Tier 2 Water Budget and Ecologically Significant Groundwater Recharge Area Assessment for the Black River and Georgina Creeks Subwatersheds

Lake Simcoe Region Conservation Authority

January 2013

Prepared for:
Lake Simcoe Region Conservation Authority 120
Bayview Parkway, Box 282
Newmarket, Ontario L3Y 4X1

Prepared by:
GENIVAR Inc.
1091 Gorham Street, Suite 301
Newmarket, Ontario L3Y 8X7

Project No. 121-17211-00-110-0414010

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Project No. 121-17211-00-110-0414010

January 24, 2013

Ms, Shelly Cuddy, P.Geo.
Hydrogeologist
Lake Simcoe Region Conservation Authority
120 Bayview Parkway, Box 282
Newmarket, Ontario
L3Y 4X1

Re: Tier 2 Water Budget and Ecologically Significant Groundwater Recharge Area Assessment for the Black River and Georgina Creeks Subwatersheds
Lake Simcoe Region Conservation Authority

Dear Shelly:

GENIVAR Inc. (GENIVAR) are pleased to provide the attached report titled "Tier 2 Water Budget and Ecologically Significant Groundwater Recharge Area Assessment for the Black River and Georgina Creeks Subwatersheds" to document the technical studies carried out to fulfill requirements of the Lake Simcoe Protection Plan.

The work program for the Tier 2 Water Budget component was based on the approach outlined in the "Technical Rules: Assessment Report, *Clean Water Act, 2006",* as released by the MOE in November 2008 and subsequent updates. The Ecologically Significant Groundwater Recharge Area (ESGRA) component was based on the methodology used by Earth*fx Inc.* (2012) and incorporates direction provided by the Lake Simcoe Region Conservation Authority (LSRCA) and Ministry of Natural Resources (MNR) project management team. The report provides an overview of the tools used to carry out the assessment and documents the approach and findings for each of the work components. Detailed documentation of the development of modelling tools and scenario analysis are presented as a series of independent Technical Memoranda as Appendices.

We trust that this draft report will meet your needs at this time. We look forward to continuing to work with you to finalize this document and to communicate the findings to your local municipalities.

On behalf of the staff at GENIVAR, we thank the LSRCA for retaining our services to assist in this important process to provide technical support for long-term management and protection of Lake Simcoe. Please contact me to address questions you may have on this report.

Yours truly,
GENIVAR Inc.

Lloyd A. Lemon, M.Sc., P.Geo.
Senior Geoscientist
LAL:nah

1091 Gorham Street, Suite 301, Newmarket, Ontario L3Y 8X7
Telephone: 905-853-3303 • Fax: 905-853-1759 • www.genivar.com

Executive Summary

A study has been completed to prepare a Tier 2 Water Budget and Water Quantity Stress Assessment, and to delineate Ecologically Significant Groundwater Recharge Areas (ESGRA) for the Black River and Georgina Creeks Subwatersheds (Study Area) in the Lake Simcoe Basin. This study was required by the Lake Simcoe Protection Plan and was carried out in accordance with methodologies for water budget and water quantity risk assessments established by the Technical Rules: Assessment Report under *The Clean Water Act*, 2006. The methodologies were modified in consultation with the technical representatives of the Lake Simcoe Region Conservation Authority (LSRCA) and the Ontario Ministry of Natural Resources (MNR) to reflect the different requirements of water budget assessment for a subwatershed that does not focus on the potential effects of a municipal water taking. The methodology for delineation of the ESGRA was developed on behalf of LSRCA by Earth*fx* Inc. in conjunction with the LSRCA and MNR project team (Earth*fx)* (2012).

The study required the development of a numerical groundwater flow model capable of carrying out the water budget and particle tracking analysis. An existing regional numerical groundwater flow model developed by Earth*fx* on behalf of the Conservation Authorities Moraine Coalition (CAMC) and the York Peel Durham Toronto (YPDT) Groundwater Management Study was successfully updated and prepared for use in this study. The updates included incorporation of recharge developed by Earth*fx* (2010*)* the Lake Simcoe Basin using the United States Geological Survey (USGS) Precipitation Recharge Management System (PRMS) model as developed for Assessment Report requirements. The model was subsequently updated to consider water takings in accordance with current Permits to Take Water, to place drains under delineated wetland features and then an updated database of water wells from the Ontario Ministry of the Environment (MOE) was used to evaluate model outputs. The GENIVAR Black River Groundwater Model was demonstrated to have similar calibration statistics to the original model and is suitable for use in evaluation of water budgets and groundwater flow path delineation within the Study Area under steady-state conditions.

The Lake Simcoe PRMS model (Earth*fx,* 2010) was provided for use in this study. Review of the model showed that this model could not be easily updated to carry out surface water analysis that would provide results that incorporated greater insight or confidence than the existing regional model. The Lake Simcoe PRMS model was subsequently used to develop recharge inputs for the temporal analysis of drought scenarios using the numerical groundwater flow model.

Water Use

Water use in the Study Area was reviewed and updated from previous studies. The estimated existing demand consumptive use within the Study Area is 5,647 m^3/day. Approximately 17% of this annual taking is used to provide a municipal water supply to the community of Mount Albert. Although recognized as consumptive use as extraction, a portion of the municipal water supply is returned to the Black River Subwatershed as treated effluent. The remainder of the observed water taking is typically used for agricultural or irrigation purposes.

An estimate of committed or planned groundwater demand was prepared using the projected future requirements of the Mount Albert water supply and the assumption that private users with Permits to Take Water would require the maximum permitted taking. Under this condition, the consumptive use in the Study Area is estimated at 11,997 m^3/day with approximately 12% of this use being to supply the community of Mount Albert. Minimal data is available to describe actual water taking outside of municipal

supplies. The estimated committed/planned groundwater demand is likely to overestimate annual use that will be realized by the existing users.

Water Budget

The GENIVAR Black River Groundwater Model was applied to provide an estimate of groundwater flow patterns and water budget information for the following scenarios:

- → Steady-state analysis of existing climate/recharge conditions and existing water demand for identified water users (2011 pumping rates for the Mount Albert municipal wells).
- → Steady-state analysis of existing climate/recharge conditions and committed/planned water demand for identified water users (2031 estimated water demand for the Mount Albert municipal wells).
- → Transient analysis of a two-year drought period represented by recharge distributions associated with the 2-year low total rainfall period climate data used to develop the Lake Simcoe PRMS Model (1997-1998) and existing water demand for identified water users.
- → Transient analysis of a two-year drought period represented by recharge distributions associated with the 2-year low total rainfall period climate data used to develop the Lake Simcoe PRMS Model and committed/planned water demand for identified water users.

These four scenarios were examined as the planned and committed water taking were observed to be the same.

Detailed analysis of the water budget shows that approximately 80% of the total water input into the Black River and Georgina Creeks Subwatersheds is received as precipitation. Lateral transfer from adjacent watersheds accounts for about 18% of the water input. The lateral inputs result from the shape of the Subwatersheds and the potential that groundwater divides do not necessarily coincide directly with the observed surface water divides. This is most noticeable to the south of the Black River Subwatershed, where the headwater of the East Branch Holland River occupies the position between the Black River Subwatershed and the regional groundwater divide at the crest of the Oak Ridges Moraine. Recharge from streams accounts for the remaining 2% of the groundwater inputs.

Discharge to surface water accounts for 72% of the water output from the Black River and Georgina Creeks Subwatersheds. Direct discharge to Lake Simcoe is only responsible for a small portion (7%) of the water outputs. Water taking under existing conditions represents approximately 3% of the total water outputs. Municipal water taking represents 17% of the total water outputs.

Water Quantity Stress Assessment

The Water Quantity Stress Assessment for existing water demand indicates that the annual Percent Water Demand for the Black River Subwatershed is 2.5% and for the Georgina Creeks Subwatershed is 6.4%.

Analysis of the effect of the Planned/Committed Water Demand is shown to have a minor effect on the water budgets. The Percent Water Demand increases by approximately 5.2% in the Black River Subwatershed and decreases by 1.5% in the Georgina Creeks Subwatershed.

The GENIVAR Black River Groundwater Model was adapted for transient use to represent the effects on groundwater flow patterns and water availability in response to a two-year drought scenario. The recharge applied outside of streams is decreased by 95% relative to the steady-state value for the monthly time step at the end of two years. The total groundwater inputs available in the groundwater flow system decreased by 70% after two years. Stream baseflows and groundwater elevations were observed to decrease steadily over the two year period with the effective minimum being observed after two years. Stream baseflows decreased variably over the study area: 90-95% reduction was observed in headwater areas and 70-90% was observed downstream in the Black River Subwatershed. Simulated baseflow was reduced by more than 99% in the Georgina Creeks Subwatershed. Simulated groundwater elevations were observed to be lower by up to 45 m in the south, headwater areas but less than 5 m in the central portion of the Black River Subwatershed. These results are considered to be a possible outcome and realistic in consideration of the amount of change in recharge. Data was not available to assess how well the transient model run reflected the response in the groundwater flow system to the recharge conditions in 1997 and 1998. While these were known to be dry years, the simulated drawdown of 45 m is considered to be an overestimate.

The transient numerical model analysis was also carried out for the committed/planned water demand scenario. The simulated model outputs are consistent with the results for the transient simulation with existing water demand with the noted area of local additional change in water levels (drawdown) around permitted wells to the northeast of Newmarket.

Ecologically Significant Groundwater Recharge Areas

Ecologically Sensitive Features were identified based on cool and cold water fish habitat, wetlands and Areas of Natural and Scientific Interest (ANSI). The Ecologically Sensitive Features occupy an area on the order of 117 km^2 (27% of the Study Area). The Ecologically Sensitive Features were then used to delineate Ecologically Sensitive Groundwater Recharge Areas (ESGRA) using the particle tracking analysis methodology developed by Earth*fx* (2012) Areas where the particle pathways were observed to remain within delineated wetland features were removed from the proposed ESGRA. The delineated ESGRA is identified to occupy approximately 135 km^2 (32% of the Study Area).

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1.0 Introduction

The Lake Simcoe Region Conservation Authority (LSRCA) contracted GENIVAR to carry out a Tier 2 Water Budget and Ecologically Significant Recharge Area Assessment for the Black River and Georgina Creeks Subwatersheds. The location of the Black River and Georgina Creeks Subwatersheds are shown in Figure 1-1. (For additional perspective on the position of these Subwatersheds within the Lake Simcoe Watershed area, please see Figure 3-3).

Water Budget studies were initiated in the southern part of the Lake Simcoe basin to comply with requirements of the Oak Ridges Moraine Conservation Plan (2003). The initial water budget study carried out by LSRCA included the Holland River Maskinonge River and the Black River Subwatersheds and was reported by Gerber Geosciences Inc. and Earth*fx* Inc. in 2008 Water budgets were subsequently required for all of the Lake Simcoe basin under *The Clean Water Act*, 2006. The basic process for Water Budget studies is described in Part III of the Technical Rules: Assessment Report – Clean Water Act, 2006 (Ontario Ministry of the Environment, November 2009 as amended). Additional information is provided in the Water Budget and Water Quantity Risk Assessment Guide prepared by AquaResources Inc. (2011). The Tier 2 Water Budget is intended to provide a “stress level” for a Subwatershed relating to the proportion of water used relative to the quantity available for surface water and groundwater systems. Tier 2 water budgets were not completed under The Clean Water Act, 2006 for Subwatersheds where the Tier 1 Water Budget identified a stress level of Low. The Lake Simcoe Protection Plan (2009) requires Tier 2 Water Budgets for all Subwatersheds in the Lake Simcoe watershed.

Ecologically Significant Groundwater Recharge Areas (ESGRAs) are identified as areas of land that are responsible for supporting groundwater systems that sustain sensitive features like coldwater streams and wetlands. To establish the ecological significance of the recharge area, a linkage must be present between the recharge area and the Ecologically Sensitive Feature (e.g. a reach of a coldwater stream, a wetland, or an Area of Natural or Scientific Interest (ANSI)). The identification of an ESGRA is not related to the volume of recharge that may be occurring, rather they represent pathways in which recharge, if it occurred, would reach that feature. While delineating ESGRAs is an important task in establishing the linkage between a recharge area and an Ecologically Sensitive Feature it is not a certainty that ESGRAs will coincide with SGRAs, as they may not support high volumes of recharge. While ESGRAs and SGRAs are not mutually exclusive, the areas where they do coincide support high volumes of recharge and support Ecologically Sensitive Features”. An initial study carried out by Earth*fx* Inc. (2012) provided an outline for the methodology to be carried out for this and subsequent ESGRA studies.

At the request of LSRCA, this study utilized an existing numerical groundwater flow models and existing surface water flow models as a starting point for the tools to be used in this study. GENIVAR has worked with the existing tools to update them and carry out the requested analysis. The preparation of the modelling tools are documented in a series of Technical Memoranda in Appendix A.

1.1 Report Structure

This report has been organized to document the work performed and to present the findings of the Tier 2 Water Budget and ESGRA Assessment for the Black River and Georgina Creeks Subwatersheds. The Executive Summary has been prepared to provide an overview of the work performed and to highlight the important findings.

This report is organized to:

- Provide an overview of the previous studies, the scope of work, and deliverables (Section 1);
- Describe the characteristics of the Black River and Georgina Creeks Subwatersheds (Section 2);
- Provide an overview of the numerical modelling tools reviewed, updated, and used in this study (Section 3);
- Present the findings of the Tier 2 Water Budget Analysis (Section 4);
- Present the findings of the ESGRA (Section 5);
- Present study conclusions (Section 6).

The Appendices have been prepared to document the technical details of steps carried out in this study. Appendix A provides a series of Technical Memoranda that document the work carried out to prepare the numerical groundwater flow models for use in this study. Appendix B provides detailed outputs from the water budget analysis, by sub-Subwatershed. Appendix C provides details of the process used to establish the Ecologically Significant Surface Water Features for use in the ESGRA analysis.

In addition to the report and technical appendices, DVDs have been prepared for the LSRCA to provide digital copies of files included in this report and digital copies of databases, models, and Geographic Information System (GIS) projects constructed to undertake this analysis.

2.0 Study Area Characteristics

The Study Area consists of the Black River and Georgina Creeks Subwatersheds. The Black River Subwatershed, at 375 km^2 in area, is the largest Subwatershed in the Lake Simcoe basin. The Georgina Creeks Subwatershed, at 49 km^2, is one of the smaller Subwatersheds and occupies a unique position on the southeastern corner between Cook's Bay and Lake Simcoe. A Watershed Plan has been prepared for the Black River Subwatershed (LSRCA, 2010). Minimal studies have been carried out on the Georgina Creeks Subwatershed.

The following sections describe the Study Area in terms of climate, physiography, drainage, geology, and hydrogeology.

2.1 Climate

The study area occurs within the Simcoe and Kawartha Lakes Climatic Region (Brown et al, 1980). The climate of the Study Area directly determines the quantity of surface and groundwater available. The cool winter months result in precipitation being observed as snow and allows for accumulation. During this time period, there is less opportunity for infiltration, and correspondingly lower baseflow in perennial water courses. Approximately 14% of the annual precipitation is received as snow. When the spring melt occurs, a large volume of water is released. This water will first infiltrate the ground. When the soil becomes supersaturated the remaining water will flow overland until it reaches the tributaries and main branch of the river. The summer periods are typically hot and can have extended dry periods, or periods with very localized, intense rainfall. The summer period between May and September is often accompanied by a deficit between the demands of vegetation and evapotranspiration and the amount of precipitation available.

Mean annual total precipitation for this portion of the Lake Simcoe Watershed is approximately 815 mm/year. The mean annual potential evapotranspiration is approximately 585 mm/year and the mean annual actual evapotranspiration is approximately 535 mm/year. It is estimated that the mean annual water surplus available for recharge and runoff is approximately 280 mm/year. (Gerber et al, 2008).

There are no active climate stations within the Study Area (Gerber et. Al., 2008). Figure 2-1 illustrates the range of average precipitation and the range of observed temperature for 30 year normal data from the King Smoke Tree Station operated by Environment Canada for the period from 1974 to 2003.

The available climate records were reviewed to identify the two year period with the lowest precipitation. This period was observed from 1997 to 1998. The monthly precipitation from this time period will be used in the transient analysis as part of the Tier 2 Water Budget Study.

2.2 Physiography and Drainage

The Study Area lies partly within four (4) Physiographic Regions as defined by Chapman and Putnam (1984) and as illustrated in Figure 2-2. The ground surface topography within the Study Area is shown in Figure 2-3. Ground elevations vary from a high of 320-340 m above mean sea level (AMSL) along the southern extent of the Black River Subwatershed. The East and West margins of the Black River Subwatershed are typically between 280 m and 300 m AMSL. The central basin of the Black River is low lying and is typically between 220 m and 240 m AMSL. The ground surface elevations in the Georgina Creeks Subwatershed are typically between 220 m and 280 m AMSL.

The Oak Ridges Moraine Physiographic Region occupies the southern portion of the Study Area and provides the source for headwaters of the tributaries to form and flow northward into Lake Simcoe. The Oak Ridges Moraine is a significant physiographic feature that lies between the Trent River and the Niagara Escarpment. The Oak Ridges Moraine was formed by meltwater discharging in a confined basin between two ice lobes during the later stages of the last glacial advance. The Oak Ridges Moraine has a total length of approximately 160 km, and has topographic elevations along the crest ranging from 305 to 395 m AMSL. The peak of the moraine forms the surface water divide separating flow north towards Lake Simcoe from flow south towards Lake Ontario. The Oak Ridges Moraine is comprised of rolling sandy hills, hummocky topography and closed depressions

The Oak Ridges Moraine plays a significant role in the groundwater flow system. The presence of relatively coarse, granular soils provides an opportunity for high rates of infiltration to the groundwater flow system. This recharge area ultimately feeds the tributaries of the Black River where groundwater elevations are observed to be greater than the stream elevation.

The Schomberg Clay Plain is observed in two, discontinuous zones along the south east and southwest margins of the Black River Subwatershed. The Schomberg Clay Plain typically occupies low lying regions around the Schomberg, Newmarket, and Lake Scugog areas. The Schomberg Clay Plain is found near the communities of Ravenshoe and Mount Albert and has an approximate elevation range of 225 to 275 mASL. The Schomberg Clay Plain is characterized as having rolling relief that reflects the underlying till plain. The Schomberg Clay Plain areas are characterised by thick deposits of fine-grained sediments that are draped over an irregular till plain and are typically 15 m in thickness (Chapman & Putnam, 1984).

The Simcoe Lowlands physiographic region comprises the majority of the Black River Subwatershed. The Simcoe Lowlands region extends from the ORM northward to Lake Simcoe, and is described as having lower elevations, with flat-floored valley features that generally correspond to current river systems (Sharpe et al., 1999). The lowlands were flooded by glacial Lake Algonquin and as a result are floored by sand, silt and clay (Chapman and Putnam, 1984).

The Peterborough Drumlin Field physiographic region is observed in a very small area near the eastern margin of the Black River Subwatershed. The Peterborough Drumlin Field is typically characterized by numerous drumlins that are on average oriented 60° west of south or 240° azimuth. On average, drumlins are 20-75 m in width and 100-450 m in length. Internally, drumlins are composed of a stone-rich, slightly silty to silty fine to medium grained sand till. Texturally, the percentage of silt increases in a southerly direction, more specifically drumlins immediately north of the Oak Ridges Moraine are composed of a stone-rich, fine to medium grained sandy, silt till.

The Black River Subwatershed is bounded on the south and west by the Holland River Subwatershed; to the west by the Maskinonge Subwatershed; to the east by the Pefferlaw Brook Subwatershed; and to the northwest by the Georgina Creeks Subwatershed.

The Black River Subwatershed drains northward and can be subdivided into approximately six sub-Subwatersheds as shown in Figure 2-4. These sub-Subwatersheds will be used within the water budget analysis. Sub-Subwatersheds 1 and 2 drain directly north from the Oak Ridges Moraine. The community of Mount Albert is within sub-Subwatershed 2. Sub-Subwatershed 3 drains easterly from the area of Warden avenue, west of Queensville. Sub-Subwatershed 4 drains westward through the Zephyr lowlands via Zephyr Creek. Sub-Subwatershed 5 includes some local drainage, but primarily reflects the main channel north of the confluence of the tributaries from sub-Subwatersheds 1 to 4. Sub-Subwatershed 6 consists of minor tributaries that flow northward and discharge directly to Lake Simcoe.

The Georgina Creeks Subwatershed consists of numerous small streams that drain directly to Lake Simcoe.

Lake Simcoe receives the drainage from the Study Area. The elevation of Lake Simcoe is to some extent controlled and is assumed to be 219 m AMSL.

2.3 Geology

The geology beneath the Study Area consists of varying thicknesses of unconsolidated sediments that have been deposited, shaped and altered by glacial and post-glacial activities. The overburden is deposited on top of the shale and limestone bedrock.

The following sections provide an overview of the geologic sequence as derived from literature sources. (CAMC-YPDT, 2006; LSRCA, 2010). The geology is described from the oldest deposits (bedrock) to youngest (recent sediments in stream valleys). The overburden deposits are described consistent with the current interpretation as developed by the CAMC-YPDT study.

2.3.1 Bedrock

Bedrock across the watersheds consists of a thick sequence of Middle to Late Ordovician shale and limestone that unconformably overlies the Precambrian basement at depth.

Figure 2-5 shows the delineated sedimentary bedrock formations. These formations are relatively undeformed and dip gently to the south or southwest.
The Lindsay Formation is the oldest bedrock sequence. The Lindsay Formation has been subdivided into two member units. The lower member unit is characterized by argillaceous, fine to coarse-grained limestone with a nodular appearance and is very fossiliferous. The upper member, called the Collingwood Member, consists of high fossil content and thick interbeds of black organic-rich limestone and shale. The lower member is typically observed beneath the Study Area. The Lindsay Formation A sharp contact has been observed between the Lindsay Formation and the overlying Blue Mountain Formation where these units are exposed at surface outside of the Study Area.

The Blue Mountain Formation is the youngest of the Ordovician age rock units found in the study area. The formation is characterized by rocks that are blue-grey, poorly fossiliferous, noncalcareous shale, with minor limestone. The Blue Mountain Formation is observed south of approximately Mount Albert. The observed distribution of the Blue Mountain Formation results from the shape of the original sedimentary basin and differential weathering of the bedrock sequence. The Blue Mountain Formation appears to have been preferentially removed from areas north and west of Mount Albert.

2.3.2 Overburden

The unconsolidated sediments that overly the bedrock have been deposited by glacial, fluvial, and lacustrine processes associated with glacial advance and retreat over the past 135,000 years. Thick, laterally extensive deposits of till often represent the periods of glacial advance. Granular sediments, ranging from silts to coarse sands and gravels, are deposited by glacial meltwaters. In the latter stages of glaciations, the deposits are typically observed as thick sequences of fine grained sediments.

The Quaternary sediments have been mapped by the OGS and are presented on Figure 2-6. Figure 2-6 may not correlate directly with the surficial representation of the 3-dimensional hydrostratigraphic interpretation developed by CAMC-YPDT that is used in this study.

The basic geological sequence is illustrated in Figure 2-7 as derived from studies by the University of Toronto, GSC and Kassenaar and Wexler (2006). The unit descriptions are based on information presented by Kassenaar and Wexler (2006). This geological sequence represents up to six periods of glacial advance of varying extent and intensity. The most recent, extensive glacial advance is represented by the Newmarket Till between 25,000 and 15,000 years ago. The Halton Till was deposited locally as a minor advance of the ice sheets after deposition of the Newmarket Till. The majority of the sediments observed at surface were either deposited during or after the glacial advance associated with the Newmarket Till. In general, earlier deposits are known only from exposure on incised stream valleys and shore bluffs along Lake Ontario. In general, the hydrostratigraphy is better defined for the more recent sediments associated with the last glaciations. The earlier sediments have been collectively referred to by the GSC as the Lower Sediments.

The Lower Sediments reflect several cycles of glacial advance and retreat and can contain deposits from the York, Don, Scarborough, Sunnybrook, and Thorncliffe Formations. The older York and Don Formations are considered to be of limited lateral extent. The Scarborough, Sunnybrook, and Thorncliffe Formations are more widely observed and stratigraphic interpretations have extended into the study area.

The Scarborough Formation is a coarsening upward sequence of sediment deposited by glacial runoff in a delta. Soil textures range from clay/silt rhythmites (fine) to channelized cross-bedded sands (coarse). The Scarborough Formation Sediments tend to be observed in bedrock valleys and are not always continuous.

The Sunnybrook Drift consists of fine grained material deposited in glacial and proglacial lacustrine depositional environments. The Sunnybrook Drift is considered to represent a deep lacustrine environment with deposits including varved silt and clay.

The Thorncliffe Formation is composed of stratified sand, silt, and clay of glaciolacustrine and glaciofluvial origin. These deposits are considered to have been deposited by drainage along the southern margin of an extensive ice sheet in the Hudson Bay Lowlands. The depositional environment of the Thorncliffe Formation is highly variable and is best described as fine grained, with interbedded coarse grained material. Areas of the Thorncliffe Formation that contain coarse grained sediment are productive regional aquifers.

The Newmarket Till is a distinct, dense glacial deposit with a fine grained matrix and up to 15% stones, deposited by the Simcoe lobe of the Wisconsinan glacier. In the field, the Newmarket Till is readily recognized by its relative hardness. The Newmarket Till is considered to be a regionally significant marker horizon and provides protection to the groundwater resources beneath it. Since the interpretation presented in 2006 (CAMC, 2005), the CAMC has conducted further work and have subsequently subdivided the Newmarket Till into three units: The Lower Newmarket Till; Inter-Newmarket Sediments; and the Upper Newmarket Till. The Lower Newmarket Till is considered to be more regionally extensive. The Inter-Newmarket Sediments are typically fine to medium grained sediments deposited by meltwater between two stages of active glaciation. The additional detail on the subdivisions of the Newmarket Till were not incorporated into the geological model used for this study.

The top of the Newmarket Till is recognized as a regional erosional unconformity. This unconformity provided an opportunity for removal of parts of the Newmarket Till, either in conjunction with later glacial processes (tunnel channels) or by subaerial exposure.

The upper surface of the Newmarket Till exhibits large-scale erosion by channels that have subsequently been infilled by a fining upward sediment sequence. The erosion of these channels is considered to have developed beneath the glacial ice and hence are referred to as tunnel channels. This interpretation was presented by the GSC in various publications and is summarized in CAMC (2006). An initial surge of glacial meltwater beneath the ice is considered to have cut these channels. As flow waned in these channels, they were partly infilled with water-borne sediments, which typically fine upwards from a cobble or boulder lag. The tunnel channels deeply dissected the Newmarket Till plain, leaving the discrete till upland areas mentioned above. Tunnel channel erosion and sedimentation was followed by or was formed at a similar time to the deposition of the east-west trending Oak Ridges Moraine, which is an important regional physiographic and hydrogeologic feature. Many tunnel channels created low-lying areas and several rivers in southern Ontario.

The Oak Ridges Moraine Sediments are a complex package of dominantly coarse grained proximal glaciofluvial and terminal outwash material. These deposits generally become finer, and typically become thinner and eventually pinch out away from the original outlets of meltwater. The Oak Ridges Moraine Sediments were deposited by meltwater flowing between two glacial lobes, with ice blocking the Lake Ontario basin and another ice sheet in the Simcoe basin.

The Halton Till is a dense glacial deposit with a fine-grained matrix and fewer stones compared to the Newmarket Till. The Halton Till was deposited in the late stages of the last glaciation by a minor advance of the Lake Ontario lobe after the sedimentation cycle that deposited the Oak Ridges Moraine Sediments. The Halton Till unit overlaps and caps portions of the Oak Ridges Moraine. The Halton Till typically is not observed north of the Oak Ridges Moraine.
As the glaciers retreated, large lakes formed in regional basins. Thick sequences of lacustrine sediment were deposited in these lakes above the glacial units. These lacustrine deposits are observed extensively in the northern part of the Study Area in association with Glacial Lake Algonquin. After these meltwaters retreated, erosion has been the dominant force with some sedimentation associated with river channels, and accumulations of organic material in poorly drained areas as deposits of peat and muck.

It is our understanding that the CAMC/YPDT are continuing to review and revise the hydrostratigraphic interpretation. It is possible that the updated interpretation may be more extensive and more representative of subsurface relationships.

2.4 Hydrogeology

The hydrostratigraphic model used in this study was prepared in a study commissioned through the CAMC-YPDT and published in 2006. The version of the hydrostratigraphy, used in this study, includes eight (8) layers and was used to construct the Groundwater Flow Model for the central Oak Ridges Moraine and York Region areas (CAMC-YPDT - 2006). It is our understanding that these interpretations are continually under review and are edited and revisited on a local basis.

The delineation of hydrostratigraphic units for the CAMC-YPDT study has focussed on identification of the deposits that form regional aquitards. These typically are associated with till units deposited during glacial advances. The layers between the till aquitards are classified as aquifers, however it is acknowledged that the texture of the sediments can vary from very fine grained deposits of silt to coarse sand and gravel deposits. Hence the units between aquitards have come to be referred to as “aquifer complexes”.

In addition to this basic interlayered package of aquifers and aquitards, there are areas where later erosion has removed all or part of an aquifer or aquitard layer and deposited either sand and gravel or silt deposits in place of the original unit. These were described above as “tunnel channels”.

2.4.1 Hydrostratigraphy

The stratigraphic units were grouped to form eight (8) hydrostratigraphic units for construction of the numerical groundwater flow model. The hydrostratigraphic units are listed from the top to bottom of the model (youngest to oldest):

- → Layer 1 - Recent Deposits and/or Weathered Halton/Kettleby Aquitard;
- → Layer 2 – Halton/Kettleby Aquitard;

- Layer 3 - Oak Ridges Aquifer Complex (ORAC) and/or Weathered Newmarket Aquitard;
- Layer 4 - Newmarket Aquitard;
- Layer 5 - Thorncliffe Aquifer Complex (TAC);
- Layer 6 - Sunnybrook Aquitard;
- Layer 7 - Scarborough Aquifer Complex (SAC); and
- Layer 8 - Bedrock.

The recent deposits tend to be relatively thin, discontinuous deposits associated with recent drainage systems.

The Halton Aquitard and the lacustrine clay sediments have been grouped into Layer 2. These deposits are also discontinuous and distributed widely at surface throughout the study area. Any occurrences of Halton Sediments are confined to the southern extent of the study area along the watershed divide associated with the ORM.

The ORAC deposits are associated with the Oak Ridges Moraine and form a thick sequence along the southern extent of the study area. The ORAC deposits thin to the north and resemble a wedge in cross-section. For the hydrostratigraphic units, other granular deposits that overlie the Newmarket Till Aquitard may be grouped into this layer.

The top of the Newmarket Aquitard represents the erosional surface where material may have been removed prior to deposition of the ORAC and more recent deposits, including the channel fill deposits.
The Thorncliffe Aquifer Complex (TAC) is regionally extensive and correlates with the Thorncliffe Formation. For the numerical model, the TAC has been expanded to include the sand and gravel deposits that are interpreted to infill the lower parts of erosional channels.

The Sunnybrook Aquitard is interpreted to be laterally extensive and forms a relatively thin layer that separates the TAC from the underlying Scarborough Aquifer Complex (SAC) layer.

The SAC consists of the Scarborough Sand unit of the Scarborough Formation. The SAC is interpreted as an extensive, thin deposit that overlies the bedrock and tends to be thicker within eroded valleys in the bedrock surface.

The upper 15 m of the bedrock was assumed to be weathered and was treated as an aquifer layer. Effectively the SAC and the bedrock are treated as one aquifer layer with variable aquifer properties. The bedrock is not known to outcrop at surface within the study area.

2.4.2 Groundwater Flow Patterns

The groundwater flow patterns observed in each of the identified aquifer layers in the study area follow a similar pattern as the surface water drainage system. The groundwater flow patterns as determined from groundwater elevations for wells screened in the Oak Ridges Aquifer Complex are presented in Figure 2-8. The screened intervals for the wells were assigned to the ORAC layer by GENIVAR and the water elevations associated with each unit were contoured. Figure 2-8 illustrates the data points (wells) used to determine the groundwater flow pattern in the ORAC.

The interpreted groundwater elevation contours illustrate a groundwater flow divide consistent with the observed surface water drainage divides. The groundwater elevations in the ORAC typically follow closely to the surface water divide.

The ORAC shows local groundwater elevation highs of 310-320 masl along divides in the, with local lows underneath and in the central basin of the Black River Subwatershed of approximately 230 masl.

2.4.3 Aquifer/Aquitard Properties

The properties of the delineated hydrostratigraphic units are typically highly variable, particularly on a local scale. The following sections provide a summary of the methods employed in assigning properties for each of the delineated aquifer and aquitard units.

2.4.3.1 Aquifers

Hydraulic conductivities for each of the aquifers were determined by Earth*fx* in the construction and calibration of the original numerical groundwater model based on assigning published values for various lithologic materials to the lithologic descriptions present in the CAMC-YPDT database. The CAMC-YPDT database incorporates the Water Well Information System (WWIS) database maintained by the Ontario Ministry of the Environment and provides additional quality control within the study area. The hydraulic conductivities were assigned based on the primary lithology observed. The hydraulic conductivity is variably distributed in each aquifer layer as illustrated in Figures 92 to 94 in CAMC-YPDT (2006).

Transmissivities for each aquifer were calculated in the numerical model by multiplying the assigned hydraulic conductivity by the unit thickness. Resulting data were examined and obvious outliers were removed.

The hydraulic conductivity assignments incorporate a considerable degree of uncertainty due to the lack of high quality data to describe lithologies within the CAMC-YPDT database. The degree of uncertainty increases with depth. Descriptions available in this database tend to be vague and commonly one value was assigned to cover a range of grain sizes due to lack of information. Uncertainty was also introduced through the process of interpolating the resulting data to create gridded surfaces.

The weathered bedrock was assigned a uniform hydraulic conductivity of 5.6×10^{-5} m/s. Uniform properties were assigned to the bedrock as a whole, as there is little data available on the spatial variation in the bulk hydraulic properties to allow for more detail at this time.

2.4.3.2 Aquitards

Little data is available on the spatial variation in hydraulic properties within the aquitard units. The hydraulic conductivity was assigned to the aquitards in consideration of the bulk characteristic of the unit. The thickness and continuity of the aquitard units were incorporated into the approach to more realistically represent the potential for vertical movement of water between the aquifer units.

The hydraulic conductivity values assigned for the aquitard units is summarized in Table 2-1.

3.0 Assessment Tools

The following sections describe the numerical modelling tools used to carry out the Tier 2 Water Budget Analysis and to identify Ecologically Significant Groundwater Recharge Areas in the Black River and Georgina Creeks Subwatersheds.

At the request of LSRCA, existing model tools were used as the basis for this study. Analysis of groundwater flow systems was carried out using the CAMC/YPDT Version 1 Groundwater Flow Model as developed by Earthfx. This model was developed between 2003 and 2006 and was also used as a basis for previous water budget studies in the adjacent Holland River basin (Gerber et al, 2008). The groundwater model was imported for use with the Groundwater VISTAS graphical user interface and updated as described below. The groundwater model was used to prepare water budgets for various scenarios, including a transient simulation. The calibrated groundwater model was also used to generate a groundwater flow field that would subsequently be used with the MODPATH utility to evaluate particle pathways between points of recharge and identified Ecologically Sensitive Features.

LSRCA provided access to the Precipitation-Runoff Modelling System (PRMS) model for the Lake Simcoe basin as created by Earthfx Inc (2010). This model will be referred to as the Lake Simcoe PRMS Model. The surface water model was primarily used to generate inputs for use in the numerical groundwater flow model.

3.1 Numerical Groundwater Flow Model

LSRCA provided access to the Version 1 CORE Model as constructed for the Conservation Authorities Moraine Coalition (CAMC)/York Peel Durham Toronto (YPDT) Groundwater Management Strategy Study by Earth*fx* and documented in the report "Groundwater Modeling of the Oak Ridges Moraine Area, CAMC-YPDT Technical Report Number 01-06" (CAMC-YPDT, 2006).

The Earth*fx* CORE model was constructed to provide an ability to improve understanding of hydrogeological conditions and to assist in carrying out specific technical analysis on a regional to local scale. The domain of the Earth*fx* CORE Model is shown in Figure 3-1. The model documented in the 2006 report has been used either directly, or as a base for a more detailed local model, as part of studies for groundwater resource exploration, evaluations of the effects of pumping in support of permit to take water applications and renewals, delineation of wellhead protection areas, water budget studies, and more.

The Earth*fx* CORE Model is constructed with a uniform 100 m x 100 m grid over the model domain. The model grid is oriented north-south. This small cell size was selected to provide better representation of interactions between groundwater and surface water. The model grid has 840 rows and 1056 columns and 8 layers that represent the hydrostratigraphic profile presented in Section 2.4.1. The local origin for the model grid is located at UTM coordinates 550665 E and 4810559 N (UTM NAD 83 (Zone 17).

The Earth*fx* CORE Model is bounded to the west by the western edges of the Mimico Creek, Humber River Watersheds flowing to Lake Ontario and the Holland River Subwatershed flowing to Lake Simcoe. On the east, the boundaries are the Duffins, Carruthers Watersheds flowing to Lake Ontario and the Uxbridge Creek Subwatershed flowing to Lake Simcoe. The Eastern and western boundaries of the model were assigned as no-flow boundaries. Lake Ontario forms the boundary to the South and was assigned a constant head boundary at 75.2 m ASL. Lake Simcoe forms the boundary to the north and was assigned a constant head boundary of 219.0 m ASL. The base of the model was also assigned as a no-flow boundary with the assumption that all horizontal groundwater flow would occur in the upper 15 m of the bedrock layer. For more detailed discussion on the boundary conditions, please refer to CAMC/YPDT 2006.

Earth*fx* used two different methods to represent boundary conditions at points where there is potential groundwater-surface water interaction. MODFLOW "drains" were assigned in locations where all groundwater arriving above the drain level is to be carried away within the surface water feature. If the water level in the aquifer adjacent to the drain goes below the drain elevation the model will not allow water to recharge to the aquifer. This type of drain is best used for headwater conditions and for intermittent streams. MODFLOW "rivers" were assigned in locations where there was potential for groundwater to move either from the groundwater to the surface water feature or from the surface water feature to the aquifer. In this case, when the water table falls below the elevation of the river, water can be recharged from the river at a rate determined by an assigned hydraulic conductivity of the boundary condition to the groundwater system as is observed in a losing stream. Earth*fx* used the Strahler Code designation to assist in assigning MODFLOW drains and rivers. Strahler codes of 1 to 3 were designated as MODFLOW drains, the remaining were designated as MODFLOW rivers.

Recharge was assigned to the Earth*fx* CORE Model by analyzing data on land use, climate and soil properties and then assigning values to the surficial materials and observed physiography and land use to obtain a suitable model calibration. Groundwater taking was considered in the Earth*FX* CORE Model through extraction from municipal wells, wells with permits to take water (withdrawal of > 50,000 L/day) and land uses that withdraw water for irrigation. Aquifer and aquitard properties were estimated for each layer. Hydraulic Conductivity was typically variable within an aquifer complex layer, but constant within an aquitard layer.

The Earth*fx* CORE Model was calibrated by adjusting the parameter inputs, primarily recharge and hydraulic conductivity to obtain an acceptable simulation of the groundwater elevations and stream baseflow. Further discussion of the detailed calibration statistics are provided in Technical Memo A1 (Appendix A).

GENIVAR first conducted a review of the Version 1 CORE Model and then carried out a series of steps to prepare the model for use in this study:

1) The Earth*fx* CORE Model was successfully imported into Groundwater Vistas™ to create the GENIVAR CORE Model and run to duplicate the calibration documented by Earth*fx.* (See Technical Memo A1).
2) The GENIVAR CORE Model was then updated to include the recharge layer generated by the Lake Simcoe PRMS Model (See Section 3.2) for the Black River and Georgina Creeks Subwatersheds (Study Area). The calibration observed after this step is documented in Technical Memo A2. The PRMS recharge improved the calibration of the model within the Study Area.
3) The groundwater elevation targets and pumping rates for municipal wells and wells with Permits to Take Water were then updated to include data within the Study Area that was not available when the original model was constructed. This step and the calibration observed after this step are documented in Technical Memo A2.

4) MODFLOW drains were added to represent the Ecologically Sensitive Features to be considered in the ESGRA analysis. Wetlands were not consistently mapped as discharge zones in the original model and this step was required to ensure that particle traces released from beneath the wetland features would move backward to an appropriate point of recharge. This step and the calibration observed after this step are documented in Technical Memo A2.

Figure 3-2 illustrates the simulated groundwater elevations for the GENIVAR Black River Groundwater Model. The groundwater elevations for the GENIVAR Black River Groundwater Model are similar to those of the Earth*fx* CORE Model and primarily reflect the changes introduced by the PRMS Recharge. Technical Memo A2 includes illustration of the differences between the groundwater elevations between the CORE Model and the GENIVAR Black River Groundwater Model. The final calibration statistics of the GENIVAR Black River Groundwater Model are provided in Table 3-1. Note that the entire domain of the original CORE Model remains active in all model runs. Statistics are provided to demonstrate the agreement between observed and simulated results in the Study Area. Additional discussion on the model statistics can be found in Technical Memo A2 (Appendix A).

3.1.1 Water Budget Analysis Methods

A Water Budget provides an accounting of the water inputs and water outputs within a defined area, in this case a watershed or subwatershed. The basic assumption of a water budget analysis is that there is a balance between water inputs and outputs, unless there is a clear understanding that water is being removed from storage within the system. The water budget is typically represented in a simple form as:

Water In = Water Out

$$P + EI = ET + IR + RO + EO$$

Where:

P = Precipitation
EI = External Inputs (including runon, irrigation, and vertical/lateral transfers)
ET = Evapotranspiration
IR = Infiltration Recharge
RO = Runoff
EO = External Outputs (including water taking, and vertical/lateral transfers)

The numerical groundwater flow model typically quantifies inputs and outputs to the groundwater flow system only. As such, components such as precipitation, evaporation, and runoff are typically determined independently. The model then considers the movement of groundwater through the soil from the point of infiltration (recharge) to the point of discharge (surface water or lateral flux across zone boundaries).

GENIVAR has used the hydrostratigraphy property tool from Groundwater Vistas™ to set up zones to account for the water flowing into and out of each of the layers in the GENIVAR Black River Groundwater Model. The mass balance tool in Groundwater Vistas™ and Zonebudget 3.01 from the USGS were carried out on the following scales:

1) Black River Subwatershed and Georgina Creeks Subwatershed (two zones);
2) Six Sub-Subwatersheds of the Black River Subwatershed and the Georgina Creeks Subwatershed (seven zones) as illustrated in Figure 2-4;

3) 750 ha subcatchments as provided by LSRCA; and
4) 125 ha subcatchments as provided by LSRCA.

The output data for analysis of the first two zones as described above was processed and is presented in a format based on that used by Earthfx in other studies. The presentation format illustrates the quantity of water that is measured to flow into and out of each layer in several directions. An additional level of detail was used to illustrate the volume of water moving laterally between adjacent watersheds.

At the request of LSRCA, GENIVAR conducted the Zonebudget analysis on 750 ha and 125 ha subcatchments. This information has been provided to LSRCA in digital format for their use along with instructions on how to retrieve relevant information for each zone. Detailed analysis of the water budget on the 750 ha and 125 ha subcatchments was not carried out as part of this study.

3.1.2 Particle Tracking

The particle tracking analysis was carried out using the calibrated GENIVAR Black River Groundwater Model under existing pumping rate conditions. Particle tracking was used as directed by the methodology developed by Earth*fx* (2012) in the preparation of the ESGRAs. The calibrated groundwater model generated a groundwater elevation distribution for each grid cell in the model and a velocity field based on the relative groundwater elevations and aquifer properties. MODPATH was then used to introduce virtual particles into the model and to trace the path that the particle would take from the release point to either the point of discharge from the model (forward tracking) or the point of entry into the model (reverse tracking).

The outputs from the particle tracking provide end points where the released particles exit the numerical groundwater flow model. The end point files were processed using ArcGIS Geographic Information System software to carry out the cluster analysis.

3.2 Surface Water Model

The Lake Simcoe PRMS Model was developed for LSRCA by Earthfx (2010) for use in carrying out studies to delineate Significant Groundwater Recharge Areas (SGRAs) as required by *The Clean Water Act,* 2006. The Significant Groundwater Recharge Areas were delineated in accordance with the Technical Rules: Assessment Report (MOE, 2009) and reflect areas where recharge exceeds a threshold of 1.15 times the average value for the whole of the related groundwater recharge area (typically Watersheds or Subwatersheds) or where the annual recharge is more than 55% of the precipitation surplus as determined by subtracting the annual evapotranspiration for the annual precipitation for the whole of the related groundwater recharge area. The Lake Simcoe PRMS Model was developed to have a consistent estimate of groundwater recharge across the Lake Simcoe Basin.

The Lake Simcoe PRMS Model was developed using the PRMS model code developed by the U.S. Geological Survey. This model can calculate components of the hydrological cycle on a watershed or subwatershed scale. Earth*fx* adapted the PRMS source code to allow for analysis to be carried out on hydrological response units (HRUs) on a 100 m grid spacing. This resulted in a model of 920 rows and 780 columns and over 700,000 cells. The model contains 286,845 active sells and covers a land area of 2868.45 km2. The Lake Simcoe PRMS Model domain is illustrated in Figure 3-3.

Values for numerous parameters were then input into the model and adjusted to achieve a calibration as documented in more detail by Earthfx (2010). The analysis parameters included:

1) Topography-related properties (slope, slope aspect and elevation)
2) Vegetative cover and imperviousness (as related to land use and ecological land classification)
3) Soil properties correlated to surficial geology.
4) Land use and soil properties, such as the SCS curve number.
5) Climate-based properties (daily inputs for precipitation, minimum temperature, average temperature, maximum temperature, solar radiation.
6) Parameters related to regional climate.

Earthfx (2010) provides detailed evaluation of the methods employed to achieve calibration of the Lake Simcoe PRMS Model to available streamflow records (permanent stations and spot flows). The outputs of the model include detailed simulations of streamflows at calibration targets and the corresponding set of data input files that successfully achieved this calibration. The distribution of recharge to groundwater is a significant output that can now be used as input to numerical groundwater flow models.

GENIVAR was provided access to a working version of the Lake Simcoe PRMS Model. Details of work carried out by GENIVAR to evaluate the Lake Simcoe PRMS Model are provided in Technical Memorandum A3. This work demonstrated that:

- The Lake Simcoe PRMS Model can be applied to carry generate recharge distributions within the Lake Simcoe watershed for specified inputs of precipitation, temperature and land use.
- The Black River and Georgina Creeks Subwatersheds could not be effectively isolated from the Lake Simcoe PRMS Model.
- The Lake Simcoe PRMS Model is not calibrated to include the time frame from 2002 to present for stream monitoring and climate data within the Black River and Georgina Creeks Subwatersheds. Information from prior to 2002 was used for the Lake Simcoe PRMS Model.

GENIVAR applied the Lake Simcoe PRMS Model to obtain results for the Study Area only. This effort produced output for the Black River Subwatershed that did not correspond to the values generated by the Lake Simcoe PRMS Model. GENIVAR did not have access to the model documentation or the source code and were unable to create a working PRMS model for the Study Area.

Through discussion with LSRCA, GENIVAR decided to utilize the Lake Simcoe PRMS Model to generate input files for recharge to the numerical groundwater model within the Study Area, and for transient analysis within the Lake Simcoe basin,

The recharge distribution from the calibrated Lake Simcoe PRMS Model was used to update the numerical groundwater flow model as described above. The Lake Simcoe PRMS Model was then used to create recharge files to reflect monthly time steps to reflect the climate in 1997 and 1998. These years were observed to have the lowest total precipitation over two years in the period of record available in the Lake Simcoe PRMS model. Twenty-four (24) recharge files were generated by the PRMS Model and prepared for use in the GENIVAR Black River Groundwater Model. The recharge layers were input into the GENIVAR Black River Groundwater Model for the entire Lake Simcoe Basin. Steady-state recharge was maintained in the portion of the model south of the Oak Ridges Moraine.

4.0 Tier 2 Water Budget

A Water Budget and Water Quantity Stress Assessment process was developed jointly by the Ontario Ministries of Natural Resources and Environment to provide a method of quantifying and assessing the potential stress to water quantity within defined areas as a component of work required to prepare an Assessment Report under *The Clean Water Act*, 2006. The Technical Rules: Assessment Report (MOE, 2009) and the Water Budget and Water Quantity Risk Assessment Guide prepared by AquaResources Inc. (2011) provide an overview of the expected requirements. The Water Quantity Stress Assessment under the Clean Water Act is focussed on assessing the risk to municipal water supplies and involves a "tiered" assessment process where in each tier Watersheds or Subwatersheds that are identified as being under moderate or significant stress are identified to be studied in more detail in the subsequent tier. In each tier, the stress assessment involves evaluating the amount of water consumed by water taking relative to the amount of water available and required by the natural environment. The additional detail of each "tier" can include consideration of additional detail, development and application of more complex models, or both.

The process starts with a "Conceptual Water Budget" intended to compile available baseline data, maps and analysis for information linking physiography, geology, surface water, groundwater, climate, land cover and water taking. The Tier 1 Water Budget is then undertaken to estimate the hydrologic stress of Subwatersheds based on the hydrologic cycle parameters. The Tier 1 Water Quantity Stress Assessment results in a calculation of Percent Water Demand for a subwatershed. The Percent Water Demand is then classified as low, moderate or significant. Subwatersheds assigned a low stress did not require further study to fulfill the requirements of the Assessment Report. Further assessment was also not required for Subwatersheds that were assigned a moderate or significant stress level and where no municipal drinking water system was present.

A Tier 2 Water Budget is required for Subwatersheds in which the Tier 1 Water Quantity Stress Assessment identified a stress level of significant or moderate. The goal of the Tier 2 Water Budget is to confirm the stress assessment established in Tier 1 using computer-based three-dimensional groundwater flow models and/or continuous surface water models. Additional data is typically required to improve the representation of surface and subsurface conditions. The Tier 2 water budget and Water Quantity Stress Assessment is intended to be more precise and reliable through consideration of additional spatial and temporal scales of analysis, evaluation of planned water use and drought scenarios and consideration of uncertainty.

A Tier 1 Water Budget and Water Quantity Stress Assessment was completed for the Black River and Georgina Creeks Subwatersheds by LSRCA (South Georgian Bay Lake Simcoe Source Protection Region, 2009). This study identified a groundwater stress of 4% for the Black River and 5% for Georgina Creeks Subwatershed. These values are less than the 25% threshold necessary to classify the water stress as moderate or significant. The surface water stress analysis showed that the Black River and Georgina Creeks Watersheds were under moderate or significant stress conditions between June and October. No further studies were required under *The Clean Water Act*, 2006 as the groundwater stress did not exceed the 25% threshold and the municipal water supplies do not take surface water within for the Black River and Georgina Creeks Subwatersheds.

The Lake Simcoe Protection Act, (2008) and the Lake Simcoe Protection Plan (2009) require that a Tier 2 Water Budget and Water Quantity Stress Assessment be prepared for all Subwatersheds in the Lake Simcoe Basin. This presents a challenge in that the Tier 2 Water Budget and Water Quantity Stress

Assessment methodology as presented is focussed on identifying impacts of municipal water supplies. Through discussions with the LSRCA and MNR Staff, this study was developed to prepare a Tier 2 Water Budget for the Study Area using a numerical groundwater flow model and to use the outputs of this analysis to update and confirm the Water Quantity Stress Estimates for the Black River and Georgina Creeks Subwatersheds. The approach for evaluating the potential changes in groundwater elevation or stream flow was modified to present the change in simulated groundwater elevation or simulated stream baseflow within the Study Area rather than to evaluate whether the change at the municipal well or intake would be tolerable.

The following sections describe the work completed to assess the water demand, prepare the water budgets and to undertake the water quantity stress analysis.

4.1 Water Demand

The purpose of the water budget study is to evaluate the relative stress that use of water within the Study Area places on the natural resources. Water users include natural features, in-line use (within a stream or groundwater system), and consumptive use. Consumptive use refers to water taken from a groundwater or surface water source and not returned to its original source. This definition can be expanded slightly to consider water that is removed, used and replaced at a point downstream in the watershed

The Tier 2 Water Budget Study requires Consumptive Water Demand to be determined for:

- Water Demand by municipal drinking water systems
- Water Demand by other users with a Permit to Take Water
- Water Demand by other users (without a Permit To Take Water).

4.1.1 Municipal Water Use

The community of Mount Albert is the only municipality in the Study Area currently serviced by a communal municipal water supply system. The Mount Albert Water System is operated by The Regional Municipality of York and consists of three (3) municipal groundwater supply wells. Well 1 has been in place since 1990; Well 2 has been operating since 1995 and Well 3 was brought on-line in 2011. The locations of the Mount Albert Municipal Wells are illustrated in Figure 4-1. Table 4-1 provides a summary of the details of the municipal wells and recent water use data input to the numerical groundwater model.

The introduction of Well 3 in 2011 has changed the relative usage of Well 1 and Well 2. Well 3 provided the primary demand of the community during 2011 after it was brought on-line. This operation pattern provided opportunity for maintenance of the previously existing wells. Well 1 and Well 2 were used in the spring of 2012.

Table 4-1 also provides the future planned/committed demand by the Mount Albert water supply. In 2011 the Mount Albert Wells provided an average of 960 m^3/day with use up to 1,450 m^3/day on average for July. The Mount Albert well system currently represents 23% of the permitted water taking within the Study Area. The future committed/planned demand for the Mount Albert water supply assumed average daily use of 1,420 m^3/day with average use in peak-demand months up to 2,105 m^3/day. This represents an increase of approximately 50%.

The Mount Albert Municipal Water Supply is considered to be consumptive relative to the local groundwater system but is only slightly consumptive within the scale of the Subwatershed. The water supply for Mount Albert is removed from the deep groundwater system. Following residential use, a significant portion of the groundwater taken is returned to the watershed as treated waste water released to the surface water system.

4.1.2 Permits To Take Water

A Permit To Take Water (PTTW), issued by the Ontario Ministry of the Environment, is required for any water taking of more than 50,000 L per day. Exceptions are granted for un-serviced domestic water use, livestock watering, agricultural use and water taken for firefighting purposes. The Provincial PTTW database stores information on permits, including the permit number, expiry dates, source name, location, the maximum permitted taking, and the general and specific purpose of the water taking. Since 2005, PTTW holders have been required to submit the recorded actual volumes of water taken on an annual basis. This information is stored within the Water Taking Reporting System (WTRS). The WTRS stores information on the permit number, source name, and reported takings but does not store specific spatial information for individual well sources.

The Water Taking Reporting System is still being established and does not contain a consistent or reliable record of individual water takings. In addition, it is typically a challenge to relate reported takings to the specific location of takings as these are not included in the database.

As such, estimates of water use by PTTW holders continues to be estimated based on the maximum permitted water taking as specified in the Permits. Experience has shown that the permitted values often overestimate the actual water taking due to:

- Water taking requirements are based on a maximum rate of pumping on a daily basis. Many users request the permitted volumes in order to be prepared for worst case usage. Actual usage in a dry summer season may be substantially more than in a wet summer season. Usage often reflects the timing between significant rainfall events rather than the total amount of rainfall.
- Permitted water taking may reflect the capacity of the installed equipment and not the actual demand of the users.
- Some PTTW specify water taking from more than one source, for example removal of groundwater for storage in a pond, and then removal of water from the pond for application. These permits must be scrutinized carefully to ensure that actual water use is not overestimated.

LSRCA obtained updated information regarding current PTTW within the Study Area for use in this study. PTTW are available for groundwater use, surface water use, or both. The distribution of PTTW are illustrated in Figure 4-1 and the details of permitted use for groundwater supplies are provided in Table 4-2 and for Surface Water Supplies in Table 4-3.

The water takings from surface water include water taking from Lake Simcoe. The municipal water supplies for Georgina and Sutton represent a potential combined taking of 66,200 m^3/day. This is approximately 84% of the potential taking allowed under permits to take water. The non-municipal water taking from surface water can be up to 12,833 m^3/day. Records are not available to document actual rates of surface water taking.

The water taking information for existing demand at Permit To Take Water 1580-744HUV in the Georgina Creeks Subwatershed was obtained from the Tier 3 Study. The value for existing demand is greater than the estimated committed/planned demand based on the Permit To Take Water Maximum. GENIVAR used the Permit to Take Water Maximum as shown in Table 4-2 for this well.

4.1.3 Non-Permitted Water Use

In addition to water taking by Permitted water use, the CAMC/YPDT model also incorporated water use estimated based on land use. The locations, aquifer assignments and pumping rates assigned for these wells are summarized in Table 4-4. Some of these takings are observed to take water at a rate that would require a Permit to Take Water.

4.1.4 Summary - Water Demand

Table 4-5 has been prepared to illustrate the estimated water use on a monthly basis for existing and committed/planned water demand. For the municipal wells, the pumping distribution was estimated as per Table 4-1. The monthly use of Permitted wells was estimated by assigning a monthly use rate for each well. Wells with seasonal takings were assigned to the relative portion of the growing season (i.e. from May to October depending upon the number of days where water taking is permitted). The non-permitted wells were assumed to be in seasonal use from April through October.

4.2 Water Budget – Existing Demand

The GENIVAR Black River Groundwater Model was applied to quantify the components of the water budget equation for the Black River and Georgina Creeks Subwatersheds. The results of this analysis are presented in Figure 4-2 for the entire Study Area, in Figure 4-3 for the Black River Subwatershed and in Figure 4-4 for the Georgina Creeks Subwatershed. An additional set of figures and tables to illustrate the water budget within the sub-Subwatersheds of the Black River are provided in Appendix B1. The information presented on Figures 4-2 through 4-4 and in Appendix B1 are summarized in Table 4-6.

Figures 4-2 through 4-4 illustrate the flow into and out of each of the hydrostratigraphic layers considered in the numerical groundwater flow model. Flow in typically occurs through recharge, recharge in the streams, or lateral transfers from adjacent watersheds. The lateral transfers from watersheds on the west, and south and east sides of the Black River and Georgina Creeks Watershed are presented as one value.

Some observations drawn from analysis of Figures 4-2 to 4-4 include:

- Recharge from Infiltration is primarily received in the three upper hydrostratigraphic layers (Recent Deposits and or Weathered Halton/Kettleby Aquitard; Halton/Kettleby Aquitard; or ORAC) and accounts for 80% of the total water input to the groundwater flow system in the Study Area. The majority of the recharge is received within the ORAC layer.
- Lateral inflow from adjacent watersheds accounts for 18% of the total water input in the Study Areas. A large portion of the observed groundwater inflow appears to enter the Study Area from the Oak Ridges Moraine area to the south. The detailed analysis of individual sub-Subwatersheds in Appendix B-1 illustrates the relative significance of the groundwater inflows. Note that lateral input to an individual sub-Subwatershed may reflect flow between

Subwatersheds whereas the analysis for the Study Area reflects inputs from outside of the Study Area only.

- Groundwater is transferred laterally out of the Black River Subwatershed to the Georgina Creeks Subwatershed on the northwest and to the Pefferlaw Brook Subwatershed to the east. Detailed analysis was not carried out to examine potential for the Black River Subwatershed to provide lateral outflow to the Maskinonge River Subwatershed, but this may be possible at the south end of the Maskinonge River Subwatershed. The net lateral transfer on the scale of the Study Area reflects a net outflow of water from the study area equal to 0.5% of the total groundwater inputs.
- Approximately 72% of the groundwater discharge is delivered to surface water features (streams and wetlands). Only 7% appears to be discharged directly to Lake Simcoe. This proportion varies within the sub-Subwatersheds as can be seen by the increased proportion of groundwater discharge to Lake Simcoe in the Georgina Creeks Subwatershed (up to approximately 60% of outflow is direct to Lake Simcoe).
- Net groundwater flux appears to be downward from surface to the bedrock layer. The bedrock layer accounts for approximately 25% of the observed discharge to Lake Simcoe.
- Approximately 78% of the water transferred to streams is discharged from Layer 3 (ORAC). North of the Oak Ridges Moraine, Layer 3 may represent upper active layer, particularly in areas where Layers 1 and 2 are dry.
- The TAC (Layer 5) appears to provide the largest proportion of lateral transfers.
- The quantity of water transferred downward below the TAC is about 40% less than the net input to this layer.
- Water taking accounts for approximately 3% of the groundwater outputs in the Study Area. Municipal water taking represents 17% of the total output.
- Water taking accounts for approximately 2% of the groundwater outputs in sub-Subwatershed 2. Approximately 50% of this water taking is from the municipal wells for Mount Albert.
- Within the Black River Subwatershed there is considerable transfer of water between sub-Subwatersheds as groundwater. There is also greater potential for downward movement of groundwater in the southern areas beneath the Oak Ridges Moraine and greater potential for discharge in the zones closer to Lake Simcoe.

4.3 Water Quantity Stress Assessment

The Technical Rules: Assessment Report (MOE, 2009) provides the following equation for calculating the percent water demand for groundwater in a subwatershed:

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

Where:

- Q_{DEMAND} is equal to the consumptive demand calculated as the estimated rate of locally consumptive takings
- Q_{SUPPLY} is the estimated annual recharge rate plus the estimated groundwater inflow to a subwatershed (water supply term)
- $Q_{RESERVE}$ is the specified amount of water that does not contribute to the available water supply. Groundwater reserve is calculated as 10% of the total estimated groundwater discharge to surface water within a subwatershed.

The Percent Water Demand is calculated below for the existing water demand, future conditions that reflect committed/planned water demand, for a two-year drought scenario, and for a two-year drought scenario that reflects the committed/planned water demand.

In completing the Percent Water Demand calculations, GENIVAR used output from the numerical groundwater flow model and considered that:

a) Total Recharge included the estimated recharge into the model from streams;
b) Lateral Groundwater Inputs reflect the net of Input – Output; and
c) Baseflow represents discharge to streams and wetlands only; direct discharge to Lake Simcoe is not considered.

4.3.1 Existing Demand

Table 4-7 presents the summary of the water quantity stress assessment in the Black River and Georgina Creeks Subwatersheds for the existing water demand. The inputs to this table were primarily generated from the steady-state simulation using the GENIVAR Black River Groundwater Model for existing pumping rates. The monthly groundwater demand was assigned as per Table 4-5.

The Percent Water Demand for groundwater in the Black River Subwatershed in response to the existing water demand is 2.5%. On a monthly basis, the Percent Water Demand can be as much as 7.7% in September. The Percent Water Demand for groundwater in the Georgina Creeks Subwatershed in response to the existing water demand is 6.4%. On a monthly basis, the Percent Water Demand can be as much as 11.8% between June and August.

4.3.2 Future Committed/Planned Water Demand

The GENIVAR Black River Groundwater Model was run to evaluate the changes to groundwater elevations, stream baseflow, and water budget that would result from the committed/planned water demand. Figure 4-5 illustrates the water budget for the Study Area. Table 4-8 provides a summary of the water budget. Table 4-9 shows the change in simulated baseflow for the two surface water monitoring stations and the assigned outlets for each of the six sub-Subwatershed zones in the Black River Subwatershed and the Georgina Creeks Subwatershed.

In the Committed/Planned Demand scenario, the total amount of water moving into and out of the model increases by 500 m^3/day in response to the increased demand from water taking. There is increased recharge drawn from streams and increased groundwater inflow. Water taking from wells is increased by 112%. Discharge to streams as baseflow is decreased by approximately 3.5% and the amount of water discharged directly to Lake Simcoe is increased by 1.5%.

Table 4-9 provides information that illustrates how the change in stream baseflow is experienced throughout the model. The headwater areas of sub-Subwatershed 1 and sub-Subwatershed 2 show a decrease in baseflow between 5 and 6%. Sub-Subwatershed 5 actually experiences a slight increase in baseflow. The remaining sub-Subwatersheds show a decrease in baseflow between 0.4% and 0.75%.

Figure 4-6 illustrates the change in groundwater elevations relative to the existing water demand scenario (Figure 3-2). The water elevations change only slightly around areas where there are multiple permitted water takings. The most substantial potential change was observed in the southwest part of sub-

Subwatershed 1. This change reflects a substantial increase between existing demand and future demand for two permitted water takings. The increased average pumping rates for the Mount Albert Wells cause a change of less than 1 m in the vicinity near the wells.

Table 4-10 presents the summary of the groundwater quantity stress assessment for the future/planned water taking for the Black River and Georgina Creeks Subwatersheds. The inputs to Table 4-10 were primarily generated from the steady-state simulation using the GENIVAR Black River Groundwater Model for existing pumping rates. The monthly groundwater demand was assigned as per Table 4-5.

The Percent Water Demand for groundwater in the Black River Subwatershed in response to the future committed/planned demand is 7.7%. On a monthly basis, the Percent Water Demand can be as much as 14.7% in September. The Percent Water Demand for groundwater in the Georgina Creeks Subwatershed in response to the future committed/planned demand is 4.9%. The Percent Water Demand for the committee/planned demand in the Georgina Creeks Subwatershed is lower than the existing demand due to the higher value used for existing demand at Permit To Take Water 1580-744HUV (See Table 4-2). On a monthly basis, the Percent Water Demand can be as much as 9.5% from June to August.

4.3.3 2-Year Drought Scenario – Existing Demand

The GENIVAR Black River Groundwater Model with the existing water demand was run in transient mode to evaluate the changes to groundwater elevations, stream baseflow, and water budget that would result from a 2-year drought period as reflected by the available climate records for 1997-1998. Recharge layers were generated for 24 monthly intervals from PRMS and then input into the GENIVAR Black River Groundwater Model for the entire Lake Simcoe Basin. Steady-state recharge was maintained in the portion of the model south of the Oak Ridges Moraine. Model properties for porosity, storativity, and specific capacity required for transient analysis were applied from values suggested by Earth*fx* (2006) or from literature. The model was not calibrated to confirm that the simulated temporal response to groundwater elevation change would match observed values.

Figure 4-7 illustrates the water budget for the Study Area at the end of the two year simulation. Table 4-11 provides a summary of the water budget at the end of two years. Table 4-9 shows the change in simulated baseflow for the two surface water monitoring stations and the assigned outlets for each of the six sub-Subwatershed zones in the Black River Subwatershed and the Georgina Creeks Subwatershed at the end of two years. Figure 4-8 illustrates the simulated change in Baseflow for the two surface water stations for the two-year drought period. The recharge input pattern for the Study Area over the two year period is also shown on Figure 4-8.

The two-year drought simulation applies a substantial change in recharge for the Study Area relative to the steady-state recharge of 7,202 m^3/hour (148.5 mm/year). The range shown in Figure 4-8 shows variation from approximately 0 to a peak of approximately 2,100 m^3/hour (148.5 mm/year) for only one month each year. The total recharge is applied (outside of streams) is reduced by approximately 95% relative to the steady-state condition (compare Table 4-11 to 4-6). The net input and output to the model is reduced by approximately 70% relative to the steady-state condition. The numerical model responds to this stress by generating flow from storage, inducing more flow from streams and Lake Simcoe, and by reducing outputs as controlled by the boundary conditions.

Figure 4-8 illustrates how the baseflow at the two HYDAT stations would change in response to the change in recharge over two years. In general, there is a steady reduction of baseflow contributions with a steady-level being reached at the end of each summer season before recharge increases. The information presented in Figure 4-8 was used to confirm that the output after two years is effectively the worst case observed during this scenario. Table 4-9 illustrates that the baseflow at these stations has reduced on the order of 90% after two years. This is consistent with the order of magnitude of change in recharge that is applied. Comparison of baseflow estimates at other outputs show that the baseflow at the outlets of the sub-Subwatersheds of the Black River are reduced between 70 and 90%. The downstream reaches in sub-Subwatersheds 4 and 5 tend to maintain a higher proportion baseflow relative to the steady-state condition. The simulated baseflow in Georgina Creeks is reduced by 99% relative to the steady-state condition.

Figure 4-9 illustrates the simulated groundwater elevations after two years and can be compared to groundwater conditions for the steady-state existing water demand scenario as presented in Figure 3-2. The difference between Figure 4-9 and Figure 3-2 is shown in Figure 4-10. The simulated groundwater elevations are observed to change by up to 45 m in the headwater area but to change less than 5 m through the central portion of the Black River Subwatershed. Groundwater elevations near Lake Simcoe are controlled by a boundary condition in the model.

Figure 4-11 has been prepared to illustrate the potential change in groundwater elevations that would be observed over the two-year drought period. The locations of the model cells selected to illustrate groundwater elevation change are shown in Figure 4-9. Locations were picked to represent the changes seen in the headwater area (South Black River), near the Mount Albert Wells, and downstream of the confluence of sub-Subwatersheds 1, 2, and 3 (North Black River). The groundwater elevations show a decreasing trend that changes in proportion to the changes in recharge. The amount of change varies with respect to position in the Study Area. The effect of seasonal pumping can be seen near the Mount Albert wells as the simulated ground water elevation is seen to be drawn below the simulated level for the South Black River station. The simulated change observed near the Mount Albert Wells is 13.7 m. The North Black River Station shows a much smaller change on the order of 2.4 m. .

Review of the model outputs show that the 2 year drought scenario can predict a possible outcome in the event of a 2-year period with low precipitation. A preliminary calculation of the Percent Water Demand indicates that an extended period of low water will have a substantial effect on the amount of water available. Since this simulation was based on a historical time period, there is question as to whether or not the model is overpredicting the amount of drawdown in response to a 2-year drought period. As the numerical model is currently not calibrated to confirm that the model response over time is accurate, the Percent Water Demand was not estimated for the 2-year drought scenarios.

4.3.4 2-Year Drought Scenario – Committed/Planned Water Demand

The GENIVAR Black River Groundwater Model with the committed/planned water demand was run in transient mode to evaluate the changes to groundwater elevations, stream baseflow, and water budget that would result from a 2-year drought period as reflected by the available climate records for 1997-1998. The model used was prepared as described in Section 4.3.3.

Figures and tables summarizing the water budget for the transient committed/planned water demand are provided in Appendix B4. In general, the results are similar to those described above for the existing water demand scenario although there is a slightly lower amount of baseflow. Figure 4-8 illustrates the simulated baseflow for the two HYDAT stations. Table 4-9 provides a summary of the simulated baseflow estimates for each of the sub-Subwatershed zones. The percent change in baseflow is calculated relative to the steady-state values for the committed/planned water demand scenario.

Figure 4-12 illustrates the difference in simulated groundwater elevations after two years relative to the steady-state existing water demand scenario as presented in Figure 3-2. Figure 4-12 is similar to Figure 4-10. There is more change observed in the areas where change was observed due to increased pumping for the committed/planned water demand in Figure 4-6.

5.0 Ecologically Significant Groundwater Recharge Areas

The procedures developed by the Barrie, Lover's Hewitts pilot study project team and documented by Earth*fx* (2012) were applied to delineate the Ecologically Significant Groundwater Recharge Areas in the Study Area. The principle is to use the calibrated groundwater flow model to trace the point of origin of water that discharges at the identified ecologically sensitive features. This process involved:

- → Identifying the Ecologically Sensitive Features for which the ESGRA are to be identified.
- → Applying Particle Tracking Methods to delineate ESGRA for these Ecologically Significant Features
- → Conducting an End Point Cluster Analysis to prioritize the areas to be described as ESGRA
- → Conducting verification analysis on the delineated ESGRA

5.1 Ecologically Sensitive Features

The following features were considered to be Ecologically Sensitive Features to be protected via the ESGRA process:

- → Cool and cold water segments of rivers and streams.
- → Wetlands
- → Areas of Natural or Scientific Interest.

Technical Memorandum C1 documents the review of individual features to compile the mapping of Ecologically Sensitive Features to be used for identifying the ESGRA as presented in Figure 5-1.

5.2 Reverse Particle Tracking

Particles were introduced beneath mapped Ecologically Sensitive Features and the pathways were determined from these points to the point of entry into the groundwater flow model. A horizontal spatial distribution of 20 m was used beneath the wetlands and 5 m beneath the stream features. Particles were also introduced into each hydrostratigraphic layer beneath the identified Ecologically Sensitive Features. Approximately 3.3 million points were released to evaluate the flow paths from the Ecologically Sensitive Features.

In reverse particle tracking mode, the particles will exit the model domain at either a horizontal boundary, a bottom layer (rare) or at the uppermost active layer. In the GENIVAR Black River Groundwater Model the uppermost active layer could vary between layers 1 through 5. The output of this process created a image of particle pathways within each layer. The output was processed to generate a database to illustrate the x-y coordinate of the end point where the particle reached the active model boundary.

Figure 5-2 illustrates the distribution of particle end points from the release of particles from the Ecologically Sensitive Features and reverse tracking. The majority of the particles originate within the Study Area. There are areas along the southern boundary of the Black River Subwatershed, the eastern boundary of the Black River Subwatershed, and the northwestern boundary of the Black River Subwatershed where the particles are observed to originate outside the Study Area. These localized areas reflect conditions where the groundwater divide does not necessarily coincide with the surface water divide.

5.3 Verification Analysis

Earth*fx* (2012) conducted a forward tracking particle analysis to assist in confirming the results of the reverse particle tracking analysis. GENIVAR carried out a forward tracking exercise to demonstrate that the reverse particle tracking results provided a reliable estimate of the areas that contribute recharge to the identified Ecologically Sensitive Features. Approximately 4.2 million particles were released from the upper most active layer on a 10 m x 10 m grid within the Study Area. The particle paths were observed to travel to the wetland and stream discharge features within the Black River and Georgina Creeks Subwatersheds. The forward tracking analysis confirmed that the reverse tracking particle endpoints provide a reliable estimate of the recharge sources to the identified Ecologically Sensitive Features

5.4 End Point Cluster Analysis

Earthfx (2012) described the methodology for delineating the ESGRA using a cluster analysis methodology to evaluate the density of the endpoints from the reverse particle tracking. This relative density is considered to identify the areas where particles that represent recharge are most likely to end up in the Ecologically Sensitive Feature. The delineation of ESGRA using the end point cluster analysis is discussed in more detail in Appendix C-2.

The cluster endpoint analysis was carried out using performed using ArcGIS. ArcGIS allows the user to vary the smoothing density (h) and normalized delineation threshold (ε) values as described by Earth*fx.* Appendix C-2 presents the results of analysis carried out to vary the smoothing parameter (h) from 25, 50, 100, 200 and 500 m and the delineation threshold (ε) from 0.001, 0.005, 0.01, 0.05, and 0.01. These results are summarized in Table C2-1 (Appendix C). The output from these scenarios were then reviewed with LSRCA to examine the proportion of the endpoints released that were captured and the area covered by each set of clusters within the Study Area.

The results of the various cluster analysis combinations were reviewed to identify the scenario that captured a high proportion of endpoints in a relatively small, but reasonable portion of the Study Area. The preferred cluster analysis scenario captured 51.6 % of more than 3 million particle end-pints within 51.6% of the Subwatershed Area. Some of the particles were observed to exit the model from within the mapped wetland features. Approximately 31.7 % of the preferred cluster area remained within the mapped wetland features. Policies for discharge areas will remain in place in these areas and they therefore do not need to be included within the ESGRA.

5.5 ESGRA

The recommended ESGRA is illustrated in Figure 5-3. The recommended ESGRA map was prepared from the preferred cluster output by:

a) removing areas that were identified to remain within identified discharge features
b) Removing isolated clusters that occupy less than one 100 m grid cell.
c) Infilling gaps within the mapped clusters that occupy less than one 100 m grid cell.

6.0 Uncertainty and Data Gaps

The study results herein were created using a pre-existing numerical groundwater flow model (Earth*fx* CORE Model) that was updated for use in this study and a surface water flow model (Lake Simcoe PRMS Model, Earth*fx,* 2010). The Earth*fx* CORE Model was the best available tool for analysis in the Study Area at the time of project initiation, although the study team was aware that an update to the Earth*fx* CORE Model was underway as part of Tier 3 Water Budget Studies in The Regional Municipality of York. Where possible, information from this ongoing study was provided to LSRCA and GENIVAR for use in updating and calibrating the GENIVAR Black River Model.

The Earth*fx* CORE Model has been created for analysis on a regional scale and thereby incorporates some simplification to address the computational size of the study area and the interpretations necessary to infer subsurface geology, and hydrogeological properties based on available datasets. The available data sets have varying data quality from water well records with minimal information to high quality research boreholes overseen by qualified professionals. Overall the accuracy of the model is limited by the distribution and quality of available data. This model is considered to represent the best available tool for carrying out the analysis on the scale of the Study Area. In preparing the Black River Groundwater Flow Model for use in this study, GENIVAR did not make changes to the structure of the Earth*fx* CORE Model, but did apply new recharge estimates, pumping rates, and calibration targets within the Study Area. The updated model produced calibration results of similar or improved quality to that published by Eart*hfx.* The model meets or exceeds industry standards and is therefore suitable for the applications as carried out in this study.

Studies of this type, particularly those relying on numerical models constructed from datasets of varying quality, can be viewed as having some level of uncertainty. The uncertainty could possibly be reduced by:

- → Obtaining additional geological data within areas where the available data density, particularly at depth, is relatively low.
- → Obtaining additional data to describe surface water responses to precipitation and runoff events.
- → Updating the structure or hydraulic properties in the numerical models to better reproduce the values at calibration targets.

One observation noted in application of the numerical model in this study is that the simulated groundwater elevations appear to be spatially identical in Layers 3, 5, and 7 in the Study Area. This was observed in the steady-state and transient simulations. This observation suggests that the model may be forcing equilibrium between the primary aquifers. The scale of the outputs provided by Earth*fx* was not sufficient to confirm whether the aquifer responses were identical, or merely similar in the 2006 report. GENIVAR did not investigate the cause of this observation further.

The GENIVAR Black River Groundwater Model has not been calibrated for use in transient analysis. Transient analysis requires consideration for properties such as porosity, storativity, and specific capacity. These properties help the model replicate the time required to generate the observed response. If these parameters are not correct, the model may reach an equilibrium result represented by the inputs faster, or slower than would be observed in reality. Data from temporal monitoring or pumping tests can be used to adjust the model parameters to improve the confidence that the model is providing a realistic and reliable result. The transient model runs presented herein provide a reasonable possible outcome that shows that baseflow can reach equilibrium with reduced recharge within a period of a month. The recharge used represents an actual condition, however in this case, baseflow data is not available to assist in evaluating whether the observed baseflow after two years is representative of the time frame from 1997/1998. The model is expected to provide a conservative simulation that will result in a simulation of baseflow that is likely less than the actual response that would be observed for real data.

The available measures to reduce uncertainty will require substantial expense and time. In the interim, the steady-state models are sufficiently accurate to support the findings with respect to water budgets and ESGRA delineations.

It is our understanding that the model under development for addressing the Tier 3 Water Budgets incorporates an updated hydrostratigraphic interpretation and additional refinement of the vertical layers used for calculations. This model, when calibrated, may be suitable for use in confirming the results of this study.

7.0 Conclusions

1) The Earth*fx* CORE Model (CAMC/YPDT, 2006) was successfully imported into the Groundwater VISTAS User Interface and produced similar outputs and calibration statistics as reported by Earth*fx.* The imported model is referred to as the GENIVAR CORE Model.

2) The GENIVAR CORE Model was updated for use in the study of the Black River Georgina Creeks Subwatershed by updating the recharge within the Study Area using the PRMS Recharge as determined by Earth*fx* 2012 and by updating the pumping rates and groundwater elevation monitoring points used for the calibration. The model was also updated to add a numerical representation of drainage beneath the identified wetland features. This updated model is referred to as the GENIVAR Black River Groundwater Model.

3) The GENIVAR Black River Groundwater Model was applied to determine the water budget within the Study Area under the existing pumping water demand scenario and for a steady-state scenario based on future pumping (committed/planned pumping were assumed to be the same).

4) An updated summary of water use within the Study Area was carried out (Tables 4-1 to 4-5). Approximately 17% of the groundwater use is for municipal purposes and the majority is for irrigation and agricultural purposes. Records of actual water use are only available for municipal water supplies. Existing demand and potential demand by others is estimated, primarily from the allowable limits in the Permit To Take Water.

5) The water budget outputs provide a visual representation of how water can enter and pass through the various hydrostratigraphic layers and be discharged to surface water features. Recharge is the primary input of water to the Study Area with lateral inflows making up approximately 18%. Approximately 72% of the groundwater output in the Study Area is discharge is to surface water features, 7% is direct discharge to Lake Simcoe, 18.5% is transferred out laterally, and 2.5% is removed as water taking.

6) The water budget analysis for existing water demand at steady-state pumping shows that the existing water demand in the Study Area is on the order of 3.5% with 2.5% in the Black River Subwatershed and 6.4% in the Georgina Creeks Subwatershed. Estimates of existing water demand on a monthly basis are up to 6% for the study area, 7.7% in the Black River Subwatershed and up to 11.8% in the Georgina Creeks Subwatershed.

7) The model simulation for future/committed water demand at steady-state shows that the groundwater elevations would change only in the local vicinity of permitted water takers. The degree of change shown is likely overestimated due to the assumption that these users would be utilizing the full capacity of their Permits to Take Water.

8) The water budget analysis for future committed/planned water demand at steady-state pumping shows that the existing water demand in the Study Area is on the order of 7.4% with 7.7% in the Black River Subwatershed and 4.9% in the Georgina Creeks Subwatershed. Estimates of existing water demand on a monthly basis are up to 12.8% for the study area, 14.7% in the Black River Subwatershed and up to 9.5% in the Georgina Creeks Subwatershed.

9) Recharge inputs were prepared using the PRMS model to reflect the average monthly conditions over the two year period with the lowest rainfall in the period of record (1997-1998). This is considered to be a low recharge or drought scenario. The GENVIAR Black River Groundwater Model was applied to determine the water budget under the existing water demand and for future/committed water demand over this two year low recharge period. The transient model provided a possible outcome after two years of pumping. Information was not available to evaluate the extent to which this outcome potentially overestimates actual conditions in 1997-1998.

10) The model simulation for the two year low recharge condition with existing water demand (transient recharge and pumping) shows a substantial reduction in the amount of water moving in the water. This reduction is in proportion to the reduction in recharge applied. Stream baseflows and groundwater elevations were observed to decrease steadily through the two year period. Stream baseflows were observed to decrease between 70 and 90% in the Black River Subwatershed and by more than 99% in the Georgina Creeks Subwatershed. Groundwater elevations were observed to be lowered by up to 45 m in the headwater areas adjacent to the Oak Ridges Moraine but by less than 5 m through the central portion of the Black River Subwatershed.

11) The model simulation for the two year low recharge condition with future committed/planned water demand (transient recharge and pumping) shows a similar outcome as observed for the transient scenario with existing water demand. Simulated groundwater elevations and stream baseflow are slightly lower. Local changes of groundwater elevations in the areas of permitted water takings were observed.

12) Ecologically Sensitive Features were identified based on cool and cold water fish habitat, wetlands and Areas of Natural and Scientific Interest (ANSI). The Ecologically Sensitive Features are shown in Figure 5-1. The Ecologically Sensitive Features occupy an area on the order of 117 km^2 (27% of the Study Area).

13) The steady-state model analysis of existing water demand was used to carry out particle tracking analysis following the methodology developed by Earth*fx* (2012) to delineate Ecologically Significant Groundwater Recharge Areas (ESGRA). The delineated ESGRA is identified to occupy approximately 135 km^2 (32% of the Study Area).

14) The numerical modelling tools developed for this project provide an ability to carry out the requested analysis. The results obtained from the numerical groundwater model operated under steady-state conditions represent observed conditions well. Sufficient data is not available to evaluate how well the model outcomes reflect specific transient inputs.

This report was prepared by Isabelle Hemmings, M.A.Sc., Tanya Peterson, and Lloyd Lemon, M.Sc., P.Geo.

Respectively Submitted
GENIVAR Inc.

Isabelle Hemmings, M.A.Sc.
Groundwater Modeller

Lloyd A. Lemon, M.Sc., P.Geo.
Senior Geoscientist

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Tables

Table 2-1 Hydraulic Conductivity Values for Aquitards (Calibrated Model)

Aquitard Layer	Horizontal Hydraulic Conductivity		Vertical Hydraulic Conductivity (Thickness dependent)	
	(m/day)	(m/sec)	(m/day)	(m/sec)
Layer 1 – Recent Deposits and/or Weathered Halton/Kettleby Aquitard	0.43	5×10^{-6}	0.43	5×10^{-6}
Layer 2 –Halton/Kettleby Aquitard	0.043	5×10^{-7}	.013	1.5×10^{-7}
Layer 3 – Weathered Newmarket Aquitard	0.43	5×10^{-6}	0.43	5×10^{-6}
Layer 4 –Newmarket Aquitard	0.0043	5×10^{-8}	0.00086	1×10^{-8}
Layer 4 – Newmarket Aquitard (Under ORM)	0.0043	5×10^{-8}	0.00011	1.25 x 10-^{9}
Layer 4 – Tunnel Channel Silts	0.043	5×10^{-7}	0.0086	1×10^{-7}
Layer 6 -Sunnybrook Aquitard	0.0043	5×10^{-8}	0.00043	5×10^{-9}

Table 3-1 - Calibration Statistics - GENIVAR Black River Groundwater Model

Model Result	Number of Wells (n)	Mean Error [ME] (m)	Mean Absolute Error [AME] (m)	Root Mean Squared Error [RMSE] (m)	Normalized Root Mean Squared Error [NRMSE] %
Black River Subwatershed	3917	-0.83	5.32	7.75	4.32%
Georgina Creeks Subwatershed	1301	0.66	4.01	5.61	9.48%
Study Area (Both Watersheds)	5218	-0.46	4.99	7.27	4.05%
Entire Model	21431	0.11	7.52	10.58	3.70%

Hydat Station	Average Annual Flow (m^3/s)	Calculated Baseflow (m^3/s)	Simulated Baseflow (m^3/s)	Percent Error
Black River at Baldwin	2.26	1.41	1.38	1.99%
Black River at Sutton	2.55	1.62	1.57	2.98%

Table 4-1 Summary of Municipal Water Use

Well Location	Permit-To-Take Water	Easting	Northing	Aquifer Assignment	Permitted Maximum Taking	Modelled Pumping Rates	
						Existing Demand	Committed/ Planned Demand
		m	m		m^3/day	m^3/day	m^3/day
Mount Albert 1	0050-7FCMMY	635250	4887650	TAC	3,993.1	297	439
Mount Albert 2	0050-7FCMMY	635225	4887647	TAC	3,993.1	327	484
Mount Albert 3	0050-7FCMMY	635950	4886250	TAC	3,273.1	336	497
System Total	**0050-7FCMMY**				**11,259.4**	**960**	**1,420**

Notes:
1) Mount Albert 3 was brought into use in 2011
2) Existing Demand for Mount Albert Wells based on 2011 usage.
3) The relative proportion of well use for 2011 was used to determine committed demand rates.
4) TAC = Thorncliffe Aquifer Complex
5) Values in Table may reflect rounding

Monthly Water Use - Mount Albert Wells

Month	Existing Demand (m^3/day)				Committed/Planned Demand (m^3/day)			
	Mount Albert 1	Mount Albert 2	Mount Albert 3	System	Mount Albert 1	Mount Albert 2	Mount Albert 3	System
January	273.8	301.8	309.9	885.5	397.7	438.3	450.0	1,286.0
February	265.3	292.4	300.2	857.9	426.5	470.1	482.7	1,379.3
March	258.9	285.4	293.0	837.3	376.0	414.4	425.5	1,216.0
April	250.8	276.4	283.8	811.1	376.4	414.8	426.0	1,217.2
May	285.4	314.5	323.0	922.9	414.5	456.8	469.0	1,340.3
June	332.0	365.9	375.7	1,073.5	498.2	549.0	563.8	1,611.0
July	448.3	494.0	507.3	1,449.6	651.0	717.4	736.7	2,105.2
August	320.6	353.3	362.8	1,036.7	465.6	513.1	526.9	1,505.6
September	295.3	325.5	334.2	955.0	443.2	488.4	501.6	1,433.2
October	262.3	289.1	296.9	848.4	381.0	419.9	431.2	1,232.0
November	278.4	306.8	315.1	900.3	417.8	460.4	472.8	1,351.0
December	289.0	318.5	327.0	934.5	419.7	462.5	474.9	1,357.2
Daily Average	**297.0**	**327.3**	**336.1**	**960.5**	**439.1**	**483.9**	**496.9**	**1,420.0**

Table 4-2 Summary of Permitted Water Use - Groundwater

Permit-To-Take Water	Easting	Northing	Subwatershed	Aquifer Assignment	Permitted Maximum Taking	Permitted Days	Permitted Hours	Water Taking		Modelled Pumping Rates		Water Use	Source Study
								Maximum Annual Taking	Annual Average	Existing Demand	Committed/ Planned Demand		
	m	m			m³/day	Days	Hours	m³/year	m³/day	m³/day	m³/day		
1416-7AEQ2L	634050	4886050	Black River	ORAC	1,244	365	24	454,118	1,244	7.9	1244.2	Aquaculture	CAMC/YPDT 2006
1416-7AEQ2L	634650	4885850	Black River	TAC	589	365	24	214,970	589	3.9	589.0	Aquaculture	CAMC/YPDT 2006
1416-7AEQ2L	634150	4886150	Black River	ORAC	786	365	24	286,978	786	18.1	786.2	Aquaculture	CAMC/YPDT 2006
2344-7FNRMT	628350	4893650	Black River	TAC	544	30	24	16,330	45	35.4	44.7	Irrigation - Crops	Tier 3 Study
2344-7FNRMT	628150	4893450	Black River	TAC	4,360	30	24	130,810	358	286.8	358.4	Irrigation - Crops	Tier 3 Study
8327-6Z3TD2	632250	4887550	Black River	TAC	1,211	365	24	442,030	1,211	968.5	1211.0	Irrigation - Crops	Tier 3 Study
2005-6TYPT6	627050	4883850	Black River	ORAC	1,637	150	24	245,484	673	70.0	672.6	Irrigation - Golf Course	CAMC/YPDT 2006
5520-6E2NFA	629750	4882950	Black River	ORAC	3,000	184	10	552,000	1,512	50.1	1512.3	Irrigation - Golf Course	CAMC/YPDT 2006
5520-6E2NFA	630250	4883150	Black River	ORAC	1,685	184	24	310,003	849	594.4	849.3	Irrigation - Golf Course	CAMC/YPDT 2006
2005-6TYPT6	627350	4883650	Black River	ORAC	1,407	150	24	211,118	578	70.0	578.4	Irrigation - Golf Course	CAMC/YPDT 2006
1580-744HUV	621550	4901850	Georgina Creeks	ORAC	981	210	24	205,934	564	805.2	564.2	Irrigation - Golf Course	Tier 3 Study
6834-699PX9	626850	4907650	Georgina Creeks	TAC	97	100	12	9,720	27	19.9	26.6	Irrigation - Golf Course	Tier 3 Study
5520-6E2NFA	630650	4883550	Black River	ORAC	38	365	2	14,016	38	26.8	38.4	Irrigation - Golf Course	Tier 3 Study
6838-6VCMLC	635550	4894550	Black River	ORAC	2,455	50	10	122,730	336	11.2	336.2	Irrigation - Sod Farm	Tier 3 Study
4435-7C2SFV	639050	4908550	Black River	TAC	459	180	24	82,685	227	181.4	226.5	Other - Agricultural	Tier 3 Study
Total					**20,494**			**3,298,926**	**9,038**	**3149.8**	**9038.2**		

Notes:

1) ORAC = Oak Ridges Aquifer Complex; TAC = Thorncliffe Aquifer Complex; SAC = Scarborough Aquifer Complex
2) Values in Table may reflect rounding

Table 4-3 Summary of Permitted Water Use - Surface Water

Permit-To-Take Water	Easting	Northing	Water Use	Permitted Maximum Taking	Permitted Days	Permitted Hours	Water Taking: Maximum Annual Taking	Water Taking: Average
	m	m		m^3/day	Days	Hours	m^3/year	m^3/day
8570-7M7QCS	633360	4907853	Campgrounds	326.9	365	24	119311.2	326.88
8570-7M7QCS	633360	4907852	Campgrounds	360.0	365	24	131400	360
8348-766JM8	627864	4879915	Irrigation - Crops	2.8	365	2	84	0
8348-766JM8	628284	4880221	Irrigation - Crops	858.6	52	18	33,485	92
6367-7MDSSU	631226	4891432	Irrigation - Crops	736.2	45	6	8,282	23
0064-7EPNM9	631588	4901910	Irrigation - Crops	4,906.1	30	24	147,182	403
8067-7HHLUP	630343	4904220	Irrigation - Crops	3,491.5	180	16	418,982	1,148
1718-6HWQN5	632770	4898820	Irrigation - Golf Course	32.4	250	18	6,075	17
1718-6HWQN5	632770	4898820	Irrigation - Golf Course	48.6	365	18	13,304	36
1580-744HUV	621516	4901850	Irrigation - Golf Course	980.6	210	24	205,934	564
6834-699PX9	627306	4907973	Irrigation - Golf Course	216.0	100	4	3,600	10
1580-744HUV	621516	4901850	Irrigation - Golf Course	1,998.7	210	24	419,731	1,150
1718-6HWQN5	631140	4908410	Irrigation - Golf Course	1,134.0	150	10	70,875	194
2005-6TYPT6	627424	4883943	Irrigation - Golf Course	1,455.4	150	8	72,768	199
0534-7GLLWN	633431	4900666	Irrigation - Sod Farm	619.2	60	12	18,576	51
8662-7FFPTD	624715	4885538	Irrigation - Sod Farm	1,307.5	150	16	130,752	358
1323-7R4JKS	638050	4896800	Irrigation - Sod Farm	1,320.0	90	10	49,500	136
7883-783SHV	633836	4897661	Irrigation - Sod Farm	1,365.0	60	10	34,125	93
7270-7LYL6N	630977	4905676	Irrigation - Sod Farm	1,309.0	69	8	30,106	82
03-P-3036	624110	4905320	Irrigation - Sod Farm	2,946.2	150	18	331,452	908
03-P-3036	624915	4906615	Irrigation - Sod Farm	5,886.0	150	18	662,175	1,814
03-P-3036	623940	4905950	Irrigation - Sod Farm	5,886.0	150	18	662,175	1,814
1268-636QNK	620620	4901330	Municipal	16,200.0	365	24	5,913,000	16,200
03-P-3008	626240	4908110	Municipal	49,999.7	365	24	18,249,883	50,000
96-P-3004	626148	4904756	Other - Commercial	1,309.0	18	24	23,561	65
1542-7QAJBG	624716	4905401	Other - Commercial	3,600.0	365	24	1,314,000	3,600
7351-7TCQ32	634255	4878672	Pumping Test	3,928.3	7	24	27,498	75
Total				**112,223.6**			**28,847,108**	**79,033**

Notes:
1) Values in Table may reflect rounding

Table 4-4 Summary of Other Water Use

Permit-To-Take Water	Easting	Northing	Subwatershed	Aquifer Assignment	Permitted Maximum Taking	Modelled Pumping Rates	
						Existing Demand	Committed/ Planned Demand
	m	m			m^3/day	m^3/day	m^3/day
n/a	629750	4883150	Black River	5	n/a	27.0	27.0
n/a	626750	4907850	Black River	7	n/a	133.1	133.1
n/a	633950	4886050	Black River	5	n/a	786.0	786.0
n/a	629250	4894150	Black River	3	n/a	53.3	53.3
n/a	628150	4904950	Black River	3	n/a	50.8	50.8
n/a	634050	4888950	Black River	5	n/a	21.9	21.9
n/a	634550	4891350	Black River	3	n/a	34.1	34.1
n/a	635950	4901450	Black River	7	n/a	50.3	50.3
n/a	632450	4882950	Black River	5	n/a	36.1	36.1
n/a	628350	4888750	Black River	5	n/a	103.1	103.1
n/a	623350	4902150	Black River	5	n/a	27.5	27.5
n/a	637550	4883750	Black River	3	n/a	29.2	29.2
n/a	637650	4883750	Black River	3	n/a	29.2	29.2
n/a	631550	4891450	Black River	7	n/a	23.4	23.4
n/a	631850	4880950	Black River	5	n/a	81.3	81.3
n/a	629550	4891050	Black River	5	n/a	50.3	50.3
Total						1,536.6	1,536.6

Notes:
1) NA - Not available
2) Information obtained from CAMC/YPDT, 2006, CORE Model Data Files
3) Water use was estimated from observed land use. Water use is assumed to be for irrigation purposes
4) Values in Table may reflect rounding

Table 4-5 Estimated Monthly Water Use - Groundwater

Month	Existing Demand (m^3/day)					Committed/Planned Demand (m^3/day)				
	Municipal Wells	PTTW Wells	Other Wells	Total	Georgina Creeks Only	Municipal Wells	PTTW Wells	Other Wells	Total	Georgina Creeks Only
January	886	1,025		1,911		1,286	3,869		5,155	
February	858	1,025		1,883		1,379	3,869		5,248	
March	837	1,025		1,863		1,216	3,869		5,085	
April	811	2,399		3,210	1,373	1,217	4,831		6,048	962
May	923	4,371	3,666	8,960	1,756	1,340	12,977	3,666	17,983	1,345
June	1,074	4,450	3,666	9,189	1,834	1,611	13,055	3,666	18,332	1,451
July	1,450	4,516	3,666	9,631	1,834	2,105	15,035	3,666	20,806	1,451
August	1,037	4,516	3,666	9,219	1,834	1,506	15,035	3,666	20,206	1,451
September	955	8,292	3,666	12,913	1,756	1,433	17,854	3,666	22,953	1,345
October	848	4,037		4,886	1,373	1,232	9,965		11,197	962
November	900	1,025		1,925		1,351	3,869		5,220	
December	935	1,025		1,960		1,357	3,869		5,226	
Daily Average	**960**	**3,150**	**1,537**	**5,647**	**985**	**1,420**	**9,040**	**1,537**	**11,997**	**751**

Notes:
1) Values in Table may reflect rounding

Table 4-6 Water Budget Summary - Existing Water Demand

Item	Units	Black River Subwatershed		Georgina Creeks Subwatershed		Total Study Area	
		Value	%	Value	%	Value	%
Subwatershed Area	km^2	375		49		425	
	m^2	375,360,000		49,333,000		424,693,000	
Water Budget							
Inputs:							
Recharge	m^3/day	158,482	79.5%	14,373	73.5%	172,855	79.9%
Stream Recharge	m^3/day	4,607	2.3%	-	0.0%	4,607	2.1%
Lateral Inflow (Adjacent)	m^3/day	36,309	18.2%	5,174	26.5%	38,781	17.9%
Lake Simcoe Inflow	m^3/day	-	0.0%	0	0.0%	0	0.0%
Total Input	**m^3/day**	**199,398**	**100.0%**	**19,547**	**100.0%**	**216,242**	**100.0%**
Outputs:							
Discharge to Stream	m^3/day	151,476	76.0%	3,098	15.9%	154,573	71.5%
Discharge to Lake Simcoe	m^3/day	4,233	2.1%	11,731	60.0%	15,964	7.4%
Lateral Outflow (Adjacent)	m^3/day	38,956	19.5%	3,725	19.1%	39,979	18.5%
Wells	m^3/day	4,662	2.3%	986	5.0%	5,647	2.6%
Total Outflow	**m^3/day**	**199,327**	**100.0%**	**19,539**	**100.0%**	**216,163**	**100.0%**

Notes:
1) Values in Table may reflect rounding
2) The lateral inflow for the Total Study Area was obtained directly from the numerical model outputs. The sum of the lateral inputs for the Black River Subwatershed and Georgina Creeks Subwatershed may not equal the value shown for the Study Area.

Table 4-7 Water Quantity Stress Assessment - Existing Water Demand

Subwatershed	Area	Month	Days	Total Recharge		Lateral Groundwater Inputs (Qin)		Baseflow		Reserve (10% Baseflow)		Groundwater Demand			% Water Demand
	km²			mm/mo	m^3/d	mm/mo	m^3/d	mm/mo	m^3/d	mm/mo	m^3/d	m^3/mo	mm/mo	m^3/d	%
Black River	375	January	31	13.5	163,089	-0.2	-2,647	12.5	151,476	1.3	15,148	59,233	0.16	1,911	1.3%
		February	28	12.2	163,089	-0.2	-2,647	11.3	151,476	1.1	15,148	52,726	0.14	1,883	1.3%
		March	31	13.5	163,089	-0.2	-2,647	12.5	151,476	1.3	15,148	57,738	0.15	1,863	1.3%
		April	30	13.0	163,089	-0.2	-2,647	12.1	151,476	1.2	15,148	55,104	0.15	1,837	1.3%
		May	31	13.5	163,089	-0.2	-2,647	12.5	151,476	1.3	15,148	223,312	0.60	7,204	5.0%
		June	30	13.0	163,089	-0.2	-2,647	12.1	151,476	1.2	15,148	220,660	0.59	7,355	5.1%
		July	31	13.5	163,089	-0.2	-2,647	12.5	151,476	1.3	15,148	241,723	0.64	7,798	5.4%
		August	31	13.5	163,089	-0.2	-2,647	12.5	151,476	1.3	15,148	228,924	0.61	7,385	5.1%
		September	30	13.0	163,089	-0.2	-2,647	12.1	151,476	1.2	15,148	334,702	0.89	11,157	7.7%
		October	31	13.5	163,089	-0.2	-2,647	12.5	151,476	1.3	15,148	108,890	0.29	3,513	2.4%
		November	30	13.0	163,089	-0.2	-2,647	12.1	151,476	1.2	15,148	57,765	0.15	1,925	1.3%
		December	31	13.5	163,089	-0.2	-2,647	12.5	151,476	1.3	15,148	60,752	0.16	1,960	1.3%
				mm/a	*m^3/d*	*mm/a*	*m^3/d*	*mm/a*	*m^3/d*	*mm/a*	*m^3/d*	*m^3/a*	*mm/a*	*m^3/d*	*%*
		Sum (Monthly)	*365*	*158.7*	*163,089*	*-2.6*	*-2,647*	*147.4*	*151,476*	*14.7*	*15,148*	1,701,529	*4.54*	*4,662*	*3.2%*
		Direct Data	***365***	***158.7***	***163,089***	***35.3***	*36,309*	***147.4***	***151,476***	***14.7***	***15,148***	***1,701,630***	***4.54***	***4,662***	***2.5%***
Georgina Creeks	49	January	31	9.1	14,373	0.9	1,449	2.0	3,098	0.2	310	0	0.00		0.0%
		February	28	8.2	14,373	0.8	1,449	1.8	3,098	0.2	310	0	0.00		0.0%
		March	31	9.1	14,373	0.9	1,449	2.0	3,098	0.2	310	0	0.00		0.0%
		April	30	8.8	14,373	0.9	1,449	1.9	3,098	0.2	310	41,189	0.84	1,373	8.9%
		May	31	9.1	14,373	0.9	1,449	2.0	3,098	0.2	310	54,440	1.11	1,756	11.3%
		June	30	8.8	14,373	0.9	1,449	1.9	3,098	0.2	310	55,017	1.12	1,834	11.8%
		July	31	9.1	14,373	0.9	1,449	2.0	3,098	0.2	310	56,850	1.16	1,834	11.8%
		August	31	9.1	14,373	0.9	1,449	2.0	3,098	0.2	310	56,850	1.16	1,834	11.8%
		September	30	8.8	14,373	0.9	1,449	1.9	3,098	0.2	310	52,684	1.08	1,756	11.3%
		October	31	9.1	14,373	0.9	1,449	2.0	3,098	0.2	310	42,562	0.87	1,373	8.9%
		November	30	8.8	14,373	0.9	1,449	1.9	3,098	0.2	310	0	0.00		0.0%
		December	31	9.1	14,373	0.9	1,449	2.0	3,098	0.2	310	0	0.00		0.0%
				mm/a	*m^3/d*	*mm/a*	*m^3/d*	*mm/a*	*m^3/d*	*mm/a*	*m^3/d*	*m^3/a*	*mm/a*	*m^3/d*	*%*
		Sum (Monthly)	365	107.1	*14,373*	10.8	*1,449*	23.1	*3,098*	2.3	310	359,591	7.34	*985*	6.4%
		Direct Data	**365**	**107.1**	**14,373**	**10.8**	**1,449**	**23.1**	**3,098**	**2.3**	310	**359,890**	**7.34**	**986**	**6.4%**
Study Area	424	January	31	13.0	177,462	-0.1	-1,198	11.3	154,573	1.1	15,457	59,233	0.14	1,911	1.2%
		February	28	11.7	177,462	-0.1	-1,198	10.2	154,573	1.0	15,457	52,726	0.12	1,883	1.2%
		March	31	13.0	177,462	-0.1	-1,198	11.3	154,573	1.1	15,457	57,738	0.14	1,863	1.2%
		April	30	12.6	177,462	-0.1	-1,198	10.9	154,573	1.1	15,457	96,292	0.23	3,210	2.0%
		May	31	13.0	177,462	-0.1	-1,198	11.3	154,573	1.1	15,457	277,752	0.66	8,960	5.6%
		June	30	12.6	177,462	-0.1	-1,198	10.9	154,573	1.1	15,457	275,677	0.65	9,189	5.7%
		July	31	13.0	177,462	-0.1	-1,198	11.3	154,573	1.1	15,457	298,574	0.70	9,631	6.0%
		August	31	13.0	177,462	-0.1	-1,198	11.3	154,573	1.1	15,457	285,775	0.67	9,219	5.7%
		September	30	12.6	177,462	-0.1	-1,198	10.9	154,573	1.1	15,457	387,386	0.91	12,913	8.0%
		October	31	13.0	177,462	-0.1	-1,198	11.3	154,573	1.1	15,457	151,451	0.36	4,886	3.0%
		November	30	12.6	177,462	-0.1	-1,198	10.9	154,573	1.1	15,457	57,765	0.14	1,925	1.2%
		December	31	13.0	177,462	-0.1	-1,198	11.3	154,573	1.1	15,457	60,752	0.14	1,960	1.2%
				mm/a	*m^3/d*	*mm/a*	*m^3/d*	*mm/a*	*m^3/d*	*mm/a*	*m^3/d*	*m^3/a*	*mm/a*	*m^3/d*	*%*
		Sum (Monthly)	365	152.8	*177,462*	-1.0	*-1,198*	133.1	*154,573*	13.3	15,457	2,061,121	4.86	*5,647*	3.5%
		Direct Data	**365**	**152.8**	**177,462**	**-1.0**	**-1,198**	**133.1**	**154,573**	**13.3**	**15,457**	**2,061,520**	**4.86**	**5,648**	**3.5%**

Note: 1) Monthly Pumping Rates assigned as per Table 4-5. Water Budget values reflect steady-state model outputs (Table 4-6).
2) Values in Table may reflect rounding
3) Sum Monthly reflects the sum of the monthly estimates. Direct Data reflects the direct outputs from the water budget for the subwatershed.

Table 4-8 Water Balance Summary - Future Committed/Planned Water Demand

Item	Units	Black River Subwatershed		Georgina Creeks Subwatershed		Total Study Area	
		Value	%	Value	%	Value	%
Subwatershed Area	km^2	375		49		425	
	m^2	375,360,000		49,333,000		424,693,000	
Water Budget							
Inputs:							
Recharge	m^3/day	158,480	79.3%	14,373	73.7%	172,853	79.8%
Stream Recharge	m^3/day	4,734	2.4%	-	0.0%	4,734	2.2%
Lateral Inflow (Adjacent)	m^3/day	36,711	18.4%	5,126	26.3%	39,125	18.1%
Lake Simcoe Inflow	m^3/day	-	0.0%	0	0.0%	0	0.0%
Total Input	**m^3/day**	**199,925**	**100.0%**	**19,499**	**100.0%**	**216,712**	**100.0%**
Outputs:							
Discharge to Stream	m^3/day	145,876	73.0%	3,076	15.8%	148,952	68.7%
Discharge to Lake Simcoe	m^3/day	4,231	2.1%	11,821	60.7%	16,052	7.4%
Lateral Outflow (Adjacent)	m^3/day	38,556	19.3%	3,840	19.7%	39,684	18.3%
Wells	m^3/day	11,243	5.6%	751	3.9%	11,995	5.5%
Total Outflow	**m^3/day**	**199,906**	**100.0%**	**19,487**	**100.0%**	**216,682**	**100.0%**

Notes:
1) Values in Table may reflect rounding
2) The lateral inflow for the Total Study Area was obtained directly from the numerical model outputs. The sum of the lateral inputs for the Black River Subwatershed and Georgina Creeks Subwatershed may not equal the value shown for the Study Area.

Table 4-9 Change in Simulated Baseflow

Hydat Station	Average Annual Flow (m3/s)	Calculated Baseflow (m3/s)	Simulated Baseflow (m3/s)				Percent Difference			
			GENIVAR Black River Model Existing Demand	Genivar Black River Model Committed Demand	Genivar Black River Model After 2 Years Low Recharge Existing Demand	Genivar Black River Model After 2 Years Low Recharge Committed Demand	GENIVAR Black River Model Existing Demand	Genivar Black River Model Committed Demand	Genivar Black River Model After 2 Years Low Recharge Existing Demand	Genivar Black River Model After 2 Years Low Recharge Committed Demand
Black River at Baldwin	2.26	1.41	1.38	1.32	0.14	0.12	1.99%	6.55%	90.11%	91.22%
Black River at Sutton	2.55	1.62	1.57	1.51	0.18	0.16	2.98%	6.87%	89.19%	90.16%

Notes:

Calculated and Simulated Values for Base Flow at individual surface water stations obtained from Table 3, Page 117 - "Groundwater Modelling of the Oak Ridges Moraine Area" - CAMC/YPDT Technical Report Number 01-06.

Zone Number	Simulated Baseflow (m3/s)				Percent Difference			
	GENIVAR Black River Model Existing Demand	Genivar Black River Model Committed Demand	Genivar Black River Model After 2 Years Low Recharge Existing Demand	Genivar Black River Model After 2 Years Low Recharge Committed Demand	GENIVAR Black River Model Existing Demand	Genivar Black River Model Committed Demand	Genivar Black River Model After 2 Years Low Recharge Existing Demand	Genivar Black River Model After 2 Years Low Recharge Committed Demand
Black River Subwatershed 1	0.49	0.46	0.04	0.03	n/a	5.66%	91.15%	93.26%
Black River Subwatershed 2	0.63	0.59	0.15	0.13	n/a	5.67%	76.43%	79.88%
Black River Subwatershed 3	0.13	0.13	0.02	0.02	n/a	0.71%	86.49%	86.80%
Black River Subwatershed 4	0.23	0.23	0.07	0.07	n/a	0.44%	69.49%	69.57%
Black River Subwatershed 5	0.14	0.14	0.03	0.04	n/a	-0.74%	77.60%	72.46%
Black River Subwatershed 6	0.14	0.14	0.02	0.02	n/a	0.41%	87.42%	87.69%
Georgina Creeks Subwatershed	0.04	0.04	5.30E-05	5.40E-05	n/a	0.71%	99.85%	99.85%

Notes:

Subwatershed Zones are compared to the Existing Demand Steady State scenario.
Values in Table may reflect rounding

Table 4-10 Water Quantity Stress Assessment - Future Committed/Planned Water Demand

Subwatershed	Area	Month	Days	Total Recharge		Lateral Groundwater Inputs (Qin)		Baseflow		Reserve (10% Baseflow)		Groundwater Demand			% Water Demand
	km^2			mm/mo	m^3/d	mm/mo	m^3/d	mm/mo	m^3/d	mm/mo	m^3/d	m^3/mo	mm/mo	m^3/d	%
Black River	375	January	31	13.5	163,214	-0.2	-1,845	12.1	145,876	1.2	14,588	159,799	0.43	5,155	3.5%
		February	28	12.2	163,214	-0.1	-1,845	10.9	145,876	1.1	14,588	146,948	0.39	5,248	3.6%
		March	31	13.5	163,214	-0.2	-1,845	12.1	145,876	1.2	14,588	157,628	0.42	5,085	3.5%
		April	30	13.1	163,214	-0.1	-1,845	11.7	145,876	1.2	14,588	152,579	0.41	5,086	3.5%
		May	31	13.5	163,214	-0.2	-1,845	12.1	145,876	1.2	14,588	515,771	1.38	16,638	11.3%
		June	30	13.1	163,214	-0.1	-1,845	11.7	145,876	1.2	14,588	506,428	1.35	16,881	11.5%
		July	31	13.5	163,214	-0.2	-1,845	12.1	145,876	1.2	14,588	599,993	1.60	19,355	13.2%
		August	31	13.5	163,214	-0.2	-1,845	12.1	145,876	1.2	14,588	581,406	1.55	18,755	12.8%
		September	30	13.1	163,214	-0.1	-1,845	11.7	145,876	1.2	14,588	648,232	1.73	21,608	14.7%
		October	31	13.5	163,214	-0.2	-1,845	12.1	145,876	1.2	14,588	317,286	0.85	10,235	7.0%
		November	30	13.1	163,214	-0.1	-1,845	11.7	145,876	1.2	14,588	156,594	0.42	5,220	3.6%
		December	31	13.5	163,214	-0.2	-1,845	12.1	145,876	1.2	14,588	162,004	0.43	5,226	3.6%
				mm/a	*m^3/d*	*mm/a*	*m^3/d*	*mm/a*	*m^3/d*	*mm/a*	*m^3/d*	*m^3/a*	*mm/a*	*m^3/d*	*%*
		Sum (Monthly)	*365*	*158.9*	*163,214*	*-1.8*	*-1,845*	*142.0*	*145,876*	*14.2*	*14,588*	*4,104,668*	*10.95*	*11,246*	*7.7%*
		Direct Data	***365***	***158.9***	***163,214***	***-1.8***	***-1,845***	***142.0***	***145,876***	***14.2***	***14,588***	***4,103,695***	***10.94***	***11,243***	***7.7%***
Georgina Creeks	49	January	31	9.1	14,373	0.8	1,284	1.9	3,076	0.2	308	0	0.00		0.0%
		February	28	8.2	14,373	0.7	1,284	1.8	3,076	0.2	308	0	0.00		0.0%
		March	31	9.1	14,373	0.8	1,284	1.9	3,076	0.2	308	0	0.00		0.0%
		April	30	8.8	14,373	0.8	1,284	1.9	3,076	0.2	308	28,869	0.59	962	6.3%
		May	31	9.1	14,373	0.8	1,284	1.9	3,076	0.2	308	41,710	0.85	1,345	8.8%
		June	30	8.8	14,373	0.8	1,284	1.9	3,076	0.2	308	43,534	0.89	1,451	9.5%
		July	31	9.1	14,373	0.8	1,284	1.9	3,076	0.2	308	44,985	0.92	1,451	9.5%
		August	31	9.1	14,373	0.8	1,284	1.9	3,076	0.2	308	44,985	0.92	1,451	9.5%
		September	30	8.8	14,373	0.8	1,284	1.9	3,076	0.2	308	40,364	0.82	1,345	8.8%
		October	31	9.1	14,373	0.8	1,284	1.9	3,076	0.2	308	29,832	0.61	962	6.3%
		November	30	8.8	14,373	0.8	1,284	1.9	3,076	0.2	308	0	0.00		0.0%
		December	31	9.1	14,373	0.8	1,284	1.9	3,076	0.2	308	0	0.00		0.0%
				mm/a	*m^3/d*	*mm/a*	*m^3/d*	*mm/a*	*m^3/d*	*mm/a*	*m^3/d*	*m^3/a*	*mm/a*	*m^3/d*	*%*
		Sum (Monthly)	365	107.1	*14,373*	9.6	*1,284*	22.9	*3,076*	2.3	308	274,280	5.60	*751*	4.9%
		Direct Data	**365**	**107.1**	**14,373**	**9.6**	**1,286**	**22.9**	**3,076**	**2.3**	308	**274,115**	**5.59**	**751**	**4.9%**
Study Area	424	January	31	13.0	177,587	0.0	-559	10.9	148,952	1.1	14,895	159,799	0.38	5,155	3.2%
		February	28	11.7	177,587	0.0	-559	9.8	148,952	1.0	14,895	146,948	0.35	5,248	3.2%
		March	31	13.0	177,587	0.0	-559	10.9	148,952	1.1	14,895	157,628	0.37	5,085	3.1%
		April	30	12.6	177,587	0.0	-559	10.5	148,952	1.1	14,895	181,449	0.43	6,048	3.7%
		May	31	13.0	177,587	0.0	-559	10.9	148,952	1.1	14,895	557,481	1.31	17,983	11.1%
		June	30	12.6	177,587	0.0	-559	10.5	148,952	1.1	14,895	549,962	1.30	18,332	11.3%
		July	31	13.0	177,587	0.0	-559	10.9	148,952	1.1	14,895	644,978	1.52	20,806	12.8%
		August	31	13.0	177,587	0.0	-559	10.9	148,952	1.1	14,895	626,391	1.48	20,206	12.5%
		September	30	12.6	177,587	0.0	-559	10.5	148,952	1.1	14,895	688,597	1.62	22,953	14.2%
		October	31	13.0	177,587	0.0	-559	10.9	148,952	1.1	14,895	347,117	0.82	11,197	6.9%
		November	30	12.6	177,587	0.0	-559	10.5	148,952	1.1	14,895	156,594	0.37	5,220	3.2%
		December	31	13.0	177,587	0.0	-559	10.9	148,952	1.1	14,895	162,004	0.38	5,226	3.2%
				mm/a	*m^3/d*	*mm/a*	*m^3/d*	*mm/a*	*m^3/d*	*mm/a*	*m^3/d*	*m^3/a*	*mm/a*	*m^3/d*	*%*
		Sum (Monthly)	365	152.9	*177,587*	-0.5	*-559*	128.2	*148,952*	12.8	14,895	4,378,948	10.33	*11,997*	7.4%
		Direct Data	**365**	**152.9**	**177,587**	**-0.5**	**-559**	**133.1**	**154,573**	**13.3**	**15,457**	**4,377,810**	**10.33**	**11,994**	**7.4%**

Note: 1) Monthly Pumping Rates assigned as per Table 4-5. Water Budget values reflect steady-state model outputs (Table 4-8).
2) Values in Table may reflect rounding
3) Sum Monthly reflects the sum of the monthly estimates. Direct Data reflects the direct outputs from the water budget for the subwatershed.
4) Committed/Planned Demand for Georgina Creeks is lower than Existing Demand (see Table 4-2, Table 4-5 and text).

Table 4-11 Water Budget Summary – 2 Year Drought – Existing Water Demand

Item	Units	Black River Subwatershed		Georgina Creeks Subwatershed		Total Study Area	
		Value	%	Value	%	Value	%
Subwatershed Area	km^2	375		49		425	
	m^2	375,360,000		49,333,000		424,693,000	
Water Budget							
Inputs:							
Recharge	m^3/day	8,627	13.7%	786	15.4%	9,414	14.2%
Storage	m^3/day	23,392	37.0%	0	0.0%	23,392	35.2%
Stream Recharge	m^3/day	19,588	31.0%	-	0.0%	19,588	29.4%
Lateral Inflow (Adjacent)	m^3/day	11,590	18.3%	4,269	83.5%	14,072	21.2%
Lake Simcoe Inflow	m^3/day	-	0.0%	60	1.2%	60	0.1%
Total Input	**m^3/day**	**63,198**	**100.0%**	**5,115**	**100.0%**	**66,526**	**100.0%**
Outputs:							
Discharge to Stream	m^3/day	28,228	44.5%	5	0.1%	28,232	42.3%
Storage	m^3/day	332	0.5%	98	1.9%	431	0.6%
Discharge to Lake Simcoe	m^3/day	1,778	2.8%	2,938	57.4%	4,716	7.1%
Lateral Outflow (Adjacent)	m^3/day	28,496	44.9%	1,088	21.3%	27,797	41.6%
Wells	m^3/day	4,635	7.3%	986	19.3%	5,621	8.4%
Total Outflow	**m^3/day**	**63,470**	**100.0%**	**5,114**	**100.0%**	**66,797**	**100.0%**

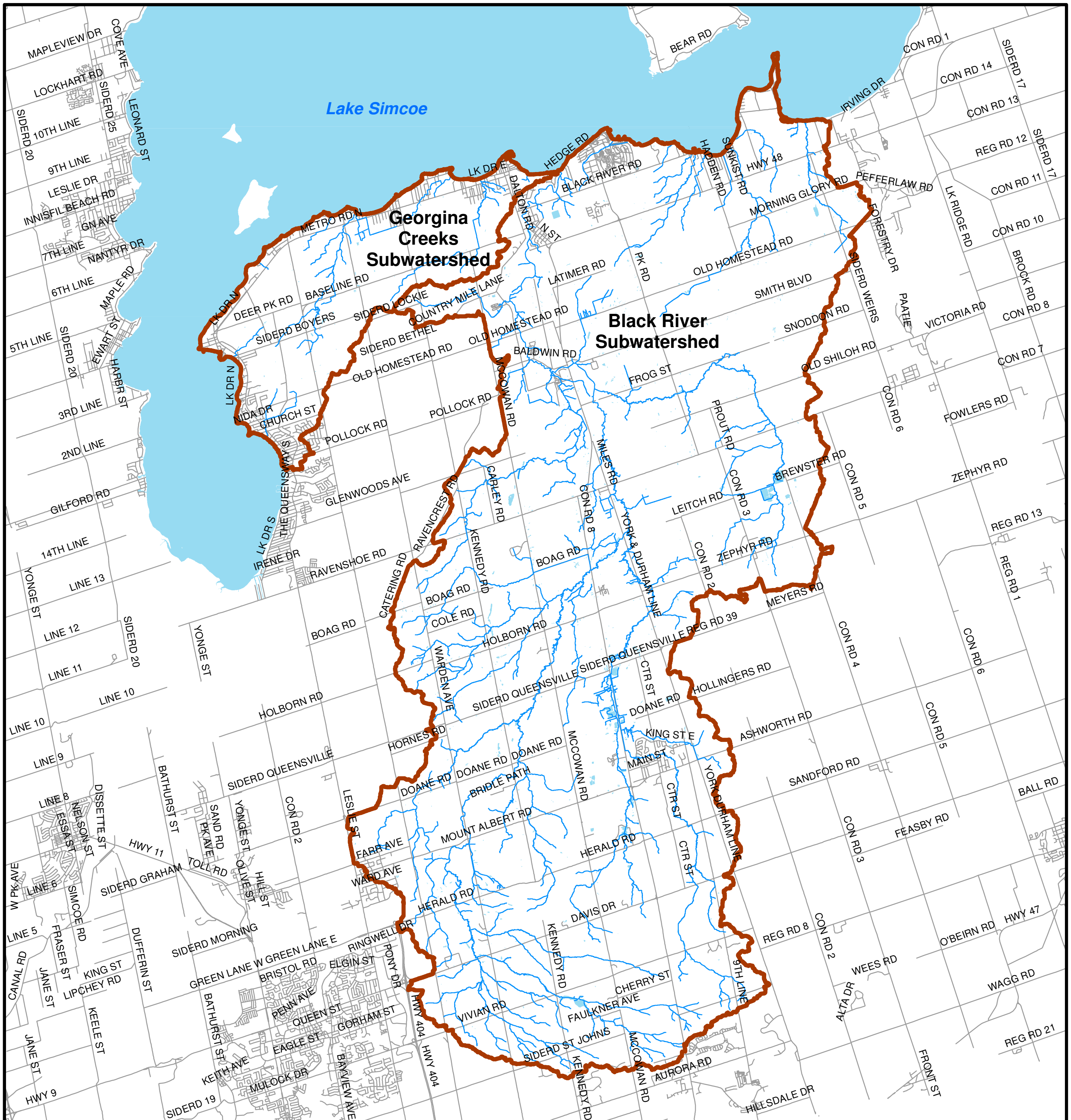
Notes:
1) Values in Table may reflect rounding
2) The lateral inflow for the Total Study Area was obtained directly from the numerical model outputs. The sum of the lateral inputs for the Black River Subwatershed and Georgina Creeks Subwatershed may not equal the value shown for the Study Area.

Table 4-12 Summary of Water Balance - 2 Year Drought – Future Committed/Planned Water Demand

Item	Units	Black River Subwatershed		Georgina Creeks Subwatershed		Total Study Area	
		Value	%	Value	%	Value	%
Subwatershed Area	km^2	375		49		425	
	m^2	375,360,000		49,333,000		424,693,000	
Water Budget							
Inputs:							
Recharge	m^3/day	8,627	13.2%	786	15.7%	9,414	13.7%
Storage	m^3/day	23,045	35.3%	-	0.0%	23,045	33.6%
Stream Recharge	m^3/day	21,525	32.9%	-	0.0%	21,525	31.4%
Lateral Inflow (Adjacent)	m^3/day	12,140	18.6%	4,178	83.6%	14,535	21.2%
Lake Simcoe Inflow	m^3/day	-	0.0%	35	0.7%	35	0.1%
Total Input	**m^3/day**	**65,337**	**100.0%**	**5,000**	**100.0%**	**68,553**	**100.0%**
Outputs:							
Discharge to Stream	m^3/day	25,992	39.6%	5	0.1%	25,997	37.7%
Storage	m^3/day	297	0.5%	85	1.7%	382	0.6%
Discharge to Lake Simcoe	m^3/day	1,772	2.7%	3,036	60.7%	4,807	7.0%
Lateral Outflow (Adjacent)	m^3/day	26,435	40.3%	1,122	22.4%	25,774	37.4%
Wells	m^3/day	11,180	17.0%	751	15.0%	11,932	17.3%
Total Outflow	**m^3/day**	**65,677**	**100.0%**	**4,999**	**100.0%**	**68,893**	**100.0%**

Notes:
1) Values in Table may reflect rounding
2) The lateral inflow for the Total Study Area was obtained directly from the numerical model outputs. The sum of the lateral inputs for the Black River Subwatershed and Georgina Creeks Subwatershed may not equal the value shown for the Study Area.

Figures



LEGEND

- Subwatersheds
- Watercourse
- Waterbodies
- Road

BLACK RIVER AND GEORGINA CREEKS SUBWATERSHEDS

TIER 2 WATER BUDGET AND
ECOLOGICALLY SIGNIFICANT GROUNDWATER
RECHARGE AREAS FOR THE BLACK RIVER AND
GEORGINA CREEKS SUBWATERSHEDS
For: Lake Simcoe Region Conservation Authority

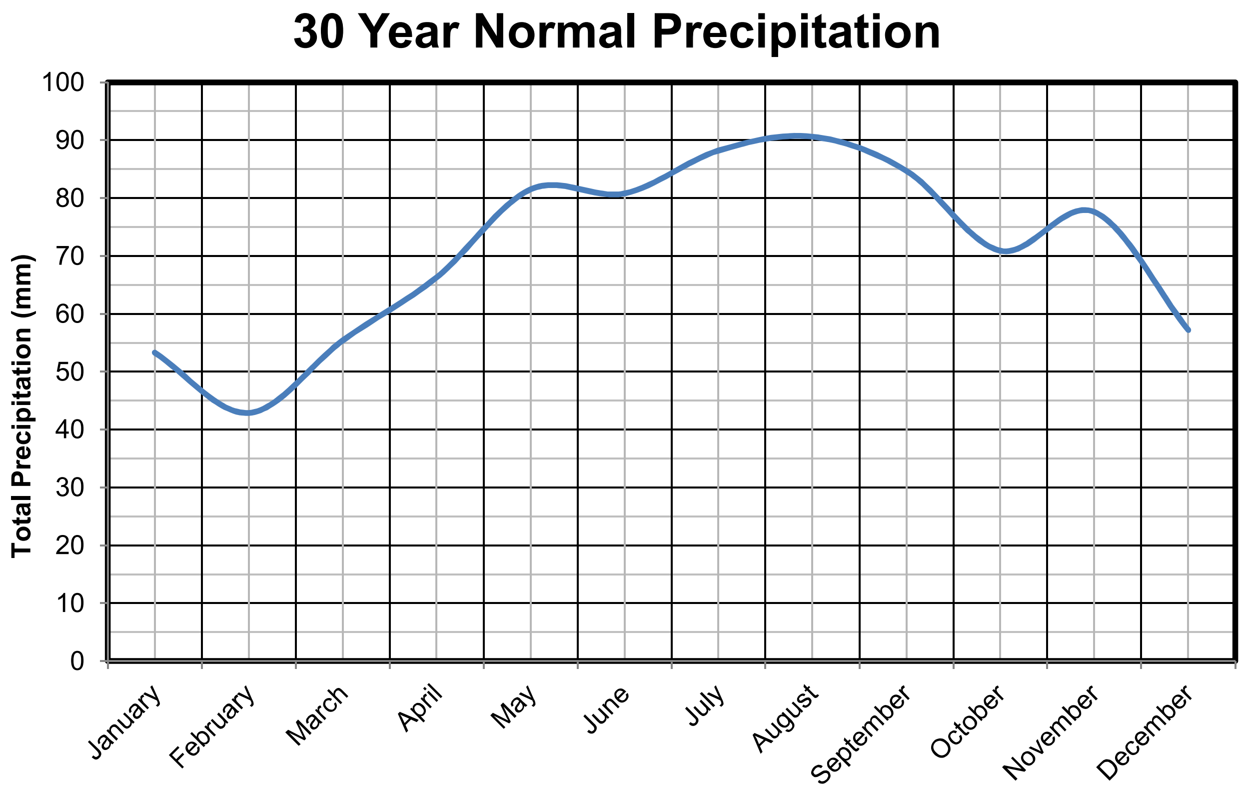
DATE: JANUARY 2013	SCALE: 1:200000
PROJECT: 121-17211-00	FILE. NO.:1211721100F1-1
GENIVAR	FIGURE 1-1

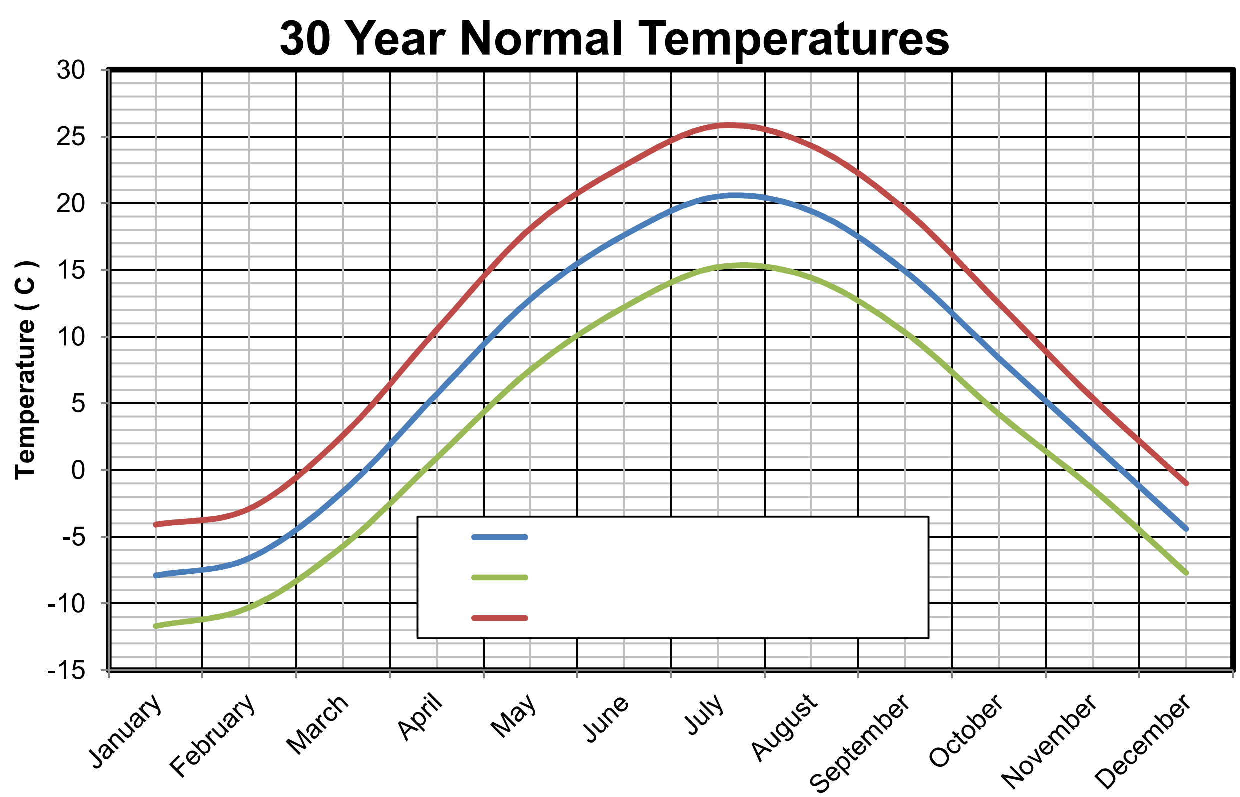
N W E S

1,500 750 0 1,500 Metres

Data Source: Lake Simcoe Region Conservation Authority.
Ministry of Natural Resources, Ontario Base Mapping, June 2012.

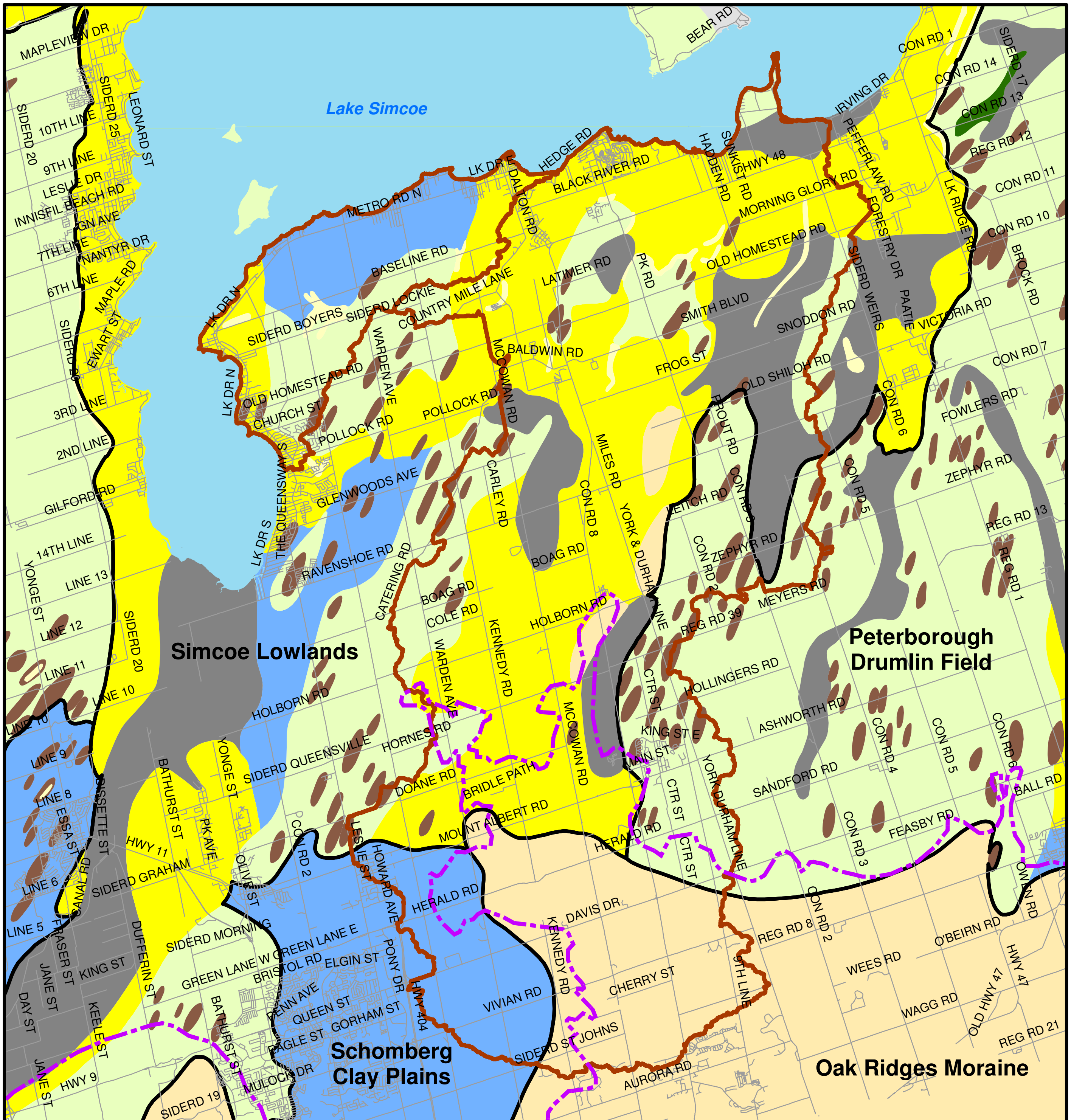
Figure 2-1 - Average Monthly Precipitation and Temperature





Source: Environment Canada - King Smoke Tree Station - 1974 to 2003

H:\Proj\12\17211-00\107 Numerical Modelling\0414010\Tech\LSRCA_ClimateInfo_EC_PRMS_Combined.xlsx *1/20/2013 12:55 PM*



LEGEND

- Peat And Muck
- Beaches
- Eskers
- Clay Plains
- Sand Plains
- Limestone Plains
- Drumlins
- Till Plains (Drumlinized)
- Kame Moraines
- Physiographic Region Boundary
- ORM Planning Area Boundary
- Subwatersheds
- Road

Data Source: Lake Simcoe Region Conservation Authority.
Ministry of Natural Resources, Ontario Base Mapping, June 2012.
Chapman, L.J. and Putnam,
D.F. 2007. Physiography of southern Ontario; Ontario
Geological Survey, Miscellaneous Release—Data 228.

N W E S

1,500 750 0 1,500 Metres

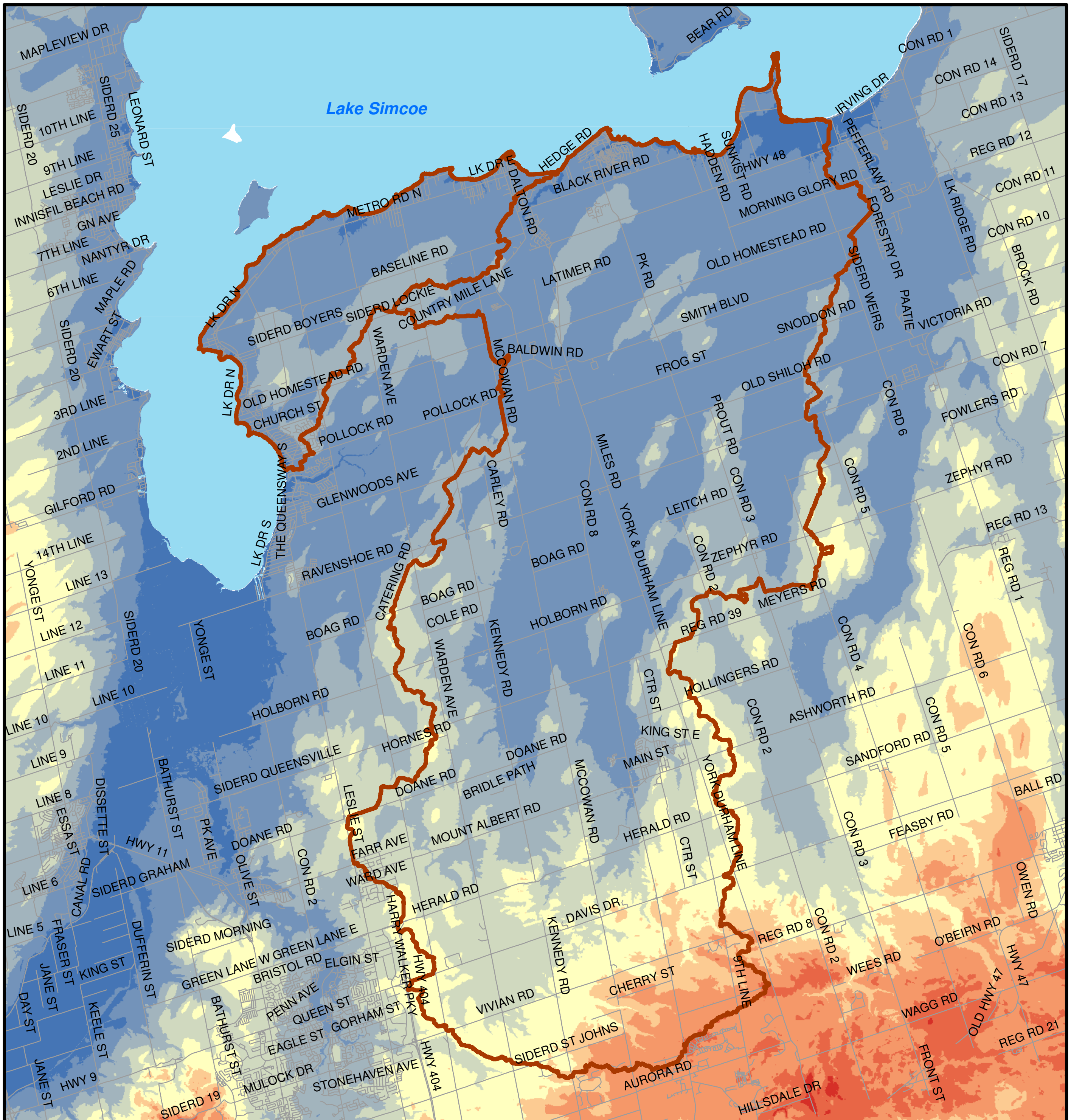
PHYSIOGRAPHY

TIER 2 WATER BUDGET AND
ECOLOGICALLY SIGNIFICANT GROUNDWATER
RECHARGE AREAS FOR THE BLACK RIVER AND
GEORGINA CREEKS SUBWATERSHEDS
For: Lake Simcoe Region Conservation Authority

DATE: JANUARY 2013	SCALE: 1:200000
PROJECT: 121-17211-00	FILE. NO.:1211721100F2-2

GENIVAR

FIGURE
2-2



LEGEND

- < 220 (mASL)
- 220 - 240 (mASL)
- 240- 260 (mASL)
- 260 - 280 (mASL)
- 280 - 300 (mASL)
- 300 - 320 (mASL)
- 320 - 340 (mASL)
- 340 - 360 (mASL)
- > 360 (mASL)
- Subwatersheds
- Road

N W E S

Data Source: DEM, Lake Simcoe Region Conservation Authority.
Ministry of Natural Resources, Ontario Base Mapping, June 2012.

1,500 750 0 1,500 Metres

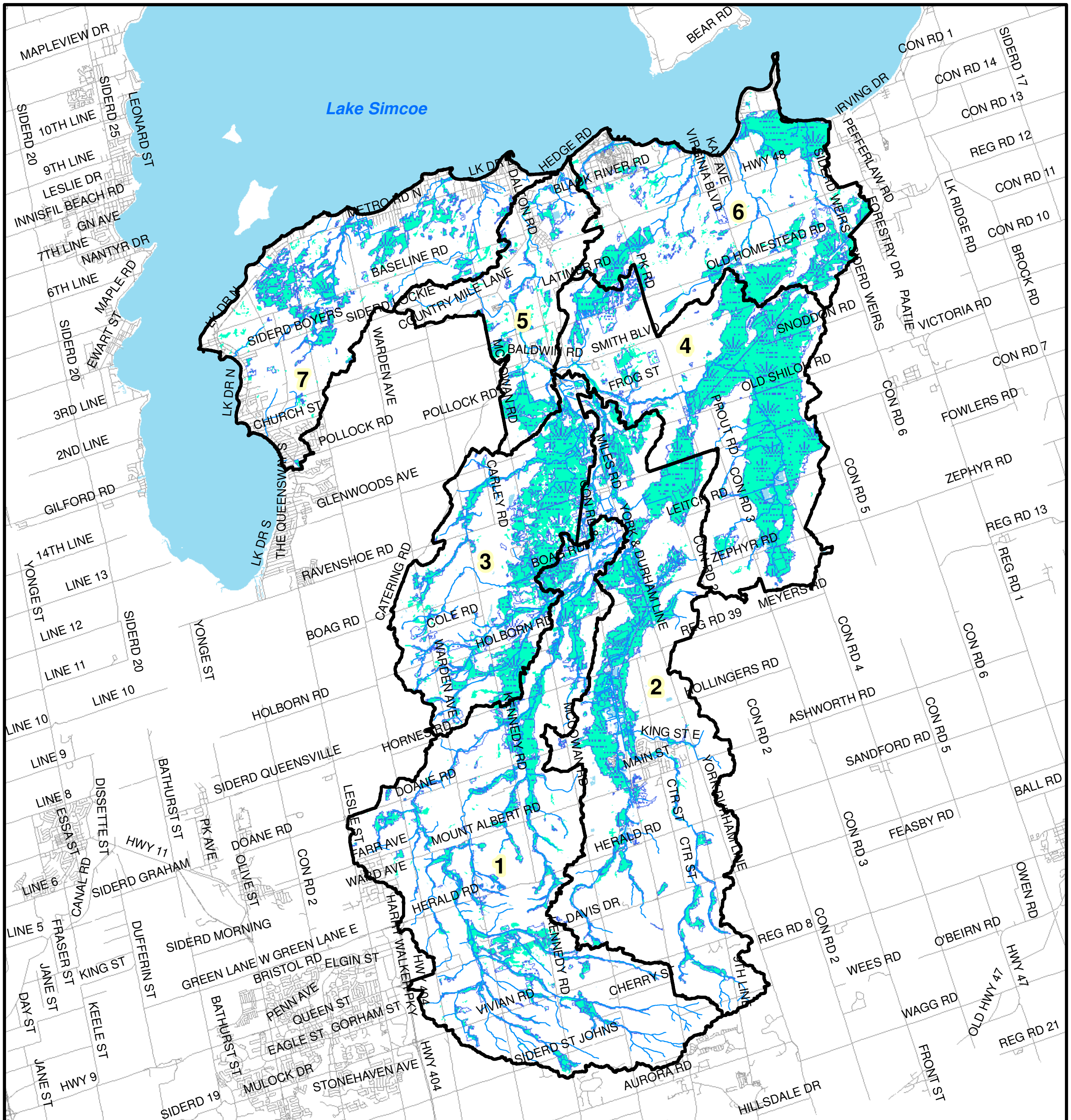
TOPOGRAPHY

TIER 2 WATER BUDGET AND
ECOLOGICALLY SIGNIFICANT GROUNDWATER
RECHARGE AREAS FOR THE BLACK RIVER AND
GEORGINA CREEKS SUBWATERSHEDS
For: Lake Simcoe Region Conservation Authority

DATE: JANUARY 2013	SCALE: 1:200000
PROJECT: 121-17211-00	FILE. NO.:1211721100F2-3

GENIVAR

FIGURE
2-3



LEGEND

- Study Area Catchments
- Watercourse
- Wetlands (LSRCA ELC)
- Wetlands (OBM)
- Waterbodies
- Road

Data Source: Lake Simcoe Region Conservation Authority.
Ministry of Natural Resources, Ontario Base Mapping, June 2012.

N W E S

1,500 750 0 1,500 Metres

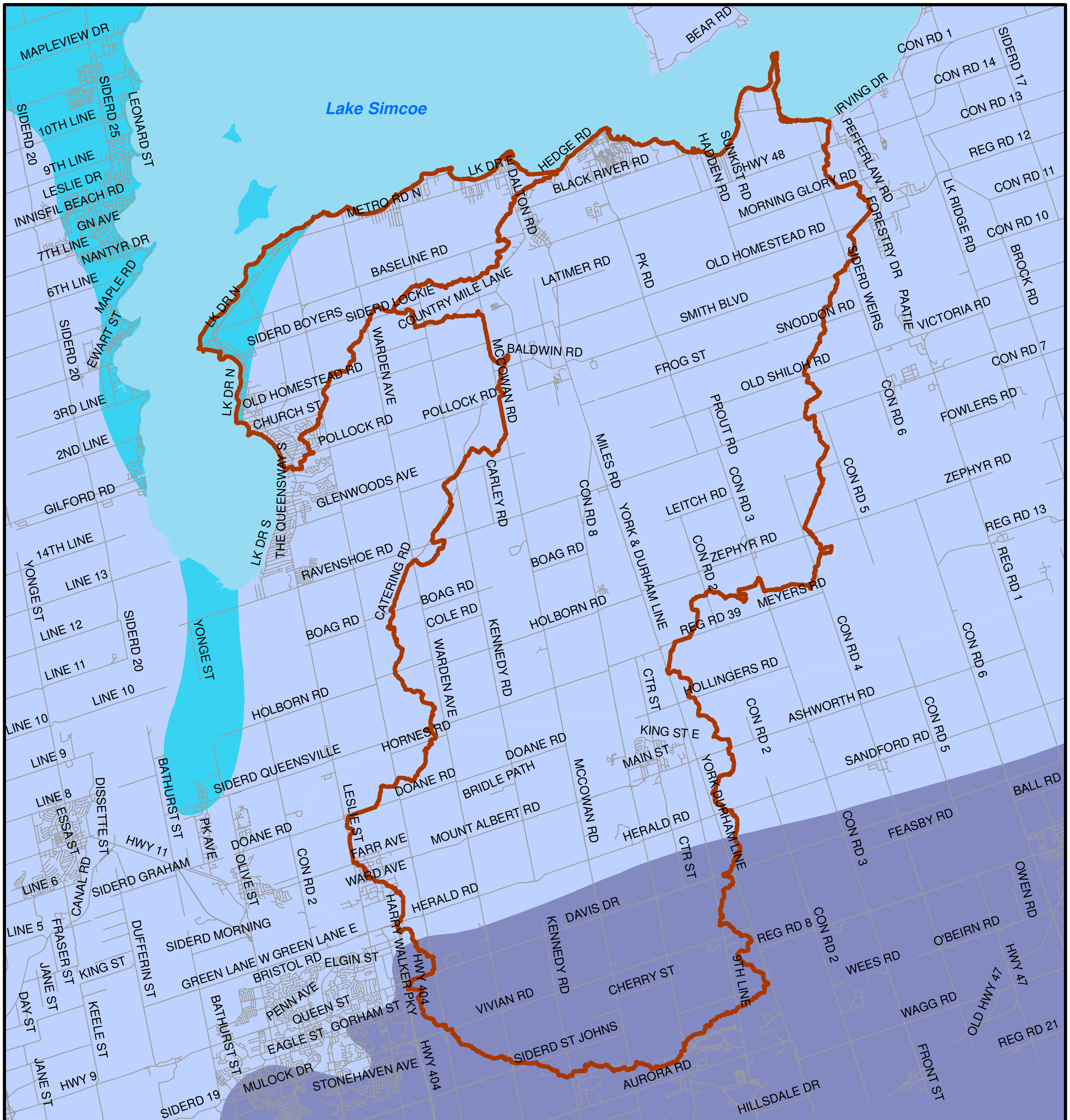
DRAINAGE

TIER 2 WATER BUDGET AND
ECOLOGICALLY SIGNIFICANT GROUNDWATER
RECHARGE AREAS FOR THE BLACK RIVER AND
GEORGINA CREEKS SUBWATERSHEDS
For: Lake Simcoe Region Conservation Authority

DATE: FEBRUARY 2013	SCALE: 1:200000
PROJECT: 121-17211-00	FILE. NO.:1211721100F2-4

GENIVAR

FIGURE
2-4



LEGEND

- Subwatersheds
- Road
- Blue Mountain Formation
- Lindsay Formation
- Verulam Formation

Data Source: Lake Simcoe Region Conservation Authority.
Ministry of Natural Resources, Ontario Base Mapping, June 2012.
Paleozoic Geology of Southern Ontario, MRD 219,
Ministry of Northern Development and Mines.

N W E S

1,500 750 0 1,500 Metres

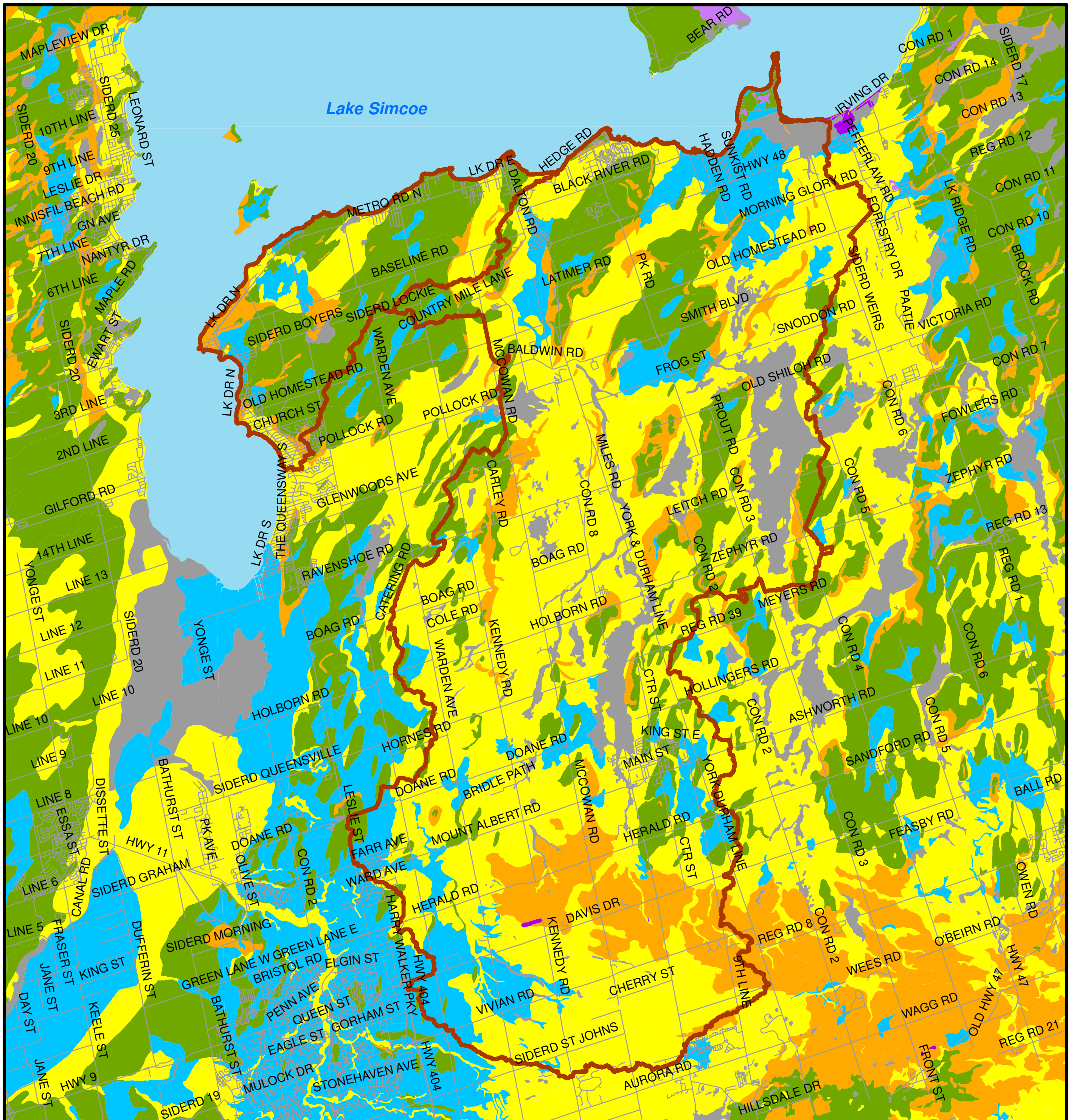
BEDROCK GEOLOGY

TIER 2 WATER BUDGET AND
ECOLOGICALLY SIGNIFICANT GROUNDWATER
RECHARGE AREAS FOR THE BLACK RIVER AND
GEORGINA CREEKS SUBWATERSHEDS
For: Lake Simcoe Region Conservation Authority

DATE: JANUARY 2013	SCALE: 1:200000
PROJECT: 121-17211-00	FILE. NO.:1211721100F2-5

GENIVAR

FIGURE
2-5



LEGEND

- Paleozoic Bedrock
- Diamicton
- Fill
- Gravel
- Organic Deposits
- Sand
- Silt
- Subwatersheds
- Road

N W E S

Data Source: Lake Simcoe Region Conservation Authority.
Ministry of Natural Resources, Ontario Base Mapping, June 2012.
Paleozoic Geology of Southern Ontario, MRD 219,
Ministry of Northern Development and Mines.

1,500 750 0 1,500 Metres

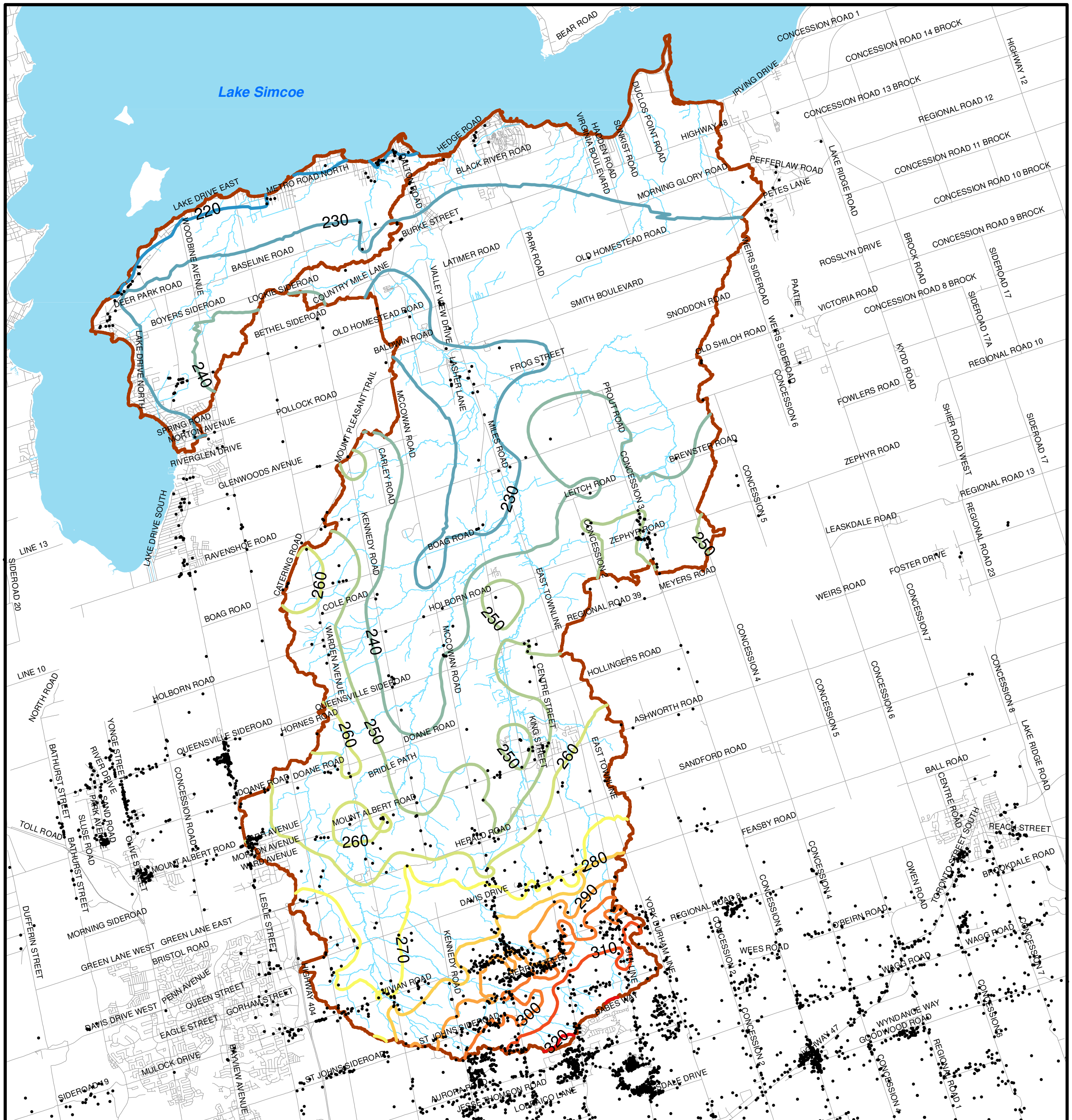
SURFICIAL GEOLOGY

TIER 2 WATER BUDGET AND ECOLOGICALLY SIGNIFICANT GROUNDWATER RECHARGE AREAS FOR THE BLACK RIVER AND GEORGINA CREEKS SUBWATERSHEDS
For: Lake Simcoe Region Conservation Authority

DATE: JANUARY 2013	SCALE: 1:200000
PROJECT: 121-17211-00	FILE. NO.:1211721100F2-6

GENIVAR

FIGURE
2-6



LEGEND

Elevation

- 220 (mASL)
- 230 (mASL)
- 240 (mASL)
- 250 (mASL)
- 260 (mASL)
- 270 (mASL)
- 280 (mASL)
- 290 (mASL)
- 300 (mASL)
- 310 (mASL)
- 320 (mASL)

- Data Points
- Subwatersheds
- Waterbodies
- Watercourse
- Roads

N W E S

2,000 1,000 0 2,000 Metres

Data Source: Ministry of Natural Resources, Ontario Base Mapping, June 2012. PTTW, Lake Simcoe Regional Conservation Authority.

GROUNDWATER ELEVATIONS - ORAC

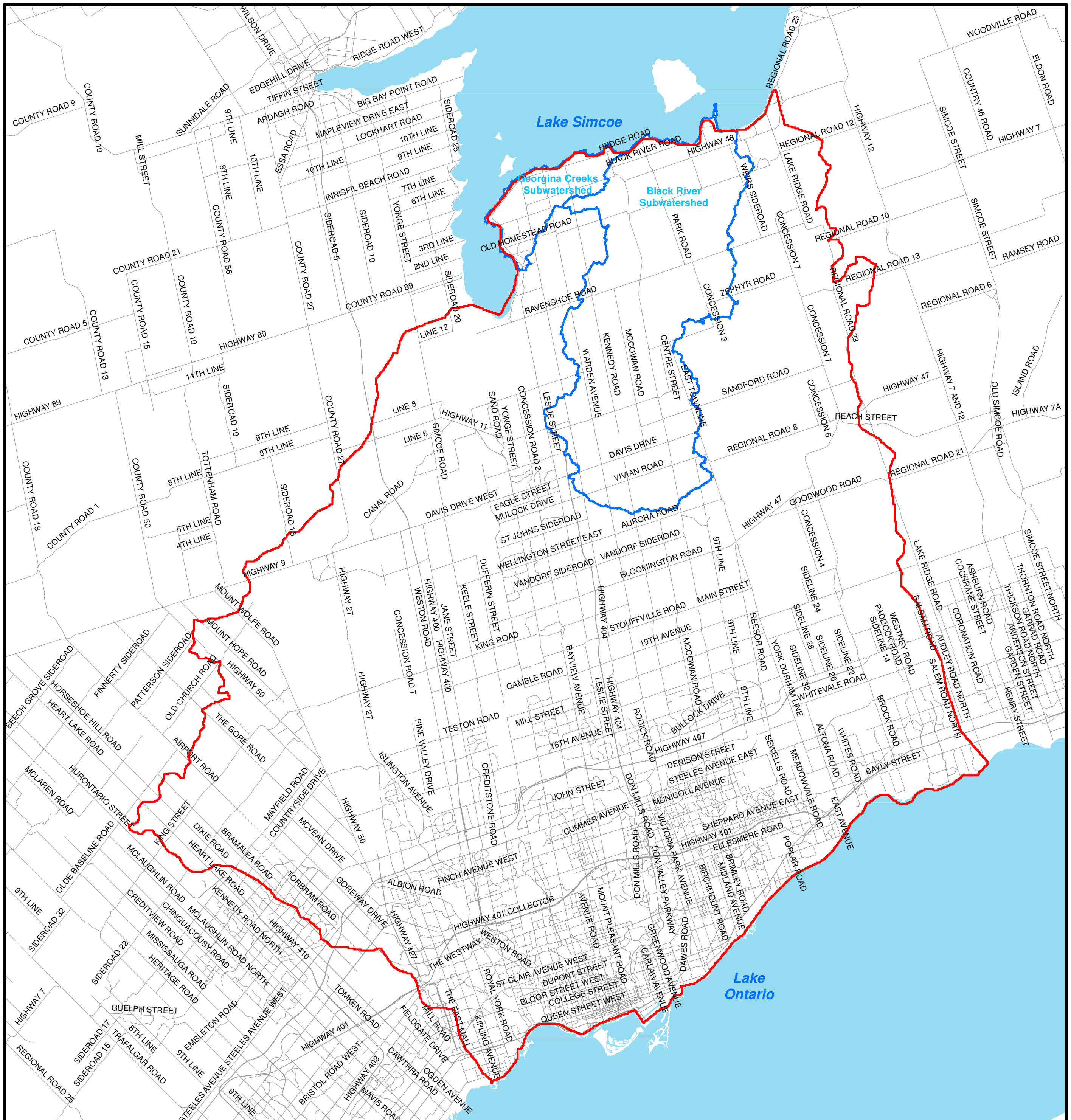
TIER 2 WATER BUDGET AND ECOLOGICALLY SIGNIFICANT GROUNDWATER RECHARGE AREAS FOR THE BLACK RIVER AND GEORGINA CREEKS SUBWATERSHEDS

For: Lake Simcoe Region Conservation Authority

DATE: JANUARY 2013	SCALE: 1:200000
PROJECT: 121-17211-00	FILE. NO.:1211721100F2-8

GENIVAR

FIGURE **2-8**



LEGEND

- Core Model Domain
- Subwatersheds
- Waterbodies
- Roads

MODEL DOMAIN - EARTHFX CORE MODEL

TIER 2 WATER BUDGET AND
ECOLOGICALLY SIGNIFICANT GROUNDWATER
RECHARGE AREAS FOR THE BLACK RIVER AND
GEORGINA CREEKS SUBWATERSHEDS
For: Lake Simcoe Region Conservation Authority

DATE: JANUARY 2013	SCALE: 1:500000
PROJECT: 121-17211-00	FILE. NO.:1211721100F3-1

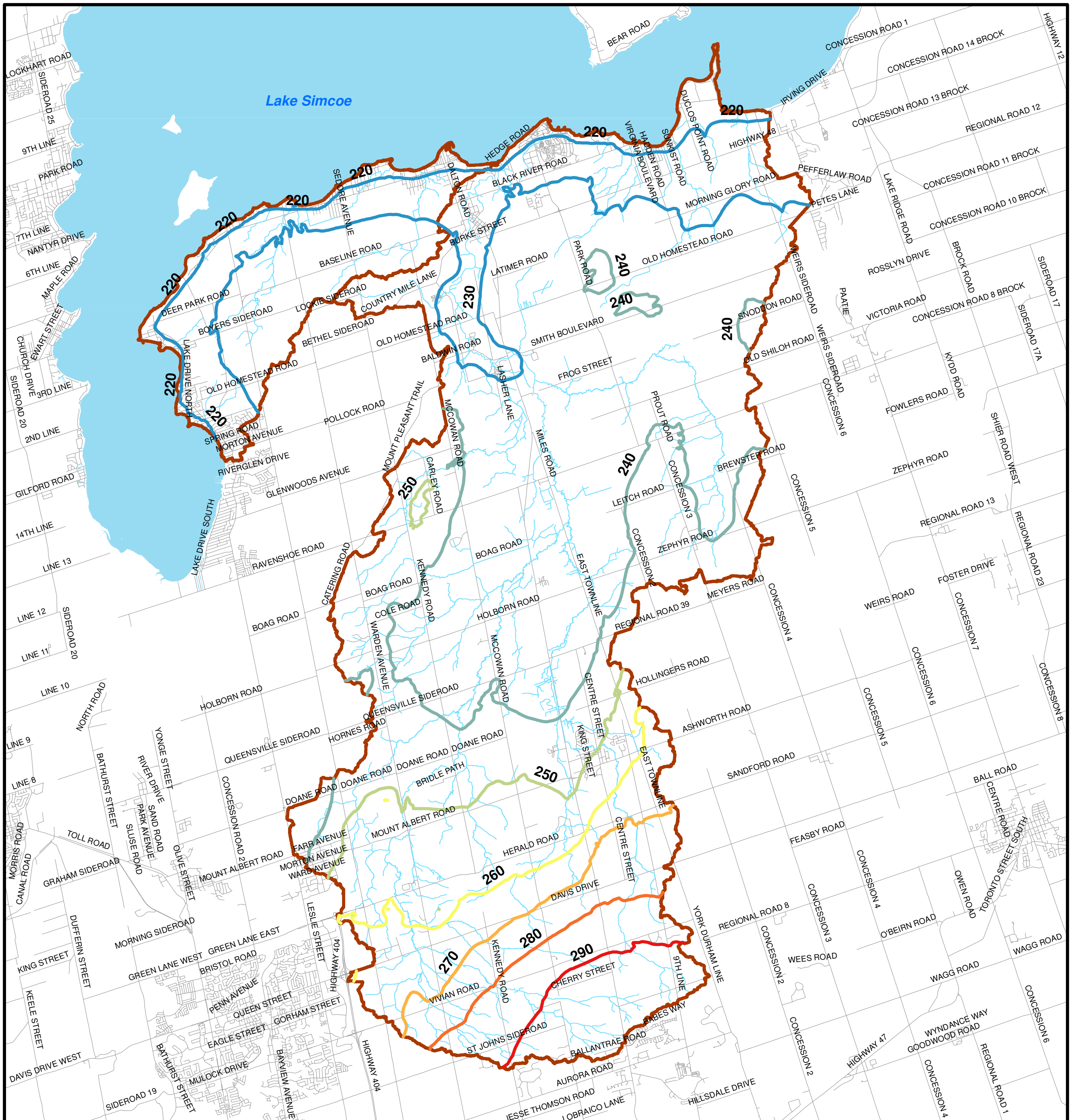
GENIVAR

FIGURE 3-1

N W E S

4,000 2,000 0 4,000 Metres

Data Source: Ministry of Natural Resources, Ontario Base Mapping, June 2012. Model Domain, LSRCA.



LEGEND

Contour

- 220 (mASL)
- 230 (mASL)
- 240 (mASL)
- 250 (mASL)
- 260 (mASL)
- 270 (mASL)
- 280 (mASL)
- Subwatersheds
- Waterbodies
- Watercourse
- Roads

Data Source: Ministry of Natural Resources, Ontario Base Mapping, June 2012. PTTW, Lake Simcoe Regional Conservation Authority.

N W E S

2,000 1,000 0 2,000 Metres

SIMULATED GROUNDWATER ELEVATIONS - ORAC

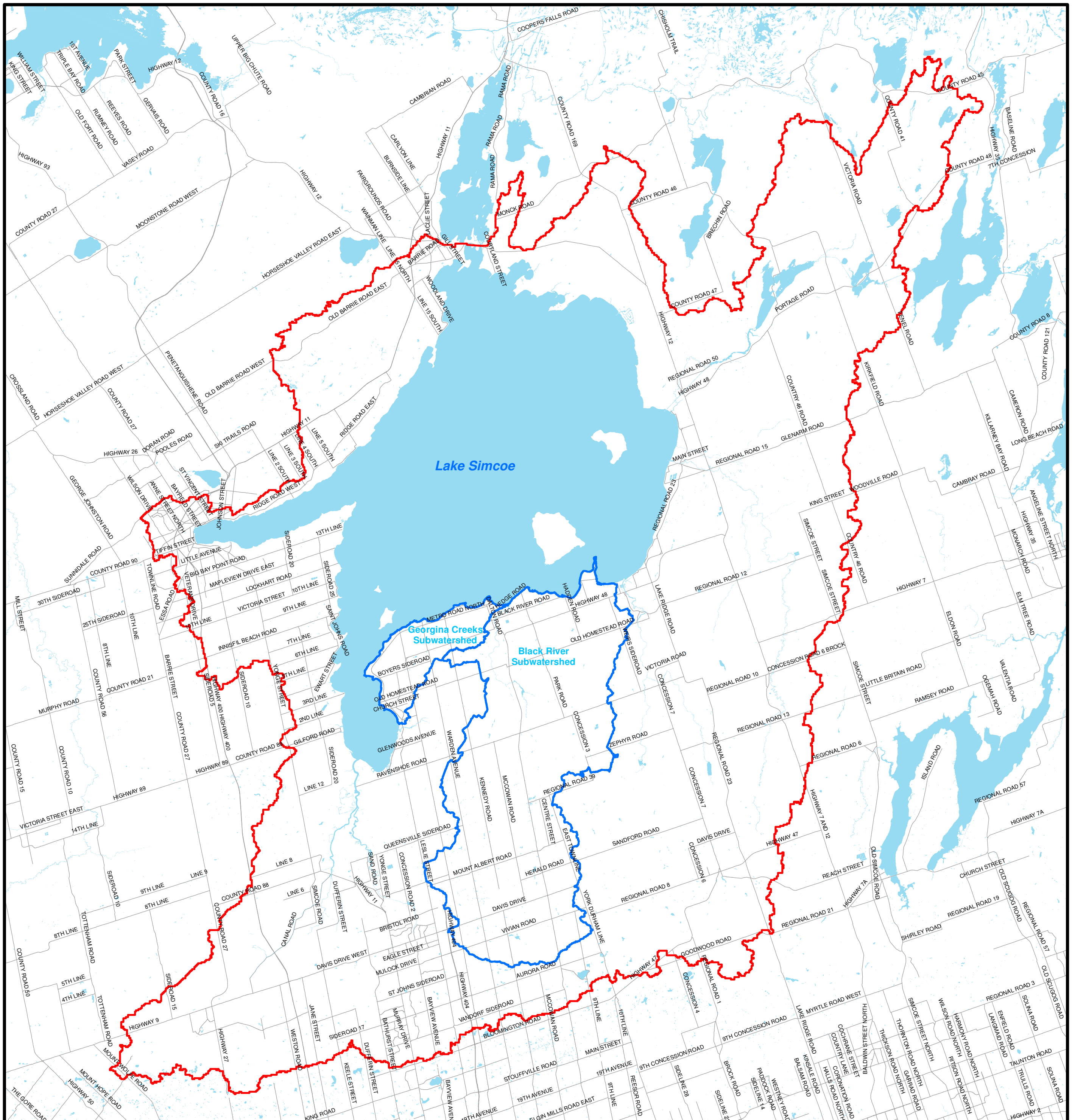
TIER 2 WATER BUDGET AND ECOLOGICALLY SIGNIFICANT GROUNDWATER RECHARGE AREAS FOR THE BLACK RIVER AND GEORGINA CREEKS SUBWATERSHEDS

For: Lake Simcoe Region Conservation Authority

DATE: FEBRUARY 2013	SCALE: 1:200000
PROJECT: 121-17211-00	FILE. NO.:1211721100F3-2

GENIVAR

FIGURE 3-2



LEGEND

- PRMS Model Domain
- Subwatersheds
- Waterbodies
- Roads

N
W E
S

Data Source: Ministry of Natural Resources,
Ontario Base Mapping, June 2012. LSRCA, 2012, EarthFX, 2010

4,000 2,000 0 4,000 Metres

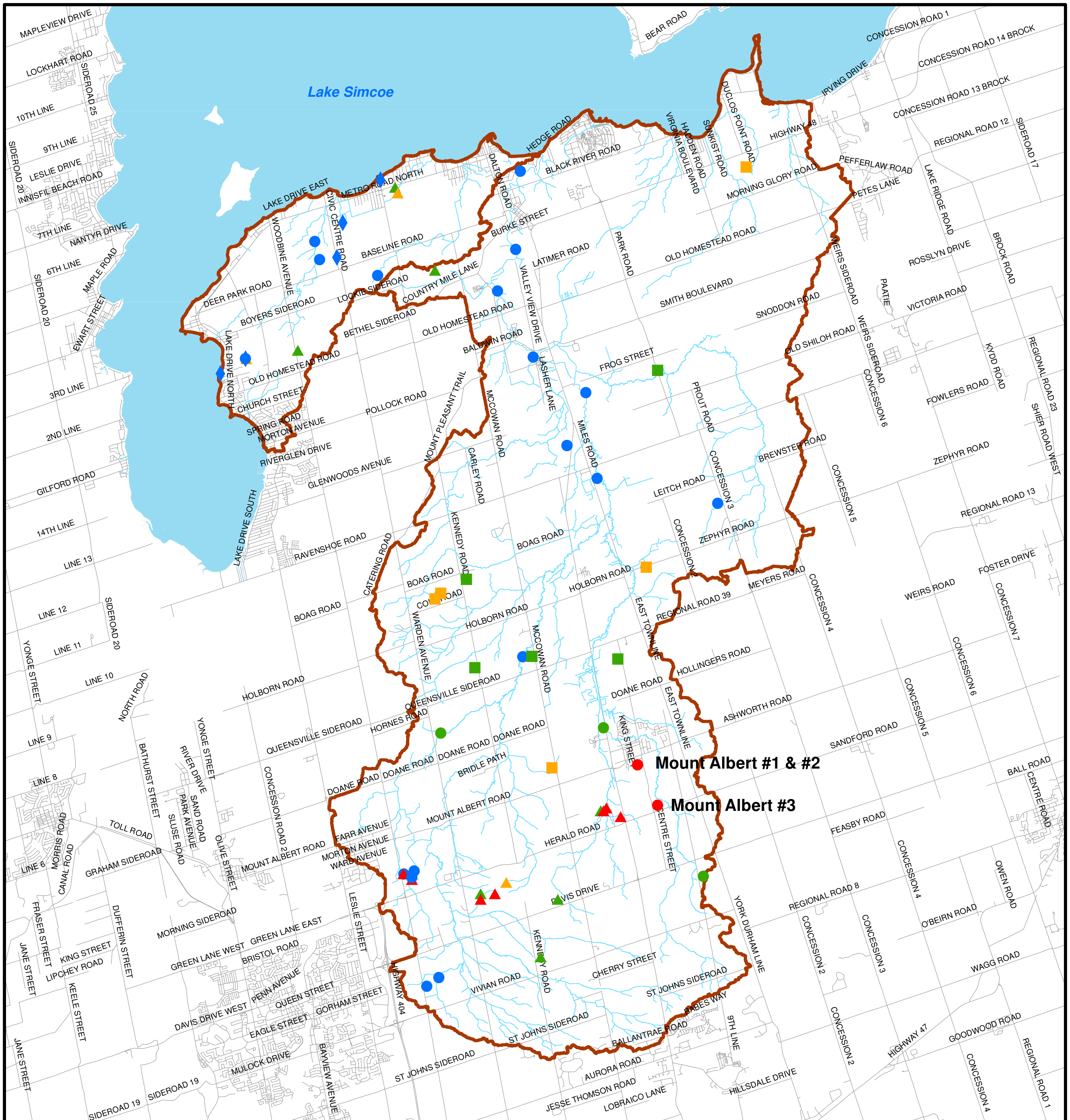
MODEL DOMAIN - LAKE SIMCOE PRMS MODEL

TIER 2 WATER BUDGET AND ECOLOGICALLY SIGNIFICANT GROUNDWATER RECHARGE AREAS FOR THE BLACK RIVER AND GEORGINA CREEKS SUBWATERSHEDS
For: Lake Simcoe Region Conservation Authority

DATE: FEBRUARY 2013	SCALE: 1:500000
PROJECT: 121-17211-00	FILE. NO.:1211721100F3-3

GENIVAR

FIGURE
3-3



LEGEND

- Agricultural - Unchanged Well
- Agricultural - New Well Not in Original Model
- Commercial - Unchanged Well
- Commercial - New Well Not in Original Model
- Commercial - Modified Well (Pumping Well Changed)
- Water Supply - Unchanged Well
- Water Supply - Modified Well (Pumping Well Changed)
- Lake Simcoe Surface Water Taking Locations
- Surface Water Taking Locations
- Subwatersheds
- Waterbodies
- Watercourse
- Roads

Data Source: Ministry of Natural Resources, Ontario Base Mapping, June 2012. PTTW, Lake Simcoe Regional Conservation Authority.

N W E S

2,000 1,000 0 2,000 Metres

LOCATION OF PERMITTED WATER TAKING

TIER 2 WATER BUDGET AND ECOLOGICALLY SIGNIFICANT GROUNDWATER RECHARGE AREAS FOR THE BLACK RIVER AND GEORGINA CREEKS SUBWATERSHEDS
For: Lake Simcoe Region Conservation Authority

DATE: JANUARY 2013	SCALE: 1:200000
PROJECT: 121-17211-00	FILE. NO.:1211721100F4-1

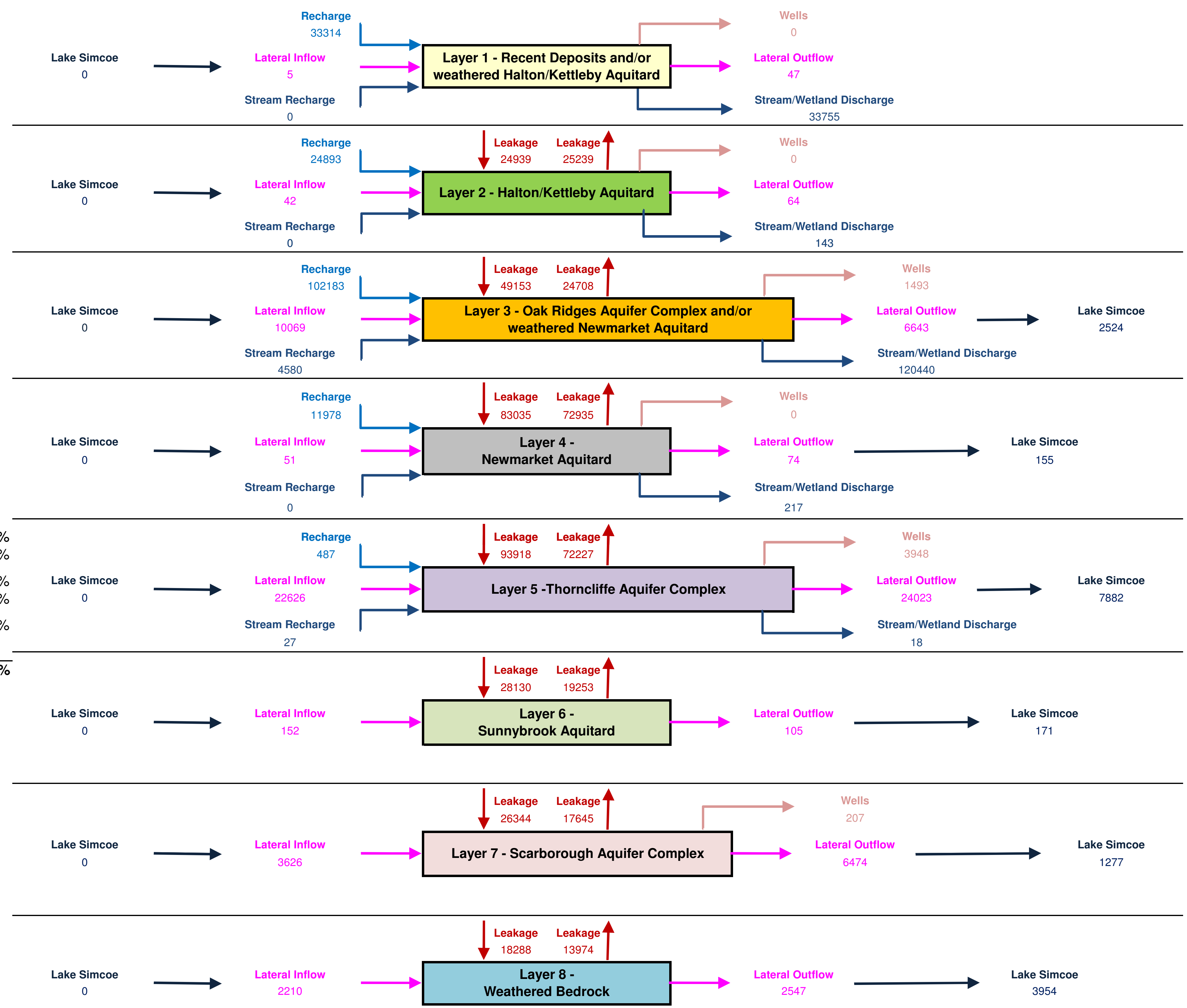
GENIVAR

FIGURE 4-1

Figure 4-2 Water Budget (Groundwater) - Study Area - Existing Water Demand

Inputs

	m³/day	%
Recharge	172855	80%
Stream Recharge	4607	2%
Wells	0	0%
Lateral Inflow	38781	18%
Lake Simcoe	0	0%
Total Inputs	**216242**	**100%**



All flow volumes expressed as m³/day

Outputs

	m³/day	%
Stream	154573	72%
Lake Simcoe	15964	7%
Wells	5647	3%
Lateral Outflow	39979	18%
Total Outputs	**216163**	**100%**

Net Water Balance (In - Out) (%)

0%

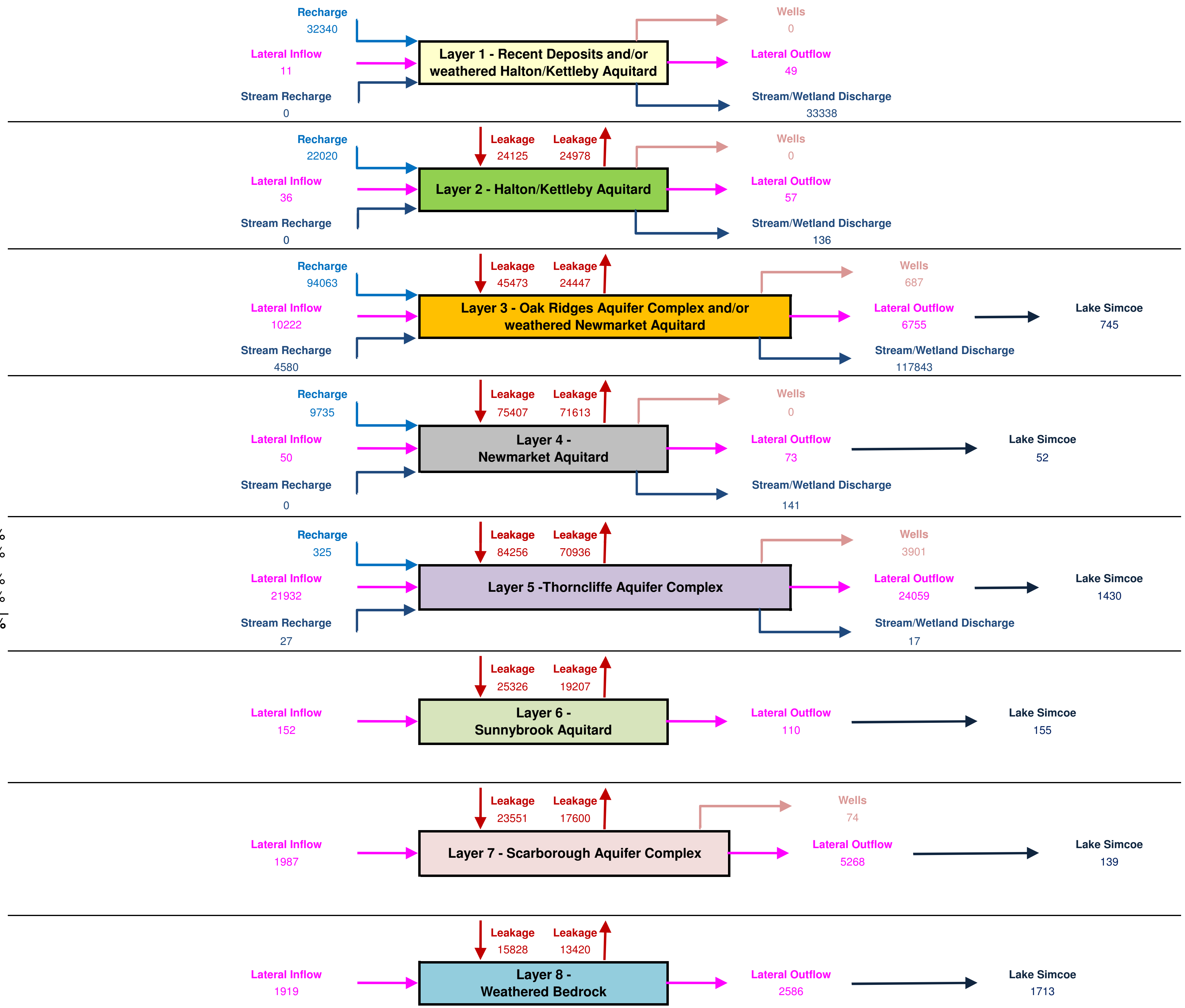
Note:

Values presented may reflect rounding. Some minor differences in water budget estimates are expected due to numerical model calculations.

Figure 4-3 Water Budget (Groundwater) - Black River Subwatershed - Existing Water Demand

Inputs

	m³/day	%
Recharge	158482	79%
Stream Recharge	4607	2%
Wells	0	0%
Lateral Inflow	36309	18%
Total Inputs	**199398**	**100%**



All flow volumes expressed as m³/day

Outputs

	m³/day	%
Stream	151476	76%
Lake Simcoe	4233	2%
Wells	4662	2%
Lateral Outflow	38956	20%
Total Outputs	**199327**	**100%**

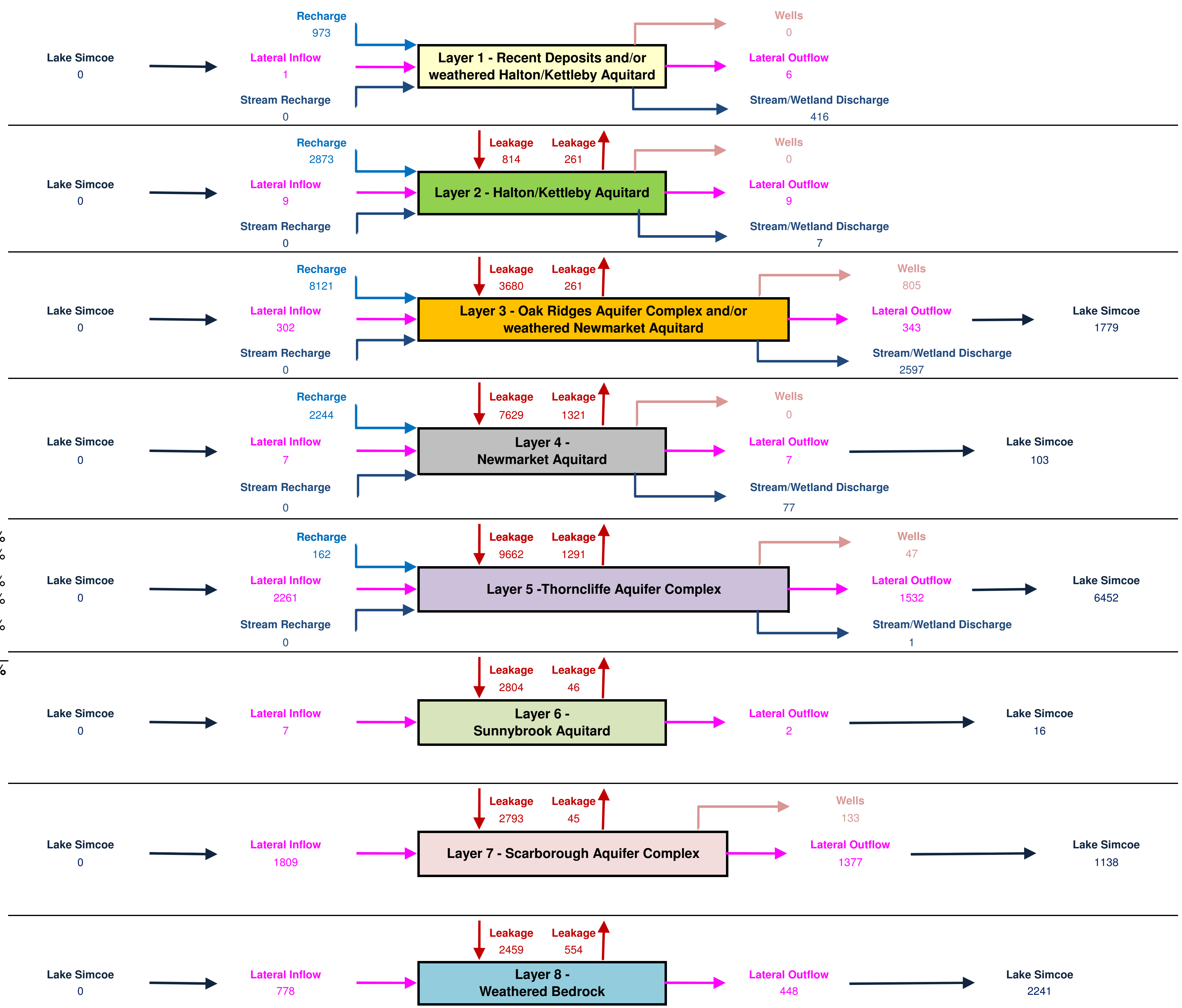
Net Water Balance (In - Out) (%)

0%

Note:

Values presented may reflect rounding. Some minor differences in water budget estimates are expected due to numerical model calculations.

Figure 4-4 Water Budget (Groundwater) - Georgina Creeks Subwatershed - Existing Water Demand



Inputs

	m^3/day	%
Recharge	14373	74%
Stream Recharge	0	0%
Wells	0	0%
Lateral Inflow	5174	26%
Lake Simcoe	0	0%
Total Inputs	**19547**	**100%**

Outputs

	m^3/day	%
Stream	3098	16%
Lake Simcoe	11731	60%
Wells	986	5%
Lateral Outflow	3725	19%
Total Outputs	**19539**	**100%**

Net Water Balance (In - Out) (%)

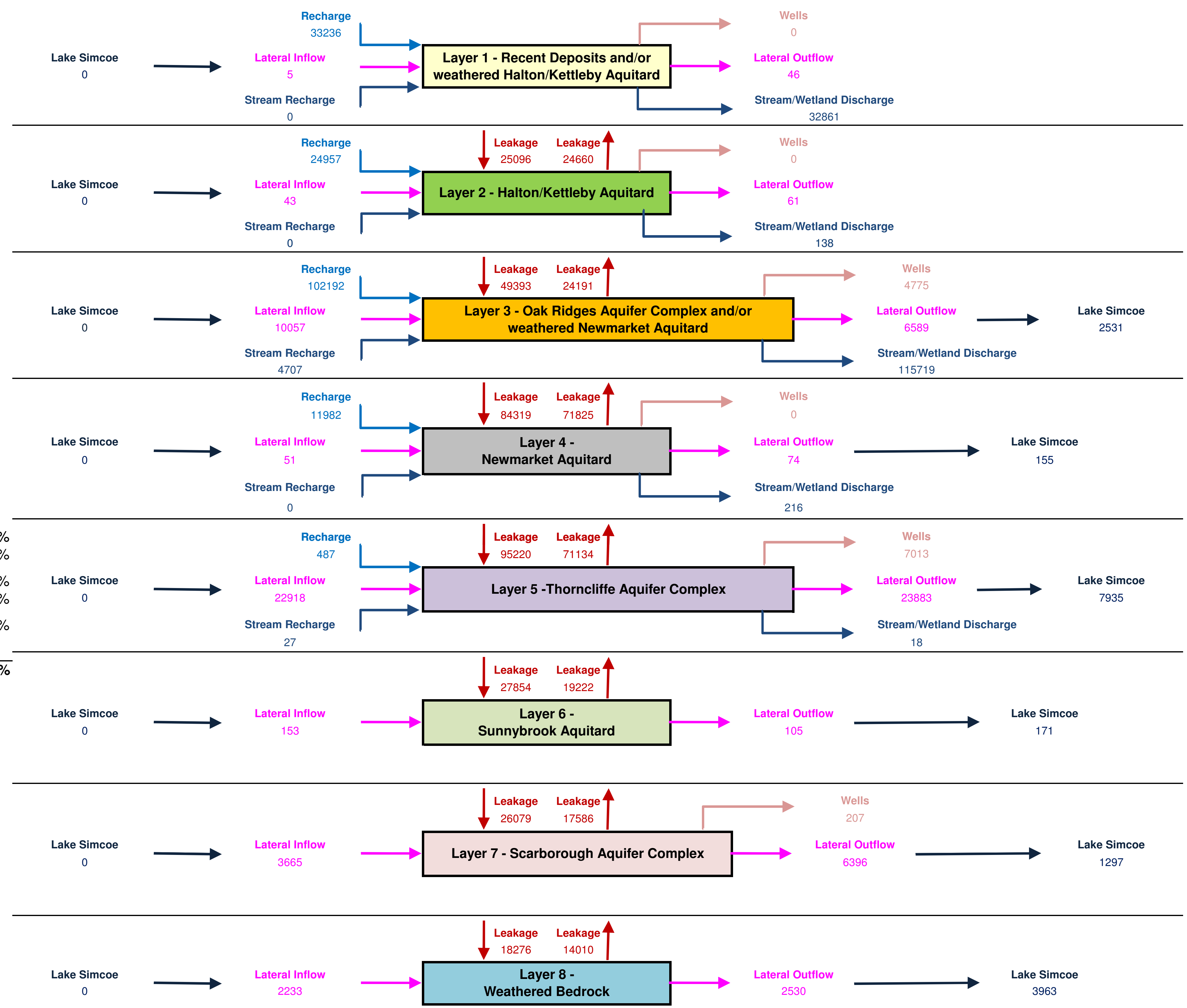
0%

Note:

Values presented may reflect rounding. Some minor differences in water budget estimates are expected due to numerical model calculations.

All flow volumes expressed as m^3/day

Figure 4-5 Water Budget (Groundwater) - Committed/Planned Water Demand - Study Area



All flow volumes expressed as m^3/day

Inputs

	m^3/day	%
Recharge	172853	80%
Stream Recharge	4734	2%
Wells	0	0%
Lateral Inflow	39125	18%
Lake Simcoe	0	0%
Total Inputs	**216712**	**100%**

Outputs

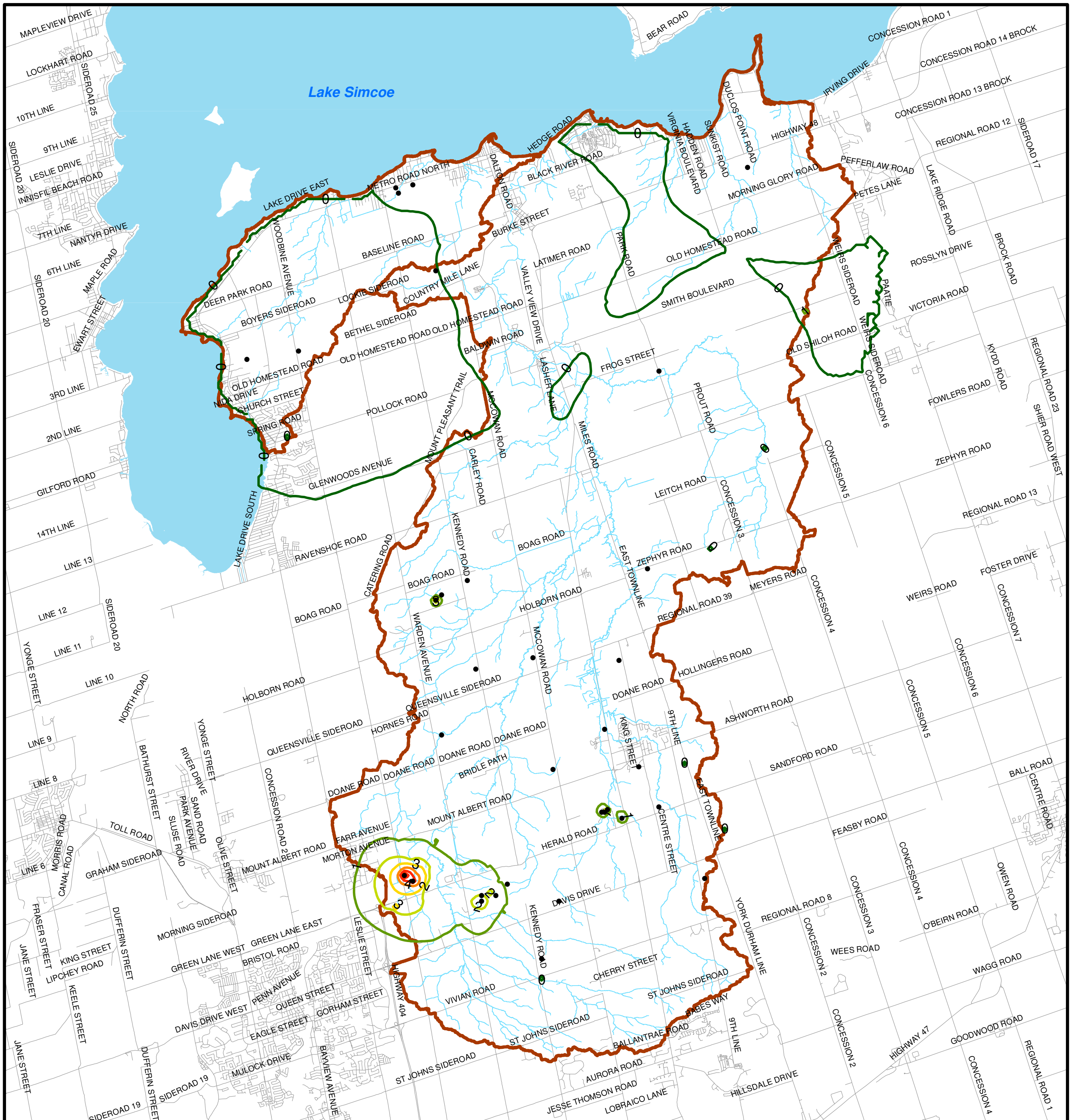
	m^3/day	%
Stream	148952	69%
Lake Simcoe	16052	7%
Wells	11995	6%
Lateral Outflow	39684	18%
Total Outputs	**216682**	**100%**

Net Water Balance (In - Out) (%)

0%

Note:

Values presented may reflect rounding. Some minor differences in water budget estimates are expected due to numerical model calculations.



LEGEND

- 0 Metres
- 1 Metres
- 2 Metres
- 3 Metres
- 4 Metres
- 5 - 9 Metres
- Subwatersheds
- Waterbodies
- Watercourse
- Roads
- Groundwater PTTW Locations

N W E S

2,000 1,000 0 2,000 Metres

Data Source: Ministry of Natural Resources, Ontario Base Mapping, June 2012. PTTW, Lake Simcoe Regional Conservation Authority.

DIFFERENCE IN SIMULATED GROUNDWATER ELEVATIONS - COMMITTED/PLANNED WATER DEMAND

TIER 2 WATER BUDGET AND ECOLOGICALLY SIGNIFICANT GROUNDWATER RECHARGE AREAS FOR THE BLACK RIVER AND GEORGINA CREEKS SUBWATERSHEDS
For: Lake Simcoe Region Conservation Authority

DATE: FEBRUARY 2013	SCALE: 1:200000
PROJECT: 121-17211-00	FILE. NO.:1211721100F4-6

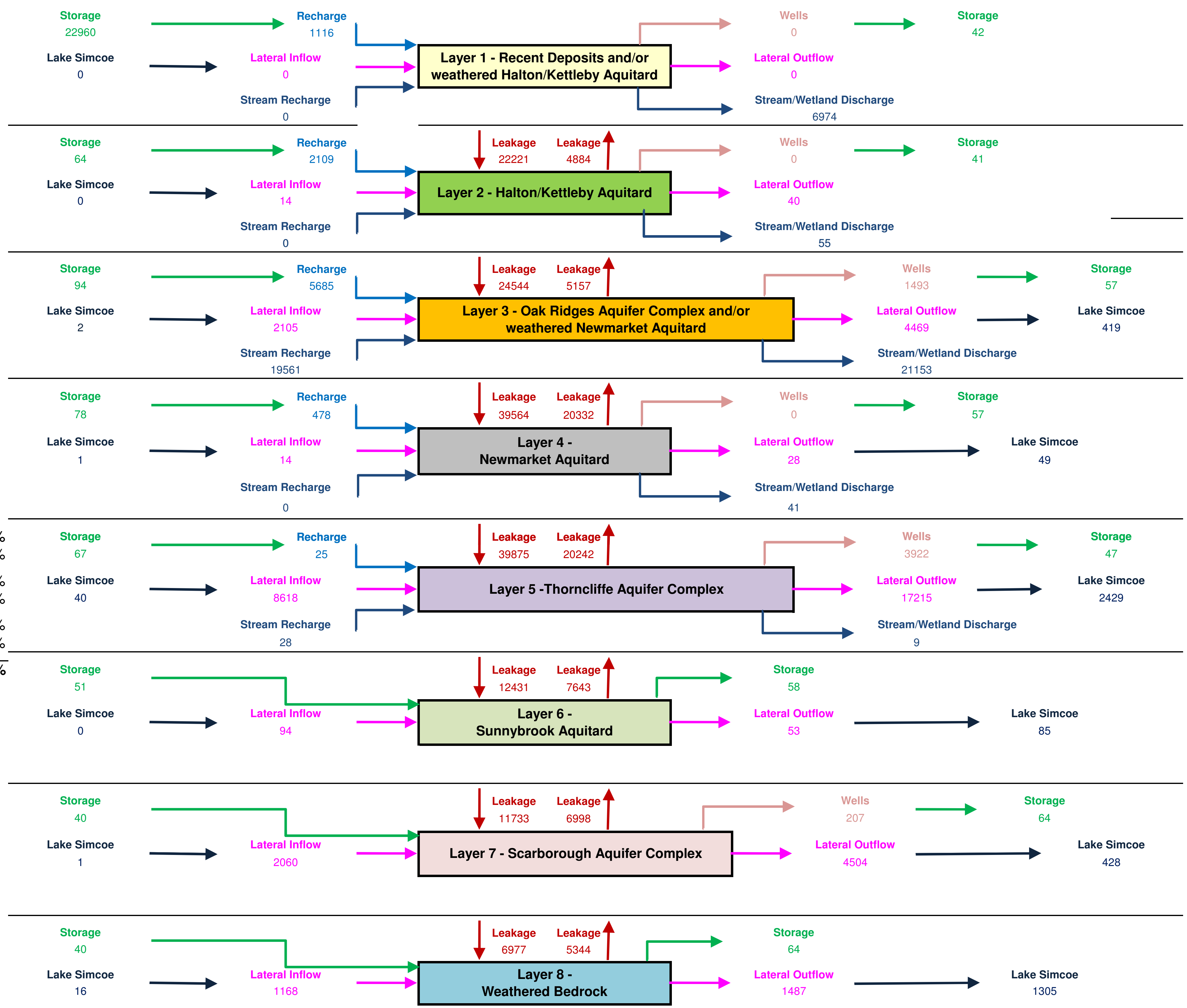
GENIVAR

FIGURE
4-6

Figure 4-7 - Water Budget (Groundwater) - 2 Year Drought - Existing Water Demand - Study Area

Inputs

	m^3/day	%
Recharge	9414	14%
Stream Recharge	19588	29%
Wells	0	0%
Lateral Inflow	14072	21%
Lake Simcoe	60	0%
Storage	23392	35%
Total Inputs	**66526**	**100%**



All flow volumes expressed as m^3/day

Outputs

	m^3/day	%
Stream	28232	42%
Lake Simcoe	4716	7%
Wells	5621	8%
Lateral Outflow	27797	42%
Storage	431	1%
Total Outputs	**66797**	**100%**

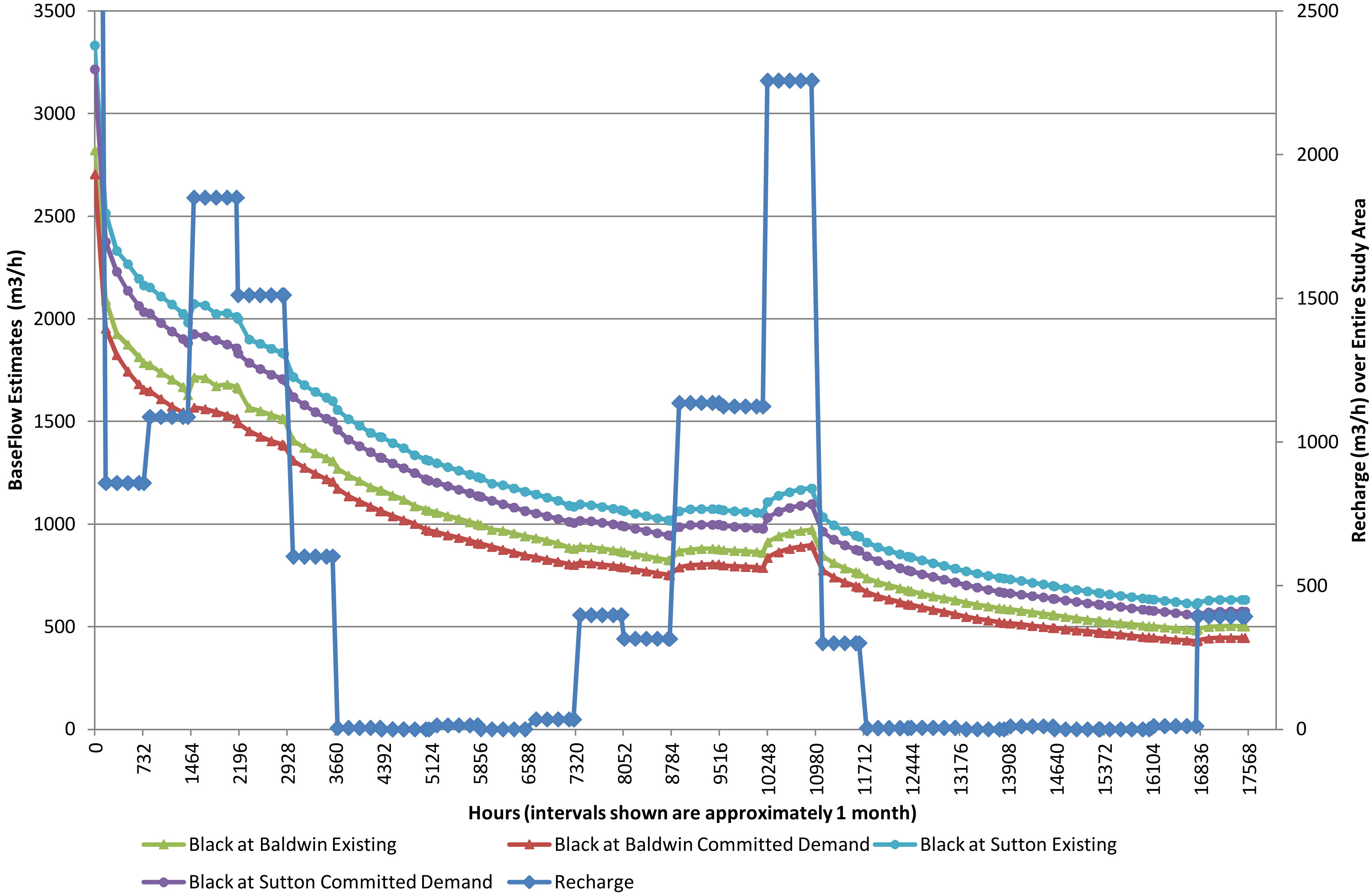
Net Water Balance (In - Out) (%)

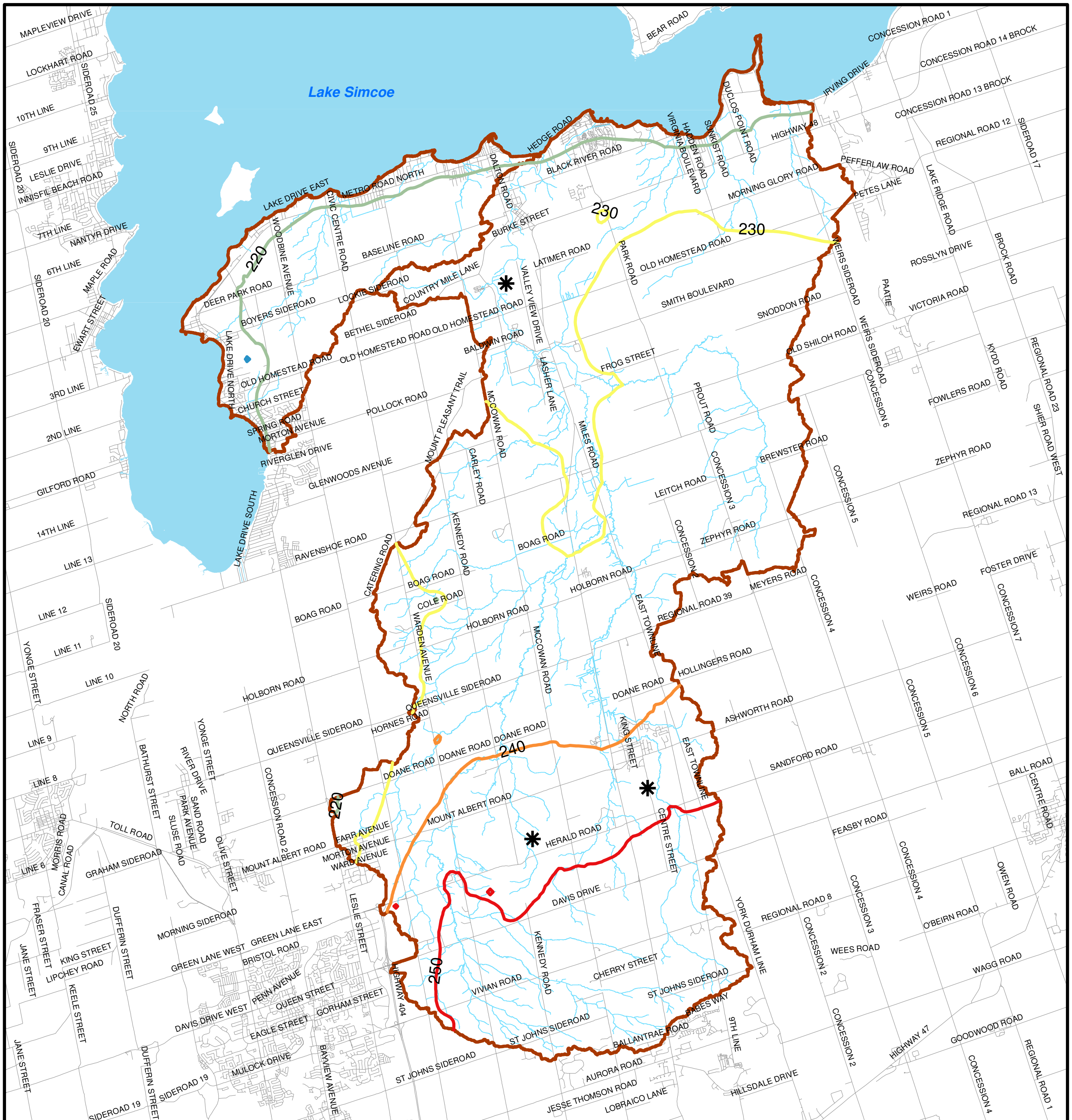
0%

Note:

Values presented may reflect rounding. Some minor differences in water budget estimates are expected due to numerical model calculations.

Figure 4-8 Simulated Change in Baseflow Over Time - 2 Year Drought - Exsiting Water Demand





LEGEND

- ✱ Target Locations
- 210 (mASL)
- 220 (mASL)
- 230 (mASL)
- 240 (mASL)
- 250 (mASL)
- Subwatersheds
- Waterbodies
- Watercourse
- Roads

N W E S

Data Source: Ministry of Natural Resources, Ontario Base Mapping, June 2012. PTTW, Lake Simcoe Regional Conservation Authority.

2,000 1,000 0 2,000 Metres

SIMULATED GROUNDWATER ELEVATIONS - 2 YEAR DROUGHT - EXISTING WATER DEMAND

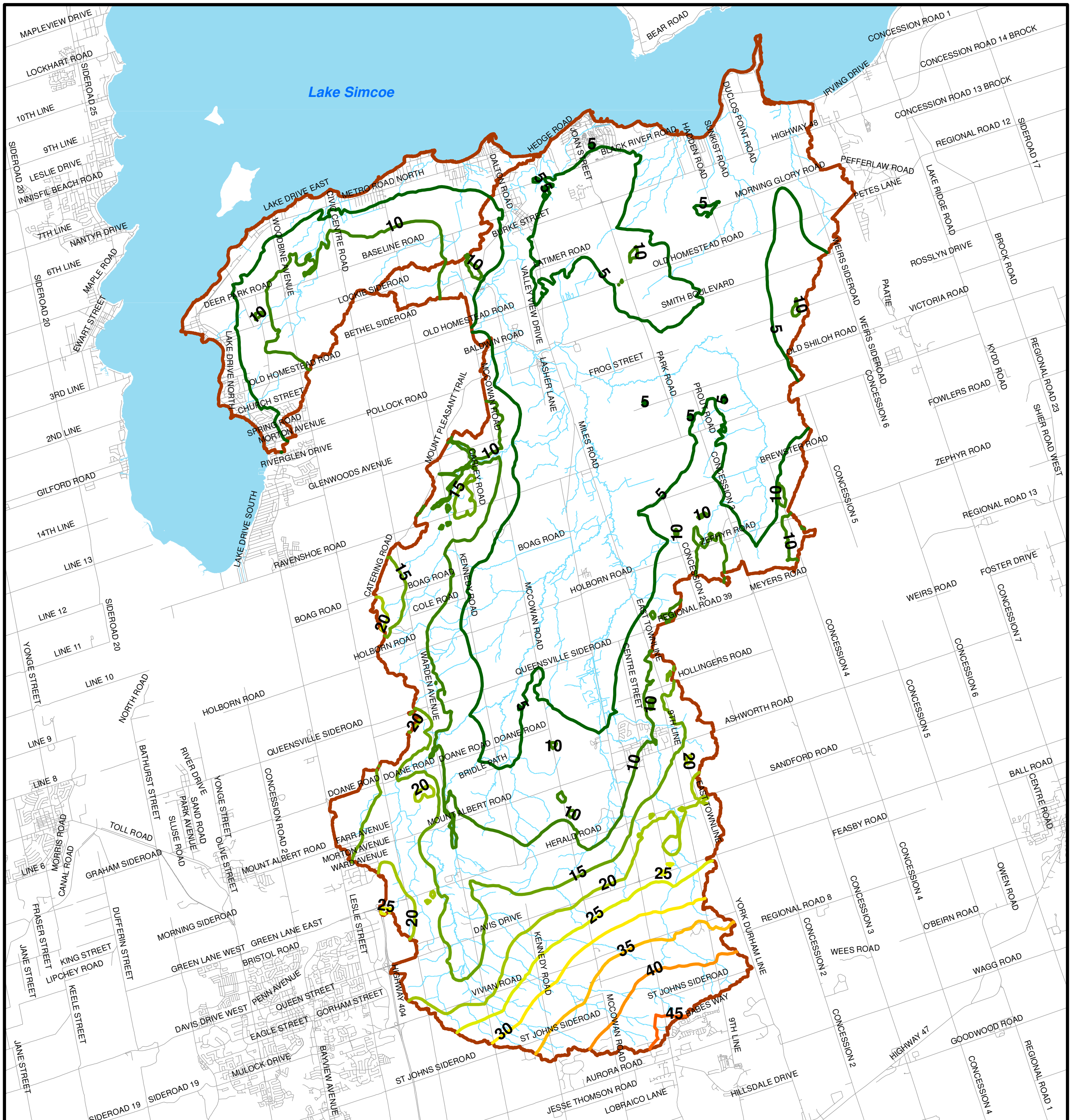
TIER 2 WATER BUDGET AND ECOLOGICALLY SIGNIFICANT GROUNDWATER RECHARGE AREAS FOR THE BLACK RIVER AND GEORGINA CREEKS SUBWATERSHEDS

For: Lake Simcoe Region Conservation Authority

DATE: JANUARY 2013	SCALE: 1:200000
PROJECT: 121-17211-00	FILE. NO.:1211721100F4-9

GENIVAR

FIGURE **4-9**



LEGEND

- 5 Metres
- 10 Metres
- 15 Metres
- 20 Metres
- 25 Metres
- 30 Metres
- 35 Metres
- 40 Metres
- 45 Metres
- Subwatersheds
- Waterbodies
- Watercourse
- Roads

Data Source: Ministry of Natural Resources, Ontario Base Mapping, June 2012. PTTW, Lake Simcoe Regional Conservation Authority.

DIFFERENCE IN SIMULATED GROUNDWATER ELEVATIONS - 2 YR DROUGHT - EXISTING WATER DEMAND

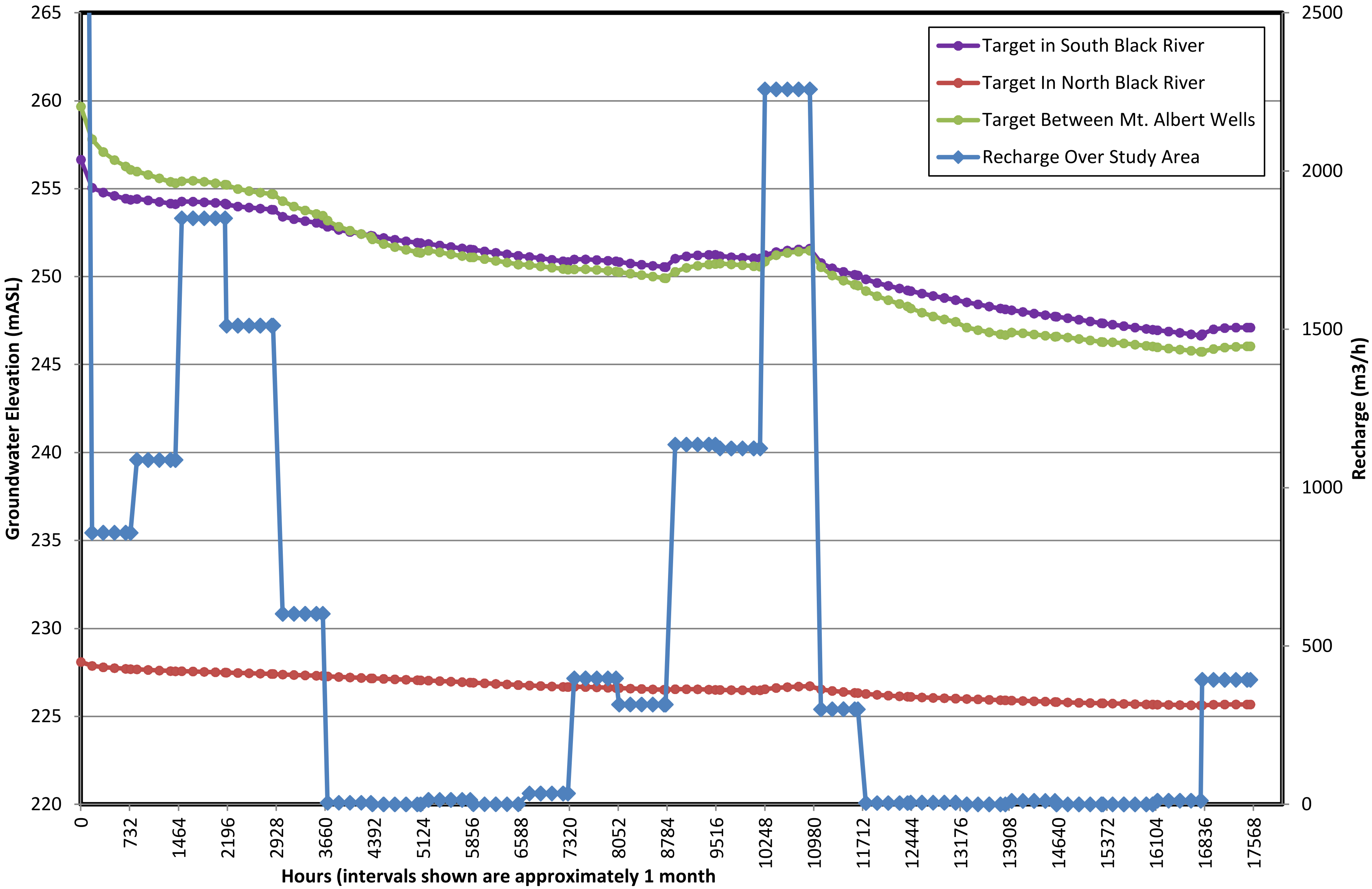
TIER 2 WATER BUDGET AND ECOLOGICALLY SIGNIFICANT GROUNDWATER RECHARGE AREAS FOR THE BLACK RIVER AND GEORGINA CREEKS SUBWATERSHEDS
For: Lake Simcoe Region Conservation Authority

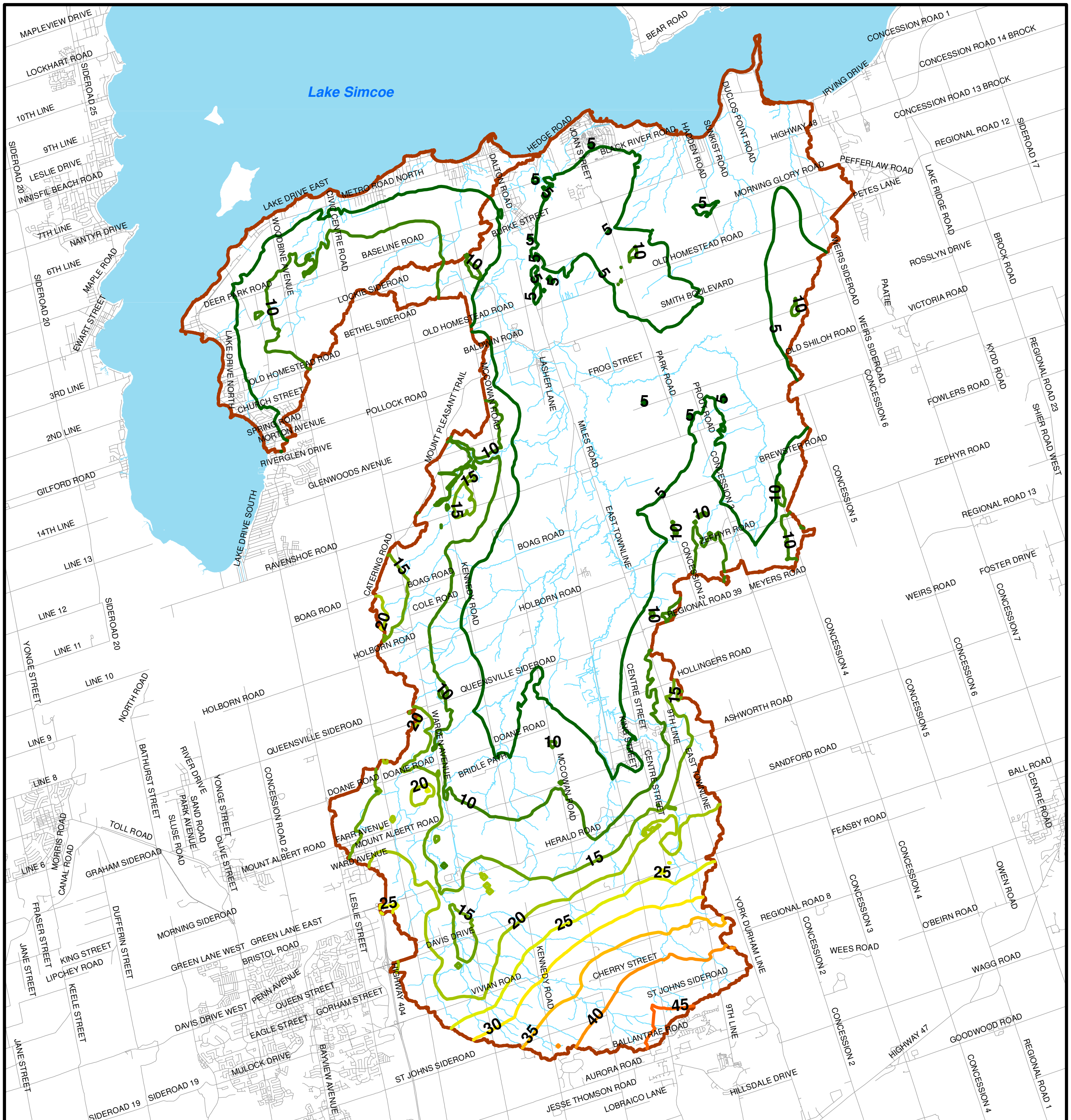
DATE: JANUARY 2013	SCALE: 1:200000
PROJECT: 121-17211-00	FILE. NO.:1211721100F4-10

GENIVAR

FIGURE
4-10

Figure 4-11 Simulated Change in Groundwater Elevations over Time - 2 Year Drought - Existing Water Demand





LEGEND

5 Metres	Subwatersheds
10 Metres	Waterbodies
15 Metres	Watercourse
20 Metres	Roads
25 Metres	
30 Metres	
35 Metres	
40 Metres	
45 Metres	

N W E S

2,000 1,000 0 2,000 Metres

Data Source: Ministry of Natural Resources, Ontario Base Mapping, June 2012. PTTW, Lake Simcoe Regional Conservation Authority.

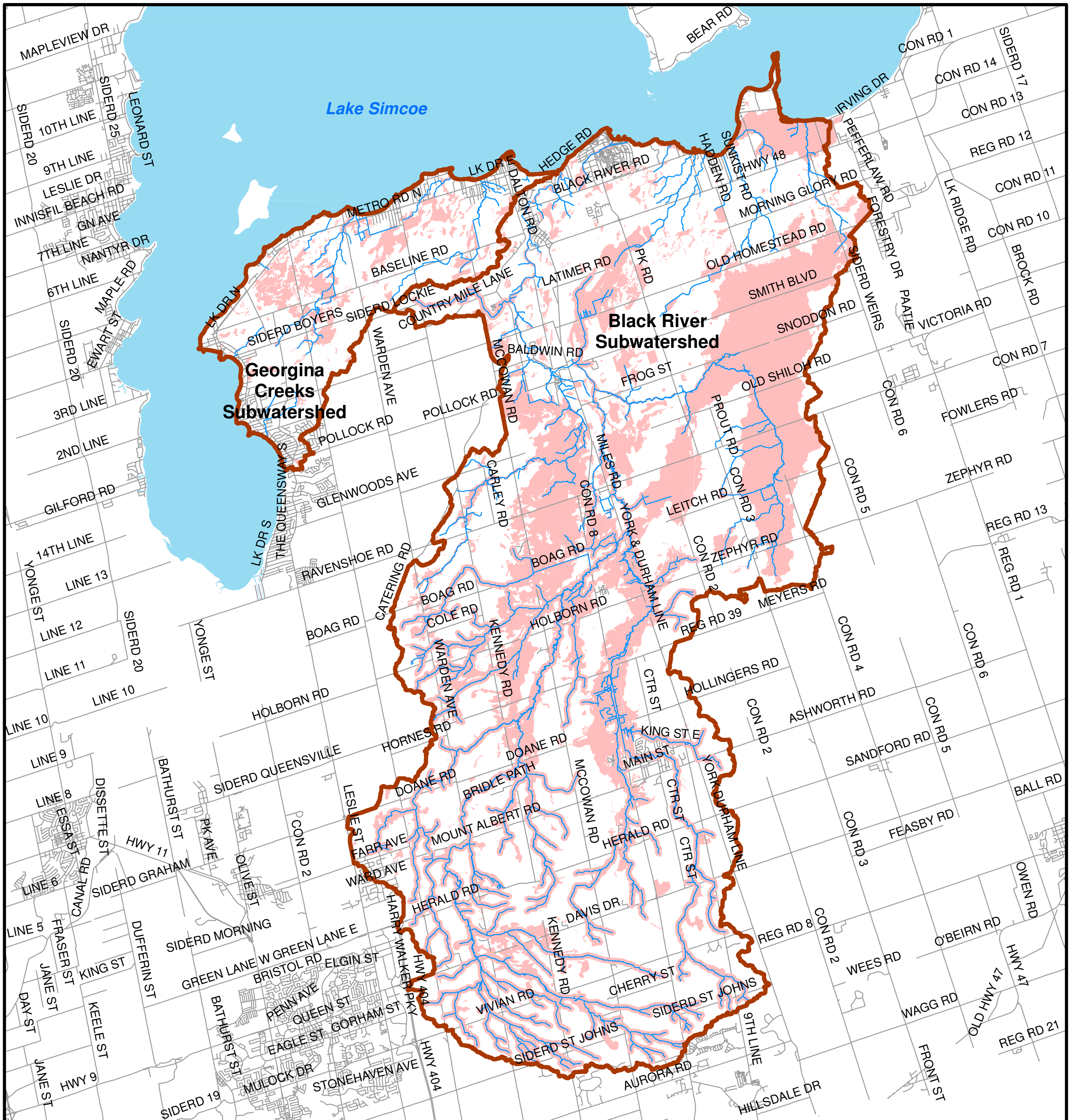
DIFFERENCE IN SIMULATED GROUNDWATER ELEVATIONS - 2 YR DROUGHT - COMMITTED WATER DEMAND

TIER 2 WATER BUDGET AND ECOLOGICALLY SIGNIFICANT GROUNDWATER RECHARGE AREAS FOR THE BLACK RIVER AND GEORGINA CREEKS SUBWATERSHEDS
For: Lake Simcoe Region Conservation Authority

DATE: JANUARY 2013	SCALE: 1:200000
PROJECT: 121-17211-00	FILE. NO.:1211721100F4-12

GENIVAR

FIGURE
4-12



LEGEND

- Subwatersheds
- Watercourse
- Road
- Ecologically Sensitive Features

N
W E
S

1,500 750 0 1,500 Metres

Data Source: Lake Simcoe Region Conservation Authority.
Ministry of Natural Resources, Ontario Base Mapping, June 2012.

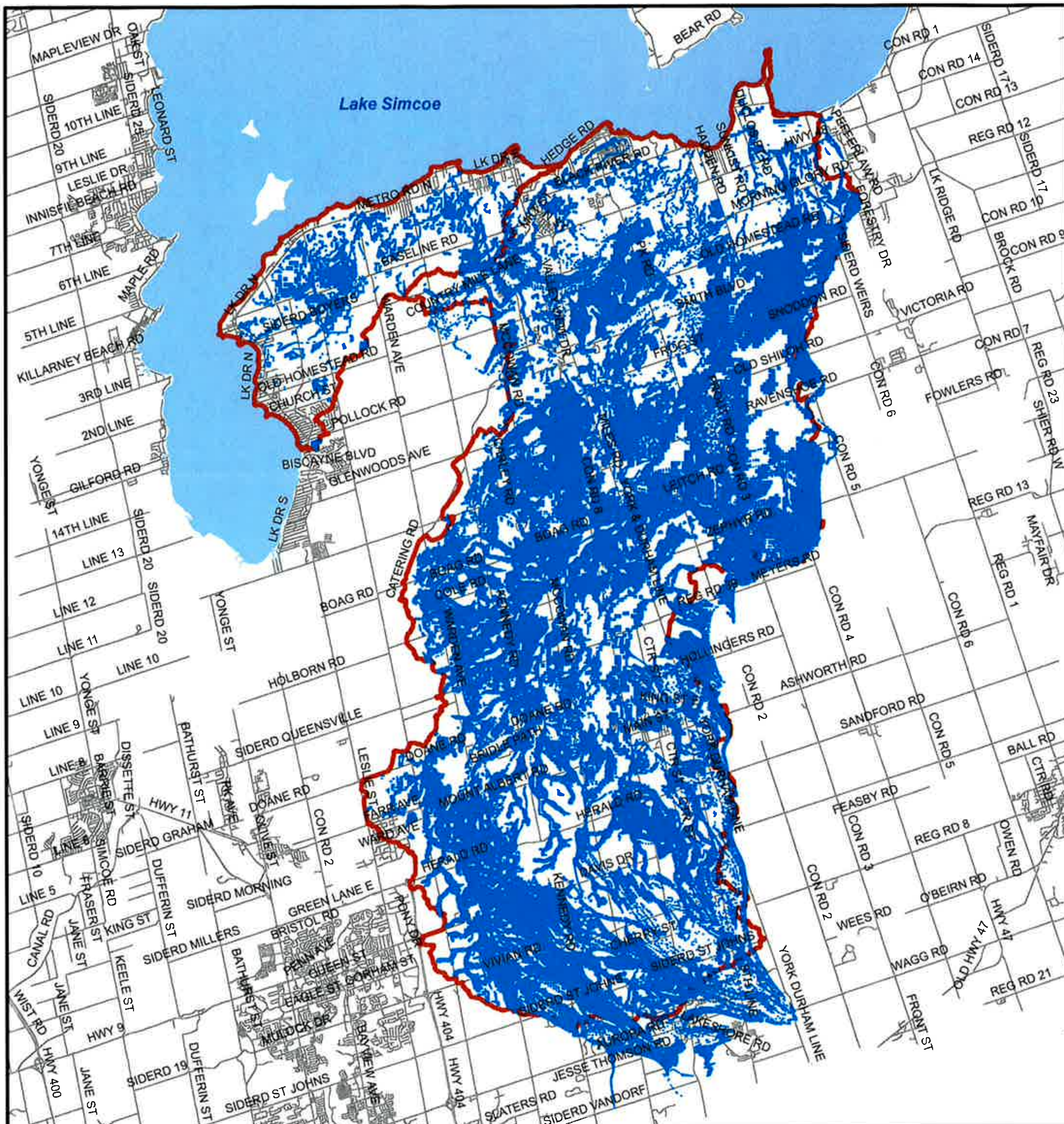
ECOLOGICALLY SENSITIVE FEATURES

TIER 2 WATER BUDGET AND ECOLOGICALLY SIGNIFICANT GROUNDWATER RECHARGE AREAS FOR THE BLACK RIVER AND GEORGINA CREEKS SUBWATERSHEDS
For: Lake Simcoe Region Conservation Authority

DATE: JANUARY 2013	SCALE: 1:200000
PROJECT: 121-17211-00	FILE. NO.:1211721100F5-1

GENIVAR

FIGURE
5-1



LEGEND

· Observed Particle Tracking End-Points - Reverse Particle Tracking

Subwatersheds

Road

N W E S

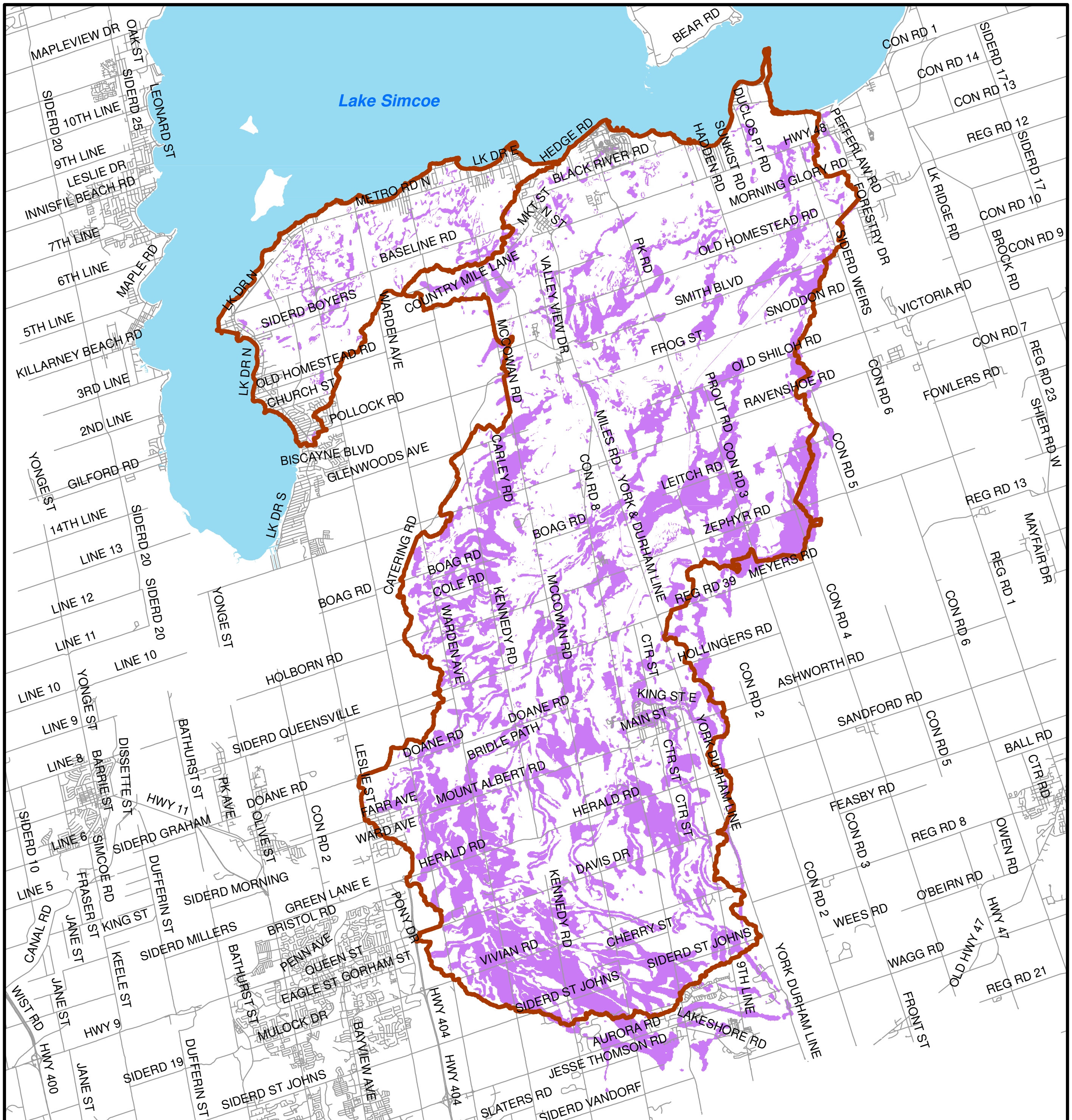
Data Source: Lake Simcoe Region Conservation Authority.
Ministry of Natural Resources, Ontario Base Mapping, June 2012.

1,500 750 0 1,500 Metres

PARTICLE END-POINTS - REVERSE PARTICLE TRACKING

TIER 2 WATER BUDGET AND
ECOLOGICALLY SIGNIFICANT GROUNDWATER
RECHARGE AREAS FOR THE BLACK RIVER AND
GEORGINA CREEKS SUBWATERSHEDS
For: Lake Simcoe Region Conservation Authority

DATE: JANUARY 2013	SCALE: 1:210000
PROJECT: 121-17211-00	FILE. NO.:1211721100F5-2
GENIVAR	FIGURE 5-2



LEGEND

- Ecologically Significant Groundwater Recharge Areas
- Subwatersheds
- Road

ECOLOGICALLY SIGNIFICANT GROUNDWATER RECHARGE AREAS (h = 100, e = 0.005)

TIER 2 WATER BUDGET AND
ECOLOGICALLY SIGNIFICANT GROUNDWATER
RECHARGE AREAS FOR THE BLACK RIVER AND
GEORGINA CREEKS SUBWATERSHEDS
For: Lake Simcoe Region Conservation Authority

DATE: FEBRUARY 2013	SCALE: 1:210000
PROJECT: 121-17211-00	FILE. NO.:1211721100F5-3

GENIVAR

FIGURE
5-3

N
W E
S

1,500 750 0 1,500 Metres

Data Source: Lake Simcoe Region Conservation Authority.
Ministry of Natural Resources, Ontario Base Mapping, June 2012.

Appendices

Appendix A

Assessment Tools

Appendix A

Assessment Tools

Technical Memorandum A1

Calibration of GENIVAR CORE Model

TECHNICAL MEMORANDUM A1

GENIVAR

Date:	January 24, 2013
To	Shelly Cuddy, Lake Simcoe Region Conservation Authority
Copy:	Katie Howson, LSRCA Scott Bates, Ministry of Natural Resources (MNR)
From:	Lloyd Lemon and Isabelle Hemmings
Project No.:	121-17211-00
Subject:	Tier 2 Water Budget and ESGRA for Black River and Georgina Creeks Subwatersheds Calibration of GENIVAR CORE Model

This memo documents the work performed by GENIVAR to re-create the YPDT-CAMC Core Model as developed by Earth*fx* Inc. (*Groundwater Modelling of the Oak Ridges Moraine Area*, CAMC/YPDT Technical Report Number 01-06, 2006) (hereafter referred to as "Earth*fx* CORE Model") for use in carrying out the Tier 2 Water Budget and ESGRA analysis for the Black River and Georgina Creeks Subwatersheds on behalf of the Lake Simcoe Region Conservation Authority (LSRCA). The electronic files for the Earth*fx* CORE Model, including calibration targets, were provided to GENIVAR. Calibration statistics are included in the model documentation.

The Earth*fx* CORE Model, as provided, is intended to run using a modified version of the USGS MODFLOW groundwater modelling code with all input and output being manipulated using the VIEWLOG™ Well Log Analysis System MODFLOW pre-/post-processor (VIEWLOG™ Systems, 2003). All of the input surfaces, aquifer parameters and various boundary arrays are stored in VIEWLOG™ format. River boundaries, drain boundaries, and pumping well extraction rates are processed by a proprietary software tool which is not included in the public release version of VIEWLOG™. For this reason, GENIVAR was not able to manipulate and work with the Earth*fx* CORE Model using the VIEWLOG™ software.

The modified MODFLOW code included in VIEWLOG™ is based on the 1996 version of the MODFLOW code. Since that time, two major updates to the MODFLOW code have been released by the USGS, the first in 2000, and the second in 2005. These updates include improved numerical solver routines and the ability to support refined child models within a parent (regional) model domain. In light of these developments, GENIVAR opted to work with a more recent version of MODFLOW since it would facilitate the use of the model at local scales within the regional model domain. MODFLOW Version 2000 was used as the solver engine.

For this study, GENIVAR has translated the input files for the Earth*fx* Core Model for use with the Groundwater Vistas™ Graphical User Interface (GUI). This allows the modeller to manipulate river and drain boundaries, and to take advantage of the Zone Budget post-processor to calculate the components of the water budget within the active model domain.

Initial attempts to import the Earth*fx* Core Model native files into Groundwater Vistas™ resulted in the computer freezing. To overcome this situation, we opted to export layer elevation files from VIEWLOG™ and import them into Groundwater Vistas™ to rebuild the model in a piecewise fashion.

Surfaces were exported from VIEWLOG™ and imported into Groundwater Vistas™ as MODFLOW 8E14.6 ASCII grid data. The remaining data (rivers, drains, well and recharge) could be imported into Groundwater Vistas™ from the MODFLOW native files.

Once the complete model had been imported into the Groundwater Vistas™ the native MODFLOW files could be generated by Groundwater Vistas™.

GENIVAR worked with the Conservation Authorities Moraine Coalition (CAMC) to re-create the database of groundwater elevations used by Earth*fx* in 2006. The CAMC provided new fields to be included in the original database of calibration data points to describe the hydrostratigraphic units to which the well screens are applied. This query was not provided with the model documentation by Earth*fx*. Values in the new datafield may differ slightly from those used by Earth*fx* as the aquifer assignments were reviewed and updated by CAMC in 2011.

The translated files were imported into a Groundwater Vistas™ model, referred to as the "GENIVAR CORE Model" from this point forward. The GENIVAR CORE Model reproduced the groundwater flow patterns of the Earth*fx* CORE Model in the major aquifers. Calibration statistics also closely matched those published for the Earth*fx* CORE Model. The GENIVAR CORE Model will be used as the base for subsequent modelling work undertaken for this study.

CORE Model Description

A detailed description of the Earth*fx* CORE Model is provided in the YPDT-CAMC, 2006 report. The following sections provide a brief summary of the model. The model properties for the GENIVAR CORE Model are the same as the Earth*fx* CORE Model, except as indicated.

Spatial Domain and Grid Discretization

The model domain for the GENIVAR CORE Model as shown in Figure A1-1 covers approximately 660,800 ha and extends from Lake Ontario to Lake Simcoe and encompasses the entire Regional Municipality of York, a portion in the east side of the Regional Municipality of Peel, the west side of the Regional Municipality of Durham and the majority of the City of Toronto. The eastern and western boundaries roughly coincide with watershed boundaries. The model grid has 840 rows and 1056 columns and eight vertical layers for a total of nearly 7.1 million cells. The model contains a uniform grid of cells with dimensions of 100 m x 100 m in the x- and y- directions.

Model Layers

The GENIVAR CORE Model contains eight (8) model layers which represent the following hydrostratigraphic units:

- Layer 1 – Recent deposits and/or weathered Halton/Kettleby Aquitard
- Layer 2 – Halton/Kettleby Aquitard
- Layer 3 - Oak Ridges Aquifer Complex (ORAC) and/or Weathered Newmarket Aquitard
- Layer 4 - Newmarket Aquitard
- Layer 5 - Thorncliffe Aquifer Complex (TAC)
- Layer 6 - Sunnybrook Aquitard
- Layer 7 - Scarborough Aquifer Complex (SAC)
- Layer 8 - Weathered Bedrock

Boundary Conditions

The north and south boundaries of the GENIVAR CORE Model coincide with Lake Simcoe and Lake Ontario, while the east and west boundaries coincide with watershed divides. All model cells outside these boundaries are set as inactive.

Constant head boundary cells are used along the shores of Lake Simcoe and Lake Ontario to represent the average water level in each of those water bodies. In the Earth*fx* CORE Model and the GENIVAR CORE Model, the constant head cells for the Lake Ontario and Lake Simcoe are present in all 8 layers.

All watercourses within the model domain were classified under the Strahler classification system. For major streams (Strahler class 3 and above), river boundary cells were used so that these sections of the watercourse could function as both gaining and losing streams, depending on the local groundwater elevation. River cells represent the main branches of the major surface watercourses within the subwatersheds of interest. Smaller streams (Strahler class 1 and 2) were modeled as drain boundary cells. This is a conservative approach as the drain boundary will remove any water as runoff when the groundwater elevation reaches the bottom of the drain. River and drain conductances were set according to Strahler class, while river stage and bed elevations were assigned relative to the surface Digital Elevation Model (DEM). Wetlands were also modeled using drain boundaries. The parameters for the river and drain boundaries were not modified in the GENIVAR CORE Model.

The recharge distribution in the Earth*fx* CORE Model is documented in the YPDT-CAMC Report. The GENIVAR CORE Model uses the same recharge layer.

Hydraulic Properties

Hydraulic conductivity (K) values for Layers 1 through 7 were imported into Groundwater Vistas™ as they were represented in VIEWLOG™. Earth*fx* reported the hydraulic properties of Layer 8 as transmissivity (T) with a reported constant thickness of 15 meters (b). This thickness was used to establish a bottom elevation for layer 8 and the relationship T =Kb was used to calculate the hydraulic conductivity for Layer 8.

Earth*fx* elected to assign a value of vertical conductance as the parameter to represent the potential for vertical flow within and between each model layer. GENIVAR imported the vertical conductance assigned by Earth*fx* to represent the vertical leakance between layers. The vertical hydraulic conductivity field was thus left blank. For Layer 8, the vertical hydraulic conductivity was set to be equal to the horizontal hydraulic conductivity as used by Earth*fx.*

Calibration Wells

The list of wells used to calibrate the Earth*fx* CORE Model was not provided in the available documentation. The complete database of wells included approximately 26,000 records. Earth*fx* used only 17,200 wells in the calibration and these were assigned to the three aquifer layers (Oak Ridges Aquifer Complex, Thorncliffe Aquifer Complex and Scarborough Aquifer Complex). Records to document the aquifer layer assignments for each well screen in the database were not available. GENIVAR worked with the staff of the Conservation Authorities Moraine Coalition to reproduce the list of wells used by Earthfx. Some of the aquifer layer assignments assigned to individual wells may have been updated in 2010. Some wells in the database may also have been removed as duplicates or incomplete well data between 2004 and 2010. GENIVAR compiled a list of 15,669 wells for which groundwater elevation data was available to calibrate the GENIVAR CORE Model.

Comparison of Calibration Statistics

Calibration statistics are used to demonstrate how well the model results statistically represent the target groundwater elevation data. The statistics are typically performed on the groundwater elevation residuals, or the difference between the simulated and observed elevations. The statistical parameters presented in Table A1-1 include:

- ***Mean Error (ME):*** The ME represents the mean of all the residuals. A low value, approaching zero is considered good. This parameter sometimes can be misleading because large negative residuals and large positive residuals can balance each other out to result in an ME value close to or equal to zero. The ME provides an indication of whether residuals are biased positively or negatively. The mean error for the entire GENIVAR CORE Model was -0.32 m.

- → ***Mean Absolute Error (MAE):*** The MAE represents the mean of the absolute values of all the residuals. This parameter will be larger than the mean error and provides the average error associated with each calibration point in the model. For the GENIVAR CORE Model the MAE is 7.73 m.
- → ***Root Mean Squared Error (RMSE***): The RMSE represents the square root of the sum of the squares of all the residuals. Squaring the residuals increases the weighting that a poor residual will have on the overall calibration statistic. A low RMSE is a good indication of an acceptable model calibration. The RMSE for the entire GENIVAR CORE Model was 10.71 m.
- → ***Normalized Root Mean Squared Error (NRMSE):*** The NRMSE is the RMSE divided by the difference between the highest and lowest observed head within the model domain. This is a more representative measure of the overall fit of the model to observed values, than the RMSE, as the NRMSE accounts for the scale of the potential range of data values. The "best practice" objective for NRMSE for numerical groundwater flow models is 10%. The NRMSE for the entire GENIVAR CORE Model was 3.75%. This is lower than the industry standard, and therefore is considered to be an acceptable calibration.

Table A1-1 provides a comparison of the calibration statistics as reported for the Earth*fx* CORE Model with those generated for the GENIVAR CORE Model. Table A1-1 includes information presented in Table 18 of the YPDT-CAMC 2006 report.

Table A1-1 provides the calibration statistics for the surface water stations within the Black River Subwatershed. The information from the Earth*fx* CORE Model was obtained from Table 3 of the CAMC/YPDT 2006 report. Given the excellent reproduction of the flow and error statistics at these stations, GENIVAR did not recalculate the surface water flows in all 106 surface water calibration points in the CORE Model.

Figure A1-2 provides a comparison of the observed and calculated groundwater elevations for the Oak Ridges Aquifer Complex layer for the Earth*fx* CORE Model (a) with the values obtained for the GENIVAR CORE Model (b).
Figure A1-3 provides a comparison of the observed and calculated groundwater elevations for the Thorncliffe Aquifer Complex layer for the Earth*fx* CORE Model (a) with the values obtained for the GENIVAR CORE Model (b).

Figure A1-4 provides a comparison of the observed and calculated groundwater elevations for the Scarborough Aquifer Complex layer for the Earth*fx* CORE Model (a) with the values obtained for the GENIVAR CORE Model (b).

<u>Conclusion</u>

The calibration statistics for the GENIVAR CORE Model are very similar to those presented for the Earth*fx* CORE Model. The difference in the estimated NRMSE by aquifer complex ranges between 4.11% and 5.57% for the GENIVAR CORE Model. Earth*fx* reported a range of 3.4% to 5.4%. The differences may be explained by the removal of some of the calibration points in the data set used for the GENIVAR CORE model. The GENIVAR CORE Model accurately replicated the surface water baseflow reported for the Black River and Georgina Creeks Subwatersheds.

The GENIVAR CORE Model is therefore a suitable base to update and carry out the Tier 2 Water Budget and Ecologically Significant Recharge Area analysis within the Black River and Georgina Creeks Subwatersheds

LAL:nah

List of Tables

List of Figures

Table A1-1 - Comparison of Calibration Statistics - Earth*fx* CORE Model vs GENIVAR CORE Model

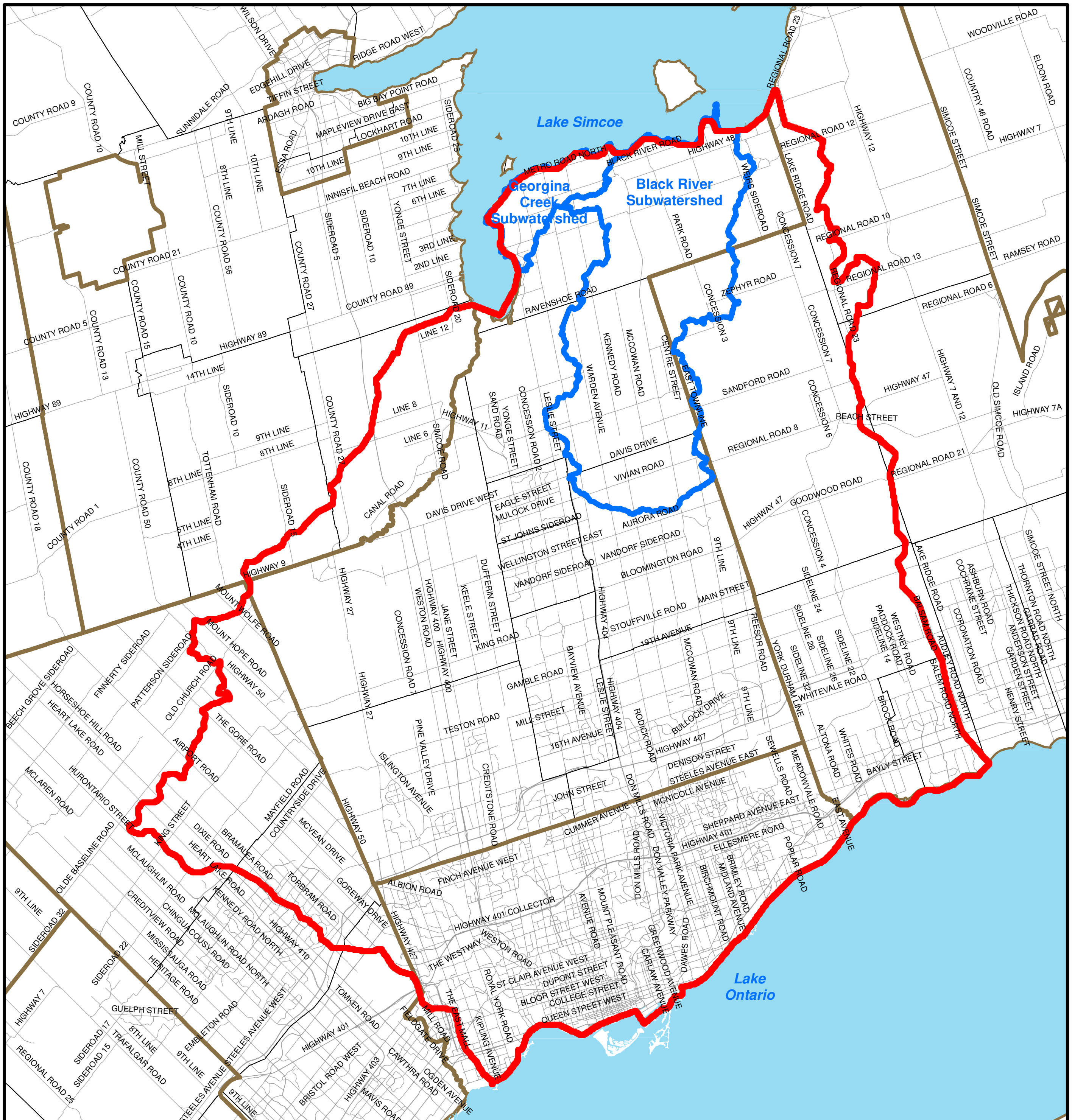
Model Result	Number of Wells (n)		Mean Error [ME] (m)		Mean Absolute Error [AME] (m)		Root Mean Squared Error [RMSE] (m)		Normalized Root Mean Squared Error [NRMSE] %	
	Earth*fx* CORE Model	GENIVAR CORE Model	Earth*fx* CORE Model	GENIVAR CORE Model	Earth*fx* CORE Model	GENIVAR CORE Model	Earth*fx* CORE Model	GENIVAR CORE Model	Earth*fx* CORE Model	GENIVAR CORE Model
Oak Ridges Aquifer Complex Heads	9939	9459	-0.41	1.42	7.13	7.16	9.5	9.81	Ranges from 3.4% to 5.4%	4.11%
Thorncliffe Aquifer Complex Heads	5657	5126	-2.31	-2.34	8.09	8.33	11.1	11.54		4.54%
Scarborough Aquifer Complex Heads	1615	1084	-5.5	-6.02	8.74	9.89	13.62	13.71		5.57%
Entire Model	na	15669	na	-0.32	na	7.73	na	10.71	na	3.75%

Hydat Station	Average Annual Flow (m^3/s)	Calculated Baseflow (m^3/s)	Simulated Baseflow (m^3/s)		Percent Error	
			Earth*fx* CORE Model	GENIVAR CORE Model	Earth*fx* CORE Model	GENIVAR CORE Model
Black River at Baldwin	2.26	1.41	1.53	1.53	-8.51%	-8.51%
Black River at Sutton	2.55	1.62	1.70	1.69	-4.94%	-4.32%

Notes:

Earthfx groundwater calibration data obtained from Table 18, Page 168 - "Groundwater Modelling of the Oak Ridges Moraine Area" - CAMC/YPDT Technical Report Number 01-06.

na - information not provided in Table 18
Calculated and Simulated Values for Base Flow at individual surface water stations obtained from Table 3, Page 117



LEGEND

- Core Model Domain
- Subwatersheds
- Waterbodies
- Upper Tier Municipal Boundaries
- Lower Tier Municipal Boundaries
- Roads

Data Source: Ministry of Natural Resources,
Ontario Base Mapping, June 2012.

N W E S

4,000 2,000 0 4,000 Metres

CORE MODEL DOMAIN

TIER 2 WATER BUDGET AND ESGRA FOR
BLACK RIVER AND GEORGINA CREEKS
SUBWATERSHEDS
CALIBRATION OF GENIVAR CORE MODEL
For: Lake Simcoe Region Conservation Authority

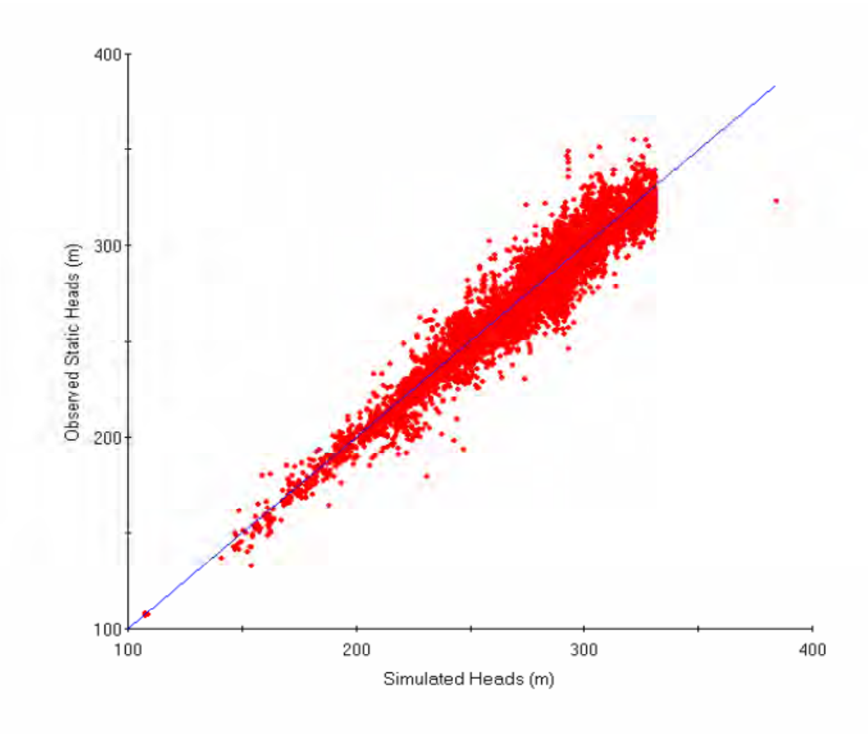
DATE: JANUARY 2013	SCALE: 1:500000
PROJECT: 121-17211-00	FILE. NO.:1211721100FA1-1

GENIVAR

FIGURE
A1-1

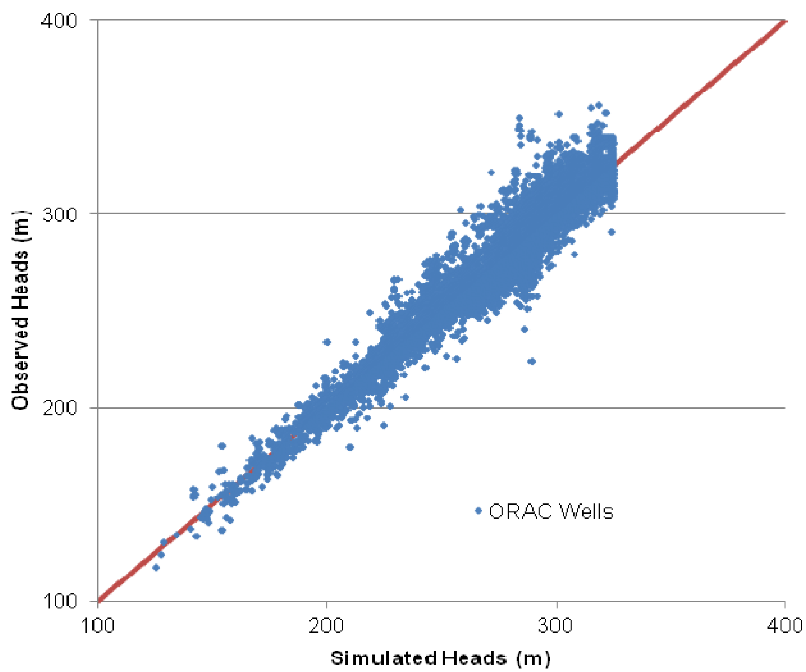
Figure A1-2 - Comparison of Calibration Plots - Oak Ridges Aquifer Complex

(a) Earth*fx* CORE Model



Number of Wells (n)	Mean Error [ME] (m)	Mean Absolute Error [AME] (m)	Root Mean Squared Error [RMSE] (m)	Normalized Root Mean Squared Error [NRMSE] %
9939	-0.41	7.13	9.50	na

(b) GENIVAR CORE Model



Number of Wells (n)	Mean Error [ME] (m)	Mean Absolute Error [AME] (m)	Root Mean Squared Error [RMSE] (m)	Normalized Root Mean Squared Error [NRMSE] %
9459	1.42	7.16	9.81	4.11%

Notes:

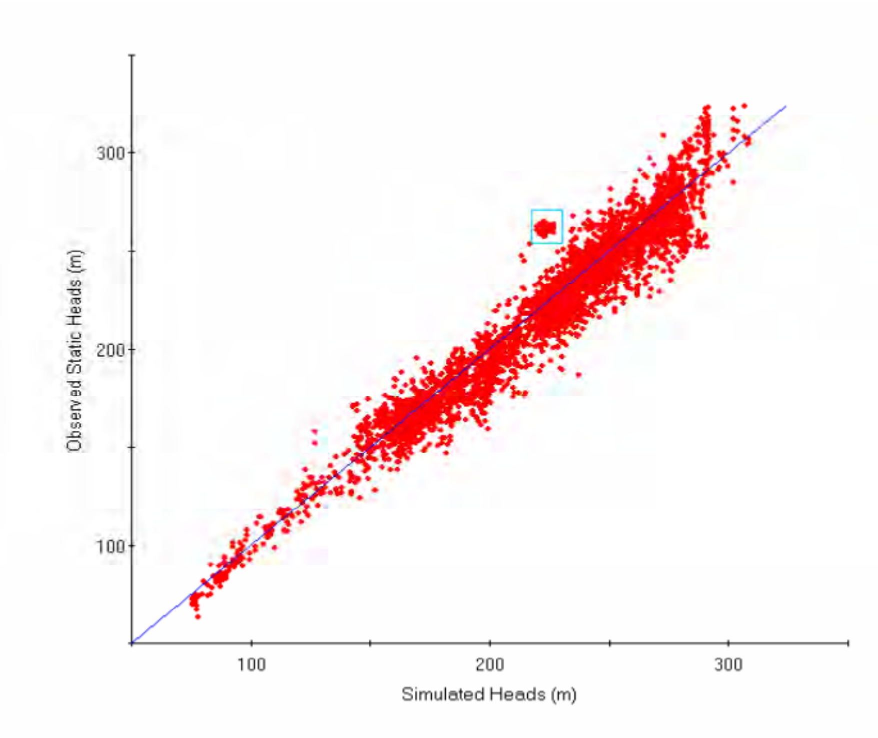
Earthfx scatter plot obtained from Figure 99, Page 169 - "Groundwater Modelling of the Oak Ridges Moraine Area" - CAMC/YPDT Technical Report Number 01-06.

Earthfx groundwater calibration data obtained from Table 18, Page 168 (Same reference)

na - information not provided in Table 18

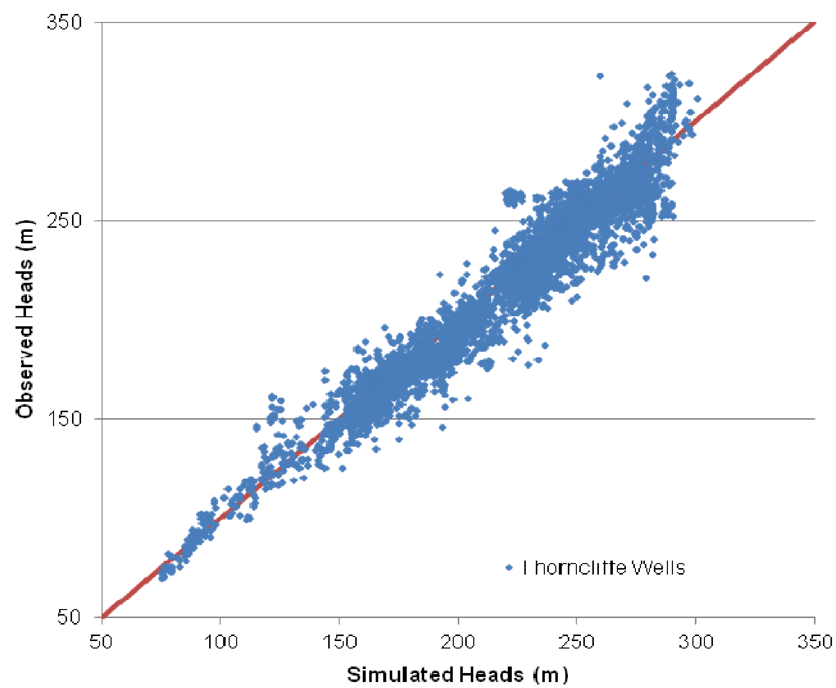
Figure A1-3 - Comparison of Calibration Plots - Thorncliffe Aquifer Complex

(a) Earth*fx* CORE Model



Number of Wells (n)	Mean Error [ME] (m)	Mean Absolute Error [AME] (m)	Root Mean Squared Error [RMSE] (m)	Normalized Root Mean Squared Error [NRMSE] %
5657	-2.31	8.09	11.10	na

(b) GENIVAR CORE Model



Number of Wells (n)	Mean Error [ME] (m)	Mean Absolute Error [AME] (m)	Root Mean Squared Error [RMSE] (m)	Normalized Root Mean Squared Error [NRMSE] %
5126	-2.34	8.33	11.54	4.54%

Notes:

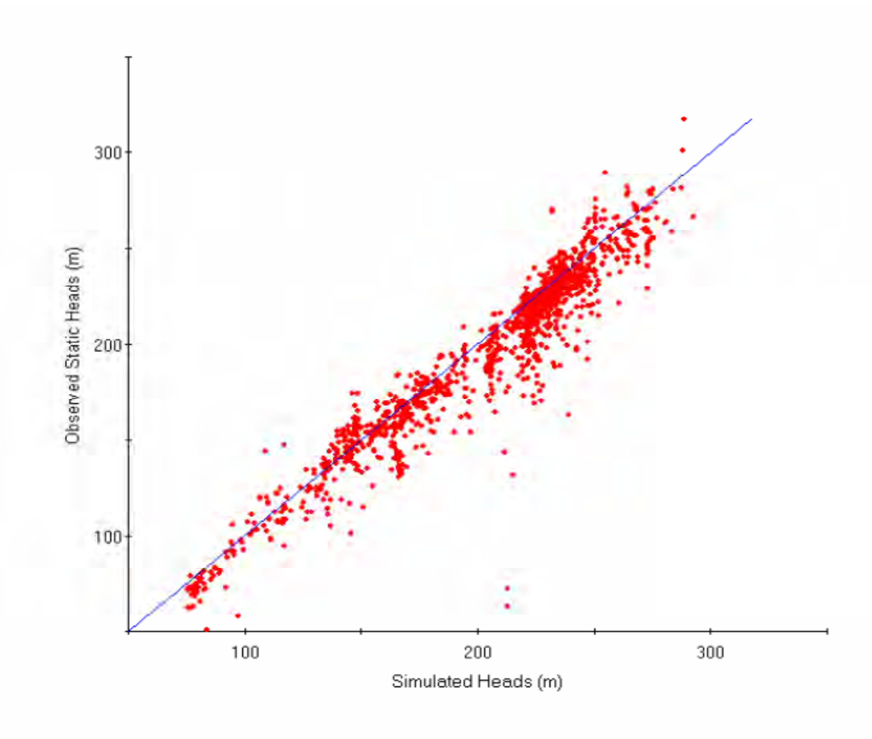
Earthfx scatter plot obtained from Figure 99, Page 169 - "Groundwater Modelling of the Oak Ridges Moraine Area" - CAMC/YPDT Technical Report Number 01-06.

Earthfx groundwater calibration data obtained from Table 18, Page 168 (Same reference)

na - information not provided in Table 18

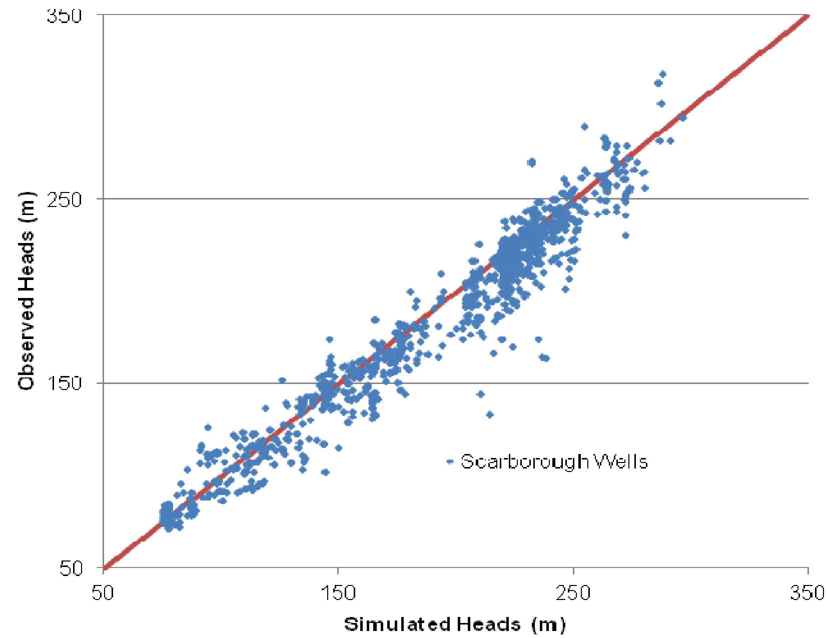
Figure A1-4 - Comparison of Calibration Plots - Scarborough Aquifer Complex

(a) Earth*fx* CORE Model



Number of Wells (n)	Mean Error [ME] (m)	Mean Absolute Error [AME] (m)	Root Mean Squared Error [RMSE] (m)	Normalized Root Mean Squared Error [NRMSE] %
1615	-5.50	8.74	13.62	na

(b) GENIVAR CORE Model



Number of Wells (n)	Mean Error [ME] (m)	Mean Absolute Error [AME] (m)	Root Mean Squared Error [RMSE] (m)	Normalized Root Mean Squared Error [NRMSE] %
1084	-6.02	9.89	13.71	5.57%

Notes:

Earthfx scatter plot obtained from Figure 99, Page 169 - "Groundwater Modelling of the Oak Ridges Moraine Area" - CAMC/YPDT Technical Report Number 01-06.

Earthfx groundwater calibration data obtained from Table 18, Page 168 (Same reference)

na - information not provided in Table 18

Technical Memorandum A2

Calibration of GENIVAR Black River Groundwater Model

GENIVAR

TECHNICAL MEMORANDUM A2

Date:	January 24, 2013
To	Shelly Cuddy, Lake Simcoe Region Conservation Authority
Copy:	Katie Howson, LSRCA Scott Bates, Ministry of Natural Resources (MNR)
From:	Lloyd Lemon and Isabelle Hemmings
Project No.:	121-17211-00
Subject:	Tier 2 Water Budget and ESGRA for Black River and Georgina Creeks Subwatersheds Calibration of GENIVAR Black River Model

This memo documents the work performed by GENIVAR to prepare the existing groundwater model for use in analysis of the Tier 2 Water Budget and Ecologically Significant Groundwater Recharge Areas (ESGRA) in the Black River and Georgina Creeks Subwatersheds (Study Area).

Technical Memorandum A1 documented the creation of the GENIVAR CORE Model to replicate the YPDT-CAMC Core Model as developed by Earth*fx* Inc. (*Groundwater Modelling of the Oak Ridges Moraine Area*, CAMC/YPDT Technical Report Number 01-06, 2006) (hereafter referred to as "Earth*fx* CORE Model"). The GENIVAR CORE Model was shown to produce similar output and calibration statistics as reported by Earth*fx* Inc.

The steps taken to construct and calibrate the GENIVAR Black River Groundwater Model for analysis of the Tier 2 Water Budget and ESGRA included:

1) Using the recharge generated by the Lake Simcoe Precipitation-Runoff Modelling System (PRMS) Model as created by Earth*fx* Inc over the Black River and Georgina Creeks Subwatersheds. (*Water Balance Analysis for the Lake Simcoe Basin using the Precipitation-Runoff Modelling System (PRMS) (2010).* This surface water model will be referred to as the Lake Simcoe PRMS Model.
2) Updating water wells, municipal water wells, and Permit To Take Water records in the GENIVAR Black River Groundwater Model
3) Adding MODFLOW drains to provide drainage for identified wetland features that were not considered in the Earth*fx* CORE Model.
4) Generating baseline groundwater elevations and calibration statistics for the updated Black River Groundwater Model.

1) Calibration Analysis of the Study Area

The model domain for the GENIVAR CORE Model is shown in Figure A2-1. The GENIVAR Black River Groundwater Model was created by making changes only within the Black River and Georgina Creeks Subwatersheds as shown in Figure A2-1. Figures depicting model outputs will be limited to the Study Area.

The calibration statistics for the Study Area within the GENIVAR CORE Model prior to upgrades are provided in Table A2-1a).

Calibration statistics are used to demonstrate how well the model results statistically represent the target groundwater elevation data. The statistics are typically performed on the groundwater elevation residuals, or the difference between the simulated and observed elevations. The statistical parameters presented in Table A2-1 include:

- ***Mean Error (ME):*** The ME represents the mean of all the residuals. A low value, approaching zero is considered good. This parameter sometimes can be misleading because large negative residuals and large positive residuals can balance each other out to result in an ME value close to or equal to zero. The ME provides an indication of whether residuals are biased positively or negatively.
- ***Mean Absolute Error (MAE):*** The MAE represents the mean of the absolute values of all the residuals. This parameter will be larger than the mean error and provides the average error associated with each calibration point in the model.
- ***Root Mean Squared Error (RMSE***): The RMSE represents the square root of the sum of the squares of all the residuals. Squaring the residuals increases the weighting that a poor residual will have on the overall calibration statistic. A low RMSE is a good indication of an acceptable model calibration.
- ***Normalized Root Mean Squared Error (NRMSE):*** The NRMSE is the RMSE divided by the difference between the highest and lowest observed head within the model domain. This is a more representative measure of the overall fit of the model to observed values, than the RMSE, as the NRMSE accounts for the scale of the potential range of data values. The "best practice" objective for NRMSE for numerical groundwater flow models is 10%.

The calibration statistics for the Study Area subset of the GENIVAR CORE Model show a relatively good fit (NRMSE = 6.25%) for the Black River Subwatershed and a marginal fit (NRMSE = 10.34 %) for the Georgina Creeks Subwatershed. The slightly poorer fit in the Georgina Creeks Subwatershed is reasonable as there is little data available for both surface water and groundwater analysis in the Georgina Creeks Subwatershed, and that this small and marginal area would not have been a focus for calibration adjustments to subsurface hydraulic properties in the original Earth*fx* CORE Model. The NRMSE for the Study Area is 5.83%. As this value is less than 10%, the model is considered to adequately represent the groundwater flow conditions within the Study Area.

The next sections describe the progressive steps taken to prepare the numerical model for use in the study area. The subdivisions of Table A2-1 reflect the individual steps. The calibration statistics observed for each step are typically compared to those of the previous step to illustrate the observed changes. The objective is to show that the model applied for the Tier 2 Water Budget and ESGRA analysis continues to be adequate for representing groundwater flow conditions and that the changes documented will provide greater confidence in the model outputs.

2) PRMS Recharge

Groundwater recharge in the GENIVAR CORE Model was determined by Earth*fx* (2006) from analysis of climate data and surficial geology and adjustments made to achieve model calibration. Subsequent to the construction of the Earth*fx* CORE Model, Earth*fx* applied the Lake Simcoe PRMS Model to generate new estimates of the distribution of recharge (Earth*fx* 2010). The PRMS Model considers climatic factors, slopes, surficial materials and land use among other parameters to generate a recharge distribution that reflects the observed behavior of surface water features.

The initial step in evaluating potential upgrades to the GENIVAR CORE Model involved exchanging the original recharge estimates with the distributed pattern determined by the PRMS Model. Figure A2-2 illustrates the two recharge distributions within the GENIVAR Black River Groundwater Model Domain. The PRMS recharge patterns illustrate greater local variability and a higher recharge across the Southern portion of the Black River Subwatershed than estimated in the CORE Model recharge patterns. The total volume of recharge predicted by PRMS was less than that used in CORE Model.

The GENIVAR Black River Groundwater Model was run with the updated PRMS recharge inputs. The results of this model run were compared to the results of the GENIVAR CORE Model within the Study Area. Table A2-1b) presents the calibration statistics for the GENIVAR Black River Groundwater Model with PRMS recharge. These values can be compared to those of Table A2-1a). The groundwater elevations in the Oak Ridges Aquifer Complex (ORAC) are illustrated for these two model scenarios in Figure A2-3. The general pattern of groundwater elevations is similar although there is local variability created by using the PRMS recharge.

The calibration statistics for groundwater elevation within the GENIVAR Black River Groundwater Model with PRMS Recharge differ slightly from the values obtained for the GENIVAR CORE Model. The magnitude of the Mean Error (ME) is smaller in the GENIVAR Black River Groundwater Model with PRMS Recharge within the Study Area (smaller is better). The values for Mean Absolute Error (MAE), Root Mean Squared Error (RMSE), and Normalized Root Mean Squared Error (NRMSE) increase slightly in each zone. The NRMSE for the entire CORE model domain increased by 0.2%. The NRMSE values for the Study Area remain less than 10%. The calibration statistics for the GENIVAR Black River Groundwater Model are shown in Figure A2-4.

The calibration information for the two HYDAT surface water stations on the Black River changes slightly between the GENIVAR CORE Model and the GENIVAR Black River Groundwater Model with PRMS Recharge. The GENIVAR CORE Model accurately reproduced the values at these two stations as obtained in Earth*fx* CORE Model (2006). The GENIVAR CORE Model over predicted the flow at the Baldwin station by approximately 8.5% and at the Sutton station by 5%. The GENIVAR Black River Groundwater Model with PRMS Recharge under predicts flow at the Baldwin station by 2.1% and at the Sutton station by 2.5%. This observation indicates that applying the PRMS recharge to the Black River and Georgina Creeks Subwatersheds improves the ability of the GENIVAR Black River Groundwater Model to predict the baseflow in the Black River, although it now tends to under predict rather than over predict. As mentioned above, the recharge volume estimated by PRMS is less than that used in the CORE Model so it is reasonable that there is less water available to be discharged through the surface water system. The magnitude of the difference between the observed and predicted baseflow estimates is lower in the GENIVAR Black River Groundwater Model with PRMS Recharge than in the GENIVAR CORE Model.

In view of the error in replicating calculated baseflow for the two HYDAT stations, the simulated baseflow for each simulation using the numerical model will be compared to the calculated baseflow. This situation will be discussed in interpretation of findings and in the data gaps/uncertainty section.

3) Updated Well and Permit To Take Water Information

The Earth*fx* CORE Model was calibrated to “current conditions” by assigning average pumping rates to municipal wells and wells with an active Permit To Take Water (PTTW). These records reflect average pumping rates for municipal wells between 1990 and 2002. The date of PTTW records were not provided, but were also assumed to reflect conditions in 2002. Calibration targets for the Earth*fx* CORE Model were obtained from the Conservation Authorities Moraine Coalition (CAMC)/ York Peel Durham Toronto (YPDT) Groundwater Management System database and were also current to approximately 2004.

The LSRCA requested that the pumping wells and calibration targets for the GENIVAR Black River Groundwater Model be updated to reflect current conditions. Several new wells have been added to the Ministry of the Environment (MOE) water well record database and the CAMC/YPDT database (based on the MOE water well record database) has undergone additional scrutiny to remove duplicate wells, update locations, and assign well screens to the aquifer layers. Many of the wells added are not associated with the defined aquifer layers.

An updated list of Permits to Take Water within the Black River and Georgina Creeks Subwatersheds was obtained from LSRCA. The most notable change in the Subwatersheds is a new municipal well, Well 3, was brought on-line in Mount Albert in 2011. York Region provided updated information on the historical pumping rates for municipal wells in the Black River and Georgina Creeks Subwatersheds. Table A2-2 provides a summary of the pumping rates used in the GENIVAR Black River Groundwater Model. The wells are shown as those that were unchanged from the Earth*fx* CORE Model, those for which pumping rate information has been updated, and those which have been added. A summary of the wells with assigned pumping rates is included in Table A2-2. Figure A2-5 presents the locations of the wells represented in the model within the Study Area coloured to reflect the changes in pumping rate relative to the Earth*fx* CORE Model values. Metadata information describing the wells and Permit To Take Water details were not available for wells in the Earth*fx* CORE Model. An attempt was made to correlate these wells with the available water well record and Permit To Take Water databases. This correlation was not achieved for all wells. Several of the wells in the Earth*fx* CORE Model were assigned based on assumed water demand based on observed land use. Information was not available to update the pumping rates for these wells. Additional discussion on the water demand is provided in the study report.

The GENIVAR Black River Groundwater Model was run with the updated PRMS recharge input and the pumping rates as shown in Table A2-2. The updated water well record database was used as a calibration target. Table A2-1c) presents the calibration statistics for the GENIVAR Black River Groundwater Model with PRMS recharge and Updated Water Taking.

The calibration statistics for groundwater in the GENIVAR Black River Groundwater Model with PRMS recharge and Updated Water Taking are very similar to those obtained for the GENIVAR Black River Groundwater Model with PRMS Recharge.

The simulated baseflows for the two surface water stations on the Black River are shown to decrease in the GENIVAR Black River Groundwater Model with PRMS Recharge and updated water taking. The baseflows are now under predicted by 2-3%.

The updates to the GENIVAR Black River Groundwater Model result in a model that continues to provide a good representation of the groundwater elevations and flow paths within the Black River and Georgina Creeks Subwatersheds. The calibrated model may underestimate baseflow to surface water features under steady-state conditions. The updated GENIVAR Black River Groundwater Model will provide a good ability to evaluate the potential changes that will occur as a result of new scenarios.

4) Adding MODFLOW Drains to Wetlands

The GENIVAR Black River Groundwater Flow Model will be used first to estimate the water budget within the Black River and Georgina Creeks Subwatersheds, and then as the basis of a MODPATH particle tracking analysis to delineate the points of origin of groundwater that discharges in identified ecologically sensitive features. The ecologically sensitive features include streams and wetlands. The Earth*fx* CORE Model was calibrated to allow for flow from streams of all orders of magnitude but does not discretely provide an opportunity for groundwater to discharge throughout other surface water features, such as wetlands. There is potential that particles released from within upland areas would preferentially arrive at the streams within the core of the wetlands and therefore not represent the sources of water within the wetlands.

GENIVAR proposed to address this issue by introducing a MODFLOW drain boundary condition to numerically represent mapped wetland areas. The distribution of proposed drains as they correspond to the wetlands is shown in Figure A2-6. The drain is intended to ensure that groundwater particles would move toward the cells beneath the wetlands but to have minimal effect on the discharge to surface water.

An initial trial drain was assigned to demonstrate that the drains could be added without significantly changing the model calibration. The groundwater calibration in this trial did not change substantially (not presented); however, the initial parameters assigned to the drains resulted in greater disparity between the simulated and observed flows at the two surface water stations. A series of model runs were then carried out with three different drain configurations to evaluate which configuration would produce the least change in the stream baseflow. The drain configuration that provided the least baseflow was then used in the next step.

The GENIVAR Black River Groundwater Model was run with the updated PRMS recharge input, the updated pumping rates, and the drain configuration described above. The updated water well record database was used as a calibration target. This model will now be referred to as the GENIVAR Black River Groundwater Model for use in scenario analysis. Table A2-1d) presents the calibration statistics for the GENIVAR Black River Groundwater Model (i.e. With changes to PRMS Recharge, updated pumping rates and drainage added to represent wetlands).

The calibration statistics for groundwater in the GENIVAR Black River Groundwater Model do not change substantially relative to Table A2-1a, b, or c) with the introduction of the drains. The groundwater elevations in the Oak Ridges Aquifer Complex (ORAC), Thorncliffe Aquifer Complex, and Scarborough Aquifer Complex are illustrated for the Black River Groundwater Model in Figure A2-7 (a, b, c, respectively). Figure A2-8 illustrates the calibration statistics for the GENIVAR Black River Groundwater Model.

The simulated baseflow for the two surface water stations on the Black River are shown to decrease in the GENIVAR Black River Groundwater Model. The baseflows are now under predicted by between 2 and 3%.

Conclusion

The GENIVAR CORE Model was used as a base to develop a representative groundwater flow model for the Black River and Georgina Creeks Subwatersheds. The Black River and Georgina Creeks areas were updated in the GENIVAR CORE Model to consider the recharge as determined by PRMS, updated pumping locations and rates, and to enable groundwater flow to be directed to wetland features via a MODFLOW drain.

The Black River Groundwater Model developed in this process is shown to provide consistent representation of groundwater elevations in the three primary aquifer units and demonstrates an overall calibration statistic for groundwater that is similar to that of the model before modifications were made. Despite the changes, the model continues to simulate the observed groundwater elevations within a satisfactory level of confidence as demonstrated by an NRMSE of less than 10% in the Study Area. The agreement of the simulated and observed groundwater elevations is variable through the model domain. This type of variability is typically observed in regional scale models, particularly where observed groundwater elevation data is collected over many years.

The addition of new pumping wells and changes to the pumping rates within the Black River Groundwater Model creates a situation where the surface water baseflow in the two surface water stations on Black River are simulated to be lower than observed by between 2 and 3%. The observed values also reflect an estimate based on interpretation of stream flow records. This condition is most likely controlled by the parameters assigned to represent the drains in the streams.

The GENIVAR Black River Groundwater Model is therefore suitable for use to carry out the Tier 2 Water Budget and Ecologically Significant Recharge Area analysis within the Black River and Georgina Creeks Subwatersheds

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Table A2-1 - Summary of Calibration Statistics GENIVAR Black River Groundwater Model

a) GENIVAR CORE Model

Model Result	Number of Wells (n)	Mean Error [ME] (m)	Mean Absolute Error [MAE] (m)	Root Mean Squared Error [RMSE] (m)	Normalized Root Mean Squared Error [NRMSE] %
Black River Subwatershed	1467	-1.24	5.28	7.19	6.25%
Georgina Creeks Subwatershed	350	1.26	3.10	4.07	10.34%
Both Subwatersheds	1817	-0.76	4.86	6.71	5.83%
Entire Model	15669	-0.32	7.73	10.71	3.75%

Hydat Station	Average Annual Flow (m^3/s)	Calculated Baseflow (m^3/s)	Simulated Baseflow (m^3/s)	Percent Error
Black River at Baldwin	2.26	1.41	1.53	-8.51%
Black River at Sutton	2.55	1.62	1.69	-4.32%

b) GENIVAR PRMS Recharge Model

Model Result	Number of Wells (n)	Mean Error [ME] (m)	Mean Absolute Error [AME] (m)	Root Mean Squared Error [RMSE] (m)	Normalized Root Mean Squared Error [NRMSE] %
Black River Subwatershed	1467	-0.46	5.57	7.67	6.67%
Georgina Creeks Subwatershed	350	1.22	3.18	4.10	10.43%
Study Area (Both Watersheds	1817	-0.14	5.11	7.12	6.19%
Entire Model	15669	0.29	8.12	11.22	3.92%

Hydat Station	Average Annual Flow (m^3/s)	Calculated Baseflow (m^3/s)	Simulated Baseflow (m^3/s)	Percent Error
Black River at Baldwin	2.26	1.41	1.38	2.13%
Black River at Sutton	2.55	1.62	1.58	2.47%

c) GENIVAR PRMS Recharge with Updated PTTW Rates Model

Model Result	Number of Wells (n)	Mean Error [ME] (m)	Mean Absolute Error [AME] (m)	Root Mean Squared Error [RMSE] (m)	Normalized Root Mean Squared Error [NRMSE] %
Black River Subwatershed	3917	-0.85	5.33	7.75	4.32%
Georgina Creeks Subwatershed	1301	0.64	4.01	5.62	9.48%
Study Area (Both Watersheds	5218	-0.16	4.97	7.31	4.07%
Entire Model	21431	-0.48	5.00	7.28	4.06%

Hydat Station	Average Annual Flow (m^3/s)	Calculated Baseflow (m^3/s)	Simulated Baseflow (m^3/s)	Percent Error
Black River at Baldwin	2.26	1.41	1.39	1.63%
Black River at Sutton	2.55	1.62	1.58	2.69%

d) GENIVAR Black River Model

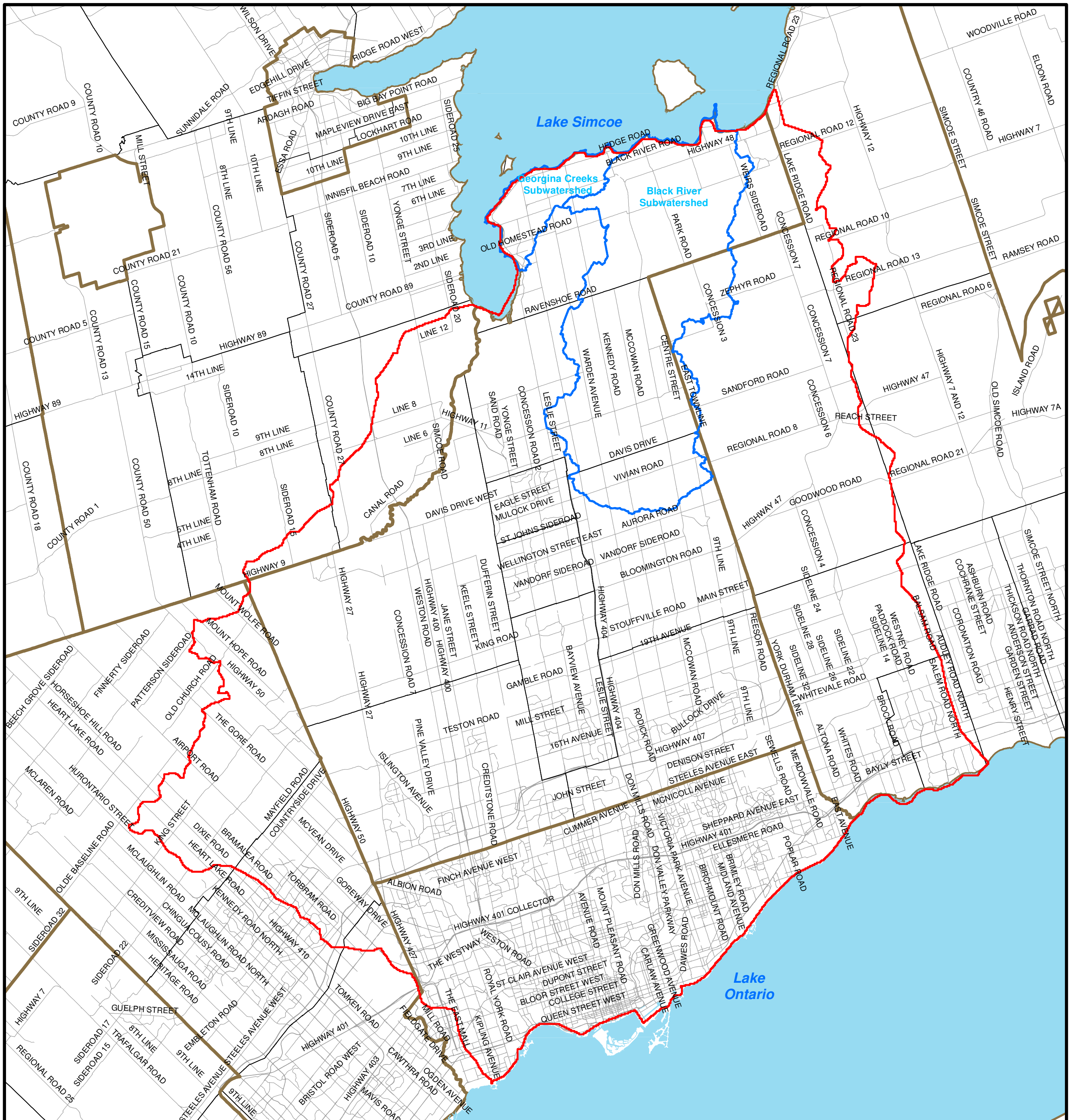
Model Result	Number of Wells (n)	Mean Error [ME] (m)	Mean Absolute Error [AME] (m)	Root Mean Squared Error [RMSE] (m)	Normalized Root Mean Squared Error [NRMSE] %
Black River Subwatershed	3917	-0.83	5.32	7.75	4.32%
Georgina Creeks Subwatershed	1301	0.66	4.01	5.61	9.48%
Study Area (Both Watersheds	5218	-0.46	4.99	7.27	4.05%
Entire Model	21431	0.11	7.52	10.58	3.70%

Hydat Station	Average Annual Flow (m^3/s)	Calculated Baseflow (m^3/s)	Simulated Baseflow (m^3/s)	Percent Error
Black River at Baldwin	2.26	1.41	1.38	1.99%
Black River at Sutton	2.55	1.62	1.57	2.98%

Table A2-2 Water Takings and Permits to Take Water in the Black River and Georgina Creeks Subwatershed

Status	Well ID	PTTW Number	Easting	Northing	Model Layer	Earth*fx* CORE Model Pumping Rate (m^3/s)	Pumping Rate Used in GENIVAR Black River Model (m^3/s)	Specific Purpose
Wells in EarthFX Core Model that are unmodified	N/A	N/A	629750	4883150	5	0.00031	0.00031	N/A
	N/A	N/A	626750	4907850	7	0.00154	0.00154	N/A
	N/A	N/A	633950	4886050	5	0.00910	0.00910	N/A
	N/A	N/A	629250	4894150	3	0.00062	0.00062	N/A
	N/A	N/A	628150	4904950	3	0.00059	0.00059	N/A
	N/A	N/A	634050	4888950	5	0.00025	0.00025	N/A
	N/A	N/A	634550	4891350	3	0.00040	0.00040	N/A
	N/A	N/A	635950	4901450	7	0.00058	0.00058	N/A
	N/A	N/A	632450	4882950	5	0.00042	0.00042	N/A
	N/A	N/A	628350	4888750	5	0.00119	0.00119	N/A
	N/A	N/A	623350	4902150	5	0.00032	0.00032	N/A
	N/A	N/A	637550	4883750	3	0.00034	0.00034	N/A
	N/A	N/A	631550	4891450	7	0.00027	0.00027	N/A
	N/A	N/A	631850	4880950	5	0.00094	0.00094	N/A
	N/A	N/A	629550	4891050	5	0.00058	0.00058	N/A
Wells in EarthFX Core model that were CHANGED	12 and 13	0050-7FCMMY	635250	4887650	5	0.01043	0.00723	Municipal
	307	2005-6TYPT6	627050	4883850	3	0.00154	0.00081	Golf Course Irrigation
	717	5520-6E2NFA	629750	4882950	5	0.00230	0.00058	Golf Course Irrigation
	715 and 716 combined	5520-6E2NFA	630250	4883150	5	0.00231	0.00688	Golf Course Irrigation
	234	1416-7AEQ2L	634050	4886050	3	0.01000	0.00009	Aquaculture
	236	1416-7AEQ2L	634650	4885850	5	0.00682	0.00005	Aquaculture
	235 and 237	1416-7AEQ2L	634150	4886150	3	0.00910	0.00021	Aquaculture
	304	2005-6TYPT6	627350	4883650	3	0.00115	0.00081	Golf Course Irrigation
Wells ADDED to Model	263	1580-744HUV	621550	4901850	3	N/A	0.00932	Golf Course Irrigation
	871	6834-699PX9	626850	4907650	5	N/A	0.00023	Golf Course Irrigation
	623	4435-7C2SFV	639050	4908550	5	N/A	0.00210	Other - Agricultural
	874	6838-6VCMLC	635550	4894550	3	N/A	0.00013	Sod Farm
	343	2344-7FNRMT	628350	4893650	5	N/A	0.00041	Field and Pasture Crops
	344	2344-7FNRMT	628150	4893450	3	N/A	0.00332	Field and Pasture Crops
	1016	8327-6Z3TD2	632250	4887550	5	N/A	0.01121	Field and Pasture Crops
	718	5520-6E2NFA	630650	4883550	3	N/A	0.00031	Golf Course Irrigation
	14	0050-7FCMMY	635950	4886250	5	N/A	0.00389	Municipal

Note: N/A - Information Not Available in Earth*fx* CORE Model Documentation
Well ID was provided in the Permit To Take Water information as supplied by Lake Simcoe Region Conservation Authority



LEGEND

- Core Model Domain
- Subwatersheds
- Waterbodies
- Upper Tier Municipal Boundaries
- Lower Tier Municipal Boundaries
- Roads

N
W E
S

4,000 2,000 0 4,000 Metres

Data Source: Ministry of Natural Resources,
Ontario Base Mapping, June 2012, LSRCA, 2012.

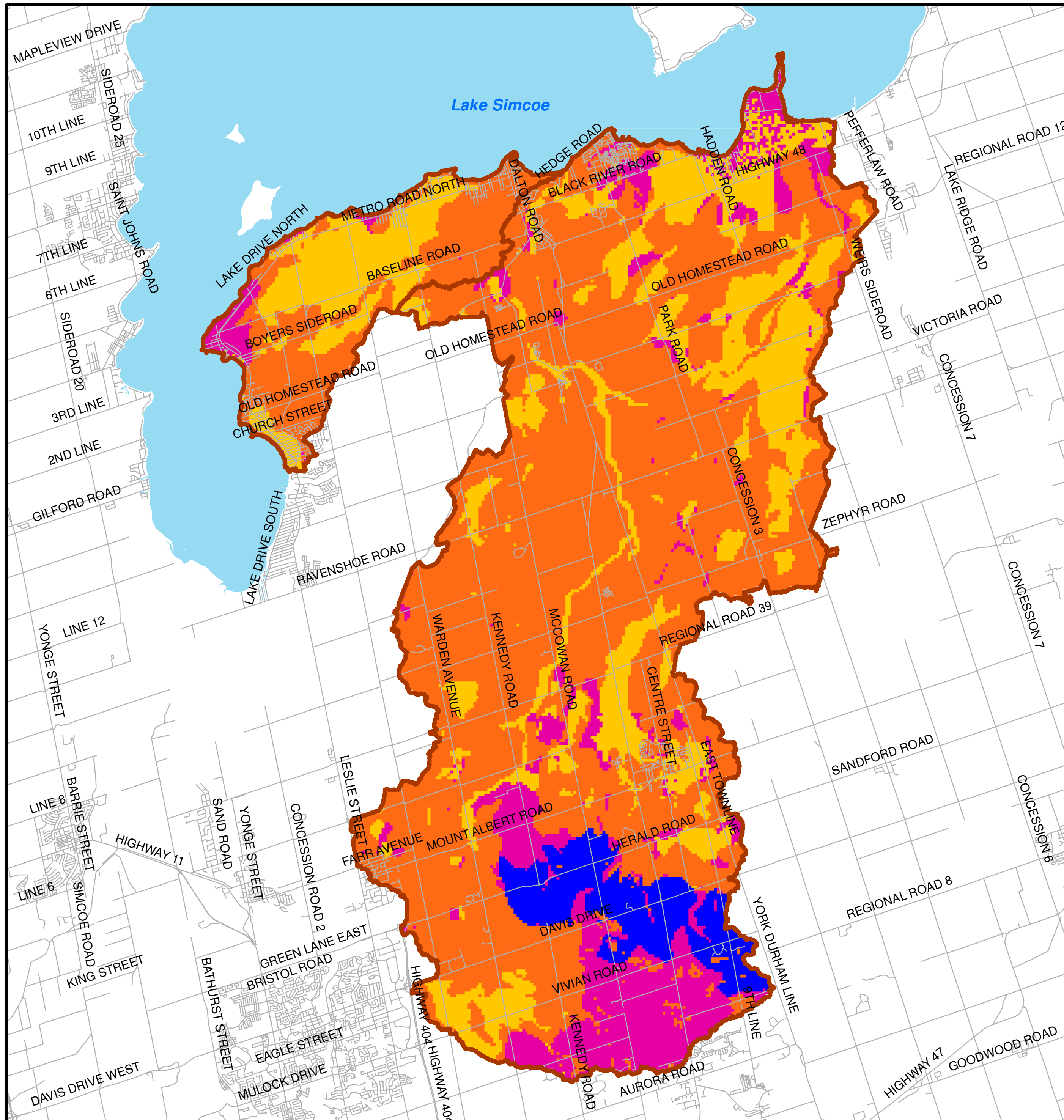
CORE MODEL DOMAIN

CALIBRATION OF GENIVAR BLACK RIVER MODEL
TIER 2 WATER BUDGET AND
ESGRA FOR THE BLACK RIVER AND
GEORGINA CREEKS SUBWATERSHEDS
For: Lake Simcoe Region Conservation Authority

DATE: JANUARY 2013	SCALE: 1:500000
PROJECT: 121-17211-00	FILE. NO.:1211721100FA2-1

GENIVAR

FIGURE
A2-1



LEGEND

Core Model Recharge

- 0 - 100 mm/yr
- 100 - 200 mm/yr
- 200 - 300 mm/yr
- 300 - 400 mm/yr
- 400+ mm/yr
- Roads
- Subwatershed Boundaries

Data Source: Ministry of Natural Resources, Ontario Base Mapping, June 2012, LSRCA, 2012.

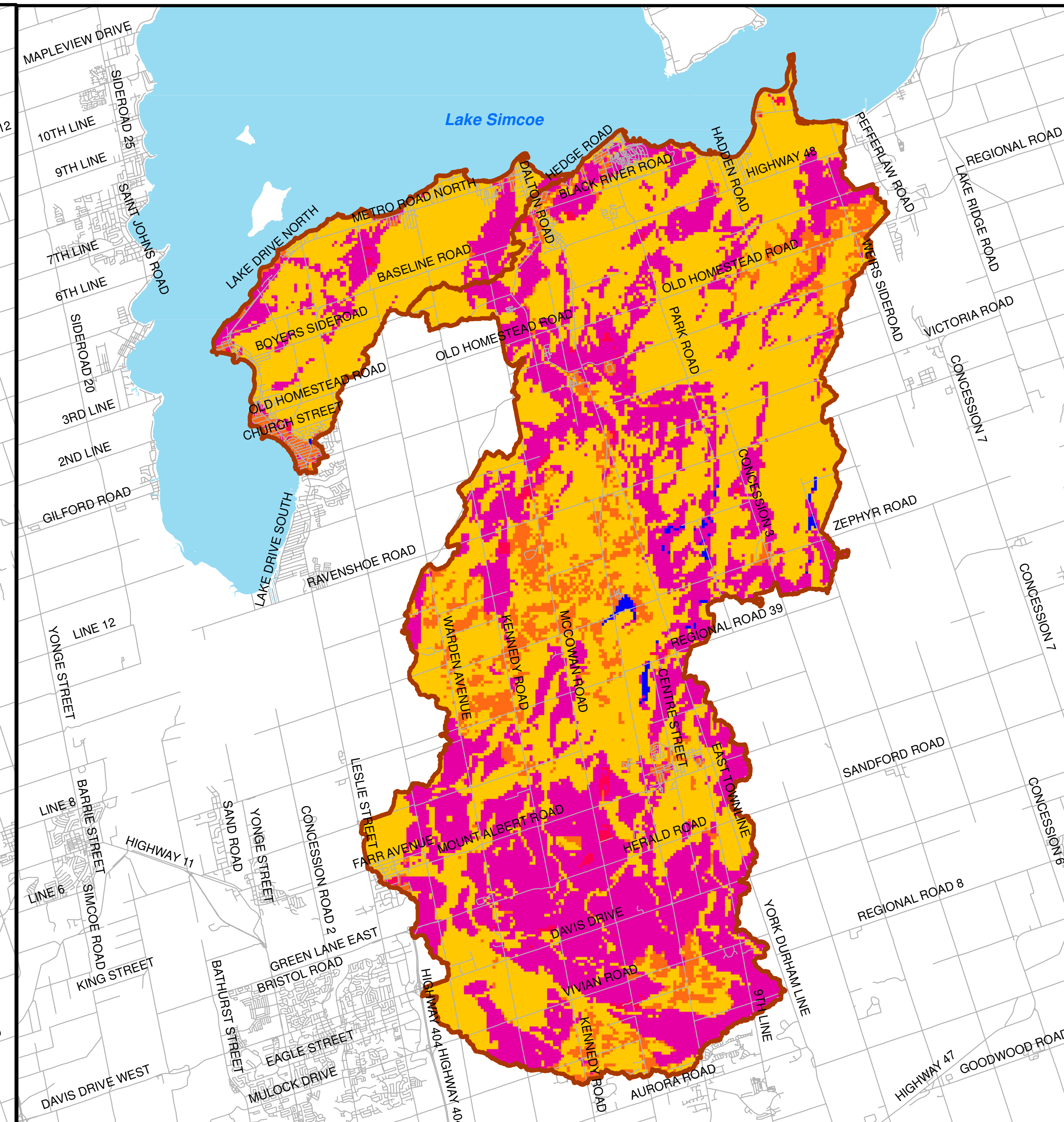
2,000 1,000 0 2,000 Metres

RECHARGE DISTRIBUTIONS - CORE MODEL

CALIBRATION OF GENIVAR BLACK RIVER MODEL
TIER 2 WATER BUDGET AND
ESGRA FOR THE BLACK RIVER AND
GEORGINA CREEKS SUBWATERSHEDS
For: Lake Simcoe Region Conservation Authority

DATE: JANUARY 2013	SCALE: 1:200000
PROJECT: 121-17211-00	FILE. NO.: 1211721100FA2-2

GENIVAR — FIGURE **A2-2**



LEGEND

PRMS Model Recharge

- 0 - 100 mm/yr
- 100 - 200 mm/yr
- 200 - 300 mm/yr
- 300 - 400 mm/yr
- 400+ mm/yr
- Roads
- Subwatershed Boundaries

Data Source: Ministry of Natural Resources, Ontario Base Mapping, June 2012, LSRCA, 2012. Earthfx, 2012

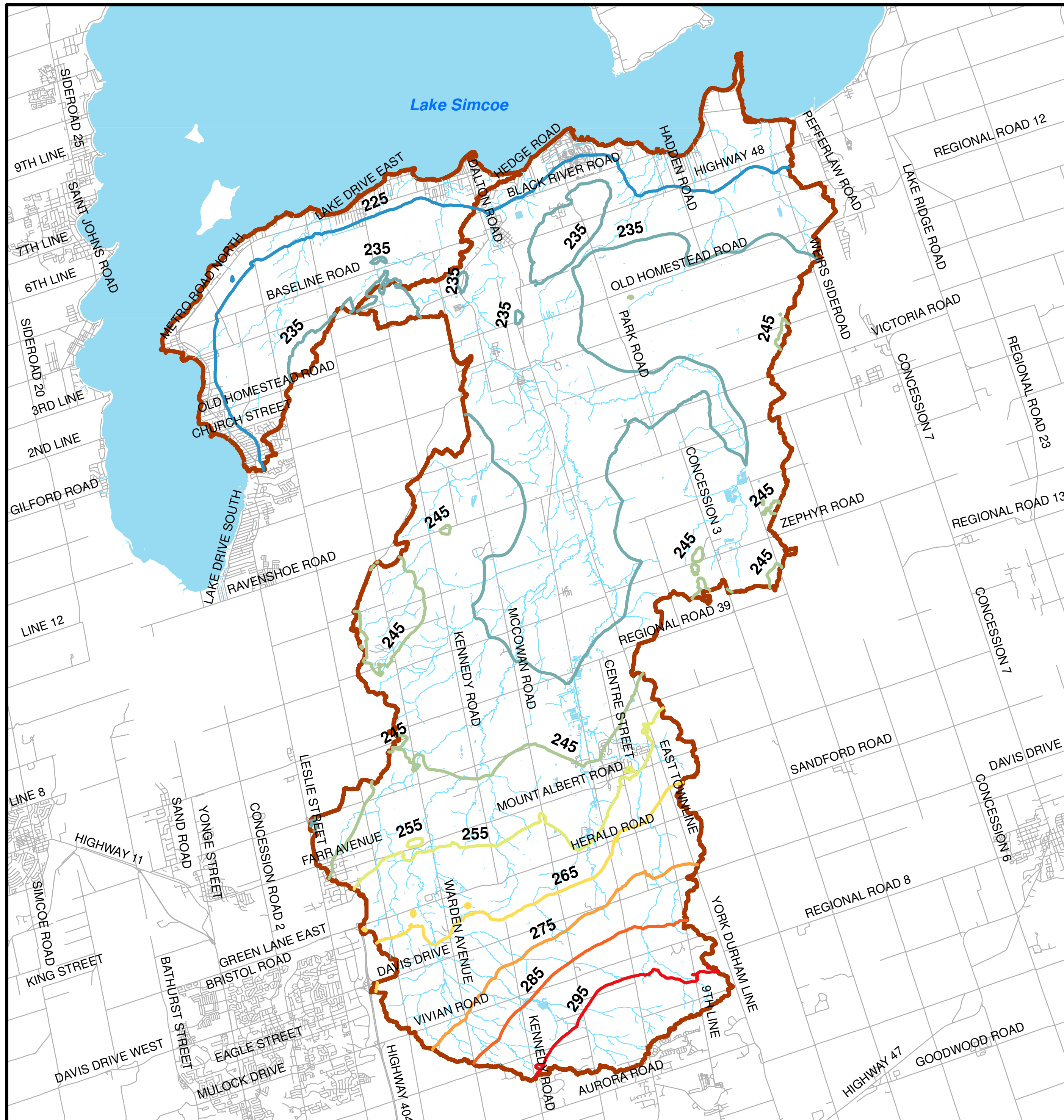
2,000 1,000 0 2,000 Metres

RECHARGE DISTRIBUTIONS - PRMS MODEL

CALIBRATION OF GENIVAR BLACK RIVER MODEL
TIER 2 WATER BUDGET AND
ESGRA FOR THE BLACK RIVER AND
GEORGINA CREEKS SUBWATERSHEDS
For: Lake Simcoe Region Conservation Authority

DATE: JANUARY 2013	SCALE: 1:200000
PROJECT: 121-17211-00	FILE. NO.: 1211721100FA2-2

GENIVAR — FIGURE **A2-2**



LEGEND

Elevation

- 225 (mASL)
- 235 (mASL)
- 245 (mASL)
- 255 (mASL)
- 265 (mASL)
- 275 (mASL)
- 285 (mASL)
- 295 (mASL)
- Roads
- Watercourse
- Waterbodies
- Subwatershed Boundaries

Data Source: Ministry of Natural Resources, Ontario Base Mapping, June 2012. LSRCA, 2012.

2,000 1,000 0 2,000 Metres

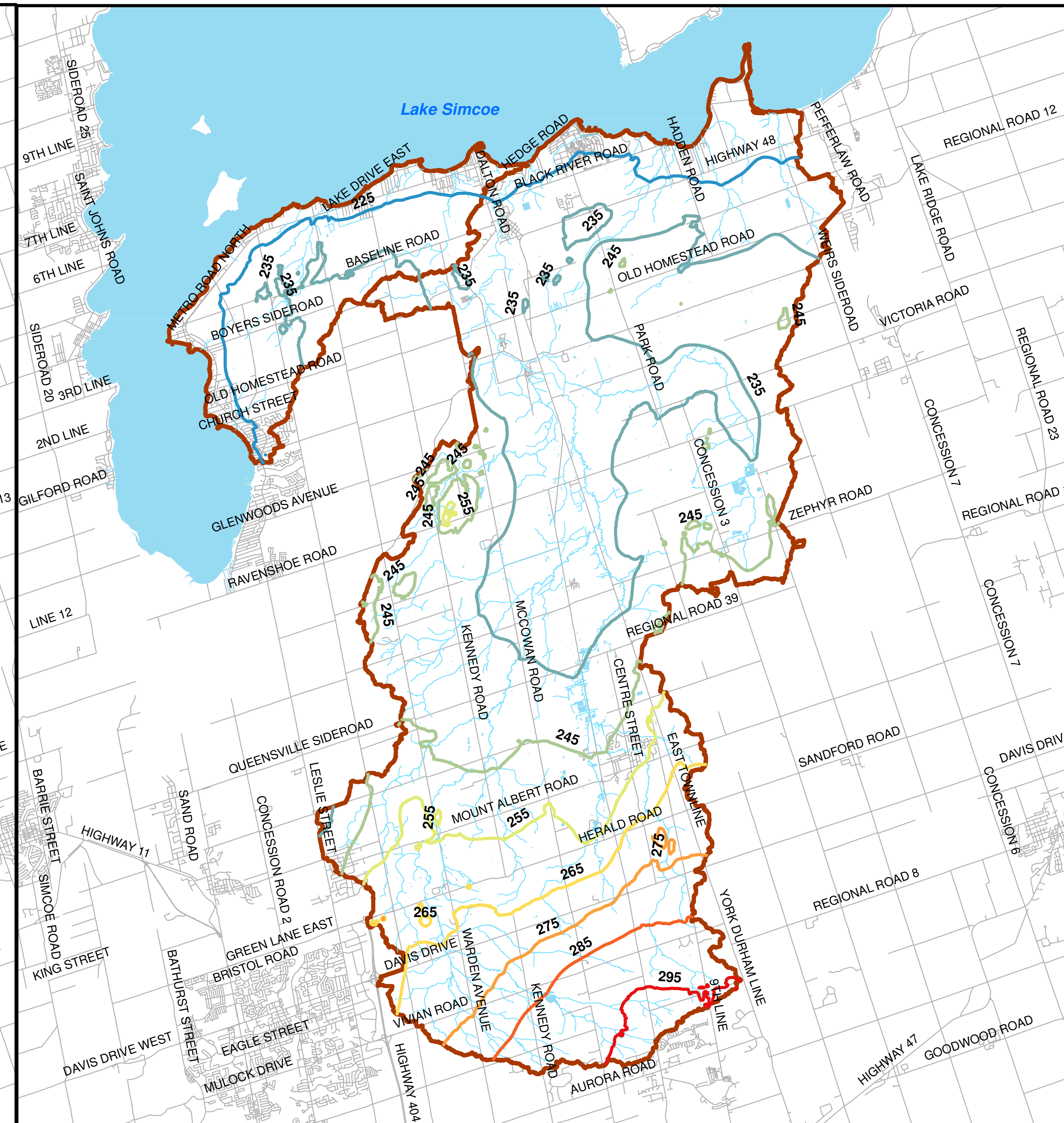
ORAC GROUNDWATER FLOW PATTERNS - CORE MODEL

CALIBRATION OF GENIVAR BLACK RIVER MODEL
TIER 2 WATER BUDGET AND
ESGRA FOR THE BLACK RIVER AND
GEORGINA CREEKS SUBWATERSHEDS
For: Lake Simcoe Region Conservation Authority

DATE: JANUARY 2013	SCALE: 1:200000
PROJECT: 121-17211-00	FILE. NO.: 1211721100FA2-3

GENIVAR

FIGURE A2-3



LEGEND

Elevation

- 225 (mASL)
- 235 (mASL)
- 245 (mASL)
- 255 (mASL)
- 265 (mASL)
- 275 (mASL)
- 285 (mASL)
- 295 (mASL)
- Roads
- Watercourse
- Waterbodies
- Subwatershed Boundaries

Data Source: Ministry of Natural Resources, Ontario Base Mapping, June 2012. LSRCA, 2012.

2,000 1,000 0 2,000 Metres

ORAC GROUNDWATER FLOW PATTERNS - PRMS MODEL

CALIBRATION OF GENIVAR BLACK RIVER MODEL
TIER 2 WATER BUDGET AND
ESGRA FOR THE BLACK RIVER AND
GEORGINA CREEKS SUBWATERSHEDS
For: Lake Simcoe Region Conservation Authority

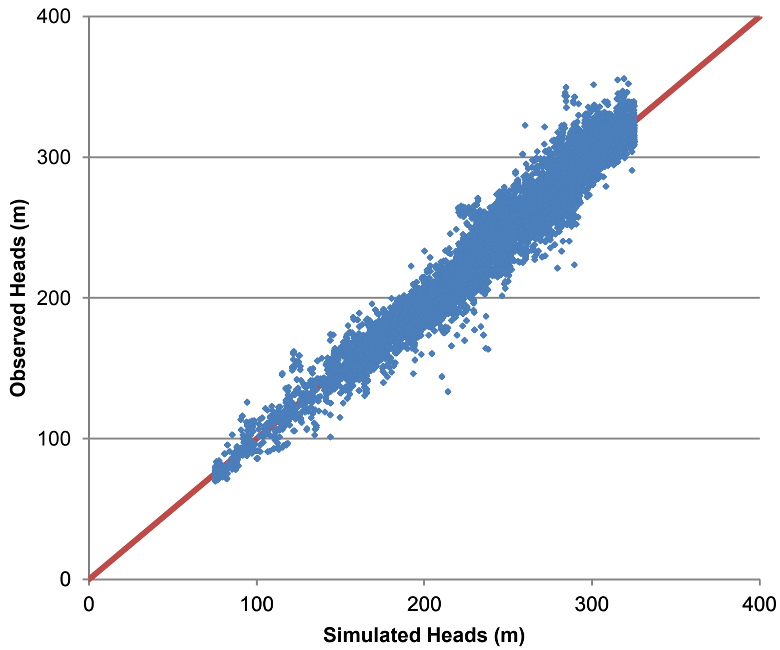
DATE: JANUARY 2013	SCALE: 1:200000
PROJECT: 121-17211-00	FILE. NO.: 1211721100FA2-3

GENIVAR

FIGURE A2-3

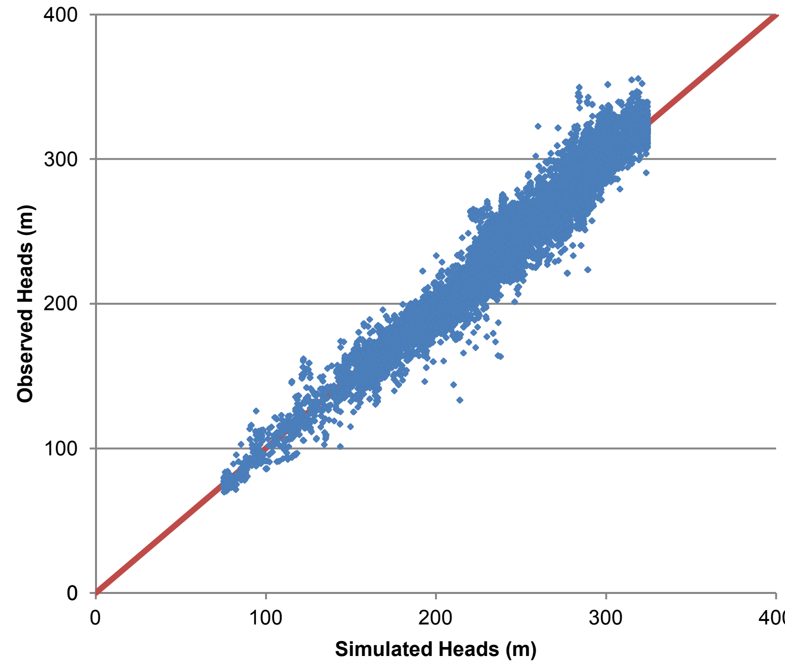
Figure A2-4 Comparison of Calibration Plots - PRMS Recharge Added

GENIVAR CORE Model

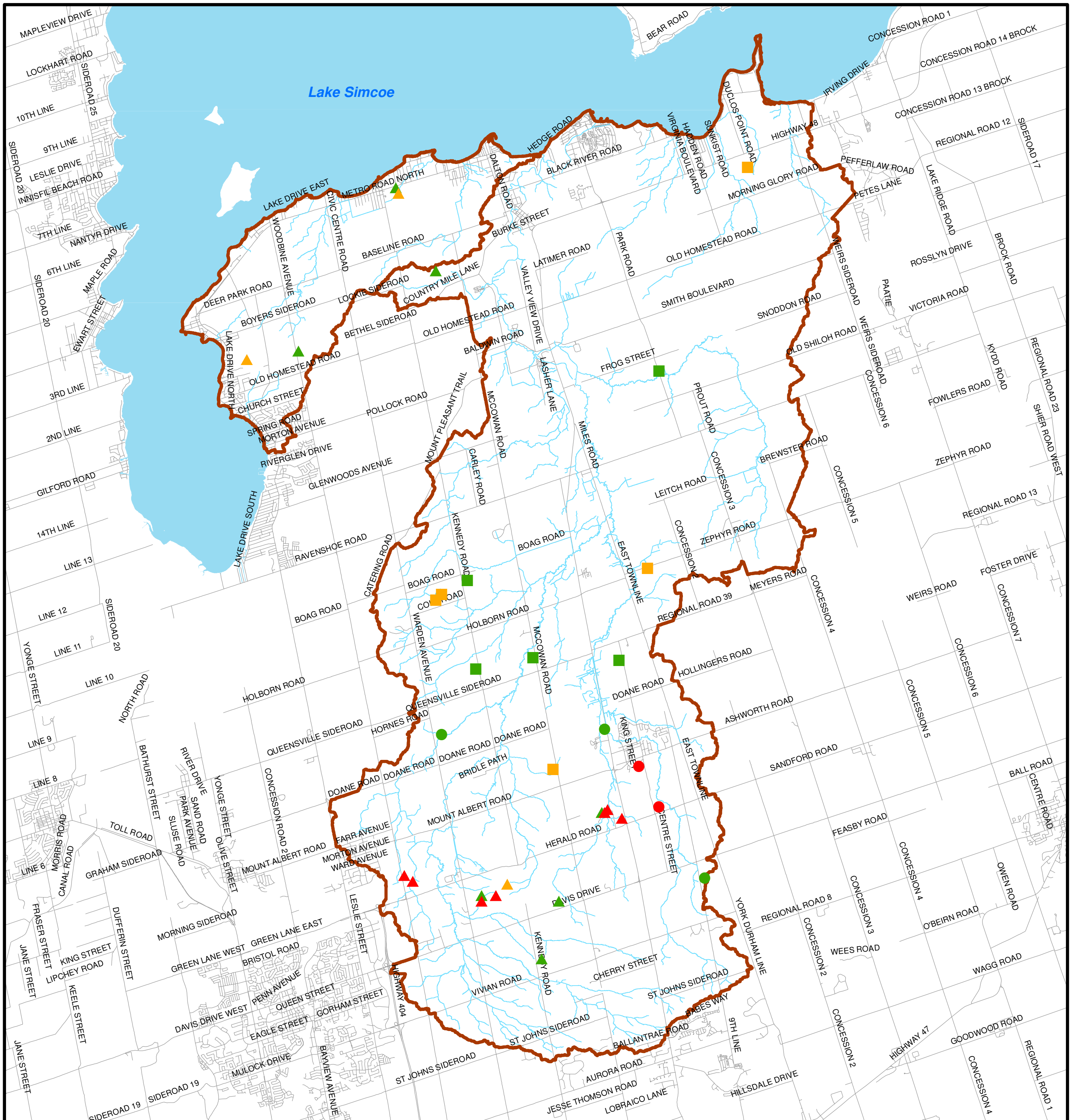


Number of Wells (n)	Mean Error [ME] (m)	Mean Absolute Error [AME] (m)	Root Mean Squared Error [RMSE] (m)	Normalized Root Mean Squared Error [NRMSE] %
15669	-0.32	7.73	10.71	3.75%

GENIVAR PRMS Recharge Model



Number of Wells (n)	Mean Error [ME] (m)	Mean Absolute Error [AME] (m)	Root Mean Squared Error [RMSE] (m)	Normalized Root Mean Squared Error [NRMSE] %
15669	0.29	8.12	11.22	3.92%



LEGEND

- Agricultural - Unchanged Well
- Agricultural - New Well Not in Original Model
- Commercial - Unchanged Well
- Commercial - New Well Not in Original Model
- Commercial - Modified Well (Pumping Well Changed)
- Water Supply - Unchanged Well
- Water Supply - Modified Well (Pumping Well Changed)
- Subwatersheds
- Waterbodies
- Watercourse
- Roads

N W E S

Data Source: Ministry of Natural Resources, Ontario Base Mapping, June 2012. PTTW, Lake Simcoe Regional Conservation Authority.

2,000 1,000 0 2,000 Metres

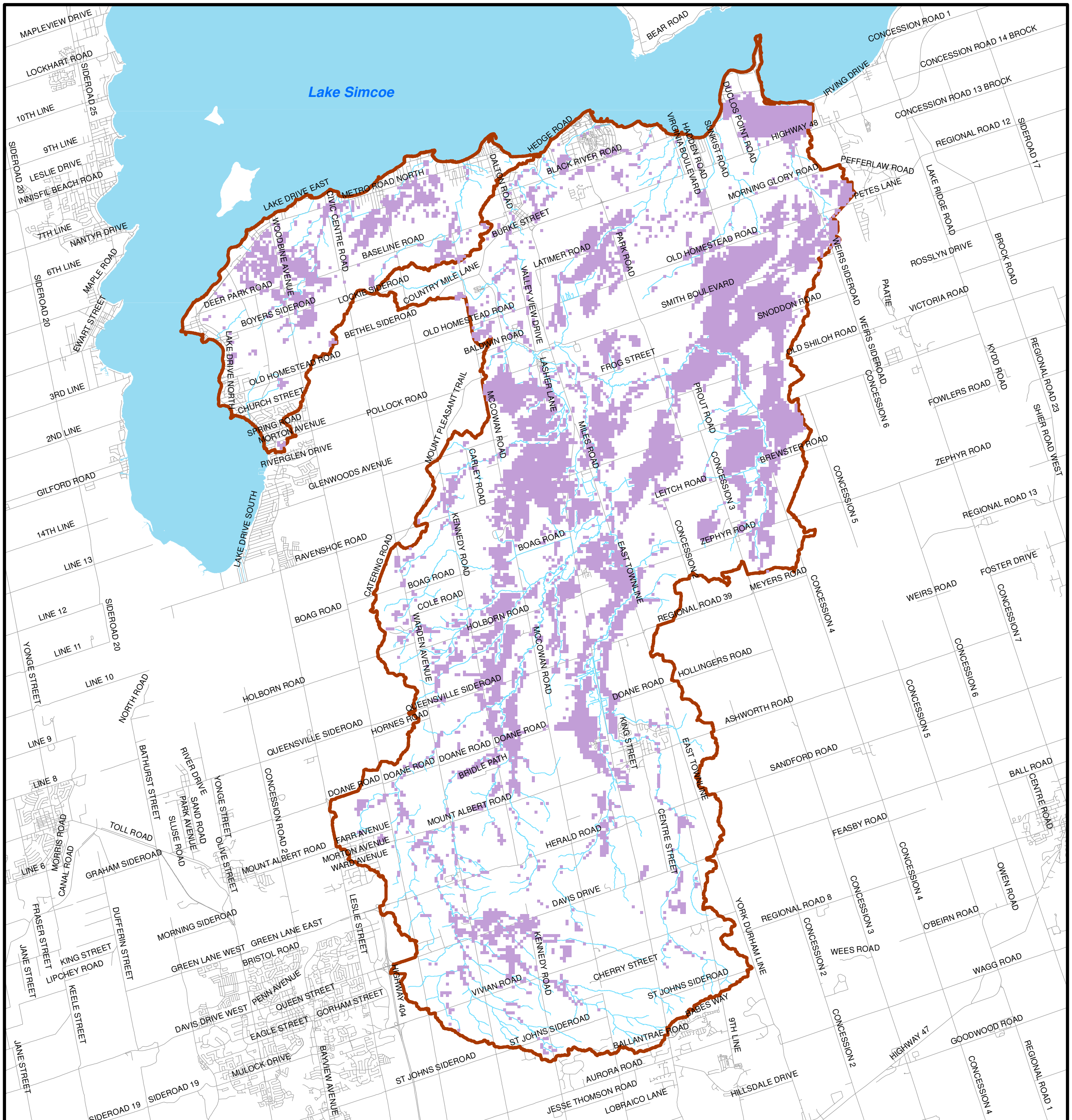
PTTW WELLS

CALIBRATION OF GENIVAR BLACK RIVER MODEL
TIER 2 WATER BUDGET AND
ESGRA FOR THE BLACK RIVER AND
GEORGINA CREEKS SUBWATERSHEDS
For: Lake Simcoe Region Conservation Authority

DATE: JANUARY 2013	SCALE: 1:200000
PROJECT: 121-17211-00	FILE. NO.:1211721100FA2-5

GENIVAR

FIGURE
A2-5



LEGEND

- Wetland Drains
- Subwatersheds
- Waterbodies
- Watercourse
- Roads

Data Source: Ministry of Natural Resources, Ontario Base Mapping, June 2012. LSRCA, 2012.

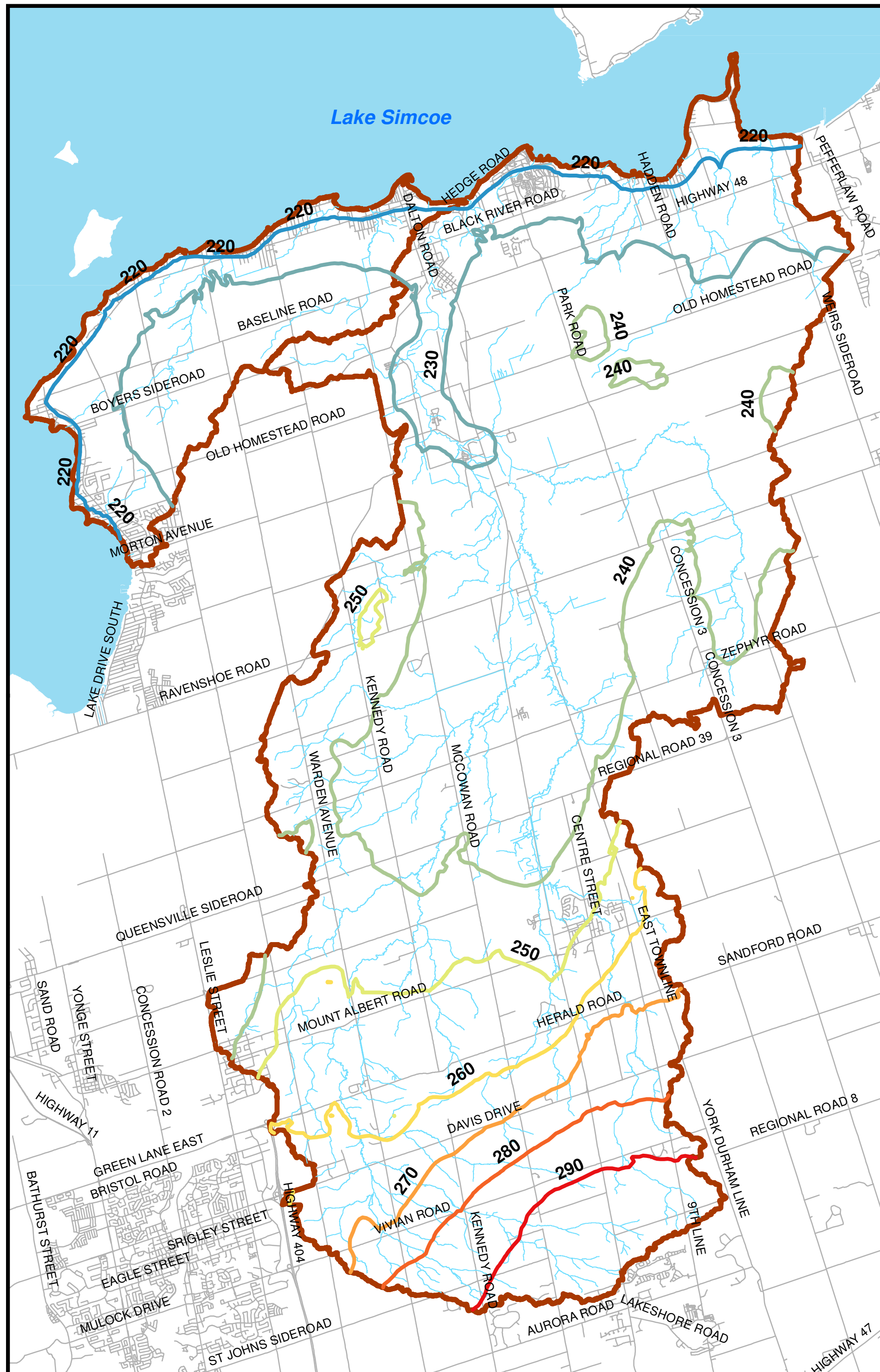
DISTRIBUTION OF WETLAND DRAINS

CALIBRATION OF GENIVAR BLACK RIVER MODEL
TIER 2 WATER BUDGET AND
ESGRA FOR THE BLACK RIVER AND
GEORGINA CREEKS SUBWATERSHEDS
For: Lake Simcoe Region Conservation Authority

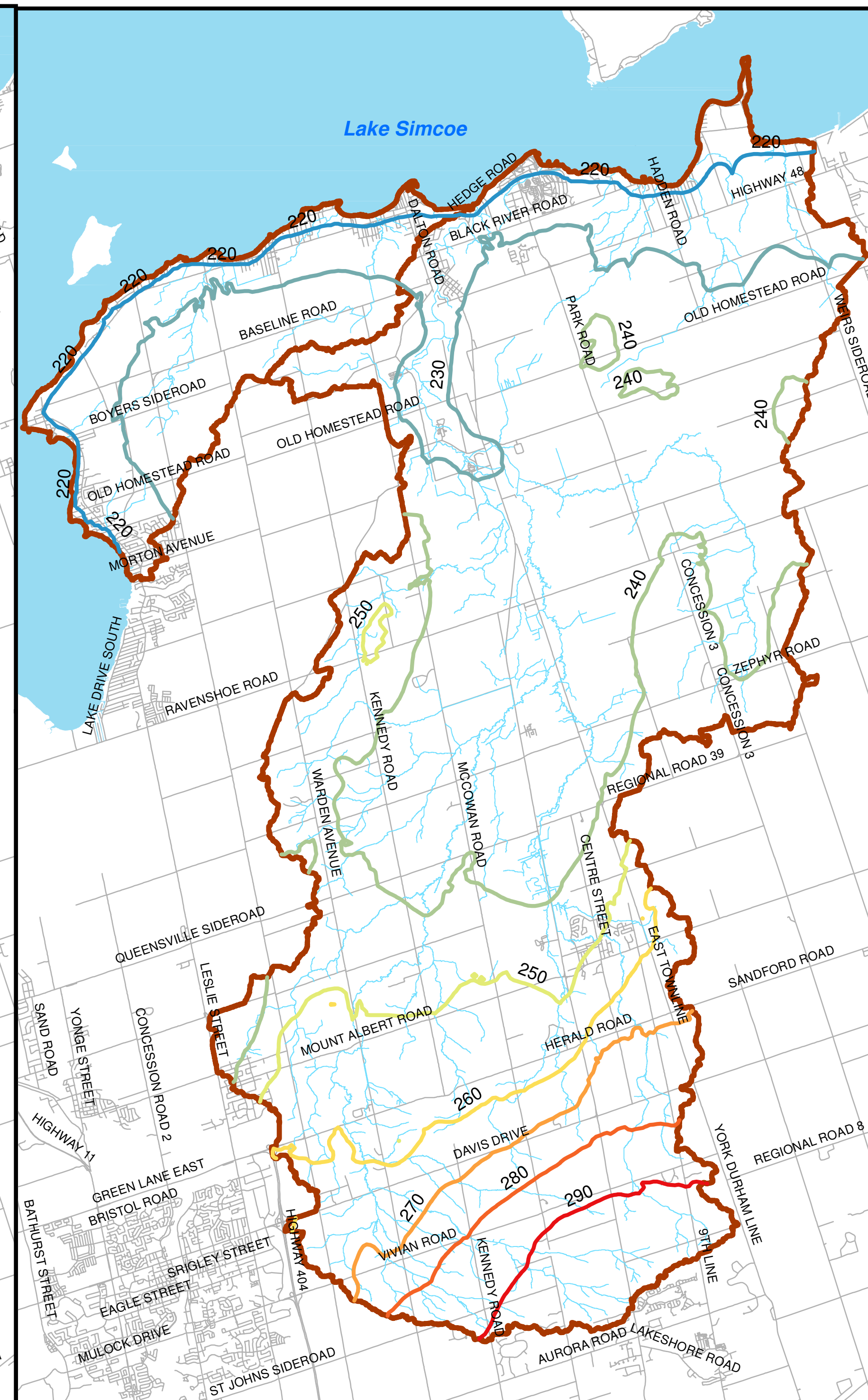
DATE: JANUARY 2013	SCALE: 1:200000
PROJECT: 121-17211-00	FILE. NO.:1211721100FA2-5

GENIVAR

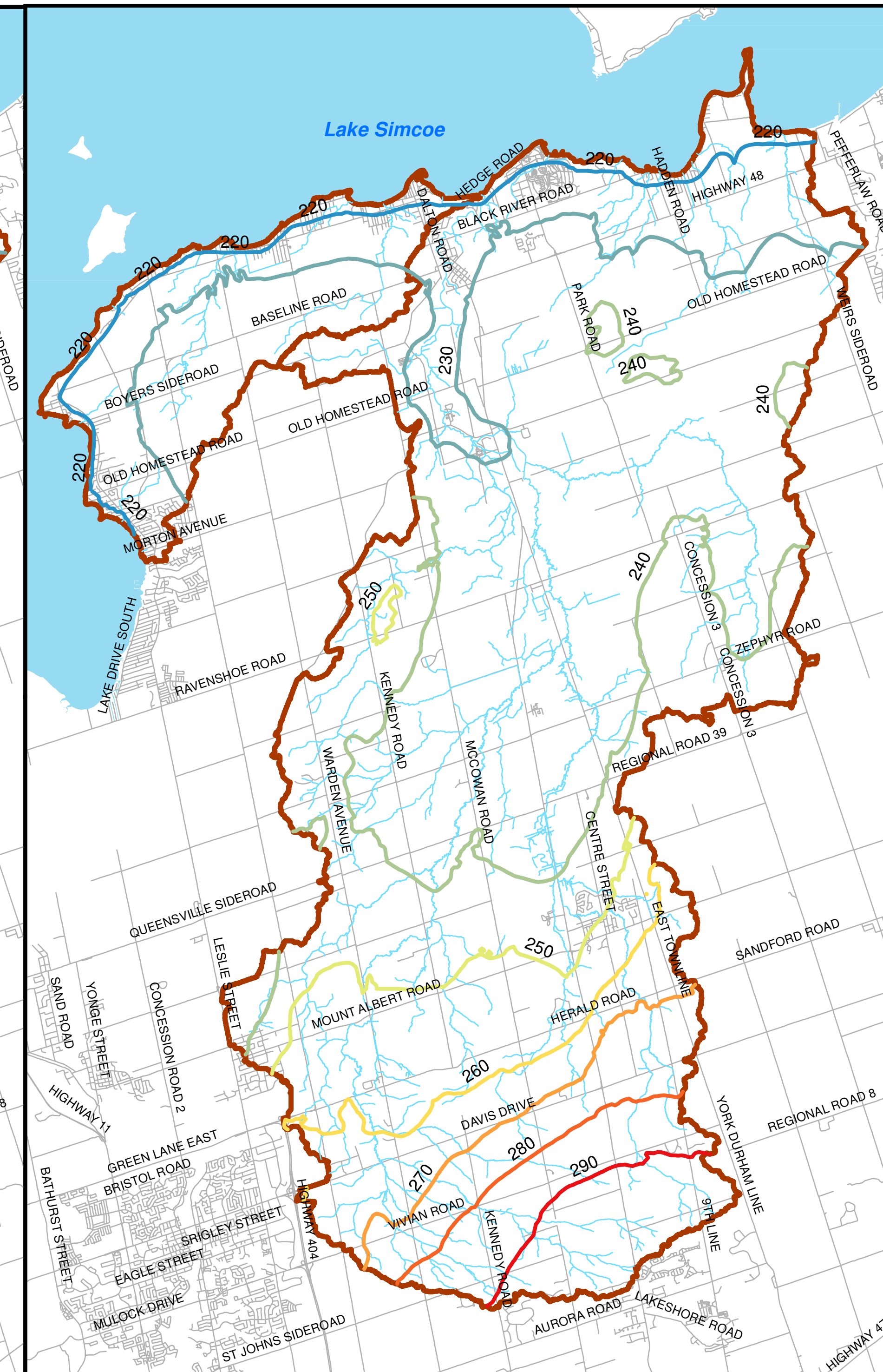
FIGURE **A2-6**



GROUNDWATER FLOW PATTERNS - ORAC



GROUNDWATER FLOW PATTERNS - TAC



GROUNDWATER FLOW PATTERNS - SAC

LEGEND

Contour

- 220 (mASL)
- 230 (mASL)
- 240 (mASL)
- 250 (mASL)
- 260 (mASL)
- 270 (mASL)
- 280 (mASL)
- 290 (mASL)
- Roads
- Watercourse
- Subwatershed Boundaries

Data Source: Ministry of Natural Resources, Ontario Base Mapping, June 2012. LSRCA, 2012.

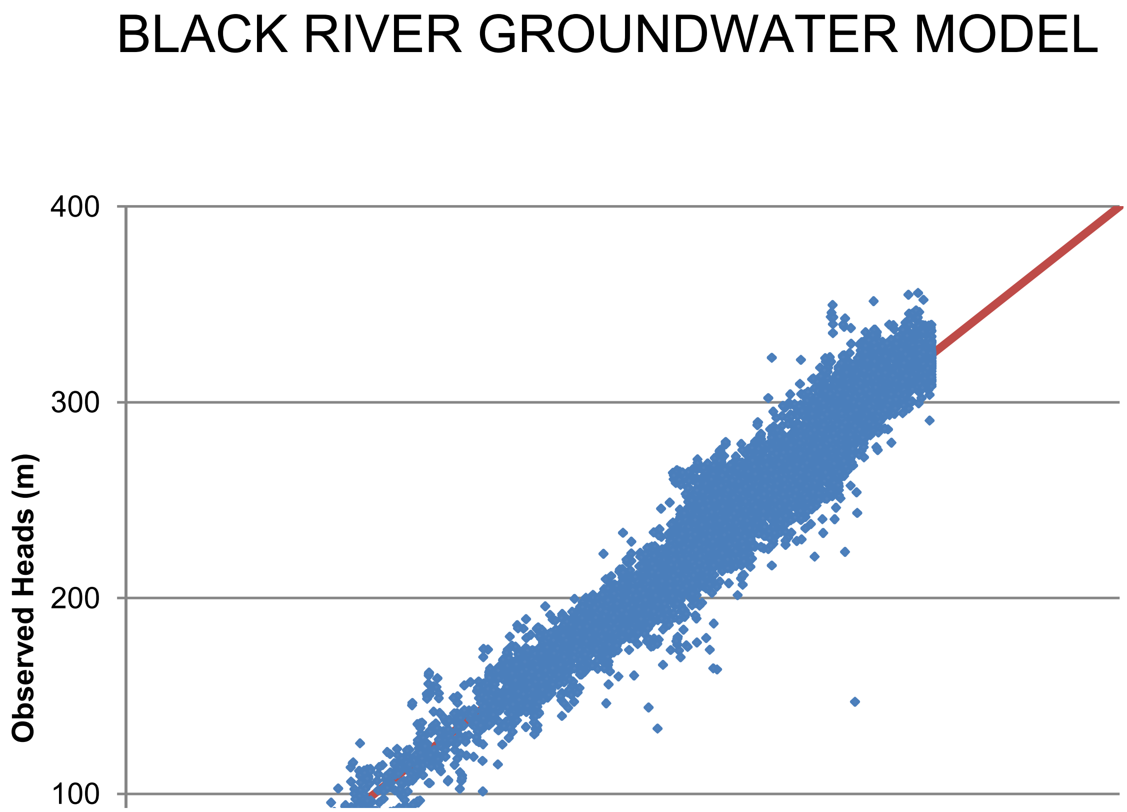
N W E S

2,000 1,000 0 2,000 Metres

CALIBRATION OF GENIVAR BLACK RIVER MODEL
TIER 2 WATER BUDGET AND
ESGRA FOR THE BLACK RIVER AND
GEORGINA CREEKS SUBWATERSHEDS
For: Lake Simcoe Region Conservation Authority

DATE: FEBRUARY 2013	SCALE: 1:200000
PROJECT: 121-17211-00	FILE. NO.: 1211721100FA2-7
GENIVAR	FIGURE A2-7

Figure A2-8 Calibration Statistics - Black River Groundwater Model



Number of Wells (n)	Mean Error [ME] (m)	Mean Absolute Error [AME] (m)	Root Mean Squared Error [RMSE] (m)	Normalized Root Mean Squared Error [NRMSE] %
21431	0.11	7.52	10.58	3.70%

Technical Memorandum A3

PRMS Model

GENIVAR

TECHNICAL MEMORANDUM A3

Date:	January 24, 2013
To	Shelly Cuddy, Lake Simcoe Region Conservation Authority
Copy:	Katie Howson, LSRCA Scott Bates, Ministry of Natural Resources (MNR)
From:	Lloyd Lemon and Isabelle Hemmings
Project No.:	121-17211-00
Subject:	Tier 2 Water Budget and ESGRA for Black River and Georgina Creeks Subwatersheds PRMS Model

This memo documents the work performed by GENIVAR to assess and utilize the Precipitation-Runoff Modelling System (PRMS) model for the Lake Simcoe Watershed as created by Earth*fx* Inc. (*Water Balance Analysis for the Lake Simcoe Basin using the Precipitation-Runoff Modelling System (PRMS) (2010).* This model will be referred to as the Lake Simcoe PRMS Model. The domain of the Lake Simcoe PRMS Model is provided in Figure A3-1.

GENIVAR carried out the following tasks using the Lake Simcoe PRMS Model:

1) Confirmed that the Lake Simcoe PRMS Model could be operated to reproduce previous results and confirm that simulations could be performed involving changes of time-frames, precipitation inputs or land use inputs.
2) Evaluated the ability to isolate the Black River and Georgina Creeks Subwatersheds within the Lake Simcoe PRMS Model
3) Evaluated the data gaps that limit the use of the Lake Simcoe PRMS Model in the Tier 2 Water Budget and Significant Groundwater Recharge Area Analysis.
4) Applied the Lake Simcoe PRMS Model to generate updated distributed recharge inputs on a monthly basis to correspond to temporal time-steps for the two-year drought scenario analysis.

1) Confirm Functionality of the Lake Simcoe PRMS Model

GENIVAR was provided access to a working version of the Lake Simcoe PRMS Model for use in this study only. The model domain encompasses the entire Lake Simcoe Basin and model runs are relatively time-consuming. The existing Lake Simcoe PRMS Model for the Lake Simcoe Watershed covers a time frame from October 1975 – September 2002, inclusive. GENIVAR has been able to modify the time frame within this time period and carry out a scenario analysis (e.g. run October 2000 – September 2002). GENIVAR was able to generate and review the model outputs in terms of stream flow, baseflow and recharge distribution. GENIVAR was able to see where input layers for land use or impervious surfaces can be updated for specific scenario analysis on the scale of the Lake Simcoe Watershed. Specific scenarios were not attempted.

2) Evaluate Ability to Isolate the Black River and Georgina Creeks Subwatersheds

GENIVAR investigated the ability to isolate the Black River and Georgina Creeks Subwatersheds from the Lake Simcoe PRMS Model to reduce the physical size of the model and the run-time but were unable to achieve results that are consistent with those reported by Earth*fx*. The full Lake Simcoe PRMS Model was thus used to carry out analysis required in this project.

NEWMARKET 1091 Gorham Street, Suite 301, Newmarket, ON L3Y 8X7 Tel.: (905) 853-3303 Fax: (905) 853-1759

3) Data Gaps and Limitations

The Lake Simcoe PRMS Model was reviewed and is considered to have the following data gaps in terms of the Black River-Georgina Creeks Subwatersheds:

- → The Lake Simcoe PRMS Model does not use the latest period of record for monitoring data in the Black River and Georgina Creeks Subwatersheds. The watershed-scale model was calibrated to reflect the longest period of record available for all watersheds.
- → The Black River and Georgina Creeks Subwatersheds cannot be readily isolated from the Lake Simcoe PRMS Model and applied to replicate the existing results. Although model conditions within the Black River and Georgina Creeks Subwatersheds can be changed in the Lake Simcoe PRMS Model, it is beyond the scope of this study to confirm that these changes would continue to result in a valid model for the rest of the Lake Simcoe watershed.
- → The Lake Simcoe PRMS Model is based on a relatively sparse data set within the Black River and Georgina Creeks Areas. There is some data available to provide base flow estimates but only two stations (both on Black River) provide long-term continuous flow monitoring.
- → The PRMS model code was modified to calculate certain parameters differently due to a paucity of data in the Lake Simcoe area. For example, the Hargreaves model was implemented by Earth*fx* to calculate PET because there was not enough solar radiation data available to cover the full model period. Input parameter entry was modified to be done only through VIEWLOG (TM) grid files for many of the parameters, including land use, slope, and vegetation coverage, among others.

The existing Lake Simcoe PRMS Model provides a useful tool for evaluating the distribution of recharge within the Black River and Georgina Creeks Subwatersheds and for estimating flow within the Black River and Georgina Creeks system.

4) Scenario Analysis – Monthly Recharge Inputs

The output from the Lake Simcoe PRMS Model was used to create the recharge inputs to the GENIVAR Black River Groundwater Model. The average annual distributed recharge as determined by Earth*fx* (2010) were used as the recharge input layer to the GENIVAR Black River Groundwater Model for steady-state analysis.

The Lake Simcoe PRMS Model was used to generate new monthly recharge surfaces for use in the temporal analysis of the two-year low recharge scenario. The climate records for the period between 1975 and 2002 for the Black River Subwatershed were reviewed to identify the two consecutive years with the lowest annual rainfall. The two consecutive years with the lowest annual rainfall were 1997 and 1998. The PRMS model was then run using monthly time-steps for this two-year period to generate data for monthly recharge input for temporal analysis using the Black River Groundwater Model.

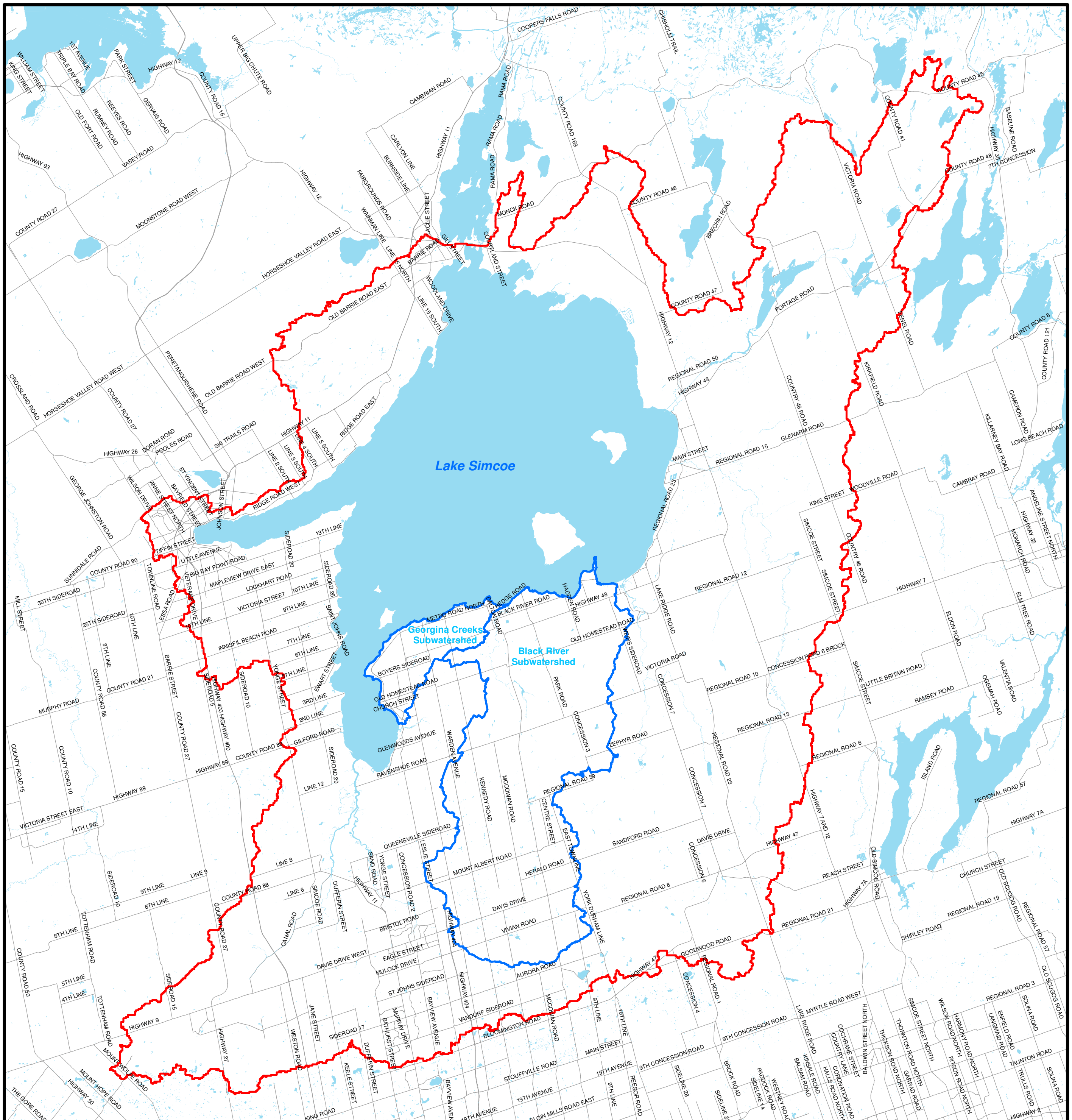
LAL:nah

List of Tables

List of Figures

Table A3-1 Average Monthly Recharge By Subwatershed

	Average Monthly Recharge (mm/year)		
	Black River Subwatershed	Georgina Creeks Subwatershed	Entire Study Area
January 1997	18.09	14.44	17.66
February 1997	23.43	14.25	22.37
March 1997	39.62	21.33	37.50
April 1997	31.66	24.51	30.83
May 1997	12.29	13.15	12.39
June 1997	0.11	0.06	0.10
July 1997	0.00	0.02	0.00
August 1997	0.30	0.33	0.30
September 1997	0.00	0.04	0.01
October 1997	0.74	1.23	0.79
November 1997	8.57	7.42	8.44
December 1997	6.75	4.74	6.51
January 1998	23.95	14.81	22.89
February 1998	23.29	20.78	23.00
March 1998	46.55	46.37	46.53
April 1998	6.19	6.05	6.17
May 1998	0.09	0.12	0.09
June 1998	0.11	0.05	0.11
July 1998	0.00	0.00	0.00
August 1998	0.22	0.14	0.21
September 1998	0.00	0.01	0.00
October 1998	0.00	0.00	0.00
November 1998	0.23	0.58	0.27
December 1998	8.45	6.52	8.23



LEGEND

- Model Domain
- Subwatersheds
- Waterbodies
- Roads

N
W E
S

Data Source: Ministry of Natural Resources, Ontario Base Mapping, June 2012.

4,000 2,000 0 4,000 Metres

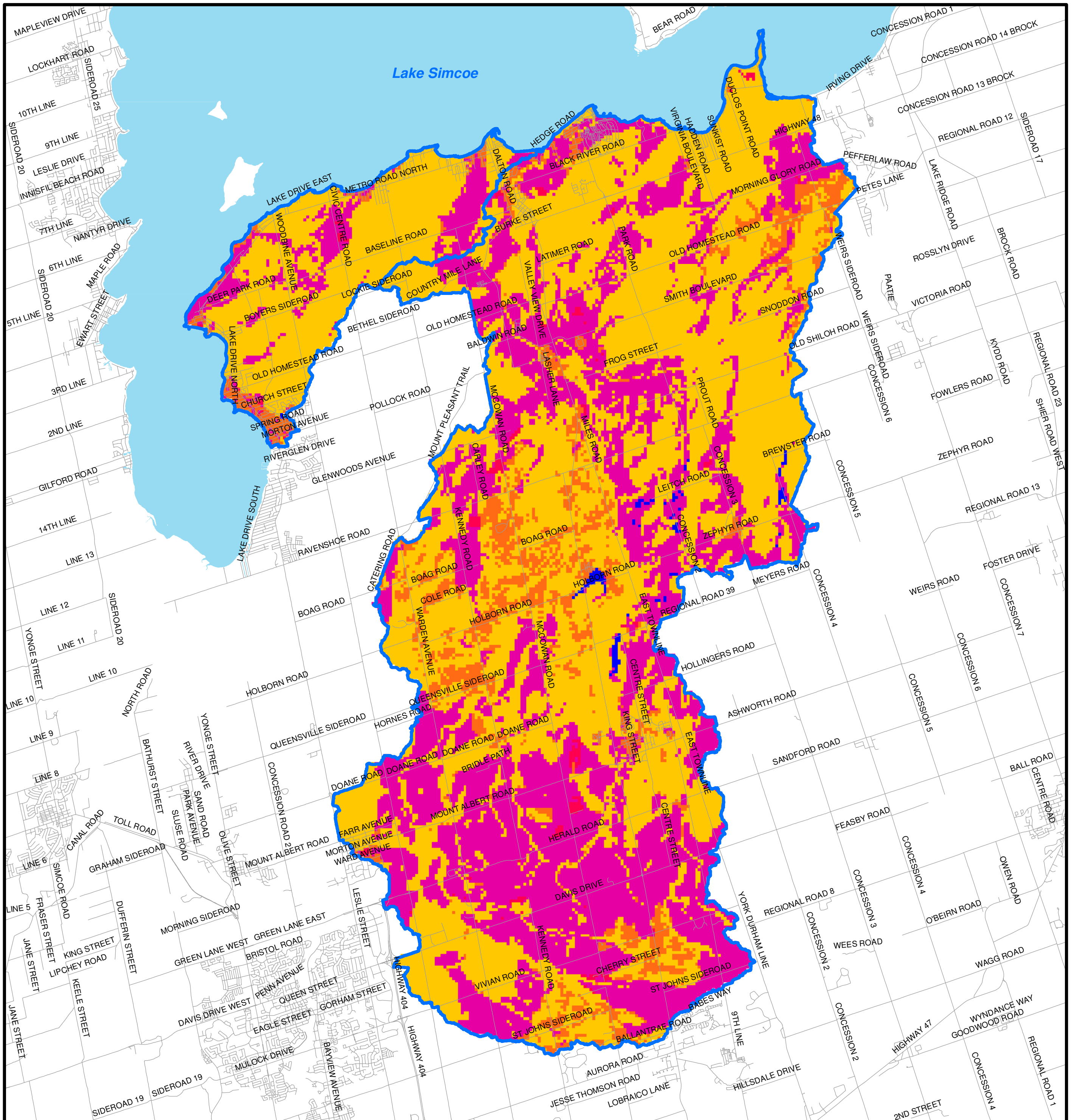
MODEL DOMAIN AND STUDY AREA

PRMS MODEL
TIER 2 WATER BUDGET AND
ESGRA FOR THE BLACK RIVER AND
GEORGINA CREEKS SUBWATERSHEDS
For: Lake Simcoe Region Conservation Authority

DATE: JANUARY 2013	SCALE: 1:500000
PROJECT: 121-17211-00	FILE. NO.:1211721100FA3-1

GENIVAR

FIGURE
A3-1



LEGEND

- 0 - 100 mm/yr
- 100 - 200 mm/yr
- 200 - 300 mm/yr
- 300 - 400 mm/yr
- 400+ mm/yr
- Subwatersheds
- Waterbodies
- Roads

N
W E
S

2,000 1,000 0 2,000 Metres

Data Source: Ministry of Natural Resources, Ontario Base Mapping, June 2012.

PRMS RECHARGE

PRMS MODEL
TIER 2 WATER BUDGET AND
ESGRA FOR THE BLACK RIVER AND
GEORGINA CREEKS SUBWATERSHEDS
For: Lake Simcoe Region Conservation Authority

DATE: JANUARY 2013	SCALE: 1:200000
PROJECT: 121-17211-00	FILE. NO.:1211721100FA3-2

GENIVAR

FIGURE **A3-2**

Appendix B

Tier 2 Water Budget

Appendix B1

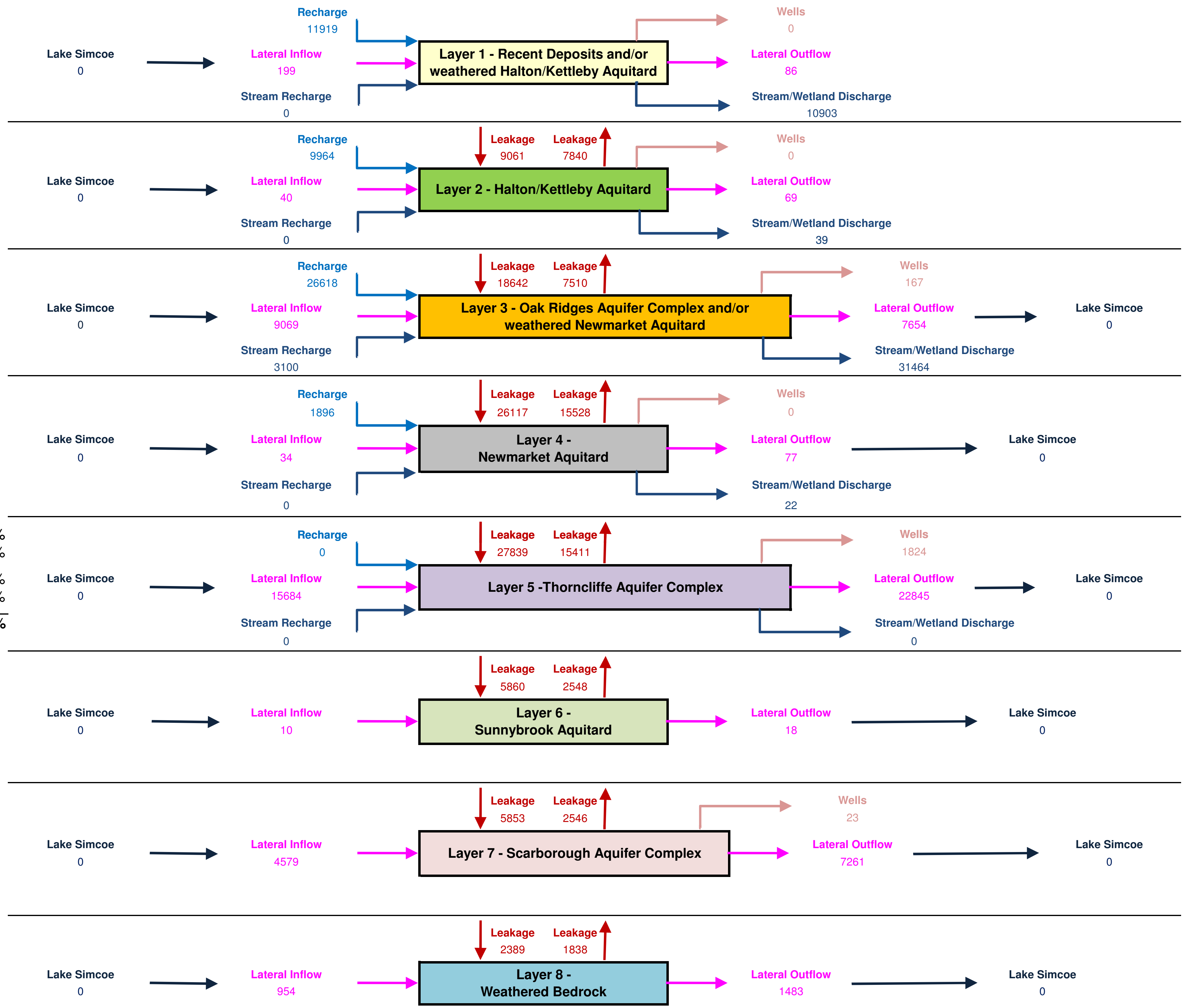
Water Budget Results by Subwatershed – Existing Water Demand

Table B1-1 Water Balance (Existing Conditions)

Item	Units	Black River Subsubwatershed 1		Black River Subsubwatershed 2		Black River Subsubwatershed 3		Black River Subsubwatershed 4		Black River Subsubwatershed 5		Black River Subsubwatershed 6		Georgina Creeks Subwatershed		Total Study Area	
		Value	**%**	**Value**	**%**	**Value**	**%**	**Value**	**%**	**Value**	**%**	**Value**	**%**	**Value**	**%**	**Value**	**%**
Subwatershed Area	km^2	99		87		47		63		26		53		49		425	
	m^2	98,856,175		87,265,386		46,992,839		63,004,675		26,326,812		52,915,189		49,333,000		424,694,077	
Water Budget																	
Inputs:																	
Recharge	m^3/day	50,397	59.9%	44,509	50.6%	14,578	74.8%	20,345	77.8%	12,116	73.6%	16,537	87.8%	14,373	73.5%	172,855	79.9%
Stream Recharge	m^3/day	3,100	3.7%	1,187	1.3%	0	0.0%	48	0.2%	217	1.3%	56	0.3%	-	0.0%	4,607	2.1%
Lateral Inflow (Adjacent)	m^3/day	30,568	36.4%	42,328	48.1%	4,924	25.2%	5,748	22.0%	4,133	25.1%	2,242	11.9%	5,174	26.5%	38,781	17.9%
Lake Simcoe Inflow	m^3/day	-	0.0%	-	0.0%	-	0.0%	-	0.0%	-	0.0%	-	0.0%	0	0.0%	0	0.0%
Total Input	**m^3/day**	**84,065**	**100.0%**	**88,024**	**100.0%**	**19,503**	**100.0%**	**26,141**	**100.0%**	**16,466**	**100.0%**	**18,834**	**100.0%**	**19,547**	**100.0%**	**216,242**	**100.0%**
Outputs:																	
Discharge to Stream	m^3/day	42,428	50.5%	54,059	61.4%	11,028	56.6%	19,847	76.0%	11,747	70.9%	12,366	65.6%	3,098	15.9%	154,573	71.5%
Discharge to Lake Simcoe	m^3/day	-	0.0%	-	0.0%	-	0.0%	-	0.0%	672	4.1%	3,561	18.9%	11,731	60.0%	15,964	7.4%
Lateral Outflow (Adjacent)	m^3/day	39,493	47.1%	32,043	36.4%	8,029	41.2%	6,210	23.8%	4,104	24.8%	2,738	14.5%	3,725	19.1%	39,979	18.5%
Wells	m^3/day	2,015	2.4%	1,939	2.2%	426	2.2%	50	0.2%	51	0.3%	181	1.0%	986	5.0%	5,647	2.6%
Total Outflow	**m^3/day**	**83,936**	**100.0%**	**88,040**	**100.0%**	**19,483**	**100.0%**	**26,107**	**100.0%**	**16,574**	**100.0%**	**18,847**	**100.0%**	**19,539**	**100.0%**	**216,163**	**100.0%**

Notes:
1) Values in Table may reflect rounding
2) The lateral inflow for the Total Study Area was obtained directly from the numerical model outputs. The sum of the lateral inputs for the Black River Subwatershed and Georgina Creeks Subwatershed may not equal the value shown for the Study Area.

Figure B1-1 - Water Budget (Groundwater) - Black River SubSubwatershed 1 - Existing Water Demand



All flow volumes expressed as m³/day

Inputs

	m³/day	%
Recharge	50397	60%
Stream Recharge	3100	4%
Wells	0	0%
Lateral Inflow	30568	36%
Total Inputs	**84065**	**100%**

Outputs

	m³/day	%
Stream	42428	51%
Lake Simcoe	0	0%
Wells	2015	2%
Lateral Outflow	39493	47%
Total Outputs	**83936**	**100%**

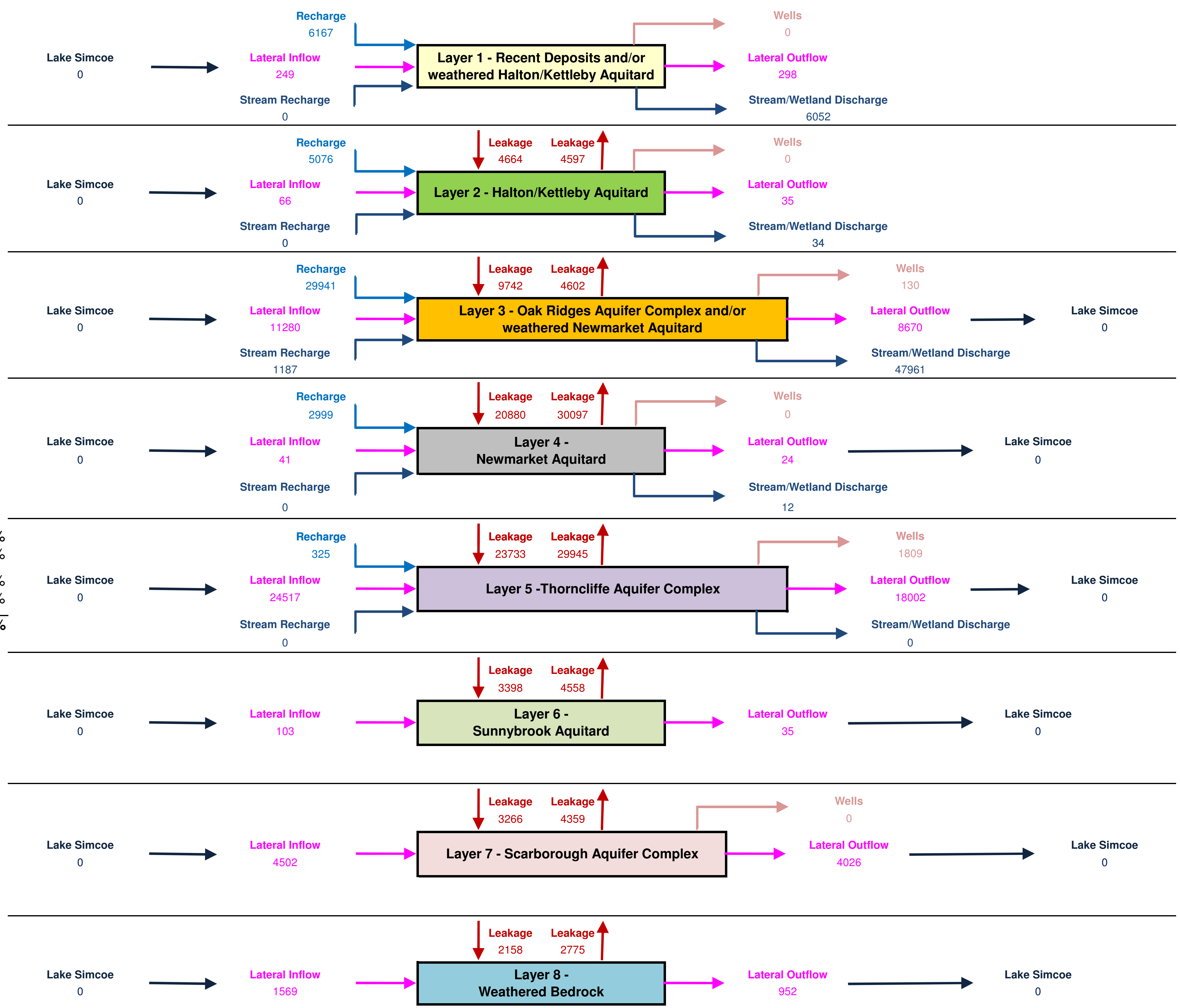
Net Water Balance (In - Out) (%)

0%

Note:

Values presented may reflect rounding. Some minor differences in water budget estimates are expected due to numerical model calculations.

Figure B1-2 - Water Budget (Groundwater) - Black River SubSubwatershed 2 - Existing Water Demand



All flow volumes expressed as m^3/day

Inputs

	m^3/day	%
Recharge	44509	51%
Stream Recharge	1187	1%
Wells	0	0%
Lateral Inflow	42328	48%
Total Inputs	**88024**	**100%**

Outputs

	m^3/day	%
Stream	54059	61%
Lake Simcoe	0	0%
Wells	1939	2%
Lateral Outflow	32043	36%
Total Outputs	**88040**	**100%**

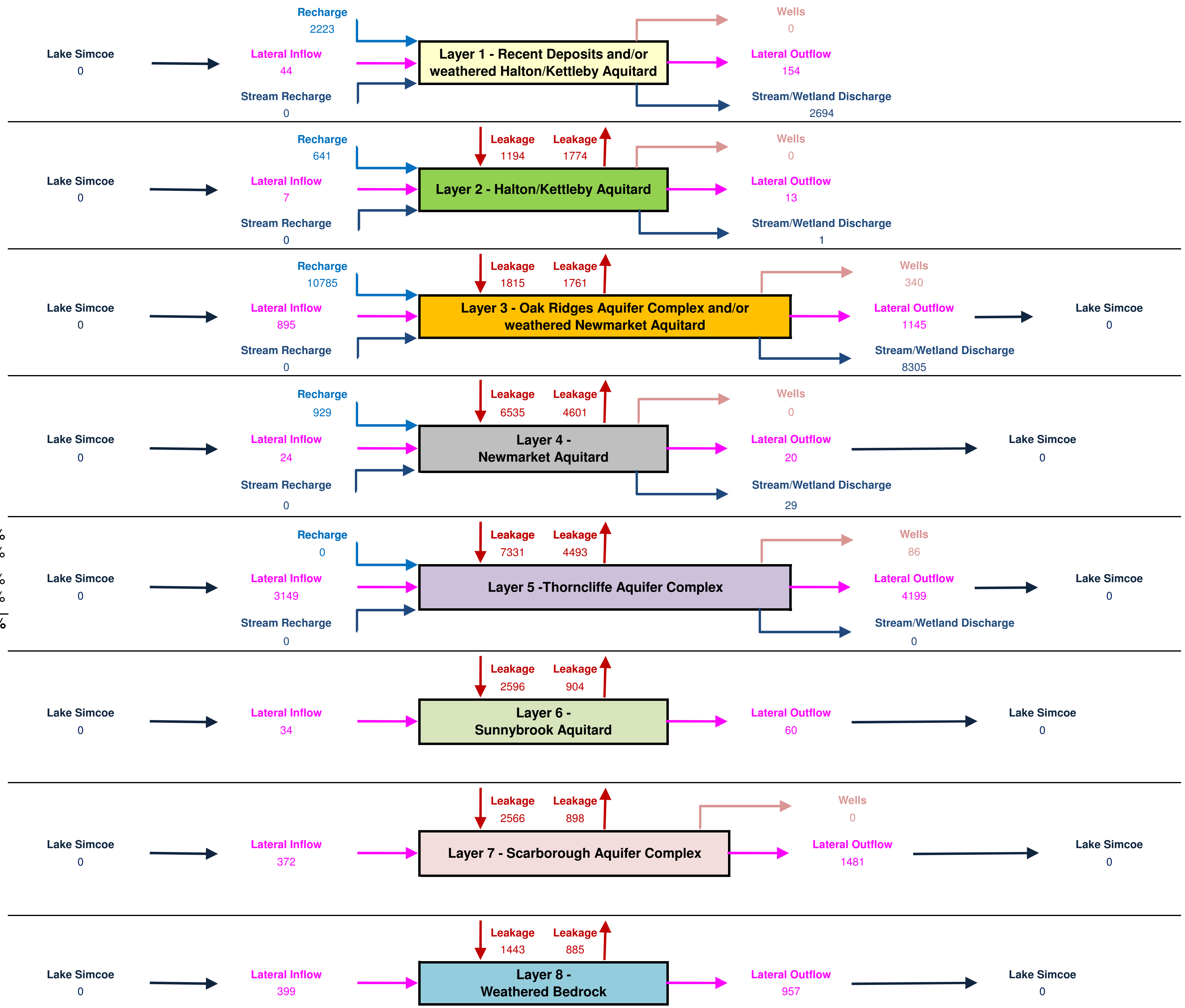
Net Water Balance (In - Out) (%)

0%

Note:

Values presented may reflect rounding. Some minor differences in water budget estimates are expected due to numerical model calculations.

Figure B1-3 - Water Budget (Groundwater) - Black River SubSubwatershed 3 - Existing Water Demand



All flow volumes expressed as m^3/day

Inputs

	m^3/day	%
Recharge	14578	75%
Stream Recharge	0	0%
Wells	0	0%
Lateral Inflow	4924	25%
Total Inputs	**19503**	**100%**

Outputs

	m^3/day	%
Stream	11028	57%
Lake Simcoe	0	0%
Wells	426	2%
Lateral Outflow	8029	41%
Total Outputs	**19483**	**100%**

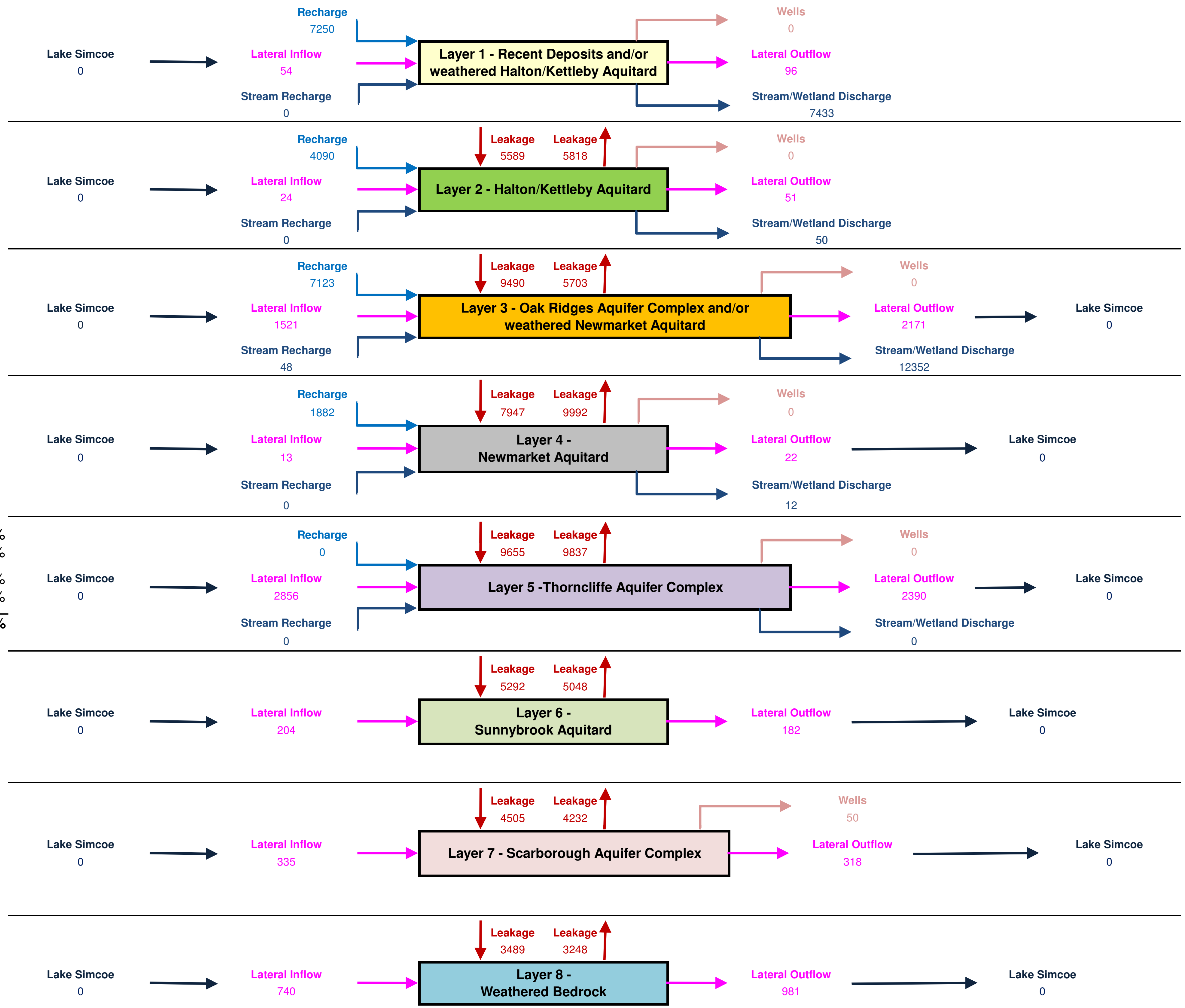
Net Water Balance (In - Out) (%)

0%

Note:

Values presented may reflect rounding. Some minor differences in water budget estimates are expected due to numerical model calculations.

Figure B1-4 - Water Budget (Groundwater) - Black River SubSubwatershed 4 - Existing Water Demand



All flow volumes expressed as m^3/day

Inputs

	m^3/day	%
Recharge	20345	78%
Stream Recharge	48	0%
Wells	0	0%
Lateral Inflow	5748	22%
Total Inputs	**26141**	**100%**

Outputs

	m^3/day	%
Stream	19847	76%
Lake Simcoe	0	0%
Wells	50	0%
Lateral Outflow	6210	24%
Total Outputs	**26107**	**100%**

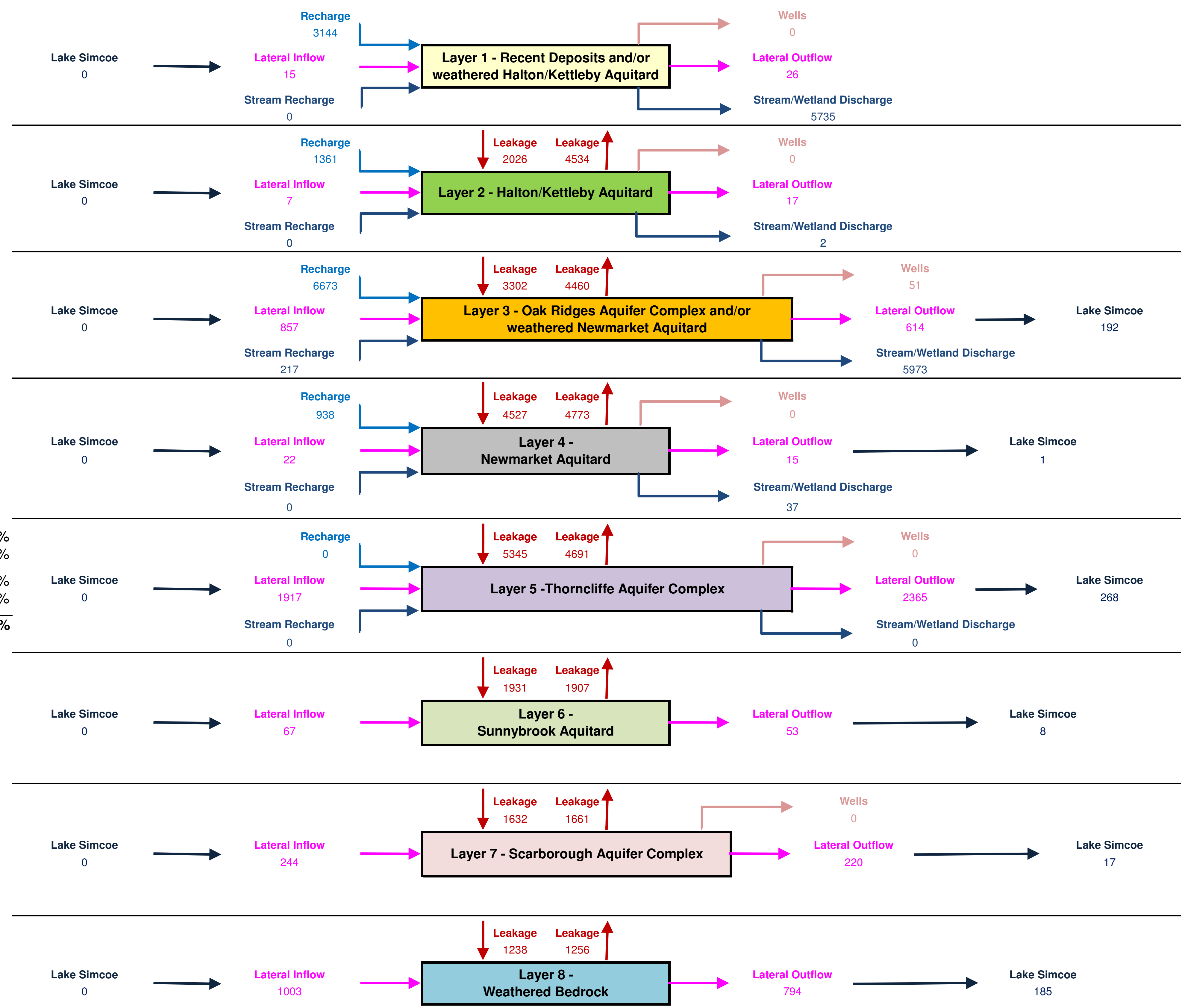
Net Water Balance (In - Out) (%)

0%

Note:

Values presented may reflect rounding. Some minor differences in water budget estimates are expected due to numerical model calculations.

Figure B1-5 - Water Budget (Groundwater) - Black River SubSubwatershed 5 - Existing Water Demand



All flow volumes expressed as m³/day

Inputs

	m³/day	%
Recharge	12116	74%
Stream Recharge	217	1%
Wells	0	0%
Lateral Inflow	4133	25%
Total Inputs	**16466**	**100%**

Outputs

	m³/day	%
Stream	11747	71%
Lake Simcoe	672	4%
Wells	51	0%
Lateral Outflow	4104	25%
Total Outputs	**16574**	**100%**

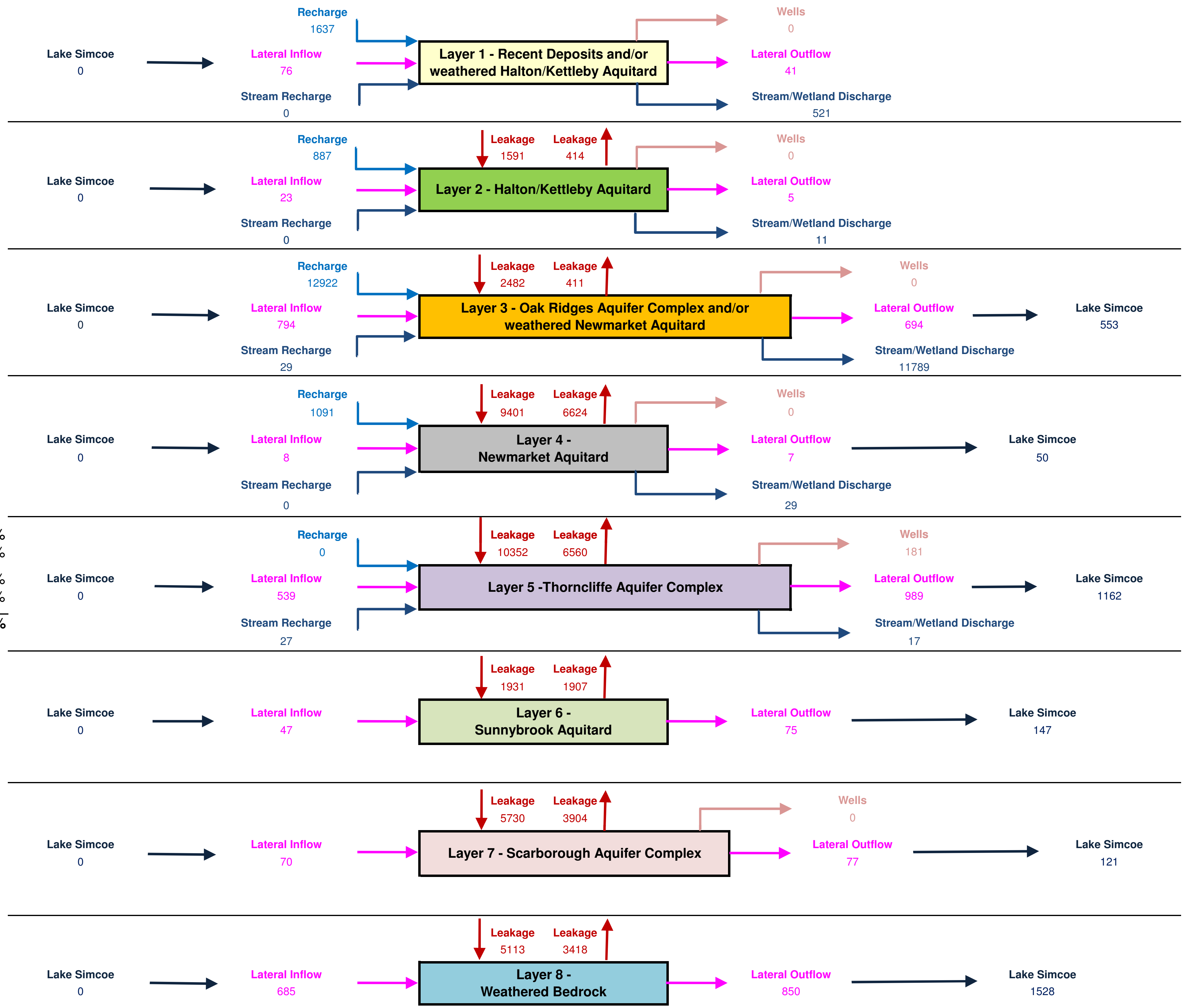
Net Water Balance (In - Out) (%)

-1%

Note:

Values presented may reflect rounding. Some minor differences in water budget estimates are expected due to numerical model calculations.

Figure B1-6 - Water Budget (Groundwater) - Black River SubSubwatershed 6 - Existing Water Demand



All flow volumes expressed as m^3/day

Inputs

	m^3/day	%
Recharge	16537	88%
Stream Recharge	56	0%
Wells	0	0%
Lateral Inflow	2242	12%
Total Inputs	**18834**	**100%**

Outputs

	m^3/day	%
Stream	12366	66%
Lake Simcoe	3561	19%
Wells	181	1%
Lateral Outflow	2738	15%
Total Outputs	**18847**	**100%**

Net Water Balance (In - Out) (%)

0%

Note:

Values presented may reflect rounding. Some minor differences in water budget estimates are expected due to numerical model calculations.

Appendix B2

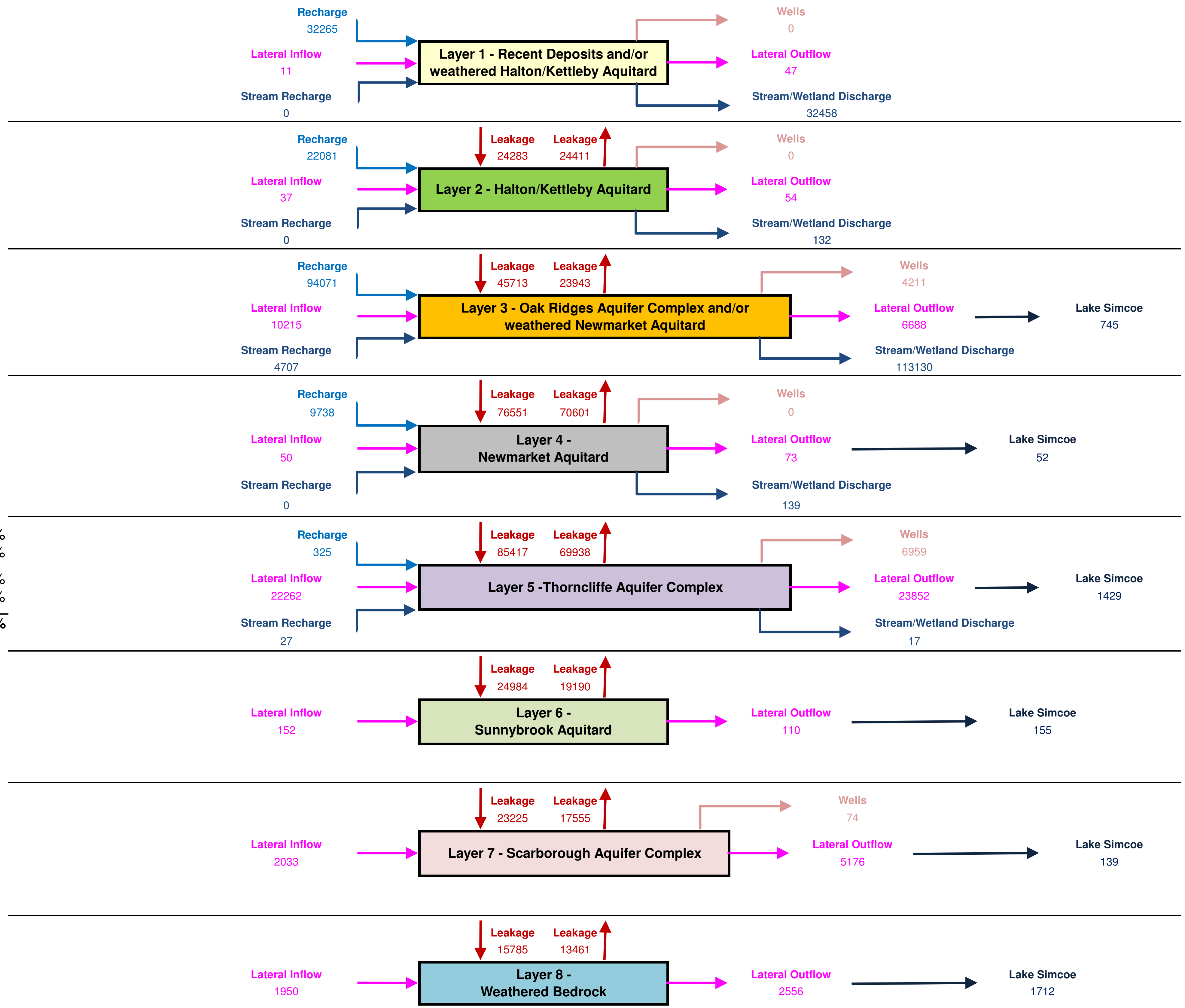
Water Budget Results – Committed/Planned Water Demand

Table B2-1 Water Balance Summary - Committed/Planned Water Demand

Item	Units	Black River Subsubwatershed 1		Black River Subsubwatershed 2		Black River Subsubwatershed 3		Black River Subsubwatershed 4		Black River Subsubwatershed 5		Black River Subsubwatershed 6		Georgina Creeks Subwatershed		Total Study Area	
		Value	%	Value	%	Value	%	Value	%	Value	%	Value	%	Value	%	Value	%
Subwatershed Area	km^2	99		87		47		63		26		53		49		425	
	m^2	98,856,175		87,265,386		46,992,839		63,004,675		26,326,812		52,915,189		49,333,000		424,694,077	
Water Budget																	
Inputs:																	
Recharge	m^3/day	50,395	59.8%	44,509	50.3%	14,578	74.9%	20,345	77.9%	12,116	72.9%	16,537	87.8%	14,373	73.7%	172,853	79.8%
Stream Recharge	m^3/day	3,133	3.7%	1,277	1.4%	1	0.0%	48	0.2%	219	1.3%	56	0.3%	-	0.0%	4,734	2.2%
Lateral Inflow (Adjacent)	m^3/day	30,698	36.4%	42,679	48.2%	4,889	25.1%	5,728	21.9%	4,287	25.8%	2,247	11.9%	5,126	26.3%	39,125	18.1%
Lake Simcoe Inflow	m^3/day	-	0.0%	-	0.0%	-	0.0%	-	0.0%	-	0.0%	-	0.0%	0	0.0%	0	0.0%
Total Input	**m^3/day**	**84,226**	**100.0%**	**88,464**	**100.0%**	**19,468**	**100.0%**	**26,121**	**100.0%**	**16,622**	**100.0%**	**18,839**	**100.0%**	**19,499**	**100.0%**	**216,712**	**100.0%**
Outputs:																	
Discharge to Stream	m^3/day	40,026	47.5%	50,992	57.6%	10,949	56.3%	19,759	75.7%	11,834	71.2%	12,316	65.3%	3,076	15.8%	148,952	68.7%
Discharge to Lake Simcoe	m^3/day	-	0.0%	-	0.0%	-	0.0%	-	0.0%	670	4.0%	3,561	18.9%	11,821	60.7%	16,052	7.4%
Lateral Outflow (Adjacent)	m^3/day	39,122	46.4%	32,153	36.3%	8,007	41.1%	6,296	24.1%	4,059	24.4%	2,761	14.6%	3,840	19.7%	39,684	18.3%
Wells	m^3/day	5,097	6.1%	5,312	6.0%	507	2.6%	50	0.2%	51	0.3%	227	1.2%	751	3.9%	11,995	5.5%
Total Outflow	**m^3/day**	**84,245**	**100.0%**	**88,457**	**100.0%**	**19,463**	**100.0%**	**26,105**	**100.0%**	**16,614**	**100.0%**	**18,864**	**100.0%**	**19,487**	**100.0%**	**216,682**	**100.0%**

Notes:
1) Values in Table may reflect rounding
2) The lateral inflow for the Total Study Area was obtained directly from the numerical model outputs. The sum of the lateral inputs for the Black River Subwatershed and Georgina Creeks Subwatershed may not equal the value shown for the Study Area.

Figure B2-1 Water Budget (Groundwater) - Committed/Planned Water Demand - Black River Subwatershed



All flow volumes expressed as m³/day

Inputs

	m^3/day	%
Recharge	158480	79%
Stream Recharge	4734	2%
Wells	0	0%
Lateral Inflow	36711	18%
Total Inputs	**199925**	**100%**

Outputs

	m^3/day	%
Stream	145876	73%
Lake Simcoe	4231	2%
Wells	11243	6%
Lateral Outflow	38556	19%
Total Outputs	**199906**	**100%**

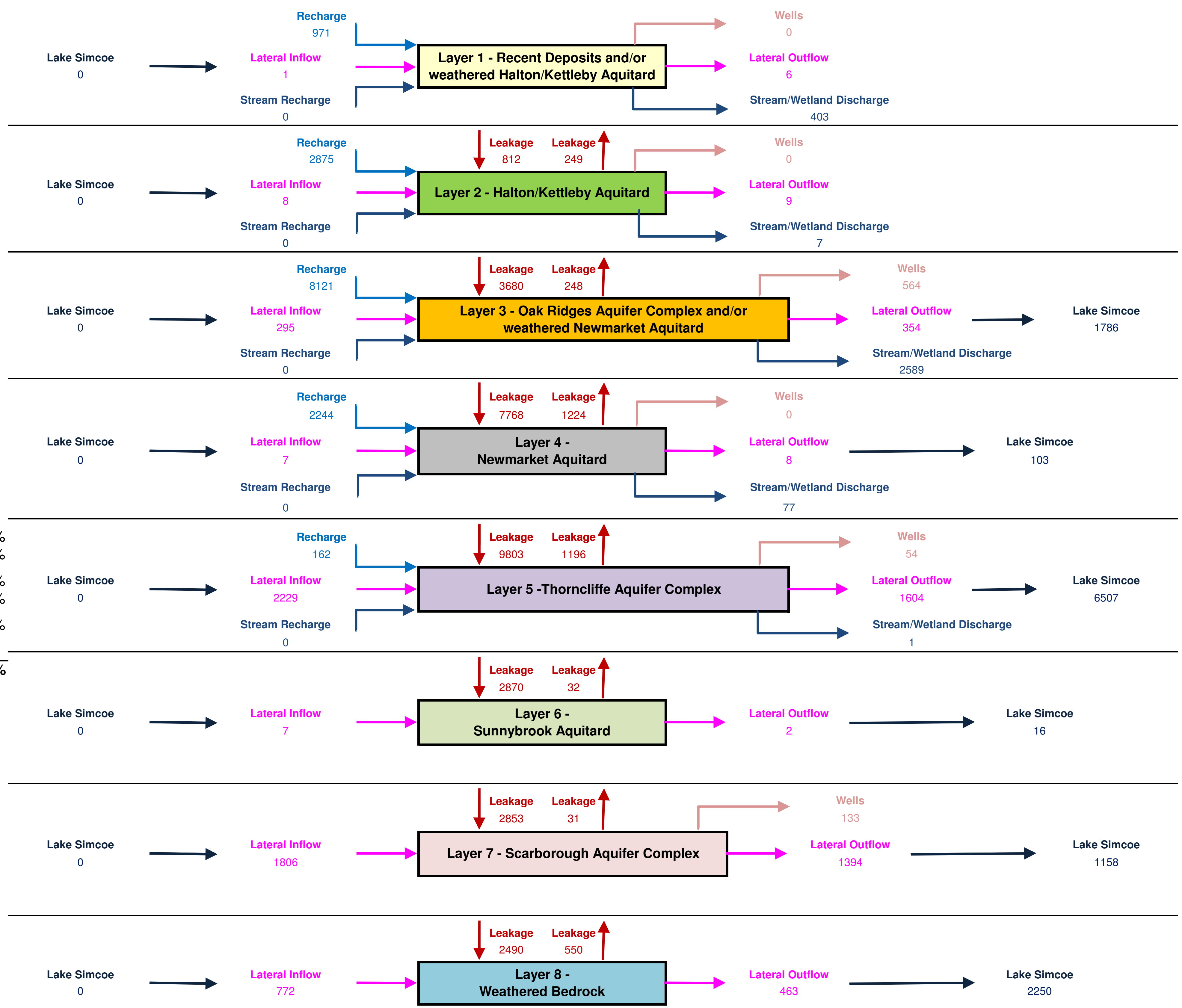
Net Water Balance (In - Out) (%)

0%

Note:

Values presented may reflect rounding. Some minor differences in water budget estimates are expected due to numerical model calculations.

Figure B2-2 Water Budget (Groundwater) - Committed/Planned Water Demand - Georgina Creeks Subwatershed



All flow volumes expressed as m^3/day

Inputs

	m^3/day	%
Recharge	14373	74%
Stream Recharge	0	0%
Wells	0	0%
Lateral Inflow	5126	26%
Lake Simcoe	0	0%
Total Inputs	**19499**	**100%**

Outputs

	m^3/day	%
Stream	3076	16%
Lake Simcoe	11821	61%
Wells	751	4%
Lateral Outflow	3840	20%
Total Outputs	**19487**	**100%**

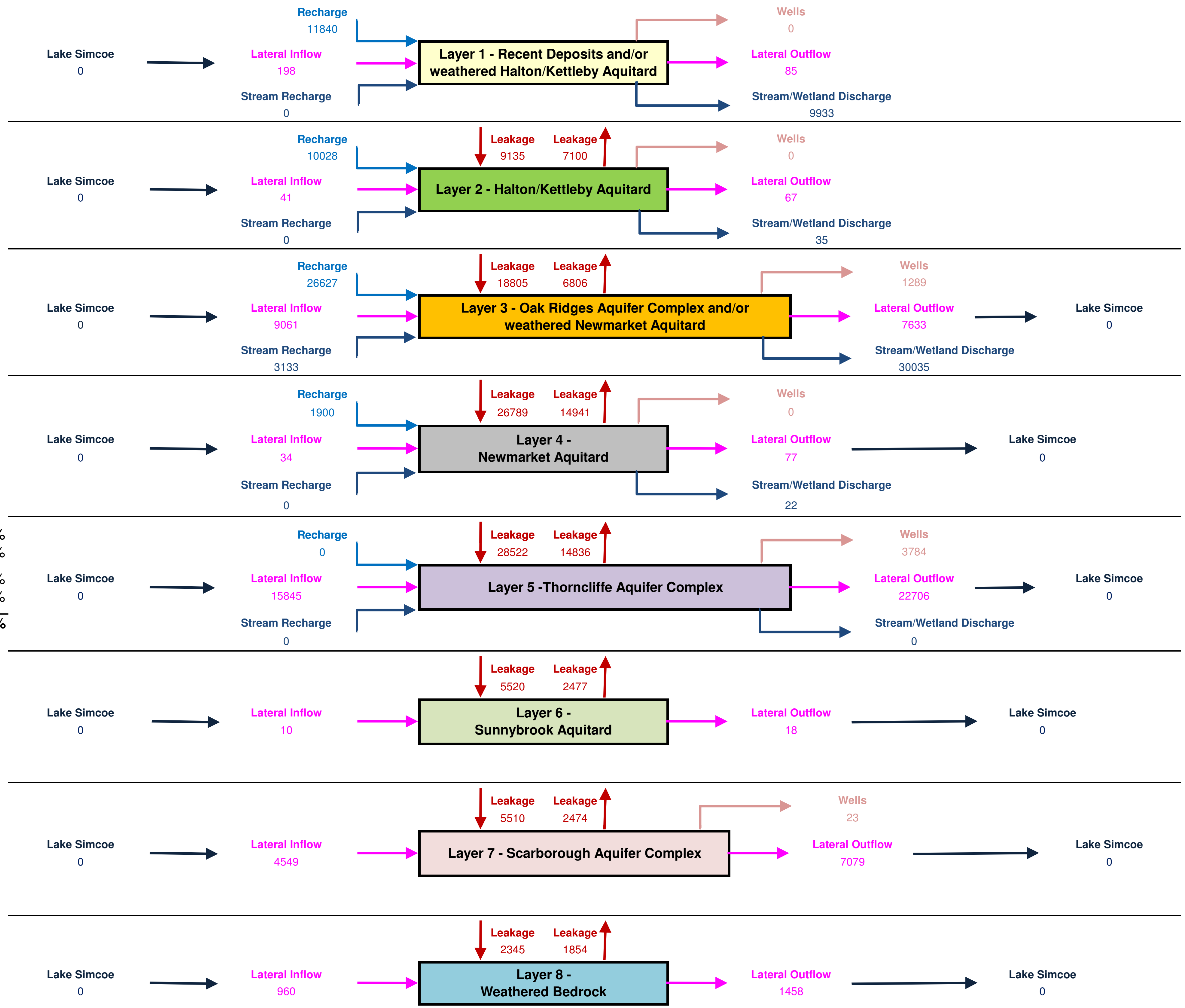
Net Water Balance (In - Out) (%)

0%

Note:

Values presented may reflect rounding. Some minor differences in water budget estimates are expected due to numerical model calculations.

Figure B2-3 - Water Budget (Groundwater) - Committed/Planned Water Demand - Black River SubSubwatershed 1



All flow volumes expressed as m^3/day

Inputs

	m^3/day	%
Recharge	50395	60%
Stream Recharge	3133	4%
Wells	0	0%
Lateral Inflow	30698	36%
Total Inputs	**84226**	**100%**

Outputs

	m^3/day	%
Stream	40026	48%
Lake Simcoe	0	0%
Wells	5097	6%
Lateral Outflow	39122	46%
Total Outputs	**84245**	**100%**

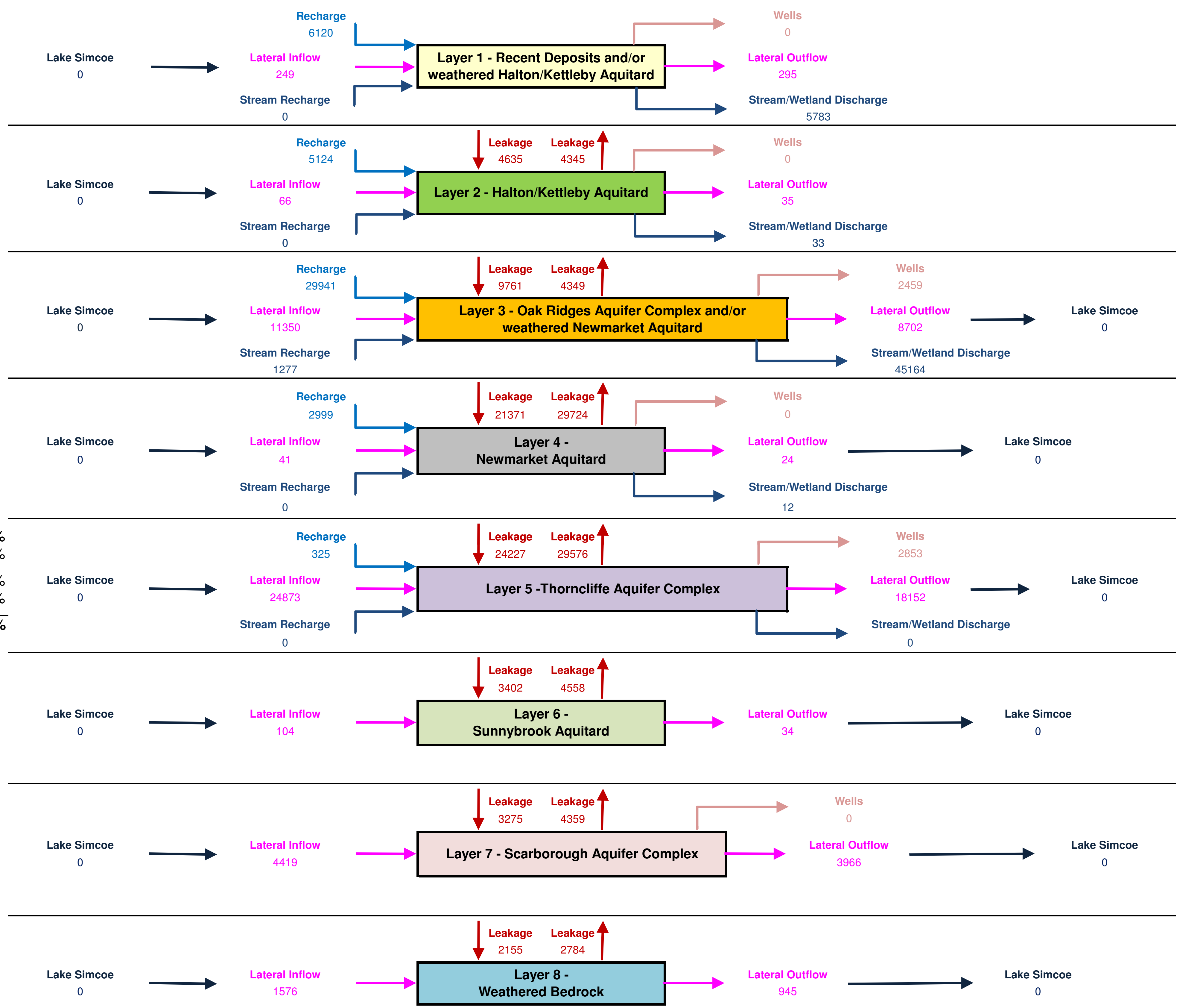
Net Water Balance (In - Out) (%)

0%

Note:

Values presented may reflect rounding. Some minor differences in water budget estimates are expected due to numerical model calculations.

Figure B2-4 - Water Budget (Groundwater) - Committed/Planned Water Demand - Black River SubSubwatershed 2



All flow volumes expressed as m^3/day

Inputs

	m^3/day	%
Recharge	44509	50%
Stream Recharge	1277	1%
Wells	0	0%
Lateral Inflow	42679	48%
Total Inputs	**88464**	**100%**

Outputs

	m^3/day	%
Stream	50992	58%
Lake Simcoe	0	0%
Wells	5312	6%
Lateral Outflow	32153	36%
Total Outputs	**88457**	**100%**

Net Water Balance (In - Out) (%)

0%

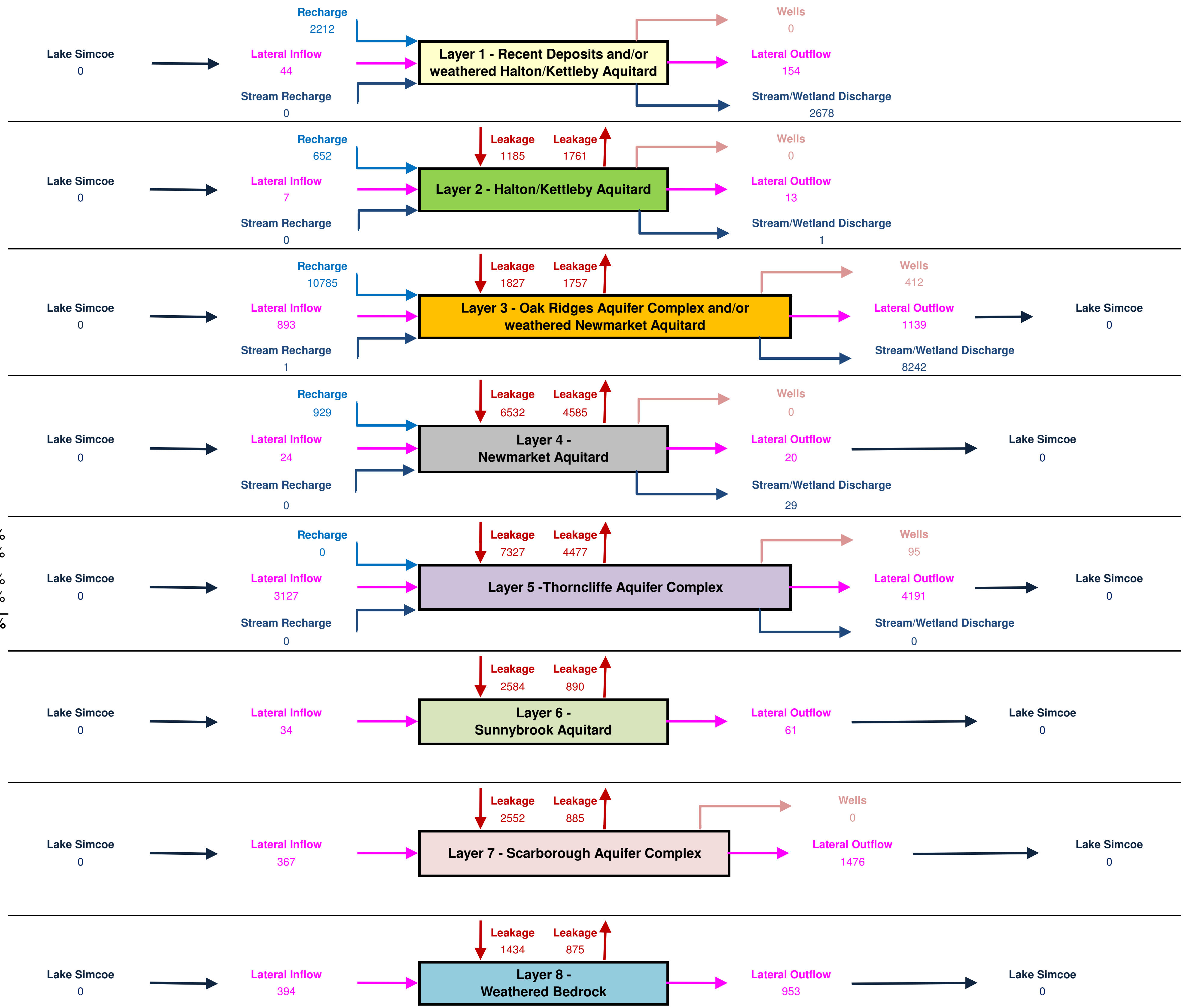
Note:

Values presented may reflect rounding. Some minor differences in water budget estimates are expected due to numerical model calculations.

Figure B2-5 - Water Budget (Groundwater) - Committed/Planned Water Demand - Black River SubSubwatershed 3

Inputs

	m^3/day	%
Recharge	14578	75%
Stream Recharge	1	0%
Wells	0	0%
Lateral Inflow	4889	25%
Total Inputs	**19468**	**100%**



All flow volumes expressed as m^3/day

Outputs

	m^3/day	%
Stream	10949	56%
Lake Simcoe	0	0%
Wells	507	3%
Lateral Outflow	8007	41%
Total Outputs	**19463**	**100%**

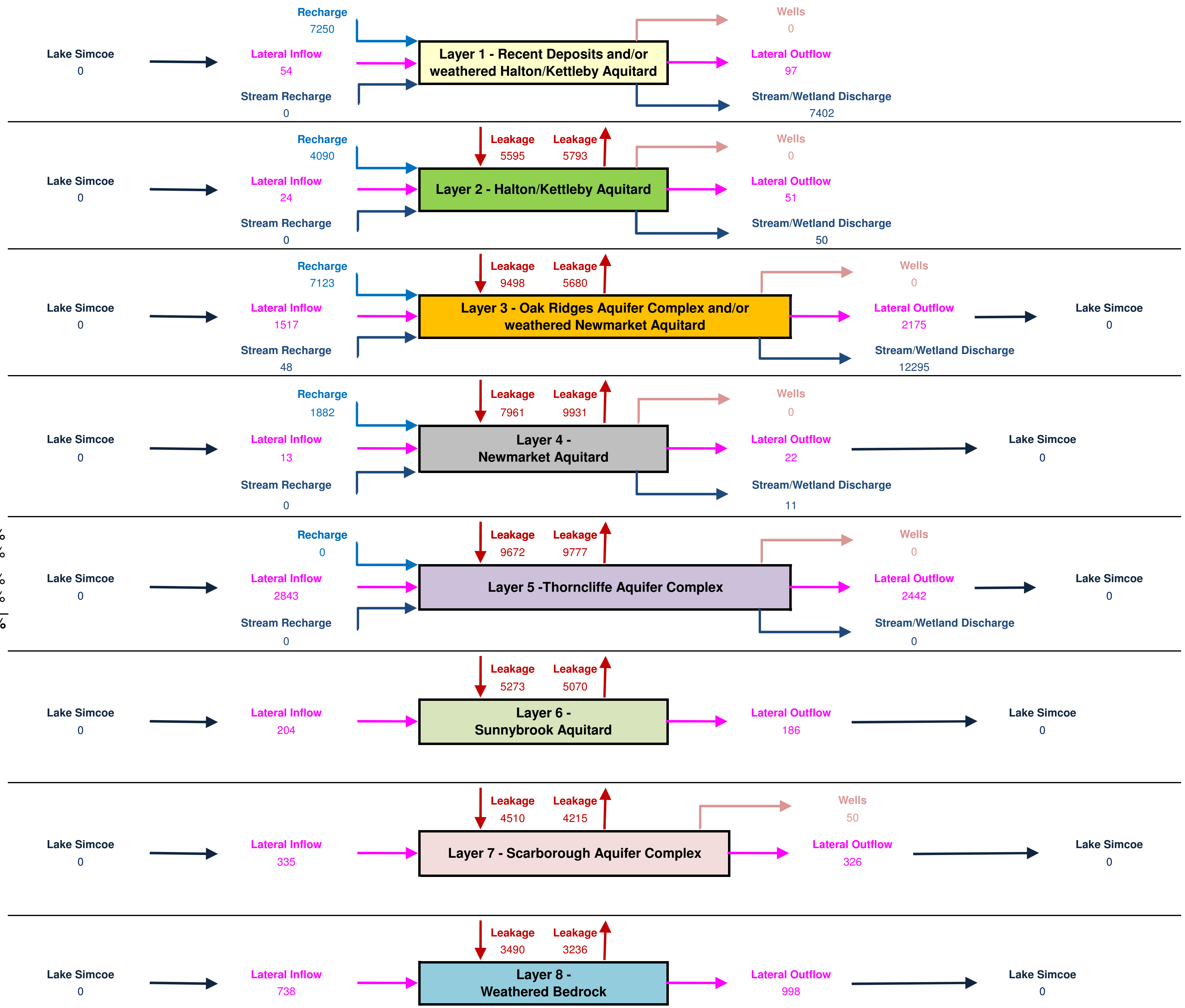
Net Water Balance (In - Out) (%)

0%

Note:

Values presented may reflect rounding. Some minor differences in water budget estimates are expected due to numerical model calculations.

Figure B2-6 - Water Budget (Groundwater) - Committed/Planned Water Demand - Black River SubSubwatershed 4



All flow volumes expressed as m^3/day

Inputs

	m^3/day	%
Recharge	20345	78%
Stream Recharge	48	0%
Wells	0	0%
Lateral Inflow	5728	22%
Total Inputs	**26121**	**100%**

Outputs

	m^3/day	%
Stream	19759	76%
Lake Simcoe	0	0%
Wells	50	0%
Lateral Outflow	6296	24%
Total Outputs	**26105**	**100%**

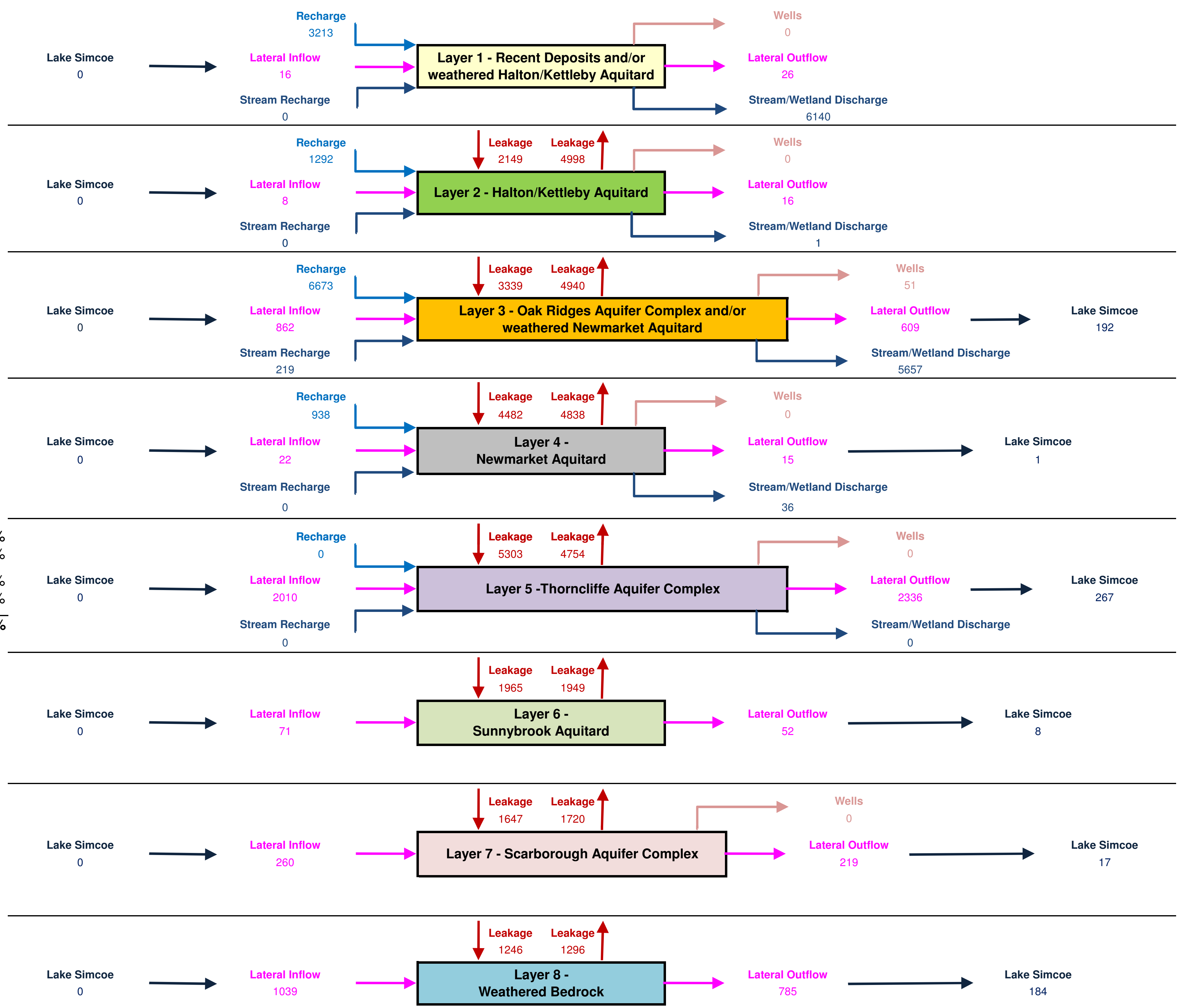
Net Water Balance (In - Out) (%)

0%

Note:

Values presented may reflect rounding. Some minor differences in water budget estimates are expected due to numerical model calculations.

Figure B2-7 - Water Budget (Groundwater) - Committed/Planned Water Demand - Black River SubSubwatershed 5



All flow volumes expressed as m^3/day

Inputs

	m^3/day	%
Recharge	12116	73%
Stream Recharge	219	1%
Wells	0	0%
Lateral Inflow	4287	26%
Total Inputs	**16622**	**100%**

Outputs

	m^3/day	%
Stream	11834	71%
Lake Simcoe	670	4%
Wells	51	0%
Lateral Outflow	4059	24%
Total Outputs	**16614**	**100%**

Net Water Balance (In - Out) (%)

0%

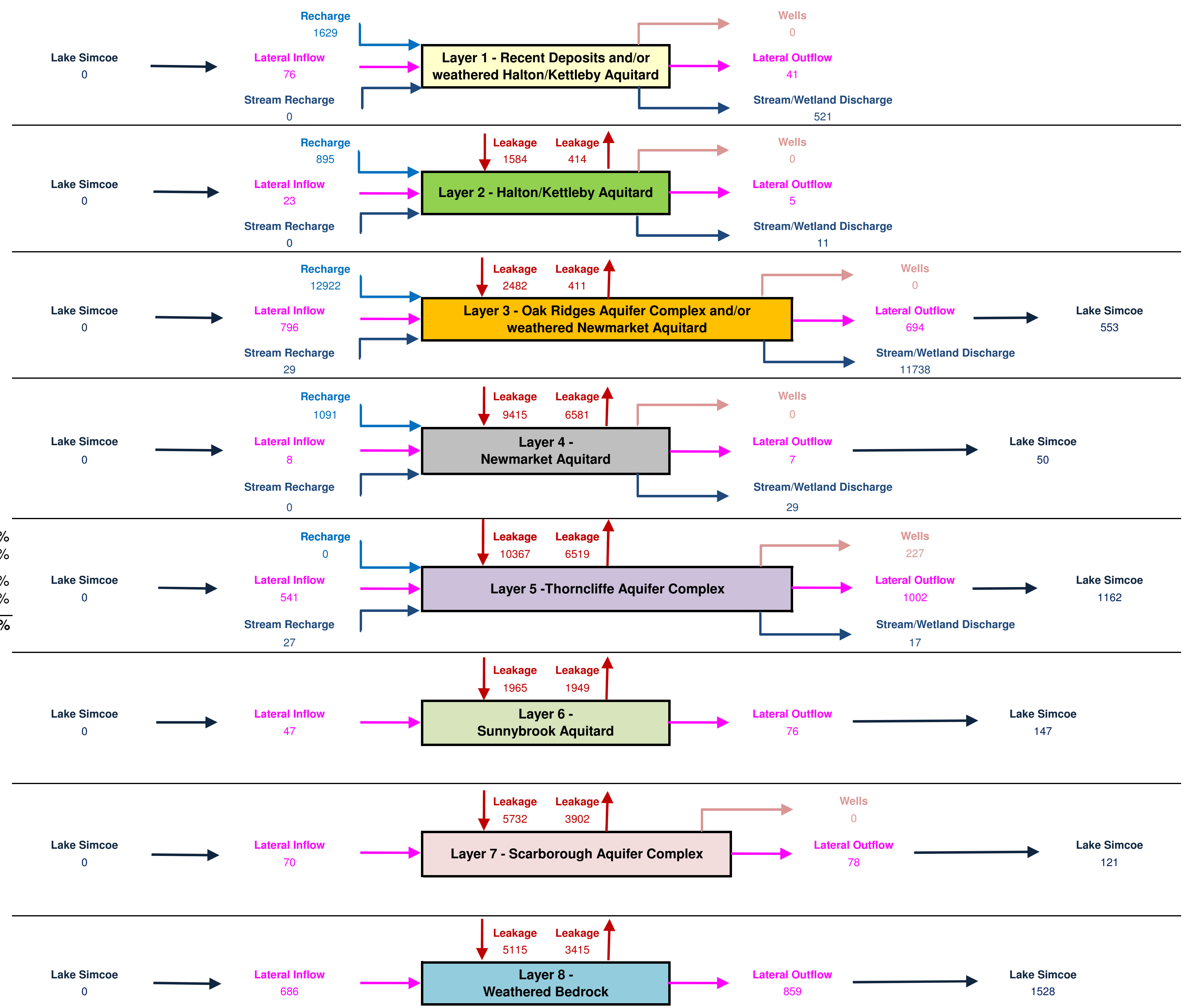
Note:

Values presented may reflect rounding. Some minor differences in water budget estimates are expected due to numerical model calculations.

Figure B2-8 - Water Budget (Groundwater) - Committed/Planned Water Demand - Black River SubSubwatershed 6

Inputs

	m³/day	%
Recharge	16537	88%
Stream Recharge	56	0%
Wells	0	0%
Lateral Inflow	2247	12%
Total Inputs	**18839**	**100%**



All flow volumes expressed as m³ /day

Outputs

	m³/day	%
Stream	12316	65%
Lake Simcoe	3561	19%
Wells	227	1%
Lateral Outflow	2761	15%
Total Outputs	**18864**	**100%**

Net Water Balance (In - Out) (%)

0%

Note:

Values presented may reflect rounding. Some minor differences in water budget estimates are expected due to numerical model calculations.

Appendix B3

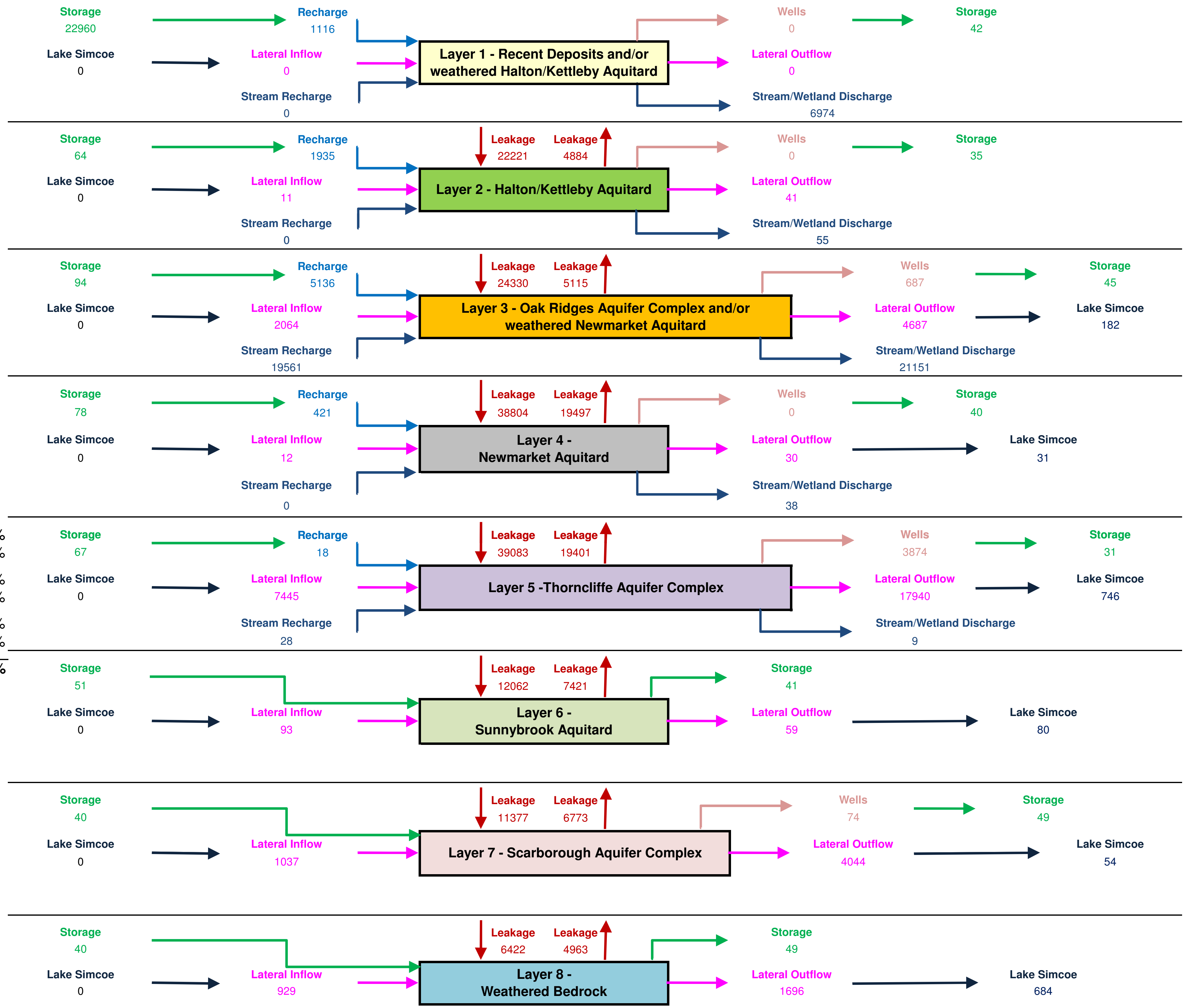
Water Budget Results – 2 Year Drought – Existing Water Demand

Table B3-1 Summary of Water Balance

Item	Units	Black River Subsubwatershed 1		Black River Subsubwatershed 2		Black River Subsubwatershed 3		Black River Subsubwatershed 4		Black River Subsubwatershed 5		Black River Subsubwatershed 6		Georgina Creeks Subwatershed		Total Study Area	
		Value	%	Value	%	Value	%	Value	%	Value	%	Value	%	Value	%	Value	%
Subwatershed Area	km^2	99		87		47		63		26		53		49		425	
	m^2	98,856,175		87,265,386		46,992,839		63,004,675		26,326,812		52,915,189		49,333,000		424,694,077	
Water Budget																	
Inputs:																	
Recharge	m^3/day	2,778	8.7%	2,430	8.7%	680	9.0%	1,172	11.2%	758	14.4%	809	17.9%	786	15.4%	9,414	14.2%
Storage	m^3/day	9,995	31.4%	3,115	11.2%	1,629	21.5%	5,758	54.9%	1,286	24.5%	1,610	35.7%	0	0.0%	23,392	35.2%
Stream Recharge	m^3/day	8,537	26.8%	8,802	31.6%	828	10.9%	379	3.6%	887	16.9%	156	3.5%	-	0.0%	19,588	29.4%
Lateral Inflow (Adjacent)	m^3/day	10,569	33.2%	13,506	48.5%	4,426	58.5%	3,175	30.3%	2,319	44.2%	1,932	42.9%	4,269	83.5%	14,072	21.2%
Lake Simcoe Inflow	m^3/day	-	0.0%	-	0.0%	-	0.0%	-	0.0%	-	0.0%	-	0.0%	60	1.2%	60	0.1%
Total Input	**m^3/day**	**31,879**	**100.0%**	**27,853**	**100.0%**	**7,562**	**100.0%**	**10,484**	**100.0%**	**5,250**	**100.0%**	**4,507**	**100.0%**	**5,115**	**100.0%**	**66,526**	**100.0%**
Outputs:																	
Discharge to Stream	m^3/day	3,755	11.9%	12,740	45.7%	1,490	19.7%	6,056	58.0%	2,631	49.9%	1,556	34.4%	5	0.1%	28,232	42.3%
Storage	m^3/day	78	0.2%	63	0.2%	85	1.1%	23	0.2%	74	1.4%	10	0.2%	98	1.9%	431	0.6%
Discharge to Lake Simcoe	m^3/day	-	0.0%	-	0.0%	-	0.0%	-	0.0%	291	5.5%	1,487	32.9%	2,938	57.4%	4,716	7.1%
Lateral Outflow (Adjacent)	m^3/day	25,609	81.4%	13,186	47.3%	5,563	73.6%	4,303	41.2%	2,222	42.2%	1,283	28.4%	1,088	21.3%	27,797	41.6%
Wells	m^3/day	2,015	6.4%	1,913	6.9%	426	5.6%	50	0.5%	51	1.0%	182	4.0%	986	19.3%	5,621	8.4%
Total Outflow	**m^3/day**	**31,456**	**100.0%**	**27,902**	**100.0%**	**7,564**	**100.0%**	**10,432**	**100.0%**	**5,269**	**100.0%**	**4,517**	**100.0%**	**5,114**	**100.0%**	**66,797**	**100.0%**

Notes:
1) Values in Table may reflect rounding
2) The lateral inflow for the Total Study Area was obtained directly from the numerical model outputs. The sum of the lateral inputs for the Black River Subwatershed and Georgina Creeks Subwatershed may not equal the value shown for the Study Area.

Figure B3-1 - Water Budget (Groundwater) - 2 Year Drought - Existing Water Demand - Black River Subwatershed



All flow volumes expressed as m^3/day

Inputs

	m^3/day	%
Recharge	8627	14%
Stream Recharge	19588	31%
Wells	0	0%
Lateral Inflow	11590	18%
Lake Simcoe	0	0%
Storage	23392	37%
Total Inputs	**63198**	**100%**

Outputs

	m^3/day	%
Stream	28228	44%
Lake Simcoe	1778	3%
Wells	4635	7%
Lateral Outflow	28496	45%
Storage	332	1%
Total Outputs	**63470**	**100%**

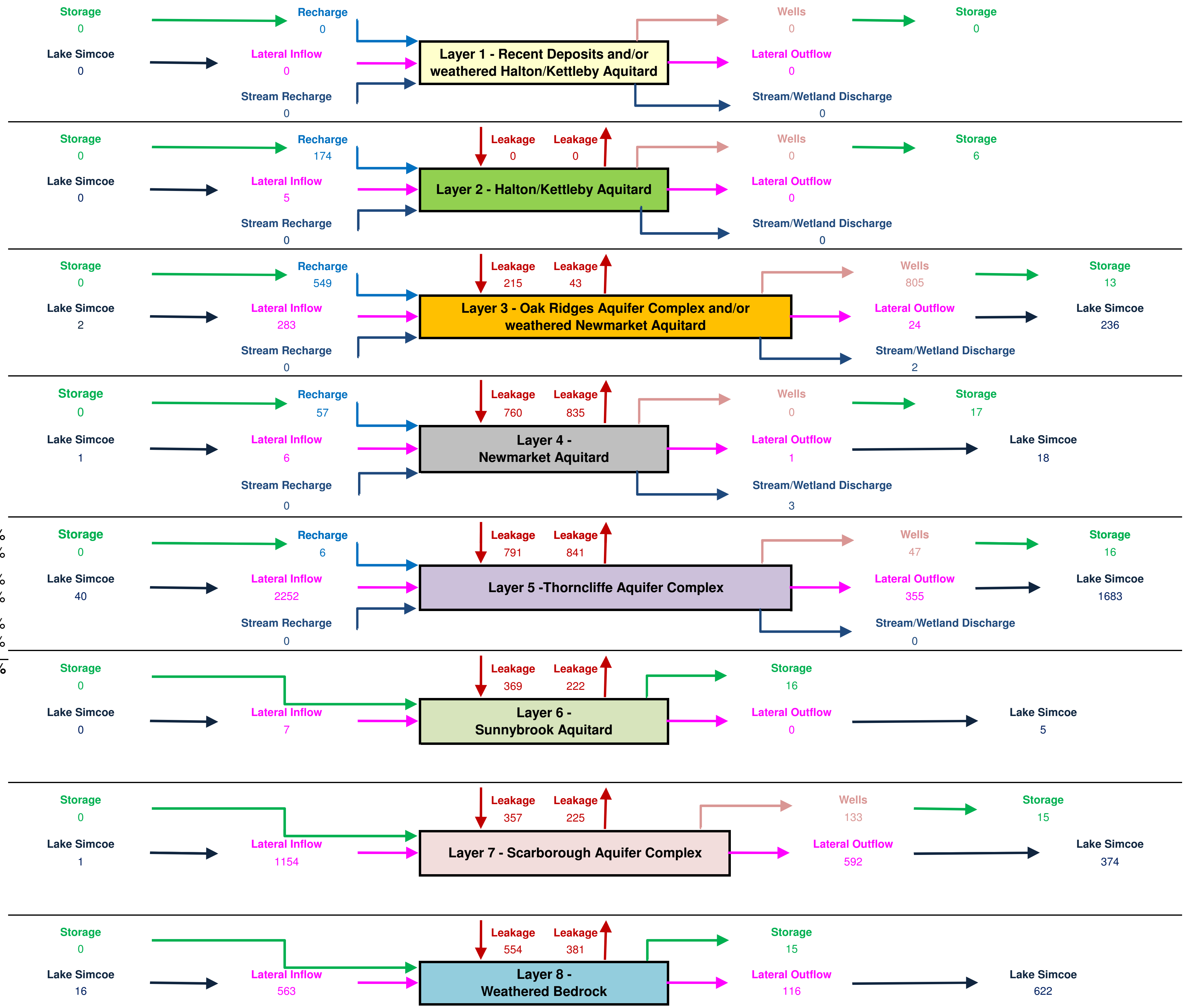
Net Water Balance (In - Out) (%)

0%

Note:

Values presented may reflect rounding. Some minor differences in water budget estimates are expected due to numerical model calculations.

Figure B3-2 - Water Budget (Groundwater) - 2 Year Drought - Existing Water Demand - Georgina Creeks Subwatershed



All flow volumes expressed as m^3/day

Inputs

	m^3/day	%
Recharge	786	15%
Stream Recharge	0	0%
Wells	0	0%
Lateral Inflow	4269	83%
Lake Simcoe	60	1%
Storage	0	0%
Total Inputs	**5115**	**100%**

Outputs

	m^3/day	%
Stream	5	0%
Lake Simcoe	2938	57%
Wells	986	19%
Lateral Outflow	1088	21%
Storage	98	2%
Total Outputs	**5114**	**100%**

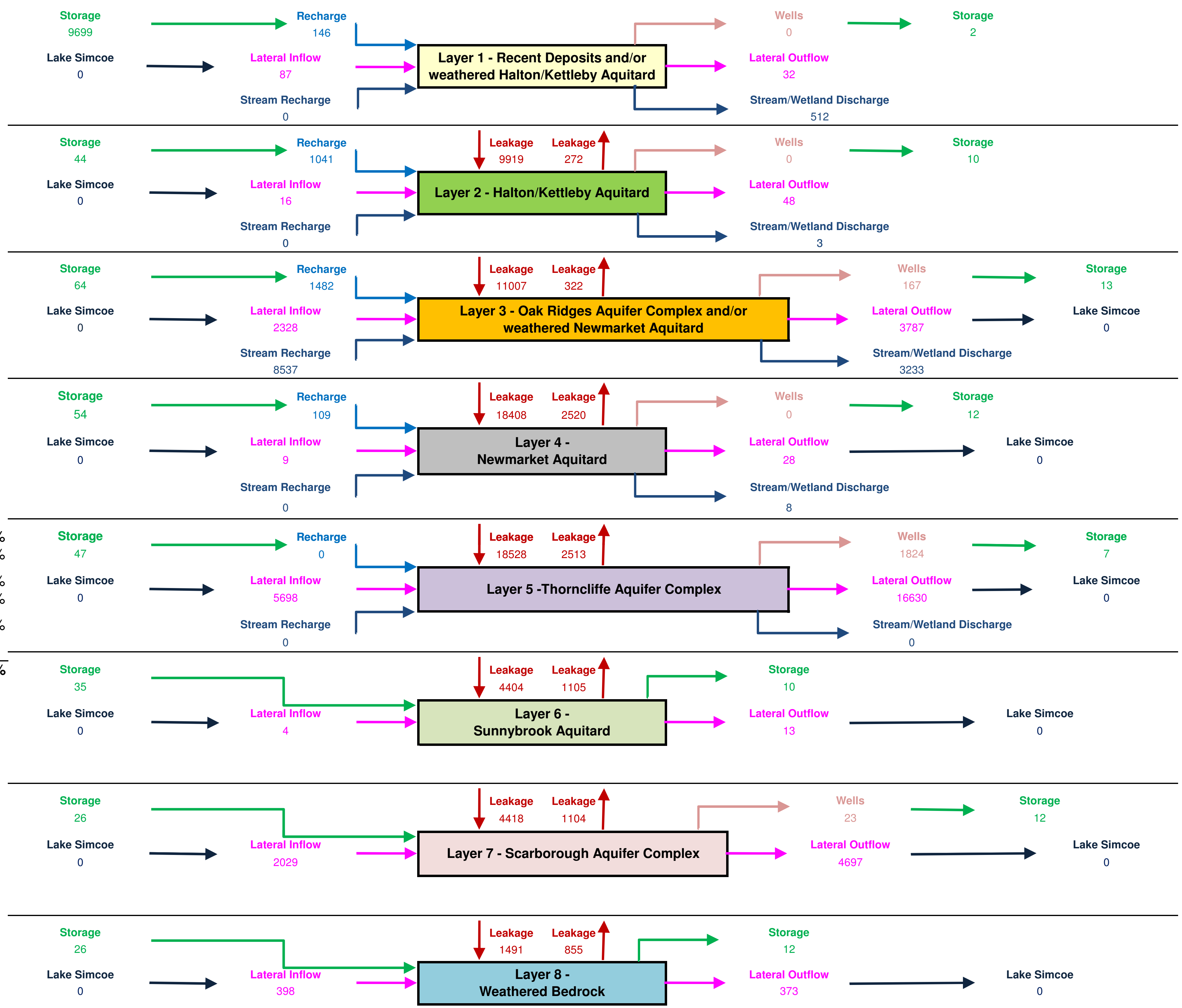
Net Water Balance (In - Out) (%)

0%

Note:

Values presented may reflect rounding. Some minor differences in water budget estimates are expected due to numerical model calculations.

Figure B3-3 - Water Budget (Groundwater) - 2 Year Drought - Existing Water Demand - Black River SubSubwatershed 1



All flow volumes expressed as m^3/day

Inputs

	m^3/day	%
Recharge	2778	9%
Stream Recharge	8537	27%
Wells	0	0%
Lateral Inflow	10569	33%
Storage	9995	31%
Total Inputs	**31879**	**100%**

Outputs

	m^3/day	%
Stream	3755	12%
Lake Simcoe	0	0%
Wells	2015	6%
Lateral Outflow	25609	81%
Storage	78	0%
Total Outputs	**31456**	**100%**

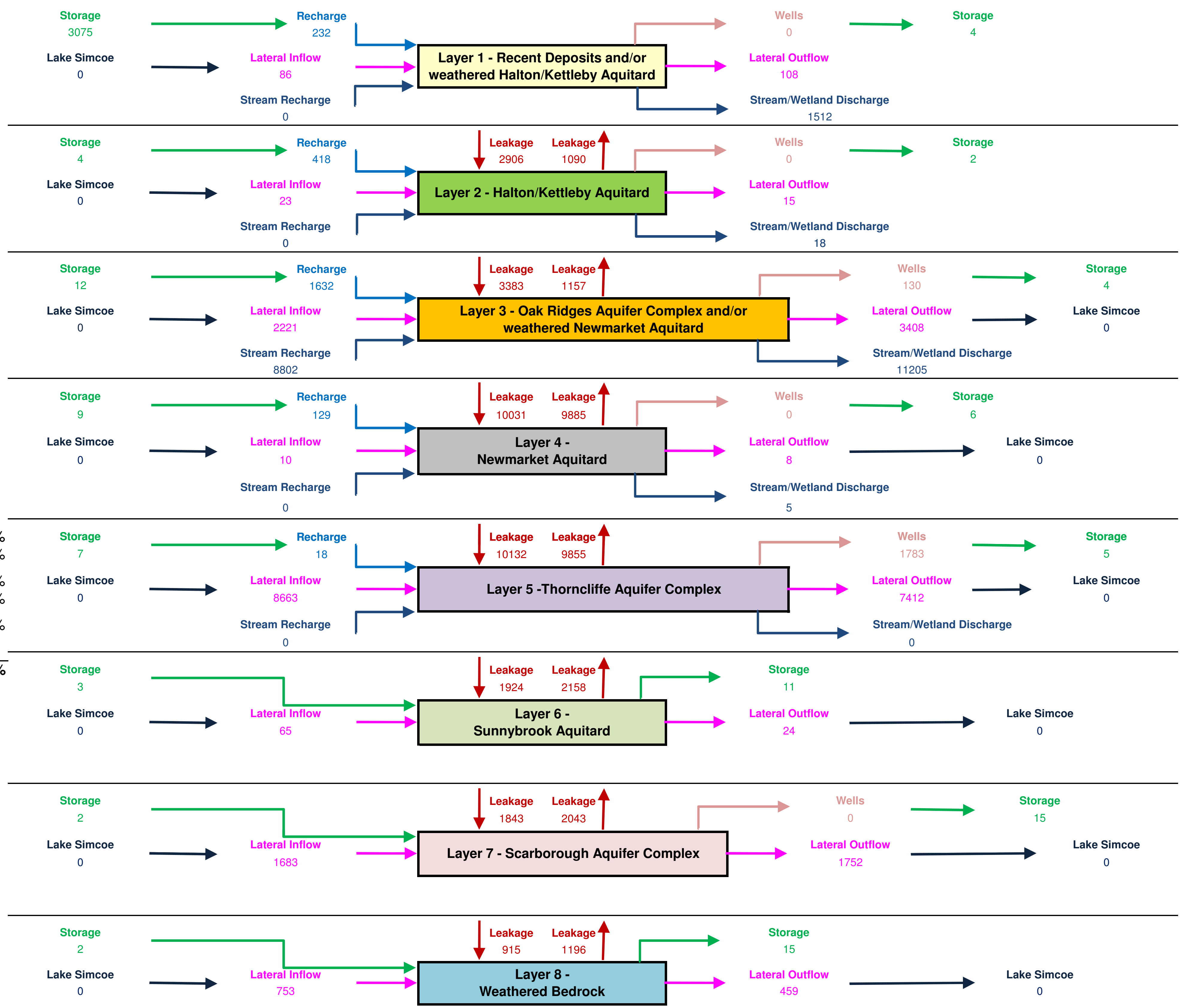
Net Water Balance (In - Out) (%)

1%

Note:

Values presented may reflect rounding. Some minor differences in water budget estimates are expected due to numerical model calculations.

Figure B3-4 - Water Budget (Groundwater) - 2 Year Drought - Existing Water Demand - Black River SubSubwatershed 2



All flow volumes expressed as m^3/day

Inputs

	m^3/day	%
Recharge	2430	9%
Stream Recharge	8802	32%
Wells	0	0%
Lateral Inflow	13506	48%
Storage	3115	11%
Total Inputs	**27853**	**100%**

Outputs

	m^3/day	%
Stream	12740	46%
Lake Simcoe	0	0%
Wells	1913	7%
Lateral Outflow	13186	47%
Storage	63	0%
Total Outputs	**27902**	**100%**

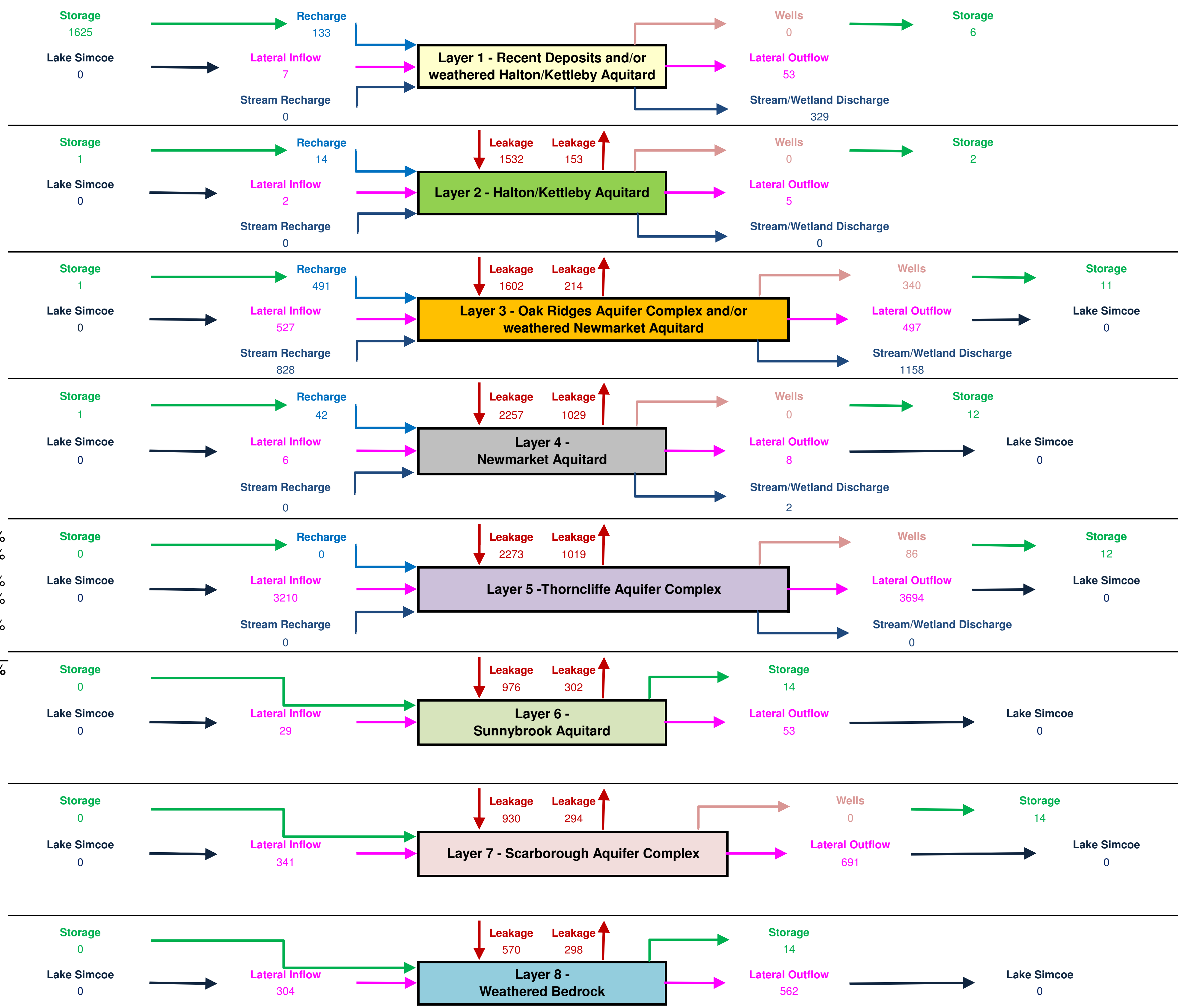
Net Water Balance (In - Out) (%)

0%

Note:

Values presented may reflect rounding. Some minor differences in water budget estimates are expected due to numerical model calculations.

Figure B3-5 - Water Budget (Groundwater) - 2 Year Drought - Existing Water Demand - Black River SubSubwatershed 3



All flow volumes expressed as m^3/day

Inputs

	m^3/day	%
Recharge	680	9%
Stream Recharge	828	11%
Wells	0	0%
Lateral Inflow	4426	59%
Storage	1629	22%
Total Inputs	**7562**	**100%**

Outputs

	m^3/day	%
Stream	1490	20%
Lake Simcoe	0	0%
Wells	426	6%
Lateral Outflow	5563	74%
Storage	85	1%
Total Outputs	**7564**	**100%**

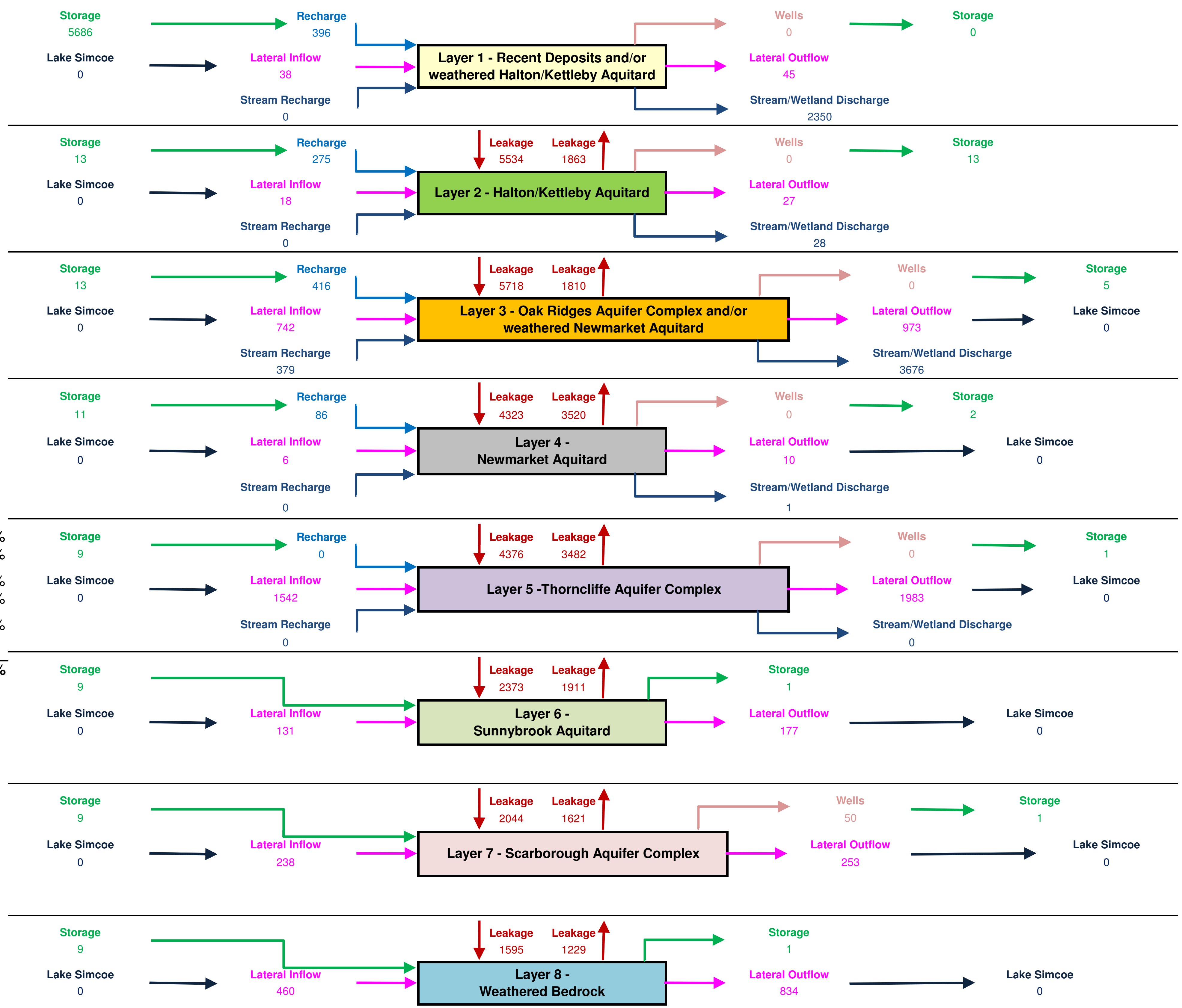
Net Water Balance (In - Out) (%)

0%

Note:

Values presented may reflect rounding. Some minor differences in water budget estimates are expected due to numerical model calculations.

Figure B3-6 - Water Budget (Groundwater) - 2 Year Drought - Existing Water Demand - Black River SubSubwatershed 4



All flow volumes expressed as m^3/day

Inputs

	m^3/day	%
Recharge	1172	11%
Stream Recharge	379	4%
Wells	0	0%
Lateral Inflow	3175	30%
Storage	5758	55%
Total Inputs	**10484**	**100%**

Outputs

	m^3/day	%
Stream	6056	58%
Lake Simcoe	0	0%
Wells	50	0%
Lateral Outflow	4303	41%
Storage	23	0%
Total Outputs	**10432**	**100%**

Net Water Balance (In - Out) (%)

0%

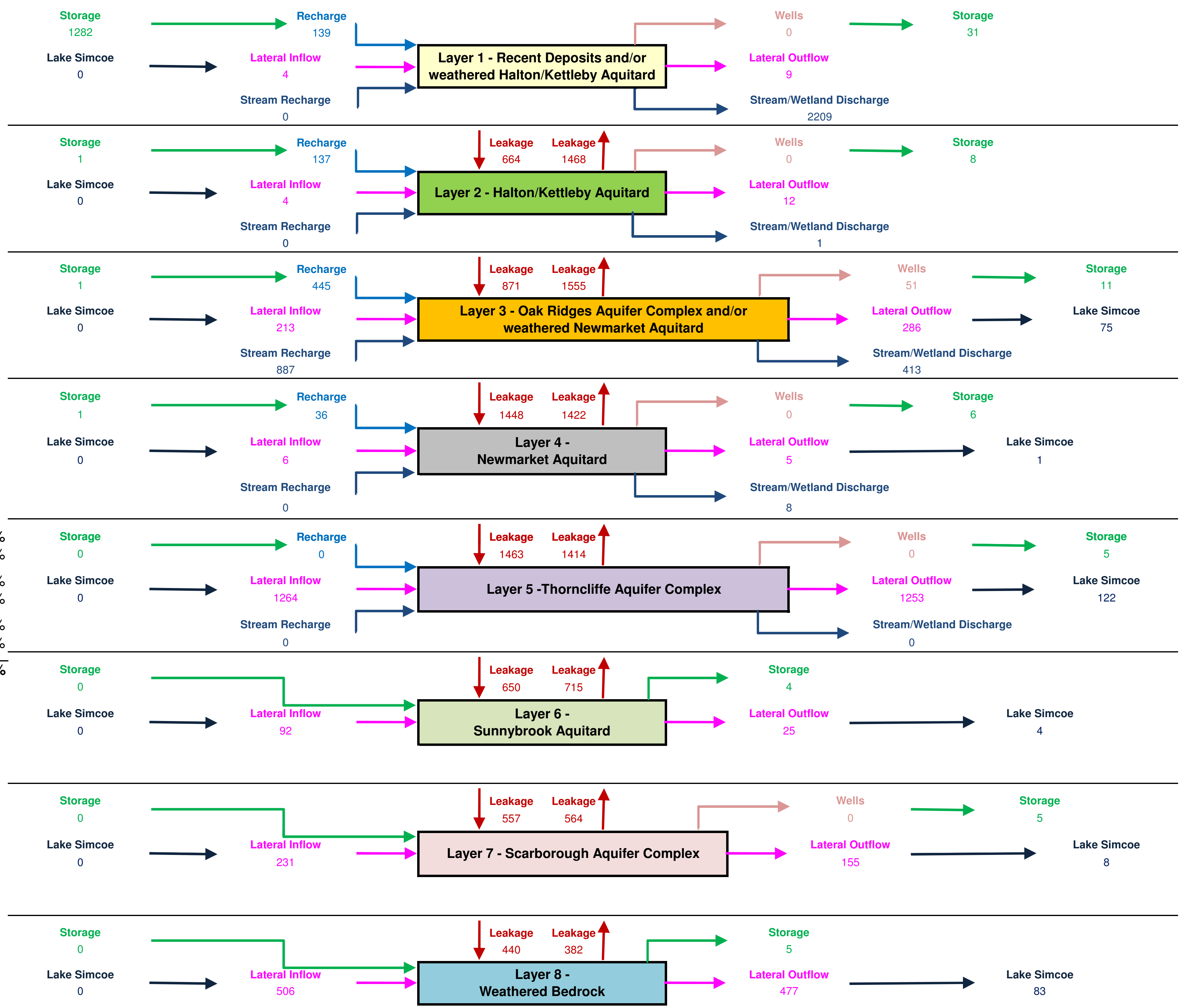
Note:

Values presented may reflect rounding. Some minor differences in water budget estimates are expected due to numerical model calculations.

Figure B3-7 - Water Budget (Groundwater) - 2 Year Drought - Existing Water Demand - Black River SubSubwatershed 5

Inputs

	m^3/day	%
Recharge	758	14%
Stream Recharge	887	17%
Wells	0	0%
Lateral Inflow	2319	44%
Lake Simcoe	0	0%
Storage	1286	24%
Total Inputs	**5250**	**100%**



All flow volumes expressed as m^3 /day

Outputs

	m^3/day	%
Stream	2631	50%
Lake Simcoe	291	6%
Wells	51	1%
Lateral Outflow	2222	42%
Storage	74	1%
Total Outputs	**5269**	**100%**

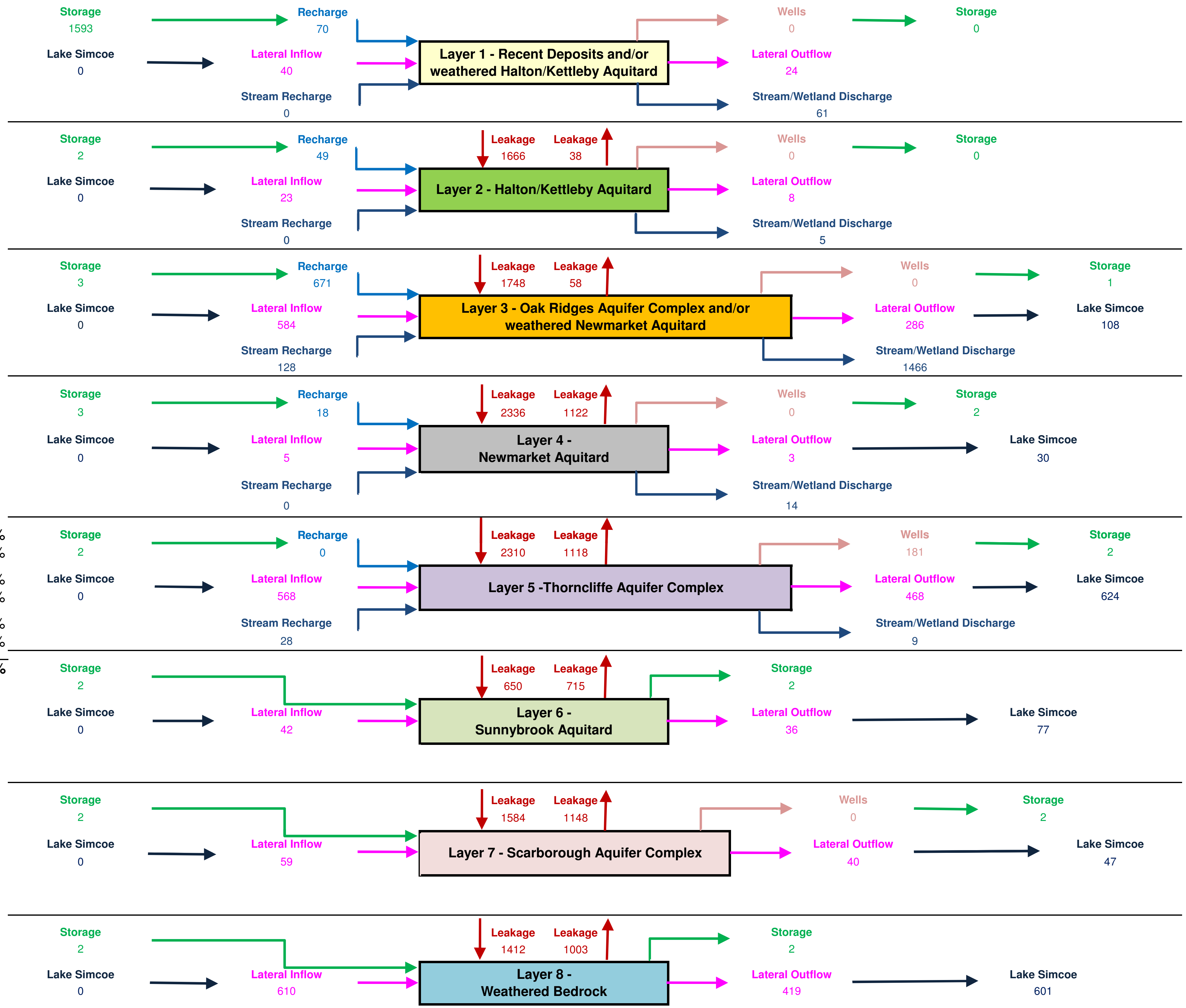
Net Water Balance (In - Out) (%)

0%

Note:

Values presented may reflect rounding. Some minor differences in water budget estimates are expected due to numerical model calculations.

Figure B3-8 - Water Budget (Groundwater) - 2 Year Drought - Existing Water Demand - Black River SubSubwatershed 6



All flow volumes expressed as m^3/day

Inputs

	m^3/day	%
Recharge	809	18%
Stream Recharge	156	3%
Wells	0	0%
Lateral Inflow	1932	43%
Lake Simcoe	0	0%
Storage	1610	36%
Total Inputs	**4507**	**100%**

Outputs

	m^3/day	%
Stream	1556	34%
Lake Simcoe	1487	33%
Wells	182	4%
Lateral Outflow	1283	28%
Storage	10	0%
Total Outputs	**4517**	**100%**

Net Water Balance (In - Out) (%)

0%

Note:

Values presented may reflect rounding. Some minor differences in water budget estimates are expected due to numerical model calculations.

Appendix B4

Water Budget Results – Committed/Planned Water Demand

Table B4-1 Summary of Water Balance

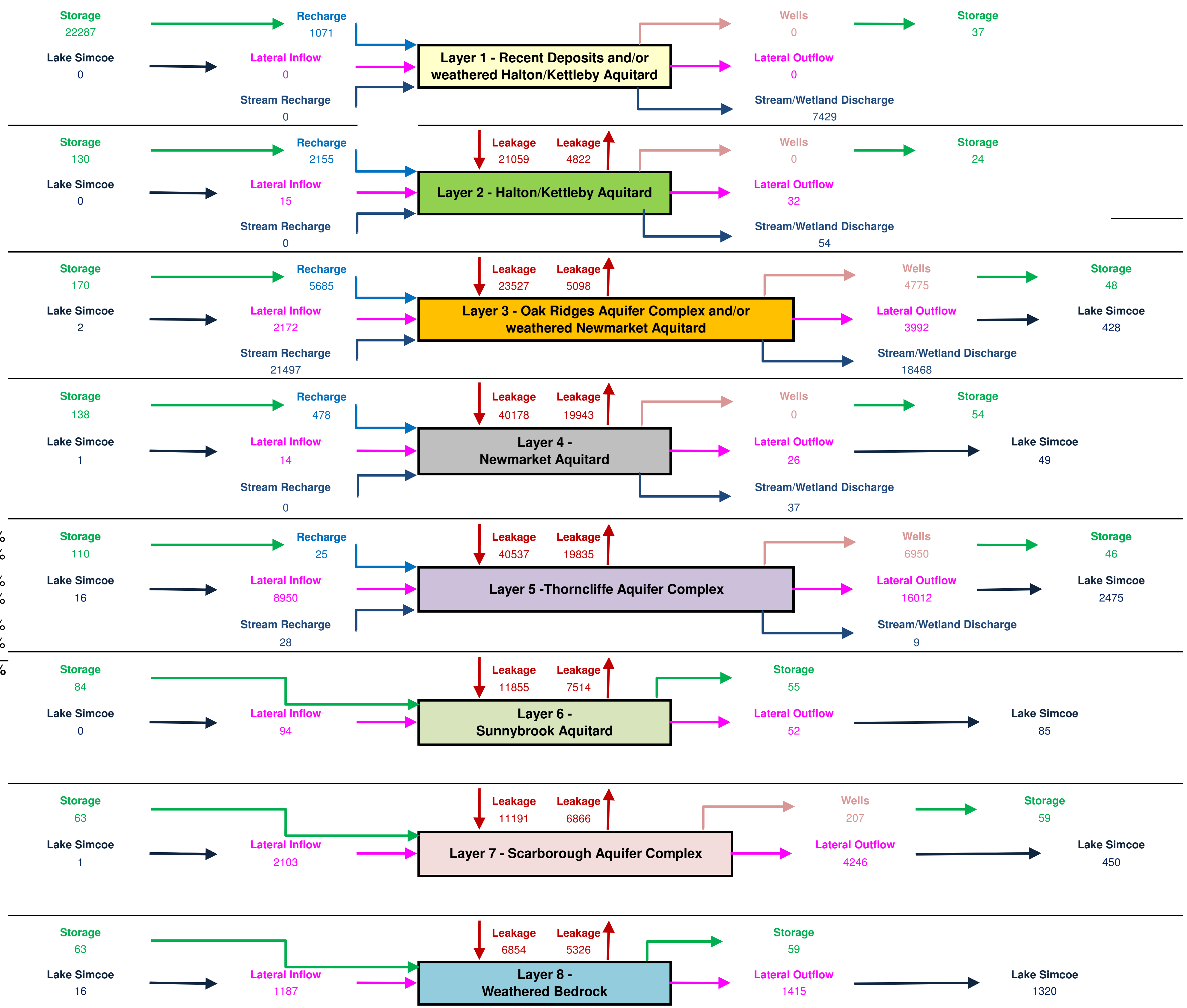
Item	Units	Black River Subsubwatershed 1		Black River Subsubwatershed 2		Black River Subsubwatershed 3		Black River Subsubwatershed 4		Black River Subsubwatershed 5		Black River Subsubwatershed 6		Georgina Creeks Subwatershed		Total Study Area	
		Value	**%**	**Value**	**%**	**Value**	**%**	**Value**	**%**	**Value**	**%**	**Value**	**%**	**Value**	**%**	**Value**	**%**
Subwatershed Area	km^2	99		87		47		63		26		53		49		425	
	m^2	98,856,175		87,265,386		46,992,839		63,004,675		26,326,812		52,915,189		49,333,000		424,694,077	
Water Budget																	
Inputs:																	
Recharge	m^3/day	2,778	8.7%	2,430	8.4%	680	9.0%	1,172	11.2%	758	13.0%	809	17.9%	786	15.7%	9,414	13.7%
Storage	m^3/day	9,248	29.1%	3,017	10.4%	1,593	21.1%	5,720	54.9%	1,847	31.7%	1,621	35.8%	-	0.0%	23,045	33.6%
Stream Recharge	m^3/day	9,049	28.5%	10,168	35.1%	881	11.6%	380	3.6%	891	15.3%	156	3.5%	-	0.0%	21,525	31.4%
Lateral Inflow (Adjacent)	m^3/day	10,722	33.7%	13,383	46.2%	4,411	58.3%	3,157	30.3%	2,325	39.9%	1,935	42.8%	4,178	83.6%	14,535	21.2%
Lake Simcoe Inflow	m^3/day	-	0.0%	-	0.0%	-	0.0%	-	0.0%	-	0.0%	-	0.0%	35	0.7%	35	0.1%
Total Input	**m^3/day**	**31,797**	**100.0%**	**28,998**	**100.0%**	**7,565**	**100.0%**	**10,429**	**100.0%**	**5,821**	**100.0%**	**4,521**	**100.0%**	**5,000**	**100.0%**	**68,553**	**100.0%**
Outputs:																	
Discharge to Stream	m^3/day	2,862	9.1%	10,878	37.5%	1,456	19.2%	6,039	58.0%	3,235	55.3%	1,523	33.6%	5	0.1%	25,997	37.7%
Storage	m^3/day	82	0.3%	58	0.2%	82	1.1%	5	0.0%	57	1.0%	13	0.3%	85	1.7%	382	0.6%
Discharge to Lake Simcoe	m^3/day	-	0.0%	-	0.0%	-	0.0%	-	0.0%	291	5.0%	1,481	32.7%	3,036	60.7%	4,807	7.0%
Lateral Outflow (Adjacent)	m^3/day	23,429	74.5%	12,852	44.3%	5,535	73.0%	4,309	41.4%	2,216	37.9%	1,287	28.4%	1,122	22.4%	25,774	37.4%
Wells	m^3/day	5,097	16.2%	5,249	18.1%	507	6.7%	50	0.5%	51	0.9%	227	5.0%	751	15.0%	11,932	17.3%
Total Outflow	**m^3/day**	**31,470**	**100.0%**	**29,038**	**100.0%**	**7,580**	**100.0%**	**10,403**	**100.0%**	**5,849**	**100.0%**	**4,531**	**100.0%**	**4,999**	**100.0%**	**68,893**	**100.0%**

Notes:
1) Values in Table may reflect rounding
2) The lateral inflow for the Total Study Area was obtained directly from the numerical model outputs. The sum of the lateral inputs for the Black River Subwatershed and Georgina Creeks Subwatershed may not equal the value shown for the Study Area.

Figure B4-1 - Water Budget (Groundwater) - 2 Year Drought - Committed/Planned Water Demand - Study Area

Inputs

	m³/day	%
Recharge	9414	14%
Stream Recharge	21525	31%
Wells	0	0%
Lateral Inflow	14535	21%
Lake Simcoe	35	0%
Storage	23045	34%
Total Inputs	**68553**	**100%**



All flow volumes expressed as m^3/day

Outputs

	m³/day	%
Stream	25997	38%
Lake Simcoe	4807	7%
Wells	11932	17%
Lateral Outflow	25774	37%
Storage	382	1%
Total Outputs	**68893**	**100%**

Net Water Balance (In - Out) (%)

0%

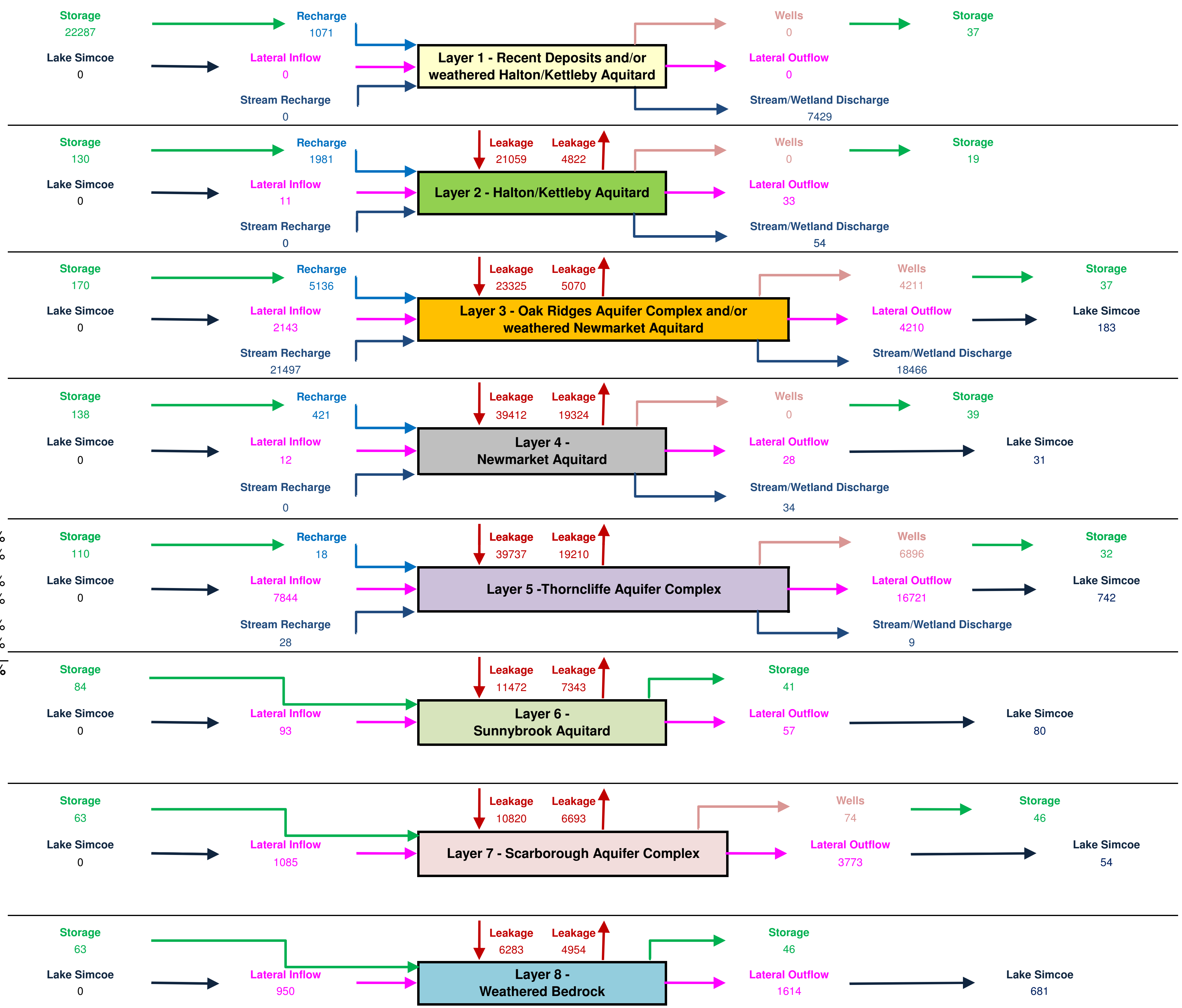
Note:

Values presented may reflect rounding. Some minor differences in water budget estimates are expected due to numerical model calculations.

Figure B4-2 - Water Budget (Groundwater) - 2 Year Drought - Committed/Planned Water Demand - Black River Subwatershed

Inputs

	m³/day	%
Recharge	8627	13%
Stream Recharge	21525	33%
Wells	0	0%
Lateral Inflow	12140	19%
Lake Simcoe	0	0%
Storage	23045	35%
Total Inputs	**65337**	**100%**



All flow volumes expressed as m³/day

Outputs

	m³/day	%
Stream	25992	40%
Lake Simcoe	1772	3%
Wells	11180	17%
Lateral Outflow	26435	40%
Storage	297	0%
Total Outputs	**65677**	**100%**

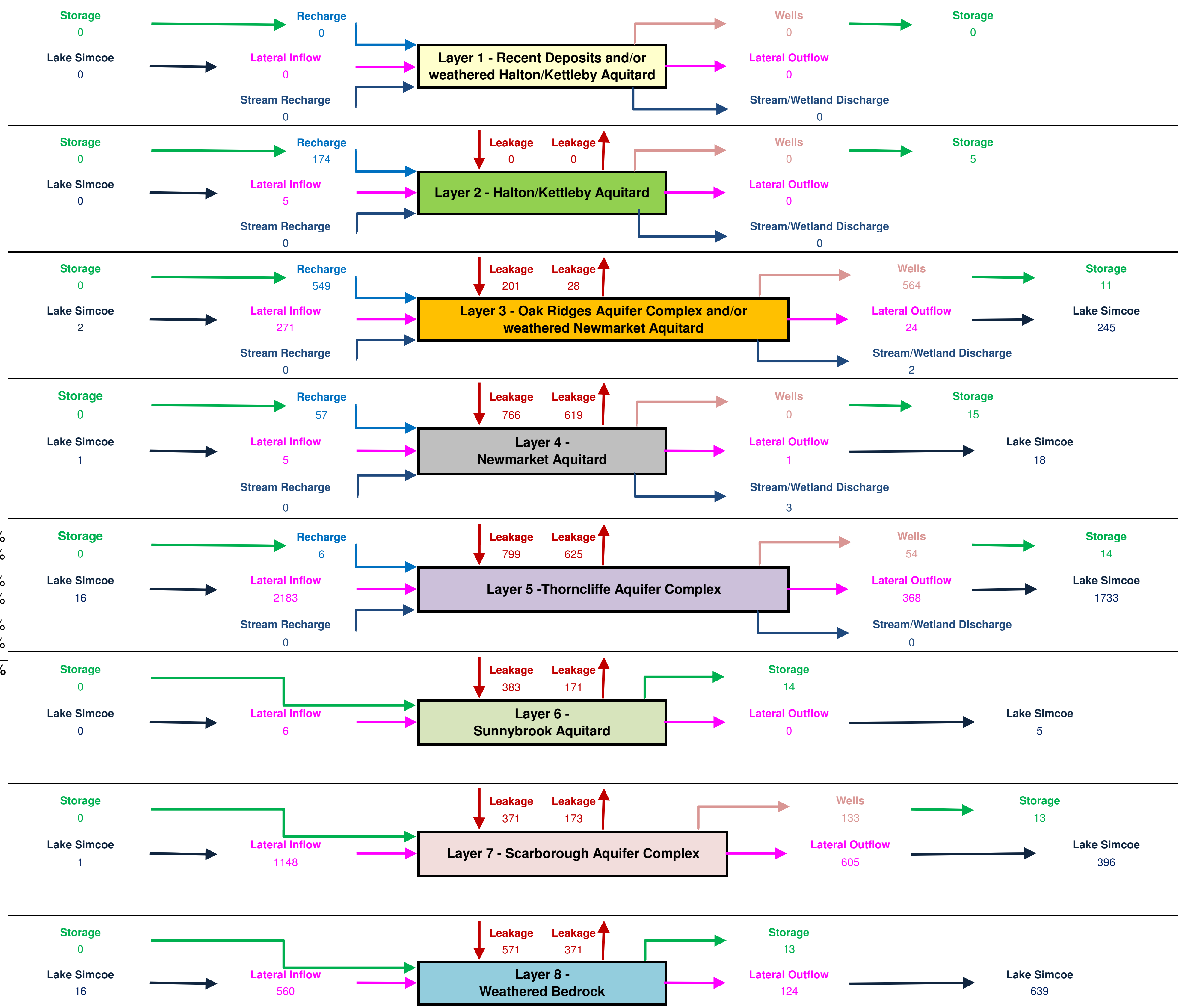
Net Water Balance (In - Out) (%)

-1%

Note:

Values presented may reflect rounding. Some minor differences in water budget estimates are expected due to numerical model calculations.

Figure B4-3 - Water Budget (Groundwater) - 2 Year Drought - Committed/Planned Water Demand - Georgina Creeks Subwatershed



All flow volumes expressed as m^3/day

Inputs

	m^3/day	%
Recharge	786	16%
Stream Recharge	0	0%
Wells	0	0%
Lateral Inflow	4178	84%
Lake Simcoe	35	1%
Storage	0	0%
Total Inputs	**5000**	**100%**

Outputs

	m^3/day	%
Stream	5	0%
Lake Simcoe	3036	61%
Wells	751	15%
Lateral Outflow	1122	22%
Storage	85	2%
Total Outputs	**4999**	**100%**

Net Water Balance (In - Out) (%)

0%

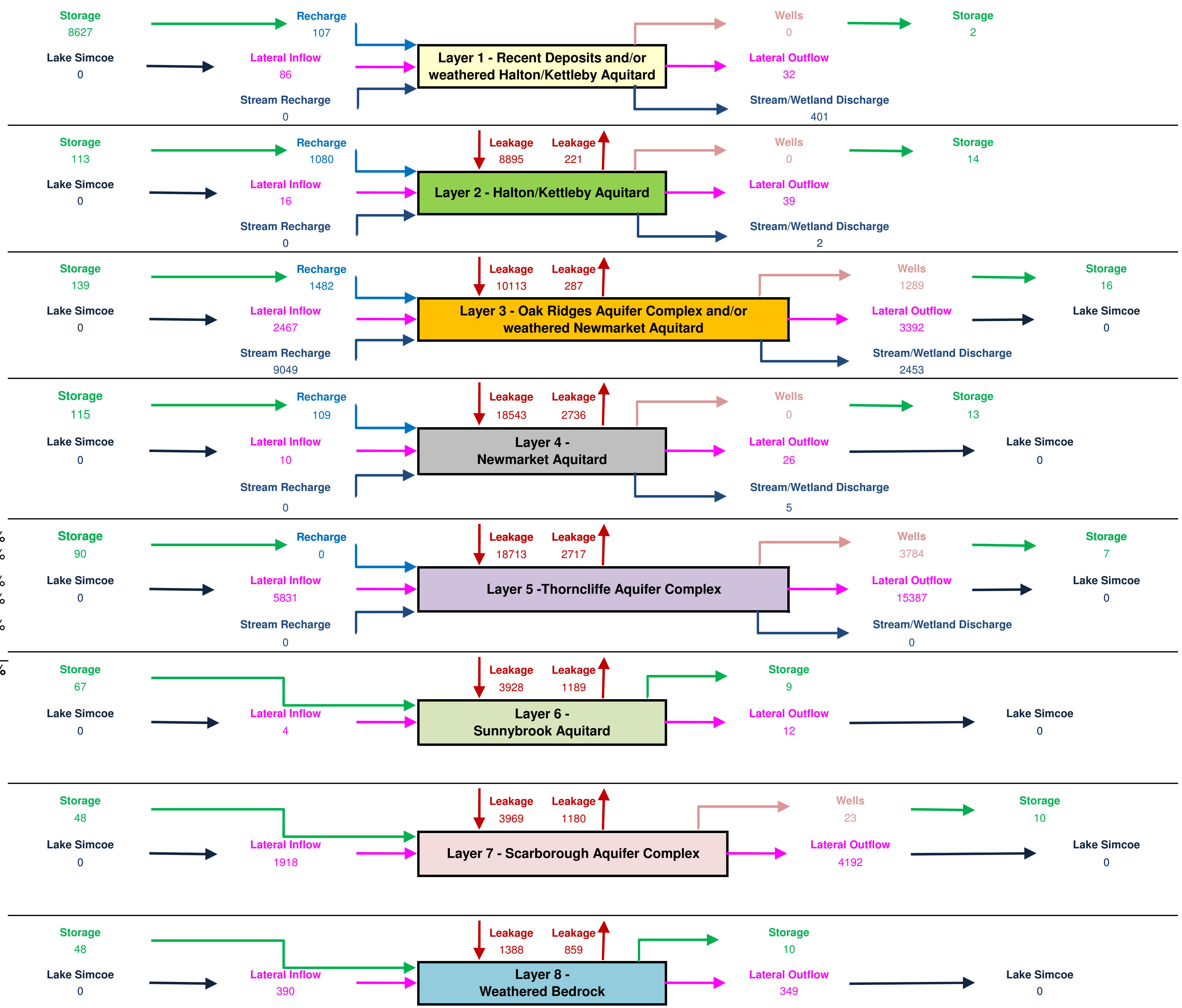
Note:

Values presented may reflect rounding. Some minor differences in water budget estimates are expected due to numerical model calculations.

Figure B4-4 - Water Budget (Groundwater) - 2 Year Drought - Committed/Planned Water Demand - Black River SubSubwatershed 1

Inputs

	m^3/day	%
Recharge	2778	9%
Stream Recharge	9049	28%
Wells	0	0%
Lateral Inflow	10722	34%
Storage	9248	29%
Total Inputs	**31797**	**100%**



All flow volumes expressed as m^3 /day

Outputs

	m^3/day	%
Stream	2862	9%
Lake Simcoe	0	0%
Wells	5097	16%
Lateral Outflow	23429	74%
Storage	82	0%
Total Outputs	**31470**	**100%**

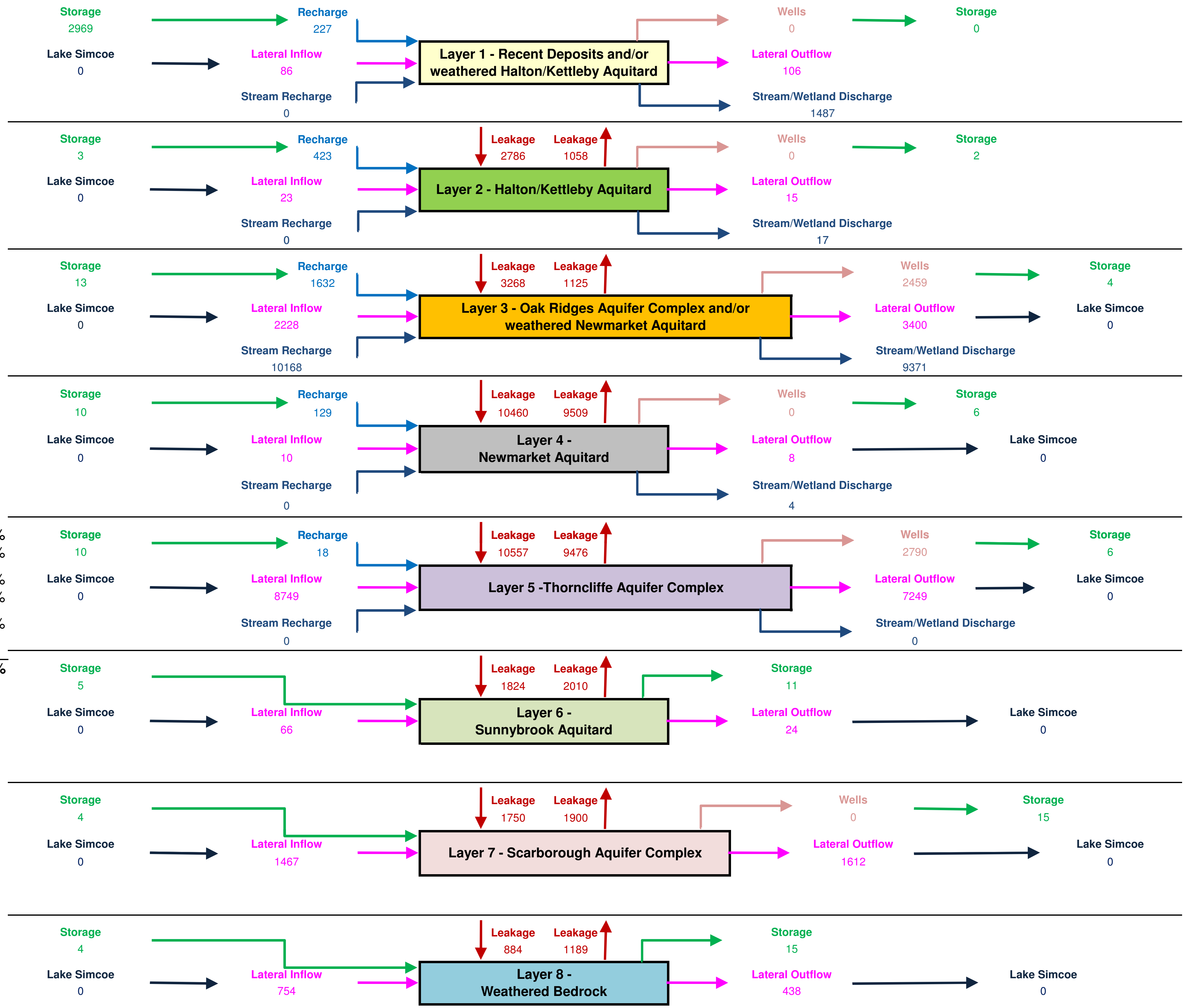
Net Water Balance (In - Out) (%)

1%

Note:

Values presented may reflect rounding. Some minor differences in water budget estimates are expected due to numerical model calculations.

Figure B4-5 - Water Budget (Groundwater) - 2 Year Drought - Committed/Planned Water Demand - Black River SubSubwatershed 2



All flow volumes expressed as m^3/day

Inputs

	m^3/day	%
Recharge	2430	8%
Stream Recharge	10168	35%
Wells	0	0%
Lateral Inflow	13383	46%
Storage	3017	10%
Total Inputs	**28998**	**100%**

Outputs

	m^3/day	%
Stream	10878	37%
Lake Simcoe	0	0%
Wells	5249	18%
Lateral Outflow	12852	44%
Storage	58	0%
Total Outputs	**29038**	**100%**

Net Water Balance (In - Out) (%)

0%

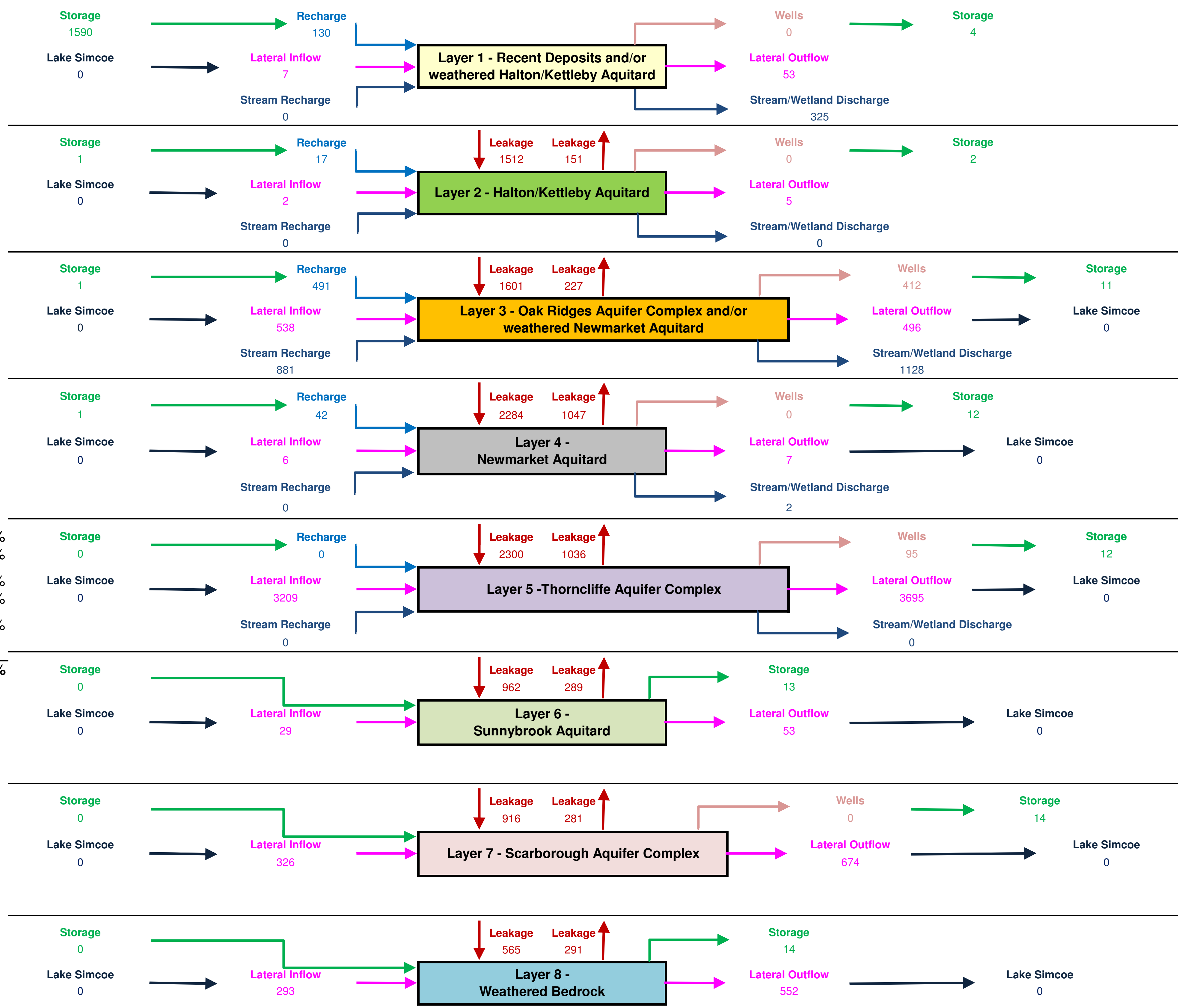
Note:

Values presented may reflect rounding. Some minor differences in water budget estimates are expected due to numerical model calculations.

Figure B4-6 - Water Budget (Groundwater) - 2 Year Drought - Committed/Planned Water Demand - Black River SubSubwatershed 3

Inputs

	m^3/day	%
Recharge	680	9%
Stream Recharge	881	12%
Wells	0	0%
Lateral Inflow	4411	58%
Storage	1593	21%
Total Inputs	**7565**	**100%**



All flow volumes expressed as m^3/day

Outputs

	m^3/day	%
Stream	1456	19%
Lake Simcoe	0	0%
Wells	507	7%
Lateral Outflow	5535	73%
Storage	82	1%
Total Outputs	**7580**	**100%**

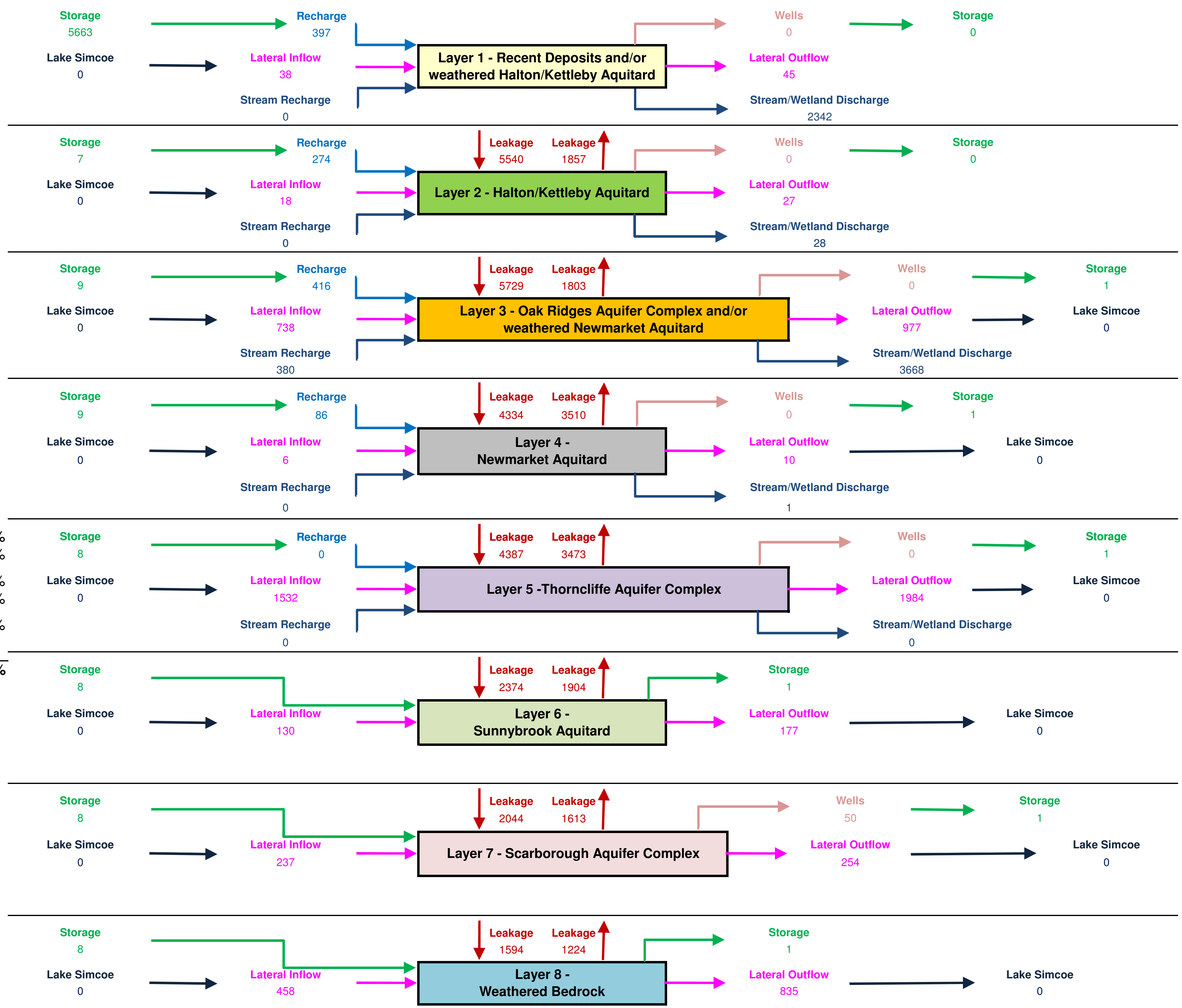
Net Water Balance (In - Out) (%)

0%

Note:

Values presented may reflect rounding. Some minor differences in water budget estimates are expected due to numerical model calculations.

Figure B4-7 - Water Budget (Groundwater) - 2 Year Drought - Committed/Planned Water Demand - Black River SubSubwatershed 4



All flow volumes expressed as m^3/day

Inputs

	m^3/day	%
Recharge	1172	11%
Stream Recharge	380	4%
Wells	0	0%
Lateral Inflow	3157	30%
Storage	5720	55%
Total Inputs	**10429**	**100%**

Outputs

	m^3/day	%
Stream	6039	58%
Lake Simcoe	0	0%
Wells	50	0%
Lateral Outflow	4309	41%
Storage	5	0%
Total Outputs	**10403**	**100%**

Net Water Balance (In - Out) (%)

0%

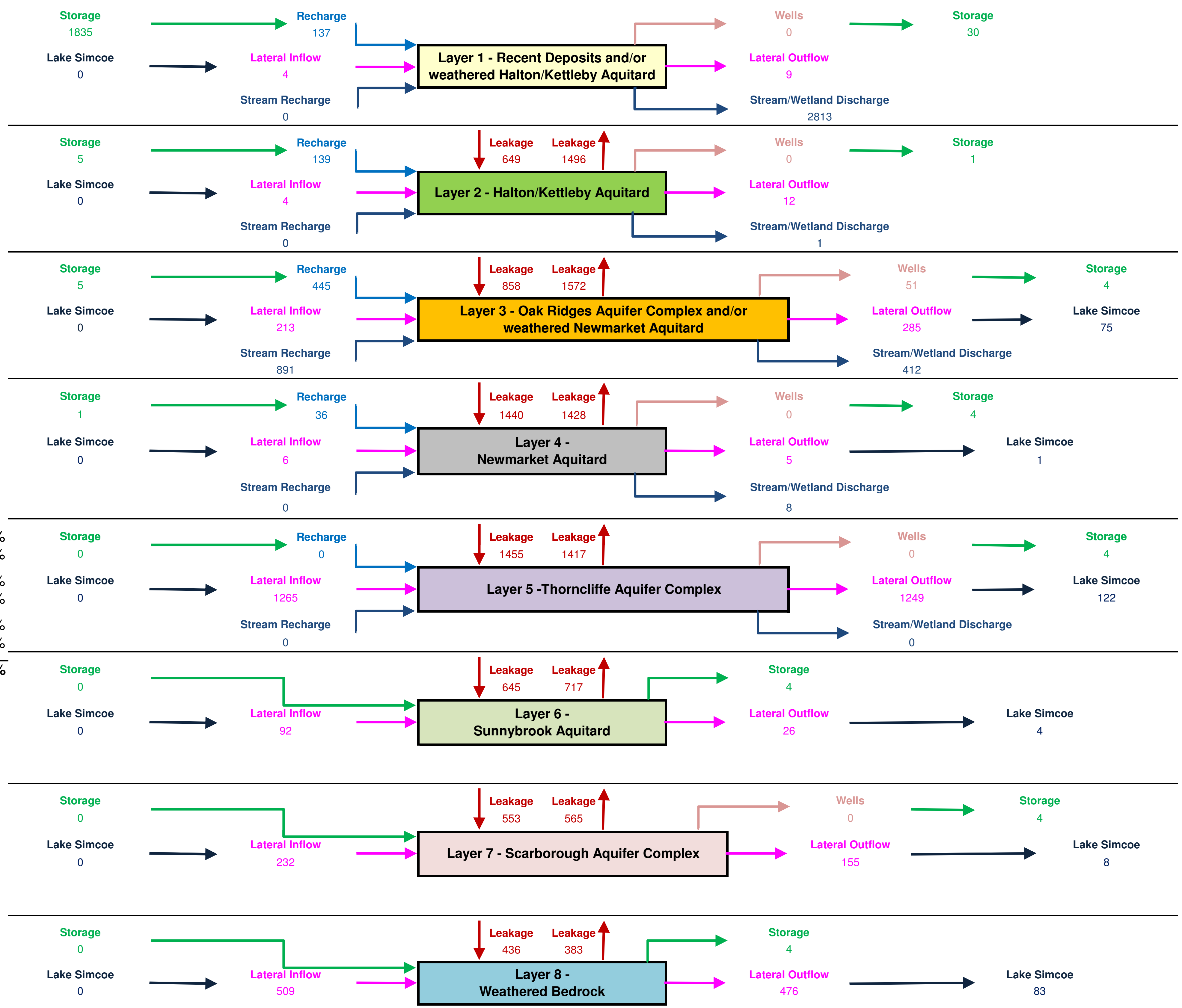
Note:

Values presented may reflect rounding. Some minor differences in water budget estimates are expected due to numerical model calculations.

Figure B4-8 - Water Budget (Groundwater) - 2 Year Drought - Committed/Planned Water Demand - Black River SubSubwatershed 5

Inputs

	m^3/day	%
Recharge	758	13%
Stream Recharge	891	15%
Wells	0	0%
Lateral Inflow	2325	40%
Lake Simcoe	0	0%
Storage	1847	32%
Total Inputs	**5821**	**100%**



All flow volumes expressed as m^3/day

Outputs

	m^3/day	%
Stream	3235	55%
Lake Simcoe	291	5%
Wells	51	1%
Lateral Outflow	2216	38%
Storage	57	1%
Total Outputs	**5849**	**100%**

Net Water Balance (In - Out) (%)

0%

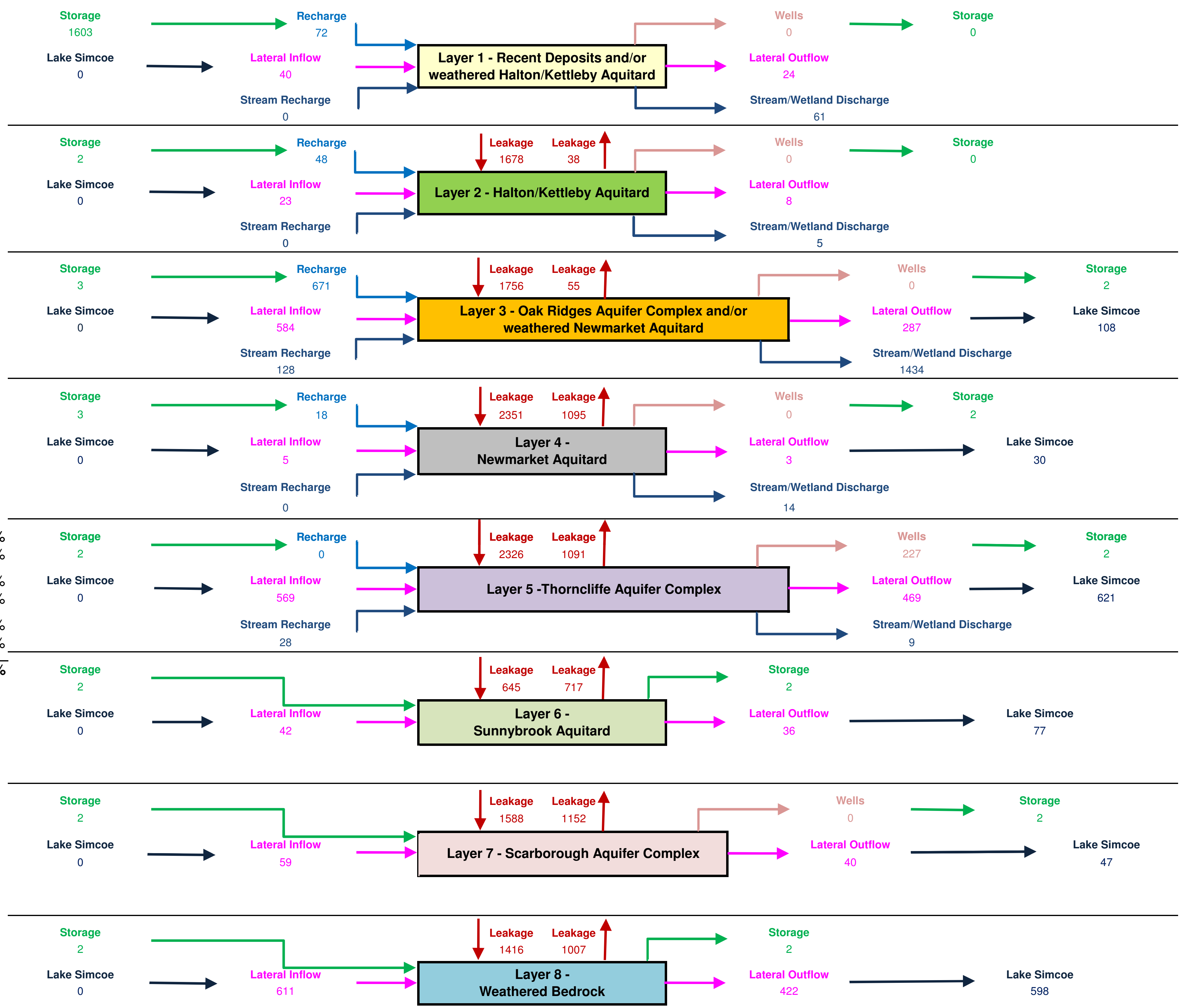
Note:

Values presented may reflect rounding. Some minor differences in water budget estimates are expected due to numerical model calculations.

Figure B4-9 - Water Budget (Groundwater) - 2 Year Drought - Committed/Planned Water Demand - Black River SubSubwatershed 6

Inputs

	m³/day	%
Recharge	809	18%
Stream Recharge	156	3%
Wells	0	0%
Lateral Inflow	1935	43%
Lake Simcoe	0	0%
Storage	1621	36%
Total Inputs	**4521**	**100%**



All flow volumes expressed as m³/day

Outputs

	m³/day	%
Stream	1523	34%
Lake Simcoe	1481	33%
Wells	227	5%
Lateral Outflow	1287	28%
Storage	13	0%
Total Outputs	**4531**	**100%**

Net Water Balance (In - Out) (%)

0%

Note:

Values presented may reflect rounding. Some minor differences in water budget estimates are expected due to numerical model calculations.

Appendix C

Ecologically Significant Groundwater Recharge Areas

Technical Memorandum C1

Identification of Ecologically Sensitive Features for ESGRA Analysis

GENIVAR

TECHNICAL MEMORANDUM C1

Date:	January 24, 2013
To	Shelly Cuddy, Lake Simcoe Region Conservation Authority
Copy:	Katie Howson, LSRCA Scott Bates, Ministry of Natural Resources (MNR)
From:	Lloyd Lemon and Isabelle Hemmings
Project No.:	121-17211-00
Subject:	Tier 2 Water Budget and ESGRA for Black River and Georgina Creeks Subwatersheds Identification of Ecologically Sensitive Features for ESGRA Analysis

This memo documents the information provided by the Lake Simcoe Region Conservation Authority (LSRCA) for use in identifying Ecologically Sensitive Features to be used in the Ecologically Significant Groundwater Recharge Area (ESGRA) analysis for the Black River and Georgina Creeks Subwatersheds.

The LSRCA have provided the following definition for ESGRA:

"Ecologically Significant Groundwater Recharge Areas (ESGRAs) are identified as areas of land that are responsible for supporting groundwater systems that sustain sensitive features like coldwater streams and wetlands. To establish the ecological significance of the recharge area, a linkage must be present between the recharge area and the Ecologically Sensitive Feature (e.g. a reach of a coldwater stream, a wetland, or an area of natural or scientific interest (ANSI)). The identification of an ESGRA is not related to the volume of recharge that may be occurring, rather they represent pathways in which recharge, if it occurred, would reach that feature. While delineating ESGRAs is an important task in establishing the linkage between a recharge area and an Ecologically Sensitive Feature it is not a certainty that ESGRAs will coincide with SGRAs, as they may not support high volumes of recharge. While ESGRAs and SGRAs are not mutually exclusive, the areas where they do coincide support high volumes of recharge and support Ecologically Sensitive Features".

The purpose of the ESGRA analysis is to identify the recharge areas that contribute to the Ecologically Sensitive Features within the Black River and Georgina Creeks Subwatersheds. The features that were reviewed to determine the Ecologically Sensitive Features to be considered in this study include:

- Lakes
- Rivers and streams
- Wetlands
- Areas of Natural or Scientific Interest

The distribution of surface water features within the watershed is shown in Figure C1-1. The following sections document the review of each feature type to identify Ecologically Sensitive Features.

Lakes

There are no naturally occurring lakes within the study area. Two man-made lakes are shown as:

- Franklin Pond, part of the Franklin Trout Farm operations west of Mount Albert, and
- Joseph's Lake, created by peat farming operations, north of Zephyr.

These man-made lakes will not be specifically modelled in this study as Environmentally Sensitive Features. Franklin Pond is part of the Mount Albert Creek drainage system. Joseph's Lake is within a large area of wetland. These ESGRA associated with the man-made lakes will be determined based on the significance of either Mount Albert Creek or surrounding wetland systems.

There are numerous small ponds, and kettle lakes within the Black River and Georgina Creeks Subwatersheds. Most of these appear to be man-made. Naturally occurring water bodies (lakes) or ponds are not considered to be Ecologically Sensitive Features, unless they are included within the mapped wetlands.

Streams

The Strahler classification of the stream network within the Black River and Georgina Creeks Subwatersheds are shown in Figure C1-2. The numerical groundwater flow model includes all streams up to a Strahler Classification of 7. Streams with Strahler Classifications of 1 and 2 are assigned boundary conditions as MODFLOW Drains. Streams with Strahler Classifications of 3 to 7 are assigned boundary conditions a MODFLOW Rivers. The use of the MODFLOW Rivers Boundary allows water to flow from the stream to groundwater (recharge) or from the groundwater to the stream (Discharge) depending on the local groundwater elevations. A MODFLOW Drain Boundary only allows water to flow from the groundwater to the stream.

Figure C1-3 illustrates the distribution of the cells containing stream boundaries in the numerical model. The total length of all mapped streams is approximately 570,430.5 m. More than 90% of the total stream length is represented in the numerical model.

Figure C1-4 illustrates the distribution of stream reaches identified as cold water fish habitat. Supporting data for temperature mapping, and observed fish species are provided in Figure C1-4. Cold water fish habitat includes stations where temperatures were recorded as cool or cold and where fish sampling identifies the presence of trout or sculpin. The cold water stream reaches are considered to be Ecologically Sensitive Features and will be used as target points in the numerical model to monitor either the backward movement of particles or the arrival of particles in a forward-tracking mode.

Wetlands

Figure C1-5 illustrates the distribution of various wetland features in the Black River and Georgina Creeks Subwatersheds by type. Figure C1-5 includes both Provincially Significant Wetlands as per the 2012 mapping available from the Ministry of Natural Resources and wetland mapping provided by the LSRCA. The majority of the area represented by wetlands is considered to be swamps. All mapped wetlands are to be considered as Environmentally Sensitive Features as there is not sufficient information available to distinguish which wetland features are supported by groundwater or surface water.

Wetlands were not assigned specific boundary conditions in the numerical groundwater flow model provided to carry out the ESGRA analysis. GENIVAR has added drains to the Black River Groundwater Model beneath the mapped wetland features to provide an ability for groundwater particle tracking within the model to be directed out of the model within the wetlands.

The wetlands shown on Map C1-5 will be considered as Ecologically Sensitive Features for the ESGRA analysis. In reverse-tracking mode, particles will be released both from the stream segment within the wetland and from the area underlying the wetland. In forward-tracking mode, the wetland area will be used as the target zone to identify areas where recharge contributes to the Ecologically Sensitive Feature.

Areas of Natural or Scientific Interest

Figure C1-5 also presents the extent of features mapped as Areas of Natural or Scientific Interest (ANSI). For the most part, the ANSI features correspond with the mapped wetlands, although in some areas the ANSI may include areas not within the wetland. The ANSI features will be included as Environmentally Sensitive Features.

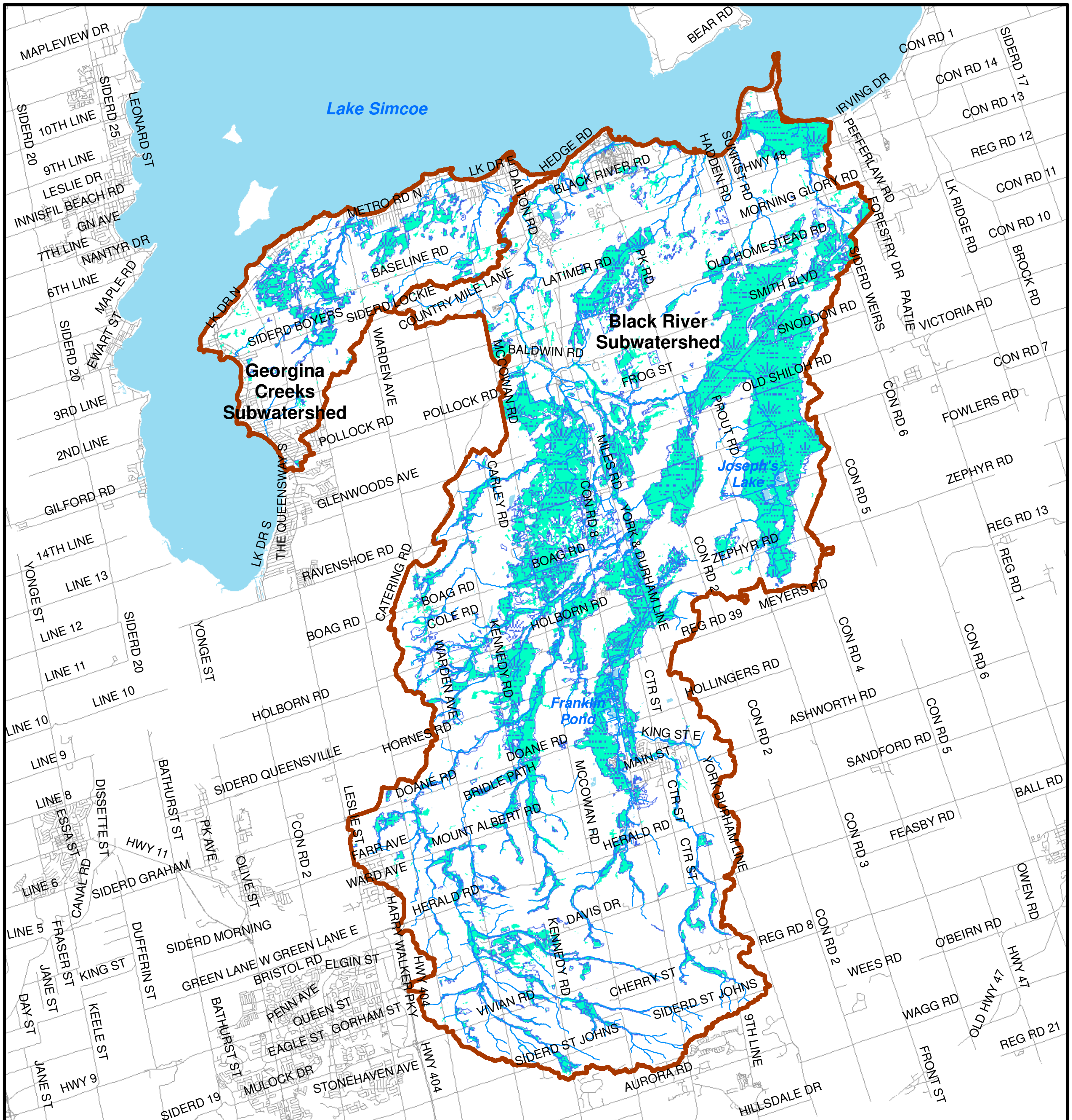
Ecologically Sensitive Features

Figure C1-6 illustrates the Ecologically Sensitive Features that will be considered in the ESGRA analysis for the Black River and Georgina Creeks Subwatersheds.

Mapping prepared by the MNR to delineate Eco-Sensitive Features associated with species at risk was reviewed and these areas were confirmed to be within the Ecologically Sensitive Features area presented on Figure C1-6.

LAL:nah

List of Figures



LEGEND

- Subwatersheds
- Watercourse
- Wetlands (LSRCA ELC)
- Wetlands (PSW)
- Waterbodies
- Road

N
W E
S

Data Source: Lake Simcoe Region Conservation Authority.
Ministry of Natural Resources, Ontario Base Mapping, June 2012.

1,500 750 0 1,500 Metres

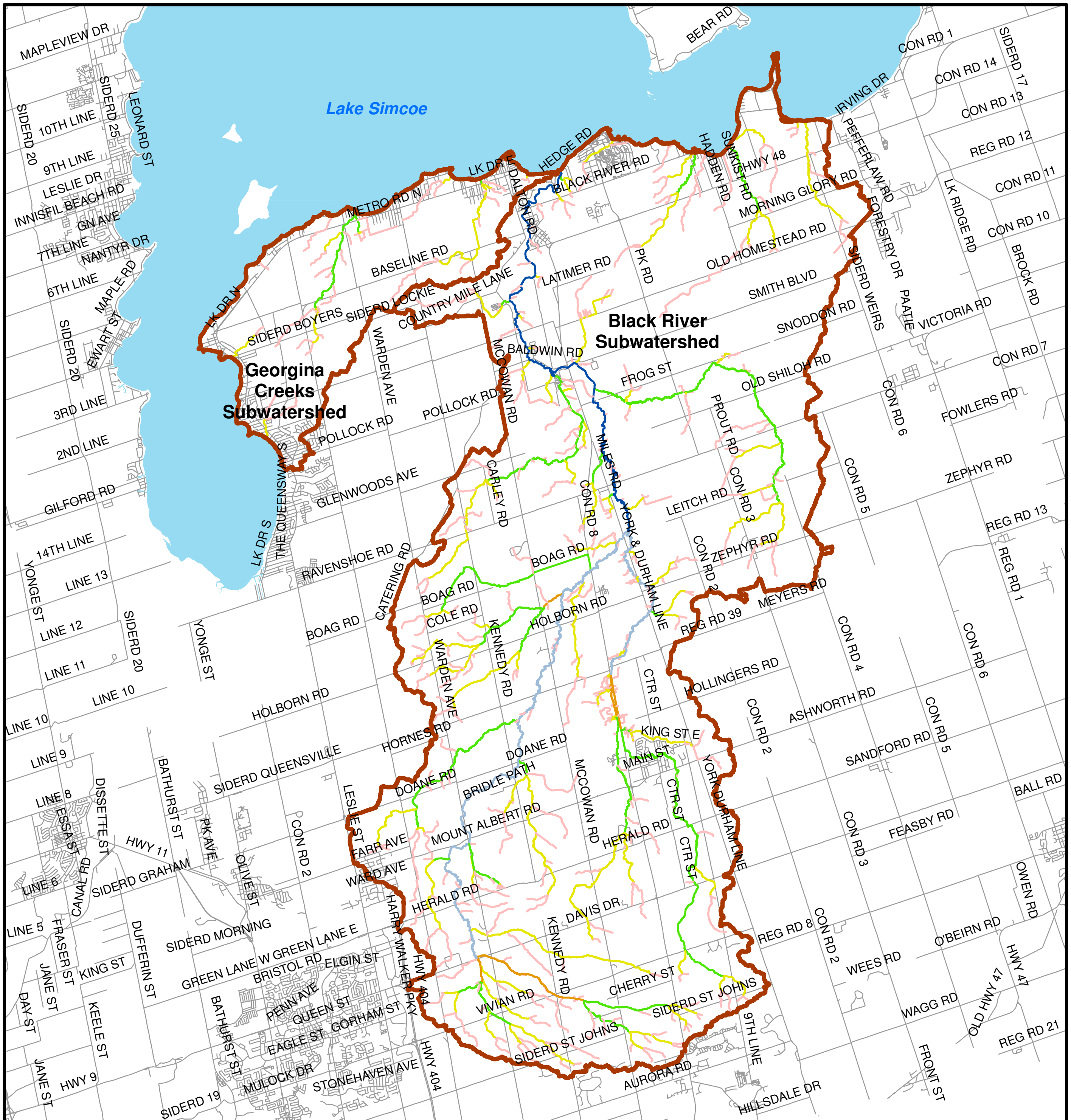
SURFACE WATER FEATURES

TIER 2 WATER BUDGET AND ECOLOGICALLY SENSITIVE GROUNDWATER RECHARGE AREAS ASSESSMENT FOR THE BLACK RIVER AND GEORGINA CREEKS SUBWATERSHEDS
For: Lake Simcoe Region Conservation Authority

DATE: FEBRUARY 2013	SCALE: 1:200000
PROJECT: 121-17211-00	FILE. NO.:1211721100FC1-1

GENIVAR

FIGURE
C1-1



LEGEND

Subwatersheds

Stream Order

- 1
- 2
- 3
- 4
- 5
- 6

Road

N
W E
S

Data Source: Lake Simcoe Region Conservation Authority.
Ministry of Natural Resources, Ontario Base Mapping, June 2012.

1,500 750 0 1,500 Metres

STRAHLER CLASSIFICATION OF STREAMS

TIER 2 WATER BUDGET AND ECOLOGICALLY SENSITIVE GROUNDWATER RECHARGE AREAS ASSESSMENT FOR THE BLACK RIVER AND GEORGINA CREEKS SUBWATERSHEDS
For: Lake Simcoe Region Conservation Authority

DATE: JANUARY 2013	SCALE: 1:200000
PROJECT: 121-17211-00	FILE. NO.:1211721100FC1-2

GENIVAR

FIGURE
C1-2

LEGEND

- Watercourse
- MODFLOW River Boundary
- MODFLOW Drain Boundary
- Subwatersheds
- Road

REPRESENTATION OF STREAMS IN GENIVAR GROUNDWATER MODEL

TIER 2 WATER BUDGET AND ECOLOGICALLY SENSITIVE GROUNDWATER RECHARGE AREAS ASSESSMENT FOR THE BLACK RIVER AND GEORGINA CREEKS SUBWATERSHEDS
For: Lake Simcoe Region Conservation Authority

DATE: JANUARY 2013	SCALE: 1:200000
PROJECT: 121-17211-00	FILE. NO.:1211721100FC1-3

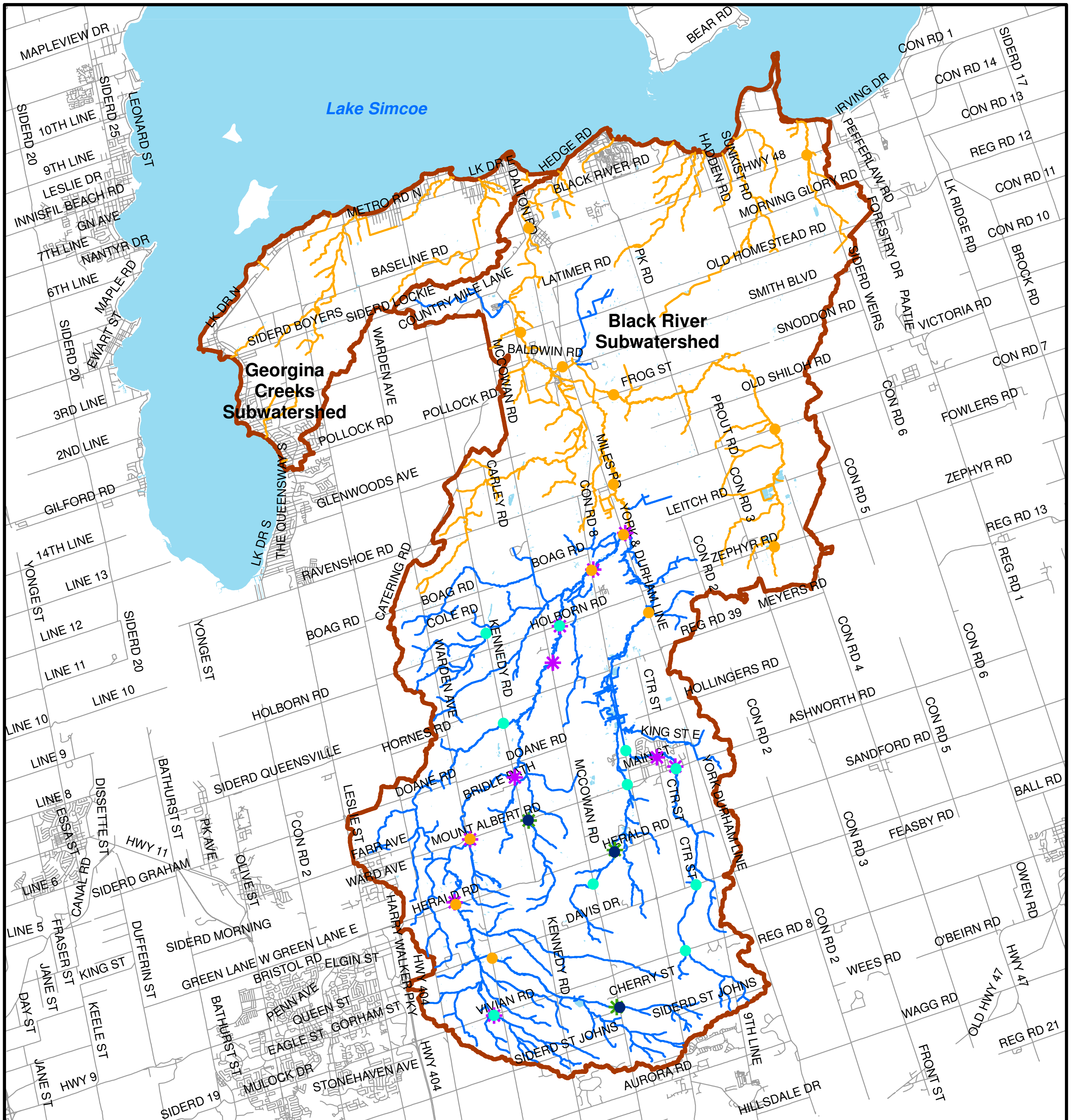
N
W E
S

1,500 750 0 1,500 Metres

Data Source: Lake Simcoe Region Conservation Authority.
Ministry of Natural Resources, Ontario Base Mapping, June 2012.

GENIVAR

FIGURE
C1-3



LEGEND

Temperature

- cold
- cool
- warm
- Trout Capture Site
- Sculpin Capture Site
- Cold Water Streams
- Warm Water Streams
- Subwatersheds
- Waterbodies
- Road

N / W / E / S

1,500 750 0 1,500 Metres

Data Source: Lake Simcoe Region Conservation Authority.
Ministry of Natural Resources, Ontario Base Mapping, June 2012.

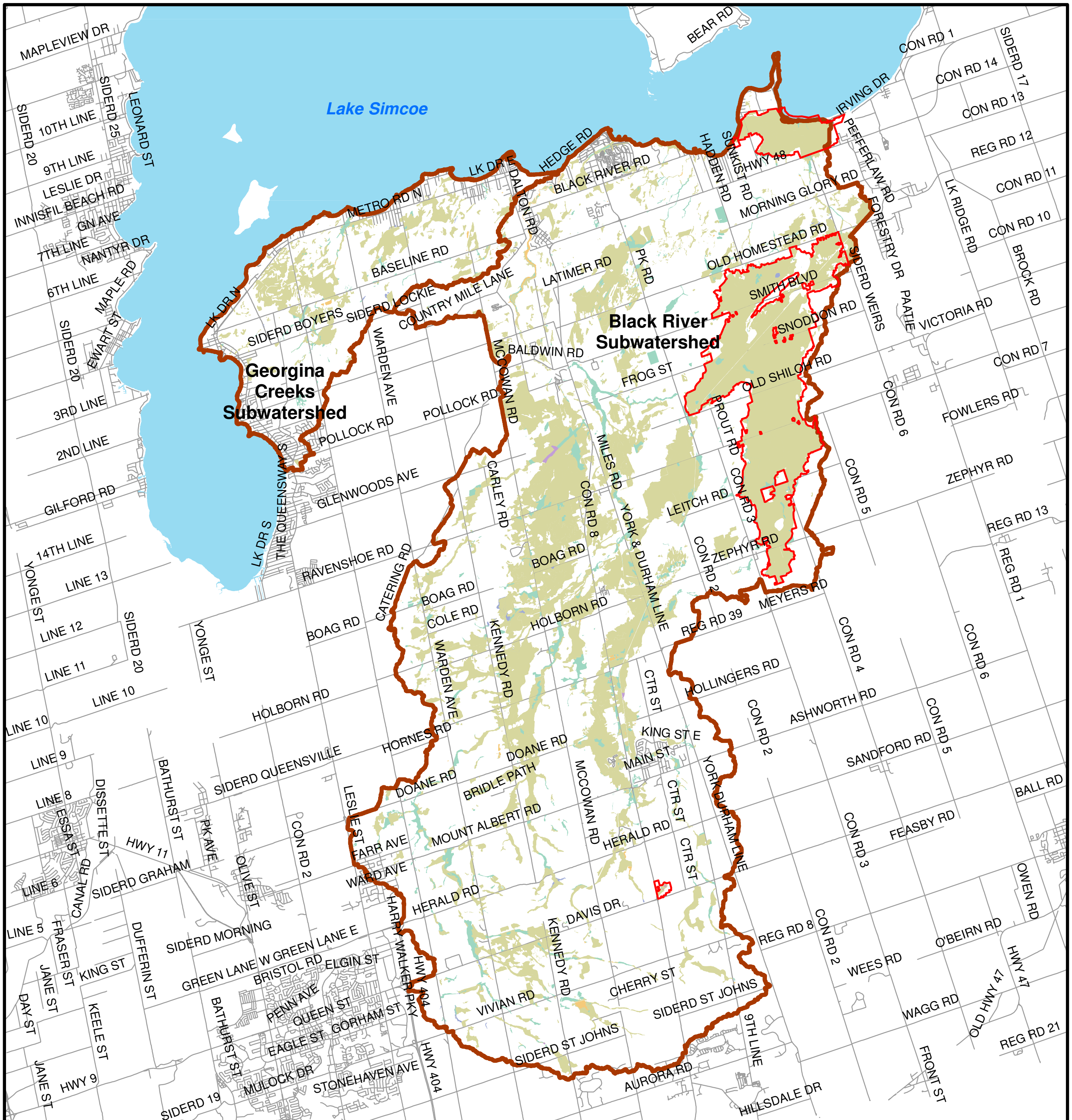
COLD WATER FISH HABITAT

TIER 2 WATER BUDGET AND ECOLOGICALLY SENSITIVE GROUNDWATER RECHARGE AREAS ASSESSMENT FOR THE BLACK RIVER AND GEORGINA CREEKS SUBWATERSHEDS
For: Lake Simcoe Region Conservation Authority

DATE: JANUARY 2013	SCALE: 1:200000
PROJECT: 121-17211-00	FILE. NO.:1211721100FC1-4

GENIVAR

FIGURE
C1-4



LEGEND

- Areas of Natural and Scientific Interest (ANSI)
- Subwatersheds
- Bog
- Fen
- Marsh
- Open Water
- Swamp
- Unknown
- Road

N
W E
S

1,500 750 0 1,500 Metres

Data Source: Lake Simcoe Region Conservation Authority.
Ministry of Natural Resources, Ontario Base Mapping, June 2012.

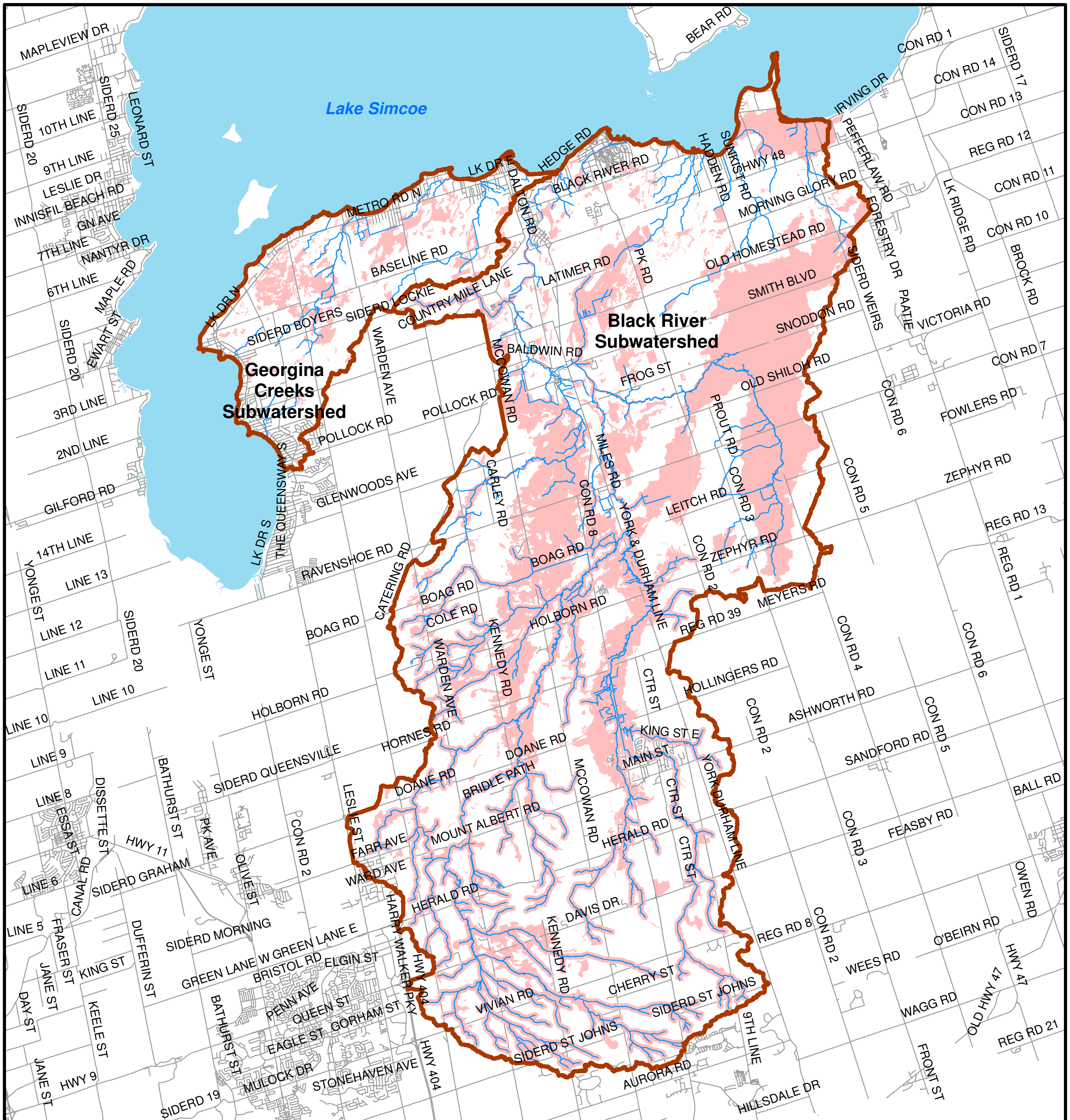
WETLANDS

TIER 2 WATER BUDGET AND ECOLOGICALLY SENSITIVE GROUNDWATER RECHARGE AREAS ASSESSMENT FOR THE BLACK RIVER AND GEORGINA CREEKS SUBWATERSHEDS
For: Lake Simcoe Region Conservation Authority

DATE: JANUARY 2013	SCALE: 1:200000
PROJECT: 121-17211-00	FILE. NO.:1211721100FC1-5

GENIVAR

FIGURE
C1-5



LEGEND

- Subwatersheds
- Watercourse
- Road
- Ecologically Sensitive Features

N W E S

1,500 750 0 1,500 Metres

Data Source: Lake Simcoe Region Conservation Authority.
Ministry of Natural Resources, Ontario Base Mapping, June 2012.

ECOLOGICALLY SENSITIVE FEATURES

TIER 2 WATER BUDGET AND ECOLOGICALLY SENSITIVE GROUNDWATER RECHARGE AREAS ASSESSMENT FOR THE BLACK RIVER AND GEORGINA CREEKS SUBWATERSHEDS
For: Lake Simcoe Region Conservation Authority

DATE: JANUARY 2013	SCALE: 1:200000
PROJECT: 121-17211-00	FILE. NO.:1211721100FC1-6

GENIVAR

FIGURE
C1-6

Technical Memorandum C2

ESGRA Delineation by Cluster Analysis

GENIVAR

TECHNICAL MEMORANDUM C2

Date:	January 24, 2013
To	Shelly Cuddy, Lake Simcoe Region Conservation Authority
Copy:	Katie Howson, LSRCA Scott Bates, Ministry of Natural Resources (MNR)
From:	Lloyd Lemon and Tanya Peterson
Project No.:	121-17211-00
Subject:	Tier 2 Water Budget and ESGRA for Black River and Georgina Creeks Subwatersheds ESGRA Delineation by Cluster Analysis

This memo documents the methods used for the endpoint cluster analysis of the backward particle tracking exercise. The methodology followed the same process as Earth*fx Inc.* (2012) used in the cluster endpoint analysis within the Barrie, Hewitt, Lovers Creek study. The distribution of particle endpoints is illustrated in Figure C2-1.

The cluster analysis was conducted in an ArcGIS environment using the spatial analyst tool – Kernel Density. This tool fits a smoothly curved surface over each point and then the density is calculated by summing the "kernel surfaces" that overlay the raster cell centre. Some variables are subjective to user interpretation; these include the Search Radius (Smoothing Parameter, h) as well as the Delineation Threshold (ε).

The Search Radius is the distance to which the density is calculated. Generally, for a smaller search radius the cluster output will be smaller and tighter. For a larger search radius the cluster output becomes more circular and generalized. The search radius is equivalent to the Smoothing Parameter or "h" value within the Earth*fx* study.

The Delineation Threshold is a percentage of endpoints that will be excluded based on the density of endpoints. For example, a delineation threshold of 0.01 removes 1% of the cluster density (i.e. 99% of the kernel density analysis is considered clustered). The Delineation Threshold is equivalent to the "ε" value within Earth*fx* study.

Several cluster analysis output scenarios were evaluated to identify the most effective combination of search radius and Delineation Threshold to provide an optimum capture of endpoints within a realistic proportion of the Subwatershed Area:

- h = 25, ε = 0.001, 0.005, 0.01, 0.05 & 0.1,
- h = 50, ε = 0.001, 0.005, 0.01, 0.05 & 0.1,
- h = 100, ε = 0.001, 0.005, 0.01, 0.05 & 0.1,
- h = 200, ε = 0.001, 0.005, 0.01, 0.05 & 0.1,
- h = 500, ε = 0.001, 0.005, 0.01, 0.05 & 0.1.

Figure C2-2 illustrates a search radius of 25 m. On this figure very few areas appear to be dense as shown in red, the majority of clustering is around single endpoints. Figure C2-3 doubles the search radius to 50 m and there are more areas of defined clustering (red, orange and yellow), especially where the delineation threshold is greater than 0.01. Figure C2-4 uses a search radius of 100 m and the more dense areas are becoming more clustered and definitive areas are observed. On Figure C2-5 the search

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radius is 200 m and the clustering is starting to become a little generalized, larger and less focussed on the endpoint locations. Figure C2-6, the search radius is 500 m and the whole area is clustered, this search radius is too high for the data as the clustered regions extend beyond the extent of the particle endpoints.

Table C2-1 Cluster Analysis Statistical Outputs is a statistical summary of the information on Figures C2-2 through C2-6. Table C2-1 presents the percentage of endpoints contained within each delineation cut off for each search radius. The higher the number and percentage the more endpoints are included within the cluster analysis. The table also outlines the percentage of land area within the subwatershed that is covered for each delineation threshold. The ideal would be to maximize the number of endpoints that are clustered within a reasonably minimized land area.

Figure C2-2 through C2-6 and Table C2-1 were provided to LSRCA for evaluation of the outputs and selection of a scenario to be used in determining the ESGRA. LSRCA reviewed the information in these tables and determined that the scenario of h = 100 and ε = 0.005 would provide an optimum degree of capture of particle endpoints and keep the areas to be included in ESGRA policies to a minimum. The preferred cluster distribution is shown in Figure C2-7.

The final ESGRA map was then prepared from the preferred cluster outputs by:

a) removing areas that were identified to remain within identified discharge features (Figure C2-8). Policies for discharge areas will remain in place in these areas.
b) Removing isolated clusters that occupy less than one 100 m grid cell.
c) Infilling gaps within the mapped clusters that occupy less than one 100 m grid cell

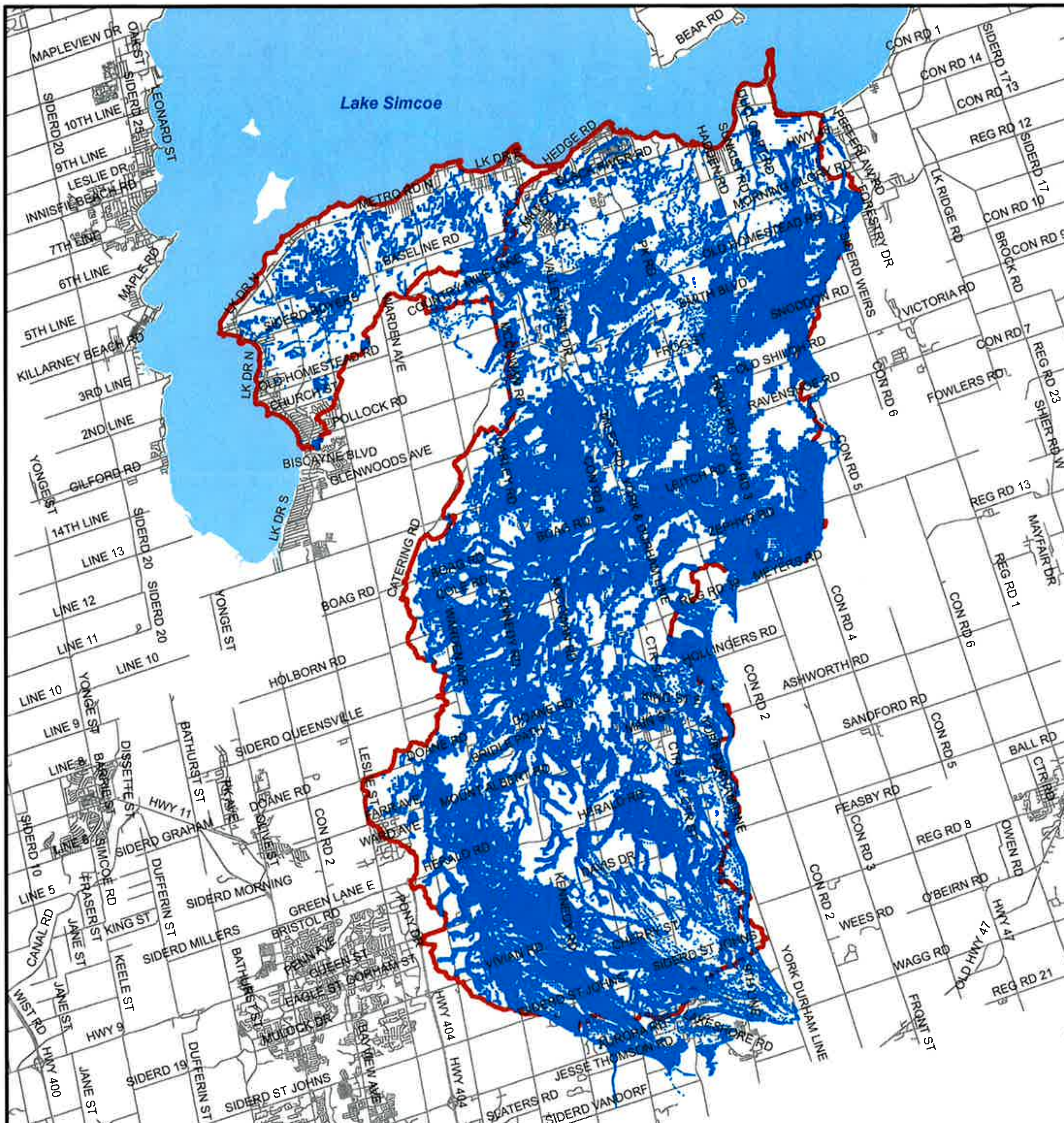
The cluster analysis was carried out on the entire dataset of backward particles. A filter was not applied to remove particle paths of short duration (i.e. less than one day or one month). The step to remove particle clusters within identified discharge features is assumed to have a similar effect to this filter.

The Final ESGRA is presented in Figure C2-9

LAL:nah

List of Figures

List of Tables



LEGEND

· Observed Particle Tracking End-Points - Reverse Particle Tracking

Subwatersheds

—— Road

N
W E
S

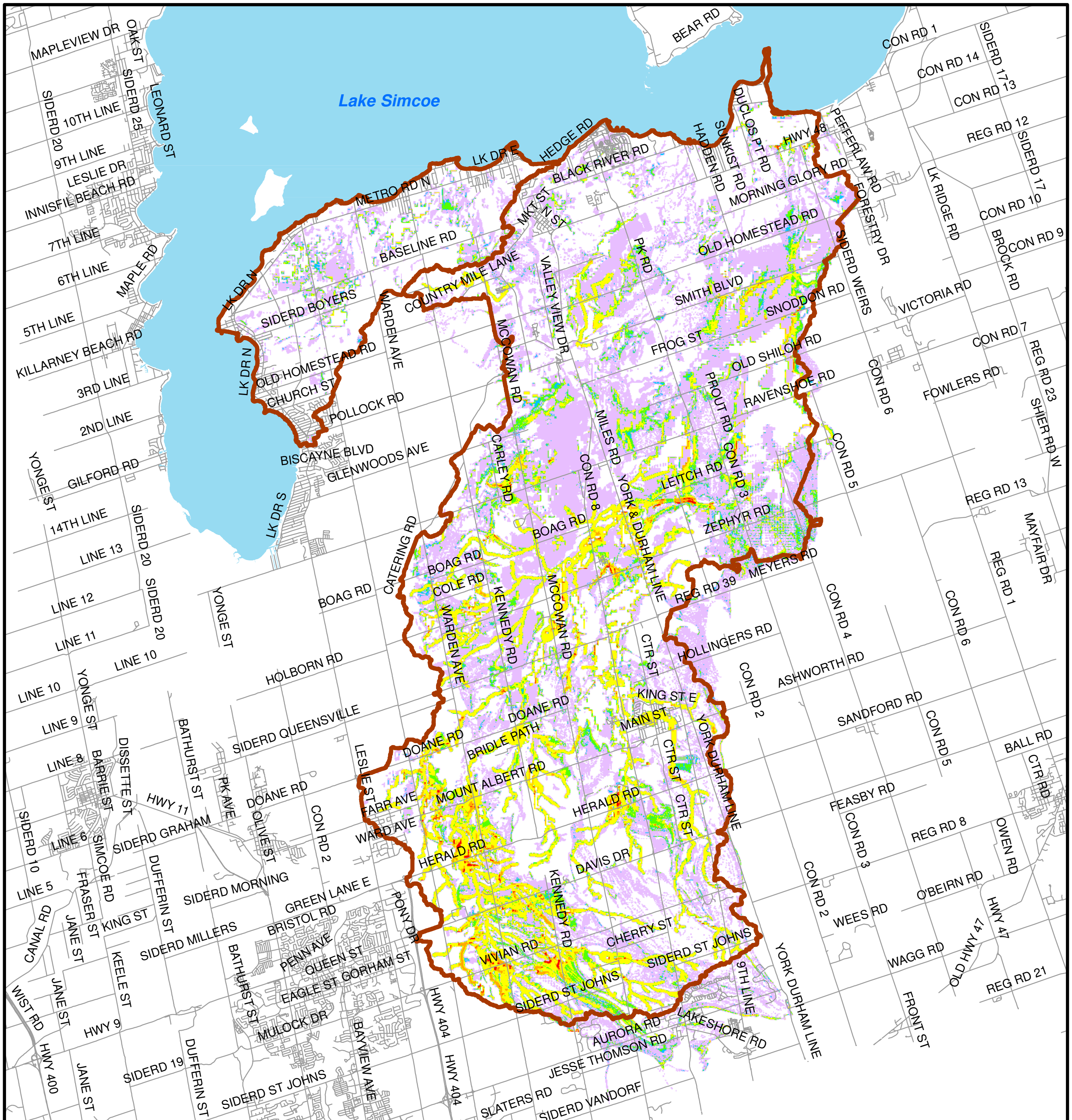
Data Source: Lake Simcoe Region Conservation Authority, Ministry of Natural Resources, Ontario Base Mapping, June 2012.

1,500 750 0 1,500 Metres

PARTICLE END-POINTS - REVERSE PARTICLE TRACKING

TIER 2 WATER BUDGET AND ESGRA
FOR THE BLACK RIVER AND
GEORGINA CREEKS SUBWATERSHEDS
ESGRA DELINEATION BY CLUSTER ANALYSIS
For: Lake Simcoe Region Conservation Authority

DATE: FEBRUARY 2013	SCALE: 1:210000
PROJECT: 121-17211-00	FILE. NO.:1211721100FC2-1
GENIVAR	FIGURE C2-1



LEGEND

Normalized Delineation Threshold

- <0.001
- 0.001 - 0.005
- 0.005 - 0.01
- 0.01 - 0.05
- 0.05 - 0.1
- 0.1 - 1
- Subwatersheds
- Road

N W E S

Data Source: Lake Simcoe Region Conservation Authority.
Ministry of Natural Resources, Ontario Base Mapping, June 2012.

1,500 750 0 1,500 Metres

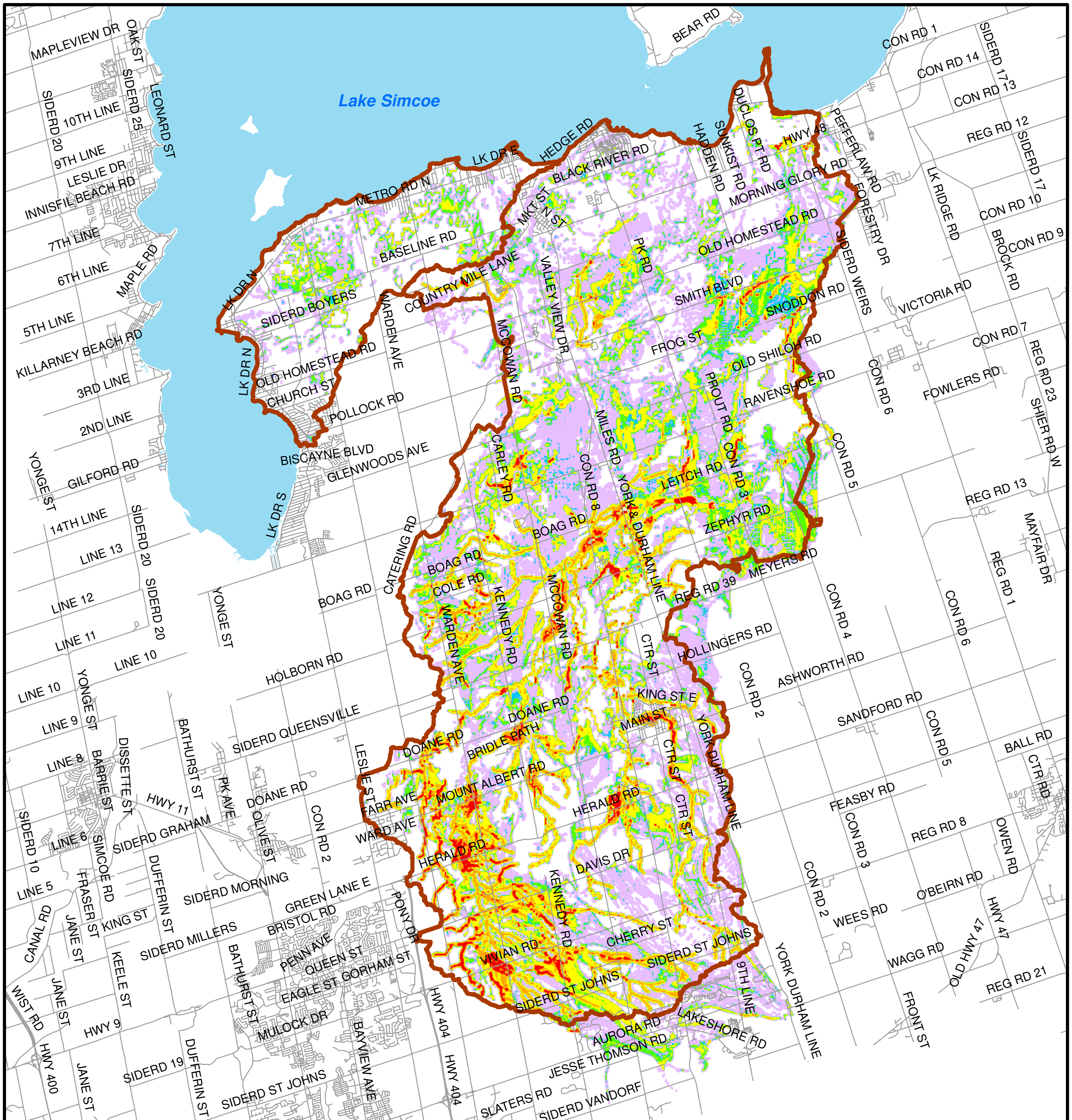
RESULTS OF CLUSTER ANALYSIS - (H = 25 m)

TIER 2 WATER BUDGET AND ESGRA
FOR THE BLACK RIVER AND
GEORGINA CREEKS SUBWATERSHEDS
ESGRA DELINEATION BY CLUSTER ANALYSIS
For: Lake Simcoe Region Conservation Authority

DATE: FEBRUARY 2013	SCALE: 1:210000
PROJECT: 121-17211-00	FILE. NO.:1211721100FC2-2

GENIVAR

FIGURE
C2-2



LEGEND

Normalized Delineation Threshold

- <0.001
- 0.001 - 0.005
- 0.005 - 0.01
- 0.01 - 0.05
- 0.05 - 0.1
- 0.1 - 1
- Subwatersheds
- Road

N W E S

Data Source: Lake Simcoe Region Conservation Authority.
Ministry of Natural Resources, Ontario Base Mapping, June 2012.

1,500 750 0 1,500 Metres

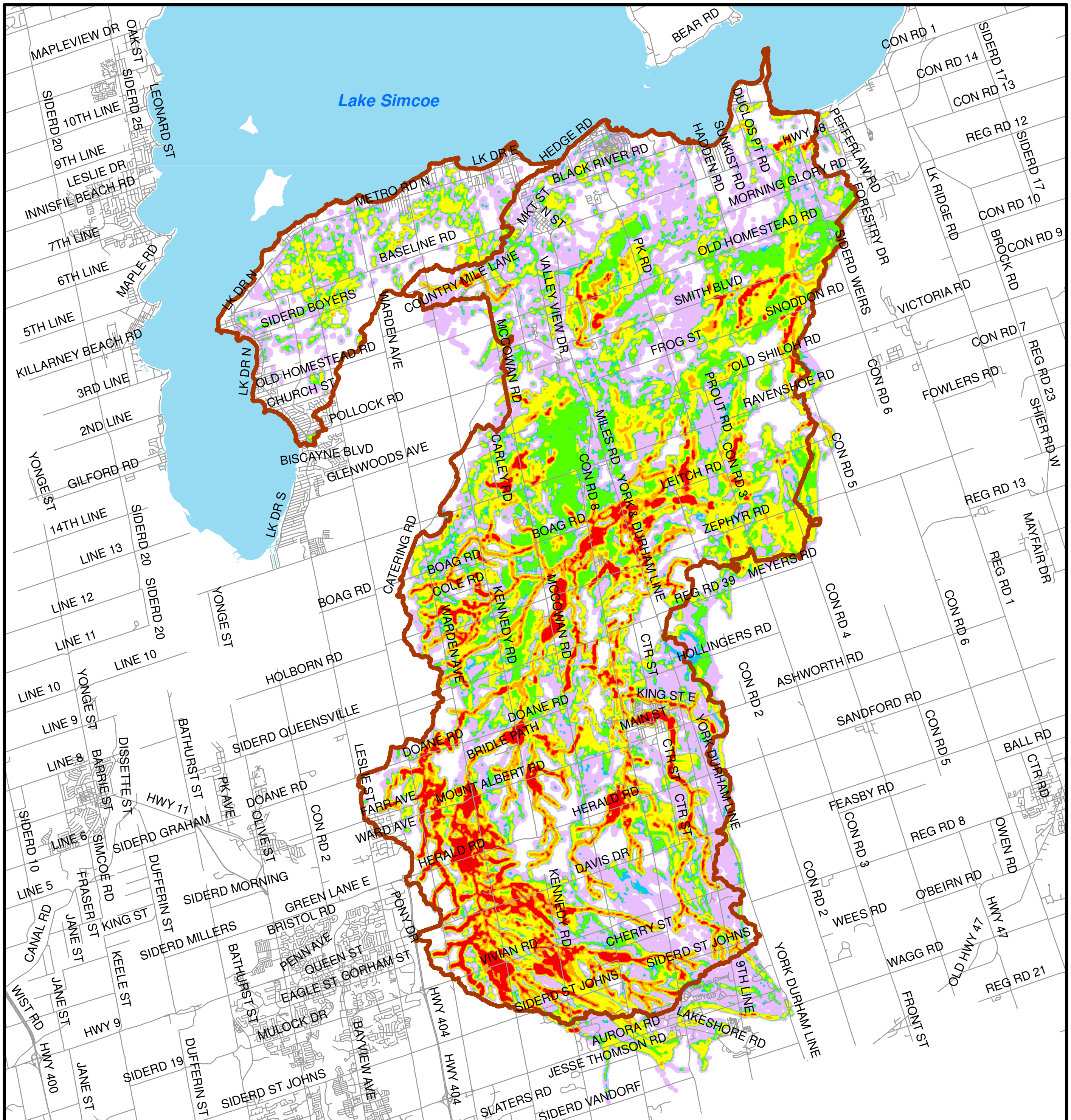
RESULTS OF CLUSTER ANALYSIS - (H = 50 m)

TIER 2 WATER BUDGET AND ESGRA
FOR THE BLACK RIVER AND
GEORGINA CREEKS SUBWATERSHEDS
ESGRA DELINEATION BY CLUSTER ANALYSIS
For: Lake Simcoe Region Conservation Authority

DATE: FEBRUARY 2013	SCALE: 1:210000
PROJECT: 121-17211-00	FILE. NO.:1211721100FC2-3

GENIVAR

FIGURE
C2-3



LEGEND

Normalized Delineation Threshold

- <0.001
- 0.001 - 0.005
- 0.005 - 0.01
- 0.01 - 0.05
- 0.05 - 0.1
- 0.1 - 1
- Subwatersheds
- Road

N W E S

Data Source: Lake Simcoe Region Conservation Authority.
Ministry of Natural Resources, Ontario Base Mapping, June 2012.

1,500 750 0 1,500 Metres

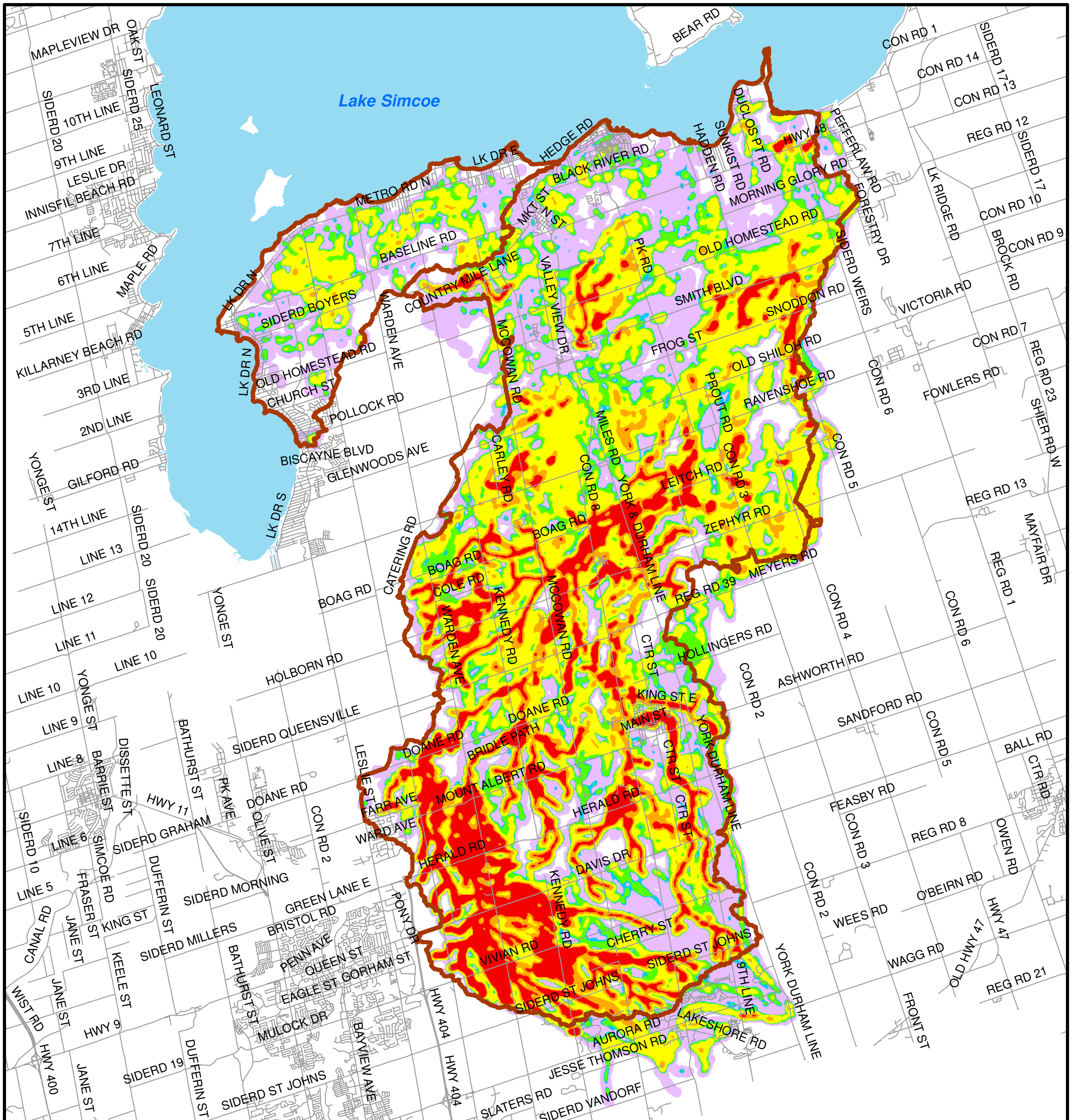
RESULTS OF CLUSTER ANALYSIS - (H = 100 m)

TIER 2 WATER BUDGET AND ESGRA
FOR THE BLACK RIVER AND
GEORGINA CREEKS SUBWATERSHEDS
ESGRA DELINEATION BY CLUSTER ANALYSIS
For: Lake Simcoe Region Conservation Authority

DATE: FEBRUARY 2013	SCALE: 1:210000
PROJECT: 121-17211-00	FILE. NO.:1211721100FC2-4

GENIVAR

FIGURE
C2-4



LEGEND

Normalized Delineation Threshold

- <0.001
- 0.001 - 0.005
- 0.005 - 0.01
- 0.01 - 0.05
- 0.05 - 0.1
- 0.1 - 1
- Subwatersheds
- Road

N W E S

Data Source: Lake Simcoe Region Conservation Authority.
Ministry of Natural Resources, Ontario Base Mapping, June 2012.

1,500 750 0 1,500 Metres

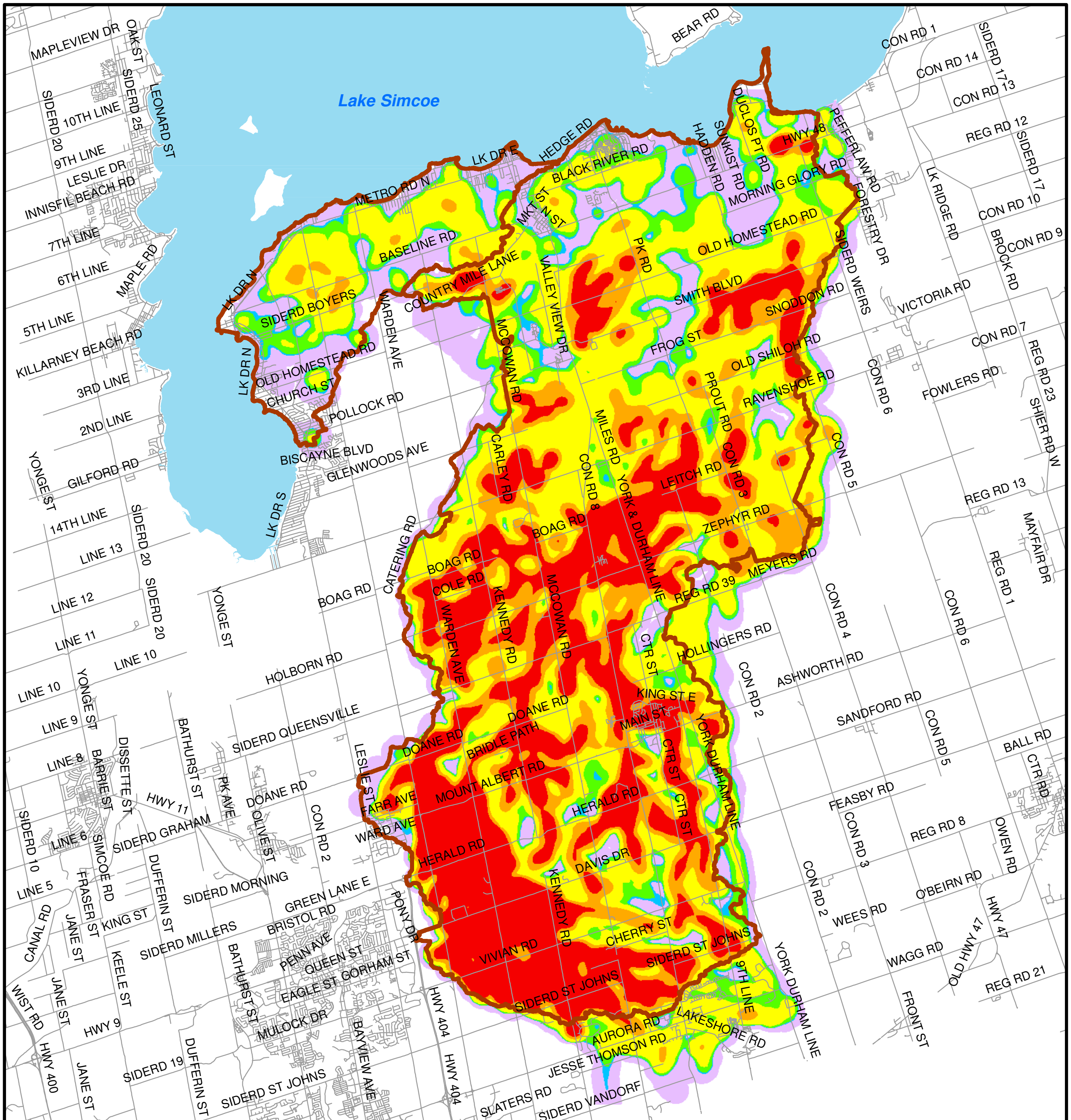
RESULTS OF CLUSTER ANALYSIS - (H = 200 m)

TIER 2 WATER BUDGET AND ESGRA
FOR THE BLACK RIVER AND
GEORGINA CREEKS SUBWATERSHEDS
ESGRA DELINEATION BY CLUSTER ANALYSIS
For: Lake Simcoe Region Conservation Authority

DATE: FEBRUARY 2013	SCALE: 1:210000
PROJECT: 121-17211-00	FILE. NO.:1211721100FC2-5

GENIVAR

FIGURE
C2-5



LEGEND

Normalized Delineation Threshold

- <0.001
- 0.001 - 0.005
- 0.005 - 0.01
- 0.01 - 0.05
- 0.05 - 0.1
- 0.1 - 1
- Subwatersheds
- Road

N W E S

Data Source: Lake Simcoe Region Conservation Authority.
Ministry of Natural Resources, Ontario Base Mapping, June 2012.

1,500 750 0 1,500 Metres

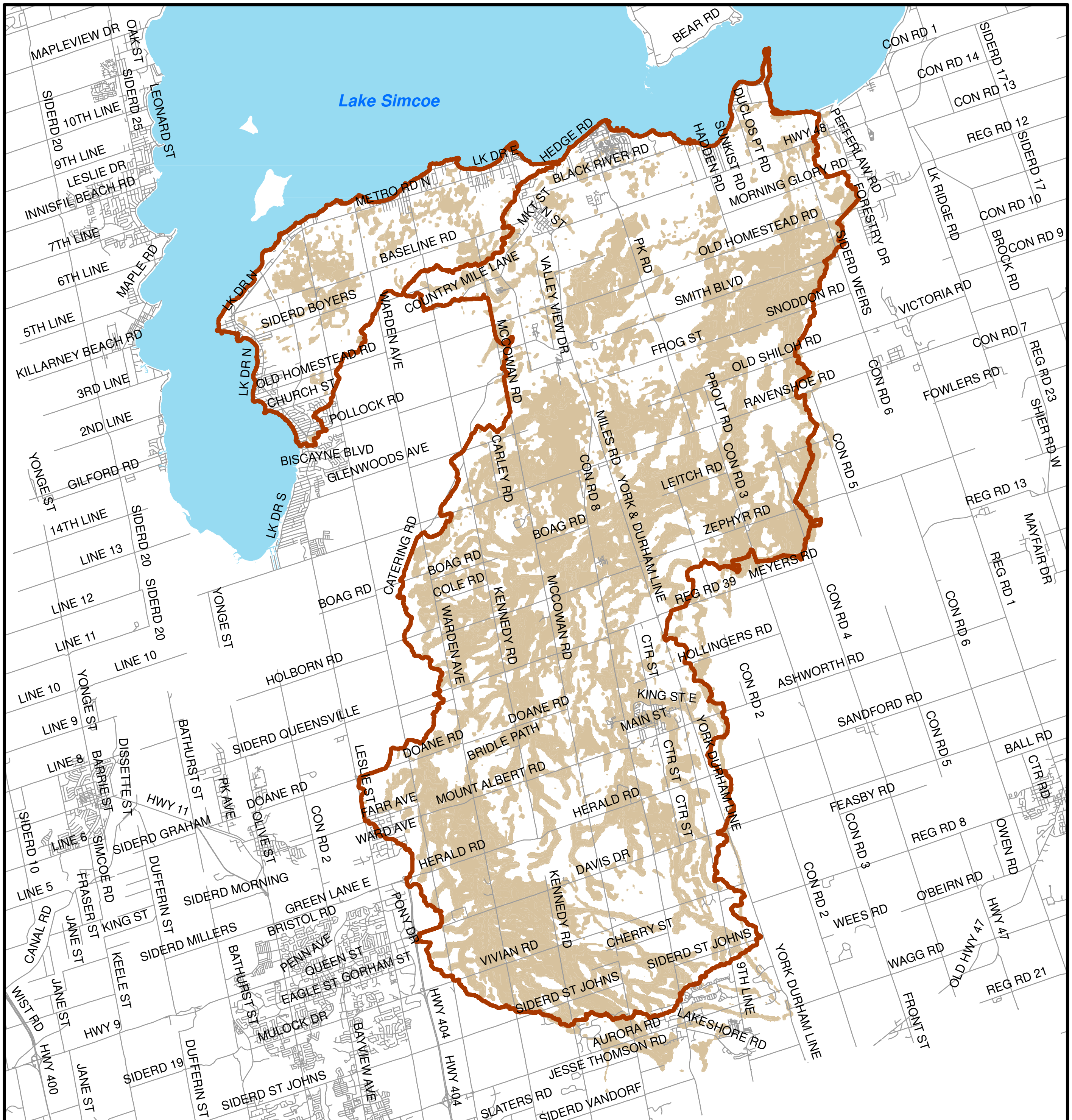
RESULTS OF CLUSTER ANALYSIS - (H = 500 m)

TIER 2 WATER BUDGET AND ESGRA
FOR THE BLACK RIVER AND
GEORGINA CREEKS SUBWATERSHEDS
ESGRA DELINEATION BY CLUSTER ANALYSIS
For: Lake Simcoe Region Conservation Authority

DATE: FEBRUARY 2013	SCALE: 1:210000
PROJECT: 121-17211-00	FILE. NO.:1211721100FC2-6

GENIVAR

FIGURE
C2-6



LEGEND

Preferred Cluster Distribution

Subwatersheds

Road

Data Source: Lake Simcoe Region Conservation Authority.
Ministry of Natural Resources, Ontario Base Mapping, June 2012.

N W E S

1,500 750 0 1,500 Metres

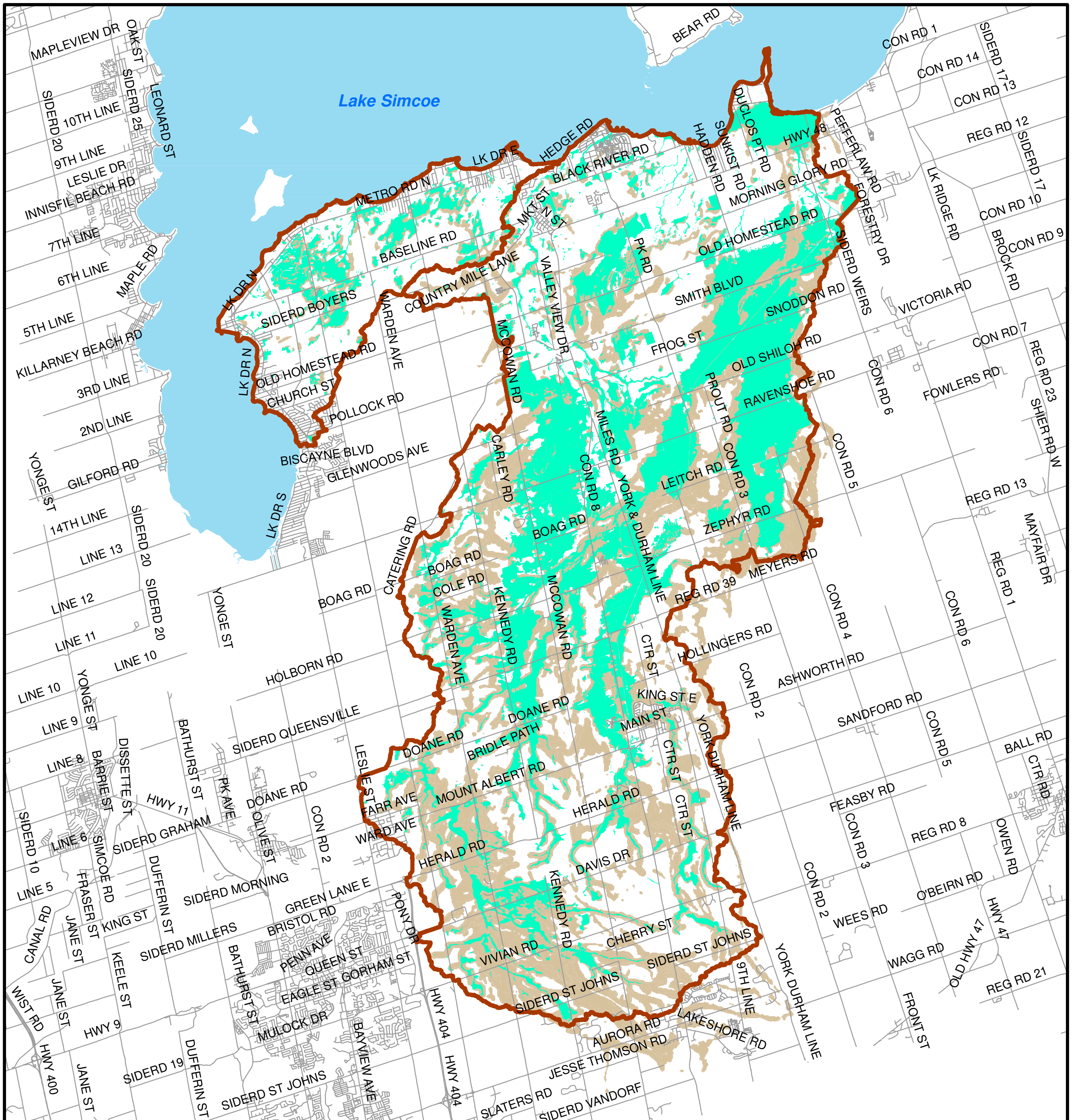
PRECLUSTER DISTRIBUTION (h = 100, e = 0.005)

TIER 2 WATER BUDGET AND ESGRA
FOR THE BLACK RIVER AND
GEORGINA CREEKS SUBWATERSHEDS
ESGRA DELINEATION BY CLUSTER ANALYSIS
For: Lake Simcoe Region Conservation Authority

DATE: FEBRUARY 2013	SCALE: 1:210000
PROJECT: 121-17211-00	FILE. NO.:1211721100FC2-7

GENIVAR

FIGURE
C2-7



WETLAND AREA - PREFERRED CLUSTER DISTRIBUTION (h = 100, e = 0.005)

LEGEND

- Preferred Cluster Distribution
- Wetland Areas
- Subwatersheds
- Road

TIER 2 WATER BUDGET AND ESGRA
FOR THE BLACK RIVER AND
GEORGINA CREEKS SUBWATERSHEDS
ESGRA DELINEATION BY CLUSTER ANALYSIS
For: Lake Simcoe Region Conservation Authority

DATE: FEBRUARY 2013	SCALE: 1:210000
PROJECT: 121-17211-00	FILE. NO.:1211721100FC2-8

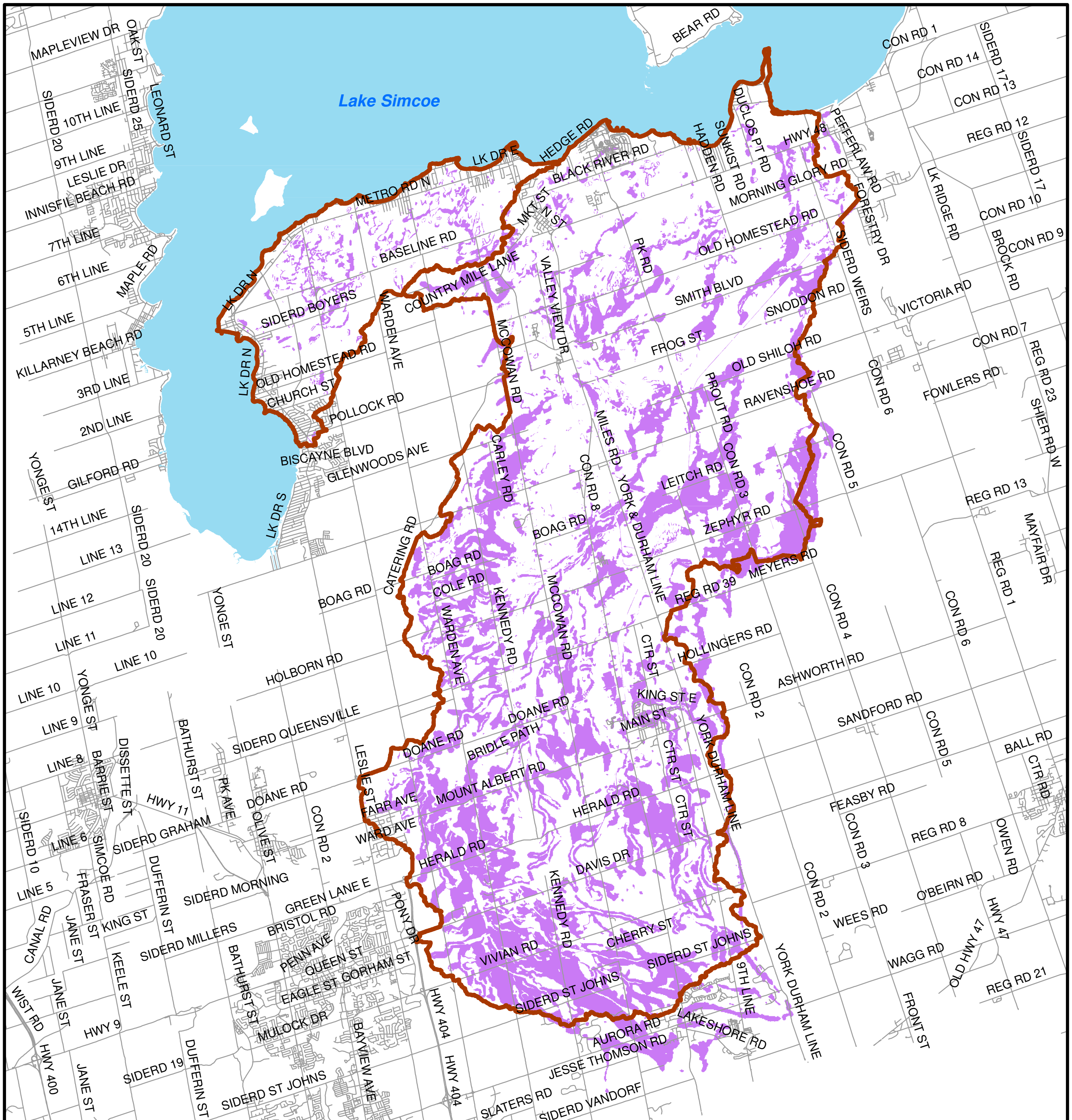
N W E S

1,500 750 0 1,500 Metres

GENIVAR

FIGURE
C2-8

Data Source: Lake Simcoe Region Conservation Authority.
Ministry of Natural Resources, Ontario Base Mapping, June 2012.



LEGEND

Ecologically Significant Groundwater Recharge Areas

Subwatersheds

Road

N
W E
S

Data Source: Lake Simcoe Region Conservation Authority.
Ministry of Natural Resources, Ontario Base Mapping, June 2012.

1,500 750 0 1,500 Metres

ECOLOGICALLY SIGNIFICANT GROUNDWATER RECHARGE AREAS (h = 100, e = 0.005)

TIER 2 WATER BUDGET AND ESGRA
FOR THE BLACK RIVER AND
GEORGINA CREEKS SUBWATERSHEDS
ESGRA DELINEATION BY CLUSTER ANALYSIS
For: Lake Simcoe Region Conservation Authority

DATE: FEBRUARY 2013	SCALE: 1:210000
PROJECT: 121-17211-00	FILE. NO.:1211721100FC2-9

GENIVAR

FIGURE
C2-9

Table C2-1 Cluster Analysis Statistical Outputs

Delineation Threshold	Smoothing Parameter / Search Radius = 25			Smoothing Parameter / Search Radius = 50			Smoothing Parameter / Search Radius = 100			Smoothing Parameter / Search Radius = 200			Smoothing Parameter / Search Radius = 500		
	Number of Endpoints	Total Endpoints %	Subwatershed Area %	Number of Endpoints	Total Endpoints %	Subwatershed Area %	Number of Endpoints	Total Endpoints %	Subwatershed Area %	Number of Endpoints	Total Endpoints %	Subwatershed Area %	Number of Endpoints	Total Endpoints %	Subwatershed Area %
0.001	3,316,959	99.0%	41.7%	3,343,553	99.8%	55.9%	3,347,194	99.9%	72.1%	3,348,605	100.0%	88.3%	3,349,537	100.0%	107.7%
0.005	2,932,448	87.5%	17.0%	3,149,321	94.0%	30.0%	3,292,664	98.3%	51.6%	3,325,614	99.3%	69.9%	3,342,382	99.8%	94.6%
0.01	2,664,217	79.5%	12.0%	2,986,607	89.2%	21.1%	3,147,485	94.0%	35.7%	3,267,216	97.5%	56.9%	3,324,441	99.2%	84.2%
0.05	769,488	23.0%	1.2%	2,014,217	60.1%	7.1%	2,600,728	77.6%	14.2%	2,792,897	83.4%	23.8%	3,001,541	89.6%	44.8%
0.1	238,834	7.1%	0.2%	958,574	28.6%	1.9%	1,740,156	52.0%	6.3%	2,287,111	68.3%	13.0%	2,591,974	77.4%	27.1%

Total Number of Endpoints	**3,349,666**

Scenario	Subwatershed Area (sq. m.)	Subwatershed Area %	Discharge Area (sq. m.)	Discharge Area %
H - 100, e - 0.005	219,291,875	51.6%	134,712,120	31.72%
H - 100, e - 0.01	151,701,875	35.7%	99,464,446	23.42%
H - 25, e - 0.005	72,305,625	17.0%	48,570,565	11.44%