APPENDIX D - Weather Data Analysis

D.1 Letter from Environment Canada (August 8, 2015)

D.2 July 12, 2015 Storm Event Analysis (Associated Engineering, August 10, 2015)

D.3 Rainfall Correlation (Associated Engineering, September 25, 2015)

Environment Canada | Environnement Canada

Meteorological Service of Canada | Service météorologique du Canada

Tuesday, 8th August, 2015

Oscar Gonzalez, PMP, M.Eng., P.Eng.
Senior Municipal Engineer & Project Manager
Transportation & Infrastructure Planning Branch
Engineering Department
Regional Municipality of Wood Buffalo

Dear Mr. Gonzalez,

The rainfall amounts recorded on July 12, 2015 at Fort McMurray Airport for the 1-hour duration was 22.5 mm and for the 2-hour duration was 37.0 mm:

- The measured 1-hour rainfall rate (22.5 mm/h) is a once in 10 year event
- The measured 2-hour rainfall rate (18.5 mm/h) is a once in 50 year event

The above return period estimates are based on the Intensity-Duration-Frequency curves from Environment Canada (IDF version 2.30, 2014).

If you have any further questions, please do not hesitate to contact us!

Regards,

Ka-Hing Yau, Ph.D. (on behalf of Philip Jarrett)

Program meteorologist | météorologue du programme
Engineering Climate Services Unit | Unité des services climatiques pour le génie
Meteorological Services of Canada | Service météorologique du Canada
Environment Canada | Environnement Canada
4905 Dufferin Street | 4905, rue Dufferin
Downsview, ON M3H 5T4
Climate.Services@EC.GC.CA
Phone: 416-739-4365

Canada

Associated Engineering | GLOBAL PERSPECTIVE. LOCAL FOCUS.

Associated Engineering Alberta Ltd.
1000 Associated Engineering Plaza
10909 Jasper Avenue
Edmonton, Alberta, Canada, T5J 5B9

TEL: 780.451.7666
FAX: 780.454.7698
www.ae.ca

August 10, 2015
File: 2015-3363.010.A01.00

Oscar Gonzalez, PMP, M.Eng., P.Eng.
Senior Municipal Engineer & Project Manager
Regional Municipality of Wood Buffalo
9909 Franklin Avenue
Fort McMurray AB
T9H 2K4

Re: JULY 12, 2015 STORM EVENT ANALYSIS

Dear Oscar:

This letter report summarizes our sanitary model simulation results for the July 12, 2015 storm event.

1 BACKGROUND

39 homes were flooded by backup in Timberlea during heavy rainfall in the morning of July 12, 2015. The Regional Municipality of Wood Buffalo retained AE to determine if the flooding was the result of pre-existing conditions, and to determine how much the risk of flooding will be reduced with the proposed upgrades.

2 STORM RAINFALL DATA

Associated Engineering (AE) obtained the July 12, 2015 storm data at the Fort McMurray Airport from Atmospheric Environment Services (AES) and processed the data to estimate the relative severity (return period of the event). The available rainfall data is in 15 minute time intervals and AES provided the data in raw form without quality control.

Figure 1 shows the time pattern of rainfall on July 12, 2015. The main event that resulted in flooding in Timberlea occurred in the morning and deposited approximately 41 mm of rain between 6AM and 10AM at the Airport. An additional 18 mm of rain fell between 10PM and midnight.

Figure 2 shows the Intensity–Duration-Frequency (IDF) profile of the July 12 storm compared with historic data for Fort McMurray. The graph shows that the July 12 storm had a return period of approximately 1:25 years for a 4-hour duration storm. Past experience in Timberlea indicates that this is the critical duration for storm events in Timberlea, producing the largest peak flows. Coincidentally, this is the return period used for the design of system upgrades in Timberlea and in the Master Drainage Plan prepared by Associated Engineering in 2014.

Note that the rainfall data was recorded at the Fort McMurray Airport, which is about 18 km to the southeast of the Timberlea area. A storm event such as occurred on July 12, 2015 varies significantly over distance such that the rainfall experienced in Timberlea may have been significantly different from that at the airport. However, due to lack of other data, the rainfall at the Airport is the best estimate available.

3 MODEL OF EXISTING SYSTEM

AE simulated the July 12, 2015 storm event using the model of the existing system ("Existing 2013 Model") developed by AE for the Wastewater Master Plan (May 2014). The model was previously updated and calibrated using flow and rainfall data in Timberlea over a 3-year period from 2011 through 2013.

Figure 3 shows the simulation results. The red and orange dots show manholes that would be surcharged above basement level and indicate that many homes in southwest Timberlea would be at risk of sewer backup during the July 12, 2015 storm event. Figure 3 also shows the locations of houses that were reported to have flooded during that event and shows that the reported houses would indeed have flooded with pre-existing conditions.

The results indicate that the model may be somewhat conservative (over-estimating the flood risk) or that the local rainfall may have been somewhat less than was assumed based on the recorded rainfall at the airport. Given that the model has been calibrated using measured rainfall and flow data within Timberlea, the latter (that local rainfall may have been less that at the Airport) is considered more likely.

4 MODEL OF FUTURE SYSTEM

The Wastewater Master Plan for the RMWB in May 2014 (Technical Memorandum B.2.5), identified system upgrades in Timberlea as shown in Figure 4. AE simulated the July 12, 2015 storm event with the Timberlea upgrades ("Upgraded 2013 Model"). The results in Figure 4 indicate that the risk of sewer backup in a similar event will be prevented with the proposed pipe upgrades.

5 CONCLUSIONS

- The July 12 storm had a return period of approximately 1:25 years, comparable to the design event used for system upgrades in Timberlea.

- With existing conditions, extensive sewer backup would be expected to occur in Timberlea such as has been reported.

- Based on system design criteria the flooding that occurred in the July 12 storm should not occur after the proposed upgrades that are underway in Timberlea are completed.

6 CLOSURE

We hope that this report meets your needs and expectations. Please contact us if you have any questions.

Yours truly,

Larry Bodnaruk, P.Eng.
Project Lead

LB/jfm

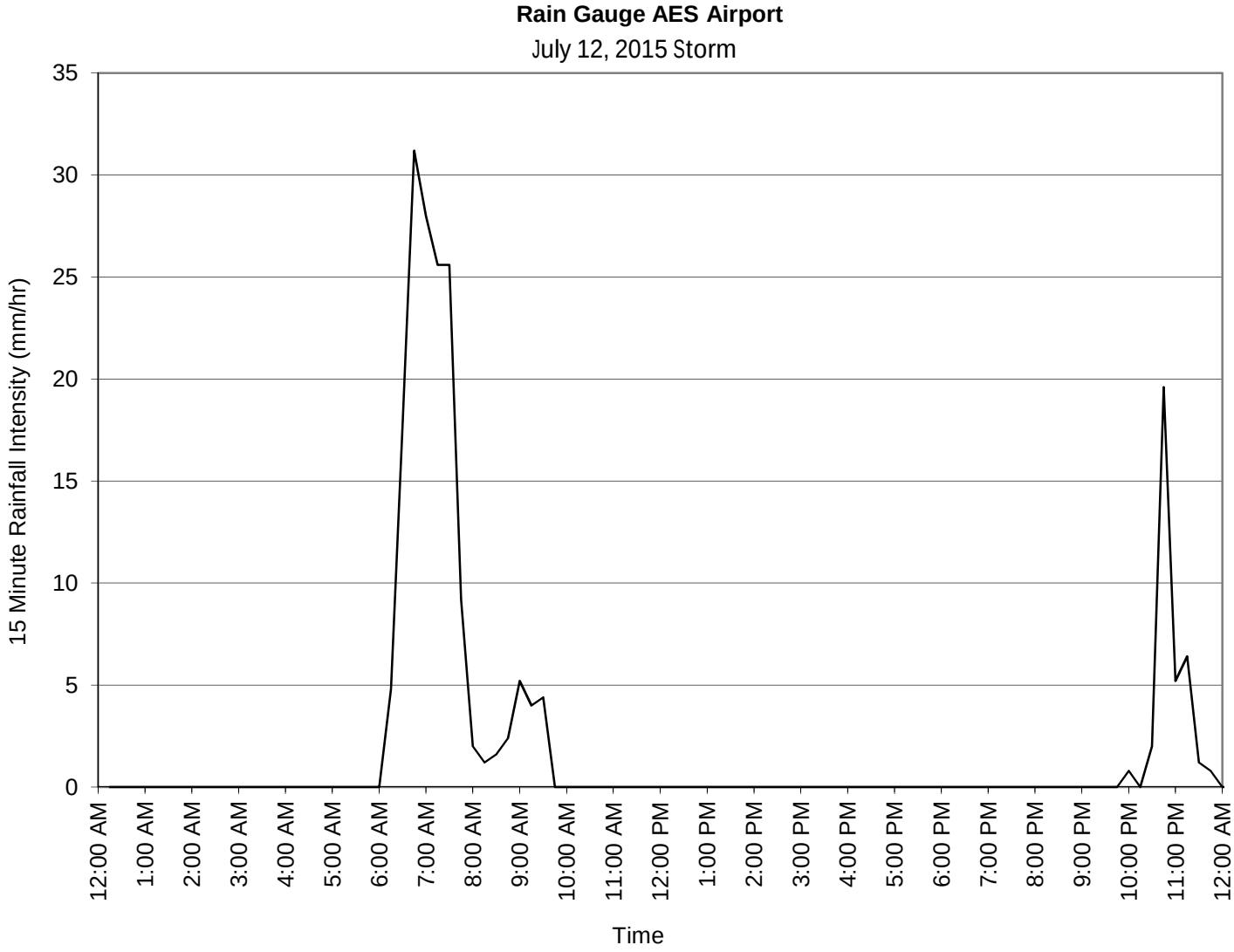


Figure 1
GAUGE stats_July 12, 2015.xls
Time Graph

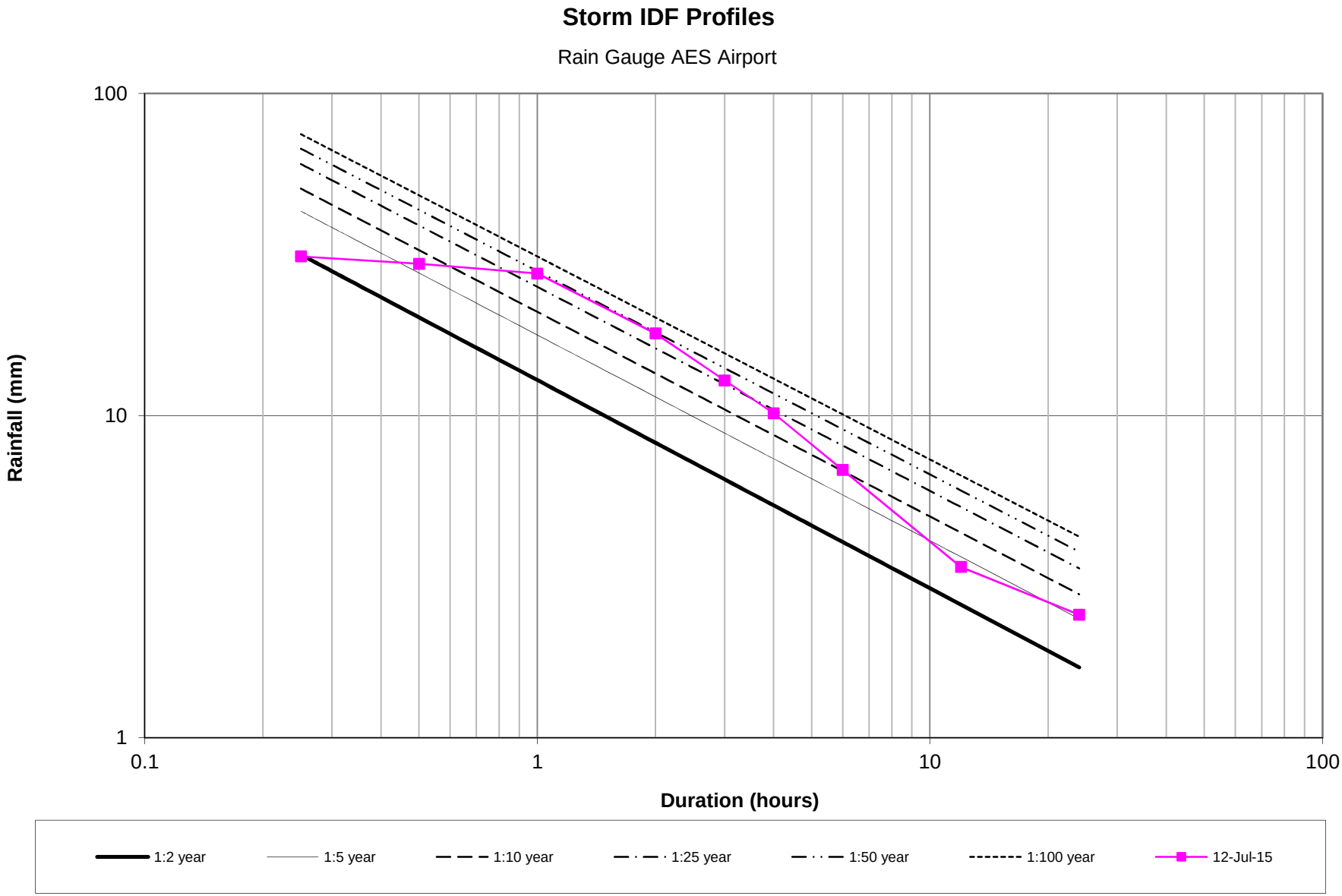
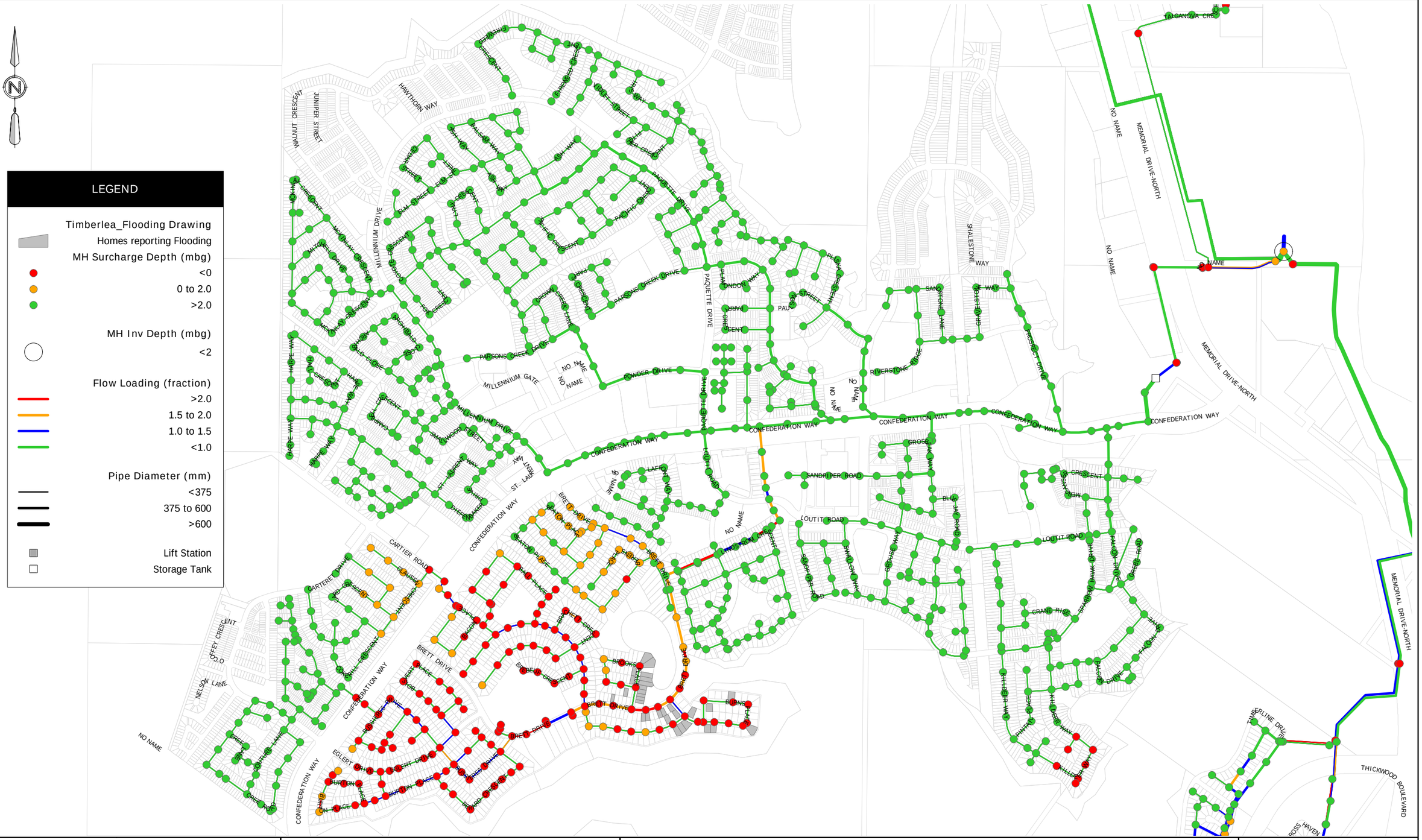


Figure 2
GAUGE stats_July 12, 2015.xls
Intensity profiles

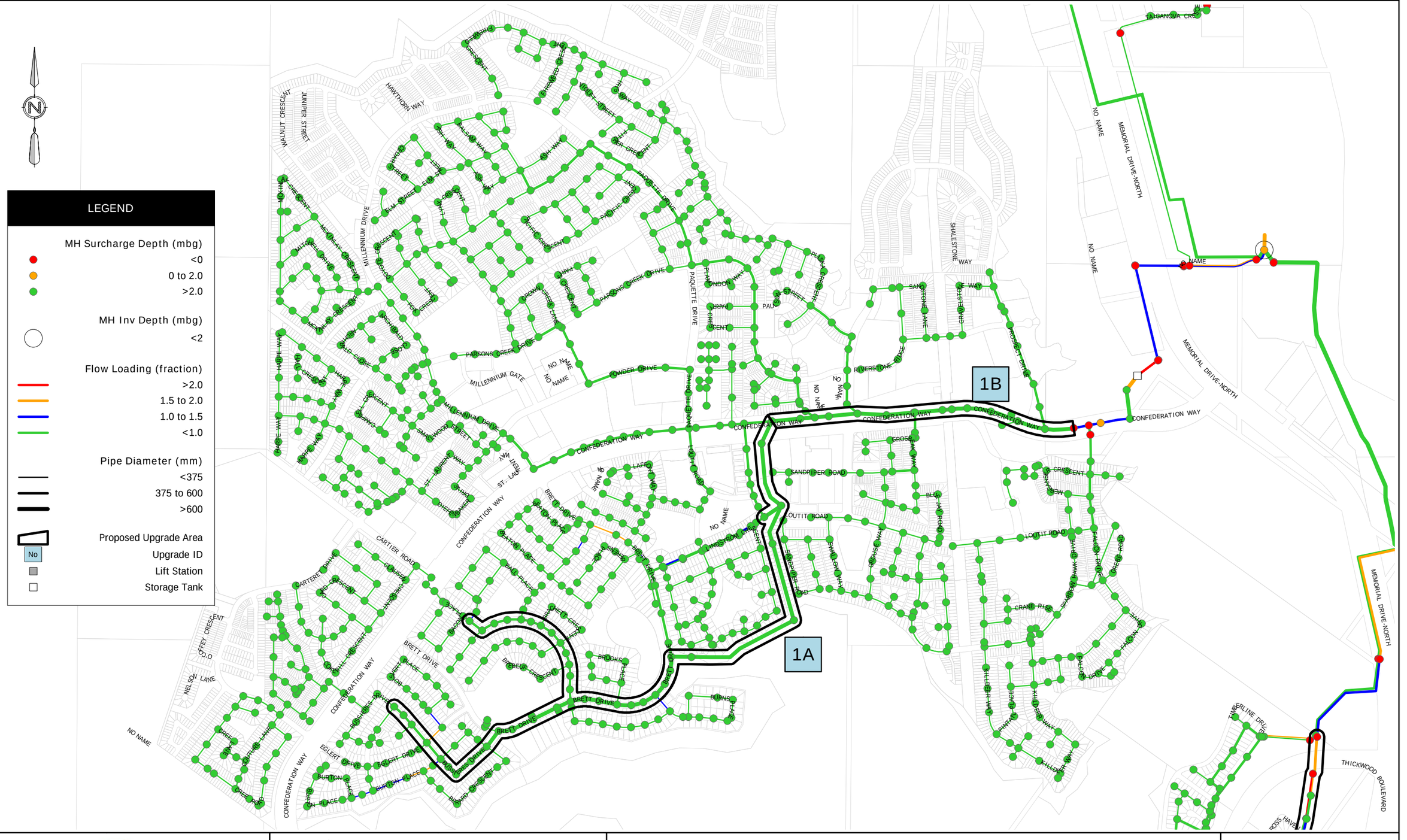
Existing 2013 Model - Timberlea



P:\2015336300_RMWB_Infrastructu\Advisory\01.00_Advice\July 12, 2015 storm\Simulated Models\map_July2015_storm_jl.map
Printed 8/7/2015

PREPARED BY: Associated Engineering	PREPARED FOR: Regional Municipality of Wood Buffalo	FIGURE 3 Existing 2013 Model - Timberlea July 12, 2015 Storm Simulation Results	PROJECT No.: 2015-3363 DATE: August 2015 SCALE: 1:15,000

Upgraded 2013 Model - Timberlea



\\S-edm-fs-01\projects\2015336\100_RMWB_Infrastructu\Advisory\01.00_Advice\July 12, 2015 storm\Simulated Models\map_July2015_storm_jl.map
Printed 8/5/2015

PREPARED BY: Associated Engineering	PREPARED FOR: Regional Municipality of Wood Buffalo	FIGURE 4 Upgraded 2013 Model - Timberlea July 12, 2015 Storm Simulation Results	PROJECT No.: 2015-3363 DATE: August 2015 SCALE: 1:15,000

Associated Engineering | GLOBAL PERSPECTIVE. LOCAL FOCUS.

Date: November 26, 2015 **File:** 01.00

To: Oscar Gonzalez, PMP, P.Eng.

From: Larry E. Bodnaruk, P.Eng.

Project: 20153363.00

Subject: Rainfall Correlation

MEMO

1 INTRODUCTION

The Regional Municipality of Wood Buffalo (RMWB) requested Associated Engineering (AE) to compare the rainfall recorded at the Airport rain gauge with other gauges in the Urban Service Area of Fort McMurray, to quantify storm variability across Fort McMurray and to determine if there is any indication that rainfall may be greater at any one location.

Associated Engineering (AE) has operated a monitoring program in Fort McMurray from 2011 to 2014 to measure flows in the sanitary sewer system and to measure rainfall for model calibration. Four rain gauges were operated during the four-year period and provided valuable data for the model calibration. In addition, Atmospheric Environment Services operates a rain gauge at the Airport for weather reporting and climate data collection. Figure 1 shows the locations of the Airport rain gauge and the four RMWB rain gauges operated as part of the flow monitoring program.

These data have demonstrated that storms are quite variable across the Urban Service Area, which is consistent with local experience. In July 2015, after the rainfall monitors were removed, a storm occurred which flooded a portion of Timbelea. AE has attempted to simulate the system performance in this event using rainfall data from the Airport and the collection system model developed for the Drainage Master Plan. Model results were inconclusive due to the fact the rainfall was not measured locally, and suggested that local rainfall in Timberlea may have been significantly less than was reported at the Airport.

The objective of the present analysis is to quantify the storm variability over Fort McMurray using the recorded rainfall data collected over the 4-year period and to compare the recorded gauge rainfall with that reported at the Airport rain gauge to determine if there were any significant differences. It was also hoped that this analysis could shed further insight into the storm rainfall that occurred in Timberlea in July 2015.

2 METHODOLOGY

The analysis involved the following key tasks:

- Compile rainfall records for the four RMWB rain gauges for the past four years.
- Compile rainfall records for the Atmospheric Environment Services of Environment Canada (AES) Fort McMurray Airport rain gauge.
- Correlate Airport rain gauge daily rainfall amounts with those recorded at the four RMWB rain gauges to determine if there are any significant differences.
- Compare rainfall amounts recorded at the five rain gauges in more detail for the 10 largest rain storm events to determine if there are any significant differences.

The analysis was based on daily rainfall amounts. The AES Climate Station rain gauge, also located on the Airport property, was used for 2011 as the Airport rain gauge was not operated that year. Typically the RMWB rain gauges were operated from May through September each year and the analysis was limited to this period.

3 RESULTS

Figure 2 to 5 provide the scatter graphs of daily rainfall at the Airport plotted against the daily rainfall recorded at each of the RMWB rain gauges for the same date, for the four-year period of record. Also shown are the least-squares regression line, the best-fit regression equations, and the Index of Determination (R^2) which provides a measure of the strength of the correlation. For comparison the 1:1 Line, which represents the condition where Airport and other rain gauge values would be equal (the line of perfect agreement), is also shown.

Table 1 provides an overall summary of the R^2 values, which represent the strength of the correlation, and the slope coefficient "b" from the regression equation which represents the average ratio of rainfall amounts for the respective rain gauges. These values and the graphs indicate a reasonable level of correlation between the various rain gauges, as would be expected, with R^2 values ranging from 0.71 to 0.84. The plots do show a significant amount of scatter, within a range of about 15-20 mm from the best-fit regression line for individual rainfall events. Generally the best correlation occurs with rain gauges closest to the Airport, as would be expected.

Table 1
Rain Gauge Correlation Summary

Rain Gauge	Rain Gauge Number	Index of Determination (R2)	Slope Coefficient (b)
Mackenzie	RG04	0.84	0.84
Lift Station 1A	RG02	0.77	0.83
Thickwood	RG03	0.71	0.72
Timberlea	RG01	0.75	0.82
Average		0.77	0.80

Interestingly, the slope coefficient "b" in the regression equations is less than 1.0 for all rain gauges, which indicates that lower rainfall amounts on average were recorded at the RMWB rain gauges than at the Airport rain gauge. This could indicate that more rainfall occurs at the Airport generally than in Fort McMurray, but this is unlikely to be the case. More likely it suggests a sampling difference due to wind effects in that the RMWB rain gauges were mostly located on rooftops and were more exposed to higher winds than the AES rain gauge. Wind effects during rainstorms are known to reduce the catch efficiency of rain gauges and could result in rain gauges indicating less rainfall than actually occurred in some events.

These effects were further examined by comparing rainfall statistics for the 5 rain gauges in the 10 largest storm events that occurred from 2011 to 2014. The rainfall data for these 10 events are summarized in Table 2 on the following page.

The top part of this table provides the rainfall amounts recorded at each gauge along with the event averages and the site averages. The data shows rainfall amounts of 12 to 41 mm for the 10 events. The bottom half of Table 2 shows the relative (dimensionless) rainfall amounts derived by dividing the site rainfall by the average rainfall for each event and provides an overall assessment of the rainfall variability by location and by event.

The data indicate that the lowest rainfall amount relative to the mean, recorded at the Thickwood rain gauge, was 40% of the average rainfall in the September 11, 2012 storm. The highest rainfall amount relative to the average, a ratio of 167% was also recorded at the Thickwood rain gauge, in the June 24, 2011 storm event. That is to say, the storm rainfall for such large events can vary over a range of 40 to 167% of the spatial average rainfall in an individual storm event. This variability is due to the nature of convective rainfall events which are localized and generate large rainfall differences over relatively short distances.

On average the rainfall amount at the Airport rain gauges was 7% greater than at the RMWB rain gauges which is consistent with the wind-induced catch efficiencies reported elsewhere and suggests that the difference at this rain gauge is a sampling phenomenon and is not related to any real difference in rainfall amount.

4 CONCLUSIONS

Results of this analysis are summarized as follows:

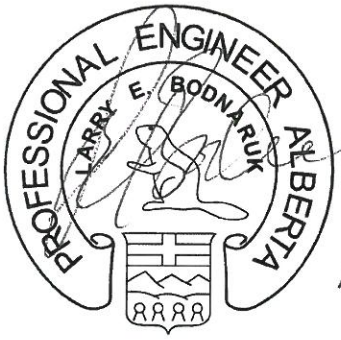
- There is significant variability in storm rainfall from place to place and from event to event, up to 20 mm or approximately +/- 60% in any one storm.
- There is no indication of more or less rainfall occurring in general at any location relative to other locations
- There is a suggestion that the RMWB rain gauges may have been under-reporting actual rainfall by about 7% in the larger storms but this cannot be stated for certain due to the natural variability of rainfall from storm to storm and from place to place that masks such phenomena.

Table 2
Rainfall Summary for 10 Largest Storms

	Daily Total Rainfall (mm)					
Date	Airport	RG04 Mackenzie	RG02 Lift Station 1A	RG03 Thickwood	RG01 Timberlea	Average
26-Sep-14	35.7	41.0	34.5	36.5	39.3	37.4
9-Jun-13	40.1	47.0	30.0	29.0	39.5	37.1
28-Jul-13	42.1	28.8	45.0	28.0	28.8	34.5
2-Sep-12	28.4	22.0	20.3	33.3	36.5	28.1
11-Sep-12	32.0	24.3	26.0	9.8	29.5	24.3
30-Sep-13	23.2	20.8	23.3	21.8	27.5	23.3
8-Jun-13	35.3	25.8	21.0	12.3	14.5	21.8
27-Jun-13	17.5	22.3	18.8	17.8	20.0	19.3
9-Jul-11	15.6	17.9	17.3	19.2	19.6	17.9
24-Jun-11	12.6	12.2	14.6	27.8	16.3	16.7
Average	28.3	26.2	25.1	23.5	27.1	26.0

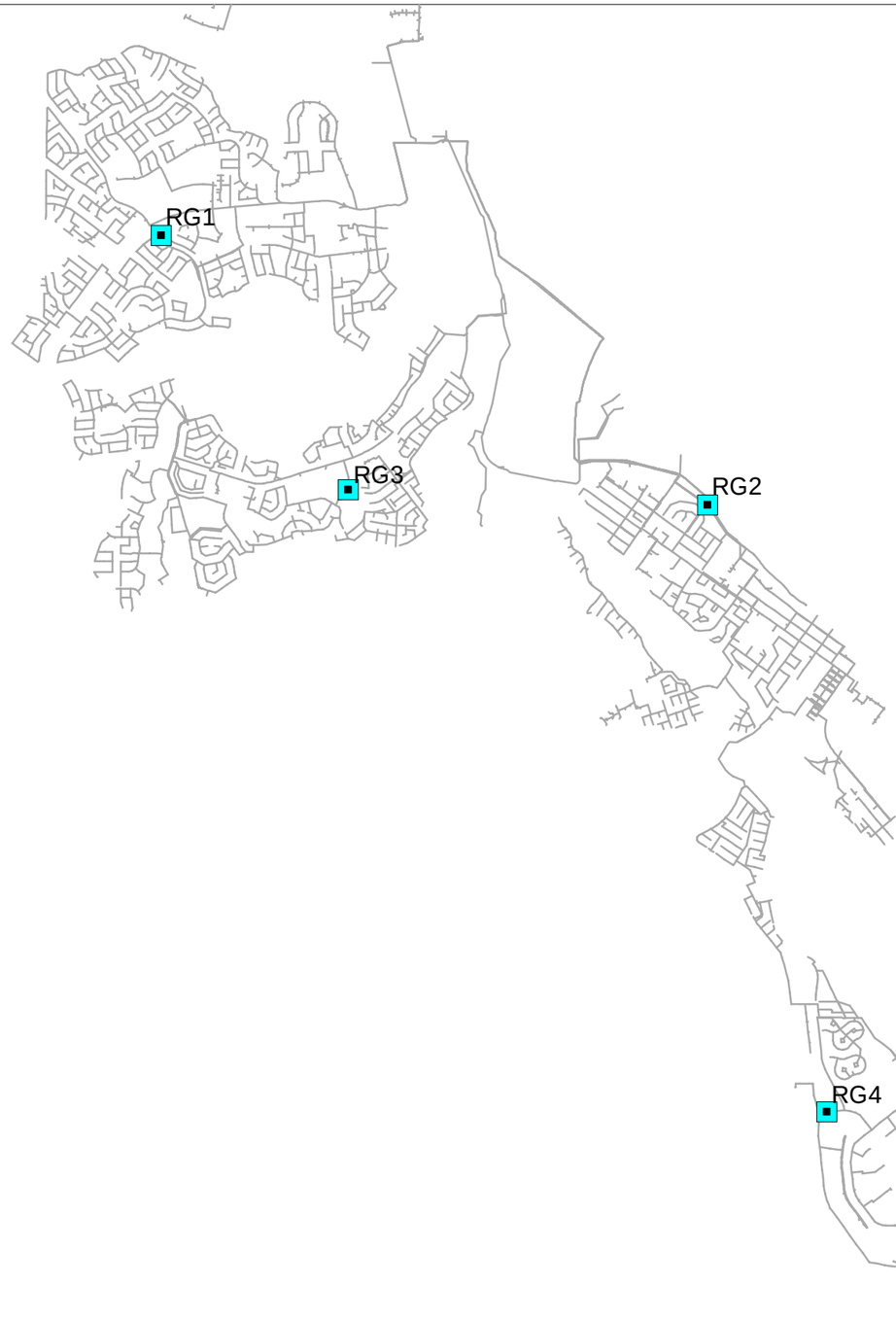
	Ratio to Average						
	Airport*	RG04 Mackenzie	RG02 Lift Station 1A	RG03 Thickwood	RG01 Timberlea	Minimum	Maximum
26-Sep-14	0.95	1.10	0.92	0.98	1.05	0.92	1.10
9-Jun-13	1.08	1.27	0.81	0.78	1.06	0.78	1.27
28-Jul-13	1.22	0.83	1.30	0.81	0.83	0.81	1.30
2-Sep-12	1.01	0.78	0.72	1.18	1.30	0.72	1.30
11-Sep-12	1.32	1.00	1.07	0.40	1.21	0.40	1.32
30-Sep-13	1.00	0.89	1.00	0.93	1.18	0.89	1.18
8-Jun-13	1.62	1.18	0.97	0.56	0.67	0.56	1.62
27-Jun-13	0.91	1.16	0.97	0.92	1.04	0.91	1.16
9-Jul-11	0.87	1.00	0.97	1.07	1.09	0.87	1.09
24-Jun-11	0.75	0.73	0.88	1.67	0.97	0.73	1.67

Minimum	0.75	0.73	0.72	0.40	0.67
Average	1.07	0.99	0.96	0.93	1.04
Maximum	1.62	1.27	1.30	1.67	1.30



Nov. 26, 2015

Larry E. Bodnaruk, P.Eng.
Senior Water Resources Engineer



REGIONAL MUNICIPALITY OF WOOD BUFFALO

September 2015

LEGEND

- Rain Gauge
- Sanitary Sewer Pipe

Scale: 1:60,000 (11X17)

Figure 1
Rain Gauge Locations in 2014

Associated Engineering

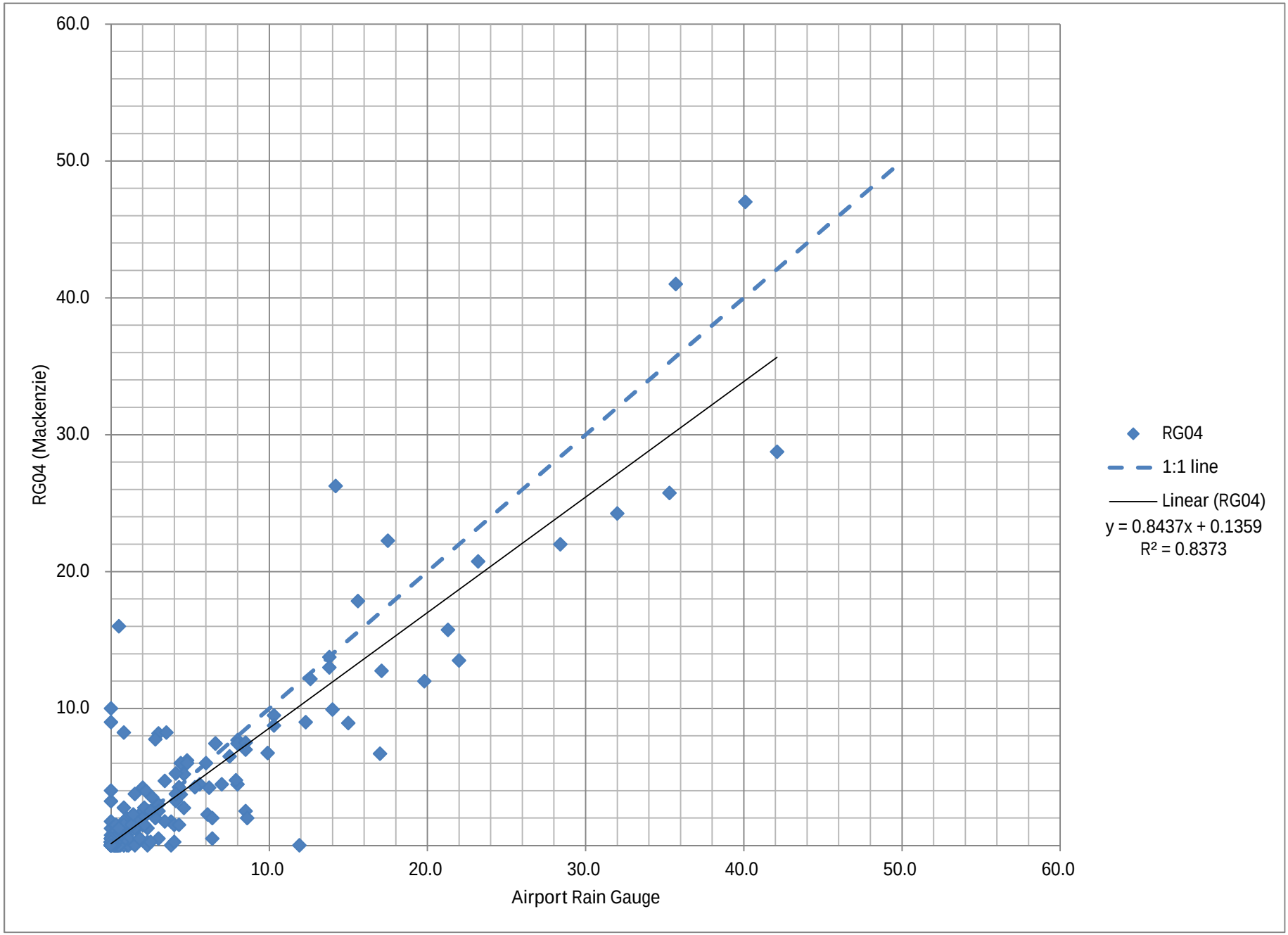


Figure 2
Correlation of Airport Rain Gauge with Mackenzie Rain Gauge

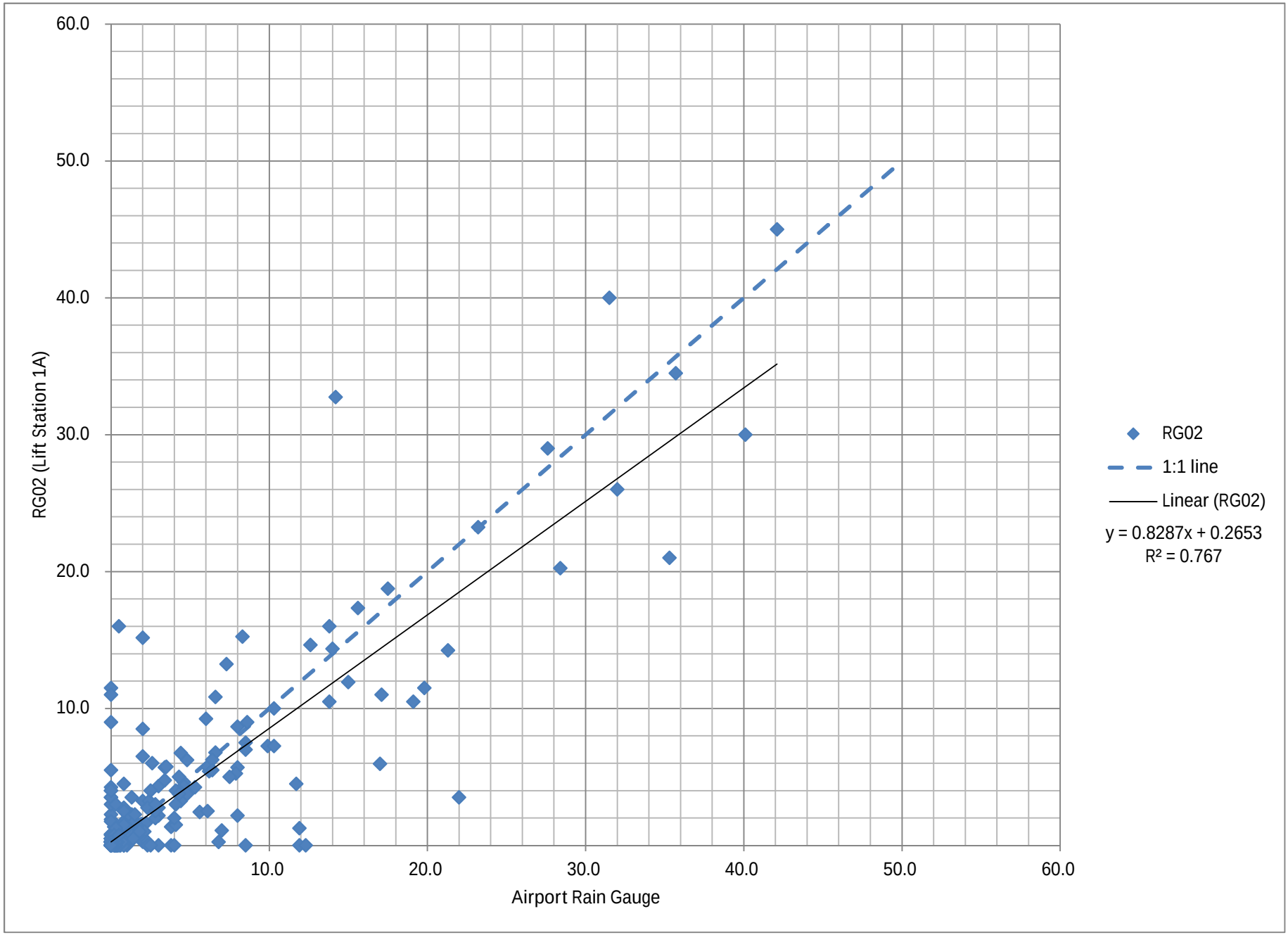


Figure 3
Correlation of Airport Rain Gauge with Lift Station 1A Rain Gauge

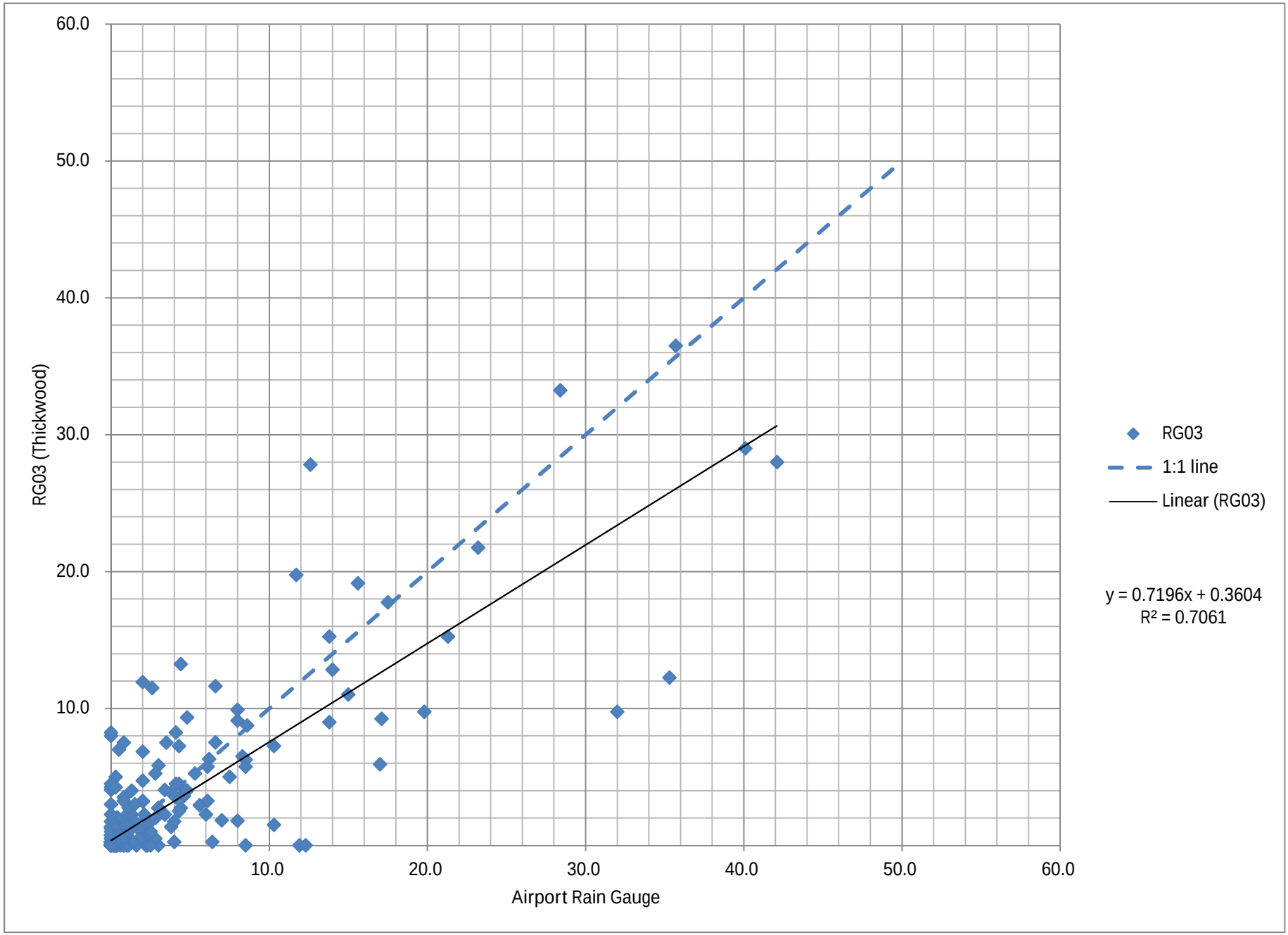


Figure 4
Correlation of Airport Rain Gauge with Thickwood Rain Gauge

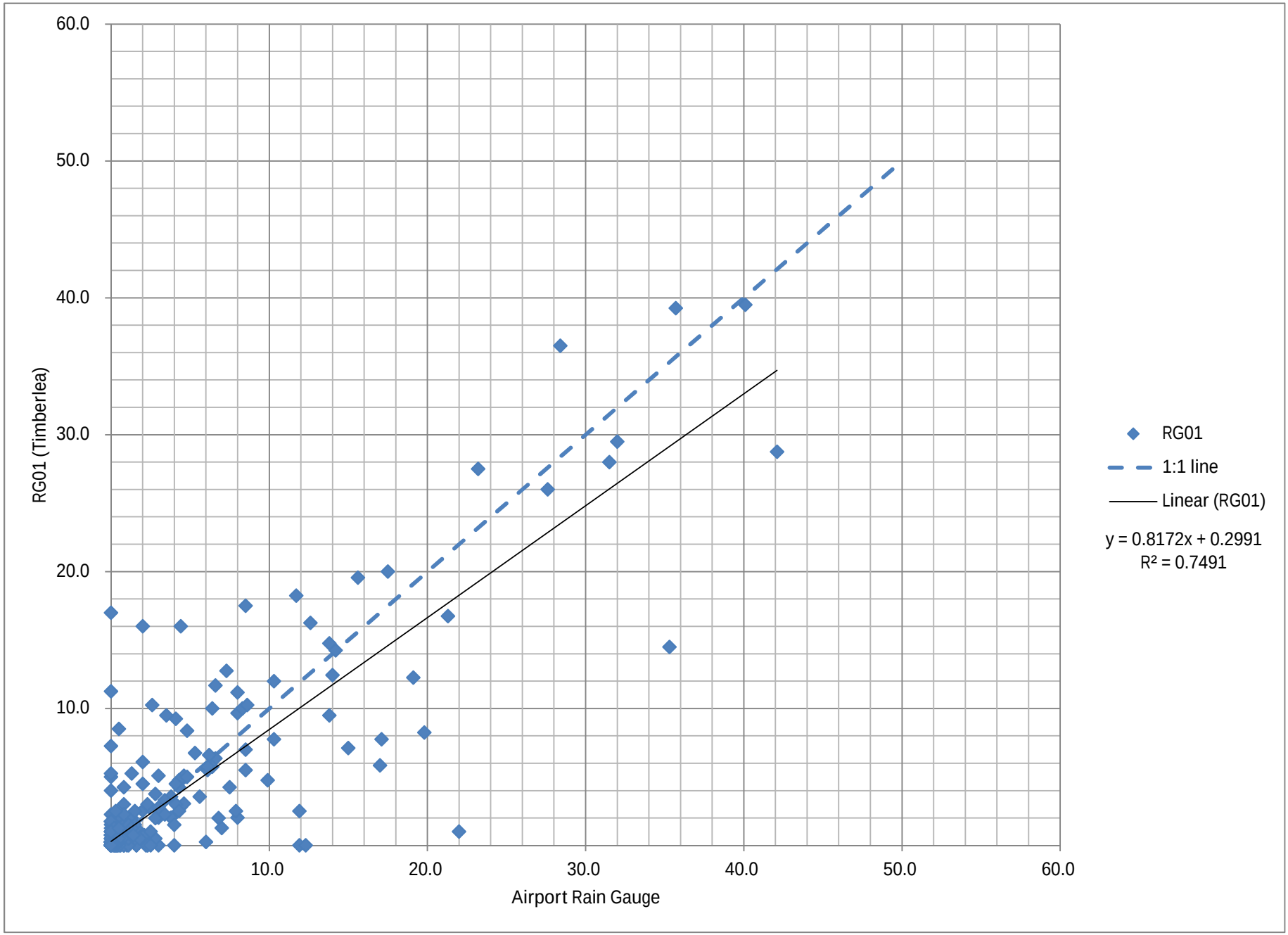


Figure 5
Correlation of Airport Rain Gauge with Timberlea Rain Gauge