SASKATCHEWAN RESEARCH COUNCIL

LIMITED

Land of Extremes – Saskatchewan Style: Characterizations of Drought and Excessive Moisture in the Milk River, Moose Jaw River, Old Wives Lake and Upper Qu'Appelle River Watersheds

Prepared for Saskatchewan Watershed Authority

By
V. Wittrock
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SRC Publication No. 13022-1E12

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ABSTRACT

Saskatchewan is a land of extreme climatic conditions. It is commonplace in this province to have both drought and excessive moisture events, sometimes occurring in the same year, sometimes are multi-year events. Droughts tend to develop slowly but can progress to cover wide areas and multi-year. Excessive moisture events are usually dramatic and can occur very suddenly. The switch from drought to excessive moisture can occur quickly. The drought of 2008-2010/excessive moisture 2010/2011 is a good example of going from severe drought in spring (March/April) of 2010 to extreme excessive moisture conditions two months later (May 2010). Four watersheds are examined for their extreme drought and excessive moisture events of the last 100 year: Milk River, Moose Jaw River, Old Wives Lake and Upper Qu'Appelle River Watersheds. Communities and their economies are usually impacted by these occurrences and adaptation measures have been implemented to offset the negative ones and also augment the positive impacts. These strategies are examined to help determine advances or different possibilities in adaptation possibilities and solutions.

Each watershed had its own extreme excessive moisture and drought years but some years were common in all four watersheds. For example, 1988 ranked within the top two years of extreme drought in all four watersheds with the Palmer Drought Severity Index while 1907 was categorized in the top two for excessive moisture for all four watersheds using the same index.

Recommendations were developed including:

- Improved information about extremes, their patterns and impacts to assist with design and implementation of effective adaptation strategies.
- Examination of the 2010 and 2011 excessive moisture patterns and compare with historic and future projected patterns.
- Water use demand should be related to drought and excessive moisture extremes.
- Expansion of this 100 year examination of drought and excessive moisture to the rest of Saskatchewan's watersheds.
- Undertake trends analysis to determine onset/decrease of extreme drought and excessive moisture events.

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BACKGROUND AND INTRODUCTION

Saskatchewan is a land of climatic extremes. It is commonly either too dry or too wet and the impacts of these events are far reaching affecting most facets of prairie life. In addition, both droughts and excessive moisture events can occur in the province at the same time resulting in adaptation challenges. The hydro-climatic variability in Saskatchewan is a major threat to water security, especially the extreme fluctuations between drought and excessive moisture. Understanding the uniqueness of each extreme event helps to further develop adaptation strategies to cope with and benefit from the next event.

With the highly variable and changing climate, as indicated by the drought to excessive moisture period of 2008-2011, the frequency of severe drought and excessive moisture events is expected to increase. It is estimated, with a 90 to 99% probability of occurrence that, the frequency of extreme precipitation events will likely increase in the future (IPCC WGI 2007). In addition, all Global Climate Models project future increased summer continental interior drying and associated risk of droughts (IPCC 2001). Also, the area affected by drought will likely increase with a 66% probability of occurrence (IPCC WGI, 2007). Recently, Min et al. (2011) demonstrated that the observed increase in heavy precipitation for the 1951-1999 period over the Northern Hemisphere land areas can be attributed to human-induced increases in greenhouse gases in the atmosphere. They also concluded that projected future changes in precipitation extremes may be under-estimated.

Therefore developing pro-active adaptation strategies is a necessity because it will decrease the cost, disruption and necessity of reactive adaptation strategies. Improved information about extremes, their past and future patterns and impacts is required to design and implement effective adaptation strategies.

As part of the Prairies Regional Adaptation Collaborative (PRAC) project, the Saskatchewan Watershed Authority and the Saskatchewan Research Council are working with local watershed groups to further develop the watersheds drought and excessive moisture preparedness plans at the watershed level. The characterization of past drought and excessive moisture events can help understand historic risks associated with extreme events and help to test ways to become better prepared for future extremes with pro-active adaptation strategies. This project also assists the Saskatchewan Watershed Authority's goal of water security by working with communities to identify potential water threats and ensure protection of the province's water resources.

This report includes six sections ranging from explaining the reasoning for using the various datasets to determining the patterns of drought and excessive moisture of the 10 most extreme years. The impacts of the most of recent extreme years are examined and examples of the adaptation strategies implemented are explored followed by a conclusion and recommendation section. Appendices are also included containing the top 10 extreme years of drought and excessive moisture tables and maps of the most extreme year for each of the four watersheds. Presentations for each watershed were prepared and are included in the final appendix.

PURPOSE AND OBJECTIVES

The purpose of this report is to provide information for improving the planning and preparation process for various watersheds located in Saskatchewan in regards to drought and excessive moisture (DEM). By focusing on four specific watersheds, this report will assist watershed stewards with current and future watershed planning. The objectives are:

- Develop databases of drought and excessive moisture indices for four selected watersheds (Milk River, Moose Jaw River, Old Wives Lake and Upper Qu'Appelle River);
- Characterize drought and excessive moisture patterns for each watershed, drawing upon methods developed with the Canada Drought Research Initiative (DRI) network, for example;
- Contrast and compare drought and excessive moisture patterns of the watersheds and of the province;
- Consider the implications for impacts and adaptations;
- Coordinate with other related projects for community vulnerability assessment and drought/excessive moisture preparedness planning;
- Document the methods and results in report, and
- Develop presentation for selected watersheds.

DATA AND METHODS

The best database to use to characterize the extreme drought and excessive moisture patterns for Saskatchewan watersheds was determined by Wittrock et al (2011a) by way of a literature review. They found that various Canadian Agencies such as Environment Canada, Agriculture and Agri-Food Canada, and Saskatchewan Ministry of Agriculture monitor drought and excessive moisture conditions. These agencies track these patterns through very large area analysis and that creates difficulty in planning for extreme drought and excessive moisture events for smaller areas.

Measured climate station data are not uniform in time or space in Saskatchewan thus creating potential gaps in the analysis. A gridded dataset is more beneficial when examining individual watersheds, especially for those watersheds that have only one or possibly no long term climate stations. The Canadian Drought Research Initiative project (Meinert et al. 2010) compared observed station data with three different gridded data sets (ANUSPLIN, CANGRID and the Climate Research Unit Time Series 2.1 (CRU)). They found the ANUSPLIN dataset compared best to observed station data and provided best spatial coverage. The ANUSPLIN dataset is on an approximate 10 km resolution covering the 1901-2005 time period. It consists of historical monthly surface grids of total precipitation and average maximum and minimum temperature generated using thin plate smoothing splines (Hutchison 2004, McKenney et al. 2006). Meinert et al. (2010) then calculated the monthly Palmer Drought Severity Index (PDSI), PDSI Z-value and Standardized Precipitation Index (SPI) for each grid.

Developed by Palmer (1965), the PDSI is a meteorological drought index utilized to evaluate periods of wet and dry conditions. The index is useful for longer-term (seasonal to annual) applications particularly for agriculture and hydrologic one (Bonsal and Regier 2007, Guttman 1998). The calculation of PDSI requires precipitation information from both the current month but also from previous months (Guttman 1998) thus giving a long-term memory of previous moisture conditions. The PDSI Z-value measures short-term drought. It represents the moisture anomaly for the current month without utilizing antecedent conditions (Keyantash and Dracup 2002). The PDSI Z-value has been used to track soil moisture changes (Quiring and Papakryiakou 2003) and thus may be preferable to PDSI for agricultural applications Akinremi et al. (1996). The Standardized Precipitation Index, developed by McKee et al. (1993) is used to monitor moisture supply conditions. The purpose of SPI is to have a single value so that regions can have precipitation levels compared with each other (Meinert et al. 2010). Guttman (1998) found the 12-month SPI had a strong correlation with PDSI values. The classifications for drought and excessive moisture for PDSI and SPI are characterized in Table 1.

Table 1 PDSI and SPI Classifications (Palmer 1965, McKee et al. 1993)

Classification		**PDSI**	**SPI**
Drought	Exceptional	≤ -5	≤ -2.5
	Extreme	> -5.0 to -4.0	> -2.5 to -2.0
	Severe	> -4.0 to -3.0	>-2.0 to -1.5
	Moderate	> -3.0 to -2.0	> -1.5 to -1.0
	Mild	> -2.0 to -1.0	> -1.0 to -0.5
Near Normal		> -1.0 to 1.0	> -0.5 to 0.5
Excessive Moisture	Mild	1.0 to < 2.0	0.5 to < 1.0
	Moderate	2.0 to < 3.0	1.0 to < 1.5
	Severe	3.0 to < 4.0	1.5 to < 2.0
	Extreme	4.0 to < 5.0	2.0 to < 2.5
	Exceptional	≥ 5.0	≥ 2.5

PDSI and SPI indices were utilized by Bonsal et al. (2011) and Wheaton and Nicolichuk (2010). Bonsal et al. (2010) tracked the life cycles of droughts. The indices have also been utilized to understand the physical characteristics and dynamic space-time processes associated with extreme events (Wheaton and Nicolichuk 2010).

The methodology for database development utilized in this report is the same as a previous companion report (for Swift Current Creek, North Saskatchewan River, Assiniboine River and Upper Souris River Watersheds) (Wittrock et al. 2011). The PDSI, PDSI Z-values and SPI values were extracted for each selected watershed. Watershed boundaries were supplied by the Saskatchewan Watershed Authority. The data analyzed include monthly and yearly durations focusing on the September to August period, that is, the agricultural year. The ten most extreme drought and excessive moisture months and years were then selected and ranked for each watershed. The extreme value is a point value within the grids of the entire watershed. Depending on the watershed size, the extreme drought or excessive moisture event could be occurring on one side of the watershed but near normal conditions may be observed on the opposite side.

The data was then imported into SURFER a GIS package (Golden Software 2010). The four watersheds were evaluated based on the above listed indices, time period, spatial pattern and spatial extent to explore the characteristics and patterns of the excessive moisture and drought events.

The databases used for the DRI work by Meinert et al. (2010) cover the 1901-2005 period. In order to obtain more recent information, Agriculture and Agri-Food Canada and Environment Canada information is utilized to extend the analysis to include the drought of 2008-2010 and the excessive moisture years of 2010-2011.

The SPI and PDSI values are compared with spring wheat productivity for each of the four watersheds to examine effects on agriculture. Yield information was obtained from the Saskatchewan Ministry of Agriculture (2011) for the period of 1938-2009. Yield data are not available pre 1938. The yield data were averaged across each of the watersheds on a yearly basis. The 10-year production average was then calculated for the 2000-2009 period. These values indicate the impact of excessive moisture and drought on production. Other factors also influence crop yields including technological improvements, farm management strategies, disease and insect information.

Presentations (Appendix 3) were developed for each of the watershed groups. The presentations were developed to assist the Saskatchewan Watershed Authority and the individual watershed planning groups with determining when the drought and excessive moisture extremes occurred historically, how exceptional they were, what impacts were the result of the extreme and how the watersheds adapted to the drought and excessive moisture events.

Study Area

The study area consists of four Saskatchewan watersheds (Figure 1) including Milk River, Moose Jaw River, Old Wives Lake and the Upper Qu'Appelle River. This complements the work completed by Wittrock et al. (2011) when the Swift Current Creek, North Saskatchewan River, Assiniboine River and Upper Souris River were examined.

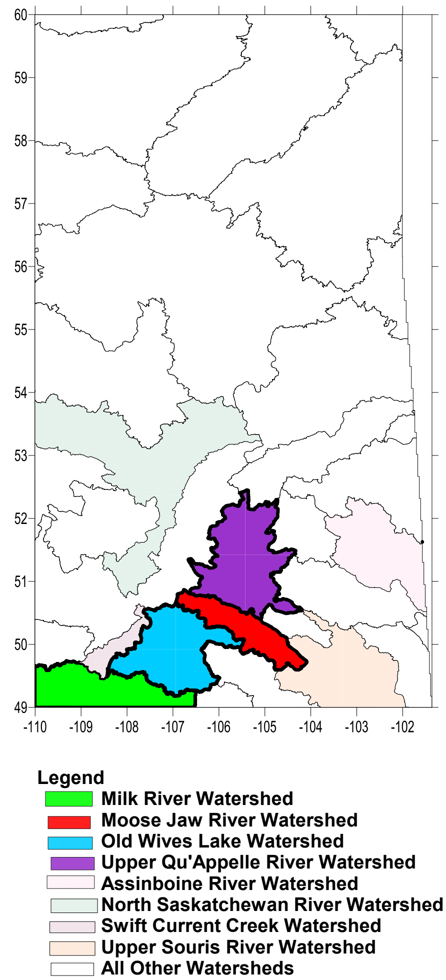

Figure 1 Watershed Map of Saskatchewan Highlighting the Four Study Area Watersheds (modified from SWA 2011)

Three of the four watersheds examined in this report are located in the Palliser Triangle (Milk River, Old Wives Lake and Moose Jaw River). The Palliser Triangle is categorized as the driest part of the Canadian Prairie Provinces (Figure 2). As such, some of the longest, most intense drought events have been reported to be in this region (Lemmen and Dale-Burnett 1999, Sauchyn 2010). The Upper Qu'Appelle watershed is the only one of the four not completely located within the boundaries of the Palliser Triangle. However, both floods and droughts have been experienced in this region, most recently the drought of 2001-2002 (Wheaton et al. 1998), the drought of 2009 and winter 2009-2010 (Wittrock et al. 2010) and the recent excessive moisture years of 2010-2011.

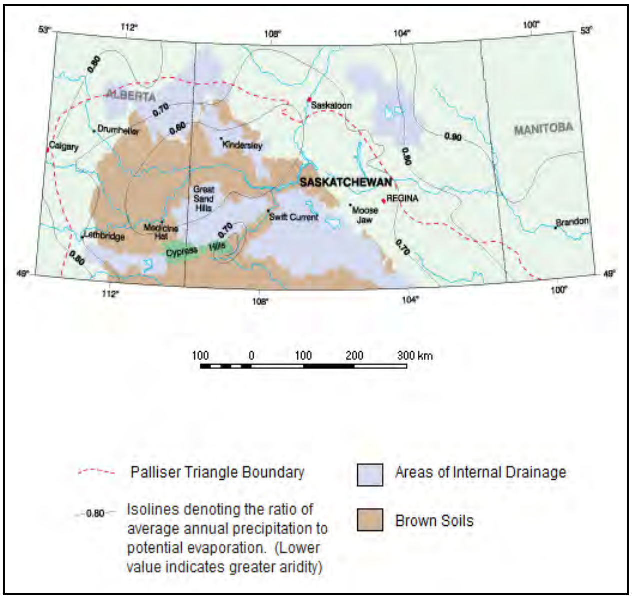

Figure 2 Palliser Triangle in the Canadian Prairies (Lemmen and Dale-Burnett 1999)

All the watersheds have unique topography, climate and river systems. These results in challenges for best management and adaptation to the challenges each watershed endures. To assist with this challenge, watershed groups have been and are planned to be established in the province with one of their objectives being to assist with the protection of the quantity and quality of source waters (Swift Current Creek Watershed Advisory Committee and SWA 2009). Thus far, the Moose Jaw River Watershed Advisory Committee and the Upper Qu'Appelle River and Wascana Creek Watershed advisory committees have completed source water protection plans for their watersheds (Moose Jaw River Watershed Advisory Committee and SWA (2006), Upper Qu'Appelle River and Wascana Creek Watersheds Advisory Committees and SWA (2008)). The Old Wives Watershed Association (OWWA) was formed at the end of 2010 (OWWA ND) and is in the beginning phases of the process. As far as the author can discover, there has not been a formal watershed association formed on the Saskatchewan portion of the Milk River Watershed.

Moose Jaw River Watershed

The Moose Jaw River Watershed is located in the south central portion of Saskatchewan (Figure 3) and is approximately 9,360 km^2 in size (Saskatchewan Watershed Authority and Moose Jaw River Watershed Advisory Committee 2005a). The river is formed by spring runoff and flows into the Qu'Appelle River system. The Moose Jaw River Watershed is made up of the Moose Jaw River (southeast side of watershed) and Thunder Creek (northwest portion of watershed). The Avonlea Reservoir is the only major reservoir in the watershed and is able to retain 6,400 dam^3 of water at full supply level (SWA and Moose Jaw River Watershed Advisory Committee, 2005). The river's outflow is into the Qu'Appelle River System (Saskatchewan Watershed Authority and Moose Jaw River Watershed Advisory Committee 2005a).

The Moose Jaw River watershed is located Palliser Triangle. The city of Moose Jaw, located in approximately the center of the watershed, has an annual average annual temperature of 4°C with January average temperature of -13.7°C and a July average temperature at 19.4°C with the averaging period of 1971-2000. Moose Jaw's extreme maximum temperature of 41.7°C occurred on August 6, 1949 and the extreme minimum temperature of -45.6°C happened on January 23, 1943. Moose Jaw's average annual precipitation amount is 270.1 mm with the majority occurring in the May to September period, approximately 66% of the yearly precipitation (Data: Environment Canada 2011).

A background report was completed for the Moose Jaw River Watershed in 2005 (SWA and Moose Jaw River Watershed Advisory Committees 2005a, 2005b). It examines the watershed characteristics including topography and soils, ecology, land use, demographics, economic activities, industry, water resources and current watershed management strategies.

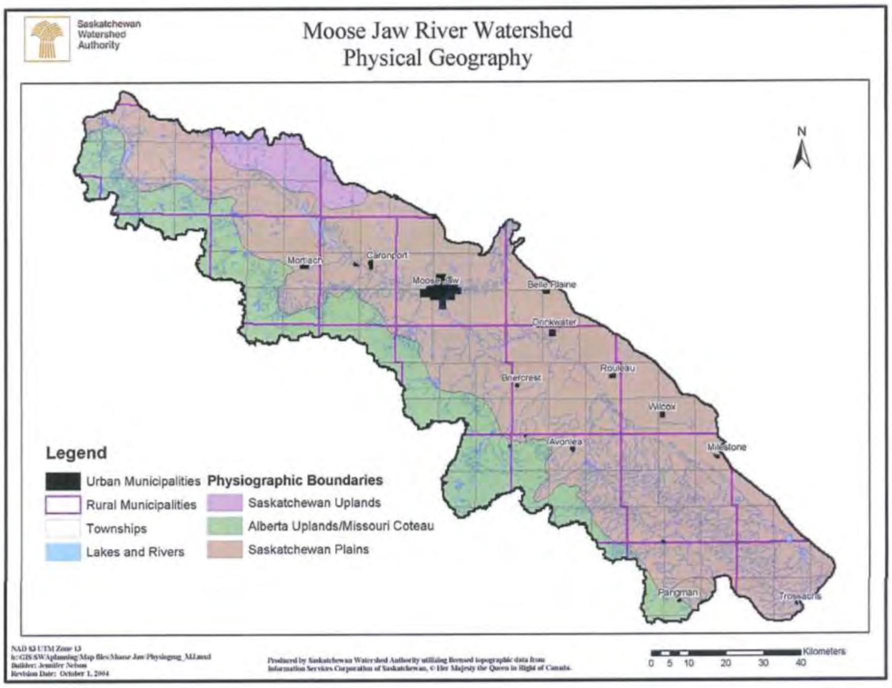

Figure 3 Moose Jaw River Watershed (SWA and Moose Jaw River Watershed Advisory Committee 2005a)

Old Wives Lake Watershed

The Old Wives Lake watershed is also located in the south central portion of Saskatchewan, west of the Moose Jaw River Basin. It is approximately 16,8500 km^2 in size (SWA ND). This watershed is considered to be a "closed basin" which means in average precipitation years, surface water does not leave the watershed. Surface water accumulates in water bodies including Old Wives Lake, Chaplin Lake, Reed Lake, Thompson Lake and Twelve Mile Lake among others. The surface water in the watershed generally flows with spring runoff and high rainfall events.

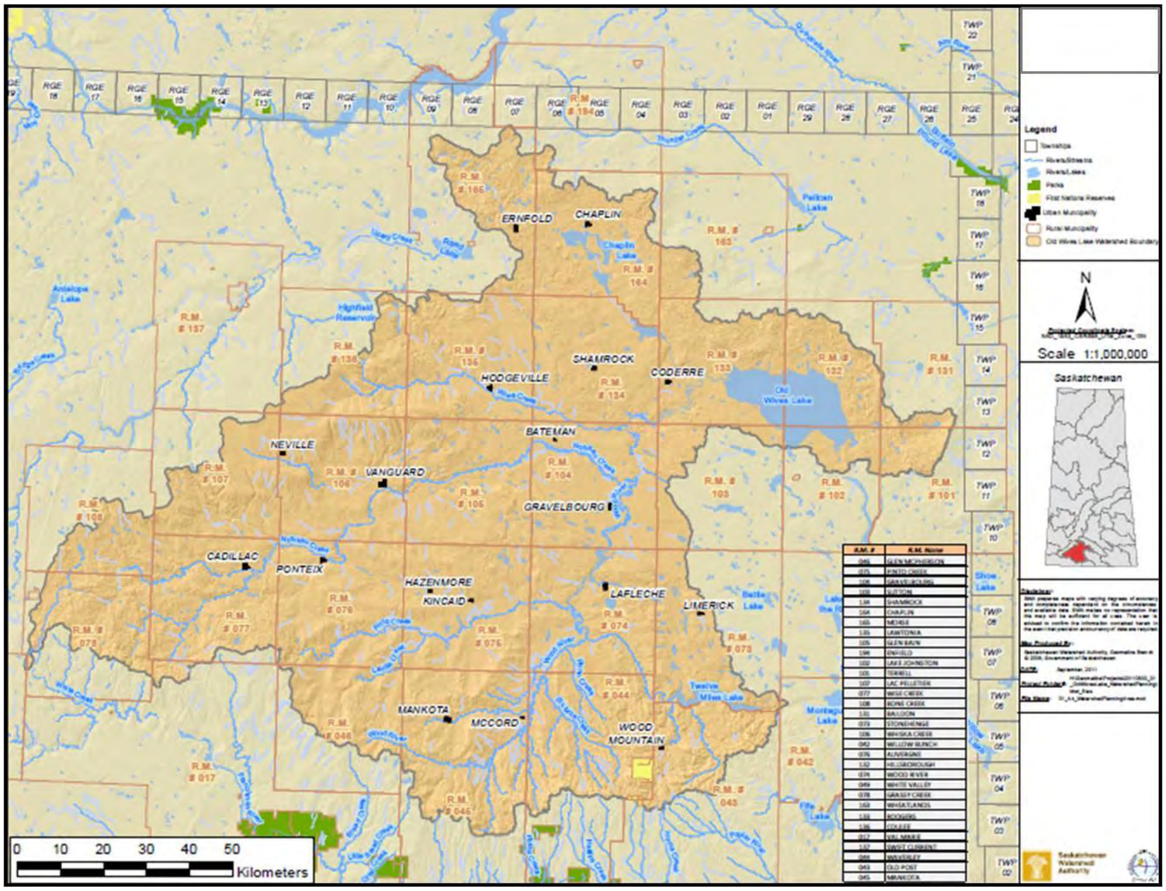

Figure 4 Old Wives Lake Watershed (SWA 2008)

The watershed has two long-term climate stations located at Chaplin and Gravelbourg plus several others located just outside the watershed, including Assiniboia, Shaunavon, Swift Current and Stewart Valley (Table 2). Based on the 1971-2000 averages, Chaplin, in the northeast corner of the watershed, is the coldest with a January average temperature of -13.0°C followed closely by Assiniboia, located just outside the southeast corner of the watershed. The warmest portion of the watershed is in the Gravelbourg area with an average July temperature of 19.0°C. The entire watershed can have a temperature fluctuation throughout the year of 80°C or more. The coldest recorded temperature was observed at Gravelbourg at -48.9°C in February 1936. Gravelbourg tied for the warmest at 42.8°C with Chaplin and Assiniboia but all three extremes were measured in different years (Chaplin June 1990, Gravelbourg July 1937 and Assiniboia July 1938).

The two climate stations located within the watershed have the greatest average annual amount for the 1971-2000 period of precipitation in the form of rain ranging from 264mm in Gravelbourg to 282mm in Chaplin. When the climate stations outside of the watershed are included in the analysis, Stewart Valley, on average, receives the most amount of precipitation (409mm) while Swift Current receives the least (353mm) (Table 2).

A few publications have examined all or portions of the Old Wives Lake Watershed (Thomson, 2010, Wood River Riparian Authority, 2010 and Thomson, 2011). A more comprehensive watershed background report is planned.

Table 2 Climatic conditions for the Old Wives Lake Watershed based on the 1971-2000 averaging period (Data: Environment Canada 2011)

	Temperature (°C)								Precipitation (Average yearly totals)	
Station	January Average Daily Maximum	January Average Daily Minimum	January Daily Average	July Average Daily Maximum	July Average Daily Minimum	July Daily Average	Extreme Maximum (for period of record)	Extreme Minimum (for period of record)	Rainfall (mm)	Snowfall (cm)
Chaplin	-8.0	-17.8	-13.0	25.6	11.9	18.8	42.8 (June 1900)	-47.2 (Dec 1916)	281.9	90.9
Gravelbourg	-7.4	-17.5	-12.5	26.7	11.4	19.0	42.8 (July 1937)	-48.9 (Feb 1936)	263.5	118.3
Assiniboia	-7.4	-18.3	-12.9	26.0	11.1	18.6	42.8 (July 1938)	-43.9 (Jan 1916)	291.6	104.1
Shaunavon 2	-5.8	-16.2	-11.0	25.8	10.5	18.2	39.0 (June 1988)	-42.2 (Dec 1977)	263.4	121.1
Swift Current CDA	-7.6	-17.0	-12.4	24.8	11.3	18.1	38.9 (Aug 1961)	-42.0 (Dec 1983)	260.8	92.2
Stewart Valley	-7.0	-17.1	-12.1	25.4	11.6	18.5	39.5 (June 1988)	-41.0 (Feb 1996)	318.5	90.6

Upper Qu'Appelle River Watershed

The Upper Qu'Appelle River Watershed is located in the south central portion of Saskatchewan (Figure 5). It covers approximately 23,440km^2 (Upper Qu'Appelle River Watershed and Saskatchewan Watershed Authority 2007). The river flows southeastward and ultimately joins the Assiniboine River. The watershed contains several large lakes including Lake Mountain Lake, Buffalo Pound Lake and Eyebrow Lake (Upper Qu'Appelle River Watershed and Saskatchewan Watershed Authority 2007).

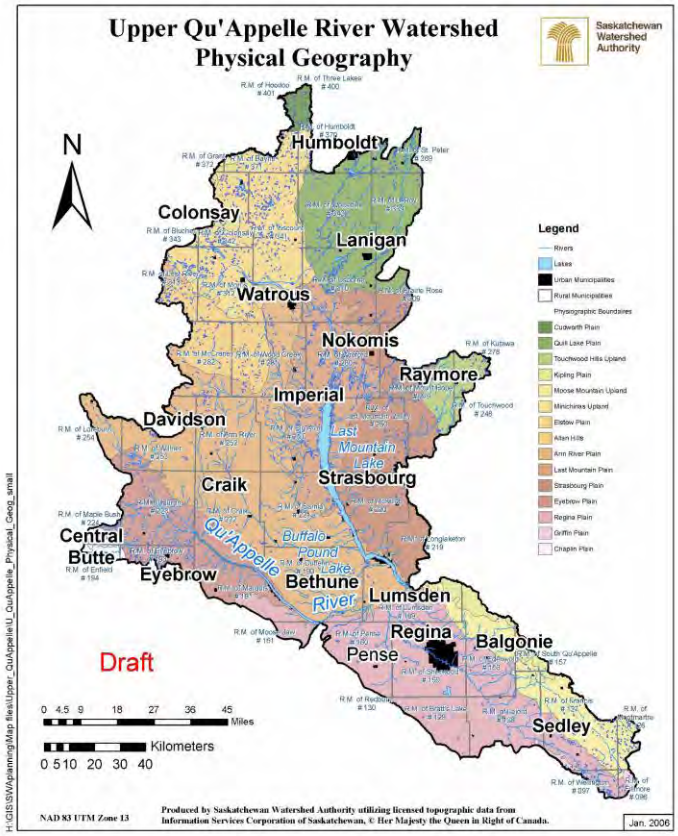

Figure 5 Upper Qu'Appelle River Watershed (Upper Qu'Appelle River Watershed and Saskatchewan Watershed Authority 2007)

Seven climate stations are scattered throughout the watershed. Based on the 1971-2000 averages, January average daily maximum temperatures range from -9.5°C on the southern side (Lumsden) of the watershed to -12.4°C on the northern edge (Humboldt). The January average daily minimum temperatures are all in the -20 to -25°C range. The July average daily maximum temperature variation is similar to January's with Lumsden being the warmest on average (26.4°C) and Humboldt having the lowest at 23.9°C. Davidson has the coolest July average daily minimum temperature at 10.7°C. Four of the seven climate stations have reported daily extreme maximum temperatures at or more than 40.0°C and all have extreme daily minimum temperatures below -40.0°C. Lumsden has recorded both the extreme high temperature of 43.3°C in Lumsden in July 1941, and the extreme low temperature of -47.8°C in January 1950 (Table 3).

The watershed receives on average for all seven climate stations about 380 mm of total annual average precipitation (Table 3). Approximately 80% of the moisture comes in the form of rain. Colonsay generally receives the least amount of precipitation (344.4 mm), while Watrous gets about 90 mm more on an average annual basis (434.5 mm).

Table 3 Climatic conditions for the Upper Qu'Appelle River Watershed based on the 1971-2000 averaging period (Environment Canada 2011)

	Temperature (°C)								Precipitation (Average yearly totals)	
Station	January Average Daily Maximum	January Average Daily Minimum	January Daily Average	July Average Daily Maximum	July Average Daily Minimum	July Daily Average	Extreme Maximum	Extreme Minimum	Rainfall (mm)	Snowfall (cm)
Lumsden	-9.5	-21.0	-15.2	26.4	12.0	19.2	43.3 (July 1941)	-47.8 (Jan 1950)	293.4	79.8
Raymore	-11.8	-21.9	-16.9	24.7	11.6	18.2	38 (July 1988)	-45 (Jan 1972)	302.9	77.4
Nokomis	-11.8	-22.5	-17.2	25.0	11.2	18.1	41.7 (July 1941)	-46.7 (Jan 1943)	303.2	55.8
Humboldt	-12.4	-22.5	-17.4	23.9	10.9	17.4	39.0 (June 1988)	-43.0 (Dec 1992)	313.8	73.7
Colonsay	-10.6	-20.3	-15.4	24.7	12.4	18.6	40.0 (June 1988)	-47.0 (Dec 1992)	280.2	64.2
Watrous	-11.7	-21.8	-16.8	24.8	11.4	18.1	39.5 (June 1988)	-43.0 (Jan 1997)	348.3	86.2
Davidson	-11.5	22.1	-16.8	25.3	10.7	18.0	42.2 (June 1941)	-46.8 (Jan 1943)	278.0	87.6

The Upper Qu'Appelle River Watershed committee has completed a Source Water Protection Plan and Background Report. These reports examine various watershed characteristics including soils, vegetation and land use as well as various economic factors including agriculture and tourism (Upper Qu'Appelle River and Wascana Creek Watersheds Advisory Committees and Saskatchewan Watershed Authority 2007 and 2008).

Milk River Watershed

The Milk River Watershed encompasses a total drainage area of 61,640 km^2 in two provinces (Alberta and Saskatchewan) and Montana (Milk River Watershed Council Canada 2011). Saskatchewan's proportion includes tributaries of the Milk River including Lodge Creek, Battle Creek and Frenchman River (Figure 6). These three tributaries originate in spring snow melt and extreme summer rainfall events. Lodge Creek, Battle Creek and the Frenchman River have a gross drainage area of almost 30,000 km^2 (Wingert p.comm. 2012). Several reservoirs (e.g., Eastend Reservoir, Nashlyn Dam, Middle Creek Reservoir) have been constructed in the watershed and are utilized for a variety of purposes including having water available for irrigation and ensuring Canada meets its requirement to the US under the Boundary Waters Agreement (Wingert p.comm. 2012).

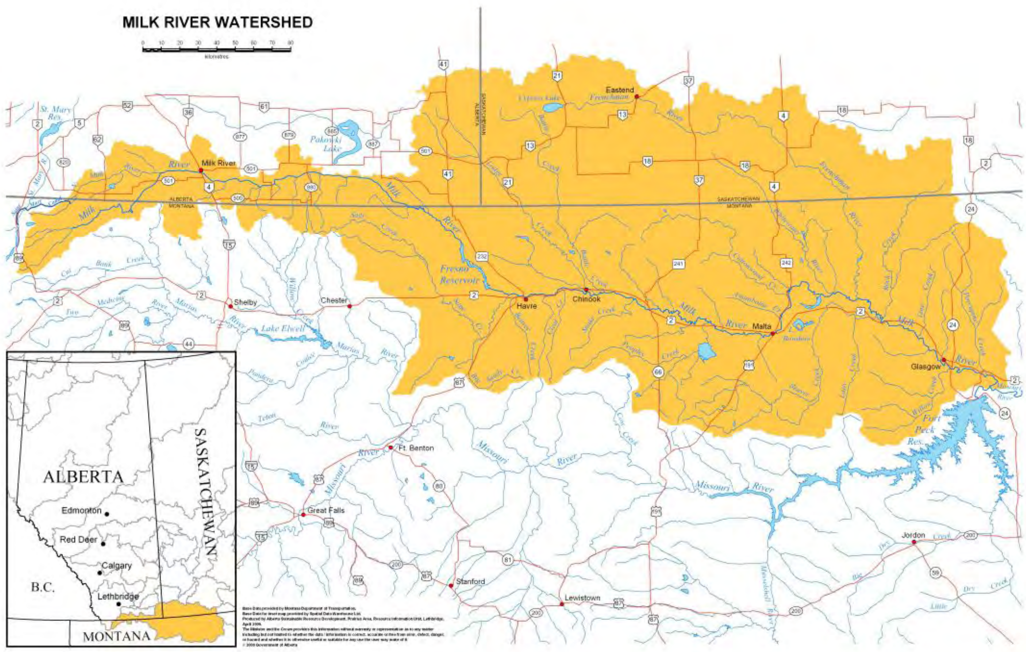

Figure 6 Milk River Watershed (Milk River Watershed Council 2011)

The Saskatchewan portion of the Milk River Watershed has two climate stations within its boundaries (Frontier and Cypress Hills) with Shaunavon and Mankota located just outside the watershed (Table 4). The average January temperatures range from -9.5°C at Cypress Hills to -13.6°C at Mankota. The average daily maximum January temperature is -5.8°C at both Frontier and Shaunavon. While the average daily temperature ranges from -15.6°C at Cypress Hills to -19.8°C at Mankota. The average daily July temperatures are in the 10°C range for minimum average temperatures to the mid 20°C for average daily maximum temperatures. All of the stations have had temperatures below -40°C with the coldest temperature of -43.3°C recorded at Mankota in January 1969. The warmest was also recorded in Mankota at 41.0°C in June 1988. Both Shaunavon and Cypress Hills also recorded their most extreme high temperatures in 1988. Shaunavon's was also in June but Cypress Hills extreme maximum occurred in May of 1988.

On an average annual basis, Frontier, Mankota and Shaunavon receive rainfall amounts in the 250 to 275mm range, while Cypress Hills records about 100 mm more. This indicates the influence of elevation on precipitation amounts. This comparison is similar when snowfall levels are compared with Frontier and Mankota in the 80 to 90 cm levels, while Shaunavon on average receives 121 cm and Cypress Hills records 100 cm more (Table 4).

Table 4 Climatic conditions for Milk River Watershed based on the 1971-2000 averaging period (Environment Canada 2011)

	Temperature (°C)								Precipitation (Average yearly totals)	
Station	January Average Daily Maximum	January Average Daily Minimum	January Daily Average	July Average Daily Maximum	July Average Daily Minimum	July Daily Average	Extreme Maximum	Extreme Minimum	Rainfall (mm)	Snowfall (cm)
Frontier	-5.8	-17.2	-11.5	26.8	10.7	18.8	38.5 (Aug 1984)	-43.0 (Feb 1996)	271.5	82.6
Mankota	-7.3	-19.8	-13.6	26.8	10.1	18.5	41.0 (June 1988)	-43.3 (Jan 1969)	253.3	87.1
Shaunavon 2	-5.8	-16.2	-11.0	25.8	10.5	18.2	39.0 (June 1988)	-42.2 (Dec 1977)	263.4	121.1
Cypress Hills	-3.4	-15.6	-9.5	22.5	8.2	15.4	40.5 (May 1988)	-41.5 (Dec 1983)	348.4	258.4

DROUGHT AND EXCESSIVE MOISTURE PATTERNS

While all four watersheds are south of the 53rd parallel, all have different extreme excessive moisture and drought years and different spatial patterns associated with the extreme years. The ten most extreme drought and excessive moisture years for each watershed are presented in Appendix 1. The spatial patterns of the most extreme drought and excessive moisture years are located in Appendix 2. This section is separated into two time periods. The first examines the four individual watersheds for the ten most extreme PDSI and SPI drought and excessive moisture years for the 1901 to 2005 period using the ANUSPLIN data set. The last section examines the most recent drought and excessive moisture years for 2009-2011 using PDSI and SPI information supplied by Agriculture and Agri-Food Canada (2011). It is recommended that the whole period of record (1901-2011) be classified to determine the driest to wettest trends but this is beyond the scope of the current project.

Moose Jaw River Watershed

PDSI

Four of the most severe drought PDSI values occurred pre-1940 (Appendix 1, Table 1.1). These occurrences were in the latter half of the most extreme ten years. The next major drought events occurred in 1958, 1959 and 1961. If crop yields are also included in the analysis, the 1961 drought, ranked 5th in extreme droughts with a PDSI value of -6.0, was the worst drought for the region and had an average 63% decline in wheat yields. Three extreme drought years occurred in the 1980s with 1988 being the most severe drought year with a value of -6.7. Spatial variability across the watershed was minimal (Appendix 2, Figure 2.1) with most of the watershed being in the PDSI range of -7.0 to -6.0. This broad drought pattern indicates the wide coverage of the drought beyond the watershed. The northwestern corner of the watershed was a little less extreme with a PDSI value of -6.0 to -5.0. The drop in wheat yields for 1988 was about 54% decline from the 2000-2009 ten year average wheat yield of 24 bushels/acre. The year with the lowest crop production was in 1961 with a decrease in crop production of more than 60%.

The PDSI 10 most extreme excessive moisture years for the agricultural year (September to August) shows that three of these years occurred pre-1910 (Appendix 1, Table 1.1) with the most extreme years in 1907 (PDSI of 8.2) and 1909 (PDSI of 7.0). There is greater spatial variability with excessive moisture conditions (Appendix 2, Figure 2.1). The northwestern portion (8.0 to 9.0 PDSI) of the watershed in the Thunder Creek portion of the watershed was much moister than the southeastern portion (3.0 to 4.0 PDSI). The 1950s were also wet years with 1951, 1954 and 1955 having PDSI values in the 5.8 to 6.8 range. The wheat yields were all lower than the 2000-2009 averages, although 1955 was very close to average. 1954 had a drop of wheat yield of more than 75% indicating that the excess moisture levels had a negative influence on agricultural production (Appendix 1, Table 1.1). Negative effects of wet years on yields also occur indirectly through diseases, for example. Additional indirect effects of dry years include effects of pests such as grasshoppers, for example.

PDSI Z-Value

The PDSI Z-values indicate how quickly and how much an area switches from being in a drought situation to excessive moisture and vice versa. The early 21st century is a good example of this with 2001 calculated as being the third most extreme drought with a PDSI value of -4.7. An extreme switch occurred in 2002 with a PDSI Z-value of 10.0 and then another dramatic switch in 2003 (PDSI -4.4) with return to drought conditions. The impact on wheat yields in all three years was below normal yields with 2001 and 2003 report 12% below normal yields and 2002 almost 8% below normal wheat yields for the Moose Jaw Watershed (Appendix 1, Table 1.2). The most extreme year of going towards drought conditions was calculated to be 1961 with a PDSI Z-value of -5.7 and a 63% drop in wheat yields compared to the 2000-2009 ten year average of 24 bushels/acre. No spatial variability appears to exist in this extreme year with the entire watershed indicating values in the -5.0 to -6.0 PDSI Z-value range (Appendix 2, Figure 2.2).

The most extreme PDSI Z-value excessive moisture year of 2002 (Appendix 1, Table 1.2) shows considerable variability across the Moose Jaw River watershed ranging from 2.0 to 3.0 in the southeast side (classified as moderate (Table 1)) to a high of 9 to 10 in the central northwest corner (Appendix 2, Figure 1.2). This designation is well above the 5.0 level that is generally the highest level for PDSI and is classified as "exceptional" (Table 1).

SPI One-month Extremes

The one-month Standardized Precipitation Index (SPI) gives a snapshot of an extreme drought or excess moisture event for a much shorter period. The extreme one month SPI value addresses the question: What month was the most extreme SPI for the 1901 to 2005 period? This analysis provides information regarding the seasonality of extreme events and is significant in terms of impacts and preparing for or adapting to future impacts.

The Moose Jaw River Watershed's most extreme excessive moisture month occurred in October of 1998 with a SPI value of 3.2 (Appendix 1, Table 1.3). This extreme month did not have any influence on wheat yields. The spatial variability that month shows the watershed ranged from 2.0 in the southeast and northwest portions to the extreme high of greater than 3.0 in the north central portion (Appendix 2, Figure 2.3). The driest month in the watershed was in August of 1961 with a SPI value of -3.4 (Appendix 1, Table 1.3). This year was an extreme drought year as indicated earlier in the PDSI and PDSI Z-value (Appendix 1, Table 1.1 and 1.2) with August 1961 having the least amount of moisture. The crop yield for that year reflected this low value with a 63% decrease in wheat yield as compared to the 24 bushels/acre 2000-2009 averaging period. Little spatial variability for SPI 01 1961 is indicated in Appendix 2, Figure 2.3. The southern half of the watershed is somewhat less extreme than the northern portion.

On a seasonal examination of monthly extremes, the one-month drought episodes occur most often during the spring months (March, April, May) followed by winter (December, January, February). The summer period (June, July, August) had two years (1961 and 2001) reporting extreme drought months in august with only one fall period (September, October, November) indicating extreme drought. Excessive moisture one-month extremes occur most often during the summer period followed by winter and spring (Appendix 1, Table 1.3). The timing of the one month SPI values has implications on for spring runoff, and ease of harvest, for example. A wet fall can cause a challenge for harvesting a crop while a dry fall usually results in easier and better quality harvest.

SPI 12-month Extremes

The SPI 12-month top ten extreme drought years range from values of -1.7 (1959 and 1945), categorized as a severe drought to -3.2 (1929). Unlike PDSI, only two of the 10 years occurred pre-1940 (1929 and 1937). All of the SPI 12-month drought analysis indicates considerable crop loss ranging from almost 25% below average in 1984 to almost 66% below average in 1949 (Appendix 1, Table 1.4) when compared with the 2000-2009 average of 24 bushels/acre. The spatial variability for the 12-month SPI for moisture deficit conditions in 1929 show that the southeast and the extreme northeast tip had values ranging from -2.0 to -2.5 categorized as extreme with the rest of the watershed in the exceptional range (-2.5 to -3.5) (Appendix 2, Figure 2.4).

The excessive moisture top ten extreme SPI 12-month years occurred four decades in the 100 years including the 1901-1910 period, the 1950s, the 1970s and the 1990s with the 1950s and 1990s both having three years in the top ten (Appendix 1, Table 1.4). The SPI 12-month values ranged from 1.7 (1951, 1976, 1954) categorized as severe to 2.4 or extreme (1907). The crop yield ranged from being very good with 1976 having 32% above average to extremely low as in 1954 with 78% below average compared to the 24 bushels/acre for the 2000-2009 averaging period. The spatial variability of 1907 (Appendix 2, Figure 2.4) shows that the southeast part of the Moose Jaw River watershed had near normal condition with the northwest being the moistest with values ranging from 2.0 to 2.5.

Old Wives Lake Watershed

PDSI

The Old Wives Lake watershed is located in what is considered to be one of the driest regions of the Canadian Prairies. Similar to Moose Jaw River watershed, four of the driest years occurred pre-1940. Three of the driest years were in the 1980s with 1988 being classified with the most extreme PDSI value of -6.4, followed very closely by 1937 which also had an extreme PDSI value of -6.4 (Appendix 1, Table 1.5). The PDSI values ranged from -5.1 in 1959 to -6.4 in 1988. Six of the ten most extreme years had PDSI values greater than -5.5. The spatial variability of 1988 shows the northeastern section of the watershed the most extreme, while the southwest was slightly less intense with values ranging from -4.0 to -5.0 but still classified as extreme drought conditions (Appendix 2, Figure 2.5). Crop yields are usually extremely low with values of less than 50% below average when compared to the 25 bushels/acre in the 2000-2009 averaging period. The only year with near normal wheat yields was 1981 (Appendix 1, Table 1.5).

PDSI excessive moisture years for the Old Wives Lake watershed indicate the 1950s tended to be a relatively moist decade with 1951, 1954 and 1955 all having exceptional PDSI values. However, it was calculated that 1907 and 1909 had the most extreme PDSI values with 1907 having a value of 8.5 (Appendix 1, Table 1.5). The spatial variability of 1907 is quite dramatic with the western portion of the watershed rating in the 3.0 to 4.0 or severe while the northeastern portion in the 8.0 to 9.0 level (Appendix 2, Figure 2.5). Crop yields in excessive moisture PDSI years are highly variable. The lowest was in 1954 with wheat yields being reported more than 50% below average while yields in 2004 were almost 30% above average when compared with the 2000-2009 averaging period of 25 bushels/acre (Appendix 1, Table 1.5).

PDSI Z-Value

The PDSI Z-values of Old Wives Lake watershed continued the display that was indicated in the Moose Jaw River watershed with extreme years fluctuated from drought to moist (2001 to 2004). The variability is quite dramatic with 2001 having PDSI z-value of -4.7, switching in 2002 to 8.8, back down to drought in 2003 with a value of -4.0 and back to excessive moisture in 2004 with a value of 5.9 (Appendix 1, Table 1.6). This switching between drought and excessive moisture also occurs in 1967 (-4.0 drought), 1968 (5.8 excessive moisture) and 1970 (-3.6 drought).

The most extreme PDSI Z-value drought year was 1961 with a value of -5.4. The wheat yields in 1961 are the lowest for the top 10 drought PDSI Z-value years at nearly 80% below the 2000-2009 average (Appendix 1, Table 1.6). There is only minor spatial variability for 1961 PDSI Z-value with the north and northeast portion of the watershed reporting the lowest (exceptional) values with the rest of the watershed in the extreme range of between -4.0 and -5.0 (Appendix 2, Figure 2.6).

A PDSI Z-value of 9.5 was calculated for the most excessive moisture year of 1993. The crop yields in this year were report to be nearly 20% above normal (Appendix 1, Table 1.6). The spatial variability of 1993 PDSI Z-value is relatively high with five categories but all classified in the exceptional range because all values are greater than 5 (Table 1). The southern edge was the "lowest" with a PDSI Z-value in the 5 to 6 range with the northwest region having the highest PDSI Z-value in the 9.0 to 10.0 range (Appendix 2, Figure 2.6).

SPI One-month Extremes

The SPI one-month top 10 extremes for drought show that all but two occurred since 1960. The most extreme SPI one month occurred in June 1974 with a SPI01 value of -3.5 with a drop in wheat yield of more than 25% when compared with the 2000-2009 averaging period (Appendix 1, Table 1.7). The spatial variation for June 1974 (Appendix 2, Figure 2.7) shows that the mid-eastern side of the watershed was the driest or severe drought with the western edge classified as being in a "mild" drought event (Table 1).

On a seasonal basis, summer had the greatest number of SPI one-month drought occurrences followed equally by spring and winter. No fall SPI one month drought occurrences in the top ten extremes were in the Old Wives Lake watershed for the 1901-2005 period. Most of the drought years had below normal yields except 2005 when the drought month was in February and a yield of 13% above normal was reported and in March 1978 with an above average whet yield of almost 12% (Appendix 1, Table 1.7).

The top 10 SPI one-month excessive moisture extremes show that six of the ten have occurred since 1970 with the most extreme SPI one-month excessive moisture happening in July 1993 with a SPI01 value of 3.4 with wheat yields were almost 20% above normal (Appendix 1, Table 1.7). The spatial variability indicates that most of the watershed is in the severe to extreme categories with the southeastern side of the Old Wives Lake watershed in the exceptional category (Appendix 2, Figure 2.7).

The seasonality of excessive moisture for SPI one-month has spring having the most occurrences (4) followed by fall (3), summer (2) and one occurrence in winter. The years of 1978 and 1986 both showed excessive moisture extremes in September which could have resulted in a challenging harvest period in terms of the crop being dry enough to get it off the field in high quality. However, both these years reported above normal wheat yields when compared against the 2000-2009 averaging period with 25 bushels/acre (Appendix 1, Table 1.7).

SPI 12-month Extremes

The 10 most extreme 12-month SPI values for the Old Wives Lake Watershed for drought range from -1.8 in 1967 to -3.2 in 1929. Five of the top 10 drought years calculated for SPI 12-month were also in the top 10 drought years calculated for PDSI including 1929, 1988, 1961, 1937 and 1984 (Table 1.8 and 1.5). All of the SPI 12-month drought years reported below normal wheat yields ranging from 9.5% below normal in 1971 to an extreme of 87.8% below normal in 1949 (Appendix 1, Table 1.8). The spatial pattern for the SPI 12-month shows that the eastern side of the watershed was in the exceptional range (lower than -2.5) while the western side is classified as a severe drought (-1.5 to -2.0) (Appendix 2, Figure 2.8).

The SPI 12-month, ten most extreme years for excessive moisture range from 1.6 in 1951 to 2.5 in 1907 (Appendix 1, Table 1.8). The wheat yields were highly variable with excessive moisture. For example, in 2004 with a SPI 12-month value of 2.1, wheat yields were 28% above average but in 1954 with a SPI 12-month value of 1.7, the wheat yields were 51.6% below average (Appendix 1, Table 1.8). Eight of the top 10 excessive moisture years are the same for both SPI

12-month (Appendix 1, Table 1.8) and PDSI (Appendix 1, Table 1.5). Both indicate 1907 as the most extreme for excessive moisture conditions with a value of 2.5 in SPI 12-month. The spatial patterns are similar as well with the northeastern side of the Old Wives Lake watershed calculated as extreme excessive moisture values in the 2 to 2.5 range with the western side in the mild to moderate excessive moisture category (Appendix 2, Figure 2.8).

Upper Qu'Appelle River Watershed

PDSI

The Upper Qu'Appelle River Watershed is outside the boundaries of the Palliser Triangle. However, it also has a prairie continental climate and as such is subject to drought and excessive moisture events.

The PDSI drought values indicate two main groupings for drought events. The first is pre-1940 when five extreme drought events occurred. The second was in the late 1950s and 1961. The most extreme drought year was 1961 with a PDSI value of -7.0. The wheat yield losses that year were in excess of 70% (Appendix 1, Table 1.9). All of the PDSI drought years, where information was available, indicate below average wheat yields. The spatial variability for PDSI 1961 shows the eastern and northern eastern edge of the Upper Qu'Appelle River watershed had the lowest PDSI values ranging, or worst droughts from -6.0 to -7.0. The south and southwestern edge had PDSI values in the extreme drought range (-4.0 to -5.0) (Appendix 2, Figure 2.9).

All of the top ten years in the PDSI excessive moisture for the Upper Qu'Appelle River watershed are in the exceptional excessive moisture category. The early 1950s dominated the 10 most extreme PDSI excessive moisture years with four years in this ranking (1951, 1953, 1954 and 1955). All four of these years reported below average crop yields compared with the 2000-2009 averaging period. The most extreme PDSI excessive moisture value for all four watersheds was found to be in the Upper Qu'Appelle River Watershed with a value of 9.9 in 1954. This year reported a crop loss of more than 75% of normal yields (Appendix 1, Table 1.9). The spatial variability of the years shows the entire watershed was in exceptional excessive moisture conditions but the most extreme side was the east central region with PDSI values ranging from 9.0 to 10.0 (Appendix 2, Figure 2.9).

PDSI Z-Value

Like the other watersheds, PDSI Z-value in the Upper Qu'Appelle River watershed shows that conditions can switch from drought to excessive moisture in a very short time frame. In this watershed it shows up in the 1960s with 1966 in excess moisture, 1967 classified as drought, and 1968 classified as excessive moisture. The switch occurs in 1970s with 1972 in drought and 1974 classified as excessive moisture. More recently was the first part of the 21st Century with 2001 classified with the 3rd lowest PDSI Z-value, 2002 with the highest Z-value, 2003 and 2005 (Appendix 1, Table 1.10).

The lowest PDSI Z-value was calculated for 1961 with a value of -5.9 (Appendix 1, Table 1.10). The entire watershed was in moisture deficit conditions at the same level. No spatial variability appears (Appendix 2, Figure 2.10). The below average wheat yield calculated at more than 70% below average also indicates the moisture deficit conditions were wide spread (Appendix 1, Table 1.10). The PDSI Z-value in 2002 was 13.1. Unlike the moisture deficit conditions, the spatial variability for PDSI Z-value was extensive. The extreme value is located in the south centre of the Upper Qu'Appelle River watershed and decrease rapidly to the edges. The northern edge of the watershed had excessive moisture conditions rated as extreme (4.0 to 5.0 range), much lower than the exceptional value (13.0 to 14.0) (Appendix 2, Figure 2.10).

SPI One-month Extremes

As explained earlier, the one-month SPI values give a snapshot of extreme events over a short period. It is also important to consider the timing of that one month SPI value. For example, SPI-01 most extreme drought month was calculated to have occurred in December 1952 with a value of -3.9. Another December with an extremely low SPI-01 value was calculated to have occurred in December 1954, the same year that had the highest PDSI excessive moisture value (Appendix 1, Table 1.11 and Table 1.9). This illustrates that even though an entire year may be considered a moist or dry year, individual months or seasons can be the exact opposite.

It is the timing of these extreme months/seasons that are important for society. For example, five of the top ten months/years of SPI drought occurred in the fall. This may have assisted the agricultural community with harvest management conditions. Three years had low SPI-01 values in winter and one each in summer and spring with values ranging from -3.1 in 1908 to -3.9 in 1952. The SPI-01 excessive moisture seasons show summer as the predominant season followed by spring, fall and winter with SPI values ranging from 2.7 in 1959 to 3.3 in 1983.

Both maps of the extreme drought and excessive moisture years indicate some variability throughout the watershed (Appendix 2, Figure 2.11). The majority of the watershed in the SPI-01drought conditions shows the majority of the watershed is in the exceptional drought zone but this zone ranges from -2.5 to -4. The northern edge of the watershed is in the extreme to severe category of drought for December 1952. July 1983 excessive moisture pattern shows the majority of the watershed in the exceptional range for excess moisture with values greater than 2.5. The northern edge of the watershed was drier categorized in the moderate excessive moisture range (1.0 to 1.5).

SPI 12-month Extremes

The SPI 12-month values for the Upper Qu'Appelle River watershed top ten extreme years for drought and excessive moisture correspond to the PDSI top ten values. Four of the ten years in the SPI 12-month extreme drought correspond to PDSI drought conditions (1961, 1937, 1958 and 1988). The SPI 12-month most extreme drought year was 1961, the same as PDSI (Appendix 1, Tables 1.12 and 1.9). The spatial pattern is also relatively similar. The entire watershed is categorized in the exceptional range but the north eastern side of the watershed is the driest with a value of -3.7 (Appendix 1, Table 1.12 and Appendix 2, Figure 2.12).

More than half of the SPI 12-month excessive moisture condition years correspond to the PDSI excessive moisture conditions. These corresponding years include 1954, 1907, 1923, 1991, 1951, 1974 and 1953. Both SPI and PDSI's most extreme excessive moisture year were calculated to be 1954 with a SPI value of 2.8 or exceptional and PDSI value of 9.9 (Appendix 1, Tables 1.12 and 1.9). The spatial pattern was also similar but the SPI values were not as extreme. The northern half of the Upper Qu'Appelle River watershed is classified in the exceptional range with values ranging from 2.5 to 3.0. The rest of the watershed had lower excessive moisture values calculated with the southern portion of the watershed having a rating of severe (1.5 to 2.0) and moderate (1.0 to 1.5) excessive moisture conditions (Appendix 2, Figure 2.12).

Milk River Watershed

PDSI

The Saskatchewan portion of the Milk River watershed is located in the extreme southwest corner of the province (Figure 1) and is in the heart of the Palliser Triangle (Figure 2) and as such historically had extreme drought conditions. Five of the top ten extreme drought PDSI values are calculated to be pre-1940 with 1919 having the lowest PDSI value at -6.6. This extreme year was followed closely by 1988 with a PDSI value of -6.5 (Appendix 1, Table 1.13). All of the PDSI drought values are in the exceptional drought range with 1984 having a PDSI value of -5.5 and 1919's low of -6.6. During the low PDSI values, where data is available, the wheat yields were extremely low ranging from nearly -47% below average in 1984 to more than 94% below average in 1949 (Appendix 1, Table 1.13). The spatial variability of the Milk River watershed shows the entire watershed the southeastern portion of the watershed was in extreme drought conditions (-4.0 to -5.0) while the rest of the watershed was in exceptional drought conditions with the northwest corner the most exceptional with values in the -6.0 to -7.0 range (Appendix 2, Figure 2.13).

The PDSI excessive moisture top ten values ranged from 5.8 in 1955 to 7.9 in 1927. These are all in the exceptionally wet category. Wheat yields are highly variable in excessive moisture situations. For example, in 2004 the wheat yields were almost 40% above normal but in 1955 they were nearly 16% below normal based on the 2000-2009 averaging period (Appendix 1, Table 1.13). The spatial pattern for 1927 is quite variable, although more than half the watershed is in the exceptional PDSI range (values greater than 5.0). The northern portion of the watershed is less wet with categories of extreme (4.0 to 5.0) and severe (3.0 to 4.0) (Appendix 2, Figure 2.13).

PDSI Z-Value

Similar to the other three watersheds, this watershed also fluctuates from drought to excessive moisture conditions over a very short period. For example, 1970 and 1971 have very low PDSI Z-values (-3.7 and -4.3) but that switched in 1975 when a Z-value of 7.5 occurred. A switch also occurred in 1988 and 1989 with Z-values going from -3.6 in 1988 to 5.6 in 1989. This switch back and forth between extreme drought and excessive moisture dominated the early 21st century with 2001 having the second lowest PDSI Z-value at -4.4, 2002 having the highest at 10.7, going back to extremely low in 2003 (-3.7) and finally back to excessive moisture conditions in 2004 with a Z-value of 6.2. Below average yields were reported in 2001 and 2003, while the excessive moisture years of 2002 and 2004 reported above normal yields based on the 2000-2009 averaging period (Appendix 1, Table 1.14).

The spatial variability between the extreme drought year of 1961 and excessive moisture year of 2002 shows drought years are generally regional in nature compared to excessive moisture years. The 1961 PDSI Z-value has two categories with the western portion of the Milk River watershed categorized as being in a severe drought condition with the eastern side in extreme drought conditions (Appendix 2, Figure 2.14). The 2002 excessive moisture year spatial variability of the

PDSI Z-value ranges from a moderate excessive moisture condition on the eastern edge of the Milk River watershed to the majority of the watershed having a category of exceptional but the centre of the watershed is the most exceptional with PDSI Z-value ranging from 10.0 to 11.0 (Appendix 2, Figure 2.14).

SPI One-month Extremes

As stated earlier, SPI one month give as a snapshot of extreme drought and excessive moisture conditions. It is the timing of these one month extreme that is important because of impact on agricultural management strategies, water conditions and vegetation growth.

Eight of the ten SPI 01 drought values occurred in spring or early summer with SPI values ranging from -3.1 in April 1988 to -3.9 in June 1985. All of the SPI 01 values are in the exceptional drought range and as such all of the wheat yields are all below the 2000 to 2009 average yields (Appendix 1, Table 1.15). The seasonality of excessive moisture events was spread throughout the four seasons with spring and summer each having three occurrences and fall and winter each having one. The change in wheat yield with excessive moisture events ranged from well above average for 2004 with a 39% increase to a 38% decrease in 1971 and both of these excessive moisture events was calculated to have occurred in January (Appendix 1, Table 1.15).

The spatial variability of the SPI 01 for June 1985 shows the entire watershed is in exceptional drought but the northern edge of the watershed less so with values in the -2.5 to -3.0 range. The southern edge of the watershed had values in the -3.5 to -4.0 range indicating more extreme drought conditions (Appendix 2, Figure 2.15). The SPI 01 for September 1986 also indicates the entire watershed is in exceptional conditions but this time with excessive moisture (Appendix 2, Figure 2.15). The spatial variability of this event is the north and eastern side is less moist than the southwestern corner of the watershed (Appendix 2, Figure 2.15). The timing of these two events, June and September, can have negative impacts on the agricultural community. June is usually the time of year when crops require moisture and any substantial loss of moisture can result in decreased yields which did occur in 1985 with a below average yield of nearly 80% (Appendix 1, Table 1.15). The September 1986 excessive moisture may not negatively impact yield but may influence grain quality and harvest management strategies.

SPI 12-month Extremes

The Milk River watershed 12-month top ten extreme drought years range from -1.9 categorized as a severe drought in 1958 to -3.7 (exceptional) in 1988. Four of the extreme years were calculated to have occurred pre-1940 but not have occurred since the extreme low year of 1988 for the 1901 to 2005 period. SPI 12-month and PDSI drought have five years in common for occurring in the top ten most extreme drought years (1988, 1961, 1949, 1937 and 1936). All of the SPI 12-month drought years reported below average yields with the most extreme year in 1949 with a yield of more than 94% below average (Appendix 1, Table 1.16). The spatial variation for 1988 SPI 12-month shows the majority of the watershed in severe to moderate drought conditions. The western side of the watershed had extreme and exceptional drought conditions with the most exceptional on the extreme western edge with values between -3.5 and -4.0 (Appendix 2, Figure 2.16).

The excessive moisture top ten extreme SPI 12-month values ranged from 1.7 in 1916 to 2.6 in 1927 with ratings of severe to exceptional. Six of the ten are rated in the severe category, three in the extreme and only one in the exceptional category for excessive moisture. Only 1974 with a rating of 1.7 had below average wheat yields (Appendix 1, Table 1.16). The spatial variability of 1927 shows that only the southwestern corner of the exceptional rating of 2.5 to 3.0. The rest of the watershed was in the 1.5 to 2.5 range with the eastern corner of the watershed rated as being in a moderate excessive moisture condition (Appendix 2, Figure 2.16).

The Prairies in 2009-2011

The above analysis is based on drought and excessive moisture indices calculated using the gridded ANUSPLIN temperature and precipitation data for 1901 to 2005. The last few years have witnessed extreme swings in the prairie climate from severe drought to exceptional excess moisture. To analyze these most recent events another data source is utilized (AAFC 2011) but the methodology in calculating the PDSI, PDSI Z-value and SPI are slightly different. For example, the AAFC classification stops at +/-5 for PDSI, -2.75/3.50 for PDSI Z-value and +/-2 for SPI. Also, the SPI 12-month for the September to August 2011 period is unavailable so the October to September 2011 period is used (Figure 17).

The autumn of 2008 to early 2010 was in severe drought in parts of Alberta and Saskatchewan to regions that had near normal to slight excessive moisture conditions (Wittrock et al. 2010). The driest regions were in the western and southern portions (e.g., Swift Current) of Saskatchewan in the August 2009 PDSI map (Figure 7). The Saskatchewan portion of the Milk River watershed had PDSI values ranging from mild excessive moisture conditions to mild drought conditions on the eastern edge. The Old Wives Lake watershed unfortunately does not have any PDSI values located in it but the perimeter of the area shows the southeastern portion of the watershed may have had moderate excessive moisture conditions while the northwestern side was in moderate drought. The Moose Jaw River watershed and the Upper Qu'Appelle River watershed had near normal moisture conditions. August 2010 PDSI values show a major shift to severe excessive moisture conditions across southern Saskatchewan (Figure 8) for all four watersheds. This trend to moist conditions was more enhanced in the southern and eastern portions of the watershed in 2012 with PDSI values in the extreme range for all four watersheds (Figure 9).

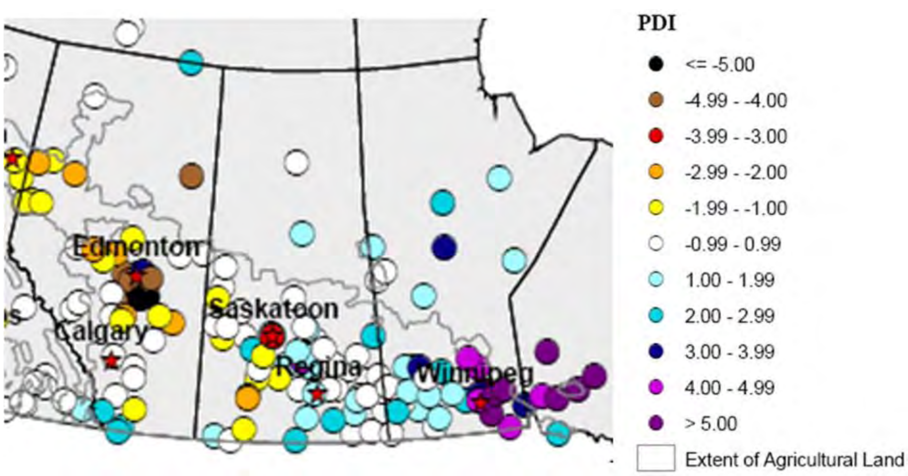

Figure 7 Palmer Drought Index August 2009 (AAFC 2010)

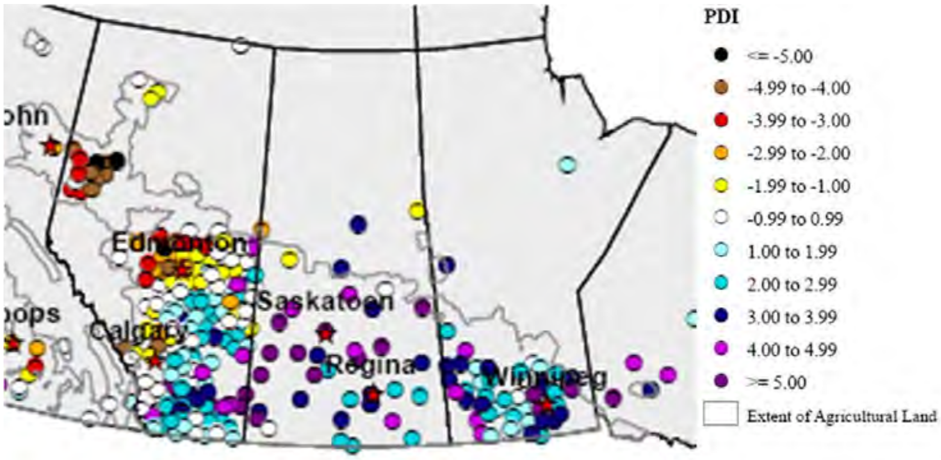

Figure 8 Palmer Drought Index August 2010 (AAFC 2010)

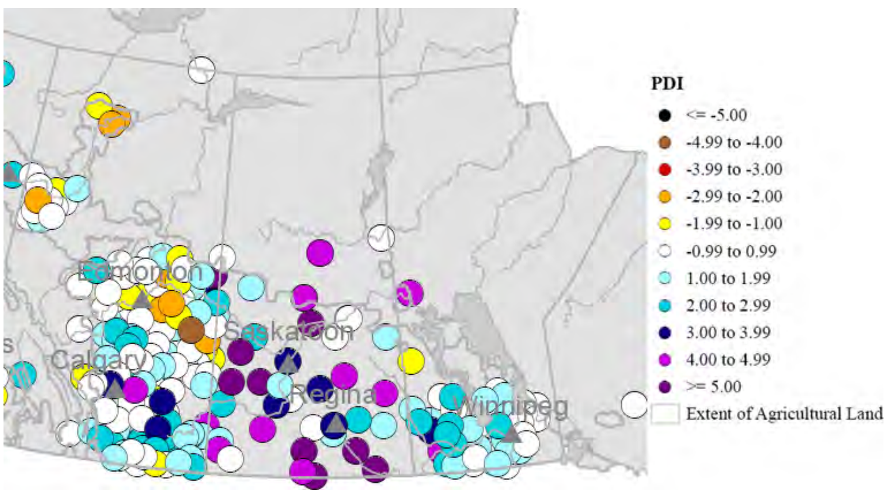

Figure 9 Palmer Drought Index August 2011 (AAFC 2011)

The August 2009 PDSI Z-values indicate that much of the agricultural zone in Saskatchewan is tending towards wetter conditions. The greatest change was in the Moose Jaw River and Upper Qu'Appelle River watersheds where the change was in excess of 3.5 (Figure 10). The PDSI Z-value in August shows the same trend towards moisture conditions but more of the province in in the exceptional excessive moisture regime (Figure 11). By August 2011 the PDSI Z-values were returned more to neutral conditions with the Milk River Region classified as being in stable scenario – neither wetter nor drier. The Old Wives Lake watershed was trending towards neutral to slightly wetter conditions with the Moose Jaw River categorized with neutral to mild drought conditions. The Upper Qu'Appelle River watershed was trending to neutral conditions with the west side of the watershed slightly drier and the east side slightly wetter.

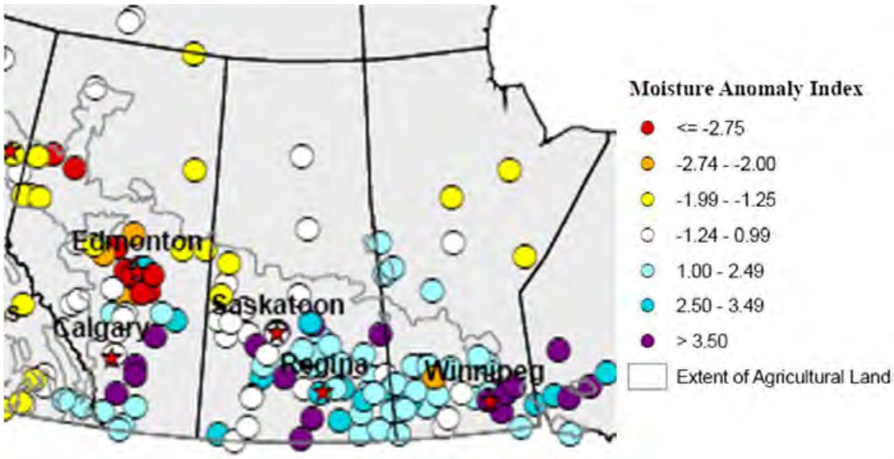

Figure 10 Palmer Drought Index (Z-value) August 2009 (AAFC 2010)

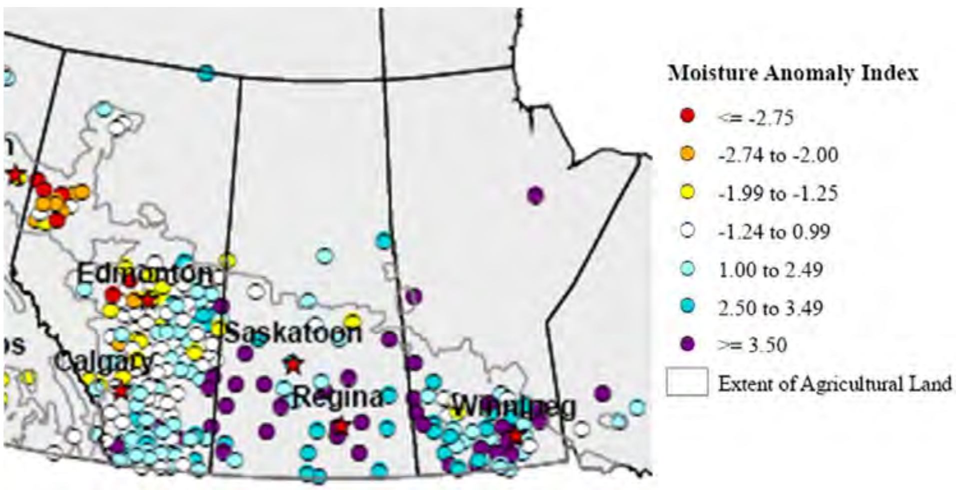

Figure 11 Palmer Drought Index (Z-value) August 2010 (AAFC 2010)

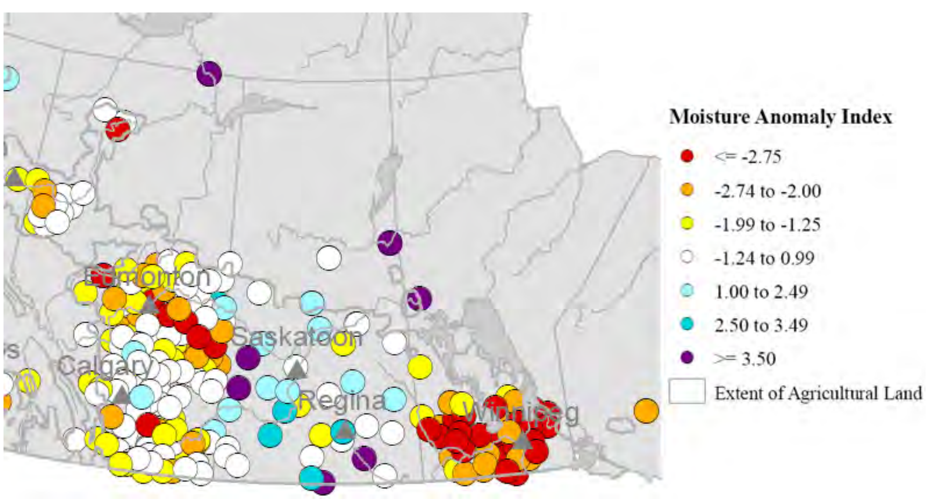

Figure 12 Palmer Drought Index (Z-value) August 2011 (AAFC 2011)

The 12-month SPI values further illustrate the moisture conditions that were occurring on the prairies in the 2009-2011 period. The August 2009 SPI map (Figure 13) shows the Saskatchewan portion of the Milk River and the Old Wives Lake Watersheds were in precipitation deficit conditions. The Moose Jaw River watershed had moisture deficit conditions on the northeastern portion (Thunder Creek region) while the southwestern region was neutral. The Upper Qu'Appelle River watershed was in normal to mild excessive moisture conditions. By August 2010, the entire agricultural zone had switched to moister conditions (Figure 14). The Milk River watershed had values in neutral to mild excessive level, with the further east and north the moisture conditions became more extreme. The majority of the Upper Qu'Appelle watershed had exceptional excessive moisture. The September 2011 SPI 12-month map (Figure 15) illustrates a further shift in moisture levels in Saskatchewan with the southern edge of the province in exceptional moisture conditions including the Milk River watershed. The further north, the conditions became drier to the extent that the northern portion of the Moose Jaw River and the Upper Qu'Appelle River were classified as having moderate to severe drought in parts of their watersheds.

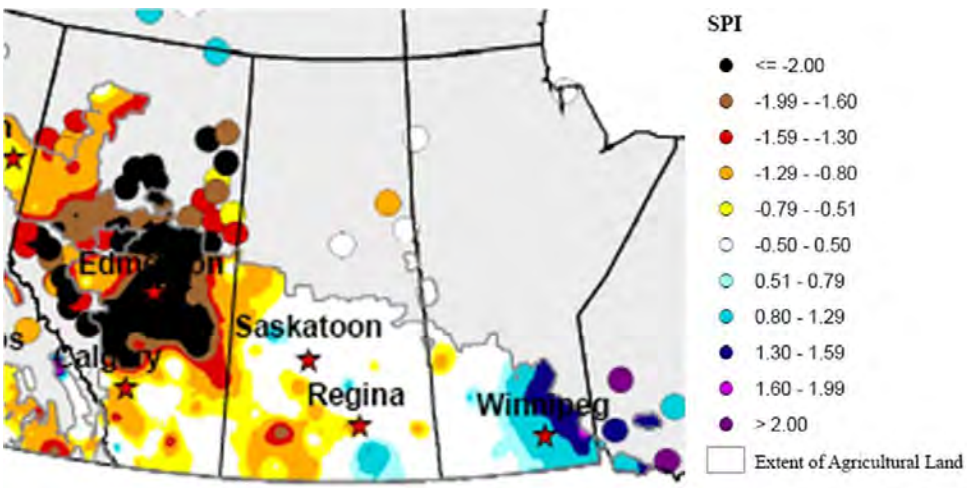

Figure 13 Standardized Precipitation Index (12-month) August 2009 (AAFC 2010)

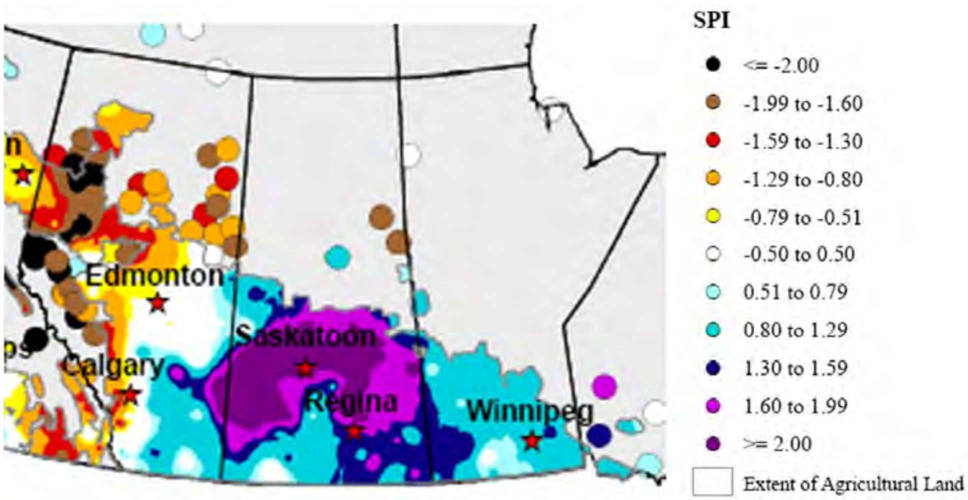

Figure 14 Standardized Precipitation Index (12-month) August 2010 (AAFC 2010)

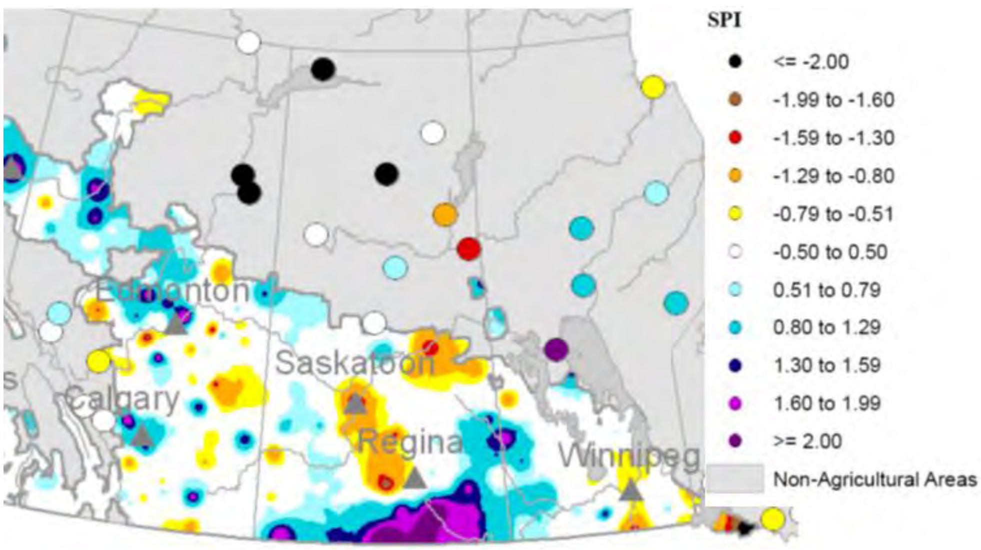

Figure 15 Standardized Precipitation Index (12-month) September 2011 (AAFC 2012)

Drought and Excessive Moisture Pattern Comparison

Often, the extreme events characterized previously did not happen in one watershed alone. Several of the extreme drought and excessive moisture events were calculated to be in all four watersheds. For example, PDSI values indicate 1988 was a wide spread extreme drought event because it placed in the top two lowest PDSI values in all four of the watersheds. The year 1988 had relatively similar values across the four watershed ranging from -6.4 (Old Wives Lake watershed), -6.5 (Milk River watershed) to -6.7 (Moose Jaw River and Upper Qu'Appelle River watersheds). Exceptional PDSI drought values were calculated to have occurred in all four watersheds in five of the top ten years including 1919, 1931, 1937, 1961 and 1988 (Appendix 1, Tables 1.1, 1.5, 1.9 and 1.13).

Spatial similarity for PDSI excessive moisture values also appeared with 1907 categorized in either first or second for being the wettest in all four watersheds. Four more years were also in the top ten PDSI excessive moisture (1909, 1954, 1955 and 1991). A couple of years had three watersheds in common including 1966 (Milk River, Olds Wives Lake and Upper Qu'Appelle) and 1974 (Old Wives Lake, Moose Jaw River and Upper Qu'Appelle) (Appendix 1, Tables 1.1, 1.5, 1.9 and 1.13).

The drought PDSI Z-values show a slightly different pattern for years in common for the four watersheds. For example, 1961 had the lowest value in all four watersheds with 2001 being either the second or third lowest Z-value. Three other years were common across all four watersheds (1929, 1971, 1984, and 2003). These years indicate that much of southern Saskatchewan was tending towards drought conditions (Appendix 1, Tables 1.2, 1.6, 1.10 and 1.14). The excessive moisture PDSI Z-values also show trends to moister conditions across wide regions of the province. For example, 2002 was the highest PDSI Z-value in the Upper Qu'Appelle, Moose Jaw and Milk River watersheds and placed third in the Old Wives Lake watershed. There were five more years in common in the four watersheds including 1907, 1951, 1954, 1974, and 1993 (Appendix 1, Tables 1.2, 1.6, 1.10 and 1.14).

The SPI 12-month shows a slightly different story. The most extreme year for drought remains to be 1961 with it being classified as the lowest SPI 12-month in the Upper Qu'Appelle watershed, second in the Moose Jaw River and Milk River watersheds and third in the Old Wives Lake watershed (Appendix 1, Tables 1.4, 1.8, 1.12 and 1.16). PDSI and SPI 12-month drought values also have 1937 and 1988 in common. The four year where SPI 12-month low value appears in all four watersheds is 1929, 1937, 1961 and 1988. Old Wives Lake, Milk River and Moose Jaw River also have 1949 and 1984 in common. SPI excessive moisture conditions show 1974 and 1991 were the two in-common years in all four watersheds (Appendix 1, Tables 1.4, 1.8, 1.12 and 1.16). The Old Wives Lake, Moose Jaw River and Upper Qu'Appelle River watersheds had SPI excessive moisture years of 1907, 1951 and 1954 in common while 1993 was the common year for Milk River, Moose Jaw River and Upper Qu'Appelle River watersheds. Comparing the SPI 12-month years with the PDSI excessive moisture years, only 1991 was the common year for the two indices with 1907, 1954 and 1974 were common excessive moisture years for three of the watersheds.

The Upper Qu'Appelle River watershed is not categorized as being located in the Palliser Triangle, it is the watershed that contains the extreme values for both PDSI and SPI. For example, the lowest PDSI value in the Upper Qu'Appelle is -7.0 (1961) with the next closest is the Moose Jaw River at -6.7 (1988). The PDSI excessive moisture values have a high of 9.9 in the Upper Qu'Appelle River watershed (1954) with Old Wives Lake watershed having second highest PDSI excessive moisture value of 8.5 (1907).

COMMUNITY VULERABILITY ASSESSMENT (IMPACTS AND ADAPTATION)

As shown above, Saskatchewan and the four watersheds examined in this study have experienced both droughts and floods. As such, the impacts of these events are varied and require various adaptation strategies. Research has been carried out looking at impacts and adaptation strategies implemented in Saskatchewan and the rest of Canada in relation to droughts (e.g., Wittrock et al. 2011, Wittrock et al. 2010, Wheaton et al. 2008, Wheaton et al. 2007, Wittrock et al. 2007, Wheaton et al. 2005, Drought Research Initiative and Institutional Adaptations to Climate Change). This section utilizes the findings from these projects.

The Canadian Prairies have implemented many adaptation strategies to both droughts and floods. Most were initially initiated as a reactionary to an extreme event but became pro-active adaptation measures. For example, in the early 20th century it became apparent that a reliable water source of potable would be needed resulting in numerous wells and small dams were built. However, in the 1930s, many of these were not sufficient to meet the needs of the communities, or agricultural sector so government assistance was required. This assistance came in the form of Agriculture Canada's Prairie Farm Rehabilitation Administration which aided many communities with designing water retention structures ranging from larger dams such as Highfield Dam in the Old Wives Lake watershed to smaller designs such as dugouts or constructed ponds.

Droughts result in numerous negative impacts including decreased yields, feed shortage, water shortage, soil degradation, and decreased income. Positive impacts also occur during drought events including higher quality grains, increased revenue for towns and cities through increased water usage, as long as there is not a water shortage and decrease in mosquitoes.

The many severe and sometimes multi-year droughts have resulted in numerous adaptation strategies. Many of the adaptation strategies utilized in the 2001-2002 drought are documented by Wittrock and Wheaton (2007) and Wheaton and Wittrock (2005). The more common adaptation strategies included increased water storage, agricultural producers obtaining off-farm income with one or both spouses and changing agriculture management strategies. These change in strategies involved decreasing herd size, increase feed storage, reducing the amount of land in summerfallow, moving towards continuous cropping or minimum tillage. To obtain more reliable water supply some producers installed water pipelines and if suitable increased the amount of land under irrigation.

Excessive moisture conditions can occur quite quickly and have devastating impacts on agriculture and communities. Less research has been carried out to determine nature of these impacts and adaptation strategies put in place to cope with them. Much of the information obtained, particularly for the 2010 and 2011 excessive moisture events are from media sources (Wittrock et al. 2011 Appendix 3). The 2010 high moisture year led to adequate or surplus soil moisture conditions in the fall of 2010 (Figure 16). These conditions, with the high snowfall that occurred in the winter of 2010/2011 (Figure 17) resulted extensive flooding in the southern and eastern parts of the province (CBC News Apr 2011) impacting all four watersheds. Impacts included water flowing over roadways, farmland flooded, towns/villages threatened (CBC News Apr 2011, Discover MooseJaw Apr 15 2011, Briere Apr 4, 2011).

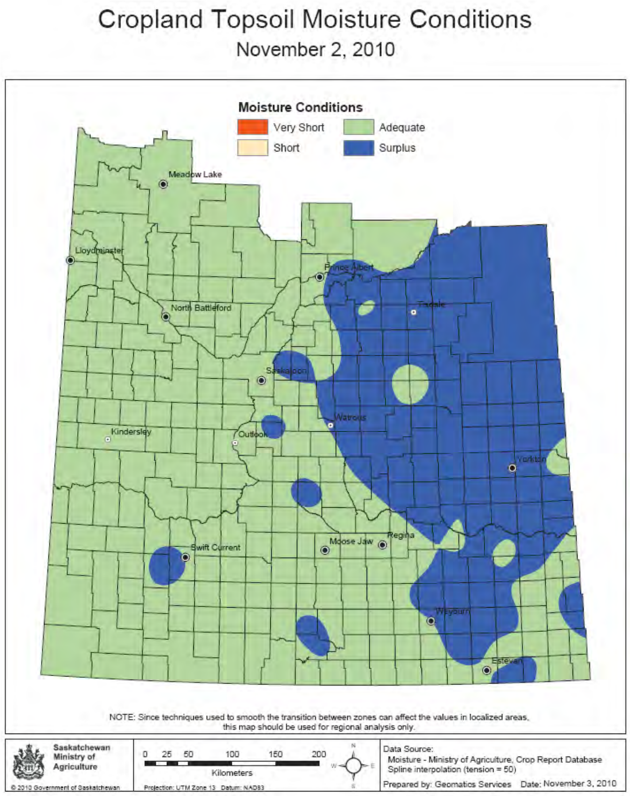

Figure 16 Saskatchewan Topsoil Moisture Conditions Fall 2010 (Saskatchewan Ministry of Agriculture 2010)

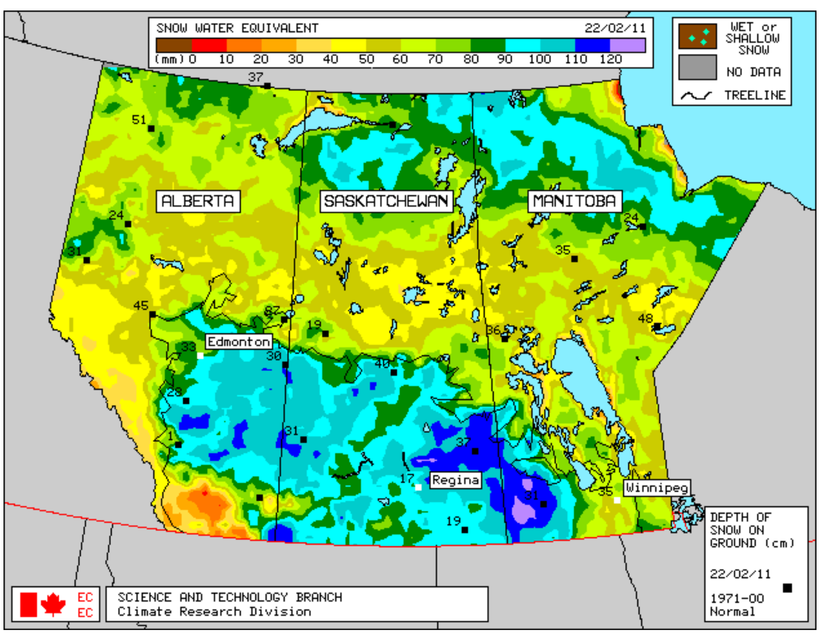

Figure 17 Prairie Provinces Snow Water Equivalent February 22, 2011 (Environment Canada 2011)

Several adaptation measures were implemented due to the excessive moisture conditions in 2010 and 2011. Some of the adaptation measures included installing flood berms in communities, assistance with improving drainage channels to assist with future flood events (Government of Saskatchewan March 31, 2011) and information on how to deal with excess moisture (Government of Saskatchewan 2010).

Extreme climate events, either floods or droughts take an economic toll. The reduction in value of agricultural losses for the 2001-2002 drought is calculated to be in the order of $1.7 billion for Saskatchewan (Wheaton et al. 2008). The 2011 floods in Manitoba and Saskatchewan were estimated to result in a loss of $1.5 to $2.5 billion (Owen June 20, 2011). More recent estimated flooding related expenses for Saskatchewan are in the order of $244 million (Hall Nov 28, 2011).

CONCLUSION AND RECOMMENDATIONS

Watershed planning is in the beginning phases in the province of Saskatchewan. It is important that this planning take into account droughts and excessive moisture. These two extremes are not uncommon occurrences in Saskatchewan with the recent examples of 1988, 2001-2002 and 2009 droughts and the floods years of 2010 and 2011. The uniqueness of each extreme event relays more information on whom and what is impacted and how the community as a whole may be able to adapt to these conditions. It is projected that the area, intensity and number of both droughts and excessive moisture events will increase in the future (e.g., IPCC WGI 2007) resulting a need to understand the events. Understanding will potentially lead to proactive adaptation strategies because these strategies will assist with decreasing the cost and necessity of reactive adaptation strategies.

The recommendations put forward in Wittrock et al. (2011) are relevant to this report, but can be expanded. The recommendations included:

- Improved information about extremes, their patterns and impacts to assist with design and implementation of effective adaptation strategies.
- Examination of the 2010 and 2011 excessive moisture patterns and compare with historic and future projected patterns.
- Water use demand should be related to drought and excessive moisture extremes.
- Expansion of this 100 year examination of drought and excessive moisture to the rest of Saskatchewan’s watersheds.
- Undertake trends analysis to determine onset/decrease of extreme drought and excessive moisture events.

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ACRONYMS

°C – degrees Celcius
cm – centimetres
IPCC – Intergovernmental Panel on Climate Change
mm – millimetres
AAFC – Agriculture and Agri-Food Canada
PDSI – Palmer Drought Severity Index
PRAC – Prairies Regional Adaptation Collaborative
SPI – Standardized Precipitation Index
SRC – Saskatchewan Research Council
SWA – Saskatchewan Watershed Authority

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Appendix 1

The 10 Most Extreme Drought and Excessive Moisture Tables for the Moose Jaw River, Old Wives Lake, Upper Qu'Appelle River and Milk River Watersheds for the 1901-2005 period

Table 1.1 PDSI for the Moose Jaw River Watershed. The 10 year average (2000-2009) wheat yield is 24 bushels/acre.

PDSI Drought (Agricultural Year)		
Year	PDSI	% Change in Wheat Yield
1988	-6.7	-54.4
1958	-6.5	-38.5
1984	-6.2	-24.8
1959	-6.0	-47.1
1961	-6.0	-62.8
1937	-5.9	Not Available
1981	-5.5	-6.0
1929	-5.2	Not Available
1931	-5.1	Not Available
1919	-5.0	Not Available

PDSI Excessive Moisture (Agricultural Year)		
Year	PDSI	% Change in Wheat Yield
1907	8.2	Not Available
1909	7.0	Not Available
1955	6.8	-2.6
1991	6.4	14.1
1954	6.2	-78.1
1902	5.8	Not Available
1927	5.8	Not Available
1951	5.3	-21.9
1974	5.3	-22.9
1947	5.3	-37.0

Table 1.2 PDSI Z-value for Moose Jaw River Watershed. The 10 year average (2000-2009) wheat yield is 24 bushels/acre.

PDSI Z-value Drought (Agricultural Year)		
Year	PDSI Z-value	% Change in Wheat Yield
1961	-5.7	-62.8
1929	-4.8	Not Available
2001	-4.7	-12.7
1984	-4.7	-24.8
2003	-4.4	-12.3
1971	-4.3	9.1
1958	-3.7	-38.5
1930	-3.6	Not Available
1970	-3.6	4.4
1959	-3.6	-47.1

PDSI Z-value Excessive Moisture (Agricultural Year)		
Year	PDSI Z-value	% Change in Wheat Yield
2002	10.0	-7.9
1968	9.3	-28.6
1993	9.1	21.5
1954	8.7	-78.1
1951	7.3	-21.9
1907	7.2	Not Available
1974	7.1	-22.9
1995	5.9	14.9
1903	5.7	Not Available
1909	5.1	Not Available

Table 1.3 SPI One-Month for the Moose Jaw River Watershed. The 10 year average (2000-2009) wheat yield is 24 bushels/acre.

SPI One-Month Drought			
Year	Month	SPI01	% Change in Wheat Yield
1961	8	-3.4	-62.8
1952	12	-3.3	12.5
2001	8	-3.3	-12.7
1997	12	-3.3	2.8
1968	4	-3.1	-28.6
1917	5	-3.1	Not Available
1978	3	-3.1	25.3
1960	9	-3.1	-0.8
1993	1	-3.0	21.5
1958	5	-3.0	-38.5

SPI One-Month Excessive Moisture			
Year	Month	SPI01	% Change in Wheat Yield
1998	10	3.2	-0.1
1993	7	3.1	21.5
1904	3	3.0	Not Available
1967	3	2.9	-36.5
1968	8	2.8	-28.6
1909	7	2.8	Not Available
1990	7	2.8	46.8
1902	2	2.7	Not Available
1999	2	2.7	18.5
2002	8	2.7	-7.9

Table 1.4 SPI 12-Month for the Moose Jaw River Watershed. The 10 year average (2000-2009) wheat yield is 24 bushels/acre.

SPI August Drought (12-Month)		
Year	SPI 12	% Change in Wheat Yield
1929	-3.2	Not Available
1961	-3.1	-62.8
1958	-2.9	-38.5
1988	-2.6	-54.4
1937	-2.4	Not Available
1967	-2.2	-36.5
1984	-2.1	-24.8
1949	-1.8	-65.9
1945	-1.7	-56.3
1959	-1.7	-47.1

SPI August Excessive Moisture (12-Month)		
Year	SPI 12	% Change in Wheat Yield
1907	2.4	Not Available
1999	2.1	18.5
1974	2.1	-22.9
1991	2.0	14.1
1993	1.9	21.5
1955	1.9	-2.6
1902	1.9	Not Available
1954	1.7	-78.1
1976	1.7	32.0
1951	1.7	-21.9

Table 1.5 PDSI for the Old Wives Lake Watershed. The 10 year average (2000-2009) wheat yield is 25 bushels/acre.

PDSI Drought (Agricultural Year)		
Year	PDSI	% Change in Wheat Yield
1988	-6.4	-67.0
1937	-6.4	Not Available
1931	-6.0	Not Available
1961	-5.9	-79.1
1919	-5.4	Not Available
1929	-5.3	Not Available
1984	-5.3	-34.2
1946	-5.3	-70.9
1981	-5.2	2.0
1959	-5.1	-50.5

PDSI Excessive Moisture (Agricultural Year)		
Year	PDSI	% Change in Wheat Yield
1907	8.5	Not Available
1909	7.2	Not Available
1954	7.1	-51.6
1955	6.8	-12.9
1966	6.2	-2.2
1991	6.1	19.9
2004	5.9	28.4
1951	5.5	-36.7
1974	5.5	-26.7
1916	5.4	Not Available

Table 1.6 PDSI Z-value for Old Wives Lake Watershed. The 10 year average (2000-2009) wheat yield is 25 bushels/acre.

PDSI Z-value Drought (Agricultural Year)		
Year	PDSI Z-value	% Change in Wheat Yield
1961	-5.4	-79.1
1971	-4.8	-14.2
2001	-4.7	-22.0
1929	-4.5	Not Available
1984	-4.1	-34.2
2003	-4.0	-21.3
1967	-4.0	-46.7
1983	-3.9	-0.1
1901	-3.6	Not Available
1970	-3.6	6.7

PDSI Z-value Excessive Moisture (Agricultural Year)		
Year	PDSI Z-value	% Change in Wheat Yield
1993	9.5	17.3
1954	9.1	-51.6
2002	8.8	-4.3
1974	7.3	-26.7
1951	7.3	-36.7
1907	7.2	Not Available
2004	5.9	28.4
1968	5.8	-36.4
1975	5.8	0.0
1995	5.7	2.3

Table 1.7 SPI One-Month for the Old Wives Lake Watershed. The 10 year average (2000-2009) wheat yield is 25 bushels/acre

SPI One-Month Drought			
Year	Month	SPI01	% Change in Wheat Yield
1974	6	-3.5	-26.7
1968	3	-3.5	-36.4
1973	1	-3.4	-15.6
2005	2	-3.3	13.2
1959	12	-3.3	-50.5
1985	6	-3.3	-68.3
1917	5	-3.3	Not Available
1967	6	-3.2	-46.7
1978	3	-3.2	11.5
1961	8	-3.1	-79.1

SPI One-Month Excessive Moisture			
Year	Month	SPI01	% Change in Wheat Yield
1993	7	3.4	17.3
1975	3	3.3	0.0
1998	10	3.2	-2.4
1904	3	3.0	Not Available
1927	5	3.0	Not Available
1986	9	3.0	14.4
1967	3	2.9	-46.7
1971	1	2.9	-14.2
1978	9	2.8	11.5
1955	7	2.8	-12.9

Table 1.8 SPI 12-Month for the Old Wives Lake Watershed. The 10 year average (2000-2009) wheat yield is 25 bushels/acre.

SPI August Drought (Agriculture Year)		
Year	SPI 12	% Change in Wheat Yield
1929	-3.2	Not Available
1988	-2.7	-67.0
1961	-2.6	-48.5
1937	-2.4	Not Available
1949	-2.2	-87.8
1984	-2.1	-45.7
1971	-2.1	-9.5
1936	-2.0	Not Available
1945	-1.8	-78.7
1967	-1.8	-37.5

SPI August Excessive Moisture (Agriculture Year)		
Year	SPI 12	% Change in Wheat Yield
1907	2.5	Not Available
1974	2.1	-26.7
2004	2.1	28.4
1991	1.9	19.9
1965	1.9	-10.2
1955	1.8	-12.9
1927	1.8	Not Available
1916	1.8	Not Available
1954	1.7	-51.6
1951	1.6	-36.7

Table 1.9 PDSI for the Upper Qu'Appelle River Watershed. The 10 year average (2000-2009) wheat yield is 29 bushels/acre.

PDSI Drought (Agricultural Year)		
Year	PDSI	% Change in Wheat Yield
1961	-7.0	-71.1
1988	-6.7	-70.8
1958	-5.8	-50.8
1959	-5.8	-43.5
1937	-5.8	Not Available
1930	-5.4	Not Available
1981	-5.4	-10.2
1931	-5.3	Not Available
1915	-5.1	Not Available
1919	-5.1	Not Available

PDSI Excessive Moisture (Agricultural Year)		
Year	PDSI	% Change in Wheat Yield
1954	9.9	-75.7
1907	7.6	Not Available
1991	6.6	0.3
1909	6.5	Not Available
1955	6.2	-21.0
1951	5.9	-24.9
1966	5.4	-5.2
1974	5.4	-36.1
1953	5.3	-8.5
1923	5.0	Not Available

Table 1.10 PDSI Z-value for Upper Qu'Appelle River Watershed. The 10 year average (2000-2009) wheat yield is 29 bushels/acre.

PDSI Z-value Drought (Agricultural Year)		
Year	PDSI Z-value	% Change in Wheat Yield
1961	-5.9	-71.1
1929	-4.9	Not Available
2001	-4.9	-39.3
1972	-4.8	-27.7
1984	-4.8	-31.5
1958	-4.2	-50.8
1930	-4.0	Not Available
1967	-4.0	-46.5
2003	-3.9	-0.4
1971	-3.8	-1.3

PDSI Z-value Excessive Moisture (Agricultural Year)		
Year	PDSI Z-value	% Change in Wheat Yield
2002	13.1	-37.5
1954	11.0	-75.7
1993	9.3	-5.7
1995	8.8	-7.1
1907	6.8	Not Available
1951	6.8	-24.9
1974	6.3	-36.1
1966	6.1	-5.2
1968	5.9	-31.3
2005	5.9	17.2

Table 1.11 SPI One-Month for the Upper Qu'Appelle River Watershed. The 10 year average (2000-2009) wheat yield is 29 bushels/acre

SPI One-Month Drought			
Year	Month	SPI01	% Change in Wheat Yield
1952	12	-3.9	-13.8
1961	8	-3.5	-71.1
1995	9	-3.3	-7.1
1968	4	-3.3	-31.3
1974	11	-3.2	-36.1
1954	12	-3.2	-75.7
1925	12	-3.2	Not Available
1965	10	-3.1	-22.2
1969	10	-3.1	-6.7
1908	9	-3.1	Not Available

SPI One-Month Excessive Moisture			
Year	Month	SPI01	% Change in Wheat Yield
1983	7	3.3	2
1955	4	3.3	-21
2002	8	3.2	-38
1977	5	3.1	0
1904	3	2.9	Not Available
1909	7	2.9	Not Available
1911	1	2.7	Not Available
1947	11	2.7	-69
1993	7	2.7	-6
1959	9	2.7	-43

Table 1.12 SPI 12-Month for the Upper Qu'Appelle River Watershed. The 10 year average (2000-2009) wheat yield is 29 bushels/acre.

SPI August Drought (12 Month)		
Year	SPI 12	% Change in Wheat Yield
1961	-3.7	-71.1
1929	-2.9	Not Available
1937	-2.6	Not Available
1958	-2.5	-50.8
2001	-2.4	-39.3
1967	-2.3	-46.5
1988	-2.3	-70.8
1924	-2.3	Not Available
1914	-2.2	Not Available
1972	-1.8	-27.7

SPI August Excessive Moisture (12 Month)		
Year	SPI 12	% Change in Wheat Yield
1954	2.8	-75.7
1907	2.2	Not Available
1923	2.1	Not Available
1991	2.0	0.3
1993	2.0	-5.7
1951	2.0	-24.9
1974	1.8	-36.1
1995	1.7	-7.1
1953	1.7	-8.5
1999	1.7	17.7

Table 1.13 PDSI for the Milk River Watershed. The 10 year average (2000-2009) wheat yield is 25 bushels/acre.

PDSI Drought (Agricultural Year)		
Year	PDSI	% Change in Wheat Yield
1919	-6.6	Not Available
1988	-6.5	-56.9
1937	-6.4	Not Available
1961	-6.4	-84.6
1949	-6.1	-94.3
1946	-5.9	-81.1
1936	-5.8	Not Available
1931	-5.8	Not Available
1905	-5.8	Not Available
1984	-5.5	-46.7

PDSI Excessive Moisture (Agricultural Year)		
Year	PDSI	% Change in Wheat Yield
1927	7.9	Not Available
1907	7.7	Not Available
1993	7.3	13.7
1975	7.0	0.0
1909	6.8	Not Available
1954	6.2	0.0
1991	6.1	18.1
2004	6.0	38.9
1966	5.8	-2.3
1955	5.8	-16.6

Table 1.14 PDSI Z-value for Milk River Watershed. The 10 year average (2000-2009) wheat yield is 25 bushels/acre.

PDSI Z-value Drought (Agricultural Year)		
Year	PDSI Z-value	% Change in Wheat Yield
1961	-4.8	-84.6
2001	-4.4	-22.2
1971	-4.3	-38.3
1967	-4.0	-56.6
1929	-4.0	Not Available
1983	-4.0	4.6
1984	-3.7	-46.7
1970	-3.7	-5.7
2003	-3.7	-13.3
1988	-3.6	-56.9

PDSI Z-value Excessive Moisture (Agricultural Year)		
Year	PDSI Z-value	% Change in Wheat Yield
2002	10.7	12.7
1993	7.6	13.7
1954	7.6	-62.3
1975	7.5	0.0
1951	7.1	-57.7
1974	7.0	-21.1
2004	6.2	38.9
1907	6.1	Not Available
1933	5.9	Not Available
1989	5.6	-5.2

Table 1.15 SPI One-Month for the Milk River Watershed. The 10 year average (2000-2009) wheat yield is 25 bushels/acre

SPI One-Month Drought			
Year	Month	SPI01	% Change in Wheat Yield
1985	6	-3.9	-79.7
1967	6	-3.8	-56.6
1959	12	-3.6	-66.3
1955	8	-3.3	-16.6
1961	3	-3.3	-84.6
1973	3	-3.3	-34.9
1917	5	-3.2	Not Available
1968	3	-3.2	-36.7
1963	3	-3.1	-10.3
1988	4	-3.1	-56.9

SPI One-Month Excessive Moisture			
Year	Month	SPI01	% Change in Wheat Yield
1986	9	3.8	5.5
1993	7	3.4	13.7
1927	5	3.3	Not Available
1975	3	3.3	0.0
1971	1	3.2	-38.3
1904	3	3.0	Not Available
1998	6	2.9	15.3
1995	10	2.8	21.1
2002	8	2.7	12.7
2004	1	2.7	38.9

Table 1.16 SPI 12-Month for the Milk River Watershed. The 10 year average (2000-2009) wheat yield is 25 bushels/acre.

SPI August Drought (12 Month)		
Year	SPI 12	% Change in Wheat Yield
1988	-3.7	-56.9
1961	-2.7	-84.6
1929	-2.6	Not Available
1977	-2.6	-18.3
1984	-2.5	-46.7
1949	-2.3	-94.3
1937	-2.2	Not Available
1919	-2.1	Not Available
1936	-2.1	Not Available
1958	-1.9	-62.9

SPI August Excessive Moisture (12 Month)		
Year	SPI 12	% Change in Wheat Yield
1927	2.6	Not Available
1993	2.3	13.7
2004	2.1	38.9
2002	2.0	12.7
1987	1.9	2.1
1991	1.8	18.1
1915	1.7	Not Available
1999	1.7	23.9
1974	1.7	-21.1
1916	1.7	Not Available

Appendix 2

Spatial Distribution of the 10 Most Extreme Drought and Excessive Moisture Episodes for the Moose Jaw River, Old Wives Lake, Upper Qu'Appelle River and Milk River Watersheds for the 1901-2005 period.

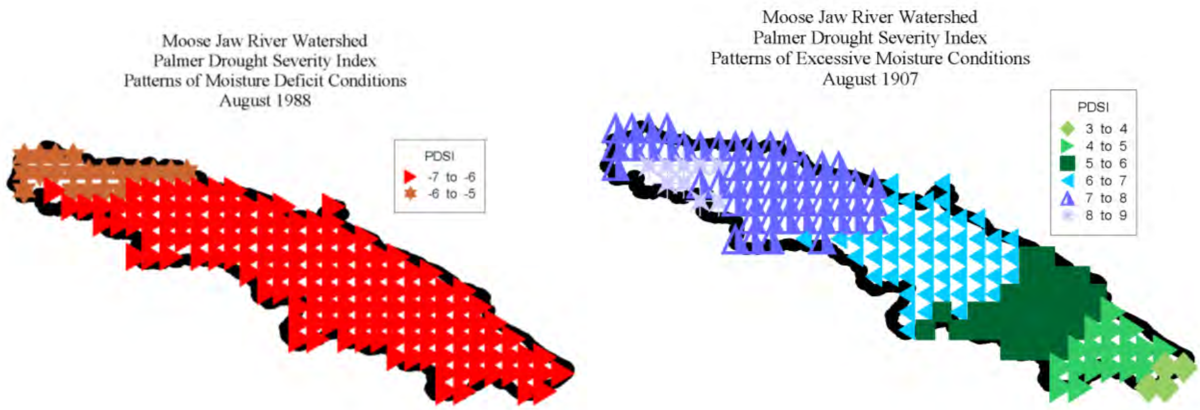


Figure 2.1 PDSI Moose Jaw River Watershed Maps for the Drought Year of 1988 and the Excessive Moisture Year of 1907

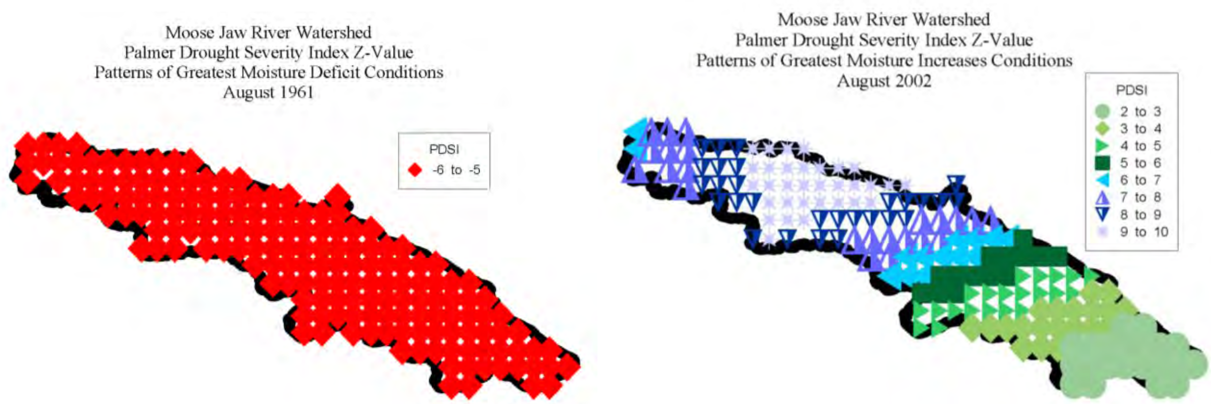


Figure 2.2 PDSI Z-value Moose Jaw River Watershed Maps for the Drought Year of 1961 and the Excessive Moisture Year of 2002

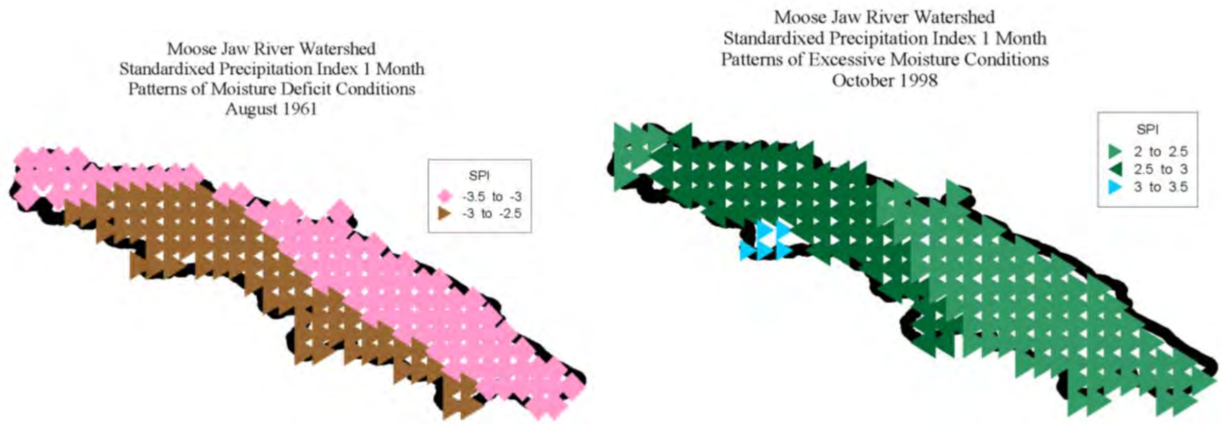


Figure 2.3 SPI 1-Month for the Moose Jaw River Watershed for the Drought Month of August 1961 and the Excessive Moisture Month of October 1998.

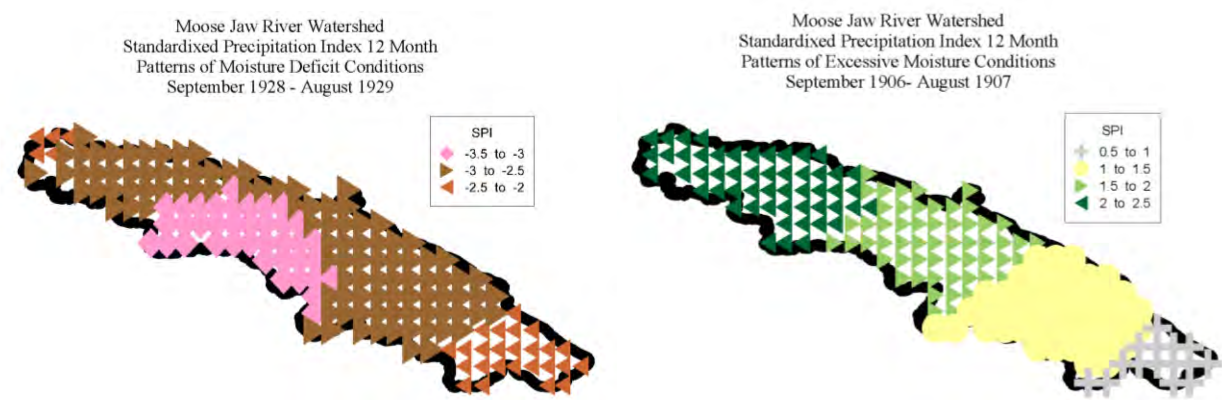


Figure 2.4 SPI 12-Month Moose Jaw River Watershed for the Drought Year 1929 and the Excessive Moisture Year of 1907.

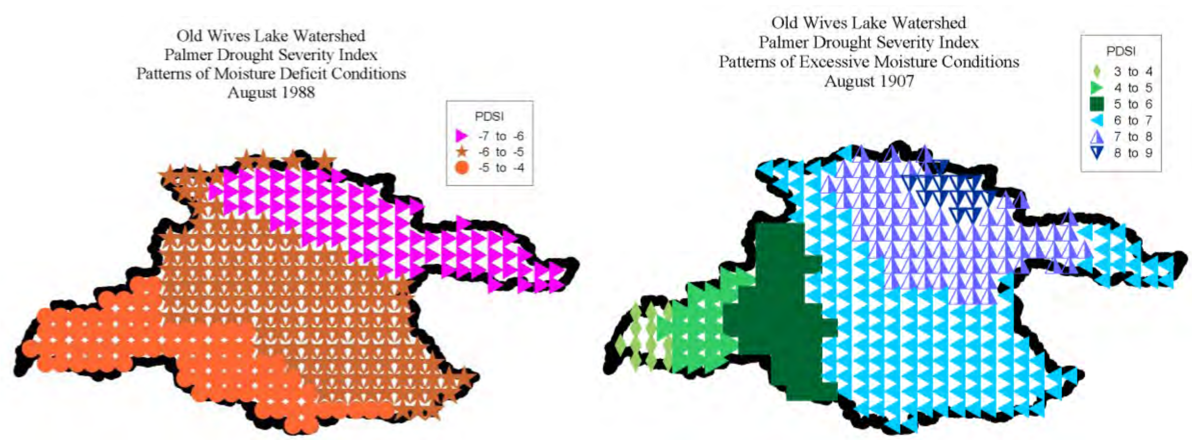


Figure 2.5 PDSI Old Wives Lake Watershed Maps for the Drought Year of 1988 and the Excessive Moisture Year of 1907

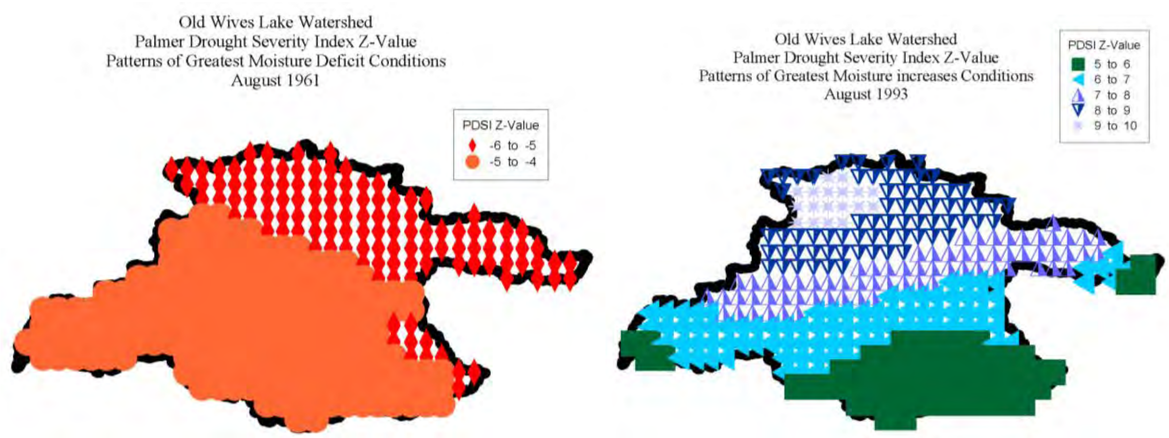


Figure 2.6 PDSI Z-value Old Wives Lake Watershed Maps for the Drought Year of 1961 and the Excessive Moisture Year of 1993

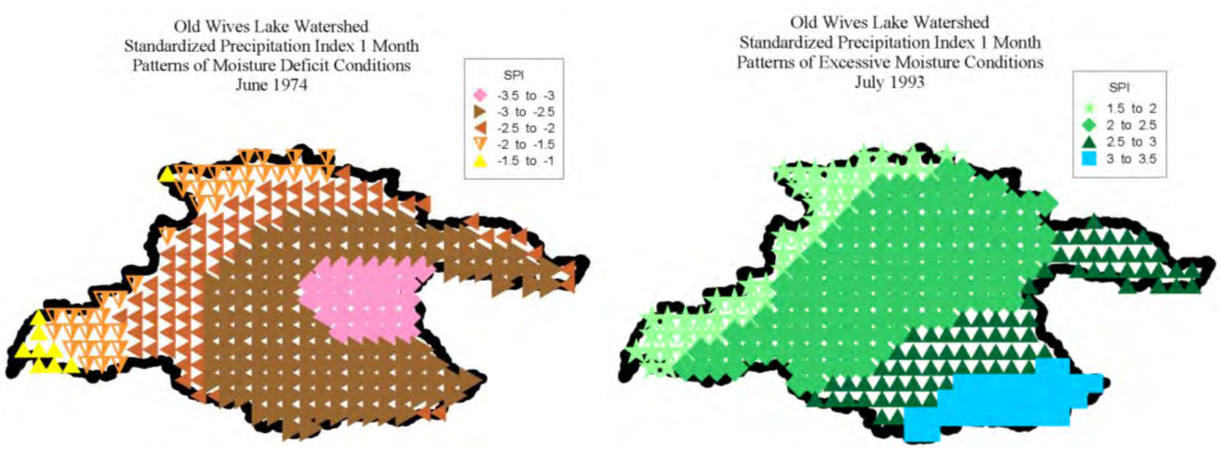


Figure 2.7 SPI 1-Month for the Old Wives Lake Watershed for the Drought Month of June 1974 and the Excessive Moisture Month of July 1993.

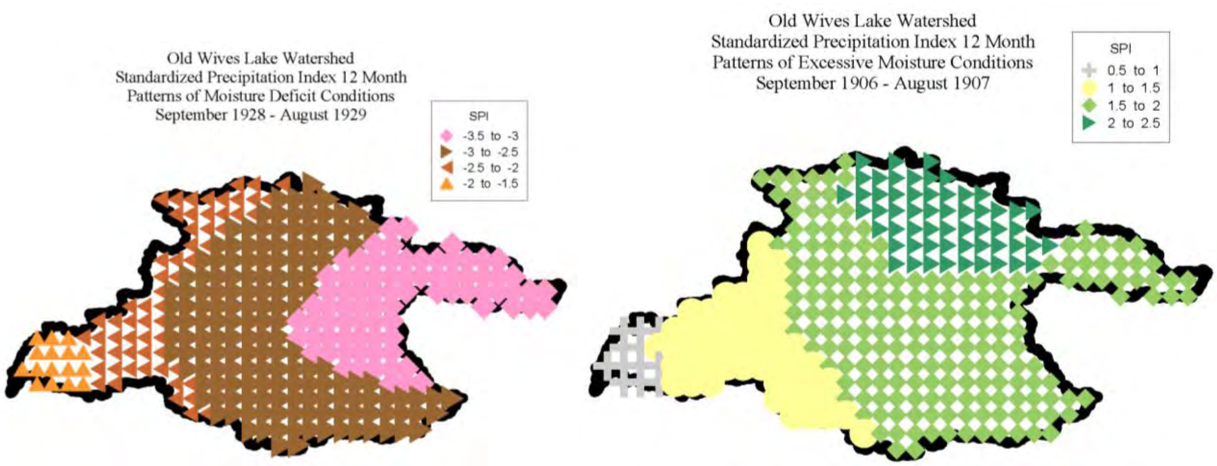


Figure 2.8 SPI 12-Month Old Wives Lake Watershed for the Drought Year 1929 and the Excessive Moisture Year of 1907.

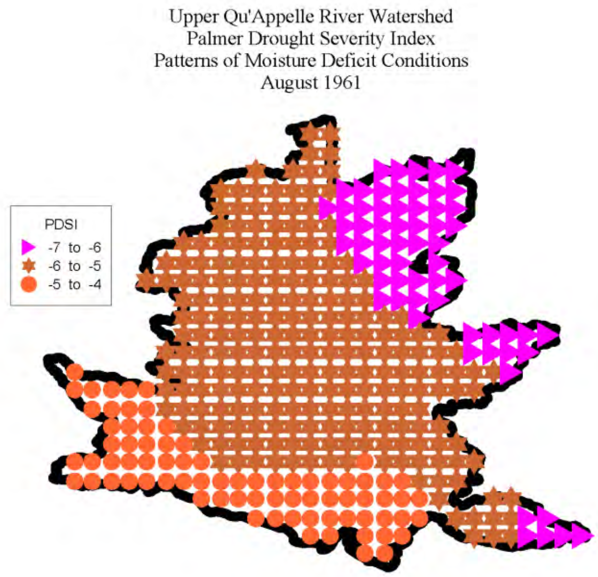


Figure 2.9 PDSI Upper Qu'Appelle River Watershed Maps for the Drought Year of 1961 and the Excessive Moisture Year of 1954

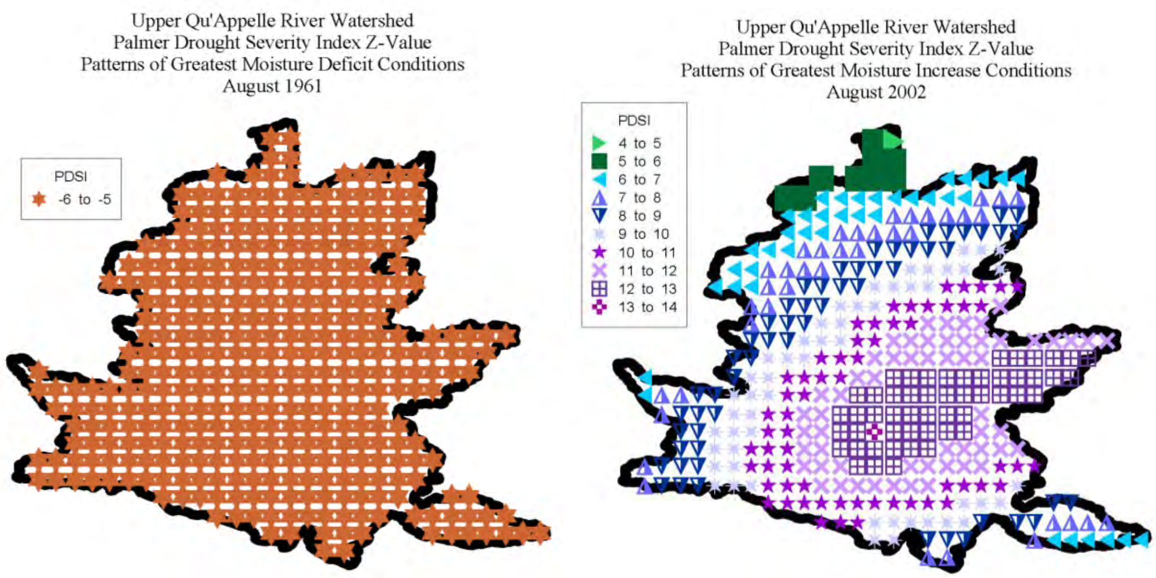


Figure 2.10 PDSI Z-value Upper Qu'Appelle River Watershed Maps for the Drought Year of 1961 and the Excessive Moisture Year of 2002

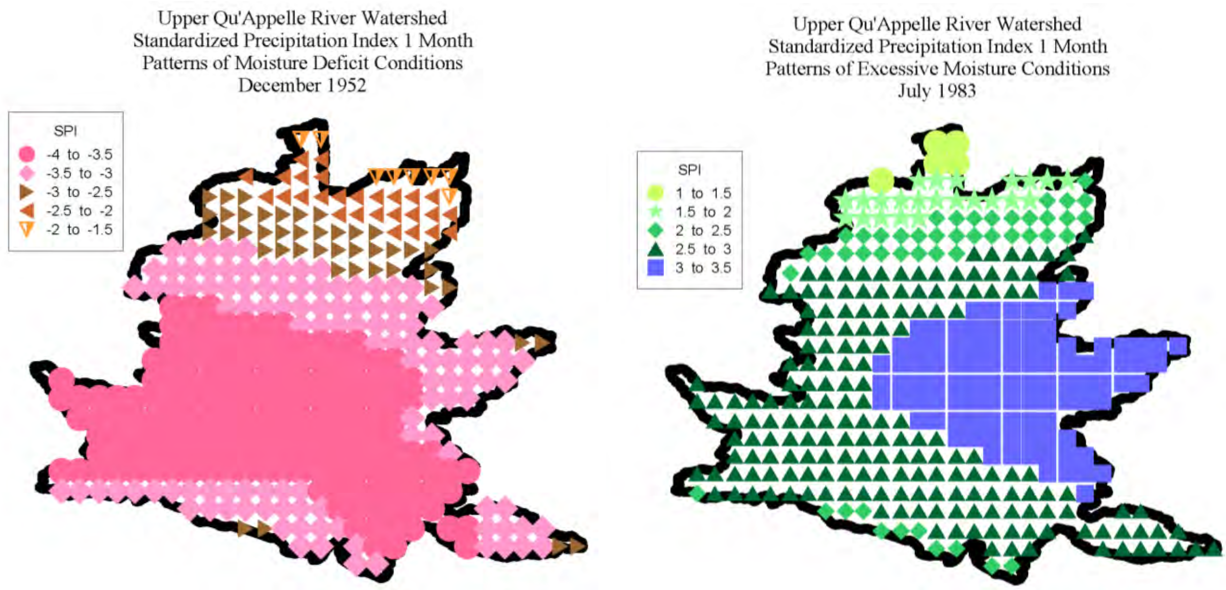


Figure 2.11 SPI 1-Month for the Upper Qu'Appelle River Watershed for the Drought Month of December 1952 and the Excessive Moisture Month of July 1983.

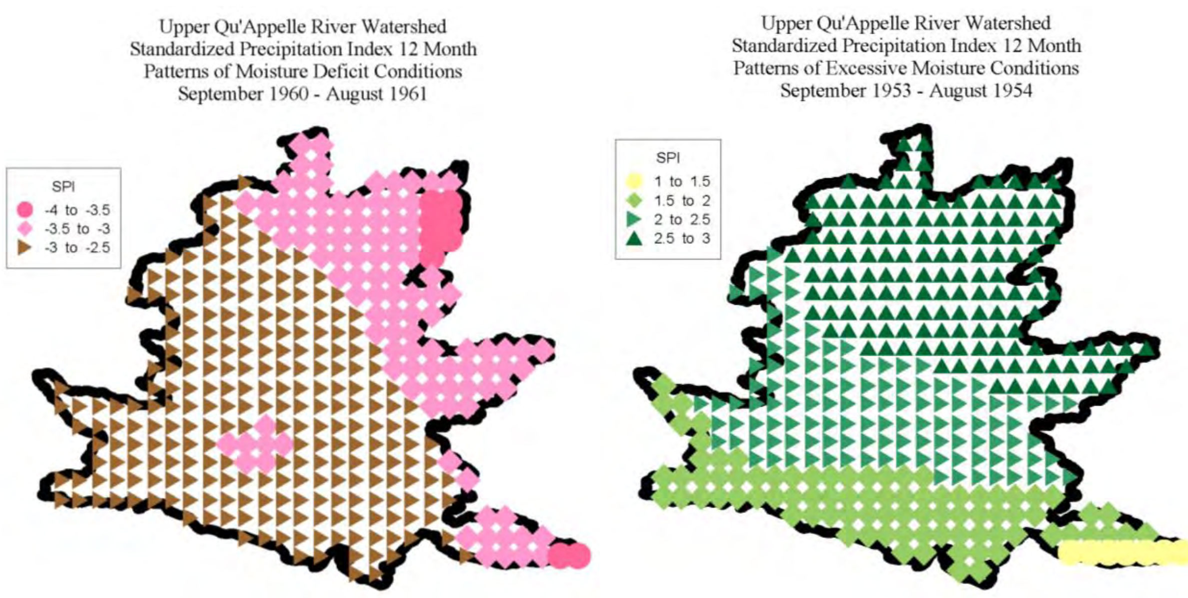


Figure 2.12 SPI 12-Month Upper Qu'Appelle River Watershed for the Drought Year 1961 and the Excessive Moisture Year of 1954.

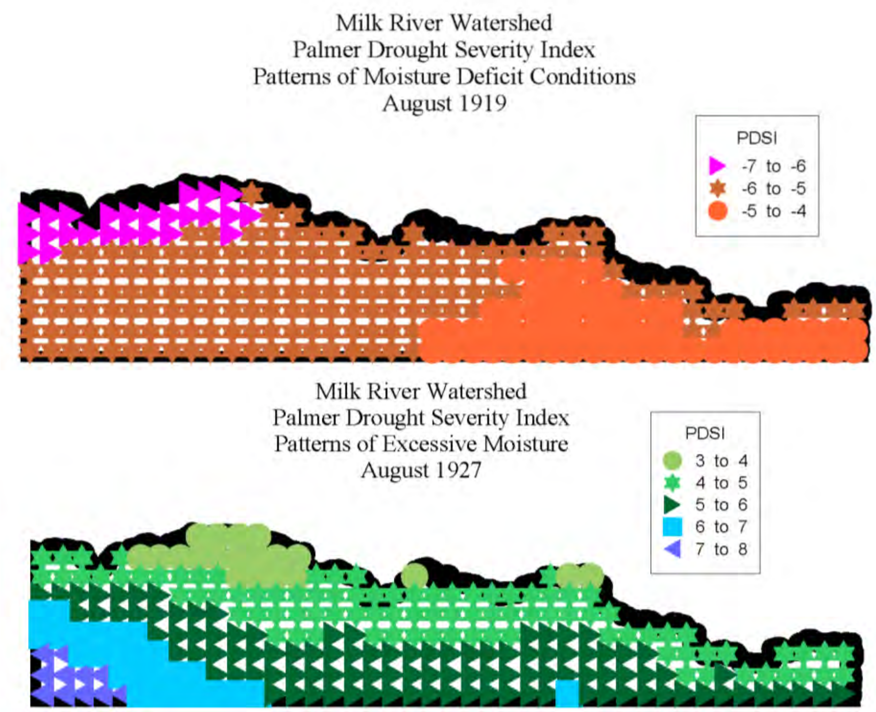


Figure 2.13 PDSI Milk River Watershed Maps for the Drought Year of 1919 and the Excessive Moisture Year of 1927

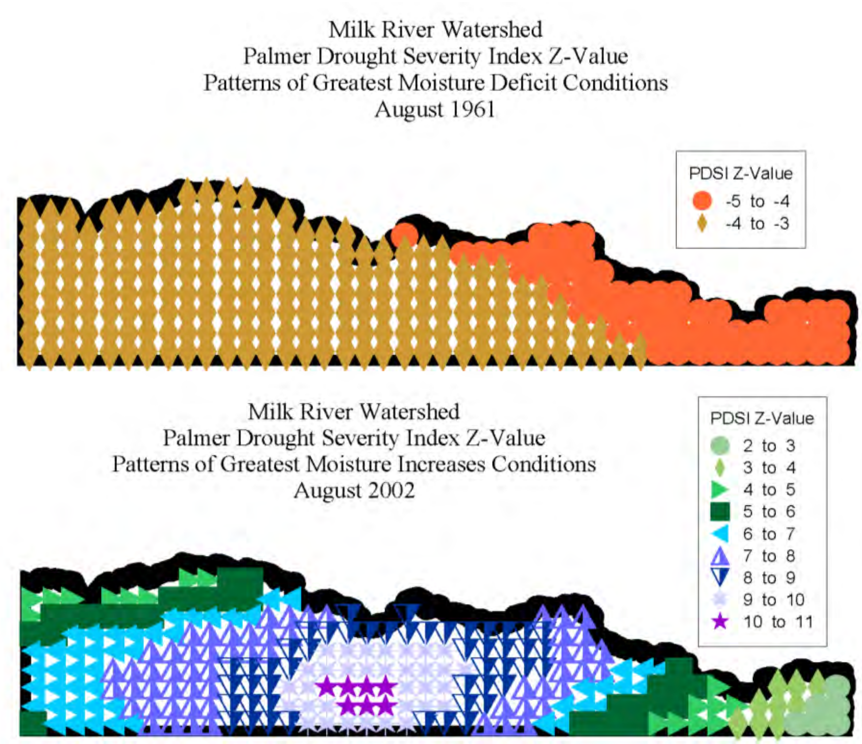


Figure 2.14 PDSI Z-value Milk River Watershed Maps for the Drought Year of 1961 and the Excessive Moisture Year of 2002

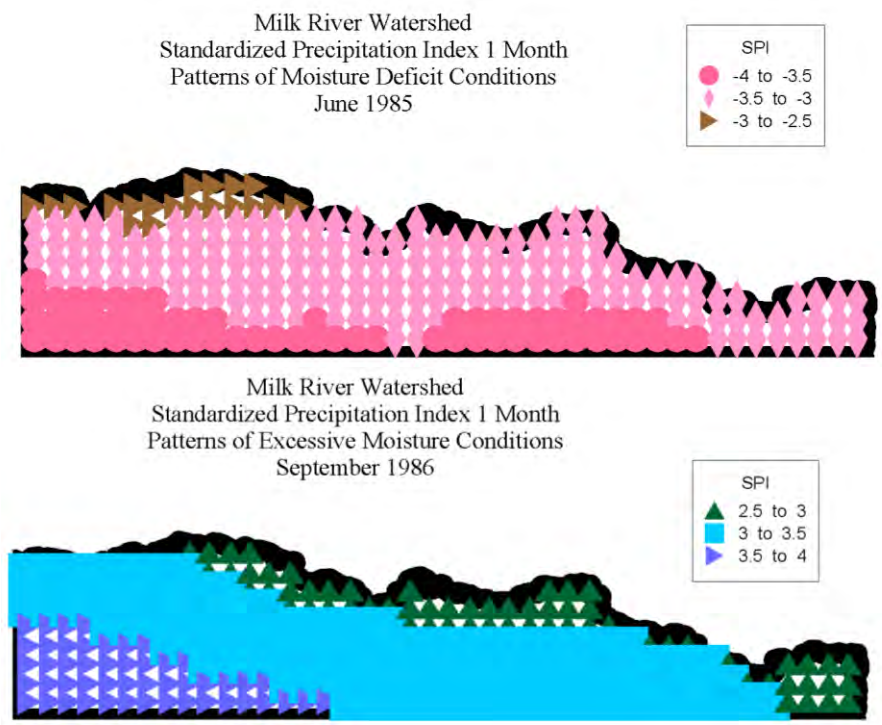


Figure 2.15 SPI 1-Month for the Milk River Watershed for the Drought Month of June 1985 and the Excessive Moisture Month of September 1986.

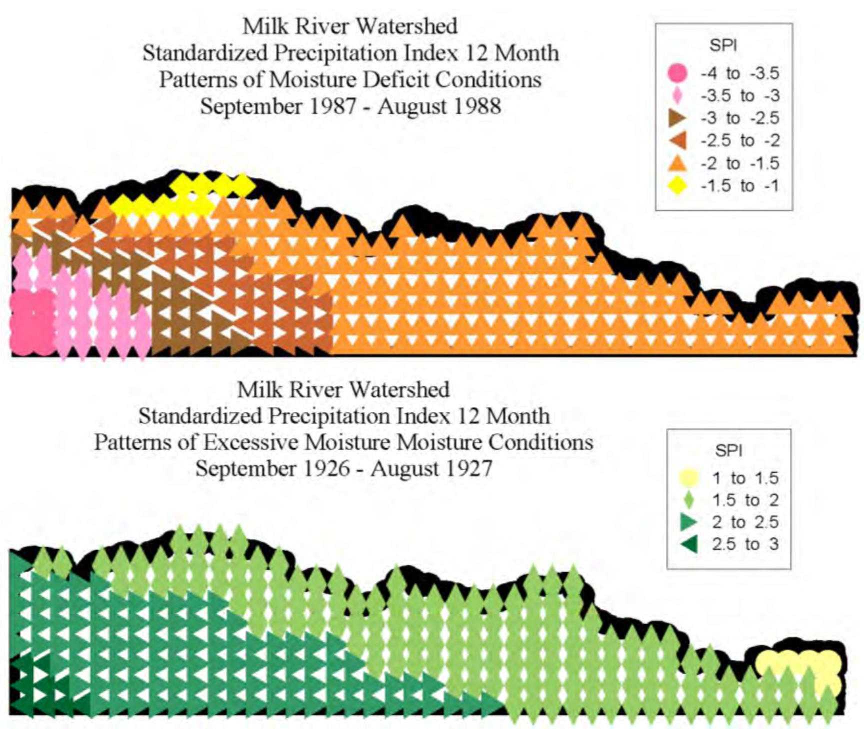
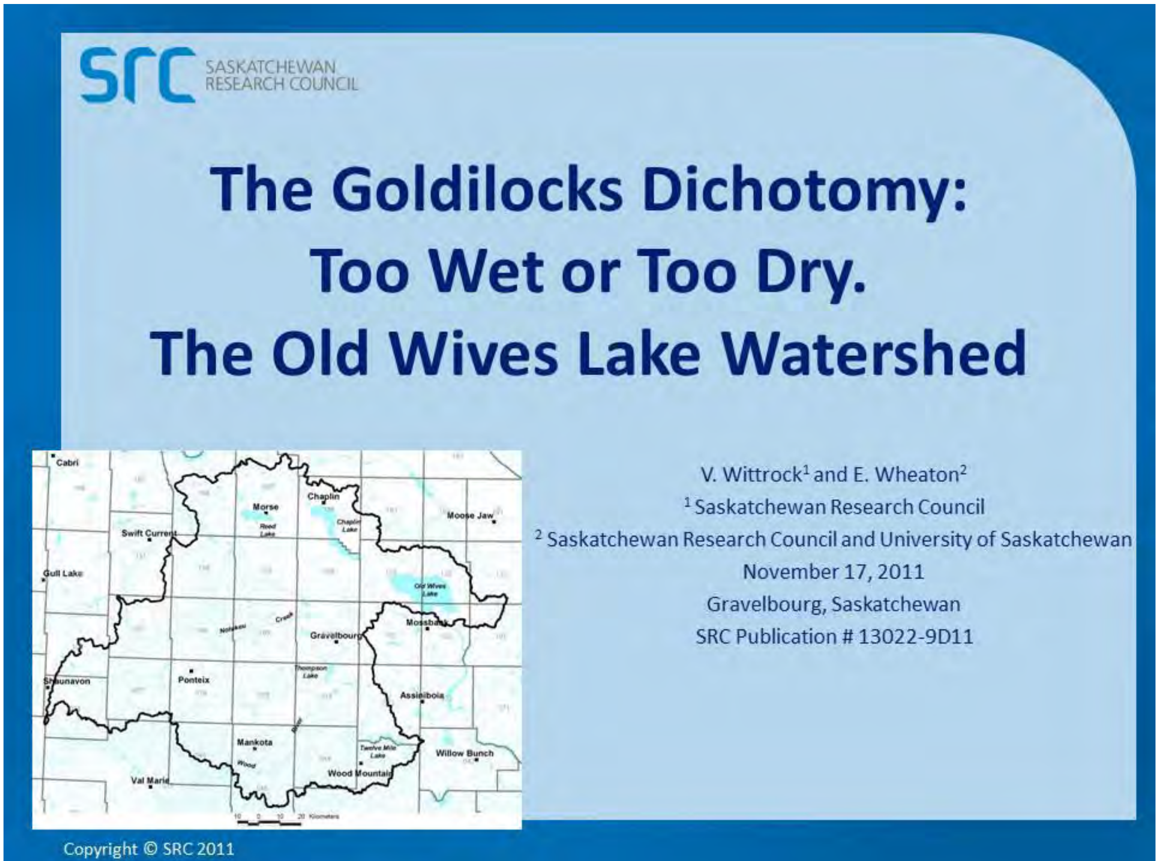


Figure 2.16 SPI 12-Month Moose Jaw River Watershed for the Drought Year 1988 and the Excessive Moisture Year of 1927.

Appendix 3

Presentations of the Drought and Excessive Moisture Patterns for the Old Wives Lake, Moose Jaw River, Upper Qu'Appelle Rive and Milk River Watersheds.


SRC SASKATCHEWAN RESEARCH COUNCIL
The Goldilocks Dichotomy:
Too Wet or Too Dry.
The Old Wives Lake Watershed
V. Wittrock[1] and E. Wheaton[2]
[1] Saskatchewan Research Council
[2] Saskatchewan Research Council and University of Saskatchewan
November 17, 2011
Gravelbourg, Saskatchewan
SRC Publication # 13022-9D11
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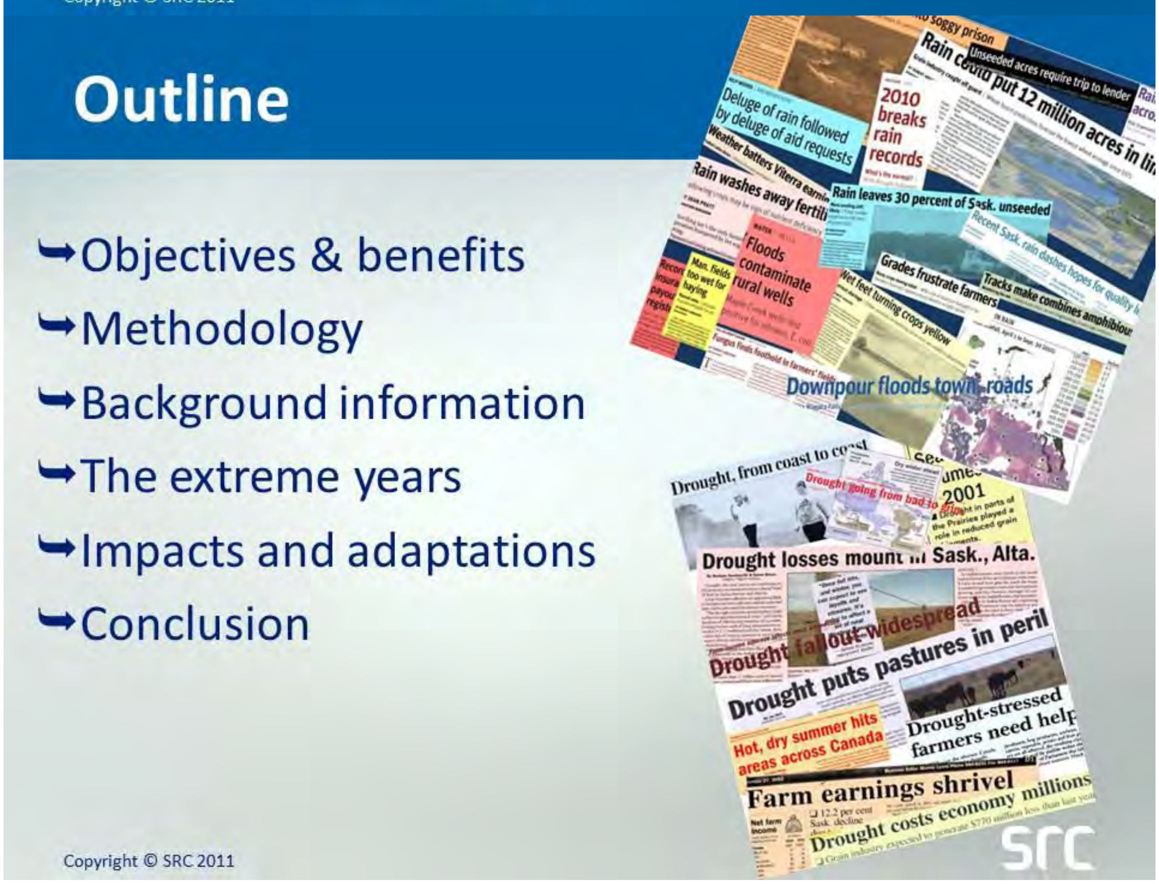
Outline
➥Objectives & benefits
➥Methodology
➥Background information
➥The extreme years
➥Impacts and adaptations
➥Conclusion
Deluge of rain followed by deluge of aid requests
2010 breaks rain records
Rain leaves 30 percent of Sask. unseeded
Floods contaminate rural wells
Downpour floods town, roads
Drought losses mount in Sask., Alta.
Drought puts pastures in peril
Hot, dry summer hits areas across Canada
Drought-stressed farmers need help
Farm earnings shrivel
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Objectives

- To **characterize** drought and excessive moisture events for selected watersheds during the past century.
- **Compare** and **contrast** driest and wettest patterns to help determine characteristics for risk assessments and planning.
- Consider the **implications** for impacts and adaptations directly related to the watershed.

src

Benefits of Examining the Past

- Assist communities, local municipalities, provincial and federal governments with **risk management** and **planning strategies** for extreme events.
- **Avoid damages and decrease** the **costs** of climate events by learning from the past.
- Help to lower the **costs of the impacts of future climatic events.**

src

What is a Drought?

- A deficiency of precipitation from expected or "normal" that, when extended over a season or longer, is insufficient to meet the demands of human activities and the environment
- Four major types of drought including Meteorological, Agricultural, Hydrological and Socio-economic

- Or when it hasn't rained, the fields are dry, the lakes or rivers are really low and it impacts the economy, environment and our way of life

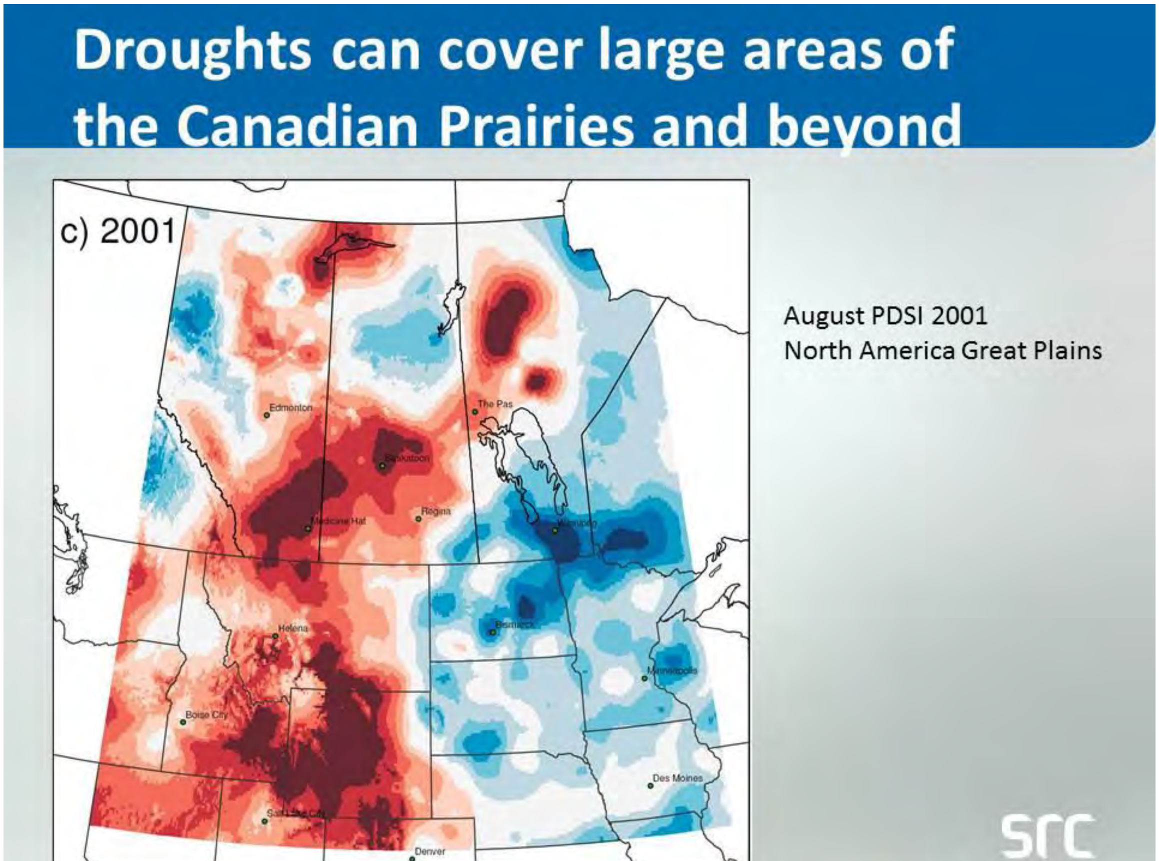
Photo: AAFC

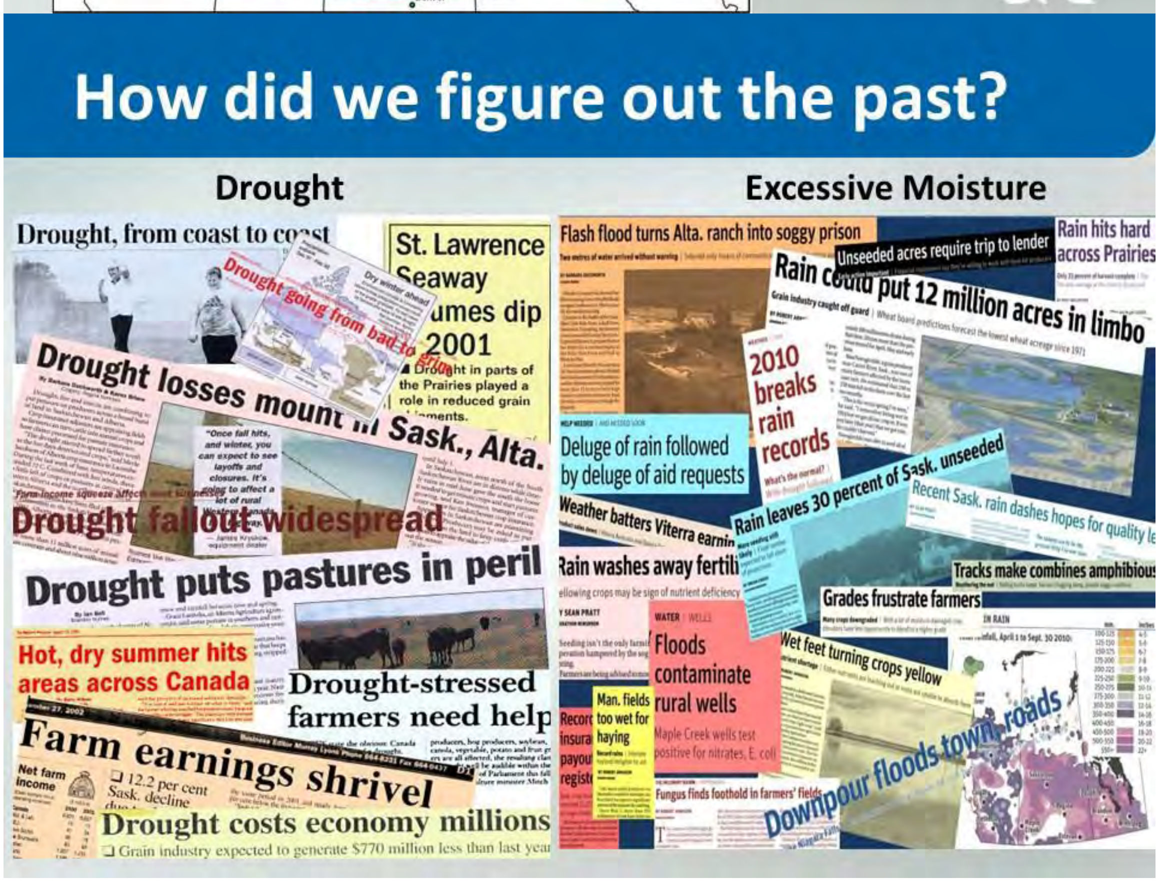
What is Excessive Moisture?

- An excess of precipitation from expected or "normal" that, when extended over a season or longer, is too much to meet the demands of human activities and the environment
- Four major types of excess moisture including Meteorological, Agricultural, Hydrological and Socio-economic

- Or it won't quit raining, the fields are saturated, the lakes or rivers are over flowing their banks and it impacts the economy, environment and our way of life

Photo: Wucher, L. St. Gregor SK Sept 6, 2010


Droughts can cover large areas of the Canadian Prairies and beyond
c) 2001
Edmonton
The Pas
Saskatoon
Regina
Medicine Hat
Winnipeg
Helena
Bismarck
Minneapolis
Boise City
Des Moines
Salt Lake City
Denver
August PDSI 2001
North America Great Plains
src

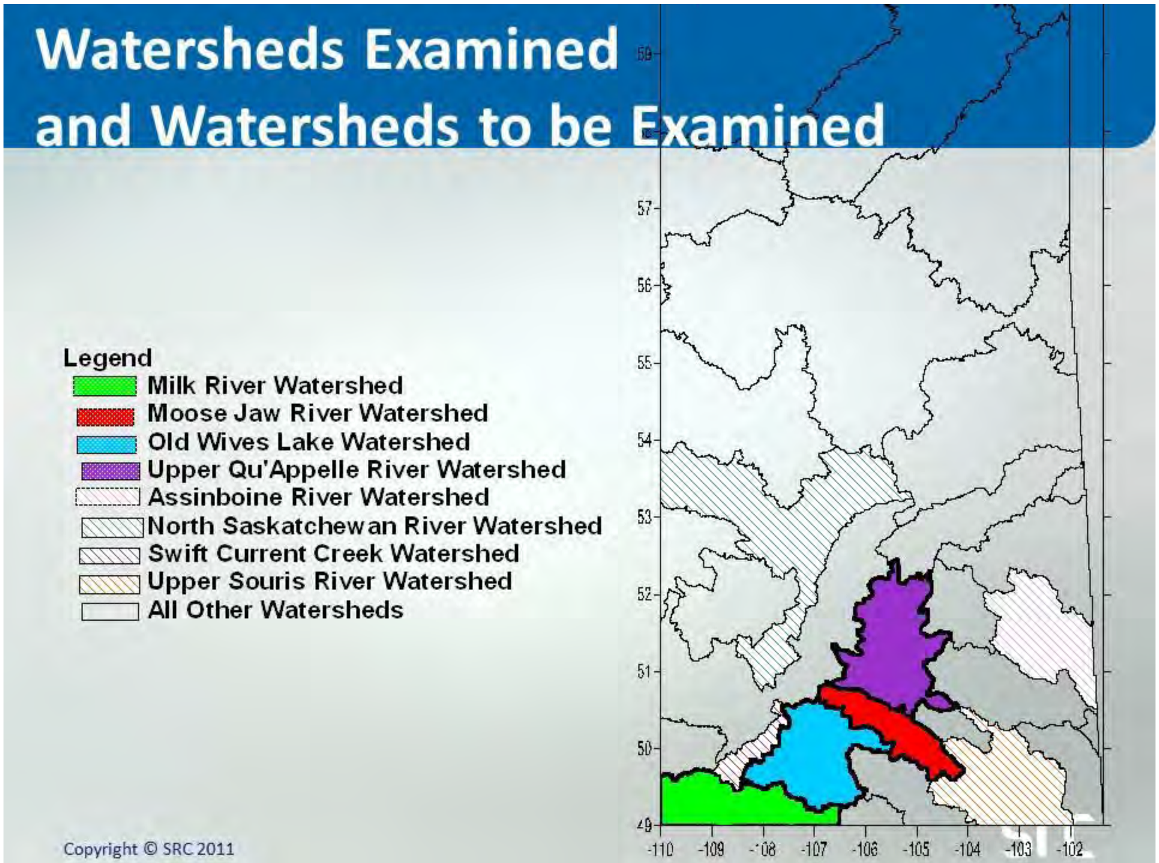

How did we figure out the past?
Drought
Excessive Moisture
Drought, from coast to coast
Drought going from bad to grim
St. Lawrence Seaway
Drought losses mount in Sask., Alta.
Drought fallout widespread
Drought puts pastures in peril
Hot, dry summer hits areas across Canada
Drought-stressed farmers need help
Farm earnings shrivel
Drought costs economy millions
Grain industry expected to generate $770 million less than last year
Flash flood turns Alta. ranch into soggy prison
Unseeded acres require trip to lender
Rain hits hard across Prairies
Rain could put 12 million acres in limbo
2010 breaks rain records
Deluge of rain followed by deluge of aid requests
Rain leaves 30 percent of Sask. unseeded
Recent Sask. rain dashes hopes for quality
Weather batters Viterra earnings
Rain washes away fertility
Tracks make combines amphibious
Grades frustrate farmers
Floods contaminate rural wells
Maple Creek wells test positive for nitrates, E. coli
Man. fields too wet for haying
Wet feet turning crops yellow
Fungus finds foothold in farmers' fields
Downpour floods town, roads

Methods

- Use a gridded **Palmer Drought Severity Index**(PDSI), **PDSI z-value** and **Standardized Precipitation Index** (SPI) to develop database for 1901 to 2005.
- Other sources are used to document the more recent drought and excessive moisture events.

Methods continued

- **Rank** the 10 driest and 10 wettest years in the watershed
- **Spatial variability** is determined from these rankings.
- Literature review and media analysis to determine the **impacts** and **adaptation** strategies undertaken


Watersheds Examined
and Watersheds to be Examined
Legend
Milk River Watershed
Moose Jaw River Watershed
Old Wives Lake Watershed
Upper Qu'Appelle River Watershed
Assinboine River Watershed
North Saskatchewan River Watershed
Swift Current Creek Watershed
Upper Souris River Watershed
All Other Watersheds
Copyright © SRC 2011


How do we classify severe drought,
excessive moisture or average conditions?
Source: V. Wittrock Aug 1 2009
Drought & cold stressed crop
(short & thin) (Field near Neidpath)
Source: Weslulz YouTube Video April 15, 2011
Aerial View of floodwaters surrounding
portions of Gravelbourg
Copyright © SRC 2011

Palmer Drought Severity Index (PDSI)

- One of the most widely used drought and excessive moisture indices
- Primarily a hydrological drought index
- Derived using a soil moisture/water balance model which requires information on the available soil water content along with daily/monthly precipitation and temperature data
- Values contain a long term memory of the previous moisture conditions because the calculated value.

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What do PDSI values mean?

Classification		PDSI Value
Drought	Exceptional	≤ -5
	Extreme	> -5.0 to -4.0
	Severe	> -4.0 to -3.0
	Moderate	> -3.0 to -2.0
	Mild	> -2.0 to -1.0
Near Normal		> -1.0 to 1.0
Wet	Mild	1.0 to < 2.0
	Moderate	2.0 to < 3.0
	Severe	3.0 to < 4.0
	Extreme	4.0 to < 5.0
	Exceptional	≥ 5.0

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Top 10 Extreme Years and Wheat Yields Palmer Drought Severity Index

(1901-2005 Agriculture Year (Sept to Aug))

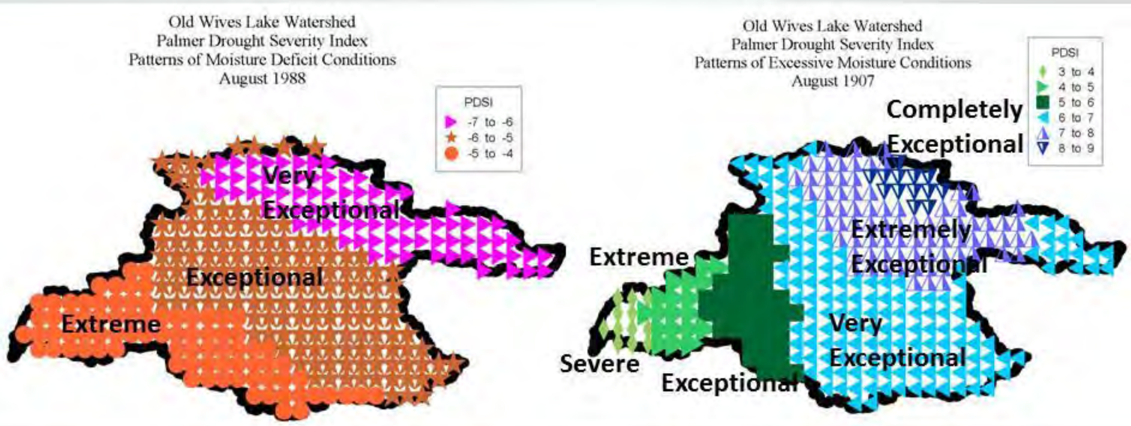
Drought			Excessive Moisture		
Year	PDSI	Change in Wheat Yield*	Year	PDSI	Change in Wheat Yield*
1988	-6.4	-67.0	1907	8.5	Not Available
1937	-6.4	Not Available	1909	7.2	Not Available
1931	-6.0	Not Available	1954	7.1	-51.6
1961	-5.9	-79.1	1955	6.8	-12.9
1919	-5.4	Not Available	1966	6.2	-2.2
1929	-5.3	Not Available	1991	6.1	19.9
1984	-5.3	-34.2	2004	5.9	28.4
1946	-5.3	-70.9	1951	5.5	-36.7
1981	-5.2	2.0	1974	5.5	-26.7
1959	-5.1	-50.5	1916	5.4	Not Available

*Spring Wheat Percent from 2000 to 2009 10 yr Average

Averaged over entire watershed

Wheat Yield data:
SK Ministry of Agriculture

Most Extreme Years (12-month PDSI)



Standard Precipitation Index (SPI)

- Developed to monitor moisture supply conditions
- Identifies emerging droughts months earlier than the PDSI because antecedent moisture conditions are not taken into account
- SPI does not calculate temperature anomalies, a critical feature for agricultural drought monitoring

What do SPI values mean?

Classification		SPI Value
Drought	Exceptional	≤ -2.5
	Extreme	> -2.5 to -2.0
	Severe	> -2.0 to -1.5
	Moderate	> -1.5 to -1.0
	Mild	> -1.0 to -0.5
Near Normal		> -0.5 to 0.5
Wet	Mild	0.5 to < 1.0
	Moderate	1.0 to < 1.5
	Severe	1.5 to < 2.0
	Extreme	2.0 to < 2.5
	Exceptional	≥ 2.5

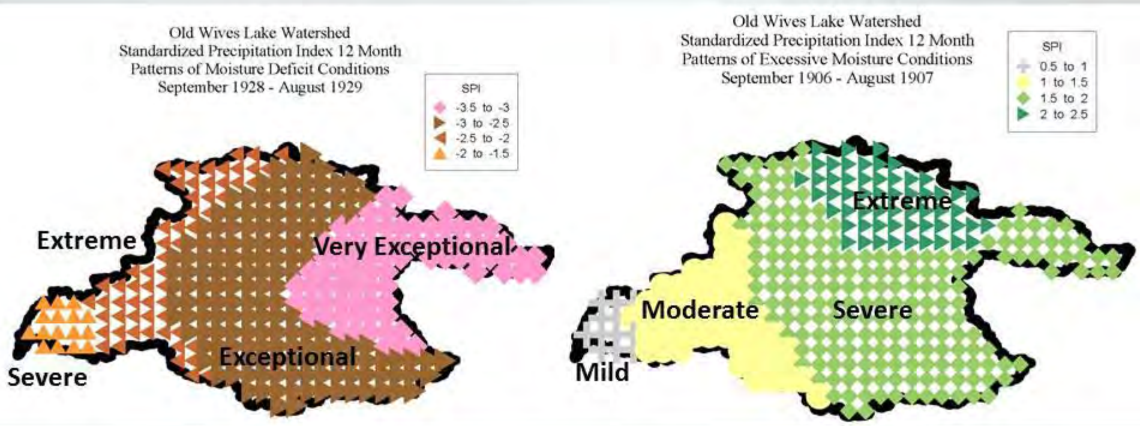
Top 10 - 12 Month Extremes (Sept – Aug) Standardized Precipitation Index (1901-2005)

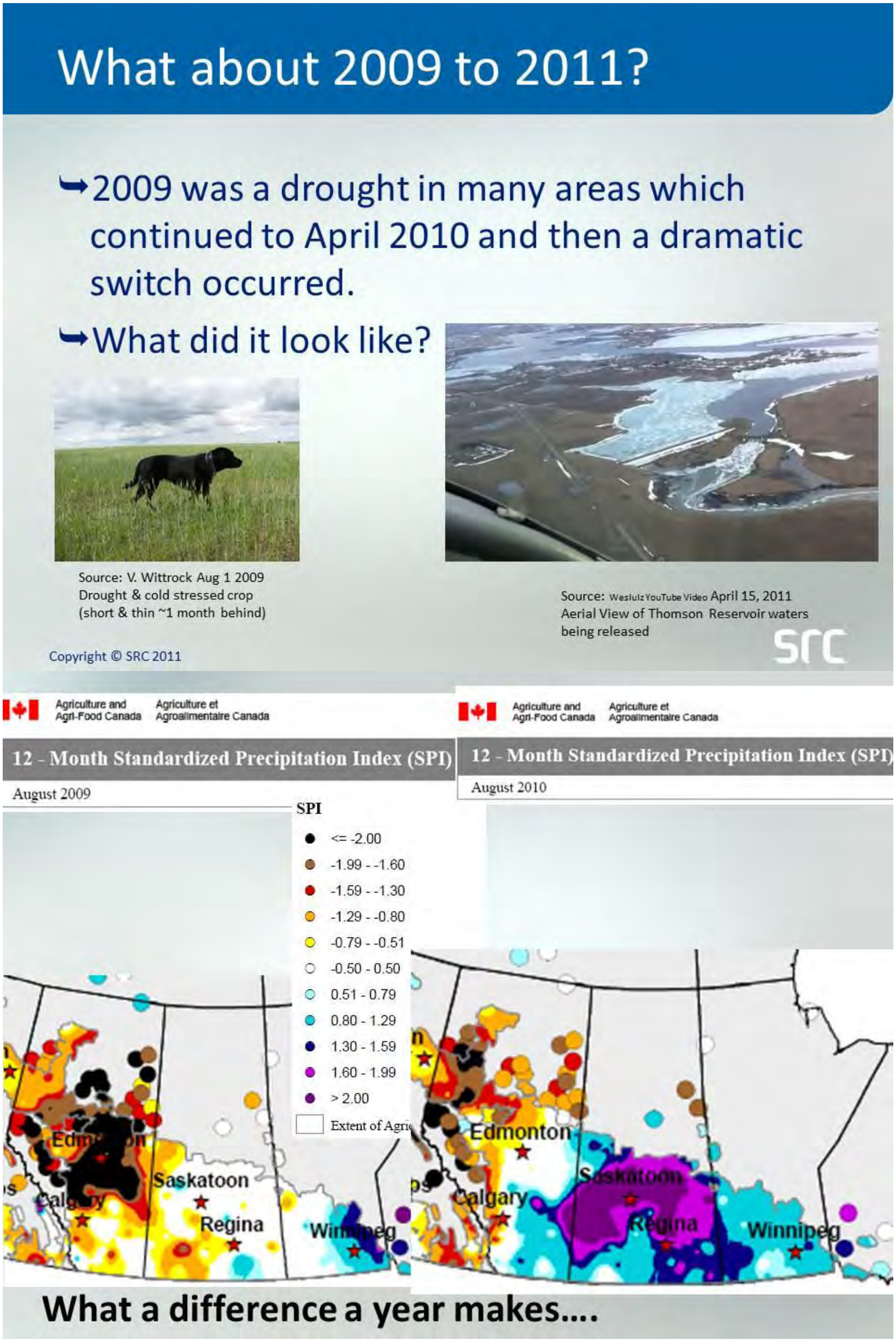
Drought			Excessive Moisture		
Year	SPI 12	Change in Wheat Yield*	Year	SPI 12	Change in Wheat Yield*
1929	-3.2	Not Available	1907	2.5	Not Available
1988	-2.7	-67.0	1974	2.1	-26.7
1961	-2.6	-79.1	2004	2.1	28.4
1937	-2.4	Not Available	1991	1.9	19.9
1949	-2.2	-87.8	1965	1.9	-10.2
1984	-2.1	-34.2	1955	1.8	-12.9
1971	-2.1	-14.2	1927	1.8	Not Available
1936	-2.0	Not Available	1916	1.8	Not Available
1945	-1.8	-78.7	1954	1.7	-51.6
1967	-1.8	-46.7	1951	1.6	-36.7

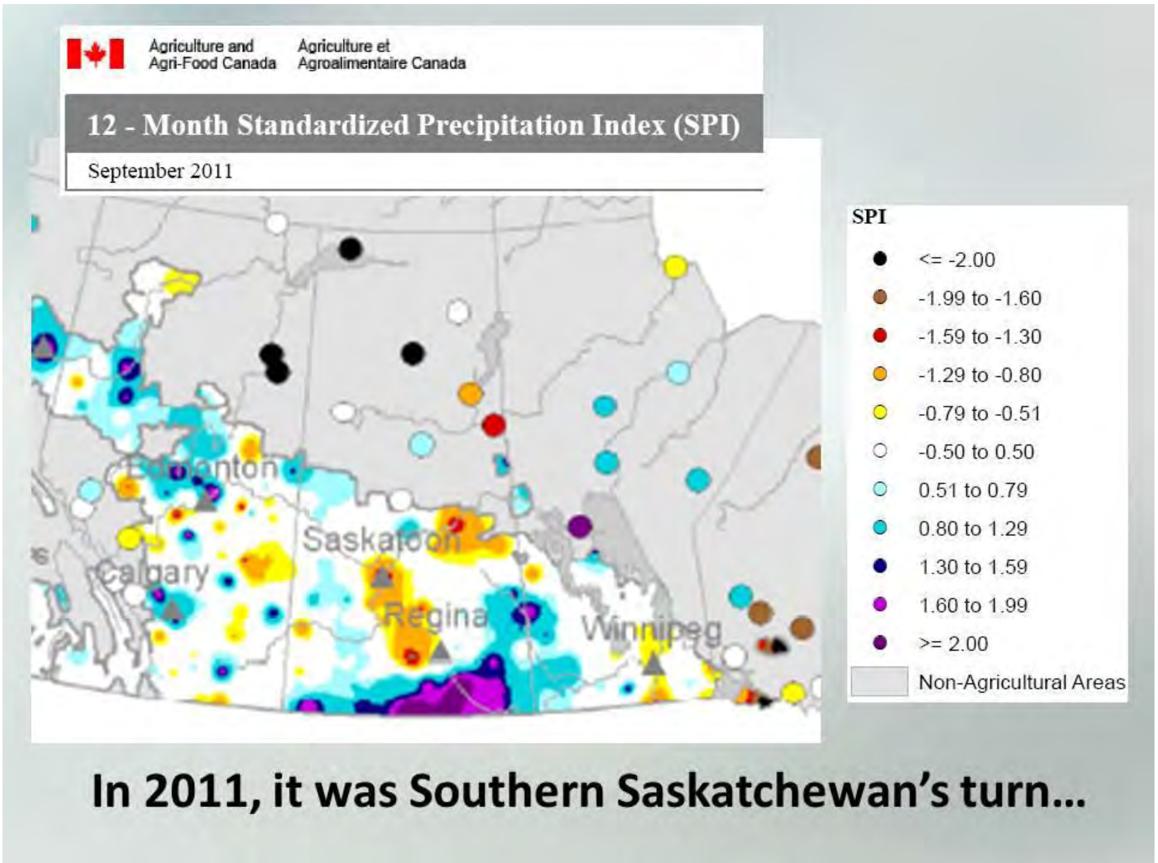
*Spring Wheat Percent from 2000 to 2009 10 yr Average
Averaged over entire watershed

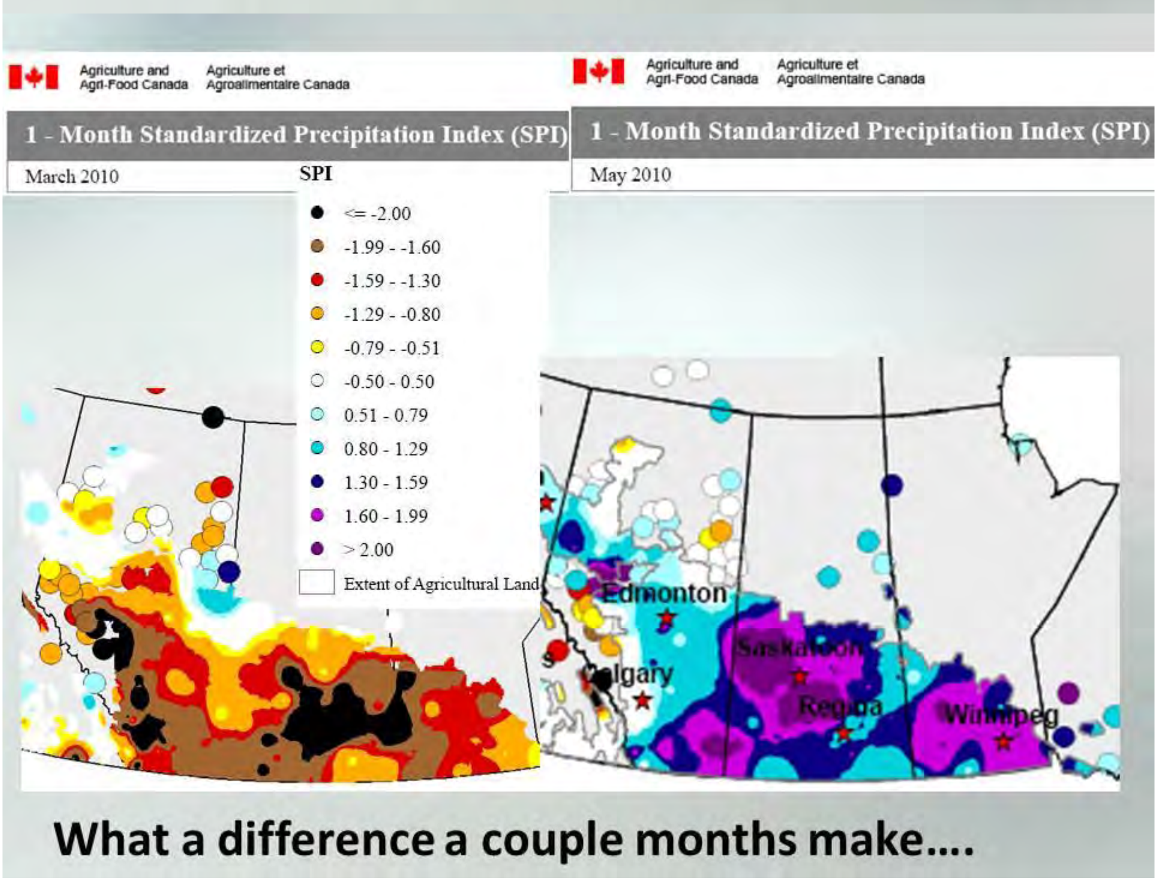
Wheat Yield data:
SK Ministry of Agriculture

SPI – 12 month extremes




What about 2009 to 2011?
2009 was a drought in many areas which continued to April 2010 and then a dramatic switch occurred.
What did it look like?
Source: V. Wittrock Aug 1 2009
Drought & cold stressed crop
(short & thin ~1 month behind)
Source: Wesluiz YouTube Video April 15, 2011
Aerial View of Thomson Reservoir waters being released
Copyright © SRC 2011
src
Agriculture and Agri-Food Canada
Agriculture et Agroalimentaire Canada
12 - Month Standardized Precipitation Index (SPI)
August 2009
SPI
<= -2.00
-1.99 - -1.60
-1.59 - -1.30
-1.29 - -0.80
-0.79 - -0.51
-0.50 - 0.50
0.51 - 0.79
0.80 - 1.29
1.30 - 1.59
1.60 - 1.99
> 2.00
Saskatoon
Regina
Agriculture and Agri-Food Canada
Agriculture et Agroalimentaire Canada
12 - Month Standardized Precipitation Index (SPI)
August 2010
Edmonton
Calgary
Saskatoon
Regina
Winnipeg
What a difference a year makes....


Agriculture and Agri-Food Canada
Agriculture et Agroalimentaire Canada
12 - Month Standardized Precipitation Index (SPI)
September 2011
Edmonton
Saskatoon
Calgary
Regina
Winnipeg
SPI
<= -2.00
-1.99 to -1.60
-1.59 to -1.30
-1.29 to -0.80
-0.79 to -0.51
-0.50 to 0.50
0.51 to 0.79
0.80 to 1.29
1.30 to 1.59
1.60 to 1.99
>= 2.00
Non-Agricultural Areas
In 2011, it was Southern Saskatchewan's turn…


Agriculture and Agri-Food Canada
Agriculture et Agroalimentaire Canada
1 - Month Standardized Precipitation Index (SPI)
March 2010
SPI
<= -2.00
-1.99 - -1.60
-1.59 - -1.30
-1.29 - -0.80
-0.79 - -0.51
-0.50 - 0.50
0.51 - 0.79
0.80 - 1.29
1.30 - 1.59
1.60 - 1.99
> 2.00
Extent of Agricultural Land
Agriculture and Agri-Food Canada
Agriculture et Agroalimentaire Canada
1 - Month Standardized Precipitation Index (SPI)
May 2010
Edmonton
Calgary
Saskatoon
Regina
Winnipeg
What a difference a couple months make….

These Extreme Years have Impacted Everyone and Adaptation Strategies have been Applied

src

Impacts from Droughts

- Soil erosion
- Water shortages
- Feed shortages
- Poor yielding crops
- Economic instability
- etc

Photo Source: AAFC

src

Adaptations to Droughts

- Installation of weirs/dams that allow for more stable water supply (e.g., Thomson Reservoir, Highfield Dam)
- Increased irrigation projects
- Drought tolerant crops
- Minimum tillage
- Water conservation
- etc

Source: Weslulz YouTube Video April 15, 2011
Aerial View of Thomson Reservoir waters being released

Photo Source: E. Stratton circa 2002
St. Mary's Irrigation District

Impacts from Excessive Moisture

- Soil erosion
- Water quality issues (both surface and ground water)
- Degraded crops (crops under water) decreased yield and quality
- Infrastructure problems (e.g., roads, basements)
- etc

S. Wittrock July 2010 East of Swift Current

Adaptations to Excessive Moisture

- Installation of dams that allow for some flood control (e.g., Highfield Dam, Thomson Reservoir)
- Different crops to adapt to diseases and excess moisture conditions
- Minimum tillage
- Re-establishment of riparian zones
- etc

Highfield Dam Road

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Conclusion and Questions

- Old Wives Lake Watershed has always had extreme events and future ones could be worse…
- **But** the trick is to learn from the past to better adapt to our ever evolving future.
- There are still many questions to be asked,
  - What if 2012 is as wet as 2011?
  - Changing infrastructure to accommodate excessive moisture occurrences e.g., Vanguard Storm in 2000?
  - What if we have a 10 year drought, how will we be impacted and will we be able to adapt?

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Questions?

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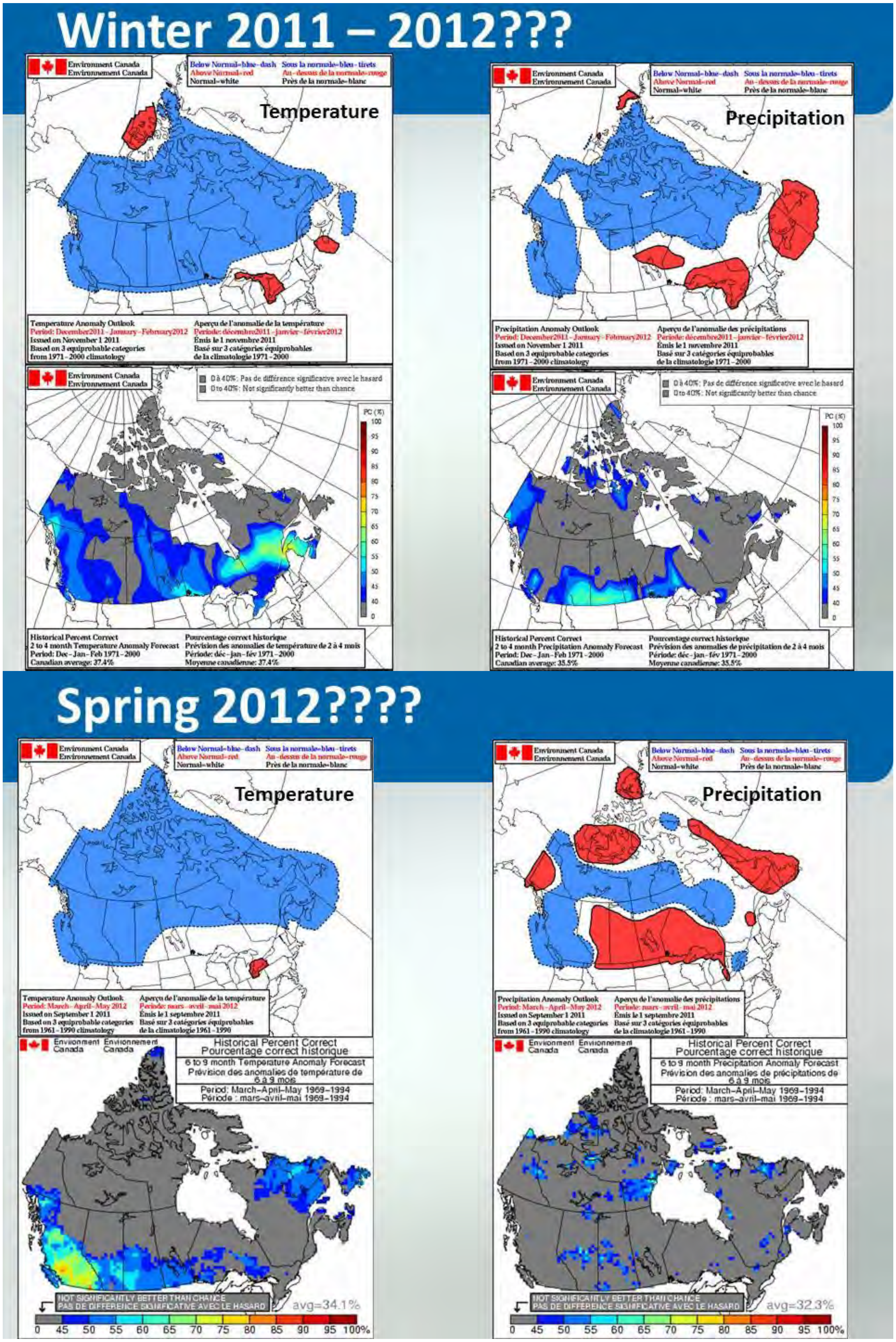
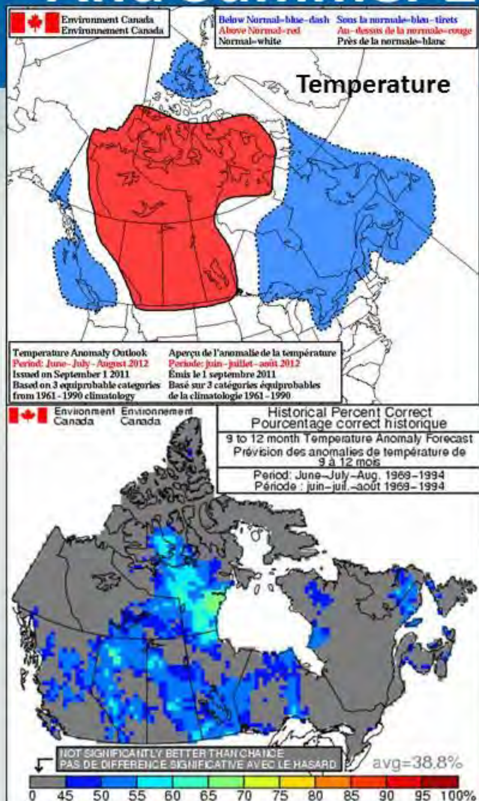
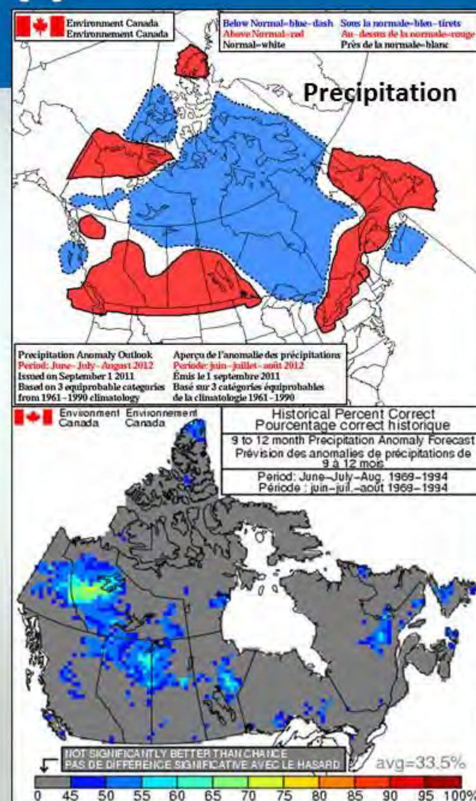
- Photos:
  - Cracked Earth and soil drifts– Agriculture and Agri-Food Canada (AAFC)
  - Tractor stuck: Wucher, L. St. Gregor SK Sept 6 2010
  - Drought and cold stress crop – V. Wittrock Aug 1, 2009 Neidpath
  - Floodwaters at Gravelbourg – Weslulz April 15, 2011 Web site: http://www.youtube.com/user/Weslulz Accessed Nov 2011
  - Thomson Reservoir – Weslulz April 15, 2011 Web site: http://www.youtube.com/user/Weslulz Accessed Nov 2011
  - St Mary's Irrigation – E. Stratton 2002
  - Thunderhead cloud – S. Wittrock 2010 East of Swift Current
  - Highfield Dam Road – Web site: http://www.pentaxforums.com/gallery/images/24373/large/1_Highfield_Damn_Road_Southeast_of_Rush_Lake.jpg Accessed Nov 2011
  - Harvest– V. Wittrock October 2010 Neidpath


Winter 2011 – 2012???
Temperature
Precipitation
Environment Canada
Environnement Canada
Below Normal–blue–dash Sous la normale–bleu–tirets
Above Normal–red Au–dessus de la normale–rouge
Normal–white Près de la normale–blanc
Temperature Anomaly Outlook
Period: December2011 – January – February2012
Issued on November 1 2011
Based on 3 equiprobable categories
from 1971 – 2000 climatology
Aperçu de l'anomalie de la température
Periode: décembre2011 – janvier – février2012
Émis le 1 novembre 2011
Basé sur 3 catégories équiprobables
de la climatologie 1971 – 2000
Precipitation Anomaly Outlook
Aperçu de l'anomalie des précipitations
0 à 40%: Pas de différence significative avec le hasard
0 to 40%: Not significantly better than chance
PC (%)
Historical Percent Correct
2 to 4 month Temperature Anomaly Forecast
Period: Dec – Jan – Feb 1971 – 2000
Canadian average: 37.4%
Pourcentage correct historique
Prévision des anomalies de température de 2 à 4 mois
Période: déc – jan – fév 1971 – 2000
Moyenne canadienne: 37.4%
2 to 4 month Precipitation Anomaly Forecast
Canadian average: 35.5%
Prévision des anomalies de précipitation de 2 à 4 mois
Moyenne canadienne: 35.5%
Spring 2012????
Temperature
Precipitation
Period: March – April – May 2012
Issued on September 1 2011
from 1961 – 1990 climatology
Période: mars – avril – mai 2012
Émis le 1 septembre 2011
de la climatologie 1961 – 1990
Historical Percent Correct
Pourcentage correct historique
6 to 9 month Temperature Anomaly Forecast
Prévision des anomalies de température de 6 à 9 mois
6 to 9 month Precipitation Anomaly Forecast
Prévision des anomalies de précipitations de 6 à 9 mois
Period: March–April–May 1969–1994
Période : mars–avril–mai 1969–1994
NOT SIGNIFICANTLY BETTER THAN CHANCE
PAS DE DIFFERENCE SIGNIFICATIVE AVEC LE HASARD
avg=34.1%
avg=32.3%
0 45 50 55 60 65 70 75 80 85 90 95 100%

And Summer 2012???





What's next?

- Study of 2010 and 2011 for excessive moisture
- Future drought and excessive moisture
- etc

src

Gridded data

- Gridded data sets preferred over station data due to improved spatial/temporal coverage
- Gridding data procedure removes unnecessary noise, resulting in smoother data for mapping
- PDSI and SPI derived from the ANUSPLIN data set
- ANUSPLIN was chosen for ability to capture several significant precipitation events, for better comparability with data and for area covered
- Develop data bases of PDSI and SPII for the watersheds (10 KM grid)

src

Top 10 most extreme years PDSI Z-Value
(1901-2005 Agriculture Year (Sept to Aug))

Drought

Year	PDSI Z-value	Change in Wheat Yield*
1961	-5.4	-79.1
1971	-4.8	-14.2
2001	-4.7	-22.0
1929	-4.5	Not Available
1984	-4.1	-34.2
2003	-4.0	-21.3
1967	-4.0	-46.7
1983	-3.9	-0.1
1901	-3.6	Not Available
1970	-3.6	6.7

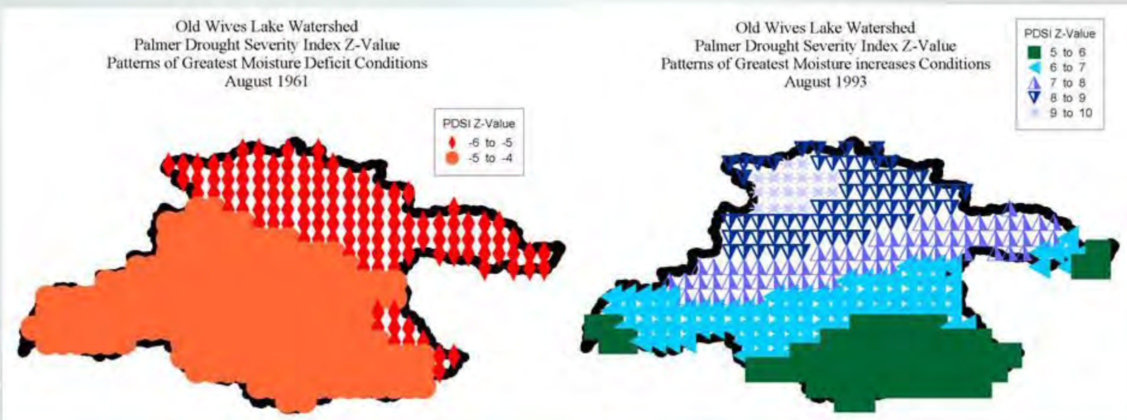
Excessive Moisture

Year	PDSI Z-value	Change in Wheat Yield*
1993	9.5	17.3
1954	9.1	-51.6
2002	8.8	-4.3
1974	7.3	-26.7
1951	7.3	-36.7
1907	7.2	Not Available
2004	5.9	28.4
1968	5.8	-36.4
1975	5.8	0.0
1995	5.7	2.3

*Spring Wheat Percent from 2000 to 2009 10 yr Average
Average over entire watershed

Wheat Yield data: SK Ministry of Agriculture

PDSI Z-Value



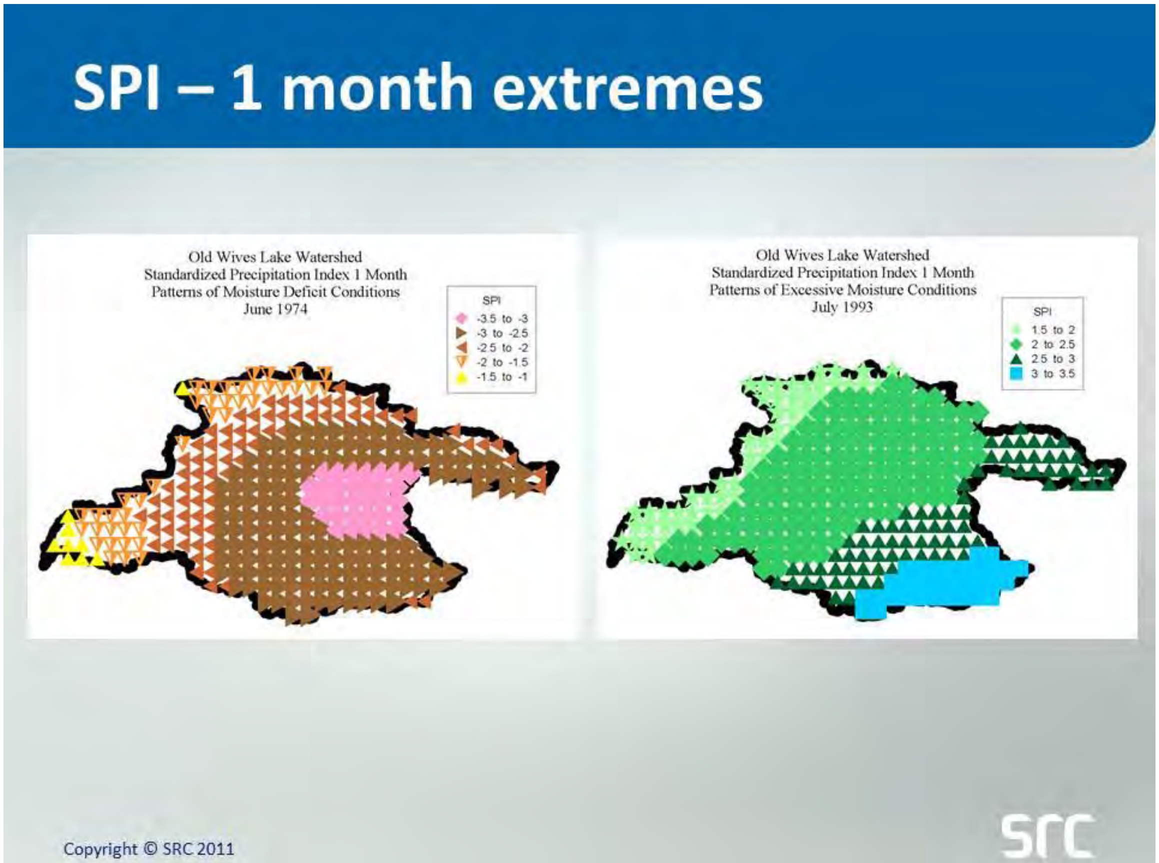
src

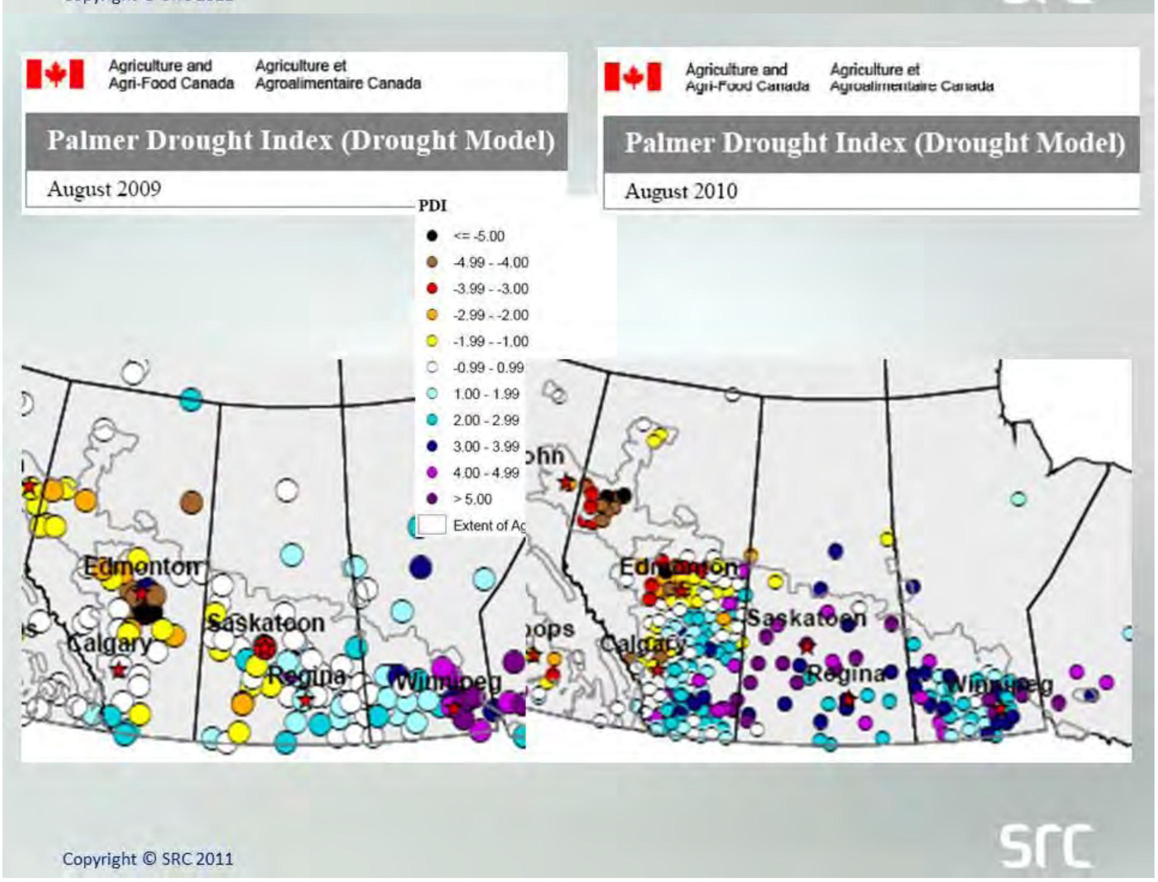
Top 10 most extreme years SPI – 1 Month (1901-2005)

Drought				Excessive Moisture			
Year	Month	SPI01	Change in Wheat Yield*	Year	Month	SPI01	Change in Wheat Yield*
1974	6	-3.5	-26.7	1993	7	3.4	17.3
1968	3	-3.5	-36.4	1975	3	3.3	0.0
1973	1	-3.4	-15.6	1998	10	3.2	-2.4
2005	2	-3.3	13.2	1904	3	3.0	Not Available
1959	12	-3.3	-50.5	1927	5	3.0	Not Available
1985	6	-3.3	-68.3	1986	9	3.0	14.4
1917	5	-3.3	Not Available	1967	3	2.9	-46.7
1967	6	-3.2	-46.7	1971	1	2.9	-14.2
1978	3	-3.2	11.5	1978	9	2.8	11.5
1961	8	-3.1	-79.1	1955	7	2.8	-12.9

*Spring Wheat Percent from 2000 to 2009 10 yr Average
Average over entire watershed

Wheat Yield data:
SK Ministry of Agriculture


SPI – 1 month extremes
Old Wives Lake Watershed
Standardized Precipitation Index 1 Month
Patterns of Moisture Deficit Conditions
June 1974
SPI
-3.5 to -3
-3 to -2.5
-2.5 to -2
-2 to -1.5
-1.5 to -1
Old Wives Lake Watershed
Standardized Precipitation Index 1 Month
Patterns of Excessive Moisture Conditions
July 1993
SPI
1.5 to 2
2 to 2.5
2.5 to 3
3 to 3.5
Copyright © SRC 2011


Agriculture and Agri-Food Canada
Agriculture et Agroalimentaire Canada
Palmer Drought Index (Drought Model)
August 2009
PDI
<= -5.00
-4.99 - -4.00
-3.99 - -3.00
-2.99 - -2.00
-1.99 - -1.00
-0.99 - 0.99
1.00 - 1.99
2.00 - 2.99
3.00 - 3.99
4.00 - 4.99
> 5.00
Edmonton
Calgary
Saskatoon
Regina
Winnipeg
Agriculture and Agri-Food Canada
Agriculture et Agroalimentaire Canada
Palmer Drought Index (Drought Model)
August 2010
Edmonton
Calgary
Saskatoon
Regina
Winnipeg
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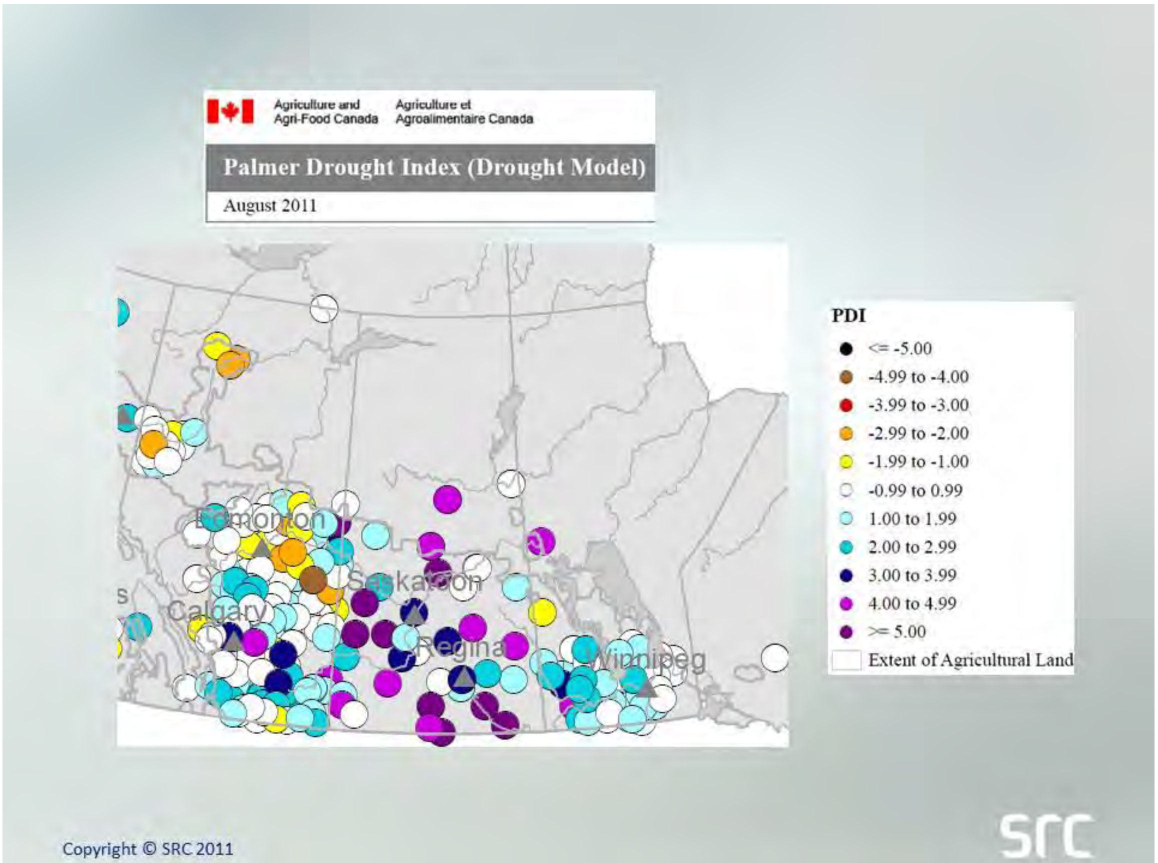
Agriculture and Agri-Food Canada
Agriculture et Agroalimentaire Canada
Palmer Drought Index (Drought Model)
August 2011
Edmonton
Saskatoon
Calgary
Regina
Winnipeg
PDI
<= -5.00
-4.99 to -4.00
-3.99 to -3.00
-2.99 to -2.00
-1.99 to -1.00
-0.99 to 0.99
1.00 to 1.99
2.00 to 2.99
3.00 to 3.99
4.00 to 4.99
>= 5.00
Extent of Agricultural Land
Copyright © SRC 2011
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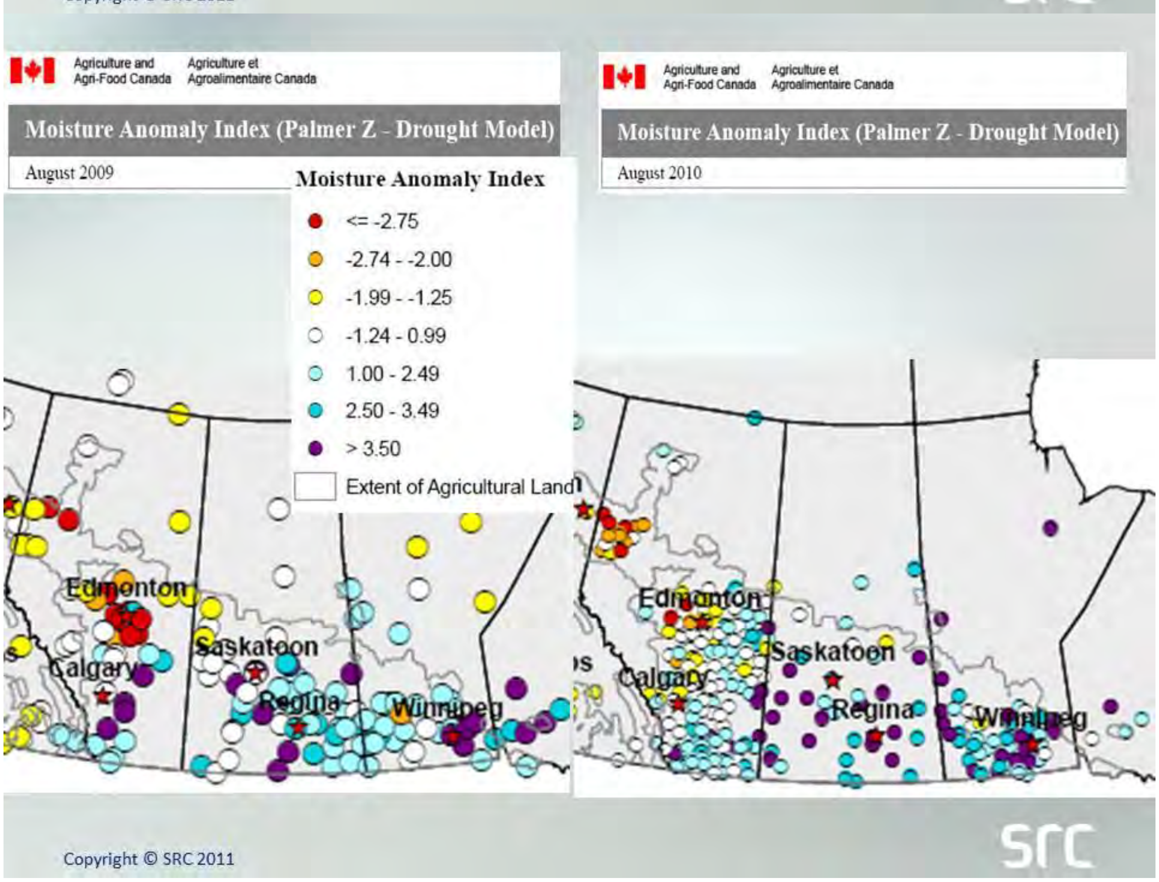
Agriculture and Agri-Food Canada
Agriculture et Agroalimentaire Canada
Moisture Anomaly Index (Palmer Z - Drought Model)
August 2009
Moisture Anomaly Index
<= -2.75
-2.74 - -2.00
-1.99 - -1.25
-1.24 - 0.99
1.00 - 2.49
2.50 - 3.49
> 3.50
Extent of Agricultural Land
Edmonton
Saskatoon
Calgary
Regina
Winnipeg
Agriculture and Agri-Food Canada
Agriculture et Agroalimentaire Canada
Moisture Anomaly Index (Palmer Z - Drought Model)
August 2010
Edmonton
Saskatoon
Calgary
Regina
Winnipeg
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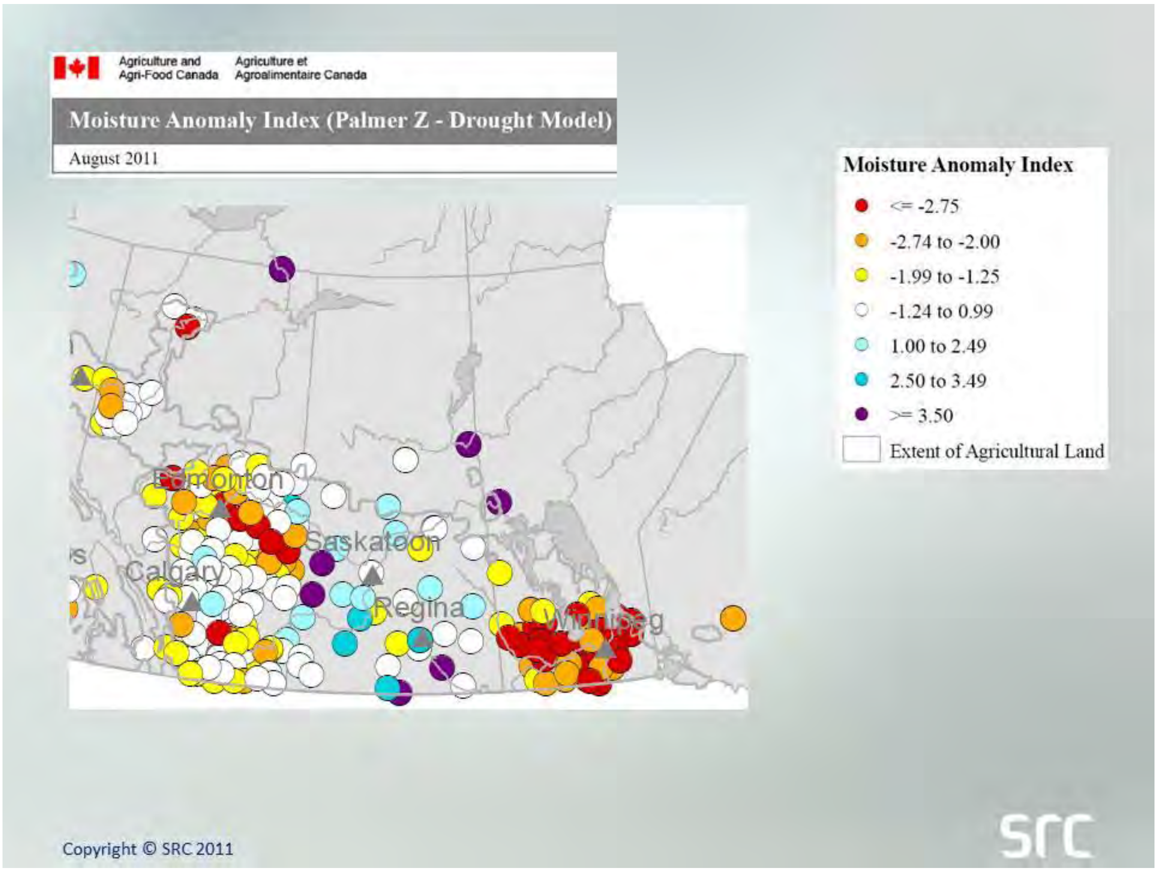
Agriculture and Agri-Food Canada
Agriculture et Agroalimentaire Canada
Moisture Anomaly Index (Palmer Z - Drought Model)
August 2011
Moisture Anomaly Index
<= -2.75
-2.74 to -2.00
-1.99 to -1.25
-1.24 to 0.99
1.00 to 2.49
2.50 to 3.49
>= 3.50
Extent of Agricultural Land
Edmonton
Saskatoon
Calgary
Regina
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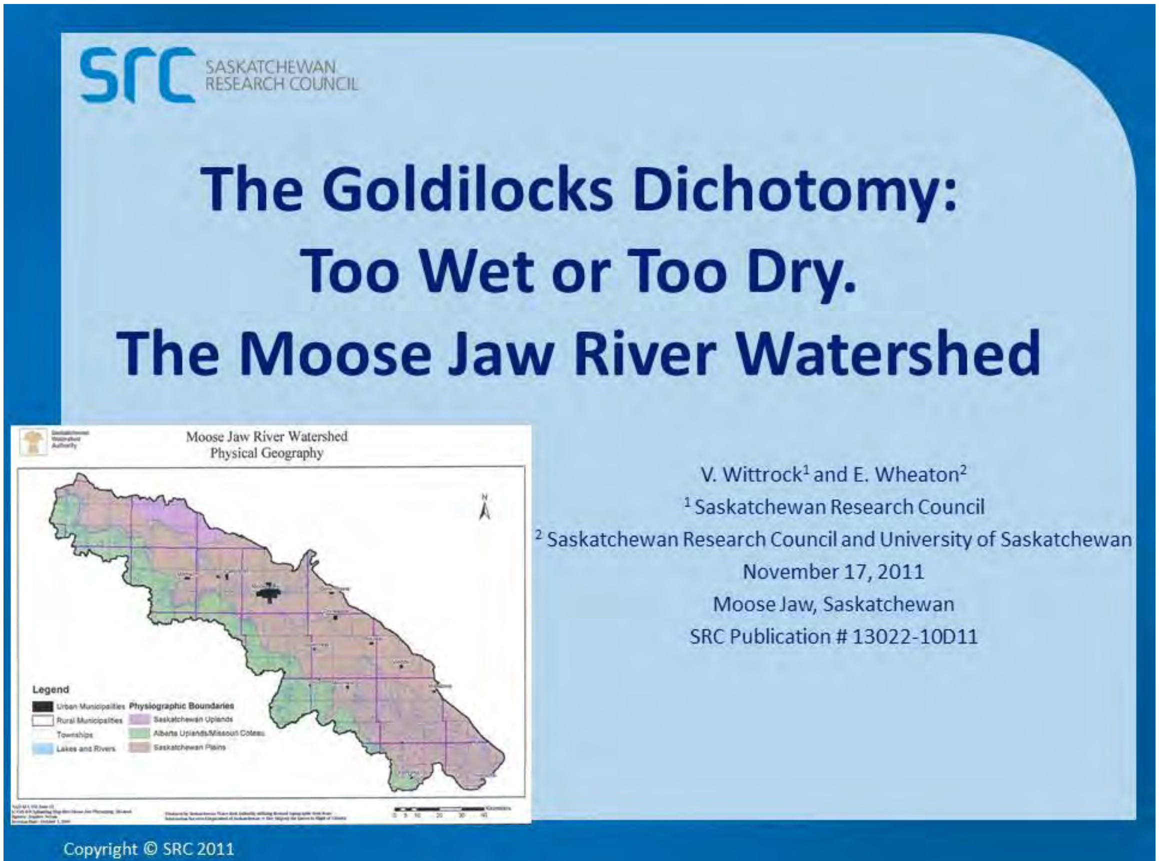
SRC SASKATCHEWAN RESEARCH COUNCIL
The Goldilocks Dichotomy:
Too Wet or Too Dry.
The Moose Jaw River Watershed
Moose Jaw River Watershed
Physical Geography
Legend
Physiographic Boundaries
V. Wittrock[1] and E. Wheaton[2]
[1] Saskatchewan Research Council
[2] Saskatchewan Research Council and University of Saskatchewan
November 17, 2011
Moose Jaw, Saskatchewan
SRC Publication # 13022-10D11
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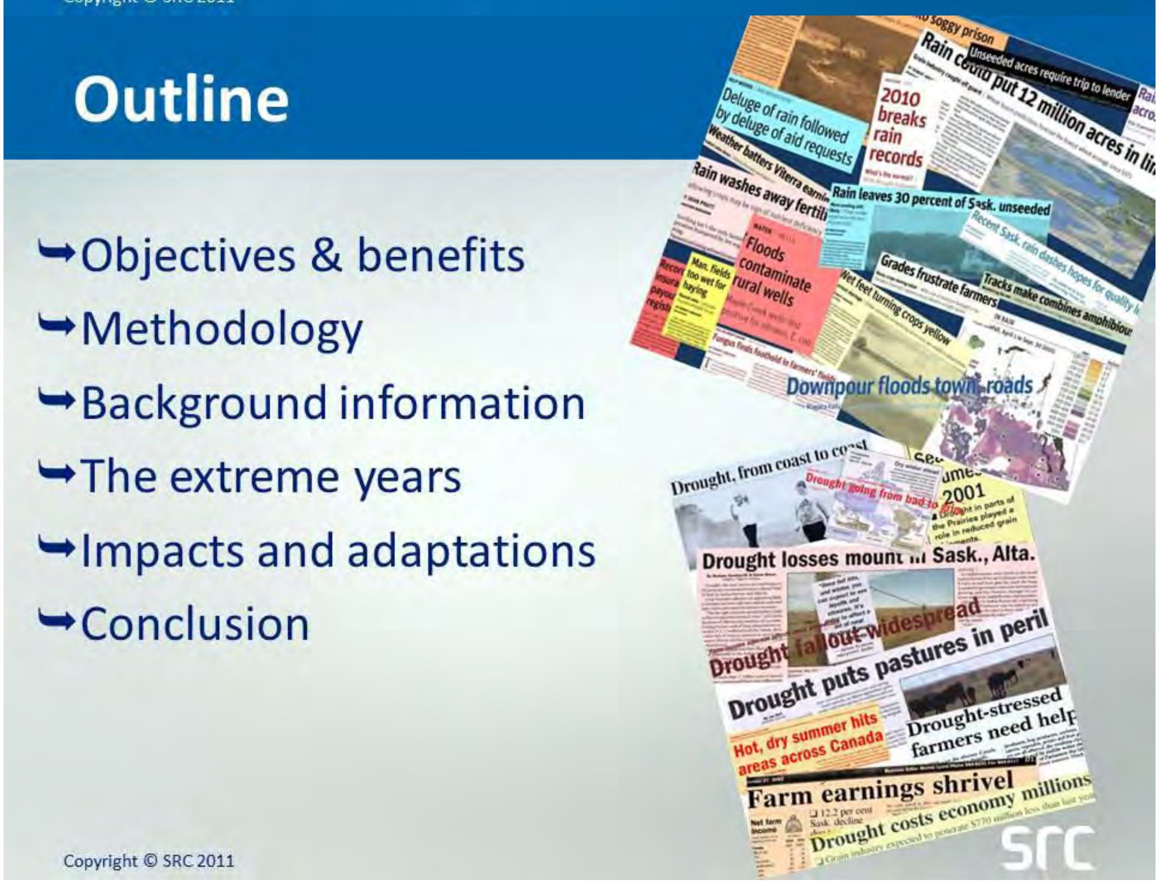
Outline
➥Objectives & benefits
➥Methodology
➥Background information
➥The extreme years
➥Impacts and adaptations
➥Conclusion
Deluge of rain followed by deluge of aid requests
2010 breaks rain records
Rain leaves 30 percent of Sask. unseeded
Floods contaminate rural wells
Grades frustrate farmers
Tracks make combines amphibious
Wet feet turning crops yellow
Downpour floods town, roads
Drought, from coast to coast
Drought losses mount in Sask., Alta.
Drought fallout widespread
Drought puts pastures in peril
Hot, dry summer hits areas across Canada
Drought-stressed farmers need help
Farm earnings shrivel
Drought costs economy millions
SRC
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Objectives

- To **characterize** drought and excessive moisture events for selected watersheds during the past century.
- **Compare** and **contrast** driest and wettest patterns to help determine characteristics for risk assessments and planning.
- Consider the **implications** for impacts and adaptations directly related to the watershed.

src

Benefits of Examining the Past

- Assist communities, local municipalities, provincial and federal governments with **risk management** and **planning strategies** for extreme events.
- **Avoid damages and decrease** the **costs** of climate events by learning from the past.
- Help to lower the **costs of the impacts of future climatic events.**

src

What is a Drought?

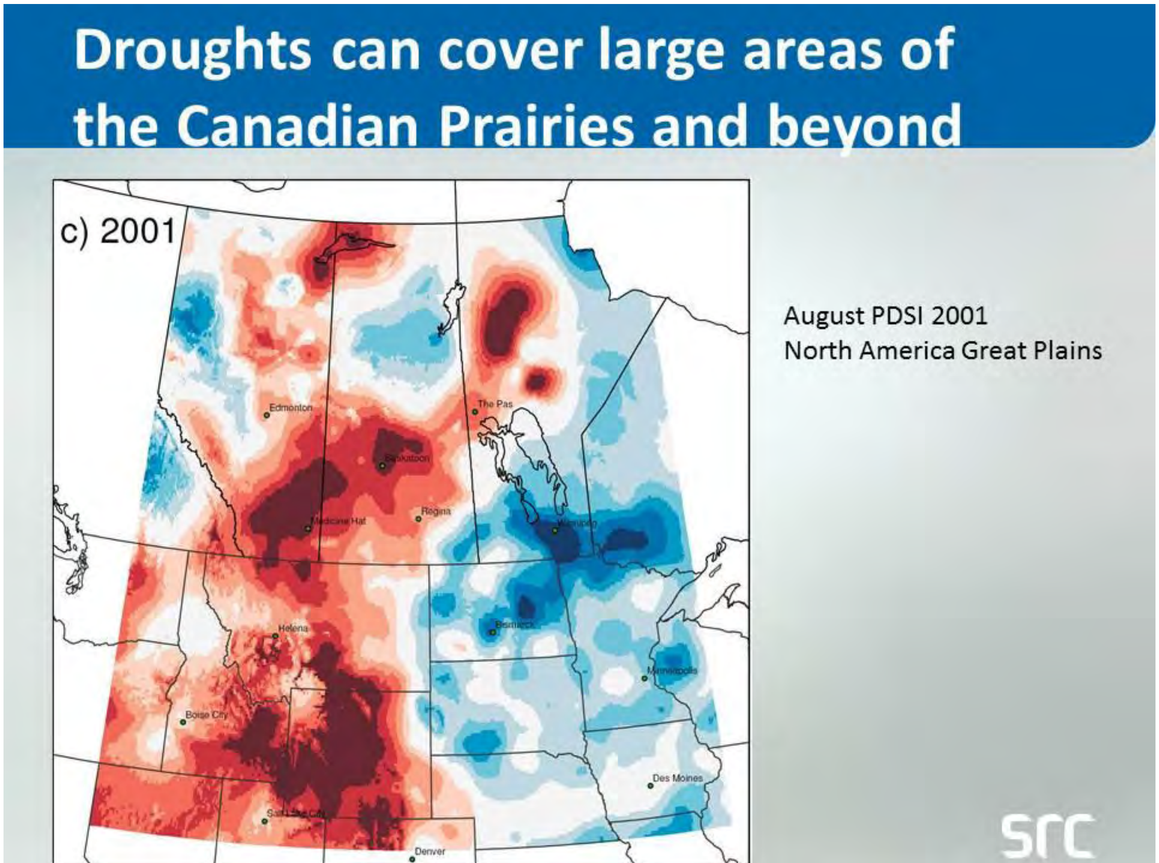
- A deficiency of precipitation from expected or "normal" that, when extended over a season or longer, is insufficient to meet the demands of human activities and the environment
- Four major types of drought including Meteorological, Agricultural, Hydrological and Socio-economic
- Or when it hasn't rained, the fields are dry, the lakes or rivers are really low and it impacts the economy, environment and our way of life

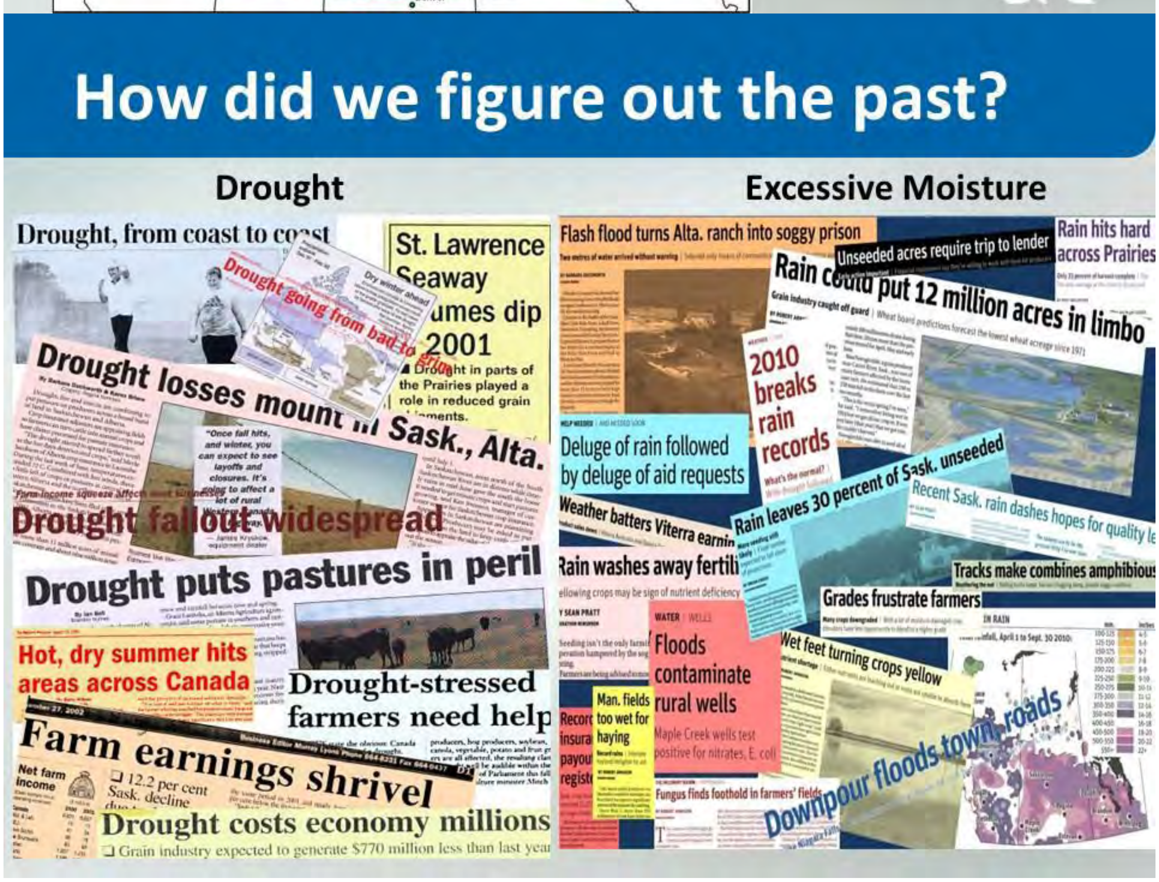
Photo: AAFC

What is Excessive Moisture?

- An excess of precipitation from expected or "normal" that, when extended over a season or longer, is too much to meet the demands of human activities and the environment
- Four major types of excess moisture including Meteorological, Agricultural, Hydrological and Socio-economic
- Or it won't quit raining, the fields are saturated, the lakes or rivers are over flowing their banks and it impacts the economy, environment and our way of life

Photo: Wucher, L. St. Gregor SK Sept 6, 2010


Droughts can cover large areas of the Canadian Prairies and beyond
c) 2001
Edmonton
The Pas
Saskatoon
Regina
Medicine Hat
Winnipeg
Helena
Bismarck
Minneapolis
Boise City
Des Moines
Denver
August PDSI 2001
North America Great Plains
src


How did we figure out the past?
Drought
Excessive Moisture
Drought, from coast to coast
St. Lawrence Seaway
Drought going from bad to grim
Drought losses mount in Sask., Alta.
Drought fallout widespread
Drought puts pastures in peril
Hot, dry summer hits areas across Canada
Drought-stressed farmers need help
Farm earnings shrivel
Drought costs economy millions
Grain industry expected to generate $770 million less than last year
Flash flood turns Alta. ranch into soggy prison
Unseeded acres require trip to lender
Rain hits hard across Prairies
Rain could put 12 million acres in limbo
2010 breaks rain records
Deluge of rain followed by deluge of aid requests
Weather batters Viterra earnings
Rain leaves 30 percent of Sask. unseeded
Recent Sask. rain dashes hopes for quality
Rain washes away fertility
Tracks make combines amphibious
Grades frustrate farmers
Floods contaminate rural wells
Man. fields too wet for haying
Maple Creek wells test positive for nitrates, E. coli
Wet feet turning crops yellow
Downpour floods town, roads
Fungus finds foothold in farmers' fields

Methods

- Use a gridded **Palmer Drought Severity Index**(PDSI), **PDSI z-value** and **Standardized Precipitation Index** (SPI) to develop database for 1901 to 2005.
- Other sources are used to document the more recent drought and excessive moisture events.

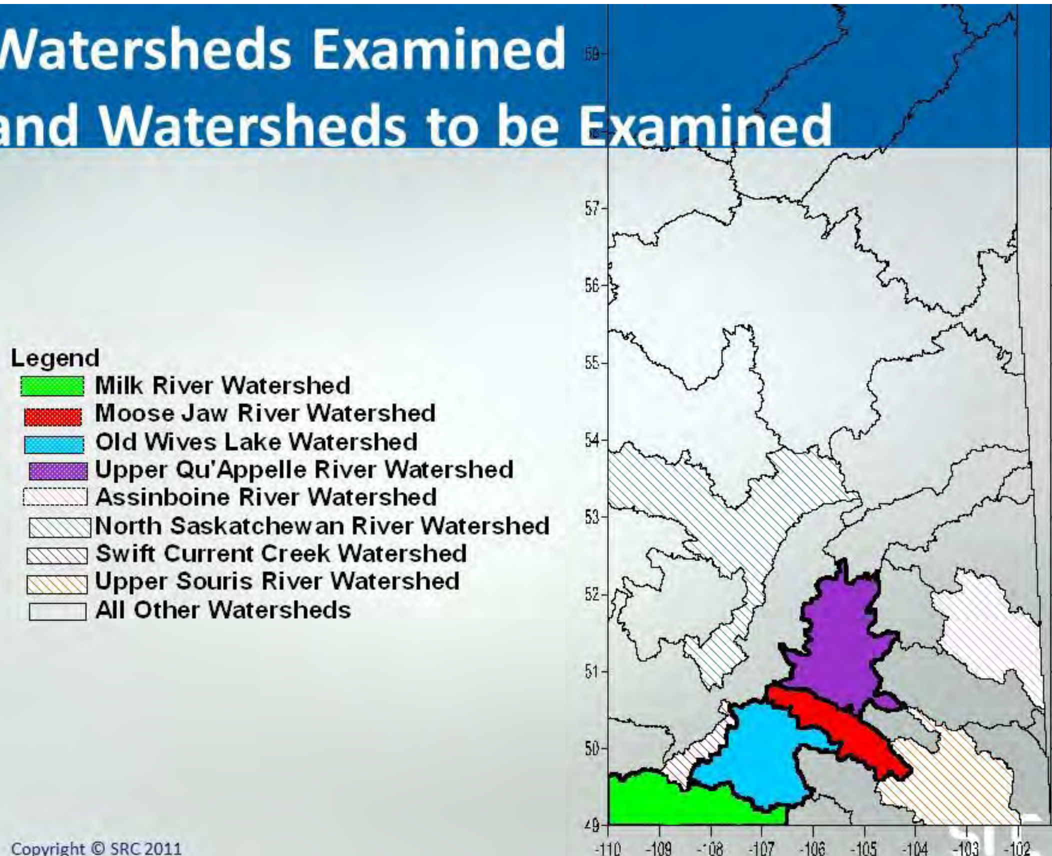
src

Methods continued

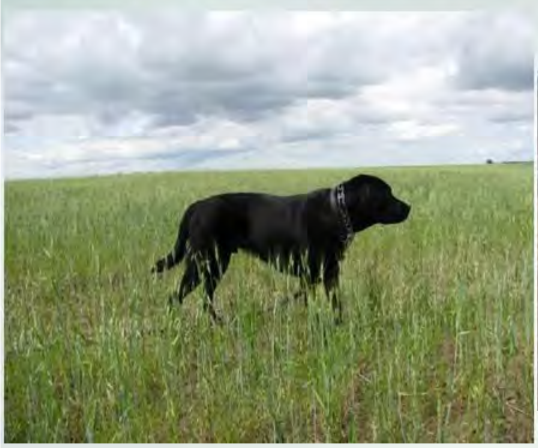
- **Rank** the 10 driest and 10 wettest years in the watershed
- **Spatial variability** is determined from these rankings.
- Literature review and media analysis to determine the **impacts** and **adaptation** strategies undertaken

src

Watersheds Examined and Watersheds to be Examined



How do we classify severe drought, excessive moisture or average conditions?



Source: V. Wittrock Aug 1 2009
Drought & cold stressed crop (short & thin) (Field near Neidpath)

Source: CBC News April 8, 2011
Bridge South of Moose Jaw

Palmer Drought Severity Index (PDSI)

- One of the most widely used drought and excessive moisture indices
- Primarily a hydrological drought index
- Derived using a soil moisture/water balance model which requires information on the available soil water content along with daily/monthly precipitation and temperature data
- Values contain a long term memory of the previous moisture conditions because the calculated value.

src

What do PDSI values mean?

Classification		PDSI Value
Drought	Exceptional	≤ -5
	Extreme	> -5.0 to -4.0
	Severe	> -4.0 to -3.0
	Moderate	> -3.0 to -2.0
	Mild	> -2.0 to -1.0
Near Normal		> -1.0 to 1.0
Wet	Mild	1.0 to < 2.0
	Moderate	2.0 to < 3.0
	Severe	3.0 to < 4.0
	Extreme	4.0 to < 5.0
	Exceptional	≥ 5.0

src

Top 10 Extreme Years and Wheat Yields Palmer Drought Severity Index

(1901-2005 Agriculture Year (Sept to Aug))

Drought

Year	PDSI	Change in Wheat Yield*
1988	-6.7	-54.4
1958	-6.5	-38.5
1984	-6.2	-24.8
1959	-6.0	-47.1
1961	-6.0	-62.8
1937	-5.9	Not Available
1981	-5.5	-6.0
1929	-5.2	Not Available
1931	-5.1	Not Available
1919	-5.0	Not Available

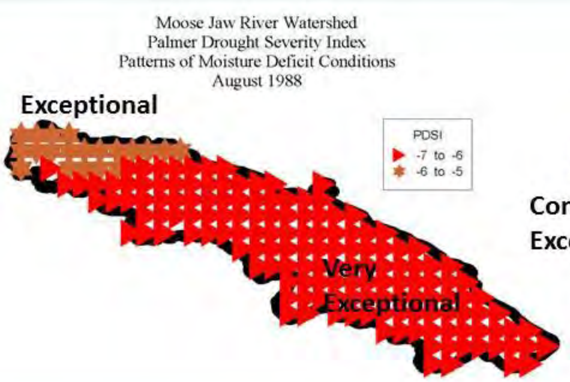
Excessive Moisture

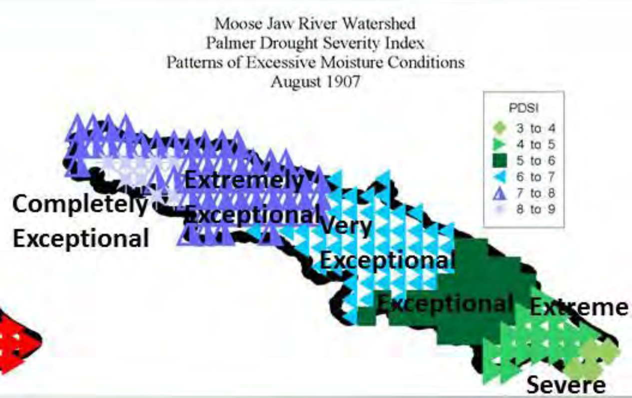
Year	PDSI	Change in Wheat Yield*
1907	8.2	Not Available
1909	7.0	Not Available
1955	6.8	-2.6
1991	6.4	14.1
1954	6.2	-78.1
1902	5.8	Not Available
1927	5.8	Not Available
1951	5.3	-21.9
1974	5.3	-22.9
1947	5.3	-37.0

*Spring Wheat Percent from 2000 to 2009 10 yr Average
Averaged over entire watershed

Wheat Yield data:
SK Ministry of Agriculture

Most Extreme Years (12-month PDSI)





Standard Precipitation Index (SPI)

- Developed to monitor moisture supply conditions
- Identifies emerging droughts months earlier than the PDSI because antecedent moisture conditions are not taken into account
- SPI does not calculate temperature anomalies, a critical feature for agricultural drought monitoring

src

What do SPI values mean?

Classification		SPI Value
Drought	Exceptional	≤ -2.5
	Extreme	> -2.5 to -2.0
	Severe	> -2.0 to -1.5
	Moderate	> -1.5 to -1.0
	Mild	> -1.0 to -0.5
Near Normal		> -0.5 to 0.5
Wet	Mild	0.5 to < 1.0
	Moderate	1.0 to < 1.5
	Severe	1.5 to < 2.0
	Extreme	2.0 to < 2.5
	Exceptional	≥ 2.5

src

Top 10 - 12 Month Extremes (Sept to Aug)
Standardized Precipitation Index (1901-2005)

Drought

Year	SPI 12	Change in Wheat Yield*
1929	-3.2	Not Available
1961	-3.1	-62.8
1958	-2.9	-38.5
1988	-2.6	-54.4
1937	-2.4	Not Available
1967	-2.2	-36.5
1984	-2.1	-24.8
1949	-1.8	-65.9
1945	-1.7	-56.3
1959	-1.7	-47.1

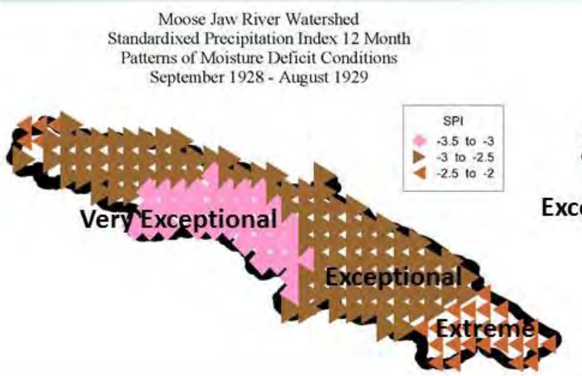
Excessive Moisture

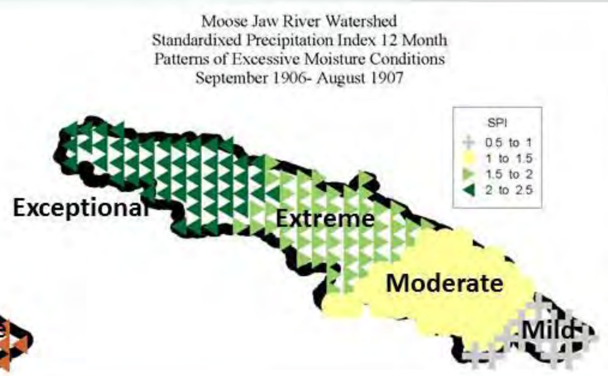
Year	SPI 12	Change in Wheat Yield*
1907	2.4	Not Available
1999	2.1	18.5
1974	2.1	-22.9
1991	2.0	14.1
1993	1.9	21.5
1955	1.9	-2.6
1902	1.9	Not Available
1954	1.7	-78.1
1976	1.7	32.0
1951	1.7	-21.9

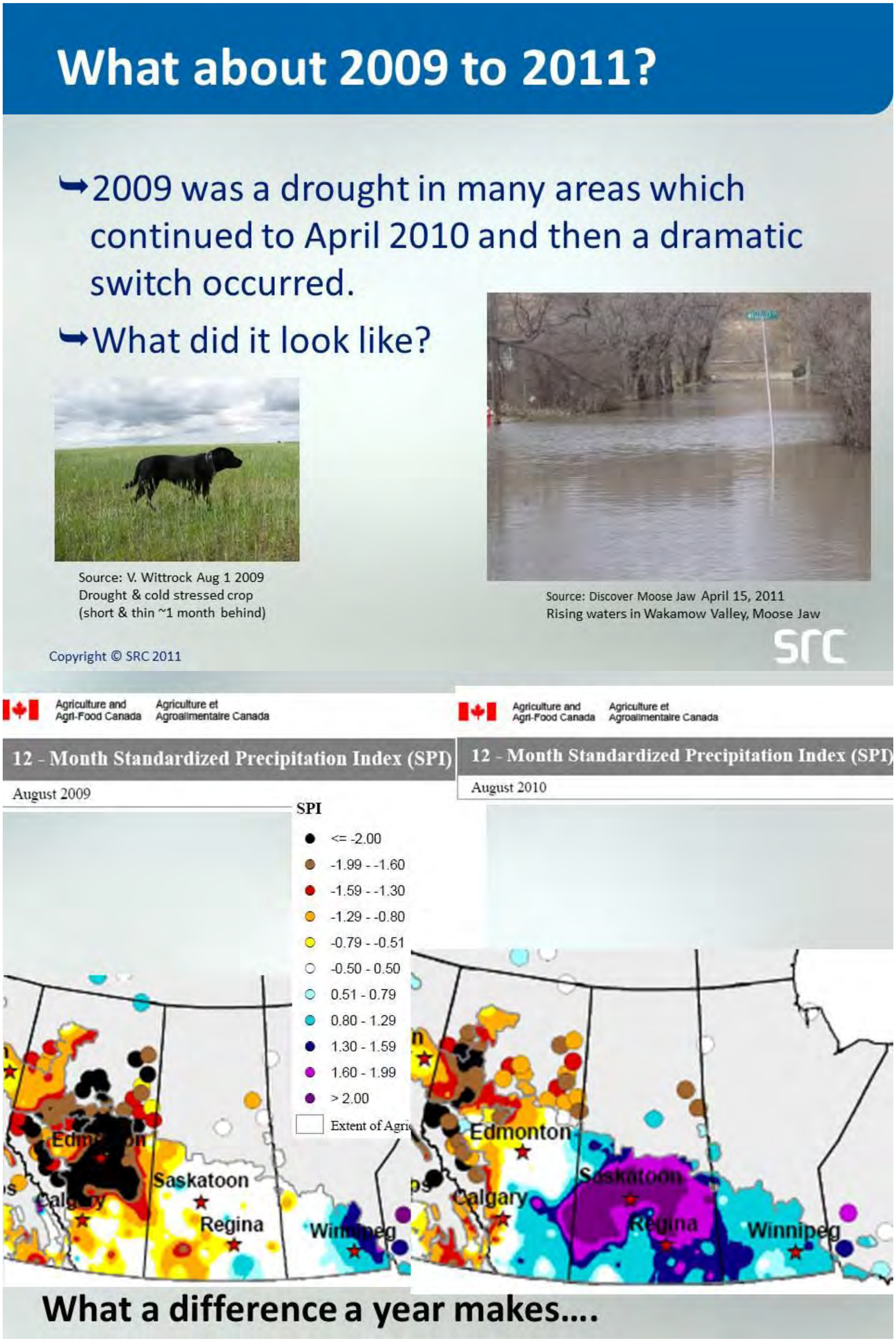
*Spring Wheat Percent from 2000 to 2009 10 yr Average
Averaged over entire watershed

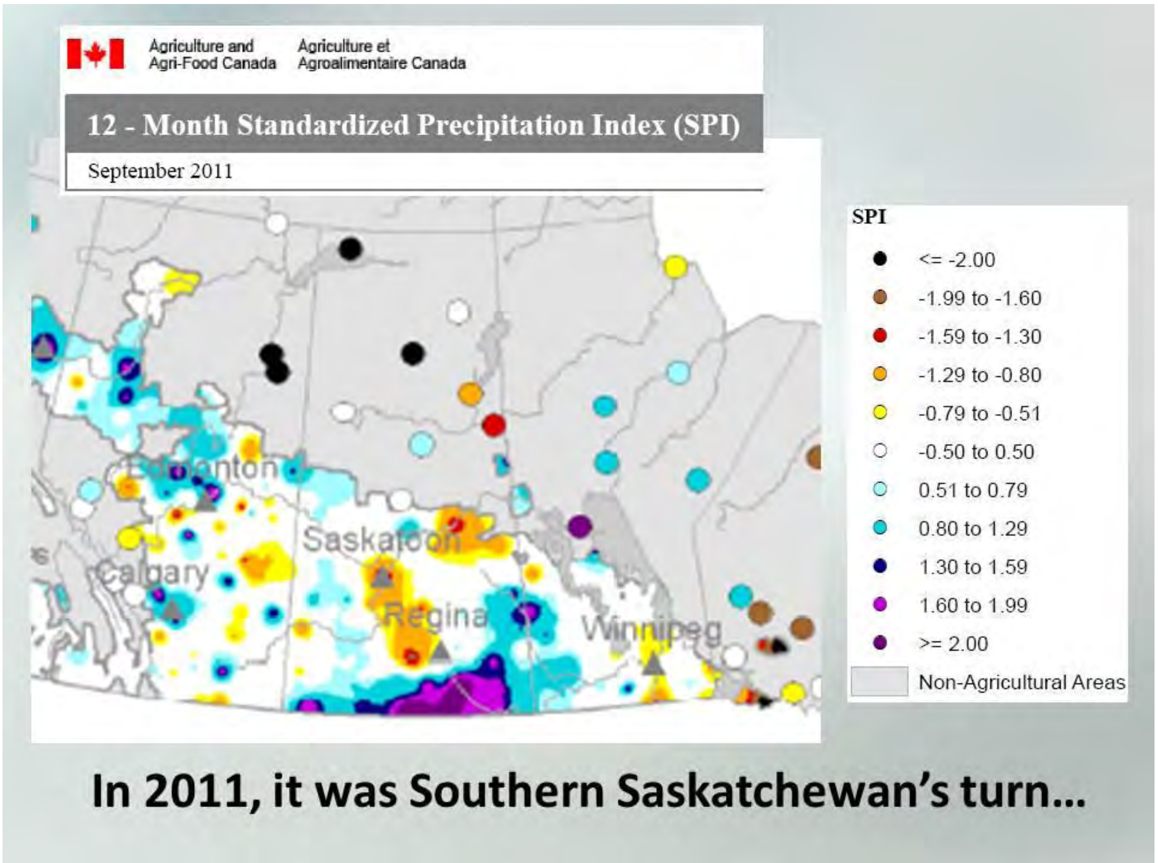
Wheat Yield data:
SK Ministry of Agriculture

SPI – 12 month extremes

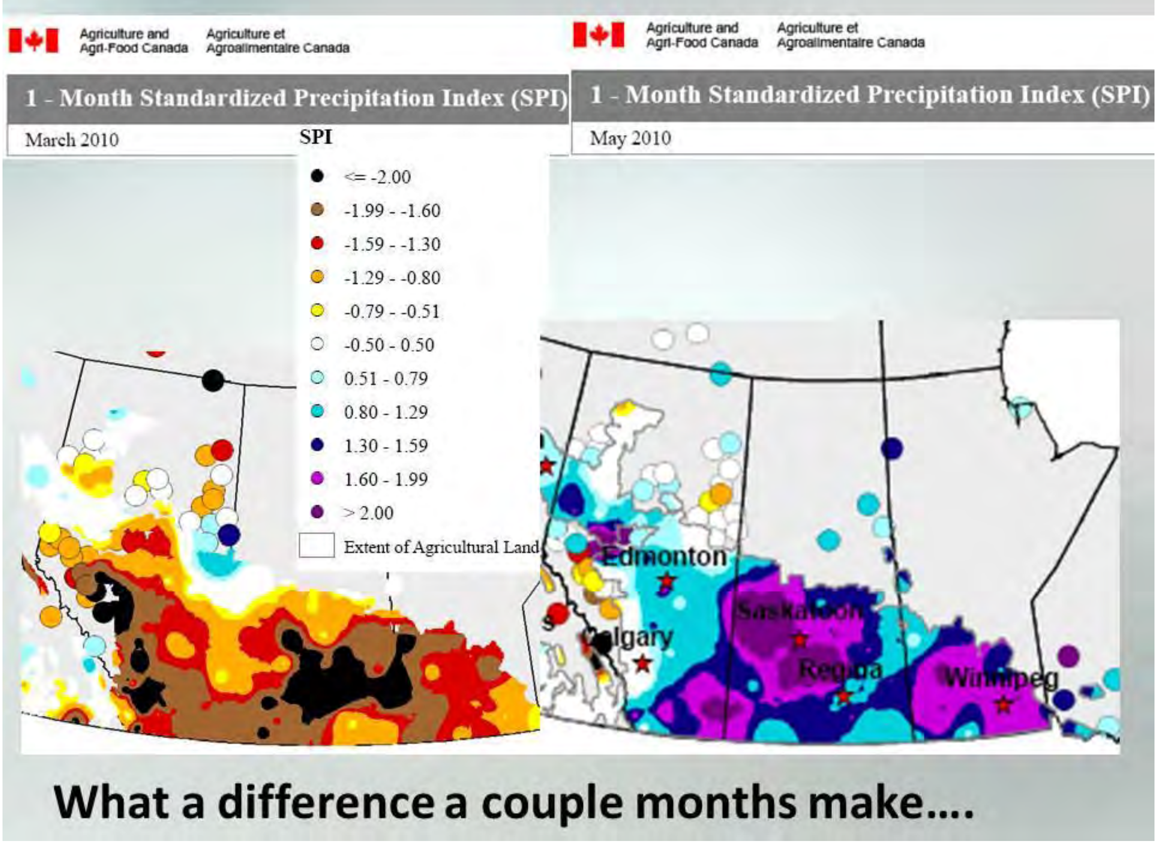





What about 2009 to 2011?
2009 was a drought in many areas which continued to April 2010 and then a dramatic switch occurred.
What did it look like?
Source: V. Wittrock Aug 1 2009
Drought & cold stressed crop
(short & thin ~1 month behind)
Source: Discover Moose Jaw April 15, 2011
Rising waters in Wakamow Valley, Moose Jaw
Copyright © SRC 2011
src
Agriculture and Agri-Food Canada
Agriculture et Agroalimentaire Canada
12 - Month Standardized Precipitation Index (SPI)
August 2009
SPI
<= -2.00
-1.99 - -1.60
-1.59 - -1.30
-1.29 - -0.80
-0.79 - -0.51
-0.50 - 0.50
0.51 - 0.79
0.80 - 1.29
1.30 - 1.59
1.60 - 1.99
> 2.00
Saskatoon
Regina
Agriculture and Agri-Food Canada
Agriculture et Agroalimentaire Canada
12 - Month Standardized Precipitation Index (SPI)
August 2010
Edmonton
Calgary
Saskatoon
Regina
Winnipeg
What a difference a year makes….



Agriculture and Agri-Food Canada
Agriculture et Agroalimentaire Canada
12 - Month Standardized Precipitation Index (SPI)
September 2011
SPI
<= -2.00
-1.99 to -1.60
-1.59 to -1.30
-1.29 to -0.80
-0.79 to -0.51
-0.50 to 0.50
0.51 to 0.79
0.80 to 1.29
1.30 to 1.59
1.60 to 1.99
>= 2.00
Non-Agricultural Areas
Edmonton
Saskatoon
Calgary
Regina
Winnipeg
In 2011, it was Southern Saskatchewan's turn…



Agriculture and Agri-Food Canada
Agriculture et Agroalimentaire Canada
1 - Month Standardized Precipitation Index (SPI)
March 2010
SPI
<= -2.00
-1.99 - -1.60
-1.59 - -1.30
-1.29 - -0.80
-0.79 - -0.51
-0.50 - 0.50
0.51 - 0.79
0.80 - 1.29
1.30 - 1.59
1.60 - 1.99
> 2.00
Extent of Agricultural Land
Agriculture and Agri-Food Canada
Agriculture et Agroalimentaire Canada
1 - Month Standardized Precipitation Index (SPI)
May 2010
Edmonton
Calgary
Saskatoon
Regina
Winnipeg
What a difference a couple months make….

These Extreme Years have Impacted Everyone and Adaptation Strategies have been Applied

SRC

Impacts from Droughts

- Soil erosion
- Water shortages
- Feed shortages
- Poor yielding crops
- Economic instability
- etc

Photo Source: AAFC

SRC

Adaptations to Droughts

- Installation of weirs/dams that allow for more stable water supply (e.g., Avonlea Dam, Stelcam Dam)
- Increased irrigation projects
- Drought tolerant crops
- Minimum tillage
- Water conservation
- etc

Source: Wakamow Valley Dec 2009
Kingsway Dam in Winter

Photo Source: E. Stratton circa 2002
St. Mary's Irrigation District

src

Impacts from Excessive Moisture

- Soil erosion
- Water quality issues (both surface and ground water)
- Degraded crops (crops under water) decreased yield and quality
- Infrastructure problems (e.g., roads, basements)
- etc

S. Wittrock July 2010 East of Swift Current

src

Adaptations to Excessive Moisture

- Installation of dams that allow for some flood control (e.g., Avonlea Dam, Stelcam Dam)
- Different crops to adapt to diseases and excess moisture conditions
- Minimum tillage
- Re-establishment of riparian zones
- etc

src

Conclusion and Questions

- The Moose Jaw River Watershed has always had extreme events and future ones could be worse…
- **But** the trick is to learn from the past to better adapt to our ever evolving future.
- There are still many questions to be asked,
  - What if 2012 is as wet as 2011?
  - Changing infrastructure to accommodate excessive moisture occurrences e.g., Vanguard Storm in 2000?
  - What if we have a 10 year drought, how will we be impacted and will we be able to adapt?

src

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- Drought Collage: Wheaton, E., with V. Wittrock, S. Kulshreshtha, G. Koshida, C. Grant, A. Chipanshi, B. Bonsal, with the rest of the Canadian Drought Study Steering Committee, P. Adkins, G. Bell, G. Brown, A. Howard and R. MacGregor. 2005. *Lessons Learned from the Canadian Drought Years of 2001 and 2002: Synthesis Report.* Saskatchewan Research Council (SRC) Publication No. 11602-46E03. 30 pp.
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- Crop Yields: Ministry of Saskatchewan Agriculture website: http://www.agriculture.gov.sk.ca/rmyields
- Photos:
  - Cracked Earth and soil drifts– Agriculture and Agri-Food Canada (AAFC)
  - Tractor stuck: Wucher, L. St. Gregor SK Sept 6 2010
  - Drought and cold stress crop – V. Wittrock Aug 1, 2009 Neidpath
  - Bridge south of Moose Jaw – CBC News http://www.cbc.ca/news/canada/saskatchewan/story/2011/04/09/sk-moose-jaw-river-110409.html Accessed Nov 2011
  - Rising Waters in Wakamow Valley– Discover Moose Jaw http://www.discovermoosejaw.com/index.php?option=com_content&task=view&id=16899&Itemid=399 Accessed Nov 2011
  - St Mary's Irrigation – E. Stratton 2002
  - Kingways Dam – Wakamow Valley Dec 2009 http://picasaweb.google.com/100996543798118358240/WakamowValley?feat=directlink#5447876915511697490 Accessed Nov 2011
  - Thunderhead cloud – S. Wittrock 2010 East of Swift Current
  - Harvest– V. Wittrock October 2010 Neidpath

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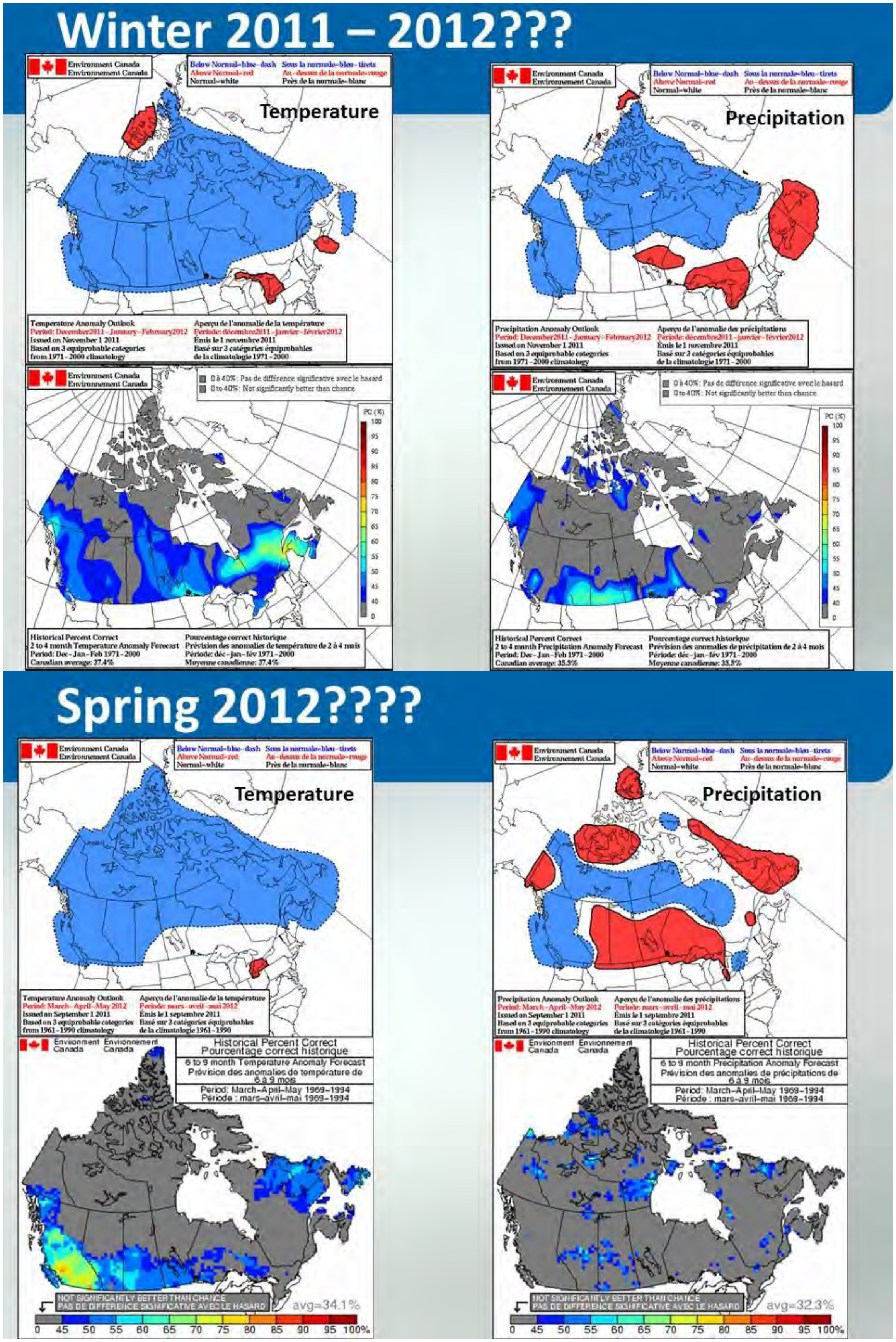
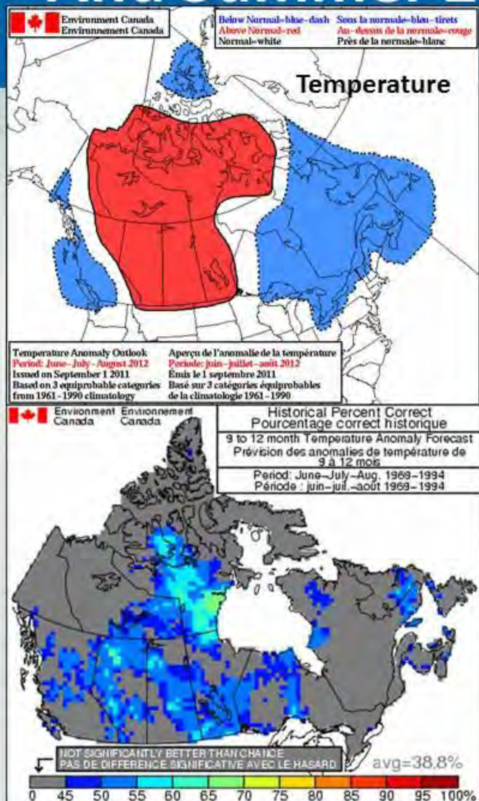
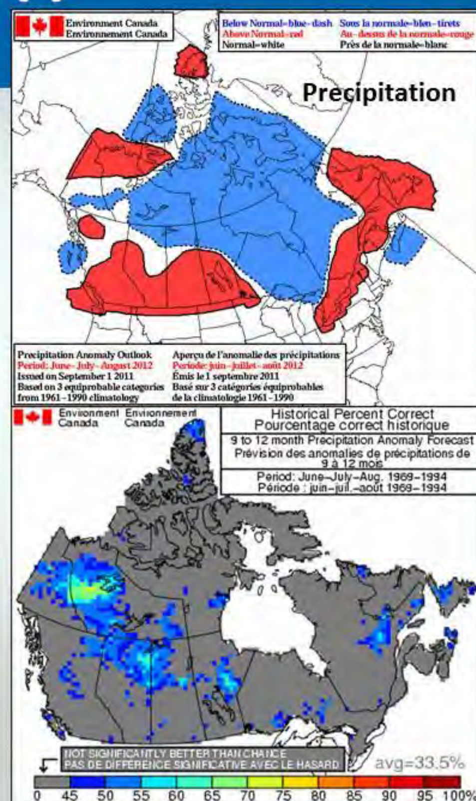


Winter 2011 – 2012???
Environment Canada Environnement Canada
Below Normal=blue-dash Sous la normale=bleu-tirets
Above Normal=red Au-dessus de la normale=rouge
Normal=white Près de la normale=blanc
Temperature
Temperature Anomaly Outlook
Period: December2011 - January - February2012
Issued on November 1 2011
Based on 3 equiprobable categories from 1971 - 2000 climatology
Aperçu de l'anomalie de la température
Période: décembre2011 - janvier - février2012
Émis le 1 novembre 2011
Basé sur 3 catégories équiprobables de la climatologie 1971 - 2000
0 à 40%: Pas de différence significative avec le hasard
0 to 40%: Not significantly better than chance
PC (%)
Historical Percent Correct
2 to 4 month Temperature Anomaly Forecast
Period: Dec - Jan - Feb 1971 - 2000
Canadian average: 37.4%
Pourcentage correct historique
Prévision des anomalies de température de 2 à 4 mois
Période: déc - jan - fév 1971 - 2000
Moyenne canadienne: 37.4%
Precipitation
Precipitation Anomaly Outlook
Period: December2011 - January - February2012
Issued on November 1 2011
Based on 3 equiprobable categories from 1971 - 2000 climatology
Aperçu de l'anomalie des précipitations
Période: décembre2011 - janvier - février2012
Émis le 1 novembre 2011
Basé sur 3 catégories équiprobables de la climatologie 1971 - 2000
Historical Percent Correct
2 to 4 month Precipitation Anomaly Forecast
Period: Dec - Jan - Feb 1971 - 2000
Canadian average: 35.5%
Pourcentage correct historique
Prévision des anomalies de précipitation de 2 à 4 mois
Période: déc - jan - fév 1971 - 2000
Moyenne canadienne: 35.5%
Spring 2012????
Temperature
Temperature Anomaly Outlook
Period: March - April - May 2012
Issued on September 1 2011
Based on 3 equiprobable categories from 1961 - 1990 climatology
Aperçu de l'anomalie de la température
Période: mars - avril - mai 2012
Émis le 1 septembre 2011
Basé sur 3 catégories équiprobables de la climatologie 1961 - 1990
Historical Percent Correct
Pourcentage correct historique
6 to 9 month Temperature Anomaly Forecast
Prévision des anomalies de température de 6 à 9 mois
Period: March–April–May 1969–1994
Période : mars–avril–mai 1969–1994
NOT SIGNIFICANTLY BETTER THAN CHANCE
PAS DE DIFFERENCE SIGNIFICATIVE AVEC LE HASARD
avg=34.1%
0 45 50 55 60 65 70 75 80 85 90 95 100%
Precipitation
Precipitation Anomaly Outlook
Period: March - April - May 2012
Issued on September 1 2011
Based on 3 equiprobable categories from 1961 - 1990 climatology
Aperçu de l'anomalie des précipitations
Période: mars - avril - mai 2012
Émis le 1 septembre 2011
Basé sur 3 catégories équiprobables de la climatologie 1961 - 1990
6 to 9 month Precipitation Anomaly Forecast
Prévision des anomalies de précipitations de 6 à 9 mois
avg=32.3%

And Summer 2012???





What's next?

- Study of 2010 and 2011 for excessive moisture
- Future drought and excessive moisture
- etc

Gridded data

- Gridded data sets preferred over station data due to improved spatial/temporal coverage
- Gridding data procedure removes unnecessary noise, resulting in smoother data for mapping
- PDSI and SPI derived from the ANUSPLIN data set
- ANUSPLIN was chosen for ability to capture several significant precipitation events, for better comparability with data and for area covered
- Develop data bases of PDSI and SPII for the watersheds (10 KM grid)

src

Top 10 most extreme years PDSI Z-Value

(1901-2005 Agriculture Year (Sept to Aug))

Drought

Year	PDSI Z-value	Change in Wheat Yield*
1961	-5.7	-62.8
1929	-4.8	Not Available
2001	-4.7	-12.7
1984	-4.7	-24.8
2003	-4.4	-12.3
1971	-4.3	9.1
1958	-3.7	-38.5
1930	-3.6	Not Available
1970	-3.6	4.4
1959	-3.6	-47.1

Excessive Moisture

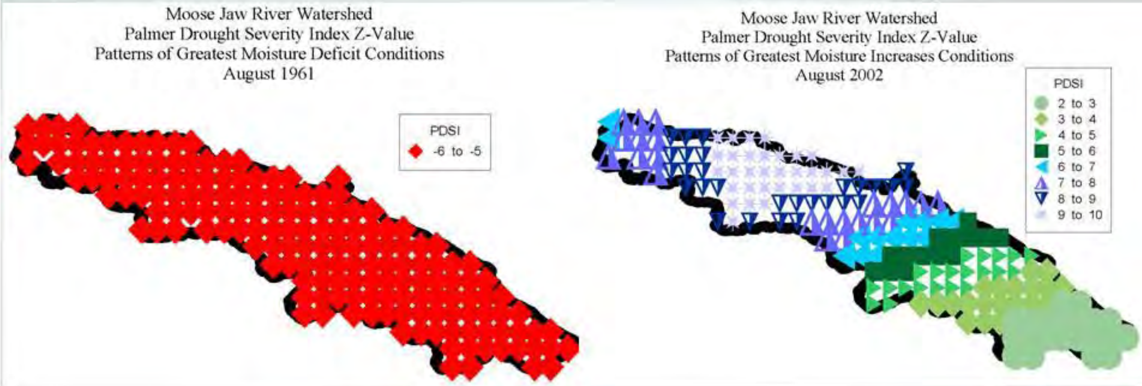
Year	PDSI Z-value	Change in Wheat Yield*
2002	10.0	-7.9
1968	9.3	-28.6
1993	9.1	21.5
1954	8.7	-78.1
1951	7.3	-21.9
1907	7.2	Not Available
1974	7.1	-22.9
1995	5.9	14.9
1903	5.7	Not Available
1909	5.1	Not Available

*Spring Wheat Percent from 2000 to 2009 10 yr Average

Average over entire watershed

Wheat Yield data:
SK Ministry of Agriculture

PDSI Z-Value



Top 10 most extreme years SPI – 1 Month (1901-2005)

Drought

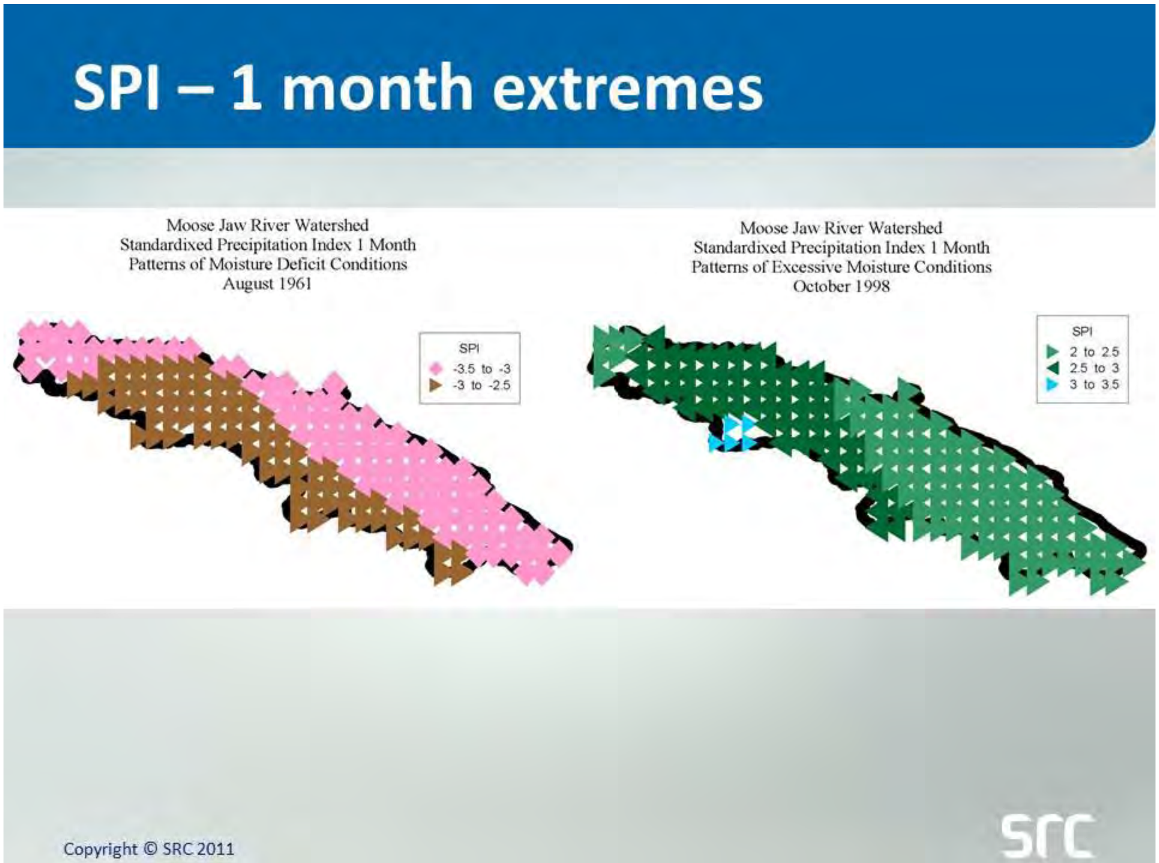
Year	Month	SPI01	Change in Wheat Yield*
1961	8	-3.4	-62.8
1952	12	-3.3	12.5
2001	8	-3.3	-12.7
1997	12	-3.3	2.8
1968	4	-3.1	-28.6
1917	5	-3.1	Not Available
1978	3	-3.1	25.3
1960	9	-3.1	-0.8
1993	1	-3.0	21.5
1958	5	-3.0	-38.5

Excessive Moisture

Year	Month	SPI01	Change in Wheat Yield*
1998	10	3.2	-0.1
1993	7	3.1	21.5
1904	3	3.0	Not Available
1967	3	2.9	-36.5
1968	8	2.8	-28.6
1909	7	2.8	Not Available
1990	7	2.8	46.8
1902	2	2.7	Not Available
1999	2	2.7	18.5
2002	8	2.7	-7.9

*Spring Wheat Percent from 2000 to 2009 10 yr Average
Average over entire watershed

Wheat Yield data:
SK Ministry of Agriculture


SPI – 1 month extremes
Moose Jaw River Watershed
Standardixed Precipitation Index 1 Month
Patterns of Moisture Deficit Conditions
August 1961
SPI
-3.5 to -3
-3 to -2.5
Moose Jaw River Watershed
Standardixed Precipitation Index 1 Month
Patterns of Excessive Moisture Conditions
October 1998
SPI
2 to 2.5
2.5 to 3
3 to 3.5
Copyright © SRC 2011
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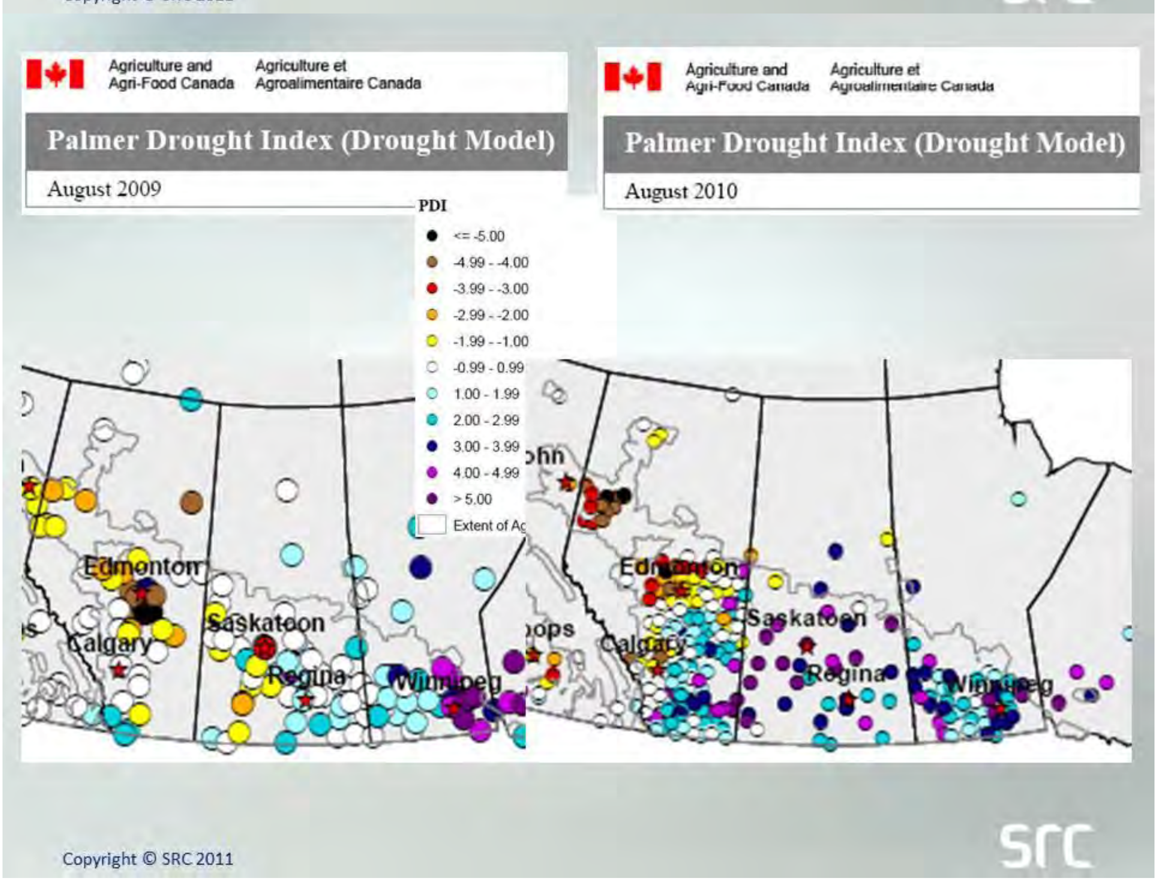
Agriculture and Agri-Food Canada
Agriculture et Agroalimentaire Canada
Palmer Drought Index (Drought Model)
August 2009
PDI
<= -5.00
-4.99 - -4.00
-3.99 - -3.00
-2.99 - -2.00
-1.99 - -1.00
-0.99 - 0.99
1.00 - 1.99
2.00 - 2.99
3.00 - 3.99
4.00 - 4.99
> 5.00
Edmonton
Calgary
Saskatoon
Regina
Winnipeg
Agriculture and Agri-Food Canada
Agriculture et Agroalimentaire Canada
Palmer Drought Index (Drought Model)
August 2010
Edmonton
Calgary
Saskatoon
Regina
Winnipeg
Copyright © SRC 2011
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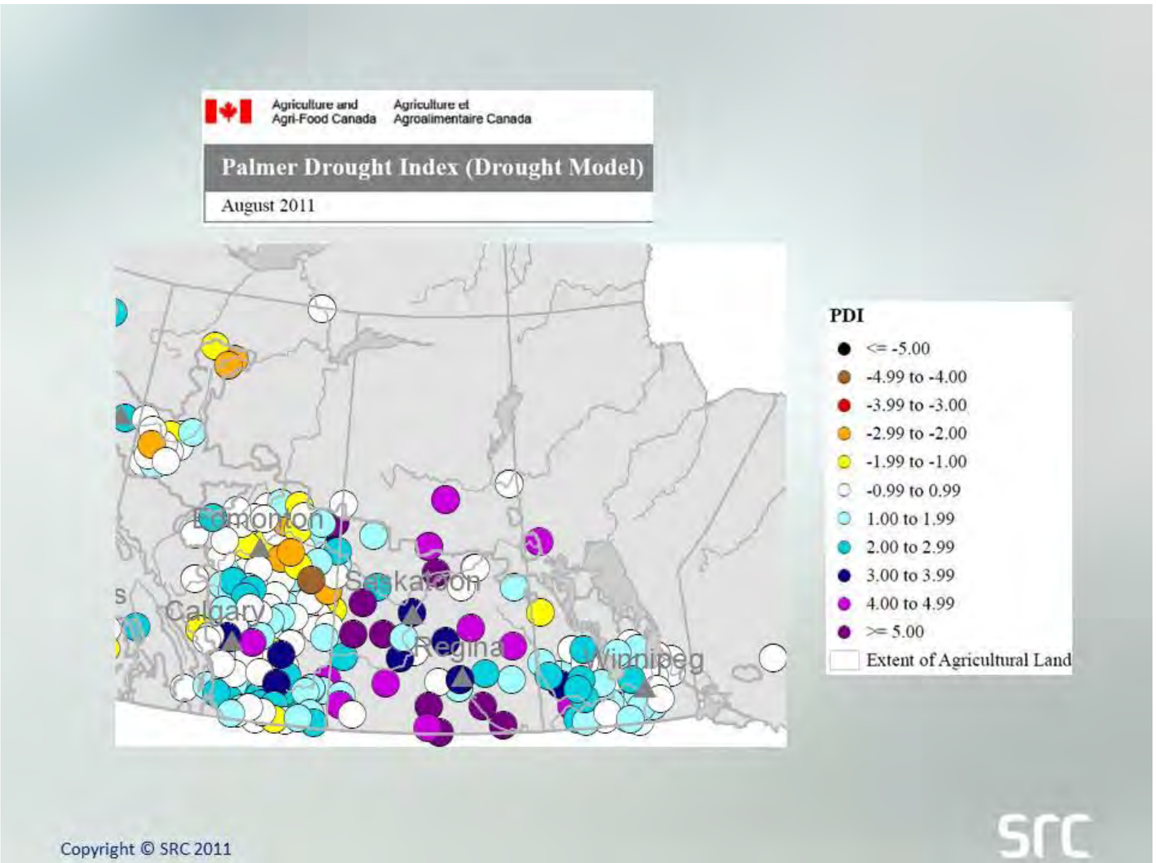
Agriculture and Agri-Food Canada
Agriculture et Agroalimentaire Canada
Palmer Drought Index (Drought Model)
August 2011
PDI
<= -5.00
-4.99 to -4.00
-3.99 to -3.00
-2.99 to -2.00
-1.99 to -1.00
-0.99 to 0.99
1.00 to 1.99
2.00 to 2.99
3.00 to 3.99
4.00 to 4.99
>= 5.00
Extent of Agricultural Land
Edmonton
Saskatoon
Calgary
Regina
Winnipeg
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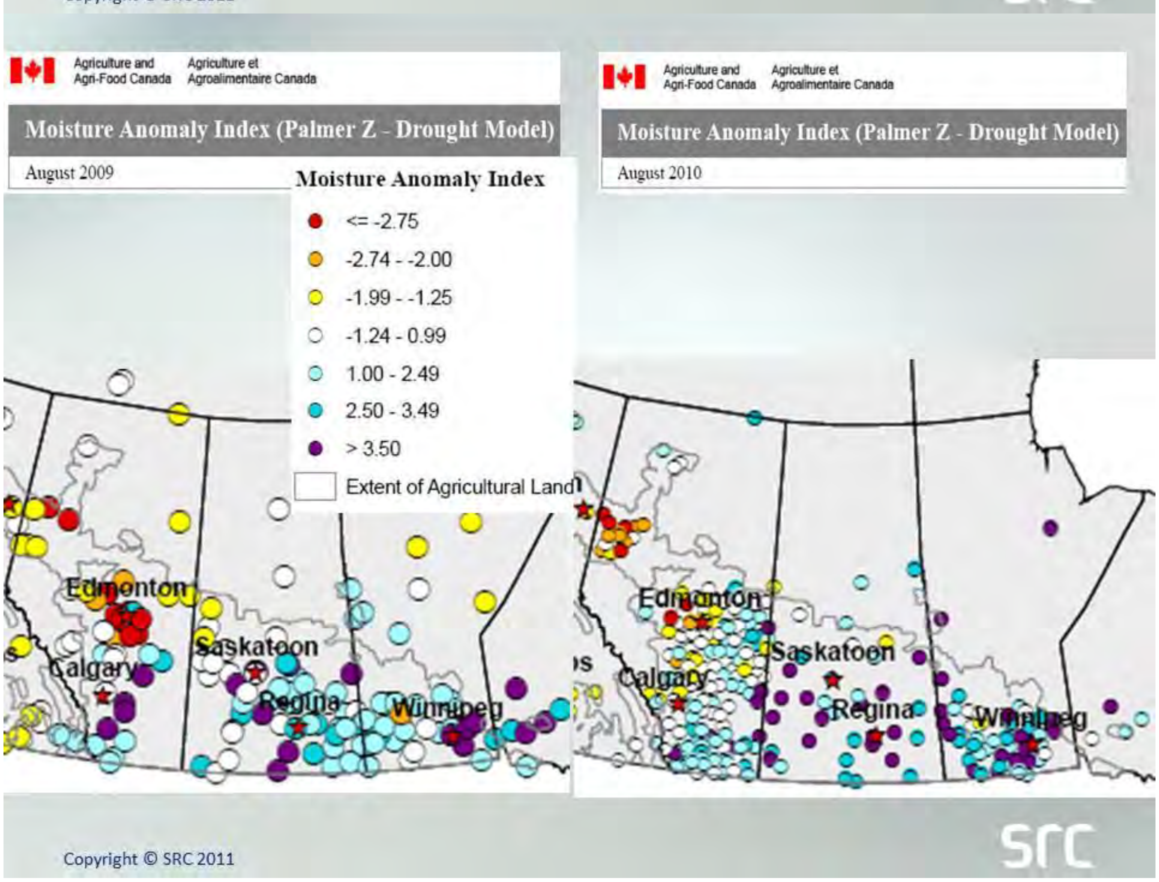
Agriculture and Agri-Food Canada
Agriculture et Agroalimentaire Canada
Moisture Anomaly Index (Palmer Z - Drought Model)
August 2009
Moisture Anomaly Index
<= -2.75
-2.74 - -2.00
-1.99 - -1.25
-1.24 - 0.99
1.00 - 2.49
2.50 - 3.49
> 3.50
Extent of Agricultural Land
Edmonton
Calgary
Saskatoon
Regina
Winnipeg
Agriculture and Agri-Food Canada
Agriculture et Agroalimentaire Canada
Moisture Anomaly Index (Palmer Z - Drought Model)
August 2010
Edmonton
Calgary
Saskatoon
Regina
Winnipeg
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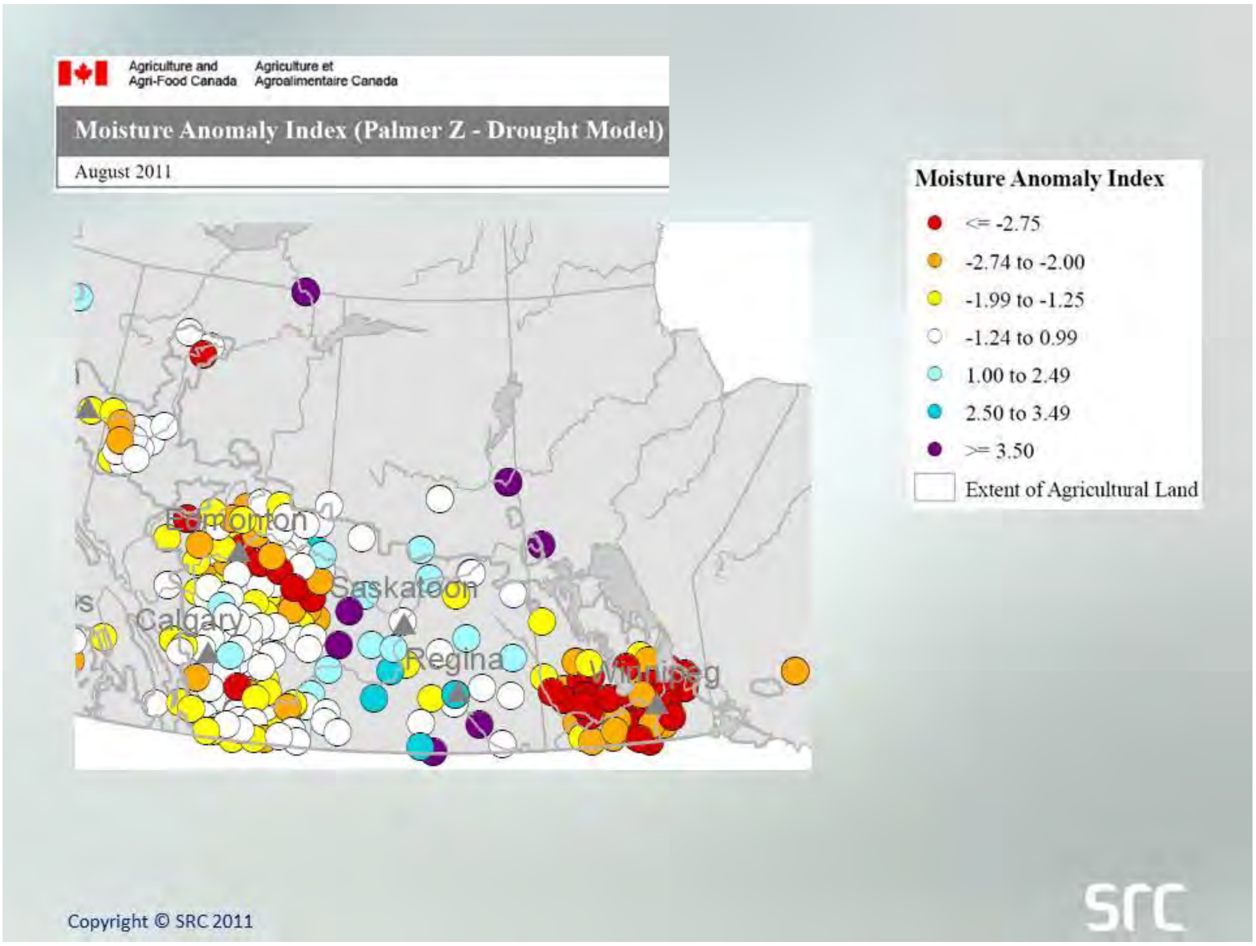
Agriculture and Agri-Food Canada
Agriculture et Agroalimentaire Canada
Moisture Anomaly Index (Palmer Z - Drought Model)
August 2011
Edmonton
Saskatoon
Calgary
Regina
Winnipeg
Moisture Anomaly Index
<= -2.75
-2.74 to -2.00
-1.99 to -1.25
-1.24 to 0.99
1.00 to 2.49
2.50 to 3.49
>= 3.50
Extent of Agricultural Land
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SRC SASKATCHEWAN RESEARCH COUNCIL

The Goldilocks Dichotomy: Too Wet or Too Dry. The Upper Qu'Appelle River Watershed

V. Wittrock[1] and E. Wheaton[2]
[1] Saskatchewan Research Council
[2] Saskatchewan Research Council and University of Saskatchewan
SRC Publication # 13022-11D11

Outline

- Objectives & benefits
- Methodology
- Background information
- The extreme years
- Impacts and adaptations
- Conclusion

Objectives

- To **characterize** drought and excessive moisture events for selected watersheds during the past century.
- **Compare** and **contrast** driest and wettest patterns to help determine characteristics for risk assessments and planning.
- Consider the **implications** for impacts and adaptations directly related to the watershed.

Benefits of Examining the Past

- Assist communities, local municipalities, provincial and federal governments with **risk management** and **planning strategies** for extreme events.
- **Avoid damages and decrease** the **costs** of climate events by learning from the past.
- Help to lower the **costs of the impacts of future climatic events.**

What is a Drought?

- A deficiency of precipitation from expected or “normal” that, when extended over a season or longer, is insufficient to meet the demands of human activities and the environment
- Four major types of drought including Meteorological, Agricultural, Hydrological and Socio-economic

- Or when it hasn’t rained, the fields are dry, the lakes or rivers are really low and it impacts the economy, environment and our way of life

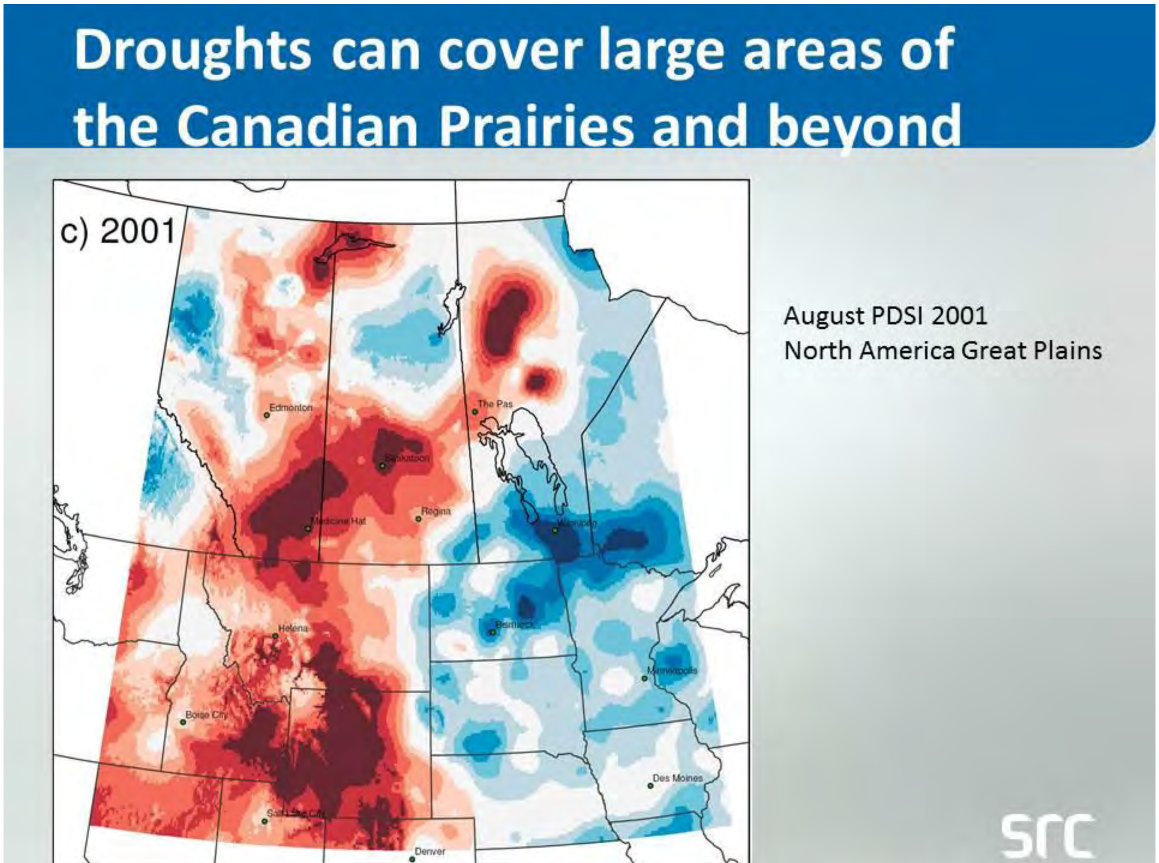
Photo: AAFC

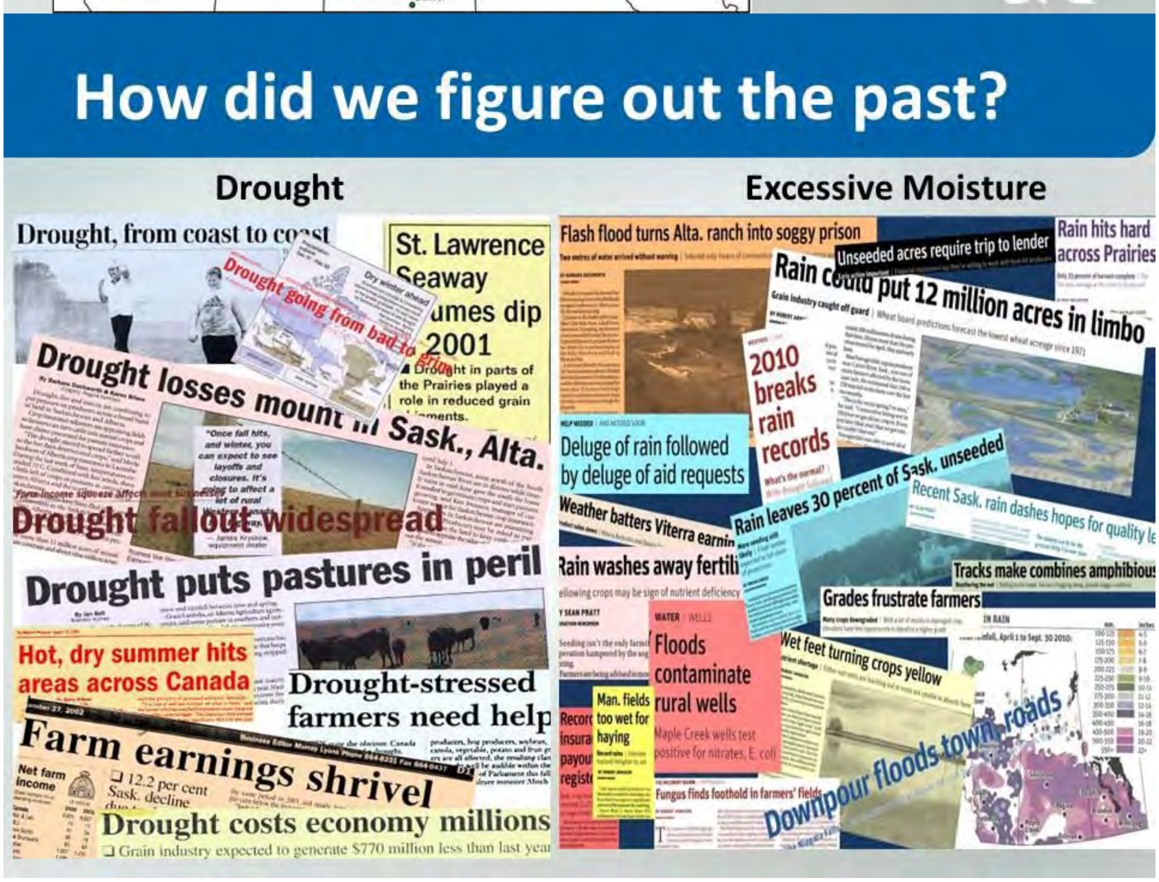
What is Excessive Moisture?

- An excess of precipitation from expected or “normal” that, when extended over a season or longer, is too much to meet the demands of human activities and the environment
- Four major types of excess moisture including Meteorological, Agricultural, Hydrological and Socio-economic

- Or it won’t quit raining, the fields are saturated, the lakes or rivers are over flowing their banks and it impacts the economy, environment and our way of life

Photo: Wucher, L. St. Gregor SK Sept 6, 2010


Droughts can cover large areas of the Canadian Prairies and beyond
c) 2001
Edmonton
The Pas
Saskatoon
Medicine Hat
Regina
Winnipeg
Helena
Bismarck
Minneapolis
Boise City
Des Moines
Salt Lake City
Denver
August PDSI 2001
North America Great Plains
src


How did we figure out the past?
Drought
Excessive Moisture
Drought, from coast to coast
St. Lawrence Seaway volumes dip
2001
Drought going from bad to grim
Drought losses mount in Sask., Alta.
Drought fallout widespread
Drought puts pastures in peril
Hot, dry summer hits areas across Canada
Drought-stressed farmers need help
Farm earnings shrivel
Drought costs economy millions
Grain industry expected to generate $770 million less than last year
Flash flood turns Alta. ranch into soggy prison
Unseeded acres require trip to lender
Rain hits hard across Prairies
Rain could put 12 million acres in limbo
2010 breaks rain records
Deluge of rain followed by deluge of aid requests
Weather batters Viterra earnings
Rain leaves 30 percent of Sask. unseeded
Recent Sask. rain dashes hopes for quality
Rain washes away fertility
Tracks make combines amphibious
Grades frustrate farmers
Floods contaminate rural wells
Maple Creek wells test positive for nitrates, E. coli
Man. fields too wet for haying
Wet feet turning crops yellow
Fungus finds foothold in farmers' fields
Downpour floods town, roads

Methods

- Use a gridded **Palmer Drought Severity Index**(PDSI), **PDSI z-value** and **Standardized Precipitation Index** (SPI) to develop database for 1901 to 2005.
- Other sources are used to document the more recent drought and excessive moisture events.

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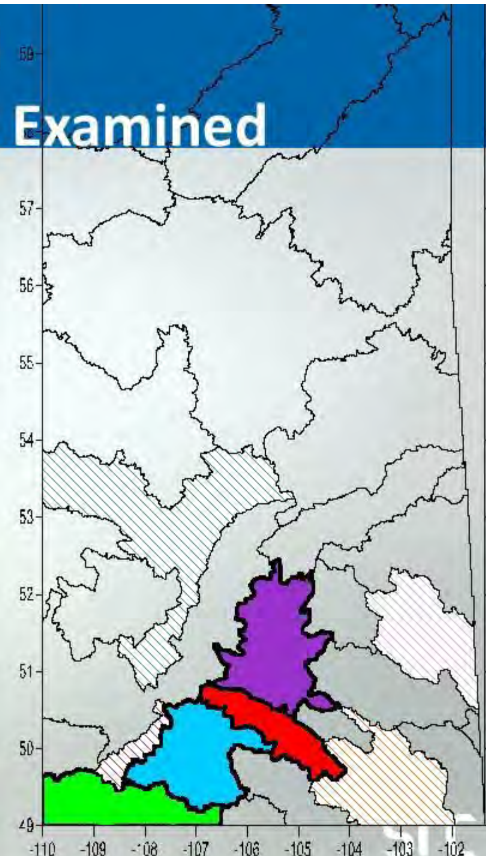
Methods continued

- **Rank** the 10 driest and 10 wettest years in the watershed
- **Spatial variability** is determined from these rankings.
- Literature review and media analysis to determine the **impacts** and **adaptation** strategies undertaken

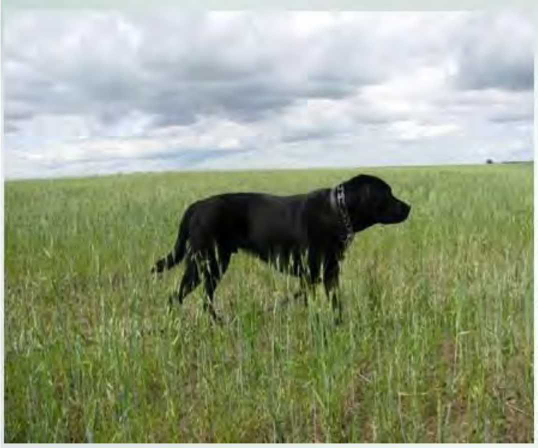
src

Watersheds Examined and Watersheds to be Examined

Legend
- Milk River Watershed
- Moose Jaw River Watershed
- Old Wives Lake Watershed
- Upper Qu'Appelle River Watershed
- Assinboine River Watershed
- North Saskatchewan River Watershed
- Swift Current Creek Watershed
- Upper Souris River Watershed
- All Other Watersheds



How do we classify severe drought, excessive moisture or average conditions?



Source: V. Wittrock Aug 1 2009
Drought & cold stressed crop (short & thin) (Field near Neidpath)

Source: SWA web site https://www.saskflood.ca/Gallery/default.aspx
Snack Shack at Lumsden April 15 2011

SRC

Palmer Drought Severity Index (PDSI)

- One of the most widely used drought and excessive moisture indices
- Primarily a hydrological drought index
- Derived using a soil moisture/water balance model which requires information on the available soil water content along with daily/monthly precipitation and temperature data
- Values contain a long term memory of the previous moisture conditions because the calculated value.

What do PDSI values mean?

Classification		PDSI Value
Drought	Exceptional	≤ -5
	Extreme	> -5.0 to -4.0
	Severe	> -4.0 to -3.0
	Moderate	> -3.0 to -2.0
	Mild	> -2.0 to -1.0
Near Normal		> -1.0 to 1.0
Wet	Mild	1.0 to < 2.0
	Moderate	2.0 to < 3.0
	Severe	3.0 to < 4.0
	Extreme	4.0 to < 5.0
	Exceptional	≥ 5.0

Top 10 Extreme Years and Wheat Yields Palmer Drought Severity Index

(1901-2005 Agriculture Year (Sept to Aug))

Drought

Year	PDSI	Change in Wheat Yield*
1961	-7.0	-71.1
1988	-6.7	-70.8
1958	-5.8	-50.8
1959	-5.8	-43.5
1937	-5.8	Not Available
1930	-5.4	Not Available
1981	-5.4	-10.2
1931	-5.3	Not Available
1915	-5.1	Not Available
1919	-5.1	Not Available

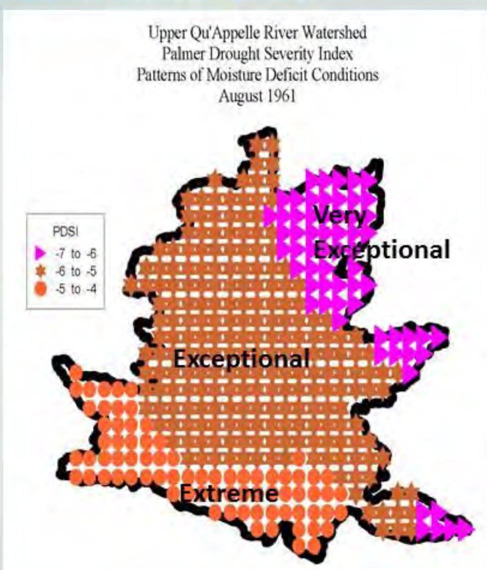
Excessive Moisture

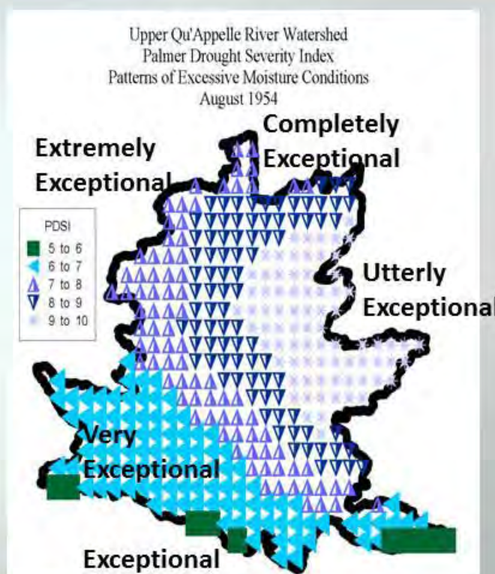
Year	PDSI	Change in Wheat Yield*
1954	9.9	-75.7
1907	7.6	Not Available
1991	6.6	0.3
1909	6.5	Not Available
1955	6.2	-21.0
1951	5.9	-24.9
1966	5.4	-5.2
1974	5.4	-36.1
1953	5.3	-8.5
1923	5.0	Not Available

*Spring Wheat Percent from 2000 to 2009 10 yr Average
Averaged over entire watershed

Wheat Yield data:
SK Ministry of Agriculture

Most Extreme Years (12-month PDSI)





Standard Precipitation Index (SPI)

- Developed to monitor moisture supply conditions
- Identifies emerging droughts months earlier than the PDSI because antecedent moisture conditions are not taken into account
- SPI does not calculate temperature anomalies, a critical feature for agricultural drought monitoring

src

What do SPI values mean?

Classification		SPI Value
Drought	Exceptional	≤ -2.5
	Extreme	> -2.5 to -2.0
	Severe	> -2.0 to -1.5
	Moderate	> -1.5 to -1.0
	Mild	> -1.0 to -0.5
Near Normal		> -0.5 to 0.5
Wet	Mild	0.5 to < 1.0
	Moderate	1.0 to < 1.5
	Severe	1.5 to < 2.0
	Extreme	2.0 to < 2.5
	Exceptional	≥ 2.5

src

Top 10 - 12 Month Extremes Standardized Precipitation Index (1901-2005)

Drought

Year	SPI 12	Change in Wheat Yield*
1961	-3.7	-71.1
1929	-2.9	Not Available
1937	-2.6	Not Available
1958	-2.5	-50.8
2001	-2.4	-39.3
1967	-2.3	-46.5
1988	-2.3	-70.8
1924	-2.3	Not Available
1914	-2.2	Not Available
1972	-1.8	-27.7

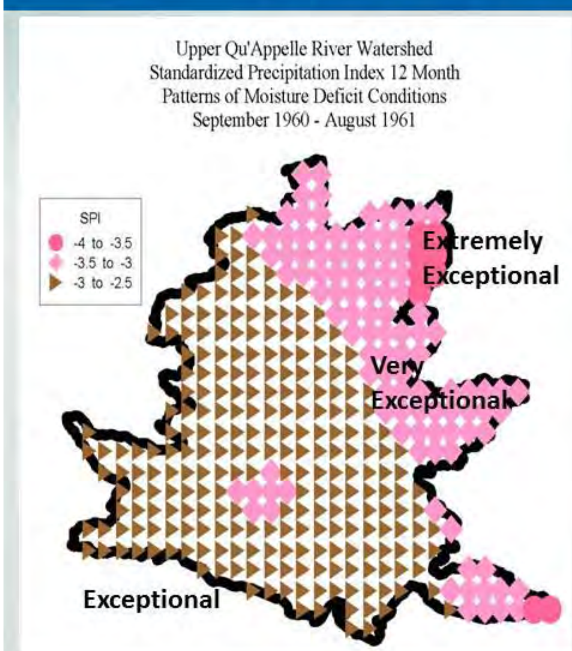
Excessive Moisture

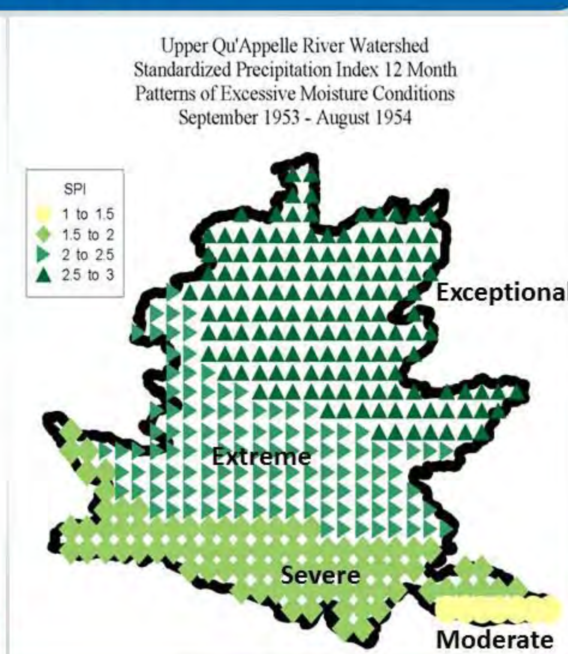
Year	SPI 12	Change in Wheat Yield*
1954	2.8	-75.7
1907	2.2	Not Available
1923	2.1	Not Available
1991	2.0	0.3
1993	2.0	-5.7
1951	2.0	-24.9
1974	1.8	-36.1
1995	1.7	-7.1
1953	1.7	-8.5
1999	1.7	17.7

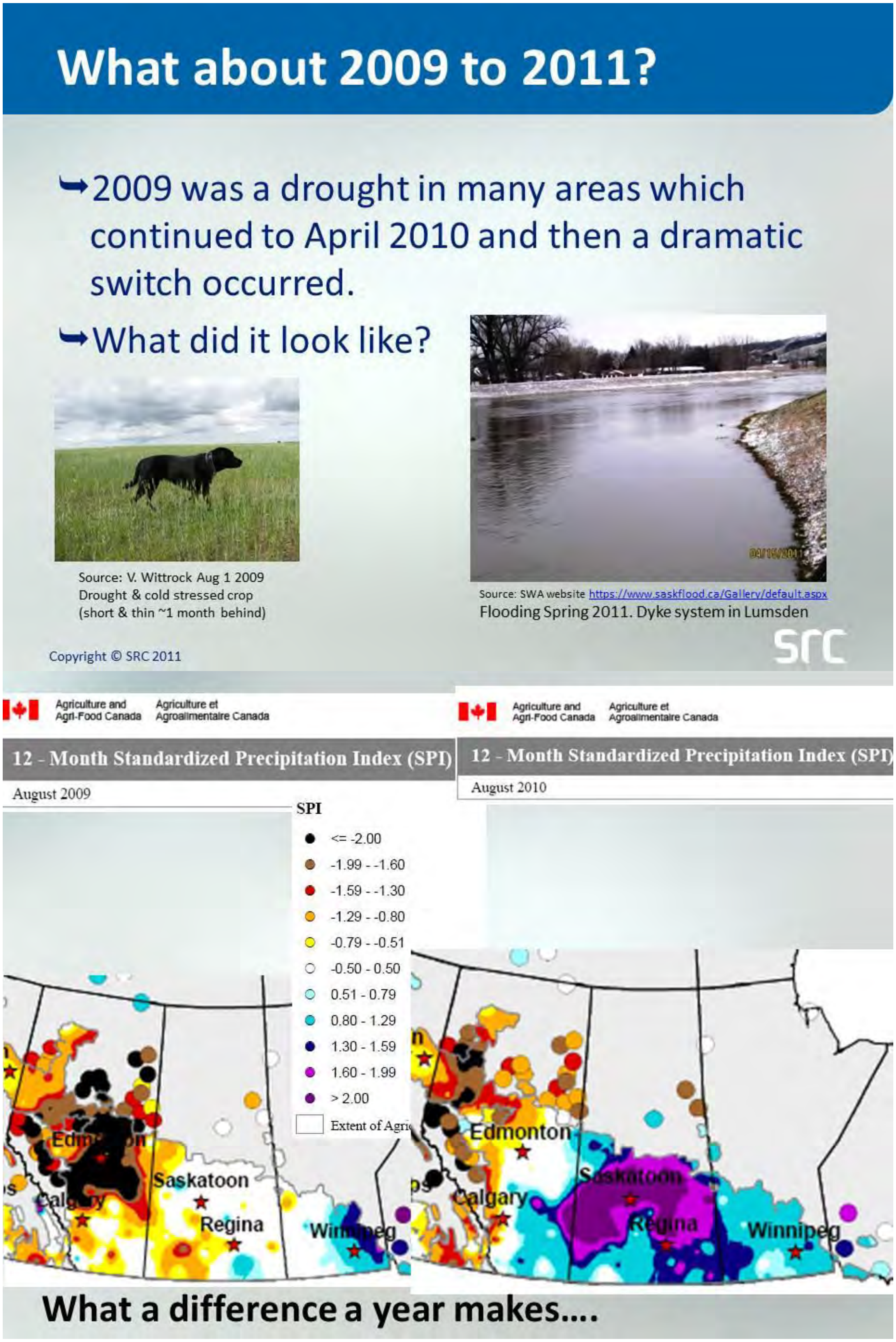
*Spring Wheat Percent from 2000 to 2009 10 yr Average
Averaged over entire watershed

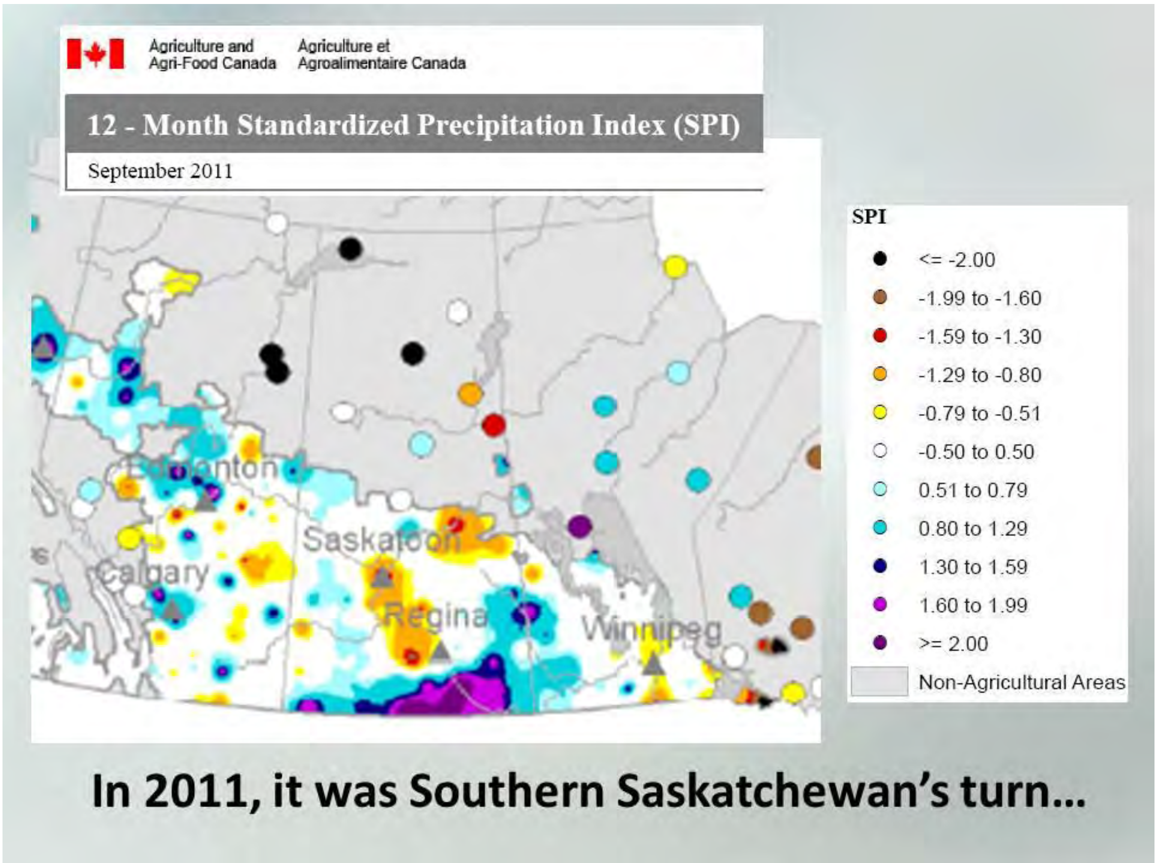
Wheat Yield data:
SK Ministry of Agriculture

SPI – 12 month extremes

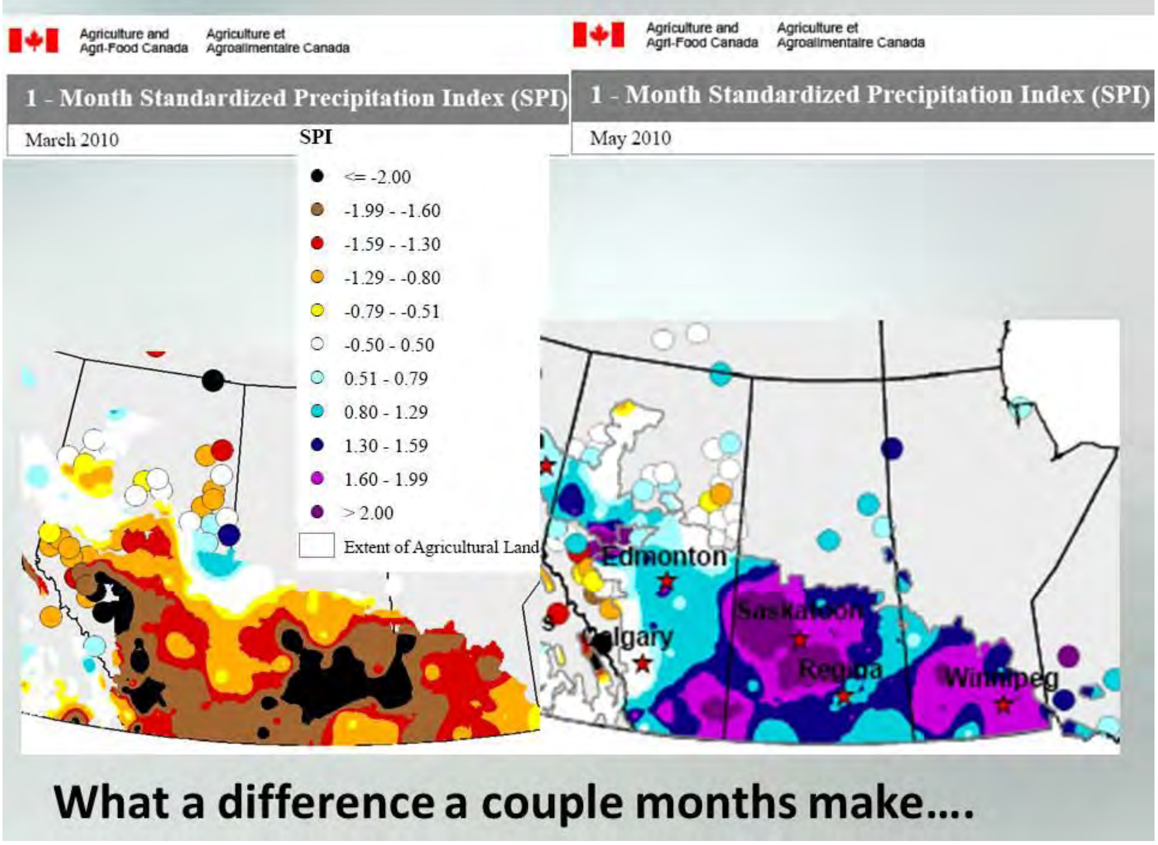





What about 2009 to 2011?
2009 was a drought in many areas which continued to April 2010 and then a dramatic switch occurred.
What did it look like?
Source: V. Wittrock Aug 1 2009
Drought & cold stressed crop
(short & thin ~1 month behind)
Source: SWA website https://www.saskflood.ca/Gallery/default.aspx
Flooding Spring 2011. Dyke system in Lumsden
Copyright © SRC 2011
src
Agriculture and Agri-Food Canada
Agriculture et Agroalimentaire Canada
12 - Month Standardized Precipitation Index (SPI)
August 2009
SPI
<= -2.00
-1.99 - -1.60
-1.59 - -1.30
-1.29 - -0.80
-0.79 - -0.51
-0.50 - 0.50
0.51 - 0.79
0.80 - 1.29
1.30 - 1.59
1.60 - 1.99
> 2.00
Saskatoon
Regina
Agriculture and Agri-Food Canada
Agriculture et Agroalimentaire Canada
12 - Month Standardized Precipitation Index (SPI)
August 2010
Edmonton
Calgary
Saskatoon
Regina
Winnipeg
What a difference a year makes....



Agriculture and Agri-Food Canada
Agriculture et Agroalimentaire Canada
12 - Month Standardized Precipitation Index (SPI)
September 2011
SPI
<= -2.00
-1.99 to -1.60
-1.59 to -1.30
-1.29 to -0.80
-0.79 to -0.51
-0.50 to 0.50
0.51 to 0.79
0.80 to 1.29
1.30 to 1.59
1.60 to 1.99
>= 2.00
Non-Agricultural Areas
Edmonton
Saskatoon
Calgary
Regina
Winnipeg
In 2011, it was Southern Saskatchewan's turn…



Agriculture and Agri-Food Canada
Agriculture et Agroalimentaire Canada
1 - Month Standardized Precipitation Index (SPI)
March 2010
SPI
<= -2.00
-1.99 - -1.60
-1.59 - -1.30
-1.29 - -0.80
-0.79 - -0.51
-0.50 - 0.50
0.51 - 0.79
0.80 - 1.29
1.30 - 1.59
1.60 - 1.99
> 2.00
Extent of Agricultural Land
Agriculture and Agri-Food Canada
Agriculture et Agroalimentaire Canada
1 - Month Standardized Precipitation Index (SPI)
May 2010
Edmonton
Calgary
Saskatoon
Regina
Winnipeg
What a difference a couple months make….

These Extreme Years have Impacted Everyone and Adaptation Strategies have been Applied

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Impacts from Droughts

- Soil erosion
- Water shortages
- Feed shortages
- Poor yielding crops
- Economic instability
- etc

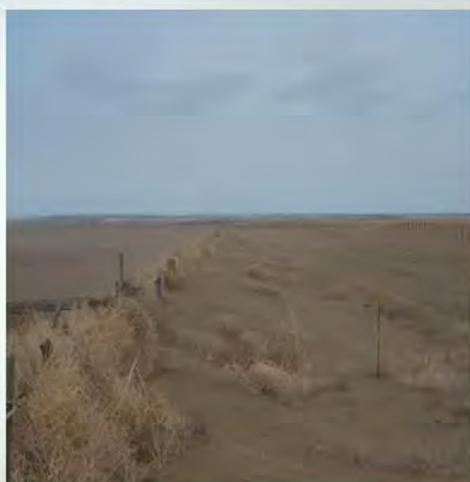

Photo Source: AAFC

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Adaptations to Droughts

- Installation of weirs/dams that allow for more stable water supply (e.g., Buffalo Pound Lake, Qu'Appelle Dam)
- Increased irrigation projects
- Drought tolerant crops
- Minimum tillage
- Water conservation
- etc

Source: SWA and Upper Qu'Appelle River Watershed Technical 2007
Outlet Channel Downstream
from the Qu'Appelle Dam on Lake Diefenbaker

Photo Source: E. Stratton circa 2002
St. Mary's Irrigation District

src

Impacts from Excessive Moisture

- Soil erosion
- Water quality issues (both surface and ground water)
- Degraded crops (crops under water) decreased yield and quality
- Infrastructure problems (e.g., roads, basements)
- etc

S. Wittrock July 2010 East of Swift Current

src

Adaptations to Excessive Moisture

- Different crops to adapt to diseases and excess moisture conditions
- Minimum tillage
- Re-establishment of riparian zones
- Dams allow for minimal flood control (e.g., Buffalo Pound Dam, Craven Sluice gates)
- etc

Buffalo Pound Dam April 9, 2011
Source: SWA website

Conclusion and Questions

- The Upper Qu'Appelle River Basin has always had extreme events and future ones could be worse…
- **But** the trick is to learn from the past to better adapt to our ever evolving future.
- There are still many questions to be asked,
  - What if 2012 is as wet as 2011?
  - Changing infrastructure to accommodate excessive moisture occurrences e.g., Vanguard Storm in 2000?
  - What if we have a 10 year drought, how will we be impacted and will we be able to adapt?

References

- Upper Qu'Appell River Watershed Map: Saskatchewan Watershed Authority (SWA) and Upper Qu'Appelle River Watershed Technical Committee. 2007. Background Report: Upper Qu'Appelle River Watershed Source Water Protection Plan. SWA, Moose Jaw, SK. Web Site: http://www.swa.ca/Publications/Documents/UpperQuAppelleRiverWatershedBackgroundReportFinal.pdf Accessed Oct. 2011
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- Flood Collage: Wittrock, V., E. Wheaton and E. Siemens. 2011. Drought and Excessive Moisture – Saskatchewan's Nemesis: Characterizations for the Swift Current Creek, North Saskatchewan River, Assiniboine River and Upper Souris River Watersheds. Saskatchewan Research Council (SRC) Publication No. 13022-6E11 188 pp.
- Drought Collage: Wheaton, E., with V. Wittrock, S. Kulshreshtha, G. Koshida, C. Grant, A. Chipanshi, B. Bonsal, with the rest of the Canadian Drought Study Steering Committee, P. Adkins, G. Bell, G. Brown, A. Howard and R. MacGregor. 2005. *Lessons Learned from the Canadian Drought Years of 2001 and 2002: Synthesis Report.* Saskatchewan Research Council (SRC) Publication No. 11602-46E03. 30 pp.
- PDSI 2001 map: Bonsal, B., E. Wheaton, and E. Siemens. 2010 July. *Characterizing the Surface Dynamics of Canadian Prairie Droughts.* Environment Canada, Saskatchewan Research Council. Water 2010: Hydrology, Hydraulics, and Water Resources in an Uncertain Environment, Quebec City, Quebec, July 5-7, 2010. SRC Publication No. 11602-3D10. 28 slides.
- PDI and SPI maps Aug 2009 to 2011: Agriculture and Agri-Food Canada Web site: http://www4.agr.gc.ca/DW-GS/historical-historiques.jspx?lang=eng&isEnabled=true
- Temperature and precipitation outlooks: Environment Canada website: http://www.weatheroffice.gc.ca/saisons/index_e.html
- Crop Yields: Ministry of Saskatchewan Agriculture website: http://www.agriculture.gov.sk.ca/rmyields
- Photos:
  - Cracked Earth and soil drifts– Agriculture and Agri-Food Canada (AAFC)
  - Tractor stuck: Wucher, L. St. Gregor SK Sept 6 2010
  - Drought and cold stress crop – V. Wittrock Aug 1, 2009 Neidpath
  - Snack Shack at Lumsden April 15, 2011– SWA website https://www.saskflood.ca/Gallery/default.aspx
  - Outlet Channel Downstream from the Qu'Appelle Dam on Lake Diefenbaker - SWA and Upper Qu'Appelle River Watershed Technical 2007
  - St Mary's Irrigation – E. Stratton 2002
  - Spring high water levels in Lumsden – SWA web site: https://www.saskflood.ca/Gallery/default.aspx April 15, 2011
  - Thunderhead cloud – S. Wittrock 2010 East of Swift Current
  - Buffalo Pound Dam – SWA website https://www.saskflood.ca/Gallery/default.aspx April 9, 2011
  - Harvest– V. Wittrock October 2010 Neidpath

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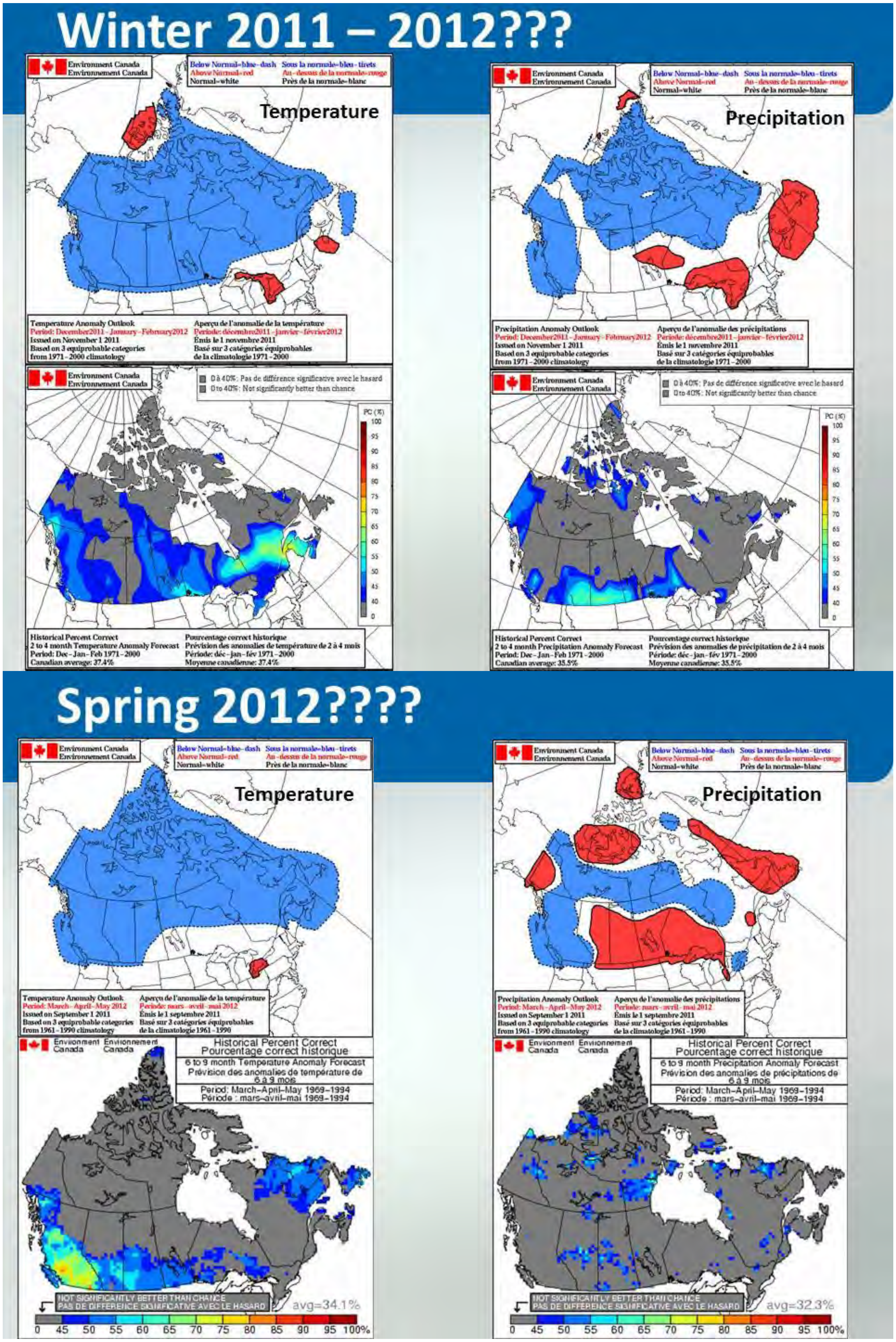
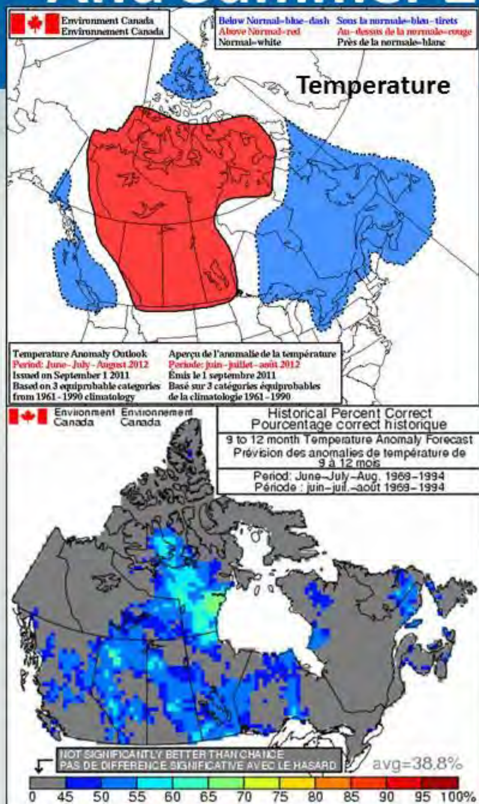
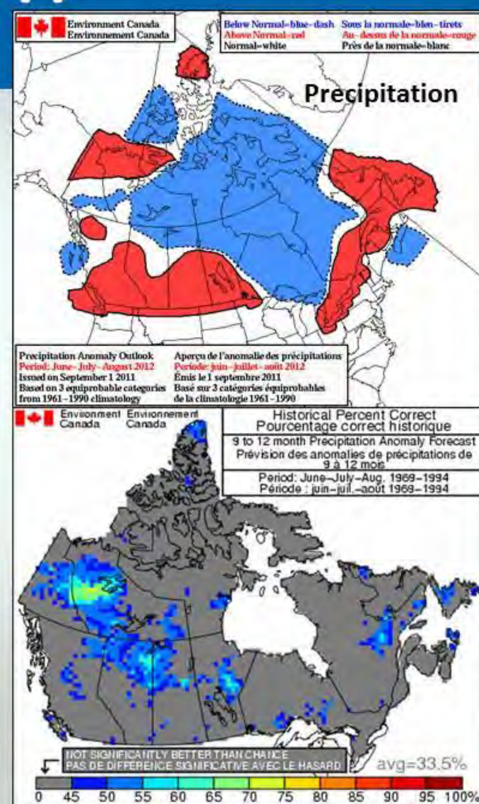

Winter 2011 – 2012???
Environment Canada Environnement Canada
Below Normal=blue-dash Sous la normale=bleu-tirets
Above Normal=red Au-dessus de la normale=rouge
Normal=white Près de la normale=blanc
Temperature
Temperature Anomaly Outlook Aperçu de l'anomalie de la température
Period: December2011 - January - February2012 Période: décembre2011 - janvier - février2012
Issued on November 1 2011 Émis le 1 novembre 2011
Based on 3 equiprobable categories from 1971 - 2000 climatology Basé sur 3 catégories équiprobables de la climatologie 1971 - 2000
Precipitation
Precipitation Anomaly Outlook Aperçu de l'anomalie des précipitations
0 à 40%: Pas de différence significative avec le hasard
0 to 40%: Not significantly better than chance
PC (%)
Historical Percent Correct Pourcentage correct historique
2 to 4 month Temperature Anomaly Forecast Prévision des anomalies de température de 2 à 4 mois
Period: Dec - Jan - Feb 1971 - 2000 Période: déc - jan - fév 1971 - 2000
Canadian average: 37.4% Moyenne canadienne: 37.4%
2 to 4 month Precipitation Anomaly Forecast Prévision des anomalies de précipitation de 2 à 4 mois
Canadian average: 35.5% Moyenne canadienne: 35.5%
Spring 2012????
Temperature
Period: March - April - May 2012 Période: mars - avril - mai 2012
Issued on September 1 2011 Émis le 1 septembre 2011
Based on 3 equiprobable categories from 1961 - 1990 climatology Basé sur 3 catégories équiprobables de la climatologie 1961 - 1990
Historical Percent Correct Pourcentage correct historique
6 to 9 month Temperature Anomaly Forecast Prévision des anomalies de température de 6 à 9 mois
Period: March-April-May 1969-1994 Période : mars-avril-mai 1969-1994
NOT SIGNIFICANTLY BETTER THAN CHANCE PAS DE DIFFERENCE SIGNIFICATIVE AVEC LE HASARD
avg=34.1%
Precipitation
6 to 9 month Precipitation Anomaly Forecast Prévision des anomalies de précipitations de 6 à 9 mois
avg=32.3%
0 45 50 55 60 65 70 75 80 85 90 95 100%

And Summer 2012???





What's next?

- Study of 2010 and 2011 for excessive moisture
- Future drought and excessive moisture
- etc

src

Gridded data

- Gridded data sets preferred over station data due to improved spatial/temporal coverage
- Gridding data procedure removes unnecessary noise, resulting in smoother data for mapping
- PDSI and SPI derived from the ANUSPLIN data set
- ANUSPLIN was chosen for ability to capture several significant precipitation events, for better comparability with data and for area covered
- Develop data bases of PDSI and SPII for the watersheds (10 KM grid)

Top 10 most extreme years PDSI Z-Value
(1901-2005 Agriculture Year (Sept to Aug))

Drought

Year	PDSI Z-value	Change in Wheat Yield*
1961	-5.9	-71.1
1929	-4.9	Not Available
2001	-4.9	-39.3
1972	-4.8	-27.7
1984	-4.8	-31.5
1958	-4.2	-50.8
1930	-4.0	Not Available
1967	-4.0	-46.5
2003	-3.9	-0.4
1971	-3.8	-1.3

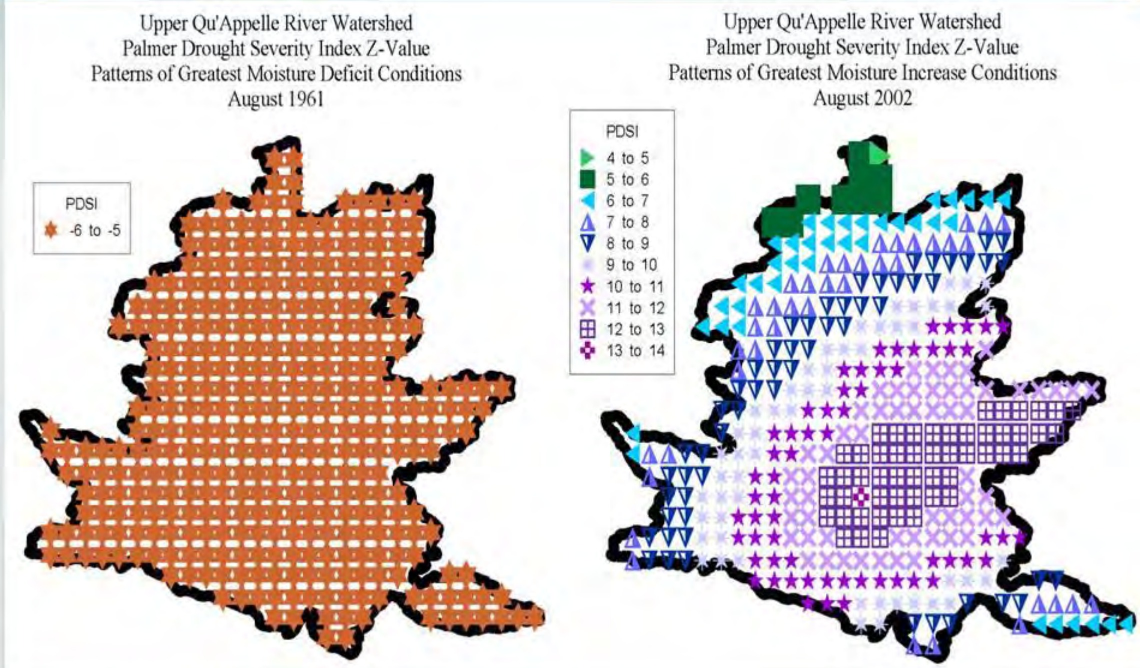
Excessive Moisture

Year	PDSI Z-value	Change in Wheat Yield*
2002	13.1	-37.5
1954	11.0	-75.7
1993	9.3	-5.7
1995	8.8	-7.1
1907	6.8	Not Available
1951	6.8	-24.9
1974	6.3	-36.1
1966	6.1	-5.2
1968	5.9	-31.3
2005	5.9	17.2

*Spring Wheat Percent from 2000 to 2009 10 yr Average
Average over entire watershed

Wheat Yield data:
SK Ministry of Agriculture

PDSI Z-Value



Top 10 most extreme years
SPI – 1 Month (1901-2005)

Drought

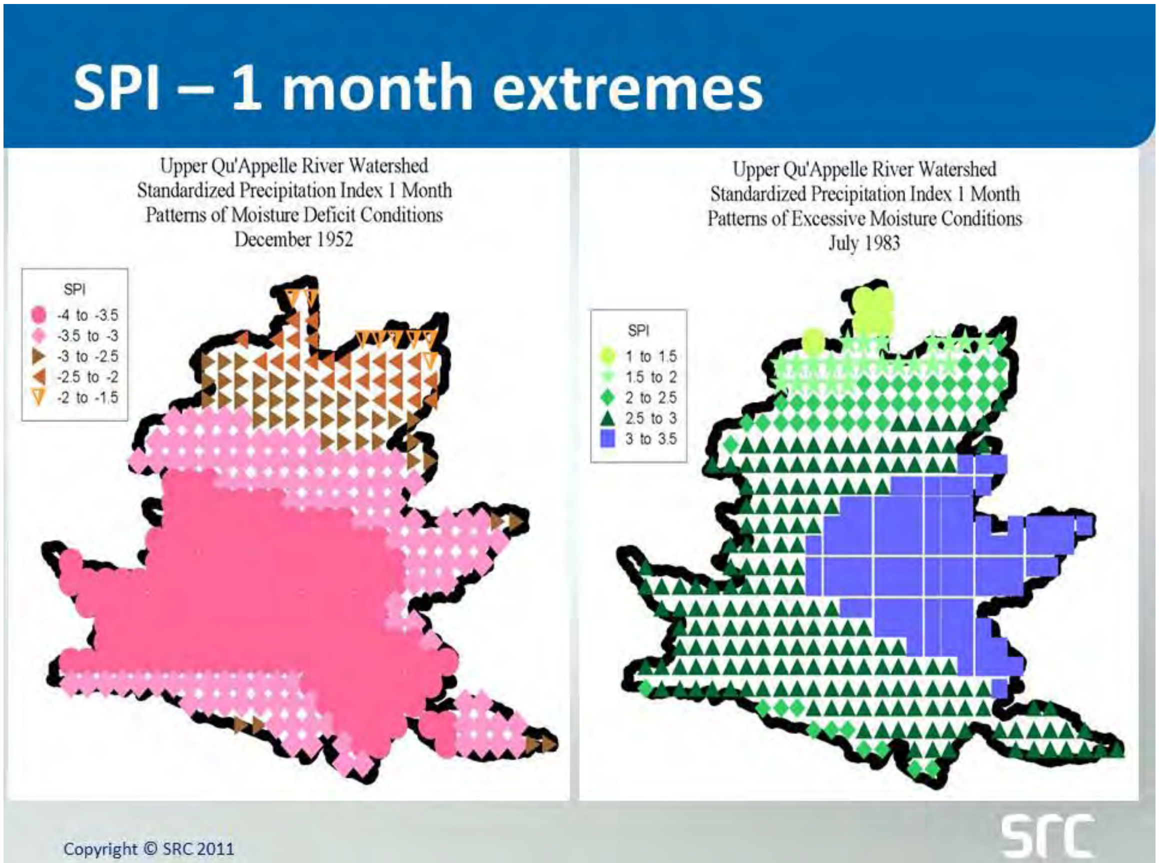
Year	Month	SPI01	Change in Wheat Yield*
1952	12	-3.9	-13.8
1961	8	-3.5	-71.1
1995	9	-3.3	-7.1
1968	4	-3.3	-31.3
1974	11	-3.2	-36.1
1954	12	-3.2	-75.7
1925	12	-3.2	Not Available
1965	10	-3.1	-22.2
1969	10	-3.1	-6.7
1908	9	-3.1	Not Available

Excessive Moisture

Year	Month	SPI01	Change in Wheat Yield*
1983	7	3.3	2.2
1955	4	3.3	-21.0
2002	8	3.2	-37.5
1977	5	3.1	0.3
1904	3	2.9	Not Available
1909	7	2.9	Not Available
1911	1	2.7	Not Available
1947	11	2.7	-68.7
1993	7	2.7	-5.7
1959	9	2.7	-43.5

*Spring Wheat Percent from 2000 to 2009 10 yr Average
Average over entire watershed

Wheat Yield data:
SK Ministry of Agriculture


SPI – 1 month extremes
Upper Qu'Appelle River Watershed
Standardized Precipitation Index 1 Month
Patterns of Moisture Deficit Conditions
December 1952
SPI
-4 to -3.5
-3.5 to -3
-3 to -2.5
-2.5 to -2
-2 to -1.5
Upper Qu'Appelle River Watershed
Standardized Precipitation Index 1 Month
Patterns of Excessive Moisture Conditions
July 1983
SPI
1 to 1.5
1.5 to 2
2 to 2.5
2.5 to 3
3 to 3.5
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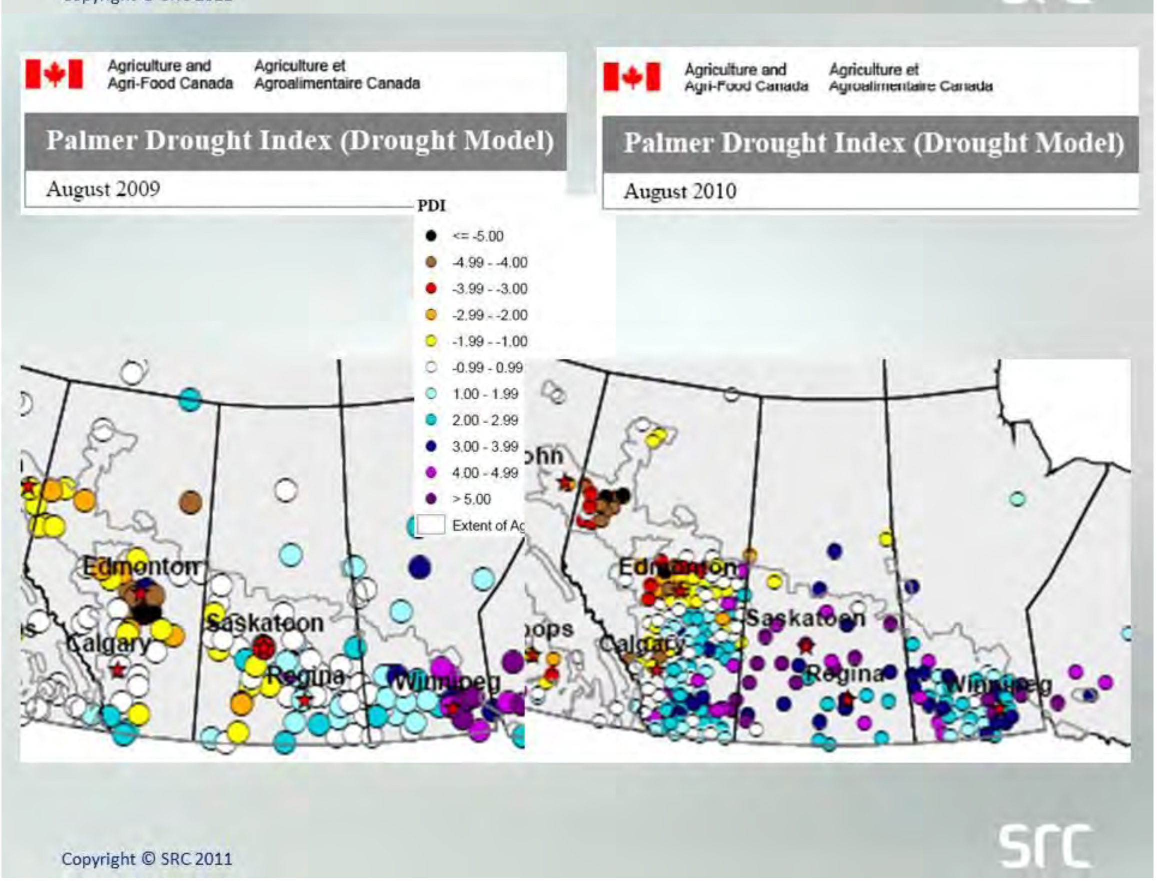
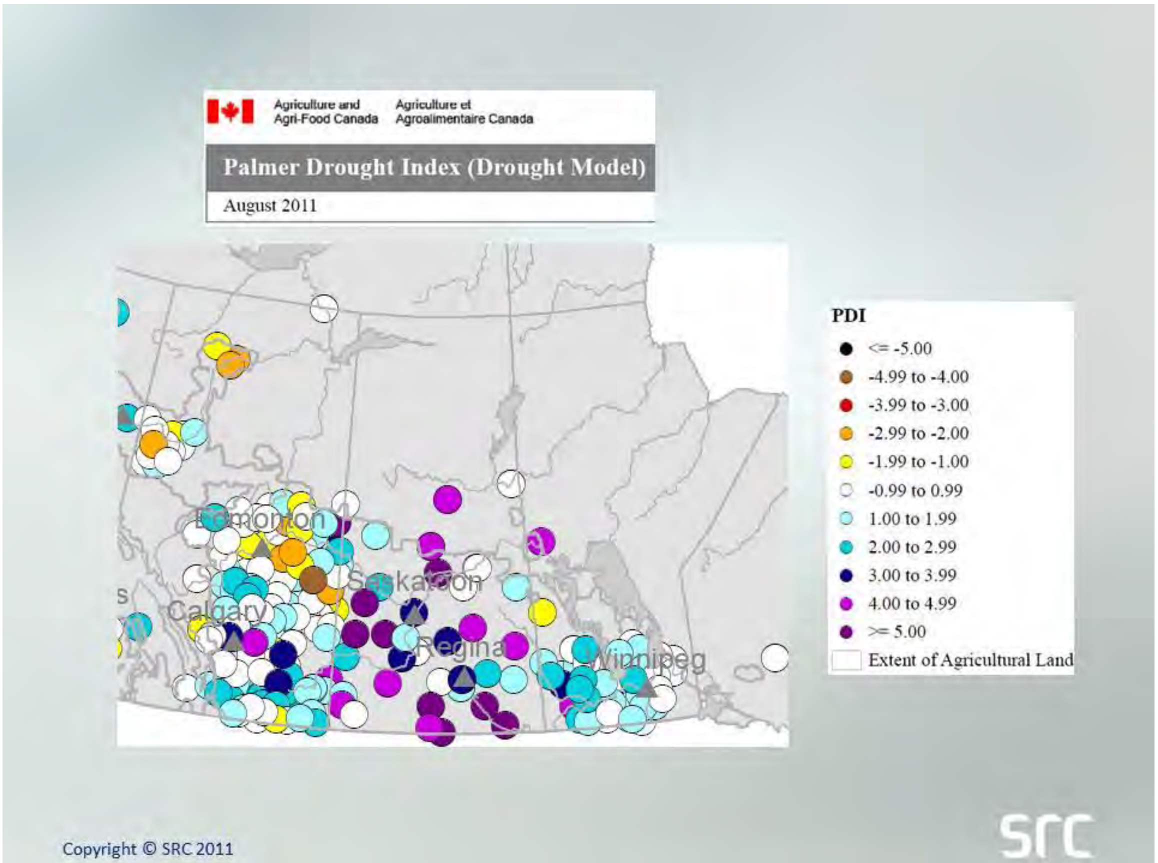
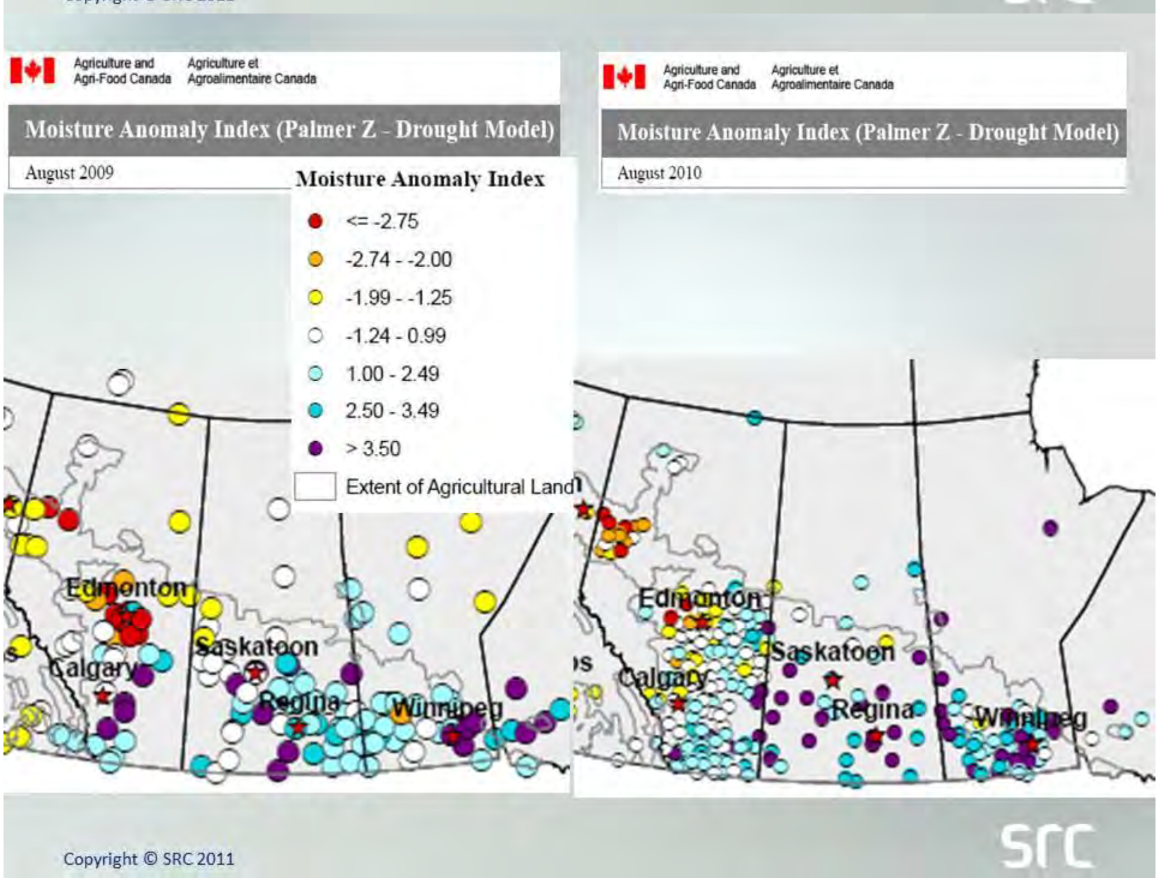
src


Agriculture and Agri-Food Canada
Agriculture et Agroalimentaire Canada
Palmer Drought Index (Drought Model)
August 2009
PDI
<= -5.00
-4.99 - -4.00
-3.99 - -3.00
-2.99 - -2.00
-1.99 - -1.00
-0.99 - 0.99
1.00 - 1.99
2.00 - 2.99
3.00 - 3.99
4.00 - 4.99
> 5.00
Edmonton
Calgary
Saskatoon
Regina
Winnipeg
Agriculture and Agri-Food Canada
Agriculture et Agroalimentaire Canada
Palmer Drought Index (Drought Model)
August 2010
Edmonton
Calgary
Saskatoon
Regina
Winnipeg
Copyright © SRC 2011
src


Agriculture and Agri-Food Canada
Agriculture et Agroalimentaire Canada
Palmer Drought Index (Drought Model)
August 2011
PDI
<= -5.00
-4.99 to -4.00
-3.99 to -3.00
-2.99 to -2.00
-1.99 to -1.00
-0.99 to 0.99
1.00 to 1.99
2.00 to 2.99
3.00 to 3.99
4.00 to 4.99
>= 5.00
Extent of Agricultural Land
Edmonton
Calgary
Saskatoon
Regina
Winnipeg
Copyright © SRC 2011


Agriculture and Agri-Food Canada
Agriculture et Agroalimentaire Canada
Moisture Anomaly Index (Palmer Z - Drought Model)
August 2009
Moisture Anomaly Index
<= -2.75
-2.74 - -2.00
-1.99 - -1.25
-1.24 - 0.99
1.00 - 2.49
2.50 - 3.49
> 3.50
Extent of Agricultural Land
Edmonton
Calgary
Saskatoon
Regina
Winnipeg
Agriculture and Agri-Food Canada
Agriculture et Agroalimentaire Canada
Moisture Anomaly Index (Palmer Z - Drought Model)
August 2010
Edmonton
Calgary
Saskatoon
Regina
Winnipeg
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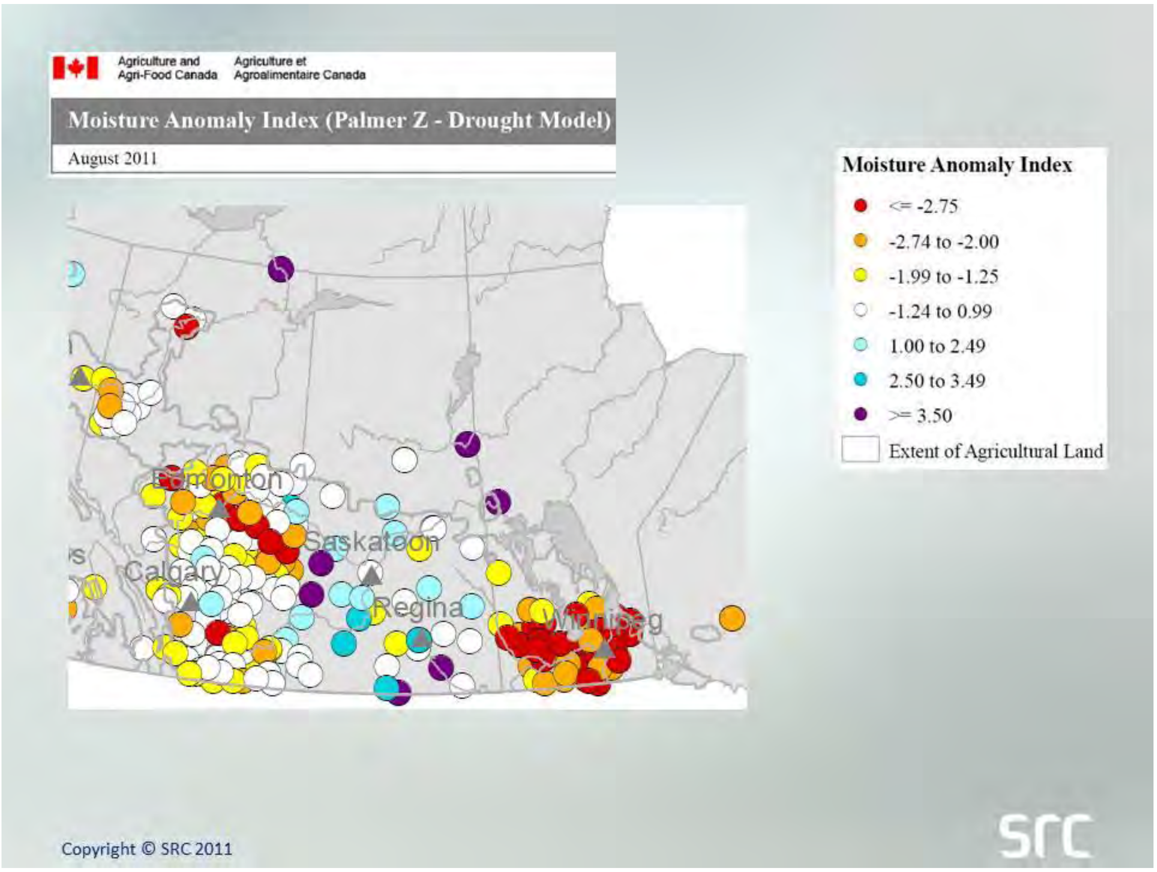
Agriculture and Agri-Food Canada
Agriculture et Agroalimentaire Canada
Moisture Anomaly Index (Palmer Z - Drought Model)
August 2011
Edmonton
Saskatoon
Calgary
Regina
Winnipeg
Moisture Anomaly Index
<= -2.75
-2.74 to -2.00
-1.99 to -1.25
-1.24 to 0.99
1.00 to 2.49
2.50 to 3.49
>= 3.50
Extent of Agricultural Land
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SASKATCHEWAN RESEARCH COUNCIL

The Goldilocks Dichotomy: Too Wet or Too Dry. The Milk River Watershed

V. Wittrock[1] and E. Wheaton[2]
[1] Saskatchewan Research Council
[2] Saskatchewan Research Council and University of Saskatchewan

SRC Publication # 13022-12D11

Outline

- Objectives & benefits
- Methodology
- Background information
- The extreme years
- Impacts and adaptations
- Conclusion

Objectives

- To **characterize** drought and excessive moisture events for selected watersheds during the past century.
- **Compare** and **contrast** driest and wettest patterns to help determine characteristics for risk assessments and planning.
- Consider the **implications** for impacts and adaptations directly related to the watershed.

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Benefits of Examining the Past

- Assist communities, local municipalities, provincial and federal governments with **risk management** and **planning strategies** for extreme events.
- **Avoid damages and decrease** the **costs** of climate events by learning from the past.
- Help to lower the **costs of the impacts of future climatic events.**

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What is a Drought?

- A deficiency of precipitation from expected or "normal" that, when extended over a season or longer, is insufficient to meet the demands of human activities and the environment
- Four major types of drought including Meteorological, Agricultural, Hydrological and Socio-economic

- Or when it hasn't rained, the fields are dry, the lakes or rivers are really low and it impacts the economy, environment and our way of life

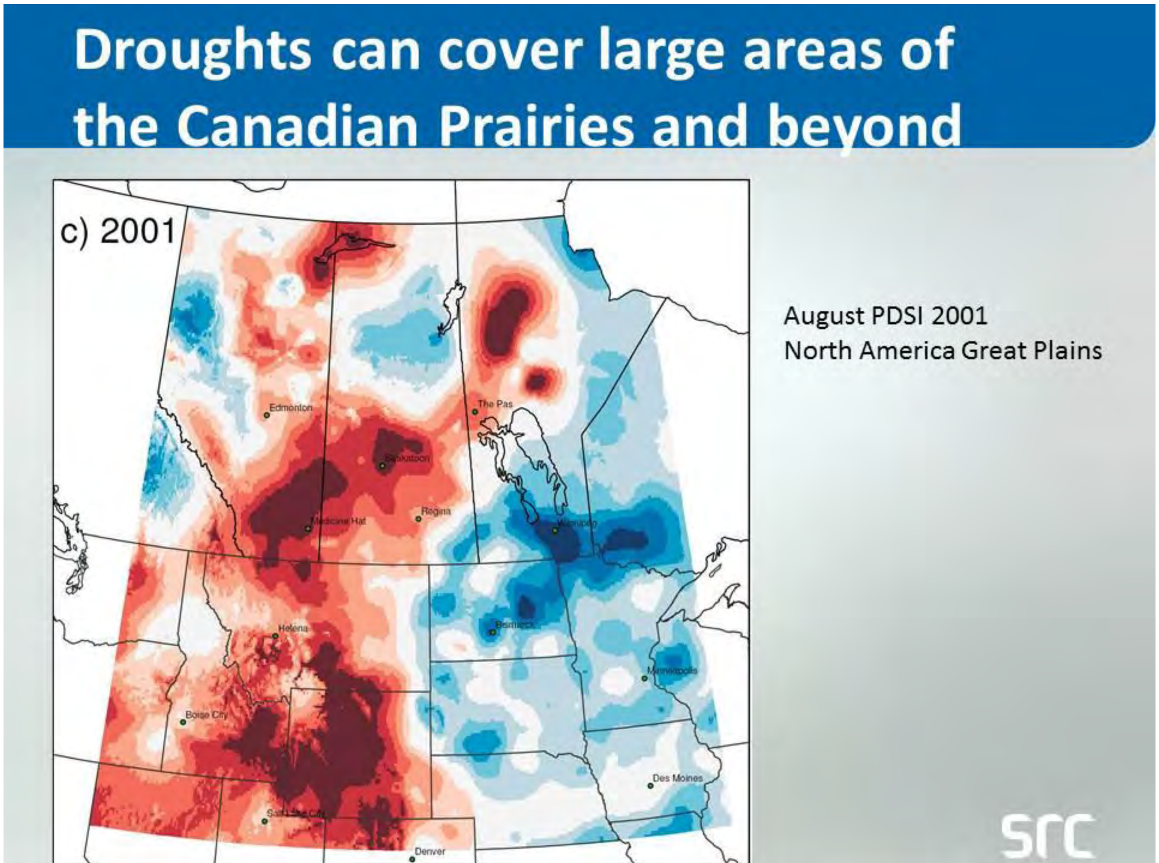
Photo: AAFC

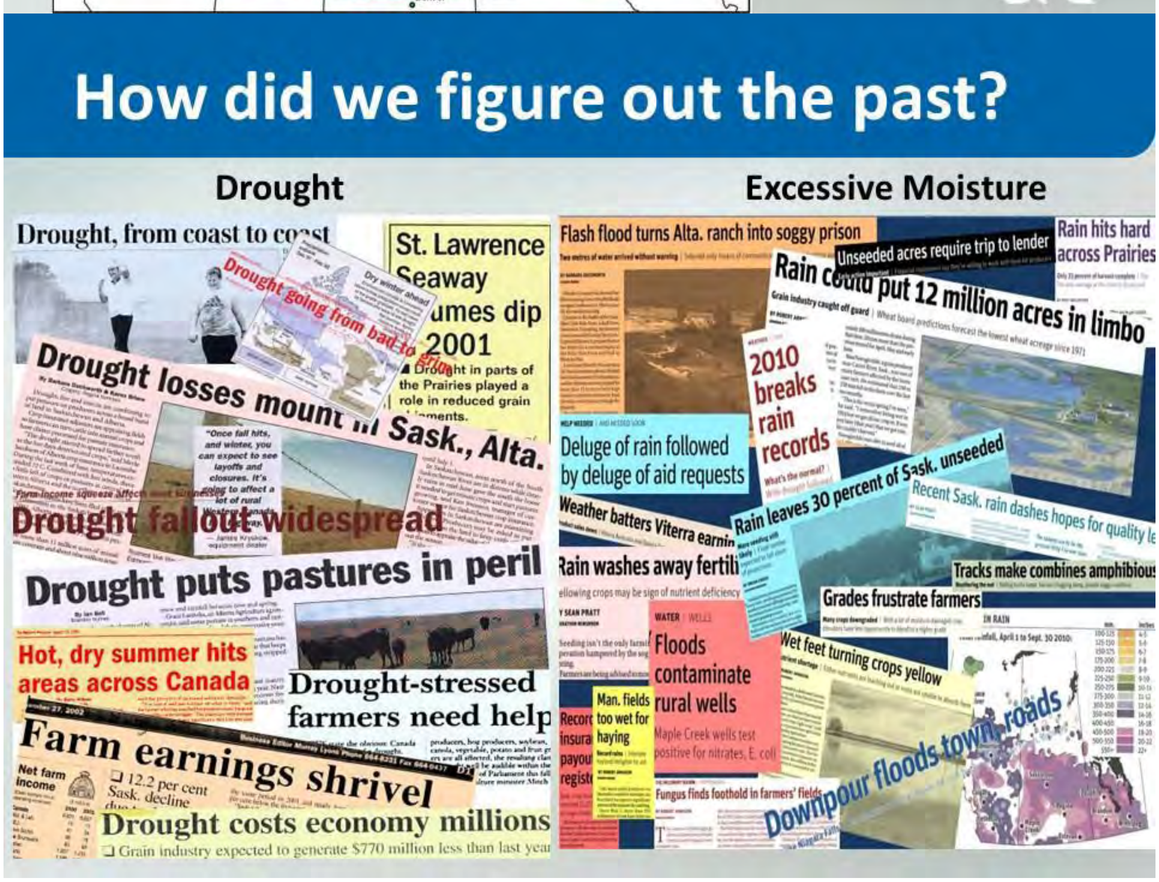
What is Excessive Moisture?

- An excess of precipitation from expected or "normal" that, when extended over a season or longer, is too much to meet the demands of human activities and the environment
- Four major types of excess moisture including Meteorological, Agricultural, Hydrological and Socio-economic

- Or it won't quit raining, the fields are saturated, the lakes or rivers are over flowing their banks and it impacts the economy, environment and our way of life

Photo: Wucher, L. St. Gregor SK Sept 6, 2010


Droughts can cover large areas of the Canadian Prairies and beyond
c) 2001
Edmonton
The Pas
Saskatoon
Regina
Medicine Hat
Winnipeg
Helena
Bismarck
Minneapolis
Boise City
Des Moines
Salt Lake City
Denver
August PDSI 2001
North America Great Plains
src


How did we figure out the past?
Drought
Excessive Moisture
Drought, from coast to coast
St. Lawrence Seaway
Drought going from bad to grim
2001
Drought losses mount in Sask., Alta.
Drought fallout widespread
Drought puts pastures in peril
Hot, dry summer hits areas across Canada
Drought-stressed farmers need help
Farm earnings shrivel
12.2 per cent Sask. decline
Drought costs economy millions
Grain industry expected to generate $770 million less than last year
Flash flood turns Alta. ranch into soggy prison
Unseeded acres require trip to lender
Rain hits hard across Prairies
Rain could put 12 million acres in limbo
2010 breaks rain records
Deluge of rain followed by deluge of aid requests
Weather batters Viterra earnings
Rain leaves 30 percent of Sask. unseeded
Recent Sask. rain dashes hopes for quality
Tracks make combines amphibious
Grades frustrate farmers
Floods contaminate rural wells
Maple Creek wells test positive for nitrates, E. coli
Man. fields too wet for haying
Wet feet turning crops yellow
Downpour floods town, roads
Fungus finds foothold in farmers' fields

Methods

- Use a gridded **Palmer Drought Severity Index**(PDSI), **PDSI z-value** and **Standardized Precipitation Index** (SPI) to develop database for 1901 to 2005.
- Other sources are used to document the more recent drought and excessive moisture events.

src

Methods continued

- **Rank** the 10 driest and 10 wettest years in the watershed
- **Spatial variability** is determined from these rankings.
- Literature review and media analysis to determine the **impacts** and **adaptation** strategies undertaken

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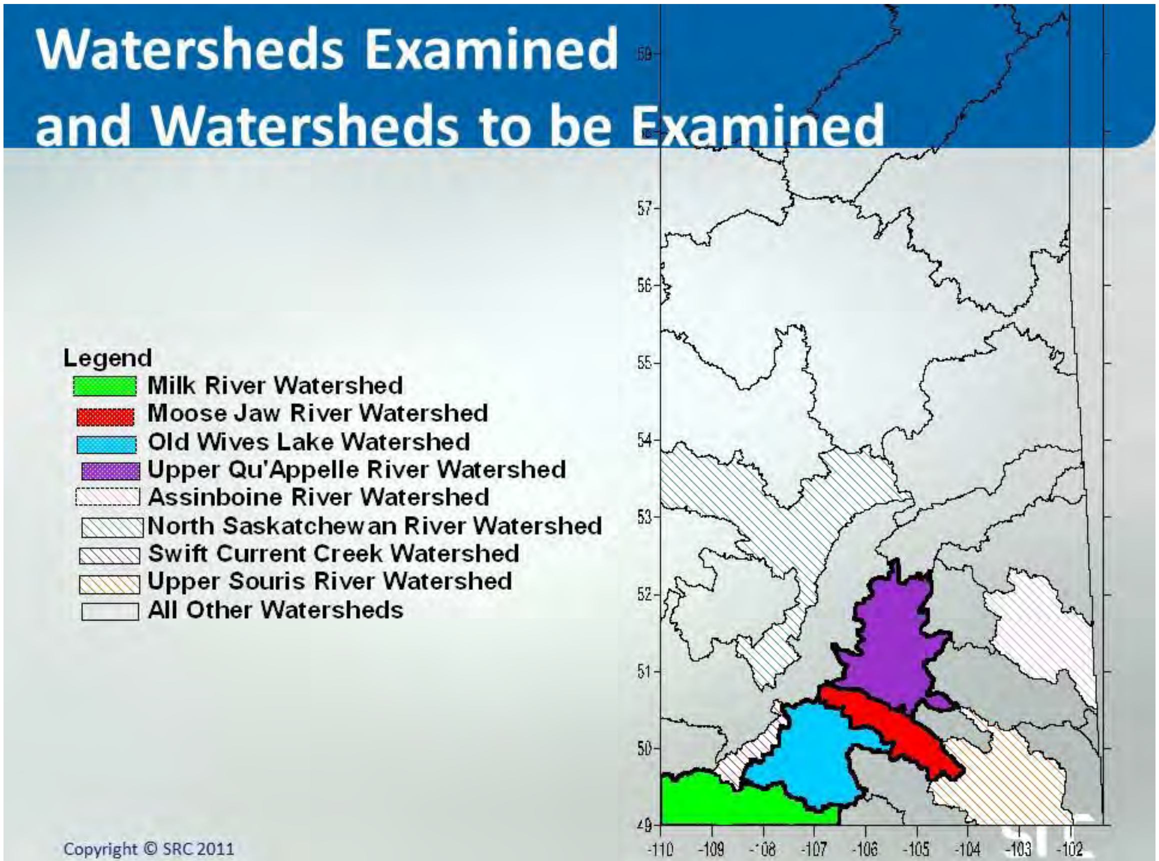

Watersheds Examined
and Watersheds to be Examined
Legend
Milk River Watershed
Moose Jaw River Watershed
Old Wives Lake Watershed
Upper Qu'Appelle River Watershed
Assinboine River Watershed
North Saskatchewan River Watershed
Swift Current Creek Watershed
Upper Souris River Watershed
All Other Watersheds
57
56
55
54
53
52
51
50
49
-110 -109 -108 -107 -106 -105 -104 -103 -102
Copyright © SRC 2011


How do we classify severe drought,
excessive moisture or average conditions?
Source: V. Wittrock Aug 1 2009
Drought & cold stressed crop
(short & thin) (Field near Neidpath)
Source: SWA https://www.saskflood.ca/#
Heavy snow pack Apr 30 2011
Davis Creek Road Cypress Hills
Copyright © SRC 2011

Palmer Drought Severity Index (PDSI)

- One of the most widely used drought and excessive moisture indices
- Primarily a hydrological drought index
- Derived using a soil moisture/water balance model which requires information on the available soil water content along with daily/monthly precipitation and temperature data
- Values contain a long term memory of the previous moisture conditions because the calculated value.

What do PDSI values mean?

Classification		PDSI Value
Drought	Exceptional	≤ -5
	Extreme	> -5.0 to -4.0
	Severe	> -4.0 to -3.0
	Moderate	> -3.0 to -2.0
	Mild	> -2.0 to -1.0
Near Normal		> -1.0 to 1.0
Wet	Mild	1.0 to < 2.0
	Moderate	2.0 to < 3.0
	Severe	3.0 to < 4.0
	Extreme	4.0 to < 5.0
	Exceptional	≥ 5.0

Top 10 Extreme Years and Wheat Yields Palmer Drought Severity Index

(1901-2005 Agriculture Year (Sept to Aug))

Drought

Year	PDSI	Change in Wheat Yield*
1919	-6.6	Not Available
1988	-6.5	-56.9
1937	-6.4	Not Available
1961	-6.4	-84.6
1949	-6.1	-94.3
1946	-5.9	-81.1
1936	-5.8	Not Available
1931	-5.8	Not Available
1905	-5.8	Not Available
1984	-5.5	-46.7

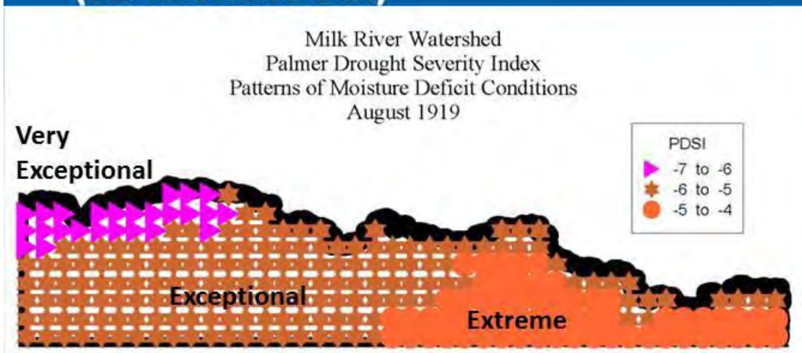
Excessive Moisture

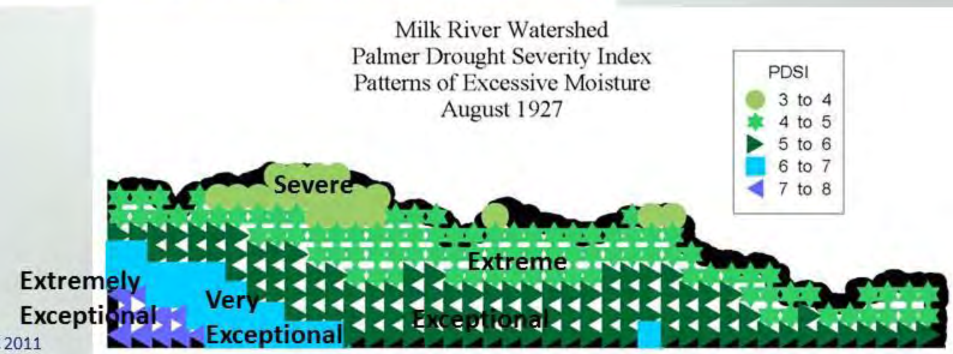
Year	PDSI	Change in Wheat Yield*
1927	7.9	Not Available
1907	7.7	Not Available
1993	7.3	13.7
1975	7.0	0.0
1909	6.8	Not Available
1954	6.2	0.0
1991	6.1	18.1
2004	6.0	38.9
1966	5.8	-2.3
1955	5.8	-16.6

*Spring Wheat Percent from 2000 to 2009 10 yr Average
Averaged over entire watershed

Wheat Yield data:
SK Ministry of Agriculture

Most Extreme Years (12-month PDSI)





Standard Precipitation Index (SPI)

- Developed to monitor moisture supply conditions
- Identifies emerging droughts months earlier than the PDSI because antecedent moisture conditions are not taken into account
- SPI does not calculate temperature anomalies, a critical feature for agricultural drought monitoring

What do SPI values mean?

Classification		SPI Value
Drought	Exceptional	≤ -2.5
	Extreme	> -2.5 to -2.0
	Severe	> -2.0 to -1.5
	Moderate	> -1.5 to -1.0
	Mild	> -1.0 to -0.5
Near Normal		> -0.5 to 0.5
Wet	Mild	0.5 to < 1.0
	Moderate	1.0 to < 1.5
	Severe	1.5 to < 2.0
	Extreme	2.0 to < 2.5
	Exceptional	≥ 2.5

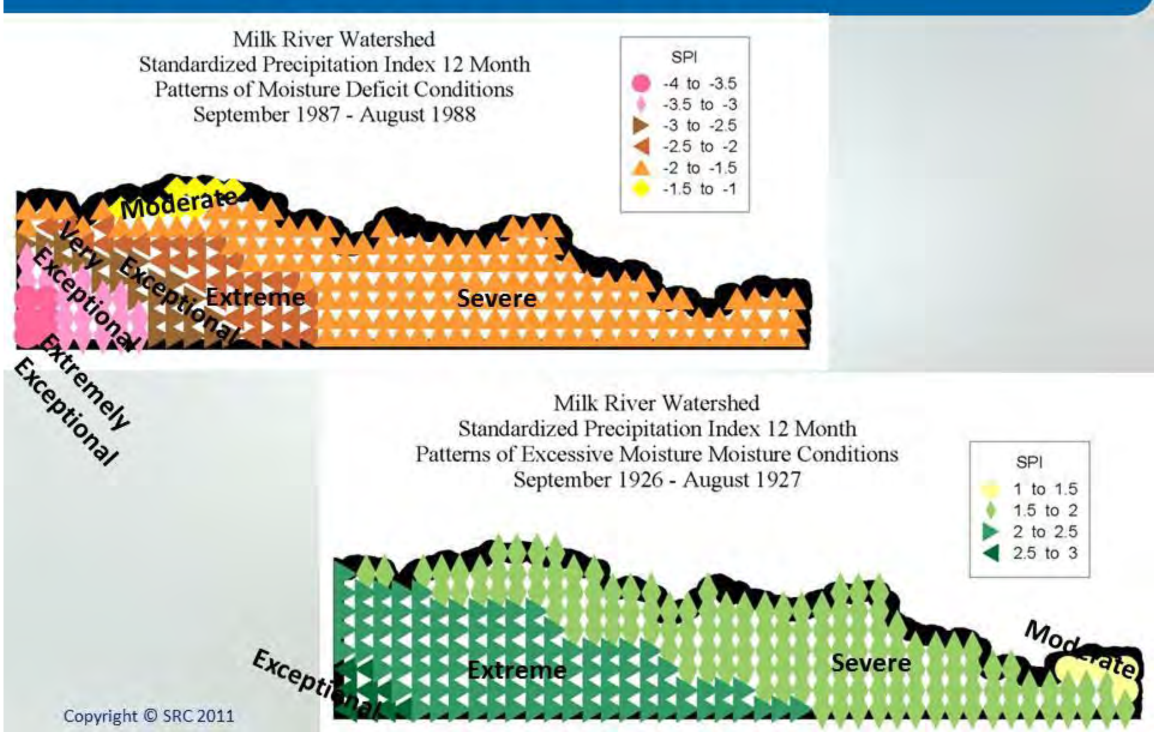
Top 10 - 12 Month Extremes (Sept – Aug)
Standardized Precipitation Index (1901-2005)

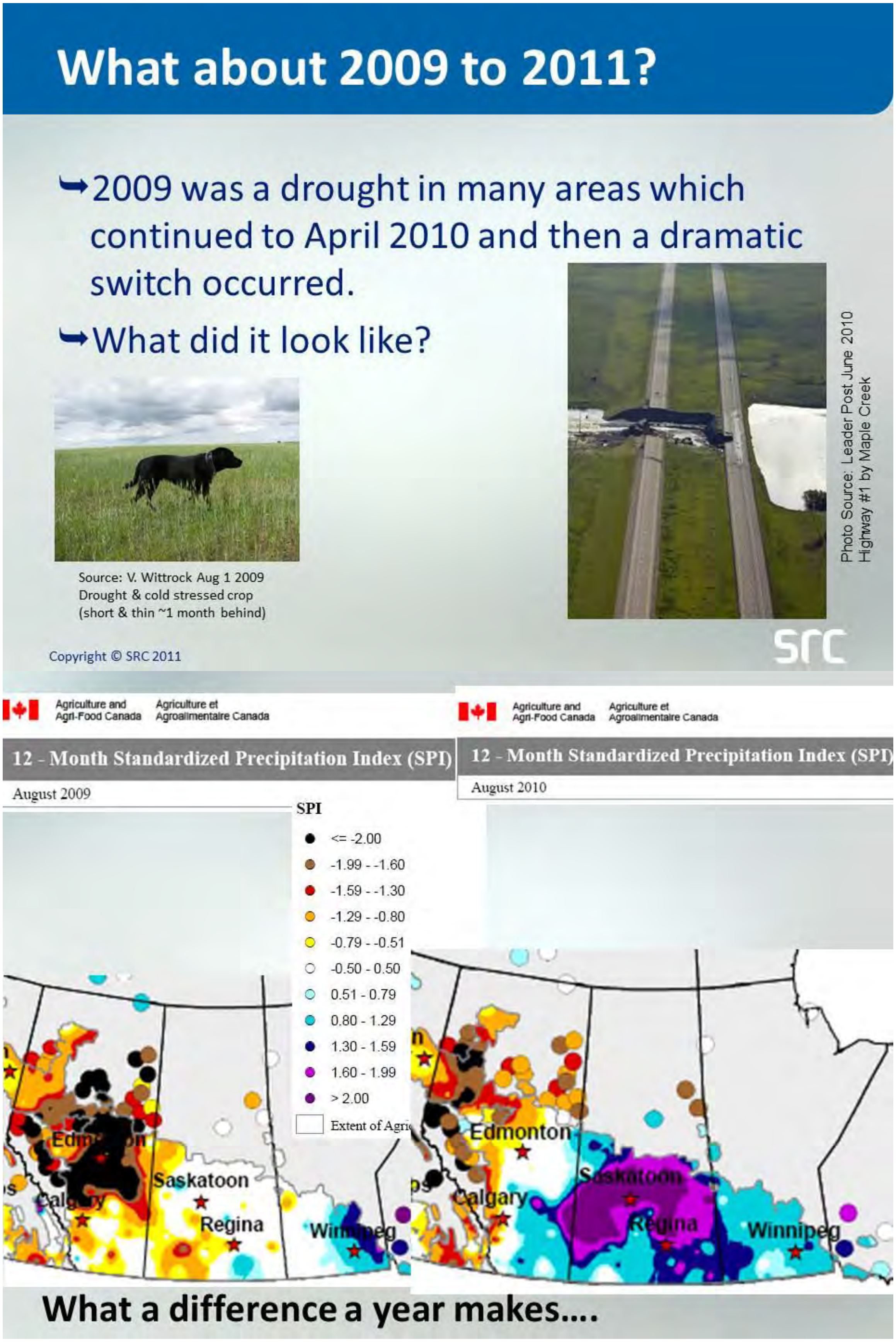
Drought			Excessive Moisture		
Year	SPI 12	Change in Wheat Yield*	Year	SPI 12	Change in Wheat Yield*
1988	-3.7	-56.9	1927	2.6	Not Available
1961	-2.7	-84.6	1993	2.3	13.7
1929	-2.6	Not Available	2004	2.1	38.9
1977	-2.6	-18.3	2002	2.0	12.7
1984	-2.5	-46.7	1987	1.9	2.1
1949	-2.3	-94.3	1991	1.8	18.1
1937	-2.2	Not Available	1915	1.7	Not Available
1919	-2.1	Not Available	1999	1.7	23.9
1936	-2.1	Not Available	1974	1.7	-21.1
1958	-1.9	-62.9	1916	1.7	Not Available

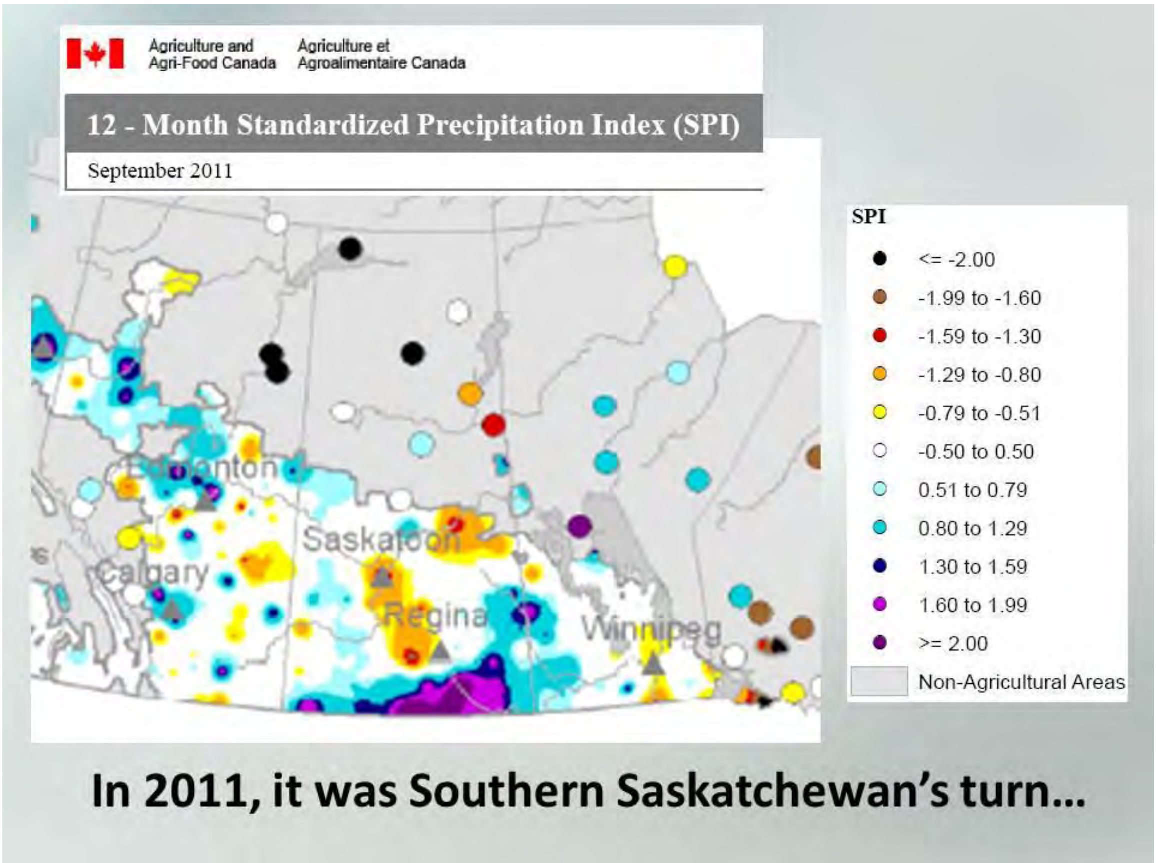
*Spring Wheat Percent from 2000 to 2009 10 yr Average
Averaged over entire watershed

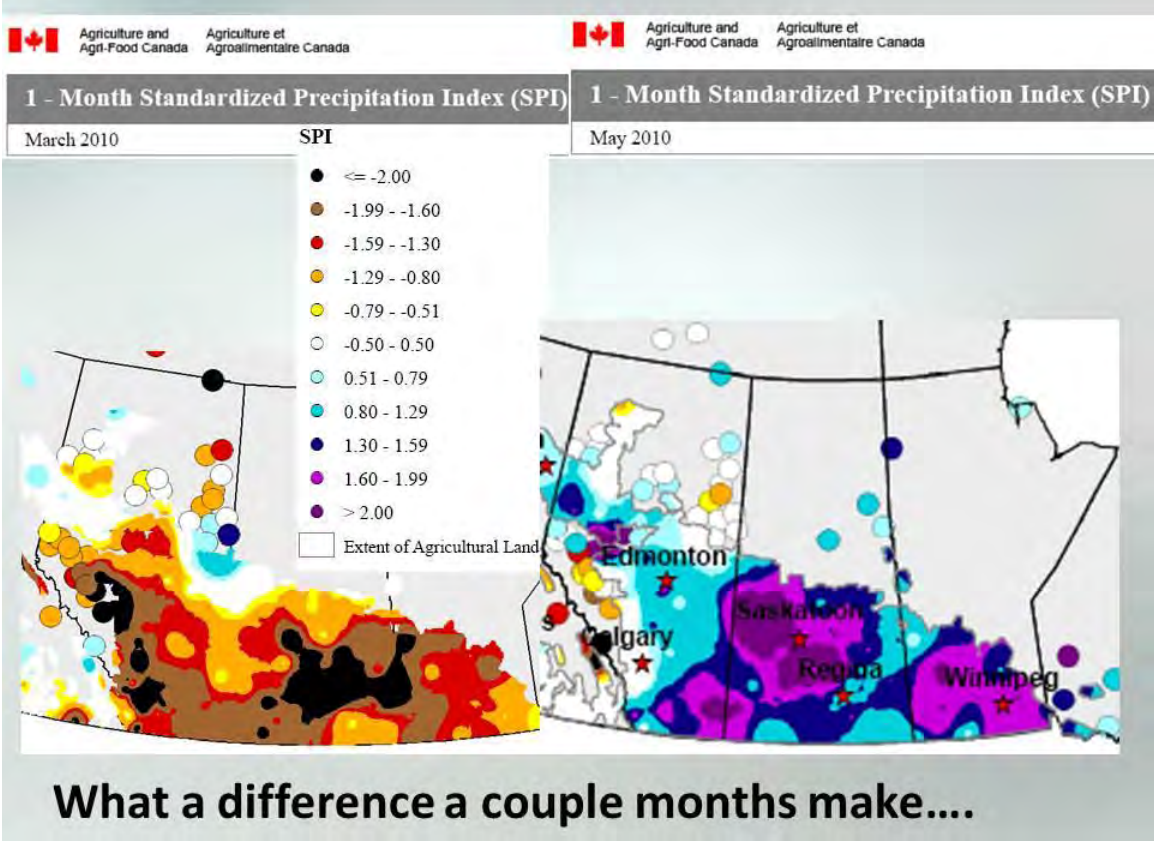
Wheat Yield data:
SK Ministry of Agriculture

SPI – 12 month extremes




What about 2009 to 2011?
2009 was a drought in many areas which continued to April 2010 and then a dramatic switch occurred.
What did it look like?
Source: V. Wittrock Aug 1 2009
Drought & cold stressed crop
(short & thin ~1 month behind)
Photo Source: Leader Post June 2010
Highway #1 by Maple Creek
Copyright © SRC 2011
src
Agriculture and Agri-Food Canada
Agriculture et Agroalimentaire Canada
12 - Month Standardized Precipitation Index (SPI)
August 2009
SPI
<= -2.00
-1.99 - -1.60
-1.59 - -1.30
-1.29 - -0.80
-0.79 - -0.51
-0.50 - 0.50
0.51 - 0.79
0.80 - 1.29
1.30 - 1.59
1.60 - 1.99
> 2.00
Saskatoon
Regina
Agriculture and Agri-Food Canada
Agriculture et Agroalimentaire Canada
12 - Month Standardized Precipitation Index (SPI)
August 2010
Edmonton
Calgary
Saskatoon
Regina
Winnipeg
What a difference a year makes….


Agriculture and Agri-Food Canada
Agriculture et Agroalimentaire Canada
12 - Month Standardized Precipitation Index (SPI)
September 2011
SPI
<= -2.00
-1.99 to -1.60
-1.59 to -1.30
-1.29 to -0.80
-0.79 to -0.51
-0.50 to 0.50
0.51 to 0.79
0.80 to 1.29
1.30 to 1.59
1.60 to 1.99
>= 2.00
Non-Agricultural Areas
Edmonton
Saskatoon
Calgary
Regina
Winnipeg
In 2011, it was Southern Saskatchewan's turn…


Agriculture and Agri-Food Canada
Agriculture et Agroalimentaire Canada
1 - Month Standardized Precipitation Index (SPI)
March 2010
SPI
<= -2.00
-1.99 - -1.60
-1.59 - -1.30
-1.29 - -0.80
-0.79 - -0.51
-0.50 - 0.50
0.51 - 0.79
0.80 - 1.29
1.30 - 1.59
1.60 - 1.99
> 2.00
Extent of Agricultural Land
Agriculture and Agri-Food Canada
Agriculture et Agroalimentaire Canada
1 - Month Standardized Precipitation Index (SPI)
May 2010
Edmonton
Calgary
Saskatoon
Regina
Winnipeg
What a difference a couple months make….

These Extreme Years have Impacted Everyone and Adaptation Strategies have been Applied

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Impacts from Droughts

- Soil erosion
- Water shortages
- Feed shortages
- Poor yielding crops
- Economic instability
- etc

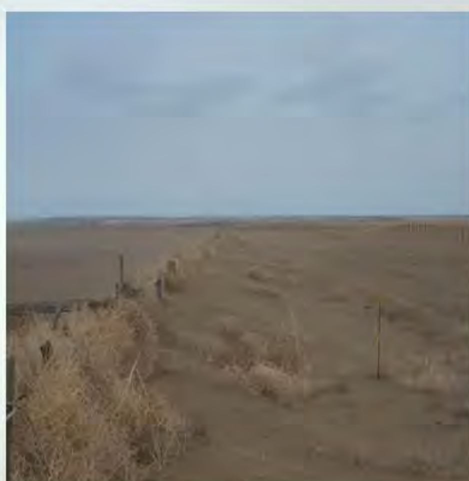

Photo Source: AAFC

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Adaptations to Droughts

- Installation of weirs/dams that allow for more stable water supply (e.g., Eastend Reservoir)
- Increased irrigation projects
- Drought tolerant crops
- Minimum tillage
- Water conservation
- etc

Photo Source: E. Stratton circa 2002
St. Mary's Irrigation District

src

Impacts from Excessive Moisture

- Soil erosion
- Water quality issues (both surface and ground water)
- Degraded crops (crops under water) decreased yield and quality
- Infrastructure problems (e.g., roads, basements)
- etc

S. Wittrock July 2010 East of Swift Current

src

Adaptations to Excessive Moisture

- Different crops to adapt to diseases and excess moisture conditions
- Minimum tillage
- Re-establishment of riparian zones
- Dams allow for minimal flood control (e.g., Eastend Reservoir)
- etc

src

Conclusion and Questions

- The Milk River Basin has always had extreme events and future ones could be worse…
- **But** the trick is to learn from the past to better adapt to our ever evolving future.
- There are still many questions to be asked,
  - What if 2012 is as wet as 2011?
  - Changing infrastructure to accommodate excessive moisture occurrences e.g., Vanguard Storm in 2000?
  - What if we have a 10 year drought, how will we be impacted and will we be able to adapt?

src

References

- Milk River Map: Adapted from map produced by Alberta Sustainable Resource Development, Prairies Area, Resource Information Unit, Lethbridge, April 2009 Website: http://www.milkriverwatershedcouncil.ca/maps.html
- What is a drought?" slide: Bonsal, B., E. Wheaton, V. Wittrock, E. Siemens and N. Nicolichuk. 2010. Everyone is Affected: Selections of Drought Characteristics, Impacts and Adaptations. Presentation at the DRI workshop May 11, 2010, Winnipeg, Manitoba. SRC Pub # 11602-1D10.
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- Drought Collage: Wheaton, E., with V. Wittrock, S. Kulshreshtha, G. Koshida, C. Grant, A. Chipanshi, B. Bonsal, with the rest of the Canadian Drought Study Steering Committee, P. Adkins, G. Bell, G. Brown, A. Howard and R. MacGregor. 2005. *Lessons Learned from the Canadian Drought Years of 2001 and 2002: Synthesis Report.* Saskatchewan Research Council (SRC) Publication No. 11602-46E03. 30 pp.
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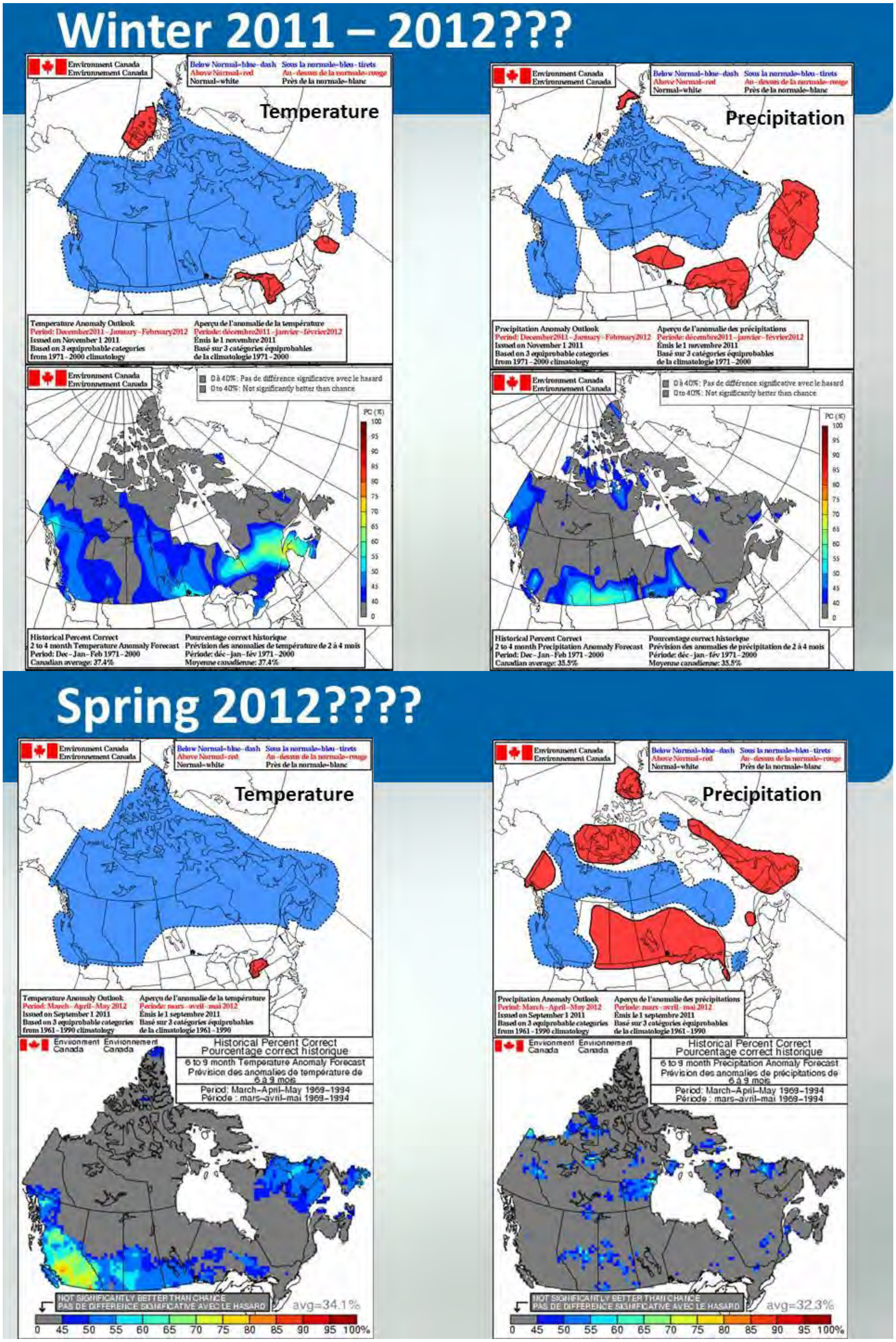
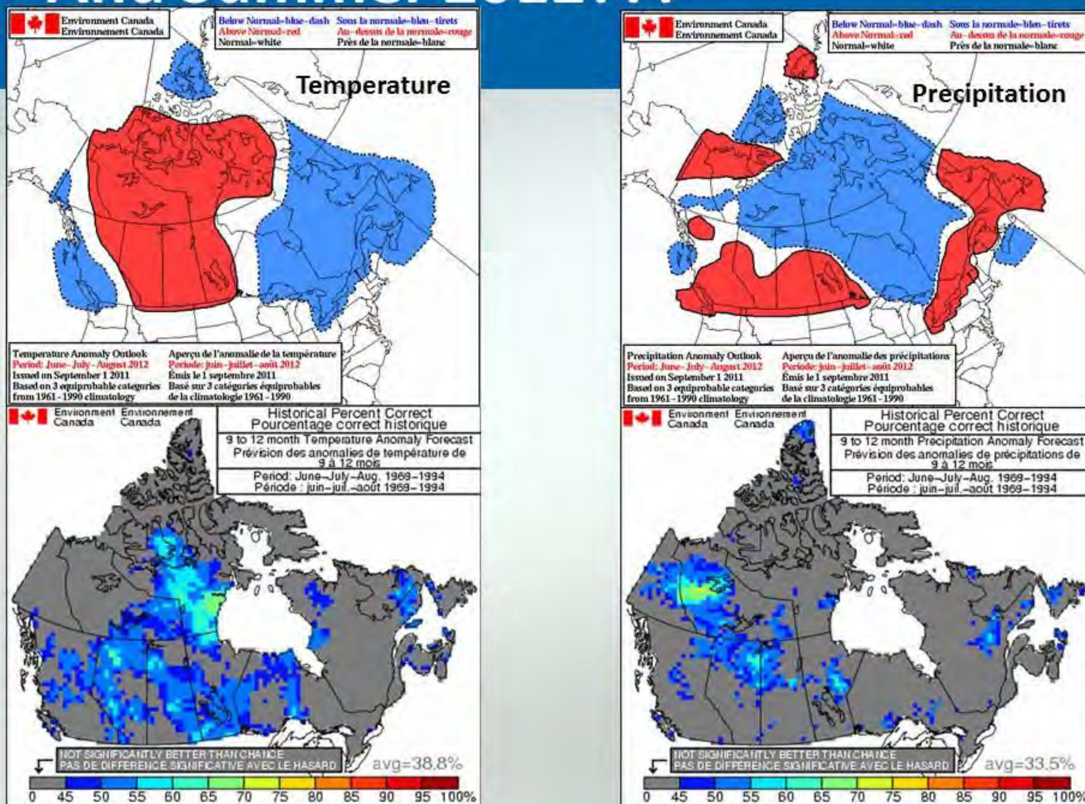
- Temperature and precipitation outlooks: Environment Canada website: http://www.weatheroffice.gc.ca/saisons/index_e.html
- Crop Yields: Ministry of Saskatchewan Agriculture website: http://www.agriculture.gov.sk.ca/rmyields
- Photos:
  - Cracked Earth and soil drifts– Agriculture and Agri-Food Canada (AAFC)
  - Tractor stuck: Wucher, L. St. Gregor SK Sept 6 2010
  - Drought and cold stress crop – V. Wittrock Aug 1, 2009 Neidpath
  - Heavy Snowpack April 30, 2011 Davis Creek Road Cypress Hills – SWA web site: https://www.saskflood.ca/#
  - St Mary's Irrigation – E. Stratton 2002
  - Highway #1 by Maple Creek – Leader Post June 2010
  - Thunderhead cloud – S. Wittrock 2010 East of Swift Current
  - Harvest– V. Wittrock October 2010 Neidpath


Winter 2011 – 2012???
Environment Canada
Environnement Canada
Below Normal–blue–dash Sous la normale–bleu–tirets
Above Normal–red Au–dessus de la normale–rouge
Normal–white Près de la normale–blanc
Temperature
Precipitation
Temperature Anomaly Outlook
Aperçu de l'anomalie de la température
Precipitation Anomaly Outlook
Aperçu de l'anomalie des précipitations
Period: December2011 – January – February2012
Issued on November 1 2011
Émis le 1 novembre 2011
Based on 3 equiprobable categories
from 1971 – 2000 climatology
Basé sur 3 catégories équiprobables
de la climatologie 1971 – 2000
Historical Percent Correct
Pourcentage correct historique
2 to 4 month Temperature Anomaly Forecast
2 to 4 month Precipitation Anomaly Forecast
Period: Dec – Jan – Feb 1971 – 2000
Canadian average: 37.4%
Moyenne canadienne: 37.4%
Canadian average: 35.5%
Moyenne canadienne: 35.5%
Spring 2012????
Period: March – April – May 2012
Issued on September 1 2011
Émis le 1 septembre 2011
from 1961 – 1990 climatology
de la climatologie 1961 – 1990
6 to 9 month Temperature Anomaly Forecast
Prévision des anomalies de température de 6 à 9 mois
6 to 9 month Precipitation Anomaly Forecast
Prévision des anomalies de précipitations de 6 à 9 mois
Period: March–April–May 1969–1994
Période : mars–avril–mai 1969–1994
NOT SIGNIFICANTLY BETTER THAN CHANCE
PAS DE DIFFERENCE SIGNIFICATIVE AVEC LE HASARD
avg=34.1%
avg=32.3%
0 45 50 55 60 65 70 75 80 85 90 95 100%

And Summer 2012???



What's next?

- Study of 2010 and 2011 for excessive moisture
- Future drought and excessive moisture
- etc

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Gridded data

- Gridded data sets preferred over station data due to improved spatial/temporal coverage
- Gridding data procedure removes unnecessary noise, resulting in smoother data for mapping
- PDSI and SPI derived from the ANUSPLIN data set
- ANUSPLIN was chosen for ability to capture several significant precipitation events, for better comparability with data and for area covered
- Develop data bases of PDSI and SPII for the watersheds (10 KM grid)

Top 10 most extreme years PDSI Z-Value
(1901-2005 Agriculture Year (Sept to Aug))

Drought

Year	PDSI Z-value	Change in Wheat Yield*
1961	-4.8	-84.6
2001	-4.4	-22.2
1971	-4.3	-38.3
1967	-4.0	-56.6
1929	-4.0	Not Available
1983	-4.0	4.6
1984	-3.7	-46.7
1970	-3.7	-5.7
2003	-3.7	-13.3
1988	-3.6	-56.9

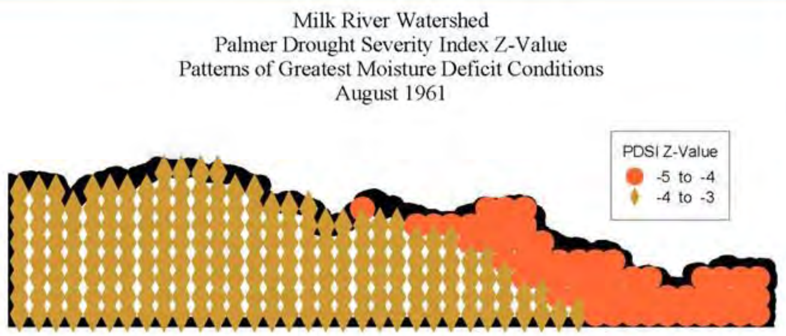
Excessive Moisture

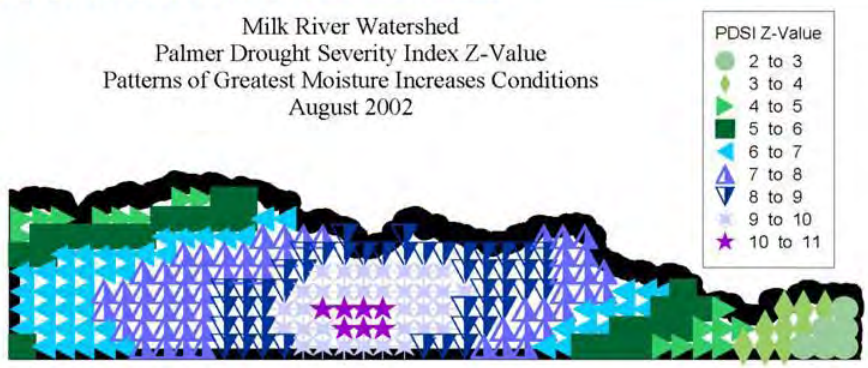
Year	PDSI Z-value	Change in Wheat Yield*
2002	10.7	12.7
1993	7.6	13.7
1954	7.6	-62.3
1975	7.5	0.0
1951	7.1	-57.7
1974	7.0	-21.1
2004	6.2	38.9
1907	6.1	Not Available
1933	5.9	Not Available
1989	5.6	-5.2

*Spring Wheat Percent from 2000 to 2009 10 yr Average
Average over entire watershed

Wheat Yield data:
SK Ministry of Agriculture

PDSI Z-Value





Top 10 most extreme years SPI – 1 Month (1901-2005)

Drought

Year	Month	SPI01	Change in Wheat Yield*
1985	6	-3.9	-79.7
1967	6	-3.8	-56.6
1959	12	-3.6	-66.3
1955	8	-3.3	-16.6
1961	3	-3.3	-84.6
1973	3	-3.3	-34.9
1917	5	-3.2	Not Available
1968	3	-3.2	-36.7
1963	3	-3.1	-10.3
1988	4	-3.1	-56.9

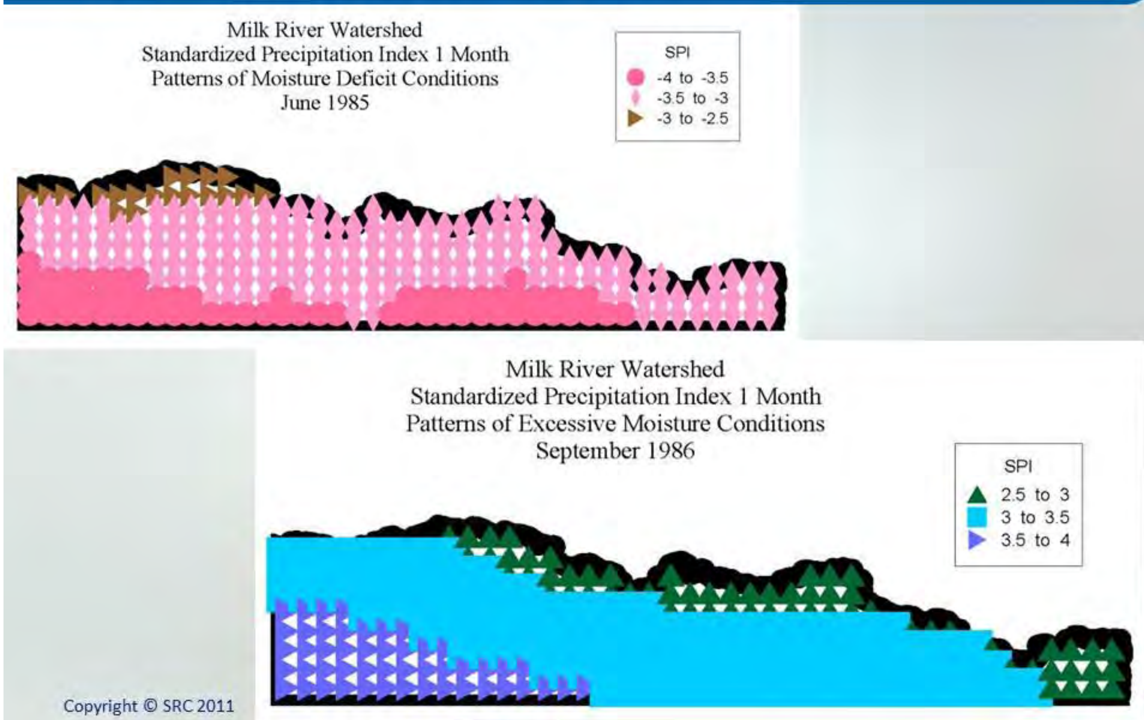
Excessive Moisture

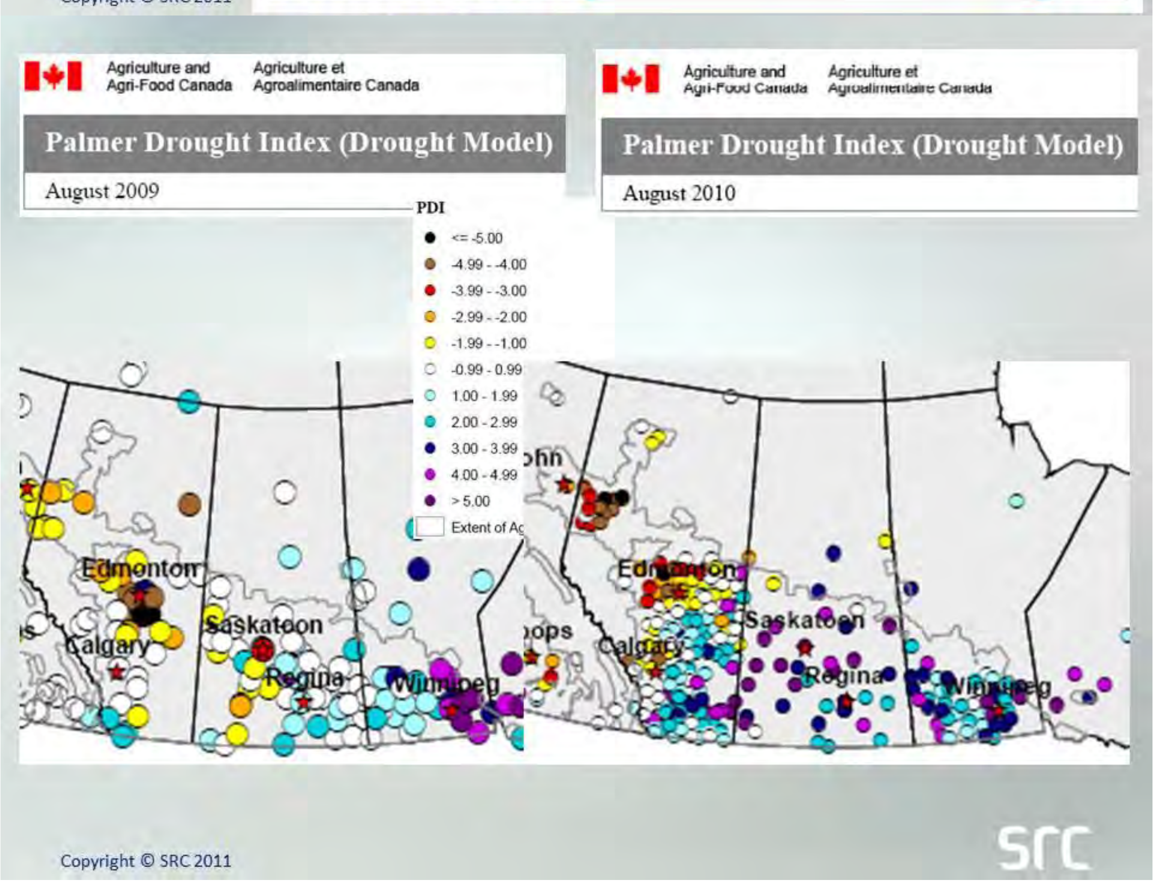
Year	Month	SPI01	Change in Wheat Yield*
1986	9	3.8	5.5
1993	7	3.4	13.7
1927	5	3.3	Not Available
1975	3	3.3	0.0
1971	1	3.2	-38.3
1904	3	3.0	Not Available
1998	6	2.9	15.3
1995	10	2.8	21.1
2002	8	2.7	12.7
2004	1	2.7	38.9

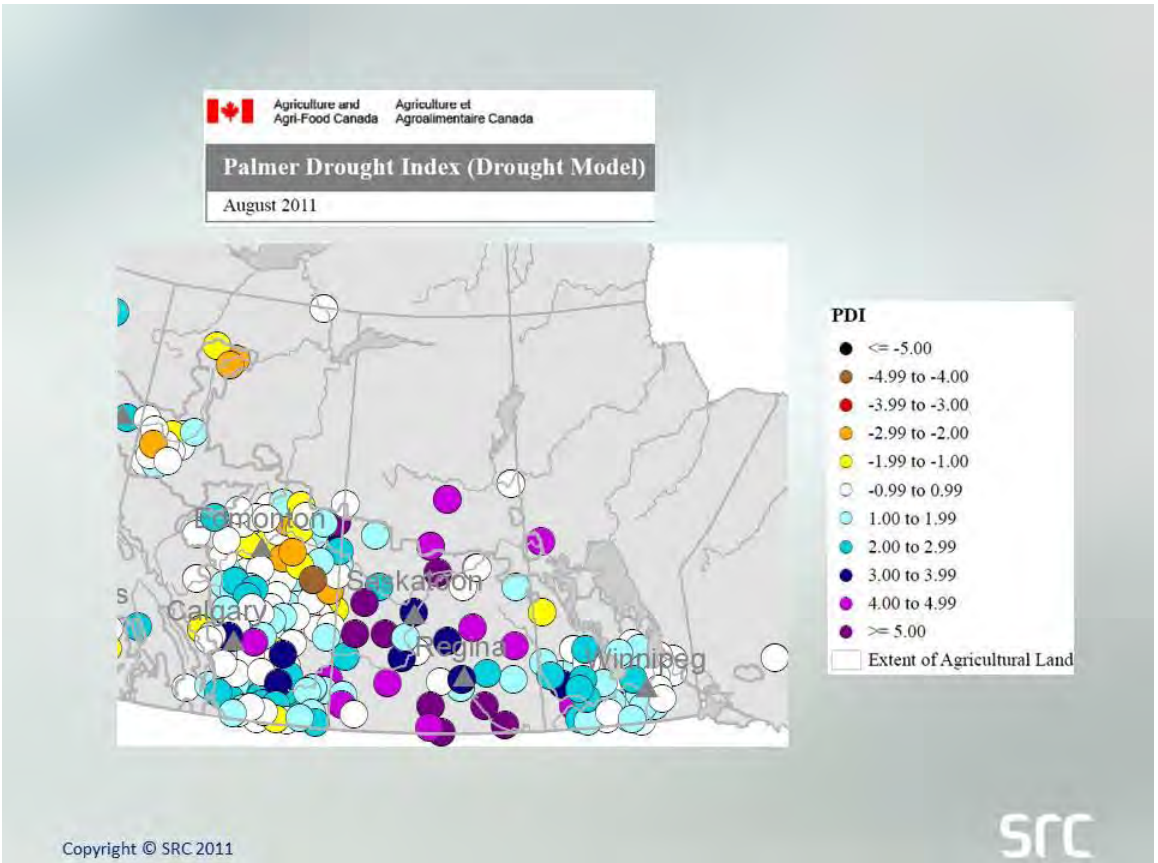
*Spring Wheat Percent from 2000 to 2009 10 yr Average
Average over entire watershed

Wheat Yield data:
SK Ministry of Agriculture

SPI – 1 month extremes






Agriculture and Agri-Food Canada
Agriculture et Agroalimentaire Canada
Palmer Drought Index (Drought Model)
August 2011
PDI
<= -5.00
-4.99 to -4.00
-3.99 to -3.00
-2.99 to -2.00
-1.99 to -1.00
-0.99 to 0.99
1.00 to 1.99
2.00 to 2.99
3.00 to 3.99
4.00 to 4.99
>= 5.00
Extent of Agricultural Land
Edmonton
Saskatoon
Calgary
Regina
Winnipeg
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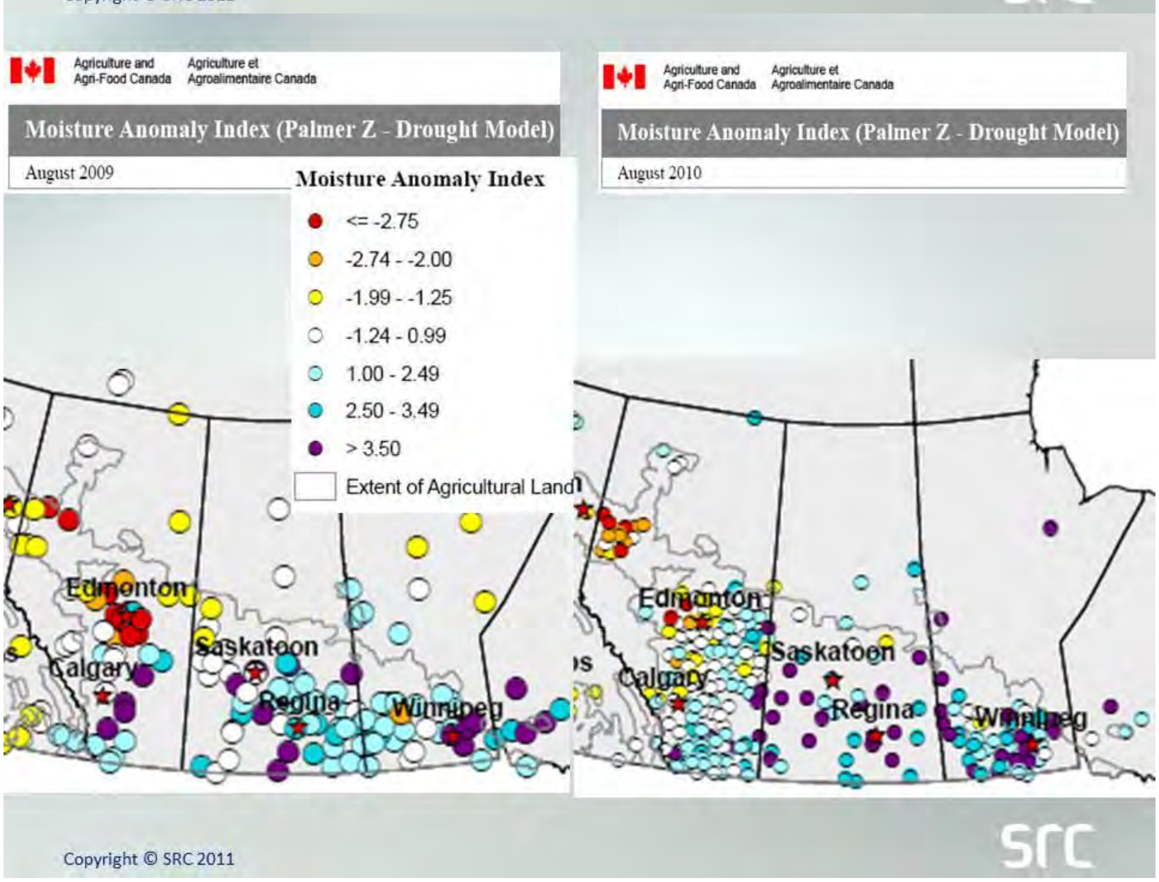
Agriculture and Agri-Food Canada
Agriculture et Agroalimentaire Canada
Moisture Anomaly Index (Palmer Z - Drought Model)
August 2009
Moisture Anomaly Index
<= -2.75
-2.74 - -2.00
-1.99 - -1.25
-1.24 - 0.99
1.00 - 2.49
2.50 - 3.49
> 3.50
Extent of Agricultural Land
Edmonton
Saskatoon
Calgary
Regina
Winnipeg
Agriculture and Agri-Food Canada
Agriculture et Agroalimentaire Canada
Moisture Anomaly Index (Palmer Z - Drought Model)
August 2010
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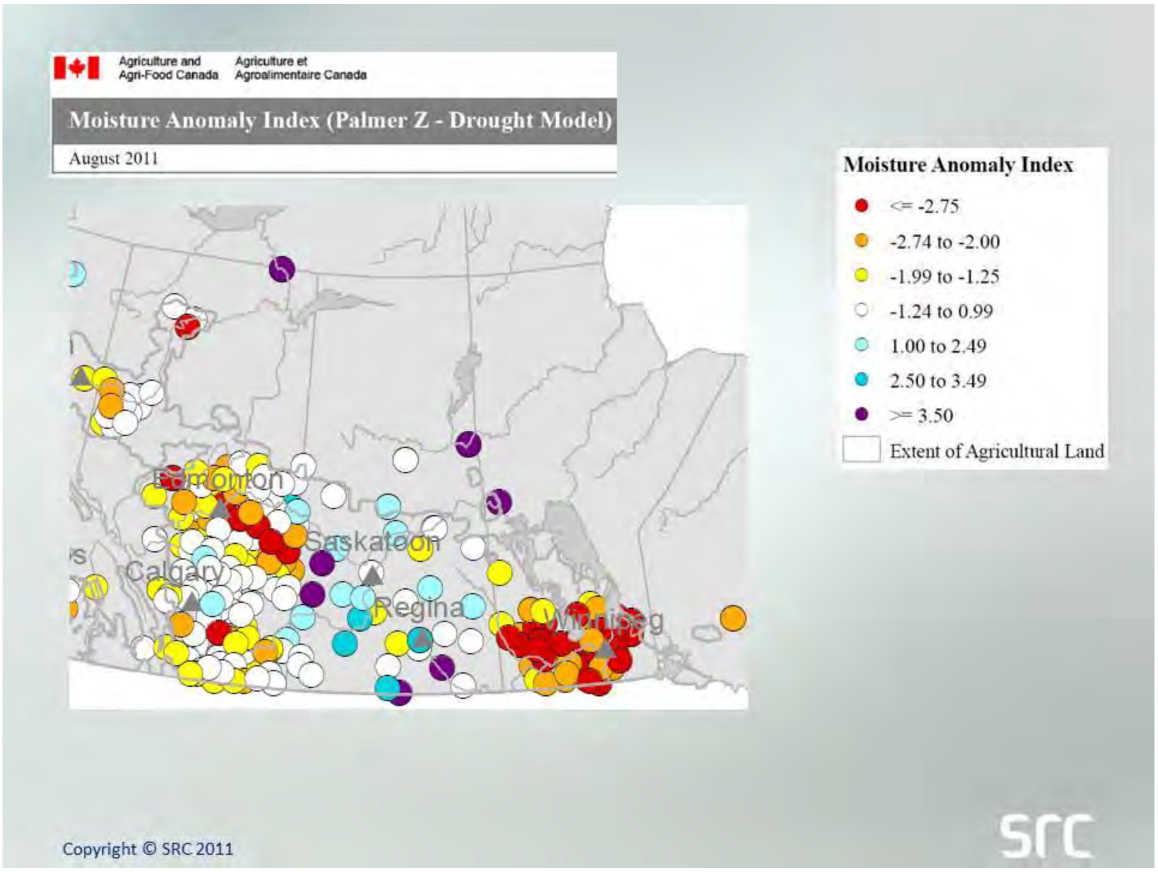
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<= -2.75
-2.74 to -2.00
-1.99 to -1.25
-1.24 to 0.99
1.00 to 2.49
2.50 to 3.49
>= 3.50
Extent of Agricultural Land
Edmonton
Saskatoon
Calgary
Regina
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