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Nickel District Conservation Authority
City of Greater Sudbury

Valley Drinking Water System Tier Three Water Budget and Water Quantity Risk Assessment

Submitted to:
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REPORT

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1.0 INTRODUCTION

The Clean Water Act (the Act) (2006) legislation was created for the purpose of the protection of current and future drinking water sources in the Province of Ontario. The Act outlines the establishment of Source Protection Areas (SPAs) and the development of Source Protection Plans (SPP) for existing or potential drinking water sources in each SPA. The SPP is the result of background technical studies completed by Conservation Authorities, municipalities, consultants and peer review committees in cooperation with the Ontario Ministry of Natural Resources (MNR) and the Ontario Ministry of the Environment (MOE).

In the Greater Sudbury Source Protection Area (GSSPA), Golder Associates Ltd. (Golder) was retained by the Nickel District Conservation Authority (NDCA) to complete background studies on water quantity for groundwater and surface water drinking water sources in the City of Greater Sudbury (CGS), as well as to characterize the waterways and aquifers of the larger GSSPA. The tiered methodology of the water budget and stress assessment (Golder 2009) has identified the Valley East municipal groundwater system (the Valley Drinking Water System) as requiring a Tier Three Water Budget Local Area Risk Level study. The Tier Three Risk Study comprises a detailed assessment of the municipal groundwater resource, and follows the methods and objectives outlined in the document “Technical Rules: Assessment Report, *Clean Water Act*, 2006”, Proposed Amendments dated March 22, 2011 (the Technical Rules).

1.1 Overview of the Valley Drinking Water System

The Valley East municipal well system is comprised of nine existing groundwater wells located within an area of approximately 50 km^2 in the community of Hanmer, in the former Town of Valley East of the CGS. These nine groundwater wells are connected via distribution pipelines to the nearby two Capreol wells, and these existing eleven wells provide municipal water to close to 40,000 residents in the communities of Valley East, Capreol, Azilda and Chelmsford. Collectively, these wells and distribution system are referred to as the Valley Drinking Water System.

The wells have been constructed throughout the 1970s, 1980s and 1990s in response to increasing municipal water demand. Within the most recent decade, an extensive aquifer characterization and groundwater resource study has resulted in the development of two additional municipal groundwater wells intended to augment the municipal water supply. The wells have progressed through a Municipal Class Environmental Assessment (Class EA) process, and construction of the well house buildings and connection to the municipal supply was underway at the time of this report.

1.2 Tier One and Tier Two Water Budget and Stress Assessment

Water budgets and stress assessments completed under the Tier One and Tier Two process for the Valley East groundwater resource utilized increasingly complex models and previously available water removal information. The results of these assessments can be summarized as:

- On a monthly basis, recharge was less than water removals during the periods with little available water in the ground surface (i.e. water held in snowpack, or rain that fell during periods of high potential evapotranspiration). This led to a Tier One Stress Assessment of ‘moderate’ for current water removals and of ‘significant’ for estimated future water removals; and
- Simulated monthly groundwater level was lower than at least one well screen elevation in several modelled scenarios, and the average annual water demand was greater than 25% of available supply. This led to a Tier Two Stress Assessment of ‘significant’.

The Tier Three Water Budget and Local Area Risk Assessment provides further refinements to the understanding of the Valley East groundwater supply. As a part of this current assessment, additional surveying was undertaken in order to re-examine well characteristics (e.g. well depth, screen elevation). Further, whereas the previous Tier One and Tier Two assessments focussed on the nine groundwater wells supplying Valley East, the Tier Three exercise incorporated the nearby Capreol wells, which are connected to the Valley Drinking Water System via distribution pipelines.

1.3 Objectives

As outlined in the Technical Rules, the objectives of the Tier Three Water Budget and Local Area Risk Assessment are to:

1) Construct a groundwater model to simulate groundwater table elevation in, and removals from, the aquifer contributing to the Valley Drinking Water System.
2) Assess groundwater levels under typical and drought climatic conditions.
3) Define the Local Area and Well Head Protection Areas for Quantity (WHPA-Q1 and WHPA-Q2).
4) Describe the tolerance and risk level associated with the water supply.
5) Delineate Significant Groundwater Recharge Areas (SGRA).

2.0 STUDY AREA – VALLEY EAST

2.1 General Background

Valley East and Capreol are former towns in the Regional Municipality of Sudbury (RMOS), and now fall under the envelope of the amalgamated CGS. The communities of Valley East are located in a low lying ‘valley’ containing glaciofluvial and glaciolacustrine deposits in the Whitson River Watershed, a subwatershed of the Vermilion River Watershed (Figure 2.1). Capreol is located in similar geological deposits adjacent to the Vermilion River. The Valley East and Capreol area is characterized by low topography and some of the deepest overburden deposits in the CGS. Drainage in the Valley East area is generally towards the Whitson River, which in turn discharges to the Vermilion River to the southwest of the community of Chelmsford. Although historically Capreol and Valley East have been described as distinct systems, they both draw from the same geological formation referred to as the Valley East aquifer in this report.

2.2 Climate

The GSSPA climate is classified as high humid continental, characterized by warm summers and cold winters (Ecoregions Working Group 1989). The Sudbury Airport Climate Station (Environment Canada ID 6068150) has been identified in previous GSSPA reports as a climate monitoring site with sufficiently long climate record and as a site appropriate for extrapolating regional climate over the Valley East and Capreol Areas (Golder 2008).

2.3 Bedrock Geology, Surficial Geology and Hydrogeology

Detailed geological and hydrogeological characterization of the Valley East aquifer has been previously compiled [e.g. Richards (2002), Golder (2005) and Waters Environmental Geosciences Ltd. (Waters) (2002, 2004)].

Briefly, overburden in the Valley East area is associated with glacial Lake Algonquin and is among the deepest quaternary deposits in the CGS (Barnett and Bajc 2002). The aquifer that contains the municipal wells is characterized by coarse glaciolacustrine and glaciofluvial sands and gravels in the east near Greens Lake and Capreol and is increasingly dominated by silt to the south and west (Figure 2.2). Precambrian metamorphic and igneous bedrock of the Whitewater Group including the Onwatin, Chelmsford and Onaping Formations is located beneath the overburden deposit (Rousell et al. 2002).

Previous hydrogeological investigations in the Valley East area have shown a relatively shallow regional water table elevation (approximately 4 m below ground surface). Groundwater gradients are generally southwest towards the Whitson River or northwest towards the Vermilion River.

2.4 Water Supply

The Valley Drinking Water System currently consists of nine groundwater wells, and is linked with the distribution system of the nearby Capreol municipal system which consists of two wells (Table 1). These 11 groundwater wells are responsible for serving three areas of the CGS:

- Valley East (Hanmer, Val Caron, Val Therese and Blezard Valley);
- Rayside Balfour (Azilda and Chelmsford); and
- Capreol.

Of these eleven municipal wells, eight are located in the Whitson River watershed and three are located in the Vermilion River watershed (Table 1; Figure 2.1). Previous groundwater studies have shown that the most favourable overburden for long term municipal supply wells are in the coarse, deep overburden that is present in the northeast area of the Whitson River watershed (e.g. Waters 2002; Golder 2005; Golder 2008).

Table 1: Valley East and Capreol Well System

Well Name	Well System	Watershed
Well A - Deschene	Valley East	Whitson River
Well B - Kenneth	Valley East	Whitson River
Well C - Phillipe	Valley East	Whitson River
Well D - Frost	Valley East	Whitson River
Well E – Notre Dame	Valley East	Whitson River
Well F - Linden	Valley East	Whitson River
Well G - Pharand	Valley East	Whitson River
Well H - Michelle	Valley East	Whitson River
Well I	Valley East	Vermilion River
Well J	Capreol	Vermilion River
Well M	Capreol	Vermilion River

The total annual amount of water removed from these wells between 2000 and 2010 was an annual average of approximately 4,400,000 m^3 (Figure 2.3). In recent years (2007 to 2010) total recorded consumption has declined. The proportion of total supply provided by the Valley East Wells, in comparison to the Capreol Wells, has increased over time, which can be attributed to population growth in the serviced areas as well as the decommissioning of municipal supply Well #6 in Capreol, which was designated as GUDI, or groundwater under the direct influence of surface water (Dennis Consultants, a Division of R.V. Anderson Associates Limited 2000). Well #6 was among the highest producing wells in the Valley East/Capreol system. Two new municipal supply wells, Well Q (Chenier Well) and Well R have been constructed and are scheduled to be commissioned in 2012. These additional wells are further described in Section 3.4.

As described by CGS staff, distribution of municipal water from these 11 wells is such that the wells located near Hanmer primarily provide water to the communities of Valley East, Azilda and Chelmsford, while the Capreol Wells provide water to Capreol. A valve within the distribution system can allow water to move from the Valley East system north to Capreol, and under emergency situations water pumped from the Capreol wells could be provided to the Valley East distribution lines.

2.5 Population

Statistics Canada (2007) reported a total population for the CGS Census Metropolitan Area (CMA[1]) of 158,258 for the Census conducted in 2006. The estimated total and municipal water serviced populations in the communities serviced by the Valley East and Capreol well system is summarized in Table 2.

CGS (2005) used 2001 Census data to project population and households to 2021 for communities of the CGS. This report projected a 19.4% increase in households and 9% increase in population in Valley East, Rayside Balfour and Capreol, along with a gradual decline in household size in these communities. In order to conservatively estimate future households serviced, it was assumed that i) the growth rates presented in CGS (2005) remained applicable with the 2006 census data and ii) population growth would receive municipal water. As of June 2011, there were 1,984 draft approved units planned for construction in Rayside-Balfour and Valley East, (CGS 2011).

Table 2: Current Population and Municipal Water Service

CGS Community	Population[1]	Number of Households[1]	Average Population per Household	Population with Municipal Service[2]	Percent Population with Municipal Service
Capreol	3,492	1,419	2.5	3,385	97%
Rayside Balfour	14,359	5,495	2.6	12,918	90%
Valley East	22,664	7,950	2.9	20,303	90%

Notes:
[1] From CGS Planning Website, 2008
[2] From CGS (2007) Sewer and Water Treatment Capacity Information 2005

3.0 WATER REMOVALS

Water removals from the Valley East aquifer were estimated based on available records and were processed within the groundwater model for prescribed scenarios.

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[1] Greater Sudbury CMA encompasses the entire CGS as well as Whitefish Lake First Nation and Wanapitei First Nation.

3.1 Municipal Well Removals

Removals from individual wells were simulated in the model based on data provided by the CGS. Each well is operated such that when pumping, the wells are operated at an instantaneous pumping rate that is approximately 10% below the maximum (PTTW) rate. The well field is operated with one well (typically the 'I' Well) as a base (24-hour) well and the remaining wells are activated as additional demand is necessary.

3.2 Other Permitted Water Takings

At this time, there are no known non-municipal active consumptive PTTW within the study watersheds. The previous Tier Two Water Budget report (Golder 2009) estimated that consumed non-municipal removals comprised approximately 2% of the total annual water removed by the municipal wells (primarily through private non-permitted well points). For the Tier Three study, only water takings requiring a permit under the *Ontario Water Resource Act* are to be considered. Therefore, non-permitted, non-municipal removals were not applied to the simulated scenarios.

3.3 Existing Pumping Rates

Previous Source Protection technical studies prescribed that pumping rates for existing conditions were to be taken from pumping records reflective of the year preceding the submission of the Terms of Reference specific to the Source Protection Area (i.e. the GSSPA). The Terms of Reference were submitted in 2008 for the GSSPA, and therefore existing pumping rates were set to 2007 removal records.

For the most recently available Technical Rules, the determination of existing pumping rates allows for professional judgement of representative pumping rates during the period for which pumping records are available. Municipal removals have been relatively stable over the previous eleven years (2000 to 2010), although the distribution of supply between the Valley East and Capreol well supply systems have changed (Section 2.4). The year 2007 was selected as representative (and conservative in the context of 2008 to 2010 records), and monthly removals associated with each well in 2007 were carried forward for the existing pumping rate for the Tier Three scenarios.

In some cases, where individual wells were offline for a period of time (for maintenance, for example), 2007 monthly pumping rates were substituted with values from 2006 or 2005, which were considered more suitable representations of long term pumping rates at that well. For modelling purposes, each of these monthly rates was divided by the number of days per month to provide a daily average pumping rate. The daily rates were reviewed against permitted rates in order to check that these rates did not exceed the maximum permitted pumping rate.

Existing pumping rates are summarized in Table 3. Although recorded pumping rates for 2007 at Well J and Well M suggest that these wells were not pumped concurrently, more recent data (e.g. 2010) indicate a more balanced monthly removal scheme currently in place

Table 3: Existing Pumping Rates

Month	Pumping Rate (m^3/month)												
	Well A Deschene	Well B Kenneth	Well C Phillipe	Well D Frost	Well E Notre Dame	Well F Linden	Well G Pharand	Well H Michelle	Well I	Well J	Well M	Well Q Chenier	Well R
Jan	34,245	31,085	38,801	37,094	42,232	52,626	16,952	45,326	26,183	604	32,283	0	0
Feb	28,407	30,070	31,146	30,175	51,520	56,313	15,547	37,183	30,303	2,323	0	0	0
Mar	31,167	34,140	37,985	36,346	50,446	50,457	17,443	45,146	33,304	11,621	0	0	0
Apr	21,868	36,746	36,680	36,787	54,281	52,876	14,791	44,154	32,975	38,359	0	0	0
May	32,265	34,612	36,269	36,300	55,232	56,245	19,126	55,372	26,497	18,841	41,041	0	0
Jun	31,567	30,316	35,582	33,399	54,826	53,970	12,381	42,217	31,902	0	57,402	0	0
Jul	28,902	30,906	33,275	31,889	52,271	46,760	11,494	35,482	31,330	51	56,100	0	0
Aug	33,499	30,525	38,096	35,782	72,912	53,283	21,718	39,569	31,841	195	67,854	0	0
Sep	30,095	27,043	35,004	33,010	52,302	54,199	17,906	36,234	38,151	276	59,907	0	0
Oct	32,452	29,667	34,831	36,909	64,233	47,563	29,326	40,062	36,203	23	46,036	0	0
Nov	25,529	20,546	32,709	36,666	59,111	43,870	31,239	35,921	31,131	249	60,944	0	0
Dec	23,947	34,279	31,130	37,888	68,325	51,920	16,215	34,493	31,663	436	61,894	0	0
Total	353,943	369,935	421,508	422,245	677,691	620,082	224,138	491,159	381,483	72,978	483,461	0	0

3.4 Planned System and Committed Demand

Although growth plans exist for the entire area serviced by the Valley East aquifer, in particular the Valley East area is designated for population growth over the timeframe of the existing Official Plan (CGS 2005). Industrial and commercial growth in Valley East is dominated by a planned expansion of the existing Valley East Industrial Park, while the bulk of residential expansion is the development of low density subdivisions.

In order to maintain effective municipal water service to the serviced areas with i) planned increases in population and ii) removal of prior municipal water source Well #6, the CGS has undertaken a study to locate and develop additional groundwater supply from within the Valley East aquifer. Ultimately, two new groundwater wells have been approved through the Municipal Class EA process and have been designated as ‘Well Q - Chenier Well’ and ‘R’ Well. These new wells are a ‘planned system’ in the context of this Tier 3 exercise. These wells have each been assigned a maximum permitted (PTTW) pumping rate and a recommended operational pumping rate based on previous hydrogeological analyses (Golder 2010; Table 4). The actual instantaneous and daily pumping rates will depend on operator experience and commissioned well performance.

Table 4: Assumed Chenier Well (Well Q) and 'R' Well Pumping Rates

Well	Maximum Permitted Pumping Rate (m^3/day)	Assumed Operational Pumping Rate (m^3/day)	Total Annual Pumping (m^3)[1]
Chenier Well	2333	2074	757,010
R Well	3162	2946	1,075,290

Note:

[1] Assumes these wells are operational 24-hours per day, 365 days per year. Actual pumping rates will depend on operations and well performance.

Committed demand from residential sources for the Valley Drinking Water System was estimated from subdivision maps as provided by the CGS (CGS 2011). The number of draft approved lots in the serviced areas of Valley East, Chemsford, Azilda and Capreol (1,984; Section 2.5) was multiplied by 2.5 people per dwelling and by household water usage (approximately 338.2 L/person/day; Golder 2009) to estimate residential committed demand. This total additional municipal water demand is therefore approximately 612,260 m^3/per year. Declining municipal demand has been recorded in Valley East over the 2007 to 2010 period (Section 2.4), and as such the per capita water usage may need to be revised periodically to better reflect current consumption rates and committed demand.

Current and predicted future industrial water usage at the Valley East Industrial park was estimated from wastewater rates provided by CGS (Mannerow 2011, pers comm.). As the existing municipal wells currently supply this area, it was assumed that this was already accounted for within the total existing well removal volume (Table 5).

Table 5: Valley East Industrial Park Estimated Water Use

Well System	Existing Municipal Demand[1] (m³/year)	Committed Municipal Demand (m³/year)	Existing Industrial Park Demand[2]	Committed Industrial Park Demand	Total Committed Demand (m³/year)	Total Existing plus Committed Demand (m³/year)
Valley Drinking Water System	4,518,620	612,260	(3,470)	1,890	614,150	5,132,770

Notes:

[1] based on total removals from Valley East and Capreol Well Field, Table 3.

[2] assumed as already included in existing municipal demand.

From Tables 4 and 5, it is apparent that the newest wells could provide the entire additional committed demand on an annual basis, if the wells are in fact able to consistently produce the estimated operational rate. CGS well operations staff has indicated that they would prefer to spread the increased demand over the entire well system, but unfortunately without these new wells in operation it is difficult to predict how pumping rates would be redistributed. In addition, CGS well operators have indicated that the following wells have little to no capacity for increased pumping:

- ‘I’ Well has known performance (drawdown) problems.
- Michelle Well (Well H), Kenneth Well (Well B) and Pharand Well (Well G) have persistent water quality issues.
- Deschene well (Well A) was ‘locked-out’ due to low water level in Summer 2010.

In general, these limitations echo the necessity for additional groundwater wells and that there exists very little flexibility for existing well pumping rate increases.

Therefore, in order to estimate the total planned plus committed demand, the following approach was taken:

1) Daily pumping rates were not increased at the existing wells.
2) The total committed demand was supplied solely by the operation of the new wells.
3) The total planned demand was calculated as the total volume of water potentially supplied by the Chenier Well (Well Q) and R Well (Table 4) minus the total committed demand (Table 5). Annual removals are summarized in Table 6.

Table 6: Existing plus Committed plus Planned Pumping Rates

Well System	Existing Municipal Demand[1] (m^3/year)	Committed Municipal Demand[2] (m^3/year)	Committed Industrial Park Demand (m^3/year)	Planned Demand (m^3/year)	Total Existing plus Committed Demand (m^3/year)	Total Existing Plus Committed Plus Planned Demand (m^3/year)
Valley Drinking Water System	4,518,620	612,260	1,890	1,218,150	5,132,770	6,350,920

Notes:

[1] based on total removals from Valley East and Capreol Well Field, Table 3.

[2] excluding industrial demand.

The monthly pumping rate distribution (i.e. the allocated pumping rate) for each municipal well is shown in Table 7. It was understood throughout the process of selecting these pumping rates that there may be a need to revisit them as the new wells provide longer term sustainable pumping rates, operations, and as pumping rates change through normal well performance loss and rehabilitation.

Table 7: Allocated Monthly Existing plus Committed plus Planned Pumping Rates

Month	Pumping Rate (m^3/month)												
	Well A Deschene	Well B Kenneth	Well C Phillipe	Well D Frost	Well E Notre Dame	Well F Linden	Well G Pharand	Well H Michelle	Well I	Well J	Well M	Well Q Chenier	Well R
Jan	34,245	31,085	38,801	37,094	42,232	52,626	16,952	45,326	26,183	604	32,283	64,294	91,326
Feb	28,407	30,070	31,146	30,175	51,520	56,313	15,547	37,183	30,303	2,323	0	58,072	82,488
Mar	31,167	34,140	37,985	36,346	50,446	50,457	17,443	45,146	33,304	11,621	0	64,294	91,326
Apr	21,868	36,746	36,680	36,787	54,281	52,876	14,791	44,154	32,975	38,359	0	62,220	88,380
May	32,265	34,612	36,269	36,300	55,232	56,245	19,126	55,372	26,497	18,841	41,041	64,294	91,326
Jun	31,567	30,316	35,582	33,399	54,826	53,970	12,381	42,217	31,902	0	57,402	62,220	88,380
Jul	28,902	30,906	33,275	31,889	52,271	46,760	11,494	35,482	31,330	51	56,100	64,294	91,326
Aug	33,499	30,525	38,096	35,782	72,912	53,283	21,718	39,569	31,841	195	67,854	64,294	91,326
Sep	30,095	27,043	35,004	33,010	52,302	54,199	17,906	36,234	38,151	276	59,907	62,220	88,380
Oct	32,452	29,667	34,831	36,909	64,233	47,563	29,326	40,062	36,203	23	46,036	64,294	91,326
Nov	25,529	20,546	32,709	36,666	59,111	43,870	31,239	35,921	31,131	249	60,944	62,220	88,380
Dec	23,947	34,279	31,130	37,888	68,325	51,920	16,215	34,493	31,663	436	61,894	64,294	91,326
Total	353,943	369,935	421,508	422,245	677,691	620,082	224,138	491,159	381,483	72,978	483,461	757,010	1,075,290

3.5 3-Dimensional Numerical Groundwater Model - MODFLOW

MODFLOW-SURFACT (HydroGeoLogic Inc., 2008) was used to model groundwater flow. MODFLOW-SURFACT is a multi-purpose three dimensional (3D) groundwater flow and transport code developed by HydroGeoLogic Inc. and based on the United States Geological Survey's MODFLOW code (McDonald & Harbaugh 1998). It is modular in nature and uses the finite difference formulation of the groundwater flow equation in its solution.

MODFLOW has been recognized as an industry standard for general purpose groundwater flow modelling and has gained wide acceptance from academia, consultants and regulatory agencies worldwide. Visual MODFLOW® (Version 4.3.0) was used as the pre- and post-processor for the simulations presented in this report. A brief overview of the Valley East MODFLOW model is presented in the following sections, and a full description of model assumptions and calibration procedures is attached in Appendix A.

3.6 Model Background

The Valley East groundwater model domain covers an area of approximately 154 km² (i.e. this represents the area of active cells in the numerical model). The numerical model was developed from a conceptual hydrogeological model that was constructed from available groundwater and aquifer properties data.

The development of the model incorporated topography, overburden properties, thickness and bedrock elevations. Within the valley, the bedrock surface is relatively low, but quite irregular; 30 to 50 m of bedrock relief is not uncommon, resulting in small outcrops in the middle of the otherwise Quaternary sediment-filled valleys.

The bedrock in the Valley East area was assumed to have a hydraulic conductivity several orders of magnitude lower than the unconsolidated sands and gravels that fill the valley. Since the groundwater flow from bedrock to the valley sediments is considered very minor compared to river-aquifer interactions and direct recharge from precipitation, bedrock has been treated as no-flow boundaries within the model domain.

The model assumed a direct hydraulic connection between the aquifer and surface water features. Major rivers and lakes (Vermilion River, Whitson River, Onwatin Lake, Greens Lake, and Moose Lake), were assigned as constant head boundary conditions that could receive water from, and provide water to, the aquifer. Smaller tributaries and municipal drains that discharge to the Vermilion and Whitson River were assigned as drain boundary conditions, or as areas that were only able to receive water from the aquifer.

Details on the municipal wells included in the model were based on data provided by original well installation borehole logs, more recent rehabilitation reports and the updated ground level survey completed by the CGS.

3.7 Model Calibration

MODFLOW was calibrated with available hydrogeological data. This included information from the MOE Water Well Information System (WWIS) as well as geological, geotechnical and hydrogeological data from earlier investigations in the Valley East area. The steady-state model was calibrated by adjusting recharge rates and hydraulic conductivities of the various overburden units until there was a reasonable match between the simulated groundwater elevations and the recorded elevations for the Valley East area wells. The results of this calibration procedure included:

- The greatest zone of recharge by area was in the sandy deposits surrounding the wells (375 mm/yr). Groundwater recharge was 425 mm/yr near selected bedrock outcrops (recharge enhanced by surface runoff), 225 mm/yr in areas with silty sand, 100 mm/yr in lacustrine silts and clays and 50 mm/yr over silty floodplain deposits.

- Hydraulic conductivities for the overburden aquifer were estimated to range from 10 to 116 m/day, with a geometric mean of 53 m/day based on earlier study results of constant rate pumping tests and grain size analysis. An effective porosity of 0.25 was assigned for the sand and gravel sediments, while 0.35 was assigned for the finer grained silty clay sediments.

The calibrated steady-state groundwater flow model provides a reasonable understanding of groundwater flow conditions in the Valley East area. Through the calibration process it was found that the modelled hydraulic conductivities of the geologic units were in general agreement with site specific information. The calibrated model values therefore represented suitable estimates for use in developing simulated head for the Valley Drinking Water System under various pumping rates.

3.8 Model Pumping Rates

Pumping Rates for the model were input from Table 3 and Table 7. Simulations with the groundwater model produced groundwater levels that are reflective of the wells pumping at a constant daily pumping rate over the assigned month or simulation timeframe. In this respect the well operation differs from the actual well field management, which is much more dynamic and dependent on demand and operator experience. As such, the water levels presented herein may include a degree of conservatism, where periods of well inactivity are not reproduced.

3.9 Land Use and Land Cover Change

Land Cover was estimated through the model calibration process, and is reflected in the recharge zones that are spatially distributed across the model domain (Appendix A).

As detailed in Appendix A, future Land Use changes within Local Areas were based upon the CGS Official Plan (CGS 2005). The following land uses are part of the Official Plan: Mixed Use Commercial; General Industrial; Low Density Residential; and Medium Density Residential. Although currently the CGS does not have infiltration policies for any of the existing/planned land use types, CGS Planning staff suggested a ratio of 65% pervious and 35% impervious for Low Density Residential development. For the remaining planned land uses the Urban Land Use Impervious percentages from the Credit Valley Conservation Tier Two Integrated Water Budget Report (CVC 2009) were adopted (Appendix A).

As described in Golder’s technical memorandum to the Ministry of Natural Resources (Golder 2010), recharge in the model was adjusted to account for the planned land use changes using a weighted average based upon the existing recharge zone in the model and the planned land use that resides within, and the percent imperviousness of the respective land use. Recognizing that infiltration is not eliminated within the areas noted as “impervious”, it was proposed to apply some recharge to the impervious areas. It was reasonably assumed that recharge for an “impervious” area was 50 mm/yr. For a Low Density Residential pocket residing in a recharge zone of 375 mm/yr, the new recharge for this area would be calculated as follows:

$$\text{Low Density Residential} = 35\%\ \text{Impervious} + 65\%\ \text{Pervious}$$

$$= 0.35 * 50\ \text{mm/yr} + 0.65 * 375\ \text{mm/yr}$$

$$= 261.3\ \text{mm/yr}$$

This process was similarly completed for each planned change in land use within the Local Areas (and outside the Local Areas when delineating the WHPA-Q2).

3.10 Simulation Scenarios

As described in the Technical Rules, Valley East aquifer simulations were completed for the scenarios relevant to groundwater supply intakes (Table 8). Climate records were examined to determine time periods for two-year and ten-year drought scenarios. As detailed in the GSSPA Valley East Tier Two study (Golder 2009), the years 1955 to 1964 yielded the 10-year lowest average precipitation in the Sudbury area (785 mm). Throughout the climate record of 1954 to 2009, the two-year minimum total precipitation was received in years 1962 (679 mm) and 1963 (735 mm).

Table 8: Groundwater Risk Scenarios

Scenario	Time Period	Land Cover	Allocated Pumping Rate (municipal)	Model Simulation
C	Climate data period	Existing	Existing	Steady state groundwater model – average annual recharge and monthly pumping rates
D	Ten Year Drought	Existing	Existing	Transient groundwater model – monthly recharge and monthly pumping
G(1)	Climate data period	Reduced recharge resultant from land cover changes	Existing plus committed plus planned	Steady state groundwater model – average annual recharge and monthly pumping rates
G(2)		Existing	Existing plus committed plus planned	
G(3)		Reduced recharge resultant from land cover changes	Existing	
H(1)	Ten Year Drought	Reduced recharge resultant from land cover changes	Existing plus committed plus planned	Transient groundwater model – monthly recharge and monthly pumping
H(2)		Existing	Existing plus committed plus planned	
H(3)		Reduced recharge resultant from land cover changes	Existing	

The Scenarios presented in Table 8 rely upon available historical climate information. Given the uncertainties related to future climate and climate change, these Scenarios should be revisited periodically in order to re-assess drought periods and analyse for emerging climatic trends (for example a persistently warmer, wetter annual climate).

4.0 TOLERANCE AND RISK LEVEL

A primary objective of the Tier Three exercise is to evaluate the tolerance and risk level associated with the ability of the drinking water source to continue to provide water supply, while considering other uses of the same water source.

4.1 Tolerance

Tolerance (designated as ‘high’ or ‘low’) refers to the ability of a drinking water intake to continue to provide the required quantities of water for identified uses during peak demand periods. For the Valley East groundwater aquifer, a tolerance level was assigned to each of the prescribed and completed Scenarios. For the Valley East Tier Three Risk Assessment, Tolerance was assigned based on simulated water level results compared against a ‘trigger’ elevation, along with a qualitative evaluation of the municipal system to meet peak demands.

4.1.1 Water Level Trigger Elevations

An applicable, realistic tolerance level trigger was the subject of substantial discussion at Peer Review meetings. The preferred tolerance trigger was consistently identified as the low-level lock out alarm, which each of the studied wells are outfitted with. This low-level lock out alarm removes the well from service if the water level in the well falls below a specific elevation, and the occurrence of a lock out alarm at a groundwater well is communicated to CGS operations staff via the SCADA system. Unfortunately, the well specific lockout elevations are not available at this time. Future well rehabilitation work by CGS is intended to include the determination of these elevations.

In the absence of this information, physical well characteristics were reviewed in order to obtain a water level below which the pumping well could no longer provide a reliable water supply. These physical features included:

- the top of the well screened interval;
- the bottom of the well screened interval;
- the top of the well screened interval, plus some amount of ‘buffer’;
- the top of the intake pump bowl assembly; and
- the bottom of the intake pump (i.e. the impeller or suction intake).

Generally, the well pump is positioned such that the suction intake is located just below the top of the well screen.

The bottom of the well screen interval was eliminated due to a likely clear lack of reliable supply prior to the water level reaching this elevation. The top of the screened interval plus a buffer as well as the top of the pump bowl assembly were eliminated as they were regarded as potentially over conservative (i.e. the well could still provide water, although perhaps at a substantially reduced efficiency).

The top of the well screen and pump suction intake are generally close in elevation within the well casing. For the purposes of this study, the pump suction elevation, or bottom of pump assembly, was chosen as the tolerance ‘trigger’, given that this elevation would be the elevation at which well production would cease. Due to well efficiency losses within the pumping well, the monitoring of the actual low level lock out elevations would provide valuable additional information towards this study as an early warning for impending decreased well yield. For Chenier Well (Well Q) and ‘R’ Well, the top of screen was used as the pump intake elevations as these were not known at the time of reporting.

4.1.2 Peak Demand Tolerance

Peak demand tolerance was assigned based on discussions with CGS water and wastewater staff who have operated the existing Valley Drinking Water System during dry periods. In addition, an understanding of the capacity of the system to store water was considered in the determination of peak demand tolerance.

4.2 Other Water Uses

As described in Rule 99 of the Technical Rules, other uses of a water source that are to be considered within the Scope of the Tier Three study can include:

- waste water assimilation;
- other water takings including agricultural, commercial and industrial water takings;
- navigation;
- recreation;
- aquatic habitat; and
- Provincially Significant Wetlands.

Waste water delivered to the Valley East WWTP or Capreol lagoons is ultimately discharged to the Vermilion River, outside of the Local Areas (Section 9.1) and the Whitson River watershed. Potential navigation and recreational water ways are also outside of the Local Areas (e.g. Whitson Lake, Garson Lake, Green's Lake, Whitson River), and there are no Provincially significant wetlands.

Agricultural removals in Valley East are minor when considered in the context of the municipal removals (Golder 2005), while industrial and commercial takings were considered minor removals and were supplied by the municipal wells (Section 3.2). There are no known active PTTW for industrial or commercial removals in the delineated Local Areas.

Communication from the Canada Department of Fisheries and Oceans (DFO) have indicated that some tributaries in the Whitson River watershed may provide sufficient habitat for trout (a cold water fish species), although it may be temporary. Although no specifics could be given, these tributaries (and municipal drains) are assessed on a case-by-case and as-needed basis by DFO with respect to habitat prior to activities in the area of these features. As such, these tributaries and drains may provide important aquatic habitat and are therefore identified as an 'other water use' which requires consideration in the Tier Three assessment with respect to Scenarios G(1) and G(2).

As per the Technical Rules, analysis of the potential effect of pumping wells on aquatic habitat was therefore based on groundwater discharge to the stream, such that:

1) A risk level of significant (See Section 4.3) is assigned when groundwater discharge to a cold water stream results in a reduction greater than:
    a. 20% of the existing estimated streamflow that is exceeded 80% of the time (Q_p80), or
    b. 20% of the existing estimated average monthly baseflow of the stream.
2) A risk level of moderate (See Section 4.3) is assigned when groundwater discharge to a cold water stream results in a reduction greater than:
    a. At least 10% but not greater than 20% of the existing estimated streamflow that is exceeded 80% of the time (Q_p80); or
    b. At least 10% but not greater than 20% of the average estimated monthly baseflow of the stream.

Streamflow statistics (e.g. Q_p80) are typically not available for the small tributaries and drains of the Whitson River. The potential effect of pumping on aquatic habitat was based on baseflow, and changes to baseflow, was extracted from the groundwater model simulations.

4.3 Risk Level

A risk level was assigned to each delineated Local Area following the assessment of simulated water levels, the municipal water demand and the water elevation triggers as outlined in Section 4.1. A risk level of ‘significant’ or ‘moderate’ was assigned to the Local Area if the triggers in Table 9 were reached.

Table 9: Risk Level Assignment Matrix

Groundwater Scenario (Table 1)	Risk Level Assignment Basis	Technical Rules Reference
Scenario C	Municipal Demand, Well Screen Elevation	Part IX.2, Rule 104 (1)
Scenario D	Municipal Demand, Well Screen Elevation	Part IX.2, Rule 104 (1)
Scenario G(1), G(2), G(3)	Municipal Demand, Well Screen Elevation	Part IX.2, Rule 104 (2) and (3)
Scenario G(2)	Other Uses, Well Screen Elevation	Part IX.2, Rule 104 (2) and (3), Rule 106
Scenario H(1), H(2), H(3)	Municipal Demand, Well Screen Elevation	Part IX.2, Rule 104 (4)

In summary, for a Local Area to receive a risk level of ‘low’, it must:

- provide sufficient water to satisfy the demand, at the prescribed allocated rate (existing or existing plus committed plus planned) and for the prescribed land cover (existing or future); applicable to Scenarios C, D, G(1), G(2), G(3), H(1), H(2) and H(3). This was assessed on a per-well basis, and the allocated rate for a well was considered not available when one or more wells drew water level below the pump intake. Although operationally, the removal of one well from service may be compensated by increased pumping at another, this was not considered in the analysis;

- provide sufficient water to satisfy the peak demand with a tolerance of high, at the prescribed allocated rate (existing) and for the prescribed land cover (existing); applicable to Scenarios C and D. The ability of a well to provide for peak demand was evaluated through the simulated water levels and operator experience (Section 4.1.1 and Section 4.1.2). Although operationally, the removal of one well from service may be compensated by increased pumping at another, this was not considered in the analysis; and

- provide sufficient groundwater discharge such that there are not unacceptable impacts to other water uses; applicable to Scenario G(2).

As detailed by MNR, risk levels were not assigned based on ‘Other Uses’ for Scenarios G(1) and G(3). In the case of these scenarios, potential impacts to aquatic habitat from a groundwater discharge reduction that results from future land use change fall outside of the scope of the Act. As such, only the ability of the municipal supply to meet the demand were considered for Scenarios G(1) and G(3).

A Water Quantity Threats Assessment must be completed for a Local Area designated as ‘moderate’ or ‘high’ risk.

5.0 WHPA-Q1, WHPA-Q2 AND LOCAL AREA DELINEATION

The delineation of the Well Head Protection Area – Quantity 1 (WHPA-Q1), WHPA-Q2 and the Local Area was an incremental process that took into consideration the following steps:

1) The area of land that would be required to provide the municipal wells with the water removed under Scenario C was simulated.

2) The calculated area was compared to the drawdown created by the assigned pumping rate.

3) The drawdown contour (the ‘zone of influence’) that most closely matched the area of recharge was assigned as the WHPA-Q1.

4) Additional areas where development is scheduled as per the Official Plan, outside of the WHPA-Q1, was assigned decreased recharge, and the zone of influence was re-simulated

5) If the additional area affected the zone of influence, these additional areas were incorporated into the WHPA-Q1 and was designated as the WHPA-Q2

6) The local area was delineated as the area within the WHPA-Q1 and WHPA-Q2.

6.0 ADDITIONAL WORK

Beyond the scope outlined within the Technical Rules, the following sections outline additional information collected for and analysis completed for the Valley Drinking Water System Tier Three study.

6.1 Well Installation Surveying

In conjunction with the Tier Three analysis, a detailed survey of above ground infrastructure at each Valley Drinking Water System municipal well installation was completed by CGS staff. These additional survey points included ground elevations outside of each well house and well pedestal elevations. These data were provided to Golder and were used along with the well detail schematics to refine the total well depth, pump installation details and screened interval elevations at each municipal well in the system. As such, the reference elevations for these well details presented herein should be considered to supersede those displayed in earlier GSSPA reports. These are attached in Appendix B.

6.2 Well Loss Analysis

An important consideration of the groundwater modelling analysis and resultant output figures is that it displays the predicted water level in the aquifer that would result under the specific pumping conditions. That is, it provides a snapshot of the aquifer behaviour outside of the well casing. In general terms, the hydraulic performance of a well is affected by i) the transition to turbulent flow across the well casing (which is influenced by pumping rate and the material adjacent to the well screen) and ii) the condition of the well screen (which can deteriorate over time through mineralization or other clogging). This is reflected in the water level within the well casing often becoming lower than the water level on the outside of the casing (in the aquifer).

Therefore, the activation of a pumping well in an unconfined aquifer will normally result in the following:

1) A lowered water table (relative to static) elevation in the aquifer at the outside of the well casing. This is known as ‘formation loss’.

2) A water level (equal to or lower than the formation loss) caused by well inefficiency, on the inside of the well casing. This is known as ‘in-well loss’.

Detailed description and calculations of formation loss and in-well loss were provided to the MNR by S.S. Papadopulos and Associates Ltd. and are included in Appendix C. The groundwater modelling output is reflective of the formation loss due to aquifer pumping (Appendix C). In the process the current Tier Three project, the estimation of in-well losses was brought forward as additional data that may be valuable when considering the tolerance of each well. Available pump test curves (from CGS well rehabilitation reports) provided data for the required coefficients.

Formation loss analysis and in-well losses were calculated for the Valley Drinking Water System under pumping rates reflective of steady-state Scenarios with existing plus committed plus planned conditions (Table 7).

7.0 WATER BUDGET

The constructed MODFLOW groundwater model allows for characterization of groundwater movement, groundwater removals and groundwater exchange with defined surface water features, but does not explicitly account for the surface water budget (rainfall, snowmelt, evaporation and runoff). As such, the monthly water surplus, which represents the total amount of water available for recharge and runoff, was calculated using a simple spreadsheet-type model (Golder 2009).

A water budget is a balance between inputs, outputs and storage changes integrated over an area. Over long periods of time (e.g. annually) storage changes become negligible and the inputs to the budget are equal to the outputs. When outputs are greater than inputs, water supply is depleted. The water budget was defined as:

$$P - ET = RO + Q_R \pm \Delta S \qquad (1)$$

where ΔS is the change in storage, P is precipitation inputs via rainfall and snowmelt, ET is evapotranspiration, RO is surface water runoff and Q_R is vertical groundwater recharge. Evapotranspiration occurs at its potential rate (PET) when water is freely available and the evaporating air mass is stable. Soil moisture conditions can restrict evapotranspiration to an actual rate (AET). Over the course of a month or day these terms vary in their contributions to change in storage in the Valley East aquifer (ΔS), however, over long periods of time (i.e. annually) ΔS will become close to zero. The estimated Q_R volume represented the total amount of water available for anthropogenic removal ($Anth_{OUT}$). The calculation of these terms is discussed in the following sections.

7.1 Precipitation Input - Rainfall and Snowmelt

Daily and monthly precipitation (rainfall and snowfall) data were collected from the Sudbury Airport climate station near the study watershed for the period of available record (1954 to 2007).

Snowmelt potential was estimated using a temperature index model as used by Environment Canada for eastern forested basins:

$$SnowMelt = 0.0397(T_a - 27.6) \qquad (2)$$

Where T_a is mean daily air temperature (ºF) and *SnowMelt* is melt in inches/day (Pysklywec et al. 1968). Results were subsequently converted to metric (SI) units. Daily snowmelt amounts were summed to give monthly equivalent water depths. The snowmelt equation (2) was chosen as it best represented monthly snowmelt in watersheds previously studied in the GSSPA (Golder 2008).

7.2 Evapotranspiration and Sublimation

Long-term temperature data from the Sudbury Airport climate station was used to calculate PET using the Thornthwaite Heat Index method (Thornthwaite and Mather 1957). PET was adjusted for day length as described by Forsythe *et al*. (1995).

Evapotranspiration occurred at its maximum rate (PET) when the soil was saturated and at AET where AET decreased with a soil moisture decrease (Holmes and Robertson 1959). Previous Tier One water budget analysis estimated annual AET at 87% of PET in the Valley East area (Golder 2008). Using the Thornthwaite Heat Index model, no ET occurred when monthly average temperature was below zero (December to February). Evaporation from snowpack is generally small compared to the total annual amount of evaporation (Black *et al*. 1996), however, there was concern expressed by the Peer Review Committee that a lack of sublimation accounting may result in overestimating the amount of water available during the spring freshet for runoff and groundwater recharge.

7.2.1 Sublimation

Sublimation, also termed ‘winter evaporation’ (Pomeroy et al. 2002), occurs when wind and solar conditions allow snow to be converted directly to water vapour, and can decrease snowpack and snow water content. The sublimation rate (mm/day) was estimated using the equation (Kuzmin 1961);

$$E_S = (0.18 + 0.098z)(e_0 - e_2) \qquad (3)$$

Where Es = Sublimation rate (mm/day), e_o is the saturated vapour pressure at the snow surface, e_2 is the actual vapour pressure at temperature gauge height, and z is the daily average windspeed (m/s). Sublimation estimates for this study were calculated from data collected from the Sudbury Airport and incorporated into the simple snowmelt model created for GSSPA Tier One watersheds (equation (2) above; Golder 2008). A more detailed methodology for sublimation calculations and related assumptions are available in Golder (2009).

7.3 Groundwater Recharge and Runoff

The water surplus (P-ET) was transferred to the MODFLOW groundwater model, and the calculated water surplus was made available to fulfill the calibrated recharge (Q_R). Water that remained after the calculation of P-ET -Q_R was applied as runoff to local streams and drainage ditches towards the Whitson River (*RO*). For example, if a 300 mm annual water surplus was calculated from equation (1), and the maximum annual recharge from the calibrated MODFLOW model was estimated at 200 mm, a value of 100 mm was applied to runoff (*RO*).

7.4 Anthropogenic Removals and Groundwater Discharge

Anthropogenic removals ($Anth_{OUT}$) were summarized from available water use records as previously outlined in Section 3.0.

7.5 Change in Storage

The change in storage (ΔS) in the Valley East aquifer is reflected in a change in water table elevation. Changes in the water table elevation in Valley East have been monitored by the NDCA as part of the Provincial Groundwater Monitoring Network (PGMN) since 2006. Groundwater levels in this well were previously summarized in Golder (2009).

8.0 UNCERTAINTY ANALYSIS

For the Tier Three analysis, uncertainty was characterized as ‘high’ or ‘low’ for risk level assigned to the Local Area. The factors for consideration in the analysis of uncertainty is i) the distribution, variability, quality and relevance of the available input data, ii) the ability of the methods and models used to accurately reflect the hydrologic system, iii) the quality assurance and quality control procedures applied and iv) the extent and level of calibration and validation achieved for any groundwater and surface models used or calculations and general assessments completed.

As noted in Golder (2009), uncertainty in the groundwater model was inherently addressed through calibration of the steady-state model and is a result of assumptions made in the aquifer formations (Appendix A). In addition, the Tier Two water budget considered the sensitivity of variables related to soil properties that influence pore drainage such as specific yield (S_y) and storativity (S_s). These parameters were adjusted individually and the model was run at current pumping rates to explore the potential effect of each changed parameter.

For the Tier Three study, uncertainty was addressed primarily through a case-specific study of the observed groundwater levels at the Linden and Notre Dame wells. The conditions of this uncertainty analysis are detailed in Section 10.1, which focussed on changes to hydraulic conductivity and pumping rates at two wells which produced different transient drawdown results, yet are located relatively close.

Formation loss analysis and in-well losses were calculated for the well system under pumping rates reflective of existing plus committed plus planned conditions (Table 7). These calculations were completed for consideration along with the modelled steady state scenarios, but were not explicitly added to the results in the steady state or transient scenarios. In this respect, the in-well losses were considered to provide an indication of the overall performance of the well as well as the sensitivity of the water level results.

9.0 RESULTS

9.1 WHPA-Q1, WHPA-Q2 and Local Area Delineations

Following the methodology provided in Section 5.0, three distinct WHPA-Q1, WHPA-Q2 and Local Areas were delineated. In each case, the surface area that provided sufficient recharge to provide the total annual water removal from the aquifer corresponded closely to a 1 m drawdown area of influence. These areas were designated as the WHPA-Q1-A, WHPA-Q1-B and WHPA-Q1-C (Figure 9.1). The WHPA-Q1-B incorporated only the ‘I’ Well, WHPA-Q1-C incorporated the J Well and M Well, while the remaining wells fell within the WHPA-Q1-A. The drawdown created by the J Well and M Well was limited in extent, and as such as per MNR direction a 100 m buffer was placed around these wells to delineate a WHPA-Q1.

The WHPA-Q2 was delineated through the reduction of recharge from planned development areas outside each of the delineated WHPA-Q1, which affected only the WHPA-Q1-A (Figure 9.2). Repeating the simulation under these reduced recharge conditions resulted in no substantial change in area required to supply the municipal wells with sufficient water on an annual basis. As such, the WHPA-Q2 was equivalent to the WHPA-Q1 in each case.

Three Local Areas were subsequently defined as the area delineated by each of the WHPA-Q2 areas, and were designated as Local Area A (with ten municipal wells), Local Area B (with one municipal well) and Local Area C (with two municipal wells) (Figure 9.3). In the case of the Local Area A, the delineated surface area (38.2 km^2) is greater than the subwatershed area calculated in earlier GSSPA Valley East Water Budget reports (34 km^2). The change in area can be attributed to the inclusion of the two additional wells and that the basis for the subwatershed area was the use of groundwater capture zone areas.

9.2 Water Budget

The annual water budget for Local Area A as shown in Table 10 was compiled using regional climate data and recharge as calculated by the calibrated MODFLOW model under steady-state conditions.

Table 10: Local Area A Annual Water Budget

	Water Budget Element (m^3)[1]				
	Rainfall	**Snowmelt**	**Evapotranspiration[2]**	**Recharge[3]**	**Runoff**
Annual Average	24,808,000	8,448,100	19,227,300	10,831,600	3,197,200

Note:

[1] All water budget elements distributed over subwatershed area (38.2 km^2)

[2] Evaporation presented is AET and includes sublimation

[3] Recharge estimated using MODFLOW calibration and weighted to recharge area in subwatershed

Annual recharge as estimated by the 3-D model MODFLOW was 283.6 mm, or approximately 10,831,600 m^3 when weighted by recharge area across the delineated Local Area A (Figure 9.4). The remainder, runoff, was available for drainage to the ditches and municipal drains that fall within the Local Area A. Sublimation accounted for approximately 3% of the total precipitation input on an annual basis and represented a small loss in the amount of water available for recharge and runoff.

The total current annual pumping amount from the municipal wells ($Anth_{OUT}$) within Local Area A (see Table 3) was approximately 41% of the calibrated MODFLOW recharge value on an annual basis.

9.3 Groundwater Risk Scenarios – Model Results

Groundwater table elevation in the Valley East aquifer was simulated for each prescribed Scenario. Steady state modelled scenarios resulted in a water level value representative of the pumping conditions, while transient scenario results were produced as daily water levels. The results presented in the following sections consider the Formation Loss component of the total drawdown, and additional in-well losses may occur during actual operations. The in-well losses component will be further described in Section 10.1.

Other uses (aquatic habitat) were investigated in the absence of certainty of the presence of cold water streams within Local Area A. Modelled scenarios produced baseflow (groundwater discharge) changes compared against Scenario (C). The other uses analysis was applicable to Scenarios G(1) and G(2), however, risk assignments based on other uses was applied only to Scenario G(2).

9.3.1 Scenario C – Long Term Climate, Existing Pumping, Existing Land Cover

Simulated steady state drawdown for each existing municipal well is summarized in Table 11. For this Scenario, water level remained above the trigger elevation (pump intake). This is consistent with the current understanding of the system, that it is able to provide water to satisfy the existing municipal demand.

The simulated water levels suggest that the allocated quantity of water removed from each Local Area would be sufficient to meet the existing water demand and peak demand at each municipal well.

Table 11: Scenario C Groundwater Model Output

Well Name	Steady-State Simulated Groundwater Elevation (masl)	Bottom of Pump intake (masl)	Top of Screen (masl)
A - Deschene	293.0	287.7	286.9
B - Kenneth	290.7	283.6	282.9
C - Philippe	291.8	285.6	284.7
D - Frost	291.4	284.1	281.9
E - Notre Dame	290.1	284.1	283.7
F - Linden	285.7	278.6	277.2
G - Pharand	288.1	285.0	285.0
H - Michelle	292.0	285.5	285.8
I Well	290.2	282.4	280.3
J Well	294.0	275.3	274.2
M Well	293.4	277.0	274.8

9.3.2 Scenario D – Drought Period, Existing Pumping, Existing Land Cover

Simulated transient water level plots for aquifer level outside of each existing municipal well are displayed on Figure 9.5. For the ten-year drought period (1955 to 1964), drawdown ranges from <1 m (Well J) to approximately 4 m (at the Michelle and Phillipe Wells). However, groundwater table elevation was maintained above the intake trigger elevation for each of the municipal wells.

These simulated groundwater levels suggest that the allocated quantity of water removed from each Local Area would be sufficient to meet the existing water demand and peak demand at each municipal well during drought periods.

9.3.3 Scenario G(1) – Long Term Climate, Existing plus Committed plus Planned Pumping, Future Land Cover

Simulated steady state drawdown for each existing and planned municipal well is summarized in Table 12. For this Scenario, water level remained above the trigger elevation (pump intake). The low simulated head at the Linden Well (282.4 masl) when compared to other wells in close proximity (Notre Dame, Chenier Well and R Well at 287.6, 288.5 and 287.3 masl, respectively) was a focus of the sensitivity analysis performed on the model (Section 10.1).

Table 12: Scenario G(1) Groundwater Model Output

Well Name	Steady-State Simulated Groundwater Elevation (masl)	Bottom of Pump intake (masl)	Top of Screen (masl)
A - Deschene	291.3	287.7	286.9
B - Kenneth	289.2	283.6	282.9
C - Philippe	289.8	285.6	284.7
D - Frost	290.0	284.1	281.9
E - Notre Dame	287.6	284.1	283.7
F - Linden	282.4	278.6	277.2
G - Pharand	287.3	285.0	285.0
H - Michelle	289.8	285.5	285.8
I Well	287.7	282.4	280.3
J Well	293.8	275.3	274.2
M Well	293.1	277.0	274.8
Q - Chenier	288.5	-	285.5
R Well	287.3	-	284.9

With respect to other uses, changes to aquatic habitat were assessed using simulated changes to baseflow to the tributaries to the Whitson River (within Local Area A). Several of these tributaries or municipal drains were simulated to show baseflow reductions of greater than 20% (Table 13). Although many of these tributaries are likely intermittent and relatively shallow features, they cannot be excluded from providing potential for transient habitat for trout species. These simulations suggest minimal (<5%) baseflow reduction to the Whitson River, and provide context for potential future land use change impacts, but were not applied to the risk assignment for Scenario G(1).

Table 13: Predicted Baseflow Reductions, Scenario G(1)

Tributary	Scenario C Baseflow (m^3/day)	Scenario G(1) Baseflow (m^3/day)	Percent Change (%)
Rivest Drain	11	8	27
Trib.5	550	524	5
Trib.6	1,007	991	2
Trib.6D	136	136	0
Trib.8	501	437	13
Trib.8A	879	799	9
Trib.10	444	410	8
Trib.11	12,260	8,910	27
Trib.12	13,910	13,767	1
Whitson	6,961	6,938	0.3
WSC Station	15,338	15,122	1

Note:
*subwatersheds as delineated in Appendix A

For Scenario G(1) the simulated groundwater levels suggest the quantity of water removed from each Local Area would be sufficient to meet the municipal water demand.

9.3.4 Scenario G(2) – Long Term Climate, Existing plus Committed plus Planned Pumping, Existing Land Cover

Simulated steady state drawdown for each existing and planned municipal well is summarized in Table 14. For this Scenario, water level remained above the trigger elevation (pump intake). The low simulated head at the Linden Well (283.4 masl) when compared to other wells in close proximity (Notre Dame, Chenier Well and R Well at 288.5, 289.4 and 288.3 masl, respectively) was a focus of the sensitivity analysis performed on the model (Section 10.1). Water levels simulated during G(2) were approximately 1 m higher than those produced under Scenario G(1), indicating the effect of land cover change on the aquifer level.

Table 14: Scenario G(2) Groundwater Model Output

Well Name	Steady-State Simulated Groundwater Elevation (masl)	Bottom of Pump intake (masl)	Top of Screen (masl)
A - Deschene	291.5	287.7	286.9
B - Kenneth	289.4	283.6	282.9
C - Philippe	290.1	285.6	284.7
D - Frost	290.2	284.1	281.9
E - Notre Dame	288.0	284.1	283.7
F - Linden	282.8	278.6	277.2
G - Pharand	287.5	285.0	285.0
H - Michelle	290.1	285.5	285.8
I Well	287.8	282.4	280.3
J Well	293.8	275.3	274.2
M Well	293.1	277.0	274.8
Q - Chenier	288.9	-	285.5
R Well	287.8	-	284.9

With respect to other uses, changes to aquatic habitat were assessed using simulated changes to baseflow to the tributaries to the Whitson River (within Local Area A). The recently constructed Rivest Drain displayed a reduction of 18% and Tributary 11 a reduction of >20% (Table 15). The Rivest Drain was designed as a shallow drain that would be constructed with an invert near or above the groundwater table (K. Smart Associates 2009), and therefore can be expected to be dry for much of the year. It was therefore considered a poor representation of the baseflow changes expected in the area. Although many of these tributaries are likely intermittent and relatively shallow features, they cannot be excluded from providing potential for transient habitat for trout species. As such, these reductions in baseflow must be considered when assigning risk level to Scenario G(2). Similar to Scenario G(1), the simulation results for Scenario G(2) suggest minimal (1 - 2%) baseflow reduction to the Whitson River.

Table 15: Predicted Baseflow Reductions, Scenario G(2)

Tributary	Scenario C Baseflow (m^3/day)	Scenario G(2) Baseflow (m^3/day)	Percent Change (%)
Rivest Drain	11	9	18
Trib.5	550	538	2
Trib.6	1,007	1,001	1
Trib.6D	136	136	0
Trib.8	501	473	6
Trib.8A	879	845	4
Trib.10	444	424	5
Trib.11	12,260	9,655	21
Trib.12	13,910	13,808	1
Whitson	6,961	6,953	0.1
WSCStation	15,338	15,253	1

Note:

*subwatersheds as delineated in Appendix A

For Scenario G(2), the simulated groundwater levels suggest the allocation quantity of water removed from each Local Area would be sufficient to meet the existing plus committed plus planned water demand. However, the other uses of the system may be affected by the increased pumping and land cover change.

9.3.5 Scenario G(3) – Long Term Climate, Existing Pumping, Future Land Cover

Simulated steady state drawdown for each existing municipal well is summarized in Table 16. For this Scenario, water level remained above the trigger elevation (pump intake). The low simulated head at the Linden Well (285.5 masl) when compared to the nearby Notre Dame Well (290.0 masl) was a focus of the sensitivity analysis performed on the model (Section 10.1).

The water levels produced from Scenario G(3) were generally 2 m higher in elevation than those simulated in Scenario G(2) (increased pumping) and were 0.1 m or less lower than those simulated for Scenario C (existing land cover), suggesting that pumping rate changes have greater influence on the aquifer water level than land use change in Valley East and Capreol.

Table 16: Scenario G(3) Groundwater Model Results

Well Name	Steady-State Simulated Groundwater Elevation (masl)	Bottom of Pump intake (masl)	Top of Screen (masl)
A - Deschene	291.8	287.7	286.9
B - Kenneth	289.5	283.6	282.9
C - Philippe	290.3	285.6	284.7
D - Frost	290.4	284.1	281.9
E - Notre Dame	289.2	284.1	283.7

F - Linden	284.6	278.6	277.2
G - Pharand	287.8	285.0	285.0
H - Michelle	290.7	285.5	285.8
I Well	288.0	282.4	280.3
J Well	293.9	275.3	274.2
M Well	293.3	277.0	274.8

The simulated water levels for Scenario G(3) suggest that the allocated quantity of water removed from each Local Area would be sufficient to meet the existing water demand and peak demand at each municipal well.

9.3.6 Scenario H(1) – Drought Period, Existing plus Committed plus Planned Pumping, Future Land Cover

Simulated transient drawdown for each existing and planned municipal well for Scenario H(1) is displayed in Figure 9.6. Under these pumping and land use conditions, Linden Well (located within Local Area A) reaches the pump intake elevation (278.6 masl). As such, the model suggests that Linden well would not be able to provide sufficient water to meet its allocated demand under these conditions in simulation year five. Although these drawdown plots also indicate that some of this demand could be transferred to other wells, it has been noted that pumping increases are limited at many wells (Section 3.4) and any such action would require operator knowledge of the well system at that particular time. Well field optimization was not completed within this work scope.

As with other Scenarios, the discrepancy in simulated head at the Linden well when compared with the Notre Dame Well was noted in Peer Review meetings and was the focus of the model sensitivity analysis (Section 10.1).

These simulated groundwater elevations suggest that the quantity of water removed from Local Area A would not be sufficient to meet the existing plus committed plus planned demand at the Linden Well during periods of drought.

9.3.7 Scenario H(2) – Drought Period, Existing plus Committed plus Planned Pumping, Existing Land Cover

For Scenario H(2), transient drawdown plots are displayed in Figure 9.7. As with Scenario H(1), the Linden well (within Local Area A) reaches the pump intake at approximately the third drought summer period. Although some additional capacity to offset the loss of Linden well with increased pumping at other wells appears possible, a well optimization study was not completed within this scope of work.

As with other Scenarios, the discrepancy in simulated head at the Linden well when compared with the Notre Dame Well was noted in Peer Review meetings and was the focus of the model sensitivity analysis (Section 10.1).

These simulated groundwater elevations suggest that the quantity of water removed from Local Area A would not be sufficient to meet the existing plus committed plus planned demand at the Linden Well.

9.3.8 Scenario H(3) – Drought Period, Existing Pumping, Future Land Cover

As displayed in the transient water level plots on Figure 9.8, groundwater elevations remain above the pump intake trigger elevation for each of the existing municipal wells. With the exception of the Linden Well, water level declines from 1 – 2 m, while at Linden water levels fluctuate within a range of approximately 8 m outside of the well casing (i.e. the well shows a strong response to pumping and recharge).

The modelled discrepancy in head at the Linden well when compared with the Notre Dame Well was noted in Peer Review meetings and was the focus of the model sensitivity analysis (Section 10.1).

For Scenario H(3), the simulated groundwater elevations suggest that the quantity of water removed from each Local Area would be sufficient to meet the existing demand.

9.3.9 Modelled Scenarios – Summary Note

These steady state and transient results presented herein represent updated estimates of the well screen elevations and pump intakes as surveyed by CGS staff for above ground infrastructure, and interpreted from well rehabilitation reports provided by CGS. As such, simulated groundwater elevations that resulted in wells designated as under ‘significant’ stress in the Tier Two Study (2009), such as Michelle Well, have much increased freeboard in the Tier Three study. This emphasizes the importance of accurate baseline information during the data collection phases and has greatly improved simulated water level estimates and interpretation of the Valley East aquifer.

9.4 Results Summary, Tolerance and Preliminary Risk Assignment

In the majority of cases, each of the delineated Local Areas was able to provide sufficient water to meet the allocated demand of each existing and planned municipal well. For ten-year drought conditions and increased pumping rate (i.e. the existing plus committed plus planned rate), the Linden Well (located in Local Area A) was predicted to draw down to the pump intake and would not be able to supply its allocated demand.

CGS well operators have provided insight into earlier droughts where wells have had difficulty in meeting demand for a period of several days. This provides an indication of the actual tolerance of the system despite the indication from the results of Scenarios C and D that peak demand periods were met. As well, the model predictions are a reflection of the water level outside of the well casing (i.e. without in-well losses, Section 10.2) and are therefore independent of physical well condition. As actual well condition and operations influence the capacity of each well to meet a short term peak demand period, and as operations staff has noted problems in supplying peak demand, the tolerance level for Scenarios C and D was designated as ‘low’ for Local Area A and Local Area B. As no such concerns have been expressed for Well J and Well M, the tolerance level was designated as ‘high’ for Local Area C.

Other uses for the Valley East Local Area A were investigated for Scenarios G(1) and G(2) through baseflow reduction analysis. Although the main Whitson River reaches did not show decreases of greater than 20%, a contributing tributary (Tributary 11) did, and given that these tributaries cannot be excluded as fish habitat, they were considered to trigger a ‘significant’ risk assignment for Scenario G(2).

Table 17 provides a summary of Scenarios and designated preliminary risk assignments. The preliminary Risk assignments are subject to confirmation following the Uncertainty and Sensitivity Analysis (Section 10.0).

Table 17: Preliminary Water Quantity Risk Assessment

Scenario	Municipal Demand	Land Cover	Triggers	Tolerance	Preliminary Risk
A (Long-Term)	Existing	Existing	Pump Intake	Local Area A Low	Significant, based on Low Tolerance
				Local Area B Low	Significant, based on Low Tolerance
				Local Area C High	Low
B (Drought)	Existing	Existing	Pump Intake	Local Area A Low	Significant, based on Low Tolerance
				Local Area B Low	Significant, based on Low Tolerance
				Local Area C High	Low
G(1) (Long-Term)	Existing + Committed + Planned	Future	Pump Intake; Baseflow Reduction	NA	Local Area A,B,C Low
G(2) (Long-Term)	Existing + Committed + Planned	Existing	Pump Intake; Baseflow Reduction	NA	Local Area A Significant, based on >20% baseflow reduction Local Area B,C, Low
G(3) Long-Term	Existing	Future	Pump Intake	NA	Local Area A,B,C Low
H(1) (Drought)	Existing + Committed + Planned	Future	Pump Intake	NA	Local Area A, Significant, based on Linden Well drawdown Local Area B,C Low
H(2) (Drought)	Existing + Committed + Planned	Existing	Pump Intake	NA	Local Area A, Significant, based on Linden Well drawdown Local Area B,C Low

H(3) (Drought)	Existing	Future	Pump Intake	NA	Local Area A,B,C Low

The greatest risk assigned to the groundwater Scenarios was carried forward as a preliminary risk level, and therefore from Table 17, the preliminary risk assessment was 'significant' for Local Area A, 'significant' for Local Area B, and 'low' for Local Area C.

10.0 UNCERTAINTY AND SENSITIVITY ANALYSIS

Uncertainty and Sensitivity in the 3-Dimensional groundwater model was assessed primarily during calibration of the model (Appendix A), and additional sensitivity of transient parameters were investigated during the Tier Two process (Golder 2009).

For the Tier Three exercise, uncertainty and sensitivity was primarily addressed through

1) Re-investigation of the Linden and Notre Dame Wells. During peer review meetings, it was noted that these wells behaved differently during transient scenarios, and ultimate drawdown was greater in the Linden Well than the Notre Dame Well, despite these wells being located within approximately 1 km of one another.

2) Estimation of In-Well Losses.

10.1 Sensitivity Analysis – Linden and Notre Dame Wells

The significance of this discrepancy was magnified once it was identified that the Linden Well would provide a trigger for assignment of a significant risk to the Valley East Local Area A. As such, further investigation of these two wells was undertaken, with a number of discussions among technical team members following.

Initially, a review of the conceptual model of each well's placement in the model was completed, which included review of as-built construction logs, MOE Water Well Information System data, and well rehabilitation reports. The following results were taken from this review:

- The Linden Well was completed to a depth of approximately 28.0 metres below ground surface (mbgs), while Notre Dame Well was completed to 18.1 mbgs.
- The Linden Well was screened over a 9.1 m interval in 'medium to fine sand' (over a range of 19.5 mbgs to 28.0 mbgs), while the Notre Dame Well was screened over approximately 6.4 m in 'sand with some gravel' (over a range of 11.8 mbgs to 18.1 mbgs).

This information was consistent with the placement of the wells within the groundwater model, where the Linden Well was placed in a layer deeper than the Notre Dame Well (see Appendix A for layer descriptions). Based on the soil description and the calibration exercise, hydraulic conductivity was set at 15 m/day within the layer at the Linden Well, and at 45 m/day at the Notre Dame Well.

In order to assess the significance of this estimated difference in hydraulic conductivity, the hydraulic conductivity was altered initially at Notre Dame Well to be consistent with the Linden Well (i.e. 15 m/day). Subsequently the estimated hydraulic conductivity at the Linden Well was set to the Notre Dame Well hydraulic conductivity (i.e. 45 m/day). Results of this sensitivity test, completed under Scenario D conditions are shown in Figures 10.1. and 10.2.

The drawdown plots display that the drawdown at Linden and Notre Dame Wells are sensitive to changes in hydraulic conductivity. With these plots in mind, it is important to recognize that the calibration of the model has considered local changes in hydraulic conductivity in best matching observed water levels throughout the aquifer. Additional aquifer testing at the Linden and Notre Dame locations would provide a better understanding of the aquifer material properties at each well.

Actual transient water level elevations from inside the municipal wells (or from monitoring wells outside the municipal wells) will ultimately provide the best validation against the assumptions made during model calibration and simulation. The lack of actual water level or groundwater table elevation remains the greatest uncertainty in the Valley East Local Areas.

Given the rigorous sensitivity analyses carried out throughout the Valley East groundwater modelling programme, the uncertainty for the current study can be considered 'low'. However, there are steps that can be taken to improve the current state of the aquifer resource, and these are expanded upon in Section 14.0.

10.2 Sensitivity Analysis – In-Well Losses

In-well losses were considered important additional data that could influence groundwater level interpretations, as they incorporate changes in water level that occur across a well screen. As a result, water level inside a well casing may be lower than the water level in the surrounding aquifer formation; however the magnitude of this difference depends upon well construction, pumping rate and current well condition (e.g. mineral build up on well screens).

A detailed methodology for calculating formation loss and in-well loss was provided by the MNR through S.S. Papadopulos and Associates, Inc. and is included in Appendix C. For the current Tier Three study, formation loss was estimated through the groundwater modelling exercise, but was recalculated here as well. In-well losses were calculated using post-rehabilitation pumping test information available from CGS well rehabilitation reports and pumping rates reflective of Scenario G(1) (i.e. existing plus committed plus planned pumping rates). Results of this analysis are presented in Table 18.

Table 18: In-Well Loss Analysis

Well	Pumping Rate (L/s)	Formation Loss (m)[1]	In-Well Loss (m)[1]	Total Drawdown (m)
Deschene (Well A)	11.2	1.3	0.2	1.5
Kenneth (Well B)	11.7	1.8	0.1	1.9
Phillipe (Well C)	13.4	1.5	0.001	1.5
Frost (Well D)	13.4	1.6	0.04	1.6
Notre Dame (Well E)	21.5	2.9	0.1	3.0
Linden (Well F)	19.7	2.6	0.3	2.9
Pharand (Well G)	7.16	0.9	0.01	0.9
Michelle (Well H)	15.6	2.1	0.01	2.1
'I' Well	12.1	3.6	1.2	4.9
Well J	2.3	0.5	0.01	0.5
Well M	15.3	3.0	0.2	3.3
Chenier (Well Q)	24.0	4.0	0.1	4.1
'R' Well	34.1	4.16	0.07	4.2

Note:

[1] Additional decimal places shown as required

In most cases, in-well losses are at least an order of magnitude less than the formation losses for the utilized pumping rates, with the exception of ‘I’ Well. This was interpreted as an indication that the aquifer drawdown provides a comparatively more important role in the total drawdown and that the Valley East Wells are considered efficient, or fall within the ‘properly designed and developed’ condition suggested by S.S. Papadopulos and Associates Ltd. The exception is the ‘I’ Well, which shows in-well loss equal to nearly one half of the formation loss. This is consistent with the operators’ suggestions that ‘I’ Well has persistent drawdown problems and is not an efficient pumping well.

In general these in-well losses would not likely further lower groundwater elevation to the pump intake given the results of the modelling Scenarios. Therefore, these results suggest that the key preliminary risk assessment designations would not be altered.

11.0 RISK LEVEL ASSIGNMENT

A risk level assignment of ‘significant’ was presented in Table 17 for Local Area A and Local Area B for Scenarios H(1) and H(2), while a risk level of ‘significant’ was presented for Local Area A for Scenario G(2). Although the Uncertainty analysis provided justification for a ‘low’ level of uncertainty, the greatest risk level assigned to a Scenario must be assigned to each Local Area. Therefore, the water quantity risk level assignment for Local Area A and Local Area B is ‘significant’. The Local Area C water quantity risk level assignment is ‘low’.

12.0 SIGNIFICANT GROUNDWATER RECHARGE AREAS

For the Tier Three analysis, Significant Groundwater Recharge Areas (SGRA) were reviewed in the context of earlier delineations (Golder 2009) and the area encompassed within each Local Area.

In the delineated Local Areas, the average annual water surplus (total precipitation – evaporation and sublimation) was estimated to be 367 mm (see Table 9). A value of 202 mm (0.55 x 367 mm) was then calculated as the amount of water to be recharged on an annual basis to aquifers within the watershed based on previous analysis (Golder 2009)

From the calibrated groundwater model, recharge zones were developed and mapped in the area of the municipal wells (see Figure 9.4). The threshold value of 202 mm was exceeded in the coarser overburden that dominates the western portion of the Local Area. Therefore, these sediments were designated as SGRAs in the delineated Local Areas (Figure 12.1).

13.0 WATER QUANTITY DRINKING WATER THREATS

As per Part X.2 of the Technical Rules, where a significant or moderate water quantity risk assessment is designated, a listing of activities that may be drinking water threats within the vulnerable area must be compiled. Table 5 of the Technical Rules outlines the activities and circumstances relevant to drinking water quantity threats, and the section of the table relevant to the current Tier Three Study is reproduced in Table 19.

Table 19: Water Quantity Threats Listing Matrix

Activity (Drinking Water Threat)	Reference Number	Circumstances	Area where Activity is a Significant Drinking Water Threat	Area where Activity is a Moderate Drinking Water Threat
An activity that takes from an aquifer or a surface water body without returning the water taken to the same aquifer or surface water body	2	1. An existing taking, an increase to an existing taking or a new taking. 2. The water is or would be taken from within a WHPA-Q1	The local area from which the water is or would be taken if the area relates to one or more wells and it was assessed to have a risk level of significant in accordance with Part IX	The local area from which the water is or would be taken if the area relates to one or more wells and it was assessed to have a risk level of moderate in accordance with Part IX

Note:
*modified from Table 5, Technical Rules March 2011

Within the delineated Local Areas, the majority of water removal from the aquifer comes from the municipal wells. Therefore the wells themselves present the greatest threat, in terms of water quantity, to the Local Areas. In addition to the municipal wells, there are a number of groundwater wells identified in the MOE WWIS records (Golder 2005) and the CGS recognizes that residents in Valley East and Capreol may have small sandpoint wells that supplement the municipal supply. Although these removals are likely small compared to the municipal wells, they are identified here as a potential threat to drinking water quantity in the Valley East Local Areas (i.e. they may threaten the ability of the Local Area to provide the allocated quantity of water).

In summary the identified threats to drinking water quantity in the Valley East Local Area are

1) Municipal Wells in Local Area A (ten) and Local Area B (one).

2) Residential (private) groundwater removals by wells or sandpoints. There are approximately 97 records of groundwater wells within the delineated Local Area A and Local Area B, and at this time the number of sandpoints is unknown.

14.0 FUTURE WORK

Through the ongoing Source Protection program and the previous Municipal Groundwater Study, improvements in understanding of groundwater transport and potential threats to groundwater quality have been made. Continued co-operation among stakeholders in the safety of the quantity and quality of the Valley East municipal water supply is encouraged beyond the scope of these projects.

Additional data that would improve future studies include:

1) Updates of water level data throughout the watershed. The NDCA Provincial Groundwater Quality Network Well in Hanmer is an excellent starting point that could be supplemented with quarterly or monthly monitoring of previously installed boreholes (for example, Waters 2002; 2004).

3) Water level records for within the municipal wells, which would help to track changes in well performance and in-well losses.

4) Monitoring wells installed in the vicinity of each municipal well. Wells placed relatively close (10 m) from each well would indicate water level in the aquifer away from the influence of head loss in the pumping well. In addition, these wells could indicate the necessity for well rehabilitation by providing a reference for aquifer water level against water level within the pumping well.

5) Confirmation/investigation of the low-level lockout alarm elevations at each municipal well.

6) Screening of aquatic habitat in the tributaries and municipal drains that resulted in substantial baseflow decreases.

7) Additional investigation to reconcile hydraulic conductivity at the Linden and Notre Dame municipal wells.

15.0 CONCLUSIONS

The Valley Drinking Water System Tier Three Water Budget and Risk Assessment was completed using a 3-Dimensional groundwater model and updated available information with respect to the pumping well infrastructure. With increased pumping and drought conditions, groundwater level declined to a level below the well pump at the Linden Well intake, indicating that the allocated demand may not be met under all circumstances. As such, the Valley East Local Area A and Local Area B were designated as ‘significant’ risk to water quantity. Despite this, initial analysis presented here suggests that the newest municipal wells should be able to provide the committed demand over the long term.

With the exception of ‘I’ Well, in-well losses were considered as minimal contributors to water level decreases but should be viewed as ‘best case’ situations where the wells have been recently rehabilitated. As such the ongoing CGS well rehabilitation program should be seen as a valuable tool in the sustainability of the Valley East water supply.

Continued water level monitoring and aquifer characterization efforts will assist in maintaining the quantity of water available from the Valley East aquifer.

16.0 CLOSURE

We trust that this report meets your current needs. If you wish to discuss any aspect of the project or our submission, please contact the undersigned.

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