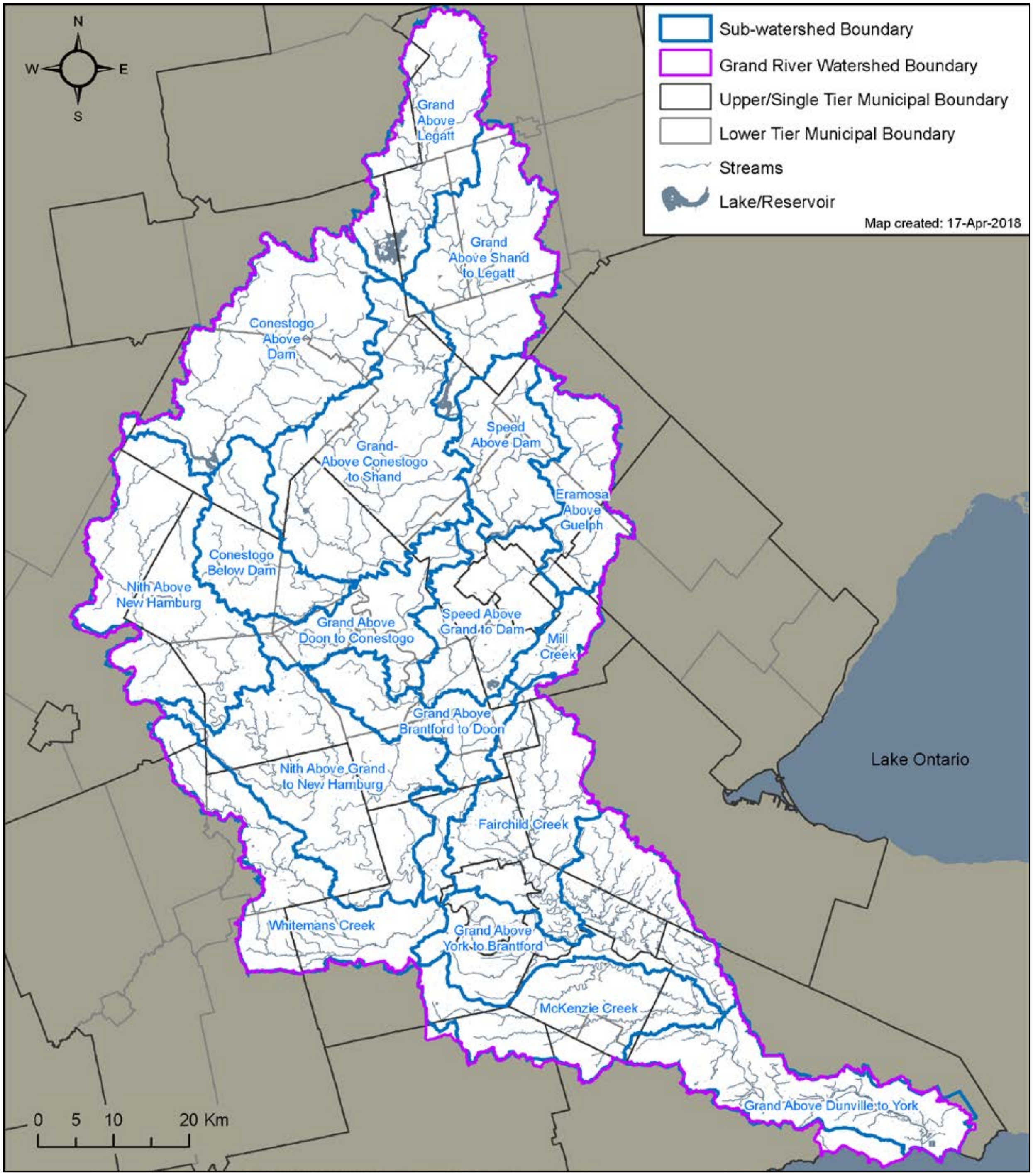
The Water Budget was calculated based on 18 subwatersheds as shown in **Map 18-1** and listed in **Table 18-1.** These same 18 subwatersheds were used for the surface water stress assessment. For the groundwater stress assessment, 19 subwatersheds that were different from the surface subwatersheds were used to better represent groundwater demand and the aquifer systems within the watershed.

Table 18-1: Average Annual Water Budget (Surface Water)

Watershed	Subwatershed	Drainage Area (km^2)
Upper Grand River	Grand Above Legatt	365
	Grand Above Shand To Legatt	426
	Grand Above Conestogo To Shand	640
Conestogo River	Conestogo Above Dam	566
	Conestogo Below Dam	254
Central Grand River	Grand Above Doon To Conestogo	248
	Grand Above Brantford To Doon	274
	Mill Creek	82
Speed and Eramosa Rivers	Eramosa Above Guelph	230
	Speed Above Dam	242

	Speed Above Grand To Armstrong	308
Nith River	Nith Above New Hamburg	545
	Nith Above Grand To New Hamburg	583
Whitemans and McKenzie Creeks	Whitemans Creek	404
	McKenzie Creek	368
Lower Grand River	Fairchild Creek	401
	Grand Above York To Brantford	476
	Grand Above Dunnville To York	356

Map 18-1: Grand River Integrated Water Budget Subwatershed Boundaries



18.1 Surface Water

Surface Water Budget

The Grand River Watershed continuous surface water model was built using the GAWSER model program. This modelling software is a physically-based deterministic hydrologic model that is used to predict the total streamflow resulting from inputs of rainfall and/or snowmelt. The infiltration routine used the Green-Ampt equation to partition precipitation into runoff and infiltrated water (recharge). Potential evapotranspiration was calculated using the Linacre model. Evapotranspiration was then calculated by removing available water from depression storage and the soil layers until wilting point was reached. Modelling procedures were documented in the GAWSER Training Guide and Reference Manual (Schroeter & Associates, 2004). Runoff, recharge and evapotranspiration were then aggregated to the subwatershed scale.

The surface water budget components – precipitation, evapotranspiration, runoff and recharge – were determined from the hydrologic model and from the Water Use Study for surface water takings (AquaResource, 2009a). The results presented below are based on average annual conditions for the 1980-1999 period; it is recognized that these results may vary significantly based on climate conditions. The analysis did not account for changes in water storage that would occur from one time period to the next.

As shown on **Table 18-2**: the average annual precipitation for the watershed is approximately 933 mm/year. The hydrologic model estimated average annual evapotranspiration to be 491 mm/year. The average runoff rate across the watershed is 266 mm/year, with an average groundwater recharge rate of 176 mm/year. Water removed from watercourses, that is not immediately returned to the surface water system, is approximately 0.59 m^3/s, or 2.7 mm/year. While precipitation and evapotranspiration rates had some degree of spatial variability, runoff and recharge rates had the most significant spatial variability due to changing soils, surficial geology, and land cover.

Table 18-1: Average Annual Water Budget (Surface Water)

Water Budget Parameter	Value (m^3/s)	Value (mm/year)
Precipitation	200	933
Evapotranspiration	105	491
Runoff	57	266
Recharge	38	176
SW Taking	0.59	2.7

Table 18-3 and Table 18-4 summarize the water budget components for each of the subwatersheds in mm and m^3/s, respectively.

Table 18-2: Surface Water Budget (mm/year)

Subwatershed	Area (km^2)	Precip	ET	Runoff	Recharge	Surface Water Taking
Grand Above Legatt	365	988	469	345	174	0.2
Grand Above Shand To Legatt	426	988	464	356	168	0.2
Grand Above Conestogo To Shand	640	925	487	282	156	1.3
Conestogo Above Dam	566	936	485	327	123	0.7
Conestogo Below Dam	254	968	487	365	117	1.6
Grand Above Doon To Conestogo	248	897	500	197	199	14.9
Grand Above Brantford To Doon	274	896	495	163	238	3.0
Mill Creek	82	888	507	89	292	0.4
Eramosa Above Guelph	230	892	506	142	244	6.2
Speed Above Dam	242	894	529	123	242	2.0
Speed Above Grand To Armstrong	308	889	510	156	223	2.9
Nith Above New Hamburg	545	992	503	346	144	0.5
Nith Above Grand To New Hamburg	583	945	508	154	284	1.6
Whitemans Creek	404	945	512	176	257	4.0
McKenzie Creek	368	945	481	337	127	2.5
Fairchild Creek	401	866	468	263	135	1.7
Grand Above York To Brantford	476	896	495	284	118	9.6
Grand Above Dunnville To York	356	945	465	392	89	1.9
Total Area	**6,769**	**933**	**491**	**266**	**176**	**2.7**

Table 18-3: Surface Water Budget (m^3/s)

Subwatershed	Area (km^2)	Precip	ET	Runoff	Recharge	Surface Water Taking
Grand Above Legatt	365	11.43	5.42	3.99	2.02	0.002
Grand Above Shand To Legatt	426	13.36	6.27	4.81	2.28	0.003
Grand Above Conestogo To Shand	640	18.77	9.88	5.72	3.17	0.026
Conestogo Above Dam	566	16.80	8.71	5.88	2.21	0.012
Conestogo Below Dam	254	7.79	3.92	2.94	0.94	0.013
Grand Above Doon To Conestogo	248	7.05	3.93	1.55	1.57	0.117
Grand Above Brantford To Doon	274	7.79	4.30	1.42	2.07	0.026
Mill Creek	82	2.32	1.32	0.23	0.76	0.001
Eramosa Above Guelph	230	6.51	3.70	1.04	1.78	0.045
Speed Above Dam	242	6.87	4.06	0.95	1.86	0.015
Speed Above Grand To Armstrong	308	8.69	4.98	1.52	2.18	0.028
Nith Above New Hamburg	545	17.15	8.68	5.97	2.49	0.009
Nith Above Grand To New Hamburg	583	17.47	9.39	2.84	5.25	0.029
Whitemans Creek	404	12.11	6.56	2.26	3.29	0.051
McKenzie Creek	368	11.04	5.62	3.94	1.48	0.029
Fairchild Creek	401	11.01	5.95	3.34	1.72	0.022
Grand Above York To Brantford	476	13.52	7.46	4.28	1.78	0.145
Grand Above Dunnville To York	356	10.67	5.25	4.42	1.00	0.021
Total Area	**6,769**	**200.4**	**105.4**	**57.1**	**37.8**	**0.588**

Uncertainty in the Surface Water Model

Many elements of the water budget modelling process using the hydrologic model are subject to uncertainty. Although the calibration process was performed in an attempt to reduce uncertainty, the model results and water budgets reflect the uncertainty in the input parameters as well as limitations in the modelling approach. The model was designed to reflect general characteristics of each catchment relating to land cover, climate, soils and vegetation, and stream and river hydraulics. Calibration is limited to the available stream flow data.

18.2 Groundwater

Groundwater Budget

The steady-state groundwater flow model developed for the Grand River Watershed was developed using FEFLOW and builds upon earlier work completed by WHI (2005a). The groundwater model is a regional numerical flow model which encompasses an area of approximately 6,800 km^2. The model has 13 primary hydrostratigraphic units which are represented as separate layers within the model. The shallow subsurface was further subdivided into two layers to provide a more detailed calculation at the groundwater/surface water interface.

Table 18-5 summarizes the average annual groundwater budget for the Grand River watershed. It is linked to the surface water budget by the recharge rate. Water removed from the aquifers that is not immediately returned to the groundwater system is approximately 4 m^3/s, or 18 mm/year. The groundwater model estimates average annual groundwater discharge to surface water features to be 33 m^3/s. A net flow of approximately 2 m^3/s flows out of the watershed.

Table 18-4: Average Annual Water Budget Summary (Groundwater)

Water Budget Parameter	Value (m^3/s)	Value (mm/year)
Recharge	37.8	176
Net Flow Out of Watershed	1.8	8
Net Discharge to Surface Water Features	32.6	152
GW Taking	4.0	18

Table 18-6 and Table 18-7 summarize the water budget components for each of the subwatersheds in mm and m^3/s, respectively.

Table 18-5: Groundwater Budget (mm/year)

Subwatershed	Area (km^2)	Recharge	External Boundary	Discharge	Groundwater Taking
Grand Above Legatt	365	173	0	-155	-1
Grand Above Shand To	426	168	-2	-163	-4
Grand Above Conestogo To	640	157	0	-125	-12
Conestogo Above Dam	566	124	-31	-70	-2

Table 18-5: Groundwater Budget (mm/year)

Subwatershed	Area (km^2)	Recharge	External Boundary	Discharge	Groundwater Taking
Conestogo Below Dam	254	118	0	-211	-4
Grand Above Doon To Conestogo	248	202	0	-203	-32
Grand Above Brantford To Doon	274	240	0	-219	-121
Mill Creek	82	287	0	-208	-40
Eramosa Above Guelph	230	243	-15	-246	-27
Speed Above Dam	242	245	0	-235	-1
Speed Above Grand To Armstrong	308	224	0	-174	-75
Nith Above New Hamburg	545	143	-28	-81	-2
Nith Above Grand To New Hamburg	583	282	0	-216	-32
Whitemans Creek	404	254	-29	-211	-14
McKenzie Creek	368	126	3	-94	-11
Fairchild Creek	401	137	2	-134	-7
Grand Above York To Brantford	476	117	-27	-127	-10
Grand Above Dunnville To York	356	88	9	-86	-5
Total Watershed	**6,769**	**176**	**-8**	**-152**	**-18**

Positive values represent flow into the groundwater system and negative values represent flow out of the groundwater system.

Table 18-6: Groundwater Budget (m^3/s)

Subwatershed	Area (km^2)	Recharge	External Boundary	Discharge	Groundwater Taking
Grand Above Legatt	365	2.01	0.00	-1.80	-0.01
Grand Above Shand To Legatt	426	2.27	-0.02	-2.19	-0.06
Grand Above Conestogo To Shand	640	3.18	0.00	-2.54	-0.24
Conestogo Above Dam	566	2.22	-0.55	-1.26	-0.03
Conestogo Below Dam	254	0.95	0.00	-1.70	-0.03
Grand Above Doon To Conestogo	248	1.59	0.00	-1.60	-0.25
Grand Above Brantford To Doon	274	2.08	0.00	-1.91	-1.05
Mill Creek	82	0.75	0.00	-0.54	-0.10
Eramosa Above Guelph	230	1.77	-0.11	-1.80	-0.20
Speed Above Dam	242	1.88	0.00	-1.81	-0.01
Speed Above Grand To Armstrong	308	2.19	0.00	-1.70	-0.73

Nith Above New Hamburg	545	2.47	-0.48	-1.40	-0.04
Nith Above Grand To New Hamburg	583	5.22	0.00	-4.00	-0.59
Whitemans Creek	404	3.26	-0.37	-2.70	-0.18
McKenzie Creek	368	1.47	0.03	-1.10	-0.13
Fairchild Creek	401	1.74	0.03	-1.70	-0.09
Grand Above York To Brantford	476	1.77	-0.41	-1.91	-0.16
Grand Above Dunnville To York	356	0.99	0.10	-0.97	-0.06
Total Watershed	**6,769**	**37.8**	**-1.8**	**-32.6**	**-4.0**
Positive values represent flow into the groundwater system and negative values represent flow out of the groundwater system.					

Uncertainty in the Groundwater Model

Any model developed to represent a natural system is inherently a simplification of that system. Most of the scientific approach involves representing physical conditions observed using approximations of larger scale functionality: hydraulic conductivity is an example of this. The Grand River groundwater flow model is designed to incorporate key hydrogeologic features for each subwatershed and their characteristics. The implication is that features at a smaller scale may not be adequately represented to support more local assessments. There is also uncertainty in the model from a lack of available subsurface data. The quality and availability of subsurface data varies throughout the watershed resulting in greater uncertainty in some areas compared to others.

18.3 Integrated Water Budget Results

This section presents the integrated water budget for the Grand River Watershed. This integrated water budget considers average annual estimates of key hydrologic parameters relating to both surface water and groundwater resources, and the integration between the two.

The values reported are based on annual averages and may exhibit significant seasonal variation. Due to the regional perspective of this analysis, the subwatershed descriptions may lack local details that may have local hydrologic significance. In addition, local scale interpretation and/or models may provide differing results than those presented here when averaged spatially and temporally. **Table 18-8 and Table 18-9** summarize the water budget components for each of the subwatersheds in mm and m^3/s, respectively. **Table 18-10** describes the components of the water budget.

Following **Table 18-10** is a summary of the integrated water budget for each of the subwatersheds based on the information provided in **Table 18-8, Table 18-9, and Table 18-10.**

Table 18-7: Integrated Water Budget (mm/yr)

		Surface Water					Groundwater				
Subwatershed	**Area (km^2)**	**Precip**	**ET**	**Runoff**	**Recharge**	**SW Taking**	**External Boundary**	**Discharge to Lakes**	**Discharge to Streams**	**GW Taking**	**Inter Basin**
Grand Above Legatt	365	988	469	345	174	0.2	0	-5	-150	-1	-17
Grand Above Shand To Legatt	426	988	464	356	168	0.2	-2	-27	-136	-4	0
Grand Above Conestogo To Shand	640	925	487	282	156	1.3	0	-2	-123	-12	-20
Conestogo Above Dam	566	936	485	327	123	0.7	-31	-14	-56	-2	-21
Conestogo Below Dam	254	968	487	365	117	1.6	0	0	-211	-4	98
Grand Above Doon To Conestogo	248	897	500	197	199	14.9	0	-6	-197	-32	34
Grand Above Brantford To Doon	274	896	495	163	238	3.0	0	-1	-218	-121	101
Mill Creek	82	888	507	89	292	0.4	0	0	-208	-40	-39
Eramosa Above Guelph	230	892	506	142	244	6.2	-15	0	-246	-27	46
Speed Above Dam	242	894	529	123	242	2.0	0	-10	-225	-1	-9
Speed Above Grand To Armstrong	308	889	510	156	223	2.9	0	0	-174	-75	25
Nith Above New Hamburg	545	992	503	346	144	0.5	-28	0	-81	-2	-31
Nith Above Grand To New Hamburg	583	945	508	154	284	1.6	0	0	-216	-32	-34
Whitemans Creek	404	945	512	176	257	4.0	-29	0	-211	-14	-1
McKenzie Creek	368	945	481	337	127	2.5	3	0	-94	-11	-23
Fairchild Creek	401	866	468	263	135	1.7	2	0	-134	-7	2
Grand Above York To Brantford	476	896	495	284	118	9.6	-27	0	-127	-10	47
Grand Above Dunnville To York	356	945	465	392	89	1.9	9	-4	-82	-5	-5
Total Watershed	**6769**	**933**	**491**	**266**	**176**	**2.7**	**-8**	**-4**	**-148**	**-18**	**0**

Positive values represent flow into the groundwater system and negative values represent flow out of the groundwater system.

Table 18-8: Integrated Water Budget (m^3/s)

		Surface Water					Groundwater				
Subwatershed	**Area (km^2)**	**Precip**	**ET**	**Runoff**	**Recharge**	**SW Taking**	**External Boundary**	**Discharge to Lakes**	**Discharge to Streams**	**GW Taking**	**Inter Basin**
Grand Above Legatt	365	11.43	5.42	3.99	2.02	0.002	0.00	-0.06	-1.74	-0.01	-0.20
Grand Above Shand To Legatt	426	13.36	6.27	4.81	2.28	0.003	-0.02	-0.36	-1.83	-0.06	0.00
Grand Above Conestogo To Shand	640	18.77	9.88	5.72	3.17	0.026	0.00	-0.04	-2.50	-0.24	-0.40
Conestogo Above Dam	566	16.80	8.71	5.88	2.21	0.012	-0.55	-0.26	-1.00	-0.03	-0.38
Conestogo Below Dam	254	7.79	3.92	2.94	0.94	0.013	0.00	0.00	-1.70	-0.03	0.79
Grand Above Doon To Conestogo	248	7.05	3.93	1.55	1.57	0.117	0.00	-0.05	-1.55	-0.25	0.26
Grand Above Brantford To Doon	274	7.79	4.30	1.42	2.07	0.026	0.00	-0.01	-1.90	-1.05	0.88
Mill Creek	82	2.32	1.32	0.23	0.76	0.001	0.00	0.00	-0.54	-0.10	-0.10
Eramosa Above Guelph	230	6.51	3.70	1.04	1.78	0.045	-0.11	0.00	-1.80	-0.20	0.34
Speed Above Dam	242	6.87	4.06	0.95	1.86	0.015	0.00	-0.08	-1.73	-0.01	-0.07
Speed Above Grand To Armstrong	308	8.69	4.98	1.52	2.18	0.028	0.00	0.00	-1.70	-0.73	0.24
Nith Above New Hamburg	545	17.15	8.68	5.97	2.49	0.009	-0.48	0.00	-1.40	-0.04	-0.54
Nith Above Grand To New Hamburg	583	17.47	9.39	2.84	5.25	0.029	0.00	0.00	-4.00	-0.59	-0.63
Whitemans Creek	404	12.11	6.56	2.26	3.29	0.051	-0.37	0.00	-2.70	-0.18	-0.01
McKenzie Creek	368	11.04	5.62	3.94	1.48	0.029	0.03	0.00	-1.10	-0.13	-0.27
Fairchild Creek	401	11.01	5.95	3.34	1.72	0.022	0.03	0.00	-1.70	-0.09	0.02
Grand Above York To Brantford	476	13.52	7.46	4.28	1.78	0.145	-0.41	0.00	-1.91	-0.16	0.70
Grand Above Dunnville To York	356	10.67	5.25	4.42	1.00	0.021	0.10	-0.04	-0.93	-0.06	-0.06
Total Watershed	**6,769**	**200.4**	**105.4**	**57.1**	**37.8**	**0.588**	**-1.8**	**-0.9**	**-31.7**	**-4.0**	**0.0**

Positive values represent flow into the groundwater system and negative values represent flow out of the groundwater system.

Table 18-9: Summary of Water Budget Components

Parameter	Source	Description
Precipitation	Climate Monitoring Data	Climate data used to represent the precipitation over each of the subwatersheds is summarized by the hydrologic model.
Evapotranspiration	GAWSER	Using potential evapotranspiration rates the hydrologic model estimates actual evapotranspiration by determining the amount of water available.
Surface Water Runoff	GAWSER	When the precipitation exceeds the infiltration capacity of a soil, overland runoff is created. Subwatersheds with tighter surficial materials tend to have a higher proportion of runoff.
Groundwater Recharge	GAWSER	By calculating the amount of infiltration, net of evapotranspiration, the hydrologic model estimates the amount of groundwater recharge for a particular HRU. Subwatersheds with more pervious materials have a higher proportion of recharge.
Surface Water Taking	Water Use Estimates	The amount of water taken from a surface water source and not immediately returned to that source. Includes estimates from permits as well as rural domestic and permit-exempt agricultural use.
Groundwater Taking	FEFLOW	This parameter refers to the flux of groundwater removed from pumping wells as reported in the actual water use estimates.
External Boundary	FEFLOW	This component identifies groundwater flow through the boundaries of the groundwater flow model. This is representative of groundwater flow out of, or into, the Grand River Watershed. Negative flows indicate water leaving the basin; positive flows indicate water entering the basin.
Groundwater Discharge to Lakes	FEFLOW	This parameter quantifies the groundwater flux into or out of lakes. Negative values indicate that flow is leaving the groundwater system to the lakes.
Groundwater Discharge to Rivers	FEFLOW	This parameter quantifies the groundwater flux to rivers and streams in the particular subwatershed. Negative values indicate that flow is leaving the groundwater system to the surface water system

Table 18-9: Summary of Water Budget Components

Parameter	Source	Description
Inter-Basin Flow	FEFLOW	This parameter is the amount of groundwater flow to another subwatershed within the Grand River Watershed. Positive values indicate that the subwatershed is experiencing a net increase of groundwater flow from adjacent subwatersheds. Negative values indicate that the subwatershed is experiencing a net loss of groundwater flow to adjacent subwatersheds.

Grand Above Legatt Subwatershed

The Grand Above Legatt subwatershed is the most northern subwatershed and is characterized by having a mixture of low to medium permeability surficial materials. Catfish Creek Till and Tavistock Till dominate the subwatershed, with isolated glaciofluvial outwash deposits. The topography is generally flat, with no hummocky features. Some areas within the subwatershed receive more precipitation (988 mm/y) than the watershed average (933 mm/y) due primarily to lake effect snowfall. The spatial distribution of lake effect snowfall, however, may not be well represented due to a lack of long term climate stations. The subwatershed experiences more surface runoff (345 mm/y) than the Watershed average (266 mm/y). Groundwater recharge (173 mm/y) is close to the average groundwater recharge rates (176 mm/y), and is highest within the pervious Catfish Creek Till and glaciofluvial deposits.

Significant overburden aquifers within the subwatershed are confined to pockets of pervious deposits, and the bedrock (Guelph/Gasport) contributes to the regional groundwater flow system. An estimated 1.8 m^3/s of groundwater discharge occurs, with most of the groundwater discharge predicted to occur in the upper reaches of the subwatershed, where Catfish Creek Till is dominant.

Consumptive water use in this subwatershed is low, with the estimated average annual consumptive groundwater demand of 25 L/s and the estimated average annual surface water demand of 2 L/s.

For the Grand Dundalk gauge, simulated baseflow estimates are higher than the range of estimated baseflow. Additionally, the hydrologic model over-predicts surface water flow. Additional model calibration would be recommended if using the models for future hydrologic or hydrogeological studies.

Grand Above Shand To Legatt Subwatershed

The Grand Above Shand to Legatt subwatershed is mainly composed of the clayey soils (57%) of Tavistock Till, with glaciofluvial deposits over 30% of the area. There are some hummocky features where portions of the Orangeville Moraine extend into the southern portions of this subwatershed. The subwatershed's average annual precipitation (988 mm/y) is similar to the Grand Above Legatt subwatershed, with similar uncertainty relating to the lake effect snow. The simulated hydrological response is very similar to that observed in the Grand Above Legatt subwatershed. Evapotranspiration is estimated to be 464 mm/y. Surface runoff is estimated to be 356 mm/y, which is higher than the watershed average (266 mm/y) due to the areas of clayey soils. The average groundwater recharge rate in the subwatershed is 168 mm/y. Higher amounts of runoff would be observed in areas with surficial materials of Tavistock Till, where the majority of the groundwater recharge occurring in the pervious glaciofluvial deposits.

Overburden aquifers in this subwatershed include the shallow glaciofluvial deposits and a lower overburden aquifer below the Tavistock Till. The primary bedrock aquifer is the Guelph/Gasport bedrock formation. Higher rates of groundwater discharge are predicted to occur along the Grand River throughout this subwatershed.

Estimated consumptive water use within the subwatershed is relatively low and a small proportion of the total water budget. Average annual groundwater demand is approximately 69 L/s and the average annual consumptive surface water demand is approximately 3 L/s.

Grand Above Conestogo To Shand Subwatershed

The Grand Above Conestogo to Shand subwatershed is the largest in the Grand River watershed. The subwatershed is predominately Tavistock Till in the north and northwest sections (particularly the Irvine Creek). The central areas of the subwatershed contain extensive deposits of outwash gravels, interspersed with Tavistock and Port Stanley Tills, and transitioning to Port Stanley Till in the southeast portion. Approximately 6% of the subwatershed is has hummocky topography. The average annual precipitation in the subwatershed receives is 925 mm/y, which is close to the watershed average of 933 mm/y. Evapotranspiration is estimated to be 487 mm/y. Surface runoff and groundwater recharge are estimated to be 282 mm/y and 156 mm/y, respectively.

The most significant aquifer in this subwatershed is the Guelph/Gasport Formation bedrock aquifer, which supplies most of the municipal systems in the area. Overburden aquifers are generally confined to isolated patches of granular material, with more continuous overburden aquifers located near Elmira. Other areas where productive lower overburden aquifers can be found include the villages of Conestoga, Winterbourne, and Floradale. Higher groundwater discharge rates are predicted into the Grand River where it passes through the Elora Gorge and West Montrose, and again immediately upstream of the Conestogo/Grand confluence.

Estimated consumptive water use within the subwatershed is moderate. The largest water demands include municipal supplies for Elora and Fergus, as well as permits for aquaculture and groundwater remediation. Average annual groundwater demand is approximately 250 L/s and the average annual consumptive surface water demand is approximately 26 L/s.

The surface water and groundwater models are reasonably calibrated to the hydrologic and hydrogeologic processes in the subwatershed; however, groundwater supplies in the area are critical for the communities of Fergus and Elora in Centre Wellington. Further calibration and conceptualization would be beneficial to better understand the regional groundwater system with respect to those communities and validate the model's predictions of groundwater discharge in the area.

Conestogo Above Dam Subwatershed

The Conestogo Above Dam subwatershed is characterized by having a large proportion of clayey soils belonging to the Tavistock Till as the primary surficial material. Elma Till is also present in the western portion of the Subwatershed, which is drained by Moorefield Creek. Granular glaciofluvial deposits are sparse and generally discontinuous. The annual average precipitation is 936 mm/y. Lake effect snowfall may have an influence on total precipitation in certain areas of the subwatershed; however, this cannot be characterized well with the available long term climate stations. Evapotranspiration is estimated to be 485 mm/y. As a result of the abundant low permeability soils, surface runoff is approximately 327 mm/y, which is significantly higher than the watershed average. Correspondingly, estimated groundwater recharge is relatively low and estimated to be 123 mm/y.

With the exception of an esker in the Damascus area, most upper overburden aquifers are localized. Deeper overburden aquifers are present over the subwatershed, typically below the Tavistock Till deposit. The Salina formation forms the uppermost bedrock formation over much of the subwatershed, and the Guelph/Gasport Formation remains the primary bedrock aquifer in the extreme eastern portions of the subwatershed. Typical of being a headwaters subwatershed, the groundwater flow model predicts a net groundwater outflow into adjacent subwatersheds (i.e., Inter-Basin Flow) equal to 0.38 m^3/s. Furthermore, an additional 0.55 m^3/s of groundwater flow leaves the Grand River watershed and flows to the west from this subwatershed. There are no significant reaches of groundwater discharge.

Permitted water use within the Conestogo Above Dam subwatershed is relatively low, with estimated average annual groundwater demand of 37 L/s and estimated average annual consumptive surface water demand of 12 L/s.

Conestogo Below Dam Subwatershed

Much like the Upper Conestogo subwatershed, the surficial materials of the Conestoga Below Dam Subwatershed are primarily composed of low permeability materials (Mornington and Tavistock Tills). There are some deposits of ice-contact sands and gravels in the lower portions of the subwatershed; however, the less permeable tills dominate the surficial geology. In the lower portions of the subwatershed there are large areas with hummocky terrain. These areas include portions of the Waterloo, Elmira and Macton Moraine. The subwatershed receives approximately 968 mm/y of precipitation per year, which is higher than the Watershed average of 933 mm/y. The hydrologic response of the Conestogo Below Dam subwatershed is very similar to the upstream Conestogo Above Dam subwatershed. Surface runoff is estimated to be 365 mm/y, which is higher than the watershed average of 266 mm/y. With the predominant low permeability soils, the average groundwater recharge rate is estimated to be 117 mm/y, which is lower than the watershed average of 176 mm/y. The highest groundwater recharge rates are predicted in the lower portions of the subwatershed where pervious deposits are present.

Significant overburden aquifers are not expected where the upper areas of the subwatershed are dominated by Tavistock and Mornington Tills. In the lower portions of the subwatershed, which intersect the northern flank of the Waterloo Moraine and the southern portions of the Elmira Moraine, there are isolated areas with upper and lower overburden aquifers near Wellesley and Crosshill. An extension of the buried Dundas Valley also extends through this subwatershed, and may contain a productive lower aquifer. The Salina Formation is the uppermost bedrock in this subwatershed and may form a weak aquifer.

The Conestoga River within the subwatershed may receive higher rates of groundwater discharge than would be expected from the lower recharge rates in the subwatershed. This is potentially a result of groundwater inflow from adjacent subwatersheds as simulated by the groundwater flow model. It is estimated that 0.8 m^3/s of groundwater flow is entering this subwatershed as Inter-Basin Flow. The large amount of groundwater inflow supports the groundwater discharge zone predicted along the lower Conestogo River.

Water use within the Conestogo Below Dam subwatershed is relatively low, with estimated average annual groundwater demand of 46 L/s and estimated average annual consumptive surface water demand of 13 L/s.

Grand Above Doon To Conestogo Subwatershed

The surficial geology of the Grand Above Doon to Conestogo subwatershed is highly variable. There are extensive ice-contact stratified drift and Maryhill Till deposits associated with the Waterloo Moraine, as well as Port Stanley Till, as mapped on the eastern portion of the subwatershed. The Waterloo Moraine is the most predominant physiographic feature, and contributes a large portion (24%) of hummocky area. Approximately 18% of the subwatershed is urbanized. The average annual precipitation is 897 mm/y. Surface water runoff is estimated to be approximately 197 mm/y, which is lower than the watershed average due to the high percentage of pervious materials. Similarly, groundwater recharge is 199 mm/y, which is higher than the watershed average.

In the western areas of the subwatershed there are extensive upper and lower overburden aquifers. Upper overburden aquifers include surficial outwash and ice-contact deposits in the Erbsville, Homer-Watson, and Forwell areas, as well as deposits near the Grand River. Lower overburden aquifers include the Greenbrook, Parkway and Strasburg aquifers. In the eastern areas of the subwatershed, there are local outwash deposits that may represent upper overburden aquifer, particularly around the Ariss area. High groundwater discharge rates into the Grand River are found in this area.

Consumptive water demand in the subwatershed is relatively high due to municipal demands. Average annual groundwater demand is 459 L/s, which represents nearly one-third of the recharge in the subwatershed. Estimated consumptive surface water demand is 117 L/s. The Region of Waterloo's Mannheim surface water intake is located within this subwatershed.

Water resources within this subwatershed are critical to municipal drinking water supplies. The hydrogeological conditions within the watershed tend to be very complex, particularly in the vicinity of the Waterloo Moraine. The Grand River watershed steady-state groundwater-flow model is not calibrated to municipal observation well data, and as a result, the model may not be fully representative of hydrogeology in or near wellfields. Further calibration and conceptualization would be beneficial to better understand the regional groundwater system, and significant hydrologic processes in the subwatershed.

Grand Above Brantford To Doon Subwatershed

The Grand Above Brantford To Doon subwatershed is situated in the centre of the watershed, and contains the urban areas of Kitchener and Cambridge. The surficial materials are predominantly icecontact stratified drift and outwash deposits. This subwatershed includes parts of both the Waterloo Moraine and the Galt/Paris Moraines and has a very high proportion of hummocky topography (42%). Annual precipitation for the subwatershed is 896 mm/y, which is lower than the watershed average of 933 mm/y. Although it is heavily urbanized (25%), the high permeability soils result in low runoff (163 mm/y) and high recharge (238 mm/y).

Upper overburden aquifers are located in the vast deposits of outwash materials, and ice-contact drift. Lower overburden aquifers exist in interconnected pockets throughout the area. The primary bedrock aquifer in the eastern portion of the subwatershed is found within the Guelph formation, whereas in the western portion of the subwatershed the Salina formation is the main bedrock aquifer. The subwatershed receives approximately 0.88 m^3/s of groundwater flow from adjacent subwatersheds as part of a deeper regional groundwater flow system. The calibrated groundwater flow model identifies significant groundwater discharge rates along the entire reach of the Grand River.

Municipal groundwater consumption within the subwatershed is relatively high. Estimated average annual groundwater demand is 1,027 L/s. Other significant groundwater use sectors include aggregate washing and golf course irrigation. Estimated average annual consumptive surface water demand is 26 L/s.

Similar to the Grand Above Doon to Conestoga subwatershed, water resources within this subwatershed are critical to municipal drinking water supplies. The hydrogeological conditions within the watershed tend to be very complex, particularly in the vicinity of the Waterloo Moraine. The Grand River watershed steady-state groundwater-flow model is not calibrated to municipal observation well data, and as a result, the model may not be fully representative of hydrogeology in or near wellfields. Further calibration and conceptualization would be beneficial to better understand the regional groundwater system, and significant hydrologic processes in the subwatershed.

Mill Creek Subwatershed

The Mill Creek subwatershed is situated between the Galt and Paris Moraines on the western edge of the Grand River watershed. The subwatershed's surficial materials include high permeability outwash deposits, and medium permeability Wentworth Till. Fifty percent of the watershed is classified as having hummocky topography associated with the moraines. Precipitation for this subwatershed is 888 mm/y, which is slightly below the watershed average (933 mm/y). Estimated runoff is much lower (89 mm/y) than the watershed average (266 mm/y). Similarly, groundwater recharge (292 mm/y) is higher than the watershed average (176 mm/y).

The most significant overburden aquifers in the subwatershed are contained within the large outwash deposits located between the Moraines. The Guelph/Gasport Formation bedrock is a significant regional aquifer within this subwatershed. Relatively high rates of groundwater discharge are predicted to occur along Mill Creek, which is consistent with the creek being identified as an important coldwater aquatic resource.

Permitted groundwater water demand is very high due to many aggregate washing operations in the subwatershed. 850 L/s of total groundwater pumping and no surface water withdrawals are permitted. Actual consumption rates for aggregate operations are much lower than permitted pumping rates. While it is estimated that the average annual pumping rate is approximately 339 L/s in the watershed, only an estimated 82 L/s of this water is being consumed and is not returned to its original source.

The calibrated groundwater levels appear to be higher on average than observed, however, the simulated groundwater discharge is within the estimated baseflow range. Currently, the hydrologic model is consistently under-predicting streamflow in comparison to the measured conditions. This may be due to the model's simplification of groundwater storage and baseflow, the effect of which is clearly demonstrated for a small subwatershed. Further work is warranted to better understand the hydrology of the watershed, and the potential interactions with the regional system.

The greatest water demands placed on the subwatershed are by the aggregate resources industry, and the cumulative effects of these activities are poorly understood. Given the importance of maintaining groundwater and surface water interactions, additional surface water and groundwater characterization and modelling is recommended to improve the understand of the hydrologic processes, and aid in assessing potential future impacts. Integrated groundwater and surface water modelling may be beneficial for this subwatershed.

Eramosa Above Guelph Subwatershed

The Eramosa Above Guelph subwatershed has a highly variable geologic composition. Extensive deposits of glaciofluvial ice-contact deposits are distributed throughout area, in addition to Port Stanley and Wentworth Tills. Due to the presence of the Galt and Paris Moraines, hummocky topography is extensive, comprising 36% of the subwatershed. Average annual precipitation in the subwatershed is 892 mm/y, which is lower than the watershed average of 933 mm/y. Due to the pervious soils and high percentage of hummocky topography, runoff (142 mm/y) is much lower than the watershed average and similarly, groundwater recharge (244 mm/y) is higher than the watershed average. The highest groundwater recharge rates would occur where pervious materials are deposited, or where hummocky topography increases the potential for groundwater recharge on the Galt and Paris Moraines.

There are generally no significant overburden aquifers in the subwatershed. The primary aquifer for this area is the Guelph/Gasport bedrock aquifer. Higher groundwater discharge rates are focused in the lower reaches of the Eramosa River, Blue Springs Creek and the headwaters of the Eramosa River. These results are consistent with the area supporting significant coldwater aquatic systems.

Consumptive water use in the subwatershed is relatively high due primarily to municipal demands. Average annual groundwater demand is approximately 286 L/s and average annual consumptive surface water demand is 45 L/s. Maximum monthly surface water demand is higher as a result of the City of Guelph’s Eramosa River water supply intake.

Hydrological and hydrogeological conditions in the Eramosa Above Guelph subwatershed are complex due to the variable complex surficial and bedrock hydrogeology. The predicted groundwater discharge rate is within the estimated baseflow range, but further work is warranted to better understand groundwater/surface water interactions, groundwater flow through the bedrock system, and the City of Guelph’s water supply. Water resources within this Subwatershed are critical to municipal drinking water supplies. The Grand River watershed steady-state groundwater-flow model is not calibrated to municipal observation well data, and as a result, the model should not be used for local or well-field scale assessments. Further calibration and conceptualization would be beneficial to better understand the regional groundwater system, and significant hydrologic processes in the subwatershed.

Speed Above Dam Subwatershed

The Speed Above Dam subwatershed is primarily composed of ice-contact stratified drift, and outwash deposits, mixed with Port Stanley Till. Orangeville Moraine deposits cover a large part of this subwatershed; however, the moraine is eroded and only 14% of the subwatershed is classified as hummocky. Precipitation for this subwatershed is 894 mm/y, which is slightly less than the watershed average of 933 mm/y. Due to the high amount of pervious materials, runoff is estimated to be 123 mm/y, which is lower than the watershed average (266 mm/y). Similarly, groundwater recharge (242 mm/y) is higher than the watershed average (176 mm/y).

Because of the extensive deposits of ice-contact and outwash deposits, upper overburden aquifers are distributed through the subwatershed. The uppermost bedrock unit in the area is the Guelph/Gasport Formation, and it is the primary aquifer for the area. Groundwater discharge is most significant in the Lutteral Creek area, a tributary of the Upper Speed River. This creek is recognized as a significant groundwater-fed coldwater stream. Other more isolated areas of groundwater discharge are found on the eastern branch of the Upper Speed River.

Consumptive water demand in the Speed Above Dam subwatershed is low. Average annual groundwater demand is 27 L/s and average annual consumptive surface water demand is 15 L/s.

Speed Above Grand to Armstrong Subwatershed

The Speed Above Grand to Armstrong subwatershed, similar to the upstream Speed Above Dam subwatershed, is primarily composed of ice-contact and outwash deposits, mixed with Port Stanley Till. Ten percent of the subwatershed is classified as hummocky. Annual precipitation for the Speed Above Grand to Dam is 889 mm/y, which is lower than the Watershed average of 933 mm/y. Due to the pervious materials and moderate level hummocky topography, runoff (156 mm/y) is much lower than the watershed average (266 mm/y) and groundwater recharge (223 mm/y) is much higher than the watershed average (176 mm/y).

Overburden aquifers are generally limited to areas of ice-contact and outwash deposits, with no significant lower overburden aquifers identified. As with other subwatersheds in this area, the primary water supply aquifer is the Guelph/Gasport bedrock aquifer. High groundwater discharge rates shown along the main Speed River, with the highest rates being predicted in the lower areas of the subwatershed.

Consumptive water use in the watershed is high due primarily to municipal water demands. Average annual groundwater demand is 831 L/s and average annual consumptive surface water demand is 28 L/s. In addition to municipal demands, other significant water users include the aggregate industry and golf courses (irrigation).

In general, the groundwater levels appear to be well calibrated. This calibration, however, does not include municipal observation wells. The Speed River is regulated by the Guelph Dam, and it is therefore difficult to develop an accurate estimate of groundwater discharge without having a series of instream baseflow measurements. The hydrogeology of the bedrock aquifer in the City of Guelph is complex, and the Grand River watershed groundwater flow model may not be fully representative of hydrogeology in or near wellfields.

Nith Above New Hamburg Subwatershed

The Nith Above New Hamburg subwatershed is similar to the Conestogo Below Dam subwatershed, in that the surficial materials are primarily Mornington Till, interspersed with ice-contact deposits. Stratford Till is also present in the southwestern portion of the subwatershed. The subwatershed encompasses the northwestern flank of the Waterloo Moraine, as well as portions of the Milverton, Macton and Easthope Moraines. As a result of these moraine deposits, a large portion of the subwatershed is classified as hummocky (27%). However, the primary surficial material over most of the hummocky areas is low permeability Mornington Till, which inhibits groundwater recharge. Precipitation for this subwatershed is 992 mm/y, which is higher than the watershed average (933 mm/y). Due to the low permeability materials present in the subwatershed, runoff (346 mm/y) is higher than the watershed average (266 mm/y) and groundwater recharge (144 mm/y) is lower than the watershed average (176 mm/y).

There are no significant upper overburden aquifers over most of the subwatershed; however more continuous deposits of surficial sands and gravels are found in the southeastern portion of the subwatershed within the Waterloo Moraine. An extension of the Dundas Valley is located within the Nith Above New Hamburg, and may also support a lower overburden aquifer. The primary bedrock aquifer is found within the Salina formation. The Nith Above New Hamburg Subwatershed has an estimated net groundwater outflow (Inter-Basin Flow) of 0.54 m^3/s to adjacent subwatersheds, and a net external groundwater outflow of 0.48 m3/s to areas beyond the Grand River watershed boundary. Groundwater discharge is generally restricted to the lower reaches of the Nith River within the subwatershed, closer to the western flank of the Waterloo Moraine.

Permitted water demands within the Nith Above New Hamburg are relatively low. Estimated average annual groundwater demand is 62 L/s and average annual consumptive surface water demand is 9 L/s.

Calibrated water levels appear to be reasonable across the subwatershed, although there are local areas within the subwatershed showing a trend of higher than observed water levels. Simulated groundwater discharge rates, however, are at the low end of the estimated baseflow range at several gauges. The result of this may be that the Inter-Basin Flow, or the amount of groundwater flow out of the watershed, is over-estimated. Since groundwater and surface water demands in the subwatershed are very small, the benefit of refining the conceptual model and calibration may not be significant.

Nith Above Grand To New Hamburg Subwatershed

The Nith Above Grand to New Hamburg subwatershed is primarily composed of outwash and ice-contact materials, mixed with lower permeability materials such as Port Stanley, Maryhill and Tavistock Tills. The subwatershed contains a large portion of the Waterloo Moraine, and therefore has 29% of the area being classified as having hummocky features. Annual precipitation for the subwatershed is 945 mm/y, consistent with the average watershed precipitation of 933 mm/y. Due to the extensive deposits of pervious materials and hummocky features, runoff (154 mm/y) is much less than the watershed average (266 mm/y), and the average groundwater recharge (284 mm/y) is much higher than the watershed average (176 mm/y).

Areas of very high groundwater recharge can be found in pervious areas containing hummocky topography on the southern flank of the Waterloo Moraine. Hummocky areas with granular materials, which drain the less permeable Maryhill Till cap, can provide estimated average annual groundwater recharge rates as high as 500 mm/y. To confirm these estimated high groundwater recharge rates, the Alder Creek groundwater study (CH2M Hill and S.S. Papadopulous, 2003) mapped localized depressions, infilled with granular material, which drain significant areas of Maryhill Till and have no drainage outlet. Very high recharge rates were estimated within these localized depressions.

Extensive upper overburden aquifers are located in this subwatershed, coinciding with the pervious surficial materials. There are also significant lower overburden aquifers in the area, particularly in the eastern portion of the subwatershed, located in the Ayr/Roseville area. The primary bedrock aquifer in the subwatershed is found within the Salina formation. Groundwater modelling results suggest a very significant net outflow of groundwater, estimated to be 0.63 m^3/s, from the Nith Above Grand to New Hamburg subwatershed. This water likely flows to the east, and partially contributes to groundwater discharge found in the Cambridge to Paris reach of the Grand River. Groundwater discharge is predicted to occur throughout the subwatershed, with particularly high discharge areas occurring along the Nith River immediately upstream of Plattsville, the lower reaches of Alder Creek, the Nith River near Ayr, Cedar Creek, and the lower Nith River near Paris.

Water demand is high in this subwatershed, with the largest water users including municipal supplies, aggregate washing, golf course and agricultural irrigation. Estimated average annual groundwater pumping is 513 L/s and average annual consumptive surface water demand is 29 L/s.

Whitemans Creek Subwatershed

The Whitemans Creek subwatershed is highly variable in terms of surficial materials, with Tavistock and Port Stanley Tills in the headwaters, and outwash and glaciolacustrine shallow water deposits in the lower reaches of the subwatershed. Topography is generally flat, with 7% of the subwatershed area containing hummocky features. Average annual precipitation for this subwatershed is 945 mm/y. Due to the high permeability materials in the middle and lower reaches of the subwatershed, runoff (176 mm/y) is much lower than the watershed average (266 mm/y) and groundwater recharge (257 mm/y) is greater than the watershed average (176 mm/y). Due to the highly variable surficial materials, hydrologic conditions are variable across the subwatershed, with the headwaters being runoff dominated and the lower subwatershed having higher amounts of groundwater recharge.

There is an extensive unconfined overburden aquifer throughout much of the lower subwatershed, where the Norfolk Sand Plain is present. In areas composed of Tavistock and Port Stanley Till, there are no significant overburden aquifers. Bedrock aquifers range from the Salina formation in the eastern portions of the subwatershed, to Bass Island/Bertie Formation in the western portions. Groundwater discharge is most significant in the lower sections of Whitemans Creek, downstream of Burford, and the middle reach of Horner Creek, immediately upstream of Princeton.

Water use within Whitemans' Creek is high, with maximum permitted groundwater takings equal to 3,543 L/s and maximum permitted surface water takings equal to 1,304 L/s. The main water use in Whitemans Creek is agricultural irrigation, and therefore water taking is seasonal in nature. Estimated maximum and average annual groundwater pumping is 465 L/s and 117 L/s, respectively. Similarly, maximum monthly and average annual consumptive surface water demand is 218 L/s and 51 L/s, respectively.

Calibrated water levels appear reasonable in the Norfolk Sand Plain portion of the watershed, however simulated water levels are higher than observed in the till areas, The predicted groundwater discharge rate is within the estimated baseflow range. Any future local-scale impact assessments may require refinements to the conceptual model and consideration of seasonal/transient groundwater flow conditions. An integrated surface water and groundwater flow model may be beneficial.

McKenzie Creek Subwatershed

Similar to the Grand Above York to Brantford subwatershed, the McKenzie Creek subwatershed is characterized by the low permeability surficial materials of the Haldimand Clay plain. In the upper reaches of McKenzie Creek there are sand deposits associated with the Norfolk Sand Plain. There are no areas within McKenzie Creek that are classified as hummocky topography. Precipitation for this subwatershed is 945 mm/y, which is similar to the average watershed precipitation of 933 mm/y. Due to the prevalence of low permeability materials over the majority of the subwatershed, runoff is estimated to be 337 mm/y, which is higher than the watershed average (266 mm/y) and groundwater recharge (127 mm/y) is lower than the watershed average (176 mm/y). Groundwater recharge rates for pervious areas in the upper reaches are higher.

Overburden aquifers are limited to the upper reaches of the subwatershed, where the Norfolk Sand Plain forms an unconfined overburden aquifer. Bedrock aquifers are the main source of groundwater for this area, with the Guelph Formation forming the main bedrock aquifer in the east, and the Salina Formation forming the bedrock aquifer in the west. Higher groundwater discharge rates are simulated in the upper reaches of McKenzie Creek, where pervious materials are most prevalent.

Similar to Whitemans Creek Subwatershed, water demand is relatively high and seasonally variable, mostly due to agriculture demands. Estimated maximum monthly and average annual groundwater pumping is 223 L/s and 53 L/s, respectively. Maximum monthly and average annual consumptive surface water demand is 108 L/s and 29 L/s, respectively.

Calibrated water levels appear to be reasonable, and simulated groundwater discharge matches well with observed baseflow estimates. The results indicate that the water demands are relatively high in relation to water supply in this subwatershed. In addition, there are historical observations of hydrologic stress due to low streamflow. Due to the seasonal water use sectors active in the subwatershed, any future local-scale impact assessments may need to consider seasonal/transient groundwater in consideration of the shallow system and seasonal groundwater discharge variability. Furthermore, an integrated groundwater/surface water flow model may be useful in better representing the hydrology and hydrogeology of this subwatershed.

Fairchild Creek Subwatershed

The Fairchild Creek subwatershed is composed primarily of low permeability materials associated with the Haldimand Clay plain, exposed bedrock in the Rockton Bedrock Plain, and veneers of shallow water glaciolacustrine deposits. In the upper reaches of the subwatershed, Fairchild Creek has some areas of Wentworth Till and hummocky topography where the Galt Moraine intersects the subwatershed. Precipitation for this subwatershed is 866 mm/y, which lower than the average watershed precipitation of 933 mm/y. Runoff is estimated to be 263 mm/y, which is similar to the watershed average (266 mm/y) and groundwater recharge (135 mm/y) is lower than the Watershed average (176 mm/y). These results are expected given the amount of low permeability soils in the subwatershed.

There are no significant upper overburden aquifers in the subwatershed. While localized, unconfined aquifers exist in pervious deposits, they are no regionally significant. Bedrock aquifers (Guelph Formation) are the primary groundwater sources. Simulated groundwater discharge rates show higher groundwater discharge in the headwaters of the creek.

Consumptive water demand in the subwatershed is relatively low. Estimated average annual groundwater demand is 92 L/s and average annual surface water consumptive demand is 22 L/s.

Grand Above York To Brantford Subwatershed

The Grand Above York to Brantford subwatershed is characterized by the low permeability soils of the Haldimand clay plain and the sand deposits associated with the Norfolk Sand Plain in the upper reaches. Precipitation for this subwatershed is 896 mm/y, which is below average watershed precipitation of 933 mm/y. Due to the prevalence of low permeability materials over the majority of the subwatershed, runoff (284 mm/y) is higher than the watershed average (266 mm/y) and groundwater recharge (118 mm/y) is lower than the watershed average (176 mm/y). Areas in the upstream reaches of the subwatershed containing granular materials, such as Mt. Pleasant Creek, are estimated to have groundwater recharge rates higher than the subwatershed average.

There are limited overburden aquifers with the majority of the subwatershed being composed of a massive laminated lacustrine deposit. Unconfined aquifers would be found in the areas in the upper reaches having pervious surficial materials. The bedrock aquifer is the primary water bearing unit for much of the subwatershed, with the Guelph formation being predominant in the eastern portions, and the Salina formation in the west. The Grand Above York to Brantford subwatershed receives a net groundwater inflow (Inter-Basin Flow) of approximately 0.70 m^3/s from adjacent subwatersheds as part of the regional groundwater flow system. Highest groundwater discharge rates are located in the upstream reaches of the subwatershed.

Water use in the Grand Above York to Brantford subwatershed is relatively high. Major water users include municipal supplies, aggregate washing, and agricultural irrigation. Average annual groundwater pumping is approximately 227 L/s and average annual surface water consumptive demand is 145 L/s. The Brantford and Six Nations municipal surface intakes are located in the subwatershed and represent the largest surface water demands.

Grand Above Dunnville To York Subwatershed

The Grand Above Dunnville to York subwatershed is characterized by the low permeability surficial materials of the Haldimand Clay plain. There is also a thin localized deposit of outwash sands located near Dunnville. Average annual precipitation is 945 mm/y and evapotranspiration is 465 mm. Due to the amount of low permeability materials over the subwatershed, average annual runoff is estimated to be 392 mm/y, which is much higher than the watershed average (266 mm/y). Similarly, groundwater recharge (89 mm/y) is much lower than the watershed average (176 mm/y).

There are no significant overburden aquifers expected within the Grand Above Dunnville to York subwatershed. Many of the current domestic wells are completed within the Salina bedrock formation.

Water use is relatively low in the Grand Above Dunnville to York subwatershed. Average annual groundwater demand is 91 L/s and average annual consumptive surface water demand is 21 L/s. There are no local baseflow estimates to compare against calibrated values; however, the impact of groundwater discharge to baseflow in the Grand River is considered to be minor in this subwatershed.

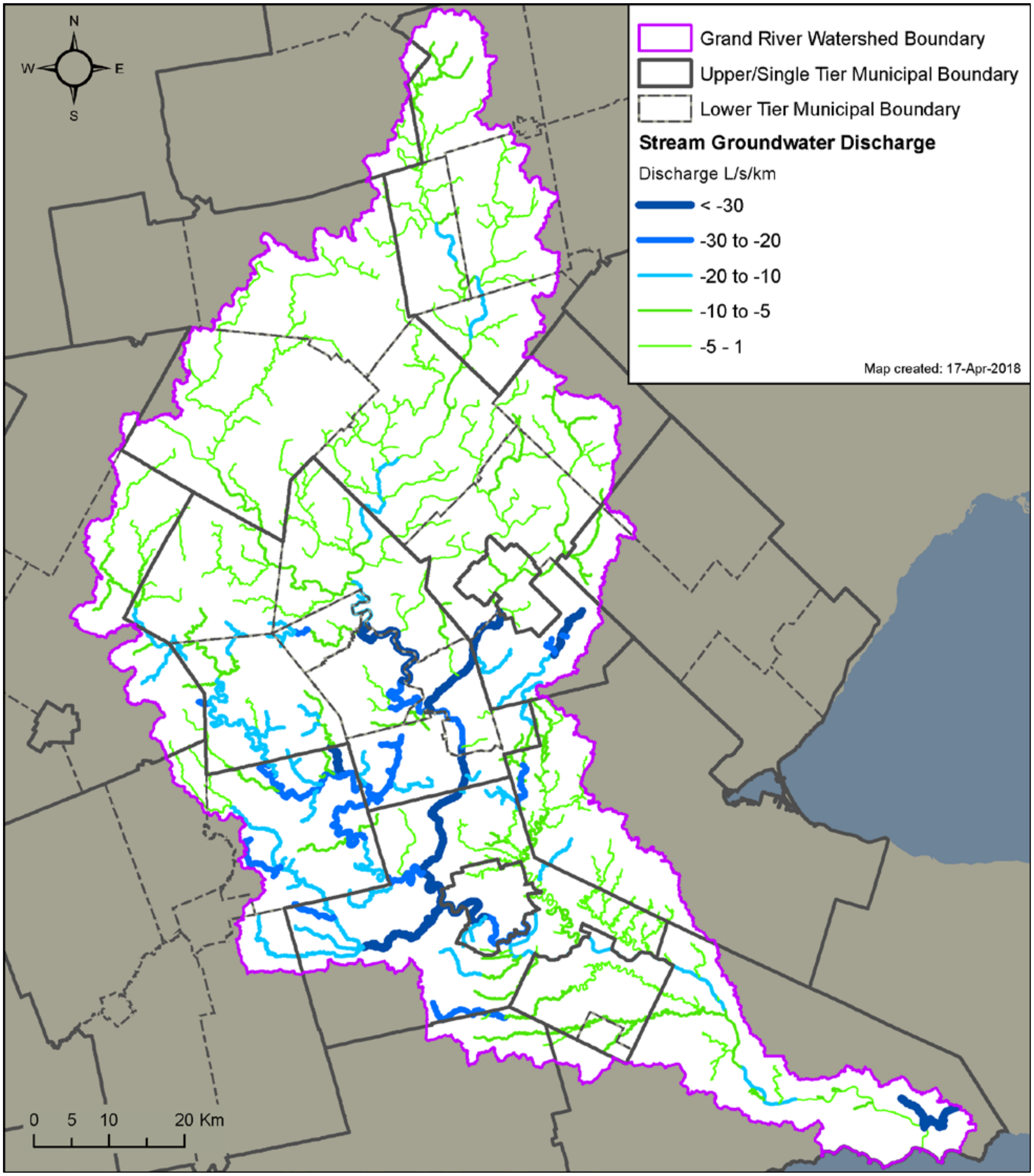
Calibrated groundwater levels tend to be higher than observed; however, due to groundwater and surface water demands being relatively low in the watershed, further calibration and conceptualization may not be warranted.

Interactions between Groundwater and Surface Water

The calibrated groundwater model provided a synthesis of available information that was used to increase the understanding about the groundwater flow system and its interaction with the surface water system. **Map 18-2** presents the simulated distribution of groundwater discharge flux to the higher order streams and rivers throughout the Grand River Watershed.

The headwater regions primarily receive smaller discharge volumes than other parts of the watershed. The highest groundwater discharge rates occur in major stream reaches in low lying areas through the middle of the watershed, such as between Cambridge and Paris. These areas of discharge aid in allowing the stream to recover after impacts from the large urban parts of the watershed. Groundwater discharge is low through the tight soils of the Haldimand Clay Plain in the lower part of the watershed although the main river may still be gaining water from groundwater discharge. The results from the calibrated groundwater model are similar to the delineation of cold and cool water streams which provide another method of identifying groundwater discharge on a regional scale.

Map 18-2: Groundwater Discharge Map in the Grand River Watershed



18.4 Tier 2 Water Quantity Stress Assessment

All subwatersheds within the Grand River watershed were evaluated at the Tier 2 level for potential stress to water quantity. This evaluation was completed for both groundwater and surface water using the percent water demand calculation given below. Subwatersheds with either a '*moderate*' or '*significant*' potential for stress and containing a municipal drinking water system were recommended to move to a Tier 3 Water Quantity Risk Assessment.

$$\textit{Percent Water Demand} = \frac{Q_{DEMAND}}{Q_{SUPPLY} - Q_{RESERVE}} \times 100\%$$

A *moderate* or *significant* potential for stress for a subwatershed did not imply the subwatershed was experiencing local hydrologic or ecologic stress. This was a screening classification to indicate where additional information was required to understand local water supply sustainability and potential cumulative impacts of water withdrawals.

18.4.1 Surface Water Stress Assessment

The results of the surface water stress classification for each of the subwatersheds are summarized in Table 18-11. The Eramosa Above Guelph, Whitemans Creek, and McKenzie Creek Subwatersheds were classified as having a *moderate* surface water potential for stress.

Table 18-10: Subwatershed Surface Water Potential for Stress Classification

Subwatershed	Potential Stress Classification	Municipal Water Supply (Surface Water)
Grand Above Legatt	Low	None
Grand Above Shand To Legatt	Low	None
Grand Above Conestogo To Shand	Low	None
Conestogo Above Dam	Low	None
Conestogo Below Dam	Low	None
Grand Above Doon To Conestogo	Low	RMOW Mannheim Intake
Eramosa Above Guelph	**Moderate**	Guelph Eramosa/Arkell Intake
Speed Above Dam	Low	None
Speed Above Grand To Dam	Low	None
Mill Creek	Low	None
Grand Above Brantford To Doon	Low	None
Nith Above New Hamburg	Low	None
Nith Above Grand To New Hamburg	Low	None
Whitemans Creek	**Moderate**	None
Grand Above York To Brantford	Low	Brantford, Ohsweken
Fairchild Creek	Low	None
McKenzie Creek	**Moderate**	None
Grand Above Dunnville To York	Low	None

The following section provides additional discussion relating to the three subwatersheds classified as having a *moderate* potential for stress.

Eramosa Above Guelph Subwatershed

The Eramosa River is located to the northeast of Guelph and joins the Speed River within the City of Guelph. The headwaters are located in the northwest portion of Erin Township. Blue Springs Creek, a major tributary of the Eramosa River, joins the Eramosa River in Halton Region. In addition to the municipal intake, at the time of the study, there were 10 known permitted surface water takings within this subwatershed; these included one agricultural use permit, three commercial use permits, three recreational use permits, and two miscellaneous use permits. The stress assessment completed for the Eramosa Above Guelph subwatershed classified the subwatershed as having a *moderate* potential for stress under current water demand conditions. The subwatershed's maximum monthly Percent Water Demand was estimated to be 25% during the month of August. The subwatershed contains the City of Guelph's Eramosa River drinking water intake.

The City of Guelph met the requirements set out by the Technical Rules (MOE, 2009b) to complete a Tier 3 Water Quantity Risk Assessment for the Eramosa River Intake. The Eramosa Above Guelph subwatershed was classified as having a *moderate* potential for stress for surface water. The objective of the Tier 3 Water Quantity Risk Assessment was to estimate the potential for the City of Guelph to not be able to obtain its permitted water pumping rates at this intake.

Whitemans Creek Subwatershed

Whitemans Creek, located in the western portion of the County of Brant near Burford, enters the Grand River just upstream of Brantford. This creek has two main tributaries, Kenny Creek (in Norwich Township) and Horner Creek (in Blandford-Blenheim Township). At the time of the study, there were 55 identified permitted agricultural surface water takings within the Whitemans Creek subwatershed. The only additional water demand estimated for the subwatershed was the unpermitted agricultural (livestock) surface water demand, estimated to be 4 L/s throughout the year.

The stress assessment completed for the Whitemans Creek assessment area classified the subwatershed as having a *moderate* potential for surface water stress under current water demand conditions. As there are no planned municipal systems in this assessment area, future demand and drought scenarios were not evaluated for this subwatershed. Without a municipal surface water intake present in the subwatershed, the completion of a Tier 3 Water Quantity Risk Assessment for surface water systems was not required as a result of the *moderate* classification.

McKenzie Creek Subwatershed

McKenzie Creek, including Boston Creek, is a tributary of the Grand River in the southern portion of the Grand River watershed. The headwaters of both creeks begin in Brant County, where the shallow Norfolk Sand Plain aquifer supplies groundwater baseflow. The subwatershed is primarily rural land use. Similar to the Whitemans Creek subwatershed, agricultural irrigation is a major water use in the summer months, especially in the Norfolk sand plain area. At the time of the study, there were 35 identified surface water permits-to-take-water in the subwatershed, mostly for irrigation.

The stress assessment classified the McKenzie Creek subwatershed as having a *moderate* potential for stress under current water demand conditions. As there are no planned municipal systems in this assessment area, future water demand and drought scenarios were not evaluated for this subwatershed. Without having a municipal surface water intake present in this subwatershed, there was no requirement for the completion of a Tier 3 Water Quantity Risk Assessment to assess surface water as a result of the *moderate* classification.

18.4.2 Groundwater Stress Assessment

Initially for the preliminary groundwater stress assessments, the 18 surface water-based subwatersheds were used. While these delineated subwatersheds reflected surface water demands and hydrology well, they did not adequately reflect the major aquifer systems in the watershed, existing municipal wells systems and capture zones for those systems. The surface-water based subwatersheds subdivided several of the large aquifers and wellfields into separate assessment areas; this resulted in groundwater demand from the same aquifer being split into separate subwatersheds.

Map 18-3 illustrates a new set of 19 groundwater assessment areas delineated to better represent groundwater demand and aquifer systems. The new groundwater boundaries were developed to encompass groundwater demand systems from the same aquifer in a single assessment area. These areas are listed in **Table 18-12** with a description of how these boundaries were derived.

Map 18-3: Groundwater Assessment Area Boundaries in the Grand River Watershed

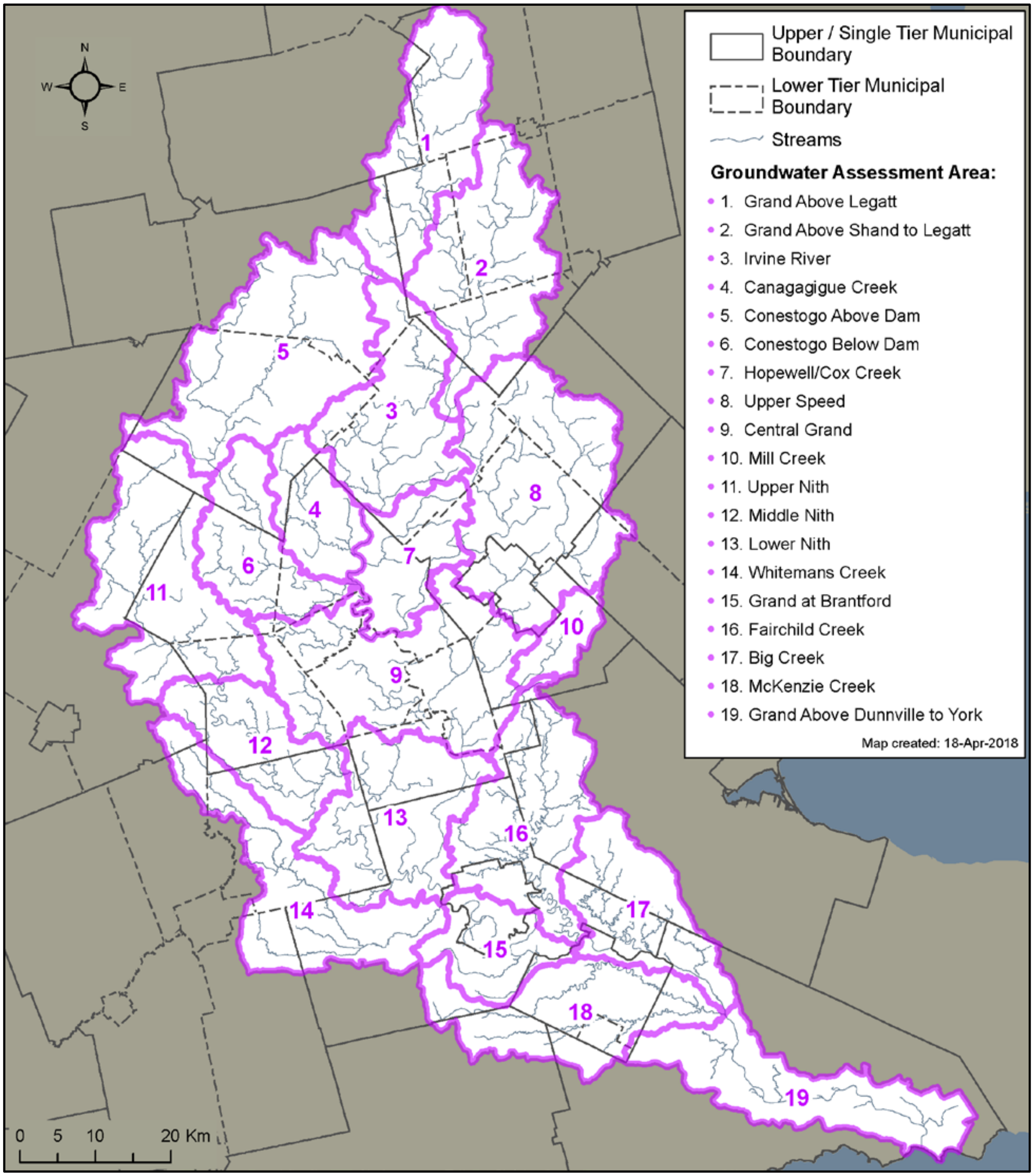


Table 18-11: Groundwater Assessment Areas		
Groundwater Assessment Area	**Area (km^2)**	**Description of Boundary Modification**
Grand Above Legatt	365	No Change from Surface Water Subwatershed
Grand Above Shand to Legatt	426	No Change from Surface Water Subwatershed
Irvine River	359	Delineated as the upper portion of the Grand Above Conestogo to Shand Subwatershed
Canagagigue Creek	177	Delineated as the southwest portion of the Grand Above Conestogo to Shand Subwatershed
Conestogo Above Dam	566	No Change from Surface Water Subwatershed
Conestogo Below Dam	254	No Change from Surface Water Subwatershed
Hopewell/Cox Creek	208	Delineated as the southeast portion of the Grand Above Conestogo to Shand Subwatershed joined with the northeast portion of the Grand Above Doon to Conestogo Subwatershed
Upper Speed	614	Delineating by combining the Eramosa River, Speed Above Dam, and upper portion of the Speed Above Grand to Dam Subwatersheds. This area encompasses the City of Guelph drinking water systems and capture zones.
Central Grand	562	Delineated by combining portions of the Nith Above Grand To New Hamburg, Grand Above Doon to Conestogo, Speed Above Grand to Dam, and Grand Above Brantford to Doon Subwatersheds. This area encompasses most of the Region of Waterloo's municipal wells.
Mill Creek	82	No Change from Surface Water Subwatershed
Upper Nith	496	Delineated as the original Nith Above New Hamburg Subwatershed, subtracting the small lower portion of the subwatershed
Middle Nith	259	Delineated as the lower portion of the original Nith Above New Hamburg Subwatershed joined with an upper portion of the Nith Above Grand to New Hamburg Subwatershed
Lower Nith	395	Delineated as the lower portion of the Nith Above Grand to New Hamburg Subwatershed combined with the lower portion of the Grand Above Brantford to Doon Subwatershed
Whitemans Creek	404	No Change from Surface Water Subwatershed
Grand at Brantford	181	Delineated as the western portion of the Grand Above York to

Table 18-11: Groundwater Assessment Areas		
Groundwater Assessment Area	**Area (km^2)**	**Description of Boundary Modification**
		Brantford Subwatershed
Fairchild Creek	401	No Change from Surface Water Subwatershed
Big Creek	295	Delineated as the eastern portion of the Grand Above York to Brantford Subwatershed
McKenzie Creek	368	No Change from Surface Water Subwatershed
Grand Above Dunnville To York	356	No Change from Surface Water Subwatershed

For groundwater systems, the Stress Assessment calculation was completed for the average annual demand conditions and monthly maximum demand conditions as groundwater supply is considered constant. The stress level for groundwater systems is categorized into three levels: Significant, Moderate, or Low, according to the thresholds listed in Table 18-13.

Table 18-12: Groundwater Potential Stress Thresholds		
Groundwater Potential Stress Level Assignment	**Average Annual**	**Monthly Maximum**
Significant	> 25%	> 50%
Moderate	> 10%	> 25%
Low	0 – 10%	0 – 25%

The results of the Groundwater Stress Assessment for current and future demand are shown in **Table 18-14 and Table 18-15** which contains the estimated potential for hydrologic stress. The tables also provide a list of the municipal groundwater supplies in each of the assessment areas.

Table 18-16 provides a summary of the uncertainty analysis through assigning a 'high' or 'low' uncertainty classification to each of the assessment areas.

Table 18-13: Groundwater Stress Classification (Current Demand)

Assessment Area	Potential Stress (Average Demand)	Potential Stress (Maximum Monthly Demand)	Existing Municipal Water Supply
Grand Above Legatt	Low	Low	Dundalk
Grand Above Shand To Legatt	Low	Low	Grand Valley, Waldemar Marsville
Irvine River	Low	Low	Elora, Fergus
Canagagigue Creek	Moderate	Low	West Montrose, Conestogo, Elmira
Conestogo Above Dam	Low	Low	Arthur, Drayton, Moorefield
Conestogo Below Dam	Low	Low	Integrated Urban System Villages (Wilmot, Woolwich)
Hopewell/Cox Creek	Low	Low	Maryhill
Upper Speed	Moderate	Low	City of Guelph, Guelph/Eramosa, Rockwood
Central Grand	**Significant**	**Significant**	Integrated Urban System (Cambridge, Kitchener, Waterloo)
Mill Creek	Moderate	Low	Puslinch Mini-Lakes (communal)
Upper Nith	Low	Low	Milverton, Wellesley (Integrated Urban System)
Middle Nith	Low	Low	Integrated Urban System, Plattsville
Lower Nith	Low	Low	Integrated Urban System, Drumbo, Paris
Whitemans Creek	Low	Low	Bright
Grand at Brantford	Low	Low	Airport, Mt Pleasant
Fairchild Creek	Low	Low	St. George
Big Creek	Moderate	Low	Lynden
McKenzie Creek	Low	Low	None
Grand Above Dunnville To York	Low	Low	None

Table 18-14: Groundwater Area Stress Classifications (Future Demand Estimates)

Assessment Area	Potential Stress (Average Demand)	Potential Stress (Maximum Monthly Demand)	Existing Municipal Water Supply
Grand Above Legatt	Low	Low	Dundalk
Grand Above Shand To Legatt	Low	Low	Grand Valley, Waldemar Marsville
Irvine River	Low	Low	Elora, Fergus
Canagagigue Creek	Moderate	Low	West Montrose, Conestogo, Elmira
Conestogo Above Dam	Low	Low	Arthur, Drayton, Moorefield
Conestogo Below Dam	Low	Low	RMOW Villages
Hopewell/Cox Creek	Low	Low	Maryhill
Upper Speed	Moderate	Moderate	City of Guelph, Guelph/Eramosa, Rockwood
Central Grand	**Significant**	**Significant**	RMOW
Mill Creek	Moderate	Low	Puslinch Mini-Lakes (communal)
Upper Nith	Low	Low	Milverton, Wellesley (RMOW)
Middle Nith	Low	Low	RMOW, Plattsville
Lower Nith	Low	Low	RMOW Villages, Drumbo, Paris
Whitemans Creek	Low	Low	Bright, Princeton
Grand at Brantford	Low	Low	County of Brant (Airport & Mt Pleasant)
Fairchild Creek	Low	Low	St. George
Big Creek	Low	Low	Lynden
McKenzie Creek	Low	Low	None
Grand Above Dunnville To York	Low	Low	None

Table 18-15: Low or High Uncertainty based on Sensitivity Analysis	
Assessment Area	**Low or High Uncertainty**
Grand Above Legatt	Low
Grand Above Shand to Legatt	Low
Irvine River	**High**
Canagagigue Creek	Low
Conestogo Above Dam	Low
Conestogo Below Dam	Low
Hopewell/Cox Creek	Low
Upper Speed	Low
Central Grand	Low
Mill Creek	**High**
Upper Nith	Low
Middle Nith	Low
Lower Nith	Low
Whitemans Creek	**High**
Grand at Brantford	Low
Fairchild Creek	Low
Big Creek	Low
McKenzie Creek	Low
Grand Above Dunnville To York	**High**

Groundwater Water Budget Results for Areas Ranked as Moderate or High Potential for Stress

Canagagigue Creek Assessment Area

The Canagagigue Creek Assessment is a relatively small assessment area with an estimated Percent Water Demand of 16% under average demand conditions and 18% under maximum demand conditions. These estimates result in the area being classified as having a *moderate* potential for stress under average demand conditions and a *low* potential for stress under maximum demand conditions. Estimated future demands do not change these classifications.

Most of the estimated consumptive demand for this area was related to a combination of commercial (61%) and remediation (21%) water uses. The estimated commercial demand was based on PTTWs for aquaculture and golf course irrigation and most of this estimate was supported by reported pumping rates. All of the groundwater demand relating to groundwater remediation was based on reported pumping rates from the PTTW database. There were very few estimated demands in this assessment area, therefore there was high certainty regarding the classification of Canagagigue Creek having a *moderate* potential for stress.

The municipal groundwater supplies for Elmira, West Montrose, and Conestogo Plains are located within this assessment area. These municipal demands represented only 1% of the total estimated consumptive water demand but, according to the Technical Rules, this assessment area met the requirements for a Tier 3 Water Quantity Risk Assessment.

This assessment area was subsequently included in the Region of Waterloo's Tier 3 Water Budget Study, which is presented in Chapter 20 of this report.

Upper Speed Assessment Area

The Upper Speed assessment area has an estimated Percent Water Demand of 20% under average demand conditions and 22% under maximum demand conditions. These estimates resulted in the assessment area being classified as having a *moderate* potential for stress under average demand conditions and a *low* potential for stress under maximum demand conditions. When accounting for estimated future municipal demands, the Percent Water Demand increased to 24% under average conditions and to 26% under maximum monthly conditions. These Percent Water Demands produced a classification of *moderate* potential for stress under average demand conditions and a *moderate* potential for stress under maximum demand conditions.

The largest water use sector in the assessment area was municipal water supply which represented 71% of the average annual consumptive water demand. Quarry dewatering was responsible for 17% of the estimated demand. Other water uses include commercial use (i.e. golf course irrigation, aquaculture, and bottled water), industrial use (i.e. brewing and soft drinks, cooling water), institutional use, miscellaneous use (i.e. heat pumps), remediation use, and agriculture. Out of the total groundwater demand in the assessment area, 90% of the estimated demand was calculated using reported pumping rates which increases the confidence of the values.

The City of Guelph was identified as the largest groundwater user in the Upper Speed Assessment Area. The City maintains an aquifer monitoring program to ensure that the City's groundwater supplies are sustainable and do not cause adverse impacts to other users. In addition, monitoring is required as part of the Permits to Take Water issued by the MECP for the groundwater supply system.

The City's ongoing groundwater monitoring results showed that the City continuously meets the requirements of its Permits to Take Water and that it is managing the groundwater resource in a responsible manner. Groundwater levels in the city did not show any significant downwards trends, indicating that current pumping rates can be maintained in the future.

The stress assessment results for the Upper Speed Assessment Area should not be interpreted as an indication of the sustainability of drinking water supplies. Rather, the stress assessment identified a need for further work under the requirements of the Clean Water Act, and the need for this work is consistent with the value of the groundwater resource in the area.

The Upper Speed assessment area met the requirements for a Tier 3 Water Quantity Risk Assessment. The municipal systems affected by the Tier 3 study include:

City of Guelph

Township of Guelph/Eramosa (Rockwood; and Hamilton Drive)

The results of the Tier 3 Water Budget and Risk Assessment Report for the areas listed above are presented in Chapter 19 of this report.

Central Grand Assessment Area

The estimated Percent Water Demand for the Central Grand assessment area was 43% under average demand conditions and 51% under maximum conditions. Based on these estimates, the Central Grand assessment area was classified as having a *significant* potential for stress under average demand conditions, and a *significant* potential for stress under maximum demand conditions. After accounting for future water demands, the Percent Water Demand for this assessment area was 56% under average demand estimates and 64% under maximum conditions. These estimates classified the area as having a *significant* potential for stress under both average and maximum future demand conditions.

The Central Grand Assessment Area contains the urban areas of Kitchener, Waterloo and Cambridge and includes a wide variety of water users, including municipal supply, commercial use, groundwater remediation and other industrial purposes. Municipal demands represented 71% the total demand. Approximately 76% of the total consumptive demand was calculated from reported pumping rates, which indicated a relatively high level of confidence in estimated demand.

The Regional Municipality of Waterloo is the largest groundwater user in the Central Grand Assessment Area. Approximately 75% of the Region's water supply is provided by groundwater, the remaining 25% by surface water. In 1994, the Region began implementing a comprehensive Water Resources Protection Strategy (WRPS) to ensure that the Region's groundwater supplies are sustainable and do not cause adverse impacts to other users. Groundwater level monitoring is an integral component of the WRPS. In addition, monitoring is required as part of the Permits to Take Water issued by the MECP for the groundwater supply system.

The Region's ongoing groundwater monitoring results show that the Region continuously meets the requirements of its Permits to Take Water and that it is managing the groundwater resource in a responsible manner. Groundwater levels in the aquifers do not show any significant downwards trends, indicating that current pumping rates can be maintained in the future.

The stress assessment results for the Central Grand Assessment Area should not be interpreted as an indication of the sustainability of drinking water supplies. Rather, the stress assessment identified a need for further work under the requirements of the Clean Water Act, and the need for this work was consistent with the value of the groundwater resource in the area.

Municipal groundwater supplies within this assessment area meet the requirements for completing a Tier 3 Water Quantity Risk Assessment, as follows:

Regional Municipality of Waterloo *Integrated* Urban System Supply Wells

The results for the Tier 3 Water Budget and Risk Assessment Report for the Region of Waterloo are presented in Chapter 20 of this report.

Mill Creek Assessment Area

The Mill Creek Assessment Area is located between the Galt and Paris Moraines, east of the City of Cambridge and South of the City of Guelph. The estimated Percent Water Demand for this assessment area was 12% and 16% under average and maximum demand conditions, respectively. These Percent Water Demands resulted in the classification of a *moderate* potential for stress under average demand conditions and a *low* potential for stress under maximum demand conditions. Major water use sectors in the Mill Creek area are the commercial (i.e. bottled water and golf course irrigation) and industrial (i.e. aggregate washing and manufacturing) sectors. Other groundwater demands include some agricultural uses, some miscellaneous uses (i.e. heat pumps), communal water supply, and unpermitted agricultural demand. Industrial uses accounted for 42% of the total groundwater demand. The commercial water use formed 37% of total demand in the Mill Creek area. A further 19% was associated with communal water supply uses.

Approximately 47% of the total demand was from reported water taking rates. While there were reported pumping rates for a number of the aggregate operations, a large portion of the estimated consumptive demand was a reflection of the consumptive factor applied to those pumping rates. Due to the uncertainty associated with aggregate washing consumptive use factors, there was a relatively high uncertainty in the estimated consumptive demand for these uses. As a result the Percent Water Demand for the assessment area may be over-estimated.

As no municipal groundwater supplies were located within this assessment area, a Tier 3 study was not required to be completed.

Irvine River Assessment Area

The Irvine River assessment area contains the municipal groundwater supplies for Elora and Fergus in the Municipality of Centre Wellington. The assessment area was classified as having a *low* potential for stress, with a Percent Water Demand of 5% under average conditions and 6% under maximum demand conditions. Estimated future municipal demands increased the Percent Water Demand to 9% which would still classified the area as having a *low* potential for stress.

However, the future average annual percent water demand was very close to the 10% threshold. Percent water demand calculations were slightly sensitive to future water use, but were more sensitive to changes in recharge estimates giving the Irvine River Assessment Area a *high* level of uncertainty and a *moderate* potential for stress using future demand estimates. A reduction in recharge or a large increase is future water use would bring values above the threshold triggering a need for a Tier 3 Risk Assessment.

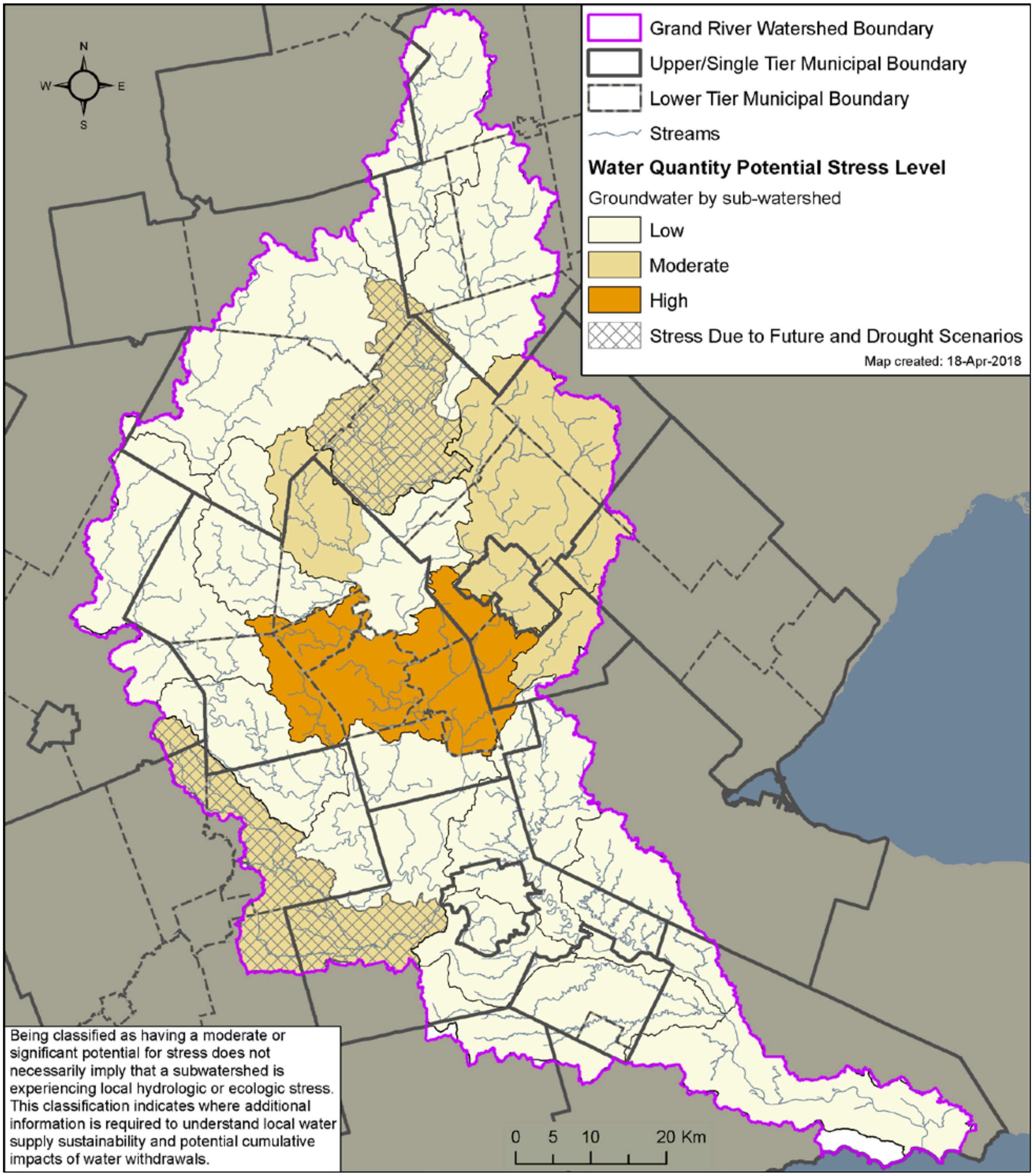
At the time of this Assessment Report, a Tier 3 Water Budget Study and Risk Assessment has been initiated to evaluate the Centre Wellington municipal groundwater supplies.

Whitemans Creek Assessment Area

The Whitemans Creek assessment area contains the municipal water supply system for the village of Bright. The assessment area was classified as having a *low* potential for stress under existing conditions, both for annual average pumping conditions (4%) and monthly maximum demand (15%). The impact of drought conditions on the Bright supply was considered using transient output from the regional groundwater flow model. This analysis indicated that there may not be a sufficient depth of water within the #4 Bright well to accommodate simulated water level fluctuations caused by drought. Following consultation with County of Oxford hydrogeological support staff, and as per the Technical Rules, the Whitemans Creek assessment area was assigned a classification of having a *moderate* potential for stress under Drought Conditions.

Based on this classification, the Bright system met the requirement for a Tier 3 Water Quantity Risk Assessment. The Tier 3 Water Quantity Risk Assessment for the Whitemans Creek Assessment Area began in 2014. The results of the study are presented in Chapter 21 of this report.

Map 18-4: Water Quantity Stress Levels by Groundwater Assessment Area within the Grand River Watershed



Uncertainty/Limitations

All water budget calculations contain inherent uncertainty due to incomplete data, data inaccuracies, and imperfect estimation and simulation tools. It is important to consider the regional-scale nature of the analysis and interpretation presented. The methods used and the amount of data available were suitable for regional water budgeting purposes.

Any model developed to represent a natural system is inherently a simplification of that natural system. The complexities of the physical system can never be known well enough to incorporate all details into a numerical context. In reality, most of the scientific approach involves representing physical conditions observed using approximations of larger-scale functionality; hydraulic conductivity is an example of this. This approximation does not negate the ability of scientists and practitioners to utilize numerical models as tools to help understand and manage natural systems; however, there is a need to recognize the limitations of such tools when interpreting model results.

Every effort was made to minimize uncertainty in the Water Quantity Risk Assessment: data was cross checked with additional sources, models were calibrated to the highest quality of monitoring data available, and an external peer review team was consulted.