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SOUTH NATION
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# Low Water Response

# in the

# South Nation Jurisdiction

May 12, 2014

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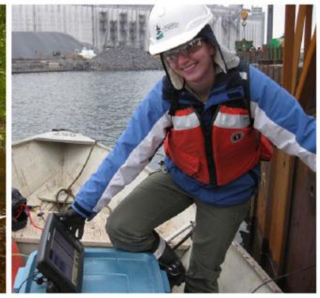

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**Executive Summary**

The Ontario Low Water Response (OLWR) program was implemented in 2001 by the Ontario Ministry of Natural Resources (MNR) to protect both the ecological and socioeconomic aspects of local communities during a drought scenario. In accordance with official OLWR guidelines, Conservation Authorities are responsible for monitoring both precipitation and streamflow patterns within their jurisdiction, which are indicators of drought. According to the OLWR guidelines, precipitation and streamflow that fall below predetermined threshold values are designated Level I, Level II, and Level III drought, with the latter being the most severe. Based on these designations, a "Low Water" status is assigned to the jurisdiction and corresponding water use restrictions are enforced.

During the 2012 drought, some concerns were raised about the applicability of the OLWR program in the South Nation River Watershed. This report outlines concerns and provides recommendations for improvement. The ultimate goal is to provide the most effective means for determining drought conditions within the SNC jurisdiction.

**Precipitation data and calculation:** Temporal data gaps present a problem when analyzing historical trends and may skew averages used in OLWR calculations. Spatial representation of gauges is also an issue, as the main gauges are located at the periphery of the Watershed and there is a lack of consistent representation of the central portion. The use of one-month and 18-month calculation intervals may be too short or long, and therefore also may not be good indicators of drought conditions.

- ***Recommendation**:*
  - Approach Environment Canada (EC) to request more consistent data readings at the Russell climate station, or consider the addition of a gauge in the central portion of the watershed, which could be used to supplement the historical Russell climate station data.
  - The Montebello, Quebec weather station has consistent data available from the 1950s. Test the applicability of this station to declare low water in the SNC Watershed.
  - Volunteer rain gauge information may be a valuable verification tool for determining the spatial accuracy of interpolated precipitation data. Effectiveness of interpolating precipitation data across the jurisdiction requires further examination.
  - Use SNC's raingauge data to interpret an event rainfall distribution.

**Streamflow data and calculation:** Temporal data gaps present a problem when analyzing historical trends and may skew averages used in OLWR calculations. Location of control structures at existing gauges also makes analysis from a streamflow perspective unreliable. The use of Lowest Average Summer Monthly Flow (LASMF) may also not adequately represent drought in non-summer months.

- ***Recommendation:***
  - *Repair datalogger downstream of Chesterville Dam.*

- *Review the possibility of assessing water levels downstream of Casselman Dam, contingent on permission of Hydro station owner.*
- *Install staff gauges at all dams, which would provide water level measurements during drought.*
- *The Provincial streamgauge network is being reviewed by MNR and EC, this year. SNC should conduct a review of its watershed streamgauge network, including deactivated gauges, and identify a minimum of two potential locations for new stations. This information can be relayed to MNR and EC.*
- *MNR is reviewing the OLWR guidelines. SNC should ensure they consider an approach to declare low water during winter and spring months.*

**Lack of groundwater and baseflow components:** Although the province is developing groundwater indicators, it was observed that groundwater and surface water baseflow data are not substantially available for Low Water declarations at this time, yet are critical indicators for ecological processes and human water usage.

- ***Recommendation:***
  - *Develop a baseflow monitoring program.*
  - *Test the OLWR groundwater indicator for the SNC jurisdiction.*

**Declaring Low Water at on a Watershed basis:** There is a range of climate across the Watershed; however, SNC's Low Water declaration is applied across the entire jurisdiction, regardless of the spatial variability between regions. This can result in unnecessary water use restrictions in some areas.

- ***Recommendation:*** *Division of watershed into climate regions with the intention of localizing Low Water declarations.*

**Climate Change Effects:**

- ***Recommendation:*** *Proposed to MNR to incorporate climate change in the OLWR program review.*

**Outreach, education and information transfer:** Education on the implications of low water conditions and availability of information in an easily understandable way would promote better water conservation by the general public during a drought event.

- ***Recommendation:*** *More public outreach and volunteer opportunities related to OLWR.*

**Ecological and socioeconomic implications:** The ecological and socioeconomic impacts of drought can be severe and irreversible. With the effects of climate change projected to increase the frequency of low water occurrence, an in-depth analysis of low water impacts is required to ensure preparedness.

- ***Recommendation:*** *Conduct a detailed analysis of ecological and socioeconomic impacts of drought to assess community needs and provide potential adaptation strategies.*

The enhancements listed above would improve the current implementation of the OLWR program within SNC's jurisdiction and provide more appropriate analyses with consideration to long-term climate change. Improvements to the program should be assessed after implementation and subsequent changes should be assessed regularly. Enhancements to the program could be transferable to other jurisdictions and may be a good resource in future strategic planning and policy development.

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# 1 Introduction

Throughout the South Nation Conservation (SNC) jurisdiction, there are several natural processes that are of concern from an ecological, social and economic perspective. One major concern is drought, due to decreased precipitation and increased temperature. The effects of drought conditions have implications for natural heritage and many resource based sectors including public health, government, industry, commercial, recreation and agriculture.

As land use in the SNC jurisdiction is 60% agricultural, the implications of a drought could have widespread negative impacts. A drought could cause water supply shortages to crops and livestock, which could result in economic and food security concerns. Monitoring low water is paramount as part of strategic planning and an early warning system. Climate change is another natural process that requires consideration and inclusion into the assessment of long-term drought impacts and adaptations. Eastern Ontario expects to experience an increase in temperature and more frequent, extreme weather events such as severe storms, wind, hail, flooding, and drought.

The Ontario Ministry of Natural Resources (MNR) introduced the Ontario Low Water Response program (OLWR) in 2001 to provide advance warning of reduced water availability; ensure provincial preparedness; assists in co-ordination of provincial and local efforts; and support local response in drought events.

**Drought definition:**
Drought is a complex term that has various definitions depending on individual perspectives. In the OLWR guidelines, drought is weather and low water conditions characterized by one or more of the following:

a) Below normal precipitation for an extended period of time (three months or more), potentially combined with high rates of evaporation, lower lake levels, streamflows and/or baseflows, and reduced soil moisture and/or groundwater storage;
b) Streamflows are at the minimum level required to sustain aquatic life, while meeting only high priority demands for water; significant decrease in water level in local wells to the point where wells become dry; and surface water in storage allocated to maintain minimum streamflows; and
c) Socioeconomic effects occurring on individual properties and extending to larger areas of a watershed or beyond.

A Level I condition is the first indication of a potential water supply problem; Level II indicates a potentially serious problem; and Level III indicates the failure of the water supply to meet the demand, which results in progressively more severe and widespread socioeconomic effects [OLWR Low Water Levels are defined in Section 2].

As defined by the OLWR program, remedial actions in response to each Low Water declaration. The response is delegated to, and managed by, a local Water Response Team or the Province. The agency initially aware of the low water condition is responsible for alerting other agencies involved. SNC delivers the program across the jurisdiction. The SNC Water Response Team includes representatives from the Province, municipalities, and local interest groups including agriculture, recreation, and industry sectors. Together, the Low Water Response Team provides a coordinated response in the event of a drought (OMNR, 2010).

In 2012, Eastern Ontario experienced an extended period of low rainfall and high temperatures. As a result, the South Nation River Watershed experienced one of the lowest surface water levels recorded in the last 50 years. Studies on changing weather patterns indicate that low water levels may become more common, which is compounded by increasing demands for water due to development and climate change.

This report addresses the applicability of the OLWR program for determining drought severity in the South Nation Watershed; identifies issues with current drought analysis methodology and resources; and provides recommendations to enhance the program.

# 2 Background

## 2.1 Ontario Low Water Response indicators

The Ontario Low Water Response indicators integrate a number of factors based on readily available data that are useful over a range of time. The indicators allow a consistent approach to determine changes in water supply. The Program uses both precipitation and streamflow measurements as primary indicators for defining low water levels and drought, subject to field verification (OMNR, 2010).

### 2.1.1 Precipitation

The OLWR guidelines prescribe a comparison of monthly precipitation data as a percentage of the average precipitation at each monitoring station. These calculations are made using averages from:

(i) Previous 18 months (long-term);
(ii) Previous three months (seasonal); and
(iii) Under a Level I condition or higher: previous one month (short-term), with weekly updates.

| **Precipitation** |
|---|
| 1) % of average = monthly precipitation/ average precipitation for that month x100<br>2) Weeks with less than 7.6 mm of rain<br>(number of consecutive readings) |

**Table 1: OLWR indicator calculation for precipitation**

#### 2.1.2 Streamflow

Stream gauges measure water levels; a measurement that is needed to ensure minimum stream levels are maintained to meet the basic needs of the ecosystem and is available for other water users.

The OLWR guidelines prescribe a comparison of monthly flow at each streamgauge to the lowest average summer month flow for that station.

| **Surface Flow** |
| --- |
| % of average flow =monthly Flow x100/ Lowest Average Summer Monthly Flow |

**Table 2: OLWR indicator calculation for streamflow**

#### 2.1.3 Precipitation and streamflow thresholds

Local precipitation and streamflow data are used to define thresholds used to declare Low Water conditions. Thresholds are based on a comparison to the average data for a given monitoring station.

The tables below show how indicator thresholds are calculated, as set out in the OLWR guidelines, and the corresponding restrictions:

| OLWR Condition | Threshold Levels of OLWR Indicators | |
|---|---|---|
| | **Precipitation** | **Streamflow** |
| Level I | 18 month precipitation < 80% of long-term average precipitation<br>**or**<br>3 month precipitation < 80% of long-term average precipitation | **Spring***** – monthly flow < 100% lowest average summer*** month flow<br><br>**Other times** – monthly flow <70% of lowest average summer month flow |
| Level II* | 18 month precipitation < 60% of long-term average precipitation<br>**or**<br>3 month precipitation < 60% of long-term average precipitation<br>**or**<br>1 month precipitation < 60% of long-term average precipitation<br>**or**<br>Weeks with less than 7.6 mm of rain. More than 1 week in high demand areas or more than 2 weeks for moderate demand areas.<br><br>**and**<br>The watershed is already in an existing Level I condition | **Spring** – monthly flow < 70% of lowest average summer month flow<br><br>**Other times** – monthly flow <50% of lowest average summer month flow |
| Level III** | 18 month precipitation < 40% of long-term average precipitation<br>**or**<br>3 month precipitation < 40% of long-term average precipitation<br>**or**<br>1 month precipitation < 40% of long-term average precipitation | **Spring** – monthly flow < 50% of lowest average summer month flow<br><br>**Other times** – monthly flow <30% of lowest average summer month flow |

* A watershed can only enter Level II from an existing confirmed Level I or Level III condition.
** A watershed can only enter Level III from an existing confirmed Level II condition.
*** Spring and summer are defined as April-May-June and July-August-September, respectively.

**Table 3: Summary of OLWR Thresholds**

### 2.1.4 Restrictions

Depending on the Low Water condition declared, voluntary reduction of water use or mandatory restrictions are put in place, as outlined in the table below.

| Condition | Response |
|---|---|
| Level I<br>*Voluntary Conservation* | The potential for water supply problems is identified.<br>*Target: 10% use reduction* |
| Level II | Monitor water supply issues are encountered |

| | |
|---|---|
| *Conservation and Restrictions on Non-Essential Use* | *Target: An additional 10% reduction, by-laws enacted.* |
| Level III<br>*Conservation, Restriction, Regulation* | Supply no longer meets demand. Social and economic impacts are experienced.<br>*Target: Reduce/manage water demands to the maximum extent (ex. amend PTTW, or by-laws)* |

**Table 4: Low water conditions and their targeted response**

## 2.2 South Nation Conservation Low Water Program

The South Nation Jurisdiction comprises an area of 4,200 $km^2$ with a total of change in elevation of 80 m over a 180 km Watershed length. Analyses for the OLWR program are based on data from a local monitoring network consisting of three weather stations, three precipitation gauges, and 10 stream gauges strategically located across the Watershed. For the purposes of OLWR, only the three weather stations and six stream gauges are used. Map 1 in Appendix 6 shows the locations of weather stations and streamgauges across the jurisdiction.

**Data Sources:**

In order to review the OLWR, streamflow and precipitation data was obtained from Environment Canada. Below is a list of gauges in or around the Watershed that have been selected based on their usefulness to the OLWR. Only active gauges or those with OLWR potential for declaring Low Water have been included.

These gauges are relevant because they possess datasets with a minimum of 30 years of historical data; are within the Watershed or in close proximity and are currently active; or have been active within the last 20 years and have potential. A full list of active and inactive stations within and around the Watershed can be found in *Appendix 4: Weather stations* and *Appendix 5: Streamgauges.*

| Gauge Name | Gauge ID | Ownership | Location | Duration of Data* | Use in OLWR |
|---|---|---|---|---|---|
| **Precipitation** | | | | | |
| Ottawa CDA | | Environment Canada | 45°23'00.000" N/ 75°43'00.000" W | 1889 – Present | Active, in use for OLWR |
| Brockville ** | | Environment Canada | 44°36'00.000" N/ 75°42'00.000" W; 44°36'00.000" N/ 75°40'00.000" W | 1965 –1980, 1971–Present | Active, in use for OLWR |
| Cornwall | | Environment Canada | 45°00'56.082" N/ 74°44'56.040" W | 1950–Present | Active, in use for OLWR |
| Russell | | Environment Canada | 45°15'46.008" N/ 75°21'34.032" W | 1954–Present | Active, not in use for OLWR |
| Montebello | | Environment Canada | 45°42'00.000" N/ 74°56'00.000" W | 1956–Present | Active, not in use for OLWR |
| Kemptville | | Environment Canada | 45°00'00.000" N/ 75°38'00.000" W | 1928–1997 | Inactive |
| **Stream** | | | | | |
| Plantagenet | 02LB005 | OMNR/DOE | 45°31'1.0¨ N/ 74°58'41.6¨ W | 1915–Present | Active, in use for OLWR |
| Bourget | 02LB008 | OMNR/DOE | 45°25'33.6¨ N/ 75°9'11.6¨ W | 1949–Present | Active, in use for OLWR |
| Casselman | 02LB013 | OMNR/DOE | 45°19'1.1¨ N/ 75°5'30.0¨ W | 1972–Present | Active, not in use for OLWR |
| Chesterville | 02LB009 | OMNR/DOE | 45°6'3.9¨ N/ 75°13'33.9¨ W | 1949–Present | Active, not in use for OLWR |
| Russell | 02LB006 | OMNR/DOE | 45°15'45.0¨ N/ 75°20'37.7¨ W | 1948–Present | Active, in use, for OLWR |
| Spencerville | 02LB007 | OMNR/DOE | 44°50'32.1¨ N/ 75°32'39.9¨ W | 1948–Present | Active, in use, for OLWR |

*Note: This duration includes years with incomplete or missing data.

** Data used for the Brockville weather station is an amalgamation of two locations within close proximity. This was done in order to increase the length of the data set.

# 3 Applicability of Low Water Response

## 3.0 Review of the 2012 drought

In 2012, the South Nation River Watershed was under a Level II Low Water declaration. During this period, various concerns were raised around the applicability of the program. A review of the effectiveness of the program during a drought was completed and several areas of improvement have been identified:

1. **Precipitation indicator:**

    - Temporal data gaps are an issue when analysing historical trends and may skew averages used in OLWR calculations.
    - Spatial Representation: the main weather stations that meet data requirements for OLWR are located at the periphery of the Watershed, with no consistent representation of the central portion.
    - The use of one-month and 18-month calculation intervals could be too variable to represent low water conditions.

2. **Streamflow indicator:**

    - Temporal data gaps are an issue when analysing historical trends and may skew averages used in OLWR calculations.
    - Stream levels are affected by water control structures, thus, flow analysis at streamgauges located upstream of water control structures are unreliable. Use of Lowest Average Summer Monthly Flow (LASMF) may not adequately represent low water conditions in non-summer months.

3. **Lack of groundwater and baseflow components:** Groundwater and surface water baseflow data are not substantially available for Low Water declarations at this time, yet are critical indicators for ecological processes and human water usage. These parameters should be considered for future monitoring and analysis. The Province is currently developing groundwater low water indicators.

4. **Declaring Low Water at a watershed scale:** SNC's low water declaration is applied across the entire jurisdiction regardless of variability between regions, which may result in unnecessary water use restrictions in some areas.

5. **Climate Change Effects:** Consideration should be given to the long term effects of climate change, i.e. long term increases and decreases in precipitation would affect the low water triggers.

6. **Statistical Distribution:** Rainfall and streamflow event frequencies do not typically follow normal distribution patterns, calling into question the applicability of using the average as the comparison value in the OLWR.

7. **Outreach, education and information transfer:** Education about low water conditions and availability plain-language information will promote better water conservation by the public during a low water event.

8. **Ecological and socioeconomic implications:** The ecological and socioeconomic impacts of drought can be severe and irreversible. With the effects of climate change projected to increase the frequency of low water occurrence, an in-depth analysis of low water impacts is required to ensure preparedness.

### 3.1 Precipitation

The following section presents issues related to triggering low water levels based on precipitation indicators.

#### 3.1.1 Temporal Data Consistency

Historically, five weather stations were located in the South Nation River Watershed and have been used for the OLWR program. Data from these gauges (Ottawa CDA, Brockville, Cornwall, Kemptville, and Russell) are stored and managed by Environment Canada. Data used for OLWR analyses are obtained directly from the Environment Canada website.

Currently, only three of the five weather stations are fully operational (Ottawa CDA, Brockville, and Cornwall). The Kemptville weather station has not been recording precipitation data since 1997. In contrast, the Russell weather station has an active precipitation gauge, but does not consistently take daily readings, making any data after 2006 unusable.

**Weather Stations as of December 2013**

| Weather Station | Status | Years of Available Data |
|---|---|---|
| Ottawa CDA | Active | 1889–Present (125 years) |
| Brockville | Active | 1915–Present (99 years)* |
| Cornwall | Active | 1950–Present (64 years) |
| Russell | Active | 1954–Present (60 years)** |
| Kemptville | Inactive | 1928–1997 (69 years) |

***Data used for the Brockville station comes from two sources in close proximity. Data collected at "Brockville" - 44°36'00.000" N/75°42'00.000" for years 1965 to 1980, and at "Brockville PCC" - W 44°36'00.000" N/75°40'00.000" W from 1871 to 2014. Only years with usable data were considered.**
**** Data from 2006 onwards is unusable for the Russell station due to inconsistent recording.**

Long-term precipitation data is necessary to obtain a representative average. Short or incomplete data sets may skew the average depending on the timing of weather occurrences in relation to the missing intervals. For example, the Cornwall weather station was out of commission for several years during the 1960s. However, it is known from historical records at other local weather stations' readings that a significant drought occurred in the 1960s, which is unaccounted for in the long-term average calculated for the Cornwall weather station. Data gaps are observed at all other weather stations except for Ottawa CDA, which has the most consistently recorded data. The inconsistent precipitation record at the other four gauges makes data analysis problematic and long-term averages unreliable.

***Recommendations:***

To better represent spatial precipitation trends across the SNC jurisdiction, all weather stations should be consistently active. The Russell station is located in the central region of the watershed. As such, consistent data from this station will be a good resource for the OLWR program.

### 3.1.2 Spatial Precipitation Data Distribution

Another issue concerning the reliable representation of precipitation data across the SNC jurisdiction is the spatial distribution of weather stations. Three weather stations currently provide precipitation data for the OLWR program; all are located outside the SNC jurisdiction. See Map 1. Assumptions are made with regards to the applicability and limitations of this data across the Watershed; with a weighted interpolation applied to the data from these stations, which is less reliable further away from each station. *Appendix 2* shows the annual precipitation at the four stations. The data shows that the precipitation varies between the stations. An example would be a comparison of the precipitation received in Brockville and the readings of the raingauge in Spencerville.

Precipitation is variable at a small scale, which indicates that interpolations across large distances may not be a valid approach to analyze the precipitation indicator—particularly at the centre of the Watershed as well as the top NE section, where there are no active weather stations within 35 km. Furthermore, the portion of the watershed adjacent to the St. Lawrence River seems to be part of a different eco-zone (weather regime) and experiences effects from the River.

***Recommendation***

In order to provide a better spatial representation of precipitation across the SNC jurisdiction, there is a need to acquire consistent precipitation data in different areas of the Watershed, with a minimum of one station in each eco-climate zone.

The central portion of the Watershed is poorly represented in terms of proximity to reliable weather stations used for OLWR. The Russell weather station is relatively central within the Watershed and would be a good resource if consistent data, as available.

The Montebello, Quebec weather station has consistent data available from the 1950s to present. This station has potential to be applied to the SNC Watershed; an assessment of data is needed to confirm its applicability.

There are precipitation gauges at Casselman, Chesterville, and South Mountain. However, due to their short data sets, it is presently not feasible to make Low Water declarations using these gauges.

An additional precipitation gauge in the NE portion of the Watershed and the St. Lawrence region would also be highly beneficial for future analysis.

Another option to expand the rain gauge network is implementing a volunteer program, through which volunteers are given their own rain gauges and instructions on data collection. Data obtained from the volunteer network could be used to verify the spatial applicability of the Environment Canada raingauge data across the Watershed.

In general, there is a need to enhance the precipitation gauge network across the SNC jurisdiction.

## 3.2 Streamflow

### 3.2.1 Calculation Methodology

The OLWR program assesses drought by comparing current streamflows to the Lowest Average Summer Monthly Flow (LASMF). This methodology is based on the assumption that summer flows represent the lowest annual flows and are subsequently an appropriate threshold to determine drought conditions.

Thresholds for low water level triggers based on streamflow are summarized in Table 6 below.

| Level I | Level II* | Level III** |
|---|---|---|
| **Spring: –** monthly flow < 100% lowest average summer month flow<br>**Other times: –** monthly flow < 70% of lowest average summer month flow | **Spring:–** monthly flow < 70% of lowest average summer month flow<br>**Other times: –** monthly flow < 50% of lowest average summer month flow | **Spring:–** monthly flow < 50% of lowest average summer month flow<br>**Other times: –** monthly flow < 30% of lowest average summer month flow |

* A watershed can enter a Level II only from an existing confirmed Level I or Level III condition

** A watershed can enter a Level III only from an existing confirmed Level II condition

**Table 5: Streamflow Thresholds according to the OLWR**

The SNC Watershed experiences a yearly spring runoff during which snowmelt runoff replenishes streamflow, groundwater, and other water reserves. An example of typical flow in the South Nation River is illustrated in Figure 1 using historical flow data at the Plantagenet stream gauge.

There are more than 1,000 municipal drains across the Watershed and most of the agricultural land includes tile drains to ensure the quick drainage of the shallow soils for farming purposes. As a result, rain water typically moves quickly to streams from the land surface (via overland flow). Depending on the intensity and duration of precipitation events and watershed conditions (i.e. land slope, vegetative cover, and soil type) this occurrence can result in decreased groundwater recharge, which would reduce the future potential for baseflow to streams. This situation could result in low water during drier summer or fall months, even with sufficient precipitation.

The OLWR program does not account for a drought in spring or winter. This fact was brought up to MNR at the 2012 Training Session and MNR is in the process of reviewing the guidelines.

***Recommendation:***

MNR is currently reviewing the OLWR guidelines. The above mentioned concerns should be brought up to MNR for consideration.

### 3.2.2 Streamgauges adjacent to water control structures

Some streamgauges are located just upstream of water control structures (i.e. dams and weirs). Thus, the readings taken at those locations represent the controlled water levels, and not natural water levels in response to the local climate.

The Chesterville gauge is currently active and located at the Chesterville Dam. The gauge measures water levels from the pond directly upstream of the structure. Since the water level at the dam is regulated, the flow data collected from this location is useful for dam operations (i.e. flood control or water retention), but not for determining natural trends in streamflow. For this reason, the Chesterville gauge cannot reliably be used as part of the OLWR program.

The Casselman gauge is similarly located next to a weir. Like the Chesterville Dam, the associated water control structure makes it unreliable to declare Low Water conditions based on flows recorded at the gauge.

***Recommendation:***

Review SNC's streamgauge network and identify the need to replace gauges/dataloggers downstream of dams and weirs.

There is a datalogger (Chesterville B) located directly downstream of the Chesterville Dam. The gauge is currently inactive due to a lightning strike. This gauge should be repaired and data should be used for the Low Water Response program.

Simple staff gauges could be installed downstream of every water control structure where a direct reading could be made by staff.

There is no gauge downstream of Casselman Weir. Considering the proximity of the water intake for the municipal residential water supply for the Village of Casselman; a new gauge could be installed downstream of the control structure.

MNR is currently reviewing the need for new stream gauge equipment in Ontario. SNC should submit a proposal based on the review herein. In addition, EC is updating equipment and providing the old equipment to interested CAs. SNC could apply for some additional equipment from EC.

### 3.2.3 Streamgauge Distribution

The South Dundas area along the St. Lawrence River became part of the jurisdiction five years ago. This section of the jurisdiction drains directly into the St. Lawrence River and is not associated with any drainage to the main portion of the Watershed. Subsequently, no historical data is available to assess stream levels. See *2* for a map with all active and historical streamgauge locations. As the St. Lawrence River is a regulated system, there might be gauges located close to this area that could be used for the OLWR program.

***Recommendation:***

Since the St. Lawrence River is highly regulated, there may be streamgauges near Morrisburg, Iroquois, or Prescott. Contact Ontario Power Generation to request access to the St. Lawrence River water levels. This area is considered independent of the South Nation River (SNR) gauge data with regard to the application of the data for the OLWR program.

### 3.2.4 Streamgauge Coverage

Several streamgauges historically located throughout the Watershed have been temporarily or permanently disabled. See *Appendix 5: Streamgauges* for a list summarizing historical gauge data available within the SNC jurisdiction.

***Recommendation:***

Evaluate the spatial coverage of watershed streamgauge network including deactivated gauges, for the purpose of determining the feasibility of reactivating those most appropriate for the OLWR. Gauges will be evaluated based on the following criteria:

- Location within the watershed
- Previous owners and operators of the gauge
- Condition and availability of the gauge
- Length and quality of dataset
- Time elapsed since deactivation
- Cost and effort associated with reactivation

A proposition could be put forth to MNR to reactivate gauges determined to be feasible for reactivation.

Ensure SNR has appropriate spatial coverage of streamgauges, representative of major reaches in the various eco-climate zones and significant subwatersheds.

### 3.3 Groundwater and Baseflow

Groundwater is situated either within soil pores or between the fractures of rocks. The depth at which these pore spaces or fractures become completely saturated is referred to as the water table. Groundwater plays an essential role in the water cycle. Streamflow is composed of two components: surface runoff and baseflow. Surface runoff is an accumulation of overland flow of precipitation into a surface water system from the surrounding land, while the baseflow component represents the contribution of groundwater input into the stream. Baseflow measurements can be taken when there is no runoff contributions present in stream, such as after an extended period with no precipitation (i.e. the streamflow is being maintained by groundwater discharge to the stream).

Groundwater levels influence both aquatic and terrestrial ecosystem function as well as socioeconomic elements. Groundwater can be withdrawn for agricultural, commercial, or industrial purposes, or for private residential wells. Many urban areas rely on groundwater as a primary drinking water source. Depleted groundwater resources can result in decreased baseflow to streams and wetlands which could compromise its ecological function.

Groundwater levels can decrease naturally in response to decreased infiltration and groundwater recharge. Overuse can also cause groundwater levels to decrease, which could ultimately result in wells drying out.

Although precipitation and streamflow monitoring are essential to determining low water conditions, groundwater levels and baseflow monitoring are also important factors that could be used as indicators of low water conditions. The OLWR program does not currently account for groundwater or baseflow as a measurement of drought stress, despite their obvious significance to anthropologic and ecological functions. Inclusion of these components could enhance Low Water declarations.

***Recommendation:***

**Baseflow:**

Baseflow is indicative of groundwater conditions, thus, baseflow measurements would be a feasible indicator of groundwater drought. Following the protocol set out by other Conservation Authorities such as the Toronto Regional Conservation Authority, SNC endeavours to develop a baseflow monitoring program. The program would involve obtaining baseflow measurements after several days of no precipitation at pre-determined sites. A more complete description of TRCA's baseflow methodology can be found in *Appendix 6: Baseflow calculations (Toronto Region Conservation Authority)* (TRCA, 2009). Since TRCA's baseflow monitoring program is not currently associated with the OLWR, threshold values will need to be evaluated and developed for use with SNC's Low Water Response program. It is recommended that a baseflow monitoring program be developed in the future for Low Water Response monitoring, and guidelines be developed for interpreting baseflow data.

**Groundwater:**

The Province is currently developing the groundwater low water indicator. A percentile method is currently undergoing review by MNR. The integration of a groundwater indicator to the program will augment SNC's LWR program and increase the overall understanding of drought conditions across the Watershed and between various components of the water budget. A map of available groundwater monitoring sites that could be assessed for this program is located in *Appendix 7: Maps*.

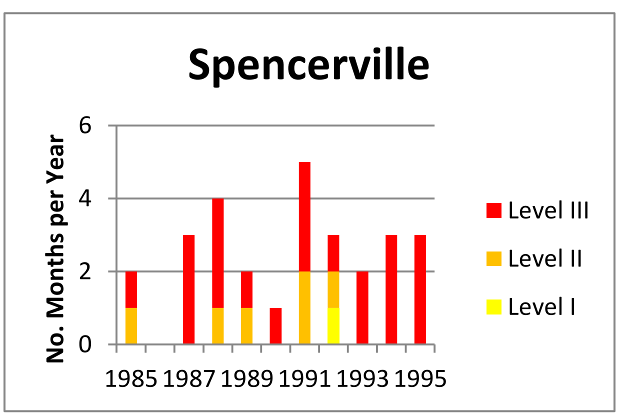
### 3.4 Declaring Low Water on a large scale

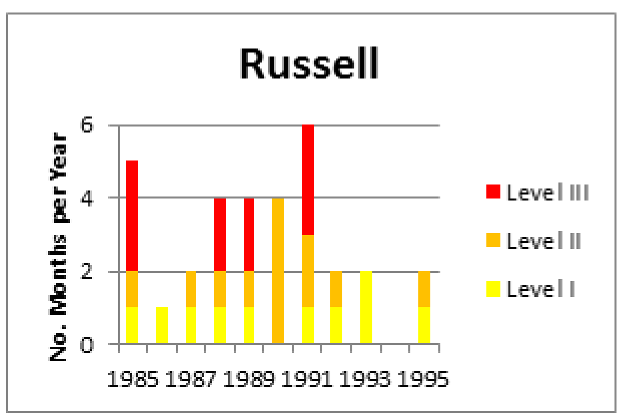
One of the issues in applying the OLWR program is the scale at which Low Water declarations are applied. Using the OLWR guidelines, SNC declares Low Water across the entire Watershed under the following circumstances:

- Any one of the six stream gauges across the jurisdiction is in a low water condition
- Any one of the three precipitation gauges across the jurisdiction is in low water status using three- and 18-month guidelines

While these declarations are applicable to the area proximal to the stream gauge or weather station in question, it is not necessarily applicable to the remainder of the jurisdiction. As mentioned in *Section 3.3:* ***Error! Reference source not found.***, precipitation, temperature, and land use are not evenly distributed across the jurisdiction. This variability frequently results in low water restrictions being placed in areas that are not experiencing drought and are not justified.

Figure 5 below demonstrates the differences in the streamflow indicator between streamgauges over a time period (1985–1995). The Spencerville stream gauge is located in Watershed headwaters, while Russell, Bourget, and Plantagenet gauges are located progressively downstream in the Watershed. Figure 5 shows that some gauges are frequently in low water; while other gauges are not experiencing the same conditions. Although not shown in the following figure, the majority of the Low Water declarations consistently occurred between the months of June and October.



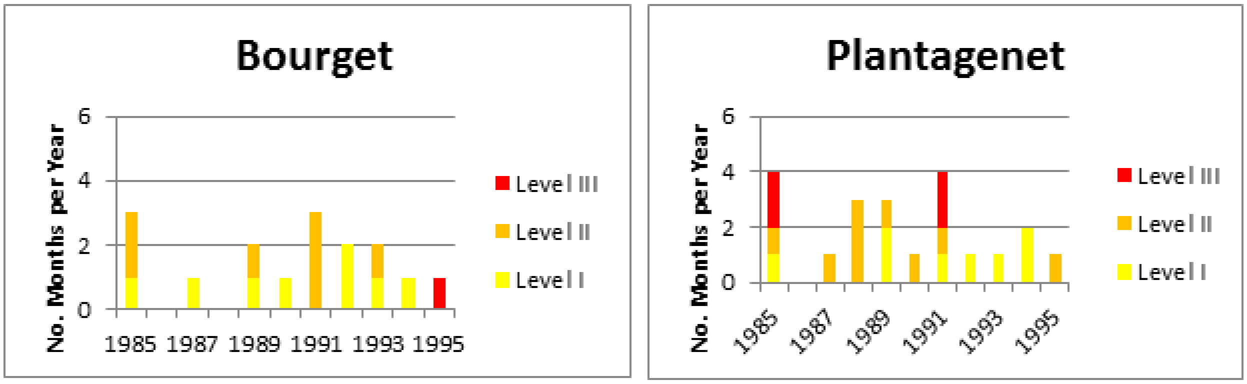



**Figure 1: The above figures depict a time period from 1985 to 1995, where all stations had a 10-year period of consistently available data. As demonstrated, Low Water declaration can be variable across the Watershed.**

In order to manage this issue, Low Water declarations are often applied selectively and based on specific watershed conditions. Procedures for a more targeted approach to address local Low Water declarations would be beneficial.

***Recommendation:***

Make localized Low Water declarations based on local information at proximal gauges. Low Water declarations would apply to the portion of the watershed directly upstream of each gauge, as this would be more reflective of conditions in that portion of the watershed. This targeted approach would resolve the issue of drought variability across the jurisdiction and allow Low Water declarations to be more appropriately assigned. See Map 6 in *Appendix 7: Maps* for a depiction of the proposed divisions based on the stream gauges, including Casselman and Chesterville.

It should be noted that the portion of the jurisdiction adjacent to the St. Lawrence River has been assigned its own low water assessment area. This area consists of several small watersheds that flow directly into the St. Lawrence River and cannot be accounted for by any of the gauges currently operating within the South Nation River Watershed (which drains to the Ottawa River).

For a consistent division of the Watershed, all active gauges were considered, however, gauges located near a water control structures require further investigation. Without useable data across large stretches of the Watershed, dividing the Watershed up appropriately would be difficult. By eliminating the Chesterville and Casselman gauges from the proposed declaration area framework, large expanses of the Watershed will be reliant on a single gauge. See Map 5 of *Appendix 7: Maps* for a demonstration of the Watershed division excluding the Casselman and Chesterville gauges. As recommended, gauges could be installed downstream of control structures to allow for better division of the Watershed.

To determine which weather station to use for each stream gauge area, proximity of the stream gauge area is taken into account. Map 8 in *Appendix 7: Maps* shows the proximity of each of the weather stations to the stream gauge areas (depicted in 5 km intervals). Brockville, Ottawa, and Cornwall gauges are currently being used to represent the entire jurisdiction. A nearby weather station located in Montebello, Quebec may also be a feasible option for future Low Water declarations, as it contains a substantial amount of historical data and would account for the more northern portion of the watershed, and may be more applicable than Ottawa or Cornwall. For this reason, it was also included on the map, but requires and assessment to determine its applicability.

Based on proximity and data availability, the following precipitation gauges have been assigned to each Low Water Response declaration area. Only active precipitation gauges were considered. Those with two assigned precipitation gauges will base declarations on whichever is in a lower water status at a given time.

| **Streamgauge Declaration Area** | **Weather Station** |
|---|---|
| Plantagenet | Montebello |
| Bourget | Ottawa CDA |
| Casselman | Cornwall |
| Russell | Ottawa CDA |
| Chesterville | Cornwall |
| Spencerville | Brockville & Cornwall |
| St. Lawrence | Brockville & Cornwall |

Other factors will likely need to be considered before producing any conclusive strategies on assigning weather stations. For example, land use, soil indexes, temperature, evapotranspiration, topography, etc. could all have an impact on the range to which each precipitation gauge is applicable.

### 3.5 Climate Change Effects

According to IPCC climate change projections, overall precipitation, temperature, and more extreme weather events such as storms, drought, flooding, and hail are expected to increase over time for Ontario. This is a phenomenon that is already being reflected in local precipitation and streamflow data. As an example shown in the figure below, annual precipitation appears to be increasing over time for the Ottawa CDA weather station. Data from other gauges show similar patterns as well, indicating that this is a consistent occurrence across the Watershed and supports modelled projections.

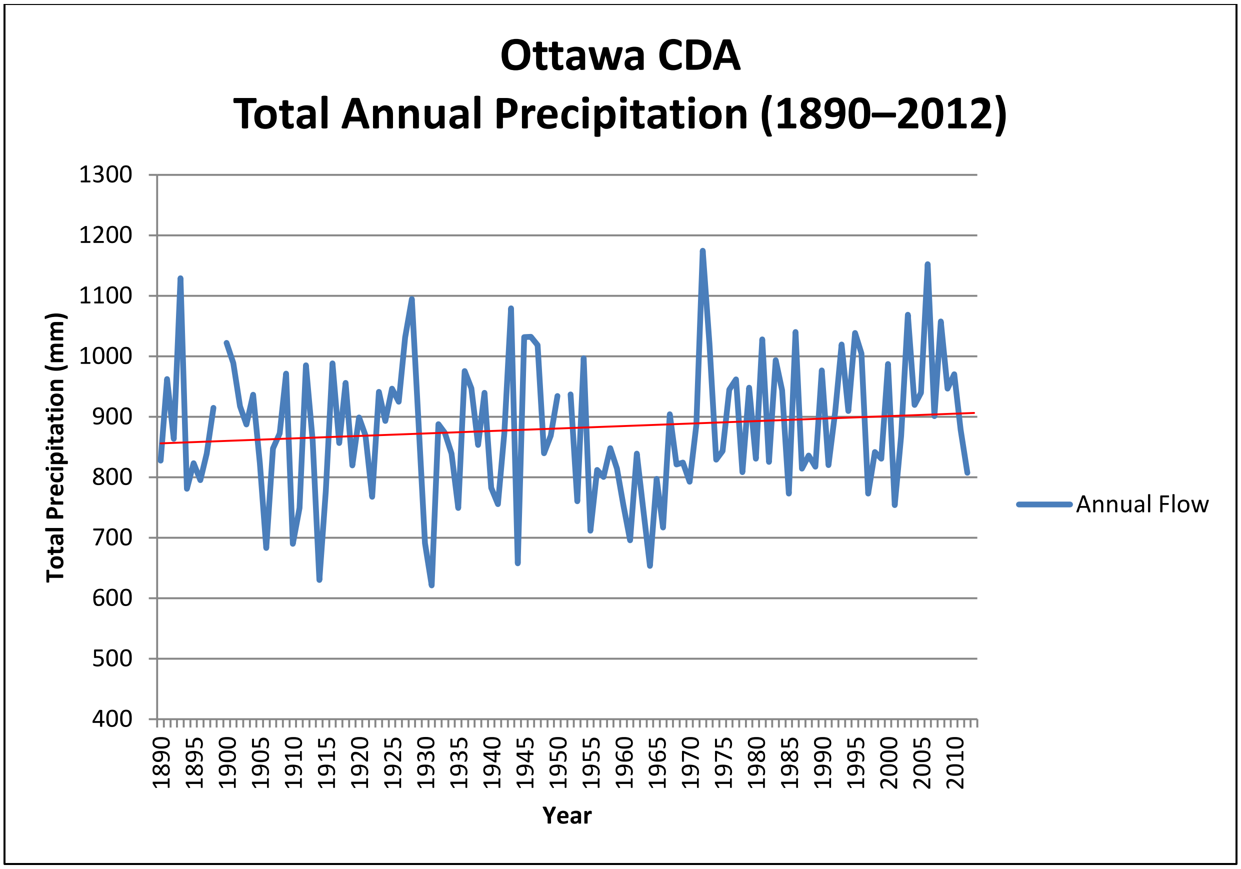



**Figure 2: Total historical precipitation for the Ottawa CDA weather station shows a gradual increase over time.**

Since streamflow is a function of precipitation, it is expected that streamflow will increase as well. This is also true of the Lowest Average Summer Monthly Flow, as is shown in Figure 9 representing Plantagenet.Annual precipitation and streamflow for all OLWR data can be found in *Appendix 2: Annual Precipitation and Streamflow*.

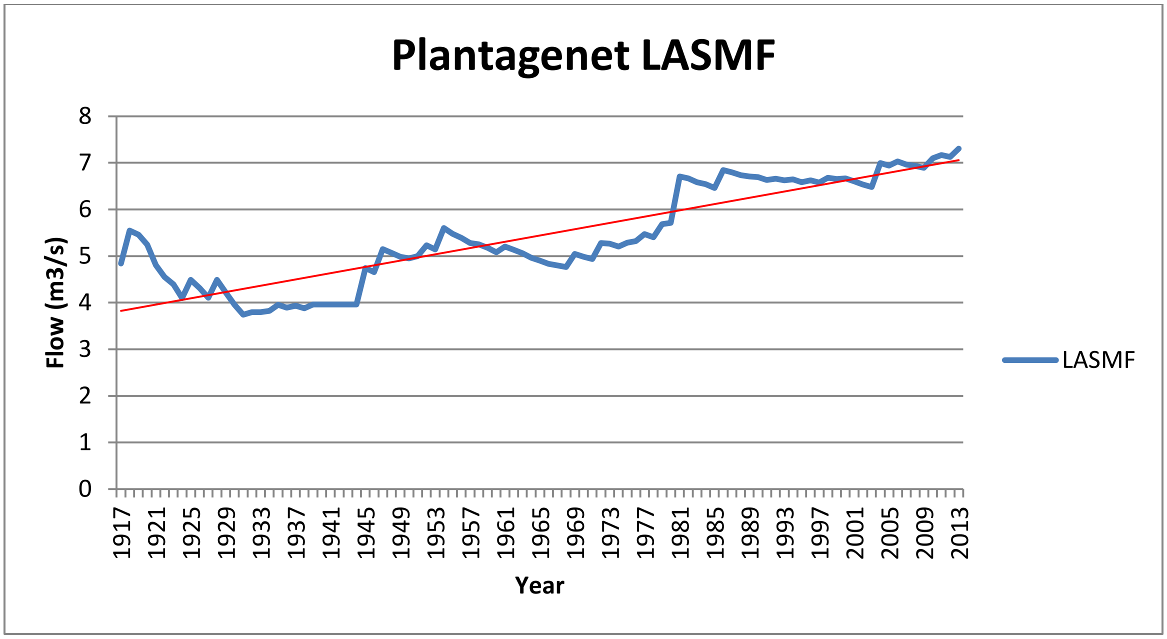



**Figure 3: Like precipitation, LASMF has also shown an increase over time**

The Ottawa CDA precipitation gauge and Plantagenet stream gauge have the longest and most complete sets of historical data, and are therefore most representative of climate change effects. By looking at Ottawa CDA's historical precipitation, a distinct change in moisture regime appears to begin between approximately 1975 and 1980, at which point it can be reasonably speculated that this is where climate change begins to manifest itself with respect to precipitation.

It is important to note that an overall increase in precipitation and streamflow over time does not indicate that drought occurrences are becoming less frequent. Since these calculations are based on monthly totals and averages, they do not reflect increased frequency of anomalies such as drought or flood events. In actuality, although the total amount of precipitation and streamflow are increasing overall (which can be attributed to the expected increase in more intense rainfall events), individual drought events are becoming more frequent and severe. See *The Water Stress Analysis Vulnerability* report for a complete analysis of drought trends within the SNC jurisdiction.

This observation brings into question the effects of climate change on what we consider "normal." Due to climate change, the average used to analyse low water for both streamflow and precipitation are being shifted in such a way that using it as a comparison value against current trends may skew the perception of the severity of weather events including drought analysis. The result of this will be an increase in the average, which if compared to current precipitation will cause drought to appear more severe than it actually is.

To reiterate from a mathematical perspective, precipitation and streamflow indicator values are calculated using the following formula according to the OLWR guidelines:

| **Precipitation** | **Surface Flow** |
|---|---|
| % of average =<br>monthly precipitation/<br>average precipitation for that month x100 | % of average flow =<br>Monthly Flow x100/<br>Lowest Average Summer Month Flow |

**Table 6: OLWR calculation methodology to determine % of average**

Since the average is in the denominator of these equations, the resulting "percent of average" value will decrease every year as the average increases. When compared to the Level I, II, and III thresholds, the expected outcome is an overestimation of drought severity when using climate change affected data.

***Recommendations:***

Since the current methodology for calculating the average is to include historical values from the year in question and all the years previous, one proposed solution to the climate change effect is assigning a cut-off year at which time using data values after this date no longer apply to the average. This cut-off date would be based on when climate change effects on precipitation and streamflow data are apparent. This should be proposed to MNR for consideration in the OLWR program.

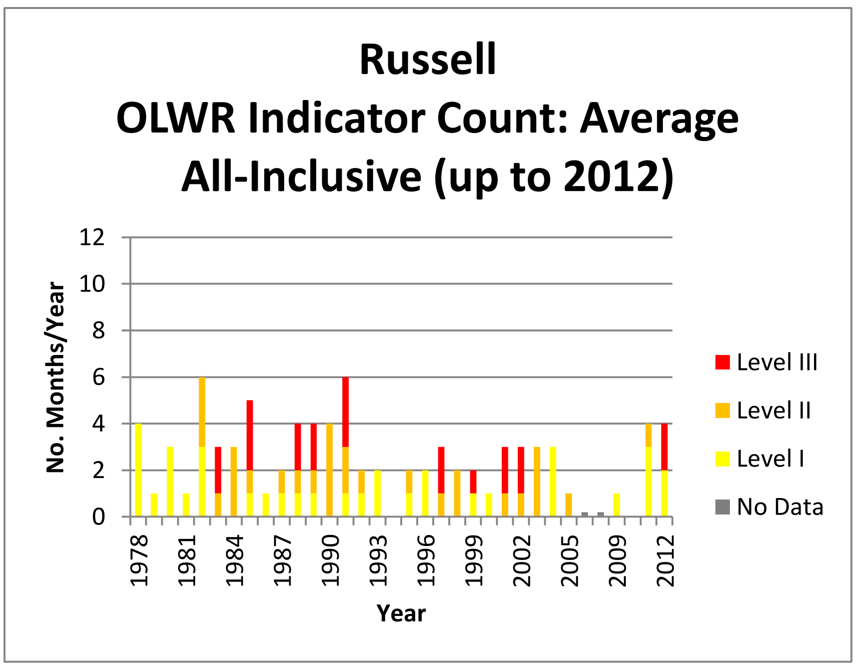



**Figure 4: The above figure is calculated using a rolling average. Each year calculates a new average based on all the previous years including the year in question. For example, the average used in 1975 is calculated using 1968 to 1975.**

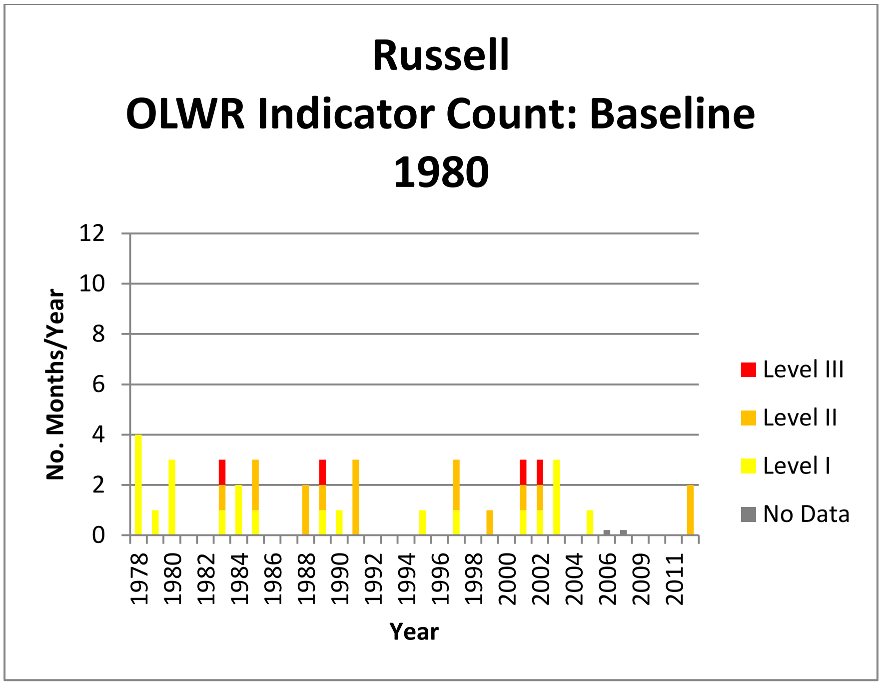



**Figure 5: The above figure is similarly calculated to the previous, except that in order to account for climate change, the rolling average only continues until 1980. After this point, (1981–2012) the average used in the indicator calculation only includes 1968–1980.**

The effects of climate change are most notable on gauges that have a shorter duration of data such as Russell, which has a total of 44 years of recorded streamflow. Russell's short dataset was the reason it was chosen to demonstrate this effect. It should be noted however that in order to use a baseline with a cut-off value most effectively, datasets should have at least 30-years' worth of data before the cut-off date. This ensures an appropriate representation of typical precipitation and streamflow patterns in the average.

In comparison to Russell with its short dataset, the effects of climate change are much less noticeable on gauges such as Ottawa CDA, which has 119 years of precipitation. The buffering effect presented by longer data sets will become less apparent in the future as the proportion of climate affected data increases over time.

Another potentially simple solution to address climate change effects is to set the Level I, Level II, and Level III thresholds lower. This would account for the increase in average by increasing the precipitation or streamflow level that is considered in "drought status." The second could be the addition of a corrective value incorporated into the OLWR calculation formula. This value would be calculated based on measured quantitative effects that climate change imposes on each gauge and would be based on trends prior to 1980. This value could be a constant, or may be different for each month depending on what has been determined as a most effective representation of drought.

### 3.6 Outreach and Education

The effects of drought on any given community can be drastic. For many, the effects are often limited to water use restrictions in residential areas and inability to participate in recreational activities such as swimming, pleasure craft operation, outdoor fire use etc. However, for those that rely on water availability for their livelihoods, such as commercial, industrial, and agricultural sectors, drought can result in loss of business, inability to continue standard operation, or production losses (i.e. crops and livestock). According to climate change projections, drought will become an increasingly frequent and severe occurrence and may present ongoing threats to water and food security. For this reason, education on the importance of Low Water declaration and drought impacts is necessary to ensure water use consciousness or that mitigation/ adaptation strategies are adopted and carried out successfully.

Currently, SNC uses their website to inform the public of low water status at any given time (Level I, Level II, Level III). This is easily accessible and is kept up to date. Other Conservation Authorities such as Grand River Conservation Authority also include a short description of the procedure used to calculate the OLWR results. This may be an effective way to ensure better understanding of Low Water declarations and encourage voluntary water use reduction. The development of an easily accessible resource about the OLWR, its procedures, and importance should be made readily available to all those interested. The ecological and socioeconomic ramifications associated with drought will further promote understanding of the importance of water conservation during dry months. Links to national drought monitoring systems such as the North American Drought Monitor (NADM) from the National Climate Data Center, and the Agriculture Canada Drought Watch websites could also be provided.

In addition, some other agencies provide a more sophisticated program in which residents can become involved in precipitation monitoring. For example, Community Collaborative Rain, Hail and Snow Network (CoCoRaHS) is a non-profit, community-based network of volunteers based out of the United States. Volunteers measure and map precipitation (rain, hail, and snow) and results are made publically available on the CoCoRaHS website (http://www.cocorahs.org/).

Using this concept, SNC would also like to engage volunteers in actively taking precipitation and streamflow measurements within the jurisdiction, as this would provide additional information that could be used for verification of Environment Canada data, as well as account for some areas not currently within close range of precipitation or stream gauges. It would also double as an education tool and promote awareness of water quantity patterns. There is potential for a mapping tool using the Geoportal software to inform the public about drought distribution in the jurisdiction. Additional resources to implement these programs could be beneficial to the OLWR program.

### 3.7 Ecological and socioeconomic impacts

Drought conditions put a strain on many different environmental and anthropogenic functions. The importance of accurately monitoring drought becomes clear when the potential damages have been analysed in a quantitative and qualitative manner.

### 3.7.1 Ecological implications:

From an ecological perspective, drought can have severe impacts, most notably on obligate aquatic biota. For South Nation, these include aquatic plants, fishes, benthic invertebrates, and amphibians in particular. However, effects of drought are not restricted to only those that reside in aquatic environments; the effects of drought extend across all ecosystems and their respective organisms.

Drought Conditions will directly or indirectly affect the following components of the natural heritage in the South Nation Jurisdiction:

- Surface water quantity deficit
- Increased water temperature
- Decreased water quality
- Decreased soil moisture availability
- Increased erosion and sedimentation
- Increased risk of forest fire
- Effects on terrestrial, wetland, and aquatic habitat
- Effects on native flora and fauna
- Stress on cold-water fish species or communities
- Stress on Species at Risk
- Promotion of invasive species or spread of disease

A more detailed analysis of ecological impacts will be available in *The Water Stress Analysis Vulnerability Report*.

### 3.7.2 Socioeconomic implications

Since there are so many sectors either directly or indirectly related to weather conditions or are reliant on natural resources, drought can have negative impacts on these industries.

From a social perspective, many outdoor recreational activities may be hindered by drought, particularly those directly related to water use. Angling and hunting, pleasure craft operating and swimming in particular, become compromised in low water conditions. SNC has an active angling community which is reliant on sport fish–many of which are cold-water species that are particularly drought sensitive. Low water conditions may also make passage by boat unfeasible, and swimming can become hazardous to human health when low water levels contribute to an increase in pathogen and toxin contamination or concentration.

From a human health perspective, reduced access to water, food security issues, heat stress, and reduced water quality are also potential hazards associated with prolonged drought conditions. Climate change makes the risks to human health exponentially greater, particularly for small children and the elderly.

Economically, droughts is expected to exert most of its impacts on industries related to natural resources or are reliant on water availability, such as forestry, government, commercial, industrial, and agricultural sectors. For these industries, drought can result in loss of business, inability to continue standard operation or production losses. The 60% of agricultural land use in the SNC jurisdiction is most at risk. The drought of 2012 resulted in crop failure and livestock culling, with a substantial portion of the cost being directly absorbed by the farming community. Food security issues arise in scenarios where adequate preparations have not been made for drought, and put a strain on both the farming community and the government agencies who subsidize losses. Liability may also become an issue, when those affected by drought lay blame on government or municipalities that are responsible for the welfare and stability of their communities.

Since it is difficult to assign monetary values to events that have not occurred, ensuring an understanding of potential losses in a way that is identifiable by the public and stakeholders is paramount for preparedness.

# 4 Conclusion

With so many factors at stake, it becomes clear that South Nation has a great need to accurately forecast and monitor drought situations.

Recommendations for improvement in different areas are provided below:

**Precipitation data and calculation:** Temporal data gaps present a problem when analyzing historical trends and may skew averages used in OLWR calculations. Spatial representation of gauges is also an issue, as the main gauges are located at the periphery of the watershed and there is a lack of consistent representation of the central portion. The use of one-month and 18-month calculation intervals could be too variable to represent drought conditions.

***Recommendation**:*

- Approach Environment Canada to request more consistent data readings at the Russell climate station, or consider the addition of a gauge in the central portion of the Watershed, which could be used to supplement the historical Russell climate station data.
- The Montebello, Quebec weather station has consistent data available from the 1950s. Test the applicability of this station to declare Low Water in the SNC Watershed.
- Volunteer raingauge information may be a valuable verification tool for determining the spatial accuracy of interpolated precipitation data. Effectiveness of interpolating precipitation data across the jurisdiction requires further examination.
- Use SNC's raingauges data to interpret an event rainfall distribution.

**Streamflow data and calculation:** Temporal data gaps present a problem when analyzing historical trends and may skew averages used in OLWR calculations. Location of control structures at existing gauges also makes analysis from a streamflow perspective unreliable. The use of Lowest Average Summer Monthly Flow (LASMF) may also not adequately represent drought in non-summer months.

- ***Recommendation:***
    - *Repair datalogger downstream of Chesterville Dam.*
    - *Review the possibility of assessing water levels downstream of Casselman Dam, contingent on permission of Hydro station owner.*
    - *Install staff gauges at all dams, which would provide water levels measurements during drought.*
    - *The provincial streamgauge network is being reviewed by MNR and EC this year. SNC should conduct a review of its watershed streamgauge network, including deactivated gauges, and identify a minimum of two potential locations for new stations. This information can be relayed to MNR and EC.*
    - *MNR is reviewing the OLWR guidelines; SNC should ensure they consider an approach to declare low water during winter and spring months.*

**Lack of groundwater and baseflow components:** Although the province is developing groundwater indicators, it was observed that groundwater and surface water baseflow data are not substantially available for Low Water declarations at this time, yet are critical indicators for ecological processes and human water usage.

- ***Recommendation:***
    - *Develop a baseflow monitoring program.*
    - *Test the OLWR groundwater indicator for the SNC jurisdiction.*

**Declaring Low Water on a Watershed basis:** SNC covers a 4,200 $km^2$ area, of which, are eco-climate zones. There is a range of climate across the Watershed; however SNC's Low Water declaration is applied across the entire jurisdiction, regardless of the spatial variability between regions. This can result in unnecessary water use restrictions in some areas.

- ***Recommendation:*** *Division of watershed into of climate regions with the intention of localizing low water declarations.*

**Climate Change Effects:**

- ***Recommendation:*** *Proposed to MNR to incorporate climate change in the OLWR program review.*

**Outreach, education, and information transfer:** Education about low water conditions and availability plain-language information will promote better water conservation by the public during a low water event.

- ***Recommendation:*** *More public outreach and volunteer OLWR-related opportunities.*

**Ecological and socioeconomic implications:** The ecological and socioeconomic impacts of drought can be severe and irreversible. With the effects of climate change projected to increase the frequency of low water occurrence, an in-depth analysis of low water impacts is required to ensure preparedness.

➢ ***Recommendation:*** *Conduct a detailed analysis of ecological and socioeconomic impacts of drought to assess community needs and provide potential adaptation strategies.*

The enhancements listed above would improve the current implementation of the OLWR program within SNC's jurisdiction and provide more appropriate analyses with consideration to long-term climate change. Improvements to the program should be assessed after implementation and subsequent changes should be assessed regularly. Enhancements to the program could be transferable to other jurisdictions and may be a good resource in future strategic planning and policy development.

## 5 References: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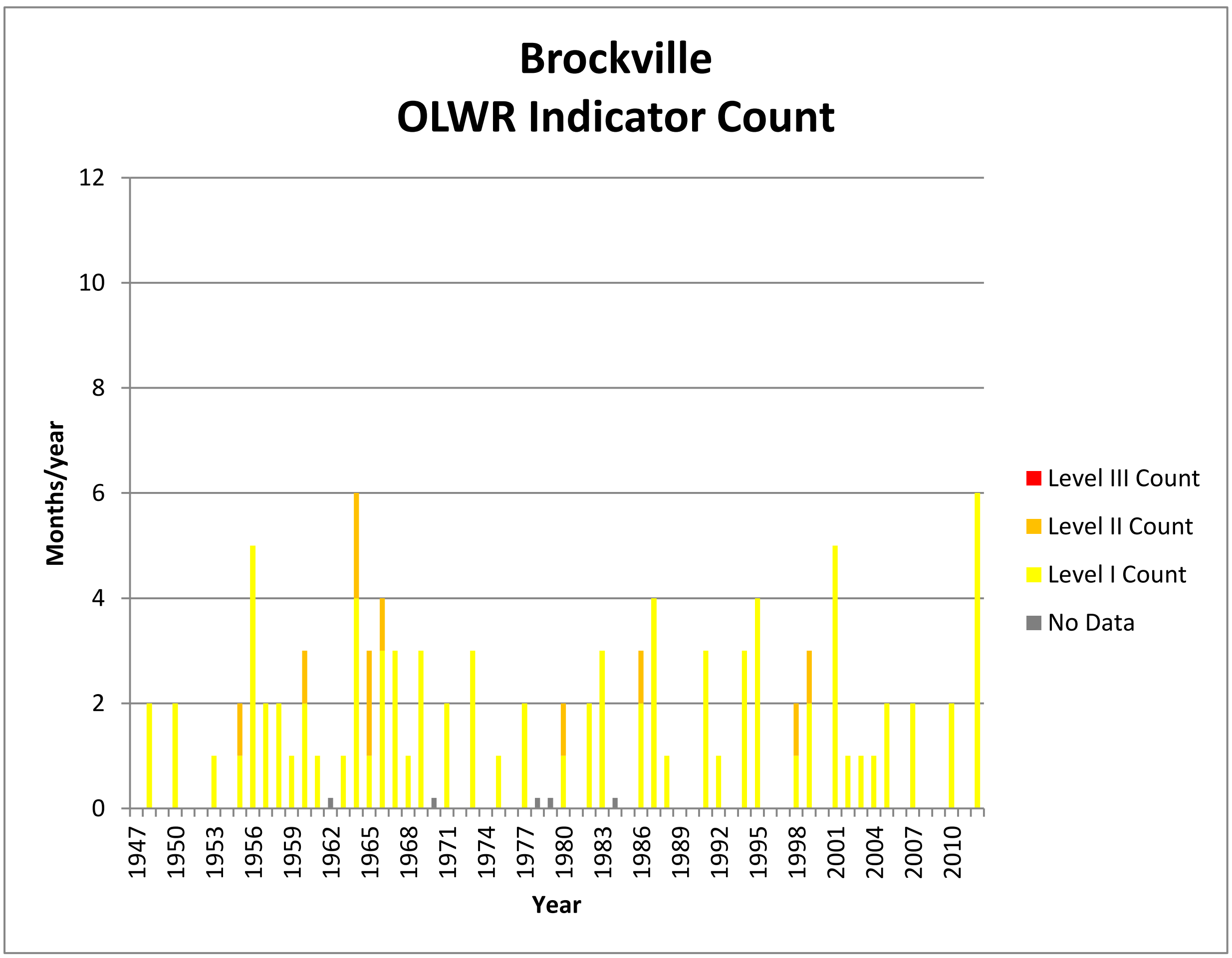
# 6 Appendices:

## 6.1 Appendix 1: Ontario Low Water Response Graphs

The following section represents precipitation and streamflow over the duration of historical data collection, excluding the first 30 years. It was decided that a 30-year minimum should be included in the average used in the OLWR calculations. This was based on Environment Canada's use of a 30-year standard in calculating climate normal. Furthermore, less than 30 years would not likely be statistically relevant, considering the variability of rainfall and melting events in the SNC Watershed. For this reason, the graphs below do not show the whole data set, only years with an average calculated from 30 years or more.**

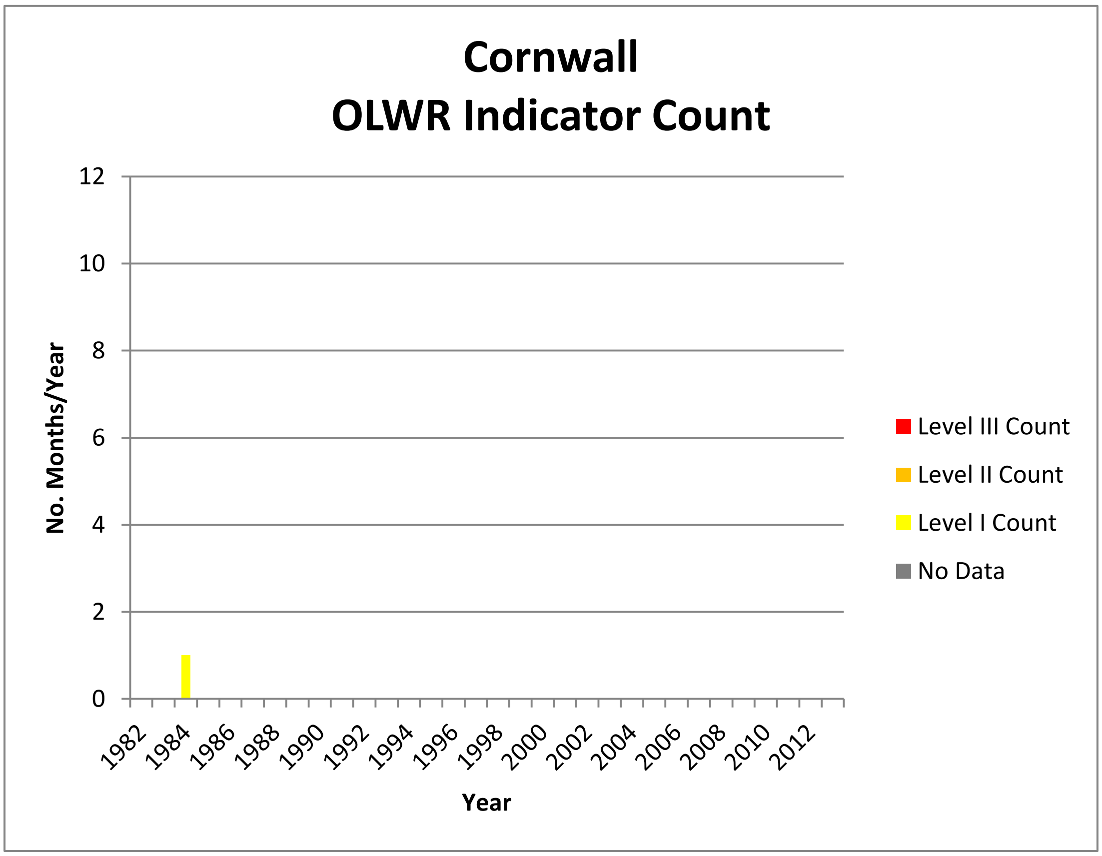
Where available, each month has been analysed according to the OLWR guidelines and classified as a "Level I", "Level II," or "Level III" drought. The results are depicted as follows, with each year exhibiting a count of the number of times each drought severity level occurs in that year. Years with missing or incomplete data sets are represented in grey.

***Two exceptions have been made to this rule: Bourget contains only 35 years of data total and Russell only contains 44years. In order to represent data for these stream gauges, only the first 10 years were excluded from these graphs.*

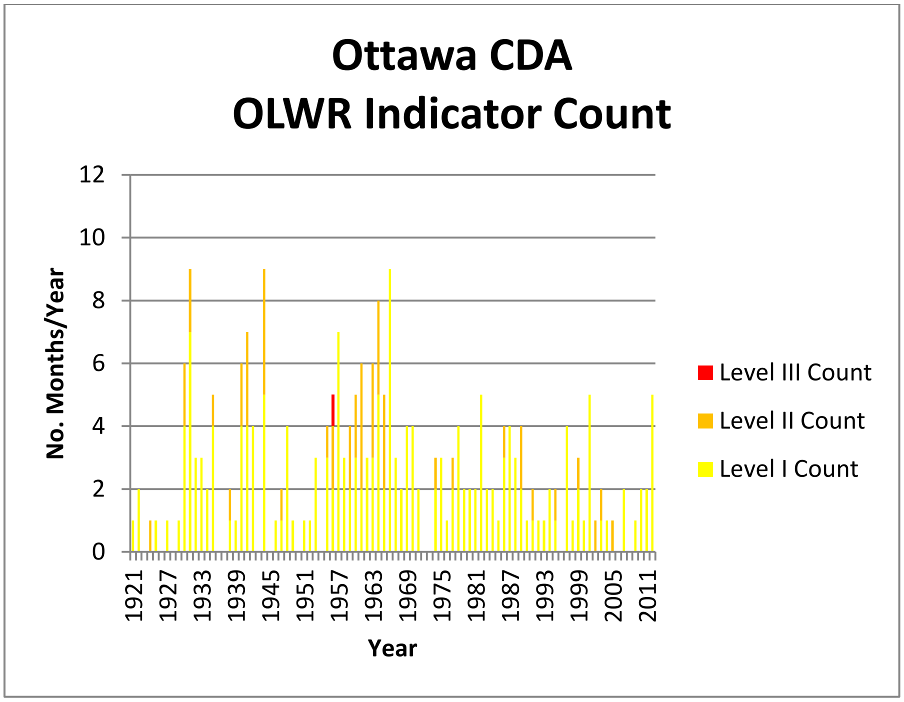


**Precipitation:**

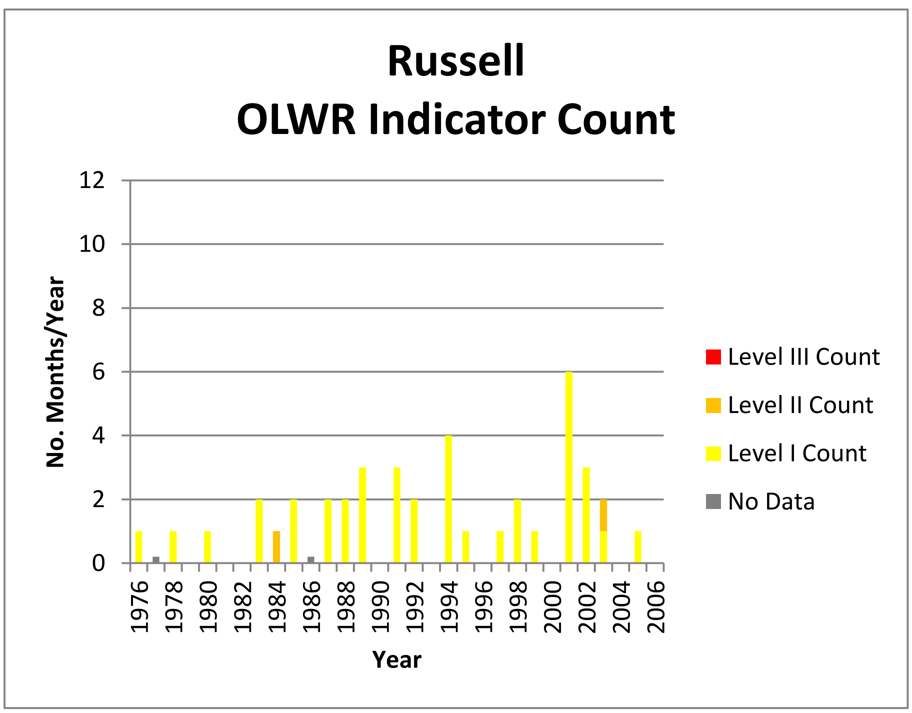
The Brockville precipitation gauge accounts for the most southern portion of the Watershed, and has the highest annual precipitation compared to the two other precipitation gauges used in the jurisdiction. The data used for this depiction is an amalgamation of two separate gauges in very close proximity. To lengthen the amount of available data, a gauge located at 44°36'00.000" N/ 75°42'00.000" W containing data from 1871 to 2014 was combined with a gauge located at 44°36'00.000" N/ 75°40'00.000" W containing data from 1965 to 1980. The distance between these two gauges is small, and the data during years where the two gauges overlapped were very similar; therefore it was decided to combine the two in order to create a longer, more usable dataset for analysis.




Although it does not experience the highest annual precipitation out of the three gauges being monitored, the Cornwall precipitation gauge appears to exhibit the most stability in terms of drought vulnerability, according to the OLWR.

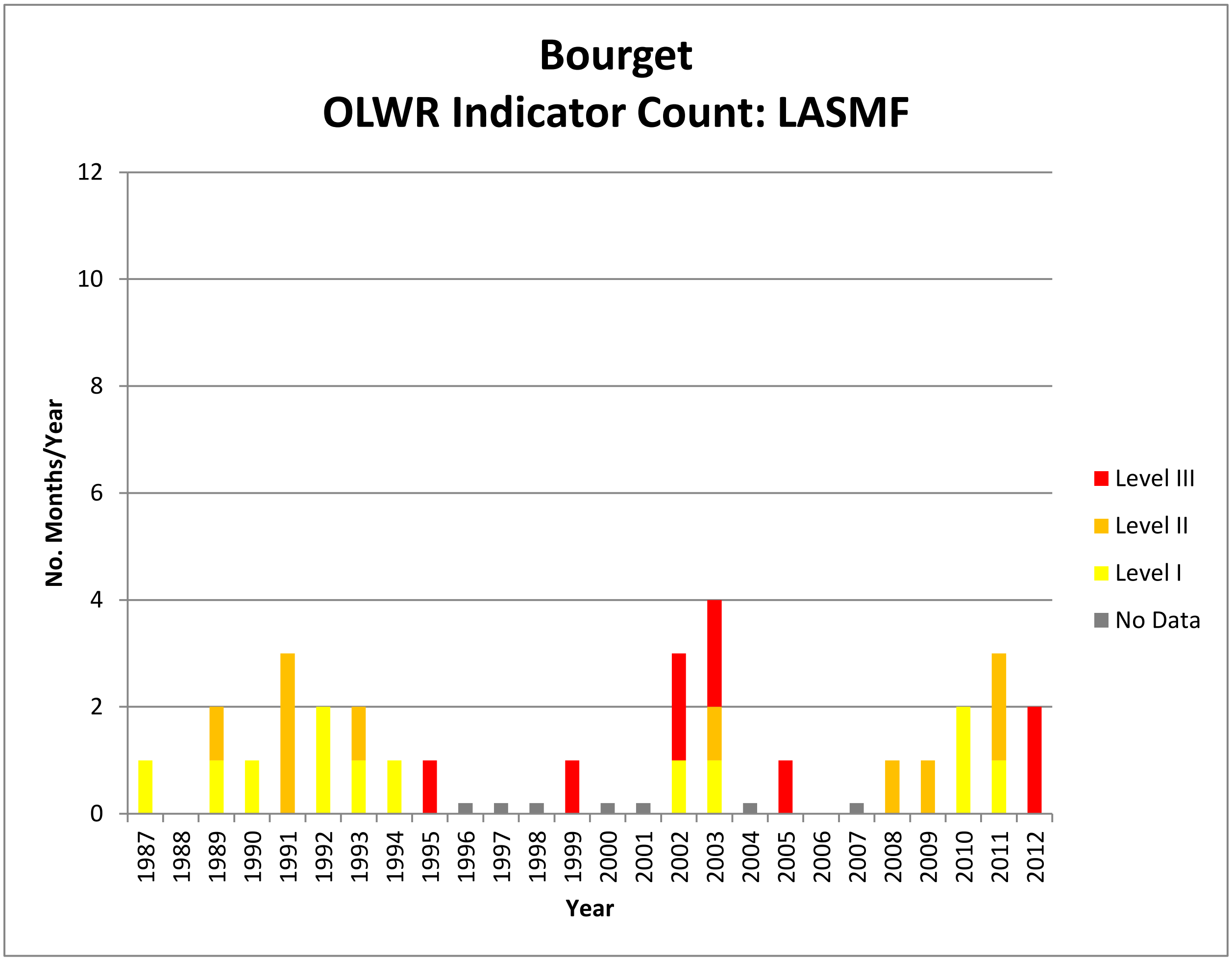



Ottawa CDA has the longest and most complete set of precipitation data, making it a valuable tool for analysing climate change effects.

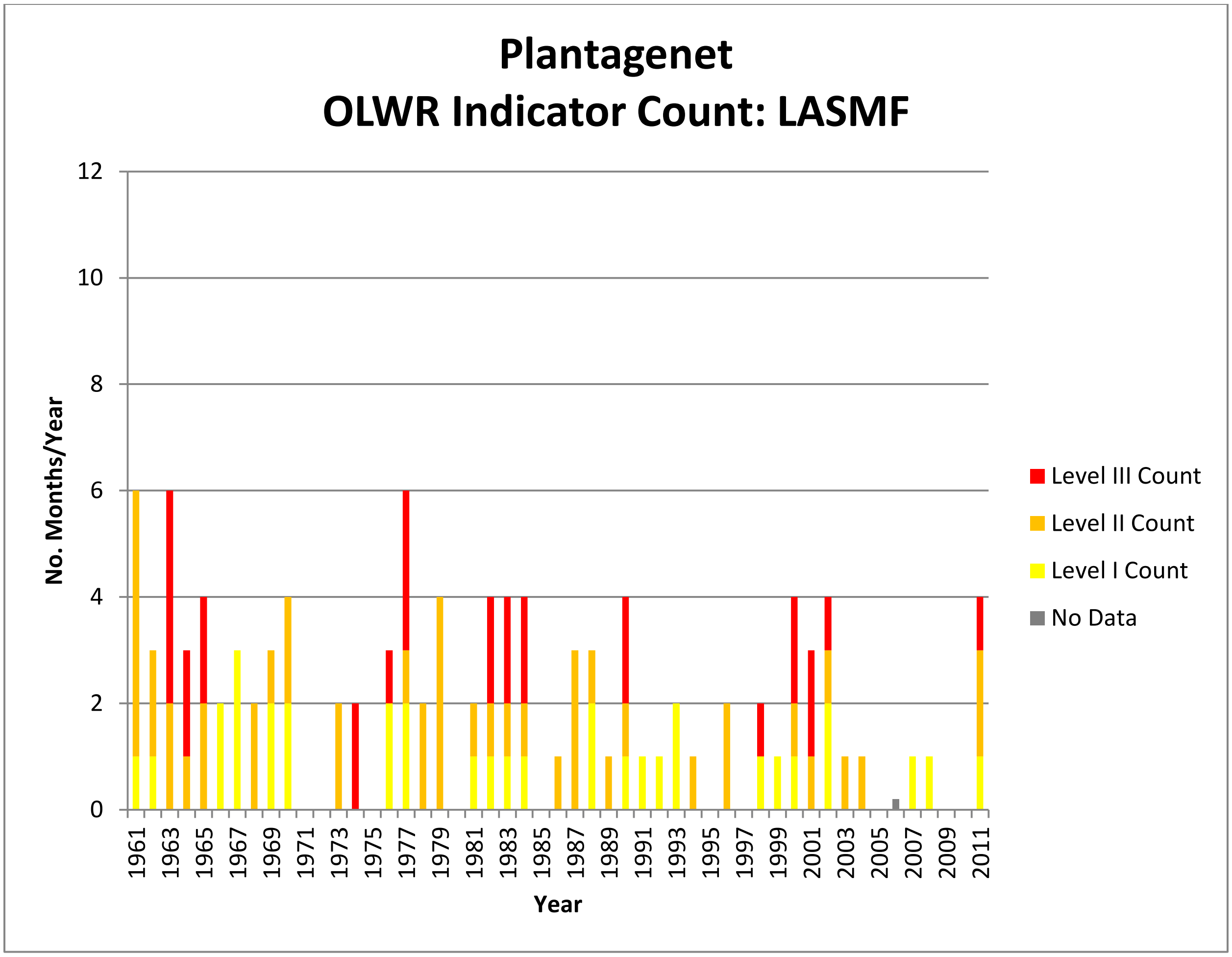



Russell data is consistently available from 1976 to 2006 and has been included specifically as a reference. Since only 30-years of data are available for this gauge, the entire data set is displayed above. Due to the limited amount of data, a longer data collection period would be required to insure OLWR calculation results are statistically relevant.

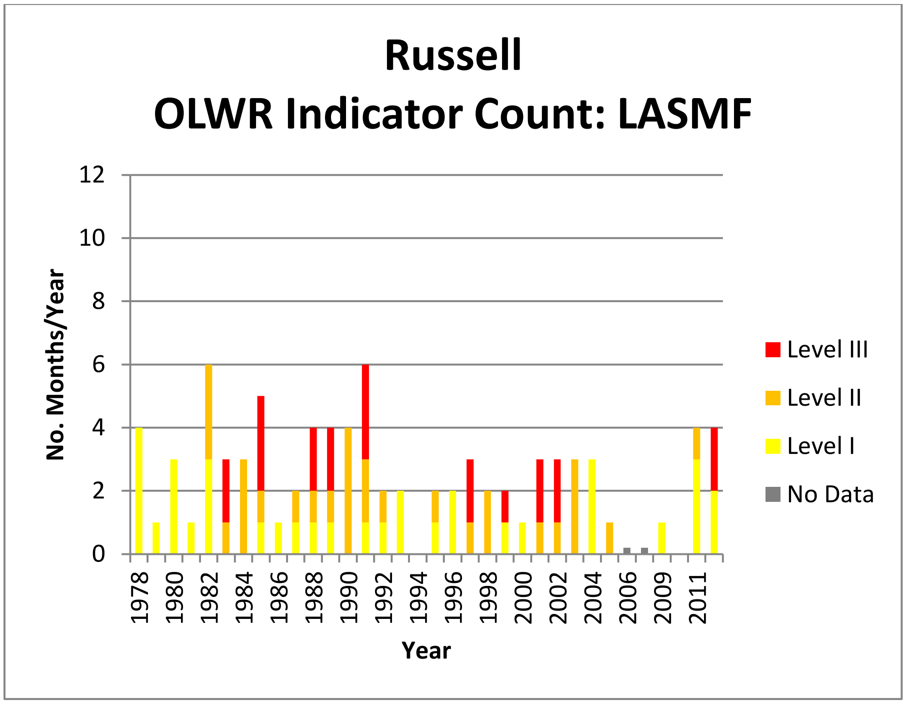
**Streamflow:**



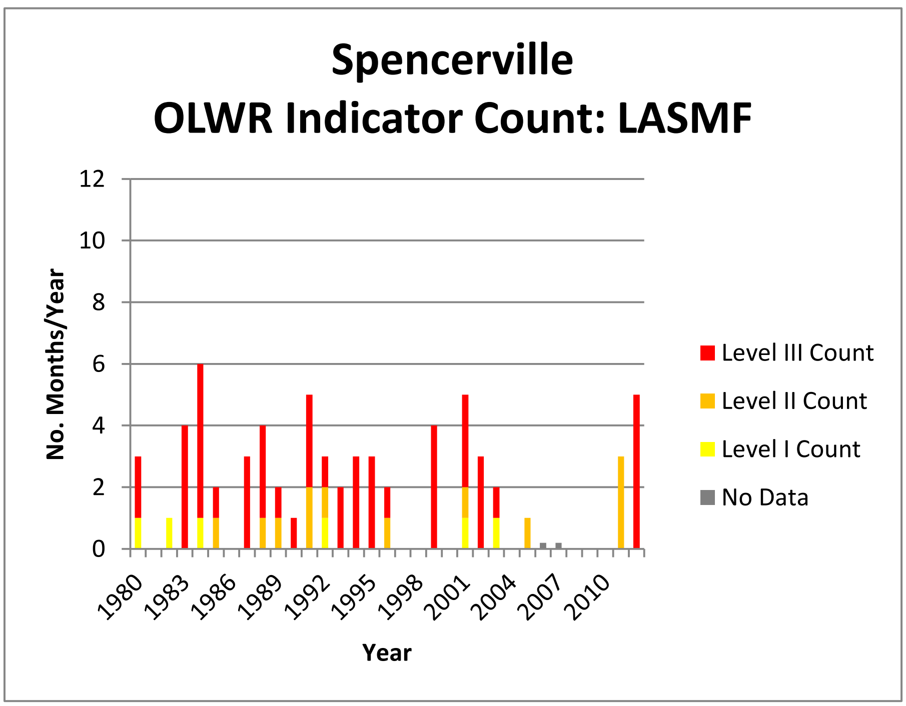

The Bourget stream gauge is the most recent stream gauge that has been implemented within the SNC Watershed that is managed by Environment Canada; data for this gauge is only available from 1977 to present day. With a limited data set, it is difficult to test the effectiveness of the OLWR for this gauge. As a result, an exception has been made when displaying the results of the OLWR calculation: only the first 10 years have been discounted in this graph, as the dataset is only 35-years long.




The Plantagenet stream gauge has the longest data set of the stream gauges available within the Watershed. There is a substantial gap of complete data from the mid-1930s until almost the 1950s. It should be noted that these years were omitted during the OLWR calculation and may exhibit a slight effect on the results; a significant drought occurred during the 1930s that is otherwise accounted for in other gauges.




The Russell stream gauge is the most central stream gauge in the Watershed. Like the Bourget Stream gauge, Russell is limited by the length of its data set. Having only 44 years of available data, it was decided that only the first 10 years of data would be excluded from this graph.

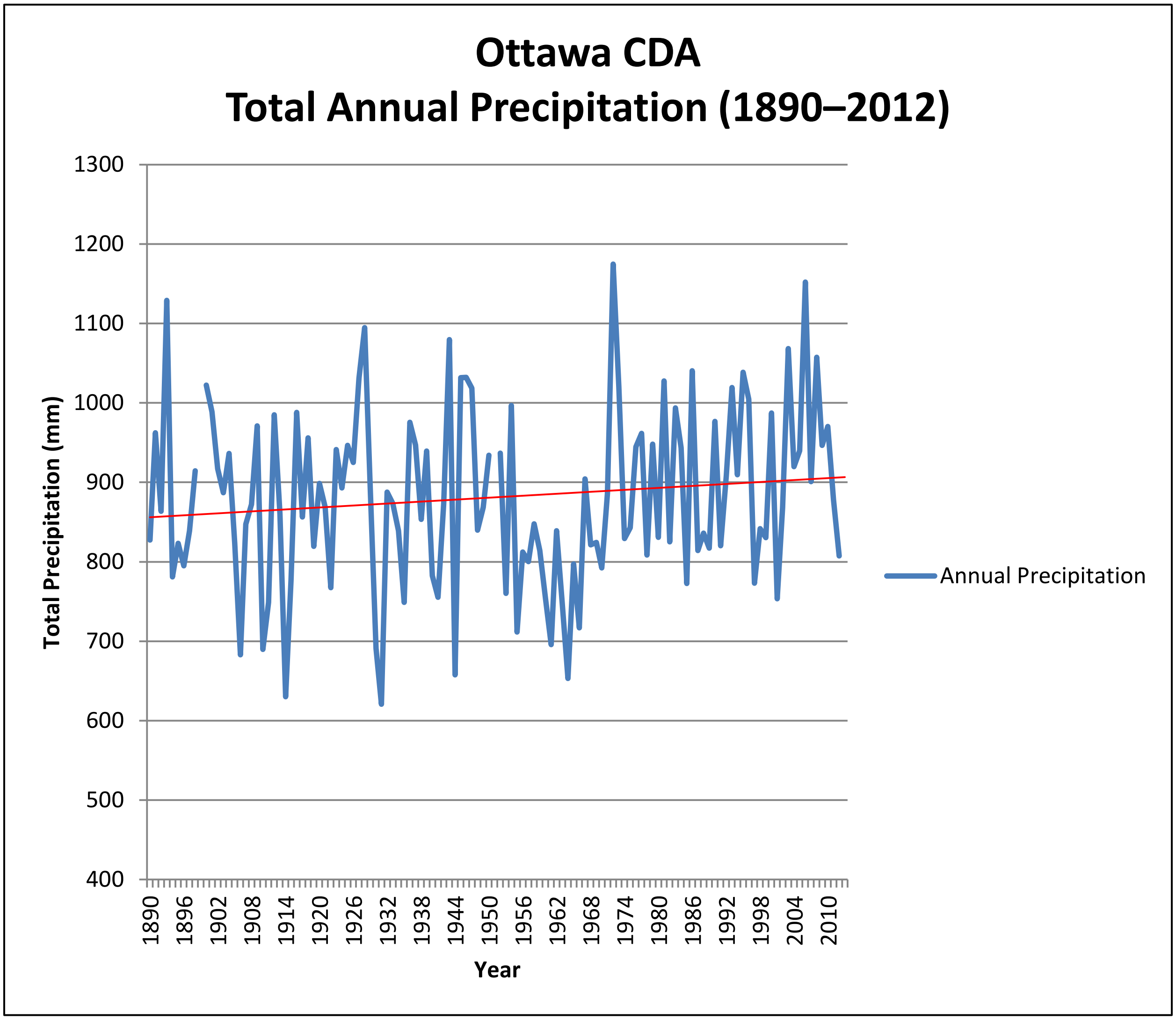


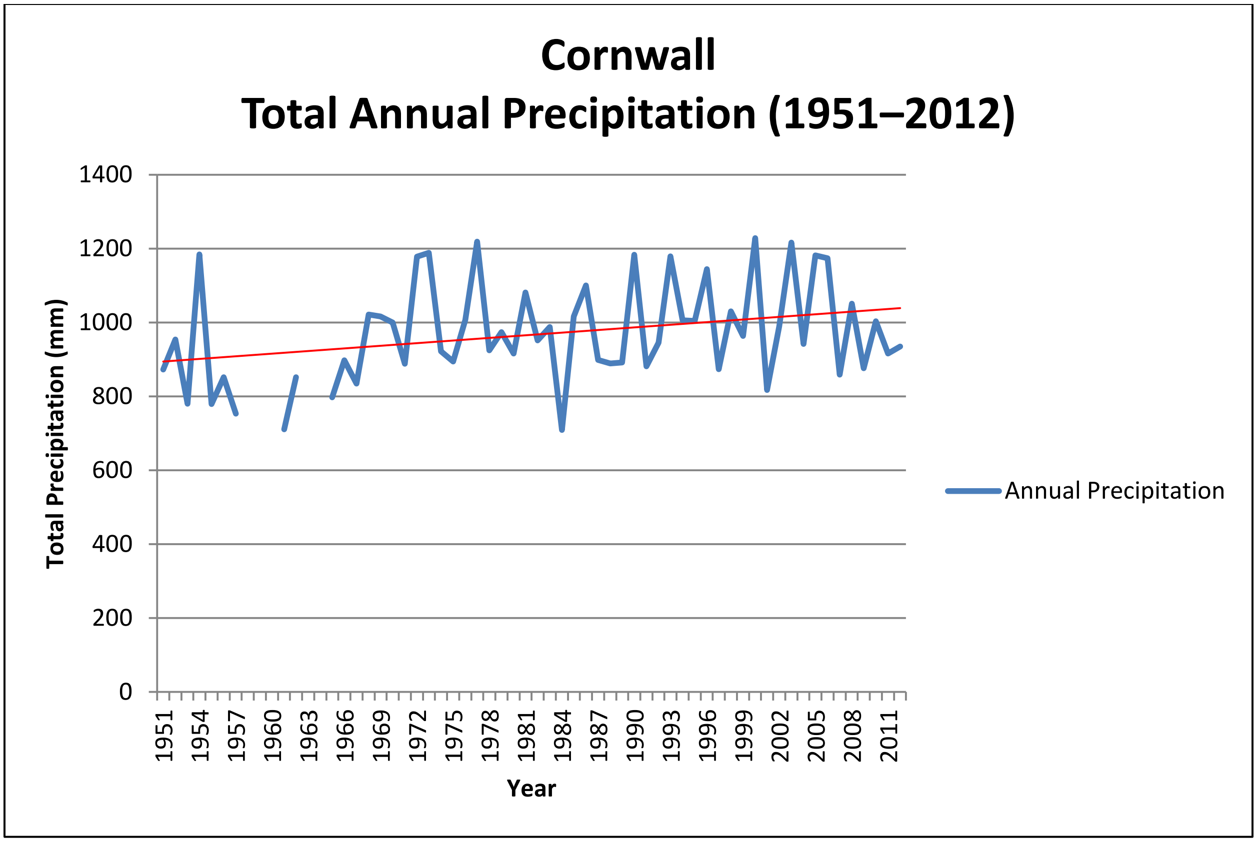

Anecdotally, the Spencerville area is typically "dry" compared to other areas in the Watershed. Despite the high volume and relatively stable precipitation in the area, the direct runoff for this portion of the Watershed is much lower than many other areas in the Watershed, which likely accounts for its frequent Low Water status. The fact that this area also has a higher annual temperature and therefore increased evapotranspiration rates are likely a factor, as is the soil permeability. Soils in the Spencerville area are typically permeable therefore water percolates through the soil instead of reaching the stream.

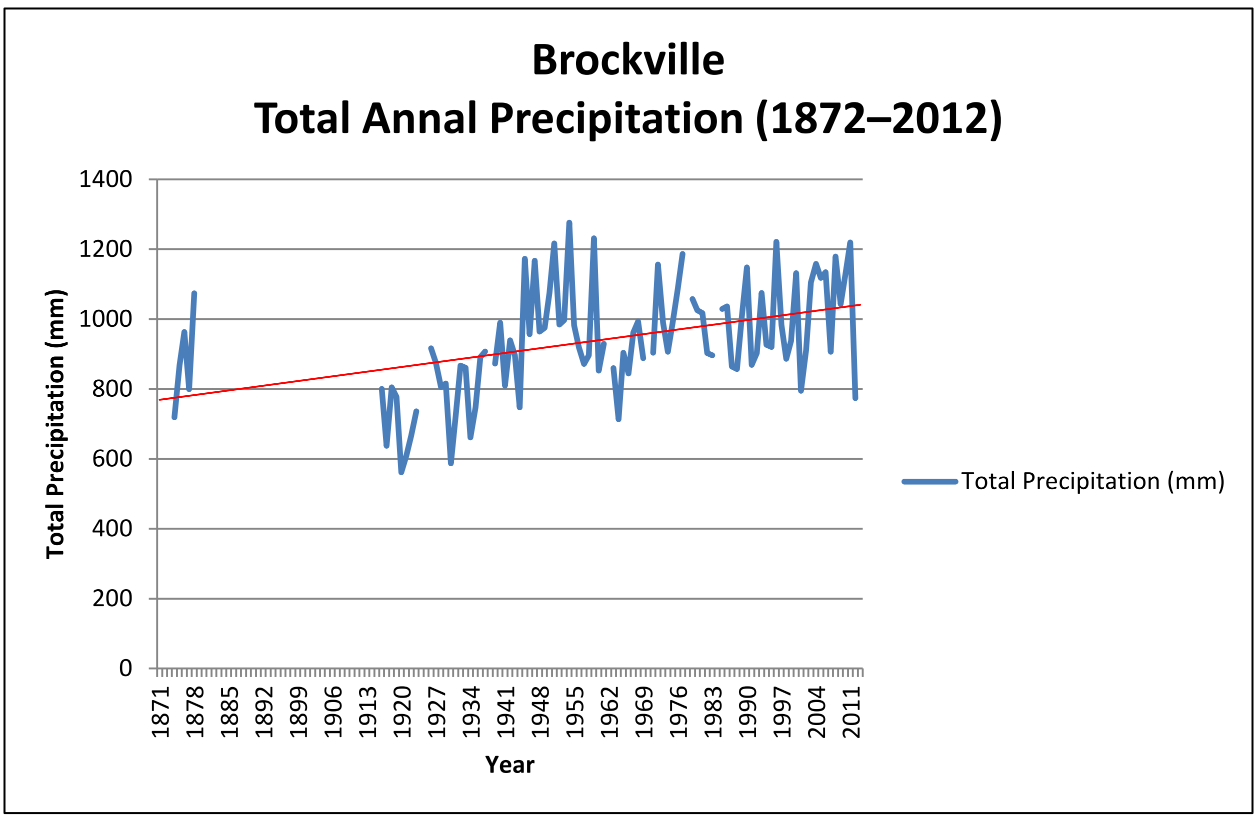
## 6.2 Appendix 2: Annual Precipitation and Streamflow

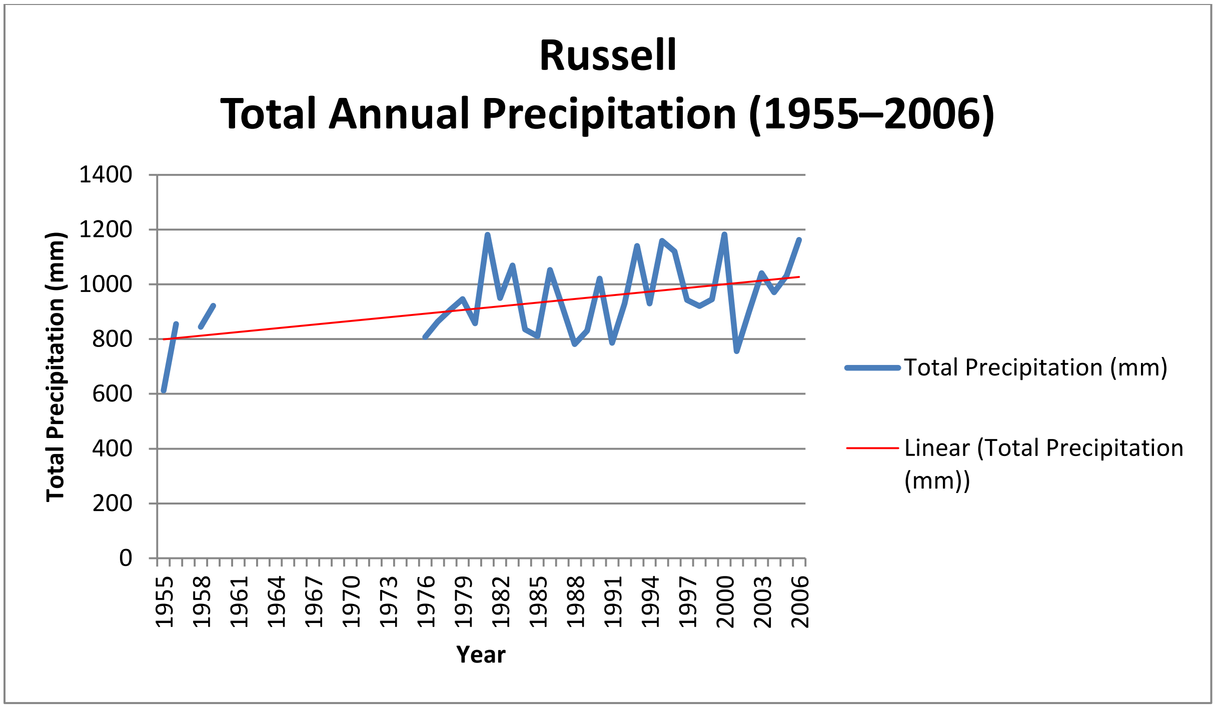
The following graphs represent total annual precipitation and average streamflow for the entire history of data. Points were omitted where there was any missing data throughout the year.

**<u>Precipitation:</u>**

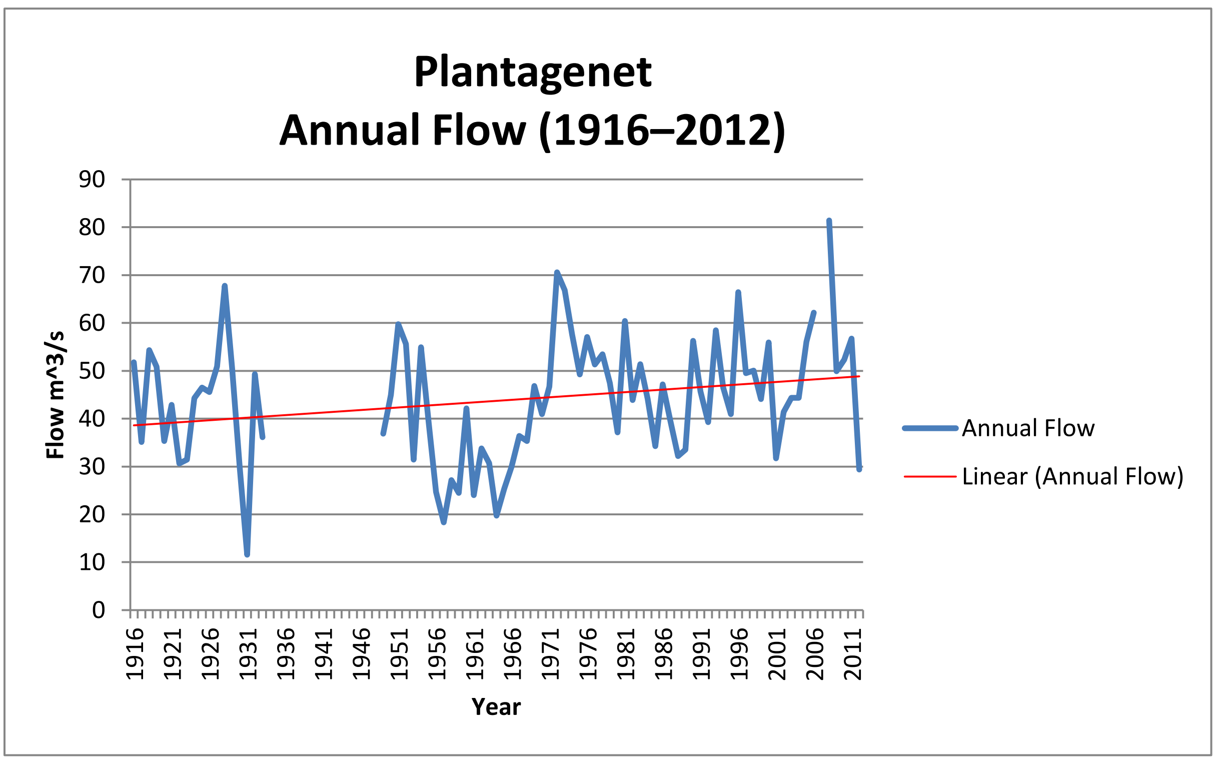


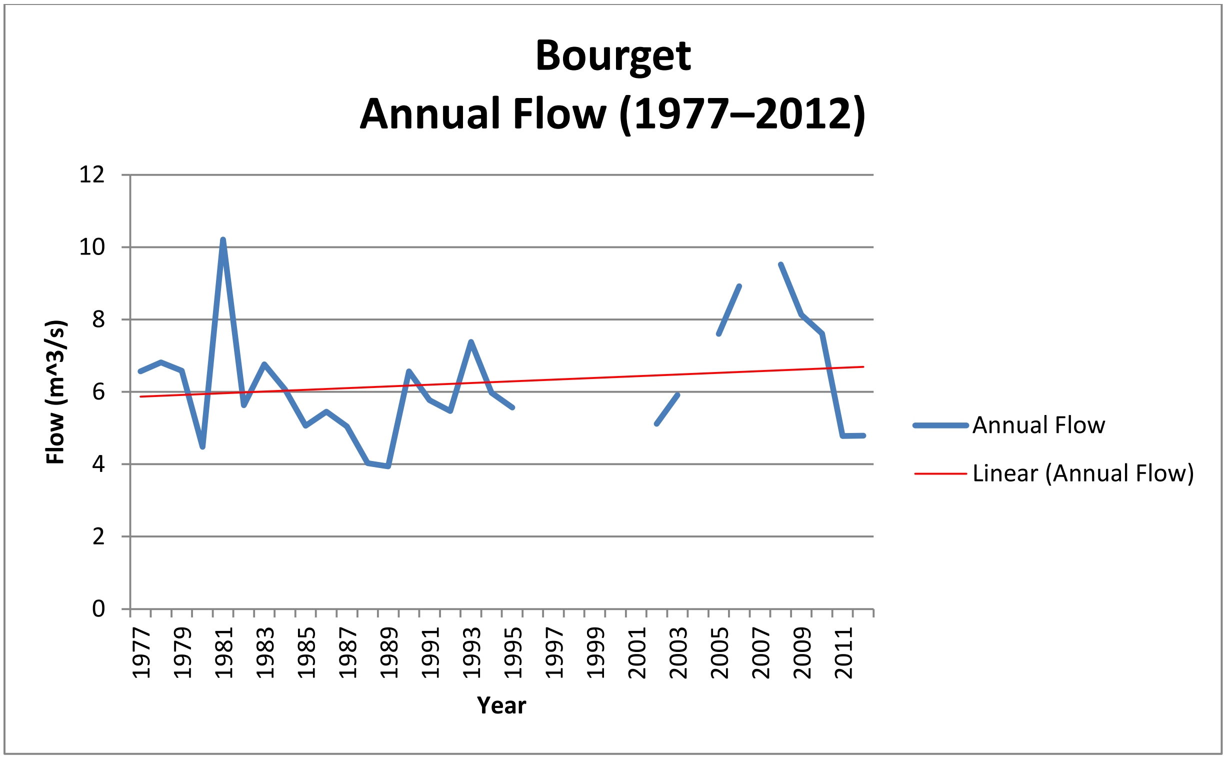

Cornwall
Total Annual Precipitation (1951–2012)
Total Precipitation (mm)
1400
1200
1000
800
600
400
200
0
1951
1954
1957
1960
1963
1966
1969
1972
1975
1978
1981
1984
1987
1990
1993
1996
1999
2002
2005
2008
2011
Year
Annual Precipitation

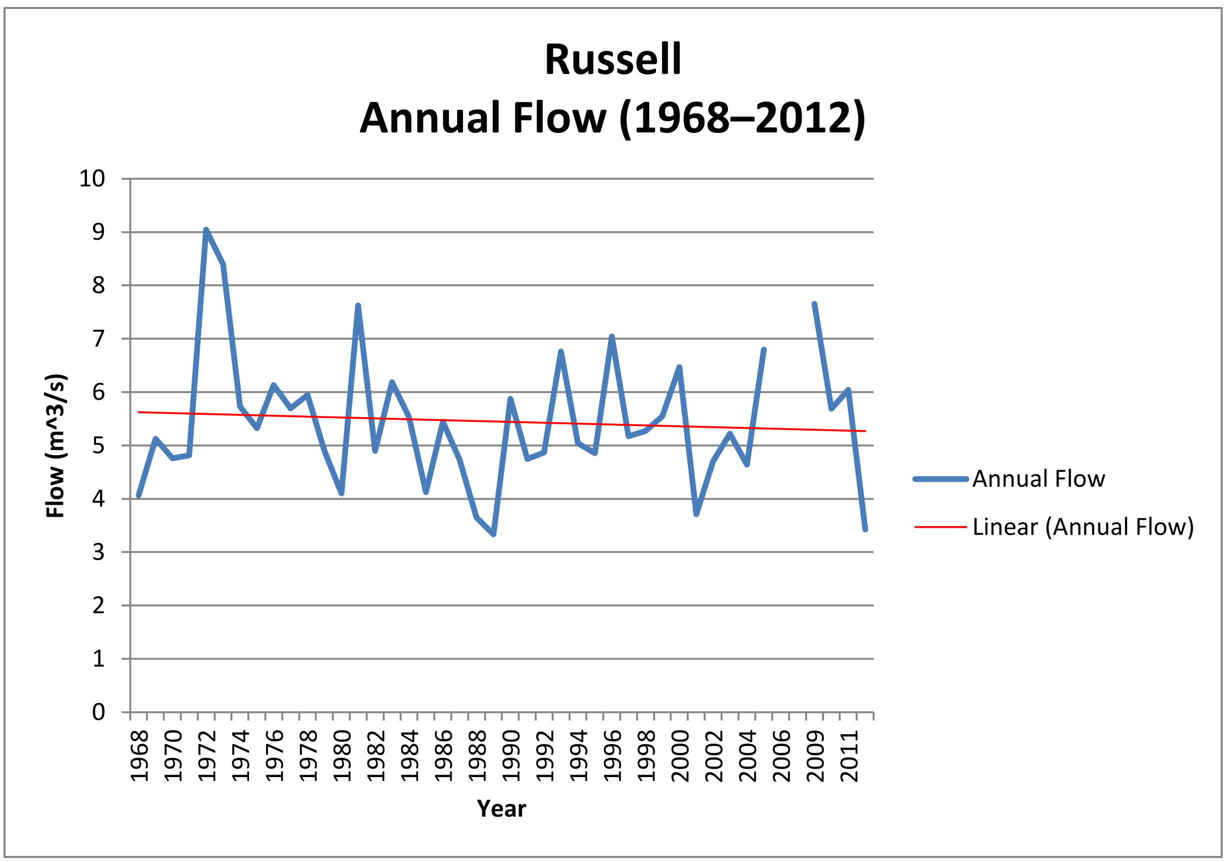

Brockville
Total Annal Precipitation (1872–2012)
Total Precipitation (mm)
1400
1200
1000
800
600
400
200
0
1871
1878
1885
1892
1899
1906
1913
1920
1927
1934
1941
1948
1955
1962
1969
1976
1983
1990
1997
2004
2011
Year
Total Precipitation (mm)

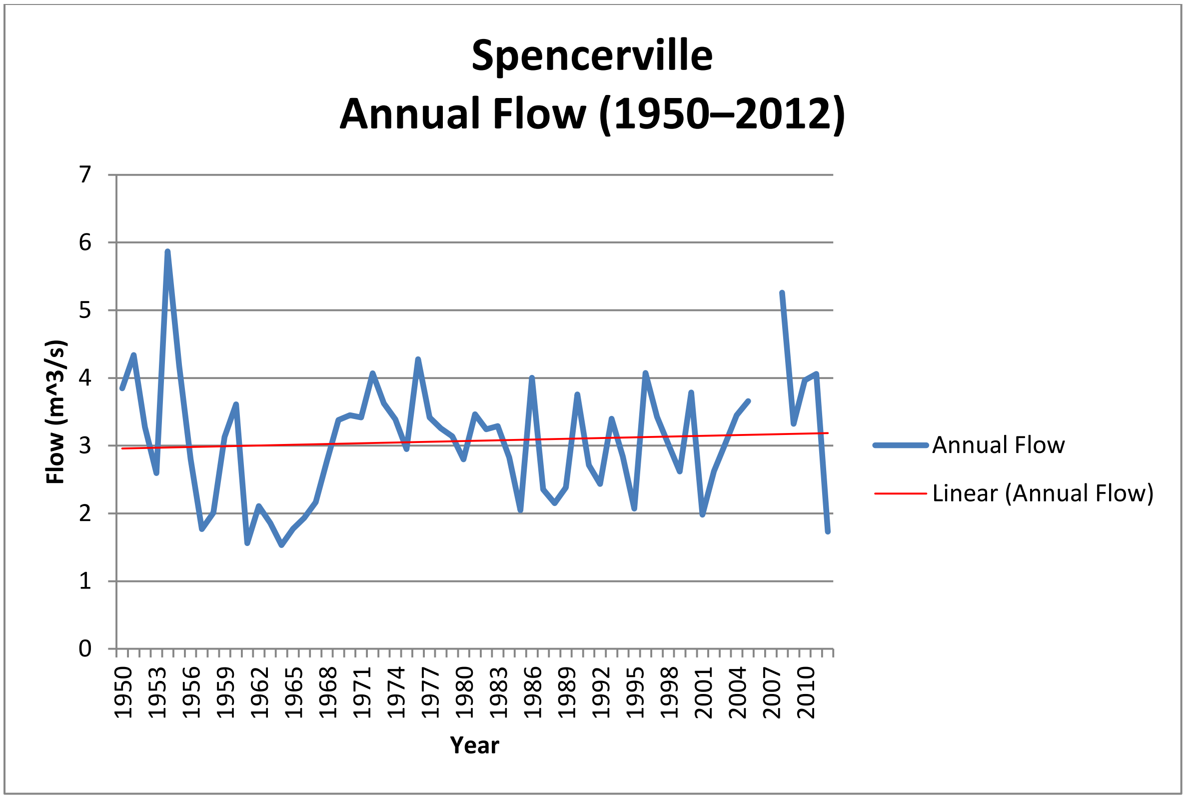

Russell
Total Annual Precipitation (1955–2006)
Total Precipitation (mm)
1400
1200
1000
800
600
400
200
0
1955 1958 1961 1964 1967 1970 1973 1976 1979 1982 1985 1988 1991 1994 1997 2000 2003 2006
Year
Total Precipitation (mm)
Linear (Total Precipitation (mm))

**Streamflow:**


Plantagenet
Annual Flow (1916–2012)
Flow m^3/s
90
80
70
60
50
40
30
20
10
0
1916 1921 1926 1931 1936 1941 1946 1951 1956 1961 1966 1971 1976 1981 1986 1991 1996 2001 2006 2011
Year
Annual Flow
Linear (Annual Flow)


Bourget
Annual Flow (1977–2012)
Flow (m^3/s)
Year
Annual Flow
Linear (Annual Flow)


Russell
Annual Flow (1968–2012)
Flow (m^3/s)
Year
Annual Flow
Linear (Annual Flow)




## 6.3 Appendix 4: Weather stations

Weather stations below are located within 25 km of the SNC jurisdiction. The stations are owned and operated by a variety of sources, including Environment Canada and are available on the Environment Canada website. Data not collected directly from Environment Canada are considered volunteer stations and data is quality controlled.

| Station | Easting | Northing | Start | End | Years Active | Data Interval |
|---|---|---|---|---|---|---|
| ALEXANDRIA | 531544 | 5018979 | 2003 | 2006 | 3 | Hourly |
| ALFRED | 509107 | 5044058 | 1984 | 1986 | 2 | Daily |
| ALFRED | 509713 | 5044614 | 2003 | 2007 | 4 | Hourly |
| ALFRED AUTOMATIC CLIMATE STATION | 509107 | 5044058 | 1989 | 1989 | 0 | Daily |
| APPLE HILL | 519629 | 5007050 | 1950 | 1961 | 11 | Daily |
| ATHENS | 427314 | 4944480 | 1969 | 1978 | 9 | Daily |
| AVONMORE | 502291 | 5001837 | 1976 | 2006 | 30 | Daily |
| BELLS CORNERS | 436008 | 5020305 | 1991 | 1991 | 0 | Daily |
| BOURGET | 486971 | 5034807 | 1950 | 1951 | 1 | Daily |
| BROCKVILLE | 444447 | 4938755 | 1871 | 1980 | 109 | Daily |
| BROCKVILLE CLIMATE | 440647 | 4942708 | 2008 | 2013 | 5 | Hourly |
| BROCKVILLE PCC | 447092 | 4938733 | 1965 | 2013 | 48 | Daily |
| CARDINAL | 471001 | 4960799 | 1970 | 2000 | 30 | Daily |

| | | | | | | |
|---|---|---|---|---|---|---|
| CHESTERVILLE | 481642 | 4994086 | 1965 | 1983 | 18 | Daily |
| CHESTERVILLE 2 | 484242 | 4984821 | 1983 | 1997 | 14 | Daily |
| CITY VIEW | 442555 | 5022094 | 1953 | 1960 | 7 | Daily |
| CORNWALL | 519785 | 4984712 | 1950 | 2013 | 63 | Daily |
| CORNWALL | 521011 | 4984837 | 1867 | 1887 | 20 | Daily |
| CORNWALL | 523631 | 4986697 | 1948 | 1950 | 2 | Daily |
| CORNWALL | 525098 | 4986487 | 2003 | 2007 | 4 | Hourly |
| CORNWALL COLLEGE | 522318 | 4986692 | 1959 | 1963 | 4 | Daily |
| CORNWALL CUMBERLAND ST | 519687 | 4988535 | 1960 | 1966 | 6 | Daily |
| CORNWALL ONT HYDRO | 515754 | 4986673 | 1955 | 1995 | 40 | Daily |
| CORNWALL ST LHS | 522318 | 4986692 | 1958 | 1963 | 5 | Daily |
| CUMBERLAND | 464843 | 5038595 | 1973 | 1980 | 7 | Daily |
| DALHOUSIE MILLS | 541803 | 5018267 | 1968 | 2004 | 36 | Daily |
| DALKEITH | 529984 | 5031162 | 1961 | 1978 | 17 | Daily |
| DALKEITH PYM | 532591 | 5031175 | 1978 | 1987 | 9 | Daily |
| DOMVILLE | 457807 | 4959020 | 1948 | 1954 | 6 | Daily |
| DUNVEGAN | 516977 | 5020004 | 1947 | 1949 | 2 | Daily |
| FOURNIER | 507822 | 5031095 | 1957 | 1959 | 2 | Daily |
| GLEN GORDON | 536674 | 5001571 | 1967 | 1999 | 32 | Daily |
| GLOUCESTER DESJARDINS | 460822 | 5020102 | 1975 | 1977 | 2 | Daily |
| GLOUCESTER KETTLES | 456916 | 5021979 | 1975 | 1982 | 7 | Daily |
| GLOUCESTER RCN | 459492 | 5016407 | 1954 | 1954 | 0 | Daily |
| GLOUCESTER TINKER | 463444 | 5021938 | 1975 | 1976 | 1 | Daily |
| GREENFIELD | 526111 | 5021886 | 1965 | 1967 | 2 | Daily |
| HAWKESBURY | 528587 | 5051523 | 1950 | 1963 | 13 | Daily |
| IROQUOIS | 473652 | 4964490 | 1994 | 1995 | 1 | Hourly |
| KEMPTVILLE | 450084 | 4983146 | 1928 | 1997 | 69 | Daily |
| KEMPTVILLE CS | 450084 | 4983146 | 1997 | 2006 | 9 | Daily |
| LAGGAN | 516962 | 5025558 | 1961 | 1961 | 0 | Daily |
| LEONARD | 475209 | 5025584 | 1960 | 1962 | 2 | Daily |
| LYN | 437815 | 4936964 | 1960 | 1969 | 9 | Daily |
| MAITLAND | 449766 | 4942415 | 1953 | 1954 | 1 | Daily |
| MALLORYTOWN GRAHAM LAKE | 429857 | 4935194 | 1961 | 1989 | 28 | Daily |
| MANOTICK | 445054 | 5009110 | 1975 | 1986 | 11 | Daily |
| MANOTICK | 446362 | 5009098 | 1953 | 1956 | 3 | Daily |
| MERIVALE TS | 442538 | 5020242 | 1983 | 1994 | 11 | Daily |
| MERIVALE CDA | 442505 | 5016539 | 1972 | 1977 | 5 | Daily |
| MONTAGUE | 425039 | 4975984 | 1895 | 1914 | 19 | Daily |
| MOOSE CREEK | 497384 | 5010723 | 1964 | 1965 | 1 | Daily |
| MOOSE CREEK | 502921 | 5010847 | 2003 | 2007 | 4 | Hourly |

| | | | | | | |
|---|---|---|---|---|---|---|
| NAVAN | 459587 | 5031220 | 1973 | 1974 | 1 | Daily |
| NORTH AUGUSTA | 437993 | 4955478 | 1971 | 1972 | 1 | Daily |
| NORTH AUGUSTA MAHONEY | 441935 | 4953589 | 1974 | 1980 | 6 | Daily |
| NORTH GOWER | 443647 | 4998012 | 1902 | 1925 | 23 | Daily |
| NORTH GOWER | 441647 | 4994327 | 2001 | 2005 | 4 | Daily |
| OAK VALLEY | 471210 | 4983110 | 1998 | 2006 | 8 | Daily |
| ORLEANS VEH PRVG GND | 455689 | 5033098 | 1953 | 1958 | 5 | Daily |
| OTTAWA ALBION RD | 450374 | 5020176 | 1954 | 1954 | 0 | Daily |
| OTTAWA ALTA VISTA | 441284 | 5025809 | 1961 | 1963 | 2 | Daily |
| OTTAWA BECKWITH RD | 447823 | 5027603 | 1955 | 1961 | 6 | Daily |
| OTTAWA BILLINGS BRIDGE | 449083 | 5022038 | 1953 | 1954 | 1 | Daily |
| OTTAWA BRITANNIA | 437351 | 5023995 | 1972 | 1984 | 12 | Daily |
| OTTAWA CDA | 452300 | 754300 | 1889 | 2013 | 124 | Daily |
| OTTAWA CDA RCS | 443894 | 5025785 | 2003 | 2006 | 3 | Hourly |
| OTTAWA CITY HALL | 445247 | 5031328 | 1966 | 1975 | 9 | Daily |
| OTTAWA HAZELDEAN | 429458 | 5018523 | 1969 | 1969 | 0 | Daily |
| OTTAWA HOGS BACK | 446488 | 5023911 | 1953 | 1954 | 1 | Daily |
| OTTAWA INT'L | 447747 | 5018345 | 2011 | 2013 | 2 | Hourly |
| OTTAWA KANATA | 428173 | 5020389 | 1969 | 1969 | 0 | Daily |
| OTTAWA LA SALLE ACAD | 445247 | 5031328 | 1954 | 1967 | 13 | Daily |
| OTTAWA LEMIEUX ISLAND | 442623 | 5029500 | 1953 | 1979 | 26 | Daily |
| OTTAWA MACDONALD-CARTIER INT'L A | 447551 | 5018347 | 1938 | 2011 | 73 | Daily |
| OTTAWA NEPEAN | 441284 | 5025809 | 1960 | 1961 | 1 | Daily |
| OTTAWA NRC | 451779 | 5033127 | 1952 | 1984 | 32 | Daily |
| OTTAWA RIDEAU WARD | 450432 | 5027582 | 1972 | 1975 | 3 | Daily |
| OTTAWA ROCKCLIFFE | 450476 | 5033137 | 1942 | 1964 | 22 | Daily |
| OTTAWA SOUTH MARCH | 426888 | 5022256 | 1969 | 1969 | 0 | Daily |
| OTTAWA STOLPORT A | 449188 | 5034999 | 1974 | 1976 | 2 | Hourly |
| OTTAWA U OF O | 446535 | 5029466 | 1954 | 1955 | 1 | Daily |
| RAMSAYVILLE CRF | 456967 | 5029386 | 1972 | 1976 | 4 | Daily |
| RICHMOND | 433221 | 5003668 | 1971 | 1972 | 1 | Daily |
| RICHMOND | 438441 | 5001764 | 1973 | 1974 | 1 | Daily |
| RICHMOND | 433221 | 5003668 | 1981 | 1984 | 3 | Daily |
| RIDEAU C BURRITS RAPIDS | 436929 | 4981410 | 1954 | 1969 | 15 | Daily |
| RIDEAU CANAL KILMARNOCK | 426290 | 4970414 | 1954 | 1969 | 15 | Daily |
| RIDEAU CANAL LONG | 445070 | 5010961 | 1954 | 1969 | 15 | Daily |

| | | | | | | |
|---|---|---|---|---|---|---|
| ISLAND | | | | | | |
| RUSSELL | 471799 | 5012206 | 1954 | 2013 | 59 | Daily |
| SARSFIELD | 472623 | 5031150 | 1985 | 1989 | 4 | Daily |
| SHIRLEY BAY | 430805 | 5022212 | 1954 | 1956 | 2 | Daily |
| SOUTH MOUNTAIN | 461884 | 4979361 | 1960 | 1996 | 36 | Daily |
| SPENCERVILLE | 456539 | 4966435 | 1953 | 1959 | 6 | Daily |
| ST ALBERT | 495011 | 5014860 | 1986 | 2011 | 25 | Daily |
| ST ELMO | 511757 | 5018140 | 1966 | 1982 | 16 | Daily |
| ST RAPHAEL | 532716 | 5007104 | 1972 | 1973 | 1 | Daily |
| VANKLEEK HILL | 527336 | 5040408 | 1902 | 1961 | 59 | Daily |
| WHITE LAKE FISH CULTURE STATION | 440870 | 4957642 | 2005 | 2005 | 0 | Daily |
| WINCHESTER | 473489 | 4988683 | 2003 | 2007 | 4 | Hourly |
| WINCHESTER CS | 473751 | 4988559 | 1998 | 2001 | 3 | Daily |

**Table 7: Historical Weather Stations within or immediately surrounding the SNC Jurisdiction.**

## 6.4 Appendix 5: Streamgauges

Streamgauges depicted below are located within the SNC jurisdiction and are either owned and operated by Environment Canada or Ontario Ministry of Natural Resources. Data can be accessed through the Environment Canada HYDAT database.

| Station ID | Location | Easting | Northing | Start Date | End Date | Years Active ** | Drainage Area ($km^2$) | Data Type * |
|---|---|---|---|---|---|---|---|---|
| 02LB005 | SNR near Plantagenet | 501700.9 | 5040379.2 | 1905 | 2014 | 109 | 3810 | L, Q |
| 02LB006 | Castor River at Russell | 473026.9 | 5012169 | 1948 | 2014 | 66 | 433 | L, Q |
| 02LB007 | SNR at Spencerville | 456974.1 | 4965570.8 | 1948 | 2014 | 66 | 246 | L, Q, R |
| 02LB008 | Bear Brook near Bourget | 488013.6 | 5030286.8 | 1949 | 2014 | 65 | 440 | L, Q |
| 02LB009 | SNR at Chesterville | 482212.5 | 4994204.4 | 1949 | 2014 | 65 | 1050 | L, Q |
| 02LB012 | East Branch Scotch River near St. Isidore | 429523.9 | 5024417.1 | 1978 | 1983 | 5 | 76 | L,Q |
| 02LB013 | SNR at Casselman | 492815.2 | 5018167.1 | 1972 | 2014 | 42 | 2410 | L, Q, R |
| 02LB014 | SNR below | 492728.7 | 5018688.7 | 1979 | 1983 | 4 | 145 | L,Q |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Casselman | | | | | | | |
| 02LB015 | SNR at Lemieux | 494868.8 | 5026833.5 | 1978 | 1983 | 5 | 72 | L,Q |
| 02LB016 | Little Castor River Near Embrun | 482873.4 | 5013122.2 | 1970 | 1994 | 24 | 77 | L,Q |
| 02LB017 | North Branch SNR near Heckston | 459301.5 | 4982518.5 | 1977 | 2014 | 37 | 69 | L, Q |
| 02LB018 | West Branch Scotch River near St. Isidore | 504071.5 | 5024647.9 | 1979 | 2012 | 33 | 100 | L, Q |
| 02LB019 | South Indian River near Limoges | 480421 | 5023313 | 1972 | 1995 | 23 | 2410 | L |
| 02LB020 | South Castor River at Kenmore | 467600.6 | 5008398.7 | 1979 | 2014 | 35 | 189 | L, Q |
| 02LB021 | East Castor River near Russell | 474443.5 | 5008398.3 | 1972 | 1982 | 10 | - | L |
| 02LB022 | Payne River near Berwick | 491780.4 | 5004241.6 | 1976 | 2014 | 38 | 152 | L, Q |
| 02LB027 | Black Creek near Bourget | 492000.2 | 5027916.6 | - | - | - | 17.7 | Q |
| 02LB028 | Bear Brook above Bourget | 477826.7 | 5027302.5 | - | - | - | 168 | L |
| 02LB029 | SNR at Sequin Bridge | 504517.5 | 5033591.4 | 1993 | 1994 | 1 | - | L |
| 02LB030 | SNR at Pendleton Bridge | 496045.1 | 5030319.8 | 1993 | 1995 | 2 | - | L |
| 02LB031 | South Branch SNR near Winchester Springs | 471461.3 | 4982785.8 | 1998 | 2014 | 16 | 303 | L, Q |

*Data Type: L (water level), Q (flow), R (rainfall)

**Note: This duration includes years with incomplete or missing data.

**Table 8: Historical streamgauges within the South Nation jurisdiction**

## 6.5 Appendix 6: Baseflow calculations (Toronto Region Conservation Authority)

The Toronto Region Conservation Authority also participates in the OLWR program. In addition to monitoring streamflow and precipitation, TRCA has developed a methodology for measuring baseflow and groundwater within their watershed. Although not specifically linked to the LWR program, groundwater and baseflow monitoring have implications for water recharge into streams and plays a significant role in the severity of drought. The long term goal of the TRCA Low Flow program is to guide the management and protection of baseflow levels to protect aquatic life and ensure sustainable human use of surface water.

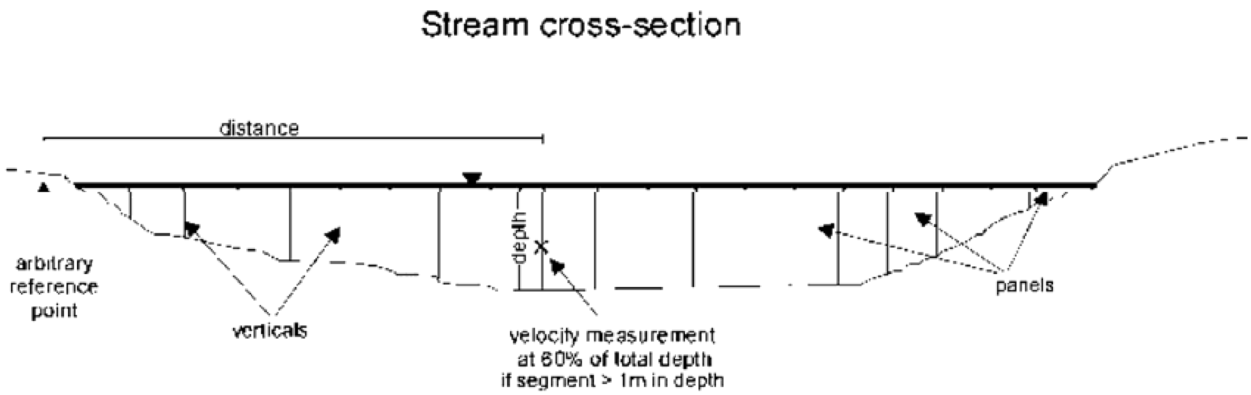
TRCA determines the following in their low flow program, relating specifically to baseflow:

1. Monitor current baseflow levels in terms of volume, flow rates, seasonal fluctuations, and spatial gains/losses of water along individual watercourses.
2. Identify key factors influencing observed baseflow patterns, including groundwater recharge/discharge zones and withdrawals for human use.
3. Review and field validate current and expired MOE Permits to Take Water through baseflow measurements and user surveys.
4. Determine "threshold" baseflow quantities for the protection of aquatic life in association with aquatic ecosystem biologists.
5. Identify options for managing sensitive recharge/discharge zones and other areas with baseflow quantities that currently pose a risk to aquatic life.
6. Develop a better understanding of groundwater/surface water interactions as part of a larger effort to refine watershed water budget estimates and hydraulic modeling.

In order to collect baseflow data, TRCA uses guidelines based on the Geological Survey of Canada protocol. Site locations termed "baseflow endpoints" are located at the outflow of the Watershed and are representative of subwatershed catchments in the TRCA region.

Measurements are taken during late summer at times when there is no surficial runoff present and at a minimum 72 hours after the most recent precipitation event. This ensures that the measurements are comprised entirely of baseflow. The following parameters are recorded:

- Baseflow discharge
- Date and time of sampling
- Water temperature
- Air temperature
- Weather conditions
- Site photographs (upstream/downstream)
- Stage/discharge measurements (where applicable)
  - Culvert / bridge heights
  - Water depths
- Low Flow Channel cross sections
  - width and depth
  - Top of bank height and width




Measurements collected at each baseflow endpoint (indicator station) can be used to determine the percentage of baseflow contribution for each subwatershed. This is derived by calculating the difference between the baseflow at the endpoints directly upstream from each other. Factors affecting the change in baseflow contribution can be evaluated as well (i.e. geology, physiography, natural, and non-natural contributions). Changes greater than 10% between sites will be examined more closely. Changes in baseflow over time can be also determined if data at these stations is collected over multiple seasons or years. This allows for valuable assessments on the effects of anthological activities and structures on groundwater recharge and baseflow.

In particular, water takings for industrial, commercial and agricultural use can have severe impacts on surface water, groundwater and baseflow. In order to quantify site specific impacts of this, TRCA has developed a vulnerability assessment using stream gauge and Permit to Take Water (PTTW) data which classifies surface water users into risk categories.

**Table A: Ratings for the potential impact of water users on baseflow.**

| Percent baseflow required for individual permitted withdrawal | Potential impact rating |
|---|---|
| 0 | No known impact |
| 0 0.01 – 5 | Low impact |
| 5.01 – 25 | Medium impact |
| >25 | High impact |

These values were determined using average daily withdrawals (L/s) based on amounts and duration. The percentage between the baseflow amount in the area and the withdrawals was used to assess the potential impacts on the low flow system, and impact ratings were assigned.

The use of these calculations and impact ratings could be modified for use in a low water program either to formulate new indicator thresholds pertaining to baseflow, or in implementing new restrictions on water takers in the SNC jurisdiction.

## 6.6 Appendix 7: Maps

1. **Streamgauge and weather stations:** Streamgauges and weather stations currently in use by the OWLR program or are monitored by SNC on a daily basis for water control structure use.

2. **Potential stream gauges:** Due to the lack of flow data available for the St. Lawrence Region, two potential gauges have been proposed for consideration.

3. **PGMN stations:** Groundwater monitoring is currently conducted by SNC at the following locations. Sites where an adequate amount of data is available, there is potential for use in the OLWR.

4. **Delineation by Streamgauge:** SNC jurisdiction divided into smaller stream gauge areas. It is recommended to declare Low Water in each stream gauge area independent of the others and can be more specific to the areas' drought conditions. Declarations would be based on the streamgauge directly downstream of the area or the precipitation gauge in closest proximity. For the purposes of an even distribution, this map makes the assumption that streamgauges at the control structures will be utilized for OLWR.

5. **Delineation by streamgauge excluding control structures:** Streamgauge Delineation without control structures to demonstrate the need for gauge readings in the central portion of the Watershed.

6. **Proximity from streamgauge**: Proximity of each declaration area based on distance from precipitation gauge (depicted in 5 km intervals). Cornwall and Ottawa gauges are currently being used to represent the entire jurisdiction. A nearby weather station located in Montebello may also be a feasible option for future Low Water declarations, as it would contains a substantial amount of historical data and would account for the more northern portion of the Watershed more applicably than Ottawa or Cornwall.

7. **Historical weather stations:** Weather stations historically within or immediately surrounding the South Nation Watershed. Information can be obtained through Environment Canada.

8. **Historical stream gauge:** Streamgauges historically within the South Nation jurisdiction. Information can be obtained through the Environment Canada HYDAT database.


# Map 1

## Stream Gauges and Weather Stations

South Nation Conservation de la Nation Sud

**Legend**

- Stream Gauge
- Weather Station
- Town
- International/Interprovincial Border
- Major Road
- Jurisdiction
- River
- Watershed

N

1:500,000

10 5 0 10 20 30

Kilometres

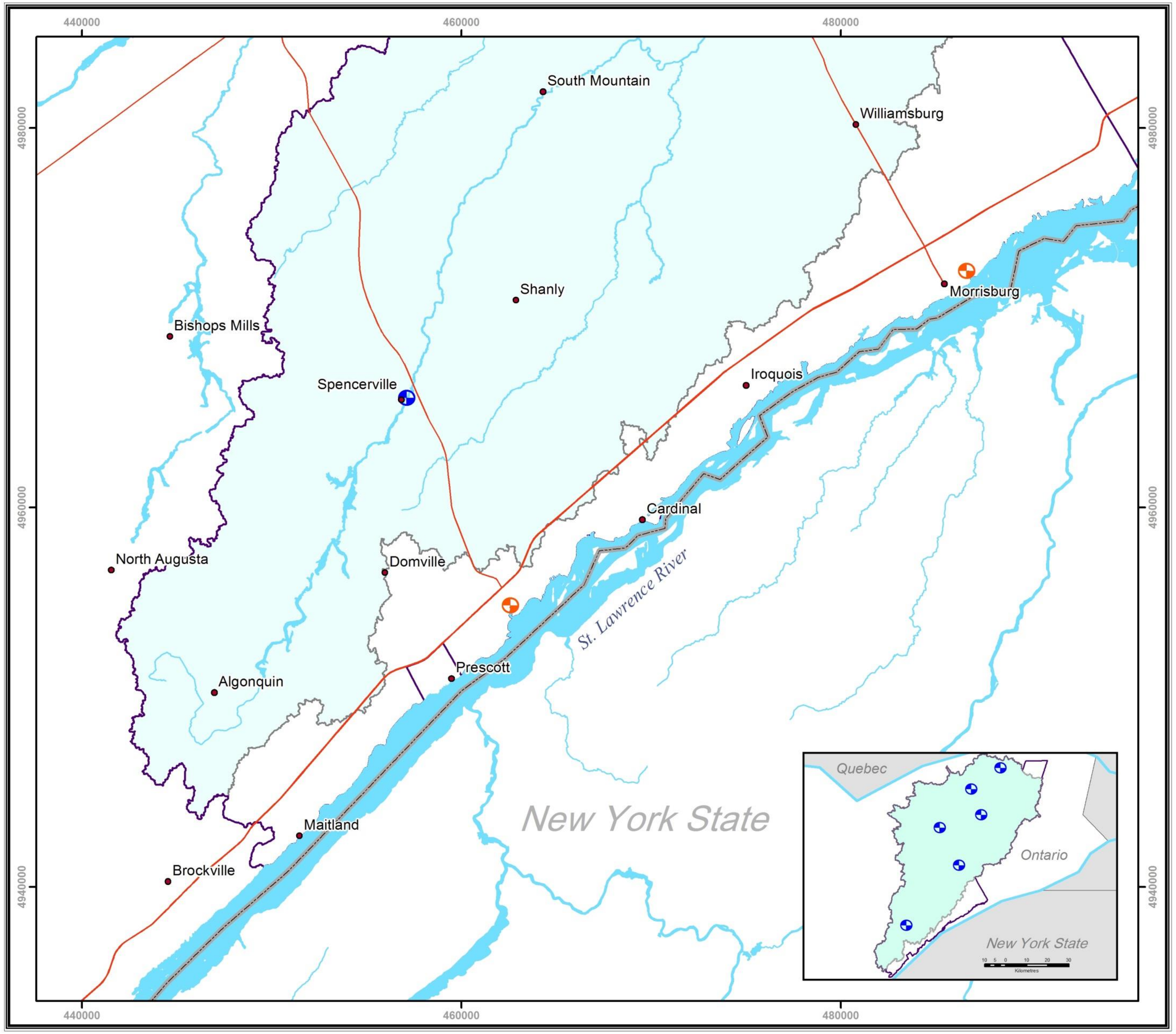
*North American Datum 1983, Zone 18*

**Created By:** *J. Edwards*
**Date Produced:** *March 31st 2014*
**Produced for:** *Water Stress Analysis Report*
**Project:** *\\1_StreamGaugeWeatherStations.mxd*

This map is for illustrative use only. Do not rely on it as being a precise indicator of routes, locations of features, nor as a guide to navigation. This map was originally produced in color and may not accurately represent the original purpose of the map if reproduced in black and white.

The source/base data is known to be the best available information provided through the Ontario Geospatial Data Exchange and by Ontario Ministry of Natural Resources, Ontario Ministry of Environment, Conservation Ontario and local Municipalities.

Additional data was provided by other provincial or municipal agencies and clearing houses.




# Map 2

## Potential Stream Gauges in the St. Lawrence Region

SOUTH NATION CONSERVATION DE LA NATION SUD

**Legend**

- Potential Gauge
- Stream Gauge
- Town
- International/Interprovincial Border
- Major Road
- River
- Jurisdiction
- Watershed

N

1:200,000

0 1.25 2.5 5 7.5 10

Kilometres

*North American Datum 1983, Zone 18*

**Created By:** *J. Edwards*
**Date Produced:** *March 31st 2014*
**Produced for:** *Water Stress Analysis Report*
**Project:** *\\2_PotStreamGauges.mxd*

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Additional data was provided by other provincial or municipal agencies and clearing houses.

# Map 5

## Provincial Groundwater Monitoring Network (PGMN) Stations

South Nation Conservation / de la Nation Sud


**Legend**

- PGMN Station
- Town
- City
- International/Interprovincial Border
- Major Road
- Jurisdiction
- River
- Watershed
- Delineated Boundary by Stream Gauge

N

1:500,000

10 5 0 10 20 30

Kilometres

*North American Datum 1983, Zone 18*

**Created By:** *J. Edwards*
**Date Produced:** *March 31st 2014*
**Produced for:** *Water Stress Analysis Report*
**Project:** *\\5_PGMNStations.mxd*

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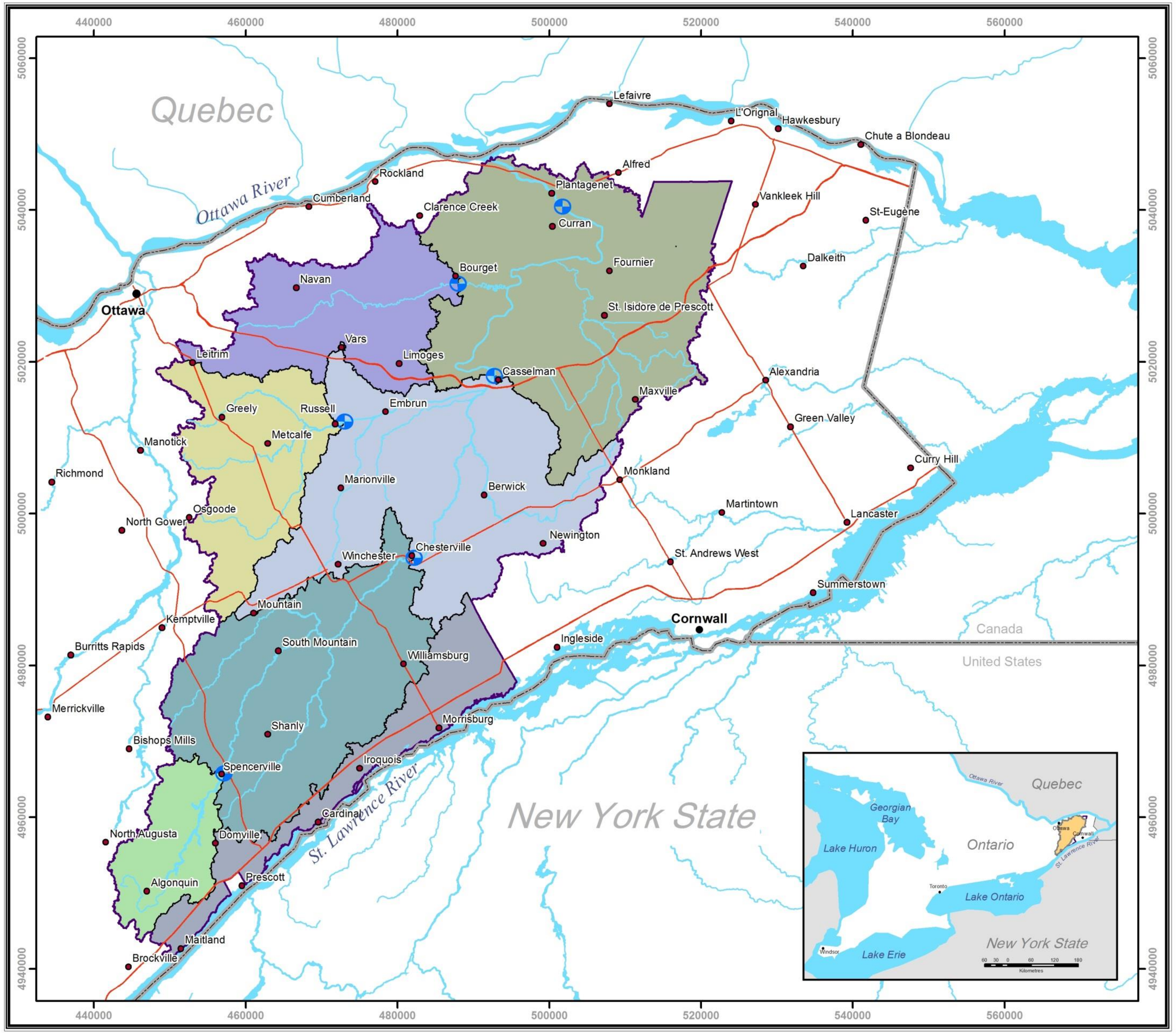
The source/base data is known to be the best available information provided through the Ontario Geospatial Data Exchange and by Ontario Ministry of Natural Resources, Ontario Ministry of Environment, Conservation Ontario and local Municipalities.

Additional data was provided by other provincial or municipal agencies and clearing houses.




# Map 6

## Delineation by Stream Gauge

South Nation Conservation de la Nation Sud

**Legend**

- Stream Gauge
- Town
- City
- International/Interprovincial Border
- Major Road
- Jurisdiction
- River

**Delineation by Stream Gauge**

- Plantagenet
- Bourget
- Casselman
- Russell
- Chesterville
- Spencerville
- St. Lawrence

N

1:500,000

10 5 0 10 20 30

Kilometres

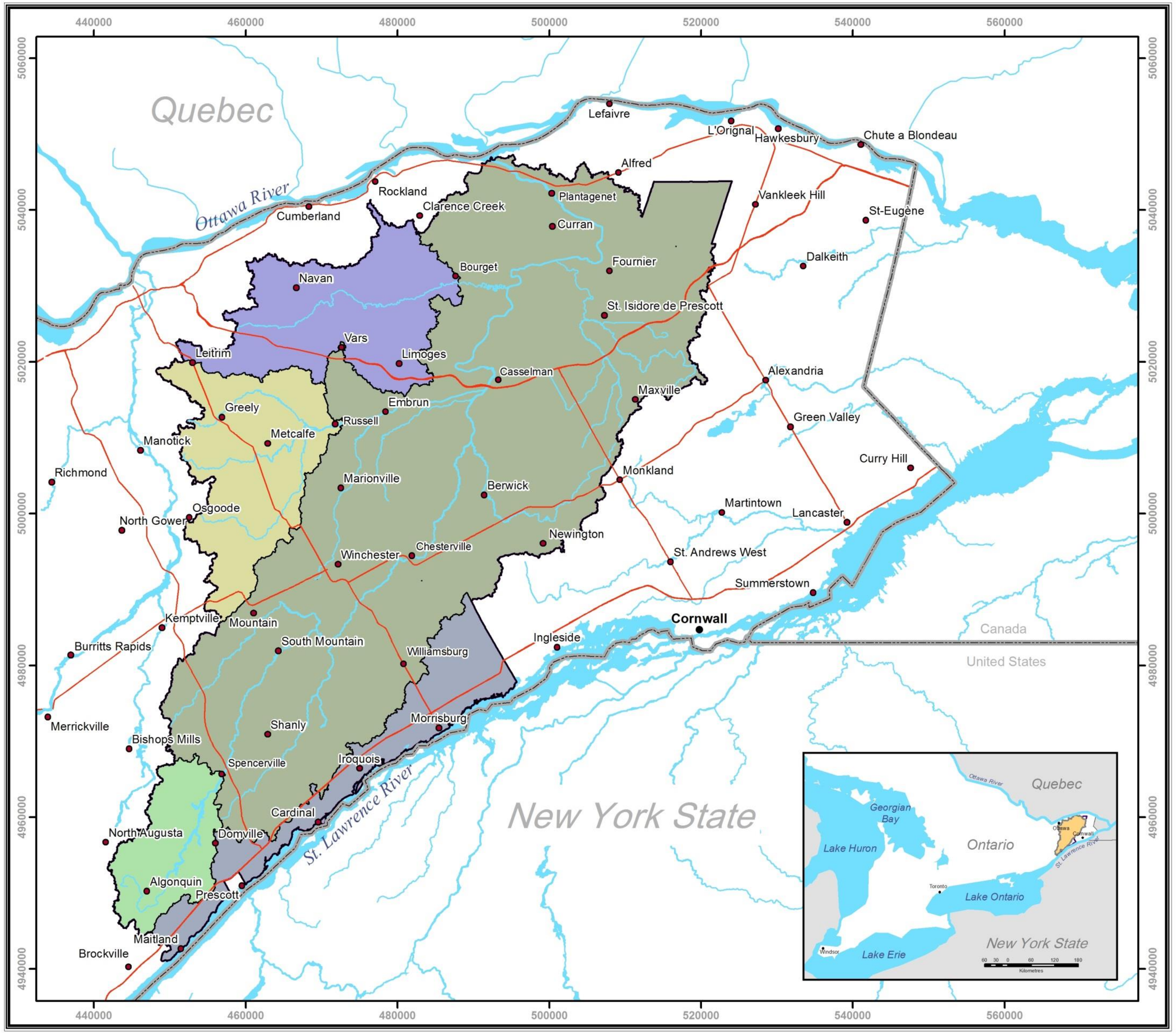
*North American Datum 1983, Zone 18*

**Created By:** *J. Edwards*
**Date Produced:** *March 31st 2014*
**Produced for:** *Water Stress Analysis Report*
**Project:** */6_StreamGaugeDelineation.mxd*

This map is for illustrative use only. Do not rely on it as being a precise indicator of routes, locations of features, nor as a guide to navigation. This map was originally produced in color and may not accurately represent the original purpose of the map if reproduced in black and white.

The source/base data is known to be the best available information provided through the Ontario Geospatial Data Exchange and by Ontario Ministry of Natural Resources, Ontario Ministry of Environment, Conservation Ontario and local Municipalities.

Additional data was provided by other provincial or municipal agencies and clearing houses.




# Map 7

## Delineation by Stream Gauge Excluding Control Structures

**Legend**

- City
- Town
- International/Interprovincial Border
- Major Road
- Jurisdiction
- River

**Delineation by Stream Gauge**

- Bourget
- Plantagenet
- Russell
- Spencerville
- St. Lawrence

N

1:500,000

10 5 0 10 20 30

Kilometres

*North American Datum 1983, Zone 18*

**Created By:** *J. Edwards*
**Date Produced:** *March 31st 2014*
**Produced for:** *Water Stress Analysis Report*
**Project:** *\\7_StreamGaugeDelineation.mxd*

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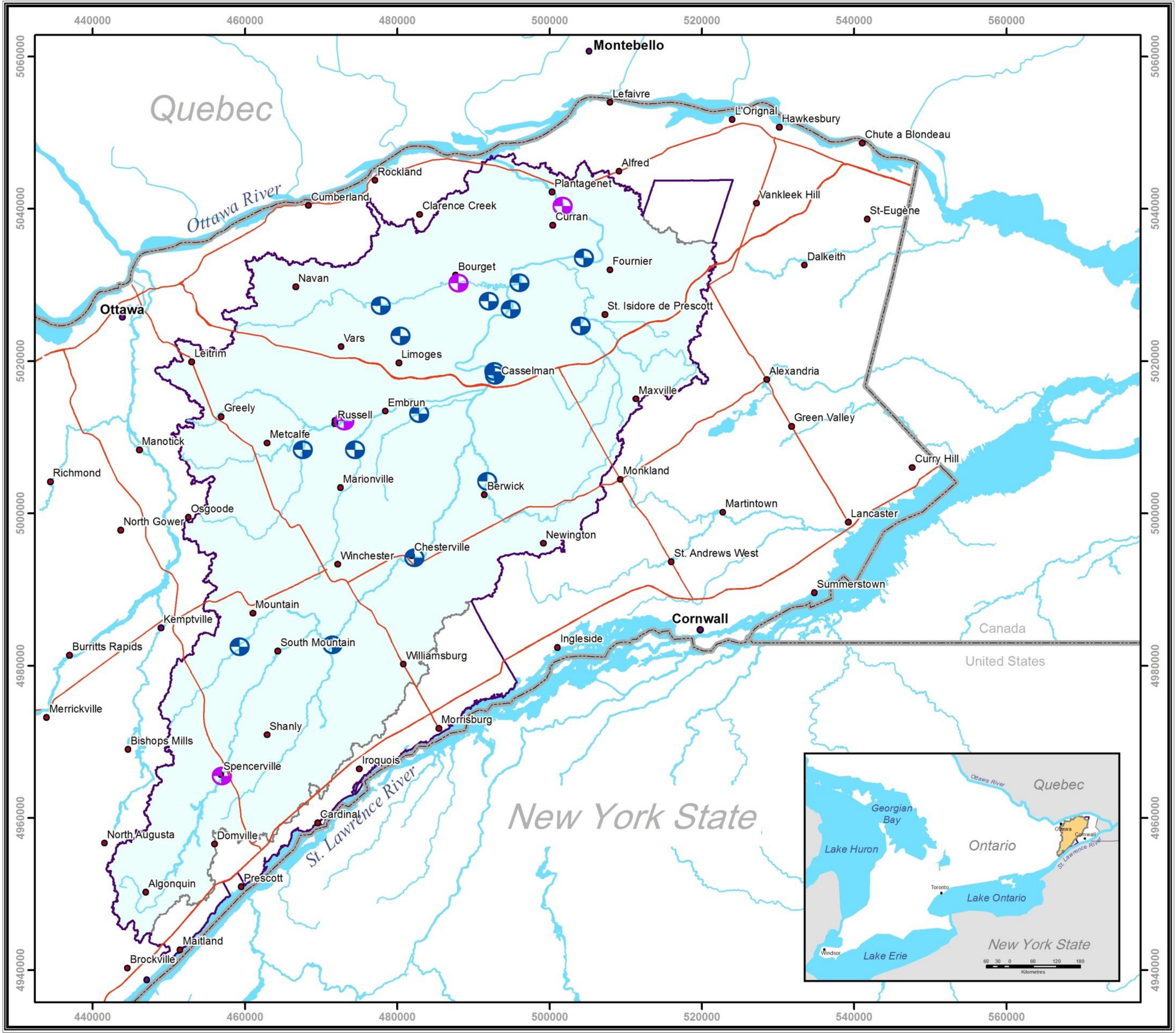
Additional data was provided by other provincial or municipal agencies and clearing houses.

# Map 15

## Historical Stream Gauges




SOUTH NATION CONSERVATION DE LA NATION SUD

**Legend**

- OLWR Stream Gauge
- Historical Stream Gauge
- City
- Town
- International/Interprovincial Border
- Major Road
- Jurisdiction
- River
- Watershed

N

1:500,000

10 5 0 10 20 30

Kilometres

*North American Datum 1983, Zone 18*

**Created By:** *J. Edwards*
**Date Produced:** *March 31st 2014*
**Produced for:** *Water Stress Analysis Report*
**Project:** *\\15_VolunteerStreamG.mxd*

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The source/base data is known to be the best available information provided through the Ontario Geospatial Data Exchange and by Ontario Ministry of Natural Resources, Ontario Ministry of Environment, Conservation Ontario and local Municipalities.

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