Appendix A

Flow Characteristics of Harrington Creek at Harrington Dam and Youngsville Drain at Embro Dam

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Purpose

To properly assess and design the different options that exist in regards to Harrington Dam and Embro Dam it is necessary to understand the streamflow characteristics of the water courses that pass through these water control structures. This report informs of the methodology, calculations, and data that has been collected to date for the Harrington Creek at the Harrington Dam and the Youngsville Drain at the Embro Dam. This report will also provide an analysis of the collected data as it relates to different stream flow characteristics including:

i) The average flow rates and the unit area flow rate of each catchment area
ii) The response of each stream to drought and low water conditions
iii) The contribution of each stream to the overall flow out of its subwatershed
iv) The effect of the water control structures on upstream and downstream flow rates

Stream flow response under flood conditions has not been evaluated in this report. Flood information is available in the respective Dam Safety reports for each dam.

Stream Flow Measurement Methods

Harrington – Stream Flow Measurement

In 2008, a HOBO data logger was installed on the pier of the Road 96 bridge in between Elizabeth St. and Victoria St. A pressure sensor in the unit measures the absolute pressure exerted upon it and the logger records this measurement every 15 minutes. Using barometric (atmospheric) pressure data from the London International Airport, pressure to head calculations, and in field measurements of water levels at the logger, it was possible to create a time series record of the water level in Harrington Creek at the location of the bridge pier.

The data logger recorded absolute pressures from:

i) May 24, 2008 – April 9, 2011
ii) March 26, 2012 – September 12, 2012
iii) April 23, 2015 – August 28, 2015

Irregular results were observed in the Harrington logger data from:

i) Nov. 11, 2008 – Mar. 11, 2009
ii) Dec. 5, 2009 – Mar. 23, 2010
iii) Nov. 20, 2010 – April 9, 2011

These irregular results were omitted from the water level calculation and the subsequent calculation and analysis of flows. The omitted irregular results coincided with colder water temperatures (<5^{o}C) and the time periods where snow and/or freezing could be expected. These winter conditions are considered to be the probable cause of the irregular logger readings.

A cross section approximately 20 – 30 m downstream from the bridge, in a stretch relatively clear of in-stream obstacles and eddies, was used to measure the flow of Harrington Creek downstream of the dam. A measuring tape was staked on both sides of the creek and was orientated perpendicular to the flow direction. A sliding depth gauge rod was used to measure the depth of the creek and to position the sensor of the Marsh McBirney 2000 Flo-mate velocity meter at 60% of the stream depth. A measurement was made approximately every 20 – 25 cm horizontally across the creek depending on the characteristics of the channel bed and the stream flow. At each measurement the stream depth, velocity at 60% of the stream depth, and the horizontal distance across the cross section was measured and recorded. The mid-section method, the primary method for calculating flows by the United States Geological Survey, was used to calculate the flow in Harrington Creek.

From July 2010 to August 2015, the field measured flow rate of Harrington Creek and the corresponding water level on the bridge pier staff gauge was recorded a total of ten times in a variety of high, low, and average flow conditions. Additionally on June 11, July 22, and August 28, 2015, the flow rate was also measured at cross sections 80 m upstream from the farm crossing South of Harrington Pond.

The location of the cross-sections where stream flow was measured at Harrington is indicated below in

Figure 1. The total catchment area for the most downstream cross section with the largest number of flow measurements is illustrated in Figure 2.

Figure 1: Locations of Cross Sections Used for Stream Flow Measurement at Harrington

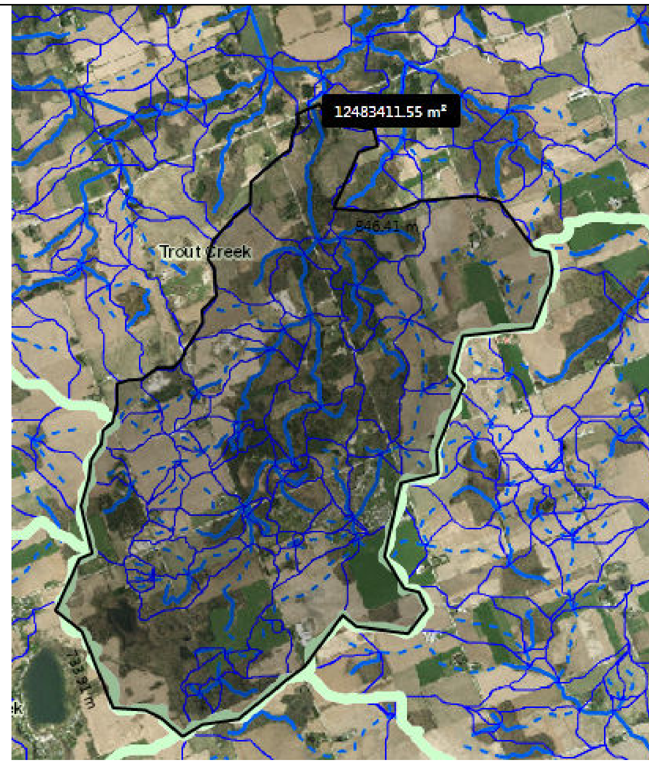

Figure 2: Catchment Area for Harrington Logger

A rating curve was developed to indicate the relationship between the stream flow measured at the most downstream cross section and water level at the Road 96 Bridge Pier; this relationship would allow the conversion of the time series of water level data into a time series of flows. It was determined that there was a logarithmic relationship between the stream flow in liters per second (L/s) and the water level in meters (m).

The observed water levels on the staff gauge and the measured flows have been provided in Table 1 and the rating curve has been provided in Figure 3.

Table 1: Observed Stage (m) and Measured Flow (L/s) of Harrington Creek by Road 96

Stage (m)	Flow (L/s)
0.140	120
0.150	120
0.170	150
0.180	150
0.182	200
0.190	180
0.220	250
0.230	280
0.275	480
0.309	680

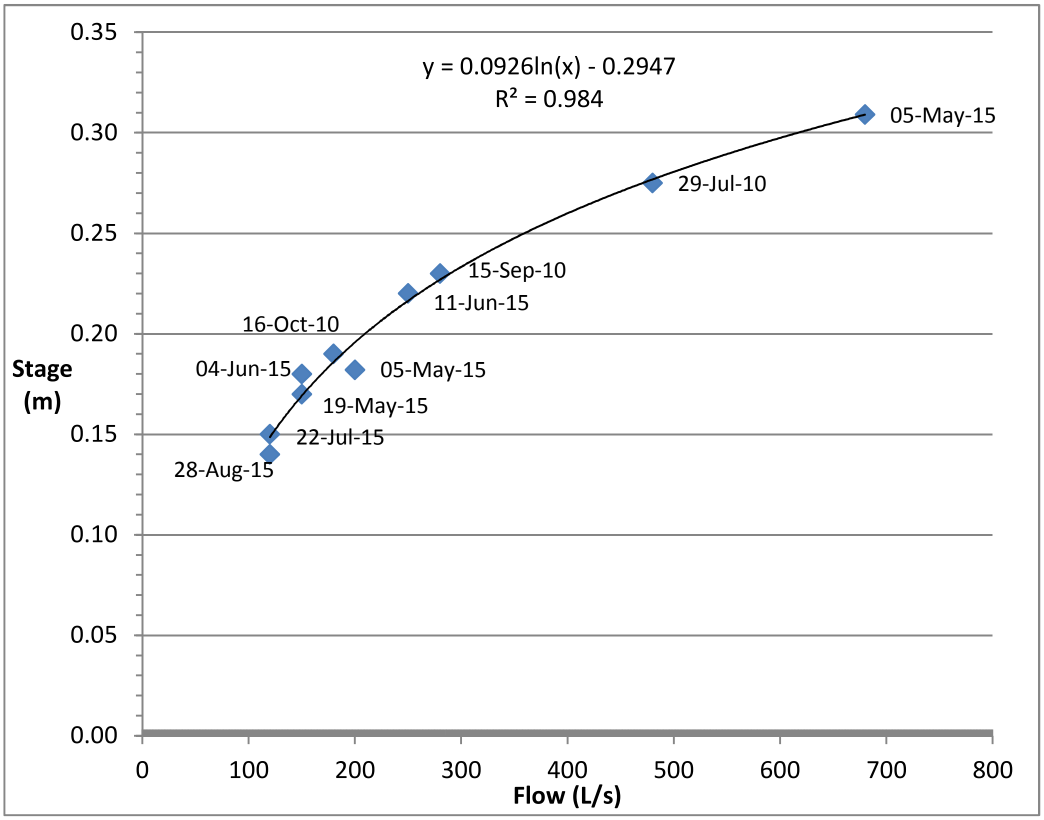

Figure 3: Rating Curve of Harrington Creek by Road 96

To determine the average unit area flow rate the average flow rate from the flow time series was divided by the total catchment area for Harrington Creek at the cross-section 20-30 m downstream of Harrington Dam. The catchment area was approximately 1,248 hectares (ha). The catchment area was determined using contour maps, tile drainage maps, outlines of subwatersheds, and the UTRCA Mapviewer calculator.

Embro – Stream Flow Measurement

There is no HOBO data logger or stream gauge to produce a record of pressure from which a time series of the water level or a time series of flows could be derived. There is also no staff gauge present at Embro which prohibits the development of a rating curve. A series of flow measurements were undertaken at Embro in conjunction with flow measurements at Harrington. The flow measurements at Embro were performed in the same manner as previously described for Harrington. The flow measurements were performed at a cross section approximately 25 m downstream of the outlet for Embro Dam. Additionally on June 11, July 22, and August 28, 2015, the flow rate was also measured at a cross section upstream of Embro pond, approximately 100 m upstream from the culvert on the North side of Road 84.

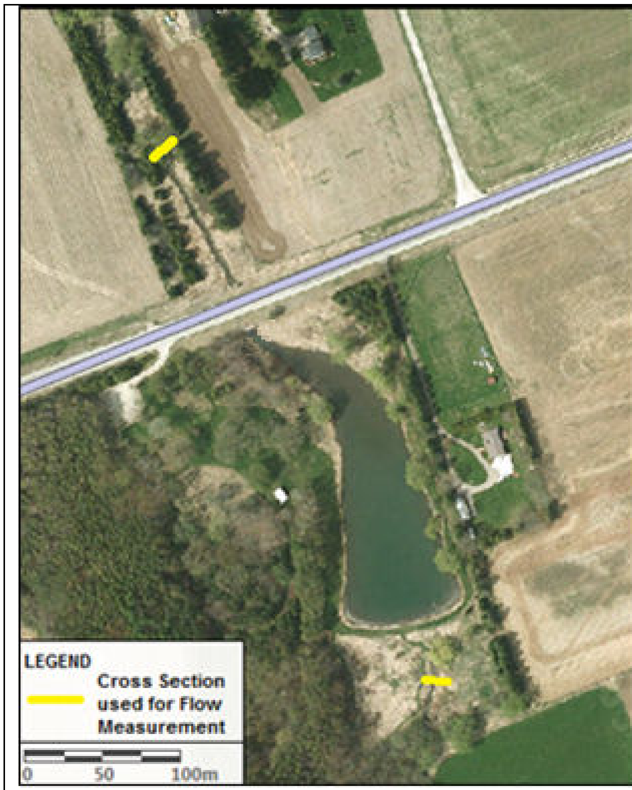

Figure 4: Locations of Cross Sections Used for Stream Flow Measurement at Embro

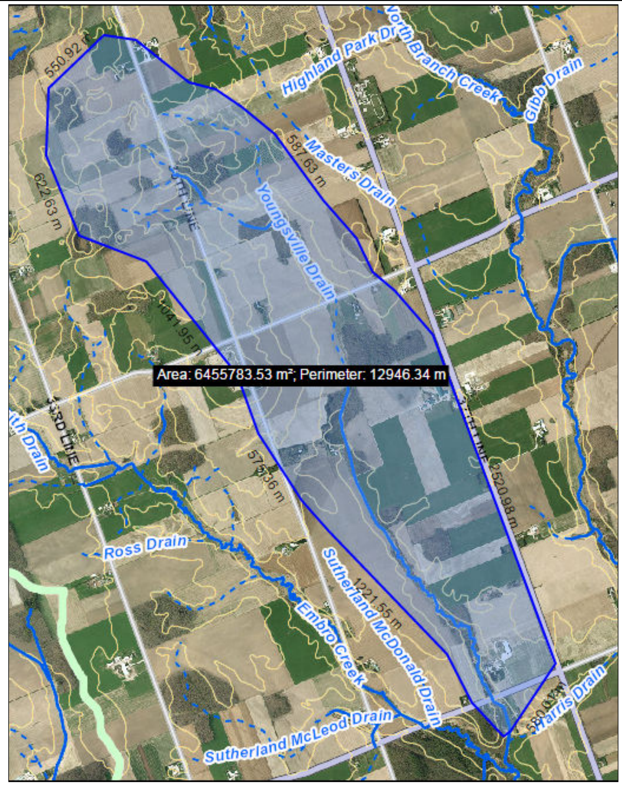

Figure 5: Catchment Area for most Downstream Cross Section at Embro Dam

The measured flow rate downstream of Embro Dam and the date of the measurement has been provided in Table 2.

Table 2: Measured Flow Rates (L/s) at Cross Section Downstream of Embro

Date	Embro Flow (L/s)
04-Jun-15	110
11-Jun-15	130
22-Jul-15	80
28-Aug-15	90
24-Sep-15	80

Analysis and Results

Harrington – Average Flow Rates and Unit Area Flow Rate

Times series flow data was used from other stream gauge monitoring stations to allow the comparison of the flow downstream of Harrington dam to the other flows from different catchment areas. A number of factors were considered when selecting which stream gauge monitoring stations to use, including:

- i) Size of the catchment area
- ii) Accuracy and reliability of the monitoring station
- iii) Unaffected by water control operations (i.e. unregulated flow)

The following stream gauge stations were determined to best fit these criteria:

- i) Fish Creek near Prospect Hill (02GD010)
- ii) Avon above Stratford (02GD019)
- iii) Trout Creek at Fairview (02GD019)
- iv) Trout Creek near St. Mary's (02G009)

It should be noted that the monitoring station Trout Creek near St. Mary's is affected by dam control operations at the Wildwood dam. Flood control operations and flow augmentation both have an effect on the flows experienced at the Trout Creek near St. Mary's monitoring station. During the summer months the readings at the Trout Creek Near St. Mary's station are also affected by vegetation growth, which result in artificially high readings. To reduce the error caused by vegetation growth the flows measured for the months of June, July and August were replaced by the outflows measured at Wildwood Dam.

To maintain consistency only flow records within the time periods of available data from the HOBO data logger of Embro were used for this comparison. The catchment areas listed on the Environment Canada Hydrometric Statistics Data Station Information were used for the unit area flow rate calculation.

Table 3 below summarizes the average flow (L/s) and the unit area flow rate ((L/s)/ha) calculated for downstream of Harrington dam and for the monitoring stations selected for comparison.

Table 3: Average Flow (L/s) and Average Unit Area Flow Rate ((L/s)/ha) for the Harrington logger, Trout Creek near Fairview, Avon River above Stratford, Fish Creek, and Trout Creek near St. Mary's

Gauge	Area (ha)	Average Flow (L/s) for:			Unit Area Flow Rate ((L/s)/ha) for:		
		May 24, 2008-April 9, 2011	Mar 26, 2012-Sept 12, 2012	April 23, 2015-August 28, 2015	May 24, 2008-April 9, 2010	Mar 26, 2012-Sept 12, 2012	April 23, 2015-August 28, 2015
Harrington Logger	1248	210	150	180	0.169	0.121	0.144
Trout Creek Near Fairview	3600	510	80	390	0.143	0.0226	0.109
Avon above Stratford	7450	860	510	540	0.115	0.0683	0.0725
Fish Creek	14435	2,020	280	1,240	0.140	0.0196	0.0859
Trout Creek Near St. Mary's	14927	2,070	1,220	1,700	0.139	0.0819	0.114

These results have been illustrated in Figure 6 and in Figure 7.

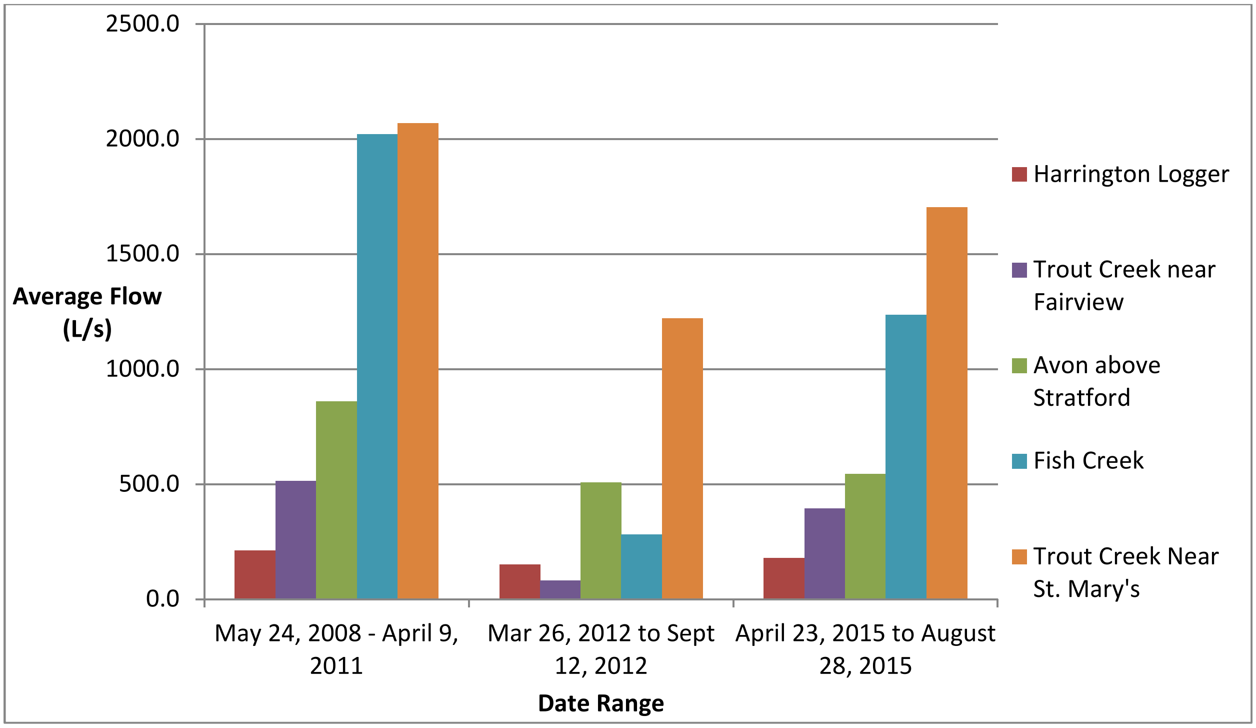

Figure 6: Average Flows (L/s) the Harrington logger, Trout Creek near Fairview, Avon River above Stratford, Fish Creek, and Trout Creek near St. Mary's

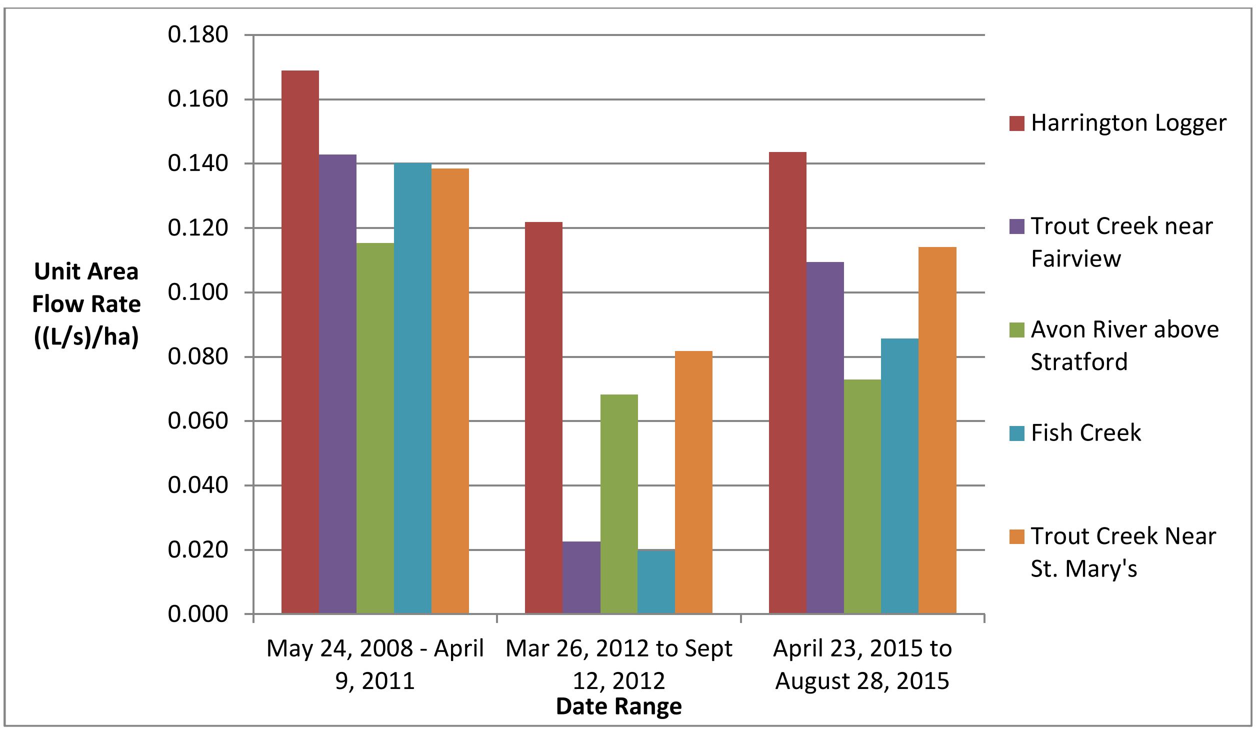

Figure 7: Average Unit Area Flow Rate ((L/s)/ha) of the Harrington logger, Trout Creek near Fairview, Avon River above Stratford, Fish Creek, and Trout Creek near St. Mary's

Harrington – Response to Drought and Low Water Conditions

From Table 3 above, it can be observed that the catchment area for the Harrington data logger was the smallest of the five catchment areas that were considered. The average stream flow at Harrington was the lowest of all of the water courses studied from May 24, 2008 – April 9, 2011 and from April 23, 2015 – August 28, 2015. The only time period where the average flow was not the lowest at Harrington was from March 26, 2012 – September 2012; this was a period of drought/low water condition as evidenced by the Low Water Level 2 status issued by the Upper Thames Low Water Response Team (UT-LWRT). The UT-LWRT implements the Ontario Low Water Response plan in the Upper Thames watershed. This plan entails communicating water conditions and advising on different water management techniques required to manage drought and low water conditions to the target audiences. A Low Water Level 2 status is only issued when stream flows are at approximately 50% of normal summer flows or when the watersheds precipitation for one month falls below 60% of the average precipitation. Figure 13, in the Precipitation section in the Appendix, illustrates the 30 Day Precipitation Totals from March 26, 2012 to September 12, 2012 measured at the Fairview station against the historical amounts. Additional precipitation data for all the flow periods of record is also located in the Precipitation section in the Appendix of this document. The percentage decrease of the average flow from May 24, 2008 – April 9, 2011 to March 26, 2012 – September 12, 2012 for each of the stream monitoring stations is summarized in Table 4.

Table 4: Percentage Decrease in Average Flow experienced from May 24, 2008 - April 9, 2011 to March 26, 2012 - September 12, 2012

Stream Flow Monitoring Station	Decrease in Average Flow Rate from May 24, 2008 – April 9, 2011 to March 26, 2012 – September 12, 2012
Harrington Logger	28%
Trout Creek near St. Mary's	41%
Avon above Stratford	41%
Trout Creek Near Fairview	84%
Fish Creek	86%

The stream gauge station on Trout Creek near St. Mary's is downstream of Wildwood dam and as such is affected by dam operations. A major factor in the moderate 41% decrease in average flow at Trout Creek near St. Mary's is due to low flow augmentation, which is the release of water stored in the Wildwood reservoir to supplement the low flows in the downstream watercourses. The moderate decrease in average flow at the Avon River above Stratford is likely due to moderate portion of the average flow being supplied by baseflow; the majority of this catchment area has been classified as having a medium groundwater recharge amount (~109 mm – 202 mm infiltrated/year) and is in close proximity to shallow overburden aquifers.

The relatively small decrease in flow at Harrington during the drought/low water condition is indicative of the fact that a large portion of the average flow at Harrington Creek is supplied by baseflow. The majority of the catchment area for the Harrington Logger has been previously classified as an area of high groundwater recharge (~415 mm – 470 mm infiltrated/year) and is in close proximity to shallow overburden aquifers. When the water level in the stream decreases below the level of the water table, groundwater flows into the stream resulting in a less significant decrease in stream flow. Areas of high groundwater recharge usually have higher volumes of water to contribute to the base flow of the streams in the area.

Figure 8 below illustrates the groundwater recharge characteristics of the Harrington catchment area and the Embro catchment area.

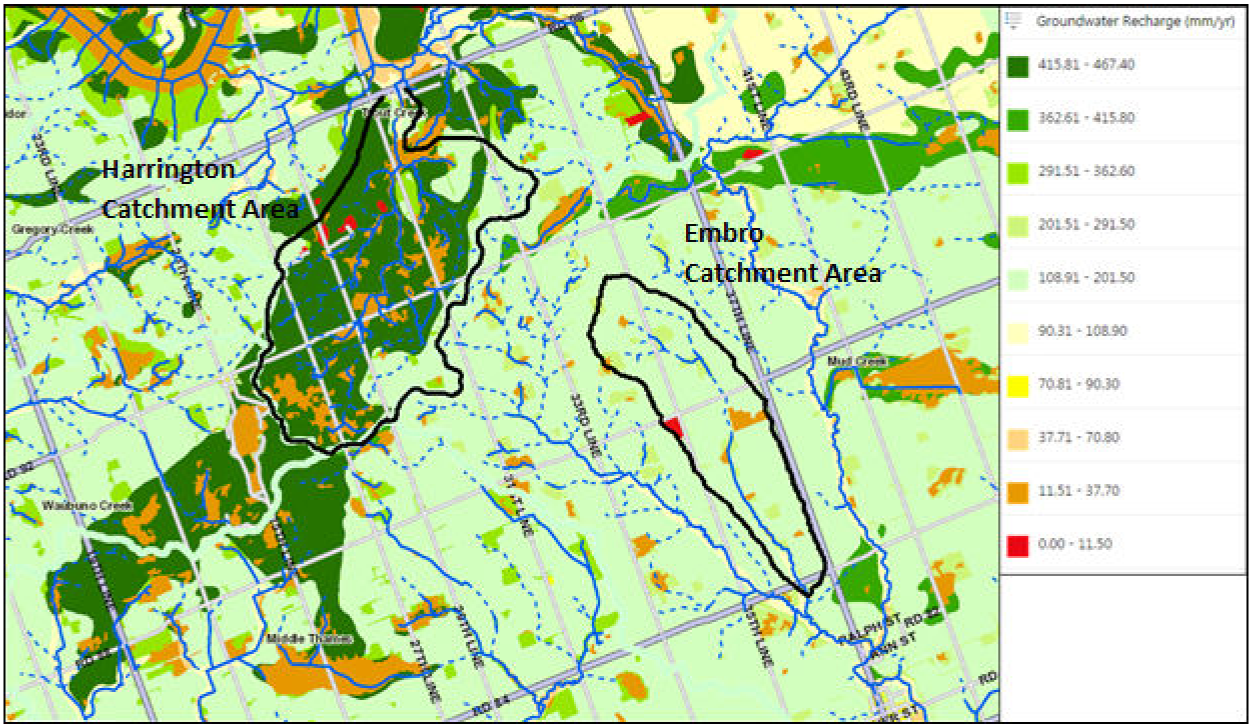

Figure 8: Groundwater Recharge Characteristics of the Harrington Catchment Area and the Embro Catchment Area

Harrington – Contribution to Subwatershed Flow

The catchment area for Harrington Creek, illustrated in Figure 2, composes approximately 8.4% of the total catchment area that drains to the Trout Creek near St. Mary's monitoring station. The Trout Creek near St. Mary's station is the most downstream stream gauge in the Trout Creek Subwatershed. From May 24, 2008 to April 9, 2011 and from April 23, 2015 to August 28, 2015, the flow from the catchment area for the Harrington logger equated to approximately 10.2% and 10.5% of the total flow that passes through the Trout Creek Subwatershed, respectively. These flow contributions are approximately 21% and 24% more than would be expected if estimates were based only on the size of the catchment area. During the drought/low water condition of 2012, the percentage of the total flow passing through the Trout Creek Subwatershed that originated in the catchment area for Harrington Creek increased to approximately 12.4%. This flow contribution during the drought/low water condition is approximately 48% more than the contribution that would be expected if estimates were based only on the size of the catchment area.

Harrington – Effect of Water Control Structures on Upstream and Downstream Flows

Table 5 summarizes the flows that were measured at the upstream and downstream locations at Harrington Dam.

Table 5: Flows measured Downstream of Harrington and Upstream of Backwater Effects from Harrington Dam

Date of Measurement	11-Jun-15	22-Jul-15	28-Aug-15
Flow downstream of Harrington Dam (L/s)	250	120	120
Flow upstream of Harrington Dam (L/s)	220	120	110
Upstream Flow as % of Downstream Flow	88%	100%	92%

At Harrington the flow upstream of the backwater effects of the dam was on average approximately 93% of the flow measured downstream of the dam.

This comparison was somewhat limited by the magnitude of the flows and the accuracy of the measurement equipment. With the flow meter only capable of measuring to the nearest 0.01 m/s and the average flow rate measured at Harrington being approximately 0.16 cubic meters per second (cms), rounding to the nearest 0.01 cms can have a significant effect on the answer. In addition to the accuracy limitations of the equipment, the effect of measuring the flow further upstream (which equates to a smaller catchment area) should also be considered when comparing the flows.

Embro – Average Flow Rates and Unit Area Flow Rate

As previously discussed there is no HOBO data logger or stream gauge monitoring station immediately downstream of Embro Dam. Obtaining a time series of flows of Youngsville Drain through Embro Dam was further complicated by the fact that there are no stream gauge monitoring stations in the Mud Creek subwatershed; the closest monitoring station is the Middle Thames monitoring station (02GD004) located near the intersection of 15th line and Road 64. The Middle Thames monitoring station is approximately 25km downstream from Embro Pond and as such, several creeks and drains have added to the flow from Embro pond, most notably:

- i) Embro Creek
- ii) Mud Creek Drain
- iii) Nissouri Creek
- iv) Kintore Creek

The catchment area that flows to Embro pond is approximately 645.6 ha and makes up approximately 2.1% of the total catchment area (30600 ha) that drains to the Middle Thames monitoring station. It was decided to not use the Middle Thames monitoring station to generate a time series estimate of the flows from downstream of Embro pond. The accuracy of back calculations from the measured flow downstream of Thamesford to a calculated flow downstream of Embro Dam would be negatively affected by weather events that occurred within the larger catchment area of the Middle Thames monitoring station but outside of the Embro pond catchment area. Back calculations would be further complicated by the different flow paths and travel times of the many different creeks and drains to the monitoring station.

With the catchment area for Embro pond being close in proximity to the catchment area for the Harrington logger it can be reasonably expected that the two catchment areas would experience similar weather patterns. As the flow measurements downstream of Embro Dam and Harrington Dam were performed on the same days it was possible to determine an estimate of the relationship between the two flows under similar conditions. Table 6 below provides the stream flow measurements obtained in 2015 downstream of the Embro dam and downstream of the Harrington.

Table 6: Embro Stream flow Measurements as a Percentage of Harrington Stream Flow Measurements

Date	Embro Flow (L/s)	Harrington Flow (L/s)	Embro flow as Percentage of Harrington flow
04-Jun-15	110	150	73%
11-Jun-15	130	250	52%
22-Jul-15	80	120	67%
28-Aug-15	90	120	75%
24-Sep-15	80	90	88%

The relationship between the flow at Harrington and the flow at Embro has been illustrated in Figure 9 below.

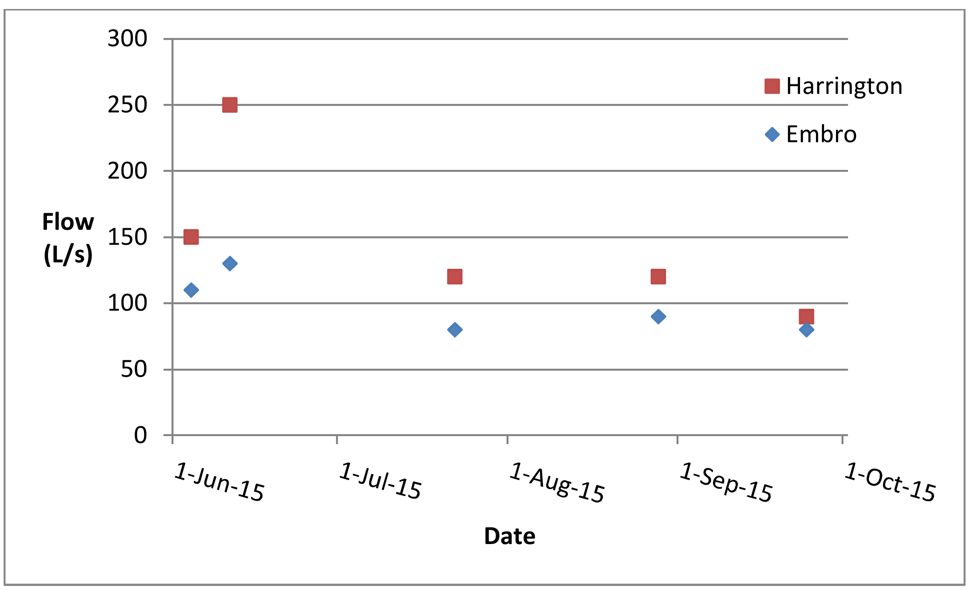

Figure 9: Comparison of Harrington and Embro Flows

Weighted average calculations were used to determine the average relationship of the flow rate measured downstream of Embro Dam in relation to the flow rate measured downstream of the data logger at Harrington. The steps for completing the weighted average calculation are detailed in Appendix - Weighted Average Calculation.

The weighted average calculations showed that the flow rate downstream of Embro Dam was approximately 69% of the flow rate near the Harrington data logger. By applying the relationship to the time series of flow rates from the Harrington data logger it was possible to estimate the average flow rate and the average unit area flow rate at downstream of Embro Dam.

Table 7 below summarizes the average flow (L/s) and the unit area flow rate ((L/s)/ha) calculated for the cross section 25 m downstream of Embro dam. These values are all based on the assumption that the flow rate downstream of Embro Dam is approximately equal to 69% of the flow rate at the Harrington data logger location.

Table 7: Average Flow (L/s) and Average Unit Area Flow Rate ((L/s)/ha) for calculated for Cross Section 25 m downstream of Embro Dam

Cross Section Location	Area (ha)	Average Flow (L/s) for:			Unit Area Flow Rate ((L/s)/ha) for:		
		May 24, 2008-April 9, 2011	Mar 26, 2012-Sept 12, 2012	April 23, 2015-August 28, 2015	May 24, 2008-April 9, 2010	Mar 26, 2012-Sept 12, 2012	April 23, 2015-August 28, 2015
Downstream of Embro Dam	645.6	150	100	120	0.232	0.155	0.186

Embro – Response to Drought and Low Water Conditions

The majority of the Embro catchment area has been classified as having a medium amount of groundwater infiltration approximately between 109 mm and 201 mm infiltrated per year. For this analysis it has been assumed that the response to drought/low water conditions of flows from the Youngsville drain will be similar to the response observed at Harrington. This assumption is based on flow measurements during non-drought years, field observations of multiple springs in the area, materials which indicate the presence of an aquifer (i.e. gravel pit), and the close proximity of areas classified as shallow aquifers to the Youngsville Drain catchment area. A map from the Thames River Basin Water Management Study Technical Report showing the predicted locations of shallow aquifers has been provided below in Figure 10.

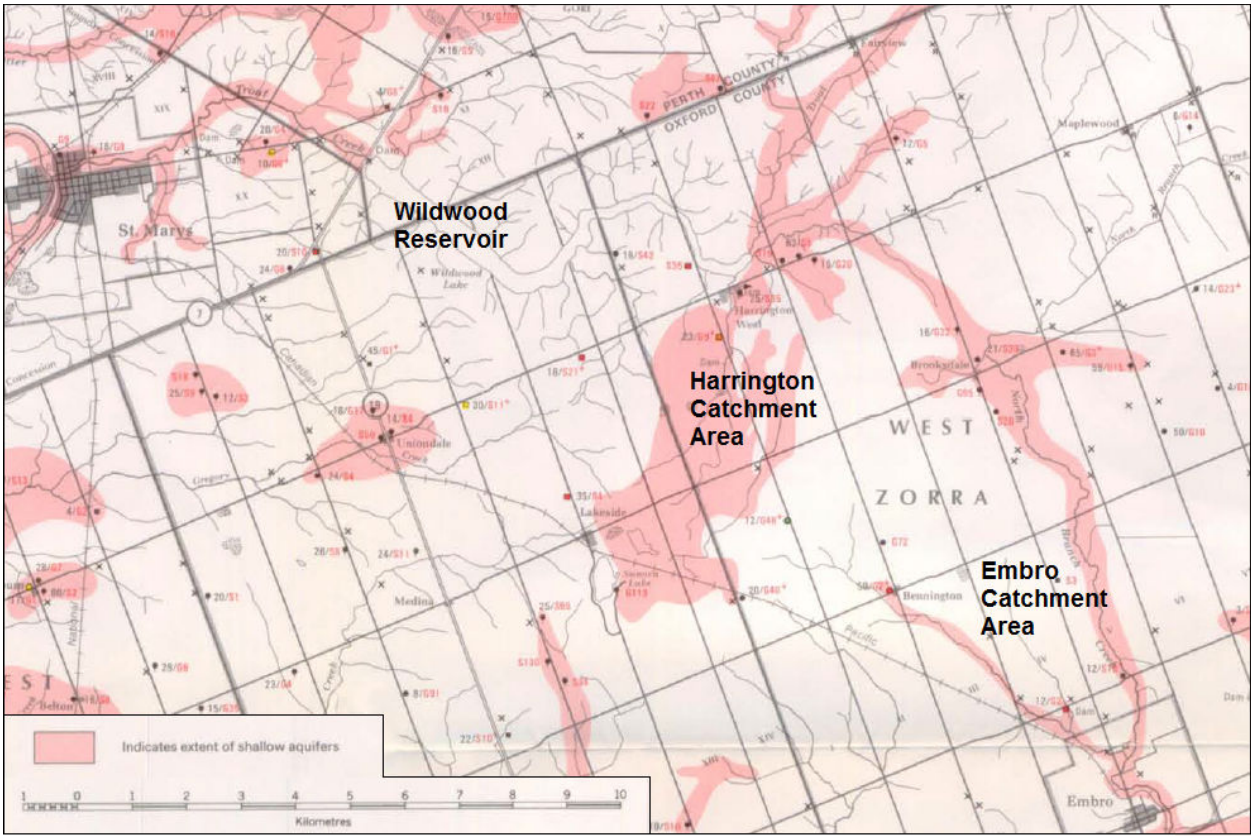

Figure 10: Areas of Shallow Overburden Aquifers from the Thames River Basin Study

Embro – Contribution to Subwatershed Flow

The catchment area that produces the flow downstream of Embro Dam is located in the Mud Creek Subwatershed. As previously noted there are no flow monitoring stations in the Mud Creek Subwatershed. The catchment area for downstream of the Embro Dam, illustrated in Figure 5, composes approximately 2.1% of the 30,600 ha catchment area of the closest monitoring station downstream of Thamesford in the Middle Thames Subwatershed. From May 24, 2008 to April 9, 2011 and from April 23, 2015 to August 28, 2015, the flow from the catchment area for downstream of Embro dam equated to approximately 3.5% and 6.4% of the total flow that passes through the monitoring station downstream of Thamesford, respectively. These flow contributions are approximately 67% and 200% more than would be expected if estimates were based only on the size of the catchment area. If the same percent decrease in flow observed at Harrington occurred at Embro during the drought/low water condition of 2012 then 12.4% of the total flow through the monitoring station downstream of Thamesford originated from the catchment area for the Embro dam. This flow contribution would represent a contribution approximately 470% more than the amount that would be expected than a contribution estimated based only on the size of the catchment area.

Embro – Effect of Water Control Structures on Upstream and Downstream Flows

Table 8**Error! Reference source not found.** summarizes the flows that were measured at the upstream and downstream locations at Harrington Dam and Embro Dam.

Table 8: Flows measured Downstream of Embro and Upstream of Backwater Effects from Embro Dam

Date of Measurement	11-Jun-15	22-Jul-15	28-Aug-15
Flow downstream of Embro Dam (cms)	0.13	0.08	0.09
Flow upstream of Embro Dam (cms)	0.13	0.07	0.08
Upstream Flow as % of Downstream Flow	100%	88%	89%

At Embro the flow upstream of the backwater effects of the dam was on average 92% of the flow measured downstream of the dam. This comparison was somewhat limited by the magnitude of the flows and the accuracy of the measurement equipment. With the flow meter only capable of measuring to the nearest 0.01 m/s and the average flow rate measured at Embro being approximately 0.10 cms, rounding to the nearest 0.01 cms has a significant effect on the answer. In addition to the accuracy limitations of the equipment, the effect of measuring the flow further upstream (which equates to a smaller catchment area) should also be considered when comparing the flows.

Conclusions

For all of the periods of records that were available for comparison the average unit area flow rates for downstream of Harrington Dam and downstream of Embro Dam were greater than the unit area flow rates calculated for:

i) Fish Creek near Prospect Hill
ii) Avon River above Stratford
iii) Trout Creek at Fairview
iv) Trout Creek near St. Mary's,

During periods of drought / low water conditions, the unit area flow rates downstream of Harrington Dam and downstream of Embro Dam did not experience a percentage decrease in flow as great as decrease that was experienced in the other water courses that were studied. The resiliency of Harrington Creek and Youngsville drain is likely due to the groundwater recharge characteristics of the catchment areas and the proximity of both catchment areas to shallow overburden aquifers.

For all of the available periods of record the contribution of flow from downstream of the Harrington Dam and the flow downstream of the Embro dam to the downstream receiving subwatershed was greater than the amount that would be expected based only on size of the catchment areas. From May 24, 2008 – April 9, 2011, March 26, 2012 – September 12, 2012, and April 23, 2015 – August 28, 2015 the contribution of the flow measured downstream of Harrington Dam to the total flow out of the Trout Creek Subwatershed was 10.2%, 12.4%, and 10.5% of the total flow, respectively.

It is more difficult to estimate the contribution of the flow measured downstream of Embro Dam to the total flow out of Mud Creek due to the absence of a flow monitoring station at the outlet of Mud Creek and the large distance between downstream of Embro Dam and the closest flow monitoring station in the Middle Thames Subwatershed downstream of Thamesford. If it is assumed that there are no losses as the water travels the distance of this flow path then from May 24, 2008 – April 9, 2011, March 26, 2012 – September 12, 2012, and April 23, 2015 – August 28, 2015, the contribution of the flow measured downstream of Embro Dam to the total flow measured at the stream gauge station downstream of Thamesford was 3.5%, 12.4%, and 6.4% of the total flow, respectively.

The three flow measurements that were taken upstream of the backwater effects of each dam indicated that the upstream flow was 93% and 92% of the flow downstream of Harrington and Embro, respectively. Due to the low magnitude of the flows, the accuracy limitations of the flow velocity meter, and inflow to the watercourses in between the upstream and the downstream measurement locations it is recommended that additional measurements and/or monitoring be performed. Additional flow measurements, or the installation of a HOBO logger and development of a rating curve at the upstream locations (and at downstream of Embro) would increase the confidence in assessing the effect of the water control structures on the flow.

It is recommended that a flow monitoring program continue at Harrington Dam and Embro Dam. Additional data would allow increased confidence in the results and the analyses of the flow characteristics and would be beneficial for future designs.

Appendix

Omitted Results

Figure 11 illustrates the Harrington creek water levels at the Rd. 96 bridge pier for the time period of May 24, 2008 to April 9, 2011. The yellow horizontal line indicates the water temperature of 5°C that was used to filter out irregular logger readings. The red rectangular outlines indicate data that was recorded at a temperature below the cut off line and as such was omitted from subsequent calculations and analyses.

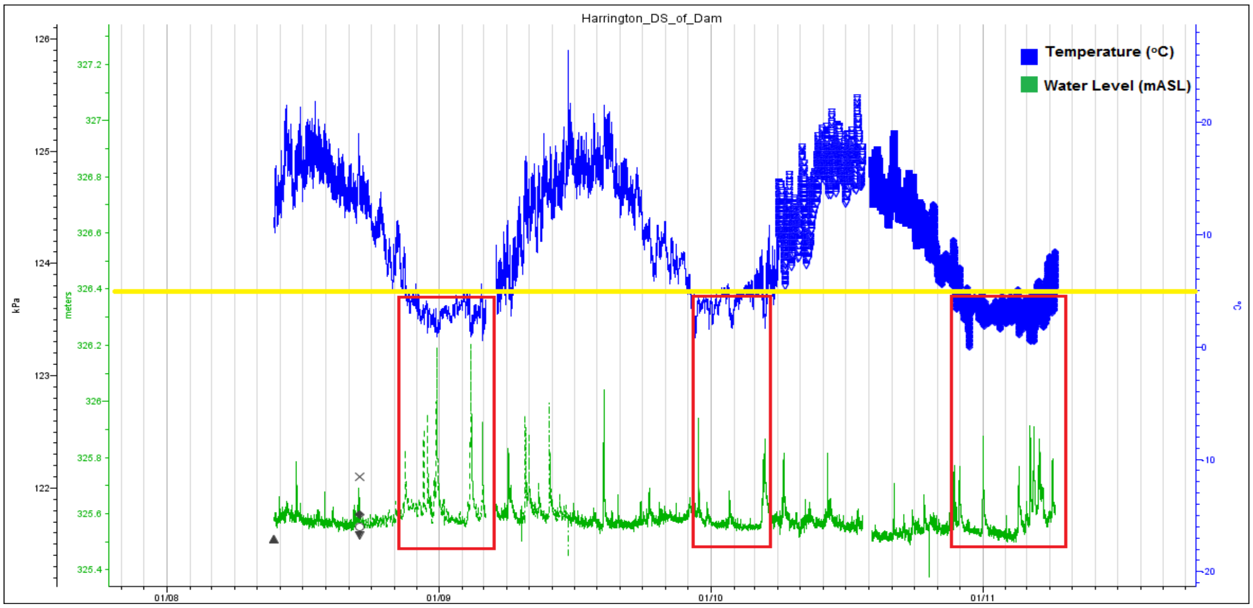

Figure 11: Water Temperature (°C) and Water Level (m) from HoboLogger Downstream of Harrington

Weighted Average Calculation

The weighted average was calculated using the following steps:

i) Average the Embro flow as a percentage of the Harrington flow at the 1st measurement (73% - June 4) and the Embro flow as a percentage of the Harrington flow at the 2nd measurement (52% - June 11)

ii) Multiply this average (62.5%) by the number of days between the 1st and 2nd measurement (7 days)

iii) Repeat this process for the 2nd and 3rd, 3rd and 4th, and the 4th and 5th measurements

iv) Sum all of the products produced in the first three steps (770 (%*days))

v) Divide the sum by the total number of days from the first measurement to the last measurement (112 days)

vi) The result is the weighted average $\frac{770\ (\% * da-)}{da-} = 69\%$

Precipitation

In order to characterize the precipitation that occurred in the catchment areas for the Harrington Pond and Embro Pond, measurements recorded during the periods of observation were compared against historical measurements.

The Ministry of Environment monitoring station in Stratford (UT-0066-01) was used to calculate the historical percentiles. This station recorded daily precipitation measurements from January 1, 1950 to December 31, 2005. The daily precipitation measurements were used to calculate the 30 day precipitation total. The 30 day precipitation total for a certain day is the sum total of all the precipitation that occurred on the day in question and all of the precipitation that occurred on the previous 29 days. When comparing data, the 30 day precipitation total is preferable to single day totals as it removes some of the statistical noise associated with single day measurements and it also provides a better indication of conditions in the study area.

The historical data was used to calculate the 25th, 50th, and 75th percentiles for the 30 day precipitation total for every day of the year.

The UTRCA monitoring station on Trout Creek near Fairview (UT-0020-01) was the source of the measurements obtained during the periods of observation. This station was chosen based on the proximity to the study areas, the availability of data for the periods of observation, and high confidence in the quality of the data. One disadvantage to this monitoring station is that it does not have the necessary instrumentation to measure snowfall; this results in the 30 day precipitation total being artificially lower than normal during the winter months.

Efforts made to collect additional precipitation information from alternative sources closer to study sites were unsuccessful due to non-standardized methods of collecting, recording, or storing information, and/or inability to obtain data from the alternative sources. The benefit of incorporating additional data from alternative sources would be limited in this circumstance as the purpose of examining precipitation in this report is to characterize general conditions as opposed to identify specific system responses to specific rainfall events.

Figure 12, Figure 13, and Figure 14, illustrate the 30 day precipitation totals during the period of observation compared to the historical 30 day precipitation total amounts for:

- March 24, 2008 to April 9, 2011,
- March 26, 2012 to September 12, 2012,
- and April 23, 2015 to September 23, 2015, respectively.

These graphs allow the interpretation as to whether the 30 day precipitation total was above, below, or within the normal range. Generally any total within the 25th to 75th percentile is considered within normal range, any value above the 75th percentile would be considered above normal range, and any value below the 25th percentile would be considered below normal range.

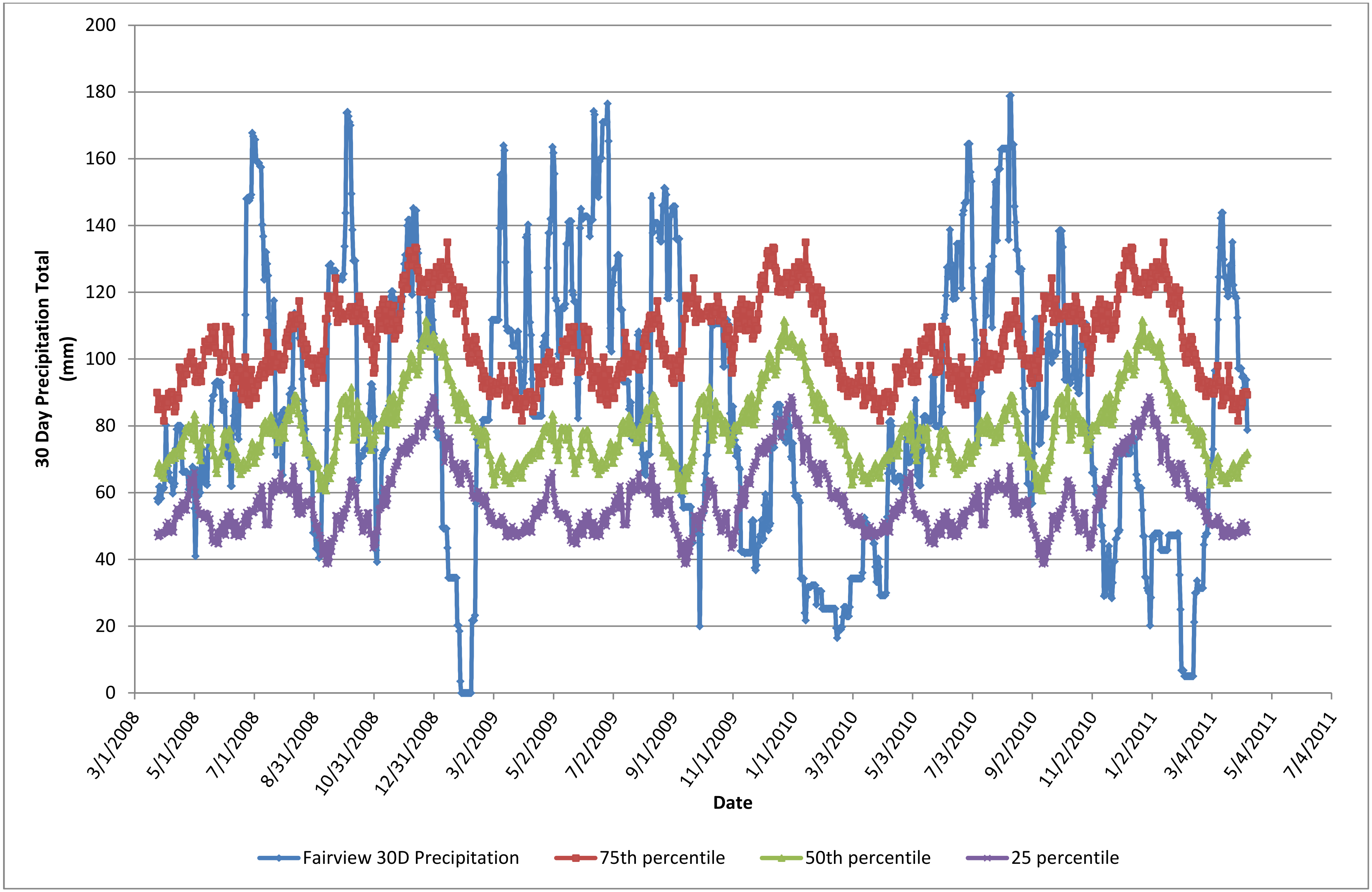

Figure 12: 30 Day Precipitation Totals from March 24, 2008 to April 9, 2011

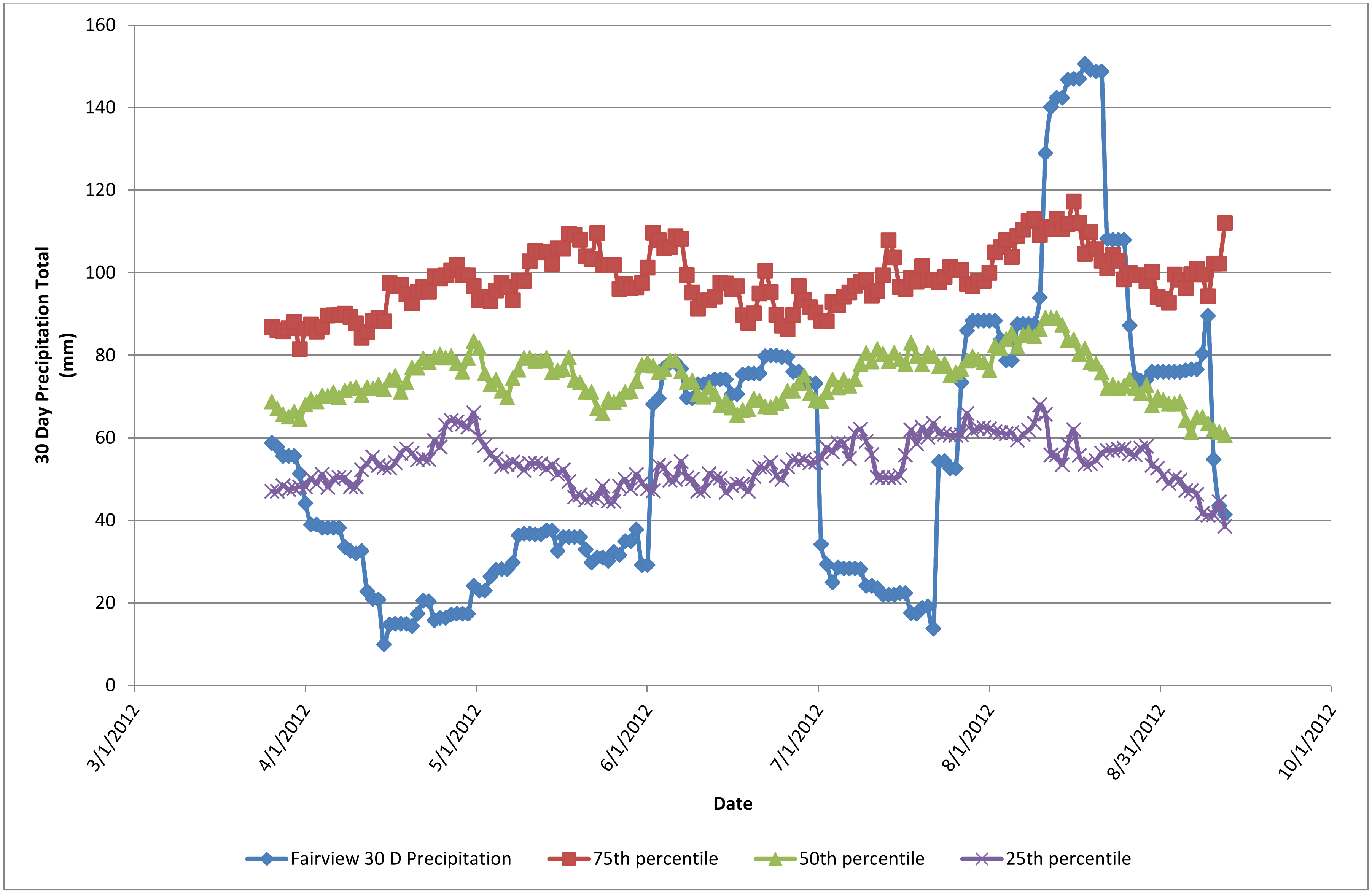

Figure 13: 30 Day Precipitation Totals from March 26, 2012 to September 12, 2012

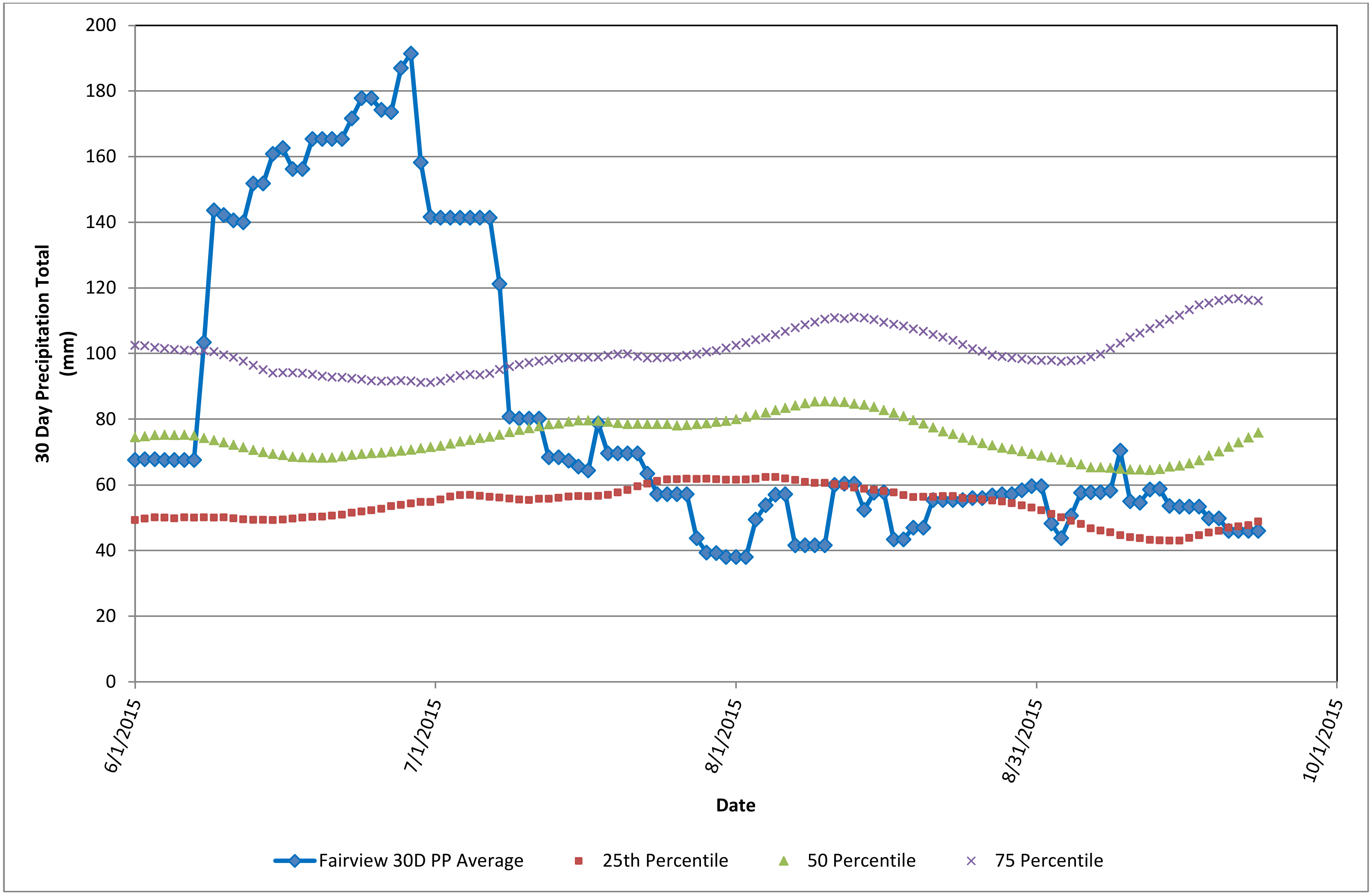

Figure 14: 30 Day Precipitation Totals from June 1, 2015 to September 23, 2015