Report on

2014 Flood Event Assessment - Southeast Saskatchewan

PROJECT NO. 2711-15006-0
Saskatchewan Water Security Agency

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1 EXECUTIVE SUMMARY

In late June 2014 large areas of southeastern Saskatchewan experienced a major precipitation event with total precipitation amounts exceeding 180 mm. This rainfall event caused significant runoff and subsequent damages throughout the area. Saskatchewan Water Security Agency (WSA) retained McElhanney Consulting Services (McElhanney) to assess the precipitation event, evaluate the magnitude of the resulting flows and water levels and to summarize the damages caused by floods. In addition WSA engaged Custom Climate Services Incorporated (CCS) to evaluate the magnitude and extent of the precipitation event. This report summarizes the findings of McElhanney and CCS.

McElhanney deployed three teams in the field for six days following the event to record the flooding through photographs, notes and observations. Damages were observed throughout the region. Municipal and provincial infrastructure damages occurred mostly to roads, culverts and bridges. Private property damages were not included in the scope of this work but were observed to include loss of topsoil due to erosion, crop damages, and property damages to cottages, homes and other buildings as well as damages to private roads. Photographs were taken and geo-referenced for later use in a GIS system.

CCS compiled data from several sources including Environment Canada. The precipitation totals for the event exceeded 180 mm in some locations and intensities were recorded as high as 19.9 mm/hour (Regina, SK). The frequency of occurrence for the precipitation event was evaluated for several climate stations and in one case the 1-day 1:100-year rainfall was observed and in several cases the 3-day 1:100-year rainfall was observed during the rain event.

After the runoff event McElhanney worked with WSA and the Water Survey of Canada (WSC) to compile and evaluate the stream flows recorded during this event. Data from about 70 stations were evaluated and a summary of the event was completed which included the peak flow in the 2014 spring runoff event, the peak flow during the summer rainstorm event and the assessment of the frequency of occurrence of peak flows at the stations. Normally WSA and WSC undertake a comprehensive assessment of the quality of the data collected at streamflow stations before that data is published. In this case provisional data was produced by these agencies and was used in this assessment. It is possible that, when the data is published in final form, flows reported will be different than the flows used for this assessment. The following table summarizes the magnitude of the flood event by comparing the number of stations reporting various return period flood peaks following the rainfall event in the study area:

Range of Flood Magnitude (Return Period)	Number of Stations
<1:10	44
>=1:10 and <1:25	5
>=1:25 and <1:50	7
>=1:50	14

The assessment of the hydrologic flood event showed that the antecedent conditions were favorable for a flood event. Local storages (sloughs and depressions) were generally full and soil moisture conditions were normal to wet following above-average precipitation during the three months prior to the rainfall event. The result was that the rain fell on a landscape that was primed for runoff and, as a result the runoff event was significantly high.

Damage information was collected from several sources for this report. The main source was direct contact with municipalities, First Nations and government agencies. The following table summarizes responses to the requests:

Agency	Number Contacted	Number of Responses	Percent Responses
Rural Municipalities	36	15	42%
Cities and Towns	20	14	70%
Villages and Resorts	27	11	41%
Provincial Parks	6	5	83%
First Nations	9	0	0%
Provincial Agencies	1	1	100%

While the response to the request for information was not complete it was possible to summarize information that was received. Reported damages from rural agencies include: 180 km of roads, 29 bridges, 144 culverts, 4 dams, and 20 water treatment plants or wells damaged. In addition were damages to other public infrastructure such as town buildings or sporting grounds. The damages to infrastructure also disrupted access to communities and rural residences immediately following the flood, and agencies continue to work to fix or replace damaged structures.

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2 INTRODUCTION

A storm that started forming on June 26, 2014 developed into a major synoptic rain storm on June 28 and tailed off on June 30, 2014. The storm affected a large area of southeastern Saskatchewan and produced flooding conditions along streams and around lakes and sloughs that caused significant damage and disruption. The flooding occurred in low areas over a broad area of about 50,000 km^2, as shown in Figure 1 – Appendix A. The Saskatchewan Water Security Agency (WSA) approached McElhanney Consulting Services Ltd. (McElhanney) on July 2 to conduct an investigation of the hydrologic conditions that occurred before, during and after this event, to document damages caused by the flooding and to comment on the emergency actions taken by various agencies in response to this situation. Custom Climate Services (CCS) was engaged by WSA to evaluate meteorological conditions. A summary of CCS findings are incorporated in this report, while the full version is available in Appendix B.

The geographic extent of this project extends from the US border in the south to about Highway 5 in the north and from the Manitoba border in the east to about Highway 35 in the west. The event to be investigated began with the storm event that began developing on June 26, and continued to about June 30 and includes the runoff that was produced by that storm.

The work involved field investigation and documentation of meteorological and hydrologic conditions, gathering of information on flood damages in the field and through contact with various agencies, reporting to and advising WSA during the field investigation as necessary, preliminary evaluation of the hydrologic flood event(s) and preparing a report documenting the findings.

The areas included in the meteorological and hydrologic investigation were approximately determined by the extent of the storm and subsequent runoff. The damage assessments were generally compiled based on Rural Municipalities (RM), First Nations, municipalities, etc. that had declared states of emergency as a result of the event.

3 BACKGROUND CONDITIONS

Measured stream flow rates and volumes are used to determine the magnitude of an event produced by a snowmelt runoff or rainfall runoff event. The magnitude of flood damages typically relates better to stream flow than to rainfall. Rainfall generated stream flow in an unregulated basin is primarily a function of the antecedent moisture condition, rainfall event, drainage area, land use and upstream storage.

Stream flow monitoring (hydrometric monitoring) is carried out at many locations in the prairies, and hydrometric gauging stations in Saskatchewan are operated by the WSA and Water Survey of Canada (WSC). This report presents a compilation of peak discharge data from WSA and WSC gauging stations in the study area (Figure 1 – Appendix A) and presents that information in context of the rainfall event occurring from June 27 to June 30 2014 in southeastern Saskatchewan. The rainfall that occurred in southwestern Saskatchewan on June 26, 2014 is not included in this report. The gauging stations, rainfall event peak discharge, spring peak discharge and return period flood events are presented in Table 1. All data presented in Table 1 was provided by either WSA or WSC. The 2014 data is preliminary at this time and therefore subject to revision prior to final publication. Although the 2014 peak flow estimates are reported to three significant figures at times throughout this report for comparative purposes, the accuracy of these estimates is likely overstated at this time as many of the basins experienced extreme events, during which it would have been difficult to obtain quality discharge measurements. The data presented in Table 1 are referenced throughout this report. It is important to note that the return period estimates provided by WSA are based on the daily average peak flows and that most of the provided frequency analyses have not yet been updated to include the 2014 peak or other recent data. In addition, the estimated return flood values may have been based on a number of different statistical distributions.

Though stream flow monitoring has been carried out for several decades in Saskatchewan several basin parameters which influence the amount of discharge in a stream are known to have changed since monitoring began. These parameters include land use, drainage patterns, infrastructure such as roads, dams and cross-drainage and potentially climate change. All of these parameters are subject to several natural and anthropogenic influences which skew the consistency of the flow record. For instance, a natural unbroken prairie landscape would generate runoff in a different fashion than an area modified for crop production and transportation. This type of change has likely occurred within the temporal distribution of a watershed which has been monitored for stream flow for several decades. The resultant record would likely yield differences in the magnitude and duration of the hydrograph given similar climatic input conditions. These changes can be assessed in an in-depth analysis but that analysis is not within the scope of this report. For the purpose of this report it is assumed that the changes of this type to a hydrograph over several decades are negligible and the statistical data provided by WSA serves in that context.

Table 1: Hydrometric Gauging Stations

Station	Station Name	Agency	Units	Spring Instantaneous Peak	Spring Daily Average Peak	Spring Daily Average Peak Return Period	June-July Rainfall Event Instantaneous Peak	June-July Rainfall Daily Average Peak	June-July Rainfall Daily Average Peak Return Period	Return Period							
										1:2	1:5	1:10	1:25	1:50	1:100	1:200	1:500
05HH002	CROMARTY CREEK NEAR BIRCH HILLS	WSA	m³/s	5.94	4.69	>=1:2	3.94	3.08	>=1:2	2.76	6.8	9.96	14.3	20	25	30	37
05JE001	MOOSE JAW RIVER ABOVE THUNDER CREEK	WSA	m³/s	-	31.2	>=1:2	34.8	34.1	>=1:2	16.7	65.5	108	161	196	224	247	269
05JE004	MOOSE JAW NEAR ROULEAU	WSA	m³/s	-	7.10	<1:2	14.5	14.3	<1:2	20	70	100	140	160	190	210	230
05JE005	AVONLEA CREEK NEAR ROULEAU	WSA	m³/s	9.42	8.24	<1:2	3.85	1.33	<1:2	13.8	28.4	38.8	53.1	64.5	76.6	89.3	107
05JF012	WASCANA CREEK BELOW KRONAU MARSH	WSA	m³/s	-	7.40	<1:2	10.6	10.3	<1:2	12	33	51	77	97	119	140	170
05JH001	ARM RIVER NEAR BETHUNE	WSA	m³/s	-	12.8	>=1:2	15.9	15.7	>=1:2	6.21	18.7	29.3	44.4	56.5	69.2	82.3	100
05JH005	LEWIS CREEK NEAR IMPERIAL	WSA	m³/s	-	12.0	>=1:50	24.3	15.9	>=1:200	1.54	3.94	5.84	8.46	10.5	12.6	14.8	17.7
05JL004	KATEPWA LAKE AT KATEPWA BEACH	WSA	m	-	-	-	479.075	479.068	No Return Period Data								
05JM006	CROOKED LAKE NEAR GRAYSON	WSA	m	-	-	-	454.474	454.389	No Return Period Data								
05JM007	ROUND LAKE NEAR WHITEWOOD	WSA	m	-	-	-	445.722	445.710	No Return Period Data								
05JM013	QU'APPELLE RIVER @ HYDE	WSA	m³/s	-	80.8	>=1:5	243	236	>=1:25	32	76	116	180	237	300	371	477
05KA001	CARROT RIVER NEAR KINISTINO	WSA	m³/s	23.9	23.0	>=1:10	10.7	10.5	>=1:2	5.55	14.1	19.2	23.9	26.3	27.8	28.8	29.5
05KA009	GOOSEHUNTING CREEK NEAR BEATTY	WSA	m³/s	28.4	27.1	>=1:2	19.5	17.9	>=1:2	14.4	35.1	51.1	73	90	107	125	149
05KB003	CARROT RIVER NEAR ARMLEY	WSA	m³/s	184	177	>=1:2	98.1	97.4	>=1:2	67.1	185	256	320	351	371	382	389
05KB005	BURNTOUT BROOK NEAR ARBORFIELD	WSA	m³/s	-	19.6	>=1:2	28.4	26.1	>=1:5	11.8	22.1	29.3	38.7	45.6	52.5	59.4	68.5
05KB006	LEATHER RIVER NEAR STAR CITY	WSA	m³/s	-	7.70	>=1:2	12.5	11.5	>=1:2	5.78	11.7	16.2	22.8	28.5	34.7	41.7	52.3
05KC001	CARROT RIVER NEAR SMOKY BURN	WSA	m³/s	420	413	>=1:5	309	304	>=1:2	202	406	553	745	890	1035	1180	1374
05KE002	TORCH RIVER NEAR LOVE	WSA	m³/s	-	102	>=1:5	124	118	>=1:5	43.1	100	127	170	200	220	250	270
05KE007	KELSEY CREEK NEAR GARRICK	WSA	m³/s	25.5	22.2	>=1:10	2.69	2.61	<1:2	4.39	11.7	17.6	25.7	32.1	38.7	45.5	54.8
05KJ014	PASQUIA RIVER AT HIGHWAY #9	WSA	m³/s	-	11.6	>=1:5	19.6	11.0	>=1:5	5.52	10.3	14.5	21.2	27.5	35.2	44.6	60.2
05LA003	DUCK CREEK NEAR KELVINGTON	WSA	m³/s	25.3	24.0	>=1:25	11.8	11.1	>=1:2	6.77	12.2	16.3	22.0	26.6	31.7	37.1	45.1
05LA004	PIPESTONE CREEK NEAR ROSE VALLEY	WSA	m³/s	37.5	37.1	>=1:10	21.7	21.3	>=1:2	11.1	22.7	32.2	46	58	70	83	100
05LA005	RED DEER NEAR ARCHERWILL	WSA	m³/s	28.2	26.4	>=1:5	23.2	22.6	>=1:5	8.6	21	30.7	44.3	56.1	68.4	81	98.4
05LB004	LOISELLE CREEK NEAR HUDSON BAY	WSA	m³/s	4.4	4.05	<1:2	2.71	2.61	<1:2	4.24	9.07	12.6	17.4	21.0	24.6	28.3	33.2
05LB005	RED DEER NEAR STEEN	WSA	m³/s	-	43.2	>=1:2	49.6	49.3	>=1:5	19.5	46.6	65.6	90.1	112	133	156	186
05LB006	SHAND CREEK NEAR DILLABOUGH	WSA	m³/s	36.9	34.6	>=1:2	27.1	26.6	<1:2	27	55.7	76.5	104	125	146	167	195
05LB007	FIR RIVER NEAR HUDSON BAY	WSA	m³/s	-	16.4	>=1:2	33.3	31.6	>=1:5	14.7	24.7	32.4	43.3	52.2	61.8	72.1	86.9
05LB010	PRAIRIE RIVER NEAR PRAIRIE RIVER	WSA	m³/s	-	-	-	18.8	17.9	>=1:5	7.2	13.7	19.3	28	36	45.5	56.9	75.4
05LD003	OVERFLOWING RIVER NEAR HUDSON BAY	WSA	m³/s	-	10.3	>=1:2	36.0	31.7	>=1:25	9.7	16.5	21.5	28.7	34.6	41.0	48.1	58.5
05LE008	SWAN RIVER NEAR NORQUAY	WSA	m³/s	-	55.0	>=1:2	170	169	>=1:50	34.5	61.5	84.1	120	152	191	237	312
05LE011	MALONECK CREEK NEAR PELLY	WSA	m³/s	14	12.7	>=1:5	9.94	8.52	>=1:2	5.72	12.2	16.9	23.2	27.9	32.7	37.6	44.1
05MB005	WILLOW BROOK NEAR WILLOWBROOK	WSA	m³/s	-	6.88	>=1:5	29.4	28.8	>=1:100	1.7	4.4	7.0	12.0	17.0	23.0	30.0	40.0
05MB006	CROOKED HILL CREEK NEAR CANORA	WSA	m³/s	40.1	39.6	>=1:10	20.3	20.0	>=1:2	9.31	20.5	28.9	40.1	48.6	57.3	66.0	77.8

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										1:2	1:5	1:10	1:25	1:50	1:100	1:200	1:500
05MB007	SPIRIT CREEK NEAR BUCHANAN	WSA	m³/s	-	28.8	>=1:10	38.2	35.7	>=1:25	8.2	17.9	25.2	34.8	42.1	49.6	57.1	67.1
05MB010	GOOD SPIRIT LAKE NEAR CANORA	WSA	m	-	-	-	485.565	485.551	No Return Period Data								
05MB013	FISHING LAKE NEAR WADENA	WSA	m	-	-	-	530.593	530.585	No Return Period Data								
05MC002	STONY CREEK NEAR STENEN	WSA	m³/s	9.9	9.88	>=1:5	3.16	3.14	<1:2	3.91	9.72	14.3	20.5	25.4	30.4	35.5	42.4
05NB031	SOURIS RIVER NEAR BECHARD	WSA	m³/s	-	4.40	<1:2	9.52	9.17	<1:2	10.6	41.1	62	80.8	89.3	94	96.3	97.3
05NC001	MOOSE MOUNTAIN CREEK BELOW RESERVOIR	WSA	m³/s	-	14.1	>=1:2	23.2	22.9	>=1:10	7	15	20	27	35	45	50	65
05JE006	MOOSE JAW RIVER NEAR BURDICK	WSC	m³/s	-	39.0	>=1:2	32.8	33.0	>=1:2	21	79	120	185	240	300	370	481
05JF001	QU'APPELLE RIVER NEAR LUMSDEN	WSC	m³/s	-	85.0	>=1:5	83.1	83.0	>=1:5	30.2	76.8	120	188	252	353	489	747
05JF005	WASCANA CREEK NEAR LUMSDEN	WSC	m³/s	-	34.0	>=1:2	64.4	58.0	>=1:5	19	43	65	98	126	157	191	239
05JF006	BOGGY CREEK NEAR LUMSDEN	WSC	m³/s	-	13.0	>=1:5	18.7	19.0	>=1:5	3.06	12.7	21.2	31.5	38.0	43.3	47.3	51.0
05JF011	COTTONWOOD CREEK NEAR LUMSDEN	WSC	m³/s	-	38.0	>=1:5	15.3	15.0	>=1:2	3.5	20	40	58	66	78	94	116
05JH004	LAST MOUNTAIN LAKE AT ROWANS RAVINE	WSC	m	-	-	-	491.59	491.55	No Return Period Data								
05JJ003	LANIGAN CREEK ABOVE BOULDER LAKE	WSC	m³/s	-	34.0	>=1:10	17.7	17.0	>=1:5	4.7	15.5	25.1	39.0	50.2	62.0	74.3	91.2
05JJ009	SALINE CREEK NEAR NOKOMIS	WSC	m³/s	-	2.50	>=1:2	3.24	3.00	>=1:5	0.81	2.6	4.5	7.7	10.6	13.8	17.5	22.9
05JK002	QUAPPELLE RIVER BELOW CRAVEN DAM	WSC	m³/s	-	89.0	>=1:25	62.1	62.0	>=1:10	18.1	42.6	61.4	86.8	107	127	147	175
05JK004	JUMPING DEER CREEK NEAR LIPTON	WSC	m³/s	4.05	3.09	>=1:2	12.7	9.54	>=1:25	2.1	4.4	6.1	8.4	10.2	11.9	13.7	16
05JK007	QU'APPELLE RIVER BELOW LOON CREEK	WSC	m³/s	-	62.0	>=1:5	46.2	46.0	>=1:2	21.3	48.4	73.1	112	147	186	231	298
05JL005	PHEASANT CREEK NEAR ABERNETHY	WSC	m³/s	11.2	10.9	>=1:2	62.6	45.3	>=1:100	6.1	14.8	21.6	31	38	45.3	53	63
05JM001	QUAPPELLE RIVER NEAR WELBY	WSC	m³/s	110	109	>=1:5	468.00	456.93	>=1:200	40	81	119	186	253	339	449	647
05JM010	EKAPO CREEK NEAR MARIEVAL	WSC	m³/s	29.2	19.9	>=1:2	61.5	56.9	>=1:50	6	21	32	46	53	59	63	67
05JM015	CUTARM CREEK NEAR SPY HILL	WSC	m³/s	17.1	16.9	>=1:10	45.1	14.6	>=1:5	5.28	11.2	16.4	24.5	31.7	39.9	49.3	63.5
05KH007	CARROT RIVER NEAR TURNBERRY	WSC	m³/s	-	180	>=1:5	-	145.00	>=1:2	113	169	208	260	299	340	382	439
05LC001	RED DEER RIVER NEAR ERWOOD	WSC	m³/s	-	130	<1:2	502	475	>=1:10	153	286	386	527	644	771	927	1174
05MA002	LITTLE QUILL LAKE NEAR WYNARD	WSC	m	-	-	-	520.28	520.27	No Return Period Data								
05MA010	BIG QUILL LAKE NEAR KANDAHAR	WSC	m	-	-	-	520.34	520.35	No Return Period Data								
05MA011	BIRCH CREEK NEAR ELFROS	WSC	m³/s	12.7	11.4	>=1:2	85.3	79.4	>=1:200	9	18.4	25.4	35.4	44.3	54.4	65.8	83.1
05MA012	IRONSPRING CREEK NEAR WATSON	WSC	m³/s	-	27.0	>=1:10	-	11.0	>=1:2	7.8	17.9	25.5	35.8	43.7	51.8	60.2	71.5
05MA016	ROMANCE CREEK NEAR WATSON	WSC	m³/s	-	17.0	>=1:5	12.3	12.0	>=1:2	6.91	13.9	19.2	26.5	32.6	39.2	46.3	56.8
05MA020	QUILL CREEK NEAR QUILL LAKE	WSC	m³/s	-	23.0	>=1:10	7.00	7.00	>=1:2	5.8	12.7	17.8	24.8	30.1	35.5	41	48.4
05MA021	MAGNUSSON CREEK NEAR WYNYARD	WSC	m³/s	4.92	4.40	>=1:2	52.5	36.1	>=1:500	4.1	8.5	11.7	15.9	19.2	22.6	25.9	30.4
05MA025	RANCH CREEK ABOVE RANCH LAKE	WSC	m³/s	-	14.0	No Return Period Data	2.81	1.50	No Return Period Data								
05MB001	YORKTON CREEK NEAR EBENEZER	WSC	m³/s	26.6	26.3	>=1:5	72.1	71.3	>=1:100	12	25	34	46	55	64	73	85
05MB003	WHITESAND RIVER NEAR CANORA	WSC	m³/s	117	116	>=1:5	385	376	>=1:500	32	86	127	177	210	239	264	290

Station	Station Name	Agency	Units	Spring Instantaneous Peak	Spring Daily Average Peak	Spring Daily Average Peak Return Period	June-July Rainfall Event Instantaneous Peak	June-July Rainfall Daily Average Peak	June-July Rainfall Daily Average Peak Return Period	Return Period							
										1:2	1:5	1:10	1:25	1:50	1:100	1:200	1:500
05MC001	ASSINIBOINE RIVER AT STURGIS	WSC	m^3/s	65.2	63.3	>=1:5	103	101	>=1:25	24.0	50.8	70.6	96.7	117	137	157	184
05MC003	LILIAN RIVER NEAR LADY LAKE	WSC	m^3/s	-	10.0	>=1:2	20.9	20.0	>=1:10	6.5	12.6	16.9	22.5	26.7	30.9	35.1	40.6
05MD004	ASSINIBOINE RIVER AT KAMSACK	WSC	m^3/s	222	213	>=1:5	430	426	>=1:50	78.3	164	229	315	381	445	510	592
05MD010	STONY CREEK NEAR KAMSACK	WSC	m^3/s	-	18.0	>=1:50	14.8	14.0	>=1:10	6.5	10.7	12.9	15.3	17	18.4	19.7	21.1
05ME007	SMITH CREEK NEAR MARCHWELL	WSC	m^3/s	18.0	17.8	>=1:25	24.4	17.8	>=1:25	3.6	7.5	10.7	15.5	19.7	24.6	30.3	39.1
05NB014	JEWEL CREEK NEAR GOODWATER	WSC	m^3/s	-	2.00	<1:2	0.51	0.40	<1:2	2.4	17	27	40	50	58	68	70
05NB016	ROUGHBARK RESERVOIR NEAR WEYBURN	WSC	m	-	-	-	-	565.60	No Return Period Data								
05NB020	NICKLE LAKE NEAR WEYBURN	WSC	m	-	-	-	563.26	563.25	No Return Period Data								
05NB021	SHORT CREEK NEAR ROCHE PERCEE	WSC	m^3/s	-	3.00	<1:2	2.67	2.50	<1:2	3.68	16.3	24.6	33.0	37.6	41.0	44.0	48.0
05NB033	MOSELEY CREEK NEAR HALBRITE	WSC	m^3/s	-	0.70	<1:2	2.30	2.20	>=1:2	1.13	2.82	4.16	5.99	7.41	8.88	10.38	12.4
05NB040	SOURIS RIVER NEAR RALPH	WSC	m^3/s	-	2.00	No Return Period Data	5.97	5.50	No Return Period Data								
05NB041	ROUGHBARK CREEK ABOVE RAFFERTY RESERVOIR	WSC	m^3/s	-	0.65	No Return Period Data	0.46	0.45	No Return Period Data								
05NC002	MOOSE MOUNTAIN LAKE	WSC	m	-		-	620.98	620.97	No Return Period Data								
05ND010	MOOSE MOUNTAIN CREEK ABOVE ALAMEDA RESERVOIR	WSC	m^3/s	46.8	39.6	No Return Period Data	35.1	33.0	No Return Period Data								
05ND011	SHEPHERD CREEK NEAR ALAMEDA	WSC	m^3/s	-	0.60	>=1:2	0.82	0.60	>=1:2	0.6	1.5	2.2	3.3	4.4	5.6	7.1	9.5
05ND012	ALAMEDA RESERVOIR NEAR ALAMEDA	WSC	m	-	-	-	562.36	562.65	No Return Period Data								
05NE002	MOOSOMIN LAKE NEAR MOOSOMIN	WSC	m	-	-	-	-	545.55	No Return Period Data								
05NE003	PIPESTONE CREEK ABOVE MOOSOMIN LAKE	WSC	m^3/s	32.2	29.2	>=1:5	76.4	65.2	>=1:25	9.4	21.1	31.5	48.9	65.6	86.5	112	157
05NF006	LIGHTNING CREEK NEAR CARNDUFF	WSC	m^3/s	18.5	17.3	>=1:5	-	169	>=1:500	2.08	11.7	21.1	32.5	39.2	44.3	47.8	50.6
05NF010	ANTLER RIVER NEAR WAUCHOPE	WSC	m^3/s	9.52	5.53	>=1:2	-	29.7*	>=1:100	1.53	6.04	10.4	16.9	22.3	28.0	34.1	42.6
05NG024	PIPESTONE CREEK NEAR THE SASKATCHEWAN BOUNDARY	WSC	m^3/s	41.8	34.8	>=1:2	128	123	>=1:50	15.4	39.6	58.8	85.3	106	127	149	179

*Station was damaged during the flood

The typical analysis used to assess the magnitude of a flooding event requires a long term data set to provide the comparison. The long term data records are filtered for the maximum instantaneous discharge in any given year and the maximum discharge for all years are assessed typically using a distribution that best fits the data. Since maximum instantaneous data is sparse, the WSA typically completes their frequency analysis on peak main daily data. The results from the analysis are a series of discharge magnitudes related to probabilities of the occurrence of that event in a given year; the probabilities are typically expressed as 1:x-year event where x is the return period. As such, a 1:100-year event has a probability of exceedance of 1% in any given year, or once in one hundred years on average. It should be noted that the probability of a specific event is the same any given year regardless of what happened the previous year; hence, it is possible to have 1:100-year events a few years apart, or even in the same year. This type of analysis is utilized in many different ways from estimation of the type of flood that occurred (such as the scope of this report) to providing the criteria for cross-drainage structure design.

As previously discussed, the return period discharge magnitudes for various stations around Saskatchewan were provided by WSA to McElhanney (Table 1). Due to the number of stations involved the return period discharges were not checked for this analysis. The peak discharges observed during the 2014 flood event are presented in Table 1 and their approximate return period intervals are presented as well.

An important influence to peak discharge is antecedent moisture conditions in advance of a flood event. If the general soil condition is 'dry' then the soil's capacity to infiltrate the rain water is high thus reducing the peak discharge of the flood and vice versa for 'wet' pre-flood conditions (high soil moisture results in increased runoff potential). For the purpose of this assessment the spring peak discharge data (provided by WSA and extracted from WSC records) are presented in Table 1 with the approximate return period of the spring runoff event estimated to provide context to the 2014 rainfall flood event.

In consideration of timelines with respect to antecedent moisture conditions the following knowledge is presented based on histories provided by WSA, local residents and McElhanney's professional experience:

- For several years up to approximately 2005, Saskatchewan had generally experienced an extended dry cycle (low soil moisture and reduced water levels in sloughs and depressions);
- Conditions were generally wet in the winter of 2010/2011 and WSA advised that creeks were flowing that typically were not;
- Flooding in 2011 in southeast Saskatchewan was observed to be some of the largest floods on record (elevated soil moisture and high water levels in sloughs and depressions);
- The following years, 2012 and 2013, were not as wet (and in some cases areas were noted as drier than normal; CCS 2014) but local storage in watersheds tended to remain near capacity in the form of sloughs and depressions (no substantial change to soil moisture);
- Snowmelt runoff in 2014 was generally above normal resulting in filling of local storage to capacity (high soil moisture); and,
- The 2014 rainfall resulted in high runoff yields.

In context of the antecedent moisture conditions, CCS (2014) indicates that the period from April 1 to June 27, 2014 was above normal precipitation. Precipitation totals in this period were generally 150 to

200 % of normal. As such, the anomalously wet period immediately prior to the storm likely led to an elevated runoff coefficient.

The hydrology of the formerly glaciated Prairie region is characterized by relatively flat topography but with many features such as moraines, flutings, drumlins, and outwash plains. Rather than being connected to a large-scale drainage system, much of the region is internally drained to small prairie pothole wetlands. These wetlands percolate groundwater extremely slowly due to the low permeability of subsurface glacial till; hence, they only have outflow as evaporation or when their storage capacity is exceeded. The change in hydrographic connectivity fluctuates by year and by season, and controls the area of the basin that contributes discharge to local streams. During the 2014 flood it is believed that many of these areas were filled to levels not observed in quite some time. In areas not dominated by 'potholes' the topography generally remains flat and local roadways may create areas of storage where flood flow is ponding behind culverts.

Prairie watersheds where the topography generally has a low slope are typically discussed in two contexts: 1) gross drainage area; and, 2) effective drainage area. The gross drainage area of a stream at a specified location is that area, enclosed by its topographic drainage divide, which might be expected to entirely contribute runoff under extremely wet conditions. Whereas the effective drainage area is some fraction of a drainage basin which might be expected to entirely contribute runoff to the main stream during a median flood (return period of two years). The effective and gross drainage areas are reported by Agriculture and Agri-food Canada (AAFC). In the context of gross and effective drainage areas, the 2014 flood event resulted from large portions, if not all, of the gross drainage areas of most of the streams studied. Thus not only was there a high input of water through the rainfall event, and high soil moisture and little basin storage available, but the largest area possible was contributing water to the streams in many instances. The major watersheds in southwestern Saskatchewan are presented in Figure 2 – Appendix A.

Beyond the previously discussed factors, it is important to consider that the statistical methods used to estimate the probability of a flood are based on the available data for the assessment. At best, stream flow measurements have been carried out continuously in Saskatchewan for up to approximately 100 years where many of the stations used in this assessment have much less data; many of the stations have several decades of data though some have been monitored intermittently with large data gaps in the period of record. Thus the probability estimates are based on somewhat abbreviated time frames which may only cover certain time periods depending on the focus and available budgets of the monitoring agencies. The accuracy of flood frequency analyses used to estimate the return period probability are limited by potential deficits in data. The validity of the predictions from the flood frequency analyses improve over time as data records become longer.

4 FIELD PROGRAM

By request from WSA, a field program was initiated in response to the rain event in the regions impacted to document conditions and damages. McElhanney met with WSA in Yorkton on July 4, 2014 and immediately thereafter began collecting observations and taking photographs in some of the areas impacted by the rainstorm. Two teams were collecting information on July 5 and 6, and by July 7 a third team was dispatched. The teams were generally travelling by vehicle, concentrating efforts either on areas known to be impacted or on high risk areas such as dams, roads, and other areas with known high water, based on discussions with WSA and road closures indicated by the Saskatchewan Ministry of

Highways and Infrastructure's (MHI) Highway Hotline. On July 7, 2014 one McElhanney team member accompanied WSA staff in a fixed wing aircraft flight over SE Saskatchewan to better document extents of impacted areas.

The teams concentrated their efforts in the following regions:

- July 4-6 – one team in the Yorkton area
- July 5-7 – one team in the area between the Qu'Appelle River and Melville
- July 7-10 – two teams in the southern region, between the US border and Qu'Appelle Valley and one team in the Yorkton area
- July 10 – three teams north of Yorkton.

High water marks were noted and photographed wherever possible, although the flood peak had already been reached by the time teams reached many of the creeks and rivers. When damages were observed, teams took photographs and recorded as much information as possible.

Photographs and field notes were geo-referenced so that they could be used in GIS software.

In general, the following observations were noted:

- Elevated water levels in most water bodies with high water marks noted above normal conditions;
- General flooding in areas which did not normally hold water;
- Infrastructure damages to roadways, cross-drainages structures and water bearing structures;
- Scour and general erosion associated with fast moving water; and
- Sloughing of steep slope faces.

5 PRECIPITATION EVENT

This section presents a summary of the report on The Southeast Saskatchewan / Southwest Manitoba Storm of June 2014 presented by CCS (2014). The complete report is presented as Appendix B.

A major synoptic rainstorm occurred over approximately 48 hours from late morning on June 28 to around noon on June 30. In addition, some rainfall occurred over southeastern Saskatchewan on June 27 and over the western part of the province on June 26. The area impacted by the storm included southeast Saskatchewan and extended into the adjacent area of Manitoba. Preliminary estimates of precipitation indicated rainfall amounts in the range of 155 to 180 mm with the larger rainfalls occurring near the Manitoba border.

The maximum observed rainfalls were not remarkable in context of other prairie storms; however, the rainfall extended over a wide area. In context of historical information the storm ranked 10th compared to storms over 24,000 km^2, 7th for storms over 58,000 km^2 and 3rd for storms over 169,000 km^2.

CCS reports 1-day return periods of the rainfall (Appendix B; Table 3) at various stations in southeastern Saskatchewan where the range of return periods of the event was approximately 1:5-year to greater than 1:100-year. Only one climate station observed rainfall in excess of the 1:100-year event while all others were within the 1:30-year (or more frequent range). The 3-day return periods of the rainfall are also reported with several stations reporting probabilities less frequent that the 1:50-year event.

6 HYDROLOGIC RESPONSE TO THE PRECIPITATION

6.1 BASIS FOR ANALYSIS

The purpose of this report is to quantify the approximate return period discharge associated with the 2014 rainfall and flood event. The results of the analysis, as presented in Table 1 are based on a greater than/less than approach against the existing return period estimates. Discussions include context to the snowmelt runoff event and context in the historical record of the station. The following stations were selected from Table 1 for detailed assessment:

- 05JM006 – Crooked Lake near Grayson
- 05JM007 – Round Lake near Whitewood
- 05JL005 – Pheasant Creek near Abernethy
- 05JM001 – Qu'Appelle River near Welby
- 05JM010 – Ekapo Creek near Marieval
- 05MA011 – Birch Creek near Elfros
- 05MB001 – Yorkton Creek near Ebenezer
- 05MD004 – Assiniboine River at Kamsack
- 05ME007 – Smith Creek near Marchwell
- 05NF010 – Antler River near Wauchope

In some instances the previous maximum observed discharge is presented with the year of occurrence. Due to data limitations the value reported may be either the instantaneous peak or the daily average peak. The reader is cautioned in consideration of these values as they are presented for context only.

6.2 BASINS ASSESSED

05JM006 – Crooked Lake near Grayson

Crooked Lake is located in the Qu'Appelle River valley approximately 85 km west of the Saskatchewan/Manitoba border within the RM of Grayson and adjacent to the Cowessess and Sakimay First Nations. Outflow from Crooked Lake can be regulated by an outlet control structure. The monitoring station at Crooked Lake has been active since 1942 with the highest recorded water level on record, prior to 2014, being 1955 where the water level in the lake rose to 454.375 m in May. The water level in Crooked Lake peaked at 454.47 m in July 2014. WSA indicates that return period stage heights have been estimated to be a 1:100-year event for this station.

05JM007 – Round Lake near Whitewood

Round Lake is located in the Qu'Appelle River valley approximately 20 km east of Crooked Lake. The RMs of Grayson and Fertile Belt are to the north with the Ochahpowace First Nation to the south. Monitoring for the Round Lake station began in 1942 with the highest year on record, prior to 2014, being 1976 when water levels rose to 444.499. The water level peaked at 445.72 m in July 2014 for Round Lake. Return period stage heights have been estimated by WSA to be greater than 1:100-year return for this station.

05JL005 – Pheasant Creek near Abernethy

Hydrometric monitoring at Pheasant Creek began in 1946. The creek flows south west to the Qu'Appelle valley through the RMs of McLeod and Abernethy. The largest peak on record was approximately 49 m^3/s in 1976. The rainfall event in 2014 recorded a peak mean daily discharge of approximately 45 m^3/s which relates to about the 1:100-year return flood. The snowmelt runoff peak in 2014 was approximately 11 m^3/s corresponding to an event less common than the 1:2-year flood but more frequent than the 1:5-year flood. It should be noted that peak flows at this location are impacted by the upstream railway embankment.

05JM001 – Qu'Appelle River near Welby

The monitoring station on the Qu'Appelle River near Welby represents the last point of monitoring on the Qu'Appelle system prior to the Saskatchewan/Manitoba border. The station was installed in 1915 but only operated semi-continuously since 1942. The largest event on record had a peak of approximately 370 m^3/s in 2011. The 2014 snowmelt runoff event registered a daily average peak of approximately 109 m^3/s (between a 1:5-year and 1:10-year return flood) and the summer flood in 2014 produced a new maximum daily average peak of 457 m^3/s (larger than the 1:200-year return flood).

05JM010 – Ekapo Creek near Marieval

Ekapo Creek monitoring began in 1956 with continuous monitoring beginning in 1969 and continuing to present. Ekapo Creek is monitored within the Cowessess First Nation prior to entering the Qu'Appelle River valley. The previous maximum peak on record occurred in 2011 with a magnitude of approximately 60.2 m^3/s. The 2014 snowmelt runoff daily average peak was about a 1:2-year return flood at 20 m^3/s while the 2014 rainfall flood daily average peak was between a 1:50-year and 1:100-year event at 56 m^3/s.

05MA011 – Birch Creek near Elfros

Birch Creek flows north towards the Quill Lakes system through the RMs of Emerald and Elfros. Birch Creek is monitored where it crosses Highway 16 via a culvert installation (established 1963). Damage to the roadway during the 2014 rainfall flood event required road closure and high priority re-construction. The previous peak was approximately 36.8 m^3/s as observed in 1971. The approximate peak discharges for the 2014 snowmelt runoff and rainfall flood events were 11 m^3/s (about 1:3-year) and 79 m^3/s (nearly a 1:500-year), respectively.

05MB001 – Yorkton Creek near Ebenezer

Yorkton Creek flows south towards the City of Yorkton through the RMs of Good Lake and Orkney. The station has been in operation since 1941 and the largest peak was observed in 1995 at approximately 55 m^3/s. The 2014 snowmelt runoff event yielded a peak of approximately 26 m^3/s (about a 1:5-year return flood) while a peak of approximately 71 m^3/s (about a 1:200-year event) was observed during the 2014 rainfall flood.

05MD004 – Assiniboine River at Kamsack

Hydrometric monitoring of the Assiniboine River at this location began in 1944. In 1995 a peak of 489 m^3/s was observed which is slightly larger than the 2014 rainfall flood event which yielded approximately 426 m^3/s (between a 1:50 and 1:100-year event). The 2014 snowmelt runoff event was approximately 213 m^3/s (about a 1:10-year event).

05ME007 – Smith Creek near Marchwell

Smith Creek flows southeast towards the Saskatchewan/Manitoba border through the RMs of Churchbridge and Langenburg. The station was established in 1975 and the largest peak on record occurred in 1995 with a discharge of approximately 24.7 m^3/s. The 2014 rainfall and flood events both produced daily average peaks of approximately 18 m^3/s corresponding to return periods between the 1:25-year and 1:50-year events.

05NF010 – Antler River near Wauchope

The Antler River is located in south east Saskatchewan and flows generally south then eastward into Manitoba through the RMs of Reciprocity, Mount Pleasant and Argyle. Hydrometric station 05NF010 records discharge in the upper portion of this basin. This station began monitoring in 1965 and has continued to do so on a seasonal basis. The 2014 rainfall flood event caused erosion in the channel. This change in channel geometry affects the relationship between water level and stream flow, typically known as the rating curve. Hence, a new rating curve will be required at this location, and an estimate of the rainfall related flood event instantaneous peak and return period for the flood is therefore not available. The 2014 snowmelt runoff instantaneous peak is estimated to be approximately 9.5 m^3/s which correlates to an event less frequent than a 1:5-year flood.

The analysis presented is based on hydrometric data that has been provided. The data indicate that in the southern part of the study area preliminary records have been estimated using high water marks and other tools; thus far, preliminary flow estimates indicate the rainfall flood event in some locations is greater than 1:500-year flood. Lightning Creek near Carnduff is an example.

7 RESULTS AND DAMAGES

This section of the report presents data and observations associated with various areas impacted by the storm. It is important to consider that this reporting is a snapshot of observations and collected data and does not likely account for all of the damages which will require repairs in the future.

In general, the following observations were made during the field program:

- Sloughing on high slope areas likely facilitated by intense rain;
- General flooding in low areas or areas impounded by roads and plugged conveyance structures;
- Several instances of overtopping on roads;
- Several locations of roads breached naturally or mechanically (some evidence of spoil piles);
- Some roads softened presumably by detour traffic and/or local saturation;
- Several detours due to road closures for overtopped bridges, roads and/or breached roads;
- Instances of residences isolated to their homes by surrounding water;
- Low spots in agricultural lands tend to be full to capacity though some areas have begun to drain;
- Flow paths in agricultural lands that have receded show high water lines via dead vegetation and debris as well as evidence of a new channel formed in the cohesive material; and

- Non-major dams displayed damages ranging from minor bank erosion to major failures.

7.1 DAMS AND CONTROL STRUCTURES

The locations of the dams discussed below are indicated in Figure 2 – Appendix A.

7.1.1 Crooked and Round Lakes

Both Crooked and Round Lakes rose quickly after the rainfall event which occurred mostly as a result of local area runoff in nearby creeks. The Qu'Appelle River upstream from Crooked Lake was impacted by the rainfall with the Qu'Appelle River near Lumsden flows increasing to about 80 m^3/s in early July. Due to the hydraulic conditions in the Craven area at the time most of the flow from Lumsden went eastward with a peak flow at the Qu'Appelle River below Craven station of about 62 m^3/s. When flows reached the downstream station, Qu'Appelle River below Loon Creek, the peak was reduced to about 46 m^3/s. The Fishing Lakes (Pasqua, Echo, Mission and Katepwa) further reduced the Qu'Appelle River peak flow from upstream and Katepwa Lake (the furthest downstream) rose only about 0.6 m as a result of the peak flows from upstream; it is believed that Katepwa Lake was primarily influenced by the ungauged watershed associated with Indianhead Creek. With most of the rainfall occurring in the Qu'Appelle basin downstream from Katepwa Lake the flows in the Qu'Appelle River at Hyde rose quickly to a peak of 243 m^3/s, estimated to be about a 1:50-year event. Even with the attenuation from Crooked and Round Lakes, the flow at the Qu'Appelle River near Welby was about 468 m^3/s, greater than a 1:200-year event. The peak water level on Crooked Lake was 454.47 m, an estimated 0.5 m higher than the recent high water level in 2011. The peak water level on Round Lake was 445.72 m, an estimated 0.6 m higher than the recent high water level in 2011. The rapid increase in water levels on Crooked and Round Lakes were a result of the precipitation onto the lakes and runoff reporting from local drainage areas.

Both Crooked and Round Lakes have control structures at their outlets; however, both structures were open at the time of the flood. The Round Lake control structure (Figure 3) has not been operated for several years and was damaged in the 2011 flood making it inoperable in its current state. The structure has not been inspected but Agriculture and Agri-food Canada (AAFC) don't anticipate major damages or added maintenance costs over and above what was needed after the 2011 flood.

WSA has roughly estimated that damages from the June 2014 flooding for the Crooked Lake Dam structure to be approximately $100,000.

Figure 3: Round lake control structure under water on July 5, 2014

7.1.2 Moosomin Dam (on Pipestone Creek south of Moosomin)

Only minor bank erosion was noted by McElhanney on July 6, 2014. The dam was later inspected by AAFC and appears to have not suffered major damages from the flood.

Figure 4: Moosomin Dam – minor side bank erosion near spillway July 6, 2014

7.1.3 Pheasant Creek Dam (north of Lemberg)

AAFC conducted a preliminary inspection of the dam and found that the spillway and embankment appear to be in good shape. A more complete inspection will be carried out at a later date when water levels have receded further; however, no major issues are anticipated.

Figure 5: Pheasant Creek Dam – water flowing swiftly down spillway July 10, 2014. No damage noted

7.1.4 Katepwa Dam

Katepwa Dam is operated by WSA, who has roughly estimated that damages from the June 2014 flooding to the structure to be approximately $55,000.

Figure 6: Katepwa Dam – July 6, 2014.

7.1.5 Welwyn Reservoir

The Welwyn Reservoir is situated in the Beaver Creek Valley in the Welwyn Centennial Regional Park, and is owned and operated by the RM of Rocanville. The flood water did not overtop the Dam; however, the emergency spillway was significantly eroded and will require repair. The RM does not currently have an assessed value of the damages.

Figure 7: Welwyn Dam – spillway significantly eroded by floodwater

7.1.6 Auburnton (southwest of Alida) Dam

McElhanney flew past Auburnton Dam on July 7, 2014. It appeared that although the dam was intact, significant erosion had occurred through the old spill channel, as shown in Figure 8.

Figure 8: Dam south of Alida, Jul 7, 2014

7.1.7 Redvers Dam

Redvers Dam is located on Lightning Creek, two kilometres north of Redvers. The control structure is currently licensed and operated by the RM of Antler. McElhanney flew over the Redvers Dam on July 7, 2014, while a ground crew arrived at the dam on July 8, 2014. At that time, flood water was flowing around one abutment, with no water flowing over the dam, however, high water marks (as seen in Figure 10) indicate that water was flowing over the dam before erosion occurred beside the abutment; causing water to flow around the dam. Minor erosion is evident near the other abutment.

Figure 9: Redvers Dam on July 7, 2014

Figure 10: Redvers Dam – eroded spillway

7.1.8 Gainsborough Dam

The Gainsborough Dam is owned and operated by the RM of Argyle, and was visited by McElhanney staff on July 8, 2014. Figure 11 shows stoplog bays partially closed and radial gates partially up. High water marks are marked with grassy debris, and it is evident that floodwater overtopped the control structure, as well as the northern part of the earthen dam structure; however, at the time of the site visit, the water level was below the usual level. The flood water breached the dam and created a new channel south of the dam, as shown in Figure 12 and Figure 13. Erosion of the landscape can be seen in the background in Figure 11 as well as in Figure 14. The RM has noted that they opened the gates during the spring of 2014; however, uncertainty remains at this time of how the dam was operated during the flood event.

Figure 11: Gainsborough Dam – control structure July 8, 2014.

Figure 12: Gainsborough Dam – eroded outlet from lake

Figure 13: Gainsborough Dam – eroded channel

Figure 14: Gainsborough Dam – eroded flood plain

7.1.9 Dam Estimated Costs Summary

WSA has roughly estimated that damages from the June 2014 flooding for the following structures:

- Crooked Lake Dam - $100,000
- Round Lake Dam (Sinfield Reservoir) - $5,000
- Katepwa Dam - $55,000
- TeePee Creek Dam - $40,000

7.2 CITIES AND RURAL AGENCIES

In order to quantify the flood damages, a questionnaire was sent out on July 31, 2014 to all RMs, cities, towns, villages, First Nations and Provincial Parks that had declared a state of emergency during or immediately after the June flood event. An example questionnaire is shown in Appendix C and the responses are summarized in Appendix D. As of September 18th, the percent responses ranged from 0% to 83% based on administration function, as shown in Table 2. First Nations had a zero percent return rate and are therefore not included in the calculations below in order to not skew the statistics.

Table 2: Questionnaire response rates

Questionnaires	RMs	Cities and Towns	Villages and Resorts	First Nations	Provincial Parks
Total sent out	36	20	27	9	6
Percent returned	42%	70%	41%	0%	83%

7.2.1 Bridges and Culverts

Table 3 shows that a total of 131 culverts and 26 bridges were damaged in the 15 RMs that returned the questionnaire, while other agencies only had a few damages. In total, the 45 responses across all the rural agencies indicated that a total of 144 culverts were lost or severely damaged, in addition to 29 bridges. Site visit observations of the bridges indicated the flood water seemed to mostly erode the outside of one or both wingwalls, and that the bridge structures generally remained intact. Figure 15 in Appendix A show the areas that declared local emergency during the flood event; cities, towns, villages and parks are marked with stars, while RMs are highlighted. Red colour indicates a percentile ≥ 50%; yellow ≥ 20%; and green <20%.

Table 3: Overview of number of damages culverts and bridges

Agency	Responses	Culverts </= 1500 mm	Culverts > 1500 mm	Bridges </= 10 m long	Bridges >10 m long
Rural Municipalities	15	76	55	22	4
Cities and Towns	14	3	3	0	2
Villages and Resorts	11	3	0	1	0
Provincial Parks	5	4	0	0	0

Figure 16: Common example of a damaged bridge – material by both wingwalls eroded by floodwater, bridge south of Tantallon

Figure 17: Three large-diameter culverts were washed away near Killaly

7.2.2 Roads

Generally, the site visits in the flooded areas revealed that roads were occasionally breached by government officials or private individuals in order to attempt to save culverts, bridges or other infrastructure. In many cases this method succeeded, while in other instances the water washed out the culverts regardless. The consequences of mechanically breaching roads is beyond the scope of this report.

Due to some inconsistencies in the way that people answered the question regarding the amount of road damage (either by length or by number of damaged locations), the following assumptions were used in the reported road damages in Table 4: each washed out road was assumed to be 10 m long, and 100 m long if general damages were reported. The opposite was assumed if the number of roads were reported instead of the length of damages.

A total of approximately 430 roads, or 180 km, were reported damaged from water overtopping the road, while 236 roads were reported cut during the flood event.

Table 4: Overview of number of damages roads

Agency	Number of Responses	Road overflow or washout		Road mechanical breaches
		Quantity	Length (km)	
RMs	15	383	172	201
Cities and Towns	14	19	3	12
Villages and Resorts	11	24	2	5
Provincial Parks	5	4	2	18

An example of a washed out road can be seen in Figure 18 below, while Figure 19 and Figure 20 show water overflowing the road. It was observed that roads often acted as dykes for the flood waters.

Figure 18: Example of a small-scale washed out road; Qu'Appelle Valley on July 5, 2014

Figure 19: Floodwater overflowing a gravel road in Southern Saskatchewan

Figure 20: Road performing as a dyke. Erosion evident

It appeared that roads and culverts were generally washed out less often when flood water was able to flow across the road on one or both sides of the culverts, as shown in Figure 21.

Figure 21: Floodwater flowing across road on either side of the culverts

7.2.3 Other Infrastructure

The questionnaires revealed that there were additional damages to towns and rural areas, as summarized in Table 5. In addition to direct damage to wastewater treatment works and lift stations, there were numerous sewage releases which caused pollution and boil water advisories in many communities. WSA recorded nearly 60 communities that had to bypass parts of their sewage collection systems, lift stations or had to go with emergency wastewater releases in the time period from June 27 to July 14, 2014. In addition, over 30 communities experienced drinking water issues or boil water advisories. WSA has estimated that there were demonstrable impacts to drinking water or waste water infrastructure in approximately 17 cases.

Other damages, as presented in Table 5, include damages to golf courses, ball diamonds, town shops or community halls and rinks, as illustrated in Figure 22. The affected Provincial Parks received additional damages to infrastructure such as boat launches, shoreline and beaches, paths, trees, and bathrooms.

Table 5: Other damaged infrastructure

Agency	Responses	Dams or Reservoirs	Sewage Treatment	Lift Stations	Water Intake	Community Wells	Other Damages
Rural Municipalities	15	3	-	-	-	3	-
Cities and Towns	14	1	2	4	2	3	11
Villages and Resorts	11	-	2	1	-	-	4
Provincial Parks	5	-	-	-	-	2	10

Figure 22: Water ponded by the Langenburg curling rink

7.3 MINISTRY OF HIGHWAY AND INFRASTRUCTURE

The June 2014 flood event caused damages to 48 Saskatchewan highways, and resulted in many closures, detours and road hazards. The soils below many highways were saturated prior to the flood event which added to the severity of the damage. Examples of damages to the highways include: sink holes, erosion, landslides, washed out culverts and bridges as well as surface damage.

During the flood event and immediately after, the MHI prioritized 43 immediate response projects in order to re-open roads, to maintain access to communities and provide basic public safety. Examples of this work include repairing a large hole in the road on Highway 361, culvert replacement and shoulder work on Highway 1 west of Wolseley, and installation of several temporary bridges to provide access to the communities of Redvers, Carievale and Gainsborough. MHI has estimated the total cost of these high priority projects in the range of approximately $60-$70 M.

In addition to the emergency flood projects, there is a significant amount of work required in order to restore the roads to the condition that existed prior to the wet weather. Furthermore, some roads throughout the province are below today's design standard, and any damage to these roads may require additional upgrades such as elevated road surfaces or larger culverts/bridges. The estimated cost for these 62 restoration and improvement projects may be in the order of $200 M, and will likely have to be completed over several years.

Figure 23: Eroded highway

7.4 OTHER DAMAGES

In addition to the damages summarized above, the June 2014 flood also affected other agencies such as rail and oil companies (Figure 24 and Figure 25) as well as numerous private residents and farmers. Documentation of these damages is beyond the scope of this report, as efforts to quantify these damages are ongoing by other agencies such as the Provincial Disaster and Assistance Program (PDAP).

Figure 24: Damage to a Rail Bridge

Figure 25: Submerged oil and gas equipment.

8 SUMMARY

This report discusses and summarizes data and observations arising from a large rainfall event occurring in southeast Saskatchewan in late June 2014. Though the storm was not necessarily unprecedented as observed at individual climate stations, the collective spatial area impacted by the event was substantial. Many hydrometric gauging stations in the province recorded daily average peak discharges with occurrences rarer than the 1:50-year return flood.

The assessment of the hydrologic flood event showed that the antecedent conditions were favorable for a flood event. Local storages were generally full and soil moisture conditions were normal to wet following above-average precipitation during the three months prior to the rainfall event. The result was that the rain fell on a landscape that was primed for runoff and, as a result, the runoff event was significantly high.

Damages observed in the field were consistent with either damages from rainfall (sloughing on hill slopes), washout of roadways and stream banks from flood water, inundation of floodplains resulting in infrastructure damages and in some cases mechanical breaching of roads to reduce upstream water levels.

Damage information was also collected directly from rural and government agencies. MHI has preliminary estimated damages to over 100 sites, totaling nearly $300 M. Damages to rural agencies' infrastructure have not been assembled; however, it is estimated to be significant based on 51% of the respondents reporting the following damages: 180 km of roads, 29 bridges, 144 culverts, 4 dams, and damages to 20 water treatment facilities or wells. In addition there were damages to other public infrastructure such as town buildings or sporting grounds.

9 CLOSURE

McElhanney Consulting Services Ltd. has prepared this document in a manner consistent with that level of care and skill ordinarily exercised by members of the engineering and science professions currently practicing under similar conditions in the jurisdiction in which the services are provided, subject to the time limits and physical constraints applicable to this document. No warranty, express or implied, is made.

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The factual data, interpretations, suggestions, recommendations and opinions expressed in this document pertain to the specific project, site conditions, objective, development and purpose described to McElhanney by the WSA and are not applicable to any other project or site location. In order to properly understand the factual data, interpretations, suggestions, recommendations and opinions expressed in this document, reference must be made to the entire document.

McElhanney would like to thank WSA for the opportunity to provide this assessment. Should WSA have any questions regarding this document please contact Ms. Line Bell in the Saskatoon office at (306) 500-9816.

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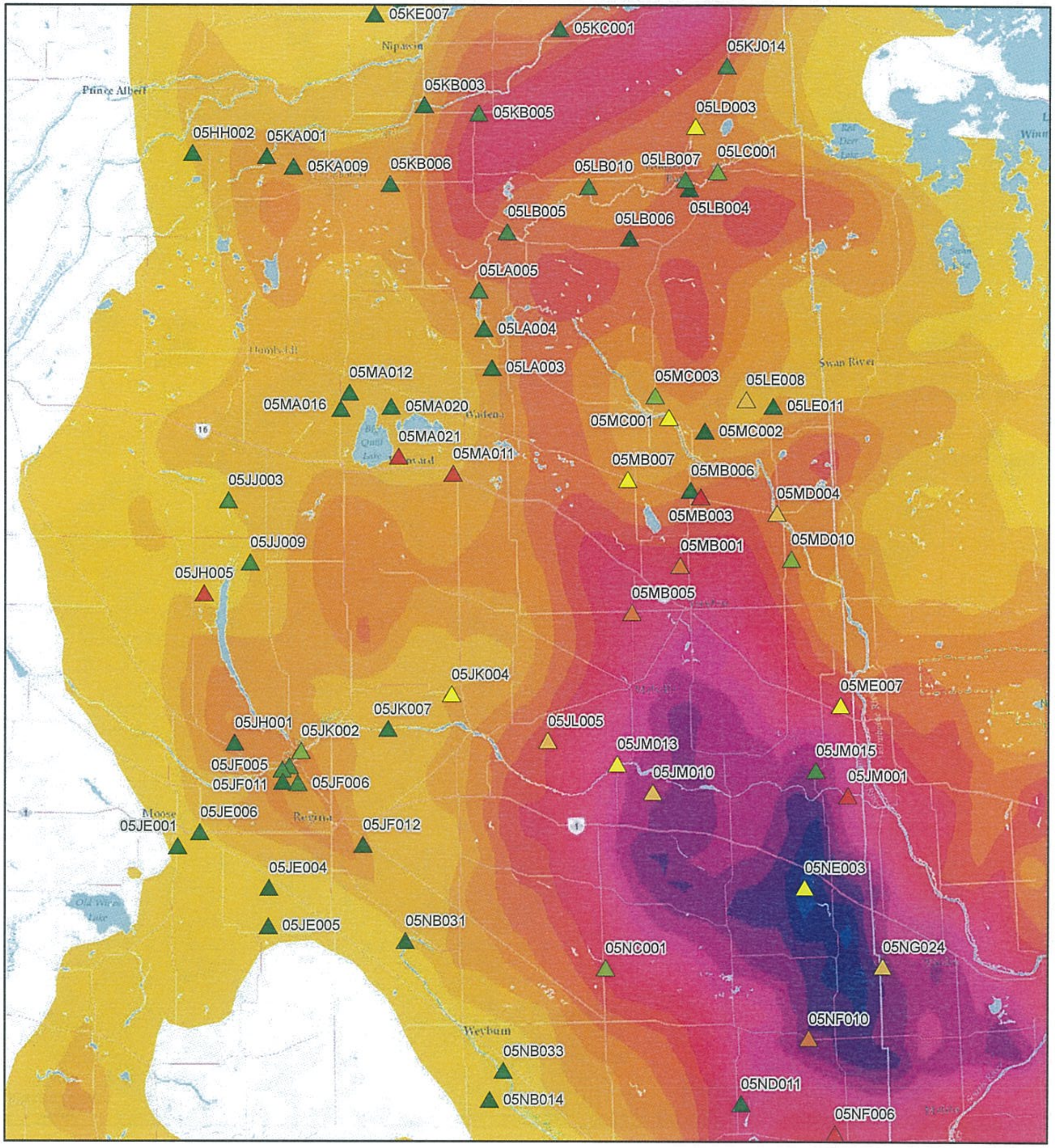
APPENDIX A: FIGURES

Figure 1:
Precipitation Map & Hydrometric Gauging Locations



Accumulated Precipitation (mm)
June 27 - July 1

30, 40, 50, 60, 70, 80, 90, 100, 110, 120, 130, 140, 150, 160, 170, 180, 190

June - July
Rainfall Return Period

<1:2
>=1:2
>=1:5
>=1:10
>=1:25
>=1:50
>=1:100
>=1:200
>=1:500

UTM NAD 83 Zone 13N
Date Modifed: Sept 17, 2014
Map Author: J. Leimanis
2711-15006-0

Accumulated precipitation data taken from Environment Canada CaPA precipitation analysis using guage data, radar data and model data.

N

0 30 60 90 120 150 km

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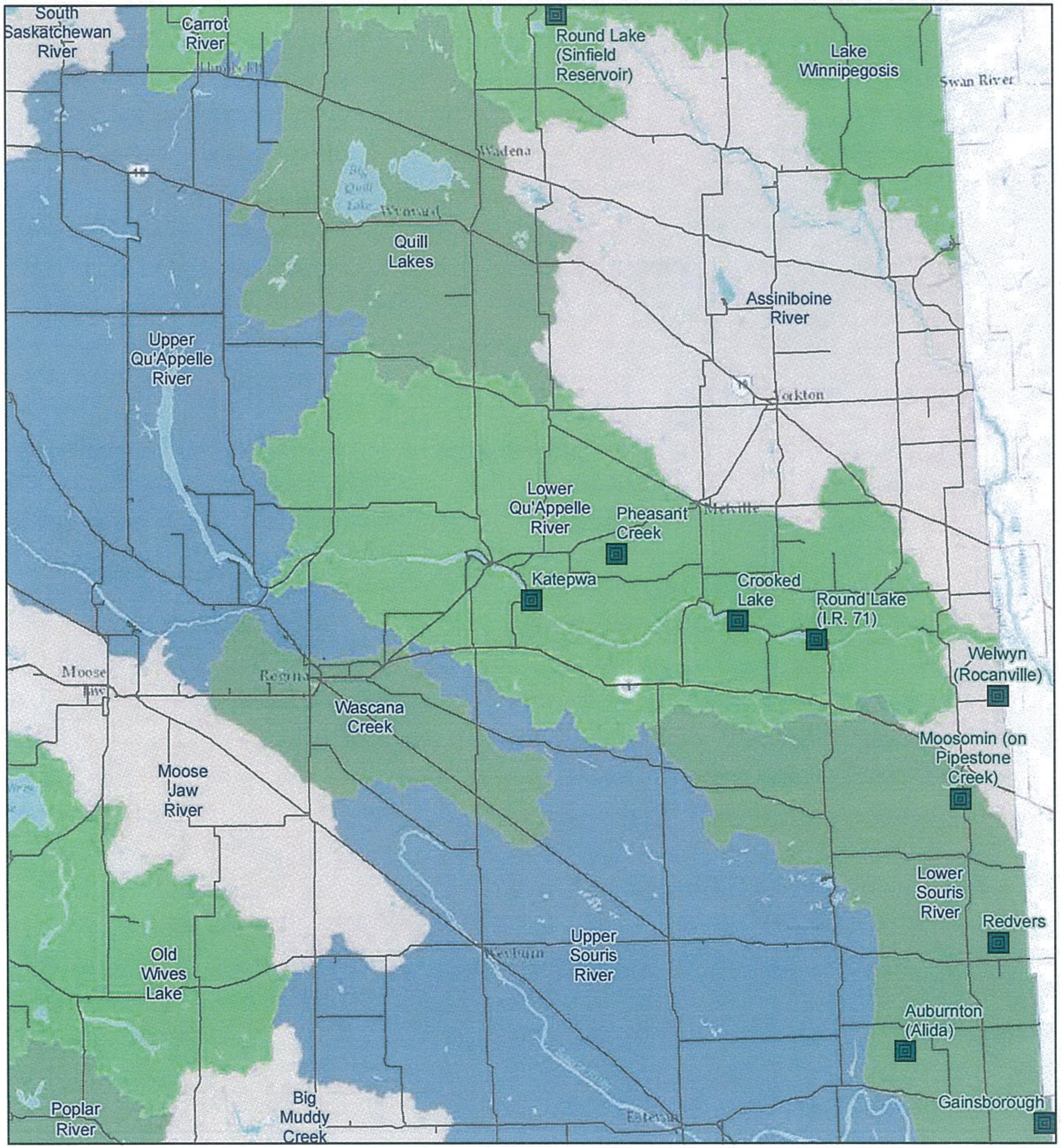

Figure 2: Southeastern Saskatchewan Watershed Map

Observed Dams

Highways

UTM NAD 83 Zone 13N
Date Modifed: Sept 17, 2014
Map Author: J. Leimanis
2711-15006-0

N

0 20 40 60 80 100 km

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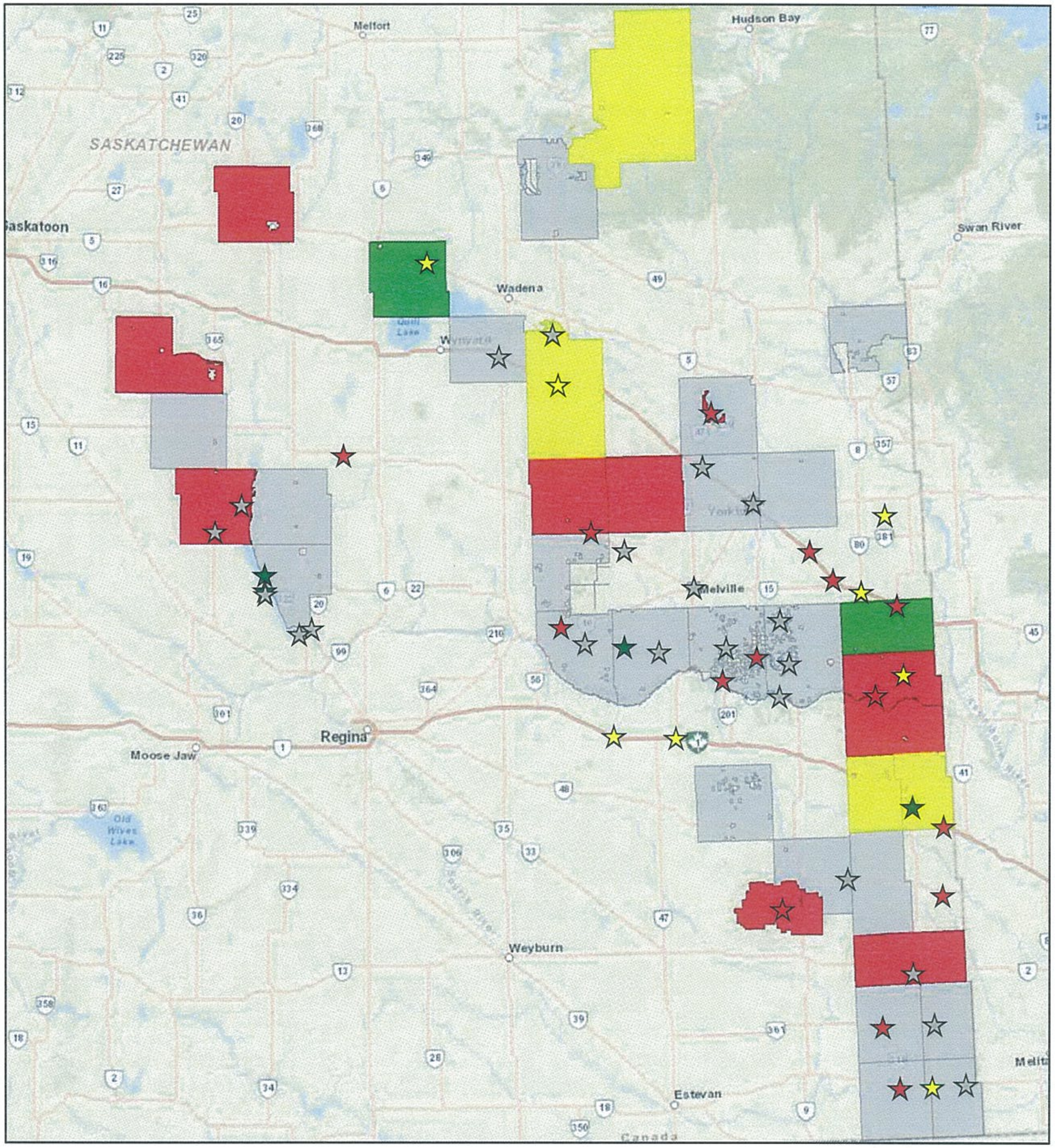
Figure 15:
Damage Survey Map



Damage Level

- Low
- Moderate
- High
- No Survey Returned

UTM NAD 83 Zone 13N
Date Modifed: Sept 17, 2014
Map Author: J. Leimanis
2711-15006-0

N

0 30 60 90 120 150 km

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APPENDIX B: CUSTOM CLIMATE SERVICES LTD. REPORT

The Southeast Saskatchewan / Southwest Manitoba Storm of June 2014

By

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September 13, 2014

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Executive Summary

A major rain storm occurred over approximately 48 hours from late morning on June 28 to around noon on June 30 over southeast Saskatchewan and extended into the adjacent area of Manitoba. The cause was a large scale synoptic storm that underwent explosive intensification between June 28 and 29. Preliminary analysis using Environment Canada and Saskatchewan Crop Insurance Corporation surface stations showed rainfall amounts of 155 mm at Atwater with a tongue of higher precipitation extending northward toward Yorkton and southeastward to Elkhorn Manitoba. The Canadian Precipitation Analysis produced by Environment Canada for a four day period June 27 to 30 showed amounts of the order of 180 mm with the highest amounts somewhat closer to the Manitoba border.

The central rainfall was not particularly remarkable compared to other prairie storms and was far exceeded by both the Parkman storm of August 1985 and the Vanguard storm of July 2000 which had peak central rainfalls of about 380 mm. Because this was a synoptic storm, significant rainfall extended over a wide area. Over 24,000 km^2 the storm ranked 10th; over 58,000 km^2 it ranked 7th and over 169,000 km^2, it ranked 3rd relative to all the storms for Saskatchewan and Manitoba in the Storm Rainfall in Canada series. Rainfall rates were in general very modest, rarely exceeding 10 mm in an hour suggesting that the rainfall was the result of large scale lifting associated with the developing low.

The flow patterns at 50 kPa showed anomalously low upper heights over the central part of the continent. This would lead to generally cooler conditions than normal and would favour the development of a low pressure system. The anomalously low heights over Saskatchewan and Montana in June would also tend to favour advection of moisture from the Gulf of Mexico.

After a wetter than normal period in 2010 to early 2011, there was a drier than normal period from late 2012 through 2013. However, the three months April to June 27, 2014 were above normal with precipitation totals generally 150 to 200 % of normal. This anomalously wet period immediately prior to the late June storm likely led to a high runoff coefficient. The June 1 to 27 total precipitation was already normal to above normal and the addition of the June 28 to 30 rainfall resulted in June precipitation totals in excess of 200 % to over 300 % of normal.

The large spatial coverage of the rainfall and the cool (low evaporation), wet spring and early summer combined to produce significant flooding and infrastructure damage across southeast Saskatchewan and southwest Manitoba.

Radar data indicated heavy rainfall over extreme southeast Saskatchewan and southwest Manitoba that was not apparent in the CaPA product or the analysis of surface observations alone. The underestimation of the rainfall by radar in most

areas might indicate that amounts in extreme southeast Saskatchewan exceeded 200 mm if the values were scaled up so that the totals more closely matched the surface observations.

Introduction

The Saskatchewan Water Security Agency contracted with Custom Climate Services to undertake an analysis of a major flood-producing storm that occurred over the last few days of June 2014. The study was meant to complement the work of McElhanney Consulting Services that was contracted to document the hydrological characteristics of the flood and the associated damages.

Standard surface measurements of precipitation and digital radar data were ordered from Environment Canada. The surface data included hourly rainfall at automatic stations across the area of interest as well as standard daily precipitation amounts. These surface data collected by automatic systems was available in almost real time to climate scientists. However the digital radar data required for further analysis was not supplied until almost the end of August. Part of the delay was the unfamiliarity of Ontario Climate Centre staff with this type of request but the major delay was because the person who could supply the data in the required format was on vacation.

The Environment Canada surface climate network has suffered a serious decline in the number of stations, particularly after November 2007 so the remaining station density is inadequate for this type of analysis. The quality of the data has also suffered because there has been virtually no quality control of the data and there have been numerous days of missing data at most stations. Supplementary data was requested from Saskatchewan Crop Insurance Corporation (SCIC) and from Weather Innovations. SCIC responded with daily data for April, May June and July 2014 but Weather Innovations never did supply any data despite an initial indication that it might do so.

The main focus of this storm study is to document the spatial and temporal characteristics of the late June storm, the antecedent conditions; the atmospheric flow anomalies at 50 kPa; the associated weather patterns both at the surface and 50 kPa; to describe the general meteorology of the storm and finally to compare the late June storm to other historic prairie storms.

Analysis of radar data was completed on September 15 and provided additional insight into the spatial distribution of the storm. The combination of the SCIC and Environment Canada stations was sufficient to provide the general characteristics of the rainfall but the radar revealed heavier precipitation over extreme southeast Saskatchewan that was not apparent from the surface observations alone. Even with the SCIC stations, the network density was inadequate to capture this feature.

Weather Maps

Weather maps for the period June 26 to July 2 are displayed in the following subsections for the 50 kPa level and the surface. These maps are available through the NOAA web site as follows:

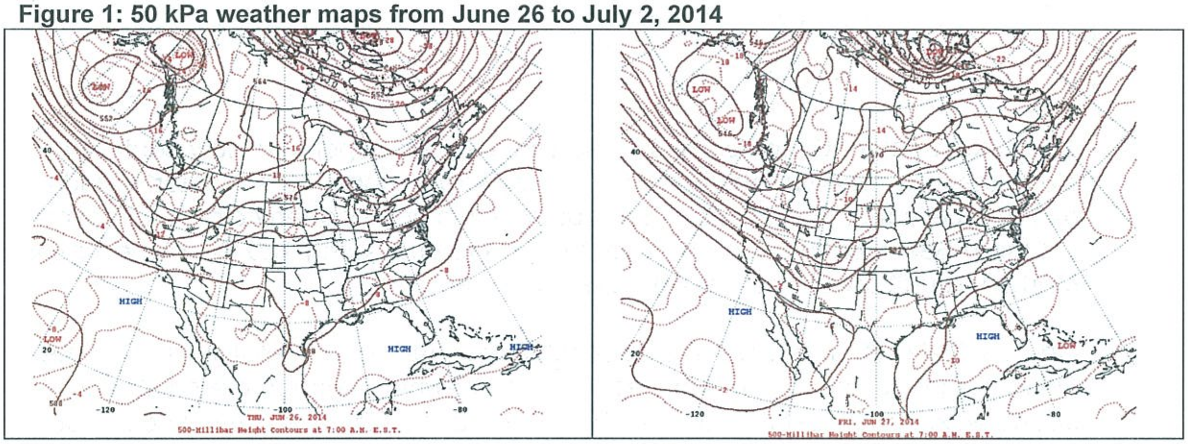
http://www.hpc.ncep.noaa.gov/dailywxmap/index.html

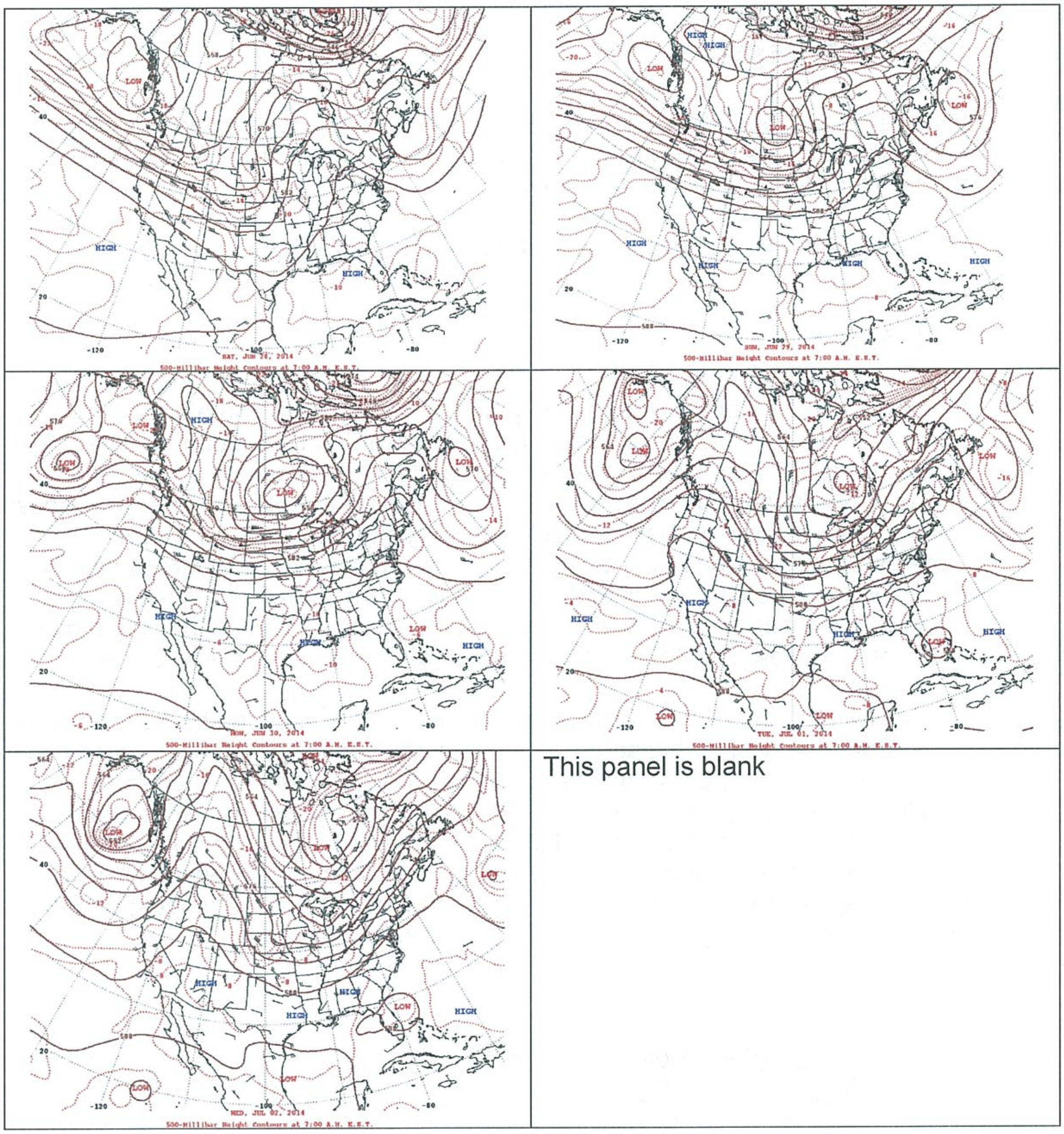
50 kPa

Figure 1 showed a broad trough along the USA west coast and a west southwesterly flow towards southern Saskatchewan and Manitoba on June 26 at 6:00 a.m. CST. There was a 50 kPa low over the Gulf of Alaska with a very strong westerly flow south of the low and a divergent flow towards the west coast trough. Such a situation was conducive to a digging trough and that was apparent in the second panel at 6:00 a.m. CST on June 27. The strong flow had moved toward the west coast and 50 kPa heights have dropped there causing the flow to the east of the trough, now situated around 110 W, to back to a more southwesterly flow over the northern Great Plains and the eastern Prairies.

On the morning of June 28 this trend continued and caused the flow ahead of the upper trough to back to the south. There was still a relatively strong westerly flow to the west of the upper trough and there was the suggestion of a closed circulation near the point where the southwest corner of North Dakota met the Montana border. By the morning of June 29, there was a closed upper low over southern Manitoba near the border with Saskatchewan. There were still very strong westerly 50 kPa winds across the northwest USA with strongest winds still southwest of the newly formed upper level low over Manitoba.

Figure 1: 50 kPa weather maps from June 26 to July 2, 2014





The next panel for 6:a.m. June 30, showed a strong upper level low centered along the Manitoba-Ontario border with very strong upper level westerly winds over the Dakotas. There was a vigorous cyclonic and northerly circulation over southern Saskatchewan as an upper level ridge built along 120 W. There was a marked trough toward southeast Saskatchewan.

On July 1 at 6:00 a.m. CST, the upper level low had moved eastward to northern Ontario and the circulation had weakened somewhat although there still was a strong west southwest flow across the Great Lakes. The upper level ridge had broadened and wais affecting western Saskatchewan but there wais still a relatively strong northerly flow over eastern Saskatchewan. The trough that was pointing back to southeast Saskatchewan on June 30 had moved southeastward to the Dakotas.

The final panel was for the morning of July 2 where the remnant of the upper level low was over eastern Hudson Bay with troughing back over the Great Lakes and a northwesterly flow across both Saskatchewan and Manitoba.

What was most striking about this series of charts is the strength of the circulation around the upper low on June 30. This was an exceptionally strong system for this time of year and no doubt the release of latent heat from the significant rain storm reinforced the dynamics of the system

Surface

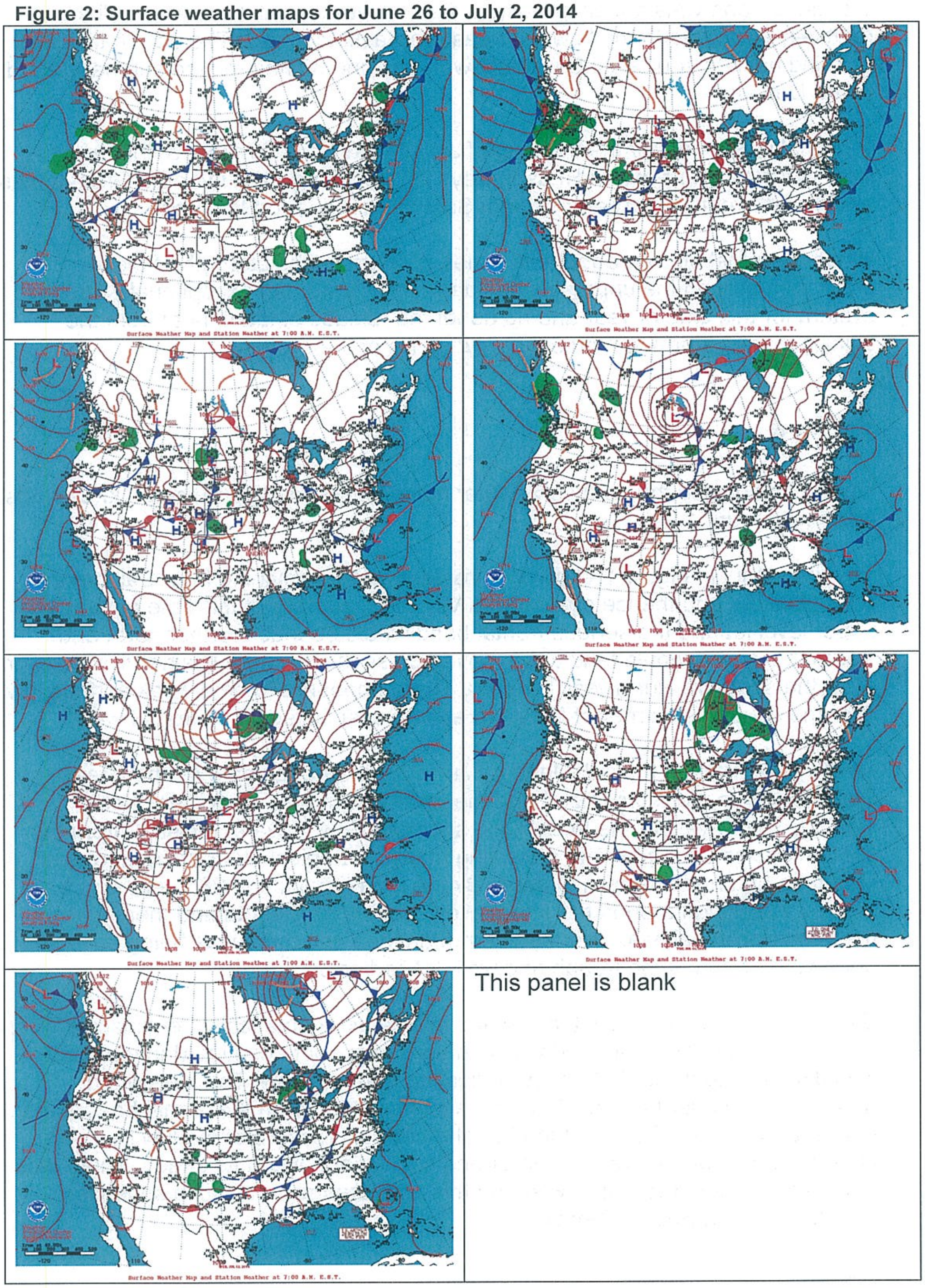
Figure 2 displayed the surface weather maps corresponding to the 50 kPa charts shown in Figure 1.

The first panel in Figure 2 showed a frontal system stretching from California to South Dakota and thence eastward to Virginia. Normally at this time of year, the upper level jet and the surface frontal band would be much further north and weather systems would tend to be move across the northern Prairie Provinces or even the southern Northwest Territory. There appeared to be a weak surface low over the southeast corner of Montana and an associated weak frontal wave.

As the upper trough moved inland on June 27, the troughing over the Great Plains became more organized and the weak low moved to western North Dakota. To the east of the trough, the southerly flow of warm moist air from the Gulf of Mexico strengthened, advecting maritime tropical air northward toward Manitoba and northwestern Ontario. By the morning of June 28, there was a defined circulation around the surface low over North Dakota and there was maritime tropical air was over southern Manitoba and more was being advected northward ahead of the trough and well defined cold front.

By the morning of June 29, the low had intensified dramatically, reminiscent of an east coast weather bomb, and was centered over south central Manitoba and was directly under the 50 kPa low indicating a mature low. The low drifted northeastward over the next 24 hours and was located on the Manitoba-Ontario border at 6:00 a.m. CST on June 30. The central pressure of the low had not changed much and there was still strong circulation toward its edges. There was a marked trough toward the west and this appeared to be rotating southward toward southern Saskatchewan.

Figure 2: Surface weather maps for June 26 to July 2, 2014



By July 1, the surface low was over northern Ontario and the circulation had weakened noticeably near its center. There was still a strong northerly circulation over Manitoba. The trough had rotated southward to extend southwest across the north shore of Lake Superior to South Dakota.

By the morning of July 2, the low was over eastern Hudson Bay and a ridge of high pressure dominated both Saskatchewan and Manitoba.

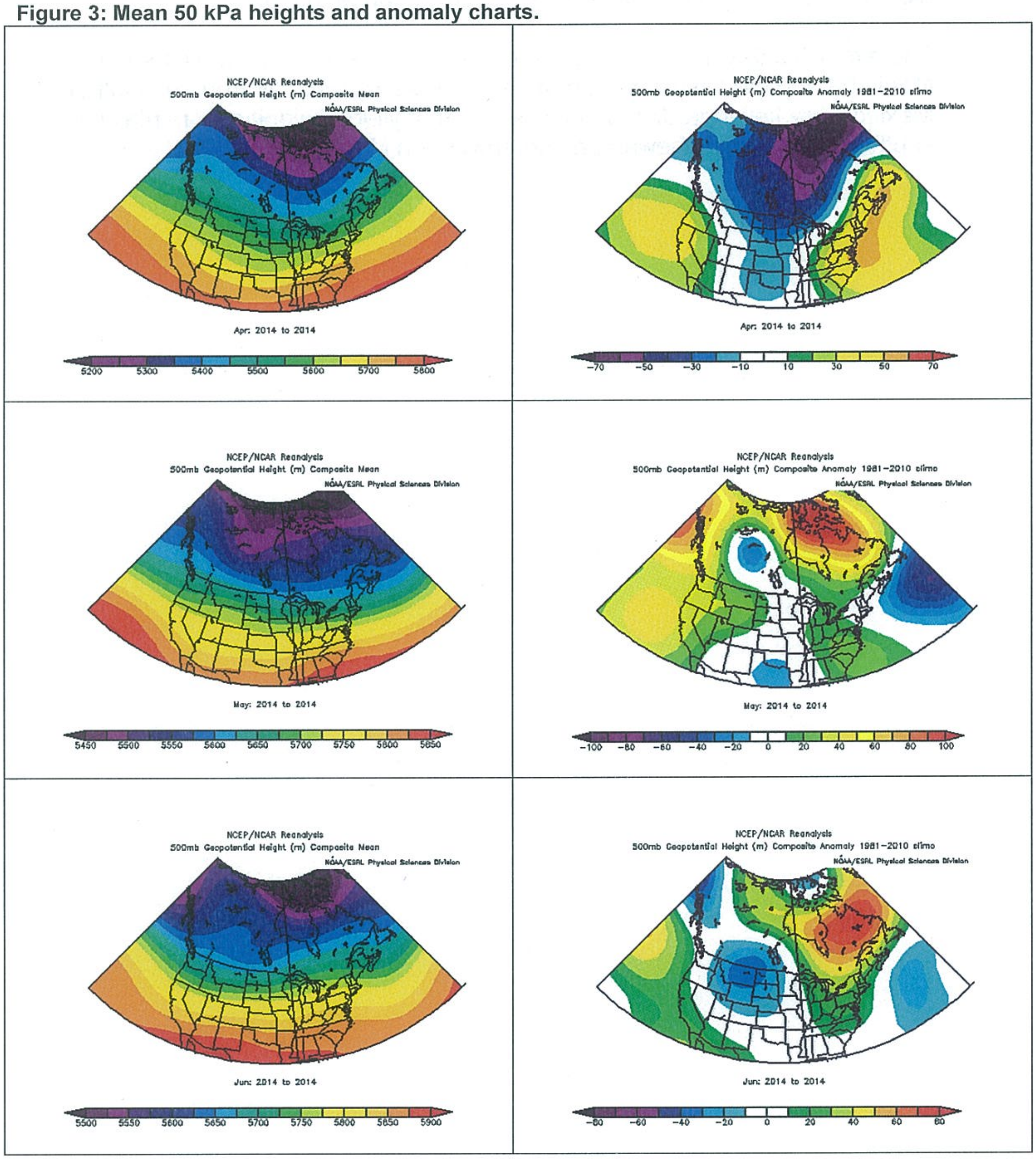
The explosive development of an intense low pressure system over southern Manitoba and the associated entrainment of warm moist air from the Gulf of Mexico were key ingredients of this storm that yielded significant rainfall over southeastern Saskatchewan and southwestern Manitoba.

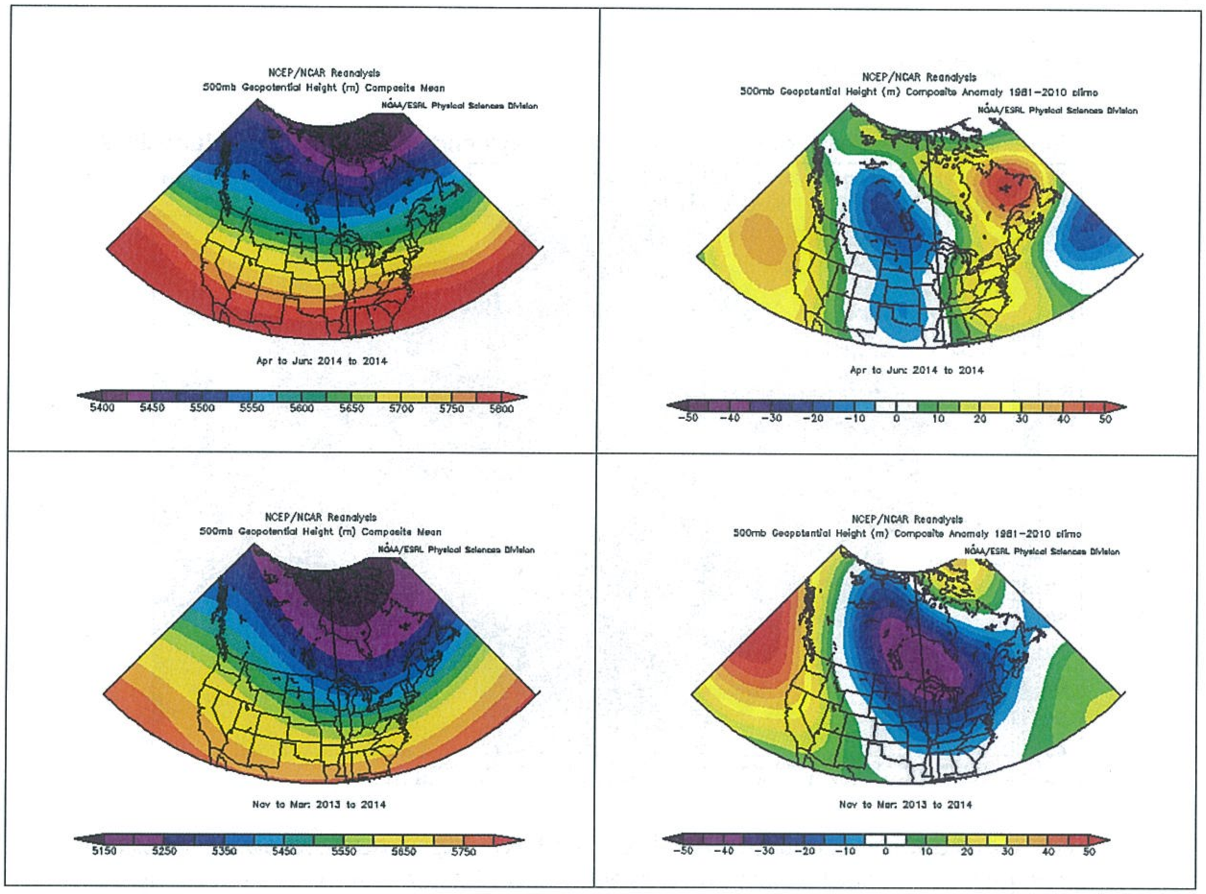
Atmospheric Flow Anomalies

The NOAA web site provided the tools to document the situation leading up to the storm of June 28 to 30, 2014:

http://www.esrl.noaa.gov/psd/cgi-bin/data/composites/printpage.pl

Figure 3: Mean 50 kPa heights and anomaly charts.



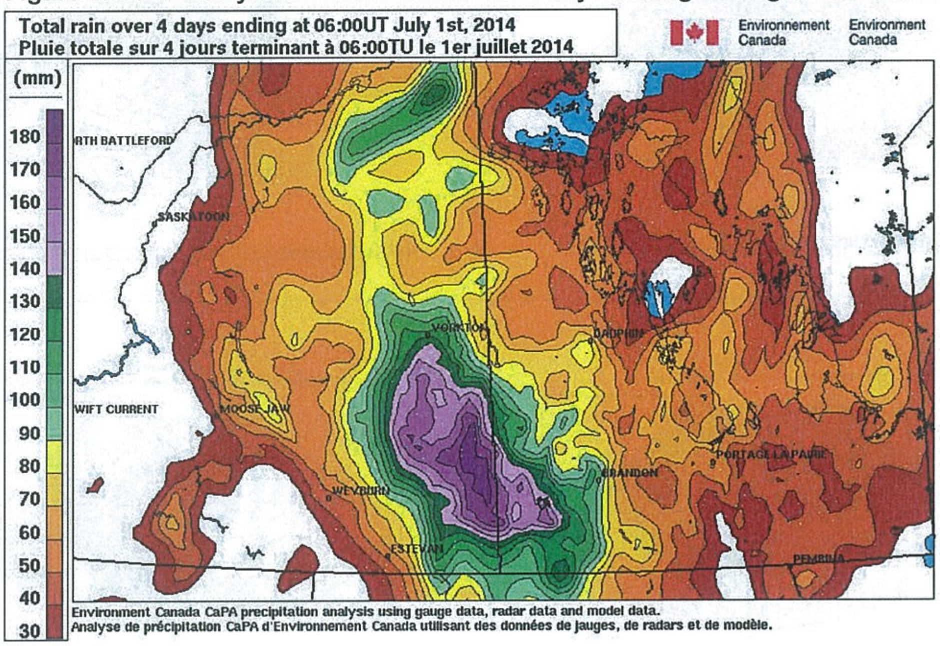


The left-hand panels in Figure 3 display the mean 50 kPa heights for April, May and June, 2014; April to June 2014 and finally for the period November 2013 to March 2014. The right-hand panels are the corresponding anomalies from the 1981 to 2010 climate normals. The last set for the winter 2013-14 clearly showed the influence of the polar vortex that dominated the weather over much of the continent through the winter period. This pattern lingered into April (top panel) leading to a cool spring. There was still a tendency toward troughing over the middle of the continent in May although much weaker and somewhat displaced from April. In June, there were anomalously low heights over Montana and southern Saskatchewan.

The combination of the anomalies from April to June 2014 indicated a well marked trough with lower 50 kPa heights over the center of the continent extending from the southern Great Plains northward to Manitoba and Saskatchewan. By contrast there were anomalously high heights off the US west coast and over Labrador in the east. This pattern would favour storm formation and development over the center of the continent.

CaPa Analysis

Figure 4: CaPa analysis of storm rainfall for 4 days ending midnight CST June 30, 2014



The Canadian Precipitation Analysis (CaPA) utilizes surface observations of precipitation, model quantitative precipitation forecast and radar. The figure above was produced by Environment Canada for emergency measures and water management agencies. The time is shown in UTC (Universal Time Coordinated). July 1, 0600 UTC corresponds to midnight CST on June 30. Thus the four day total corresponds to the four calendar days from June 27 to June 30 inclusive.

It is a useful initial analysis and shows the highest rainfall amounts in an area just west of the Saskatchewan-Manitoba border stretching northward toward Yorkton and east into southwest Manitoba. The highest contour shows amounts exceeding 180 mm.

Environment Canada Data

Hourly rainfall and daily rainfall data for 2014 for all available Saskatchewan and Manitoba climate stations were ordered from Environment Canada. The hourly data was available only at automatic climate stations. Daily precipitation was available for the same stations in the dly02 system. Daily data for ordinary climate stations was available through COOLTAP and stored in the dly44 system. There was no dly04 (quality controlled) data for Saskatchewan or Manitoba.

Hourly Rainfall

Eight stations in Saskatchewan in the main rain area of the late June storm recorded hly01 element 262, hourly precipitation. None was at the center of the storm but still the stations provided information on the temporal distribution of the rainfall in different parts of the storm. Broadview was the closest station to the center of the highest rainfall and it recorded over 134 mm of precipitation as shown in Figure 5. The rain at Broadview commenced in the afternoon of June 28 and it rained more or less steadily until late on June 29. Then there was some additional rainfall on June 30 but the bulk of the rain fell on June 28 and 29.

Figure 5: Cumulative rainfall at Broadview June 28 to July 1, 2014

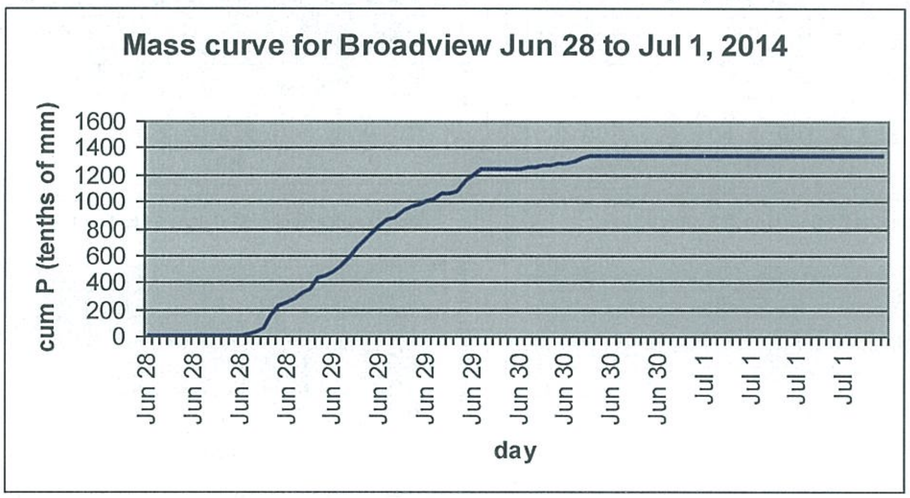


Figure 6 displays the hourly rainfall and revealed rainfall rates from less than 2 mm/hour to more than 9 mm/hour. There were no heavy downpours but the long duration of the rain resulted in a very significant rainfall total over June 28 to 30, 2014. Only 0.3 mm fell on July 1 and thereafter no significant rain fell for the rest of the day or for the next couple of weeks! There may have been some embedded convection but the Broadview mass curve is more indicative of general organized lift associated with a large scale synoptic system. The distribution at the other Saskatchewan stations is shown in Figure 7.

Figure 6: Hourly rainfall for Broadview June 28 to July 1, 2014

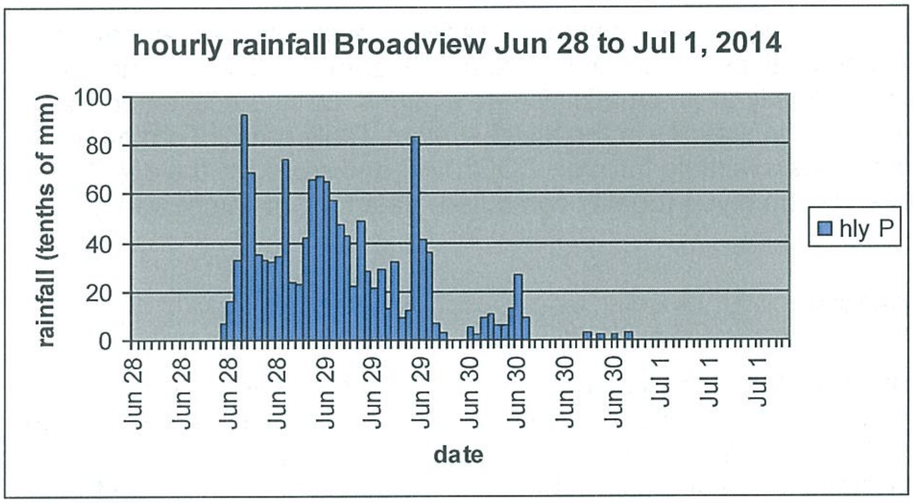
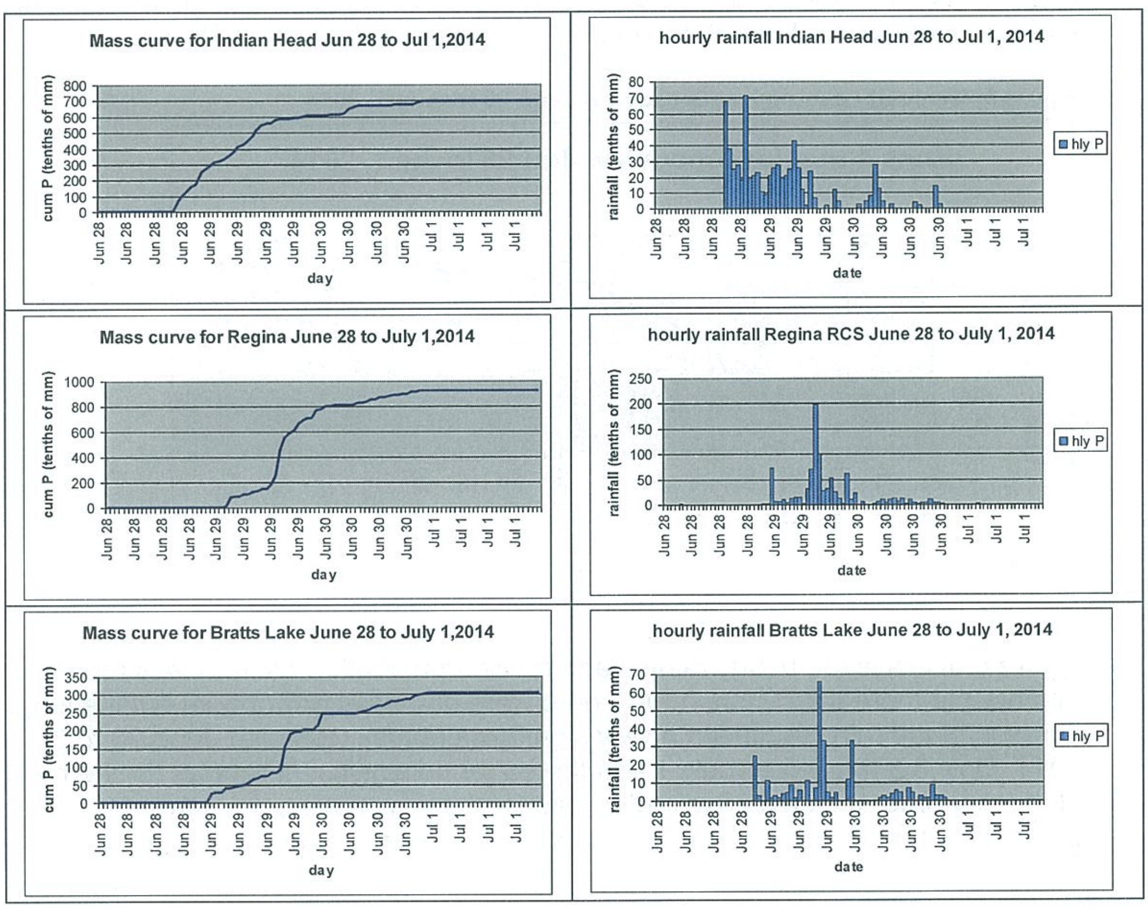
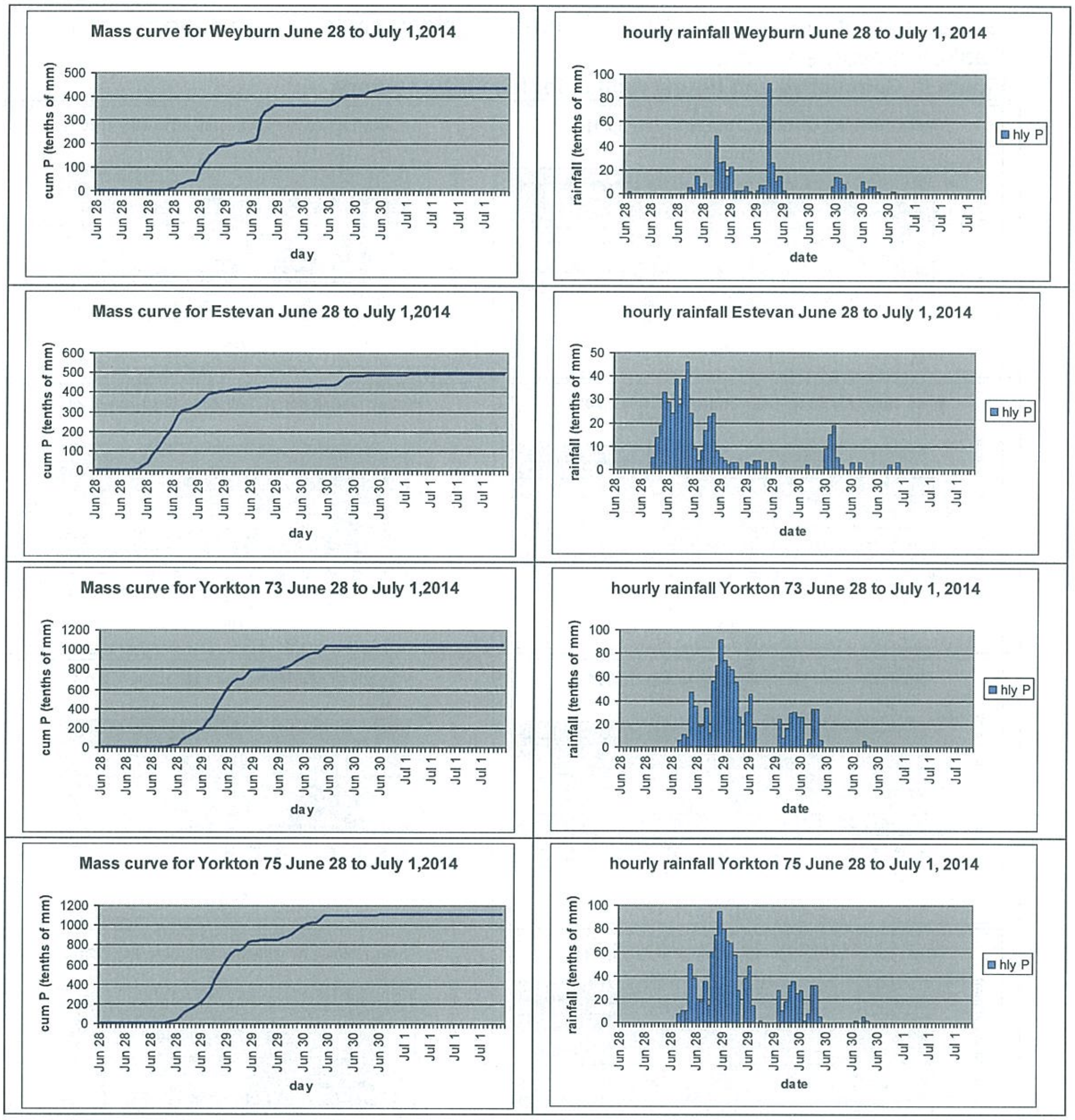


Figure 7: Cumulative and hourly rainfall for other Saskatchewan stations

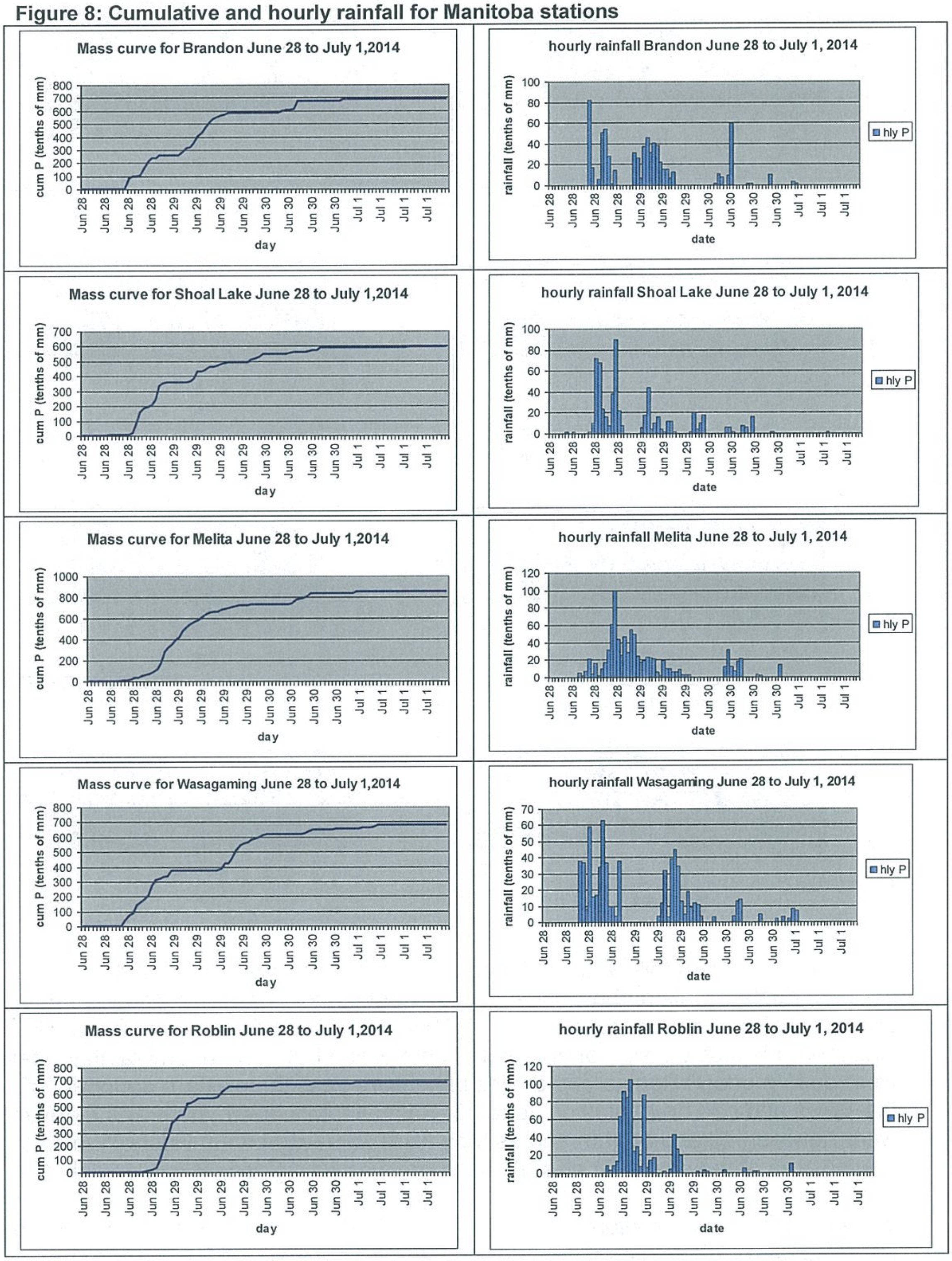


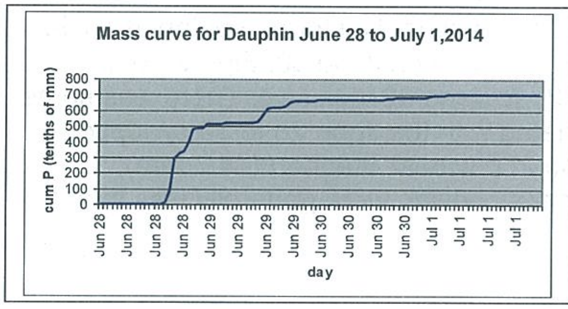


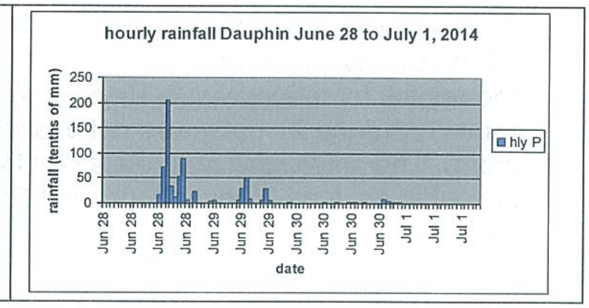
Yorkton (110.5 mm) followed by Regina (92.3 mm) had the second and third greatest rainfall totals of the Saskatchewan hourly rainfall stations. Regina had one burst of 19.9 mm in the hour from 2:00 to 3:00 p.m. CST on June 29 which was more obviously a sign of embedded convection but other hourly rainfall rates were quite modest. Regina and Bratt's Lake were near the western periphery of the storm and had no rainfall on June 28. Rainfall totals at Weyburn and Estevan were between 40 and 50 mm and as they were somewhat southwest of the main rainfall area of the storm. At all stations, there was no significant rain on July 1.

The Manitoba hourly stations shown in Figure 8 showed the rainfall commencing earlier on June 28. Again rainfall rates were quite modest and the total storm rainfall was of the order of 60 to 80 mm – significantly less than several of the Saskatchewan stations.

Figure 8: Cumulative and hourly rainfall for Manitoba stations



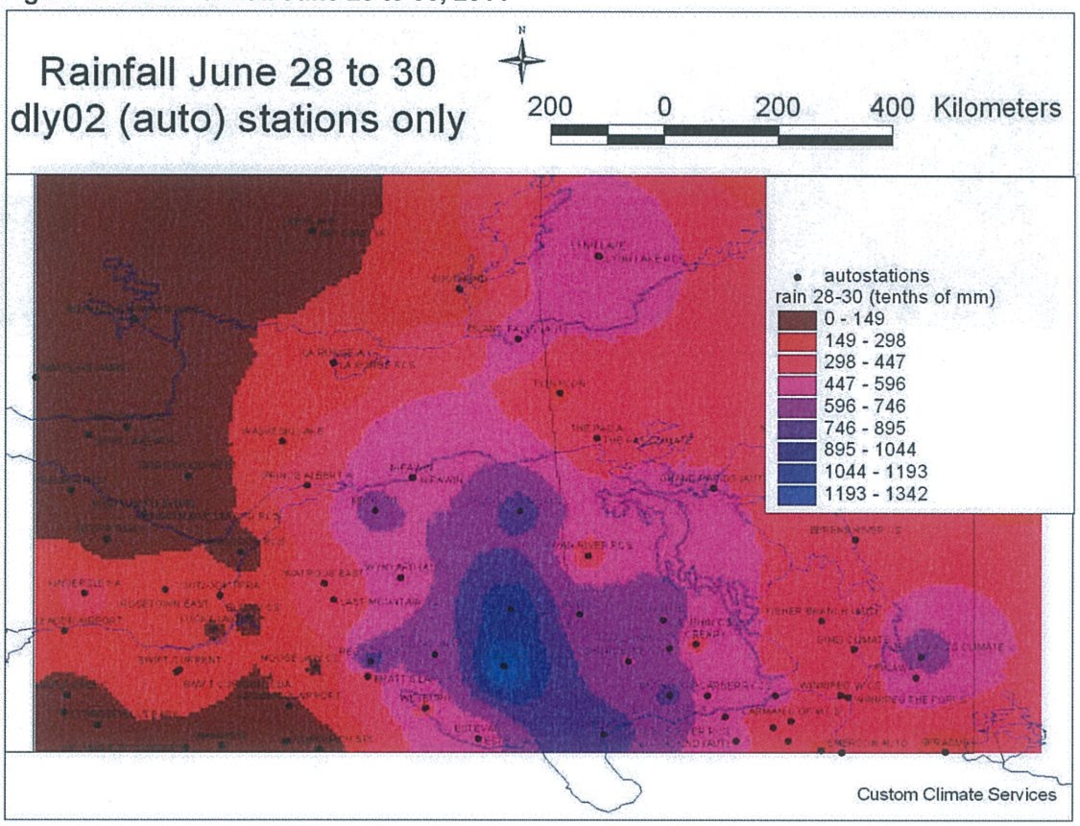




Total Storm and Daily Rainfall

Figure 9 shows the total storm rainfall as measured at the Environment Canada dly02 (auto) stations. The maximum rainfall was 134.2 mm at Broadview, Saskatchewan with an axis north to Yorkton and Hudson Bay and another maximum axis southeast to Melita, Manitoba. There were no dly02 stations in Saskatchewan closer to the Manitoba border so the maximum axis was displaced somewhat west of what was shown in the CaPA analysis. The other difference was that the CaPA analysis was for the four days from June 27 to June 30 inclusive.

Figure 9: Storm rainfall June 28 to 30, 2014



A review of the meteorology indicated that the synoptic storm developed on June 28, was at its maximum on June 29 and tailed off on June 30. Figure 10 displays the rainfall for the individual days June 27 to June 30 inclusive. There was some rainfall on June 27 but it was not associated with the June 28 to 30 synoptic storm. The only significant rainfall on the 27th was at Brandon (44.7 mm). Amounts on June 27 over southeast Saskatchewan were generally less than 9 mm.

Figure 10: Daily rainfall for June 27, 28, 29 and 30

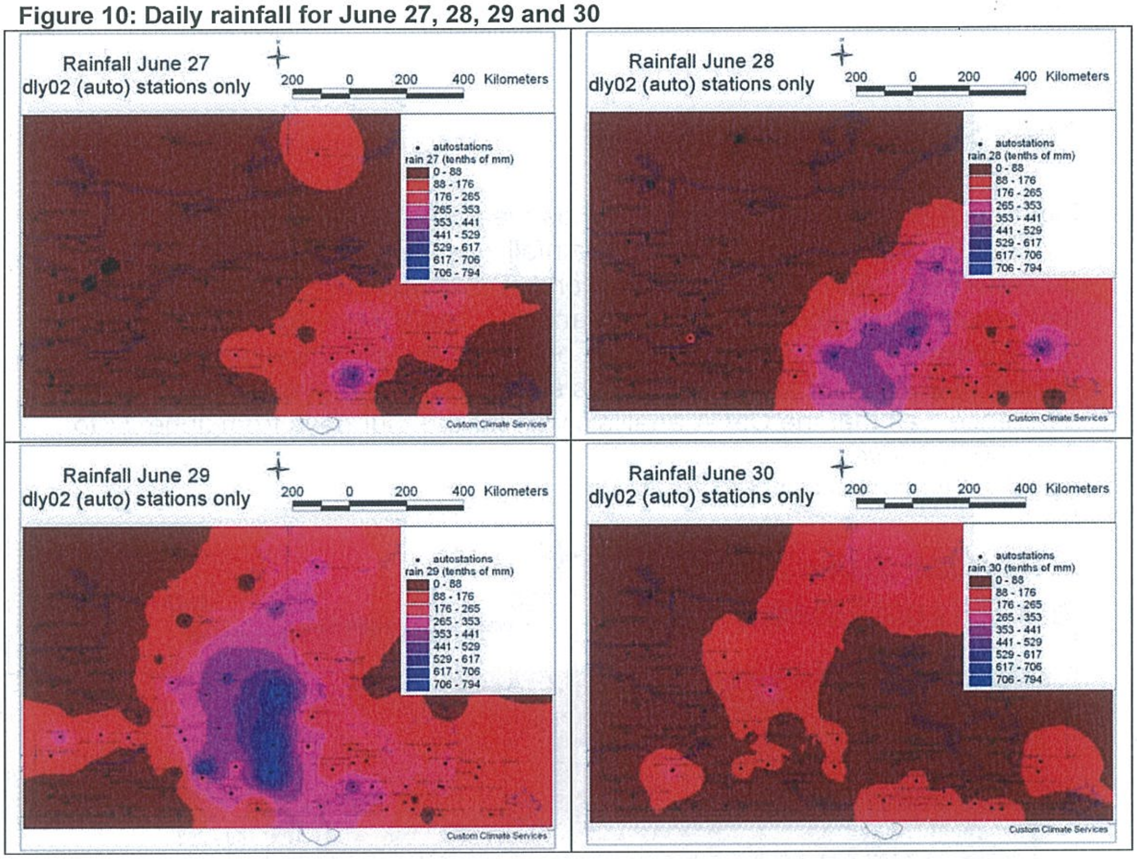
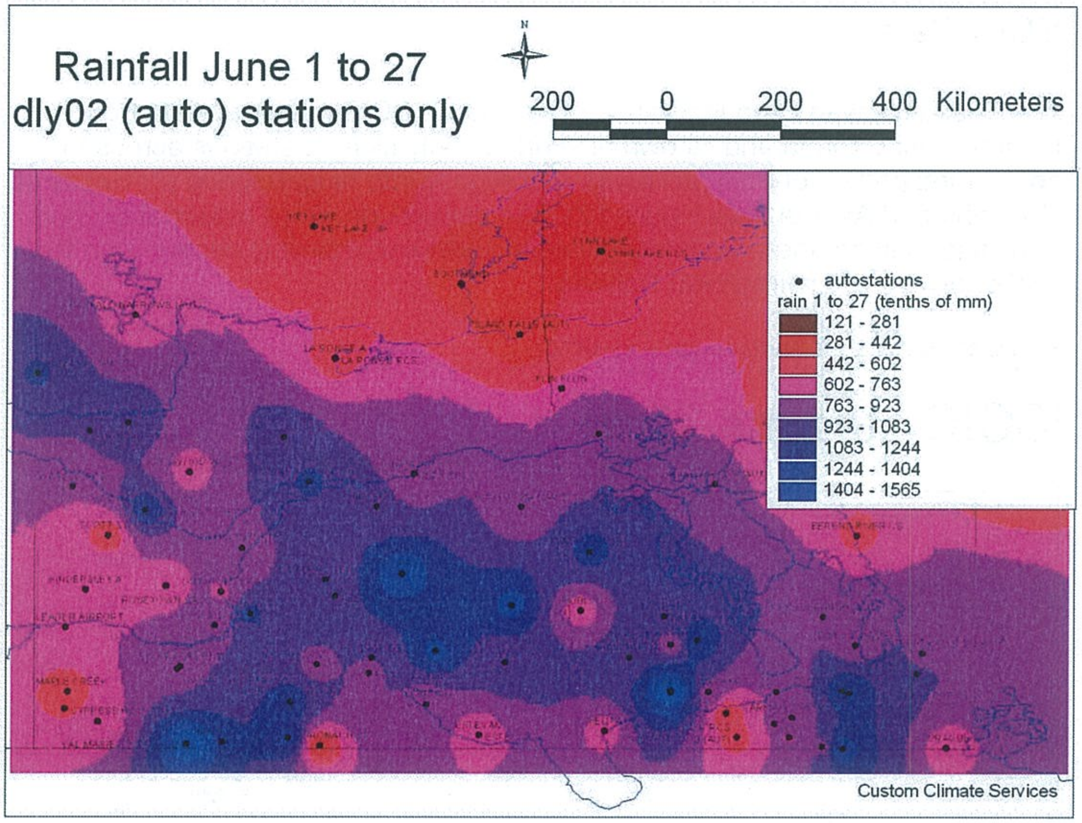


Figure 11: Total rainfall from June 1 to 27 inclusive.

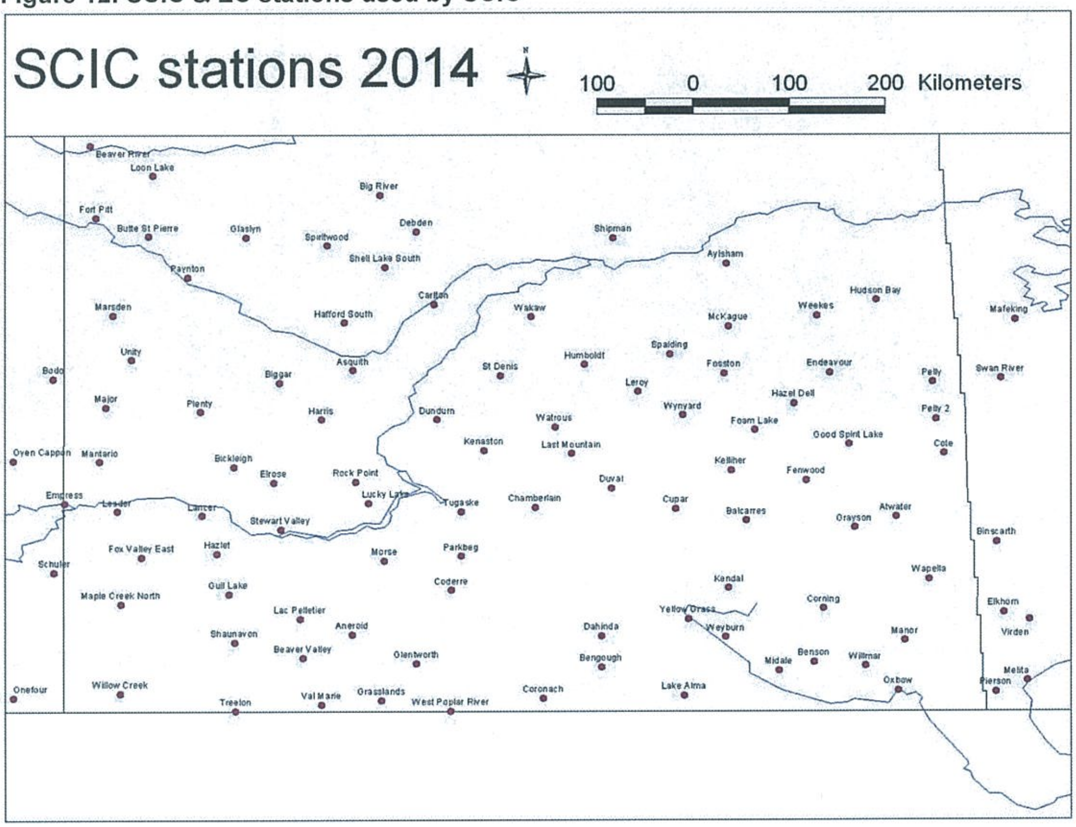


The total rainfall from June 1 to 27 is shown in Figure 11. Generally, there was a band of much higher than normal precipitation for the month to date stretching from Prince Albert to Wynyard, Indian Head and Yorkton and then across to Swan River, McCreary and Brandon in Manitoba. Typical normals for the month of June are of the order of 80 mm and most stations in this band had significantly exceeded this prior to the onset of the June 28 to 30 storm.

SCIC Data

The Saskatchewan Crop Insurance Corporation (SCIC) colleced data from Environment Canada and its own network of daily climate stations across the agricultural portion of Saskatchewan and slightly into neighbouring provinces of Manitoba and Alberta (see Figure 12). The network provided reasonably good coverage over southern Saskatchewan and was considerably denser than the dly02 network of Environment Canada.

Figure 12: SCIC & EC stations used by SCIC



Antecedent conditions

Agriculture and AgriFood Canada maintain a drought watch web site which provides much better spatial and temporal resolution than Envrionment Canada Climate Trends and Variation Bulletin:

http://www.agr.gc.ca/eng/?id=1326402878459

Figure 13 was copied from AAFC's site and showed that the area of southeast Saskatchewan and southwestern Manitoba was between 150 and 200 % of normal for the period April 1 to June 23, 2014. After the late June storm, this same area was well in excess of 200% of normal (Figure 14). This agreed well with Table 1 which summarized the monthly precipitation for April, May and June for selected stations together with the 1981 to 2010 normals and percentage of normal. In general, April had much above normal precipitation; May was above normal along the Saskatchewan Manitoba border but slightly below normal from Broadview west while June varied from over 200 % of normal to over 300% of normal.

Figure 13: AAFC's % of normal precipitation Apr 1 to June 23, 2014

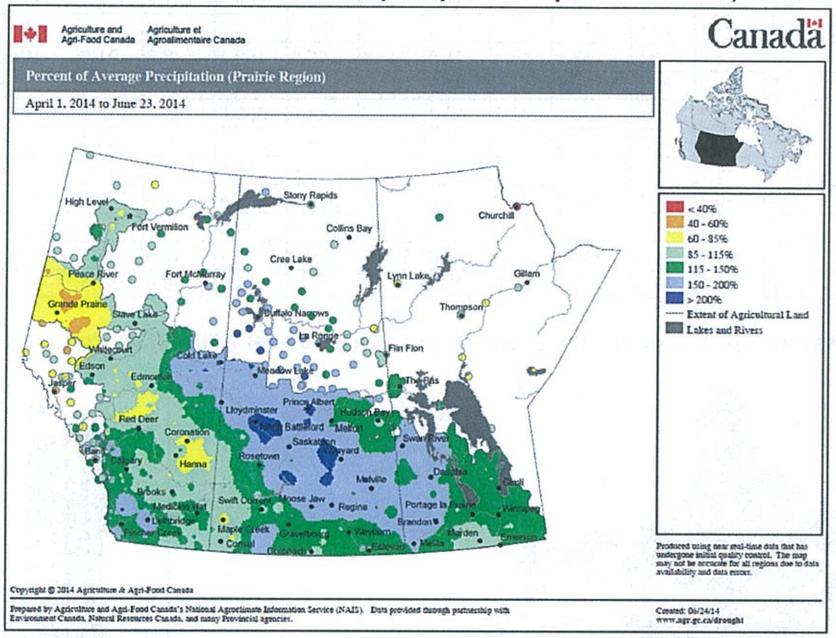


Figure 14: AAFC's % of normal precipitation Apr 1 to June 30, 2014

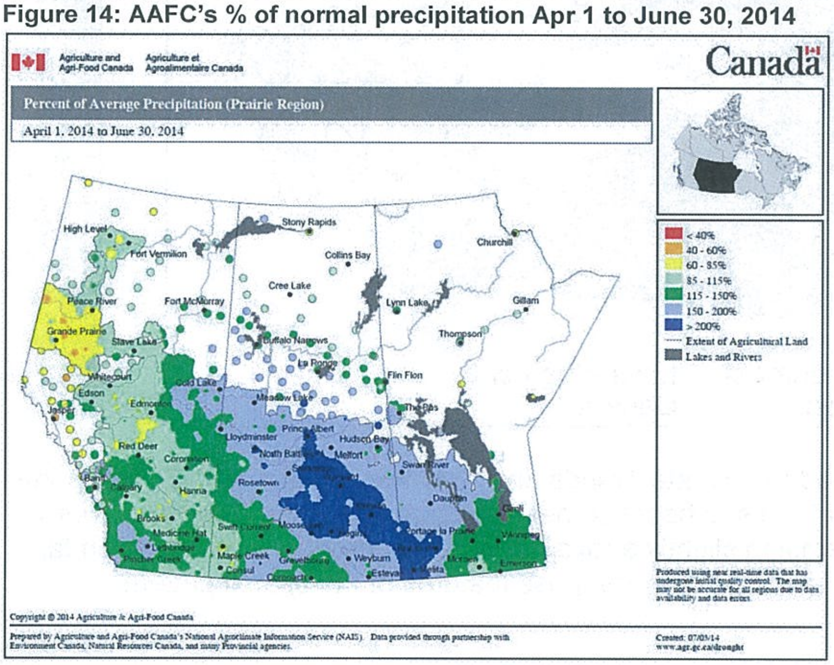
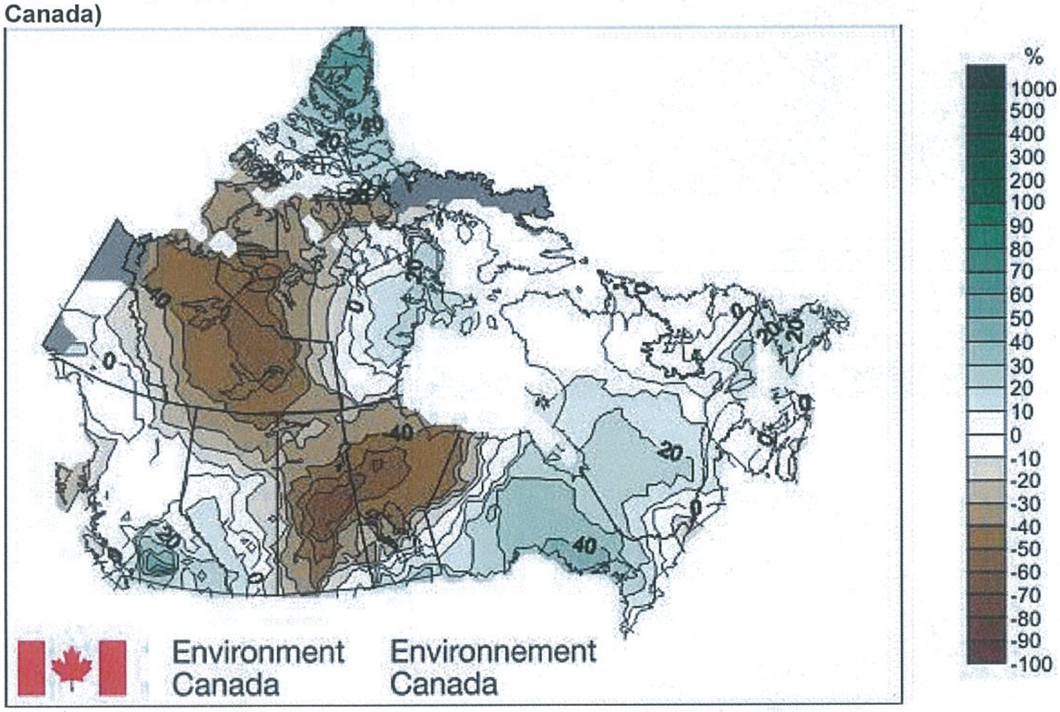


Table 1: normal Apr, May and June precipitation, actual values 2014 and % normal

	Apr norm	May norm	Jun norm	total norm	Apr 2014	May 2014	Jun 2014	Total	Apr %	May %	Jun %	Total %
Fenwood	21.7	52.6	86.6	160.9	83.0	60.6	284.8	428.4	382.5	115.2	328.9	266.3
Atwater	22.8	57.5	81.5	161.8	58.6	49.4	296.2	404.2	257.0	85.9	363.4	249.8
Virden	28.6	54.1	82.2	164.9	61.2	83.4	246.6	391.2	214.0	154.2	300.0	237.2
Elkhorn	27.6	66.8	102.3	196.7	62.0	71.0	248.4	381.4	224.6	106.3	242.8	193.9
Good Spirit Lake	25.8	60.1	86.1	172.0	87.0	48.0	246.4	381.4	337.2	79.9	286.2	221.7
Melita/Pierson norm	27.5	55.1	77.7	160.3	85.4	120.6	167.2	373.2	310.5	218.9	215.2	232.8
Leroy	22.4	49.1	72.0	143.5	64.4	37.8	263.6	365.8	287.5	77.0	366.1	254.9
Yorkton	21.6	51.3	80.1	153.0	57.2	51.9	252.1	361.2	264.8	101.2	314.7	236.1
Duval	26.7	49.1	77.9	153.7	57.0	78.4	219.0	354.4	213.5	159.7	281.1	230.6
Wapella	27.1	55.7	79.5	162.3	43.4	71.4	231.8	346.6	160.1	128.2	291.6	213.6
Binscarth	26.5	55.7	88.6	170.8	51.2	94.2	201.0	346.4	193.2	169.1	226.9	202.8
Wynyard	20.4	46.2	71.9	138.5	73.4	43.2	228.0	344.6	359.8	93.5	317.1	248.8
Pierson	27.5	55.1	77.7	160.3	79.2	80.0	183.2	342.4	288.0	145.2	235.8	213.6
Broadview	23.1	55.9	76.9	155.9	59.1	39.2	233.6	331.9	255.8	70.1	303.8	212.9
Pelly 2	29.1	56.7	88.5	174.3	49.0	72.0	189.0	310.0	168.4	127.0	213.6	177.9
Balcarres	25.7	46.4	76.0	148.1	70.4	35.0	199.4	304.8	273.9	75.4	262.4	205.8
McKague	23.7	42.9	78.4	145.0	55.0	20.0	224.0	299.0	232.1	46.6	285.7	206.2
Indian Head CDA	22.6	51.7	77.4	151.7	60.4	36.0	199.2	295.6	267.3	69.6	257.4	194.9

Figure 15: Spring (March, April & May) 2014 precipitation % of normal (CTVB Environment Canada)

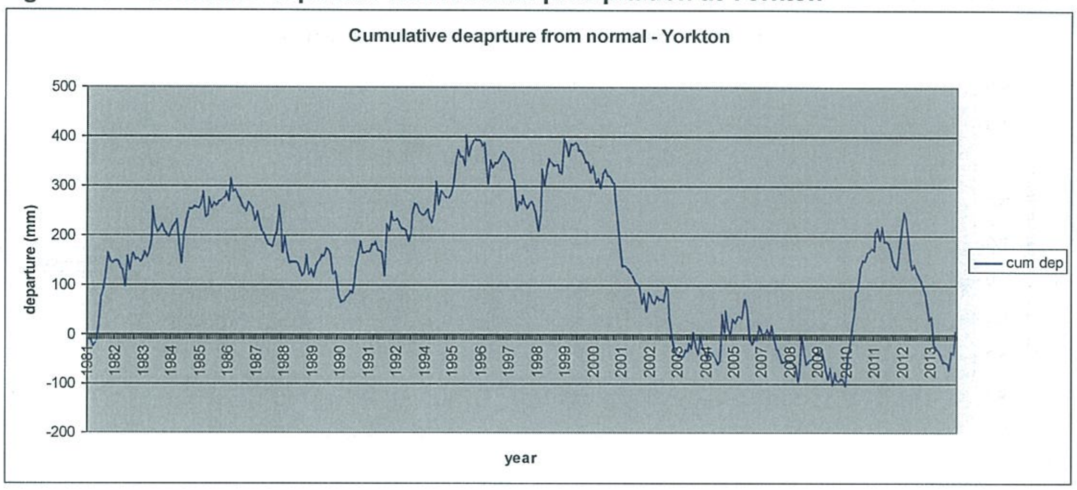


Environment Canada's Climate Trends and Variation Bulletin (CTVB) for spring 2014 indicated that the southeast corner of Saskatchewan and all of southern Manitoba was normal to slightly above normal. This product was based on far fewer stations so captured only the gross features of the spatial pattern.

One analysis technique that can be helpful in some situations is a cumulative departure from normal assessment. When conditions are near normal over a period of time there is no overall positive or negative slope to the cumulative departure from normal. If the slope is negative with time, then there is a prolonged drier than normal period. Wetter than normal periods are indicated by an overall positive slope to the curve.

Figure 16 for Yorkton indicated that the immediate few months before the end of June storm were most significant. There was a very wet period in 2010 (positive slope) but late 2012 and 2013 were drier than normal (negative slope). There was some question about winter precipitation at Yorkton over the past few years so this plot may have been drier than reality. The positive slope immediately before the June 2014 appeared to have been sufficient to make the local landscape relatively wet. In particular, the rainfall up to June 27 of 130.6 mm was well above the normal June precipitation of 80.1 mm!

Figure 16: Cumulative departure from normal precipitation at Yorkton



For western Manitoba, Elkhorn had one of the better records since 2007. In Figure 17, there was some reflection of the wet period in 2010 and 2011 at Yorkton but otherwise the traces are quite different. The June precipitation up to June 27 of 2014 at Elkhorn was near the monthly normal and May was near normal while April was almost twice normal.

Unfortunately, none of the stations like Atwater, Fenwood and Wapella closer to the area of highest precipitation had Environment Canada records much past 2007. The closest Environment Canada station with continuous data to 2014 was Broadview. The cumulative departure from normal trace for Broadview (Figure 18) was different again from the other two but showed the wetter period in 2010 and then drier conditions in 2013 and a small upward trend just in the final few months similar to Yorkton.

Figure 17: Cumulative departure from normal precipitation at Elkhorn 2 East

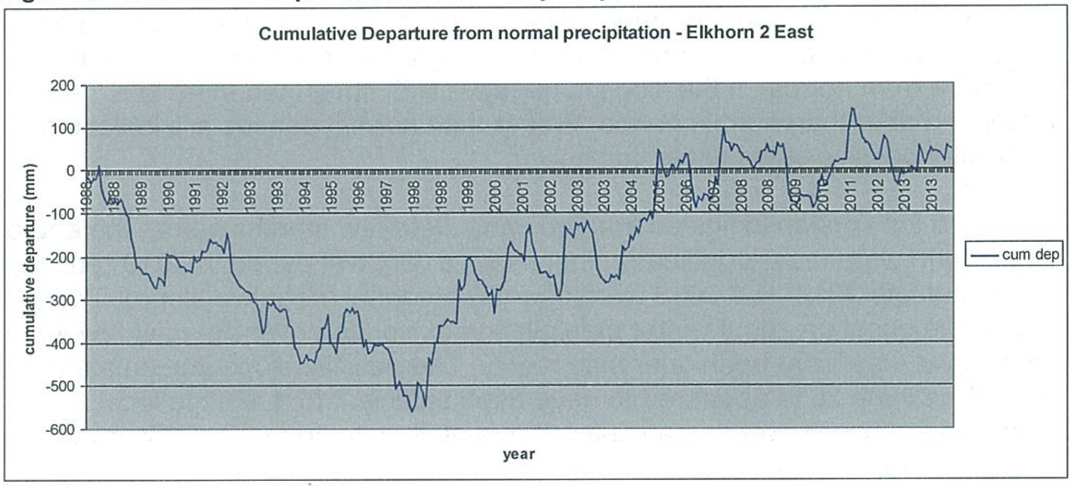
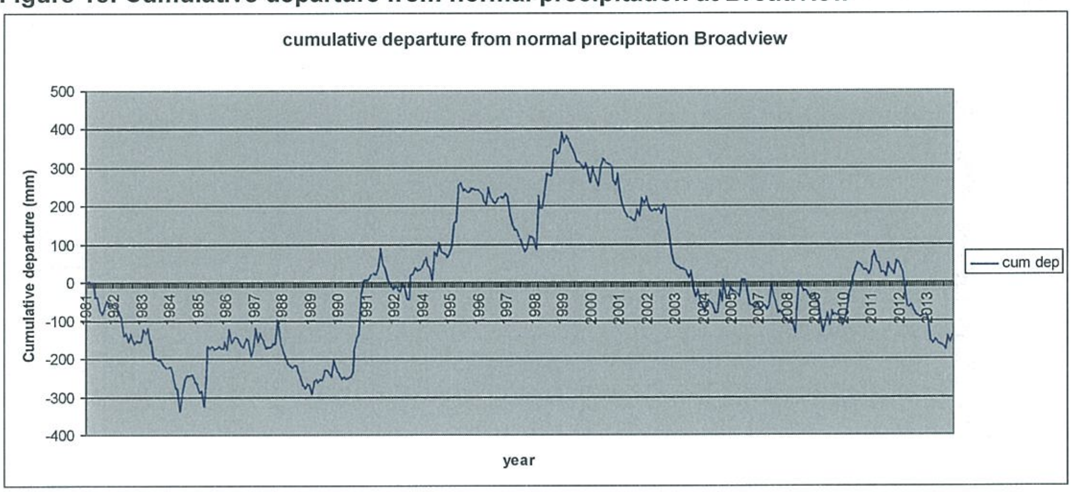


Figure 18: Cumulative departure from normal precipitation at Broadview



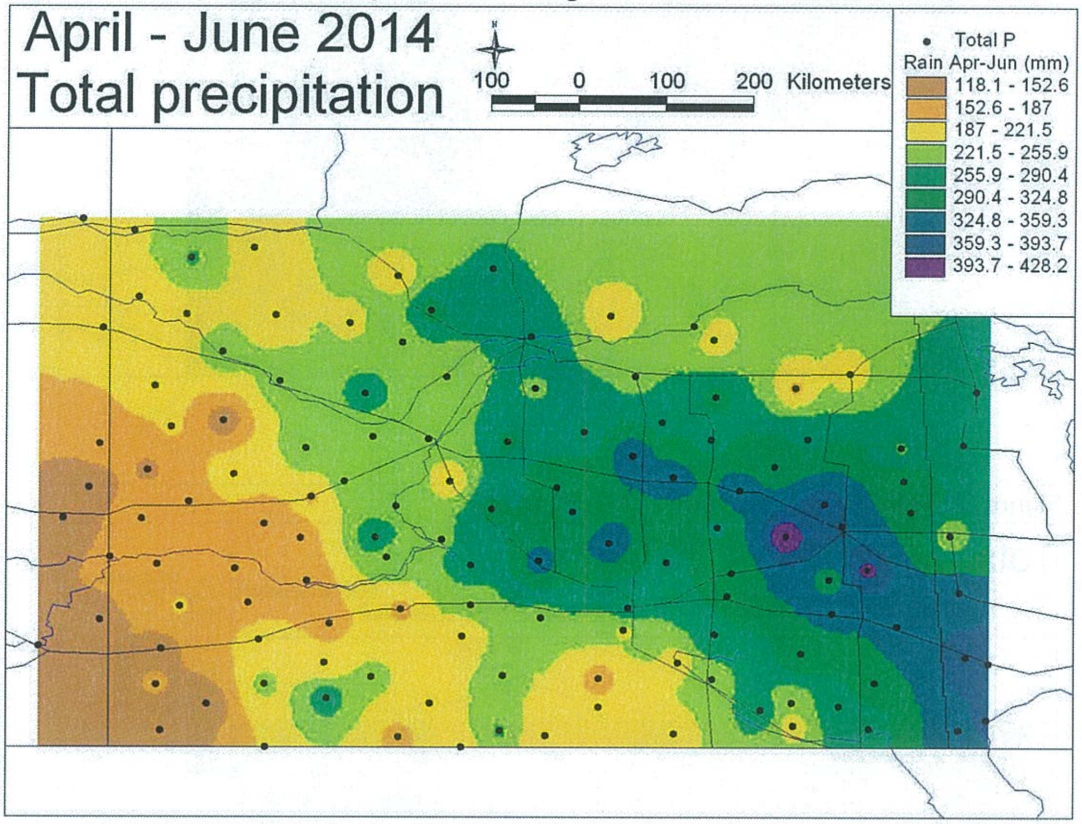
None of these precipitation records used here was perfect. There were sporadic missing days from all three records especially for Elkhorn since November of 2007. Also the automatic precipitation gauges at Yorkton and Broadview yielded suspiciously low winter precipitation in recent years. However it appeared that there was no systematic long-term wet condition in the region. A wet period in 2010 wais evident but this was followed by generally below normal precipitation in 2012-2013.

The anomalously high precipitation from April 1 to June 27, 2014 associated with cool conditions likely led to wetter than normal soil moisture conditions just prior to the late June 2014 storm.

Storm Analysis

As shown in Figure 19, the total precipitation for the three months April to June 2014 including the end of June storm was equal to a year's worth of rainfall (~ 325 to 375 mm) and in some cases, almost a year's worth of precipitation (~ 425 to 475 mm).

Figure 19: Total precipitation April to June using SCIC data – includes end of June storm



Almost half of that total fell during the four days June 27 to June 30 but the synoptic storm was actually just June 28 to 30 (see Figure 20). There were showers on June 27 and they added as much as 30 mm to the totals at some locations (Figure 21). There was an area of heavier showers in extreme southwestern Manitoba on June 27 (Figure 22) but this was separate from the June 28 to 30 synoptic storm rainfall.

The overall pattern of highest rainfall did not change appreciably with the addition of June 27 data but that rainfall was not associated with the synoptic storm of June 28 to 30. There was a tongue of higher rainfall along the SK/MB border extending southward to the US border, reflecting the higher rainfall amounts on June 27 from Pierson to Elkhorn.

Figure 20: Total precipitation June 28 to 30, 2014

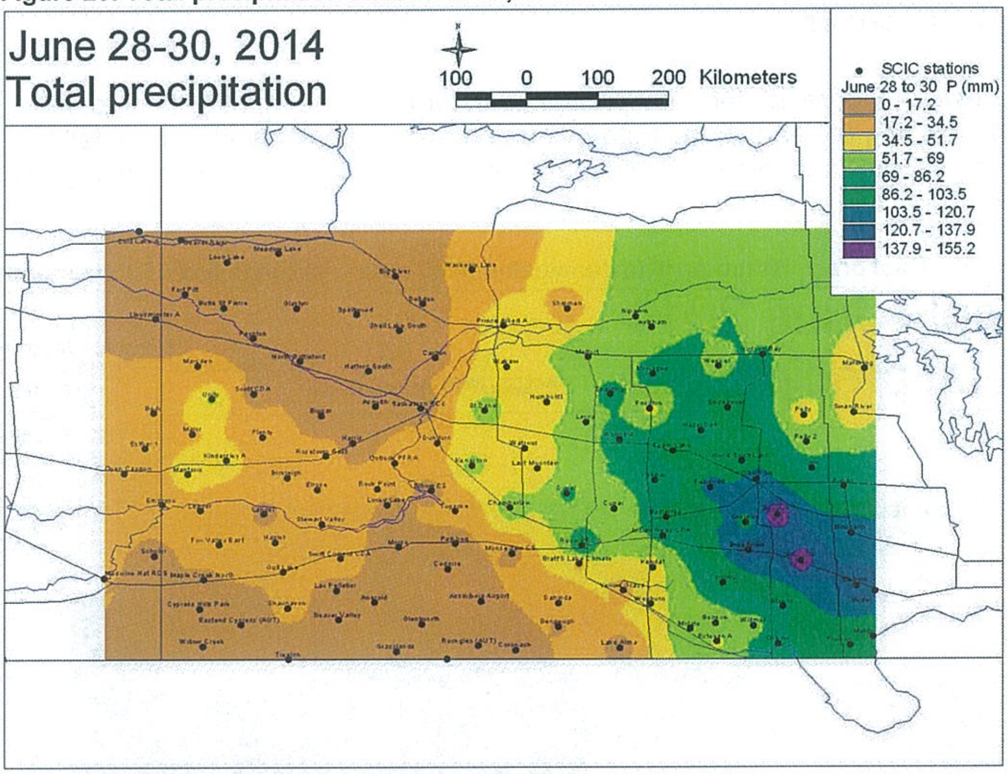


Figure 21: Total precipitation June 27 to 30, 2014

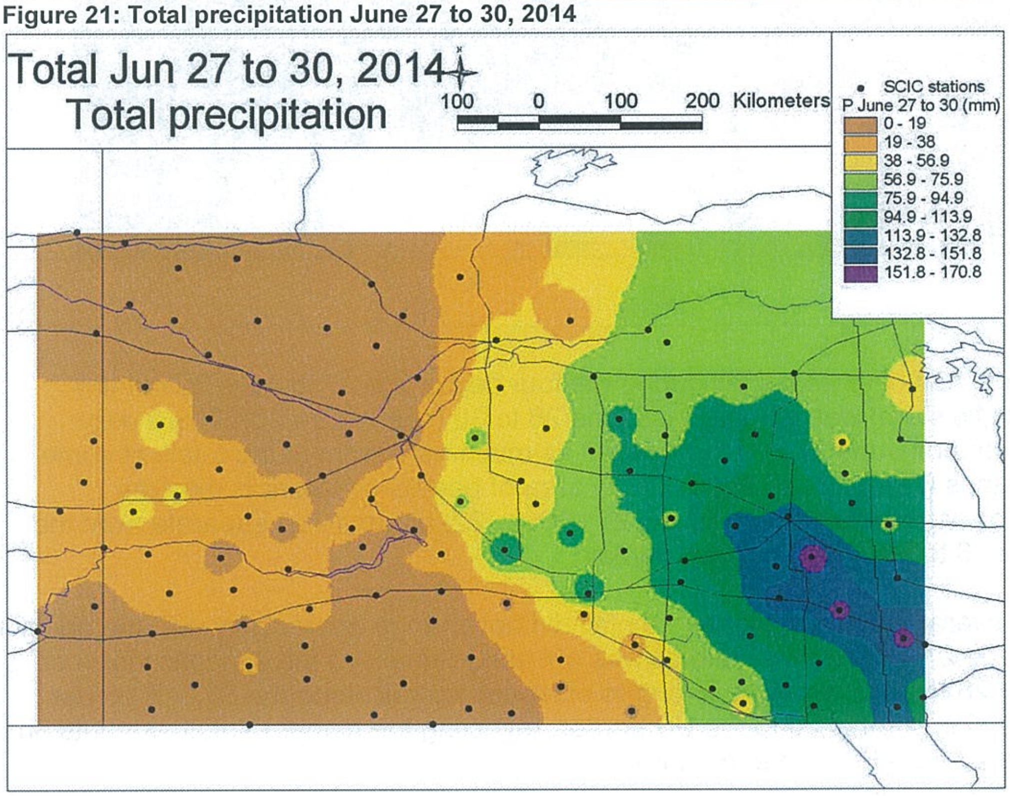


Figure 22: Daily rainfall June 27, 28, 29 and 30, 2014

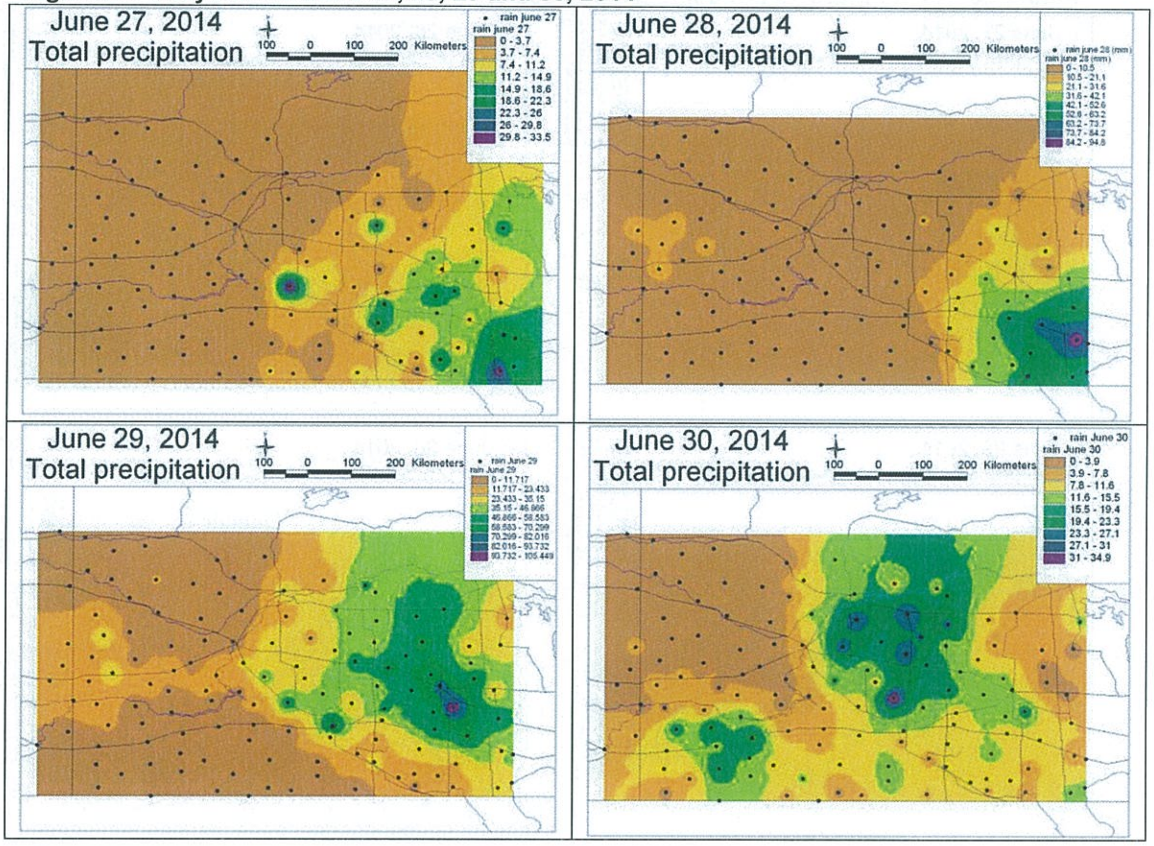


Figure 22 shows the rainfall for each day June 27 to June 30 but it was a bit misleading because the scale was different for each analysis. However these maps do show more clearly the showery rainfall on June 27 with a maximum over southwest Manitoba. The storm rainfall developed on June 28 and extended northward and westward into southeast Saskatchewan with a maximum axis from Elkhorn, MB to Wapella, SK. June 29 had the heaviest rainfall and that was when the main rainfall area was over eastern Saskatchewan with a maximum axis from Atwater to Yorkton with a minor axis toward Broadview. The higher rainfalls at Regina and Chamberlain on June 29 were somewhat divorced from the main rain area to the east and were suggestive of embedded convection. On June 30, the rainfall over southeast Saskatchewan had virtually ended but there was an area of heavier rainfall from Duval to Melfort and east of Saskatoon with amounts of 25 to 35 mm.

Figure 23 has analyses for the same days but used the scale for June 29 for all days. This showed clearly that the heaviest precipitation fell on June 29 followed by June 28. The showery rainfall on June 27 was generally under 20 mm. Over the main flooding area of eastern Saskatchewan, there was generally less than 10 mm of rain on June 30 on the back side of the system.

Figure 23: As in Figure 19 but using a static scale.

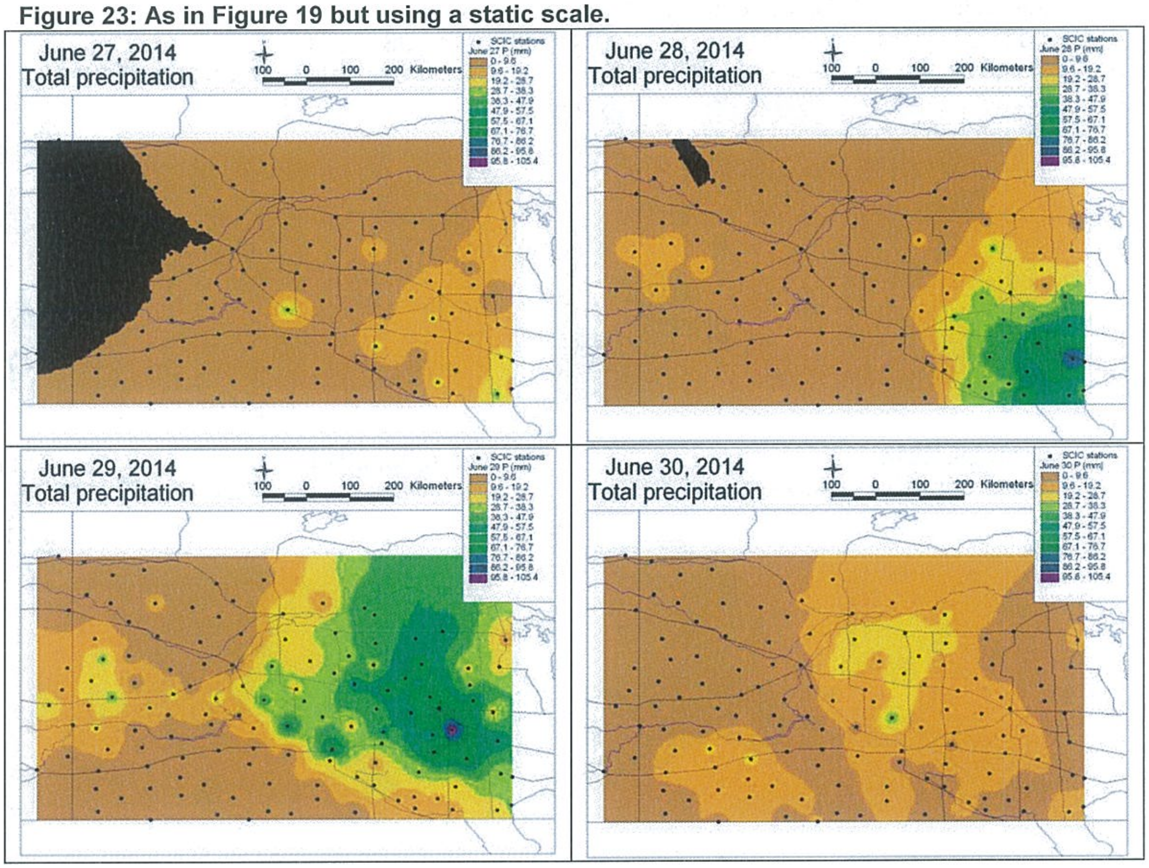
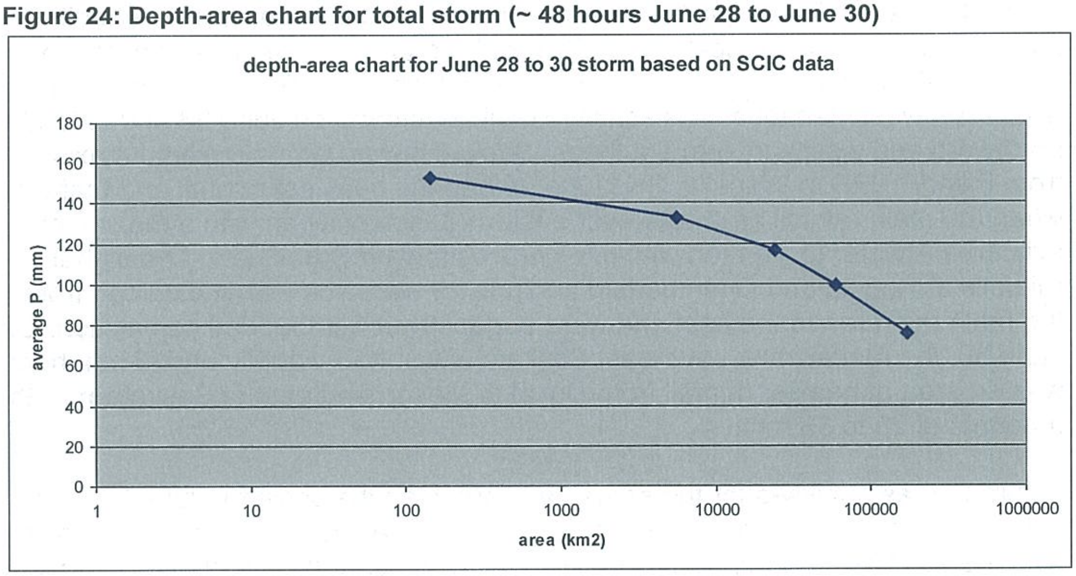


Figure 24: Depth-area chart for total storm (~ 48 hours June 28 to June 30)



Using ArcView, a depth-area curve was developed for the total storm June 28 to 30 (Figure 24). The actual duration of the storm was approximately 48 hours, extending from the late morning of June 28 to noon of June 30. Very small amounts accumulated after noon on June 30 but the bulk of the precipitation occurred in a 48 hour period.

The values in the depth area curve were compared to other historic storms from Environment Canada's Storm Rainfall in Canada series. For areas larger than 24,000 km^2, the June 28 to 30 storm of 2014 was significant, ranking 10th of all Manitoba and Saskatchewan storms in the Storm Rainfall in Canada series. The collection of storms used for comparison included the Alberta storm of June 1973 because it was a significant non-orographic prairie storm. Table 2 provides a relative ranking of the June 28 to 30 storm against historic storms in the Storm Rainfall in Canada series. The Vanguard storm of July 2000 appeared as second ranked for 144 km^2, mainly because of the long duration of the late June 2014 event. The Vanguard storm was mainly concentrated into an eight hour period but produced more than twice the depth of rainfall than the June 28 to 30, 2014 storm produced in 48 hours. The Alberta storm was the top ranked storm for 169,000 km^2 but for all other areas, the Springbrook, Montana storm of June 1921 was top ranked.

Table 2: Depth-area value for June 28 to 30 storm and comparative storm data

area (km2)	avg P (mm)	rank	highest	Storm ID	2nd highest	Storm ID
169000	75.4	3	120.5	AJun1473	83.7	MJun0337
58669	99.0	7	155.0	SJun1721	151.0	AJun1473
24113	116.4	10	194.2	SJun1721	162.1	AJun1473
5565	132.7	27	284.4	SJun1721	259.9	SJul1074
144	152.5	38	358.1	SJun1721	356.4	SJul0300

For very large areas, the late June 2014 storm was highly significant ranking third for 169,000 km^2 and 7^{th} for 58,669 km^2. These numbers are still preliminary and require the radar spatial data to confirm these findings. The relatively wet landscape prior to the storm was likely a major factor in the amount of runoff generated by the late June 2014 storm. Rainfall rates were in general very modest and the total rainfall significant only for areas larger than or equal to 24,000 km^2.

In terms of individual rainfalls, only Atwater with 105.6 mm in one day was greater than the 100-year return period rainfall (Table 3). Other stations' one-day return periods were more of the order of 25 years or less. The totals for multiple days were of more significance with 2 and 3-day return periods of the order of 100-years or more at Atwater, Broadview and Wapella. The return period statistics were assessed against the output of Rain30 which was run for each of the stations in Table 3.

Table 3: 1, 2 and 3 day rainfall totals and respective return period

	1 day	return period	2-day	return period	3-day	return period
Elkhorn	94.2	~30 year	127.6	<100 year	134.0	~ 50 year
Atwater	105.6	> 100 year	138.0	>> 100 year	155.4	>> 100 year
Broadview	77.2	>25 year	124.4	> 100 year	134.2	> 100 year
Fenwood	55.6	< 5 year	93.0	~10 year	107.0	~ 25 year
Good Spirit Lake	57.2	~ 5 year	82.0	< 5 year	94.6	< 10 year
Regina RCS	79.9	> 10 year	92.0	> 5 year	92.2	~ 5 year
Wapella	74.4	> 10 year	136.2	> 100 year	146.8	> 100 year
Yorkton	78.4	< 25 year	98.7	> 25 year	110.6	> 50 year

Radar Analysis

The Bethune and Foxwarren radars were both operational through the storm and provided good spatial and temporal records of the storm rainfall. Figure 25 was taken from the historic radar image site maintained by Environment Canada.

http://climate.weather.gc.ca/radar/index_e.html

Figure 25: Prairie composite radar image for June 29, 2014 0100 UTC

Figure 26 shows the radar image from the Environment Canada web site at 0930 UTC on June 28. There were small regions of higher rainfall rates but generally the rates agreed with those observed at the hourly rainfall stations.

Figure 26: Foxwarren radar image for June 28 1930 UTC

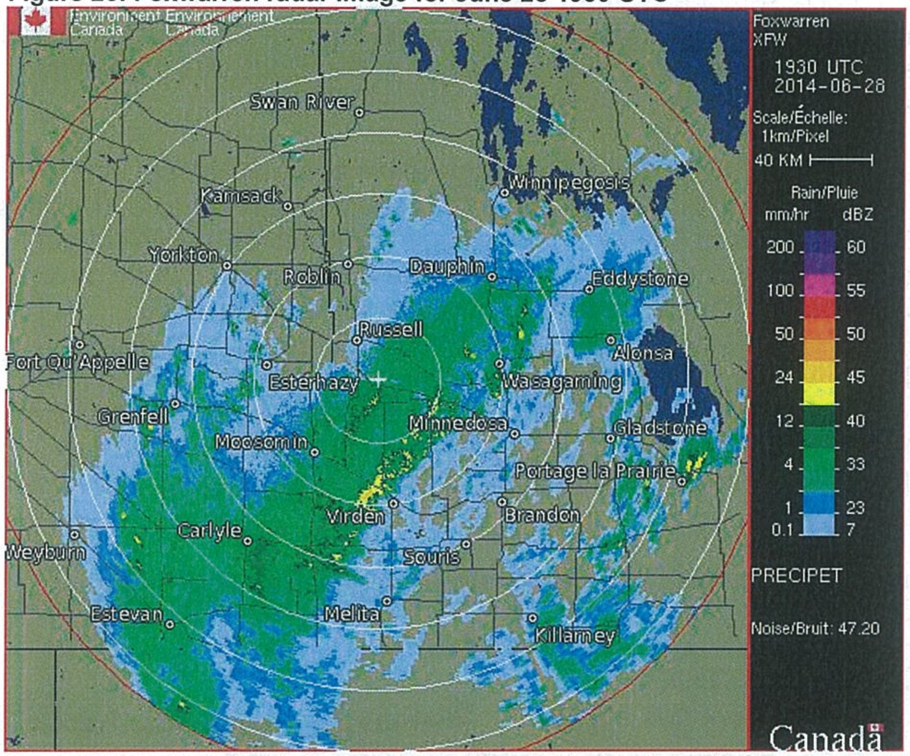


Figure 27: Radar reflectivity processed from digital radar data for June 28 1930 UTC

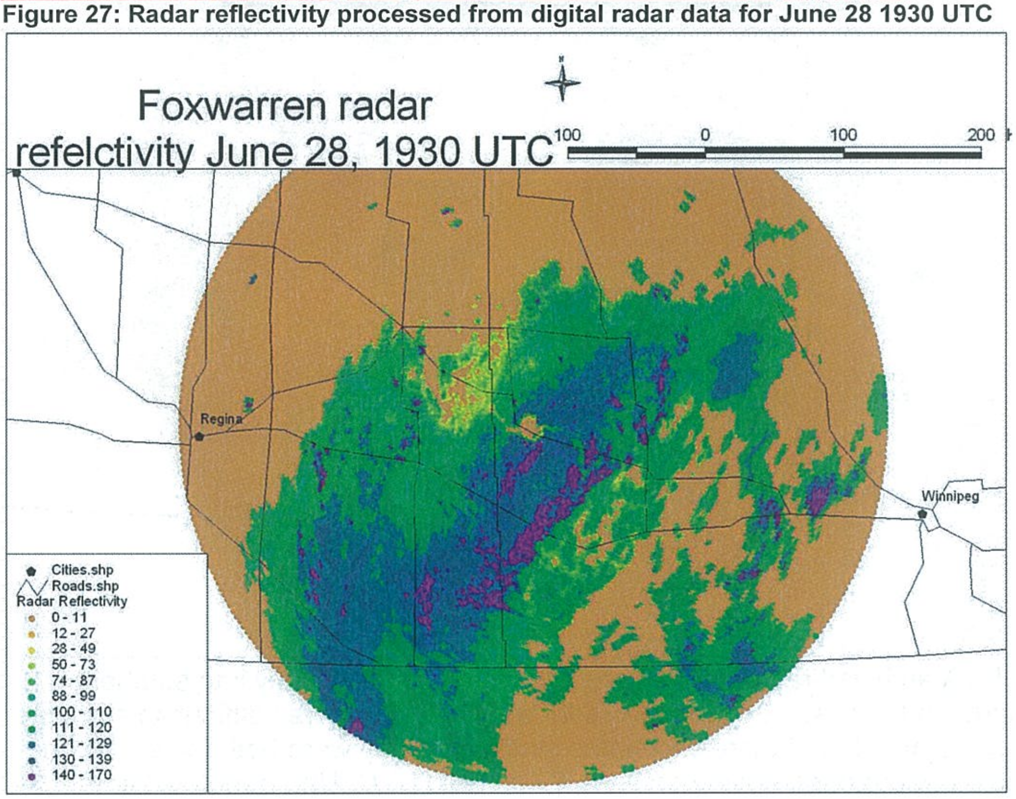
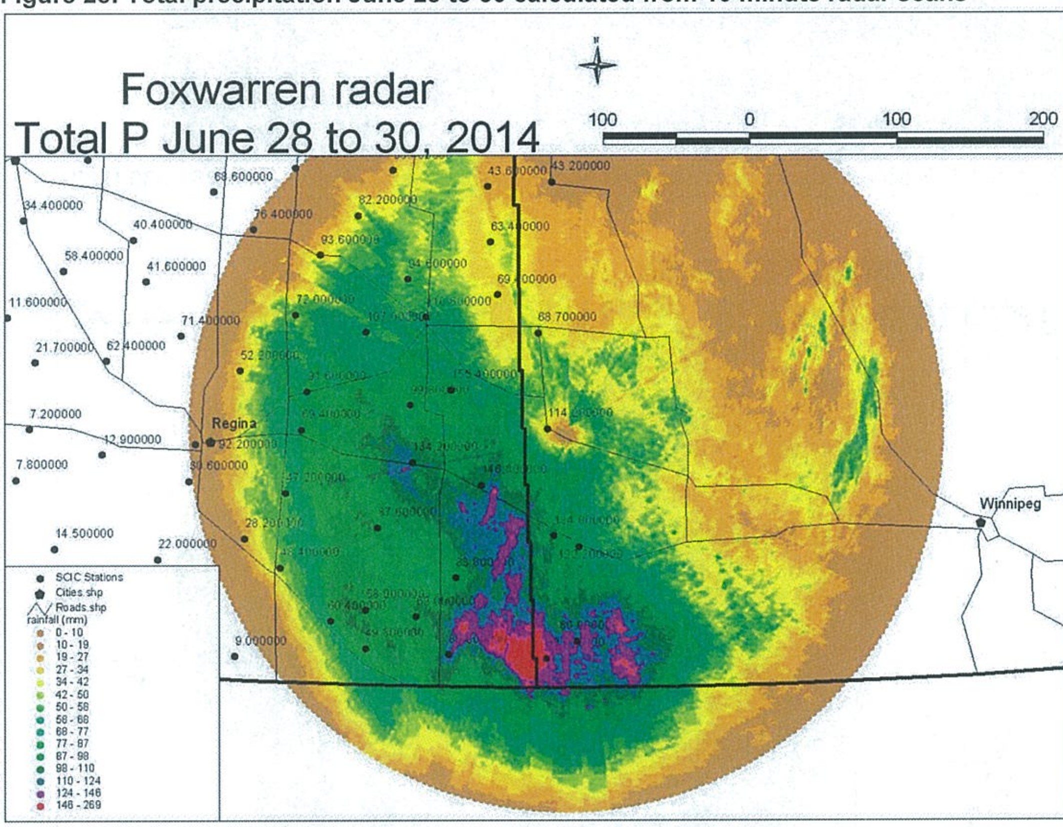


Figure 27 was processed directly from the digital radar files ordered from Environment Canada. The correspondence between Figures 26 and 27 provided reassurance that the radar processing undertaken in this study was consistent with Environment Canada's own processing.

The processing program RadarCalP_3 was applied to every 10 minute scan from June 28 0600 UTC to July 1 0600 UTC which corresponded to the calendar days June 28 to 30. The resulting Figure 28 looked quite different from CaPA (Figure 4) or the analysis of the SCIC data (Figure 20). The area just around the radar station has been masked to eliminate ground clutter so the radar is not representative of Binscarth which falls just at the end of the mask. The radar values at Elkhorn, Virden, Yorkton and Atwater are all less than the observed rainfall and were close enough to the radar station that attenuation of the signal should not be an issue. There is probably attenuation to the west of the high rainfall band in southeast Saskatchewan and south of the high rainfall just north of the US border.

Figure 28: Total precipitation June 28 to 30 calculated from 10 minute radar scans



The USA archived radar derived precipitation extends slightly into southern Canada and is based on the USA radar at Minot, ND. It was difficult to compare Figure 29 and 30 but there was some similarity. They were both for exactly the same 24 hour period ending on June 29 at 1200 UTC. Unfortunately the really interesting region just west of SK-MB border appears to be masked out.

Figure 29: USA radar precipitation for the 24 hours ending June 29 1200 UTC

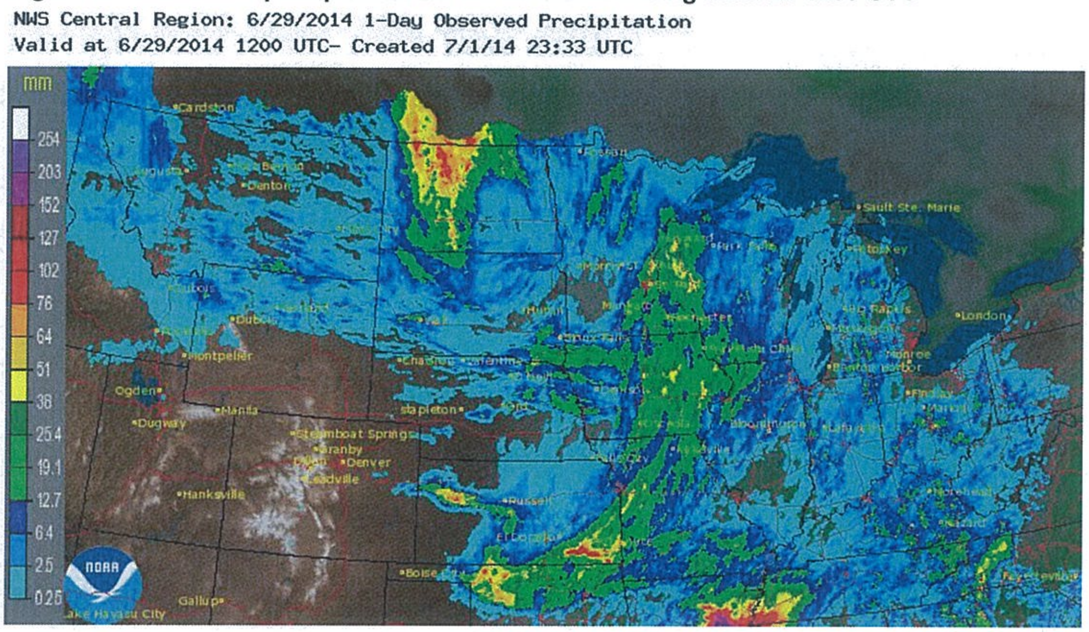


Figure 30:Foxwarren radar precipitation for the 24 hours ending at June 29 1200 UTC

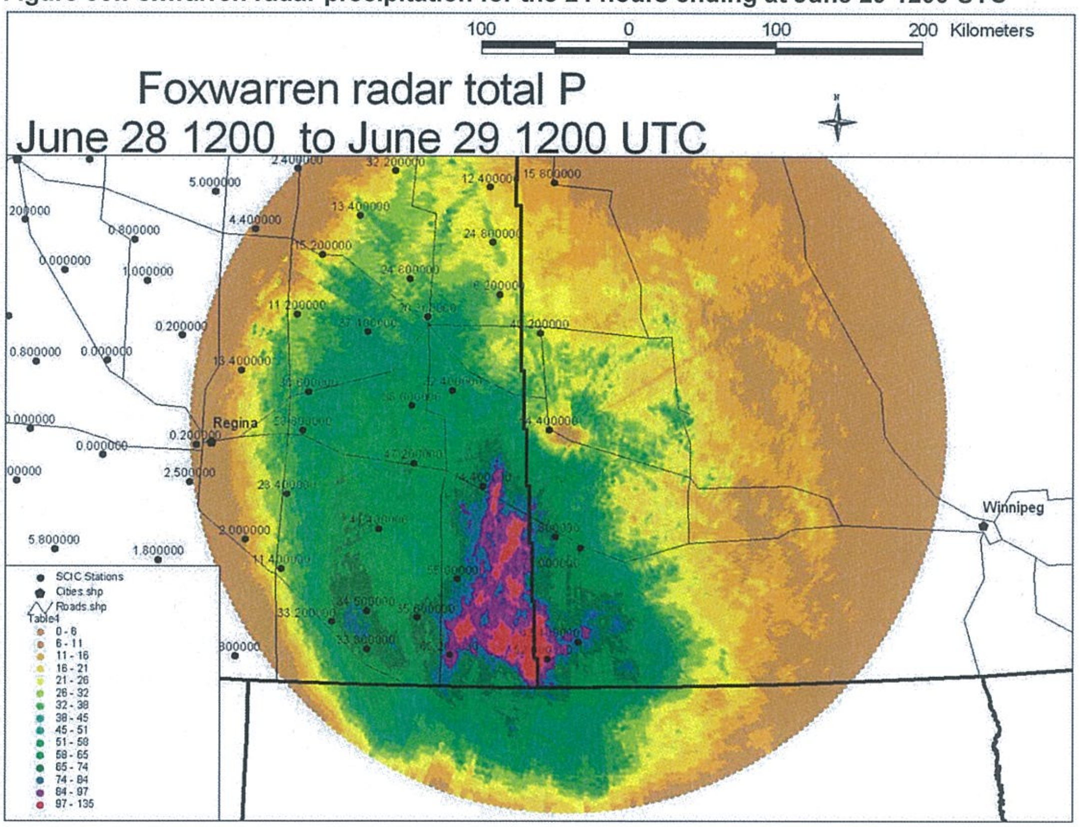


Figure 31: USA radar precipitation for the 24 hours ending June 30 1200 UTC

NWS Central Region: 6/30/2014 1-Day Observed Precipitation
Valid at 6/30/2014 1200 UTC- Created 7/2/14 23:32 UTC

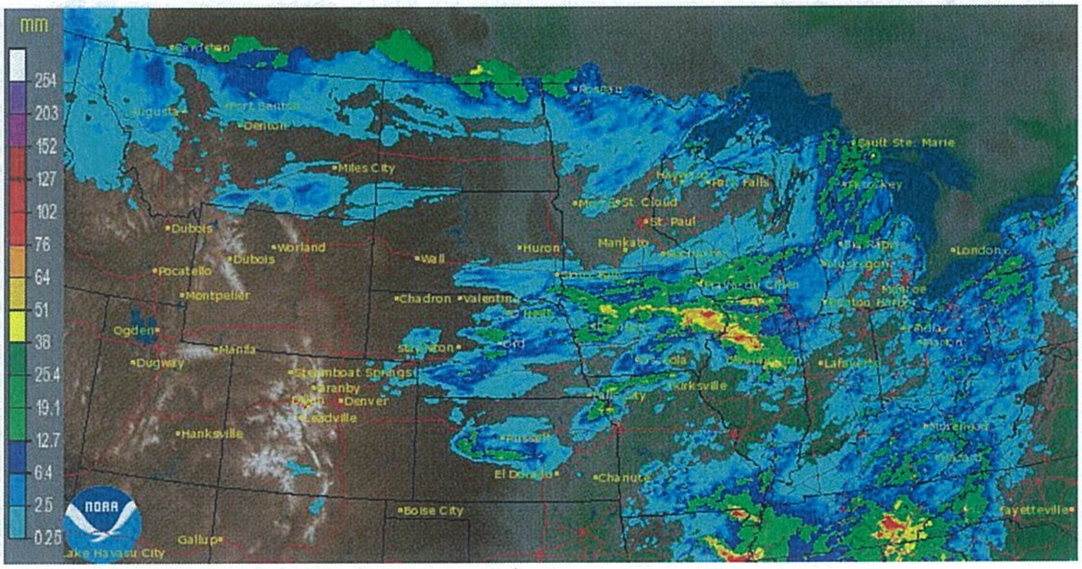


Figure 32: Foxwarren radar precipitation for the 24 hours ending at June 30 1200 UTC

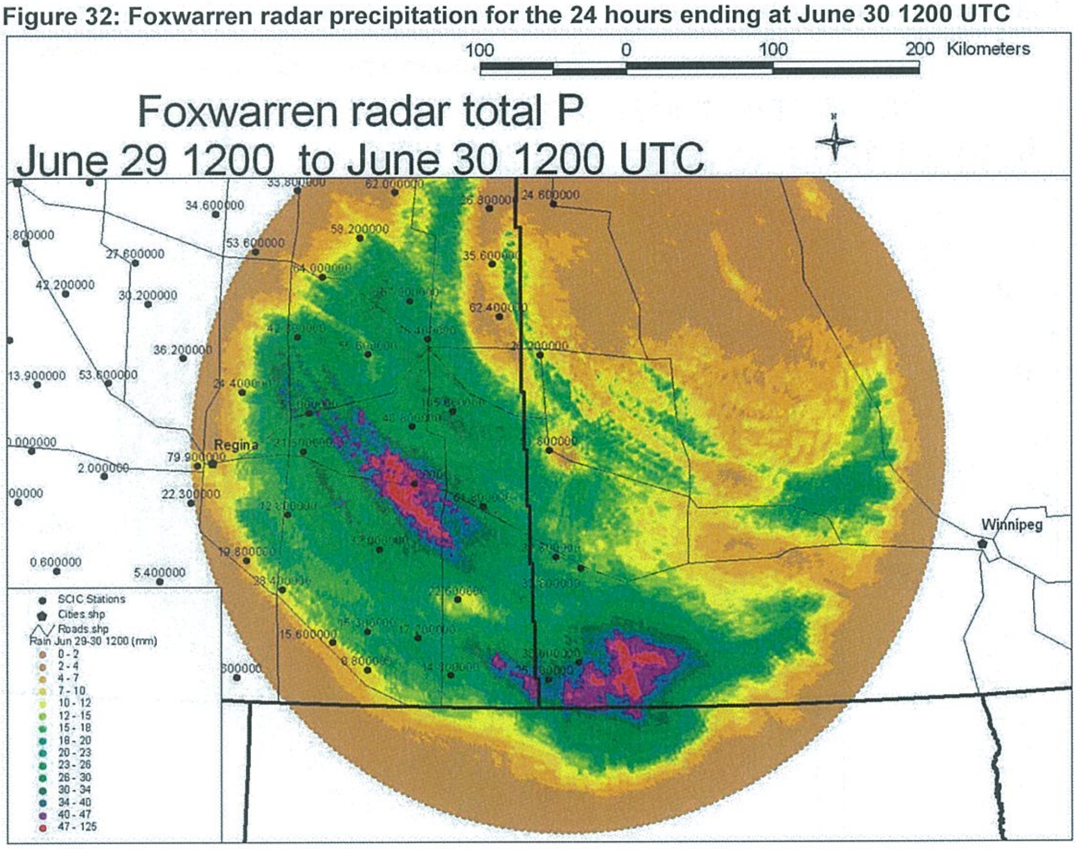


Figure 31 and 32 were the comparative 24-hour radar rainfall analyses ending at 1200 UTC on June 30. The orientation of the rainfall was similar and there was a suggestion of higher values just over southwest Manitoba. In general, the radar totals over Saskatchewan were considerably less than the SCIC values which suggested that the radar values from Foxwarren were underestimating the true rainfall. Still the general pattern appeared consistent with the SCIC stations except at Atwater. The band of higher precipitation near Broadview had values in the high 40 to low 50 mm range, again less than the measured value at Broadview (77.2 mm). However, the climate days were slightly different.

Toward the northwestern portion of the radar scan, the values were much less than the SCIC values and this implied attenuation of the signal at distances close to the maximum range of the Foxwarren radar. This was particularly noticeable at Regina where the Foxwarren value was far less than the observed value. To view this portion of the storm, the Bethune radar was processed.

A comparison of the Environment Canada radar image at Bethune for June 29 at 1600 UTC (Figure 33) was made with the radar reflectivity processed from digital radar data for the same time (Figure 34). The figures corresponded well except close to Bethune where a processing mask was applied to the latter to eliminate ground clutter. This provided assurance that the processing undertaken in this study was correct – image in the right quadrant and displaying the same spatial pattern.

Figure 35 showed the total radar derived rainfall as seen by the Bethune radar for the three days June 28 to June 30. There was a band of maximum precipitation between Indian Head and Broadview with a north south orientation. The radar signal was strongly attenuated to the east of this band. The Foxwarren radar was much closer to the eastern part of the storm. Rainfall amounts were again less than what was observed at the SCIC and Environment Canada stations even where attenuation was not an issue. There was a narrow band of higher rainfall near Regina but no radar derived rainfall amounts came close to the 92 mm recorded by the Regina RCS station. There were a few anomalously high values northeast of Watrous but it was not possible to confirm or reject these points. The 373 mm value did not appear realistic.

Figure 33: Bethune radar image for June 29 1600 UTC

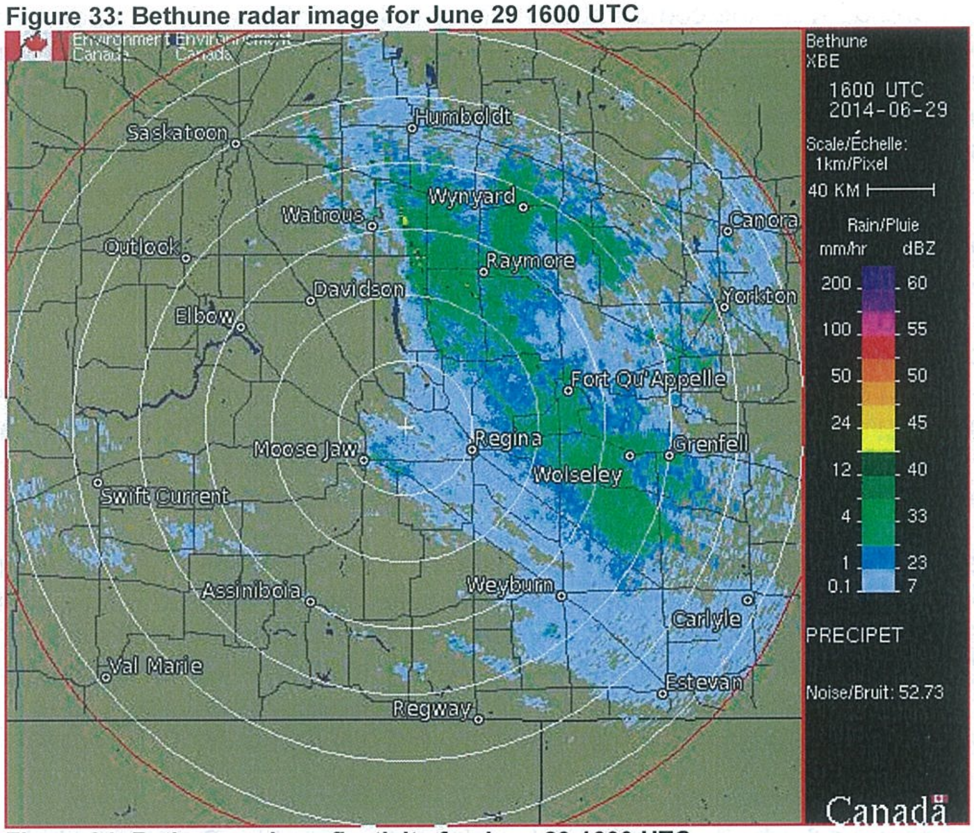


Figure 34: Bethune radar reflectivity for June 29 1600 UTC

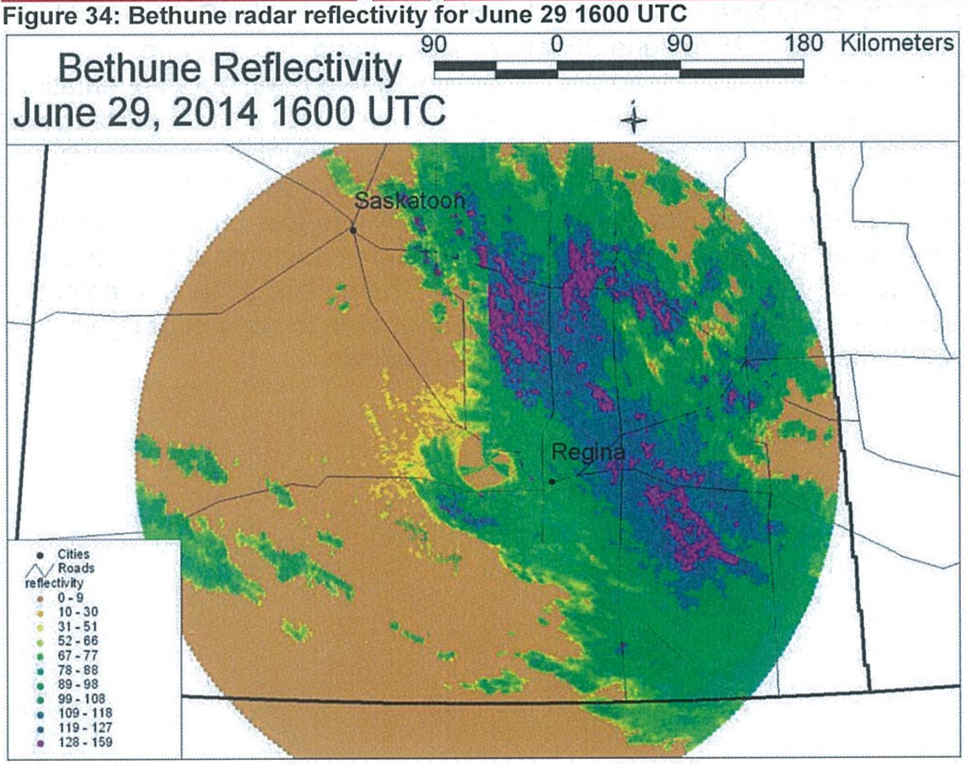


Figure 35: Bethune radar rainfall June 28 to 30, 2014

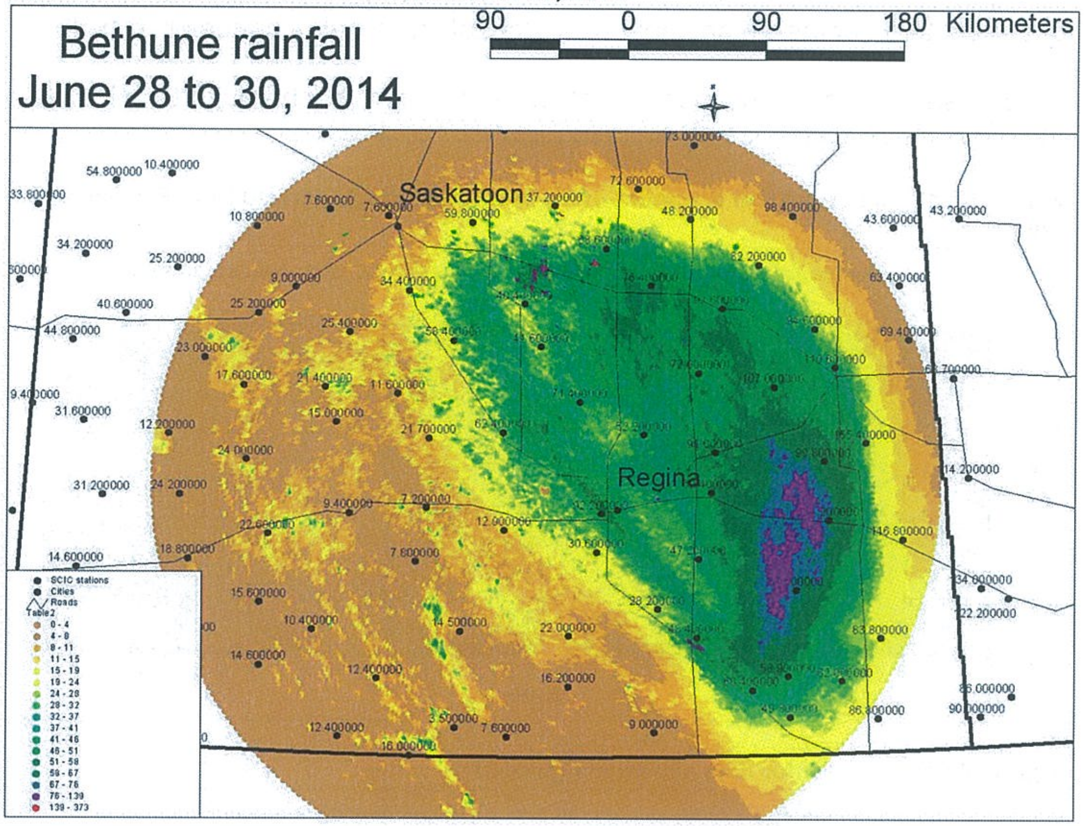


Figure 36: Comparison of rainfall at Broadview and Bethune point 25003

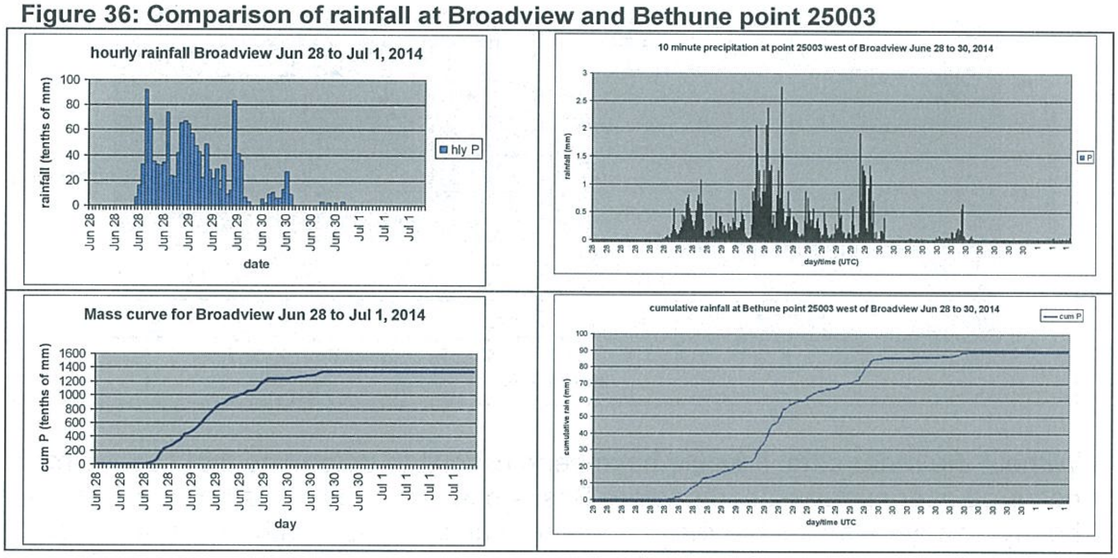


Figure 36 provided a comparison of the hourly rainfall observed at Broadview and the radar derived rainfall 10-minute rainfall rates at Bethune point 25003 just to the west of Broadview. The cumulative rainfall panels displayed a similar shape although the magnitude was less in the radar derived panel on the right.

The general underestimation of the rainfall by the radar had been noted earlier but attenuation of the radar signal was probably a contributing factor as well.

A point was chosen in the high rainfall area north of Gainsborough to calculate the mass curve during the storm (see Figure 37 and 38).

Figure 37: 10-minute rainfall at a point north of Gainsborough derived from Foxwarren radar

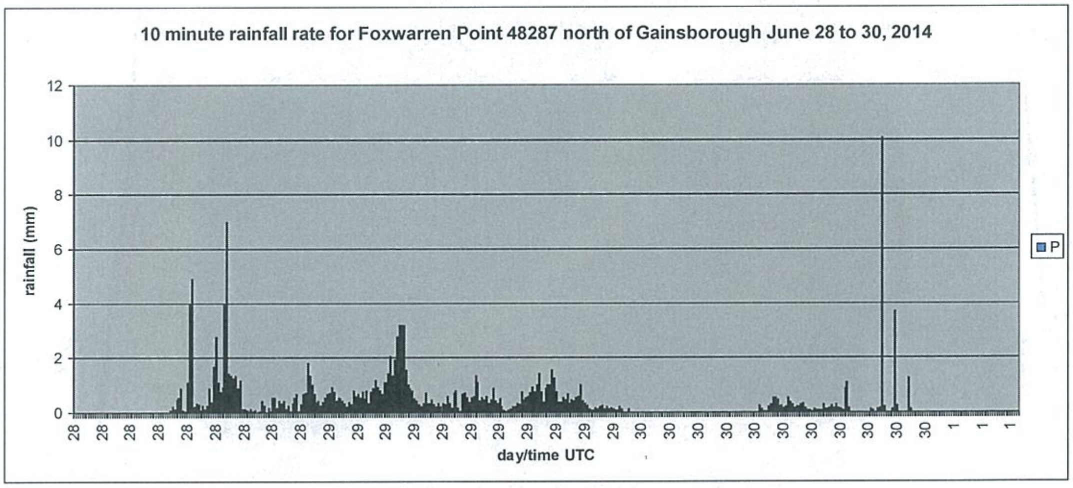
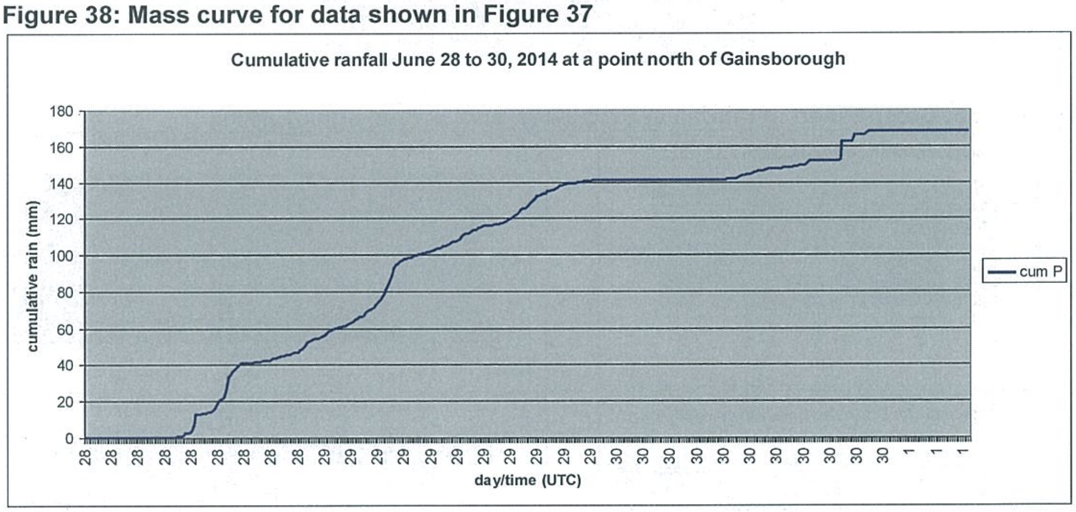


Figure 38: Mass curve for data shown in Figure 37



Without the radar data, it would have been difficult to determine that such rainfall occurred over extreme southeastern Saskatchewan. There was no comparative hourly weather stations but the distribution was consistent with the radar images as reviewed on the Environment Canada web site.

Summary

A synoptic scale storm intensified rapidly over southern Manitoba on June 28, 2014 and reached its mature stage on June 29. The track of the low was such that prolonged precipitation fell over southeast Saskatchewan and southwest Manitoba from late morning on June 28 to noon on June 30. The rainfall analyses all showed the highest precipitation over southeast Saskatchewan but the surface data had the center further west than CaPA which also made use of the radar data.

While the peak rainfall was significant (~155 mm), it was much less than the Parkman or Vanguard storms. The very nature of this synoptic storm was very different from the meso-scale convective clusters that gave rise to the Parkman and Vanguard storms. However, over large areas (greater or equal to 24,000 km^2) the late June 2014 storm ranks among the top ten storms documented in the Storm Rainfall in Canada series. The slow motion of the storm during its rapid intensification led to prolonged rainfall over a large area of the agricultural portions of eastern Saskatchewan and western Manitoba. The station rainfalls were not particularly rare for a single day but a few stations had two or three-day totals with return periods of the order of 100 years or longer.

Antecedent conditions were relatively wet during the period April 1 to June 27 with well above normal precipitation. Including the June storm total precipitation for April through June 2014 was over 200% of normal with the storm alone doubling the total June precipitation at most stations.

Radar data was processed into rainfall rates for the Foxwarren and Bethune radars. The total rainfall from the Foxwarren radar indicated significantly higher rainfall over extreme southeastern Saskatchewan and extreme southwestern Manitoba. Rainfall amounts did not agree well with surface observations and in general the radar values were less than the surface observations. The pattern of heavier precipitation was significantly different in the radar images from Foxwarren than it was possible to infer from surface observations alone.

References

Environment Canada (various): Storm Rainfall in Canada. Downsview, ON.

APPENDIX C: SAMPLE QUESTIONNAIRE

McElhanney

July 30, 2014

McElhanney Consulting Services Ltd. has been hired by the Saskatchewan Water Security Agency to evaluate the magnitude of the flood that occurred in eastern Saskatchewan due to the rain event between June 27 and June 30, 2014 and compile an early estimate of approximate damages to public works such as roads, bridges, culverts etc. caused by the flood. The purpose of this project is to compare approximate damages with the magnitude of the flood event in different regions of the province affected by the flood.

McElhanney staff will be compiling estimates of damages by contacting municipalities directly to gather information that is available at this time. Information collected by McElhanney is not associated with any damage claims that might be made to PDAP or other programs but is solely for the purposes of this report.

If you are able to complete the form and return it by email (gswinnerton@mcelhanney.com) or by fax (306-649-0772) it would be greatly appreciated. If we do not hear from you by email a representative from McElhanney be calling in the next few days to ask for your help in filling in information as best you can. We recognize that not all damages will have been assessed but would appreciate your input as we attempt to describe the magnitude of the damages your municipality has suffered.

If you have any questions concerning this survey please contact me at the number listed below or by email. If you would like to contact Saskatchewan Water Security Agency to confirm McElhanney's involvement you can call Gary Neil at 306 694-3906.

Sincerely,

Graeme Swinnerton, CAPM
Senior Project Manager

300, 402 – 21st Street E
Saskatoon SK
Canada S7K 0C3

Tel 306 649 0740
Fax 306 649 0772
www.mcelhanney.com

Flood Damage Questionnaire

RM Information

RM of ______________________________________

Contact Name/Title: ____________________________

Phone Number: ________________________________

Culverts

of culverts washed out or damaged </= 1500mm (60") dia: _______
# of culverts washed out or damaged > 1500mm (60") dia: _______

General Comments

____

____

____

Bridges

of damaged bridges </= 10m (30 ft) length: _______
# of damaged bridges > 10m (30 ft) length: _______

General Comments

____

____

____

Roads

# of roads washed out: ________ Length: _______

# of roads mechanically breached: ________ Length: _______

Length of roads, neither washed out or breached, damaged by water overflowing road: _________

General Comments

____

____

____

Dams/Reservoirs

Was there damage to any dams or reservoirs due to the flood event? ___ Yes ___ No

If Yes, please describe the damage below.

____

____

____

____

Community Wells

# of community wells contaminated: ________

General Comments

____

____

____

Any other damage to community works, please indicated below:

____

____

____

____

____

____

____

APPENDIX D: QUESTIONNAIRE SUMMARY RESPONSE DATA

Rural Municipality	Culverts		Bridges		Road Repairs Due to Overflow or Washout		Road Repairs Due to Mechanical Breach	Dams / Reservoirs	Community Wells	Sum damages	% of highest	Rating
	</= 1500 mm	> 1500 mm	</= 10m Length	> 10m Length	Number of Roads	Length (m)						
RM of Argyle #1										0	0%	
RM of Mount Pleasant # 2										0	0%	
RM of Storthoaks #31										0	0%	
RM of Reciprocity #32										0	0%	
RM of Antler #61	12		6		6	30	60	1	2	87	62%	🔴
RM of Walpole #92										0	0%	
RM of Wawken #93										0	0%	
RM of Moosomin #121	7	8	0	0	11	110	0	0	0	26	19%	🟡
RM of Martin #122	0	0	4	0	3	5,230	5	0	0	12	9%	🟡
RM of Kingsley #124										0	0%	
RM of Rocanville #151	12	24	1	2	30	3,700	70	1		140	100%	🔴
RM of Spy Hill #152	1	3	1	2	45	3,600	7	0	1	60	43%	🔴
RM of Langenburg #181	1	3	0	0			5	0	0	9	6%	🟢
RM of Fertile Belt #183										0	0%	
RM of Grayson #184										0	0%	
RM of McLeod #185										0	0%	
RM of Abernethy #186										0	0%	
RM of Saltcoats #213	1	2	0	0	4	5,000	3	0	0	10	7%	🟢
RM of Tullymet #216										0	0%	
RM of McKillop #220										0	0%	
RM of Wallace #243										0	0%	
RM of Orkney #244										0	0%	
RM of Garry #245	20	10	1	0	70	9,858	16	0	0	117	84%	🔴
RM of Ituna Bon Accord #246		1			55	5,500		0	0	56	40%	🔴
RM of Last Mountain Valley #250										0	0%	
RM of Big Arm #251	12		8		37	1,360	2	1	0	60	43%	🔴
RM of Good Lake #274										0	0%	
RM of Foam Lake #276	5	4			9	5,380				18	13%	🟡
RM of Wood Creek #281										0	0%	
RM of St. Philips #301										0	0%	
RM of Elfros #307										0	0%	
RM of Morris #312	1	0			75	120,700	0		0	76	54%	🔴
RM of Lakeside #338	0	0	0	0	1	7,000	3			4	3%	🟢
RM of Kelvington #366										0	0%	
RM of Humboldt #370					31	3,100	30	0	0	61	44%	🔴
RM of Porcupine Plain #395	4	0	1	0	6	1,914	0	0	0	11	8%	🟡
TOTAL	**76**	**55**	**22**	**4**	**383**	**172,482**	**201**	**3**	**3**	**747**		

Cities and Towns	Culverts		Bridges		Road Repairs Due to Overflow or Washout		Road Repairs Due to Mechanical Breach	Dams / Reservoirs	Sewage Lagoons or Sewage Treatment Works		Lift Station	Water Intake Works	Water Treatment Works	Commun-ity Wells	Other Damage / Notes	Sum damages	% of highest	Rating
	</= 1500 mm	> 1500 mm	</= 10m Length	> 10m Length	Number of Roads	Length (m)			Damage	Release								
City of Melville																0	0%	
City of Yorkton																0	0%	
Town of Balcarres	1	0	0	0	3	900	4	0	1	1	0	0	0	0		10	100%	
Town of Bredenbury						500	2	0	1	1	2	0	0		2	8	80%	
Town of Carnduff		3			1	250	2		0		2	0	0	0		8	80%	
Town of Churchbridge			0	0	1	100	0	0	0		0	0	0	0	3	4	40%	
Town of Fleming					5	500	0	0	0	1		1	0		2	9	90%	
Town of Foam Lake	0	0			2	30	2		0		0	0	0			4	40%	
Town of Grenfell	1	0			0	0	0	0	0	1		0	0	0	2	4	40%	
Town of Langenburg					5	500			0		0	0	0	0		5	50%	
Town of Lemberg												1		2		3	30%	
Town of Moosomin	0	0	0	0	1	10	0	0	0	0	0	0	0	0	1	2	20%	
Town of Redvers																0	0%	
Town of Regina Beach																0	0%	
Town of Saltcoats	1	0			1	183	2		0	1	0	0	0	1	0	6	60%	
Town of Springside																0	0%	
Town of Watson	0	0	0	0	0	0	0	0	0		0	0	0	0		0	0%	
Town of Wawota																0	0%	
Town of Whitewood	0	0	0	0	0	0	0	0	0	0	0	0	0	0		0	0%	
Town of Wolseley	0	0	0	2	0	0	0	1	0	0	0	0	0	0	1	4	40%	
TOTAL	**3**	**3**	**0**	**2**	**19**	**2973**	**12**	**1**	**2**	**5**	**4**	**2**	**0**	**3**	**11**	67		

Villages and Resorts	Culverts		Bridges		Roads - Overflow or Washout		Roads - Mechanically Breached	Sewage Lagoons or Sewage Treatment Works	Lift Station	Community Wells	Other Damage / Notes	Sum damages	% of highest	Rating
	</= 1500 mm	> 1500 mm	</= 10m Length	> 10m Length	Number of Roads	Length (m)								
Resort Village of Alice Beach												0	0%	
Resort Village of Bird's Point												0	0%	
Resort Village of Etters Beach												0	0%	
Resort Village of Glen Harbor												0	0%	
Resort Village of Leslie Beach												0	0%	
Resort Village of WeeToo Beach	0	0	0	0	0		0			0		0	0%	
Village of Abernethy												0	0%	
Village of Alida	0	0	0	0	1	10	0			0	1	2	10%	🔴
Village of Bangor												0	0%	
Village of Calder								0			1	1	5%	🟡
Village of Carievale	0	0	0	0	0	0	0	0	0	0	1	1	5%	🟡
Village of Dubuc	1	0			1	137	0	0		0	1	3	15%	🔴
Village of Elfros												0	0%	
Village of Gainsborough												0	0%	
Village of Goodeve												0	0%	
Village of Grayson												0	0%	
Village of Hubbard	0	0	0	0	20	2000				0		20	100%	🔴
Village of Liberty												0	0%	
Village of Maryfield	0	0	0	0	1	30	0	1	0	0		2	10%	🔴
Village of Neudorf												0	0%	
Village of Quill Lake									1			1	5%	🟡
Village of Semans	2				1	10	2					5	25%	🔴
Village of Silton												0	0%	
Village of Spy Hill	0	0	0	0	0	0	1	0	0	0		1	5%	🟡
Village of Stockholm												0	0%	
Village of Storthoaks												0	0%	
Village of Tantallon			1				2	1	0	0		4	20%	🔴
TOTAL	**3**	**0**	**1**	**0**	**24**	**2187**	**5**	**2**	**1**	**0**	**4**	40		

Provincial Parks	Culverts		Bridges		Road Repairs Due to Overflow or Washout		Road Repairs Due to Mechanical Breach	Commun-ity Wells	Other Damage / Notes	Sum damages	% of highest	Rating
	</= 1500 mm	> 1500 mm	</= 10m Length	> 10m Length	Number of Roads	Length (m)						
Duck Mountain										0	0%	
Good Spirit						1500	12	2		14	100%	
Crooked Lake						700	6	0	7	13	93%	
Moose Mountain & Cannington Rec site	4	0			2	6				6	43%	
Echo Valley and Katepwa Point	0	0	0	0	0	0	0	0	3	3	21%	
Rowans Ravine and Regina Beach rec			0	0	2	22		0		2	14%	
TOTAL	**4**	**0**	**0**	**0**	**4**	**2228**	**18**	**2**	**10**	38		