APPENDIX A
Threats Ranking

MEMORANDUM

TO: Project Team, Guelph/Guelph-Eramosa Water Quantity Policy Development Study

FROM: Paul Chin and Jeff Melchin, Matrix Solutions Inc.

SUBJECT: Threats Ranking – Guelph/Guelph-Eramosa WHPA-Q1 Risk Management Measures Evaluation Process

DATE: June 14, 2018

1 WATER QUANTITY THREATS RANKING PROCESS

A Water Quantity Threats Ranking process was undertaken as part of the Guelph/Guelph-Eramosa Water Quantity Risk Management Measures Evaluation Process (RMMEP). The RMMEP is undertaken for municipalities where the Tier Three Assessment estimated a *moderate* or *significant* water quantity risk level (TRCA 2013a). The purpose of the RMMEP is to evaluate risk management measures that could be used to manage the water quantity risk. The results of the RMMEP will be used to inform the development of water quantity source protection policies.

The *City of Guelph and Township Of Guelph/Eramosa Tier Three Water Budget and Local Area Risk Assessment* (Tier Three Assessment; Matrix 2017) identified a *significant* risk level for WHPA-Q1-A encompassing the City of Guelph (Guelph) municipal wells, and the Hamilton Drive wells owned by the Township of Guelph/Eramosa (GET). The GET municipal wells in Rockwood were found to be contained within separate WHPA-Q1s that had *low* water quantity risk levels and are thus not included in this RMMEP.

An Intake Protection Zone for Quantity (IPZ-Q) was also identified as under being under a *significant* risk level. This IPZ-Q is the upstream catchment for the Eramosa River intake that supplies surface water to the Arkell artificial recharge system which provides water to a shallow aquifer that is recovered through a shallow groundwater collection system (the Glen Collector), and the overburden well, Arkell Well 1. Due to the interconnection between the surface water supplies, and the groundwater system, the IPZ-Q and WHPA-Q1-A were considered together in the Tier Three Assessment.

S*ignificant* drinking water quantity threats were evaluated and ranked according to the impact they created, relative to the safe available drawdown (SADD), at the municipal wells within WHPA-Q1-A. A detailed methodology for the ranking of the *significant* threats is presented in the *Water Quantity Threats Ranking Scenarios Guide* (MOE and MNR 2009).

This memo reports on the Threats Ranking process conducted for WHPA-Q1-A. Recommendations for a Threats Ranking process for the IPZ-Q will be brought to the project team at a later date.

2 IDENTIFICATION OF SIGNIFICANT DRINKING WATER QUANTITY THREATS

As outlined in the Ministry of the Environment and Climate Change (MOECC) Technical Rules (MOECC 2015), a drinking water quantity threat is defined as 1) any consumptive water demand, or 2) any activity that reduces groundwater recharge to an aquifer. Consumptive demands are activities that extract water from an aquifer or surface water body without returning that water to the same aquifer or surface water body.

2.1 Consumptive Water Demands

For each vulnerable area identified under clause 15 (2) (d) or (e) of the *Clean Water Act* (MOE 2006), drinking water threats that are or would be classified as *moderate* or *significant* need to be identified within each vulnerable area. In the Tier Three Assessment, WHPA-Q1-A was assigned a water quantity risk level of *significant*; as such, all consumptive demands within WHPA-Q1-A are classified as *significant* water quantity threats.

Figure 1 illustrates the *significant* threats within WHPA-Q1-A as identified in the Tier Three Assessment. These include 28 municipal wells and 71 non-municipal permitted water takers. There are additional municipal water supply wells (e.g., wells in Cambridge, Rockwood and surrounding municipalities) and other permitted water takers found outside of WHPA-Q1-A as reported in the Tier Three Assessment. Although these are not considered *significant* threats, the ranking scenarios considered all takings found in the study area to understand the sensitivity of the municipal wells within WHPA-Q1-A to these takings.

Municipal water demands within WHPA-Q1-A are given in Table 1. These correspond to the existing and future demand identified in the Tier Three Assessment as follows:

- Existing demand for the "Study Year" – Based on actual pumping for 2008 (Guelph) and 2009- 2010 (GET)
- Future water demands based on projections using:
  - Water Conservation and Efficiency Strategy Update (2009) for Guelph to year 2031
  - Water use and infrastructure studies (2011, 2013) for GET to the year 2020

TABLE 1 Municipal Water Demand within WHPA-Q1-A

Municipal System	Municipal Pumping Rates (m^3/d)		% Increase	Time Horizon
	Existing	Future		
City of Guelph	47,700	71,600 (to 2031)	50%	2031
Hamilton Drive (GET)	179	185 (to 2020)	3%	2020
Total	47,879	71,785	50%	

Permitted, non-municipal consumptive groundwater demand within the WHPA-Q1-A was estimated as 17,200 m^3/d in the Tier Three Assessment.

Non-municipal, non-permitted groundwater demands were identified in the Tier Three Assessment as a *significant* threat, but their consumptive demand was not estimated for that study. An estimate of this non-permitted demand was made for the Threats Ranking and this is discussed under the scenarios below.

2.2 Reductions in Recharge

The Technical Rules (MOECC 2015) specify that land use development activities that have the potential to reduce groundwater recharge are potential water quantity threats within WHPA-Q1-A. The Tier Three Assessment scenarios considered the impact of future land use development activities on water levels in the municipal wells. All reductions in groundwater recharge within WHPA-Q1-A are also classified as *significant* water quantity threats and are shown on Figure 1. These areas of recharge reduction were identified in the Tier Three Assessment and were a total of 16 km^2 or 5% of the WHPA-Q1-A area.

3 THREATS RANKING SCENARIOS

A series of scenarios were conducted using the Tier Three Assessment groundwater budget model. These scenarios were designed to evaluate and rank the *significant* threats according to the impact they created relative to the SADD at the municipal wells within WHPA-Q1-A.

A baseline scenario was conducted which was the benchmark against which all modelling results were compared. When a municipal system was assigned a *significant* risk level for future demands the baseline scenario is to be one with existing conditions (MOE and MNR 2009). This situation exists for this WHPA-Q1-A and thus the Baseline scenario included the existing land use conditions and municipal groundwater pumping at the existing conditions (as defined in the Tier Three Assessment; Matrix 2017). For this study, the Baseline scenario included all municipal pumping wells in the whole Tier Three study area including that of Cambridge, Rockwood, and surrounding municipalities for total municipal pumping from wells of 71,266 m^3/d as shown in Table 2

TABLE 2 Municipal Well Pumping Rates – Baseline and Future Rates

Well	Existing Pumping Rates (2008)	Future Pumping Rates	Difference between Existing & Future Pumping Rates
	m^3/day	m^3/day	m^3/day
City of Guelph[2]			
Arkell 1	730	1,400	670
Arkell 14	-	3,300	3,300
Arkell 15	-	3,300	3,300
Arkell 6	3,774	4,900	1,126
Arkell 7	3,689	4,900	1,211
Arkell 8	3,694	4,900	1,206
Burke	5,385	6,000	615
Calico	748	1,100	352
Carter Wells	3,400[1]	4,000	600
Clythe Creek	-	2,200	2,200
Dean Ave.	1,215	1,500	285
Downey Rd.	3,940	5,100	1,160
Emma	2,600[1]	2,100	-500
Helmar	800[1]	1,100	300

Well	Existing Pumping Rates (2008)	Future Pumping Rates	Difference between Existing & Future Pumping Rates
	m^3/day	m^3/day	m^3/day
Membro	3,036	4,200	1,164
Paisley	762	800	38
Park 1 & 2	6,400[1]	6,400	-
Queensdale	702	2,000	1,298
Sacco	-	1,150	1,150
Smallfield	-	1,400	1,400
University	1,648	2,500	852
Water Street	1,184	2,300	1,116
SUB-TOTAL	**43,707**	**66,550**	**22,843**
Hamilton Drive			
Cross Creek	87[3]	90	3
Huntington	92[3]	95	3
SUB-TOTAL	**179**	**185**	**6**
Rockwood			
Rockwood Well 1	283[3]	396	112
Rockwood Well 2	262[3]	367	105
Rockwood Well 3	422[3]	572	150
Rockwood Well 4	0[4]	572	572
SUB-TOTAL	**967**	**1,907**	**940**
Region of Waterloo[5]			
C2	4	4	-
C5	111	111	-
G16	1,664	2,938	1274
G17	1,995	2,160	165
G18	992	1,296	304
G38	0	1,296	1296
G39	0	3,024	3024
G5	1,638	1,296	-342
G6	1,347	864	-483
G7	2,306	1,728	-578
G8	1,206	864	-342
G9	1,002	0	-1002
H3	563	864	301
H4	0	1,296	1296
H5	383	864	481
MH1	18	18	-
MH2	22	22	-
P10	2,943	3,110	167
P11	1,131	1,728	597
P15	962	1,296	334
P6	883	0	-883
P9	1,474	1,296	-178
SUB-TOTAL	**20,644**	**26,075**	**5,431**
Other Municipal Wells in Study Area[6]			
4th Line Well A	1,031	1031	-
Davidson 1	780	780	-
Davidson 2	780	780	-

Well	Existing Pumping Rates (2008)	Future Pumping Rates	Difference between Existing & Future Pumping Rates
	m^3/day	m^3/day	m^3/day
Prospect Park 2	1344	1344	-
Erin 7	734	734	-
Erin 8	648	648	-
Hillsburgh 2	216	216	-
Hillsburgh 3	216	216	-
SUB-TOTAL	**5,749**	**5,749**	**-**
TIER THREE STUDY AREA TOTAL	**71,246**	**100,465**	**29,220**

Notes:

[1]Same rates were used in the Tier Three Assessment and are based on the typical pumped rates for which a typical pumped water level has been observed, rather than the 2008 average pump rate used for the water demand calculations (see Section 5.5.1.1 and Appendix F in Matrix 2017).

[2]Does not include that recovered by the Arkell Glen Collector or introduced by the Arkell recharge system

[3]Same rates were used in the Tier Three Assessment and are based on the 2009 to 2010 average pump rate.

[4]Rockwood Well 4 was commissioned in 2016 and was not pumped during the Tier Three Study Period (2009 to 2010).

[5]Region of Waterloo well rates taken from Region of Waterloo Tier Three Matrix 2017b.

[6]Municipal well rates outside of area of influence of Tier Three wells were held constant in Tier Three Assessment.

The municipal demand referenced in the following Threats Ranking analysis does not include the amount of water pumped from the Eramosa River intake and delivered to the Arkell recharge system, nor does it include the volume of water recovered by the Arkell Glen Collector. The latter is a passive, gravity-fed system, and it is simulated in the model as a constant head boundary, rather than a pumping well. The municipal demand quoted below only includes that represented by pumping wells in the groundwater flow model.

The relative measure of a threat's impact on a municipal well in WHPA-Q1-A is given as a "percent impact" as defined in Section 3.1. This measure is used to rank the threats in the Threats Ranking scenarios described in Sections 3.2 to 3.4.

3.1 Percentage Impacts and Threats Ranking

For the scenarios described in the following sections, the percent impacts at each WHPA-Q1-A municipal well for each scenario were calculated according to the following formula:

$$Percent\ Impact = \frac{Incremental\ Drawdown\ Scenario\ 'a'}{Safe\ Available\ Drawdown\ (baseline)} \times 100\%$$

Where:

Percent Impact is the modelled drawdown in a municipal well resulting from the simulation of Scenario 'a', relative to the total SADD (baseline of that municipal well.

Incremental Drawdown Scenario 'a' is the difference between the simulated water level in a municipal well under the baseline (existing) conditions, and the simulated water level for a particular scenario.

Safe Available Drawdown (baseline) is the distance between the water level at a municipal well in the baseline (existing) condition and the minimum elevation at which the well can pump at an unrestricted rate. This is different from the Safe Additional Available Drawdown used in the Tier Three Assessment that was based on the average pumped water level in the municipal wells when all wells in the study area are pumping at their existing rates (Scenario C; Matrix 2017).

3.2 Level I Scenarios

Level I scenarios are mandatory scenarios that examined the cumulative impact of all current or future consumptive water uses, or future land use developments, on the municipal water supplies. Level I scenarios identify which groups of takings or land use developments warrant a more detailed level of investigation. Table 3 summarizes the Baseline scenario and the Level I scenarios conducted for this study.

TABLE 3 Threats Ranking Scenarios – Baseline and Level I

Scenario	Description	Municipal Takings[1]	Permitted Takings[2]	Non-Permitted Takings	Land Use	Rationale
Baseline	Baseline Scenario	Existing 71,266 m^3/d	None	None	Existing	This scenario forms the baseline against which all model scenarios were compared. Pumping from all municipalities was included.
I-A	Municipal Water Use (Allocated rates)	Future Rates (Allocated)[3] 100,485 m^3/d	None	None	Existing	Quantify the impact of increasing municipal pumping to Allocated rates (from Existing rates) on the municipal water supplies.
I-B	All Non-permitted Takings (i.e., Domestic)	Existing 71,266 m^3/d	None	Existing 2,990 m^3/d	Existing	Quantify the impact of all non-permitted demands on the municipal supplies.
I-C	All Permitted, Non- municipal	Existing 71,266 m^3/d	Existing Total Consumptive use: 31,331 m^3/d	None	Existing	Quantify the impact of all permitted water demands on municipal water supplies.
I-D	Recharge Reductions – Official Plans	Existing 71,266 m^3/d	None	None	Official Plans	Quantify the cumulative impact of recharge reduction from all developments in the Official Plans on municipal water supplies.

Notes:

[1]Does not include that recovered by the Arkell Glen Collector or introduced by the Arkell recharge system

[2]The consumptive use rates are from the Tier Three Assessment and represent actual or estimated pumping during or prior to 2008.

[3]Future Rates include all municipal wells in Study Area (i.e., Guelph, Hamilton Drive, Rockwood, Cambridge, and other surrounding municipalities).

3.2.1 Scenario I-A

Scenario I-A quantified the impact of increased municipal pumping throughout the study area on the municipal wells within the WHPA-Q1-A. Municipal wells were pumped at their Allocated rates as defined in the Tier Three Assessment while all other water takings remained off. Total Allocated rate for all municipal wells was 100,485 m^3/d and including wells for Guelph, Hamilton Drive, Cambridge, Rockwood, and other surrounding municipalities. Existing land use development was used for this scenario.

3.2.2 Scenario I-B

Scenario I-B quantified the impact of all non-permitted demands on the water supplies. For this scenario, non-permitted demands were estimated using the MOECC Water Well Information System (WWIS). Over 11,500 water wells were identified throughout the study area that were not already included as wells in the model. These water wells were assumed to be domestic wells using an average of 260 L/day per household as per the *Water Quantity Threats Ranking Scenarios Guide* (MOE and MNR 2009). These were considered as 100% consumptive use as a majority of wells source their water from the deep bedrock aquifers and do not return the water to those aquifers. Total non-permitted groundwater demand for the study area was estimated as 2,990 m^3/d. This was added to the baseline municipal pumping for this scenario. Existing land use conditions were applied in this scenario.

3.2.3 Scenario I-C

Scenario I-C quantified the impact of permitted, non-municipal takings throughout the Tier Three study area on municipal wells inside WHPA-Q1-A. A total of 147 permitted, non-municipal, groundwater takings were represented for a total additional water demand of 31,331 m^3/d. This demand is based on consumptive use rates tabulated for the Tier Three Assessment and represent actual or estimated pumping during or prior to 2008. Existing land use conditions and municipal pumping at the existing pumping rates were represented in this scenario.

3.2.4 Scenario I-D

Scenario I-D quantified the impact of recharge reduction from future land developments specified in the Official Plans. Future land use throughout the study area, not just within WHPA-Q1-A, was considered in this scenario to evaluate the sensitivity of municipal wells to all land use changes occurring nearby. Baseline municipal pumping at existing pumping rates was included in this scenario.

3.2.5 Results

The Level I scenarios determined that the greatest percent impacts are caused by increasing pumping at municipal wells to their Allocated (planned) rates. The next greatest impact is caused by the permitted takings pumping at their existing, consumptive rates. Detailed results are given in **Attachment 1: Level I Results** and summarized in Table 4. For Scenario I-A, increasing municipal pumping to the Allocated rates caused a 91% impact at Queensdale Well (i.e., the increased pumping caused increased drawdown equivalent to 91% of the SADD at Queensdale Well). Scenario I-C, with permitted, non-municipal pumping added to the baseline pumping, accounted for an increase drawdown at Dean Ave. Well of 47% of the SADD. Domestic wells and recharge reductions due to future development (Scenarios I-B and I-D)

had minor impacts at the municipal wells. These results led to Level II scenarios focusing on the municipal and permitted, non-municipal sectors.

TABLE 4 Level I Scenario Results

Scenario	Greatest % Impact	Well Under Greatest % Impact
I-A: Municipal Planned	91%	Queensdale
I-B: All Non-Permitted (Domestic)	1%	Helmar
I-C: All Permitted, Non-Municipal	47%	Dean Ave.
I-D: Recharge Reductions	7%	Burke

3.3 Level II Scenarios

Level II scenarios examine sector-based scenarios which identify the potential impact that classes of permitted and non-permitted water takings and future land development have on municipal water supplies. Sectors selected for Level II scenarios were based on the results of the Level I scenarios.

Table 5 summarizes the Level II scenarios that were conducted for the municipal sector and Table 6 lists the scenarios conducted for the permitted, non-municipal sectors.

TABLE 5 Threats Ranking Scenarios - Level II-A Municipal Sector

Scenario	Description	Municipal Takings[1]	Permitted Takings	Non-Permitted Takings	Land Use	Rationale
II-A-i	Guelph Planned Municipal Water Use (Allocated rates)	Guelph - Future Rates (Allocated) 66,550 m^3/d Others – Existing Rates 27,558 m^3/d Total: 94,108 m^3/d	None	None	Existing	Quantify the impact of increasing Guelph municipal pumping to Allocated rates (from Existing rates) on the municipal water supplies.
II-A-ii	Hamilton Drive (GET) Planned Municipal Water Use (Allocated rates)	Hamilton Drive (GET) - Future Rates (Allocated) 185 m^3/d Others – Existing Rates 71,087 m^3/d Total: 71,272 m^3/d	None	None	Existing	Quantify the impact of increasing Hamilton Drive (GET) municipal pumping to Allocated rates (from Existing rates) on the municipal water supplies.
II-A-iii	Cambridge Planned Municipal Water Use (Allocated rates)	Cambridge - Future Rates (Allocated) 26,075 m^3/d Others – Existing Rates 50,624 m^3/d Total: 76,699 m^3/d	None	None	Existing	Quantify the impact of increasing Cambridge municipal pumping to Allocated rates (from Existing rates) on the municipal water supplies.

Scenario	Description	Municipal Takings[1]	Permitted Takings	Non-Permitted Takings	Land Use	Rationale
II-A-iv	Rockwood (GET) Planned Municipal Water Use (Allocated rates)	Rockwood (GET) - Future Rates (Allocated) 1,907 m^3/d Others – Existing Rates 70,299 m^3/d Total: 72,206 m^3/d	None	None	Existing	Quantify the impact of increasing Rockwood (GET) municipal pumping to Allocated rates (from Existing rates) on the municipal water supplies.

Note:
[1]Does not include that recovered by the Arkell Glen Collector or introduced by the Arkell recharge system

TABLE 6 Threats Ranking Scenarios - Level II-C Permitted, Non-Municipal Sectors

Scenario	Description	Municipal Takings[1]	Permitted Takings[2]	Non-Permitted	Land Use	Rationale
II-C-i	Dewatering Permits inside WHPA-Q1-A	Existing 71,266 m^3/d	1 Dewatering Permit Total consumptive use: 8,800 m^3/d	None	Existing	Quantify the impact of Dewatering Permits inside WHPA-Q1-A on the municipal water supplies.
II-C-ii	Commercial Permits inside WHPA-Q1-A	Existing 71,266 m^3/d	4 Commercial Permits Total consumptive use: 2,667 m^3/d	None	Existing	Quantify the impact of Commercial Permits inside WHPA-Q1-A on the municipal water supplies.
II-C-iii	Industrial Permits inside WHPA-Q1-A	Existing 71,266 m^3/d	16 Industrial Permits Total consumptive use: 3,887 m^3/d	None	Existing	Quantify the impact of Industrial Permits inside WHPA-Q1-A on the municipal water supplies.
II-C-iv	All Other Permits outside WHPA-Q1-A	Existing 71,266 m^3/d	94 other Permits outside WHPA-Q1-A Total consumptive use: 14,106 m^3/d	None	Existing	Quantify the impact of all other Permits outside WHPA-Q1-A on the municipal water supplies.
II-C-v	All Other Permits inside WHPA-Q1-A	Existing 71,266 m^3/d	32 other Permits inside WHPA-Q1-A Total consumptive use: 1,872 m^3/d	None	Existing	Quantify the impact of all other Permits inside WHPA-Q1-A on the municipal water supplies.

Notes:
[1]Does not include that recovered by the Arkell Glen Collector or introduced by the Arkell recharge system
[2]The consumptive use rates are from the Tier Three Assessment and represent actual or estimated pumping during or

3.3.1 Results

Detailed results for the Level II scenarios for the municipal sector are given in **Attachment 2: Level II-A Results** and summarized in Table 7. The Level II-A scenarios determined that the greatest impacts are caused by increasing pumping at the Guelph municipal wells to their Allocated (Planned) rates. 91% of the SADD at Queensdale Well is used by the increase in pumping rates at the Guelph municipal wells. The remaining scenarios had negligible percent impacts.

TABLE 7 Level II-A Municipal Sector Results

Scenario	Greatest % Impact	Well under Greatest % Impact
II-A-i: Guelph Planned	91%	Queensdale
II-A-ii: Hamilton Drive (GET) Planned	<1%	
II-A-iii: Cambridge Planned	<1%	
II-A-iv: Rockwood Planned	1%	Arkell 1

Results for the Level II-C permitted, non-municipal sectors are presented in **Attachment 3: Level II-C Results** and summarized in Table 8. The Level II-C scenarios determined that the greatest impacts are caused by the dewatering permit inside WHPA-Q1-A, followed by the industrial and commercial permits. 45% of the SADD at Membro Well was used by adding the pumping of the dewatering permit to the baseline municipal pumping. These results helped focus the Level III scenarios to examining individual takings within these particular sectors.

The other sectors resulted in 10% impact or less at the wells. For Scenario II-C-v, the other permits inside WHPA-Q1-A were relatively small water takings and a single water taking (registered to Homewood Corp. [Permit No. 3036-6QPKHE]) located 400 m south of the Emma Well was identified as responsible for the 9.8% impact at Emma Well. Therefore, Level III scenarios were not necessary for this sector.

TABLE 8 Level II-C Permitted, Non-Municipal Sectors Results

Scenario	Greatest % Impact	Well under Greatest % Impact
II-C-i: Dewatering	45%	Membro
II-C-ii: Commercial	3%	Burke
II-C-iii: Industrial	4%	Queensdale
II-C-iv: All Others (outside WHPA Q1)	<1%	Downey Road
II-C-v: All Others (inside WHPA Q1)	10%	Emma

3.4 Level III Scenarios

Level III scenarios are locally-relevant scenarios which estimate the influence of specific water users or land use changes on municipal water supplies. Level III scenarios were chosen based on the Level II scenario results.

3.4.1 Impact of Individual Guelph Municipal Wells

The relative impact of each of the Guelph municipal wells was tested through the Level III-A scenarios. Each Guelph municipal well was individually increased to its Allocated rate and the percent impacts were calculated at all the municipal wells within WHPA-Q1-A. The municipal water supplies in Arkell

were treated as a group as there is complex interaction amongst the five bedrock wells, the overburden well and the artificial recharge and Glen Collector systems. The results are given in **Attachment 4: Level III-A Results** and summarized in Table 9.

TABLE 9 Level III-A Guelph Municipal Well Results

Scenario	Greatest % Impact	Well under Greatest % Impact
III-A: Queensdale	72%	Queensdale
III-A: Water Street	17%	Water Street
III-A: Dean Ave.	4%	Dean Ave.
III-A: Membro	13%	Membro
III-A: Clythe Creek	32%	Clythe Creek
III-A: Helmar	19%	Helmar
III-A: University	7%	University
III-A: Downey Road	12%	Downey Road
III-A: Paisley	2%	Paisley
III-A: Sacco	22%	Sacco
III-A: Calico	24%	Calico
III-A: Smallfield	19%	Smallfield
III-A: Carter Wells	17%	Carter Wells
III-A: Burke	15%	Burke
III-A: Arkell System	53%	Arkell 8

3.4.2 Impact of Individual Permitted, Non-Municipal Wells

The relative impact of permitted, non-municipal wells within the dewatering, industrial and commercial sectors within WHPA-Q1-A was tested through the Level III-C scenarios. Each well was individually added to the baseline pumping and the percent impacts were calculated at all the municipal wells within WHPA-Q1-A. The results are given in **Attachment 5: Level III-C Results** and summarized in Table 10.

TABLE 10 Level III-C Permitted, Non-Municipal Sectors Results

Scenario	Greatest % Impact	Well under Greatest % Impact
III-C-i: 5080-8TAKK2 (Dewatering)	45%	Membro
III-C-ii: 1381-95ATPY (Commercial)	1%	Burke
III-C-iii: 88-P-2069 (Industrial)	4%	Queensdale
III-C-iv: 1245-AB8RMW (Industrial)	2%	Emma
III-C-v: 2768-6QXRCC (Industrial)	<1%	
III-C-vi: 1204-62XKA (Industrial)	<1%	

- Scenario III-C-i quantified the impact of the single dewatering permit in WHPA-Q1-A. Permit No. 5080-8TAKK2 (previously 7240-65YKTN) issued to River Valley Developments was simulated in the Tier Three model as removing 8,800 m^3/d. 45% of the SADD at Membro Well was used by this permit.

- Scenario III-C-ii quantified the impact of a large commercial permit in WHPA-Q1-A belonging to Nestle Waters Canada. Permit No. 1381-95ATPY (previously 7043-74BL3K) is simulated in the Tier Three model as removing 2,396 m^3/d. This permit had a negligible impact on the nearest municipal well, Burke Well, with only 1% of the SADD being used.

- Scenario III-C-iii involved an industrial permit located to the west of the City in GET. Permit No. 88-P-2069 was issued to Coldpoint Industries, but it is currently listed as expired as of 2009. It was simulated in the Tier Three model as pumping 655 m^3/d and caused a minor drawdown in Queensdale Well equivalent to 4% of the SADD.

- Scenario III-C-iv to vi simulated three industrial permits located in various locations of WHPA-Q1-A. Permit Nos. 1245-AB8RMW (Gay Lea Foods; previously 6800-72CLQH), 2768-6QXRCC (Flowchem Ltd.) and 1204-62XKA (Holody Electro Plating Ltd.) were individually simulated as pumping 105 m^3/d, 79 m^3/d and 53 m^3/d, respectively. In these three scenarios, the permits had negligible impacts on municipal wells.

3.5 Threats Ranking

The results from the Threats Ranking scenarios outlined above allow the *significant* water quantity threats in WHPA-Q1-A to be ranked according to the greatest percent impact they caused relative to the SADD at the municipal wells. This serves to identify the threats that have the greatest potential to benefit from risk management measures to reduce the overall impact. The Threats Ranking is summarized in Table 11.

TABLE 11 Threats Ranking – WHPA-Q1-A

Rank	Water Quantity Threat	Greatest % Impact	Well under Greatest % Impact
1	Queensdale Well	72%	Queensdale
2	Arkell System	53%	Arkell 8
3	5080-8TAKK2 (River Valley Developments)	45%	Membro
4	Clythe Creek Well	32%	Clythe Creek
5	Calico Well	24%	Calico
6	Sacco Well	22%	Sacco
7	Helmar Well	19%	Helmar
8	Smallfield Well	19%	Smallfield
9	Carter Wells	17%	Carter Wells
10	Water St. Well	17%	Water St.
11	Burke Well	15%	Burke
12	Membro Well	13%	Membro
13	Downey Well	12%	Downey
14	All Permitted, Non-Municipal Takings Inside WHPA-Q1-A except Dewatering, Commercial, and Industrial (32 permits as of 2008)	10%	Emma
15	University Well	7%	University
16	Recharge Reduction (due to future Land Use)	7%	Burke
17	Dean Well	4%	Dean
18	88-P-2069 (Coldpoint Industries - Expired)	4%	Queensdale
19	Paisley Well	2%	Paisley
20	1245-AB8RMW (Gaylea Foods)	2%	Emma

Rank	Water Quantity Threat	Greatest % Impact	Well under Greatest % Impact
21	1381-95ATPY (Nestle Waters)	1%	Burke
22	Planned Municipal Takings: Rockwood (GET)	1%	Arkell 1
23	All Non-Permitted Takings (WWIS - Domestic)	1%	Helmar
24	Planned Municipal Takings: Hamilton Drive (GET)	<1%	
25	1204-62XKA (Holody Electro Plating)	<1%	
26	2768-6QXRCC (Flochem)	<1%	
27	Planned Municipal Takings: Cambridge	<1%	
28	All Permitted Non-Municipal Takings Outside WHPA-Q1-A	<1%	

This ranking shows that the Guelph municipal wells were the water quantity threats that had the most impact in WHPA-Q1-A. A total of 13 out of the top 15 ranked threats are Guelph municipal wells having the greatest percent impact on themselves. The increase of pumping at Queensdale Well from the existing rate to the future rate is responsible for 72% impact within Queensdale Well. The Arkell System is ranked second accounting for a 53% impact at Arkell 8 and 39% or more at the other Arkell bedrock wells (see **Attachment 4**).

The dewatering permit for River Valley Developments is ranked third, impacting Membro at 45% of the SADD. The next highest ranked non-municipal threat group was the permitted, non-municipal takings inside WHPA-Q1-A minus the dewatering, commercial, and industrial permits. This group ranked 14th and impacted Emma Well at 10%, but this can be accounted for by a small institutional taking (137 m^3/d) 400 m to the south.

Recharge reductions due to land use development to Official Plans was ranked 16th related to the impacts of 7% of the SADD at Burke Well. It is noted that at the time of the Tier Three Assessment (using Guelph Official Plan Amendment 48), the Clair-Maltby development lands were listed as "Reserve Lands" and were not assigned any imperviousness change from the existing conditions. These reserve lands within the Clair-Maltby development total about 1.2 km^2.

The remaining threats did not have notable impacts (<5%) on the municipal wells.

The results of the Threats Ranking were used to inform the next tasks, which involved selecting Risk Management Measures (RMM) and designing RMM Scenarios.

4 EVALUATING WATER QUANTITY RISK MANAGEMENT MEASURES

The purpose of this task is to evaluate the potential for RMM to mitigate the water quantity threats and reduce the water quantity risk level identified through the Tier Three Assessment. This task makes use of the RMM Catalogue (TRCA 2013b), a web-based tool that is used to select management measures. It presently contains about 80 water quantity RMM, that are grouped into one or more of the following water conservation and "terrain" (e.g., land-use and land-practice) management targets to address water quantity threats:

- indoor water use reduction
- outdoor water use reduction
- industrial, commercial, and institutional (ICI) water efficiencies

- municipal water loss management
- water resource awareness
- increase in recharge
- increase in water supply
- municipal water efficiencies
- agricultural water efficiencies - crop management
- agricultural water efficiencies - livestock management

The RMM Catalogue contains a dataset that is divided into these groups to allow the user to search for measures that are most applicable for managing the water quantity threats activities in the WHPA-Q1 and that will be evaluated under the RMMEP. The Tier Three Assessment water budget model may be used to evaluate certain measures, while other previously implemented measures may be evaluated with historical data.

4.1 Water Conservation

In evaluating the potential for RMM to mitigate the identified water quantity risks, the water conservation measures implemented in the WHPA-Q1 should be documented and the success of those conservation measures characterized. This will determine if other conservation-related RMM could have the potential to succeed in reducing the water demand, and in turn, reducing the risk level assigned to the WHPA-Q1.

The City of Guelph recently completed the Water Supply Master Plan Update (WSMPU; AECOM and Golder 2014) which projected future water demand out to 2038. The baseline projected demand considered historical customer demand and an analysis of recent trends to conclude that the recent declines in per capita residential demands were likely sustainable for the purposes of the projections, but the ICI demands were partly due to economic factors (AECOM and Golder 2014). Table 12 below, taken from the WSMPU, shows the projected average water demand (2013 to 2038). The average water demand for 2038 is projected to be 69,872 m^3/d.

TABLE 12 City of Guelph Projected Average Water Demand (2013-2038; from AECOM and Golder 2014)

Year	Population			Demand by Sector			NRW (m^3/d)	Average Water Demand (m^3/d)
	Resid.	Employ.	Total Equiv.	Resid.	Employ.	Total		
2013	130,670	66,730	197,400	23,536	19,059	42,595	5,658	48,253
2018	143,480	73,874	217,354	25,843	21,100	46,943	6,175	53,117
2023	156,290	81,017	237,307	28,150	23,140	51,290	6,691	57,982
2028	168,190	90,340	258,530	30,293	25,803	56,096	7,208	63,305
2033	178,464	96,947	275,411	32,144	27,690	59,834	7,628	67,462
2038	186,299	99,480	285,779	33,555	28,413	61,969	7,903	69,872

Note:
NRW – Non-Revenue Water includes unbilled authorized consumption, apparent losses, and real losses.

A review of conservation efforts and assumptions made for these estimates is available in the WSMPU and the *2016 Water Efficiency Strategy Update* (C3 and Gauley 2016).

4.2 Identification of Preliminary Risk Management Measures

The RMM Catalogue web-tool was used to identify measures to be re-revaluated with the Tier Three Assessment model. Based on the results of the Threats Ranking, the Catalogue was consulted under the specific category of threat: "Consumptive water use - wells". As the impacts from land use changes and recharge reductions were not significant, RMM related to the threat from recharge reductions were not explored.

From this category of threat, two RMM were selected from the Catalogue to be used to re-evaluate the risk to the WHPA-Q1-A using the Tier Three Assessment model. These measures fall within the "Municipal Water Efficiencies" Management Target, and are all applicable to the "Municipal Sector". The selection of these measures was based on the results of the ranking process, which showed a high percent impact from the Guelph municipal wells. Table 13 lists the measures chosen from the Catalogue. Detailed information sheets from the RMM Catalogue for these RMM are provided in Appendix A.

TABLE 13 Selected Preliminary Water Quantity Risk Management Measures

Measure Name	Measure Description from Catalogue	Reference ID
Water conservation education systems	This measure includes production of best management practices guides, fact sheets, self-assessment workbooks, documentation of irrigation benchmarks and water use efficiency case studies, and water/energy saving kits for homeowners.	QT026
Land Securement	Purchase properties where one or more significant drinking water threat activities are present. This measure is a last resort generally used only for cases where significant drinking water threats cannot be managed or mitigated.	QT063
Optimization of Pumping Rates for Sustainable Yield	Optimization is a process of re-allocating pumping rates considering a target of maximum amount of ground water that could be withdrawn from aquifers without violating hydraulic-head constraints, thus determining the "sustainable yield" for the source of water. Water budgets - optimization modeling can be used for the purpose of evaluating potential pumping scenarios and optimizing maximum ground-water withdrawal rates to determine sustainable yield for the aquifer while maintaining desirable hydraulic heads in the aquifer. Additionally, the optimization models can determine the maximum available withdrawals from major streams for supplementing ground water to meet the total water demand.	QT067

4.3 Preliminary Risk Management Measures Scenarios

Based on the above choices of RMM, Matrix recommends these preliminary RMM scenarios be conducted:

1) Under RMM "Water conservation education systems" - Incorporate the average day demand of 69,872 m^3/d projected in the WSMPU for 2038. The Allocated rate used in the Tier Thee Assessment was 73,450 m^3/d which is 3,578 m^3/d more than the revised projections which already included conservation measures as a RMM. This lower demand will be distributed amongst the Guelph wells in an effort to reduce the risk level for those wells found to have the greatest percent impact in the Threats Ranking. This will be done in consultation with the City to ensure operational constraints are considered.

2) Under RMM "Optimization of Pumping Rates for Sustainable Yield" - Based on the results of the first scenario, design and execute up to 3 more scenarios to optimize the pumping of the Guelph wells such that the risk level of WHPA-Q1-A is reduced from *significant* to *moderate* or *low*. This scenario is conducted under RMM "Water conservation education systems".

3) Under RMM "Land Securement" - Reduce the water demand from the dewatering permit for River Valley Developments by raising the simulated pond level. As the quarry was ranked as the third *significant* threat, a scenario should be conducted to understand how enhancing operations could reduce the water quantity risk level. A 2007 jurisdictional review entitled *Water Quantity Risk Management Measures for Ontario's Source Protection Initiatives* (AquaResource 2007) observed that "…various methods are used to reduce the impact on local groundwater levels including the use of grout walls, and recycling of water through infiltration facilities". Matrix proposes to conduct a scenario to understand what minimum elevation the pond level needs to be raised to mitigate the risk level in WHPA-Q1-A (note the pond is currently simulated at 290 m above sea level).

Before these scenarios are performed, Matrix will also conduct the following:

1) Review the Permit to Take Water database and the Water Taking Reporting System (WTRS; 2009 to 2016) to ensure that the permitted takings represented in the Tier Three Assessment model are still representative of the existing conditions. Where significant changes have occurred, consumptive water takings will be updated in the model.

2) Potential recharge reductions due to the proposed Clair-Maltby development will be incorporated into another Threats Ranking scenario to determine the percent impact to municipal wells. Based on this result, updates to the model could be made before running the preliminary RMM scenarios above.

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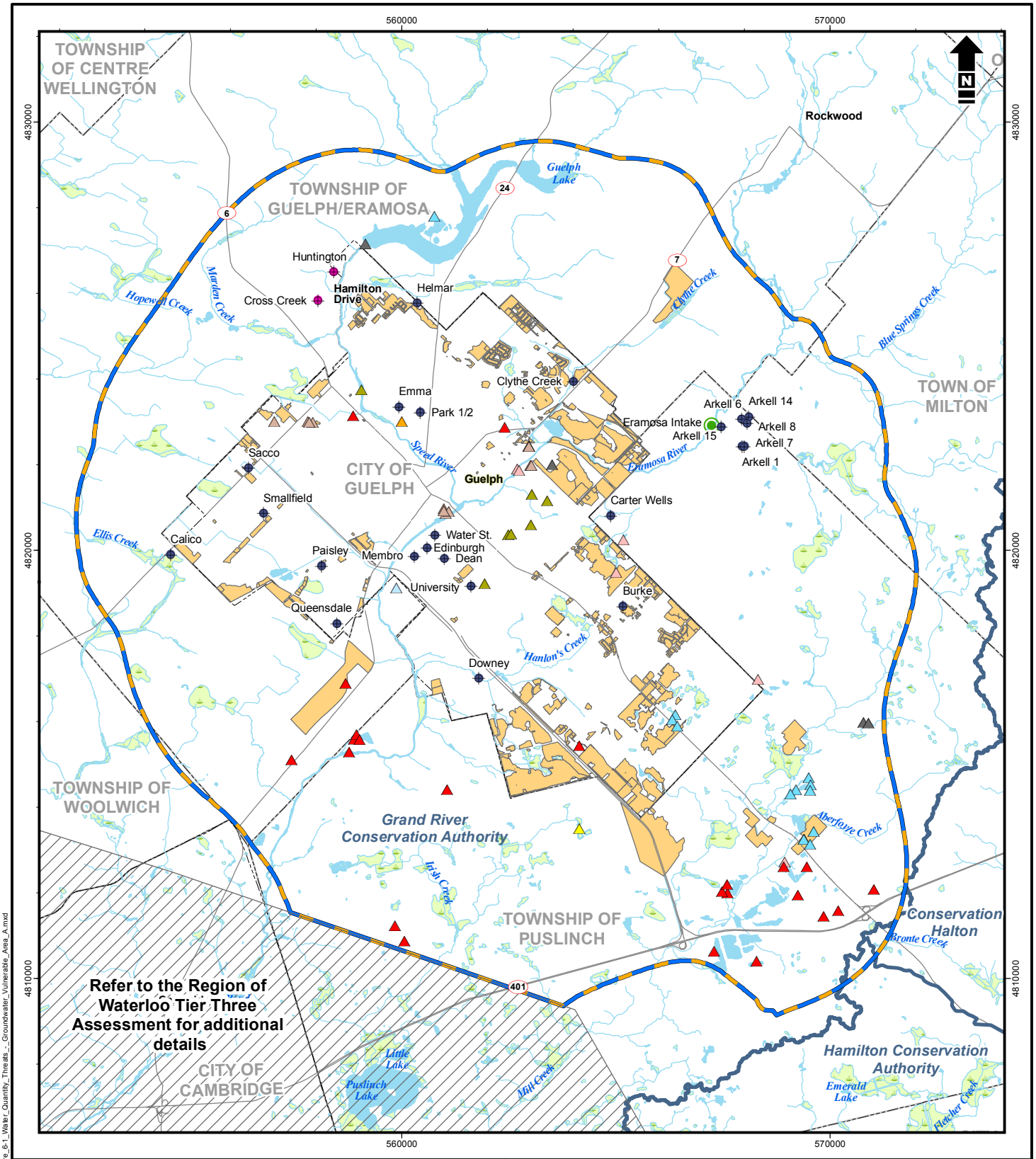

Tier Three Model Boundary (Study Area)
Grand River Watershed Regulatory Boundary
Groundwater Recharge Reduction Activities
Community
Wetland
Water Body
Watercourse
Major Road
Niagara Escarpment
Groundwater Vulnerable Area A
Municipal Well (City of Guelph)
Municipal Well (Guelph/Eramosa Township)
River Intake

Water Quantity Threat

- Agricultural
- Commercial
- Dewatering
- Industrial
- Institutional
- Miscellaneous
- Recreational
- Remediation
- Water Supply

1:125,000
1 0 1
Kilometres
NAD 1983 UTM Zone 17N

Referenece: Base Data - City of Guelph, 2009; GRCA, 2008, CVC, 2008, Ministry of Natural Resources, 2008. Produced using information under License with the Grand River Conservation Authority. Copyright © Grand River Conservation Authority, 2013 Produced using information provided by the Ministry of Natural Resources, Copyright © Queen's Printer, 2013

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Matrix Solutions Inc.
ENVIRONMENT & ENGINEERING

City of Guelph and Township of Guelph/Eramosa
Tier 3 Water Budget and Local Area Risk Assessment

Water Quantity Threats
Groundwater Vulnerable Area A

Date: 10 Mar 2017	Project: 15072-527	Technical: P. Chin	Reviewer: D. VanVliet	Drawn: M. Urtheil

Figure 1

Attachment 1: Level I Results		**Model Scenario**	I-A: Municipal Planned		I-B: All Non-Permitted (Existing)		I-C: All Permitted (Existing)		I-D: Recharge Reduction	
			Incremental Drawdown		Incremental Drawdown		Incremental Drawdown		Incremental Drawdown	
Municipal Supply Well	Safe Available Drawdown (m)		(m)	(% Impact)	(m)	(% Impact)	(m)	(% Impact)	(m)	(% Impact)
Arkell_1_PW	1.9		0.2	9%	0.0	0%	0.0	1%	0.0	-1%
Arkell_14_PW	12.0		7.6	64%	0.0	0%	1.0	9%	0.1	1%
Arkell_15_PW	12.2		7.7	63%	0.0	0%	1.1	9%	0.1	1%
Arkell_6_PW	15.4		7.4	48%	0.0	0%	1.0	7%	0.1	0%
Arkell_7_PW	13.7		7.3	53%	0.0	0%	1.1	8%	0.1	1%
Arkell_8_PW	11.5		7.4	65%	0.0	0%	1.0	9%	0.1	1%
Burke_PW	4.5		1.0	22%	0.0	1%	0.2	5%	0.3	7%
Calico_PW	18.1		6.2	34%	0.0	0%	0.8	4%	0.1	1%
Carter_Wells_PW	2.3		0.6	25%	0.0	0%	0.1	4%	0.1	4%
Clythe_Creek_PW	15.5		9.5	61%	0.0	0%	1.8	12%	0.1	1%
Dean_Ave._PW	18.6		7.4	39%	0.0	0%	8.7	47%	0.2	1%
Downey_Road_PW	20.0		6.4	32%	0.0	0%	6.4	32%	0.2	1%
Emma_PW	7.8		-1.1	-14%	0.0	1%	3.1	40%	0.2	2%
Helmar_PW	9.3		4.0	43%	0.1	1%	1.4	15%	0.1	1%
Membro_PW	22.0		8.3	38%	0.0	0%	10.2	46%	0.2	1%
Paisley_PW	20.5		6.0	29%	0.0	0%	5.2	26%	0.3	1%
Park_1_2_PW	11.6		3.8	33%	0.0	0%	3.1	27%	0.2	1%
Queensdale_PW	18.2		16.7	91%	0.0	0%	6.8	37%	0.4	2%
Sacco_PW	31.5		10.9	35%	0.0	0%	2.0	6%	0.2	1%
Smallfield_PW	42.0		11.7	28%	0.0	0%	2.4	6%	0.3	1%
University_PW	20.2		6.5	32%	0.0	0%	6.7	33%	0.2	1%
Water_Street_PW	17.3		8.5	49%	0.0	0%	8.0	46%	0.2	1%
CrossCreekWell	14.2		1.8	13%	0.1	1%	1.0	7%	0.1	1%
HuntingtonEstatesWell	11.2		1.6	14%	0.1	1%	0.8	7%	0.1	1%
		Greatest Percent Impact	Queensdale_PW	91%	Helmar_PW	1%	Dean_Ave._PW	47%	Burke_PW	7%

Attachment 2: Level II-A Results		**Model Scenario**	II-A-i: Guelph Planned		II-A-ii: Hamilton Drive (GET) Planned		II-A-iii: Cambridge Planned		II-A-iv: Rockwood (GET) Planned	
			Incremental Drawdown		Incremental Drawdown		Incremental Drawdown		Incremental Drawdown	
Municipal Supply Well	Safe Available Drawdown (m)		(m)	(% Impact)	(m)	(% Impact)	(m)	(% Impact)	(m)	(% Impact)
Arkell_1_PW	1.9		0.2	10%	0.0	0%	0.0	0%	0.0	1%
Arkell_14_PW	12.0		7.6	64%	0.0	0%	0.0	0%	0.0	0%
Arkell_15_PW	12.2		7.7	63%	0.0	0%	0.0	0%	0.0	0%
Arkell_6_PW	15.4		7.4	48%	0.0	0%	0.0	0%	0.0	0%
Arkell_7_PW	13.7		7.3	53%	0.0	0%	0.0	0%	0.0	0%
Arkell_8_PW	11.5		7.4	65%	0.0	0%	0.0	0%	0.0	0%
Burke_PW	4.5		1.0	22%	0.0	0%	0.0	0%	0.0	0%
Calico_PW	18.1		6.2	34%	0.0	0%	0.0	0%	0.0	0%
Carter_Wells_PW	2.3		0.6	26%	0.0	0%	0.0	0%	0.0	0%
Clythe_Creek_PW	15.5		9.5	61%	0.0	0%	0.0	0%	0.0	0%
Dean_Ave._PW	18.6		7.3	39%	0.0	0%	0.0	0%	0.0	0%
Downey_Road_PW	20.0		6.4	32%	0.0	0%	0.0	0%	0.0	0%
Emma_PW	7.8		-1.1	-14%	0.0	0%	0.0	0%	0.0	0%
Helmar_PW	9.3		4.0	43%	0.0	0%	0.0	0%	0.0	0%
Membro_PW	22.0		8.3	38%	0.0	0%	0.0	0%	0.0	0%
Paisley_PW	20.5		5.9	29%	0.0	0%	0.0	0%	0.0	0%
Park_1_2_PW	11.6		3.8	32%	0.0	0%	0.0	0%	0.0	0%
Queensdale_PW	18.2		16.6	91%	0.0	0%	0.0	0%	0.0	0%
Sacco_PW	31.5		10.9	35%	0.0	0%	0.0	0%	0.0	0%
Smallfield_PW	42.0		11.7	28%	0.0	0%	0.0	0%	0.0	0%
University_PW	20.2		6.4	32%	0.0	0%	0.0	0%	0.0	0%
Water_Street_PW	17.3		8.5	49%	0.0	0%	0.0	0%	0.0	0%
CrossCreekWell	14.2		1.8	12%	0.0	0%	0.0	0%	0.0	0%
HuntingtonEstatesWell	11.2		1.6	14%	0.0	0%	0.0	0%	0.0	0%
		Greatest Percent Impact	Queensdale_PW	91%		0%		0%	Arkell_1_PW	1%

Attachment 3: Level II-C Results		**Model Scenario**	II-C-i: Dewatering		II-C-ii: Commercial		II-C-iii: Industrial		II-C-iv: All Others (outside WHPA Q1)		II-C-v: All Others (inside WHPA Q1)	
			Incremental Drawdown		Incremental Drawdown		Incremental Drawdown		Incremental Drawdown		Incremental Drawdown	
Municipal Supply Well	Safe Available Drawdown (m)		(m)	(% Impact)	II-C-ii: Commercial	(% Impact)	(m)	(% Impact)	(m)	(% Impact)	(m)	(% Impact)
Arkell_1_PW	1.9		0.0	1%	0.0	0%	0.0	0%	0.0	0%	0.0	1%
Arkell_14_PW	12.0		0.6	5%	0.0	0%	0.0	0%	0.0	0%	0.3	3%
Arkell_15_PW	12.2		0.7	6%	0.0	0%	0.0	0%	0.0	0%	0.4	3%
Arkell_6_PW	15.4		0.6	4%	0.0	0%	0.0	0%	0.0	0%	0.3	2%
Arkell_7_PW	13.7		0.7	5%	0.0	0%	0.0	0%	0.0	0%	0.4	3%
Arkell_8_PW	11.5		0.6	6%	0.0	0%	0.0	0%	0.0	0%	0.3	3%
Burke_PW	4.5		0.1	1%	0.1	3%	0.0	0%	0.0	0%	0.0	1%
Calico_PW	18.1		0.6	3%	0.0	0%	0.1	0%	0.0	0%	0.1	0%
Carter_Wells_PW	2.3		0.0	1%	0.0	2%	0.0	0%	0.0	0%	0.0	1%
Clythe_Creek_PW	15.5		1.2	7%	0.0	0%	0.1	0%	0.0	0%	0.6	4%
Dean_Ave._PW	18.6		8.3	45%	0.0	0%	0.2	1%	0.0	0%	0.3	2%
Downey_Road_PW	20.0		6.1	30%	0.1	0%	0.2	1%	0.0	0%	0.2	1%
Emma_PW	7.8		2.2	28%	0.0	0%	0.2	3%	0.0	0%	0.8	10%
Helmar_PW	9.3		1.0	10%	0.0	0%	0.1	1%	0.0	0%	0.3	4%
Membro_PW	22.0		9.9	45%	0.0	0%	0.2	1%	0.0	0%	0.3	1%
Paisley_PW	20.5		4.8	23%	0.0	0%	0.3	2%	0.0	0%	0.2	1%
Park_1_2_PW	11.6		2.2	19%	0.0	0%	0.2	2%	0.0	0%	0.7	6%
Queensdale_PW	18.2		6.0	33%	0.0	0%	0.7	4%	0.0	0%	0.2	1%
Sacco_PW	31.5		1.5	5%	0.0	0%	0.2	1%	0.0	0%	0.4	1%
Smallfield_PW	42.0		2.0	5%	0.0	0%	0.2	0%	0.0	0%	0.3	1%
University_PW	20.2		6.3	31%	0.0	0%	0.2	1%	0.0	0%	0.3	2%
Water_Street_PW	17.3		7.6	44%	0.0	0%	0.2	1%	0.0	0%	0.4	2%
CrossCreekWell	14.2		0.6	5%	0.0	0%	0.1	1%	0.0	0%	0.2	2%
HuntingtonEstatesWell	11.2		0.5	5%	0.0	0%	0.1	1%	0.0	0%	0.2	2%
		Greatest Percent Impact	Membro_PW	45%	Burke_PW	3%	Queensdale_PW	4%		0%	Emma_PW	10%

Attachment 4: Level III-A Results		**Model Scenario**	III-A: Queensdale_PW		III-A: Water_Street_PW		III-A: Dean_Ave._PW		III-A: Membro_PW		III-A: Clythe_Creek_PW		III-A: Helmar_PW		III-A: University_PW		III-A: Downey_Road_PW		III-A: Paisley_PW		III-A: Sacco_PW		III-A: Calico_PW		III-A: Smallfield_PW		III-A: Carter_Wells_PW		III-A: Burke_PW		III-A: Arkell System	
			Incremental Drawdown		Incremental Drawdown		Incremental Drawdown		Incremental Drawdown		Incremental Drawdown		Incremental Drawdown		Incremental Drawdown		Incremental Drawdown		Incremental Drawdown		Incremental Drawdown		Incremental Drawdown		Incremental Drawdown		Incremental Drawdown		Incremental Drawdown		Incremental Drawdown	
Municipal Supply Well	Safe Available Drawdown (m)		(m)	(% Impact)	(m)	(% Impact)	(m)	(% Impact)	(m)	(% Impact)	(m)	(% Impact)	(m)	(% Impact)	(m)	(% Impact)	(m)	(% Impact)	(m)	(% Impact)	(m)	(% Impact)	(m)	(% Impact)	(m)	(% Impact)	(m)	(% Impact)	(m)	(% Impact)	(m)	(% Impact)
Arkell_1_PW	1.9		0.0	-1%	0.0	-1%	0.0	-1%	0.0	-1%	0.0	0%	0.0	-1%	0.0	-1%	0.0	-1%	0.0	-3%	0.0	-1%	0.0	-1%	0.0	-1%	0.0	-1%	0.0	-1%	0.1	7%
Arkell_14_PW	12.0		0.0	0%	0.1	1%	0.0	0%	0.1	1%	0.7	6%	0.0	0%	0.1	1%	0.1	1%	0.0	0%	0.0	0%	0.0	0%	0.0	0%	0.0	0%	0.0	0%	6.3	53%
Arkell_15_PW	12.2		0.0	0%	0.1	1%	0.0	0%	0.1	1%	0.8	6%	0.0	0%	0.1	1%	0.1	1%	0.0	0%	0.0	0%	0.0	0%	0.0	0%	0.0	0%	0.0	0%	6.3	52%
Arkell_6_PW	15.4		0.0	0%	0.1	1%	0.0	0%	0.1	1%	0.7	5%	0.0	0%	0.1	0%	0.1	0%	0.0	0%	0.0	0%	0.0	0%	0.0	0%	0.0	0%	0.0	0%	6.1	39%
Arkell_7_PW	13.7		0.0	0%	0.1	1%	0.0	0%	0.1	1%	0.7	5%	0.0	0%	0.1	1%	0.1	1%	0.0	0%	0.0	0%	0.0	0%	0.0	0%	0.0	0%	0.0	0%	6.0	43%
Arkell_8_PW	11.5		0.0	0%	0.1	1%	0.0	0%	0.1	1%	0.7	6%	0.0	0%	0.1	1%	0.1	1%	0.0	0%	0.0	0%	0.0	0%	0.0	0%	0.0	0%	0.0	0%	6.1	53%
Burke_PW	4.5		0.0	0%	0.0	0%	0.0	0%	0.0	0%	0.0	1%	0.0	0%	0.0	0%	0.0	0%	0.0	0%	0.0	0%	0.0	0%	0.0	0%	0.0	0%	0.1	1%	0.7	15%
Calico_PW	18.1		0.2	1%	0.1	0%	0.0	0%	0.1	0%	0.0	0%	0.0	0%	0.0	0%	0.0	0%	0.0	0%	0.5	3%	4.3	24%	0.7	4%	0.0	0%	0.0	0%	0.1	0%
Carter_Wells_PW	2.3		0.0	0%	0.0	0%	0.0	0%	0.0	0%	0.0	0%	0.0	0%	0.0	0%	0.0	0%	0.0	0%	0.0	0%	0.0	0%	0.0	0%	0.4	17%	0.1	3%	0.1	2%
Clythe_Creek_PW	15.5		0.1	1%	0.2	1%	0.0	0%	0.2	1%	5.0	32%	0.1	0%	0.1	1%	0.1	1%	0.0	0%	0.1	0%	0.0	0%	0.1	1%	0.0	0%	0.0	0%	3.4	22%
Dean_Ave._PW	18.6		0.5	3%	1.3	7%	0.8	4%	1.3	7%	0.3	2%	0.0	0%	0.6	3%	0.7	4%	0.0	0%	0.2	1%	0.0	0%	0.3	1%	0.0	0%	0.0	0%	0.9	5%
Downey_Road_PW	20.0		0.4	2%	0.6	3%	0.2	1%	0.6	3%	0.2	1%	0.0	0%	0.7	4%	2.3	12%	0.0	0%	0.1	1%	0.0	0%	0.2	1%	0.0	0%	0.0	0%	0.7	3%
Emma_PW	7.8		0.2	3%	0.3	4%	0.1	1%	0.3	4%	0.6	8%	0.3	3%	0.2	2%	0.2	3%	0.0	0%	0.4	6%	0.0	0%	0.5	6%	0.0	0%	0.0	0%	1.3	17%
Helmar_PW	9.3		0.1	1%	0.1	2%	0.0	0%	0.1	1%	0.5	5%	1.8	19%	0.1	1%	0.1	1%	0.0	0%	0.2	3%	0.0	0%	0.2	3%	0.0	0%	0.0	0%	1.0	10%
Membro_PW	22.0		0.6	3%	1.2	5%	0.3	1%	2.9	13%	0.3	1%	0.0	0%	0.5	2%	0.6	3%	0.0	0%	0.2	1%	0.0	0%	0.3	1%	0.0	0%	0.0	0%	0.8	4%
Paisley_PW	20.5		1.4	7%	0.4	2%	0.1	0%	0.5	2%	0.2	1%	0.0	0%	0.2	1%	0.3	1%	0.4	2%	0.6	3%	0.1	0%	1.1	6%	0.0	0%	0.0	0%	0.4	2%
Park_1_2_PW	11.6		0.2	2%	0.4	3%	0.1	1%	0.3	3%	0.7	6%	0.2	2%	0.2	2%	0.2	2%	0.0	0%	0.3	3%	0.0	0%	0.4	3%	0.0	0%	0.0	0%	1.5	13%
Queensdale_PW	18.2		13.0	72%	0.4	2%	0.1	1%	0.5	3%	0.1	1%	0.0	0%	0.3	2%	0.4	2%	0.0	0%	0.3	2%	0.1	0%	0.6	3%	0.0	0%	0.0	0%	0.4	2%
Sacco_PW	31.5		0.3	1%	0.2	0%	0.0	0%	0.2	1%	0.1	0%	0.1	0%	0.1	0%	0.1	0%	0.0	0%	7.1	22%	0.1	0%	2.2	7%	0.0	0%	0.0	0%	0.3	1%
Smallfield_PW	42.0		0.5	1%	0.2	0%	0.1	0%	0.2	1%	0.1	0%	0.1	0%	0.1	0%	0.1	0%	0.0	0%	1.8	4%	0.2	0%	7.9	19%	0.0	0%	0.0	0%	0.3	1%
University_PW	20.2		0.4	2%	0.7	4%	0.2	1%	0.7	4%	0.3	2%	0.0	0%	1.4	7%	1.0	5%	0.0	0%	0.1	1%	0.0	0%	0.2	1%	0.0	0%	0.0	0%	0.9	5%
Water_Street_PW	17.3		0.5	3%	3.0	17%	0.3	2%	1.3	7%	0.4	2%	0.0	0%	0.6	3%	0.6	4%	0.0	0%	0.2	1%	0.0	0%	0.3	2%	0.0	0%	0.0	0%	1.0	6%
CrossCreekWell	14.2		0.1	1%	0.1	1%	0.0	0%	0.1	1%	0.2	1%	0.2	2%	0.0	0%	0.1	0%	0.0	0%	0.4	3%	0.0	0%	0.3	2%	0.0	0%	0.0	0%	0.4	3%
HuntingtonEstatesWell	11.2		0.1	1%	0.1	1%	0.0	0%	0.1	1%	0.2	2%	0.3	3%	0.0	0%	0.0	0%	0.0	0%	0.3	2%	0.0	0%	0.2	2%	0.0	0%	0.0	0%	0.4	3%
		Greatest Percent Impact	Queensdale_PW	72%	Water_Street_PW	17%	Dean_Ave._PW	4%	Membro_PW	13%	Clythe_Creek_PW	32%	Helmar_PW	19%	University_PW	7%	Downey_Road_PW	12%	Paisley_PW	2%	Sacco_PW	22%	Calico_PW	24%	Smallfield_PW	19%	Carter_Wells_PW	17%	Burke_PW	15%	Arkell_8_PW	53%

Attachment 5: Level III-C Results		**Model Scenario**	III-C-i: 5080-8TAKK2		III-C-ii: 1381-95ATPY		III-C-iii: 88-P-2069		III-C-iv: 1245-AB8RMW		III-C-v: 2768-6QXRCC		III-C-vi: 1204-62XKA	
			Incremental Drawdown		Incremental Drawdown		Incremental Drawdown		Incremental Drawdown		Incremental Drawdown		Incremental Drawdown	
Municipal Supply Well	Safe Available Drawdown (m)		(m)	(% Impact)	(m)	(% Impact)	(m)	(% Impact)	(m)	(% Impact)	(m)	(% Impact)	(m)	(% Impact)
Arkell_1_PW	1.9		0.0	1%	0.0	0%	0.0	0%	0.0	0%	0.0	0%	0.0	0%
Arkell_14_PW	12.0		0.6	5%	0.0	0%	0.0	0%	0.0	0%	0.0	0%	0.0	0%
Arkell_15_PW	12.2		0.7	6%	0.0	0%	0.0	0%	0.0	0%	0.0	0%	0.0	0%
Arkell_6_PW	15.4		0.6	4%	0.0	0%	0.0	0%	0.0	0%	0.0	0%	0.0	0%
Arkell_7_PW	13.7		0.7	5%	0.0	0%	0.0	0%	0.0	0%	0.0	0%	0.0	0%
Arkell_8_PW	11.5		0.6	6%	0.0	0%	0.0	0%	0.0	0%	0.0	0%	0.0	0%
Burke_PW	4.5		0.1	1%	0.0	1%	0.00	0%	0.00	0%	0.0	0%	0.0	0%
Calico_PW	18.1		0.6	3%	0.0	0%	0.0	0%	0.0	0%	0.0	0%	0.0	0%
Carter_Wells_PW	2.3		0.0	1%	0.0	1%	0.0	0%	0.0	0%	0.0	0%	0.0	0%
Clythe_Creek_PW	15.5		1.2	7%	0.0	0%	0.0	0%	0.0	0%	0.0	0%	0.0	0%
Dean_Ave._PW	18.6		8.3	45%	0.0	0%	0.2	1%	0.0	0%	0.0	0%	0.0	0%
Downey_Road_PW	20.0		6.1	30%	0.0	0%	0.2	1%	0.0	0%	0.0	0%	0.0	0%
Emma_PW	7.8		2.2	28%	0.0	0%	0.1	1%	0.1	2%	0.0	0%	0.0	0%
Helmar_PW	9.3		1.0	10%	0.0	0%	0.0	0%	0.1	1%	0.0	0%	0.0	0%
Membro_PW	22.0		9.9	45%	0.0	0%	0.2	1%	0.0	0%	0.0	0%	0.0	0%
Paisley_PW	20.5		4.8	23%	0.0	0%	0.3	1%	0.0	0%	0.0	0%	0.0	0%
Park_1_2_PW	11.6		2.2	19%	0.0	0%	0.1	1%	0.1	1%	0.0	0%	0.0	0%
Queensdale_PW	18.2		6.0	33%	0.0	0%	0.7	4%	0.0	0%	0.0	0%	0.0	0%
Sacco_PW	31.5		1.5	5%	0.0	0%	0.1	0%	0.1	0%	0.0	0%	0.0	0%
Smallfield_PW	42.0		2.0	5%	0.0	0%	0.1	0%	0.0	0%	0.0	0%	0.0	0%
University_PW	20.2		6.3	31%	0.0	0%	0.2	1%	0.0	0%	0.0	0%	0.0	0%
Water_Street_PW	17.3		7.6	44%	0.0	0%	0.2	1%	0.0	0%	0.0	0%	0.0	0%
CrossCreekWell	14.2		0.6	5%	0.0	0%	0.0	0%	0.1	0%	0.0	0%	0.0	0%
HuntingtonEstatesWell	11.2		0.5	5%	0.0	0%	0.0	0%	0.0	0%	0.0	0%	0.0	0%
		Greatest Percent Impact	Membro_PW	45%	Burke_PW	1%	Queensdale_PW	4%	Emma_PW	2%		0%		0%

APPENDIX A

INFORMATION SHEETS FROM THE WATER QUANTITY RISK MANAGEMENT MEASURES CATALOGUE

Risk Management Measures: Measure Information Sheet

Reference ID	**QT026**
Measure Name	**Water conservation education systems**
Measure Description	**This measure includes the following programs: best management practices guides and fact sheet on water efficiency, workshops and self assessment workbooks, documentation of irrigation benchmarks and water use efficiency case studies, free water/energy saving kits with educational material, and free water saving inspections for homeowners.**
Climate Change Adaptation	**Yes**

Management Targets:

- Education and Awareness

Applicable Sectors:

- Agriculture
- Commercial
- Government / Institutional
- Industry
- Municipal
- Residential

Associated Threats:

Order	Threat Name	Effectiveness Comments	Applicability
19.1	Consumptive water use - surface water intakes	Generally low cost for high benefit to families regarding education. Friendly (usually free) home audits would find problem areas and potential savings within a resident's home. Recommendations could be made for improvements.	Groundwater: No Surface Water: Yes
19.2	Consumptive water use - wells	Generally low cost for high benefit to families regarding education. Friendly (usually free) home audits would find problem areas and potential savings within a resident's home. Recommendations could be made for improvements.	Groundwater: Yes Surface Water: No

Additional Information Sources:

Case Study - The POLIS Project on Ecological Governance, University of Victoria, 2006 (Canada)
Thinking beyond Pipes and Pumps (http://www.polisproject.org/PDFs/ThinkingBeyond_eng_lowres.pdf)
Reference: Brandes, O.M., Maas, T., and Reynolds, E., 2006. "Thinking Beyond Pipes and Pumps: Top 10 Ways Communities can Save Water and Money". The POLIS Project on Ecological Governance, October, 2006.

Case Study - Violes, France, 2001 (Europe)
Water metering; pre-evaporation in the distillation process
(http://www.eea.europa.eu/publications/Environmental_Issues_No_19)
Reference: Lallana, C., Krinner, W, Estrela, T, et al., 2001. "Sustainable Water Use in Europe, Part 2: Demand Management". Published by the European Environment Agency, Copenhagen.

Publication - York Region - Ontario, 2011 (Ontario)
York Region Long Term Water Conservation Strategy
(http://www.waterfortomorrow.ca/en/aboutus/resources/LongTermWaterConservationStrategy.pdf)
Reference:

Risk Management Measures: Measure Information Sheet

Reference ID	**QT063**
Measure Name	**Land Securement**
Measure Description	**Purchase properties where one or more significant drinking water threat activities are present. Th measure is a last resort generally used only for cases where significant drinking water threats cannot be managed or mitigated.**
Climate Change Adaptation	**No**

Management Targets:

Applicable Sectors:

- Agriculture
- Commercial
- Government / Institutional
- Industry
- Municipal
- Residential

Associated Threats:

Order	Threat Name	Effectiveness Comments	Applicability
19.1	Consumptive water use - surface water intakes	In discussions with CT renamed TRCA measure - is this actually a duplicate with setback measures?	Groundwater: No Surface Water: Yes
19.2	Consumptive water use - wells	In discussions with CT renamed TRCA measure - is this actually a duplicate with setback measures?	Groundwater: Yes Surface Water: No
20.1	An activity that reduces recharge to an aquifer - surface water intakes	In discussions with CT renamed TRCA measure - is this actually a duplicate with setback measures?	Groundwater: No Surface Water: Yes
20.2	An activity that reduces recharge to an aquifer - wells	In discussions with CT renamed TRCA measure - is this actually a duplicate with setback measures?	Groundwater: Yes Surface Water: No

Additional Information Sources:

Website - Ontario Ministry of Nature Resources, 2007 (Ontario)
Land Securement Principle
(http://www.mnr.gov.on.ca/en/Business/CrownLand/2ColumnSubPage/STEL02_165794.html)
Reference: MNR, 2007. Land Securement Principles.

Risk Management Measures: Measure Information Sheet

Reference ID	**QT067**
Measure Name	**Optimization of Pumping Rates for Sustainable Yield**
Measure Description	**Optimization is a process of re-allocating pumping rates considering a target of maximum amoun of ground water that could be withdrawn from aquifers/streams without violating hydraulic-head c stream-discharge constraints, thus determining the "sustainable yield" for the source of water. Water budgets - optimization modeling can be used for the purpose of evaluating potential pumpi scenarios and optimizing maximum ground-water withdrawal rates to determine sustainable yield for the aquifer while maintaining desirable hydraulic heads in the aquifer and streamflow in the outcrop. Additionally, the optimization models can determine the maximum available withdrawals from major streams for supplementing ground water to meet the total water demand.**
Climate Change Adaptation	**Yes**

Management Targets:

- Municipal Water Efficiencies
- Water supply increase

Applicable Sectors:

- Municipal

Associated Threats:

Order	Threat Name	Effectiveness Comments	Applicability
19.2	Consumptive water use - wells		Groundwater: Yes Surface Water: No
19.1	Consumptive water use - surface water intakes		Groundwater: Yes Surface Water: No

Additional Information Sources:

Literature Review - USGS, 2004 (North America)
CONJUNCTIVE-USE OPTIMIZATION MODEL AND SUSTAINABLE-YIELD ESTIMATION FOR THE SPARTA AQUIFER OF SOUTHEASTERN ARKANSAS AND NORTHCENTRAL LOUISIANA (http://pubs.usgs.gov/wri/wri03-

4231/WRIR03-4231.pdf)
Reference:

Journal Article - Nato Science Series, 2002 (North America)
Managing Groundwater Supplies to Meet Municipal Demands — The Role of Simulation — Optimisation — Demand Models and Data Issues (http://link.springer.com/content/pdf/10.1007%2F978-94-010-0409-1_10.pdf)
Reference: