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Hurricane Season Flood Alert System
End of Season Report 2016 - 2017

Submitted to:

Water Resources Management Division
Department of Environment and Climate Change

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1.0 FLOOD ALERTS SUMMARY

The Amec Foster Wheeler Hurricane Season Flood Alert System (HSFAS) Product is the result of professionally trained meteorologists applying their full knowledge of atmospheric science to Newfoundland and Labrador's weather patterns and pairing that with existing trends, known observations, and weather prediction models. Examining maximum precipitation predictions from many different dynamic models allows forecasters to produce a better forecast of the maximum precipitation potential based on the strength of different models in handling the atmospheric physics of differing weather patterns.

From July 2016 to December 2016, 104 alerts were issued in total. There were also 10 potential events where the Water Resources Management Division (WRMD) or Environment Canada (EC) data exceeded alert limits. An excel spreadsheet of all the flood alerts issued has been provided to WRMD, and here is a summary of these alerts:

Table 1-1: Summary of Flood Alerts

Alert #	Site Name	Alert Issue Date	12-hourly Precipitation Forecast (mm)	24-hourly Precipitation Forecast (mm)
1	Appleton/Glenwood	2016-07-11 09:00	60	75
2	Gander (GANDER AIRPORT CS)	2016-07-11 09:00	65	75
3	Appleton/Glenwood	2016-07-11 16:00	60	75
4	Gander (GANDER AIRPORT CS)	2016-07-11 16:00	65	75
5	Churchill Falls	2016-08-04 16:00	46	61
6	Happy Valley-Goose Bay (GOOSE A)	2016-08-04 16:00	48	80
7	Wabush (WABUSH LAKE A)	2016-08-04 16:00	45	50
8	Churchill Falls	2016-08-05 09:00	45	50
9	Happy Valley-Goose Bay (GOOSE A)	2016-08-05 09:00	51	55
10	Wabush (WABUSH LAKE A)	2016-08-05 09:00	45	50
11	Churchill Falls	2016-08-05 16:00	40	60
12	Mary's Harbour (MARY'S HARBOUR	2016-08-05 16:00	55	70
13	Battle Harbour (BATTLE HARBOUR	2016-08-05 16:00	55	69
14	Churchill Falls	2016-08-06 09:00	40	60
15	Happy Valley-Goose Bay (GOOSE A)	2016-08-06 09:00	60	80
16	Mary's Harbour (MARY'S HARBOUR	2016-08-06 09:00	55	80
17	Battle Harbour (BATTLE HARBOUR	2016-08-06 09:00	60	70
18	Churchill Falls	2016-08-06 16:00	48	53
19	Churchill Falls	2016-08-21 16:00	47	61
20	Churchill Falls	2016-08-22 16:00	62	74
21	Churchill Falls	2016-08-23 09:00	57	60
22	Nain (NAIN A)	2016-08-23 09:00	59	74

Alert #	Site Name	Alert Issue Date	12-hourly Precipitation Forecast (mm)	24-hourly Precipitation Forecast (mm)
23	Appleton/Glenwood	2016-08-29 17:00	59	78
24	Bishops Falls	2016-08-29 17:00	60	78
25	Comfort Cove (COMFORT COVE)	2016-08-29 17:00	69	86
26	La Scie (LA SCIE)	2016-08-29 17:00	69	86
27	Corner Brook	2016-09-08 09:00	34	54
28	Corner Brook	2016-09-09 09:00	46	55
29	Nain (NAIN A)	2016-09-12 09:00	52	60
30	Burgeo (BURGEO NL)	2016-10-08 09:00	59	71
31	Gander (GANDER AIRPORT CS)	2016-10-08 09:00	60	68
32	Burgeo (BURGEO NL)	2016-10-09 09:00	53	80
33	Carbonear	2016-10-09 09:00	73	99
34	Deer Lake, Steady Brook	2016-10-09 09:00	39	58
35	Gander (GANDER AIRPORT CS)	2016-10-09 09:00	55	73
36	Mount Pearl, St. John's	2016-10-09 09:00	70	104
37	Mount Pearl, St. John's	2016-10-09 09:00	70	104
38	Hant's Harbour	2016-10-09 09:00	73	99
39	Heart's Delight-Islington	2016-10-09 09:00	80	99
40	Hickman's Harbour-Robinson	2016-10-09 09:00	80	107
41	Hodges Cove	2016-10-09 09:00	83	111
42	La Scie (LA SCIE)	2016-10-09 09:00	44	54
43	Salmon Cove	2016-10-09 09:00	72	112
44	Clarenville (Shoal Harbour)	2016-10-09 09:00	70	109
45	St. Alban's (ST ALBANS)	2016-10-09 09:00	95	126
46	St. Lawrence (ST LAWRENCE)	2016-10-09 09:00	103	138
47	Victoria	2016-10-09 09:00	76	101
48	Whitbourne	2016-10-09 09:00	80	102
49	Winterton	2016-10-09 09:00	78	97
50	Bay Roberts (Shearstown)	2016-10-09 09:00	74	97
51	Appleton/Glenwood	2016-10-10 09:00	109	150
52	Bishops Falls	2016-10-10 09:00	132	174
53	Burgeo (BURGEO NL)	2016-10-10 09:00	239	287
54	Carbonear	2016-10-10 09:00	92	118
55	Great Codroy (Codroy Valley)	2016-10-10 09:00	158	215
56	Cold Brook, Kippens (Gaudon's Brook)	2016-10-10 09:00	122	166
57	Comfort Cove (COMFORT COVE)	2016-10-10 09:00	97	146
58	Deer Lake, Steady Brook	2016-10-10 09:00	114	154
59	Gander (GANDER AIRPORT CS)	2016-10-10 09:00	99	146
60	Glovertown	2016-10-10 09:00	101	125
61	Hant's Harbour	2016-10-10 09:00	97	123

Alert #	Site Name	Alert Issue Date	12-hourly Precipitation Forecast (mm)	24-hourly Precipitation Forecast (mm)
62	Heart's Delight-Islington	2016-10-10 09:00	94	124
63	Hickman's Harbour-Robinson	2016-10-10 09:00	97	127
64	Hodges Cove	2016-10-10 09:00	97	127
65	La Scie (LA SCIE)	2016-10-10 09:00	94	136
66	Channel-Port aux Basques (Port Aux	2016-10-10 09:00	162	202
67	Salmon Cove	2016-10-10 09:00	92	118
68	Clarenville (Shoal Harbour)	2016-10-10 09:00	101	128
69	St. Alban's (ST ALBANS)	2016-10-10 09:00	189	246
70	St. Lawrence (ST LAWRENCE)	2016-10-10 09:00	106	140
71	Stephenville	2016-10-10 09:00	131	185
72	Trout River	2016-10-10 09:00	93	118
73	Victoria	2016-10-10 09:00	92	118
74	Whitbourne	2016-10-10 09:00	77	96
75	Winterton	2016-10-10 09:00	97	124
76	Bay Roberts (Shearstown)	2016-10-10 09:00	77	98
77	Stephenville Crossing, Black Duck Siding	2016-10-10 09:00	158	215
78	Corner Brook	2016-10-10 09:00	132	155
79	Appleton/Glenwood	2016-10-10 16:00	97	129
80	Bishops Falls	2016-10-10 16:00	101	140
81	Burgeo (BURGEO NL)	2016-10-10 16:00	205	236
82	Carbonear	2016-10-10 16:00	92	118
83	Great Codroy (Codroy Valley)	2016-10-10 16:00	148	185
84	Cold Brook, Kippens (Gaudon's Brook)	2016-10-10 16:00	133	163
85	Comfort Cove (COMFORT COVE)	2016-10-10 16:00	97	134
86	Deer Lake, Steady Brook	2016-10-10 16:00	131	161
87	Gander (GANDER AIRPORT CS)	2016-10-10 16:00	95	120
88	Glovertown	2016-10-10 16:00	101	125
89	Hant's Harbour	2016-10-10 16:00	97	123
90	Heart's Delight-Islington	2016-10-10 16:00	94	124
91	Hickman's Harbour-Robinson	2016-10-10 16:00	97	127
92	Hodges Cove	2016-10-10 16:00	97	127
93	La Scie (LA SCIE)	2016-10-10 16:00	152	185
94	Channel-Port aux Basques (Port Aux	2016-10-10 16:00	152	202
95	Salmon Cove	2016-10-10 16:00	92	118
96	Clarenville (Shoal Harbour)	2016-10-10 16:00	101	128
97	St. Alban's (ST ALBANS)	2016-10-10 16:00	157	186
98	St. Lawrence (ST LAWRENCE)	2016-10-10 16:00	76	110
99	Stephenville	2016-10-10 16:00	136	165
100	Trout River	2016-10-10 16:00	94	109

Alert #	Site Name	Alert Issue Date	12-hourly Precipitation Forecast (mm)	24-hourly Precipitation Forecast (mm)
101	Victoria	2016-10-10 16:00	92	118
102	Whitbourne	2016-10-10 16:00	69	95
103	Winterton	2016-10-10 16:00	97	124
104	Bay Roberts (Shearstown)	2016-10-10 16:00	74	98
105	Stephenville Crossing, Black Duck Siding	2016-10-10 16:00	141	167
106	Corner Brook	2016-10-10 16:00	146	171
107	Deer Lake, Steady Brook	2016-10-11 09:00	10	10
108	Corner Brook	2016-10-11 09:00	10	10
109	Deer Lake, Steady Brook	2016-10-21 09:00	62	74
110	La Scie (LA SCIE)	2016-10-21 09:00	71	83
111	Corner Brook	2016-10-21 09:00	68	75
112	St. Lawrence (ST LAWRENCE)	2016-11-18 17:00	78	110
113	Mount Pearl, St. John's	2016-12-30 10:00	68	98
114	Bay Roberts (Shearstown)	2016-12-30 10:00	68	96

Note:

Exceeded 12-Hourly 20-yr flood limit	Exceeded 24-Hourly 20-yr flood limit
Exceeded 12-Hourly 100-yr flood limit	Exceeded 24-Hourly 100-yr flood limit
WRMD or EC Exceeded flood limit	

Of the 114 alerts and observed precipitation events that occurred during the period from July 2016 to December 2016, 79 of the events occurred during the October 10-11 transit of post-hurricane Matthew. Note that in the October monthly report, we identified a total of 137 alerts being generated, because in many cases, an alert corresponded to exceedance of multiple thresholds.

Over the entire season, the majority of the alerts (66%) were 12-hour accumulation thresholds. The post-hurricane Matthew event triggered alerts that predominantly exceeded the 100-year thresholds.

Examining the monthly breakdown, it is evident that excluding the post-hurricane Matthew event, most of the season's alerts occurred in August. In comparison, September was the most active month of the 2015 hurricane season. July, September, November and December were all relatively inactive months with four being the maximum number of alerts for those months.

Table 1-2: Monthly Analysis of Flood Alerts

Month	Total Alerts	12-hourly 20-yr alerts	12-hourly 100-yr alerts	24-hourly 20-yr alerts	24-hourly 100-yr alerts	Env. Can. & WRMD Obs.
July	4	4	0	0	0	0
August	22	16	2	4	0	0
September	3	1	0	0	0	2
October	82	9	37	12	16	8
November	1	0	0	1	0	0
December	2	0	0	2	0	0
Total:	114	30	39	19	16	10

There was a greater geographical spread of the alerts this season, compared to last season:

Table 1-3: Regional Analysis of Flood Alerts

Community	Region	Total # of Alerts
Churchill Falls	Labrador	8
Happy Valley-Goose Bay (GOOSE A)	Labrador	3
Battle Harbour (BATTLE HARBOUR	Labrador	2
Mary's Harbour (MARY'S HARBOUR	Labrador	2
Nain (NAIN A)	Labrador	2
Wabush (WABUSH LAKE A)	Labrador	2
Corner Brook	Western	6
Deer Lake, Steady Brook	Western	5
Channel-Port aux Basques (Port Aux	Western	2
Cold Brook, Kippens (Gaudon's Brook)	Western	2
Great Codroy (Codroy Valley)	Western	2
Stephenville	Western	2
Stephenville Crossing, Black Duck Siding	Western	2
Trout River	Western	2
Gander (GANDER AIRPORT CS)	Central	6
Appleton/Glenwood	Central	5
La Scie (LA SCIE)	Central	5

Community	Region	Total # of Alerts
Bishops Falls	Central	3
Comfort Cove (COMFORT COVE)	Central	3
Glovertown	Central	2
Burgeo (BURGEO NL)	Southern	4
St. Lawrence (ST LAWRENCE)	Southern	4
St. Alban's (ST ALBANS)	Southern	3
Bay Roberts (Shearstown)	Eastern	4
Carbonear	Eastern	3
Clarenville (Shoal Harbour)	Eastern	3
Hant's Harbour	Eastern	3
Heart's Delight-Islington	Eastern	3
Hickman's Harbour-Robinson	Eastern	3
Hodges Cove	Eastern	3
Mount Pearl, St. John's	Eastern	3
Salmon Cove	Eastern	3
Victoria	Eastern	3
Whitbourne	Eastern	3
Winterton	Eastern	3

Churchill Falls received the highest number of alerts during 2016, a total of eight (8). The second highest number of alerts issued were for Corner Brook and Gander, each receiving six (6) alerts. Western Newfoundland was more active during 2016 receiving a total of 23 alerts, compared to only six (6) in 2015. The proportional distribution of the number of alerts for the other regions was approximately the same from 2015 to 2016. The exception was Central Newfoundland which saw a proportional decrease however, the total number of alerts for the Central Newfoundland did increase from 19 in 2015 to 24 in 2016. No alerts were issued for the Northern Peninsula this season.

Eastern Newfoundland received the most alerts overall, as well as the majority of the 12-hourly, 20-year alerts. Eastern Newfoundland received 37 of the total 114 alerts issued. All regions of the province listed in Table 1-3 were more active and received more alerts than in 2015.

2.0 VERIFICATION OF ALERTS

The flood alerts were verified on a monthly basis using three data sources/methods to compare with the forecasted values: EC rain gauge data, WRMD rain gauge data, and qualitative community-based reports. However, there remain some significant challenges with verification. Validation was not possible for 60 of the alerts because there were no nearby gauges to compare with. Five of the WRMD gauges were within 10 kilometers of the communities of concern, so Amec Foster Wheeler was able to utilize this data.

The available data indicated that 38 of the 114 alerts issued were not required. However, only 2 of these 38 occasions were corroborated by two gauges, and sometimes the two gauge totals differed significantly from each other due to the distance between them. In order for verification to be irrefutable, ideally we would compare forecasted values to all verification sources and the sources would report comparable figures. In most cases, Amec Foster Wheeler only had a single gauge verification source for an alert or there was a substantial discrepancy between the EC and WRMD gauges. Often one source agreed better with the forecast, but it is difficult to determine which should be considered the correct measurement.

2.1 Community Based Flood Reports

Amec Foster Wheeler worked with Fire & Emergency Services – NL (FES-NL) this season, with monthly calls to discuss the alerts. The concept was to create a qualitative field verification measurement that could further validate the statistical methods. Following a forecasted flood event, the intention was for local officials to classify the event as having no, minor, or catastrophic flooding and these eyewitness reports would be noted on the monthly verification. In the absence of community accounts, local newspapers were checked to qualitatively verify the alerts.

2.2 Potential Missed Alerts

There were ten occasions where the WRMD or EC gauges recorded amounts that exceeded the threshold limits while there were no corresponding alerts for these amounts. The missed alerts all related to events on September 9 or October 10; there were multiple missed forecast alerts for the same events that total the ten missed alerts. The October 10 events were missed in the early forecasts, but were triggered in subsequent forecasts for the same period. Table 2-1 shows the missed alerts:

Table 2-1: Potential Missed Alerts

Community	Issue Date	Potential Miss	Conclusion
Corner Brook	September 8, 2016, September 9, 2016	WRMD Exceeded 24-hourly, 100-year limit	37 mm reported from Corner Brook EC station from September 8-9
Corner Brook	October 11, 2016	WRMD Exceeded 24-hourly, 100-year limit	11 mm reported from Corner Brook EC station from October 9-10
Burgeo	October 8, 2016, October 9, 2016	EnvCcan Exceeded 24-hourly, 100-year limit	152 mm reported from Burgeo EC station on October 9-10
Gander	October 8, 2016, October 8, 2016	EnvCcan Exceeded 24-hourly, 100-year limit	154 mm reported from Gander EC station from October 9-10
Deer Lake, Steady Brook	October 9, 2016, October 11, 2016	WRMD Exceeded 24-hourly, 100-year limit	140 mm reported from Deer Lake EC station from October 9-10
La Scie	October 9, 2016	EnvCcan Exceeded 24-hourly, 20-year limit	85 mm reported from La Scie EC station from October 9-10

For the September 9th event listed in Table 2-1, rainfall occurred along a stationary front on September 8th, followed by the development of a slow-moving area of low pressure along the front on September 9th. Based on data from Environment Canada and after an examination of archived radar scans, the precipitation totals likely verified closer to the Environment Canada station versus the WRMD.

For the October 10th events listed in Table 2-2, the heavy rainfall amounts reported were attributed to the passage of Post-Tropical Storm Matthew, which slowly approached the province from eastern Nova Scotia early on October 10th and then passed over eastern Newfoundland on the morning of October 11th. It is unclear why the observed total precipitation totals from the Corner Brook EC station for the event were so low but the under-forecasted precipitation totals for all stations was likely due to the very slow movement of Post-Tropical Storm Matthew as it encountered a blocking ridge to the north as it approached from Nova Scotia and slowly moved over the Avalon Peninsula early on October 11.

2.3 Climate Normals

Airport reports of rainfall across NL were examined to determine how the 2016 HSFAS season compared to the climatological normals. 2016 Months are colour-coded in red if they were substantially above normal and blue if they were substantially below normal.

Table 2-2: Monthly Rainfall Totals (in millimetres) compared to climate normals

Location	Jul 2016	Jul Norm	Aug 2016	Aug Norm	Sep 2016	Sep Norm	Oct 2016	Oct Norm	Nov 2016	Nov Norm	Dec 2016	Dec Norm
St. John's	101	91.6	105.8	100.0	138.6	129.6	147.6	153.7	241.4	124.8	204.6	102.9
Gander	126.4	95.4	109.6	104.2	102.6	114.7	242.2	102.3	118.4	75.2	109.9	48.9
Deer Lake	80.6	95.1	138	109.6	132.6	99.9	190.1	84.9	99.0	60.2	130	27.6
Goose Bay	67.8	121.3	126.1	99.3	59.4	90.6	126.2	63.3	64.8	22.7	37.4	6.6

St. John's experienced a rainy November and December. Most of the Avalon alerts occurred in October however due to the impact of Post-Tropical Storm Matthew.

Gander recorded above average rainfall from October through December. Most of the Central NL alerts occurred in October as well, again due to the impacts from Matthew.

Goose Bay recorded below normal rainfall totals in July and again in September. Goose Bay experienced a rainy August which is when two of the three alerts of the season were issued. Overall, this season's alerts showed much more correlation with the climate data than in the previous season.

2.4 Summary

This year through the use of the Weather Web Portal, the raw Esri Shapefiles and the data services the forecast details were available to a larger audience. It would benefit WRMD to solicit feedback from the users of the service to determine the effectiveness of the current data distribution formats. Feedback from the users can then be taken into consideration for enhancements to the services. It is also

recommended to consider adding the WRMD rain gauge data to these data services thus providing users with another source of near real-time validation of an ongoing event.

3.0 LESSONS LEARNED

There does not appear to be a consistent trend in the geographical spread of the alerts from season to season. Eastern Newfoundland was the hardest hit this season, whereas Central Newfoundland was most active last season. The largest factor for this was the impacts from Post-Tropical Storm Matthew. The impact of Post-Tropical Storm Matthew was a general increase in alert activity for all regions. Labrador also continued its trend from last year, with many alerts received, especially for the Churchill Falls region.

From a forecasting perspective, the team relied more on the GEM-LAM and WRF atmospheric model, which provided increased accuracy. In general, the verification was greatly improved from last year and the use of the WRMD gauges was a major improvement for the verification. The forecasting team must continue to reduce the over-forecasting of alerts, but in honing forecasting practices to reduce false alarms, care must be taken to ensure that forecasters do not start missing flood events.

There are still several gaps in the monitoring networks that inhibit our ability to verify the forecasts in some areas. Many communities require additional measurements, access, and/or studies. There are only a limited number of rain gauges in the areas that had the most alerts, which makes it very difficult to determine if those alerts were warranted. Without adequate instrumentation for measuring precipitation, it can be almost impossible to know for certain in high terrain areas whether the forecasted precipitation was accurate. Additional rain gauges could be installed, particularly in the regions that generated significant alerts, and access must be obtained for other gauge networks in use across the Province by commercial/private agencies.

4.0 CONCLUSION

It would be highly beneficial to pursue additional improvements to the data sources:

1. Additional rain gauges could be installed, particularly in the regions that generated significant alerts.

2. Access could be obtained for other rain gauge networks in use across the Province, and the existing Department of Transportation Road Weather Information System monitoring network could add rain gauges to their existing stations.

3. Flood Risk Mapping Studies could be considered for the communities that triggered alerts based on Intensity-Duration-Frequency (IDF) curves.

Without the implementation of several of these recommendations, it will remain difficult to accurately verify the flood alerts in some regions.

5.0 CLOSURE

We trust that this report meets your needs. Please do not hesitate to contact the undersigned if you have any questions or comments regarding the hurricane season outlook.

Yours sincerely,

Amec Foster Wheeler Environment & Infrastructure,
a Division of Amec Foster Wheeler Americas Limited

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