Ausable Bayfield Maitland Valley Region
Tier I Numeric Water Budget

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Table of Contents

Appendices

List of Tables

List of Maps

1.0 INTRODUCTION

The following report is an extension of the existing Draft Conceptual Water Budget report completed for the Ausable-Bayfield-Maitland Source Protection Planning Partnership. This report has been completed in compliance with the Draft Water Budget and Water Quantity Risk Assessment Module 7, issued by the Ministry of Environment dated March 30, 2007.

A Tier I water budgeting exercise is intended to estimate the hydrologic stress of subwatersheds for the purpose of screening out areas from further, more detailed assessment. This is to be done using the best available data for the major hydrologic components and processes of these subwatersheds ("watershed elements"). These data are then compared to the amount of consumptive water demand within a given subwatershed to determine the degree of stress in the hydrologic system due to human water usage.

The following report outlines the major sources of data for characterizing the "watershed elements" within the Ausable-Bayfield-Maitland Source Protection Planning Partnership region, as well as estimating the degree of stress for the designated subwatersheds in the area.

Stress can be calculated independently for both groundwater and surface water systems. Although within each system (i.e. groundwater and surface water) efforts were made to account for the interaction between the systems, the two were not correlated with each other for the purposes of the Tier I water quantity stress assessment.

1.1 Subwatersheds for Tier I water Quantity Stress Assessments

Subwatersheds for analysis were originally defined as part of the conceptual water budget report for the Ausable-Bayfield-Maitland Source Protection Planning Partnership. Subwatersheds can be delineated at many different scales according to the purpose of the investigation, and were originally defined as the basins for which stream gauge data were available.

For the Tier I Water Budget, new subwatersheds were identified for the purposes of performing subwatershed stress assessments. These subwatersheds were delineated according to a hierarchy of factors, developed with the assistance of the Peer Review Committee, including:

The total water contributing area to the municipal water supply or supplies

All municipal supplies in the ABMV planning area are either groundwater based or situated on Lake Huron, a major international waterway. According to guidance, Tier I water budgets are not required on Great Lake water supplies. As a result, the focus of this effort was on groundwater supplies.

Groundwater supplies are predominantly situated within the bedrock aquifer, a regional scale, and largely confined aquifer system. The total water contributing area was determined manually using the piezometric surface for the bedrock aquifer. Attempts to delineate the total water contributing area using GIS methods were not fruitful, due to the coarse resolution of the piezometric surface data. The Hensall supply is located in a partially confined, overburden aquifer; accordingly, the water table surface was used in order to estimate the total water contributing area.

The limits of existing subwatersheds used for modeling purposes

Once the total water contributing areas were defined for the groundwater supplies, the extents of the subwatersheds were expanded in order to accommodate the pre-existing subwatersheds used for surface water modeling, identified by numbers on Map 1. This was done in order to facilitate interaction between the existing surface water models and the groundwater model. The scale of the available groundwater model limited the size of the watersheds, as it is a regional scale model. Extracting detailed subwatersheds from a regional-scale groundwater model results in oversimplification of the conceptual hydrogeology and outputs from the model.

Areas of concentrated water use

Areas of concentrated water use were extracted from larger subwatersheds in order to properly assess the potential subwatershed stress due to the extraction. As water use is generally considered to be low throughout the area, the impact of concentrated water use on the selection of Tier I subwatersheds was not significant.

Physiographic and Hydrological characteristics

Areas with similar physiographic and hydrologic characteristics, often separated by a distinct hydrologic boundary (Major river, lake, etc) were grouped where appropriate.

Based on the developed criteria, twelve (12) different watersheds were delineated for the purposes of the Tier I surface water quantity stress assessment, namely: the Ausable River (Including Mud Creek); Parkhill Creek; the Bayfield River; the Lakeshore Gullies within the ABCA Jurisdiction, south of the Bayfield River (ABCA Gullies), the North Maitland River; the Little Maitland River, the Middle Maitland River, the South Maitland River, the Lower Maitland River, the Lakeshore Gullies between the mouths of the Maitland and Bayfield Rivers (Goderich-Bayfield Gullies), the Nine Mile River and the remaining Lakeshore Gullies in the MVCA jurisdiction (MVCA Gullies). These units are shown on Map 1. A detailed rationale for the delineation of Tier I subwatersheds can be found in Appendix A to this report.

Quantitative estimates of the flow of water between the watershed elements for these subwatersheds were derived from existing surface and groundwater models.

1.2 Surface Water Modeling

Surface water modeling was carried out for the entire study area using the Surface Water Assessment Tool (SWAT). This tool was used to simulate long-term evapotranspiration, streamflow, and deep drainage for all the major river systems located within the Planning Region including the Nine Mile River, the Maitland River, the Bayfield River, the Parkhill River, the Ausable River as well as the extensive set of lakeshore gullies and streams situated along the Planning Region's Lake Huron shoreline. A report outlining the steps required to complete the modeling was developed by McKague and Mao (2007).

The simulated quantification of these watershed elements is essential in determining the Tier 1 subwatershed stress assessments for the region. Detailed output from the Surface water modeling efforts are included in Appendix B to this document.

1.3 Groundwater Modeling

A fully calibrated 3D groundwater flow model was developed for the region using FeFlow groundwater modeling software. An existing model was completed at a coarse, regional scale for the combined jurisdictions of the Maitland, Ausable-Bayfield, St. Clair, Upper Thames, Lower Thames and Essex Region Conservation Authorities, and as such, is collectively known as the 6 CA groundwater model. Details on this project, including information on development and calibration of the conceptual and groundwater flow models is available in the 6CA groundwater Modeling Report (WHI, 2007)

The Groundwater flow within the model was calibrated against static water levels from MOE Water Well records, Provincial Groundwater Monitoring Network wells throughout the region and to 4th order or greater streams. Water Well Records were screened out based on confidence in locations, and elevations from these Water Well Records were adjusted using the DEM for the area.

For the purposes of this project, each of the twelve (12) Tier I subwatersheds were separated and refined from the 6 CA scale model. In order to extract models, the regional scale model was overlain with a layer outlining the Tier I subwatersheds. As the individual elements within the model were of a coarse scale, some elements traversed subwatershed boundaries. In order to address this problem, the finite element mesh near subwatershed boundaries was refined, to 100m, 50m and finally 25m sizes at subwatershed boundaries prior to extraction using FeFlow. Boundary conditions for each Tier I subwatershed groundwater model were extracted along with the models from the fully calibrated regional-scale model.

Tier I subwatershed models were simulated for the period 1985-2005. Groundwater fluxes were developed using the continuous boundary flux methodology within the FeFlow water budgeting module. Detailed outputs from the groundwater modeling efforts are included in Appendix C to this document.

2.0 WATER BUDGET ELEMENTS

The degree of water budget analysis required in this Tier 1 assessment will be relatively simple, utilizing estimates of several elements of the hydraulic cycle, mainly, precipitation, evapo-transpiration, recharge, streamflow, and baseflow. Each of these estimates can be distributed within the watershed according to land use, surficial geology, and slope.

While the sources of data available in each subwatershed may vary, in general, an estimation of the water supply using the above variables could be carried out in the following order. First, a climate evaluation could be conducted to obtain precipitation information. Next, based on the climate data, evapotranspiration and recharge can be estimated. Finally, an analysis of baseflow and streamflow can occur.

2.1 Precipitation

Precipitation may be defined as the discharge of water out of the atmosphere on to a watershed and includes rainfall, snow, hail, and sleet. For the study area precipitation data is measured at gauge stations and has been processed for use as part of the Tier I Water Budget (see Conceptual Water Budget for more information). Precipitation data for the selected subwatersheds are summarized below in Table 1 and spatially on Map 2.

These data were corrected for spatial and temporal gaps using methodology established in Schroeter et al. (2000). This methodology is particularly useful in fractionating the available data into snow and rainfall amounts, an often-difficult task due to the lack of collected snowfall data for the area. Precipitation data, in concert with Land-Use, Soils and Geological Data are key inputs into the surface water models that have been developed.

Seasonal and annual variation of precipitation is considered normal for southern Ontario. The primary driver of the spatial distribution of precipitation for the study area is Lake Huron, with areas immediately to the lee of the Lake having higher precipitation. This effect, however, is not accurately represented once the available data has been distributed to the selected Tier I subwatersheds

Table 1. Average Monthly and Annual Precipitation Data expressed in equivalent mm of precipitation for the Tier 1 subwatersheds

Tier 1 Subwat	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
ABCA-Gully	67.9	55.1	54.7	78.3	86.7	75.7	89.1	73.4	113.3	93.2	104.3	79.4	971
Ausable	68.6	54.2	59.2	78.3	83.6	79.1	87.6	76.4	110.4	91.4	96.8	77.1	962
Bayfield	81.8	56.7	58.9	75.4	87.3	78.4	88.0	71.7	119.5	94.9	104.5	74.2	991
South Maitland	89.8	68.8	71.7	85.0	99.7	85.2	81.6	91.3	120.2	102.5	121.1	102.0	1119
Lower Maitland	93.5	76.0	77.8	86.7	105.3	89.4	80.8	95.9	119.8	101.4	123.7	114.0	1164
Middle Maitland	69.1	56.4	57.2	78.0	94.4	84.1	90.1	97.9	111.5	94.3	115.9	82.5	1031
Little Maitland	64.0	53.2	55.0	74.0	93.6	83.8	90.0	96.6	107.1	90.1	111.5	76.6	996
Parkhill	63.6	55.0	58.2	78.2	80.8	77.2	88.4	81.1	104.2	92.5	96.4	59.8	935
God-Bay-Gullies	81.8	66.3	74.7	79.9	91.9	81.7	77.0	81.4	114.6	97.8	112.3	98.5	1058
MVCA-gullies	100.9	77.1	75.2	82.8	102.7	92.7	80.0	91.2	119.7	106.6	124.0	115.6	1168
Nine Mile	98.2	76.1	75.7	82.0	101.3	91.6	78.9	90.3	118.5	105.5	122.5	114.6	1155
North Maitland	63.3	53.9	58.7	65.7	94.9	85.5	85.7	86.8	99.1	86.0	105.3	71.8	957

2.2 Evapotranspiration

Evapotranspiration refers to the combined processes of evaporation from water surfaces and transpiration from vegetation of water from the earth's surface into the atmosphere. Evapotranspiration information for the subwatersheds was estimated using the calibrated SWAT models for the area following methodology of Penman and Montieth (see McKague and Mao, 2007 for more information). Results for Tier I subwatersheds are summarized below in Table 2 and are graphically represented on Map 3.

Table 2. Average Estimated Monthly and Annual Evapotranspiration derived from SWAT Analysis for the period 1985-2005 expressed in equivalent mm of precipitation.

Tier 1 Subwat	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
ABCA-Gully	0.3	2.0	16.6	38.0	47.8	57.5	67.3	51.1	31.8	14.6	3.0	0.1	330
Ausable	19.7	4.8	12.1	45.3	51.8	66.9	65.7	67.1	42.8	39.2	13.3	1.8	430
Bayfield	22.2	10.4	8.8	43.4	50.9	65.0	62.6	61.6	40.7	39.9	12.1	2.7	421
South Maitland	10.4	8.0	19.9	50.4	57.0	70.5	72.2	68.5	46.6	40.8	14.9	8.5	468
Lower Maitland	8.4	7.7	26.4	50.2	54.8	69.0	72.6	68.9	48.0	41.2	16.4	12.0	476
Middle Maitland	6.1	5.5	18.5	51.1	57.1	68.6	71.6	66.3	44.0	33.1	9.9	5.6	437
Little Maitland	5.6	5.3	21.0	52.3	56.8	69.0	72.4	66.8	44.8	33.4	10.2	5.7	443
Parkhill	22.0	1.7	13.4	44.2	49.6	67.1	66.0	63.4	40.4	40.1	15.7	2.1	426
God-Bay-Gullies	0.4	1.9	18.2	41.5	50.8	72.0	74.7	63.9	43.8	17.2	2.9	0.1	387
MVCA-gullies	0.2	1.2	15.6	37.2	43.8	64.6	68.1	61.0	42.8	16.7	2.7	0.0	354
Nine Mile	2.5	4.5	23.1	42.9	49.4	60.9	64.3	65.6	43.6	36.9	14.9	9.9	419
North Maitland	8.4	7.9	26.0	53.1	56.0	71.9	73.6	67.7	46.3	37.5	12.7	7.6	469

It is important to note that these are estimated values, based on the SWAT model's AET approach, calibrated to all available long-term streamflow monitoring stations in the study area. It is not possible to directly calibrate AET estimates as there is a lack of any long term evaporation data in the study area. This leads to a very high level of uncertainty for this element. However, the presented ET data is representative of the relative differences between subwatersheds. Additionally, ET values developed herein are considered conservative, and lie within generally accepted ranges of values developed for the study area and southern Ontario (see discussion in McKague and Mao, 2007).

2.3 Recharge

Groundwater recharge refers to the replenishment of an aquifer with water from the land surface. Groundwater recharge can be estimated through a number of techniques. The 6CA Groundwater model used a simplistic methodology of approximating recharge based on precipitation, land-use and the surficial geology of the study area. Recharging water is then input into the model during simulation. Recharge rates are then adjusted as part of the calibration and verification of the model. Recharge estimates used in the 6CA model were developed at annual intervals only and are shown below in the right-most column of Table 3 in order to facilitate comparison with SWAT results. The spatial variance of recharge throughout the region is described in Maps 6 and 7 and show values derived from SWAT and FeFlow, respectively.

Table 3. Average Monthly (SWAT derived) and Annual (both SWAT and FeFlow Derived) Recharge values for the study area expressed in equivalent mm of precipitation.

Tier 1 Subwat	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual	FeFlow
ABCA-Gully	4	3	44	45	21	10	6	6	26	50	63	18	295	121
Ausable	2	2	31	45	19	9	6	5	18	28	40	13	218	132
Bayfield	1	1	22	46	23	10	7	4	23	33	44	8	221	133
South Maitland	1	1	18	54	27	10	6	8	26	39	45	8	243	127
Lower Maitland	3	4	35	69	39	18	11	15	39	46	52	11	342	152
Middle Maitland	0	1	12	53	30	15	11	12	31	41	39	3	249	143
Little Maitland	1	2	14	55	35	17	13	14	33	42	40	3	268	134
Parkhill	1	1	32	39	17	8	6	7	17	28	38	12	206	144
G-B-Gullies	4	4	49	58	26	9	4	5	23	47	62	17	307	141
MVCA-gullies	2	3	45	64	30	14	5	7	25	55	60	14	324	105
Nine Mile	3	6	45	78	41	26	13	17	43	52	55	12	393	149
North Maitland	1	3	18	46	31	14	10	9	23	36	43	4	237	144

Recharge can also be estimated from the SWAT modeling completed for the study area. SWAT fractionates a portion of precipitation to be designated as recharge (Percolation). This value is partially based on the texture of the deepest soil layer input into the model, which is coeval with the surficial geology, but is mostly identified from being the last unknown variable in the surface water balance equation employed by SWAT. SWAT provides a useful tool in that it can be used to simulate daily, monthly and seasonal variations in deep infiltration. The monthly results are incorporated into Table 3, above.

Analyzing streamflow data and separating baseflow graphically can also estimate recharge. However, this approach would be entirely reliant on the location of existing stream gauges, and would not provide meaningful data for the application of the Tier I water budget. This methodology also assumes no change in storage in the aquifer system, and as a result, was not incorporated into this document. Section 2.5 discusses baseflow for the study area in greater detail.

Differences in annual recharge values derived from SWAT and FeFlow (shown in Table 3) highlight the differences between the two modeling packages. At this point, there is no methodology available for rectifying these differences or for validating either data set. For the purposes of the Tier I water quantity stress assessment, the lowest, most conservative value (derived from FeFlow) will be utilized.

2.4 Surface Runoff

Surface Runoff refers to the amount of water that flows over land before leaving a watershed through natural (streams, rivers, etc.) or constructed channels. Surface Runoff for the study area has been simulated using SWAT on daily intervals (McKague and Mao, 2007). Monthly Surface Runoff data for the selected subwatersheds is shown below in Table 4. The spatial variation of streamflow throughout the region is illustrated graphically in Map 4.

Table 4. Average (mean) monthly and annual surface runoff data for the study area expressed in equivalent mm of precipitation as estimated from long-term simulations (1985-2005) using SWAT.

Tier 1 Subwat	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
ABCA-Gully	29.2	42.9	49.5	17.6	17.8	17.8	23.2	13.9	33.5	17.3	23.8	24.8	311
Ausable	27.0	37.5	58.0	18.4	14.8	16.9	18.4	12.2	26.8	15.1	21.8	25.6	292
Bayfield	26.5	39.3	78.1	21.6	15.4	16.7	20.3	12.4	30.9	16.8	23.9	24.0	326
South Maitland	22.6	37.9	107.1	42.5	15.9	14.4	10.7	13.2	23.4	12.7	21.3	23.0	345
Lower Maitland	23.4	43.8	103.7	39.7	13.6	11.0	5.7	9.6	16.5	7.2	16.0	21.2	311
Middle Maitland	14.1	25.6	105.0	40.7	12.1	10.1	10.1	14.7	17.6	11.1	27.8	16.3	305
Little Maitland	12.2	25.0	88.4	34.3	9.5	7.5	7.3	11.1	12.1	7.5	23.4	13.8	252
Parkhill	25.5	40.4	46.3	18.0	15.4	17.4	19.9	15.1	25.8	16.1	24.1	21.9	286
God-Bay-Gullies	35.6	53.1	67.0	21.6	16.2	15.9	11.1	13.8	24.0	13.8	22.7	29.4	324
MVCA-gullies	36.7	66.4	99.9	28.1	24.3	23.5	13.3	21.5	30.0	19.2	30.8	38.0	432
Nine Mile	18.6	42.4	111.5	32.2	12.5	11.9	5.7	10.2	15.5	7.7	16.0	20.0	304
North Maitland	13.5	30.2	55.7	23.6	10.3	9.6	7.8	7.7	9.3	5.5	14.7	13.1	201

In addition to surface runoff, daily streamflow data has been statistically analyzed in order to develop median (50th percentile) and decile (10th percentile) flows for the selected subwatersheds. These analyses are critical in determining the surface water supplies and reserves for the subwatersheds shown in sections 4.1 and 4.2 of this report.

2.5 Baseflow

Baseflow, or groundwater discharge, refers to water that flows into surface water bodies (i.e. streams, wetlands, lakes) from groundwater. Baseflow information is available from three sources for the study area. Baseflow separation was undertaken for stream gauges, where appropriate, and this information was then used to assist with the calibration of SWAT models. SWAT can then estimate the portion of streamflow that is derived from groundwater discharge. Table 5, below, shows baseflow data for the study area derived from SWAT. The spatial variation of baseflow throughout the region is illustrated graphically in Map 5.

Table 5. Average Monthly and Annual Baseflow (groundwater discharge) expressed in equivalent mm of precipitation developed from SWAT Analyses.

Tier 1 Subwat	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
ABCA-Gully	21.0	9.7	12.9	34.2	29.4	16.2	8.3	4.3	6.8	20.9	38.5	38.8	241
Ausable	12.6	7.4	8.7	16.7	13.2	6.9	4.5	3.1	3.6	7.1	13.4	18.2	115
Bayfield	10.7	5.1	6.4	14.6	11.5	5.7	3.3	2.1	3.2	6.9	14.6	19.5	104
South Maitland	13.2	7.6	7.4	18.2	17.9	9.3	4.5	3.0	4.5	10.3	18.8	19.7	134
Lower Maitland	14.7	7.5	11.1	29.2	28.7	16.4	9.5	7.1	10.2	21.4	31.1	26.6	214
Middle Maitland	5.0	1.8	3.3	19.2	21.7	10.1	5.9	5.3	8.0	17.1	24.9	15.4	138
Little Maitland	11.6	6.5	6.1	13.4	16.6	10.9	8.0	6.9	9.0	16.3	23.0	19.6	148
Parkhill	8.7	4.9	7.2	15.3	10.6	4.0	2.4	1.8	2.4	5.3	11.5	16.5	91
God-Bay-Gullies	17.6	7.9	15.8	42.8	34.1	15.5	5.2	2.0	4.5	17.6	36.9	35.6	235
MVCA-gullies	16.1	6.4	13.2	45.8	37.0	19.7	7.6	3.5	5.4	22.1	42.5	35.1	254
Nine Mile	22.5	13.4	16.6	35.8	33.1	22.2	15.6	11.6	13.8	25.8	37.3	34.0	282
North Maitland	13.6	8.6	8.7	15.9	19.1	13.8	8.9	6.7	7.2	13.5	20.8	20.2	157

Additionally, baseflow is a key output from the 6CA groundwater model. It should be noted that annual baseflow data derived from the separation of actual streamflow data was used to calibrate the groundwater model, and that an acceptable level of calibration for a groundwater model is ± 50% of actual flows. As a result, baseflow data derived from SWAT analysis is considered more representative of actual conditions.

3.0 CONSUMPTIVE WATER USAGE ESTIMATES

Consumptive water usage is defined as water taken from groundwater or surface water, as a result of an anthropogenic activity, (e.g. municipal drinking water takings, private water well takings, as well as other permitted takers) which is not returned locally in a reasonable time period. An understanding of the consumptive demand is vital to the creation of a reliable water budget.

Consumptive use estimates are based on the Consumptive Factors defined within the Guidance Document (MOE, 2007). These factors take into consideration not only the amount of water extracted from the system for a class of water taking, but also the amount of water that is returned. These factors are expressed as a ratio, ranging from 0 to 1.0, depending on the type of taking, with a factor of 0 meaning that the takings is completely non-consumptive, and a factor of 1.0 meaning the taking is 100% consumptive.

3.1 Permit to Take Water Database Update

The majority of consumptive demand can typically be estimated using the Permit to Take Water (PTTW) database. This database is used to regulate water users who take greater than 50,000 L/day from either a groundwater or surface water source. Since the quantities listed within the PTTW database are reported as maximum allowable takings over a permitted period of time, using these values in the creation of a water budget will generally lead to an overestimation of the actual takings. As such, using permitted water taking to estimate consumptive demand and calculate the degree of stress will often mean an overestimation of the actual stress conditions.

In order to rectify this issue, and develop a better understanding of the actual takings through the study area, a project was undertaken to update the PTTW database. A desktop exercise was completed using the average daily takings identified by the applicants in the database and the permitted period of takings to estimate average takings on a monthly and annual basis. This desktop exercise, however, would still be considered a high estimate for water takings as few takers (particularly surface water takers) are pumping every day throughout the designate pumping interval.

Further work was done to update the database for actual water takings. Recording actual water takings is a requirement of any large water takers. These records were solicited from the permit holders through telephone and site visits (see Luinstra, 2006).

In order to evaluate the permitted takings, the best available data were used. If actual takings were available they were given first priority, estimated average takings given second priority, and finally maximum permitted rates were used if the other two potential sources of data were not available. This was done to ensure the most accurate takings data available were used for the consumptive use estimates and Tier I Water Budget.

3.2 Consumptive Surface Water Usage Estimate

3.2.1 Permitted Surface Water Usage

Permitted users are the only reliable source for surface water takings for the area. Surface water takings are generally confined to irrigation activities, with the exception of the two Lake Huron – based municipal water supply systems, which are necessarily excluded from the Tier 1 water budgeting exercise.

A study was completed in 2006 in order to attempt to determine actual takings for PTTW holders in the area (Luinstra, 2006). The results of this work have been included in the calculations of consumptive surface water use for the study area. The best available water taking data (actual, estimated average, maximum permitted) were used to estimate permitted amounts, which were subsequently adjusted using the consumptive factor outlined in the MOE guidance document (2007).

Table 6 and 7, below, show maximum monthly and annual surface water takings, respectively. The spatial variation of annual consumptive water use throughout the region is illustrated graphically in Map 10. These takings have been adjusted by the consumptive factor for the selected subwatersheds. A detailed listing of surface water takings are included as Appendix E to this Report.

Table 6. Maximum estimated monthly consumptive surface water usage, expressed in equivalent mm/month of precipitation.

	PTTW(L/mth)	**PTTW(m3)**	**Area (m2)**	**mm**
ABCA Gullies	0.00	0.00	196,540,842.91	**0.000**
Ausable and Mud Creek	1,456,831,856.00	1,456,831.86	1,251,937,273.20	**1.164**
Bayfield	0.00	0.00	501,829,521.06	**0.000**
Goderich and Bayfield Gullies	0.00	0.00	109,349,871.17	**0.000**
Little Maitland	0.00	0.00	370,949,346.29	**0.000**
Lower Maitland	3,974,485.20	3,974.49	533,717,780.27	**0.007**
Middle Maitland	0.00	0.00	646,444,198.04	**0.000**
MVCA Gullies	0.00	0.00	377,712,529.17	**0.000**
North Maitland	0.00	0.00	575,960,639.26	**0.000**
Parkhill	789,825,886.40	789,825.89	465,783,570.43	**1.696**
South Maitland	0.00	0.00	447,646,311.62	**0.000**
Upper Nine Mile	914,400.80	914.40	245,713,661.47	**0.004**
Totals	**2,251,546,628.40**	**2,251,546.63**	**5,723,585,544.90**	**2.87**

Table 7. Estimated annual consumptive surface water usage, expressed in equivalent mm/year of precipitation.

	PTTW(L/yr)	PTTW(m3)	Area (m2)	mm
ABCA Gullies	0.00	0.00	196,540,842.91	**0.000**
Ausable and Mud Creek	2,352,374,282.20	2,352,374.28	1,251,937,273.20	**1.879**
Bayfield	0.00	0.00	501,829,521.06	**0.000**
Goderich and Bayfield Gullies	0.00	0.00	109,349,871.17	**0.000**
Little Maitland	0.00	0.00	370,949,346.29	**0.000**
Lower Maitland	24,140,340.00	24,140.34	533,717,780.27	**0.045**
Middle Maitland	0.00	0.00	646,444,198.04	**0.000**
MVCA Gullies	0.00	0.00	377,712,529.17	**0.000**
North Maitland	0.00	0.00	575,960,639.26	**0.000**
Parkhill	517,296,528.00	517,296.53	465,783,570.43	**1.111**
South Maitland	0.00	0.00	447,646,311.62	**0.000**
Upper Nine Mile	4,542,494.40	4,542.49	245,713,661.47	**0.018**
Totals	**2,898,353,644.60**	**2,898,353.64**	**5,723,585,544.90**	**3.05**

The consumptive usage estimate included in Tables 6 and 7 are still considered a conservative, over-estimate of actual takings. It is important to note that the watersheds, which drain directly into Lake Huron (“the Gullies”), have no documented surface water takings. In certain cases, the monthly maximum takings may exceed the average annual takings (i.e. Parkhill Creek) due to short intervals of increased usage during summer months.

3.3 Consumptive Groundwater Usage Estimate

3.3.1 Permitted Usage

Permitted groundwater usage is primarily documented through the PTTW database, as well as through municipal drinking water supply records. Similar to the permitted surface water takings, the best available water taking data (actual, estimated average, maximum permitted) was used to estimate permitted amounts, which were subsequently adjusted using the consumptive factor outlined in the MOE guidance document (2007). Tables 8 and 9, below shows the monthly and annual groundwater takings, adjusted by the consumptive factor for the selected subwatersheds.

3.3.2 Non-Permitted Agricultural Usage

Agricultural usage, particularly those not related to crop irrigation are exempt from requiring a Permit to Take Water. As a result, no documentation of this usage is available for analysis. Estimates of agricultural usage were developed based on agricultural data and projected watering requirements from the 2001 census data as part of De Loe (2001). This information is broken into watersheds for all of southern Ontario and was incorporated into the consumptive usage estimates. Estimated takings were then adjusted according to consumptive use factors provided by the MOE guidance document (MOE, 2007). These adjusted consumptive takings are shown below in Table 8 and 9.

3.3.3 Private-Domestic Usage

Private domestic usage is not considered within the MOE guidance document (MOE, 2007). It was felt, due to the high reliance on groundwater for private potable water sources, that this taking should be incorporated into this Tier 1 water budgeting exercise.

Private well records for each subwatershed, available in the Ministry of Environments Well Record Information System (WWIS) were assigned a minimum taking value of 450 L/day, based on usage requirements set out in Ministry best practice documents for the sizing and evaluation of septic systems. These values were then adjusted according to consumptive use factors for domestic water takings provided by the MOE guidance document (MOE, 2007). These adjusted consumptive takings are shown below in Table 8 and 9 and Appendix F to this document.

This methodology for estimating private domestic usage has a number of caveats. Firstly, the WWIS is not considered to be complete and has a number of errors, including the omission of many wells as well as improper locations of wells. Secondly, a number of the wells may have been drilled or are in use for both domestic and agricultural purposes and therefore, usage from these wells may already be accounted for in the agricultural water usage statistics. As such, the estimates for domestic consumption may vary from the actual consumption significantly.

Table 8. Maximum estimated monthly consumptive groundwater usage, expressed in equivalent mm of precipitation.

	PTTW(m3)	Wells(m3)	AG (m3)	Total	Area (m2)	mm
ABCA Gullies	0	1,403	31,115	32,519	196,540,843	**0.17**
Ausable	618,286	8,669	382,474	1,009,428	1,251,937,273	**0.81**
Bayfield	542,128	2,787	81,257	626,172	501,829,521	**1.25**
God-Bay Gullies	286,770	923	24,925	312,619	109,349,871	**2.86**
Little Maitland	32,857	1,406	66,095	100,358	370,949,346	**0.27**
Lower Maitland	283,122	2,628	80,943	366,694	533,717,780	**0.69**
Middle Maitland	0	3,362	115,204	118,566	646,444,198	**0.18**
MVCA Gullies	10,147	1,652	42,910	76,446	377,712,529	**0.20**
North Maitland	0	3,242	85,037	88,279	575,960,639	**0.15**
Parkhill	49,997	1,130	93,952	145,079	465,783,570	**0.31**
South Maitland	23,150	2,137	86,865	112,152	447,646,312	**0.25**
Upper Nine Mile	0	1,088	27,156	28,245	245,713,661	**0.11**
Totals	**1,846,457.00**	**30,427.74**	**1,117,934**	**3,016,556.22**	**5,723,585,545**	**0.53**

Table 9. Maximum estimated annual consumptive groundwater usage, expressed in equivalent mm of precipitation.

	PTTW(m3/yr)	Wells(m3/yr)	AG Use (m3/YR)	Total	Area (m2)	mm
ABCA Gullies	0	16,524	373,384	389,907	196,540,843	**1.98**
Ausable	2,012,645	102,065	4,589,686	6,704,396	1,251,937,273	**5.36**
Bayfield	917,848	32,817	975,083	1,925,748	501,829,521	**3.84**
God-Bay Gullies	3,218,756	10,873	299,104	3,528,733	109,349,871	**32.27**
Little Maitland	117,651	16,556	793,134	927,341	370,949,346	**2.50**
Lower Maitland	3,320,502	30,945	971,319	4,322,765	533,717,780	**8.10**
Middle Maitland	0	39,584	1,382,445	1,422,029	646,444,198	**2.20**
MVCA Gullies	64,875	19,447	514,924	599,246	377,712,529	**1.59**
North Maitland	0	38,172	1,020,445	1,058,616	575,960,639	**1.84**
Parkhill	290,304	13,304	1,127,427	1,431,035	465,783,570	**3.07**
South Maitland	111,310	25,163	1,042,382	1,178,855	447,646,312	**2.63**
Upper Nine Mile	0	12,812	325,878	338,689	245,713,661	**1.38**
Totals	**10,053,891**	**358,262**	**13,415,209**	**23,827,362**	**5,723,585,545**	**4.16**

3.3.4 Summary

As is shown in Tables 8 and 9, above, average monthly and annual consumptive water usage for most subwatersheds, when presented in equivalent mm of precipitation over the subwatersheds, is extremely low. Notable from the rest is the Goderich-Bayfield Gullies subwatershed, with relatively high groundwater use. The spatial variation of annual consumptive groundwater use throughout the region is illustrated graphically in Map 11.

3.4 Future Usage Projections

Future increases in the usage of both (non-Lake Huron) surface water and groundwater are not considered significant for the study area. The study area is considered to be “fully developed” in that it has very little natural area that will likely be converted to either agricultural or residential land uses. Potential does exist that, with significant climate changes and commodity price increases, irrigation will become a more commonplace agricultural practice. However, not enough data is available to discern any trends in this practice.

Population growth is projected to be minimal in the immediate future, with growth centered along the shore of Lake Huron and in existing Towns and Villages. Given the low consumptive water uses in the area it seems unlikely that future usage, based on today’s projections, will lead to any additional stress on the natural system. Caution should be added that not all future uses can be accounted for or anticipated, and that no additional stresses are anticipated for the subwatersheds at the scale being investigated, however, large takings within specific areas may still lead to significant problems.

4.0 TIER I SURFACE WATER QUANTITY STRESS ASSESSMENT

4.1 Surface Water Supply Estimate

At any given time, the available drinking water supply in a river or stream is limited to the instantaneous flow rate. Surface water supply is a method for determining the amount of flow available based on streamflow data for the study area. The prescribed approach for determining the surface water quantity stress takes into consideration seasonal variability and is therefore evaluated using an estimate of expected monthly flow values.

For each subwatershed within the study area, median flows were calculated to provide an estimate of surface water supply. 50th percentile flows were derived from the 1985 to 2005 daily SWAT model output for each month and then converted to monthly flows (mm/month) and are available in Appendix D to this document. Monthly 50th percentile flows are presented in Table 10, below.

Table 10. Surface water supply (50th percentile flows) for the study area, expressed as equivalent mm of precipitation/ month.

Tier 1 Subwat	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
ABCA-Gully	47.0	27.9	49.1	32.2	28.1	12.0	6.9	5.3	6.7	17.4	38.1	53.7
Ausable	374.2	264.0	738.7	387.8	217.5	134.2	100.3	112.6	88.6	154.3	286.7	560.0
Bayfield	94.2	58.0	176.1	117.4	81.7	38.9	22.8	47.0	27.7	47.3	97.5	150.8
South Maitland	382.4	256.6	878.0	737.3	536.0	347.2	215.2	125.0	200.3	397.1	843.3	628.9
Lower Maitland	521.0	362.6	1324	986.0	702.2	436.1	264.7	205.4	239.3	505.9	1076	845.4
Middle Maitland	67.9	40.1	284.9	264.4	179.2	86.4	49.8	38.0	58.8	130.1	259.8	157.8
Little Maitland	66.9	44.8	155.2	109.7	81.4	52.8	32.8	13.9	35.0	74.2	150.3	110.5
Parkhill	73.4	53.8	162.4	98.2	62.6	25.8	20.8	27.3	19.8	37.0	94.9	137.2
God-Bay-Gullies	28.1	18.5	51.9	36.9	27.9	17.3	9.0	10.4	7.3	17.4	40.2	38.7
MVCA-gullies	89.6	59.4	221.6	152.8	102.4	68.7	34.4	53.1	31.8	77.6	164.1	146.0
Nine Mile	74.4	50.4	141.1	133.1	90.4	62.1	41.6	46.2	33.4	73.2	129.3	112.2
North Maitland	126.2	93.3	161.6	158.3	145.0	105.9	66.5	32.3	47.1	88.0	208.7	178.9

4.2 Surface Water Reserve Estimate

The water reserve estimate for a surface water system in Tier 1 is based on the maximum of a statistical measure of low flow or a known anthropogenic need (i.e. wastewater assimilation). The water reserve estimate is the means by which a portion of water may be protected from being considered within the stress calculations. The concept behind its use is to support other uses of water within the watershed including both ecosystem requirements (instream flow needs) as well as other human uses (primarily permitted uses). The reserve quantity is subtracted from the total water source supply prior to evaluating percent water demand.

For the scale of this Tier 1 assessment surface water reserve is not complicated by the need for assimilative capacity and is therefore most simply expressed as the 10th percentile flows for each subwatershed. 10th percentile flows were derived from the daily SWAT analyses for each month and then converted to monthly flows (mm/month) and are available in Appendix D to this document. Monthly 10th percentile flows are presented in Table 11, below. In order to be consistent with MOE guidance (2007) for the Tier I surface water stress assessment, reserve values are used for the months with the lowest monthly water supply estimates, rather then the lowest monthly water reserve estimates.

Table 11. Surface water reserves (10th percentile flows) for the study area, expressed as equivalent mm of precipitation. Note that lowest 10th percentile flows do not necessarily occur in the same month as lowest 50th percentile flows.

Tier 1 Subwat	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
ABCA-Gully	8.3	7.0	6.1	8.3	4.3	1.2	0.3	0.1	0.1	0.8	2.8	6.7
Ausable	72.8	70.2	144.2	131.2	75.5	27.8	22.5	17.5	15.6	22.2	48.9	105.6
Bayfield	15.6	9.8	31.0	34.2	20.2	6.8	5.0	3.5	1.7	5.2	15.3	40.7
South Maitland	111.3	111.5	157.8	272.2	159.3	66.1	45.1	42.6	21.8	61.7	198.8	249.1
Lower Maitland	155.0	156.6	232.5	345.0	191.3	86.5	65.5	50.4	32.6	75.8	220.7	337.8
Middle Maitland	13.4	9.9	16.4	85.9	33.8	10.2	6.6	5.0	4.4	16.6	68.4	49.3
Little Maitland	22.1	18.8	25.3	36.9	19.3	8.5	5.6	4.1	2.0	9.7	42.7	42.2
Parkhill	15.7	16.6	24.3	32.1	16.9	3.9	3.1	1.8	2.2	3.9	13.8	27.7
God-Bay-Gullies	6.7	4.9	6.4	10.4	6.6	3.6	0.9	0.3	0.1	1.0	3.6	12.4
MVCA-gullies	29.5	18.9	29.5	53.9	27.8	15.2	4.7	3.4	2.2	7.3	28.5	43.4
Nine Mile	35.6	26.6	33.5	68.1	36.9	25.4	12.6	7.8	3.2	5.7	33.0	50.3
North Maitland	33.2	39.5	45.7	50.9	41.8	22.8	16.9	20.6	10.2	18.4	44.1	64.3

4.3 Tier I Surface Water Stress Assessment

The Tier 1 surface water stress assessment is designed to screen and flag those subwatersheds where the degree of stress is considered moderate or significant for further study. The stress assessment evaluates the ratio of the consumptive demand for permitted and non-permitted users to water supplies, minus water reserves within a given subwatershed.

Within the study area, for each subwatershed, the monthly water reserve (10th percentile flows) were subtracted from the monthly water supply (median flows) for the month with the lowest monthly water supply in order to determine water availability. The percentage water demand was then calculated as a percentage of the consumptive demand versus this water availability, where:

$$\%\ \text{Water Demand} = \frac{\text{Consumptive Demand}}{(\text{water supply} - \text{water reserve})} \times 100$$

Subwatershed stress levels are defined as: less than 20% - Low; Between 20 and 50% - Moderate; more than 50% - Significant. Table 12, below, outlines the water supplies, reserves, availability, consumptive demand, percentage water demand, and surface water quantity stress levels for each subwatershed in the study area. The stress levels are presented graphically in Map 12. All subwatersheds are considered to have low surface water quantity stress at the scale analyzed for the Tier 1 water budget. There are no municipal water takings from surface water bodies.

Table 12. Percentage water demand for surface water subwatersheds in the study area. Supply, Reserve and Consumptive Use expressed as equivalent mm of precipitation.

Tier 1 Subwat	Supply	Reserve	Consumptive Use	% Water Demand
ABCA-Gully	5.3	0.1	0	0.0
Ausable	88.6	15.6	1.164	1.6
Bayfield	22.8	5	0	0.0
South Maitland	125	42.6	0	0.0
Lower Maitland	205.4	50.4	0.007	0.0
Middle Maitland	38	5	0	0.0
Little Maitland	13.9	4.1	0	0.0
Parkhill	19.8	2.2	1.696	9.6
God-Bay-Gullies	7.3	0.1	0	0.0
MVCA-gullies	31.8	2.2	0	0.0
Nine Mile	33.4	3.2	0.004	0.0
North Maitland	32.3	20.6	0	0.0

5.0 TIER I GROUNDWATER QUANTITY STRESS ASSESSMENT

5.1 Groundwater Supply Estimate

An estimation of the amount of groundwater available to supply a subwatershed’s groundwater users is determined as a summation of groundwater recharge and lateral groundwater flow into the subwatershed. The percent water demand can then be calculated as both average annual and average monthly conditions for current and future (25-year) scenarios. For this Tier 1 analysis, aquifer storage is not considered and as such the water supply terms for the subwatersheds are assumed to be consistent on an average annual basis.

Groundwater Flux through the system was developed from the 6 CA FeFlow model. Tier I subwatersheds were refined and extracted and flux values determined using continuous boundary flux within the FeFlow water budgeting module. Results derived from FeFlow are shown below in Table 13, and graphically represented on Maps 7 (recharge), 8 (groundwater flow in) and 9 (groundwater flow out, including baseflow). Netflux (Table 13) is the summation of Groundwater flows in (Recharge and Flux In) minus groundwater flows out (Flux out + Anthropogenic takings).

For the study area, two sources of recharge data are available, estimates derived from the 6 CA groundwater model (annual only) and from the SWAT analysis (monthly and annual). Table 13, below, summarizes groundwater flux through the Tier I subwatersheds derived from FeFlow. Groundwater recharge, based on the SWAT methodology accounts for changes in aquifer storage, whereas the recharge determined for the 6 CA model does not. As a result, and following MOE guidance (MOE, 2007), the recharge values derived from FeFlow for the 6 CA model will be used for the Tier 1 assessment. These data are also considered the more conservative value, consistent with expectations for a Tier I water budget.

Table 13. Groundwater flux and Supply for the ABMV study area, expressed as mm/year of equivalent precipitation.

Tier 1 SubWat	GW-IN	GW-Out	Recharge	Net Flux	Supply
ABCA-Gully	568	607	121	81	689
Ausable	132	206	132	-36	264
Bayfield	13	63	133	85	146
South Maitland	74	120	127	81	201
Lower Maitland	34	107	152	60	186
Middle Maitland	12	67	143	82	155
Little Maitland	462	710	134	96	596
Parkhill	13	135	144	22	157
G-B-Gullies	217	1	141	217	358
MVCA-gullies	90	215	105	128	195
Nine Mile	275	305	149	120	424
North Maitland	9	193	144	39	153

5.2 Groundwater Reserve Estimate

The groundwater reserve for Tier 1 analysis is determined by estimating the reserve quantity as 10% of the existing groundwater supply (see section 5.1). Alternatively, a value equal to 10% of average annual baseflow can be used to represent groundwater reserve. Based on input from the Peer Review Committee, the more conservative value of 10% of groundwater supply will be used for the Tier I assessment..

5.3 Tier I Groundwater Stress Assessment

Similar to the Tier 1 surface water stress assessment, the Tier 1 stress assessment for groundwater is designed to determine the degree of stress within each subwatershed. The stress assessment evaluates the ratio of the consumptive demand for permitted and non-permitted users to water supplies, minus water reserves within a subwatershed.

Within the study area, for both the MVCA and ABCA jurisdictions, the groundwater reserve (10% of Supply) was subtracted from the groundwater supply (Recharge plus Groundwater influx) in order to determine Groundwater availability. The percentage water demand was then calculated as a percentage of the consumptive demand versus this water availability, where:

$$\% \text{ Water Demand} = \frac{\text{Consumptive Demand}}{(\text{water supply} - \text{water reserve})} \times 100$$

Subwatershed stress levels are defined for average annual fluxes, as: less than 10% - Low; Between 10 and 25% - Moderate; more than 25% - Significant, and for monthly maximum fluxes as: less than 25% - Low; Between 25 and 50% - Moderate; more than 50% - Significant. Table 14, below, outlines the water supplies, reserves, availability, consumptive demand, percentage water demand and groundwater quantity stress levels on an annual basis for each subwatershed in the study area.

Table 14. Annual percentage groundwater demand for groundwater subwatersheds in the study area. Units are mm/year unless otherwise specified.

Tier 1 Subwat	GW IN	Recharge	Supply	Baseflow	Reserve	Cons. Use	% Water Demand
ABCA-Gully	568	121	689.0	241	68.9	1.98	**0.32**
Ausable	132	132	264.0	115	26.4	5.36	**2.26**
Bayfield	13	133	146.0	104	14.6	3.84	**2.92**
South Maitland	74	127	201.0	134	20.1	2.63	**1.45**
Lower Maitland	34	152	186.0	214	18.6	8.1	**4.84**
Middle Maitland	12	143	155.0	138	15.5	2.2	**1.58**
Little Maitland	462	134	596.0	148	59.6	2.5	**0.47**
Parkhill	13	144	157.0	91	15.7	3.07	**2.17**
God-Bay-Gullies	217	141	358.0	235	35.8	32.27	**10.02**
MVCA-gullies	90	105	195.0	254	19.5	1.59	**0.91**
Nine Mile	275	149	424.0	282	42.4	1.38	**0.36**
North Maitland	9	144	153.0	157	15.3	1.84	**1.34**

It should be noted that the data presented in Table 14 reflect average annual conditions and not monthly values, as the two assessments (Annual and Monthly) were conducted separately.

The annual groundwater stress levels are presented graphically in Map 13. All subwatersheds are considered to have low annual groundwater quantity stress, with the exception of the Goderich-Bayfield Gullies, which are over the threshold developed for moderate stress. It is important to note that these stress assessment are relevant only at the scale analyzed for the Tier 1 water budget.

Based on the criteria for determining surface water quantity stress, the Goderich-Bayfield Gullies subwatershed is considered to be under stress, passing the threshold for moderate stress with approximately 10.02% of available water under demand. This is a result of very high consumptive takings that create a water demand above the threshold for moderate stress despite the high water supply. There are several municipal groundwater supplies within the Goderich-Bayfield Gullies subwatershed.

Monthly groundwater stress is shown below in Table 15. Monthly stress values remain well under stress thresholds for most subwatersheds, with the exception of the Bayfield River, which is considered to be under significant stress. This is a result of very high consumptive takings related to several municipal water supplies, which create a water demand over the threshold for significant stress despite the high water supply. The monthly groundwater stress levels are presented graphically in Map 14.

Table 15. Monthly percentage groundwater demand for groundwater subwatersheds in the study area. Units are mm/month unless otherwise specified.

Tier 1 Subwat	Supply	Baseflow	Reserve	Cons. Use	% Water Demand
ABCA-Gully	52.09	241	5.2	**0.17**	**0.36**
Ausable	11.88	115	1.2	**0.81**	**7.58**
Bayfield	1.98	104	0.2	**1.25**	**70.15**
South Maitland	6.44	134	0.6	**0.25**	**4.31**
Lower Maitland	39.64	214	4.0	**0.69**	**1.93**
Middle Maitland	1.37	138	0.1	**0.18**	**14.60**
Little Maitland	3.3	148	0.3	**0.27**	**9.09**
Parkhill	1.99	91	0.2	**0.31**	**17.31**
God-Bay-Gullies	20.86	235	2.1	**2.86**	**15.23**
MVCA-gullies	9.94	254	1.0	**0.20**	**2.24**
Nine Mile	26.47	282	2.6	**0.11**	**0.46**
North Maitland	1.36	157	0.1	**0.15**	**12.25**

Both the Goderich-Bayfield Gullies and Bayfield River subwatersheds will need further investigation to determine to verify any potential stresses, as both are host to several municipal groundwater supplies.

6.0 Tier I Numerical Water Budget

A preliminary numerical water budget can be developed for the Region based on the annual fluctuation of water through the subwatersheds within the study area. It is important to note that significant errors occur in estimating these values, and as a result all numbers may not add to zero. Note that the GW Out value derived from FeFlow includes baseflow, which is also included as part of the streamflow portion. As a result, in determining the net flux through the system baseflow values were subtracted from the Groundwater out values. Table 16, below outlines the assigned values for each subwatershed element, expressed as equivalent mm precipitation.

Table 16. Tier 1 water budget for the ABMV study area. All values expressed as mm/year of equivalent precipitation

Tier 1 SubWat	GW-IN	PPT	**IN**	ET	Sur. Q	Rech.	Anthro	GW-Out*	Bflow	**Out**	**Net**
ABCA-Gully	568	971	**1539**	330	311	295	2	607	241	**1304**	**235**
Ausable	132	962	**1094**	430	292	218	7	206	115	**1038**	**56**
Bayfield	13	991	**1004**	421	326	221	4	63	104	**931**	**73**
South Maitland	74	1119	**1193**	468	345	243	3	120	134	**1044**	**149**
Lower Maitland	34	1164	**1198**	476	311	342	8	107	214	**1031**	**167**
Middle Maitland	12	1031	**1043**	437	305	249	2	67	138	**923**	**120**
Little Maitland	462	996	**1458**	443	252	268	3	710	148	**1528**	**(70)**
Parkhill	13	935	**948**	426	286	206	4	135	91	**966**	**(18)**
G-B-Gullies	217	1058	**1275**	387	324	307	32	1	235	**816**	**459**
MVCA-gullies	90	1168	**1258**	354	432	324	2	215	254	**1072**	**186**
Nine Mile	275	1155	**1430**	419	304	393	1	305	282	**1141**	**289**
North Maitland	9	957	**966**	469	201	237	2	193	157	**945**	**21**

GW-IN = Groundwater flow in; PPT = Precipitation; ET = Evapotranspiration; Sur. Q = Streamflow; Rech. = Recharge; Anthro= Total Consumptive Water Use; GW-Out = Total groundwater flow out (includes Baseflow); Bflow = Baseflow. IN = (GW-IN + PPT), OUT = (ET+SurQ+Rech.+Anthro+GW-Out), Net = IN-OUT

7.0 Significant Recharge Areas

As part of the water budget process, the determination of recharge rates across the region is required. Section 2.3 of this report outlines the different methodologies used to estimate recharge in our area, and Appendix B and Appendix C include the data developed through those processes.

Areas which are contributing relatively more recharge to the system are defined as “significant” and are to be delineated for protection through the water budget process. This involves a two-step process where high volume recharge areas are delineated, after which their significance in the overall system is evaluated to determine whether these areas are considered “significant” recharge areas.

MOE guidance (2007) outlines a number of potential methodologies for determining high volume recharge areas (hereafter referred to as significant recharge areas). Several of these methods, appropriate for the quality and quantity of data made available through this process, have been identified below and can be seen graphically in Maps 15 through 18.

7.1 Baseflow Spot Measurement Program Data Method

Baseflow measurement can be used to approximate areas of high recharge, assuming minimal change in storage of aquifers. Although this simplification is not considered accurate given present knowledge of seasonal fluctuations in groundwater levels, identification of areas of high baseflow (groundwater discharge) may continue to be used to approximate significant recharge areas.

A spot flow measurement program was initiated by the Ausable Bayfield Maitland Drinking Water Source Protection Region for the summer field season of 2007. Results of this work, including methodologies and monitoring site locations, are available in a report by Boorse and Napper (2007). The goal of this work was to measure baseflow from numerous ungauged basins in the study area.

The extreme drought in the summer of 2007 led to ideal conditions for measurement of groundwater discharge into smaller tributaries. Results were reported in mm of equivalent precipitation per day and are shown graphically on Map 15. Catchment areas with significant amounts of baseflow can be considered significant recharge areas, as an initial estimate.

7.2 Sinkhole Drainage Areas

Sinkholes are large structures into which water is drained directly into the bedrock aquifers. They are considered to enhance local aquifer vulnerability as they provide a direct pathway for surface water and potential contaminants to otherwise well protected aquifers.

From a water quantity perspective, sinkholes can have large drainage areas, including municipal drains that have been historically diverted into them. In the drainage areas of the sinkholes, all runoff and surface water is diverted into the subsurface. Therefore, sinkhole drainage areas must be considered significant recharge areas.

Sinkholes were previously identified in several studies conducted for the ABCA (WHI 2004; WHI 2006). Sinkhole drainage areas were developed from topographic data and known drainage patterns as part of this previously completed work. Map 15 shows locations of sinkholes and their respective drainage areas.

7.3 Net Available Water Method

Methodology recommended in the MOE guidance document (2007) identifies the potential use of available hydrologic data produced from modeling efforts. The first of these methodologies takes into account the percentage of recharge versus available water (available water = PPT – ET). Should recharge equal a value greater than 55% of the net available water for a given subwatershed, that subwatershed could be considered a significant recharge area.

For the study area, PPT, ET and recharge data are available (see sections 2.1, 2.2 and 2.3 respectively) for all the subwatersheds created for surface water modeling purposes (Shown as numbered subwatersheds on Map 1). These subwatersheds were employed to develop significant recharge areas.

Calculations of net available water, and the percentage of which is recharging are shown in Appendix G and the results graphically represented on Map 16.

7.4 Average Annual Recharge Methodology – SWAT Modeling

Methodology recommended in the MOE guidance document (2007) identifies the potential use of available hydrologic data produced from modeling efforts. The second of these methodologies takes into account the relative percentage of recharge for a given subwatershed versus the average (areally corrected mean) for all subwatersheds. Should recharge within a given subwatershed equal a value greater than 15% of the study area average, that subwatershed could be considered a significant recharge area.

For the study area recharge data are available (see section 2.3) for all the subwatersheds created for surface water modeling purposes (Shown as numbered subwatersheds on Map 1). These subwatersheds were employed to develop significant recharge areas.

Areally corrected mean recharge values were developed from the surface water modeling data and compared with recharge values for all subwatersheds. Subwatersheds with recharge values more than 15% greater than average were identified and graphically represented on Map 17.Calculations of recharge as a percentage of the average are shown in Appendix G.

7.5 Average Annual Recharge Methodology – FeFlow Modeling

Methodology recommended in the MOE guidance document (2007) identifies the potential use of available hydrologic data produced from modeling efforts. The second of these methodologies takes into account the relative percentage of recharge for a given subwatershed versus the average (areally corrected mean) for all subwatersheds. Should recharge within a given subwatershed equal a value greater than 15% of the study area average, that subwatershed could be considered a significant recharge area.

For the study area recharge data are also available (see section 2.3) from groundwater modeling efforts for the entire study area. These data were then distributed from the regional-scale model to all the subwatersheds created for surface water modeling purposes (Shown as numbered subwatersheds on Map 1) in a GIS environment. These subwatersheds were then employed to develop significant recharge areas based on groundwater modeling-derived recharge values.

Areally corrected mean recharge values were developed from the surface water modeling data and compared with recharge values for all subwatersheds. Subwatersheds with recharge values more than 15% greater than average were identified and graphically represented on Map 18.

7.6 Analysis

The significant recharge area delineations employed for this phase of the water budget should be considered preliminary in scope. Future work will focus on refining these areas with assistance of the Peer Review Committee and will be combined with Tier II water budget work planned for 2008.

8.0 Uncertainty and Data gaps

7.1 Uncertainty

The uncertainty associated with the Tier 1 watershed stress assessments are specific to the subwatersheds that they have evaluated. Uncertainty, in this context, is a function of the confidence in the final stress assessment, including the cumulative uncertainty inherent in the data used to develop that stress assessment.

In cases where a subwatershed is considered in low stress but approaches the moderate threshold, this uncertainty must be examined more carefully, given the inherent inaccuracy of the model outputs for natural water flux and estimated consumptive water use. The fundamental principle is that Tier I stress assessments should be conservative and over-estimate stress.

8.1.1 Uncertainty associated with Consumptive Water Usage

In general, there is a high degree of uncertainty associated with consumptive water usage estimates due to the inherent inaccuracy of the available water takings data. In most cases, data on water takings are not reflective of actual takings, but rely on estimates based on permitted values.

In the case of the ABMV study area, permitted values were contacted and attempts made to gather actual pumping values (Luinstra, 2006). These values were incorporated into the Tier I consumptive use estimates. However, actual takings were not available for all PTTWs, and as a result, the estimates contained herein can be considered conservative, in that they are likely overestimating takings.

7.1.2 Uncertainty associated with Model Outputs

Model outputs are inherently uncertain. SWAT modeling for the study area was calibrated to measured streamflow where possible and generally is felt to be reasonably representative of actual conditions. However, it must be noted that it cannot be established that SWAT derived values are more conservative than measured or actual values. FeFlow modeling available for the study area was initially developed for a large, regional scale model. As a result of this, significant simplification of the hydrogeologic system for the study area was required. The resultant uncertainty must be considered high for groundwater flux data derived from this model.

7.1.3 Aggregate Subwatershed Uncertainty

Subwatershed uncertainty for groundwater and surface water stress is included in Table 17, below.

The aggregate uncertainty for all subwatersheds is low, with the exception of the Goderich-Bayfield Gullies subwatershed. Uncertainty within the Goderich-Bayfield Gullies must be considered high due to the relatively high percentage water demand (10.02%) and the potential that the groundwater influx values derived from the FeFlow model have significant uncertainty. In addition, the high takings in this subwatershed are a function of one large taking to which actual taking data is not available. Although monthly groundwater stress in the Bayfield River subwatershed is significant, due to the high percentage water demand the result is not believed to be uncertain.

Table 17. Surface water and groundwater stress assessment uncertainty for Tier I subwatersheds

Tier 1 SubWat	GW Stress	SW Stress	Cons. Use	Aggregate uncertainty
ABCA-Gully	low	low	low	low
Ausable	low	low	low	low
Bayfield	low	low	low	low
South Maitland	low	low	low	low
Lower Maitland	low	low	low	low
Middle Maitland	low	low	low	low
Little Maitland	low	low	low	low
Parkhill	low	low	low	low
G-B-Gullies	**high**	low	**high**	**high**
MVCA-gullies	low	low	low	low
Nine Mile	low	low	low	low
North Maitland	low	low	low	low

7.2 Data and Knowledge Gaps

A number of data and knowledge gaps have been identified in the text for the Tier 1 water budget, and include:

1. Evaporation data
2. Streamflow and baseflow data for ungauged watersheds;
3. Accurate WWTP discharge data and a system for keeping this data up to date;
4. Certificate of Approval data in order to determine appropriate surface water reserves as defined by assimilative capacity;
5. Actual water takings for all PTTW holders, and a system for keeping this data up to date

7.3 Limitations

The key limitation to this work is scale. The stress assessments preformed for the Tier I water budget were completed at a crude, subwatershed scale. For the surface water system, this scale may be considered appropriate for the purposes of Source Water Protection given the lack of municipal or any other drinking water supply from the surface water system. For the groundwater system, the scale should be considered appropriate for the Bedrock aquifer, which, although it is host to numerous municipal and private drinking water systems, is a regional scale system and the analysis preformed herein considered sufficient. However, overburden aquifers are less well understood and are not well represented in the regional scale groundwater model developed for the study area. Although host to only one (1) municipal supply (Hensall), the stress assessments completed as part of this report are not considered relevant to this shallow, overburden dependant system. The Hensall well is scheduled for decommissioning in the near future and will not be included in the Source Protection Plan.

8.0 Summary

The available data supports initial observations that water demands are only rarely developing stress in the overall watershed area. This is primarily a result of the lack of water takings relative to the overall size of the study area. The exception to this is the Goderich-Bayfield Gullies and Bayfield River subwatersheds, where high groundwater takings have led to moderate and significant groundwater stress levels, respectively. These areas are also host to numerous groundwater supplied municipal drinking systems.

The lack of significant surface water based municipal and private drinking water systems mean that any stress on the surface water system will not impact the drinking water supplies of the population.

The overburden aquifer systems, however, are poorly represented at the scale of analysis at which the Tier 1 stress assessments were undertaken. Fortunately, only one (1) municipal drinking water supply is exploiting the overburden as a source of water (Hensall) and it is scheduled fro decommissioning in the near future as the municipality joins the Lake Huron Water Supply System.

9.0 Recommendations for Further Work

Recommendations for further work are designed to fill data gaps identified in the preceding section, as well as to identify those subwatersheds where Tier 2 assessments may be warranted.

Filling Data Gaps

The following are recommended to fill the identified data gaps:

1. Development of an ongoing spot flow program in order to collect accurate baseflow and streamflow data, as well as to delineate significant recharge areas.
2. Survey of all WWTP operators to develop a system whereby outflow data is shared with the SWP technical team.
3. Confirmation of PTTW takings for subwatersheds with moderate or significant stress, or with high uncertainty, and development of a system whereby actual takings data are shared with the SWP technical team.

Tier 2 Water budgeting

Tier 2 water budgets are recommended for the Goderich-Bayfield Gullies and Bayfield River subwatersheds. A proposed work plan includes:

- Verification on the actual consumptive takings of PTTW holders in the subwatershed, including accurately locating the sources, quantifying taking volumes and the volume returned to the source.
- Extracting and iteratively refining both surface and groundwater models for the subwatersheds, particularly focusing on the recharge data used to determine water supplies.
- Employing the Tier 2 water budget screening tool
- Further refinement of significant recharge areas for the study area

References

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Schroeter, H.O., Boyd, D.K., and Whitely, H.R., 2000. Filling Gaps in Meteorological data sets used for long term watershed modeling.

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Appendices

Maps