RAISIN REGION CONSERVATION AUTHORITY

SOUTH NATION CONSERVATION DE LA NATION SUD

Tier 2 Water Budget

Subwatersheds 29 and 37
South Nation River Watershed

Raisin-South Nation
Source Protection Region

DILLON CONSULTING

Final Report
August, 2010

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Attention: Phil Barnes, P.Eng.
Water Resources Engineer

Tier 2 Water Budget for Raisin-South Nation Source Protection Region. Subwatersheds 29 and 37 – South Nation River Watershed.

Dear Mr. Barnes:

We are pleased to provide a copy of the final report Tier 2 Water Budget for Raisin-South Nation Source Protection Region. Subwatersheds 29 and 37 - South Nation River Watershed.

We thank you for the opportunity to work on this challenging project.

We look forward to assisting you with further Water Budget and Source Protection initiatives in the Raisin-South Nation Source Protection Region.

If you have any questions, please contact the undersigned.

Yours sincerely,

DILLON CONSULTING LIMITED

Igor V. Iskra, Ph.D., P.Eng

Encl.

Our file: 09-1780

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ACRONYMS

AAFC	Agriculture and Agri-Food Canada
BASINS	Better Assessment Science Integrating Point and Nonpoint Sources
DEM	Digital Elevation Model
ET	Evapotranspiration
HRU	Hydrological Response Unit
HSG	Hydrological Soil Group
HSPF	Hydrologic Simulation Program FORTRAN
HYDAT	Hydroclimatological Data Retrieval Program
OF	Objective Function
PEST	Parameter Estimation Tool
RRCA	Raisin River Conservation Authority
SCE-UA	Shuffled Complex Evolution method – University of Arizona
SNC	South Nation Conservation
USEPA	United States Environmental Protection Agency
USGS	United States Geological Service

1. INTRODUCTION

1.1 Overview

The Clean Water Act requires Source Protection Committees to prepare an assessment report for each source protection area it represents, following the requirements of regulations, Technical Rules and approved terms of reference for that source protection area. One requirement is the assessment of risks to water quantity for drinking water systems in the area. These risks are assessed following a tiered framework for water budget analysis using successively more detailed methods and data.

A Tier 1 water budget and water quantity stress assessment has recently been completed for the entire Raisin-South Nation Source Protecting Region to broadly assess stress levels in all of the region's subwatersheds (*Intera Engineering Ltd., 2010*). The report concluded that two subwatersheds in the South Nation Watershed are moderately to highly stressed in regard to municipal groundwater supplies and should be evaluated at a Tier 2 assessment level. The stressed subwatersheds were those for Greely (Subwatershed #29) and Winchester (Subwatershed #37). The study areas with these subwatersheds are shown on **Figure 1.1**. This report presents the results of the Tier 2 assessment.

Technical Rules and related Technical Bulletins describe the analysis requirements for Tier 2 water budget analyses including the evaluation of stress levels under a number of potential scenarios representing existing and future demands and a range of meteorological conditions from average to drought type conditions. To complete the detailed analysis requires the building and application of a three dimensional groundwater flow model and continuous surface water model to assess groundwater flows and levels, surface water flows and levels, and the interaction between them. The Tier 2 assessment provides a more in-depth stress assessment under a range of scenarios considering refined water budget components, which include various supplies and demands. Where subwatersheds are found to be stressed in any one of these scenarios further detailed evaluation is required under a Tier 3 assessment.

The methodology followed in this report is consistent with the Technical Rules prepared by the Ministry of Environment (MOE, 2009). Also, the Provincial Guidance Module 7 Water Budget and Water Quantity Risk Assessment (MOE, 2007) was used to complete a subwatershed stress assessment.

1.2 Study Approach

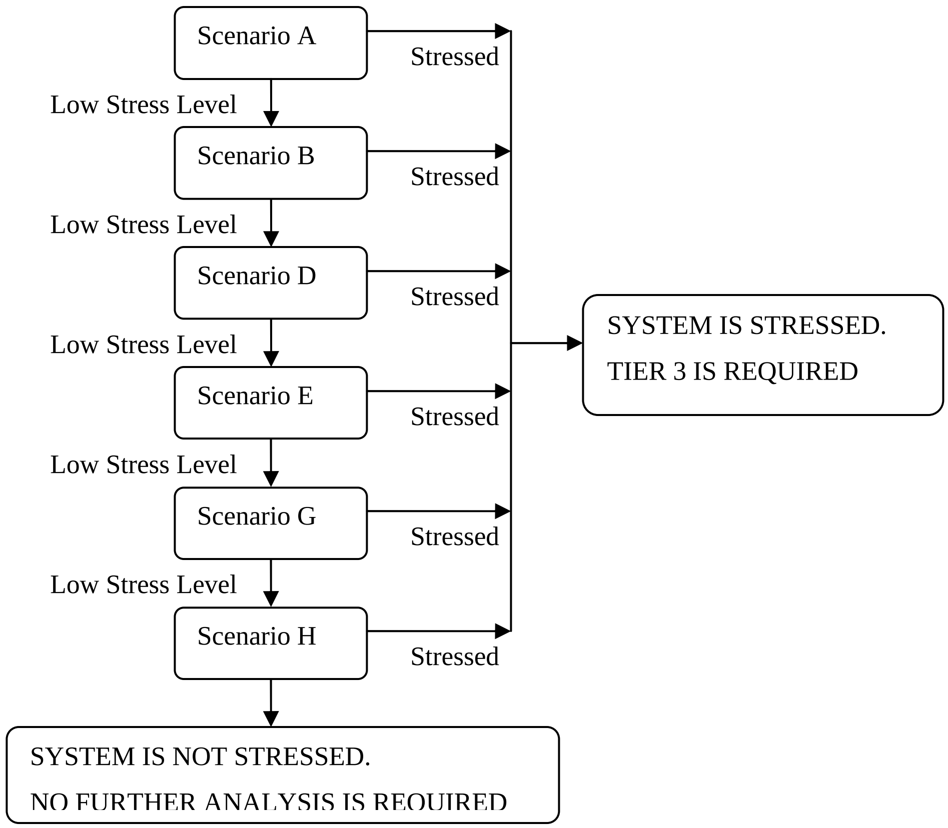
The stress assessment is based on three conditions that are combined to define the various scenarios evaluated in this study. These include:

a) Average conditions - to identify subwatersheds under stress with existing water takings and average climate conditions;

b) Future demand - to identify additional subwatersheds that may become stressed with increased water takings or planned land use changes. The future demand projections are to be consistent with local municipal Official Plans; and,

c) Drought conditions - to evaluate stress levels under a prolonged drought (2 and 10 years).

Based on the above conditions, nine scenarios are defined for existing and planned systems. A 3D groundwater model and a continuous surface water model are used to generate the water budget components and water levels at municipal wells that are used to evaluate stress conditions under each scenario. A subwatershed, and by association its aquifer supply system, can be assigned a stress level of low, moderate or significant. When a subwatershed is found to be moderately or significantly stressed under any scenario, it is automatically moved on to the Tier 3 analysis. If a subwatershed has a “low” stress level in Scenario A (i.e., is not stressed based on scenario A evaluation criteria), it will undergo a stress assessment under Scenario B, then Scenario C and so on as described in the chart below. Subsequent scenarios are only considered if the previous scenario has a low level of stress.



The nine scenarios, the analysis requirements, and the stress evaluation criteria considered in this study are provided in **Table 1.1** and **Table 1.2** below. It should be noted that neither Winchester nor Greely have a planned system (e.g., EA approved wells with known locations and pumping rates) and therefore an assessment of scenarios related to planned systems (i.e., scenarios C and F) are not required.

Table 1.1. Subwatershed Stress Level Scenarios

Scenario A	• historical climate and flows and current land use used in surface water (SW) model • average annual recharge and reserve values obtained from SW model. Recharge is an input to groundwater model (GW) • steady-state GW modelling • current (average annual) demands used in GW model and % water demand • average annual lateral flow obtained from GW model (input to % water demand) • exceeds / does not exceed stress thresholds in **Table 1.2**
Scenario B	• historical climate and flows and current land use used in SW model • average annual recharge and reserve values obtained from SW model (input to

	GW model) • steady-state GW modelling • future municipal demands used in GW model and % water demand • average annual lateral flow obtained from GW model (input to % water demand) • exceeds / does not exceed stress thresholds in **Table 1.2**
Scenario C	• does not apply for Winchester or Greely (planned systems only)
Scenario D	• zero recharge values for 24 month simulation used in GW model • transient GW modelling • current demands used in GW model vary monthly based on seasonal adjustments • month with lowest water level is compared with screen elevation of municipal well • stressed / not stressed based on occurrence of screen exposure
Scenario E	• zero recharge values for 24 month simulation used in GW model • transient GW modelling • future demands used in GW model vary monthly based on seasonal adjustments • month with lowest water level is compared with screen elevation of municipal well • stressed / not stressed based on occurrence of screen exposure
Scenario F	• does not apply for Winchester or Greely (planned systems only)
Scenario G	• 10 year drought climate and flow and current land use conditions used in SW model • 10 year drought average annual recharge values obtained from SW model (input to GW model) • transient GW modelling • current demands used in GW model vary monthly based on seasonal adjustments • month with lowest water level is compared with screen elevation of municipal well • stressed / not stressed based on occurrence of screen exposure

Scenario H	• 10 year drought climate and flow and future land use conditions used in SW model • 10 year drought average annual recharge values obtained from SW model (input to GW model) • transient GW modelling • future demands used in GW model vary monthly based on seasonal adjustments • month with lowest water level is compared with screen elevation of municipal well • stressed / not stressed based on occurrence of screen exposure

A Tier 3 assessment is only required if the current or future scenarios yield a moderate to significant stress level and/or if the drought scenario will result in moderate to significant stress. Groundwater stress thresholds for Scenarios A and B are based on percentage water demand calculations and these threshold values are summarized in **Table 1.2**. The stress thresholds for Scenarios D, E, G and H are based on the well screen elevation or a safe operating water level. Professional judgment and municipal input on the safe operating water level may be necessary if the drought scenario produces a drawdown that approaches the well screen elevations.

Table 1.2 Groundwater stress thresholds

Groundwater Quantity Stress Assignment (% Water Demand)	Current Conditions		Future Demand	
	Average Annual	Monthly Maximum	Average Annual	Monthly Maximum
Significant	> 25 %	> 50 %	> 25 %	> 50 %
Moderate	10 - 25 %	20 - 50 %	10 - 25 %	20 - 50 %
Low	0 - 10 %	0 - 20 %	0 - 10 %	0 - 20 %

Water demands considered in the percentage water demand calculations for Scenarios A and B, which were used as groundwater model inputs for all scenarios, are described in **Section 2** of the report. Refinement in these values relative to previous Tier 1 analysis is one of the key activities in the study.

Groundwater modelling details including findings are presented in **Section 3.1**. These findings include the estimate of one component of water supply in Scenarios A and B (i.e., lateral groundwater inflow to a subwatershed), and the estimate of wellhead levels under the transient, drought scenarios.

Surface water modelling details and findings are presented in **Section 3.2**. The surface water model findings include recharge values, both under average climate conditions and 10 year drought conditions. Recharge values are a key component of water supply used in the percentage water demand calculation and are used a groundwater model input in Scenarios A, B, G and H.

Stress Assessment Results considering the scenarios above and the findings from the surface and groundwater models are presented in **Section 4.**

2. WATER DEMANDS

The Water Demand component (QDEMAND) of the water budget refers to water taken as a result of anthropogenic activity. It is calculated as the sum of three parts: permitted demands, unpermitted agricultural demands and unpermitted domestic demands. Considerable efforts were made in Tier 1 to document various sources of water demand as well as seasonal adjustment and consumptive use factors to evaluate the amount of water removed from a geo-hydrological system that is not returned back to the same system. The following sections described how these values were refined or adopted as part of the current assessment.

2.1 Unpermitted Demands

The summary of groundwater takings for each subwatershed provided in the Tier 1 report shows municipal demands, permitted takings and unpermitted agricultural and domestic demands on a subwatershed basis. These demands were analyzed on a per-area basis for the subwatersheds identified as both stressed and having municipal water sources in Tier 1 assessment. As indicated in **Table 2.1**, unpermitted demands were determined to be relatively small in relation to other water budget components and were not incorporated in the numerical groundwater model. These demands are however included in the stress assessment as part of the total demand.

Table 2.1. Monthly Unpermitted demands on a per-area unit

Subwatershed	Monthly Agricultural Demands	Monthly Private (Domestic)

	(per-area basis)	Demands (per-area basis)
29 (Greely Water Supply)	0.03 mm (Jan-Jun, Sep-Dec) 1.74 mm (Jul-Aug)	0.01 mm (Jan-Dec)
37 (Winchester Water Supply)	0.06 mm (Jan-Jun, Sep-Dec) 0.25 mm (Jul-Aug)	0.02 mm (Jan-Dec)

2.2 Permitted Demands

Permitted demands are those included in the MOE's Permit to Take Water (PTTW) program. A PTTW is required for any taking exceeding 50,000 L/day with some exceptions. The PTTW provincial database provided by the MOE was used by WESA for the *Raisin-South Nation Source Protection Area's Water Use and Evaluation* study (June 2008). The analyses conducted on the PTTW database by WESA were carried forward for the Tier 1 assessment. As demands were derived from the maximum permitted water taking values as opposed to actual takings, this resulted in a conservative stress assessment, consistent with the prescribed framework. For this study's assessment, actual - as opposed to maximum permitted - water demand values are used. These actual values have been incorporated into the groundwater model for the study subwatersheds (i.e., the Tier 1-stressed subwatersheds); permitted demands were carried forward for the other subwatersheds.

To provide a better understanding of the geological environment of a permitted demand, the MOE WWIS database was used to match up permits to wells in the MOE database. The PTTW database does not provide geological information about groundwater takings.

As part of the PTTW program, the Water Taking Reporting System requires permit holders to record data on the volume of water taken daily and to report this data annually to the Ministry. The first year of available water taking data is 2005. The most recent available actual water taking data is for 2008.

Actual PTTW data was made available in February 2010 for Source Protection Authorities and Committees for the purposes of preparing Assessment Reports under the *Clean Water Act, 2006*. **Table 2.2** summarizes the permits of interest in the Tier 1-stressed subwatersheds; several permit holders did not report actual takings. Rather large discrepancies between permitted and actual takings were observed likely because permit holders often request a volume of water that greatly exceeds requirements based on a worse-case scenario. For those permit holders who did not report actual taking data, the maximum permitted volumes were used in the groundwater model.

Table 2.2. Actual Demand Volumes for Permitted Takings

Subwatershed	Permit Number	Purpose of Taking	2008 Actual Demand (m^3/yr)	Permitted Demand for Comparison (m^3/year)
SWS 29	03-P-4094	Commercial - Golf Course Irrigation	151,687	1,503,954
	98-P-4099	Municipal - Greely Water Supply	incomplete WTRS (see **Section 2.3**)	
	7255-5ZSKTL	Industrial - Aggregate Washing (Lafarge Canada)	did not report (Lafarge Canada confirmed that there is no pumping at the site, i.e., 0 m^3/yr)	1,672,503
SWS 37	01-P-4013	Industrial - Aggregate Washing (Lafarge Canada)	452,972	72,204,300
	2350-5ZZKM4	Industrial - Aggregate Washing (Lafarge Canada)	did not report (Lafarge Canada confirmed site is not operational, i.e., 0 m^3/yr)	3,583,541
	04-P-4011	Municipal - Winchester Water Supply (“Well #6”)	130,110	358,459
	86-P-4015	Municipal - Winchester Water Supply (“Well #5”)	74,358	202,822
	88-P-4090	Municipal - Winchester Water Supply (“Well #1”)	64,728	298,541

The aggregate washing permit in SWS 29, *Permit 7255-5ZSKTL* was issued to Lafarge Canada. Actual water taking details were not reported, therefore the maximum permitted volume was used in the numerical groundwater model. Information from the permit holder later revealed that there is currently no pumping of groundwater at the site which is not operational due to limited aggregate reserves. However, the permit holder indicated that if the site were to become operational in the future it would be for aggregate washing purposes. While the likelihood of near term operations is not clear, to be conservative, maximum permitted demands were maintained in the model to account for potential future operations.

Within SWS 37, *Permit 01-P-4013* is a large aggregate washing permit also issued to Lafarge Canada. The calculated stresses for SWS 37 for Tier 1 were significant from April to November, due to a potential misunderstanding about this permit holder. The PTTW database lists three “Industrial - Aggregate Washing” takings for this permit for the following volumes:

- 9,820,000 L/day (Redmond Pit)
- 168,000,000 L/day (East Pond)
- 20,000,000 L/day (West Pond)

The Water Taking Reporting System (part of the PTTW program that requires permit holders to report water taking data to the MOE) did not include data for this permit. Lafarge provided actual water taking data for 2008. The data includes water taking volumes from the Redmond Pit only which is explained by this text on the permit:

"the rate of taking shall not exceed 9,820,000 litres per day and the maximum volume of water impounded in storage ponds shall not exceed 168,000,000 litres for the East pond and 20,000,000 litres for the West pond."

Therefore, the Tier 1 East Pond and West Pond takings are believed to be erroneous and are in fact impoundment volumes. These have been removed from that permitted takings for the Tier 2 analysis. The Richmond Pit is the only actual taking and Lafarge indicated that approximately 90 to 95% (i.e., 5 to 10% consumption) of the extracted water is returned to the same source. However, the consumptive factor from the Technical Rules is 25% and this was used in the Tier 2 stress assessment to ensure a conservative evaluation.

Lafarge also confirmed that the other aggregate washing permit in SWS 37, *Permit 2350-5ZZKM4*, was issued for a site that is no longer operational. However it may become operational anytime. In order to be conservative the demand was added into the stress assessment (**Table 4.1**).

It is uncertain if the permits *7255-5ZSKTL* and *2350-5ZZKM4* will be operational in the future. In order to be conservative these permits were included into the future scenario calculations (**Table 4.2**).

2.3 Municipal Demand

Table 2.3 summarizes current and future municipal gross demand within the Tier 1-stressed subwatersheds:

Table 2.3 Average Municipal Groundwater Demand (Gross Takings)

Subwatershed	Municipal System	Current Average Demand (m^3/day)	Future Average Demand (m^3/day)
29	Greely	133	133
37	Winchester (Wells #1, #5, #6)	738	1477

The Greely supply in SWS 29 is a small groundwater taking that services the Shadow Ridge Subdivision. Future demand was assumed to be equal to the current demand in Greely due to the fact that alternate water supplies from the Ottawa River will accommodate future growth in this area (*Intera, 2010*). Current (and future) demand was reported in Tier 1 to be 16.4 m^3/day based on a value provided by the Greely system operator. This value is slightly less than the average taking value obtained from the Water Taking Reporting System for 2008 of 24 m^3/day, however; only values from April to October were reported. The Technical Rules require that the estimates of the average monthly demands are to be used in the assessment. However, the recently opened Greely well does not have sufficient amount of data to calculate averages. Due to lack of data from October to April, the conservative DWIS maximum daily demand of 133 m^3/day was used as a “surrogate” of the average demand. That number was used in the groundwater model and subsequent stress assessment calculations.

As required by the Technical Rules a consumptive factor of 0.2 was applied to the Greely well pumping rate. A pumping rate of 26.6 m^3/day was used in the model and in the current and future percent demand calculations (**Tables 4.1** and **4.2**).

The Winchester municipal groundwater supply is serviced by four wells: #1, #5, #6 and #7a. Only wells #1, #5 and #6 are located in SWS 37. According to *Intera (2010)* and data from the municipality the average actual daily demand in 2008 for well #1 was 198 m^3/day, for well #5 was 214 m^3/s and for well #6 was 357 m^3/s.

In Tier 1, the future demand for wells #1, 5 and 6 was increased from the current demand values by 100% to account for predicted population growth. The Official Plan for Winchester predicts the population growth from 2,577 to 4,421 people. That is a 72% growth. In order to be consistent with Tier 1 and be conservative in future demand estimation the same increase of 100% in population growth was used in the current assessment.

For the current and future conditions the consumptive factor of 0.2 was applied to the model input and percent demand calculations **(Table 4.1 and 4.2.**).

3. MODELING APPROACH AND RESULTS

The modeling approaches and results of various model simulations are presented in this section. **Section 3.1** presents the groundwater model development and results and **Section 3.2** presents surface water modeling. The groundwater recharge and groundwater discharge were estimated using HSPF and used in MODFLOW for the lateral groundwater movement estimation.

3.1. GROUNDWATER MODEL

The United States Geological Survey (USGS) numerical groundwater flow model MODFLOW 2005 (*Harbaugh, 2005*) was used to develop a numerical model of the groundwater systems associated with the study subwatersheds (Greely (#29) and Winchester (#37)) including their municipal well systems and other prominent water takings. The key requirements of the model are i) to provide estimates of lateral groundwater inflows to the subwatershed areas as part of the water supply used in percentage water demand calculations, and ii) to assess water levels at the municipal wells under drought conditions.

The model limits extend beyond the subwatershed limits in order to adequately represent boundary conditions and so that groundwater discharge could be estimated at downstream stream gauge locations as part of the calibration procedure.

MODFLOW is a three dimensional, finite difference groundwater flow model that solves the groundwater flow equation for each cell within a grid, with respect to each cell surrounding it. The program is also able to simulate other hydrologic processes, such as recharge and flow into and out of rivers, and lakes. A pre-processor and post-processor computer program developed for MODFLOW called VISUAL MODFLOW (SWS, 2010) was used to develop the model and obtain graphical output. An adjunct mass balance program to MODFLOW called ZONEBUDGET was used to delineate the study subwatershed areas and to calculate water balance components for each subwatershed.

3.1.1. Model Setting and Geologic Data

The program computes flow between adjacent cells and determines the rate of movement of water to and from the groundwater system ("storage"). Flow is calculated based on hydraulic conductivity, crosssectional area perpendicular to flow and hydraulic gradient. Input parameters include grid spacing, layer types, and aquifer properties (e.g., hydraulic conductivity and storativity). Output, in the form of hydraulic head and drawdown values, is generated for each cell in the grid.

For the flow model, a 76 km (west-east) by 116 km (north-south) domain boundary was chosen. A diagram of the limits of the flow model is shown on **Figure 3.1**. The limits generally correspond to the subwatersheds upstream of Casselman, including the study subwatersheds and extend to boundary conditions described in the next section.

The hydrostratigraphic model is based on the conceptual model developed by the Geological Survey Of Canada (*Logan et. al, 2009).* The model defines the top surfaces of the seven main Quaternary stratigraphic units plus bedrock. These units are (from oldest to youngest):

- Paleozoic Bedrock
- Sub-Till Sediment
- Sandy Silt Till
- Glaciofluvial (Esker) Sediment
- Basin Mud
- Basin Sand
- Organic Deposits
- Recent Deposits

The GSC model area covers over 11,000 km^2 of eastern Ontario. It is bounded by the Ottawa River to the north and by the St. Lawrence River to the south. In the east it is bounded by the Quebec border and extends to the Frontenac Axis and exposed Precambrian rocks of the Canadian Shield located west of Smiths Falls, Ontario (*Logan et. al, 2009*).

In the south part of the GSC model, the surficial geology is dominated by a massive, overconsolidated sandy-silt till that overlies bedrock and decreases in thickness in the north. Another important hydrostratigraphic unit are five eskers which trend north-south and were formed sub-glacially in long (<50 km) streams. In the south, they become broad sandy outwash fans that were likely deposited under water in a glacial lake or inland sea. Generally, the eskers consists of a gravel core with sand margins. They generally directly overlie bedrock except in the south where the outwash deposits may overlie till.

After the glaciers retreated northward, a glacial lake formed and later merged with marine waters forming the Champlain Sea, which existed for approximately 2000 years. During this time, a significant thickness (up to 40 m) of marine and lacustrine clays were deposited. Stratigraphic Units 6 and 7 are younger organic (bog) deposits and alluvial and aeolian deposits.

The raster stratigraphic files developed by the GSC were converted to GIS shapefiles and then imported in MODFLOW. Since MODFLOW is a "layered" model, the lateral extent of discontinuous hydrostratigraphic units were defined by GIS and then transferred to MODFLOW. For laterally discontinuous units, the remainder of the layer where the unit is not present was designated as having the same hydraulic properties as the upper or lower layer (as appropriate).

3.1.2. Boundary Conditions

In MODFLOW, a study area (domain) is defined by a set of boundary conditions (e.g., constant head and no flow). Layers were used to simulate confined, unconfined or a combination of confined/unconfined aquifer conditions. Some cells within the grid were defined to behave like drains (e.g., wells, streams, etc.). Recharge was also simulated. Aquifer properties such as hydraulic conductivity and porosity were assigned for each cell in the domain. Boundary conditions such as a "no flow" boundary or a "constant head" boundary were specified on a cell-by-cell basis. **Figure 3.2** illustrates these boundary conditions.

Type 1 (Dirichlet Boundary Conditions)

To approximate the rate and direction of groundwater flow in the watershed, under pumping and non-pumping conditions, a number of type-1 (or Dirichlet) boundary conditions were assigned to cells in the model domain (**Figure 3.2**). Constant head type-1 boundary conditions were assigned to the Ottawa River, on the northern edge of the model as well as to the St. Lawrence River, on the southern edge of the model domain. Water levels in each of the water bodies were taken from Environment Canada gauging stations (long term mean), and applied as a linear gradient along each surface water feature between the gauging stations.

No Flow Boundary Conditions (Type 2)

Beyond each of these constant head boundaries, the cells in the model domain were rendered "inactive", meaning a no flow type-2 boundary condition was assigned to these cells.

No flow type-2 boundary conditions were also assigned on the western (beyond Rideau River), and eastern (beyond South Nation River) edges of the model. On the western edge of the model, the inactive cells were assigned directly adjacent to river cells which define the Rideau River. Inactive cells on the north eastern edge of the model were assigned directly adjacent to the South Nation River, until the South Nation River and Castor River converge. Beyond this point, inactive cells generally follow the South Nation watershed boundary to the St. Lawrence River. In all instances, no flow boundaries extend to the bottom layer of the model.

River Boundary Conditions

River boundary conditions were used to define major surface water features in the watershed, shown in **Figure 3.2**. The river stage was applied to the top of the topographic DEM, and conductivity was determined by the default conductance formula used by MODFLOW. The following surface water features (and major tributaries) were defined using the river boundary condition:

- South Nation River
- Rideau River
- Castor River
- Bear Brook

The river boundary condition simulates groundwater / surface water interaction via a seepage layer separating the surface water body from the groundwater system. As part of this boundary condition, assumptions have to be made on the hydraulic conductivity (10^{-5} m/s assumed), width and thickness of the seepage layer.

Recharge Boundary Condition

Recharge in the model is determined independently of the groundwater model, and values are set using HSPF model results described in **Section 3.2**. The calibrated recharge values were imported into the model as a GIS shapefile, with values generally ranging from approximately 100 to 290 mm/year. **Figure 3.12** represents the recharge levels through the model domain obtained from the HSPF model. Overall, there were 97 different recharge zones assigned over the entire model domain.

Recharge levels used for calibration represent average conditions corresponding to Scenario A. These values are modified to simulate subsequent drought scenarios considered in the stress assessment. These scenarios include a 2 year drought scenario where there was assumed to be no recharge. In addition, a reduced recharge scenario was performed that assumed reduced recharge for a period of 10 years.

3.1.3 Water Demands

Various demands from the groundwater system have been identified in **Section 2**. As noted earlier, unpermitted demands were determined to be relatively small in relation to other water budget components, and therefore were not incorporated in the numerical groundwater model. The dominant components of demand, municipal and permitted demands are incorporated into the model.

The municipal and permitted demands were each represented as extraction wells within the numerical model domain. Demands specified by the "pumping wells" option in MODFLOW require X- and Y-coordinates, as well as screened interval and withdrawal rate. Details of the municipal wells of interest (Greely wells #1, #2, Winchester wells #1, #5, and #6) were obtained from the Tier I stress assessment (completed by Intera Engineering), as well as from Phil Barnes and Nell van Walsum from the Raisin Region Conservation Authority and WESA Group Inc. respectively. Permitted demands input into the model were obtained from the PTTW database compiled during the Tier 1 stress analysis. The MOE water well database was used to assist in determining wells details (i.e. depth, and screened intervals) for permitted demands. In cases where large seasonal permitted demands were identified during the Tier 1 assessment (such as Lafarge Inc.'s aggregate washing facilities), user's were contacted directly in order to accurately determine water takings and/or schedule. In all other cases, maximum permitted demands were used as withdrawal rates in the model.

3.1.4. Model Calibration

Figure 3.3 shows how the different hydraulic conductivity zones derived from the GSC shapefiles were assigned to various layers in the model. Each of the hydrostratigraphic units were assigned initial hydraulic conductivity values based on a previous model developed for the area (*Charland, 2009*). The MOE Water Well Record database was used to select wells that were used to calibrate the model. Overall, 155 wells were selected based on their location to calibrate the model. These wells were not selected based on their water levels but only on their location because the accuracy of water levels recorded on Water Well Records varies significantly.

The model was calibrated using WinPEST, a computer algorithm that adjusts hydraulic conductivity to provide the "best fit" based on the selected water levels from the Water Well Record database. Water levels recorded in Water Well Records are considered to be very uncertain and are therefore low quality data. They were recorded over many years by various well drillers and were converted to elevation values using the DEM and uncertain well coordinates. Recharge values are often used as a variable in the calibration process. However, for this application, recharge rates derived from the HSPF were held constant in the calibration process. **Table 3.1** summarizes the hydraulic conductivity values for the hydrostratigraphic units determined in the calibration process. Hydraulic conductivity values for the various layers are shown on **Figure 3.3**. A calibration plot comparing measured (based on Water Well Records) and modeled water levels is found in **Figure 3.4**. The standard error of estimate was 0.6 m with a normalized root mean square (RMS) of 12%. Ordinarily, a normalized RMS of less than 10% is considered to be adequate. However, given the low quality of the measured water level data and the number of hydraulic conductivity zones, and constant recharge values, an RMS of 12% is considered to be adequate.

To provide some validation of the calibrated model, recorded streamflow data from HYDAT stations located within the area were used. ZONEBUDGET was used to calculate the amount of net discharge to the rivers in the model. The results of this analysis are summarized in **Table 3.2**. ZONEBUDGET areas are shown on **Figure 3.5**.

Overall, the model overpredicts the amount of baseflow contributed by the groundwater system to the streams. Due this overestimation, the results of the mass balance discussed below are considered to be conservative.

Table 3.1. MODFLOW Validation Results.

Hydrostratigraphic Unit	Conductivity Zone	Hydraulic Conductivity (m/s)	
		Published Values (Charland, 2009)	Calculated WINPEST Values
Organics/Surficial Deposits	2	K_x = 1.0E-3 K_y = 1.0E-3 K_z = 1.0E-4	K_x = 1E-3 K_y = 1E-3 K_z = 1E-4
Champlain Sea Deposits	3	K_x = 1.0E-6 K_y = 1.0E-6 K_z = 1.0E-7	K_x = 5.06E-7 K_y = 1E-6 K_z = 1.22E-7
Esker Materials (sand and gravel)	4	K_x = 7.5E-3 K_y = 7.5E-3 K_z = 7.5E-4	K_x = 7.7E-3 K_y = 7.5E-3 K_z = 1.86E-4

Till	5	K_x = 2.0E-4 K_y = 2.0E-4 K_z = 2.0E-5	K_x = 2.77E-4 K_y = 2.0E-4 K_z = 2.0E-4
Bedrock	1	K_x = 1.0E-4 K_y = 1.0E-4 K_z = 1.0E-5	K_x = 9.75E-5 K_y = 1E-4 K_z = 8.1E-6

Table 3.2. ZONEBUDGET results.

Gauging Station	HYDAT Average August Flow (m^3/s)	HYDAT Average Summer Flow (m^3/s)	MODFLOW Calculated Baseflow (m^3/s)
Castor River at Russell	0.99	1.65	1.62
South Nation River at Chesterville	0.78	5.63	5.96
Bear Brook at Bourget	1.26	1.9	0.93

3.1.5. Model Simulation Results – Scenario A and B

The modeled regional groundwater flow system is shown in **Figure 3.6**. This figure illustrates lines of equal water levels (called equipotentials) with groundwater flow perpendicular to the equipotential contours. **Figure 3.6** is from a bedrock layer. The general direction of groundwater flow in the region is from west (Rideau River) to west. Significant discharge of groundwater to the Castor River and the South Nation River is predicted n the model. The influence of Bear Creek on the equipotentials is less than that of the major surface water streams. Although there is some influence on the shape of the equipotentials from the Ottawa River and the St. Lawrence River (both modeled as a constant head boundary), this is not present in the identified subwatersheds.

Table 3.3 summarizes water budget components within the overall model domain and within the study subwatersheds for average recharge conditions under existing demands (i.e., Scenario A). Results are presented in graphical form in **Figure 3.7**. With respect to the overall water budget, most of the water into the model (92.7%) is predicted to come from recharge, and a lesser amount is expected to come from the Rideau River (6.6%). The contribution from the Ottawa River is a relatively minor 0.7%. Most of the water that is predicted to discharge from the model is to rivers (71.7% - chiefly South Nation River, Castor River and to a less extent Bear Creek and the Rideau River), while 28.0% is predicted to be discharged through the constant head boundaries (chiefly the St. Lawrence River with a minor amount discharging to the Ottawa River). The amount extracted by wells is a relatively minor amount of the overall balance (0.3%).

Table 3.3 MODFLOW Water Budget (Scenario A)

Source	Water In (m^3/day)		Water Out (m^3/day)	
Overall Model				
Recharge	2572812	92.7%	-	
Wells	-		8034	0.3%
Constant Head*	18922	0.7%	776073	28.0%
Groundwater / River Interaction	183181	6.6%	1986669	71.7%
Total	2774916		2770775	
Difference (In-Out)	4140	0.1%		
Greely Subwatershed (#29)				
Recharge	77093	52.1%	-	
Wells	-		2125.2	1.5%
Groundwater / River Interaction	563	0.4%	14475	9.9%
Groundwater Outside Subwatershed	70245	47.5%	129200	88.6%
Total	147901		145800	
Winchester Subwatershed (#37)				
Recharge	81244	57.6%	-	
Wells	-		626.15	0.4%
Groundwater / River Interaction	0	0.0%	2041.2	1.4%
Groundwater Outside Subwatershed	59912	42.4%	133050	91.3%
Total	141156		135717	

For the Greely subwatershed, the proportion of water into the subwatershed is divided between recharge (52.1%) and groundwater upgradient of the subwatershed (47.5 %) with only a minor amount predicted to be from river leakage (0.4%). Water exiting the subwatershed is chiefly via groundwater (88.6%) while

9.9% is predicted to discharge into rivers. Only 1.5% is predicted to be extracted by wells. For Scenario B (future municipal demand), there is no changes in the well withdrawal because the Greely municipal system is not expected to expand (future demand equals existing demand – see **Table 2.3)**.

In the Winchester subwatershed, the proportion of water into the subwatershed is divided between recharge (57.6%) and groundwater upgradient of the subwatershed (42.4 %). Water exiting the subwatershed is chiefly via groundwater (91.3%) while 1.4% is predicted to discharge into rivers. Only 0.4% is predicted to be extracted by wells. Note that with the use of ZONEBUDGET there is a larger discrepancy between the water in and water out predictions than the overall model (e.g., the difference in Winchester is 5440 m3/day - 3.9%). For Scenario B (future municipal demand), there is only a slight change in the water balance, the withdrawal rate is expected to increase by 148 m^3/day which increases the withdrawal rate from all wells in the subwatershed to 774 m^3/day from 626.15 m^3/day or from 0.4% of the water budget to 0.6%.

The assessments above have been used to determine the net groundwater inflow to each study subwatershed as presented in **Section 4** as part of the Scenario A and B assessments. These scenarios represent steady state conditions under existing and future demands and average recharge conditions. Note that the same groundwater inflow values were used for both Scenarios A and B.

3.1.6. Model Simulation Results – Drought Conditions

Two drought scenarios were modeled: a two year drought assuming no recharge and a 10 year drought based on the 10 year period with the lowest precipitation on record. In contrast to Scenario A and B, drought scenarios require transient modelling of water level conditions so that the potential for exposure of the wells can be determined. For each drought condition, two simulations were completed representing existing water demands and future estimated water demand in the municipal supplies. Initial conditions were set to the calibrated steady state conditions determined for average recharge conditions.

The predicted water level in each of the municipal production wells were compared against both the base case (average recharge, existing demands) and the elevation of the top of the well screens. **Table 3.4** summarizes the results of this analysis for the five production wells. As this table indicates, water levels are not predicted to decrease significantly and are predicted to be well above the well screens.

The two Greely overburden production wells are located close together (i.e., within the same model cell) and therefore the water level drop will be equal for each well. For the Winchester bedrock production wells, no change in water level is predicted in the drought simulations, although there are relatively minor water level decreases in the (overburden) on the vicinity of the Winchester wells. This is a reflection of the relative hydraulic isolation of the bedrock system caused by lower permeability overlying till soil. The changes in the water level in bedrock were not observed likely due to relatively low pumping rates of the Winchester well. Also, it is possible that MODFLOW is not sufficiently sensitive to respond to the minor water level variations. If the drought conditions lasted longer than 2 or 10 years, there may be some change in the water level in the bedrock wells at this location.

Table 3.4 Summary of Drought Simulations

	Greely 1	Greely 2	Winchester 1	Winchester 5	Winchester 6
Screen Elevation (masl)	82.0	82.2	65.9	64.7	71.0
Predicted Water Level Above Well Screen (m)					
Base Case (Average Recharge, Existing Demand)	10.1	10.1	9.8	10.9	10.1
Scenario D Two Year Drought Existing Demand	6.3	6.3	9.8	10.9	10.1
Scenario E Two Year Drought Future Demand	6.3	6.3	9.8	10.9	10.1
Scenario G Ten Year Drought Existing Demand	9.5	9.5	9.8	10.9	10.1
Scenario H Ten Year Drought Future Demand	9.5	9.5	9.8	10.9	10.1

3.2. SURFACE WATER MODEL

3.2.1. Model Setting

To run the surface water model properly, HSPF requires a large amount of data including topography, land use, soil data, hydrological characteristics and detailed meteorological datasets. Acquisition, reformatting and management of input time series consume most of the time in model application. In addition, the model has a wealth of empirical calibration parameters that must be determined from handbooks, field measurements and by calibration.

Model calibration is a critical step in its development and application. Parameter values need to be adjusted to reproduce the simulated watershed response as closely as possible to the observed data. The nonlinear parameter estimation tool (PEST) with Shuffled Complex Evolution method developed at the University of Arizona (SCE-UA) was used for HSPF calibration in the current study.

The existing HSPF model (*Dillon, 2008*) with available hydraulic, hydrological, meteorological and land use data for the South Nation River was used. The model was further refined and the following components were added in the Tier 2 work:

- South Nation River was subdivided into 33 subwatersheds. Only the portion of the watershed upstream of Casselman (gauge 02LB013) was modeled in this study.
- Land use data were coupled with soil type data. The Tier 1 modeling took into account 5 land uses, while the current Tier 2 modeling has 11 Hydrological Response Units (land uses coupled with the hydrological soils groups) doubling the number of parameters to be calibrated.
- The calibration and validation period was extended to 1990-2004.

The calibration period of 15 years is assumed to be sufficient for the study objectives. The longer period will require collection of significant amount of data. Also, this period is consistent with the previous studies.

It is important to state the assumptions and limitations, which underlie the current study:

The modeling was performed for meteorological data between 1990 and 2004, and it is assumed that the land use layers for 2003 provided by the Agriculture and Agri-Food Canada (AAFC) and soil type data provided by SNC are representative of these years.

HSPF as a mathematical model has intrinsic limitations and assumptions. Some of them are listed below:

- Certain model input (topography, cross-sections, land use, etc.) are assumed to be constant over the entire period of modeling, and other inputs vary in time but are assumed to be uniform in space (e.g., air temperature and other meteorological characteristics).
- The subsurface budget in HSPF is modeled in two-layers, which can interact with the surface through plants or interflow. The aquifer is not modeled but treated as a sink of water.
- The receiving watercourse for each subwatershed is modeled as completely (longitudinally, laterally, and vertically) mixed.

3.2.2. Data Acquisition and Processing

Extensive meteorological data for the study period of 1990-2004 were collected to set up the model. Hourly data included precipitation, air temperature, wind speed, solar radiation, and dewpoint temperature. Data from the Ottawa Airport meteorological station (6006000) were used in the study.

The 2 and 10 year drought periods were defined based on the historical precipitation data for the Ottawa Airport as per Rule 1 in the Technical Rules (MOE, 2009). The 10 consecutive years with the lowest annual precipitation were 1955-1964 and the 2 consecutive years with the lowest precipitation were 1960-1961. Daily precipitation and hourly air temperature for the period of 1955-1964 were used in HSPF for the drought scenario analysis. The daily precipitation data were disaggregated into hourly using the internal HSPF subroutine, WDMUtils.

A land use raster data with a resolution of 30 m was provided by AAFC (2003). A provincial Digital Elevation Model (DEM) layer with a 10 m resolution was used for subwatershed delineation and for deriving watershed characteristics. Soil data in GIS format were provided by South Nation Conservation (SNC). Cross-section data were imported from the existing HEC-RAS model provided by RRCA or generated from the DEM. Additional base data in GIS shapefile format (streams, roads, towns, tile drainage) were also provided by SNC.

HYDAT data were used to obtain flows in the South Nation River. A summary of available data is presented in **Table 3.5**. Data from station 02LB006 were used to calibrate the model.

Table 3.5. Hydrological gauges in the study area

Station	Name	Characteristic	Years
02LB007	South Nation at Spencerville	Daily Flows	1990-2004
02LB006	Castor River at Russell	Daily Flows	1990-2002 and 2004
02LB009	South Nation at Chesterville	Daily Flows	Only spring data for 1990, 1993, 1994
02LB013	South Nation at Casselman	Daily Flows	Many gaps in data: 1990-1996, 2000-2004

3.2.3. Surface Water Subwatersheds

For the purposes of HSPF calibration the study area was subdivided into 39 subwatersheds (**Figure 3.8**). The subdivisions were created based on available hydrological gauges, similarity in topography and soils and location of the stressed watersheds identified in the Tier 1 assessment. Each stream segment (or reach) was chosen to be short enough to reduce numerical dispersion and accurately represent water balance components, yet long enough that the residence time in every reach exceeds the simulation time step. Each subwatershed was assumed homogeneous in hydrologic and hydraulic response. The subwatersheds were further subdivided into 7 landuses (agriculture, forest, urban, rock, shrubs, water and wetlands) and 3 Hydrological Soil Groups (A, B and D). The Hydrological Soil Groups (HSG) are classified based on the soil's runoff potential by the US Natural Resource Conservation Service. Details of this classification can be found in "Urban Hydrology for Small Watersheds" (*USDA*, *1986*). For the purpose of this study Soil Group A was represented by sand, loamy sand and sandy loam. This group has low runoff potential and high infiltration rates. Soil Group B consists of silt loam and loam with a moderate infiltration rate. In order to simplify the model Soil Group C was omitted in this study and split between Group B and Group D. Soil Group D are clay, clay loam, silty clay, loam, sandy clay and silty clay soils. This HSG has the highest runoff potential and very low infiltration rates. The landuses and soils groups were combined into 11 Hydrological Reponses Units (HRU) presented in **Table 3.6.** Hydrological Response Units in the South Nation Watersheds and neighboring areas are shown on **Figure 3.9**.

Table 3.6. Hydrological Response Units for the South Nation River Watershed

	HSG Class A	HSG Class B	HSG Class D
Agriculture	AGCa	AGCb	AGCd
Forest	FORa	FORb	FORd
Urban	URBN	URBN	URBN
Rock	ROCK	ROCK	ROCK
Scrubs and unclassified	SCHR	SCHR	SCHR
Water	WATR	WATR	WATR
Wetlands	WETL	WETL	WETL

It should be noted that HSPF subwatersheds do not exactly correspond to Tier 1 and Tier 2 subwatersheds. HSPF/BASINS uses the internal GIS delineation method based on the available 10 m DEM. Tier 1 subwatersheds were delineated by SNC staff using the refined contour maps and/or a DEM of different resolution. This inconsistency does not constitute a problem since the HSPF recharge results are reported in mm/year over the different HRUs. Then, the recharge values for various HRUs were applied to the Tier 1 subwatersheds.

The percentage of area in the South Nation watershed represented by each HRU is shown in **Table 3.7**. It can be seen that close to 60 % of the South Nation watershed are agricultural lands. Forested land is the next major land use category covering 28 % of the area. Urban territories and wetlands occupy 6 % and 5 % respectively. Water, shrubs and rocks represent only minor landuse components.

Table 3.7. Percentage of area in the South Nation watershed represented by each HRU

AGCa	AGCb	AGCd	FORa	FORb	FORd	URBN	ROCK	SCHR	WATR	WETL
23.5%	1.6%	33.3%	18.2%	0.8%	9.3%	6.3%	0.4%	1.2%	0.3%	5.0%

3.2.4. Optimization Technique

The nonlinear Parameter Estimation Tool (PEST) with its SCE-UA subroutine was used throughout the study. The SCE-UA method is a global optimization method developed by *Duan et al. (1992)* at the University of Arizona explicitly for calibration of watershed models. The SCE-UA method is based on synthesis of genetic algorithms, simplex downhill search, control random search method, and complex shuffling.

An integral part of the calibration process is a sensitivity analysis, which was performed on the HSPF parameters. Parameter sensitivity reflects the effect of parameter changes on the output function. The sensitivity of each parameter with respect to all weighted observations was computed.

Calibration is an iterative procedure of parameter evaluation and adjustment, with the objective to reproduce a modeled response identical to the observed reality. The aim of calibration is to minimize the error between observed and model data. In the present study, the error, or the objective function (OF), was expressed in weighted squared residuals. The compound objective function (ϕ) minimized during optimization was a combination of the following two single OFs: weighted squared differences between simulated and observed daily flows (OF1) and weighted squared differences between simulated and observed monthly volumes (OF2). ϕ was defined as:

$$\phi = \sum_{i=1}^{n} [\log q_{obsr}^{i} \times (\log q_{obsr}^{i} - \log q_{sim}^{i})]^2 + \sum_{i=1}^{k} [w^i \times (V_{obsr}^{i} - V_{sim}^{i})]^2$$

where n is number of daily flow observations, k is number of months, q_{obsr} and q_{sim} are the values of daily observed and simulated flows, V_{obsr} and V_{sim} are the values of monthly observed and simulated volumes and w is the weighting factor.

The log was added to the OF to increase impact of low flows on the total OF. Based on the study objectives the weight (*w*) was assigned in a way to achieve approximately 66% contribution from the flows and 33% from the monthly volumes. Depending on the objectives of the study, the weighting factors as well as OF itself can vary. In this particular study the minimum flows were critical which is why weighting of the low flows was amplified.

3.2.5. Model Calibration

More than 50 hydrologic parameters are used in HSPF for water budget calibration in a pervious land segment. Some of these parameters are fixed for a period of modeling and others vary monthly. A number of HSPF parameters can be obtained from land use maps, high resolution topographical maps, and geographical information system or field surveys. Other parameters are estimated from climatological conditions, geology, soil types and literature. The upper and lower limits for the calibrated parameters were taken from the literature (*USEPA,2000)*. Based on the conducted sensitivity analysis, the 12 most sensitive hydrologic parameters were identified (**Table 3.8)**.

HSPF has more than 20 parameters in its snow modeling subroutine that simulates accumulation and melting of snow and ice. Some parameters, such as the latitude of a watershed segment, mean elevation, and others of similar nature are straightforward and do not require calibration. Based on literature reviews and sensitivity tests, 5 parameters were singled out to adjust during calibration. These parameters, as well as their minimum and maximum values, are shown in **Table 3.8**. All calibrated snow parameter values were numerically similar to those found in literature.

Table 3.8 shows the calibrated values for the HSPF model. The range of values is shown for the HRU variable parameters and for monthly variable parameters.

Table 3.8. HSPF Calibration Parameters

	Minimum Value	Maximum Value	Calibrated value or range
Hydrological Parameters			
LZSN, Lower zone nominal storage, in.	2.00	12.0	2.1-3.9
INFILT, Index of infiltration capacity of soil, in/h	0.01	0.40	0.08-0.30
UZSN, Upper zone nominal storage, in. (varied monthly)	0.05	2.0	0.4-1.25
IRC, Interflow recession parameter	0.30	0.85	0.71
AGWRC, Base groundwater (GW) recession	0.85	0.99	0.99
LZETP, Lower zone ET (varied monthly)	0.05	0.90	0.4-0.9

CEPSC, Interception storage (varied monthly), in.	0.00	0.6	0.0-0.6
NSUR, Manning's roughness for overland flow	0.10	0.45	0.10-0.43
BASETP, Fraction of ET from baseflow	0.01	0.20	0.14
INTFW, Interflow inflow parameter	1.00	9.9	1.09
DEEPFR, Fraction of ground water inflow to deep recharge	0.01	0.50	0.2
KVARY, Variable GW recession, 1/in.	0.0	3.0	4.75
Snow parameters			
SHADE, Fraction of land segment shaded from solar radiation	0.01	0.80	0.45
SNOWCF, Snow gauge catch correction factor	1.0	1.5	1.08
TSNOW, Temperature at which precipitation become snow, °F	30.0	35.0	30.5
CCFACT, Condensation/convection melt factor	0.5	7.0	0.5
MWATER, Liquid water storage capacity in snowpack in/in	0.01	0.20	0.015

Average simulated and observed monthly flows in Castor River at Russell are presented in Figure 3.10. Observed and simulated annual volumes in Castor River at Russell are presented in Figure 3.11. Note that 2003 is disregarded from the annual volume comparison since no data is available from HYDAT.

Based on performance statistics and a graphical comparison of modeled and observed daily flows and monthly volumes, it was concluded that sufficient precision of hydrological calibration was achieved.

3.2.6. Recharge Calculations

One of the principal objectives of HSPF modeling in the current study was to obtain the recharge values which can be used by MODFLOW in the groundwater simulation. Recharge values are also used in the supply term of water demand calculations for stress assessments under Scenarios A and B. HSPF estimates recharge from pervious segments. An assumption was made that all HRUs in the current model set-up are pervious except urban landuse (40% impervious) and rocks (50% impervious).

HSPF estimates groundwater outflow (baseflow) as the difference between groundwater inflow (AGWI) and groundwater evapotranspiration (AGWET). Deep percolation was not separated; it was considered as a portion of groundwater recharge.

The results of HSPF simulation for the average year are shown in **Table 3.9**. It can be seen that annual recharge values for the pervious segments vary between 106 and 287 mm per year. The monthly recharge values are high during spring snowmelt and low during winter and summer months. Figure 3.12 shows annual recharge values in the studied subwatersheds and neighboring areas. The recharge values outside the surface model domain were estimated based on similarity of the HRUs. The assumption was made that a landuse and soil combination in the HSPF model domain has the same recharge value as in the neighboring area.

Table 3.9. Monthly recharge values from various HRUs (average year).

	AGCa mm	AGCb mm	AGCd mm	FORa mm	FORb mm	FORd mm	URBN mm	ROCK mm	SCHR mm	WETL mm
Jan	13.2	11.7	8.6	13.1	11.6	9.2	4.0	3.4	8.4	9.4
Feb	8.5	7.2	5.0	8.5	7.1	5.3	8.3	7.0	9.8	12.0
Mar	36.4	29.5	19.7	36.8	29.6	21.0	7.5	6.4	15.9	19.2
Apr	62.4	52.8	37.9	62.9	53.1	39.8	17.0	14.4	32.9	38.5
May	32.9	28.3	20.7	30.2	25.9	18.9	12.3	10.5	22.7	24.7
Jun	20.6	17.1	11.7	17.5	14.6	10.3	10.1	8.2	15.4	17.8
Jul	11.6	9.4	7.1	6.9	5.4	3.6	8.9	6.6	11.4	14.0
Aug	6.9	5.6	5.0	4.8	3.8	3.0	6.9	6.2	8.3	11.4
Sep	9.6	8.4	7.5	7.0	6.1	5.2	10.8	10.7	14.5	23.3
Oct	24.9	23.1	22.5	20.5	19.6	15.9	16.6	13.9	30.2	46.4
Nov	37.2	37.6	37.9	32.9	34.0	34.2	14.3	11.8	25.9	30.1
Dec	22.4	21.2	18.6	21.9	21.4	18.9	8.7	7.3	15.9	17.1
SUM	286.7	251.9	202.1	263.0	232.1	185.5	125.4	106.4	211.4	263.9

Table 3.10. Monthly recharge values from various HRUs (10 year drought).

	AGCa mm	AGCb mm	AGCd mm	FORa mm	FORb mm	FORd mm	URBN mm	ROCK mm	SCHR mm	WETL mm
Jan	6.1	5.4	4.2	5.7	5.2	4.2	2.0	1.6	4.0	4.5
Feb	4.1	3.8	3.2	3.8	3.7	3.1	7.2	6.2	7.8	9.7
Mar	36.6	30.7	20.9	36.1	30.6	22.0	8.0	6.7	17.1	20.9
Apr	72.7	61.5	43.4	73.1	61.8	46.0	19.2	16.3	37.7	45.0
May	25.9	22.4	16.2	23.0	19.8	14.4	11.2	9.6	20.8	22.9
Jun	12.6	10.5	6.7	8.6	7.1	4.9	7.6	5.9	10.6	13.2
Jul	7.3	5.8	4.6	3.8	2.9	1.9	7.6	5.5	8.8	11.8
Aug	3.5	2.6	3.1	1.3	0.8	0.6	7.3	6.7	7.5	13.1
Sep	4.8	3.9	3.4	3.1	2.5	1.8	7.6	7.5	9.5	15.2
Oct	15.3	13.9	13.0	11.5	11.0	8.5	13.5	11.7	21.6	36.1
Nov	23.5	24.1	28.1	18.2	18.8	19.8	13.0	10.9	21.7	27.7

Dec	11.9	12.1	11.7	10.3	11.0	10.9	5.5	4.6	9.4	10.8
SUM	224.2	196.6	158.6	198.5	175.1	138.3	109.7	93.3	176.3	230.9

The computed average recharge values are used to set recharge boundary conditions in the MODFLOW model.

Simulations were preformed to assess recharge values for a 10 year drought (1955-1964) (Scenarios G and H). The results for a 10 year drought are presented in **Table 3.10.**

The average annual recharge for Subwatershed #29 (Greely) was estimated as 214 mm/year. The average annual recharge for Subwatershed #37 (Winchester) was estimated as 226 mm/year. Considering the respective areas of each subwatersheds (i.e., 124 sq.km for Subwatershed #29 and 125 sq.km for Subwatershed #37), the recharge component of water supply can be determined for use in the percentage water demand calculations (Scenarios A and B) in **Sections 4.1** and **4.2.**

Average recharge during the 10 year drought (1955-1964) was estimated to be 164 mm/year for Subwatershed #29 (Greely) and 171 mm/year for Subwatershed #37 (Winchester). These values are incorporated into the groundwater model in order to assess water levels as part of the Scenario G and H assessments.

The percentage of various HRUs in both subwatersheds are shown in **Table 3.11**.

Table 3.11. Percent of HRU in each subwatershed (%).

	AGCa	AGCb	AGCd	FORa	FORb	FORd	URBN	ROCK	SCHR	WETL
Subwatershed 29	28.1	0.2	31.8	8.8	0.1	13.0	7.9	0.7	1.7	7.4
Subwatershed 37	35.5	0.0	36.6	13.6	0.0	10.3	3.5	0.3	2.0	4.4

3.2.7. Reserve Calculations

According to the Technical Rules the groundwater reserves used in percent water demand estimates are calculated as 10% of the estimated average annual groundwater discharge rate, if available; or, if such information is not available, 10% of the estimated annual groundwater supply. For the purpose of this study groundwater reserve is estimated using the average annual groundwater discharge rate (baseflow) at the outflow locations of the subwatersheds as determined in the HSPF model. It should be noted that although the actual monthly baseflow data are available, the Technical Rules require that monthly values be set to the annual value divided by 12. **Table 3.12** presents monthly groundwater discharge rates for average year and the 10 year drought.

Table 3.12. Monthly groundwater discharge rate estimation (in mm)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Subwatershed #29													
Average year	15.8	15.8	15.8	15.8	15.8	15.8	15.8	15.8	15.8	15.8	15.8	15.8	189.3
10 year drought	11.7	11.7	11.7	11.7	11.7	11.7	11.7	11.7	11.7	11.7	11.7	11.7	140.0
Subwatershed #37													
Average year	14.2	14.2	14.2	14.2	14.2	14.2	14.2	14.2	14.2	14.2	14.2	14.2	170.6
10 year drought	10.5	10.5	10.5	10.5	10.5	10.5	10.5	10.5	10.5	10.5	10.5	10.5	125.9

4. STRESS ASSESSMENT SCENARIOS

According to Part 1.1 of the Technical Rules (*MOE, 2009*) the following equation is to be used where the Percent Water Demand calculation is required (i.e., Scenarios A and B).

$$\begin{array}{c}\text{\% Water Demand}\\ \text{(Groundwater)}\end{array} = \frac{\text{DEMAND}}{\text{SUPPLY- RESERVE}} \times 100;$$

Where, QDEMAND is Groundwater Consumptive Use, calculated as the portion of estimated average annual and monthly rate of groundwater takings in a subwatershed that is not returned to the aquifer that is the source of the water taking;

QSUPPLY is Groundwater Supply, calculated as the estimated annual groundwater recharge rate plus the annual estimated groundwater inflow into a subwatershed. To establish monthly amounts the annual amount shall be divided by 12;

QRESERVE is Groundwater Reserve, calculated as 10% of the estimated average annual groundwater discharge rate, if available, or if such information is not available to make such a calculation, 10% of the estimated annual groundwater supply (Q SUPPLY);

The calculated percent Water Demand was compared against appropriate Tier 2 threshold values from the Technical Rules (*MOE, 2009*).

Significant stress level has to be assigned to the system when one of the following is true:

- During scenario A or B the annual percent water demand for groundwater for the subwatershed would be greater than or equal to 25%.
- During scenario A or B the maximum monthly percent water demand for groundwater for the subwatershed would be greater than or equal to 50%.

Moderate stress level has to be assigned to the system if one of the following is true:

- During scenario A or B the annual percent water demand for groundwater for the subwatershed would be less than 25% but greater than 10%.
- During scenario A or B the maximum monthly percent water demand for groundwater for the subwatershed would be less than 50% but greater than 25%.
- At any time after January 1, 1990 one or both of the following circumstances occurred: the groundwater level in the vicinity of the well was not at a level sufficient for the normal operation of the well and the operation of a well pump was terminated because of an insufficient quantity of water being supplied to the well.
- If previous one or both circumstances are true during Scenarios D, E , G and H.
- During scenario A or B the annual percent water demand for groundwater for the subwatershed would be between 8% and 10% inclusive and the uncertainty associated with the percent water demand calculations is high (according to Rule 36). Also, a sensitivity analysis of the data used to prepare the Tier Two Water Budget suggests that the stress level for the subwatershed could be moderate.
- During scenario A or B the maximum monthly percent water demand for groundwater for the subwatershed would be between 23% and 25% inclusive and the uncertainty associated with the percent demand calculations is high. (according to Rule 36). Also, a sensitivity analysis of the data used to prepare the Tier Two Water Budget suggests that the stress level for the subwatershed could be moderate.

4.1. Scenario A. Average Conditions – Current Demand

In general terms "water supply" is the amount of available water at any given time for potential use. In the current study "water supply" is referred to in the context of groundwater. According to the Technical Rules the Groundwater Supply is calculated as the estimated annual groundwater recharge rate plus the annual estimated groundwater inflow into a subwatershed. To establish monthly amounts the annual amount was divided by 12. The recharge and reserve values were obtained from the HSPF simulations as described in **Section 3.2.6** and **3.2.7**.

The lateral groundwater inflow into each subwatershed was estimated using MODFLOW as described in **Section 3.1.6**.

Table 4.1 shows the annual and monthly percent Water Demand for the studied watersheds. It can be seen that both subwatersheds have a low level of stress. It is noted that stress levels would be low regardless of whether lateral groundwater inflow values are included in the water supply term .

4.2. Scenario B. Average Conditions – Future Demand

For Scenario B, the groundwater supply term was the same as for the Scenario A since no significant landuse changes are expected in the next 20 years in the study area. Groundwater reserve also remained unchanged compared to Scenario A. Future monthly demand was estimated based on projected pumping rates as described in **Section 2**.

The results of the percent water demand under future conditions are presented in **Table 4.2** It can be seen that both subwatersheds are not stressed and therefore proceed to the drought conditions evaluations presented in the following sections. It is noted that stress levels would be low regardless of whether lateral groundwater inflow values are included in the water supply term.

Table 4.1. Average Conditions Percent Water Demand, % (Scenario A)

SWS	Components of Stress Assessment		Area, m^2	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Average Annual
29	Recharge, mm/month		124,720,689	17.6	17.6	17.6	17.6	17.6	17.6	17.6	17.6	17.6	17.6	17.6	17.6	211.0
	Reserve, mm/month			1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6	18.9
	GW_{in} (mm/month)			16.4	16.4	16.4	16.4	16.4	16.4	16.4	16.4	16.4	16.4	16.4	16.4	197.3
	Permitted Demands (m^3/month)	Permit 7255-5ZSKTL** (Industrial - Aggregate Washing)		0	0	0	0	35,512	35,512	35,512	35,512	35,512	35,512	35,512	0	248,584
		Permit 03-P-4094 (Commercial - Golf Course Irrigation)		0	0	0	0	20,552	21,429	23,758	28,436	12,006	0	0	0	106,181
		Permit 98-P-4099 (Municipal - Greely Water Supply)		825	745	825	798	825	798	825	825	798	825	798	825	9,709
	Total Permitted Demands, m^3/month			825	745	825	798	56,889	57,739	60,095	64,772	48,316	36,337	36,310	825	364,474
	Total Permitted Demands, mm/month			0.01	0.01	0.01	0.01	0.46	0.46	0.48	0.52	0.39	0.29	0.29	0.01	2.9
	Unpermitted Agricultural Demands, mm/month (from Tier 1)			0.03	0.03	0.03	0.03	0.03	0.03	1.74	1.74	0.03	0.03	0.03	0.03	3.8
	Unpermitted Domestic Demands, mm/month (from Tier 1)			0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.1
	% Demand			0.2%	0.1%	0.2%	0.1%	1.5%	1.6%	6.9%	7.0%	1.3%	1.0%	1.0%	0.2%	1.8%
37	Recharge, mm/month		125,067,888	18.8	18.8	18.8	18.8	18.8	18.8	18.8	18.8	18.8	18.8	18.8	18.8	225.0
	Reserve, mm/month			1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	17.1
	GW_{in} (mm/month)			13.1	13.1	13.1	13.1	13.1	13.1	13.1	13.1	13.1	13.1	13.1	13.1	156.8
	Permitted Demands (m^3/month)	Permit 01-P-4013 (Industrial - Aggregate Washing)		0	0	0	0	5,706	10,325	18,317	23,005	23,005	23,005	9,879	0	113,243
		Permit 2350-5ZZKM4** (Industrial - Aggregate Washing)		0	0	0	0	38,044	38,044	38,044	38,044	38,044	38,044	38,044	0	266,311
		Permit 04-P-4011 (Municipal - Winchester Water Supply Well#6)		2,239	2,015	2,197	2,032	2,185	2,212	2,245	2,283	2,133	2,306	2,098	2,078	26,022
		Permit 86-P-4015 (Municipal - Winchester Water Supply Well#5)		1,287	1,204	1,397	1,207	1,282	1,328	1,282	1,314	1,245	1,304	814	1,207	14,872
		Permit 88-P-4090 (Municipal - Winchester Water Supply Well#1)		1,358	997	386	1,127	1,225	1,044	1,310	1,148	1,087	1,193	1,054	1,016	12,946
	Total Permitted Demands, m^3/month			4,884	4,216	3,980	4,366	48,443	52,953	61,199	65,795	65,515	65,852	51,890	4,301	433,393
	Total Permitted Demands, mm/month			0.04	0.03	0.03	0.03	0.39	0.42	0.49	0.53	0.52	0.53	0.41	0.03	3.5
	Unpermitted Agricultural Demands, mm/month (from Tier 1)			0.06	0.06	0.06	0.06	0.06	0.06	0.25	0.25	0.06	0.06	0.06	0.06	1.1
	Unpermitted Domestic Demands, mm/month (from Tier 1)			0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.2
	% Demand			0.4%	0.3%	0.4%	0.4%	1.5%	1.6%	2.5%	2.6%	2.0%	2.0%	1.6%	0.4%	1.3%

** Permit no longer operational

Table 4.2. Future Conditions Percent Water Demand, % (Scenario B)

SWS	Components of Stress Assessment	Area, m^2	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Average Annual
29	Recharge, mm/month	124,720,689	17.6	17.6	17.6	17.6	17.6	17.6	17.6	17.6	17.6	17.6	17.6	17.6	211.0
	Reserve, mm/month		1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6	18.9
	GW_{in} (mm/month)		16.4	16.4	16.4	16.4	16.4	16.4	16.4	16.4	16.4	16.4	16.4	16.4	197.3
	Permitted Demands (m^3/month): Permit 7255-5ZSKTL** (Industrial - Aggregate Washing)		0	0	0	0	35,512	35,512	35,512	35,512	35,512	35,512	35,512	0	248,584
	Permit 03-P-4094 (Commercial - Golf Course Irrigation)		0	0	0	0	20,552	21,429	23,758	28,436	12,006	0	0	0	106,181
	Permit 98-P-4099 (Municipal - Greely Water Supply)		825	745	825	798	825	798	825	825	798	825	798	825	9,709
	Total Permitted Demands, m^3/month		825	745	825	798	56,889	57,739	60,095	64,772	48,316	36,337	36,310	825	364,474
	Total Permitted Demands, mm/ month		0.01	0.01	0.01	0.01	0.46	0.46	0.48	0.52	0.39	0.29	0.29	0.01	2.9
	Unpermitted Agricultural Demands, mm/month (from Tier 1)		0.03	0.03	0.03	0.03	0.03	0.03	1.74	1.74	0.03	0.03	0.03	0.03	3.8
	Unpermitted Domestic Demands, mm/month (from Tier 1)		0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.1
	% Demand		0.2%	0.1%	0.2%	0.1%	1.5%	1.6%	6.9%	7.0%	1.3%	1.0%	1.0%	0.2%	1.8%
37	Recharge, mm/month	125,067,888	18.8	18.8	18.8	18.8	18.8	18.8	18.8	18.8	18.8	18.8	18.8	18.8	225.0
	Reserve, mm/month		1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	17.1
	GW_{in} (mm/month)		13.1	13.1	13.1	13.1	13.1	13.1	13.1	13.1	13.1	13.1	13.1	13.1	156.8
	Permitted Demands (m^3/month): Permit 01-P-4013 (Industrial - Aggregate Washing)		0	0	0	0	5,706	10,325	18,317	23,005	23,005	23,005	9,879	0	113,243
	Permit 2350-5ZZKM4** (Industrial - Aggregate Washing)		0	0	0	0	38,044	38,044	38,044	38,044	38,044	38,044	38,044	0	266,311
	Permit 04-P-4011 (Municipal - Winchester Water Supply Well#6)		4,485	4,036	4,401	4,070	4,377	4,432	4,497	4,573	4,273	4,619	4,203	4,163	52,128
	Permit 86-P-4015 (Municipal - Winchester Water Supply Well #5)		2,579	2,412	2,799	2,417	2,569	2,660	2,569	2,633	2,494	2,611	1,631	2,417	29,791
	Permit 88-P-4090 (Municipal - Winchester Water Supply Well #1)		2,720	1,997	773	2,258	2,453	2,091	2,625	2,300	2,178	2,389	2,112	2,036	25,933
	Total Permitted Demands, m^3/month		9,783	8,445	7,973	8,745	53,150	57,552	66,052	70,555	69,995	70,670	55,870	8,616	487,407
	Total Permitted Demands, mm/ month		0.08	0.07	0.06	0.07	0.42	0.46	0.53	0.56	0.56	0.57	0.45	0.07	3.9
	Unpermitted Agricultural Demands, mm/month (from Tier 1)		0.06	0.06	0.06	0.06	0.06	0.06	0.25	0.25	0.06	0.06	0.06	0.06	1.1
	Unpermitted Domestic Demands, mm/month (from Tier 1)		0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.2
	% Demand		0.5%	0.5%	0.5%	0.5%	1.7%	1.8%	2.6%	2.7%	2.1%	2.1%	1.7%	0.5%	1.4%

** Permit no longer operational

4.3. Scenario D. 2 year drought – Current Demand

According to the Technical Rules (2009), Rule 25(2), a subwatershed can be assigned a groundwater stress level of moderate or significant if either of the following circumstances occur:

(i) The groundwater level in the vicinity of the well was not sufficient for the normal operation of the well.
(ii) The operation of a well pump was terminated because insufficient quantity of water being supplied to the well.

The screen elevation data for Greely wells were obtained from the City of Ottawa and the screen elevation data for Winchester wells were obtained from DWIS.

The groundwater model was run in a transient mode with current demands and no recharge. The results of MODFLOW simulations show that a depth of water of 6.3 m is maintained over the Greely well screens and a depth of at least 9.8 m is maintained over the Winchester well screens. Both systems have a low level of stress in this scenario.

4.4. Scenario E. 2 year drought – Future Demand

Scenario E is identical to scenario D except that the future municipal demands were used for modelling. The results of MODFLOW simulations show that a depth of water of 6.3 m is maintained over the Greely well screens and a depth of at least 9.8 m is maintained over the Winchester well screens. Both systems have a low level of stress in this stress assessment scenario.

4.5. Scenario G. 10 year drought – Current Demand

Scenario G is identical to Scenario D except that recharge based on a 10 year drought conditions were used for modelling. The results of MODFLOW simulations show that a depth of water of 9.5 m is maintained over the Greely well screens and a depth of at least 9.8 m is maintained over the Winchester well screens. Both systems have a low level of stress in this scenario.

4.6. Scenario H. 10 year drought – Future Demand

Scenario H is identical to Scenario G except that the future municipal demands were used for modelling. Scenario D is identical to Scenario H except that the future municipal demands were used in the transient groundwater modeling. The results of MODFLOW simulations show that a depth of water of 9.5 m is maintained over the Greely well screens and a depth of at least 9.8 m is maintained over the Winchester well screens. Both systems have a low level of stress in this scenario.

5. UNCERTAINTY

According to the Technical Rules the uncertainty has to be estimated for the Tier 2 Water Budget. Rule 36 describes the factors which should be considered during the uncertainty analysis.

- The distribution, variability, quality and relevance of the available input data.
- The ability of the methods and models used to accurately reflect the hydrologic system.
- The quality assurance and quality control procedures applied.
- The extent and level of calibration and validation achieved for any groundwater and surface models used or calculations and general assessments completed.

Following the evaluation criteria set out in the Technical Rules, the study team proposes that a low level of uncertainty is appropriate for this study based on the fact that extensive meteorological data were used, both models were satisfactory calibrated, and permitted water demands are certain.

6. CONCLUSIONS

A Tier 2 Water Budget and Stress Assessment has been completed for two subwatersheds identified as part of the previous Tier 1 analyses. These include Subwatershed #29 in which contains the Greely municipal well supply and Subwatershed #37 which contains the Winchester well supply. These systems had been identified as having, moderate and significant stress levels respectively as part of the Tier 1 analysis. The previous analysis included an assessment of percent water demand during Scenarios A and B described in this report.

A refinement in permitted water demands that are considered in percentage water demand estimates was completed as part of the current study. In addition, updated water supply quantities were determined through refined surface water modeling that determined recharge and groundwater modeling that determined later groundwater inflows. Primarily as a result of updated lower demand values in Subwatershed #29 (i.e., removal of a significant non-operational aggregate washing demand) the percentage water demand was determined to be lower than in the Tier 1 analysis. Consequently the stress level under average climate conditions for both existing and future demand scenarios is ‘low’. Similarly as a result of lower demand values in Subwatershed #37 (i.e., removal of a significant non-operational aggregate washing demand, removal of erroneous pond storage demands, and use of actual demands) the stress levels under average climate conditions for both existing and future demand scenarios is ‘low’.

An evaluation of water levels at the well screens in both systems was completed considering 2 year and 10 year drought conditions using the numerical groundwater model developed as part of this study and inputs from the surface water analysis. The model results indicate that no well screens in either of the systems is exposed under these conditions, considering existing and future demand scenarios.

Based on the study findings, both subwatersheds are considered to have low stress levels and Tier 3 analysis is not required.

7. REFERENCES

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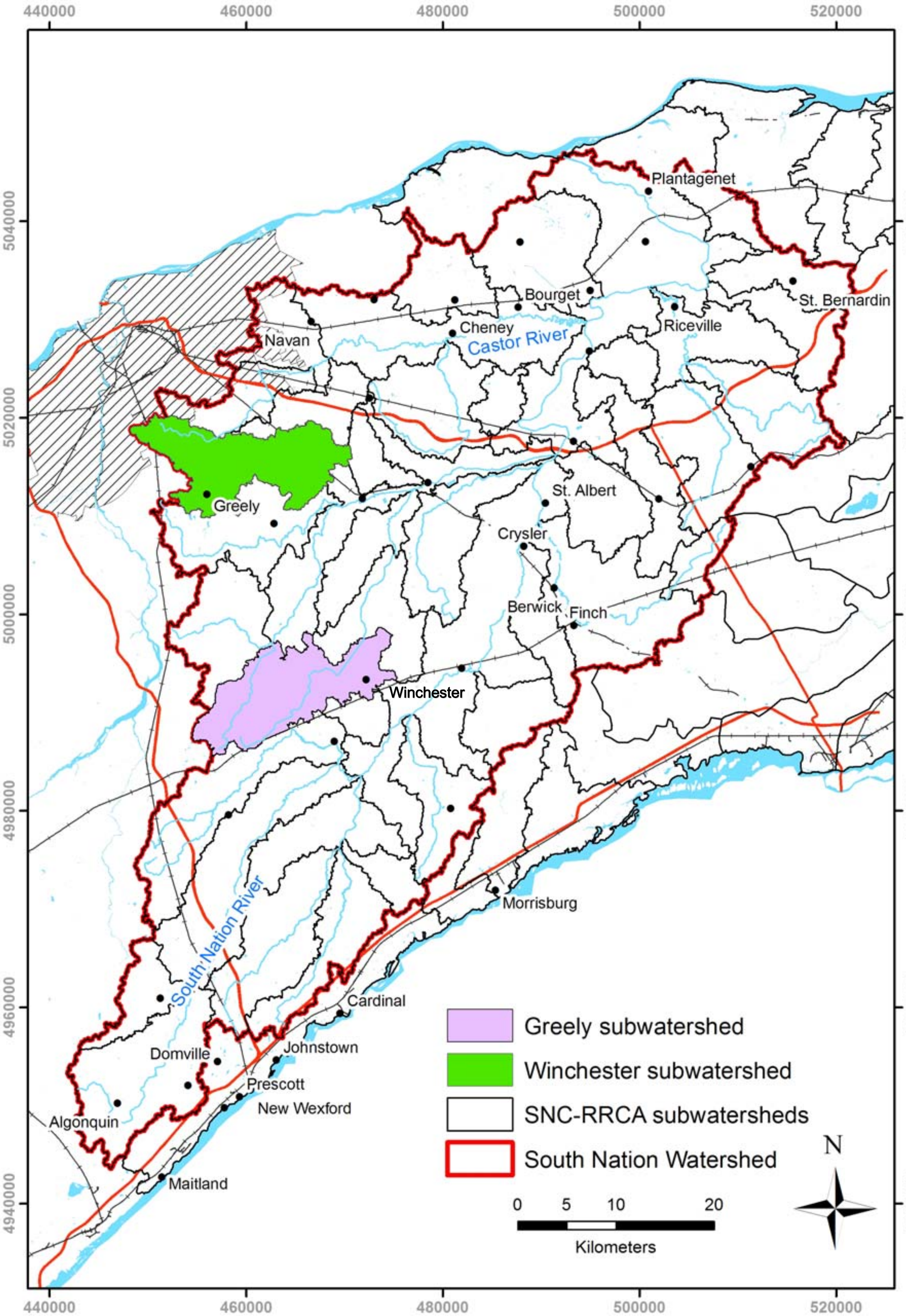
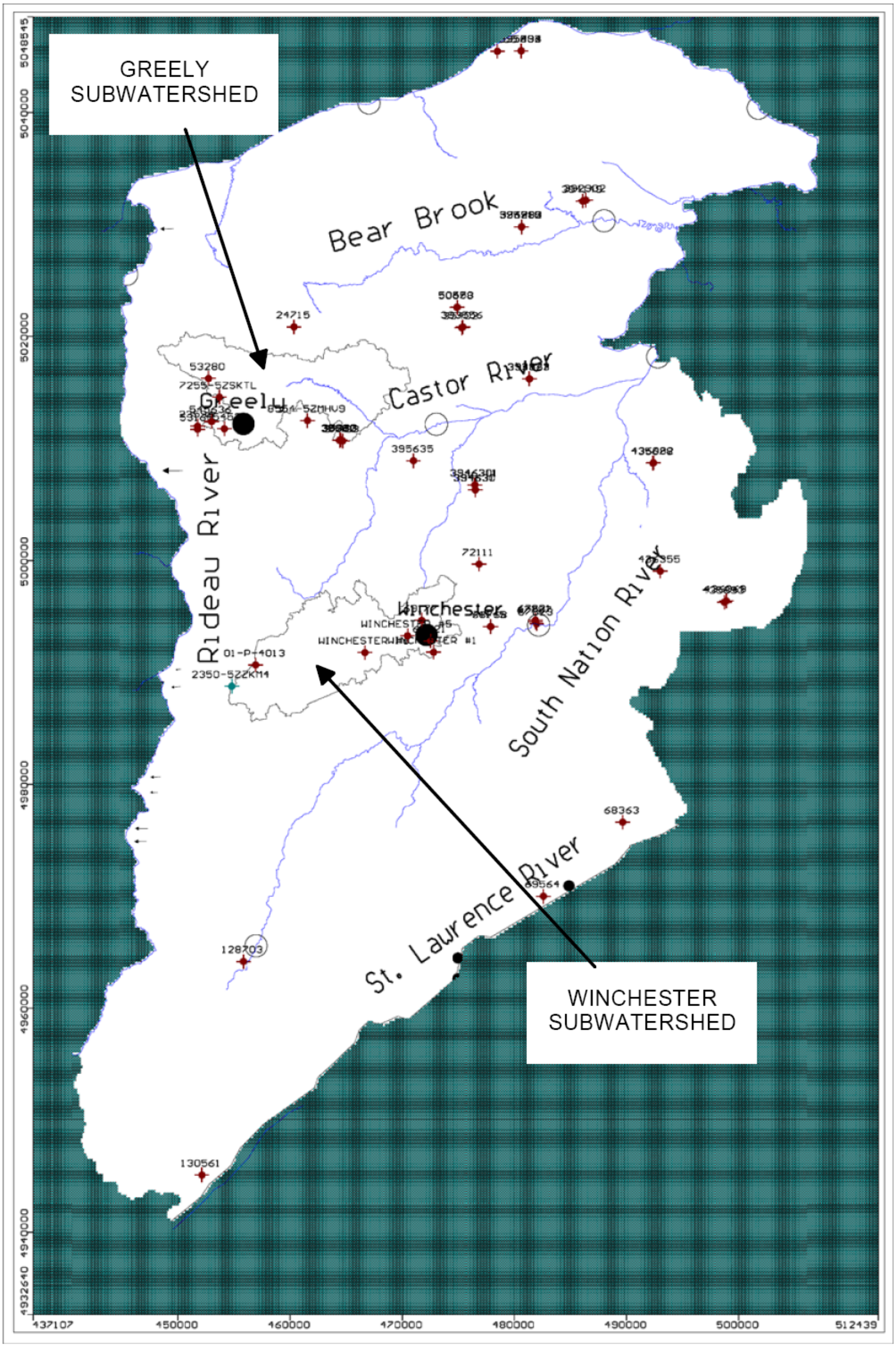
FIGURES



Tier 2 Water Budget Winchester and Greely Groundwater Intakes
for Raisin-South Nation Source Protection Region

Study Area with Winchester and Greely Subwatersheds

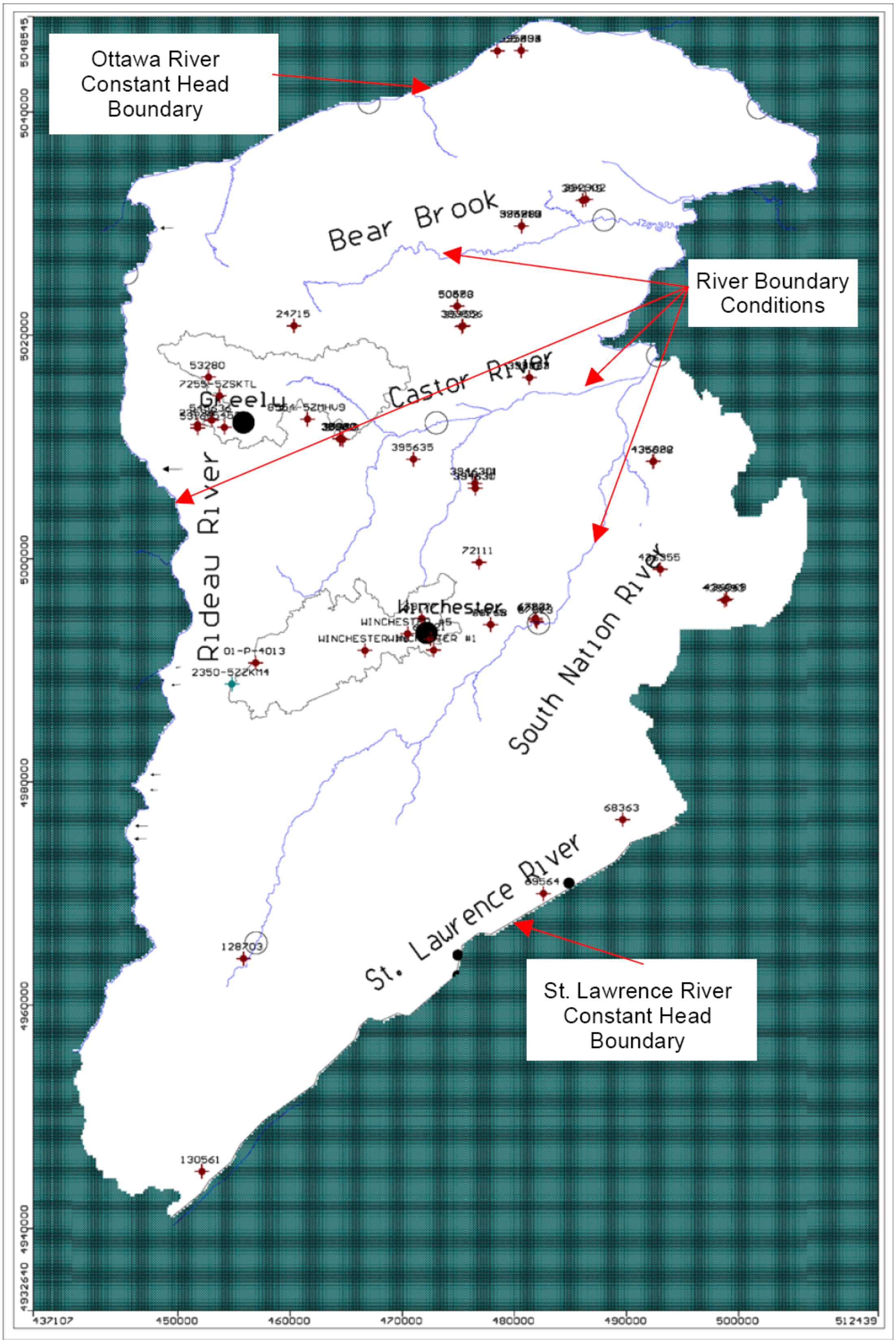
Figure 1.1



Tier 2 Water Budget Winchester and Greely Groundwater Intakes for Raisin-South Nation Source Protection Region

Groundwater Model Area

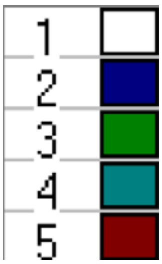
Figure 3.1



Tier 2 Water Budget Winchester and Greely Groundwater Intakes for Raisin-South Nation Source Protection Region

Model Boundary Conditions

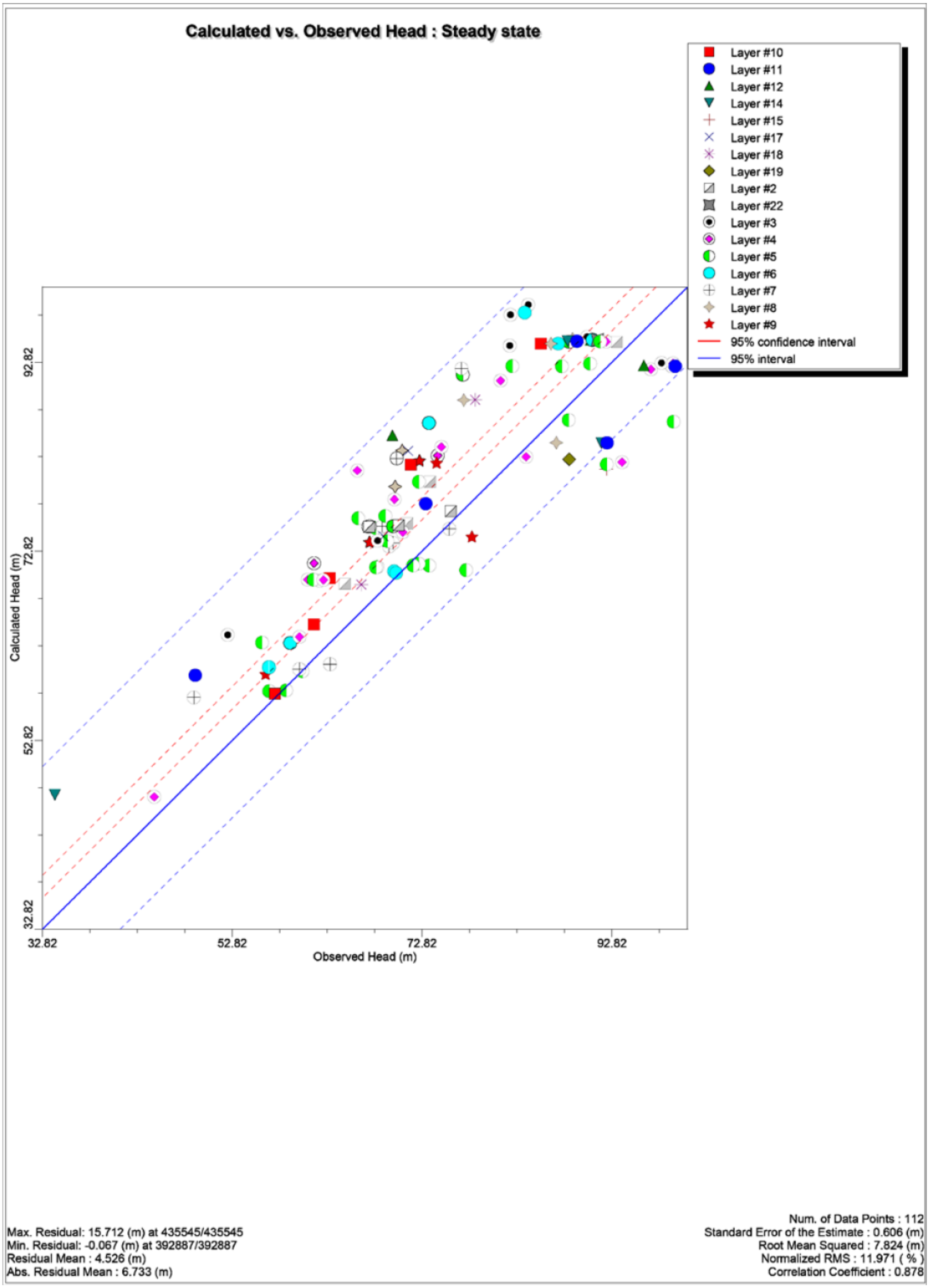
Figure 3.2



Tier 2 Water Budget Winchester and Greely Groundwater Intakes for Raisin-South Nation Source Protection Region

Hydraulic Conductivity Zones

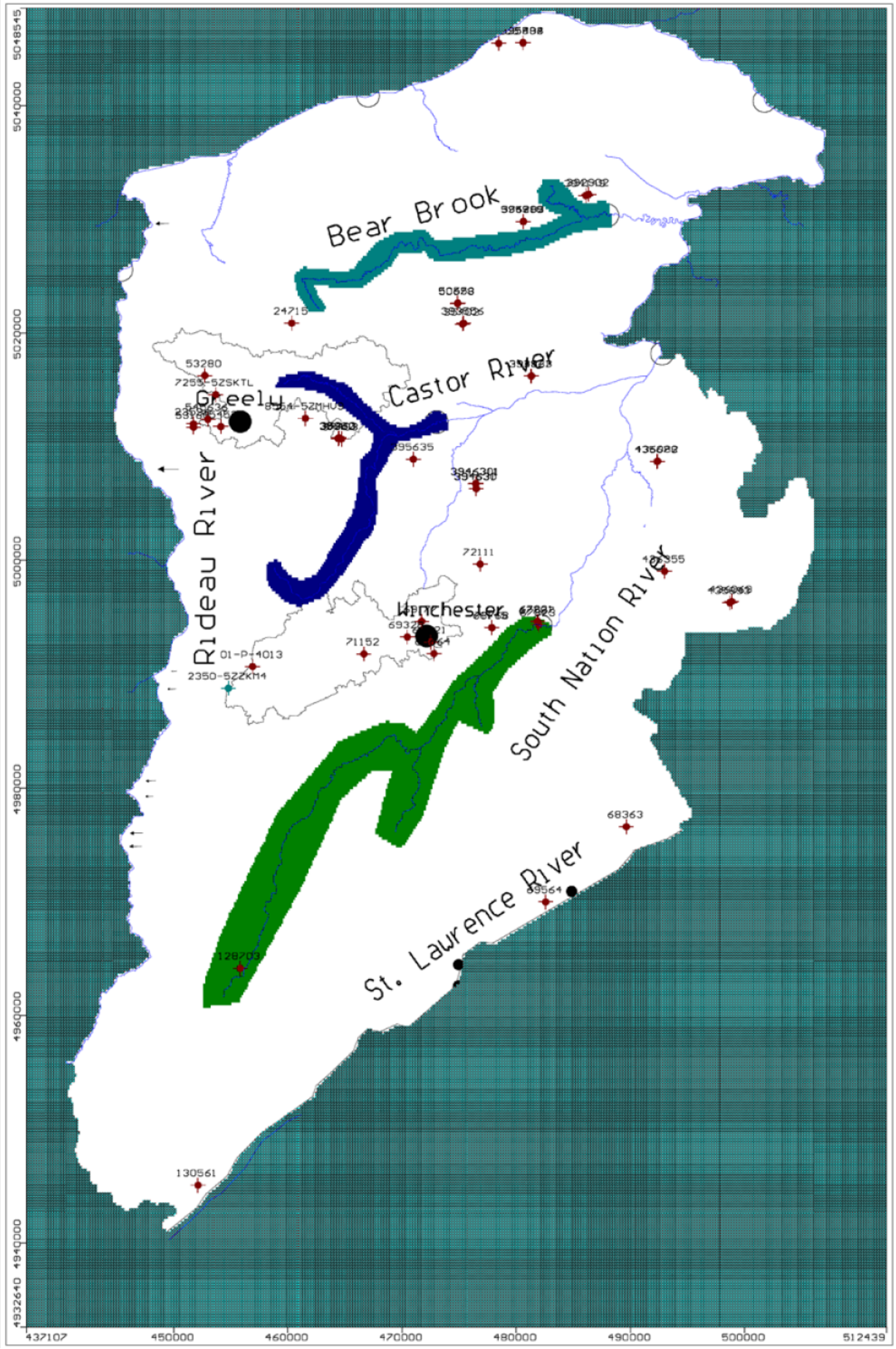
Figure 3.3



Tier 2 Water Budget Winchester and Greely Groundwater Intakes for Raisin-South Nation Source Protection Region

Calibration Plot

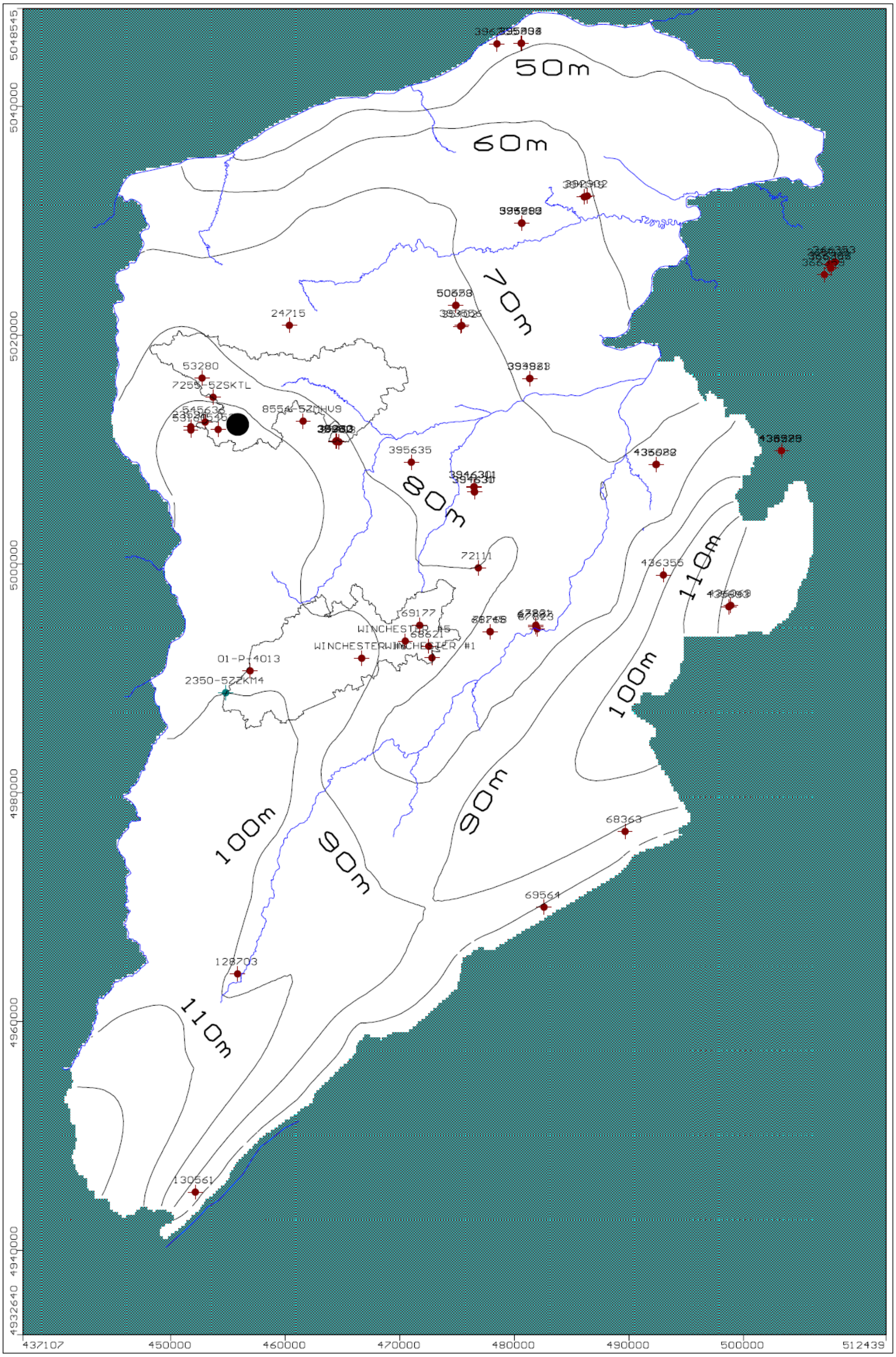
Figure 3.4



Tier 2 Water Budget Winchester and Greely Groundwater Intakes
for Raisin-South Nation Source Protection Region

Zone Budget and HYDAT Validation

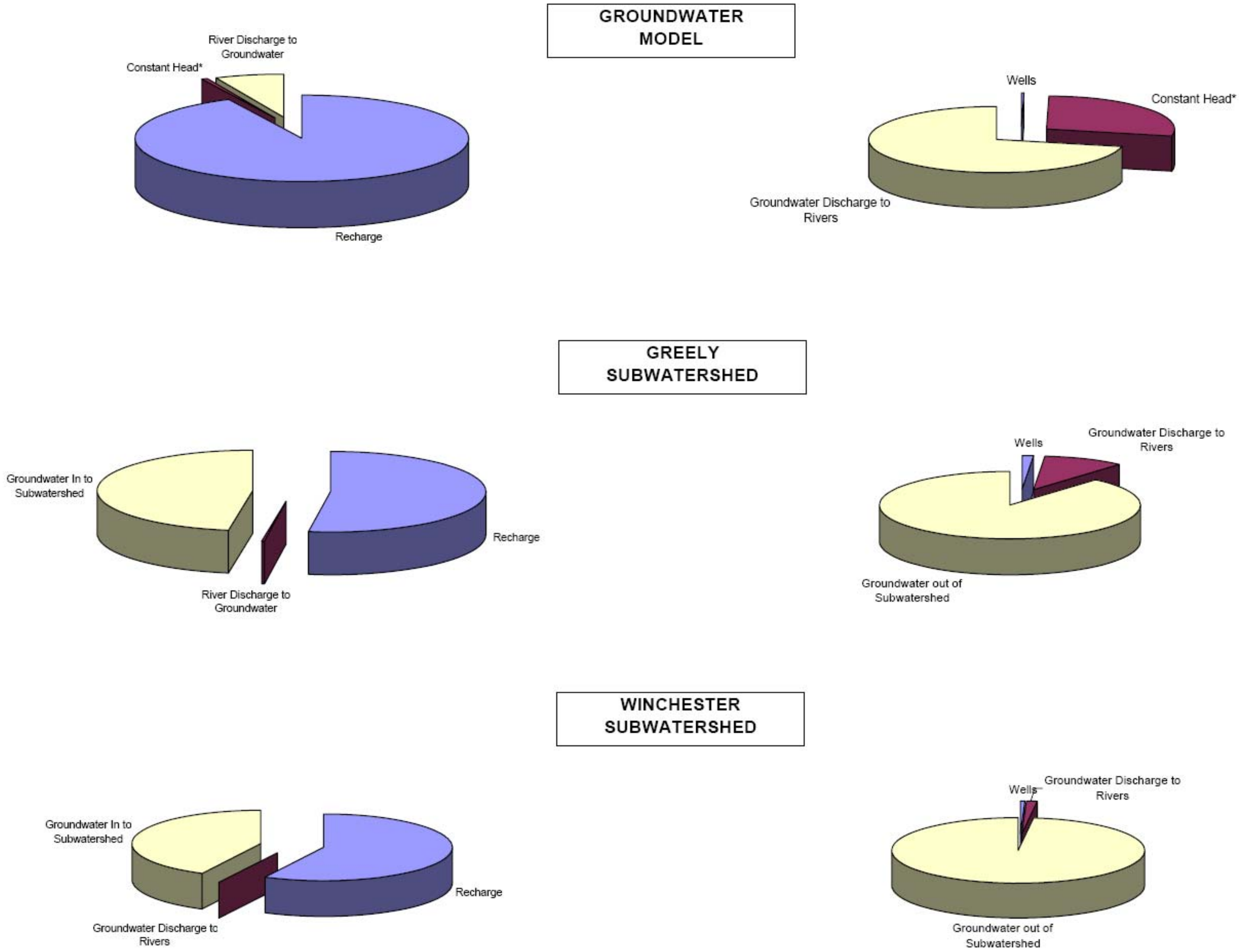
Figure 3.5



Tier 2 Water Budget Winchester and Greely Groundwater Intakes
for Raisin-South Nation Source Protection Region

Head Equipotentials

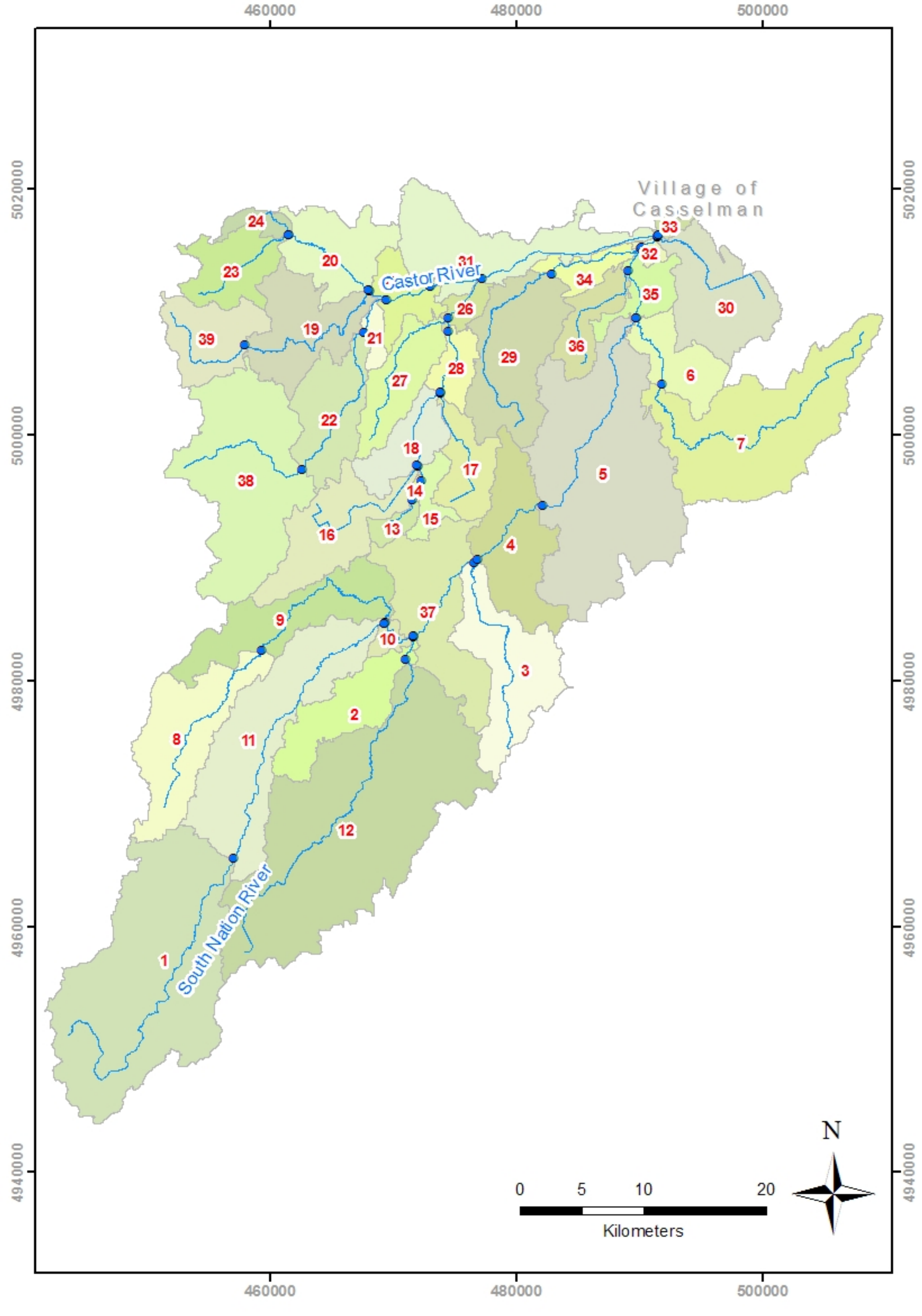
Figure 3.6



Tier 2 Water Budget Winchester and Greely Groundwater Intakes
for Raisin-South Nation Source Protection Region

Distribution of Fluxes in the Subwatersheds

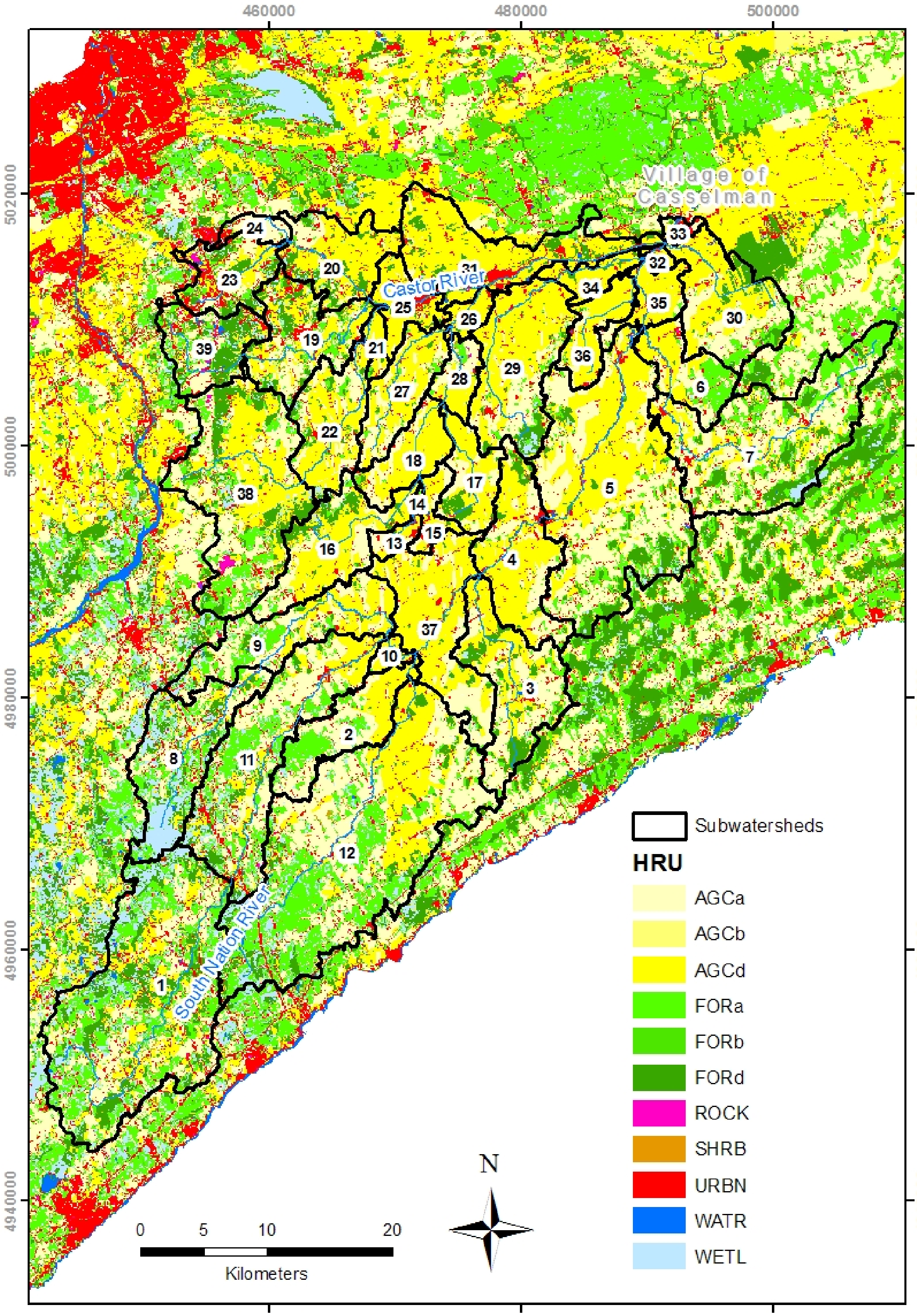
Figure 3.7



Tier 2 Water Budget Winchester and Greely Groundwater Intakes for Raisin-South Nation Source Protection Region

HSPF Subwatersheds in the Study Area

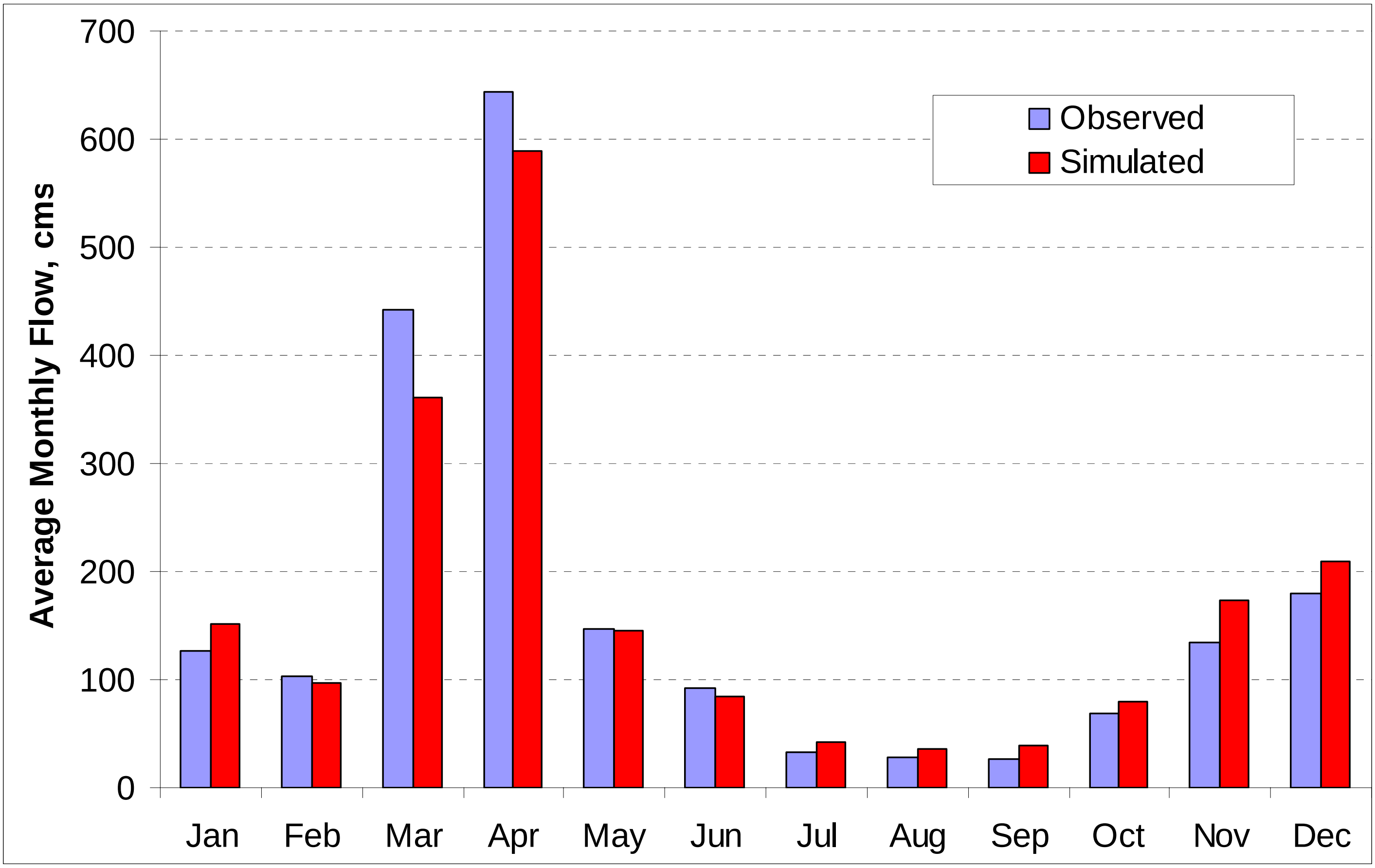
Figure 3.8



Tier 2 Water Budget Winchester and Greely Groundwater Intakes for Raisin-South Nation Source Protection Region

Hydrological Response Units in the Study Area

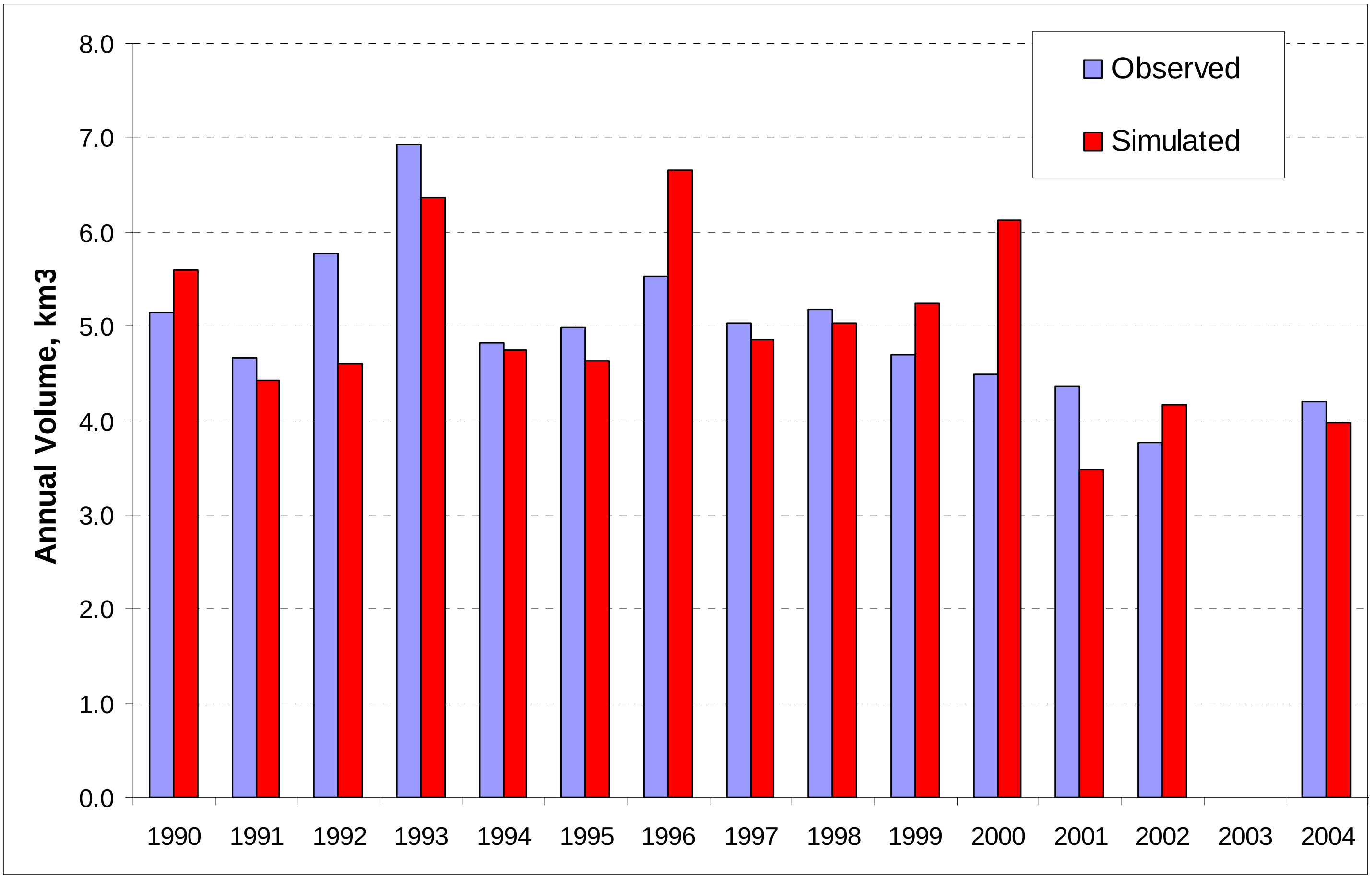
Figure 3.9



Tier 2 Water Budget Winchester and Greely Groundwater Intakes for Raisin-South Nation Source Protection Region

Average observed and simulated monthly flows in Castor River at Russell (1990-2004)

Figure 3.10

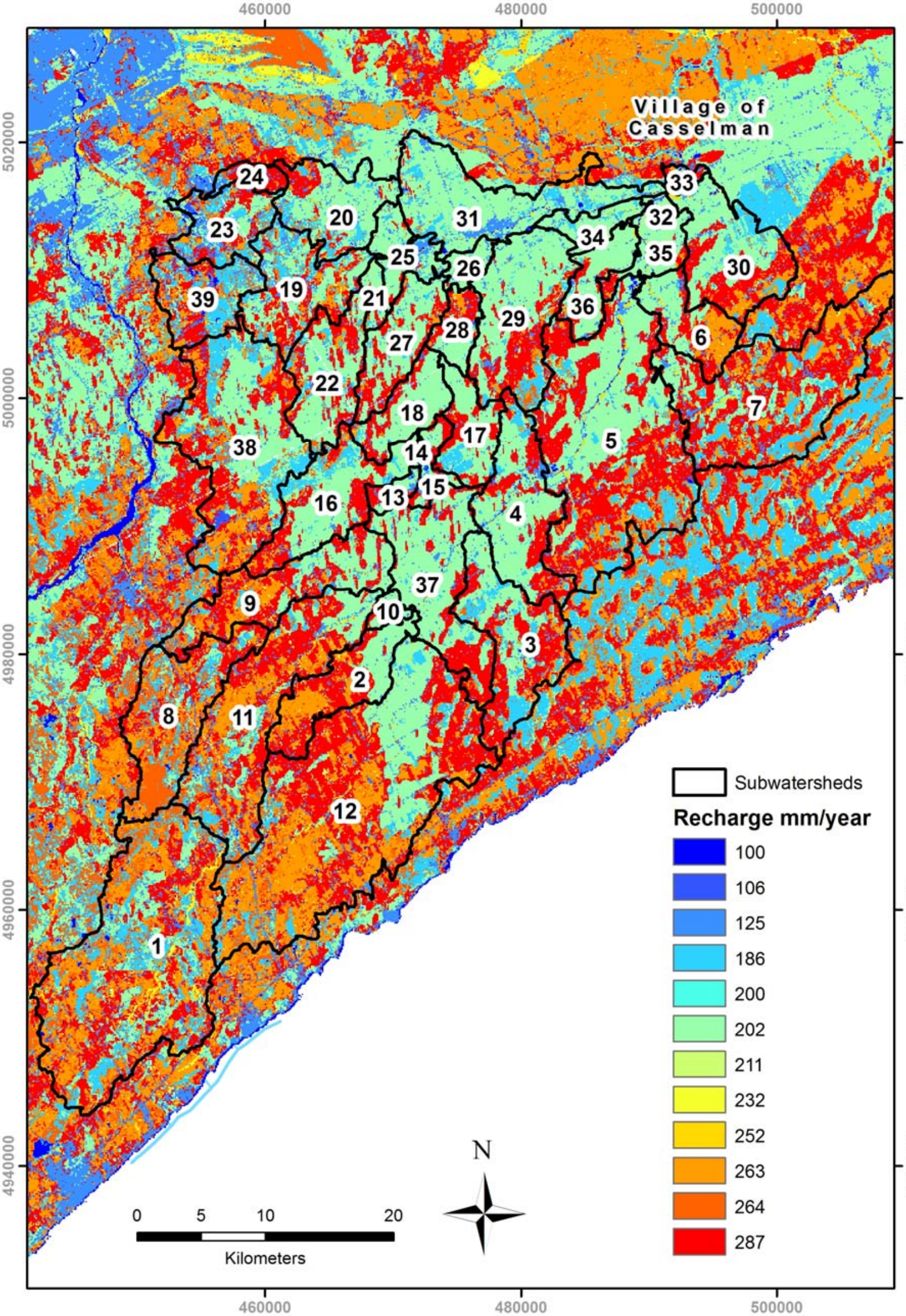


Tier 2 Water Budget Winchester and Greely Groundwater Intakes
for Raisin-South Nation Source Protection Region

Observed and Simulated Annual Volumes in Castor River at Russell

(1990-2004)

Figure 3.11



Tier 2 Water Budget Winchester and Greely Groundwater Intakes
for Raisin-South Nation Source Protection Region

Annual Recharge Values in the South Nation and Neighboring Areas

Figure 3.12

Peer Review Record

		Comment	Resolve
Scott Bates - MNR. Comments of June 25, 2010			
1	Page 6 – Line 103	Please make a minor change of the word "Quality" to "Quantity".	Fixed
2	Page 7 – Line 110	Reference to future demand should be revised to remove the terminology related to "25-year projection" throughout the document. Although the former guidance module used a 25-year time period this is no longer a requirement in the Technical Rules. All future projections should be consistent with local municipal Official Plans (both time period and population forecasts) regardless of the time period out to which forecasts have been made. Please remove the "25-year" terminology throughout the report and confirm that your future estimates are related to local municipal Official Plans.	Fixed
3	Page 7 – Line 113	Please clarify in the report that neither Winchester nor Greely have a planned system (e.g. EA approved wells with known locations and pumping rates) and will therefore not be required to undertake assessments of scenarios related to planned systems. Please also make this clarification in Table 1.1 and throughout the document where necessary.	Clarified
4	Page 7 – Line 118	Please remove the terminology on this page, and on all subsequent pages, that refers to the stress assessment being "passed" or "failed". This terminology is not used within the Technical Rules or Water Budget Guidance and should be replaced with reference to the assignment of a stress level (low, moderate, significant).	Addressed
5	Page 10 – Line 131	Please make a minor addition to this sentence to indicate, "… well screen elevation or a safe operating water level…". Professional judgment and municipal input on the safe operating water level may be necessary if the drought scenario produces a drawdown that approaches the well screen elevations, although this does not appear to be the case.	Fixed
6	Page 13 – Line 190	In the report it states, "Due to the late receipt of this data (received during the final completion of the report documentation on April 16, 2010), the pumping	Correspondence with operator following the June 1, 2010 peer review meeting (June 3, 2010)

		simulation was kept in the groundwater model at the maximum permitted rate, however the % water demand calculations were updated with zero demand values from this permit holder". Please provide some additional context and information regarding the two aggregate washing permits (7255-5ZSKTL and 2350-5ZZKM4) that were determined not to be in operation. It is certainly appropriate to omit these takings from the demand for the "existing conditions" scenario in the stress assessment; however it is important to know how these permits are intended to be used in the near-future (e.g. 2-5 years) and how they may have been used in the past. With the permitted demands of these two takings being left in the groundwater model is it assumed that groundwater supply would be underestimated (less supply by pumping it) or overestimated (more supply by inducing inflow) based on pumping at these permitted rates? Depending on the answer to the past and near-future pumping plans for these two permits it may (or may not) be necessary to update both the groundwater model and water demand estimates with more appropriate pumping rates. Please enquire further or provide additional detail about the past and near-future plans for pumping at these two locations	indicated no current pumping (non operational sites due to limited aggregate resources) but that sites could become operational for aggregate washing. Percent water demand calculations were updated to provide conservative demands reflecting potential future operations. No change to stress levels occurs as a result of the update.
7	Page 13 – Line 202	In the report it states, "After receiving permission Tier 2 Water Budget for Raisin-South Nation Source Protection Region Winchester and Greely Groundwater Drinking Systems from the MOE Liaison Officer for Source Protection Implementation to contact Lafarge directly…". Please consider removing this portion of the sentence from the report because the SPR does not really require the permission of the MOE to make contact with a permit holder to enquire about an actual taking. You may also wish to remove reference to individual names (e.g. Joel Potvin) from the report to maintain a level of privacy. It is, however, valuable to know that the appropriate contact was made and that actual pumping rates were obtained.	Fixed
8	Page 15 – Line 228	This page of the report discusses the Greely municipal demand values obtained from several different sources including the municipal operator, the Water Taking Reporting System and the DWIS report for the system. It does not seem appropriate for the monthly (or annual) water quantity stress assessment to use a <u>maximum</u> day demand value of 133 m^3/day to represent the demand when information is available about longer-term <u>average</u> day demands between 16 m^3/day and 24 m^3/day.	Text was revised. We agree that the long-term averages should be used for the demand calculations. However the Greely well is relatively new and there is not sufficient data to calculate averages. Accordingly the conservative DWIS maximum daily demand

		Although the report indicates that using the 133 m^3/day is conservative it does not meet the intent of the Technical Rules which require estimates of average monthly demand. A conservative estimate of longer-term average day demand would likely be closer to 30-40 m^3/day. Additionally, this demand should be calculated using a consumptive factor which is not mentioned in the report. If the municipal pumping from this system is being returned to the subsurface via septic beds then a consumptive factor of 0.2 (e.g. 20% consumptive) should also be applied to the estimate of actual pumping rates. Please update the percent water demand and stress assessment results to account for these revisions in demand	of 133 m^3/day was used as a "surrogate" of the average demand. As required by the Technical Rules a consumptive factor of 0.2 was applied to the pumping rate. A pumping rate of 26.6 m^3/day was used in the model and in the percent demand calculations (Tables 4.1 and 4.2).
9	Page 15 – Line 231	Please discuss the details of the Winchester municipal supply in more detail on this page. Similar to the Greely municipal demand, the report should discuss the actual pumping rates for each well in Winchester and indicate how this information has been obtained (e.g. municipality or WTRS). The future demand for this system should also be based on the local municipal Official Plan. It is unclear whether an increase of 100% (e.g. doubling of demand) is based on actual population projections provided by the municipality or if it is simply a conservative "best guess". Please also discuss the consumptive factors that are applied to this system	Text was added
10	Page 24 – Line 446	It is interesting to note that there was no modeled change in water level for the Winchester bedrock wells. Typically, during the drought scenarios we have observed at least some minor changes in water levels. The report provides some explanation of why no change occurs but I also wondered if it was simply due to the relatively small pumping rates at the Winchester wells and depth at which they have been completed. Any additional information or rationale would be helpful to the reader	Fixed
11	Page 25 – Line 472	Please provide some additional information and rationale for selecting the HSPF modelling period of record 1990-2004. The rationale for selecting this period would be helpful to the reader	Fixed
12	Page 33 – Line 629	Please make a minor revision to the Percent Water Demand calculation to specify "Groundwater" rather than "Surface Water" in the equation.	Fixed