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ABOUT DROUGHT IN CANADA

AU SUJET DE LA SÉCHERESSE DU CANADA

by/par
Grace Koshida

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ABSTRACT

Although Canadian droughts have been measured and described in detail over the years, there are many questions to be answered. The increased number of droughts in Canada over the past decade has led to greater interest in learning how to adapt to this climatic extreme. However, progress in drought monitoring and prediction has been hindered by a lack of standard definitions and data on this complex phenomenon. There is not even a universal definition of drought for Canada. This publication was produced to help clarify misconceptions about drought. The various types of drought are defined and the characteristics and causes of drought are discussed. Trends in drought monitoring and prediction in Canada are examined. Sources of information on drought are provided through a contacts list and a detailed list of available publications on this topic.

RÉSUMÉ

Au cours des ans, on a bien mesuré et décrit en détail les sécheresses du Canada, mais nombre de questions attendent une réponse. Le nombre accru des sécheresses survenues cette dernière décennie au Canada incite à mieux apprendre comment s'adapter à cet extrême climatique. Le manque de définitions et de données standards relatives à ce phénomène complexe a toutefois entravé les progrès de la surveillance et de la prévision de la sécheresse. Il n'existe même pas, au Canada, de définition universelle de la sécheresse. On définit les divers types de sécheresses et étudie les caractéristiques et les causes de la sécheresse. On examine les tendances de la surveillance et de la prévision de la sécheresse au Canada. La liste des responsables et la liste détailée des publications qu'on peut se procurer sur ce sujet indiquent les sources d'information sur la sécheresse.

ACKNOWLEDGEMENTS

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Q. What is drought?

A. Drought has various meanings for Canadians, depending on how a water shortage affects their lives. The meteorologist, water engineer, farmer and city dweller all define drought differently. However, a general definition for drought is:

> "A prolonged period of abnormally dry weather producing a moisture shortage that affects crops and forests, and reduces water resources to a degree, thus creating serious environmental, economic or social problems.".

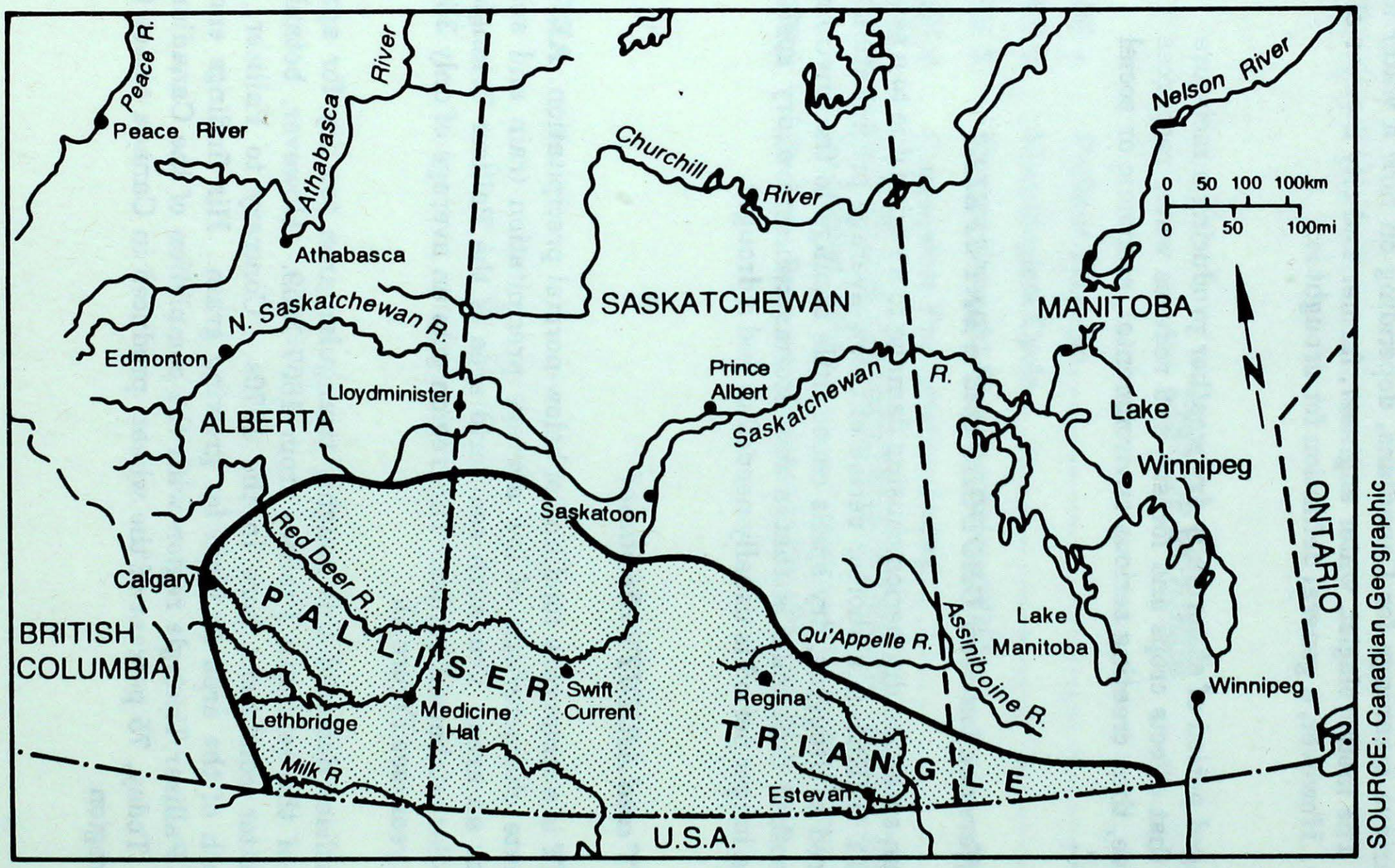
Q. What is the difference between DROUGHT and a DRY SPELL?

A. **DROUGHT** is an extended dry period causing damage to a region due to a severe lack of moisture. A **DRY SPELL** is a shorter period of below-average precipitation and soil moisture. Compared to droughts, dry spells cause little damage to the environment or the economy. Another difference is that a few storms can end a dry spell. More precipitation over a longer period is usually needed to end a drought.

Q. Are DROUGHT and ARIDITY the same?

A. No. **DROUGHT** is a *temporary* condition of below-normal precipitation. **ARIDITY** is a *permanent* climate characteristic of low average precipitation (rain and snow) and available water for an area. One such semi-arid area is the Palliser Triangle region along the Alberta-Saskatchewan border. This region gets an average of only 350 mm of precipitation each year (see Figure 1).

Explorer John Palliser declared this roughly triangular area too dry for agriculture during a survey of the southern Prairies from 1857-1859. However, botanist John Macoun found better conditions here in the 1870s. Contrary to Palliser, Macoun recommended much of the area as ideal for growing grain. His findings encouraged settlement of the Palliser Triangle region with the completion of the Canadian Pacific Railway in 1885. Today, 75 percent of the wheat produced in Canada comes from the Palliser Triangle region.



SOURCE: Canadian Geographic

Figure 1 The Palliser Triangle

Q. Are there different types of drought?

A. Yes. There are three basic types of droughts. **METEOROLOGICAL DROUGHT** is caused by significantly below-normal precipitation for a prolonged period. The degree of moisture shortage causing a meteorological drought depends on each region's sensitivity to drought. However, when precipitation is below 50% of normal for at least 30 days, it is often considered that a meteorological drought may have begun. The next two types of droughts may also develop depending on the timing, intensity and duration of the meteorological drought.

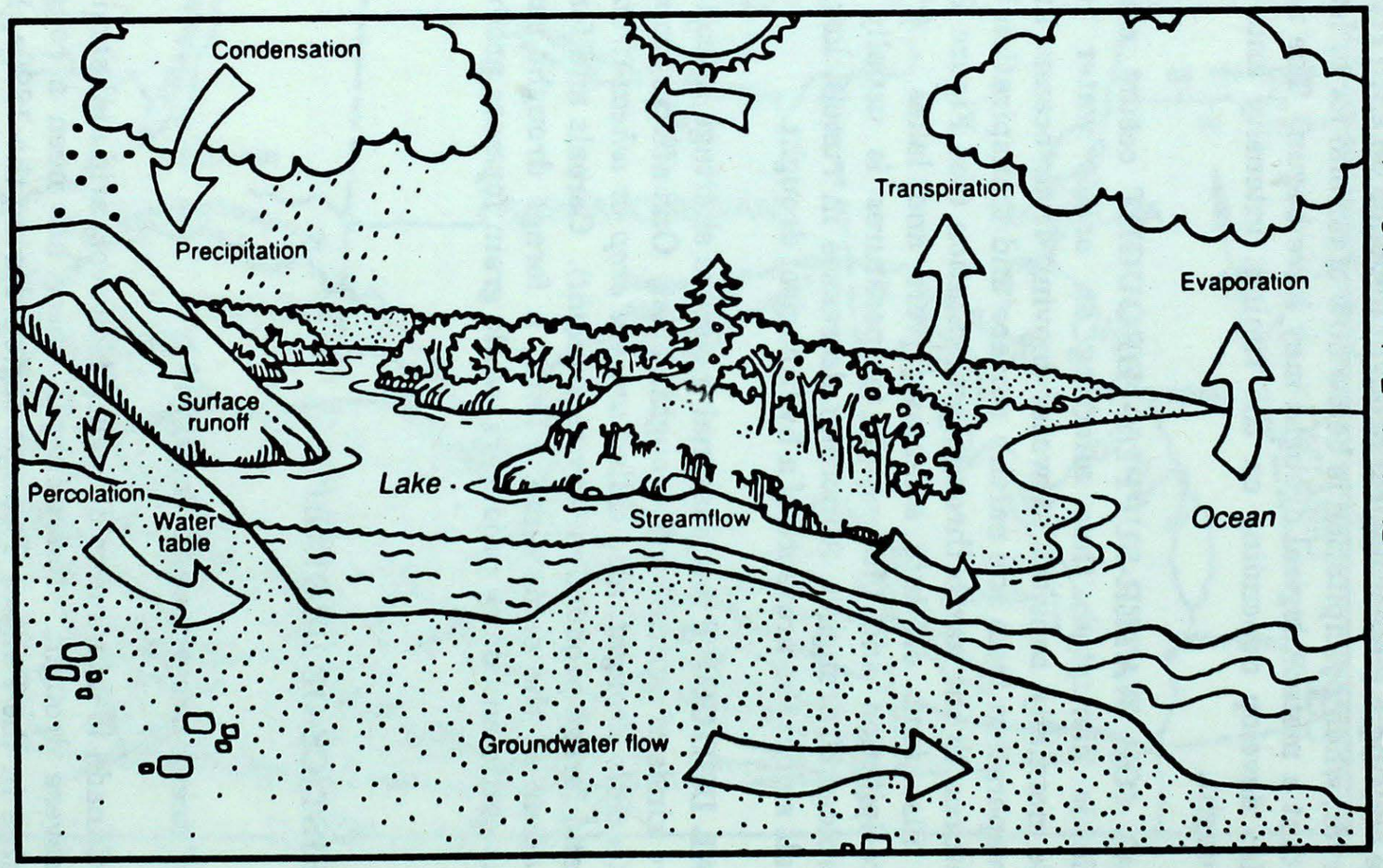
HYDROLOGICAL (OR WATER-SUPPLY) DROUGHT occurs when the natural hydrological cycle is disrupted, thus affecting an area's water resources. The hydrological cycle normally consists of water moving from oceans and lakes to the atmosphere by evaporation from the earth's surface and transpiration by plants. This moisture then returns to the earth through precipitation (see Figure 2). Some of this returning water also runs off into streams, rivers and lakes. A long period of below-normal precipitation and often high temperatures is usually responsible for triggering a hydrological drought. Abnormal decreases in runoff, low river, lake and ground water levels signal the presence of a hydrological drought.

AGRICULTURAL DROUGHT is a seasonal moisture shortage affecting livestock and crop growth. Two kinds of agricultural droughts exist. One affects crops such as wheat, barley and oats (*cereals drought,* also called *annual crop* or *wheat drought*). The other affects pastures and forage production (*forage drought*). Cereals and forage droughts do not necessarily occur at the same time. Thus, a forage drought can exist, causing economic losses to cattle and dairy producers, while grain farmers produce average crop yields.

2. CHARACTERISTICS OF DROUGHT

Q. What types of areas are prone to drought?

A. No region of Canada is immune to drought. However, arid and semi-arid regions are more prone to severe drought. For example, there has been a rough recurrence of multi-year droughts in the Palliser Triangle region during the 1890s, 1930s and 1980s. In total, at least 40 severe droughts have occurred throughout western Canada during the past 200 years. Table 1 lists some of the major Canadian droughts. By contrast, droughts in eastern Canada are usually brief, cover a smaller area and are less frequent and severe.



SOURCE: Inland Waters Directorate, Environment Canada

Figure 2 The hydrologic cycle

TABLE 1

FAMOUS CANADIAN DROUGHTS

1805	SCORCHED POTATO CROP IN THE RED RIVER (MANITOBA) AREA
1816-1819	ALMOST CONTINUOUS DROUGHT AND HORDES OF GRASSHOPPERS ON THE PRAIRIES
1846	COMPLETE CROP FAILURE IN THE RED RIVER AREA
1862-1864	LOW RIVER LEVELS ON THE RED RIVER; SEED GRAIN IMPORTED FROM USA
1868	PRAIRIE CROP FAILS; GRASSHOPPER PLAGUE
1890s	9 YEARS OF DROUGHT FORCE FARM ABANDONMENT ON THE PRAIRIES
1929-1931	SEVERE B.C. INTERIOR DROUGHT
1933	GRASSHOPPER PLAGUE AND DROUGHT RESULT IN SMALLEST WHEAT CROP IN SASKATCHEWAN SINCE 1920
1936	SEVERE HEAT STRESS IN ONTARIO REDUCES CROP YIELDS BY 25%
1936-1938	RECURRENCE OF DROUGHT ON PRAIRIES A NATIONAL EMERGENCY
1961	WORST DROUGHT YEAR THIS CENTURY FOR PRAIRIE WHEAT
1963	SEVERE ONTARIO DROUGHT DRASTICALLY CUT SOYBEAN AND CORN PRODUCTION; LOW GREAT LAKES LEVELS
1967	EXTENSIVE DROUGHT FROM PEACE RIVER TO SOUTHERN MANITOBA
1973	RECORD WARM SUMMER AND LOCAL DROUGHT HURT POTATO AND APPLE PRODUCTION IN ONTARIO
1977	SEVERE WINTER DROUGHT IN SOUTHERN ALBERTA AND WESTERN SASKATCHEWAN
1978	EXTENSIVE CENTRAL ONTARIO DROUGHT
1979-1980	TWO YEARS OF AGRICULTURAL DROUGHT DEVASTATE PRAIRIE FORAGE AND WHEAT PRODUCTION; $2.5 BILLION LOSS TO NATIONAL ECONOMY
1983	SOUTHERN ONTARIO AND QUEBEC DROUGHT
1984-1985	SOUTHEASTERN PRAIRIES GOT 50% OF NORMAL RAIN; INSECT INFESTATIONS; DROUGHT IN SOUTHWESTERN NOVA SCOTIA DRIED UP MANY STREAMS AND WELLS
1985	ONE OF WORST FOREST FIRE SEASONS IN B.C.'S HISTORY MAINLY DUE TO DROUGHT
1987	B.C. INTERIOR GOT 60% OF NORMAL RAIN; SUMMER DROUGHT IN ATLANTIC PROVINCES AFFECT CROPS AND WATER SUPPLIES
1988	EXTENSIVE DROUGHT ACROSS THE PRAIRIES, ONTARIO AND QUÉBEC; WORST B.C. INTERIOR DROUGHT IN 60 YEARS
1991	WORST SUMMER DROUGHT IN NOVA SCOTIA IN OVER 40 YEARS AFFECTS WATER SUPPLIES, INCREASES NUMBER OF FOREST FIRES

SOURCE: D.W. PHILLIPS, 1990. THE CLIMATES OF CANADA; ISSUES OF ***CLIMATIC PERSPECTIVES***

Q. How large an area can a drought cover?

A. Droughts vary in size, ranging anywhere from a city to large portions of a province, country or continent. The boundaries and area covered also change as a drought evolves over time. In general, long, severe droughts cover a wide area. For example, the severe 1988 drought expanded from the interior of British Columbia, across the southern Prairie Provinces, into parts of Ontario and Québec.

Q. How does the timing of a drought affect its severity and type?

A. A summer drought causes more problems since this is usually the period of highest water demand for many users. The timing of a drought may also determine the drought type. For example, a forage drought occurs when a meteorological drought and low soil moisture conditions exist during the spring. This may not affect cereal crops since they have a later growing season and different moisture demands. However, if the dry conditions continue into the summer, a cereals drought may also develop.

Q. How is drought severity measured?

A. The severity of a drought can be determined by comparing and ranking it against past droughts. However, such comparisons are usually done only after the drought is over. Table 2 shows an evaluation between the droughts of the 1980s and other historical droughts in western Canada.

Several indices provide more current information on the severity of a drought. These indices may give different drought severity ratings for the same drought depending on the drought definition used. In general, as the water shortage becomes more serious and the number of activities affected increase, the more severe a drought is.

United States Weather Bureau meteorologist Wayne Palmer developed the **PALMER DROUGHT SEVERITY INDEX (PDSI)**. The PDSI can be a useful tool in detecting meteorological or hydrological drought. Certain regional offices of Environment Canada's Atmospheric Environment Service (AES) calculate the PDSI each month. A single numerical value represents existing soil moisture conditions for an area. As shown in Figure 3, *droughts have negative PDSI values*, while wet areas have positive PDSI values.

AES also calculates the **CUMULATIVE PRECIPITATION INDEX (CPI)** to identify wet and dry regions in Canada. The CPI is a ratio (expressed in percentage) comparing precipitation totals accumulated over eight-week periods with normal precipitation values for the same period. CPI values of *less than 60 percent* represent a *drought warning*. CPI values *less than 40 percent* represent a *drought emergency* (see Figure 4).

TABLE 2

DROUGHT INTENSITY ON THE PRAIRIES *

STATION NAME (YEAR)	1936	1937	1961	1984	1988
WINNIPEG, MAN.	26	6	42	6	38
BRANDON, MAN.	31	(-35)	43	6	22
SASKATOON, SASK.	5	19	19	24	21
REGINA, SASK.	16	53	57	34	27
SWIFT CURRENT, SASK.	20	50	35	39	25
PRINCE ALBERT, SASK.	33	13	23	(-34)	(-3)
LETHBRIDGE, ALTA.	30	0	31	33	45
CALGARY. ALTA.	37	(-1)	12	32	10
EDMONTON, ALTA	(-5)	(-1)	20	32	(-18)
AVERAGE**	25	28	31	26	27

* Drought intensity represented by precipitation shortages (%) from normal for the period September 1 of the preceding year to August 31 of the year listed.

** Average calculated using only stations with PRECIPITATION SHORTAGES (NOTE: minus signs indicate a PRECIPITATION SURPLUS). The MOST INTENSE DROUGHT occurred in 1961.

SOURCE: "THE 1988 DROUGHT IN CANADA" BY P. SCHOLEFIELD, T. GUEZEN AND R. RADDATZ, 1989. CHINOOK, P P. 14-17

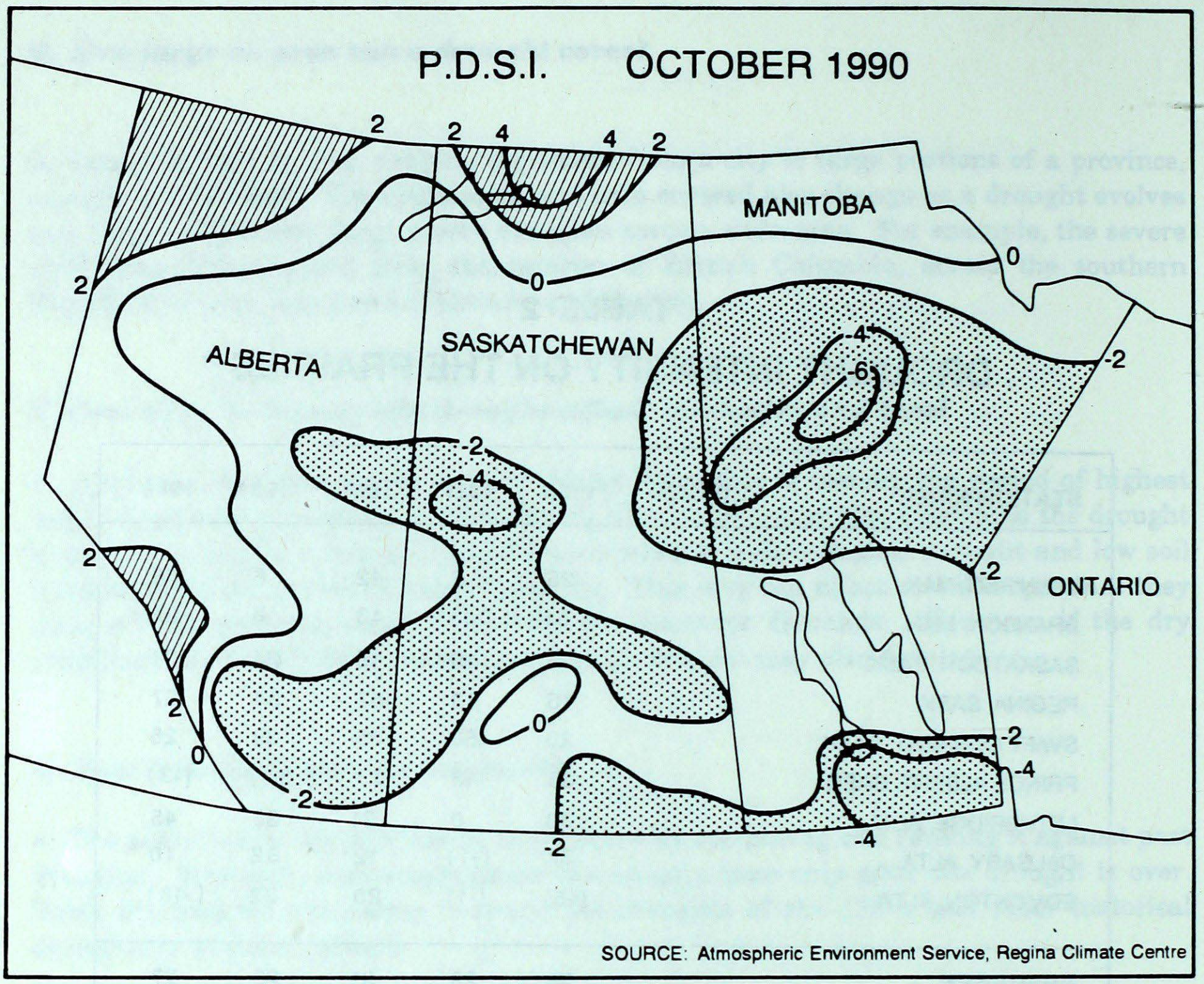


Figure 3 Palmer Drought Severity Index

PALMER DROUGHT SEVERITY INDEX* (PDSI)

NUMERICAL VALUE	CONDITION
ABOVE +4	EXTREME WETNESS
+3 TO +4	SEVERE WETNESS
+2 TO +3	MODERATE WETNESS
-2 TO +2	NEAR NORMAL
-2 TO -3	MODERATE DROUGHT
-3 TO -4	SEVERE DROUGHT
BELOW -4	EXTREME DROUGHT

* VALUES INDICATE DEVIATIONS FROM NORMAL CLIMATE

The **CANADIAN FOREST FIRE WEATHER INDEX** uses a *drought code*. This code rates the effect of variables such as rainfall and temperature on the moisture content of thick organic layers. Dried layers are a potential fuel source for forest fires. This drought code can provide warnings of drought and extreme forest fire weather conditions across Canada.

Although these drought indices show *large-scale, regional conditions*, this information is also useful at the local level. Municipalities can use information from these indices to decide when and how to respond to a drought. (See section 4, **DROUGHT PREDICTION AND MONITORING** for more details on drought management plans).

Q. How is the start of a drought announced?

A. Drought announcements are not made quickly in Canada. In the past, provincial and federal governments responded to droughts only once they were well-advanced. Such inactivity was usually due to a lack of up-to-date information on the seriousness of the drought.

Q. How long do droughts usually last?

A. Droughts can last anywhere from months to several years. The **MINIMUM** period is usually three months (a season) of low precipitation. However, once in place, drought conditions persist. Drier soils yield less moisture to the air. The drier air becomes warmer than normal, which reduces cloud formation and precipitation.

The drought type also affects a drought's duration. For example, hydrological droughts develop and end more slowly than other types of droughts due to the larger water storages involved.

Q. How do we know a drought has ended?

A. The end of a drought is hard to define. A few rainy days will not end a drought. Above-average precipitation is needed over a long period to bring water supplies back to normal. Even once the drought is over, it can take a long time for a region to recover from the **EFFECTS** of drought. For example, new impacts can continue to arise months after the end of an agricultural drought. These impacts may include job losses in food processing industries, higher food prices for consumers and more farm closures.

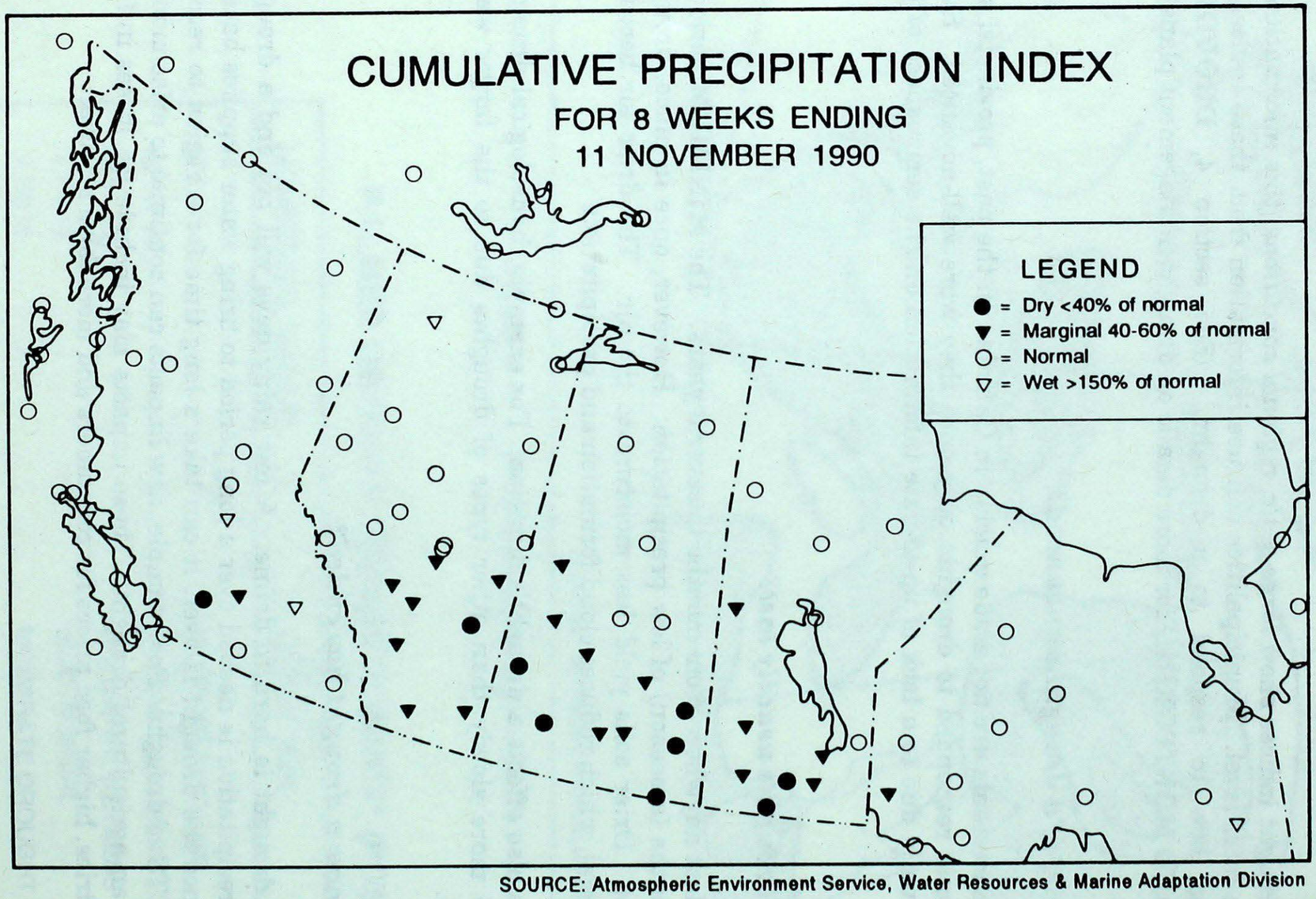


Figure 4 Cumulative Precipitation Index

3. CAUSES OF DROUGHT

Q. Do droughts occur in a cycle in Canada?

A. No. Droughts take place over parts of Canada in an irregular pattern. A possible relationship between changes in sunspot activity and a cycle of extreme drought in North America is being studied.

Q. What meteorological factors play a role in drought?

A. Droughts occur due to abnormal changes in weather patterns. For example, major shifts in the jet stream's course may prevent moisture-bearing storms from reaching an area. The large high-pressure systems dominating the region during such periods produce few clouds and contain very little moisture. Above-normal temperatures, low humidity and high winds also affect drought intensity and severity.

Q. What other factors affect the severity of drought impacts?

A. The economic diversity of a region affects its sensitivity to drought. For example, a region highly dependent on a climate-sensitive industry such as agriculture will be more directly affected by drought than a region with a broader economic base.

How long a drought lasts greatly affects the severity of its impacts on a region. Multi-year droughts tend to intensify drought impacts. For example, a prolonged drought reduces winter snowcover and crop stubble which normally protects the soil from erosion. Extended droughts also provide continuous hot and dry weather conditions which increase the breeding success of grasshoppers and moths. Such insect infestations cause additional crop losses and other negative impacts in an area already suffering from the drought.

The water use patterns of a region also affect drought severity. Outdated water delivery systems and wasteful water usage can result in shortages even during wet years. During a drought, competition for the increasingly scarce water tends to occur between major water users such as domestic water supply and irrigation. Prolonged droughts can eventually strain both rural and urban water supplies.

Q. What connection exists between large-scale rises in sea-surface temperature (El Niño) and drought?

A. There may be a relationship between the El Niño phenomenon and severe drought events. This warming of coastal waters near Peru is followed by world-wide shifts in

precipitation patterns. Such shifts can bring drought to agricultural areas and heavy rains to normally arid regions. For example, the strongest El Niño in over 100 years took place in 1982. Figure 5 shows that several major droughts, including two in Canada, occurred from 1982 to 1983. Another El Niño has started forming in the Pacific since late 1991, however, its potential impacts on Canada pertaining to drought are not yet certain.

Q. Is there any connection between the formation of ozone holes and drought?

A. A group of industrial chemicals known as CFCs (chlorofluorocarbons) is causing holes to develop in the ozone layer over Antarctica and the Arctic. CFCs are also one of the gases responsible for the global warming phenomenon. However, there is no known relationship between the thinning of the ozone layer and recent droughts in Canada.

4. DROUGHT PREDICTION AND MONITORING

Q. How are droughts detected and monitored?

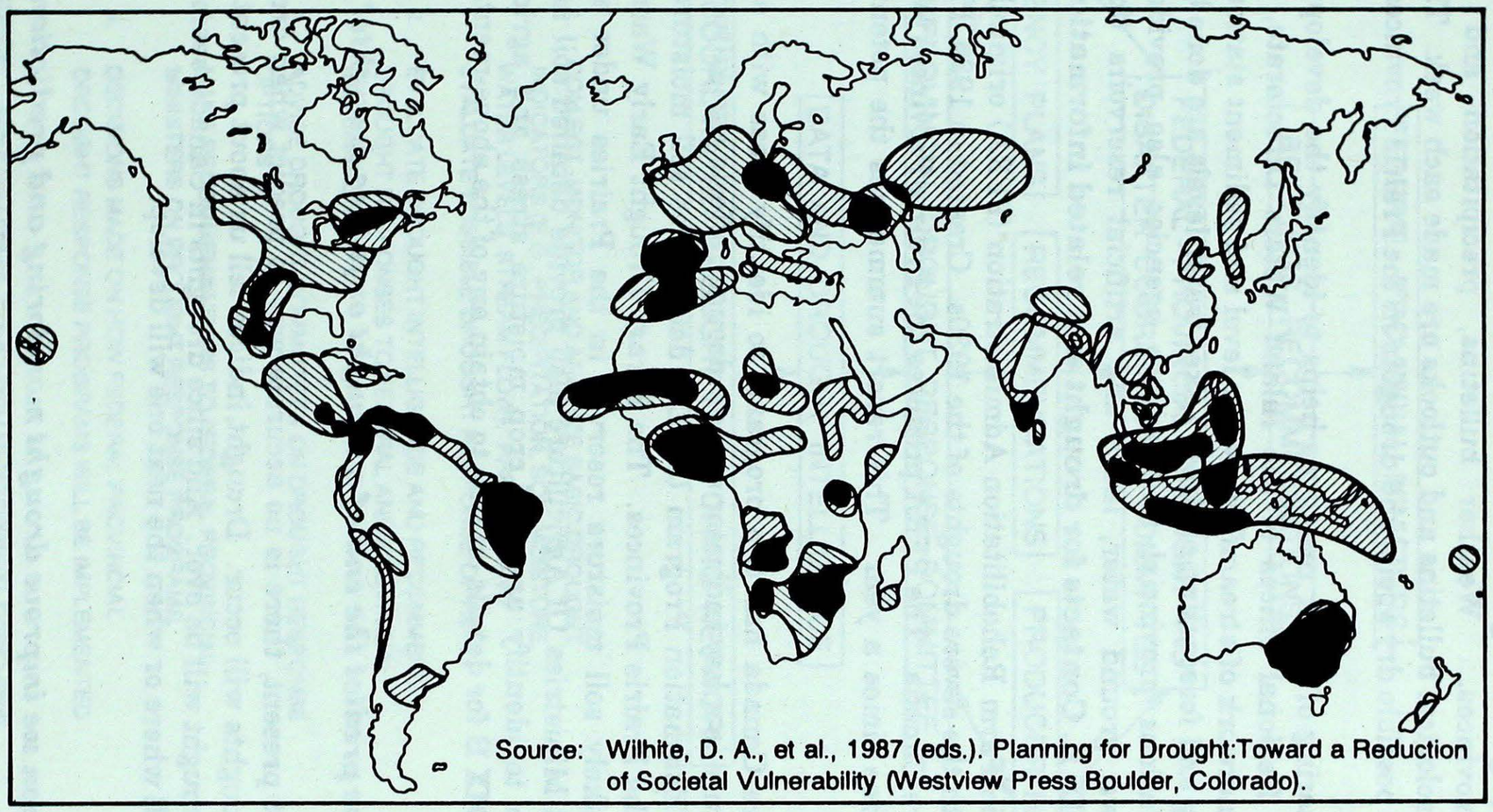
A. Drought managers have to first determine whether a meteorological, hydrological or an agricultural drought is developing since each of these affects different activities. As a result, a large range of variables are needed to monitor for, and detect drought. Basic climatic and hydrological indicators such as precipitation, temperature, soil moisture, crop conditions, streamflows and water supply conditions are regularly monitored. Abnormal values from these data may suggest the start of a drought. Various drought indices also are calculated using this information (see Section 2, **CHARACTERISTICS OF DROUGHT** for more details).

Some networks exist in Canada to improve the drought monitoring and response process. For example, Alberta and Manitoba have formed **DROUGHT MONITORING COMMITTEES**. These provincial committees act as liaisons with the federal government. With such drought committees in place, federal and provincial ministers can receive up-to-date information on drought conditions, and advice on how to respond to the drought *as it evolves*. Figure 6 outlines the structure of such a response system in the Prairie Provinces.

Q. What information is available on drought conditions in Canada?

A. AES publishes a weekly bulletin called *Climatic Perspectives*. It contains temperature, precipitation, soil moisture and other climate data for stations across Canada. This information plus the monthly and seasonal climatic reviews within *Climatic Perspectives* may provide details on the extent of a drought and its impacts.

NOTE: Drought is defined as dry years with less than 60% of normal precipitation within a sub-region of 250,000 square kilometres



Source: Wilhite, D. A., et al., 1987 (eds.). Planning for Drought:Toward a Reduction of Societal Vulnerability (Westview Press Boulder, Colorado).

Figure 5 El Niño and the occurrence of drought, January 1982 to August 1983

AES can calculate the Palmer Drought Severity Index (PDSI) and Cumulative Precipitation Index (CPI) to identify drought areas.

The Winnipeg and Regina Climate Centres provide more detailed climatic data for the Prairie Provinces. Weather bulletins, precipitation and soil moisture maps, agrometeorological bulletins and outlooks are made each week. This information is used to identify possible dry spells and droughts in the Prairie Provinces.

The monitoring of water resources helps to identify the development of a hydrological drought. Regional offices of the Inland Waters Directorate, Environment Canada, operate a network of streamflow, water level and sediment stations across Canada. The monitoring and forecasting of Great Lakes water levels are done by the Ontario regional office. Various provincial and private agencies also provide data on snowpacks, streamflows, ground water, lakes and artificial reservoirs (for further details, see **APPENDIX B. Contacts for drought and related information in Canada**).

The Prairie Farm Rehabilitation Administration (PFRA) originally developed programs to deal with the severe droughts of the 1930s. Created in 1935, PFRA is now a branch of Agriculture Canada. The PFRA produces the Prairie Provinces Water Supply Conditions Report three times a year. This report summarizes the potential for drought on the Prairies.

Agriculture Canada has two programs to identify areas with soil moisture shortages. Soil moisture is a key indicator on how drought affects agricultural production. The Soil Moisture Estimation Program (SMEP) determines soil moisture conditions for annual crops in the Prairie Provinces. The Forage Drought Early Warning System (FoDEWS) projects likely soil moisture reserves in the Prairies under a forage pasture. The provincial Ministries Of Agriculture also provide detailed soil moisture reports. These data help to identify areas of crop moisture stress and agricultural drought. (See **APPENDIX B** for details on how to obtain any of the above-mentioned information).

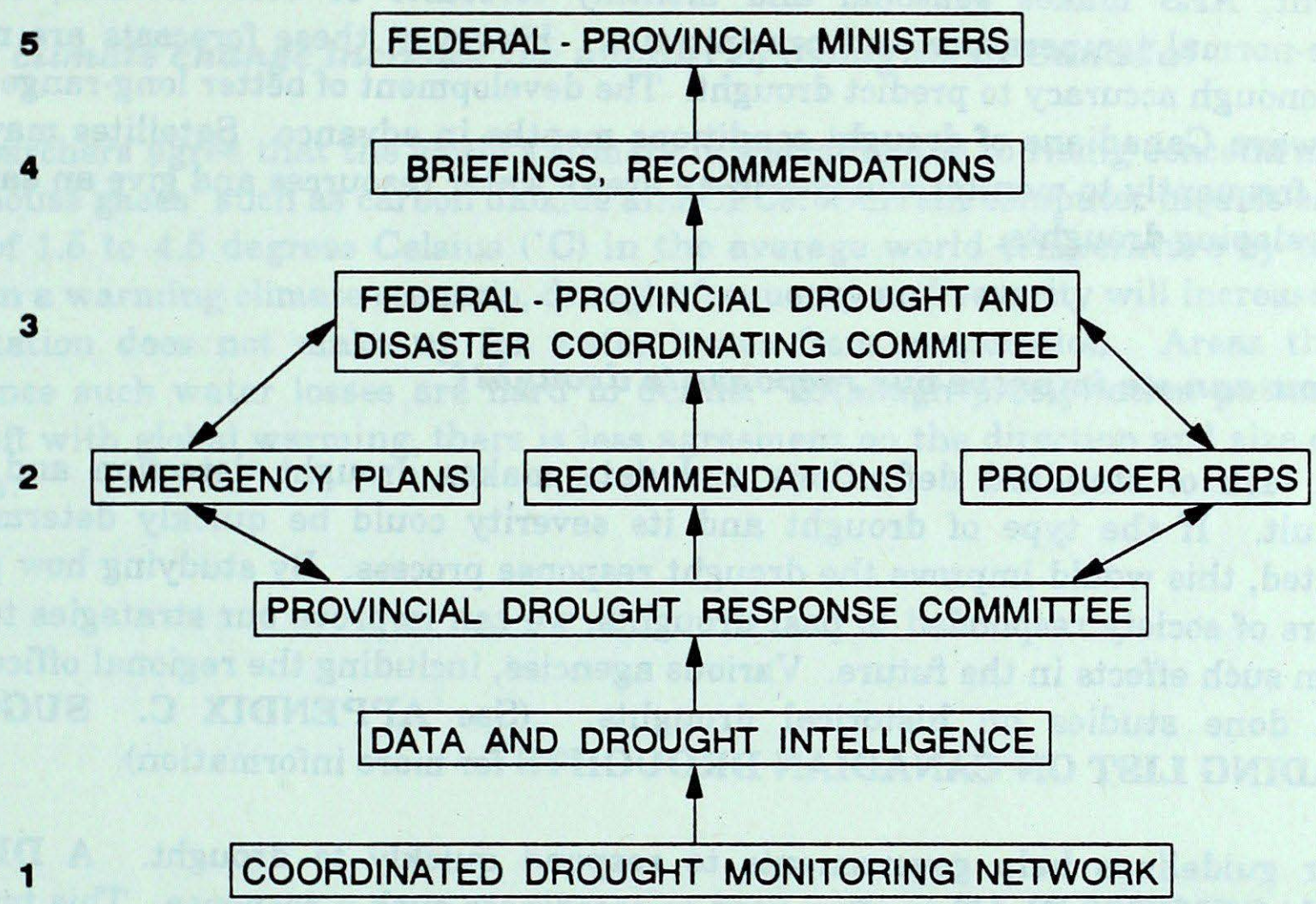
Q. Can we predict the end of a drought or future droughts?

A. No. At present, there is no accurate way to predict when droughts will end or when future droughts will occur. Drought indices tell us about present drought conditions, not when a drought will be over. And since droughts in Canada seem to occur irregularly, we cannot tell where or when the next one will develop.

Q. How can we improve drought monitoring and prediction in Canada?

A. Decision-makers, media and the public need accurate and up-to-date information on drought conditions. The setting up of drought monitoring networks would help to provide this information. At present, the PFRA coordinates the **PRAIRIE DROUGHT MONITORING NETWORK**, which consists of various federal, provincial and private

FIGURE 6. DROUGHT RESPONSE PROCESS IN THE PRAIRIE PROVINCES



1. COLLECT, MONITOR AND ANALYZE BASIC DROUGHT INDICATORS (E.G., PRECIPITATION, SOIL MOISTURE, WATER LEVELS, STREAM FLOW). PREPARE AND EVALUATE POSSIBLE DROUGHT RESPONSE OPTIONS

2. EVALUATE DROUGHT INTELLIGENCE AND RECOMMEND DROUGHT RESPONSES TO FEDERAL AND PROVINCIAL GOVERNMENTS

3. ADVISE DROUGHT COMMITTEES ON DROUGHT RESPONSE OPTIONS

4. MAKE RECOMMENDATIONS TO FEDERAL PROVINCIAL MINISTERS ON DROUGHT RESPONSE PROGRAMS

5. DECISIONS MADE ON HOW FEDERAL PROVINCIAL DROUGHT RESPONSE PROGRAMS WILL BE IMPLEMENTED

SOURCE: ADAPTED FROM "PROPOSED GOVERNMENT RESPONSE PROCESS FOR PRAIRIE DROUGHT", PFRA DROUGHT TASK FORCE REPORT, DECEMBER 1987, P. 24.

agencies. A **CLIMATE EXTREMES MONITORING PROGRAM** also exists, started by the Atmospheric Environment Service (AES) and Inland Waters Directorate (IWD) of Environment Canada.

New technology can improve our drought monitoring and predicting capabilities. At present, AES makes seasonal and monthly forecasts of below-normal, normal or above-normal temperature and precipitation. However, these forecasts are not yet of high enough accuracy to predict drought. The development of better long-range forecasts may warn Canadians of drought conditions months in advance. Satellites may be used more frequently to monitor changes in an area's water resources and give an early signal of developing droughts.

Q. How can we improve our response to drought?

A. A lack of standard definitions and data makes drought detection and response difficult. If the type of drought and its severity could be quickly determined and updated, this would improve the drought response process. By studying how particular sectors of society responded to past droughts, we can improve our strategies to avoid or lessen such effects in the future. Various agencies, including the regional offices of AES, have done studies on historical droughts. (See **APPENDIX C. SUGGESTED READING LIST ON CANADIAN DROUGHTS** for more information).

Clear guidelines help governments to respond quickly to drought. A **DROUGHT MANAGEMENT PLAN** is often used to coordinate such a response. This type of plan outlines what government, industries, citizens and others should do both before and during a drought. Steps on how to ensure adequate water supplies and reduce drought impacts are included in the plan. Communities can decide when to start a drought management plan based on drought severity indices and information on local water conditions.

Canadians can learn lessons on drought response from parts of the United States. In many states, a drought task force monitors a state's water supply. When serious drought conditions develop, the designated state agency (or state governor) implements the state drought management plan.

5. FUTURE DROUGHTS IN CANADA

Q. Have there been more droughts in Canada lately?

A. Yes, there were many droughts across Canada during the 1980s. The Prairie Provinces had droughts in 1980, 1983, 1984-1985 and 1988. There were also droughts in southern Ontario and Québec in 1983 and 1988. Less serious droughts took place in the

Atlantic Provinces in 1985, 1987 and 1991; in British Columbia in 1985, 1987 and 1988. The droughts of the 1980s rival those of the 1930s in their intensity, duration and areal coverage. However, such frequent droughts have occurred before (1890s, 1930s) and are part of natural fluctuations in the Canadian climate.

Q. Will climate change increase the number of droughts in Canada?

A. Researchers agree that the world's climate is warming due to rising concentrations of "greenhouse gases" such as carbon dioxide and CFCs. Current computer models estimate a rise of 1.5 to 4.5 degrees Celsius (°C) in the average world temperature by the year 2050. In a warming climate scenario, drought frequency and severity will increase where precipitation does not make up for water losses from evaporation. Areas that will experience such water losses are hard to define. Although precipitation patterns will also shift with global warming, there is less agreement on the direction and size of these changes.

APPENDIX A.

GLOSSARY OF TERMS

AGROMETEOROLOGY - The study of the effects of atmospheric conditions and weather on agriculture.

AIR MASS - A large, horizontal body of air with the same distribution of moisture and temperature throughout. Weather is affected by different air masses. For example, a warm, dry air mass will cause different weather from a cold, wet air mass.

ARID ZONE - A zone in which precipitation is low or occurs at such times that **IRRIGATION** must be practised to support agriculture.

CLIMATE SCENARIO - Use of a climate model to calculate the properties of the atmosphere under certain conditions (e.g., doubling of atmospheric carbon dioxide). This provides us with a *snapshot* of a possible future climate.

CROP STUBBLE (OR CROP RESIDUES) - Plant matter that has not been worked into the soil and may be standing, lying flat or chopped up.

DIRTY THIRTIES - Popular term used to describe the 1930s in Canada. This decade was characterized by a global economic depression and severe, prolonged drought in the agricultural plains of North America.

DUGOUT - A small impoundment or artificial basin, often located in land depressions, used to collect water from a relatively small area.

EL NIÑO - A Spanish term given to a warm ocean phenomenon, and the unusually warm and rainy weather associated with it off the coast of Peru. In contrast, mid-latitude regions such as North America tend to experience very dry conditions during an El Niño. Several years may pass without this phenomenon appearing.

EVAPORATION - The loss of water into the atmosphere by its conversion from a liquid into a gaseous state.

EVAPOTRANSPIRATION - The amount of water transferred from the soil to the atmosphere by evaporation and plant transpiration.

FORAGE - Vegetable food, as in hay and grains, for use by domestic animals.

FORECAST - A description of the weather conditions expected during the current and next day. The exact content of the forecast depends upon the intended user (e.g., Marine and Farm forecasts).

GROUND WATER - The supply of fresh water under the earth's surface which forms a natural reservoir in specific geological zones or layers known as aquifers.

HIGH PRESSURE SYSTEM - An area where the atmospheric pressure is high compared to the areas surrounding it. This area of high pressure forms a distinctive pattern on a weather map. At or near the centre of a high pressure system, the weather is usually calm and settled. A high pressure system is also known as an *anticyclone*. The opposite of a **LOW PRESSURE SYSTEM**.

HUMIDITY - A measure of the amount of water vapour in the air. Usually *relative humidity* is expressed as a percentage of total possible moisture content.

HYDROMETEOROLOGY - A branch of meteorology having to do with water in the atmosphere, especially precipitation and evaporation.

IRRIGATION - The artificial application of water to agricultural land to prevent crop loss from a lack of rain.

JET STREAM - A band of strong high-altitude wind which affects the location of storm tracks. The location of storm tracks determines which areas receive precipitation. In Canada, the jet stream travels mostly from west to east at a height of about 9,000 metres and may extend over hundreds of kilometres.

LOW PRESSURE SYSTEM - An area where the atmospheric pressure is low. The opposite of a **HIGH PRESSURE SYSTEM** and a distinctive feature on a weather map. Usually associated with clouds and rain and sometimes with strong winds. A low pressure system is also known as a *cyclone* or *depression*.

MOISTURE STRESS - The adverse effect on plant development caused by lack of a sufficient amount of moisture.

OUTLOOK - An indication of the trend in the weather, in very general terms, for one to three days beyond the current **FORECAST**.

OZONE - A pungent-smelling, slightly bluish gas which is a close chemical cousin to molecular oxygen. About 90% of the earth's ozone is located in a part of the atmosphere called the *stratosphere*. Here, the ozone protects the earth and its inhabitants from the harmful effects of ultraviolet radiation from the sun.

PRECIPITATION - Any form of water that falls from the atmosphere, either as a liquid or a solid, and reaches the ground. This includes rain, snow, sleet, drizzle and hail.

PREVAILING WINDS - The wind direction most frequently observed during a given period.

SALINIZATION - A serious soil degradation problem caused by the upward movement and evaporation of soil moisture. This results in the deposition of salt at or near the soil surface. Saline soils reduce crop yields and is of special concern in western Canada.

SEMI-ARID ZONE - A zone in which, in some years, precipitation is insufficient to maintain agriculture.

SOIL CONSERVATION - Prevention of soil loss and the repair of degraded soils. Such measures are used to reduce soil losses by **WIND EROSION**, maintain soil fertility, and manage saline soils.

SOIL MOISTURE - The amount of water held within the soil. In agriculture, it usually refers to moisture within the root zone of crop plants.

WIND EROSION - The transfer and loss of soil by blowing winds. This wind action causes soil particles to tumble, break up and dislodge other soil particles.

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Rahn, J. J., 1979. *Making the Weather Work For You*. (Garden Way Publishing, Charlotte, Vermont). pp. 167-177.

APPENDIX B.

CONTACTS FOR DROUGHT (AND RELATED INFORMATION) IN CANADA

Contacts for drought information are organized by territory/province and are in the following order: federal government (*), provincial government (x), private agencies (■). Some sources provide indirect information on drought conditions: weather and climate data indicate meteorological drought; streamflow, lake and ground water level monitoring can identify hydrological drought; soil moisture and crop conditons indicate agricultural droughts. Other sources provide information on past droughts and drought management.

NORTHWEST TERRITORIES

*** Department of Indian Affairs and Northern Development (DIAND)**
Water Resources Division, Northern Affairs Program
P.O. Box 1500
Yellowknife, Northwest Territories X1A 2R3
(403) 920-8240

(water resources management issues for the Northwest Territories)

*** Environment Canada**
Yellowknife Weather Office
P.O. Box 1199
Yellowknife, Northwest Territories X1A 2N8
(403) 873-4020

(weather and climate related information for the Northwest Territories)

YUKON TERRITORY

*** Department of Indian Affairs and Northern Development (DIAND)**
Water Resources Division, Northern Affairs Program
200 Range Road
Whitehorse, Yukon Territory Y1A 3V1
(403) 668-5151

(water resources management issues for the Yukon Territory)

*** Environment Canada**
Yukon Weather Office
Room 205, Airport Operations Building
Whitehorse, Yukon Territory Y1A 3E4
(403) 668-2291

(weather and climate related information for the Yukon Territory)

BRITISH COLUMBIA

• Environment Canada
Atmospheric Environment Service (AES)
Scientific Services Division
Bordigan Building, Suite 700
1200 West 73rd Avenue
Vancouver, British Columbia V6P 6H9
(604) 664-9120

(weather and climate related information for British Columbia)

• Environment Canada
Inland Waters Directorate-Pacific Region
Water Planning and Management
1001 West Pender Street
Vancouver, British Columbia V6E 2M9
(604) 666-6313

(streamflow and lake level data)

• Agriculture Canada
Land Resource Research Institute
6660 Northwest Marine Drive
Vancouver, British Columbia V6T 1X2
(604) 224-4355

(soil moisture conditions, conservation and management)

• Forestry Canada
Pacific Forestry Centre
508 West Burnside Road
Victoria, British Columbia V8Z 1M5
(604) 388-0600

(Canadian Forest Fire Weather Index)

• Emergency Preparedness Canada
British Columbia and Yukon Region
203-2881 Nanaimo Street
P.O. Box 10000
Victoria, British Columbia V8W 3A5
(604) 388-3621 and (604) 363-3621

(financial assistance program during disasters, including severe droughts)

x British Columbia Ministry of Environment and Parks
Water Management Branch
10334-152A Street
Surrey, British Columbia V3R 7P8
(604) 584-8822

(snow survey bulletins, groundwater, streamflow conditions)

x British Columbia Ministry of Agriculture and Fisheries
17720-57th Avenue
Cloverdale, British Columbia V3S 4P9
(604) 576-2911

(crop conditions, irrigation and stockwater supplies)

ALBERTA

x Alberta Drought Monitoring Committee
Alberta Agriculture
Conservation and Development Branch
206-7000-113 Street
Edmonton, Alberta T6H 5T6
(403) 422-4385

(drought monitoring, response strategies)

*** Environment Canada**
Atmospheric Environment Service (AES)
Scientific Services Division
Twin Atria Building, Room 240
4999-98 Avenue
Edmonton, Alberta T6B 2X3
(403) 495-3143

(weather and climate related information for Alberta and the Northwest Territories)

*** Environment Canada**
Inland Waters Directorate-Western and Northern Region
Water Resources Branch
Twin Atria #2 Building, Room 210
4999-98 Avenue
Edmonton, Alberta T6B 2X3
(403) 468-8075

(streamflow, lake level data)

• Agriculture Canada
Prairie Farm Rehabilitation Administration (PFRA)
Suite 1620, Canada Place
9700 Jasper Avenue
Edmonton, Alberta T5J 4G5
(403) 495-4048
(see entry for PFRA, Regina, Saskatchewan)

• Agriculture Canada
Prairie Farm Rehabilitation Administration (PFRA)
Room 832, 220-4th Avenue SE
Calgary, Alberta T2P 3C3
(403) 292-5638
(see entry for PFRA, Regina, Saskatchewan)

• Agriculture Canada
Agriculture Development Branch
Suite 810, Canada Place
9700 Jasper Avenue
Edmonton, Alberta T5J 4G5
(403) 495-4141

(crop conditions, soil conservation and management)

• Agriculture Canada
Land Resource Research Branch
Soil Survey Unit
Room 653, Terrace Plaza Tower
4445 Calgary Trail South
Edmonton, Alberta T6H 5R7
(403) 495-4243

(soil moisture conditions)

• Emergency Preparedness Canada
Alberta and Northwest Territories Region
10420-157 Street Room 112
Edmonton, Alberta T5P 2V6
(403) 495-3005

(financial assistance program during disasters,
including severe droughts)

x Alberta Environment
9820-106 Street
Edmonton, Alberta T5K 2J6
(403) 427-0047

(1986 Environment Views issue on drought in Alberta)

x Alberta Agriculture
206-7000-113 Street
Edmonton, Alberta T6H 5T6
(403) 427-4021

(crop and weather condition reports)

■ Environmental Council Of Alberta
8th Floor Weber Centre
5555 Calgary Trail Southbound NW
Edmonton, Alberta T6H 5P9
(403) 427-5792

(publications on climate change, past droughts)

SASKATCHEWAN

*** Environment Canada**
Atmospheric Environment Service (AES)
Regina Climate Centre
Airport Operations Building
P.O. Box 4800
Regina, Saskatchewan S4P 3Y4
(306) 780-6413

(weather and climate information for Saskatchewan;
monthly Palmer Drought Severity Index for the Prairies)

*** Environment Canada**
Atmospheric Environment Service (AES)
Hydrometrical Research Division
National Hydrology Research Centre
11 Innovation Boulevard
Saskatoon, Saskatchewan S7N 3H5
(306) 975-5755

(drought-related publications; drought research)

*** Environment Canada**
Conservation and Protection Service
Inland Waters Directorate-Western and Northern Region
Water Planning and Management Branch
1st Floor, 1901 Victoria Avenue
Regina, Saskatchewan S4P 3R4
(306) 780-5326

(drought fact sheet; climate change and water resources
fact sheet; water conservation)

• Environment Canada
Inland Waters Directorate
National Hydrology Research Institute
National Hydrology Research Centre
11 Innovation Boulevard
Saskatoon, Saskatchewan S7N 3H5
(306) 975-5750

(drought research, climate change fact sheet)

• Agriculture Canada
Prairie Farm Rehabilitation Administration (PFRA)
Motherwell Building
1901 Victoria Avenue
Regina, Saskatchewan S4P 0R5
(306) 780-5070 English and (306) 780-5019 French

(soil conservation and water management issues related to agriculture; Prairie Provinces Water Supply Conditions Report)

• Agriculture Canada
Prairie Farm Rehabilitation Administration (PFRA)
North Road, University of Saskatchewan Campus
P.O. Box 908
Saskatoon, Saskatchewan S7K 3M4
(306) 975-5140
(see entry for PFRA, Regina)

• Agriculture Canada
Agriculture Development Branch
Room 310, 2100 Broad Street
P.O. Box 8035
Regina, Saskatchewan S4P 4C7
(306) 780-5545

(crop conditions, soil conservation and management)

• Agriculture Canada
Research Branch
Saskatchewan Soil Survey Unit
210 John Mitchell Building
University of Saskatchewan
Saskatoon, Saskatchewan S7N 0W0
(306) 975-4060

(soil moisture conditions; prairie regional land evaluation)

• Emergency Preparedness Canada
Saskatchewan Region
2002 Victoria Avenue, Room 850
Regina, Saskatchewan S4P 0R7
(306) 780-5005

(financial assistance program during disasters, including severe droughts)

x Saskatchewan Agriculture
Economics Branch, Statistics Section
Walter Scott Building
3085 Albert Street
Regina, Saskatchewan S4S 0B1
(306) 787-5951

(crop and weather reports for Saskatchewan)

■ Saskatchewan Research Council (SRC)
Communications Department
15 Innovation Boulevard
Saskatoon, Saskatchewan S7N 2Y8
(306) 933-5490

(publications related to drought, climate change)

MANITOBA

x Manitoba Drought Committee
Manitoba Agriculture
Soils and Crops Branch
401 York Avenue
Winnipeg, Manitoba R3C 0P8
(204) 945-1927

(drought monitoring, response strategies)

• Environment Canada
Atmospheric Environment Service (AES)
Winnipeg Climate Centre
266 Graham Avenue, Room 1000
Winnipeg, Manitoba R3C 3V4
(204) 983-2082 and (204) 983-6223

(drought monitoring; near real-time climate products; (agrometeorological bulletins; soil moisture analyses)

• Environment Canada
Inland Waters Directorate
Water Resources Branch
Room 521, 269 Main Street
Winnipeg, Manitoba R3C 1B2
(204) 983-2434
(streamflow and lake level data)

• Agriculture Canada
Prairie Farm Rehabilitation Administration (PFRA)
Room 401, 1 Wesley Avenue
Winnipeg, Manitoba R3C 4C6
(204) 983-2241

(see entry for PFRA, Regina, Saskatchewan)

• Agriculture Canada
Land Resource Research Centre
Room 362, Ellis Building
University of Manitoba
Winnipeg, Manitoba R3T 2N2
(204) 474-6118

(SMEP, FoDEWS reports)

• Emergency Preparedness Canada
Manitoba Region
391 York Avenue, Room 306A
Winnipeg, Manitoba R3C 0P4
(204) 983-6790

(financial assistance program during disasters, including severe droughts)

x Manitoba Department of Natural Resources
Water Resources Branch
1577 Dublin Avenue
Winnipeg, Manitoba R3E 3J5
(204) 945-6398

(streamflow data, soil moisture analyses, snow surveys)

ONTARIO/GREAT LAKES REGION

*** Environment Canada**
Atmospheric Environment Service (AES)
Canadian Climate Centre
4905 Dufferin Street
Downsview, Ontario M3H 5T4
(416) 739-4351

(drought fact sheet; Cumulative Precipitation Index, water budget output, CCC reports)

*** Environment Canada**
Great Lakes Water Level Communications Centre
P.O. Box 5050
867 Lakeshore Road
Burlington, Ontario L7R 4A6
(416) 336-4712

(information and warnings about Great Lakes water levels)

*** Agriculture Canada**
Canadian Crop Drought Assistance Program
Policy Branch
Sir John Carling Building
930 Carling Avenue
Ottawa, Ontario K1A 1J3
(613) 995-5880

(financial assistance during severe drought)

*** Emergency Preparedness Canada**
Ontario Region
20 Holly Street, Suite 205
Toronto, Ontario M4S 3B1
(416) 973-6343

(financial assistance program during disasters, including severe droughts)

*** Agriculture Canada**
Land Resource Research Centre
Central Experimental Farm
Ottawa, Ontario K1A 0C6
(613) 995-5011

(agrometeorological research, prairie regional land evaluation)

• Statistics Canada
Agriculture Division, Remote Sensing Unit
Jean Talon Building, 12th floor
Ottawa, Ontario K1A 0T6
(613) 951-3872

(crop monitoring with remote sensing)

x Ontario Ministry of Natural Resources
Conservation Authorities and Water Management Branch
Room 5620, Whitney Block
99 Wellesley Street West
Toronto, Ontario M7A 1W3
(416) 965-6295

(water conservation strategies for Ontario;
streamflow and lake level data)

x Ontario Ministry of Agriculture and Food
Soil and Water Management Branch
Guelph Agricultural Centre
P.O. Box 1030
Guelph, Ontario N1H 6N1
(519) 767-3561

(advice on soil and crop management to
reduce soil erosion)

■ Centre for the Great Lakes
320½ Bloor Street West
Toronto, Ontario M5S 1W5
(416) 921-7662

(drought of 1988 fact sheet; fact sheets on
climate change in the Great Lakes Basin

■ Great Lakes Commission
The Argus II Building
400 South Fourth Street
Ann Arbor, Michigan USA 48103-4816
(313) 665-9135
(drought management guidebook for the
Great Lakes Region, including Ontario)

QUÉBEC

*** Environment Canada**
Atmospheric Environment Service (AES)
Scientific Services Division
100 Alexis-Nihon Boulevard, 3rd floor
Ville St.-Laurent, Québec H4M 2N8
(514) 283-1107

(weather and climate related information for Québec)

*** Environment Canada**
Inland Waters Directorate-Québec Region
Water Quantity and Quality Programs
1001 Pierre Dupuy
Longueuil, Québec J4K 1A1
(514) 651-6860

(streamflow and lake level data)

*** Agriculture Canada**
Agricultural Development Branch
Guy Favreau Complex, East Tower, Room 1002-D
200 René-Lévesque Boulevard West
Montréal, Québec H2Z 1Y3
(819) 285-8888

(crop conditions, soil conservation and management)

*** Agriculture Canada**
Land Resource Research Centre
Scientific complex, Suite 208
2700 Einstein Street
Sainte-Foy, Québec G1P 3W8
(418) 648-7749

(soil moisture conditions)

*** Emergency Preparedness Canada**
Québec Region
St. Laurent Building
250 Grande Allée West, Room 701
Québec City, Québec G1R 2H4
(418) 648-3111

(financial assistance program during disasters, including severe droughts)

x Environnement de Québec
2360 Sainte-Foy Road
Sainte-Foy, Québec G1V 4H2
(418) 643-6071

(climate conditions in Quebec; water resources)

NEW BRUNSWICK

*** Environment Canada**
Atmospheric Environment Service (AES)
Scientific Services Unit
Federal Building, 633 Queen Street
Fredericton, New Brunswick E3B 1C3
(506) 452-3837

(weather and climate-related information for New Brunswick)

*** Environment Canada**
Inland Waters Directorate
Water Resources Branch
Room 214, 633 Queen Street
Fredericton, New Brunswick E3B 1C3
(506) 452-3095

(streamflow data)

*** Agriculture Canada**
Atlantic Regional Office
Government of Canada Building, 4th floor
P.O. Box 6088
Moncton, New Brunswick E1C 8R2
(506) 851-7400

(soil and water conservation and management strategies)

*** Emergency Preparedness Canada**
New Brunswick Region
590 Brunswick Street, Lower Level
P.O. Box 534
Fredericton, New Brunswick E3B 5A6
(506) 452-3020
(financial assistance program during disasters, including severe droughts)

x New Brunswick Environment
Environmental Services
P.O. Box 6000
Fredericton, New Brunswick E3B 5H1
(506) 453-2669

(water resources)

NOVA SCOTIA

*** Environment Canada**
Atmospheric Environment Service (AES)
Scientific Services Division
1496 Bedford Highway
Bedford, Nova Scotia B4A 1E5
(902) 426-9226
(weather and climate information for the Atlantic Region)

*** Environment Canada**
Inland Waters Directorate-Atlantic Region
Water Planning and Management Branch
45 Alderney Drive
Dartmouth, Nova Scotia B2Y 2N6
(902) 426-3266

(streamflow data for the Atlantic Region)

*** Agriculture Canada**
Agriculture Development Branch
Suite 200, 35 Commercial Street
P.O. Box 698
Truro, Nova Scotia B2N 5E5
(902) 893-0068

(crop conditions; soil and water conservation
and management strategies)

*** Emergency Preparedness Canada**
Nova Scotia Region
6009 Quinpool Road, Suite 801
Halifax, Nova Scotia B3K 5J7
(902) 426-2082

(financial assistance program during disasters, including severe droughts)

PRINCE EDWARD ISLAND

*** Environment Canada**
Atmospheric Environment Service (AES)
Charlottetown Weather Office
97 Queen Street
Charlottetown, Prince Edward Island C1A 4A9
(902) 566-7060
(weather and climate related information for Prince Edward Island)

*** Environment Canada**
Inland Waters Directorate
Water Resources Branch
Room 308, 97 Queen Street
P.O. Box 2529
Charlottetown, Prince Edward Island C1A 8C2
(902) 566-7062

(streamflow data)

*** Agriculture Canada**
Agriculture Development Branch
P.O. Box 2949
141 Kent Street
Charlottetown, Prince Edward Island C1A 8C5
(902) 566-7300
(soil conservation and water management strategies)

*** Emergency Preparedness Canada**
Prince Edward Island Region
Dominion Building, Room 210
P.O. Box 1175
Charlottetown, Prince Edward Island C1A 7M8
(902) 566-7047

(financial assistance program during disasters, including severe droughts)

x PEI Department of Agriculture
P.O. Box 2000
Charlottetown, Prince Edward Island C1A 7N8
(902) 368-4875

(agricultural conditions related to drought)

NEWFOUNDLAND/LABRADOR

• Environment Canada
Atmospheric Environment Service (AES)
Scientific Services Unit
Building No. 303, Pleasantville
P.O. Box 9490
St. John's, Newfoundland A1A 2Y4
(709) 772-4695

(weather and climate related information for Newfoundland/Labrador)

• Environment Canada
Inland Waters Directorate
Water Resources Branch
Suite 812, Atlantic Place
215 Water Street P.O. Box 72
St. John's, Newfoundland A1C 6C9
(709) 772-4844

(streamflow and lake level data)

• Agriculture Canada
Agriculture Development Branch
P.O. Box 1878
St. John's, Newfoundland A1C 5R4
(709) 772-4063

(soil conservation and water management strategies)

• Emergency Preparedness Canada
Newfoundland Region
P.O. Box 188, Station C
St. John's, Newfoundland A1C 5J2
(709) 772-5522

(financial assistance program during disasters, including severe droughts)

APPENDIX C.

SUGGESTED READING LIST ON CANADIAN DROUGHTS

DROUGHT-BRITISH COLUMBIA

Taylor, E. and K. Johnstone (eds.), 1989. *Proceedings of the Symposium on the Impacts of Climate Variability and Change on British Columbia, December 14, 1988, Vancouver.* Scientific Services Division Report PAES-89-1. (Atmospheric Environment Service, Vancouver, British Columbia). 87 pp.

DROUGHT-PRAIRIE PROVINCES

AES Drought Study Group, 1986. *An Applied Climatology of Drought in the Prairie Provinces.* Unpublished manuscript. Canadian Climate Centre (CCC) Report No. 86-4. (Atmospheric Environment Service, Downsview, Ontario). 197 pp.

Berry, M. O. and G. D. V. Williams, 1985. "Thirties Drought on the Prairies - How Unique Was It?", in *Climatic Change in Canada 5.* C. R. Harington (ed.). (National Museums of Canada, Ottawa). Syllogeus 55, pp. 63-74.

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Environment Canada, 1988. *Proceedings of the Prairie Drought Workshop, October 11-13, 1988, Saskatoon, Saskatchewan.* D. J. Bauer (ed.). 366 pp.

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Inland Waters Directorate, 1988. *1988 Drought Information-Notes*. (Inland Waters Directorate, Western and Northern Region, Regina, Saskatchewan). 26 pp

Inland Waters Directorate, 1989. *Water Shortages in the Canadian Prairies: Living With Drought*. (Inland Waters Directorate, Western and Northern Region, Regina, Saskatchewan). 4 pp.

Lang, T.-A., and K. Jones, 1988. *A Comparison of the Meteorological Conditions During the Droughts of the 1930s and the 1980s for the Prairie Provinces*. Report No. CSS-R89-01. (Atmospheric Environment Service, Scientific Services, Regina, Saskatchewan).

Lilley, J. and C. Webb, 1990. *Climate Warming? Exploring the Answers*. ECA90-ST/1. (Environmental Council of Alberta, Edmonton). 73 pp.

Liverman, D. M., 1978. *Perception and Communication in Government Response to the 1977 Drought in Western Canada*. University of Toronto, Emergency and Risk Research Working Paper No. 1. (University of Toronto Press, Downsview). 92 pp.

McKay, G., 1980. "Mitigation of the effects of drought with special reference to the Canadian experience", *Drought In The Great Plains: Research On Impacts and Strategies*. (Water Resources Publications, Littleton, Colorado). pp. 168-180.

Maclean's, June 27, 1988, pp. 32-40.

Magill, B. L. and F. Geddes (eds.), 1988. *The Impact of Climate Variability and Change on the Canadian Prairies: Symposium / Workshop Proceedings, September 9-11, 1987*. (Alberta Department of the Environment, Edmonton, Alberta). 412 pp.

National Research Council Canada, 1987. *Proceedings of the Canadian Hydrology Symposium No 16-1986*. Drought: The Impending Crisis?, Regina, Saskatchewan, June 3-6, 1986. 680 pp.

Regional Economic Expansion, 1978. *Discussion Paper on Drought in Western Canada.* (Canada Department of Regional Economic Expansion, Ottawa). 104 pp.

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DROUGHT-GREAT LAKES REGION

Centre for the Great Lakes, 1988. *The Drought of '88 and the Great Lakes* (fact sheet). 9 pp.

Great Lakes Commission, 1990. *A Guidebook to Drought Planning, Management and Water Level Changes in the Great Lakes.* 61 pp.

Ontario Ministry of Natural Resources, 1988. *1988 Drought Conditions in Ontario.* (Ontario Ministry of Natural Resources, Toronto, Ontario). 28 pp.

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Warrick, R. A., 1975. *Drought Hazard In The United States: a Research Assessment*. (University of Colorado, Program on Technology, Environment and Man Monograph #NSF-RA-E-75-004). 199 pp.

DROUGHT INDICES

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Jones, K. H., 1984. *An Evaluation of the Palmer Drought Index in Southern Saskatchewan*. Report No. CSS-R84-01. (Atmospheric Environment Service, Scientific Services Regina, Saskatchewan). 33 pp.

Mapanao, L. O., 1988. *On Monitoring Wet/Dry Areas Across Canada*. (Atmospheric Environment Service, Downsview). Paper presented at the Prairie Drought Workshop, Saskatoon, Saskatchewan, October 11-13, 1988. 4 pp. + attachments.

Mather, J. R., 1985. *Drought Indices For Water Managers*. *Publications in Climatology*, Vol. 38, No. 1. (C. W. Thornthwaite Associates, Centerton, New Jersey). 69 pp.

MAGAZINES/PERIODICALS ON DROUGHT

Drought Network News. Published three times a year. Information on drought events from around the world.

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