Thames-Sydenham and Region Source Protection Committee

Upper Thames River Source Protection Area

Draft Proposed

Assessment Report

Section 3 – Water Budget and Water Quantity Stress Assessment

3.0 Water Budget and Water Quantity Stress Assessment

The Clean Water Act is intended to reduce the threats to the quality and quantity of drinking water sources. In order to do this, threats within *vulnerable areas* are identified and assessed to determine the relative *risk* to the drinking water source. The Clean Water Act and its regulations identify 21 activities which can be drinking water *threats*. These activities include two which are related to the quantity of drinking water. One is an *activity* that takes water from an aquifer or a surface water body without returning the water taken to the same aquifer or surface water body. The other water quantity threat is an *activity* that reduces the recharge of an aquifer. To determine the risks to drinking water quantity from either of these threats, it is necessary to understand the level of *stress* on a drinking water system's source. The Water Budget is the tool used to understand the level of *stress* on a system or within a *watershed*.

Where there is little potential for *stress*, there are no *threats*. On the other hand, where there is a significant potential for *stress*, activities contributing to the *stress* will be assessed to determine if they constitute significant threats. This is done through the Tier 3 Water Budget in only those areas where the potential for stress warrants this detailed local analysis. The Clean Water Act requires that the *Source Protection Committee* develop a *Source Protection Plan* that reduces the *risk* associated with *significant threats* so that they cease being significant and prevents new *significant threats* from being undertaken in these areas.

The Water Budget looks at the balance of water within an area known as a *watershed*. A Water Budget can be assessed at different scales, but generally this is undertaken on a *watershed* or a part of the *watershed* referred to as a *subwatershed*. It considers inputs or supply to the *watershed* or *subwatershed* which include: precipitation (rain and snow), flow into the watershed from up river, flow into the watershed through groundwater and flow imported into the watershed such as that which is piped water from the Great Lakes. The Water Budget balances these inputs with removals from the *watershed*, or *demand*, which include: discharges into the next

watershed through stream flow or groundwater, use of water which is consumptive in nature (and therefore does not return the water to the same source from which it was removed), evaporation and transpiration (use of the water by plants). The water budget considers a balance between supply and *demand* that includes a *reserve* quantity that is removed from the supply in the stress calculation. The components of the water budget are described in detail in the Conceptual Water Budget (attached as Appendix 6), the Tier 1 Water Budget and summarized in the following sections.

The Water Budget is developed in stages referred to as tiers. As they progress, these tiers involve more detailed analysis, refined data and generally reduced study area. In this manner, only those areas with the potential to be stressed require detailed modelling and analysis; those which appear not to be stressed receive a less detailed screening. Each of these tiers is described in the following sections. *The Upper Thames River Source Protection Area* is included with the other Source Protection Areas in the Thames-Sydenham and Region in the Conceptual Water Budget and the Tier 1 Water Budget. Only areas where there is a moderate or significant *potential for stress* on drinking water systems included in the Terms of Reference (only municipal systems in the *UTRSPA*) proceed to a Tier 2 Water Budget. Only those areas which are confirmed to have a significant or moderate stress level in the tier 2 assessment proceed to a Tier 3 Water Budget. It is only through a Tier 3 Water Budget, or Local Area Assessment, that water quantity threats are assessed. As the potential for *stress* on some drinking water sources was determined to be moderate or significant through the Tier 1,and Tier 2 Water Budgets, Tier 3 Local Area Risk Assessments are required for the Upper Thames River Source Protection Area. Work is underway for the completion of the Tier 3 study and the results will be included in future updates to the Assessment Report.

3.1 What is a Water Budget?

A water budget quantifies and compares the components of the hydrologic cycle. Much like a bank account, if more water is leaving than is entering, the water in the *watershed* will be depleted over time. If in balance, the water use is sustainable. Each component of the water budget must be quantified so that the *demand* can be compared to the supply. If the *demand* is greater than the supply, the reserves, like the savings in a bank account, will be depleted. Over

time this would result in reduced water levels in water bodies and aquifers. Normal and cyclical fluctuations in water level make it necessary to look at the components of the water budget over long periods of time rather than looking at short-term trends in levels. This is especially true in groundwater systems where changes in water levels are more difficult to monitor and analyze.

3.2 Components of the Water Budget

3.2.1. Precipitation

Precipitation, or rain and snow, is the primary component of the supply component of the water budget. Long-term precipitation was analyzed from various meteorological stations around the region. Map 3-2 illustrates the precipitation stations used in the water budget and the spatial variation of the average annual precipitation over the region. Annual average precipitation decreases moving North to South along the UTRSPA from about 1060 millimetre per annum (mm/a) in the north (Stratford) to about 990 mm/a In the south (London) and 950 mm/a in Woodstock. On average, the Upper Thames River Source Protection Area receives about 1000 mm per year of precipitation.

3.2.2. Evapotranspiration

Evapotranspiration (or ET) is the precipitation which either evaporates into the atmosphere or is used by the plants. Water used by plants is also given back to the atmosphere through a process known as transpiration. Together the evaporation and transpiration are known as Evapotranspiration. There is little variation across the region other than as a result of the variation in precipitation. Map 3-3 shows the evapotranspiration across the region. Water which evaporates or is used by the plants is not available as supply and is therefore subtracted from the precipitation in the supply calculations. ET accounts for more than half of the precipitation in the region.

Irrigation, although also used by plants and lost back to the atmosphere through evaporation and transpiration, is considered in the *demand* part of the water budget. Irrigation water is removed from a groundwater or surface water source, and is consumptive to that source. ET, on the other hand, is loss from the precipitation component of the water budget. Another

important distinction is that irrigation occurs only in very localized areas where it is required by a crop. ET is directly related to precipitation, temperature and is fairly uniformly distributed across the watershed.

3.2.3. Surface Runoff

Precipitation which falls in the watershed and does not evaporate or get absorbed into the plants either infiltrates into the ground or runs off into streams and rivers. The runoff from the watershed is not available for the supply as it leaves the watershed quickly. Although some of the water which infiltrates into the ground also leaves the watershed relatively quickly, most of the water which seeps deeper into the ground is said to recharge the aquifers which is discussed in the following section.

3.2.4. Recharge

Recharge is the water from precipitation which soaks into the ground and recharges the aquifers in the ground. This is the water which maintains stream flow during periods between runoff events and is referred to as base flow. The water budget assumes that over time the recharge is equivalent to the base flow discharge from the watershed. This relationship is considered more closely in Tier 2 and 3 of the water budget work where calibrated surface and groundwater models are used to describe the components of the water budget including recharge.

In the Tier 2 Water Budget for the Upper Thames River Source Protection Area, recharge was estimated based on a combination of surficial geology and land use. The landscape is examined using Geographic Information System (GIS) software, and all possible combinations of land use and surficial geology are considered and combined to form one of nine different hydrologic response units (HRU). Each of these response units is then associated with recharge value for a particular climate zone, which has been calibrated for these HRUs throughout south western Ontario using a surface water model (GAWSER), and further refined for the UTRSPA ..

3.2.5. Water Use (Demand)

Water use in the water balance and stress calculations is referred to as *Demand*. While *demand* would be the simplest of the terms to monitor, records of water use are not required,

except where permits for the use are required. Water use of more than 50,000 L/day, other than domestic and livestock watering, requires a Permit to Take Water, however until recently, records of water used were not required to be recorded and submitted. Even where the records are required as part of the permit process, they have only been required for the past few years. This recent record keeping is undertaken by the permit holder with little or no quality control on the data entered. This information is submitted by the permit holder and has only become available to the water budget team near the completion of much of this water budget work. In future revisions to the water budget the actual use records will provide a better estimate of the *demand*. For the Tier 1 and Tier 2 Water Budget work, estimations of actual use were based on adjusted maximum permitted values, or other sources of estimation in some cases. Large water users were polled to provide a better estimate of water *demand*.

Estimates of water use not requiring a permit to take water (often referred to as *non-permitted* water use) were also included in the calculations of *demand*. While municipal systems require a permit to take water and records of this *demand* is well established through municipal pumping records, an estimate of the water used from private water systems is also required. Generally, this *demand* is minor; however it is important that it not be neglected in the water budget and stress assessment. Non-municipal system domestic *demand* is estimated based on per capita consumption estimations multiplied by population reported in census data.

Livestock watering also does not require a permit. This *demand* was estimated in a similar manner using livestock census data and typical water use by livestock type (Kreutzwiser & de Loë, 1999).

Both of these non-permitted uses are assumed to be distributed evenly across groundwater and surface water sources.

The Permit to Take Water information was analyzed to determine the *demand* in each *subwatershed* and combined with the *non-permitted demand* discussed above. Water use was considered separately for surface water and groundwater as required by the *Technical Rules: Assessment Reports*. Consumptive factors were applied to the surface water *demand* based on the use of the water taken. These factors were recommended by the province in the water

budget guidance. The consumptive factors applied to water use are shown in the Tier 1 and Tier 2 Water Budgets. Consumptive factors were generally not applied to groundwater use as water removed from aquifers is generally not returned to the same aquifers. Groundwater is usually returned to surface water bodies after it is used, resulting in the use being completely consumptive. Water taken for aggregate washing and wildlife conservation are exceptions where consumptive factors were applied. In these cases, permits allow for large quantities to initially fill ponds, but then only a small amount is taken to compensate for evaporation and/or water removed in product in the case of aggregate extraction.

Irrigation *demand* is estimated based on permitted values. As discussed in the section on evapotranspiration, most of the water applied to crops is used by the crops or evaporates back into the atmosphere. This is even truer for irrigation where the amount of water applied is intended to saturate the root zone and not result in any significant runoff or recharge. As such, the consumptive factors for irrigation reflect that little, if any, water is returned to the source from which it was taken.

Table 3-1 summarizes the water *demand* in the area by type and source. It is important to realize that water use by industry and institutions supplied by municipal systems does not require a separate permit and is therefore included in the permitted values for the municipal system. Demands are only considered if they are taken from within the subwatershed under examination. Water taken from the Great Lakes for municipal supply is not included in Table 3-1 as a demand. Lake water discharged to the surface water through sewage treatment effluent is however considered as part of the supply for surface water.

Table 3-1 Groundwater and Surface Water use in the UTRSPA (m^3/day)

Groundwater Use	Data Source	SW Code	Agricultural	Commercial	Construction	Dewatering	Industrial	Institutional	Miscellaneous	Recreational	Remediation	Water Supply	Non-Permitted	**Total**
North Thames River/ Whirl Cr.	T1	401	151	0	0	1364	0	0	0	0	0	2502	1592	**5609**
Flat Cr./North Thames	T1	402 403	0	0	0	0	0	0	0	0	0	0	352	**352**

Tributaries														
Black Cr.	rT1	405												
Avon River	T2	404												
Trout Cr./ North Thames River	T2	406 407 408 410												
N. Thames/ Medway R.	rT1	409 411 412 413												
Thames R. above Pittock Reservoir	T1	303	395	1503	0	0	0	0	0	0	0	3549	1606	**7053**
Cedar Cr.	T2	301 302												
Thames R. above Ingersoll	T2	304 305												
Reynolds Cr.	rT1	306												
Middle Thames R.	T1	307	121	3315	0	4259	5357	0	0	0	0	931	1576	**15559**
Waubuno Cr./ Thames R. Tributaries	T1	308	293	1084	0	0	4392	0	1218	409	0	79	1677	**9153**
Thames R. between the Forks and Dutton*	T1	501	3439	2423	0	0	720	0	0	0	0	1755	2002	**10337**
Total														

Surface Water Use	SW Code	Agricultural	Commercial	Construction	Industrial	Miscellaneous	Recreational	Water Supply	Non-Permitted	**Total**
North Thames River/Whirl Cr.	01T	0	215	0	0	0	0	0	907	**1123**
Flat Cr./North Thames Tributaries	02T	0	0	0	0	0	0	0	240	**240**
Black Cr./Avon River	03T	10	199	0	0	0	0	0	930	**1139**
Trout Cr.	04T	0	31	0	0	0	16	0	584	**630**
N. Thames/Medway R.	05T	0	4050	0	4248	0	0	0	952	**9250**
Thames R. above Pittock Reservoir	06T	256	0	0	818	331	0	0	860	**2265**
Cedar Cr.	07T	0	532	0	0	0	0	0	195	**726**
Reynolds Cr./Thames R. above Ingersoll	08T	158	86	0	3125	267	0	0	833	**4468**
Middle Thames R.	09T	200	88	0	115	0	0	0	959	**1361**
Waubuno Cr./Thames R. Tributaries	10T	1325	540	0	0	13998	41	0	371	**16275**
Thames R. between the Forks and Dutton*	11T*	3633	2708	0	0	183	44	0	430	**6999**
Total		**5581**	**8450**	**0**	**8306**	**14779**	**101**	**0**	**7259**	**44476**

* Subwatershed 11T crosses over the Upper and Lower Thames boundary, and as such numbers reported are for both source protection authorities in this subwatershed

Data sources: In groundwater water use, T1 refers to Tier 1 Water Budget, T2 refers to Tier 2 Water Budget, rT1 refers to revised Tier 1 assessment. All Surface water use data is from Tier 1.

3.2.6. Water Budget Summary

Each *subwatershed* in the region is examined in terms of the water budget components for both surface and ground water systems on an annual average basis. Components include:

Q_P, precipitation,
$Q_{SW\text{-}in}$, surface water flows in,
$Q_{GW\text{-}in}$, groundwater flows in, (assumed zero in Tier 1)
Q_{ET}, Evapotranspiration,
$Q_{SW\text{-}out}$, surface water flows out,
$Q_{GW\text{-}out}$, groundwater flows out, (assumed zero in Tier 1)
$Q_{GW\text{-}C}$, consumptive groundwater use,
$Q_{SW\text{-}C}$, consumptive surface water use, and
ΔS, change in storage (assumed zero in Tier 1)

The water budget equation can be summarized as:

$$Q_P + Q_{SW-in} + Q_{GW-in} = Q_{ET} + Q_{SW-out} + Q_{GW-out} + Q_{GW-C} + Q_{SW-C} + \Delta S$$

Table 3-2 summarizes the annual water budget in units of annual average m^3/day. As only groundwater systems were carried over to a Tier 2 analysis, and because at Tier 2 the subwatershed boundaries were altered from those examined in Tier 1, the annual water budget summary is taken from the Tier 1 work. There is no surface water analysis completed with the new subwatershed boundary definitions. In the Tier 1 analyses, the $Q_{GW\text{-}in}$ and $Q_{GW\text{-}out}$ components are assumed to be zero. This simplifies the above equation to:

$$Q_P + Q_{SW-in} = Q_{ET} + Q_{SW-out} + Q_{GW-C} + Q_{SW-C} + \Delta S$$

Water budget balances are compared to the total water supply for each subwatershed (i.e. Precipitation + Surface Water supply), and the error is less than 10% of the estimated supply, which indicates that estimates are reasonable, given the inherent uncertainties in each individual component. Although stress calculations rely on monthly information, average annual water budget components are included as a summary to demonstrate the balance.

Table 3-2 Water budget summary (m^3/day)

Subwatershed	Code	Q_{ET}	Q_P	$Q_{sw\text{-}out}$	$Q_{sw\text{-}in}$	$Q_{gw\text{-}c}$	$Q_{sw\text{-}c}$	ΔS	Balance	% error (of total supply)
North Thames River/Whirl Cr.	01T	491681	891209	414829	0	5609	1123	0	-22033	-2.5%
Flat Cr./North Thames Tributaries	02T	198536	360714	136520	0	352	240	0	25067	6.9%
Black Cr./Avon River	03T	510473	1007574	415069	0	15196	1139	0	65698	6.5%
Trout Cr.	04T	352794	650015	270738	0	5392	630	0	20462	3.1%
N. Thames/Medway R.	05T	1028674	1804668	1902466	1237156	37067	9250	0	64367	2.1%
Thames R. above Pittock Reservoir	06T	428667	711314	295316	0	7053	2265	0	-21987	-3.1%
Cedar Cr.	07T	144884	239859	92259	0	19815	726	0	-17825	-7.4%
Reynolds Cr./Thames R. above Ingersoll	08T	547797	917526	791869	387576	562793	4468	0	-601825	-46.1%
Middle Thames R.	09T	526818	863974	364871	0	15559	1361	0	-44636	-5.2%
Waubuno Cr./Thames R. Tributaries	10T	465791	841084	1500043	1156740	9153	16275	0	6563	0.3%
Thames R. between the Forks and Dutton*	11T*	1167292	1998777	4224578	3402509	10337	6999	0	-7920	-0.1%

* Subwatershed 11T crosses over the Upper and Lower Thames boundary, and as such numbers reported are for both source protection authorities in this subwatershed
Data from Tier 1 Water Budget

3.3 Phases of Water Budget Work

3.3.1. Conceptual Water Budget

The Conceptual Water Budget, or conceptual understanding, is the first phase of the water budget development. In this stage, background information is collected on the components of the water budget. The information is analyzed to determine the various components of the water budget based on historical and readily available data on a coarse scale. The conceptual Water Budget was completed for the entire region. The region was divided into 6

subwatersheds for the purposes of this analysis. The Conceptual Water Budget is included as Appendix 6 of the Assessment Report.

3.3.2. Tier 1 Water Budget

The Tier 1 Water Budget utilizes the information collected and analyzed in the Conceptual Water Budget. In Tier 1, the potential for stress is assessed in *subwatersheds* within the region. As with the Conceptual Water Budget, the Tier 1 Water Budget was documented in one report for the entire Thames-Sydenham and Region. For the purposes of the Tier 1 Water Budget, the region was subdivided into 32 *subwatersheds*, as shown in Map 3-1. A water budget and stress assessment was calculated for each of these *subwatersheds*, and was used to determine if any subwatersheds required a Tier 2 analysis. The Stress assessment is discussed further in Section 3.4.

Tier 1 considers a future demand scenario, where municipal takings are increased according to the municipalities' Official Plans, and the stress assessment was recalculated with the increased demand. This is discussed in greater detail later in this document.

3.3.3. Tier 2 Water Budget

During the process of conducting the Tier 1 water budget, five subwatersheds containing groundwater-based municipal drinking water systems, within the UTRSPA,,, were found to exhibit a moderate or significant potential for stress. A Tier 2 investigation was undertaken for those subwatersheds, however the scope included all of the subwatersheds in the UTRSPA upstream of the forks of the Thames River in London to account for flow into the subwatersheds of interest. Information derived from the Tier 2 study is presented in this assessment report for groundwater systems in the UTRSPA. The subwatersheds used for the stress assessment are slightly altered from those examined in the Tier 1 phase, to focus on the municipal systems being investigated, and these revised subwatersheds are illustrated in Map 3-7, which also shows the results of the stress assessment on groundwater systems based on Tier 2 work.

As there are no surface water based municipal drinking water systems within the UTRSPA, Tier 2 investigation of the surface water system was limited to the assessment of groundwater recharge for input to the groundwater model. Therefore any surface water data reported in this assessment report are derived from the Tier 1 work. Furthermore, no Tier 2 work was done in the part of the UTRSPA below the forks of the Thames (11T) in ground or surface water systems, as there are no municipal supplies in this subwatershed with evidence of potential stress. Any data presented on subwatershed 11T are therefore based on the Tier 1 analysis.

In the Tier 2 analysis, future water use is again considered, as in Tier 1, as well as 2 and 10 year drought scenarios. This scenario analysis is discussed in greater detail in Section 3.4.

3.3.4. Tier 3 Water Budget

The Tier 3 Water Budget, or local area risk assessment, is a local water balance undertaken on the scale of a single drinking water supply system and is intended to examine the reliability of that supply, including testing of drought and future demand scenarios. The Tier 2 analysis completed in the Upper Thames River Source Protection Area requires that 6 municipal systems undergo a Tier 3 analysis. These systems are illustrated in Map 3-6, and this analysis has just begun at the time of publication of the Assessment Report.

3.3.5. Peer Review of the Water Budget

Each phase of the water budget is subject to a peer review process. The project team and consultants work closely with the peer reviewers to ensure that the work undertaken is technically sound and meets the requirements of the *technical rules* and relevant provincial guidance. As work on the project progresses, the materials are presented to the peer review committee for their comments. Those comments are considered by the peer review team and consultants and are generally incorporated into the final report. The comments, along with their responses, are also incorporated into a peer review record which becomes a companion to the water budget report. Following completion of the peer review, the draft water budget document is submitted with the peer review record to the Ministry of Natural Resources for acceptance.

The Conceptual and Tier 1 Water Budgets have both successfully completed the peer review process and the drafts have been accepted by the MNR. Work on the Tier 2 Water Budget has been reviewed at various stages. The comments of the peer reviewers have been considered in revised reports. The stress assessment has been considered by the peer reviewers, however their comments have not yet been incorporated into the reports. Final peer review acceptance of the Tier 2 Water Budget is anticipated to be completed during the posting of this report. The material included in this draft of the Assessment Report is based on a final drafts of the Tier 2 analyses submitted to the peer reviewers for their review and comment and comments received on that material., Peer review of the work included in this Assessment Report is not a requirement of the *technical rules*; however the Source Protection Committee relies on the technical experts on the peer review committee to ensure that the work is suitable for the purposes of developing a Source Protection Plan for the area. The Ministry of Natural Resources also relies on the peer review process as part of their review and acceptance of the water budget work.

Due to the peer reviewers having reviewed much of the material as the work progressed, it is not anticipated that changes resulting from the review will have a substantial effect on the stress assessment, the delineation of SGRAs, or the other information presented in this draft of the Assessment Report. It is, however, anticipated that the comments will continue to improve the documentation and interpretation of the work undertaken. Minor changes may be incorporated into the report prior to posting the draft proposed Assessment Report for consultation. If, however, significant changes are required, the need for these changes will be acknowledged in the next version (the proposed Assessment Report), and dealt with through the amended Assessment Report discussed in other sections.

3.4 Water Quantity Stress Assessment

The level of potential for stress is calculated based on the following formula as defined in the *Technical Rules: Assessment Reports*:

$$\%\ \text{Water Demand} = \frac{Demand}{Supply - Reserve} x100$$

Percent Water Demand is calculated separately for groundwater and surface water as are the other terms in the above *percent water demand* equation. Percent Water Demand is calculated at both the Tier 1 and Tier 2 stages and is one of the main criteria in determining if more detailed analysis is required.

For surface water, *Demand* is the monthly estimated *demand* of all surface water sources, *Supply* is the monthly estimated median daily flow, and *Reserve* is the 90th percentile monthly flow, or the flow that is exceeded 90 percent of the time for the month being analyzed.

For groundwater, supply includes a number of components as discussed above. For the Tier 1 Water Budget, supply is simplified to include only recharge in the subwatershed. For the Tier 2 water budget, a calibrated groundwater model is used to estimate groundwater flows into the subwatersheds., and this quantity, plus the estimated recharge, is used as the supply. Groundwater flow into the watershed can be calculated through the use of a calibrated groundwater model.

Groundwater reserve is 10% of the supply, as required in the *Technical Rules: Assessment Reports*. A water reserve estimate is intended to protect a portion of water from being considered within the stress calculations, adding a conservative element to this calculation. This water is removed from the supply in the stress assessment.

The *Percent Water Demand* is used as an indication of the stress level in the *watershed* or *subwatershed*. This stress level is described in this document as the "potential for stress" as it better describes the situation given the *uncertainty* associated with the calculations. Generally, a Tier 1 and Tier 2 *stress assessment* are understood to have *uncertainty* associated with the *percent water demand* calculations. The uncertainty is reduced in Tier 2 over that in Tier 1, but cannot be eliminated entirely. At the completion of the Tier 1 and Tier 2 Water Budgets, it is important to understand that conclusions drawn from these analyses are indicative of whether more analysis is required but are not an absolute determination that there is *stress*. Given the level of conservatism, as discussed above, this is especially important when considering the *subwatersheds* which are being described as having a significant potential for *stress*. However,

for the *subwatersheds* which are described as having a low potential for *stress*, this conservatism clearly indicates that they do not have a significant level of *stress*.

The sensitivity analysis required for *subwatersheds* which are almost moderate gives even more confidence in this conclusion. This sensitivity analysis ensures that all *subwatersheds* with a moderate potential for *stress* also advance to the next stage of analysis, along with those identified with a significant potential for *stress*. At the next stage, additional analysis is required to improve the *water demand estimate* and, in the case of Tier 2 , the *stress* level, with a higher level of confidence. If a moderate or significant potential for *stress* is determined to exist in the Tier 1 or Tier 2 analysis and affects a municipal water supply, additional analysis would be undertaken through the Source Protection program. If a *subwatershed* with a municipal system is found to have a moderate or significant potential for stress in Tier 2, it then moves to a Tier 3 local area risk assessment. In Tier 3 new stress assessments are not made, rather a risk assessment of the reliability of individual systems to be able to meet demand is conducted.

In assessing the potential for *stress*, various scenarios as identified in the *technical rules* must be considered. These scenarios consider current and future municipal *demand* under both average and drought scenarios. Drought scenarios are not considered in the Tier 1 Water Budget, but need to be included in the Tier 2 assessment. These scenario analyses are conducted on *subwatersheds* which contain municipal systems, but under average conditions exhibit low potential for stress. If under average conditions a moderate or significant potential for stress is identified, the next tier work is required, and there is no need for the scenario analysis. The intent of scenario analysis is to ensure *subwatersheds* which exhibit a low potential for stress under average conditions will not be pushed to a higher level by increased future municipal demand, or by drought.

The *subwatersheds* in the *UTRSPA* which this applies to contain small communities with no future growth forecasted, and thus the future analysis does not change the stress assessment. The stress assessment *subwatersheds* have been refined since Tier 1 therefore the revised *subwatersheds* were re-assessed using the Tier 1 methodologies to determine if further Tier 2 assessment was required. In re-conducting the Tier 1 stress assessment with these new *subwatersheds*, all are the *subwatersheds* having a moderate or significant potential for stress

in the Tier 1 analysis were confirmed in Tier 2 to have a moderate or significant potential for stress under the average conditions and therefore no additional drought scenario analysis was required.

Scenario A and B discussed in Table 3-3 below relate to the current and future municipal *demand* (respectively). As there are no additional planned systems in the Upper Thames River Source Protection Area, the scenario related to planned systems (scenario C) is not applicable and therefore not included in Table 3-3. Table 3-4 describes the potential for *stress* based on the *percent water demand* for the applicable scenarios which must be compared to the ranges shown in Table 3-3. Additional criteria as described in Rule 32 and 33 are also considered in the stress assessment. If the intake or well was not able to operate due to insufficient quantity of water or a low water level, the potential for *stress* is described as moderate and the *subwatershed* would advance to the next tier.

Table 3-3 potential for stress based on *percent water demand* under current and future municipal water demand

Potential for Stress	Surface Water % Water Demand	Groundwater % Water Demand	
Based on	Max'm monthly	Max'm monthly	Avg annual
Significant	Greater than or equal to 50%	Greater than or equal to 50%	Greater than or equal to 25%
Moderate	Less than 50% but greater than 20% (or between 18 and 20%, inclusive, but under sensitivity analysis increases to greater than 20%)	Less than 50% but greater than 25%	Less than 25% but greater than10% (or between 8 and 10%, inclusive, but under sensitivity analysis increases to greater than 10%)
Low	Less than or equal to 20% (after sensitivity analysis if between 18 and 20%, inclusive)	Less than or equal to 25%	Less than or equal to 10% (after sensitivity analysis if between 8 and 10%, inclusive)

Table 3-4 Surface water potential for stress based on Tier 1 stress assessment (Month of August)

Subwatershed	Code	Supply (Q_{50})	Reserve (Q_{90})	Demand	Potential for stress
North Thames River/Whirl Cr.	01T	8251	907	1466	Low
Flat Cr./North Thames Tributaries	02T	0	0	241	Low
Black Cr./Avon River	03T	36202	20779	1464	Low
Trout Cr.	04T	148349	91584	708	Low
N. Thames/Medway R.	05T	293371	162346	17115	Low
Thames R. above Pittock Reservoir	06T	161784	99878	3585	Low
Cedar Cr.	07T	18749	8640	1692	Low
Reynolds Cr./Thames R. above Ingersoll	08T	226757	157594	7548	Low
Middle Thames R.	09T	51840	24970	2602	Low
Waubuno Cr./Thames R. Tributaries	10T	396835	258854	23554	Low
Thames R. between the Forks and Dutton*	11T*	933120	606874	29659	Low

* Subwatershed 11T crosses over the Upper and Lower Thames boundary, and as such numbers reported are for both source protection authorities in this subwatershed

Table 3-5 Groundwater potential for stress (Average Annual Conditions)

Subwatershed	Source of data	Code	Q_{supply}	$Q_{reserve}$	Q_{demand}	Potential for stress
North Thames River/Whirl Cr.	Tier 1	401	114872	11487	5609	5%
Flat Cr./North Thames Tributaries	Tier 1	402, 403	38459	3846	352	1%
Black Cr.	Revised Tier 1	405	64800	3456	2160	4%
Avon River	Tier 2	404	53568	3456	12442	25%
Trout Cr./North Thames River	Tier 2	406, 407, 408, 410	133056	8640	19872	16%
N. Thames/Medway R.	Revised Tier 1	409, 411, 412, 413	289440	17280	22464	8%
Thames R. above Pittock Reservoir	Tier 1	303	140934	14093	5757	5%
Cedar Cr.	Tier 2	301, 302	50112	1728	18922	39%
Thames R. above Ingersoll	Tier 2	304, 305	87264	5184	864	1%
Reynolds Cr.	Revised Tier 1	306	133920	3456	71712	55%
Middle Thames R.	Tier 1	307	158916	15892	15558	11%
Waubuno Cr./Thames R. Tributaries	Tier 1	308	201081	20108	9153	5%
Thames R. between the Forks and Dutton*	Tier 1	501	445491	44549	10337	3%

* Subwatershed 501 crosses over the Upper and Lower Thames boundary, and as such numbers reported are for both source protection authorities in this subwatershed

Table 3-6 Groundwater potential for stress (Maximum Monthly Conditions)

Subwatershed	Source of data	Code	Q_{supply}	$Q_{reserve}$	Q_{demand}	Potential for stress
North Thames River/Whirl Cr.	Tier 1	401	114872	11487	7743	7%
Flat Cr./North Thames Tributaries	Tier 1	402, 403	38459	3846	352	1%
Black Cr./Avon River (405)	Revised Tier 1	405				
Black Cr./Avon River (404)	Tier 2	404				
Trout Cr./N. Thames River	Tier 2	406, 407, 408, 410				
N. Thames/Medway River.	Revised Tier 1	409, 411, 412, 413				
Thames R. above Pittock Reservoir	Tier 1	303	140934	14093	13589	11%
Cedar Cr.	Tier 2	301, 302				
Reynolds Cr.	Tier 2	304, 305				
Thames R. above Ingersoll	Revised Tier 1	306				
Middle Thames R.	Tier 1	307	158916	15892	19133	13%
Waubuno Cr./Thames R. Tributaries	Tier 1	308	201081	20108	12342	7%
Thames R. between the Forks and Dutton*	Tier 1	501	445491	44549	34032	8%

* Subwatershed 501 crosses over the Upper and Lower Thames boundary, and as such numbers reported are for both source protection authorities in this subwatershed

Map 3-5 indicates the Tier 1 potential for stress on surface water sources, Map 3-6 and illustrates the Tier 1 and Tier 2 potential for stress on groundwater sources.

From the Tier 2 Stress Assessment, municipal systems which are moving to a Tier 3 analysis include:

- Stratford
- St. Marys
- St Pauls
- Woodstock
- Beachville
- Ingersoll

Tier 3 work is underway for these systems as of May 2010, and is expected to be completed by December 2011. Data compilation has begun, and should be completed by October 2010. Modelling will begin in October 2010, and should be completed by July 2011. The risk assessment and final reporting is expected to begin in July 2011, and being finished in Dec 2011. This schedule is highly dependant on data availability and funding.

3.4.1. Uncertainty in the Stress Assessment

As the *stress* assessment for the Upper Thames River Source Protection Area was completed as part of the Tier 1 and Tier 2 Water Budgets, some uncertainty in the data and analysis is expected. Tier 2 work does reduce uncertainty from what is expected in Tier 1, but does not eliminate it, and thus the requirement to move ahead with Tier 3 in some areas, where uncertainly must be further reduced. It is especially important that the uncertainty associated with the Tier 1 analysis be considered in interpreting the surface water stress assessment. Although this *uncertainty* has no effect on the Source Protection Plan it is of considerable importance in interpreting this analysis for use in other programs such as the Permit to Take Water Program.

3.5 Significant Groundwater Recharge Areas

Significant Groundwater Recharge Areas (*SGRA*s) are delineated through the water budget work. These areas are determined through the use of the recharge calculated in the Tier 2 Water Budget and discussed in Section 3.2.4 above. Rule 44 allows recharge to be compared

with the average recharge of the area, or to the effective precipitation (precipitation less evaporation) of the area to determine if the recharge at that location is significant. Rule 44 identifies the criteria for determining whether a recharge area is significant:

- the area annually recharges water to the underlying aquifer at a rate that is greater than the rate of recharge across the whole of the related groundwater recharge area by a factor of 1.15 or more; or
- the area annually recharges a volume of water to the underlying aquifer that is 55% or more of the volume determined by subtracting the annual evapotranspiration for the whole of the related groundwater recharge area from the annual precipitation for the whole of the related groundwater recharge area.

Rule 44(1) was used in the TSR to determine the *SGRA*s, and the entire Upper Thames basin was used as "the whole of the groundwater recharge area" for the purposes of determining average recharge. The average recharge of the entire Upper Thames River is 132 mm/a. According to Rule 44(1), this is multiplied by 1.15 to provide the criteria of *SGRA*. Therefore 151 mm/a is the threshold used to determine the significance of groundwater recharge areas in the Upper Thames River Source Protection Area.

Rule 45 indicates that the area must have "a hydrological connection to a surface water body or aquifer that is a source of drinking water for a drinking water system". For the purposes of this rule a drinking water system can be any water well including a single residential water well. Map 34 in Thames Watershed Characterization Report summary included as Appendix 5 illustrates that wells are located throughout the region. In areas where shallow sandy deposits provide for recharge areas, well installation is simple through the use of sand points driven to a modest depth. These types of water wells are, in most cases, installed without a permit and therefore not included in the water well information system used to produce Map 34. Further, it is not intended by the *technical rules* that the connection be direct or immediate, but rather that there is a "hydrologic connection". This recognizes that water not only flows vertically through the ground but also flows laterally from areas of higher levels to areas of lower water levels. Thus, it is generally accepted that aquifers are recharged from areas up gradient from the aquifer as well as directly above. Thus, a precautionary and conservative approach is warranted and all areas which meet the criteria for significance are included as *SGRA*.

Map 4-8 illustrates the *Significant Groundwater Recharge Areas* in the Upper Thames River Source Protection Area. The vulnerability of the *SRGAs* is considered in the Vulnerability Assessment section of the Assessment Report. It is, however, important to point out that the *SGRAs* which are coincident with *Highly Vulnerable Aquifers* (*HVA*), will receive a vulnerability score of 6 which can result in a moderate threat, while activities in the other *SGRAs* cannot result in water quality *threats* due to the *vulnerability* score being 4 or less.

3.6 Data Gaps and Next Steps

Table 3-7 summarizes data gaps identified through the Tier 1 and Tier 2 Water Budgets and Water Quality Stress Assessments. As the *stress* assessment was completed through a combination of Tier 1 and Tier 2 Water Budgets, it is expected that there would be data gaps. In the case of surface water analysis, if work was to proceed to Tier 2, many of these gaps would need to be addressed at that time. In the case of groundwater analysis, work proceeding to tier 3 will address many of the data gaps found in Tier 2.

These gaps do not affect the reliability of the analysis for use in the development of the Source Protection Plan.

Table 3-7 Data gaps related to Water Budget and Water Quantity Stress Assessment

Gap	Description
	•
Improved understanding of water use	• Obtain actual water use data from all significant water users through the PTTW reporting system • Requires reassessment after sufficient data has been reported, perhaps when Assessment Report requires future update • Where Tier 3 assessment will be undertaken, updated PTTW will be considered to the extent that the data is available
Completion of the peer review of the T2WB	• Receive and consider comments of the peer reviewers prior to submission of the T2WB report to MNR for acceptance • Finalize the peer review record
Un-gauged Areas	• Surface Water Model to better understand distribution of flows in un-gauged subwatersheds
Climate Change	• Requires an understanding of the local climactic conditions resulting from global climate change which is not yet available • Consider the change in local climactic conditions in the water budget and the stress assessment when that information is available
Refine ET	• Improve calculation of ET to include consideration of soil types and

	land use at a local level