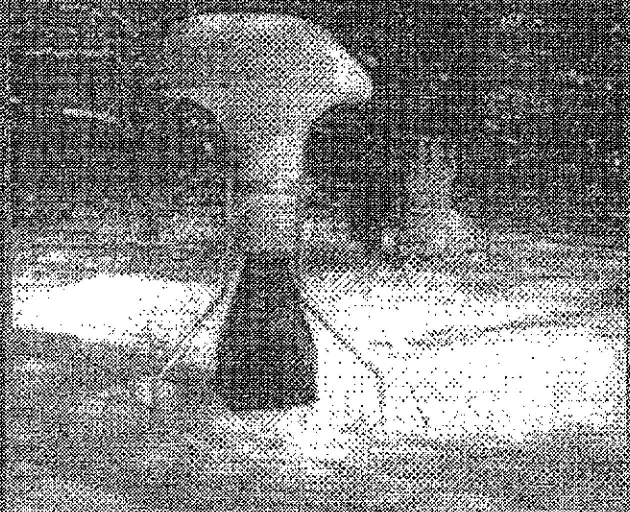
Degradation in Environment Canada's Climate Network, Quality Control and Data Storage Practices:

A Call to Repair the Damage



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Bio

Pierre Perron
Commissaire adjoint
SP

Editor's Notes

The accounts in this document have been compiled with the assistance and advice of a large number of dedicated individuals both inside and outside Environment Canada. These individuals are not responsible for any points of view other than those they themselves have expressed. The editor wishes to convey his thanks to each and every one, and to the individuals who sacrifice their time and effort to ensure that this information is presented to the highest levels of government.

In his first speech as the Chief of the Defense Staff, General Rick Hillier said about the military: "*In this country, we could probably not give enough resources to the men and women to do all the things that we ask them to do. But we can give them too little, and that is what we are now doing. Remember them in your budgets.*" Similar sentiments would appear to apply to Environment Canada.

Quotes taken from other publications or documents are highlighted in *italics*. Quotes from individuals are highlighted in *blue italics*. Substantial edits and editorial comments are indicated in [square brackets]. Deleted words and phrases are indicated by ellipses (...).

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Summary

The infrastructure required to collect and process atmospheric climate data in Canada has suffered increasing damage over the past ten to fifteen years. That trend is accelerating. The ability of Environment Canada (EC) to meet its goal of ensuring the safety and security of Canadians by gathering, interpreting and disseminating information on the state of the national climate system has been compromised by a period of sustained budget cuts to the Meteorological Service of Canada (MSC). Environment Canada is on the road to junior partner status with respect to other agencies, both provincial and international, in the area of climate data gathering, quality control and archiving. This publication is a call to assess the current situation, put in place a recovery plan and carry out the plan in cooperation with all those who share the vision and the need for a comprehensive climate program for all Canadians.

Key Findings

- Automatic precipitation sensors are subject to significant errors which are well known. These errors have significantly compromised the integrity of Canada's precipitation data.
- National coverage of certain climate elements such as hours of bright sunshine has been effectively terminated.
- Human quality control of climate data ceased as of April 1, 2008. Automated quality control is essentially non-existent. There is no program in place to prevent erroneous data from entering the national climate archive.
- Climate data which could be gathered at minimal additional cost is not being gathered due to lack of funds.
- Climate data which could be gathered with minimal additional effort is not being gathered due to lack of personnel.
- Some existing data which needs to be interpreted and processed before being placed into the national archive is being ignored due to lack of resources.
- A significant portion of the volunteer climate network will likely be lost due to a decision on the part of MSC to discontinue processing paper forms and to emphasize electronic input.
- Clients of EC (both internal and external) cannot obtain the information they need. This has significant implications for programs carried out by all levels of government, the private sector and the international scientific community.
- Lack of resources and delayed quality control of climate data have resulted in updates of Intensity/Duration/Frequency (IDF) curves that proceed in fits and starts. Systematic and regular updates are desired by the engineering community in order to design public infrastructure (roads, buildings, sewers) that will be able to cope with severe storms and phenomena associated with changing climate.
- These program integrity issues are widely recognized by operational staff within the department, and are becoming increasingly obvious to outside partners and clients, damaging morale within and credibility outside the department.

Repairing the Damage

Given the current fiscal climate, it is unlikely that significant new and sustained resources will be allocated to the atmospheric climate program. However, avenues of cooperation with clients and partner agencies remain underexplored. It is recommended that the department develop a recovery program in cooperation with these partners to ensure sustainable funding and comprehensive climate network coverage for the benefit of current and future generations.

1 Background

By the 1980s, the Meteorological Service of Canada in the course of meeting its goal of providing safety and security information to Canadians had built up a network of meteorological data gathering sites across Canada. Most medium and large sized communities had weather offices, usually located at airports, at which trained observers took hourly and synoptic (expanded 6 hourly) observations. A number of these offices were more advanced in capability, and in addition to carrying out weather observations, provided weather briefings to the public and aviation communities, media interviews, low altitude pilot balloon observations, and acted as local interpreters for the regional forecasts. Weather observations at these "manned" stations could not cover all the geographical areas for which information was needed, so numerous automatic weather stations were installed to measure a subset of the types of weather manned stations were capable of observing. In addition to surface stations, MSC maintained an upper air observing program (that employed high altitude radiosonde balloons) at approximately 35 sites across Canada. MSC also instituted a program to install weather radars across the southern tier of the country where the bulk of the population was located. Finally it acquired U.S. satellite data on a continuous basis at ground tracking stations. This collection of data gathering networks was operated by employees of MSC and met the real-time needs of weather reporting and forecasting across the country. At the same time, it formed the core of the climate data network which was instituted to provide a long-term overview of climate and its variations. This core was supplemented by a network of several thousand non-paid volunteers who provided observations (typically twice daily measurements of temperature and precipitation), in some cases for decades. To deal with the mountain of information that was gathered by weather offices, automatic weather stations, volunteers and upper air sites, MSC operated a central repository for data, and relied substantially on its regional offices to archive radar and satellite imagery. The regional MSC offices also employed staff to perform critical quality control of most of the incoming data and to respond to requests from government, industry and the public for information. This system which had been gradually built up over decades, and which functioned well, was shattered by Program Review 1 and Program Review 2 in the early to mid 1990s.

With the drive on to eliminate the deficit, significant cuts to most government departments were instituted. Significantly, departmental mandates were not altered to reflect diminished resources. MSC was hit particularly hard and managers were forced to cast about for ways to save money while attempting to preserve services. Existing timelines for the replacement of human weather observers by automatic weather stations were drastically accelerated. Over a period of several years, all MSC briefing and observing offices across Canada were closed, and their staff reassigned, given buyouts or early retirement. At least one upper air site (Mould Bay) was closed, and private contractors took over at most others.

Another significant development was the formation of Nav Canada, a private not-for-profit entity whose mandate is to operate the air navigation system. Conforming with legislation and international practice, Nav Canada assumed the role of supplying aviation-related observations and forecasts. MSC managers negotiated a contract with Nav Canada whereby MSC would supply data feeds and aviation forecasts as well as other meteorological services, and Nav Canada would run the hourly observing network at airports as well as provide some 6-hourly climate observations.

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Background (continued)

As a result, a number of stations with significant relevance to climate studies had their observing programs significantly altered, with MSC unable (due to lack of resources) to intervene. Observing programs varied from station to station with a mix of Nav Canada personnel, contractors, or local Community Aerodrome Radio Station (CARS) personnel doing the manned observations.

A number of sites went to a manned program during the day and autostations at night. Some had humans taking hourly observations and autostations handling the 6-hourly synoptic reports (which are the most important for climate data). The end result was a patchwork quilt of measurements, with certain critical items (such as snowfall and snow depth) no longer observed at various sites. MSC bears its share of the responsibility for this. During the re-negotiation of the observing contracts early in this century, Nav Canada indicated its willingness to provide human synoptic observations at airports if they were compensated for it. MSC decided that the AWOS numbers were good enough.

Various attempts to salvage some data gathering capabilities were tried, including hiring parking lot commissionaires to take snow depth measurements, but these produced mixed results.

Along with these negative developments came pressure to reduce costs in the regional climate sections. Significant reductions in staffing occurred, with retiree positions no longer filled and climate staff either terminated or shuffled off to other positions in MSC. In the case of Prairie and Northern region (which is responsible for over half of Canada), the climate section was completely shut down in 2003.

2 World Meteorological Organization (WMO) Guidelines and Obligations

A l'heure des doigts...

Climate has become a critical area of study. Not only does it affect all life on the planet, but the fact that it is changing and changing rapidly places a premium on correct information and correct decision making. The 2007 Intergovernmental Panel on Climate Change (IPCC) Fourth Assessment Report concluded that *"warming of the climate system is unequivocal with changes in long-term climate being observed at continental, regional and ocean basin scales. These include changes in arctic temperatures and ice, widespread changes in precipitation amounts, ocean salinity, wind patterns and aspects of extreme weather including droughts, heavy precipitation, heat waves and the intensity of tropical cyclones."*

The WMO Guide to Climatological Practices (draft 3rd edition) states that climate is intrinsically bound up with *"agriculture; forestry; ecosystems; energy; industry; production and distribution of goods; engineering design and construction; human well being; transportation; tourism; insurance; water resource management; fisheries and coastal development."*

In addition it states that *"today many users need this information to be coupled and analyzed with other social, economic and physical data. Further, the crucial role of climate data and climate predictions in planning for disaster mitigation and sustainable development, and in addressing all impacts of climate change are now firmly established within various conventions including the UNFCCC."*

The Guide to Climatological Practices emphasizes the foundational nature of observations: *"All climate products and services, from information derived from past climate and weather data, to estimations of future climate, for use in research, operations, commerce and government, are underpinned by observations. The adequacy of a climate service is very dependent on the spatial density and accuracy of the observations and on the data management processes. Without observation of the climate system, there can be no climate services."*

Canada, as a member of the WMO, took part in the Geneva Declaration of the 13th World Meteorological Congress in May 1999. Government representatives, together with the other members of the WMO, stated the following:

"We urge that whatever form or model the National Meteorological and Hydrometeorological Services take, government financial support be provided to operate and maintain the required relevant basic infrastructure, monitoring and services in the national and global public interest, and that such support be strengthened where needed."

The full declaration can be found at **http://www.wmo.ch/pages/governance/policy/geneva_declaration_en.html.**

MSC, in order to meet its goal of providing safety and security information to Canadians, has adopted WMO service standards. Given this, the following questions need to be asked. Has the decision been taken to revoke those standards or are they still in place? If they are still in place, then the evidence appears to show that despite our lofty sounding words, we ourselves are not committed to doing what we have urged others to do. The evidence appears to show that we have failed, in some cases spectacularly so, at applying the WMO's ten principles of monitoring climate that are outlined on the following page (Figure 2.1).

Appendix A provides a more extensive treatment of what is involved in maintaining a climate system. The complete guidelines are to be found in the various technical publications issued by the WMO.

World Meteorological Organization (WMO) Guidelines and Obligations (continued)

1. The impact of new systems or changes to existing systems should be assessed prior to implementation.
2. A suitable period of overlap for new and old observing systems is required.
3. The details and history of local conditions, instruments, operating procedures, data processing algorithms and other factors pertinent to interpreting data (metadata) should be documented and treated with the same care as the data themselves.
4. The quality and homogeneity of data should be regularly assessed as a part of routine operations.
5. Consideration of the needs for environmental and climate monitoring products and assessments should be integrated into national, regional and global observing priorities.
6. Operation of historically uninterrupted stations and observing systems should be maintained.
7. High priority for additional observations should be focused on data poor areas, poorly observed parameters, areas sensitive to change, and key measurements with inadequate temporal resolution.
8. Long term requirements should be specified to network designers, operators and instrument engineers at the outset of system design and implementation.
9. The conversion of research observing systems to long term operations in a carefully planned manner should be promoted.
10. Data management systems that facilitate access, use and interpretation of data and products should be included as essential elements of climate monitoring systems.

Figure 2.1 Ten Monitoring Principles for a proper climate observing program as contained in the WMO Guide to Climatological Practices (draft 3rd edition).

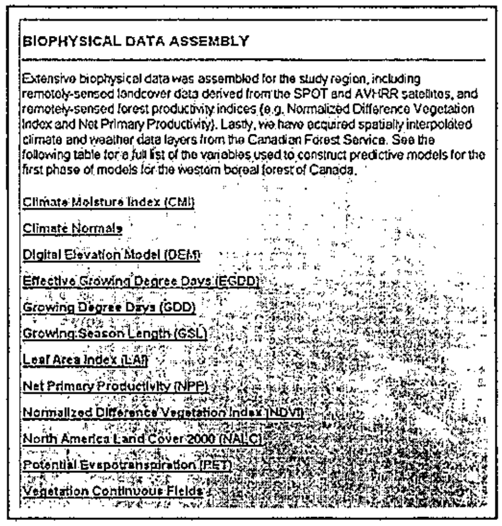
3 Meeting our Needs: The State of Climate Network Infrastructure

Real-life decisions that affect the lives of all Canadians are currently being made based on the data provided by Canada's climate network. The common assumption among users is that the data has been observed accurately, checked for mistakes and stored properly. It is profoundly disturbing to discover the true state of our climate data network and the data we offer to ourselves and the world. This section contains the perspectives of a wide variety of users of Canadian climate data.

3.1 Canadian Wildlife Service

Canadian Wildlife Service (CWS) researchers continually stress the need for dense coverage of a variety of climate elements and for accuracy in data collection. Climate data has been put to a number of interesting uses such as:

- **modelling bird habitat**. The distribution, abundance and productivity of many species is intimately linked with aspects of the climate within which they live. To improve EC's ability to manage migratory birds in boreal forests, climate data, along with other variables, are being employed to develop predictive, spatially-explicit models of the relationships between bird species and various habitat characteristics. Sources of accurate climate data are important to ensure reliability of modelling outputs. Products from these modelling efforts are relevant to EC's migratory bird agenda, assessments for species considered for listing under the Species At Risk Act (SARA), environmental assessments, etc. The screenshot on this page gives some idea of the types of climate data currently utilised by the Boreal Avian Modelling Project (**http://www.borealbirds.ualberta.ca**), a collaborative effort between EC and its partners.



BIOPHYSICAL DATA ASSEMBLY

Extensive biophysical data was assembled for the study region, including remotely-sensed landcover data derived from the SPOT and AVHRR satellites, and remotely-sensed forest productivity indices (e.g. Normalized Difference Vegetation Index and Net Primary Productivity). Lastly, we have acquired spatially interpolated climate and weather data layers from the Canadian Forest Service. See the following table for a full list of the variables used to construct predictive models for the first phase of models for the western boreal forest of Canada.

Climate Moisture Index (CMI)

Climate Normals

Digital Elevation Model (DEM)

Effective Growing Degree Days (EGDD)

Growing Degree Days (GDD)

Growing Season Length (GSL)

Leaf Area Index (LAI)

Net Primary Productivity (NPP)

Normalized Difference Vegetation Index (NDVI)

North America Land Cover 2000 (NALC)

Potential Evapotranspiration (PET)

Vegetation Continuous Fields

Figure 3.1 Sample climate variables used in bird-habitat modelling efforts (URL: http://www.borealbirds.ualberta.ca)

- **plant ecology work with protected areas management and plant species at risk.** This work often uses climate normal data as the basis of models for range maps of plant species, and to help predict species assemblages, predicting susceptibility to invasion by non-native weeds (this is essential to meet the needs of the federal Invasive Alien Species Strategy under the Canadian Food Inspection Agency), predict grasshopper outbreaks (an Agriculture and Agri-Food Canada responsibility), and to predict the expected range of plant species at risk relative to observed range contractions (essential to meet recovery goals under SARA). A network of sites across the prairies is needed to make these models work. The Cypress Hills and Wood Mountain plateau have always been problematic gaps in this network, as these highlands are much cooler and moister than the surrounding plains, but only one station provides long-term normal data from a biased location (Klintonel).

- **studying plant life cycles.** Seasonal trends in temperature are predictors of phenological events in a plant life cycle and together are important climate change indicators. The Plant Watch program supported by EC depends on long-term historical data for interpretation.

- **studying fire weather behaviour.** The combination of normals, variation, and seasonal changes, in addition to current meteorological data, are used for fire weather behaviour prediction by forest and plant ecologists. This allows the development of fire management plans, back-casting of fire weather and potential ecological consequences, in addition to the execution of prescribed burns and fighting of wildfires. The Canadian Forest Fire Behaviour Prediction System uses largely meteorological and climate inputs, and is a world renowned product that has been copied and implemented widely.

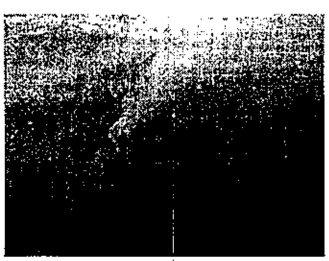


Figure 3.2 Smoke from fires in Banff National Park

- **tracking wetlands.** One researcher finds that the existing meteorological network in central Saskatchewan is adequate but that there is a need for more stations reporting "blowing snow" which is a key parameter for wetland dynamics (hydrology, chemical, biological). At present, automatic weather stations do not observe blowing snow.

Figure 3.3 Peregrine Falcon (Gordon Court)

- **tracking population changes.** The productivity of peregrine falcons (Figure 3.3), burrowing owls (Figure 3.4) and the prairie loggerhead shrike is thought to depend on seasonal weather influences such as severe or cold weather in spring. This research depends on accurate prairie climate data.

Figure 3.4 Burrowing owl

3.2 Environment Canada Climate Research

Environment Canada climate scientists work in a number of climate related disciplines such as climate modelling, the cold climate system, measurement science and observation research, climate trends and variability, land process studies and global circulation patterns. Some of their comments about the climate network are included below.

- *"Stations are too few and too far [between] as everyone is asking for site-specific data, information and analyses to develop decision making models, and verify climate change models, especially regional climate models."*

- *"[EC has] no climate stations in the forest. Consider, for example, the social and economic consequences of the mountain pine beetle in Western Canada. Half of Canada is forested and we have yet to understand the buffering capacity of the forest environment to a changing climate."*

- *"Integrated monitoring is a hopeless top of the house effort without a high degree of commitment of resources and political will to rebuild and modernize the climate observation network in Canada."*

In order to facilitate study of climate trends for the entire country, EC's climate research scientists have prepared carefully controlled and checked datasets of historical climate observations such as homogenized daily temperatures and adjusted daily rain and snow. These are special datasets that meet the exacting needs of researchers doing trend analysis and climate change studies. The data have been adjusted for site relocation, changes in observing programs and corrections for known instrument changes or measurement program deficiencies. In addition, some stations are joined in time to create long time series. In other words, a huge amount of effort has gone into making these datasets accurate and consistent, so that conclusions that are drawn from them are valid. Scientists have this to say about the trend toward automated stations:

"[We] can not include the "modernized" automated stations in [our] datasets, because:
- *snow measurements are not available*
- *[there is a] huge inhomogeneity between the [manned station] and auto station*
- *unreliable results*
- *even the type of auto station [is] not finalized yet (AWOS, Geonor, etc.)"*

The downward trend over the past two decades in the amount of data available for these special datasets is striking (see Figure 3.5). [*It should be noted that several years are required for the majority of available climate data to be placed into the archive. Consequently the data availability for 2006 and 2007 will be somewhat better than depicted here. Ed.]*

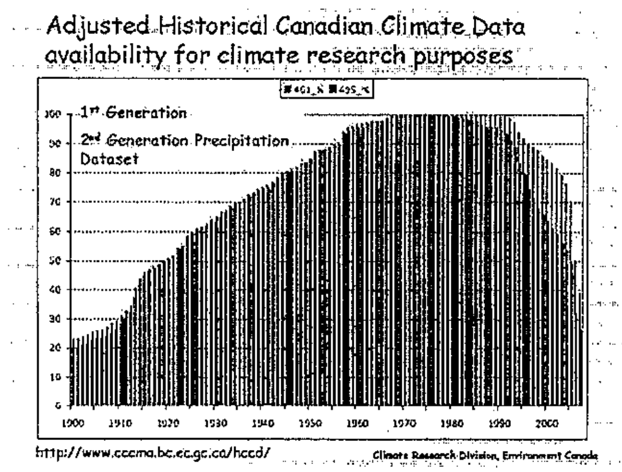


Figure 3.5 Historical Canadian climate data suitable for use in high quality climate datasets.

Two recent MSC-Ontario studies investigated a total of 10 extreme rainfall events in Ontario during 2000 and 2004 (including the 2000 Walkerton and the 2004 Peterborough storms). The study reports concluded that:

- Detailed and accurate precipitation analyses of such events require a dense network of quality precipitation recording stations
- Long term climate records of at least 50 years are of particular importance to improving the estimates of the longest return periods that are associated with the more extreme rainfall events
- It is important to maintain existing Intensity Duration Frequency (IDF) climate stations and create as long a station precipitation record as possible.

The studies also demonstrated the importance of a co-operative climate network where information was shared freely amongst agencies to document severe events.

The Toronto and Region Conservation Authority's report on the August 19, 2005 Toronto rainstorm used over 90 rain gauges (six EC gauges, the rest supplied by the Conservation Authority, municipalities and others) to provide an accurate analysis of the rainfall amounts, intensity and spatial coverage of the storm. [*Somewhat different numbers of gauges are mentioned in the MSC response to Ontario in Appendix D. The numbers in this paragraph are correct. Ed.*] It found that radar, for a number of reasons, severely underestimated the storm totals, echoing a finding of the MSC rainfall studies. (See section 3.8 for a similar discussion from the perspective of the Ontario Provincial Flood Forecasting Committee.)

Rainfall data from storms such as these, together with high quality long-term datasets, are critical inputs to the development of infrastructure design codes and standards. Short-term extreme event data from tipping bucket rain gauges (TBRGs) are analyzed and used in development of statistical information on short duration rainfall IDF curves. The IDF data is used in the design and construction of, for example, water conveyance systems such as road culverts and municipal storm sewer systems. In an environment of changing climate, it is all the more critical that updated IDF curves are made available to the engineering community, municipalities, industry and agencies in order to properly design, construct and in some cases retrofit or upgrade infrastructure (see section 3.5 below for Canadian engineering community and NRTEE perspectives). Although the above discussions have focused on rainfall and associated water conveyance infrastructure, other kinds of climate data are required as input for design standards of infrastructure, for example, the design of electrical power lines.

3.3 Environment Canada Air Quality Research

MSC air quality researchers and forecasters support an increasingly important aspect of environmental forecasting, namely that of air quality. Staff are involved in a wide range of activities from basic research to regulatory hearings to the provision of daily forecasts.

- *"I found out yesterday that the consultant hired to evaluate the monitoring network, plans to use EC's climate [precipitation] data to infer acid deposition in areas where there are no acid deposition monitors. I alerted the [air quality] group that the [precipitation] is likely to be in error after 2006 due to lack of adequate checking. Just another case where it is assumed that the ... records are reliable and hence will be used to support significant environmental advice."*

3.4 MSC Weather Forecasting

MSC maintains forecast centers in all of its regions across Canada. Forecasters work around the clock to produce a wide variety of products including short term public forecasts, aviation area and terminal forecasts, marine forecasts, watches and warnings.

- *"My opinion? Standard climatic data is becoming increasingly unreliable. From the daily forecasting perspective, such information is extremely important (long term data to the short term, like [precipitation] amounts, snow depth, erroneous [precipitation] events, malfunctioning sensors, etc.). We do far more 'weeding out' than we used to because the information can't be trusted. So our diminishing network becomes even less useful. Already, a lot of crummy data is being ingested into statistics that likely govern SCRIBE/UMOS (forecast generation and forecast statistics)* *output. Regularly poor information is also often not allowed to enter the calculation of MOS (Model Output Statistics) and suppressed from verification schemes. In other words, even downstream mechanisms are being 'taught' not to trust the data. Our climate network is likely already below WMO standards (especially in the north), and the change from [observations] gathered and checked by humans to [observations] being automated if not completely removed because of financial 'pressure', makes it even more so. We admit that automation has its place in the forecast process, but to what extent? In other words, how much automation should be allowed before it becomes detrimental? Eventually, maybe, all the equipment and software that does the work will be robust and dependable enough to be trusted, but that is still a long way off. The same could be said when it comes to the gathering and processing of climate data. We have really jumped the gun on that one. One could say that climate records are at the root of everything we do. That root is rotting."*

- *"Another example today, Champion XCP (Alberta) reached a record high of 27.6 degrees Celsius while the highest hourly ob[servation] was 5.0. I sent it to Climate but does this really go anywhere or will it in the future? And again today, YXD (Edmonton Municipal Airport), YET (Edson, Alberta) and YMM (Fort MacMurray) recorded 0.5 mm of pcpn under clear skies. This will affect our verification as well as precipitation records for climate records and for researchers. And not having an accurate idea of how much snow fell affects credibility (fortunately/unfortunately we are not usually the ones doing the media interviews) and verification of forecasts/warnings. Calling around you get reports but how reliable are these? This is really a great loss..."*

- *"Our existing mainstay network is not comprehensive and what it does tell us can be misleading to both the human forecasters and to the computer models ... It's called ground truthing! Of radar, of satellite imagery, of models. How can we improve and validate the ever improving [weather] models such as GEM-LAM (Global Environmental Multiscale – Local Area Model) without the level of detail that the climate stations provide ... precipitation-wise in particular. Without climate data how will anyone know when the models are to the point that the human factor in generating forecasts can be reduced (even more) or eliminated?"*

- *"The quality control of the data is something we never should have let go of. I was working last week when Key Lake SK reached an official low of -50 [degrees Celsius] on Friday morning. Were they the cold spot of the province? No, because an error caused Wynyard SK to record a low of -54. By the way, every other station in southern Saskatchewan had lows that ranged from -35 to -25. Will this piece of data throw off some long term climate statistic? Absolutely."*

- *"Speaking for [north] of 60 [degrees latitude].. and hearing from time to time about 'planned' climate stations for the north that aren't even in a community but rather are in some box where someone believes that we need to have data to meet global climate observing station 'needs'....I point out that there is a basic human and computer data need in the north."*

- *"Re: Saskatoon rain events Aug 17th & 19th 2007 (no [precipitation] data 17th-21st because of autostation failure). [Staff] really frustrated by this. Major flooding, and no precip amounts to give the media.*

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the Automatic Weather Station. Have enclosed weather obs for both Aug 17 2007 and Aug 19 2007. ad /RXX/ (rain amount) groups for the 17th adding up to 60mm by the end of the climate day at 180600Z. Not so for the 19th. Assumption is that they had some kind of readout from the AWOS to the end of the 17th, but nothing to read for the 19th."

- *"The degradation of our climate network has been an emotional and upsetting sore point with me for a while.*

  A) Concerning our climate stations: these have always offered the most bang for the buck and in my wildest dreams, I could not understand the reasoning and logic behind letting this system deteriorate. Especially at a time when weather is such a high profile news story these days. They are fundamental in assessing high impact weather. Without them we cannot assess [forecast] or model performance. This is especially important in BC where because of terrain issues, variability in weather elements is great over short distances. We need more climate stations to adequately cover this variability!!

  B) Concerning our real-time observing network: Verifying snowfall is probably the biggest headache ... and I think the quality of manned [observations] at airports is not as good as in the past (sometimes we see snow[fall amount] groups [in the observations] and other times we don't). Autostations don't report snow, or if they do, they are oftentimes suspect. Concerning rain, reliability of other reporting networks to provide data is just not there. Many forestry sites may/can/do close down in the winter when they are needed for verifying rainfall events. Again we need more observing sites on a realtime basis in such key areas as Kitimat, Prince Rupert proper, and the interior of the Queen Charlottes. Our realtime wind network has been pretty good but I see proposed cuts would mean some of key observing sites would no longer be available for verification purposes.

  [On] the forecast desk, having a reliable realtime reporting network is the key to assessing if and when to issue weather warnings. This is getting increasingly difficult. Furthermore, a lack of supporting data such as that obtained from climate stations means assessing the impacts of a synoptic situation and numerical guidance related to said situation is not possible. To me, quality weather observations are the CORE of this organization. Without them, we simply cannot perform to a level we are capable of. We cannot be expected to adequately provide weather warnings for high impact events, and we cannot learn from our mistakes if, in retrospect, we don't have a clue what has happened."

For a more detailed picture of what is involved in verification of one region's weather forecasts, see Appendix B.

3.5 Canadian Engineering Community/National Round Table on the Environment and the Economy (NRTEE)

Civil infrastructure holdings within Canada have an estimated worth of over $5.5 Trillion (1999$) (National Research Council). Climate data are used to develop climatic design criteria that are key inputs to building codes and standards for the design and building of Canadian infrastructure.

In a September 2005 letter from the CEO of the Canadian Council of Professional Engineers to Environment Canada's DM (Watson), the following concerns of the **Canadian Council of Professional Engineers** (CCPE) were expressed:

"Our municipal engineers and scientists in Environment Canada have advised us that your department has not analysed or quality-controlled meteorological data from storms occurring after 1999 in Canada and has not incorporated these data into updated Intensity, Duration and Frequency (IDF) curves since 1999. We understand this has been an ongoing issue for the department over the past several years.

Our concern is that professional engineers rely on storm water IDF curves for the prediction of extreme weather events, which are used to size drainage systems. With no recent data and no updated IDF curves, engineers are designing new municipal drainage systems without consideration of the climate that your scientists have confirmed is changing. CCPE respectfully requests information on what your department is doing to address this important issue and on future plans so that we may inform our engineers when newly updated IDF curves will become available.

Furthermore, we are also concerned that Environment Canada is considering further reductions in its national meteorological data collection network. These reductions will undoubtedly mean that extreme rainfall will not be recorded in some regions, and therefore analysis will be less reliable and somewhat haphazard..."

".... ***We respectfully urge your department to re-consider any further reductions in the weather data collection network."***

Environment Canada's response letter in February 2006 noted that:*"The task of updating the IDF curves will begin in 2007."* The issue of network reductions was not directly addressed. The letter simply noted that: *"Traditional precipitation data used in IDF curves can now be supplemented by Environment Canada's new Doppler radar data"* and *"...Environment Canada is continuing to modernize the observing stations so that all the parameters, including the precipitation data, can be available online in real time. This will eliminate the long delay caused by using paper records."* This latter statement is of course referring to automation of monitoring stations as well as quality control (QC) procedures. [*It should be noted that as of this writing such vital data as rainfall intensity is not available in real time. Historically, intensity data has been recorded down to 5 minute increments but the current interface in Climate Online is incapable of even displaying hourly or even 6 hourly precipitation data. It is questionable whether sub-hourly totals are even being stored anymore. Ed.*]

A followup letter was sent by the CCPE to the DM (Horgan) in August 2006 which noted the professional engineering community's concern that: *"the (IDF update) work is proceeding too slowly"*. It also indicated that professional engineers (with input from municipalities, provincial and territorial governments, and federal departments (including EC)) were engaging in a National Climate Change Assessment of Infrastructure and expressed their view that: *"...the effective collection and management of rainfall data are vitally important elements for engineers to design cost-effective drainage infrastructure to accommodate the changing climate"*.

The Climate Change Adaptation Program, National Round Table on the Environment and the Economy, (NRTEE) has recently prepared a draft report that addresses the development of a Climate Change Adaptation Strategy for northern Canada's infrastructure (final report to be released later in 2008). The report identifies the limitation of climate data available in northern Canada as one of the key challenges in the process of developing the strategy. It stresses the importance of having regionally and locally relevant climate data and information for use in understanding past and current climate trends. The quality, as well as quantity, of location specific weather data collected in northern Canada is reported as being poor (with specific mention of the quality of automated station data and snowfall observations).

3.6 Canadian Commission on Building and Fire Codes (National Research Council)

In March 2005, in support of the Canadian Commission on Building and Fire Codes, the Standing Committee on Structural Design (SCSD) agreed that: "*The source of the climatic data in Appendix C in the National Building Code (NBC) is Environment Canada and that the source of alterations to the climatic data in Appendix C of the NBC should only come from Environment Canada.*" This statement clearly supports a requirement for Environment Canada to provide quality climate data in support of Canada's National Building Code.

3.7 Ontario Climate Advisory Committee

The Ontario Climate Advisory Committee (OCAC) was formed in the early 1980s to identify climatological needs in Ontario and recommend suitable measures to appropriate agencies to fulfil these needs. Although similar Committees were struck in other provinces across Canada, these Committees were dissolved by the 1990s, leaving the OCAC as the only remaining committee of its kind in Canada. Members of the OCAC include MSC-Ontario (as well as other EC representatives), Ontario provincial ministries, private industry, academia and consultants that are specifically involved in climate issues within Ontario. One of the six tasks of the Committee, as outlined in the Committee's Terms of Reference is to "identify, analyze and evaluate climatological needs of various users and make recommendations to appropriate agencies on suitable measures to meet these needs". Since the 1990s, the Committee has been listening to Ontario climate agencies' concerns over the direction that EC has been taking with respect to its climate network, data quality procedures as well as other climate related issues. Therefore, in accordance with the Committee's directive, the OCAC prepared a "climate issues" recommendations letter that was sent to the Regional Director General of MSC-Ontario in July 2005 (a copy of the letter is provided in Appendix C).

As a backgrounder to the climate issues detailed in the letter, the OCAC provides the MSC-Ontario Regional Director General (RDG) with information on the importance of climate data that is also relevant to other provinces and territories in Canada:

"*Climate information is a fundamental need for government and private sector resource management program areas at all levels. The determination of design standards for public safety and their application in project and infrastructure design are dependent on climate data. The data are used on a daily basis to make short and long term decisions. Recent source water protection initiatives in Ontario are a good example of this. Climate data are fundamental components of the hydrologic cycle and the overall water budget, which is being examined as part of the source water protection program. Climate change is another example of a program that requires high-quality long-term climate data for assessing climatic trends. A third key area is weather radar: the science around weather radar is evolving and requires a robust ground-based rain gauge network for ground truthing purposes. Weather data will also be critical to the success of research at the new National Labs being created by Environment Canada.*

Changes in federal program direction, technology, agencies collecting climate information and funding of the federal climate program have all had an impact on the overall Canadian, and specifically Ontario, climate program. A role of the Ontario Climate Advisory Committee is to make recommendations to Environment Canada, the lead agency for climate data collection in Ontario. The Climate Advisory Committee offers Environment Canada a unique opportunity to obtain input from practitioners and the user community. Not all regions of Canada have active Climate Advisory Committees. This emphasizes the unique opportunity for Ontario Region to be *a leader in this area.* ***The purpose of this letter is to offer suggestions to Environment Canada from the Ontario Climate Advisory Committee for consideration with respect to the climate program in Ontario.***"

Climate monitoring, network management and network density recommendations from the Committee included requests to:

- encourage MSC to maintain the existing climate network density
- if possible increase the number of stations in urban and more densely populated areas of southern Ontario.
- encourage MSC to conduct a network design to determine deficiencies in the existing network
- encourage MSC to seek climate station volunteers in datasparse areas to expand the volunteer network in these regions

In July 2006, the Regional Director of MSC Ontario region sent a response letter to the OCAC (see Appendix D for a copy of the letter, and the discussion in Chapter 8, "Repairing the Damage and Reversing the Trend").

3.8 Ontario Provincial Flood Forecasting Warning Committee

Based on the results of an Environment Canada, MSC-Ontario study on a number of extreme rainfall events in Ontario during 2000 (including Walkerton), the Ontario Provincial Flood Forecasting Warning Committee sent a letter (dated 2003) to Environment Canada with an overall conclusion as well as specific recommendations, including recommendations on Climate Networks (see Appendix E).

The Committee concluded that: "*Documentation of the severe events that occurred in 2000 could not have been undertaken without information from precipitation networks operated by Conservation Authorities, Ministry of Natural Resources, Municipalities and Environment Canada.*"

As noted in the report, the density of the existing Environment Canada network was insufficient to allow an accurate assessment of the events. It needed to be supplemented by the dense rain gauge networks of the partner agencies. This was especially important as the Environment Canada radar (and adjusted radar products) severely underestimated the rainfall during many of these extreme events.

On the issue of Climate Networks, the Committee recommended that: "*Environment Canada complete a network design to define the networks needed in Ontario, to describe climate normal statistics, IDF statistics and 1 to 30 day rainfall statistics*" and that once the network design was completed, Environment Canada should meet with Provincial Ministries, Conservation Ontario and the Ontario Federation of Municipalities to: "*explore how the recommended network can be implemented in a co-operative manner.*"

Environment Canada's network designs still do not take into account climatic design considerations, and as of this writing, the suggested meeting has not occurred.

3.9 Ontario Municipal Politician

> *"I am totally disgusted with the lack of climate information available to develop sound IDF curves that govern the building of bridges and roads (e.g., culverts) that has translated into the waste of millions of taxpayer dollars in infrastructure designs. We expect this expertise and monitoring capacity to be provided by Environment Canada. Does this mean that municipalities must now develop this expertise*

and monitoring ability locally or do we have to wait for the next major disaster that will cost lives in order to get action on this issue?"

3.10 Member of the Ontario Agricultural Community

"With the closure of climate stations, I can no longer count on reliable climate information for my region. This information is needed to help farmers understand their current conditions and forecast the potential to be able to conserve and efficiently utilize scarce water sources."

3.11 Non-EC Researchers

Several scientists were contacted for their opinions on the state of the Canadian climate network and climate science. They responded with the following:

- **Funding.** *"There are no longer any pools of money to which university researchers, in partnership with government scientists, can apply to get research funding with which to analyze the data ... that has [been] and will continue to be collected (and produced from climate models). These funds typically go to pay the salaries of students and postdocs".*

- **Predicting species distribution.** *"...we [have used climate] and related data [for] decades in order to predict species distributions... It becomes obvious from the above that climate data ARE THE FOUNDATION for our work, and for management & sustainability!! A traditional view for wildlife might be to just use habitat layers and altitude. But our and other people's work shows clearly, [for] over a decade, that the real power is actually in the climate layer. [It] trumps all (almost). Needless to say... we need better climate layers in time and space, with STATISTICAL ACCURACIES, STANDARDS & METADATA... [For] areas that are undersampled for wildlife (large wilderness, marine and Arctic regions, world-wide...) we rely on ... climate models to get ... wildlife distributions and abundances. Alaska is probably among the worst I [have seen] in the western world for climate measures (see WORLDCLIM website in Methods for global climate station distributions; Papua New Guinea is better than [Alaska]). [So] far Yukon is better but also not [as] good as it should [be]..."*

- **Studying survival and reproduction of predators.** *"I examined cougar survival and reproduction, using existing demographic data collected during 1981 - 1994, and habitat and seasonal weather data from this period... Correct local meteorological data is essential to understanding population and predator-prey dynamics of large terrestrial carnivores and herbivores. I used data from two weather stations in southern Alberta (Pekisko and Elbow). There were clear links between cougar survival and reproduction and seasonal weather. Without the climate data, we would not have been able to develop these informative demographic models. Also, I think our models would have been stronger if all weather data was available (data were missing for some years)."*

- **Studying population changes in ungulates.** *"Climate is an important factor when studying ungulate population dynamics. Studies first started back in the 1980s (red deer in Scotland) and have increased with climate change. [A number of] reputable journals [discuss] the importance of local seasonal weather and large-scale climatic indices on ungulate populations."*

, offers a number of insights on the Canadian climate network. He notes that many records in Canada are too short to allow reliable detection of cycling weather/climate

s.19(1)

functions. These are important in separating cyclic phenomena from weather trends. For example, in a recent treatment of weather and climate at the Experimental Lakes Area, (37 years of data) group found significant apparent trends in precipitation. In this case a site with a long-term period of record was found nearby at Kenora. Upon analysis of the 67 year Kenora dataset, a cyclic pattern in precipitation with a period of 31 years was discovered. After removing this cycle from the Experimental Lakes data, the previous long-term trend in precipitation disappeared. also notes that Canada has very few high elevation sites that record weather, climate or water flow. Even Banff and Jasper are in valley bottoms. In his opinion, the lack of high elevation sites will probably be revealed as a critical mistake down the road.

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4 Automation - A Decidedly Mixed Blessing

Reference has already been made in this document to autostations. It is worth looking in greater depth at these observing systems which have become a significant part of the climate observing network.

During Program Reviews 1 and 2 in the 1990s, budgets were slashed, and senior MSC management needed to get rid of bodies. However, the need for weather and climate observations did not disappear simply because the MSC budget was cut. Senior management was reluctant to eliminate such visible programs (and in fact would have been sanctioned by their political masters had they done so). There was therefore no other option but to accelerate existing plans and rapidly replace humans with automatic stations. There were a number of questions that such a changeover raised. "What capabilities can automation give us? Can automation really replace a trained human observer? Can automation allow MSC to continue as if things were back to normal? Can automation take up all or a portion of the slack, and if so, what part?"

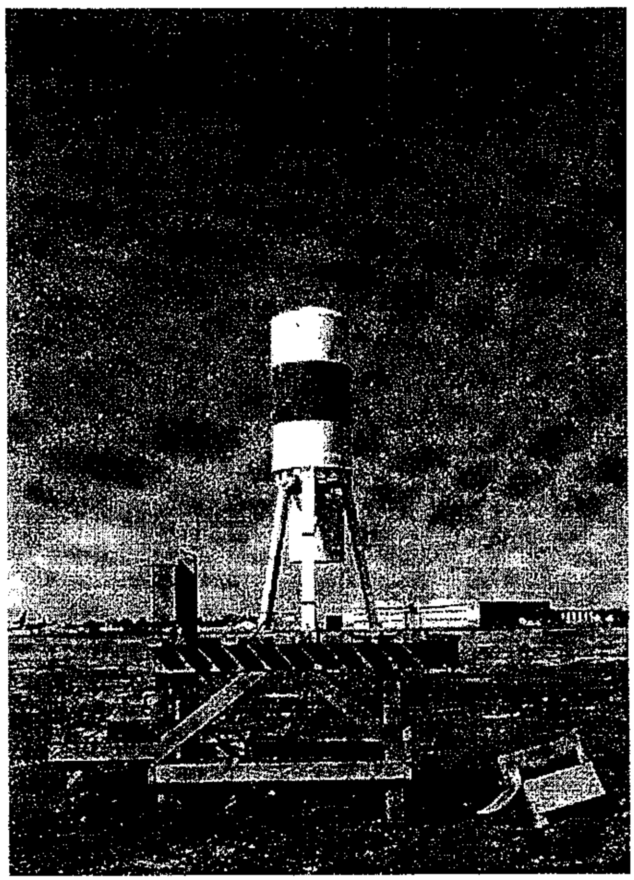

Figure 4.1 A cloud sensing laser ceilometer

Answering these questions would take time, and time was a luxury that could not be afforded. Autostations had to go in immediately and observers had to leave immediately. There was very little overlap, if any. As soon as the changeover occurred, it became clear that automatic weather stations had considerable problems, and that the testing phase had not been of sufficient length to allow corrective action to be taken. Some of the problems were partially addressed over the succeeding years, and some were not addressed at all.

Autostations also introduced an entirely new wrinkle into the task of Quality Assurance/ Quality Control (QA/QC). That wrinkle was the software upgrade. The process of improving the performance of an autostation (or the fixing of errors) results in new software being loaded into the sensors. When this is done, the affected sensors behave differently, even though the hardware remains the same. As a result, the climate that is recorded can be suddenly changed. Unless detailed records are kept and archived along with the data, these changes will hide within the normal day to day variation of weather and can pass unnoticed, even though they may have had a considerable effect on how the autostation senses its surroundings over the long term.

It must be said that autostations do have some advantages. They observe constantly without breaks, and function similarly day and night. There are certain elements such as temperature, humidity and pressure that they observe every bit as well as humans. Also in their favour is the fact that humans typically have other tasks in addition to weather observing, and may get distracted. And as in any area of endeavour, humans exhibit a spectrum of dedication, discipline and ability. It seems clear that the ideal observing site would have a human observer, supplemented by an automatic station. The two offer different capabilities and advantages and can compensate for each other's weaknesses. However, if a choice has to be made, there is no question that the human observer is the more capable of the two.

4.1 One Account of Autostation Performance

"Monday, July 23, 2007 in Edmonton was sunny and extremely hot, with noon-time temperatures approaching 30 degrees Celsius. The dewpoint was around 10 degrees Celsius and winds were light. Shortly after 1 pm, I noticed that EC's Weatheroffice website displayed the 'actual' weather based on the autostation observation at the City Centre Airport. Note the report of drizzle! Drizzle typically occurs with cool temperatures, thick low stratus cloud and with temperatures very close to the dewpoint, not at temperatures of 29 and dewpoints of 10 under virtually clear skies. The autostation precipitation sensor algorithms can be fooled by a number of phenomena. Whatever the case here, there was zero chance that this was actual drizzle.

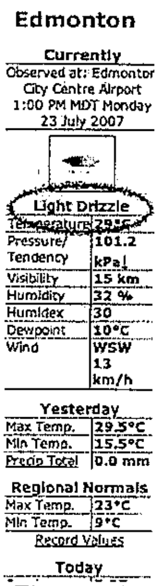

Figure 3.6 Weatheroffice website display for Edmonton

Aside from the obvious public credibility issues involved with reporting drizzle out of a sunny sky, the greater problem has to do with the fact that this error and others like it are saved into the long-term climate archive, forcing future generations to deal with them."

4.2 Human vs Autostation

It is worth taking a detailed look at the capabilities of automatic stations to see what they can do well, do partially and what they do poorly or not at all. Table 4.1 on the following page compares these capabilities with those of human observers. It must be noted that autostations can be configured quite differently depending on their purpose. Some stations, such as those located at airports, have a standard full suite of sensors. Others, perhaps part of a supplementary network, may only have a precipitation gauge along with wind, temperature and dewpoint sensors.

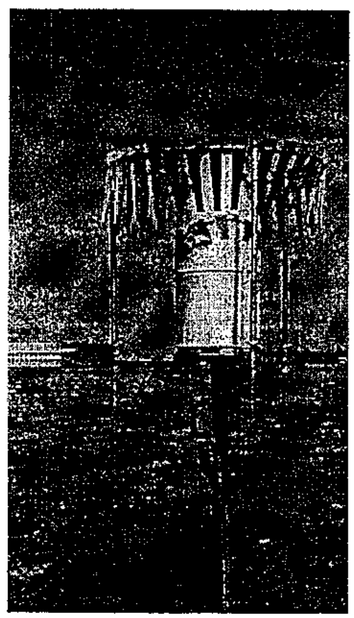

Figure 4.2 An autostation rain gauge.

The table contains typical weather elements observed by the most advanced autostations, and compares them with human observers at a standard airport station.

Weather Element	Observed by Autostation	Autostation Performance	Observed by Human	Human Performance
Temperature	Yes	Superior*	Yes	Excellent
Dewpoint	Yes	Superior*	Yes	Excellent
Wind Direction	Yes	Superior*	Yes	Excellent
Wind Speed	Yes	Superior*	Yes	Excellent
Pressure	Yes	Superior*	Yes	Excellent
Sky Condition (extent and heights of cloud layers)	Partial	Based on the amount of time one vertical pointing laser can bounce off clouds directly above the autostation. Only clouds below certain heights are sensed (typically within 10-15,000 feet above ground)	Yes	Humans can scan the entire sky and convert a mental snapshot of clouds at all layers into a numeric summation of extents. Estimated heights and extents of cloud layers may be inaccurate at times, although this can be overcome with additional sensors. **
Cloud type	Nil	Non-existent	Yes	Humans can determine cloud types across the entire sky. This can be critical in diagnosing processes occurring in the atmosphere, and assist in diagnosing the type of precipitation that is falling.
Precipitation type, intensity and character	Partial	Only certain types of precipitation can be sensed. Typically, these are rain, snow, drizzle and freezing precipitation. Intensity can be assessed to a limited degree when taken in connection with other sensors if they exist. Precipitation character (showery or continuous) can be inferred from duration	Yes	Humans observe the complete range of precipitation types, These include rain, freezing rain, drizzle, freezing drizzle, snow, snow pellets, ice pellets, ice crystals and hail. Humans can also assess precipitation intensity (very light, light, moderate, heavy) and character (showery or continuous).
Precipitation Amount	Poor	Precipitation sensors exist, but have been problematic. They are prone to phenomena such as wind pumping, snow capping, thermal effects, etc. which induce errors. These errors can be quite significant in some cases.	Yes	Humans observe amounts of all falling precipitation, and can take immediate steps to correct sensors that have become full or clogged. In cases where strong winds render amounts difficult to measure, humans can provide reasonable estimates.
Visibility	Partial	Autostations typically sense visibility by sensing the amount of light an obscuring phenomenon reflects in a small area (~1 cubic foot) directly at the sensor.	Yes	Humans assess visibility by determining which pre-designated objects (e.g. a tall building, a stand of trees, mountain peaks, a moderate intensity light, the shack at the end of a runway) are visible. Humans can also divide the area around the observing site into sectors and describe representative visibility in each sector.
Weather at and around the site	Nil	Non-existent		Humans can observe the following obstructions to vision: fog, mist, blowing snow, blowing sand, blowing dust, smoke, volcanic ash. They can also observe the following phenomena: thunder, lightning, dust devils, squalls, tornadoes, funnel clouds, duststorms, sandstorms. Finally humans can observe characteristics of the phenomena, such as if they are normal or heavy, drifting, shallow, patchy or in the vicinity.
Snow depth	Partial	Snow depth sensors can assess local snow depth around the autostation itself, but cannot take a representative sample around the observing site and average the number.	Yes	Humans can assess if an area to measure snowdepth in is representative; i.e. has it been scoured or heaped by wind, if the snow has melted since it fell, if it is in sun or shadow; and then measure in the appropriate spot.

Table 4.1 Comparison of Autostation vs Human Observing Capabilities

* High accuracy combined with minute by minute sampling makes these sensors more capable than human observers

** Darkness hinders visual assessment of cloud and visibility although night-vision goggles can compensate somewhat

5 The Requirement for Human Quality Control of Climate Data

The work of quality control staff is critical to the maintenance of a good climate observing program. (See Appendices F, G and H for more information.) Among other duties, climate section staff carry out the following:

- Call human observers when their observations are not received by a certain time, or when there are gaps in the reports
- Input data electronically when received in paper form
- Note discrepancies between reports from adjoining stations and call the observers or revise their reports in order to resolve the problem
- Remove spurious readings when appropriate (see Appendix G on QC and Autostations)
- Note systematic errors and notify technical services that a fix is necessary
- Provide quality controlled data to industry and the public
- Act as regional eyes and ears for a central climate branch
- Insert data into the national climate archive and into regional databases after quality control is complete
- Prepare IDF curves for various clients including the engineering community, as well as government agencies at all levels
- Act as liason with the network of volunteer observers
- Maintain metadata on the changes that occur at each observing site
- Maintain regional computer databases of climate data (see Appendix H)
- pursue data from other agencies.

One thing that may not always be appreciated is the need for immediate action. Problems can be averted quickly if climate staff are watching out for erroneous values and procedures. For example, an observer at a site may be following incorrect procedures when measuring snow depth or may be reporting temperatures which are inconsistent with the phase (liquid or solid) of the precipitation. An autostation may report wind directions from only one direction or from only one quadrant, indicating some type of mechanical difficulty. A quick phone call to the site or to a repair technician will salvage readings which might otherwise have gone uncorrected for a long period of time.

5.1 Regional Experiences

With over one thousand stations in EC's Prairie and Northern region (PNR) alone, climate staff went to considerable effort to make sure that data from each station made it into the archive. A typical month saw over 100 stations whose data was missing and had to be recovered and quality controlled. As a stopgap since its climate branch was disbanded in 2003, PNR assigned one position from its Technical Services section to continue working on some aspects of data input and QA/QC. The training and experience level of the individuals in this position varied significantly, as it was never the job of Technical Services to function as a defacto regional climate section. Given these limited resources, tracking down the 100 or so missing stations each month was physcially impossible. So what happened to all that data?

An excellent report from the Pacific and Yukon Region (PYR) Climatology branch goes into significant detail on the degradation of the PYR network and the effect of removing human intervention. It also outlines policy changes such as the reduction in volunteer climate stations and talks about altered observing and quality control practices and an increasing reliance on automation. (See Appendix I for an edited version of the report).

An incident which was not included in the report came to the attention of PYR staff recently. A climate scientist interested in precipitation data contacted PYR and asked about suspicious summer rainfall records at Osoyoos in the Okanagan Valley of BC. One of the summer months he was looking at apparently showed precipitation occurring every single day; this in an area known for its dry, oven-like summer climate. Fortunately, PYR climate staff knew that the precipitation gauge was within range of a lawn sprinkler, and were able to enlighten him. They also removed the erroneous sprinkler-induced precipitation prior to insertion into the national archive.

5.2 Automated Quality Control

As of April 1, 2008, MSC Transition Program funding for human quality control of climate data ceased. **This means that MSC no longer carries out human quality control of Canadian climate data.** Senior management has decided that QC will be done by programs run on computers. Unfortunately, at the present time MSC's Data Management Framework project which encompasses automated QA/QC is still under development and not able to do the job for which it was envisioned. Doubly unfortunate is that the DMF and automated QC projects have been used to deflect criticism about elimination of human QC for a number of years.

At present, automated QC programs can only carry out a small number of easy duties. They can check for things like temperatures that are significantly too high or too low (bounds checking). They can send automated messages regarding suspicious values to the observer of the data, assuming the observer is a human. They can flag data going into the archive that they think is dubious. However, they cannot assess whether precipitation at Osoyoos is due to a passing shower or a lawn sprinkler. They cannot determine whether the increasing snow depth being reported by an autostation in spring is really due to growing grass. They cannot phone sites whose data has ceased to arrive, enquire as to the cause of the problem and make arrangements for alternate means of obtaining the information. They cannot coach a remote climate observer in proper observing techniques or compensate when the previous day's maximum temperature is erroneously recorded in the place on the form where the the current day's maximum should go.

5.3 The need for QC - A Case Study

The following chart shows MSC's climate summaries for the month of February, 2008 for an autostation (identifier WON) near Dawson, Yukon.

Daily Data Report for February 2008

Notes on Data Quality.

DAWSON
YUKON TERRITORY

Latitude: 64° 3.000' N Longitude: 139° 7.800' W Elevation: 370.00 m
Climate ID: 2100LRP WMO ID: 71966 TC ID: WON

Previous Month | February | 2008 | Go | Next Month

Daily Data Report for February 2008

Day	Max Temp °C	Min Temp °C	Mean Temp °C	Heat Deg Days °C	Cool Deg Days °C	Total Rain mm	Total Snow cm	Total Precip mm	Snow on Grnd cm	Dir of Max Gust 10's Deg	Spd of Max Gust km/h
01†	-34.0	-46.6	-40.3	58.3	0.0	M	M	0.4			<31
02†	-35.0	-43.7	-39.4	57.4	0.0	M	M	1.5			<31
03†	-31.0	-40.8	-35.9	53.9	0.0	M	M	0.5			<31
04†	-38.7	-46.5	-42.6	60.6	0.0	M	M	1.2			<31
05†	-41.3	-49.6	-45.5	63.5	0.0	M	M	1.2			<31
06†	-42.1	-50.2	-46.2	64.2	0.0	M	M	1.0			<31
07†	-43.0	-50.8	-46.9	64.9	0.0	M	M	0.8			<31
08†	-40.6	-51.3	-46.0	64.0	0.0	M	M	2.1			<31
09†	-42.0	-49.5	-45.8	63.8	0.0	M	M	1.9			<31
10†	-32.1	-48.8	-40.5	58.5	0.0	M	M	0.0			<31
11†	-19.6	-32.2	-25.9	43.9	0.0	M	M	0.6			<31
12†	-13.5	-19.8	-16.7	34.7	0.0	M	M	0.8			<31
13†	-9.3	-14.1	-11.7	29.7	0.0	M	M	14.2			<31
14†	-5.5	-17.1	-11.3	29.3	0.0	M	M	7.5			<31
15†	-5.4	-22.7	-14.1	32.1	0.0	M	M	6.6			<31
16†	-5.4	-26.7	-16.1	34.1	0.0	M	M	14.0			<31
17†	-6.1	-24.3	-15.2	33.2	0.0	M	M	8.6			<31
18†	-6.7	-17.1	-11.9	[illegible]	[illegible]	[illegible]	M	12.7			<31
19†	4.5	-19.9	-7.3	[illegible]	[illegible]	M	M	13.2			<31
20†	-5.0	-5.2	[illegible]	[illegible]	[illegible]	M	[illegible]	3.7		M	[illegible]
21†	2.4	-10.3	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	0.0			<31
22†	-5.7	-19.3	-12.[illegible]	[illegible]	[illegible]	M	[illegible]	0.5			<31
23†	-12.9	-26.7	-19.0	[illegible]	[illegible]	M	M	0.0			<31
24†	-15.5	-28.2	-21.9	[illegible]	[illegible]	[illegible]	M	0.0			<31
25†	-11.4	-23.6	-17.5	35.5	0.0	M	M	0.0			<31
26†	-13.9	-22.2	-18.1	36.1	0.0	M	M	0.0			<31
27†	-11.7	-27.4	-19.6	37.6	0.0	M	M	0.6			<31
28†	-15.5	-33.9	-24.7	42.7	0.0	M	M	0.0			<31
29†	-15.3	-35.6	-25.5	43.5	0.0	M	M	0.0			<31
Sum				1245.2	0.0	M	M	93.6			
Avg	-18.7	-31.2	-24.92								
Xtrm	-5.3	-51.3								[illegible]	[illegible]

93.6

Table 5.1 Climate summary for Dawson Autostation WON for February, 2008.

According to a Government of Yukon employee, the early part of the month of February was clear and cold. Much of this time the autostation was reporting precipitation (in this case, snow). Anecdotal accounts from people living in the area indicated nowhere near the total amount of snow the autostation reported for February (93.6 mm of snowfall water equivalent, approximately seven and a half times the normal value). Further checking with data from a snow survey showed that the Dawson area had only 60 percent of the normal snow cover. Additionally, the employee checked records from the nearby manned site at Dawson airport (Dawson A). These indicated only 4.0 cm of snowfall for February with a water equivalent of 2.2 mm (dry snow due to the cold conditions).

It is possible that these extreme autostation values have been incorporated into an Environment Canada map of precipitation anomalies for the winter of 07/08 (see Figure 5.1 below). The map indicates precipitation 30 percent above normal over Dawson. This runs counter to a March 1, 2008 Government of Yukon Snow Survey Bulletin which gave Dawson and area precipitation totals as follows: half of normal values for December, near normal values for January and 60 percent of normal values for February.

PRECIPITATION DEPARTURES FROM NORMAL
Winter (Dec, Jan, Feb) 2007/2008
ANOMALIES DES PRECIPITATIONS PAR RAPPORT A LA NORMALE
Hiver (dec, jan, fev) 2007/2008

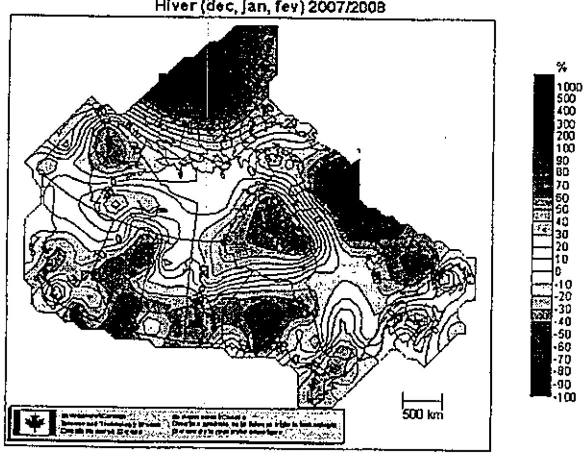

Figure 5.1 EC Precipitation Anomaly map for December 2007, January 2008 and February 2008.

If human quality control was being done and bad values removed, such sensor performance might be tolerable. However, given these anomalies, and knowing that human QC will not occur, it would appear to be high time to re-examine precipitation sensor performance in the field under a variety of meteorological conditions and institute the required improvements.

Dawson A Precipitation Summary - February 2008				
Date	DAILY RAIN-FALL (mm)	DAILY SNOW-FALL (cm)	DAILY WATER EQUIVA-LENT (mm)	TOTAL DAILY PRECIPITA-TION
1		0	0	0
2				
3		0.8	0.2	0.2
4				
5				
6				
7				
8				
9		0	0	0
10		0.6	0.4	0.4
11		0	0	0
12		0.4	0.2	0.2
13		0	0	0
14				
15		1.2	0.8	0.8
16				
17				
18				
19				
20				
21				
22				
23				
24		1	0.6	0.6
25		0	0	0
26		0	0	0
27				
28				
29				
Total	0	4	2.2	2.2

Table 5.2 Precipitation totals for February 2008 from Dawson airport (human observations).

6 The Upper Air and Supplementary Observing Networks

While it may not get much attention, the upper air radiosonde balloon program is another important element of a climate observing program. Due to the fact that most of the readings are above the surface mixing layer and relatively unaffected by immediate human activities, they provide an excellent means of checking for long-term trends. The number of sites is extremely sparse however (approximately 30 for the entire country), and is in significant need of expansion, especially in the prairies and the high Arctic.

Due to the expense in training and running upper air sites, MSC has frequently considered cuts to this vital program over the course of various program reviews, and as mentioned before, terminated Mould Bay in the high Arctic during the 1990s. Another cost-cutting measure saw the replacement of most MSC upper air observers by contractors. An unfortunate side effect of this move was a sudden jump in missed radiosonde "flights". An anecdote serves to illustrate the type of problem encountered with some contractors.

"When the first contract was issued ..., I was still working down at the airport weather office. We were asked by regional HQ to drop in unannounced during flights to see how the contractor was doing. On my first visit, (the first week the contract had started), the contractor was filling up the balloon. I noticed he was putting too much gas in it. His answer was: 'when I do that, the balloon explodes just above 100 millibars (mb) and I can go home faster'. This contractor had been on the job for less than one week and already he was cutting corners." "Now flights only have to reach 400 mb (around 24,000 feet above sea level). Why did MSC lower the minimum height requirements from their previous requirement of 100 mb (around 50,000 feet above sea level) ?"*

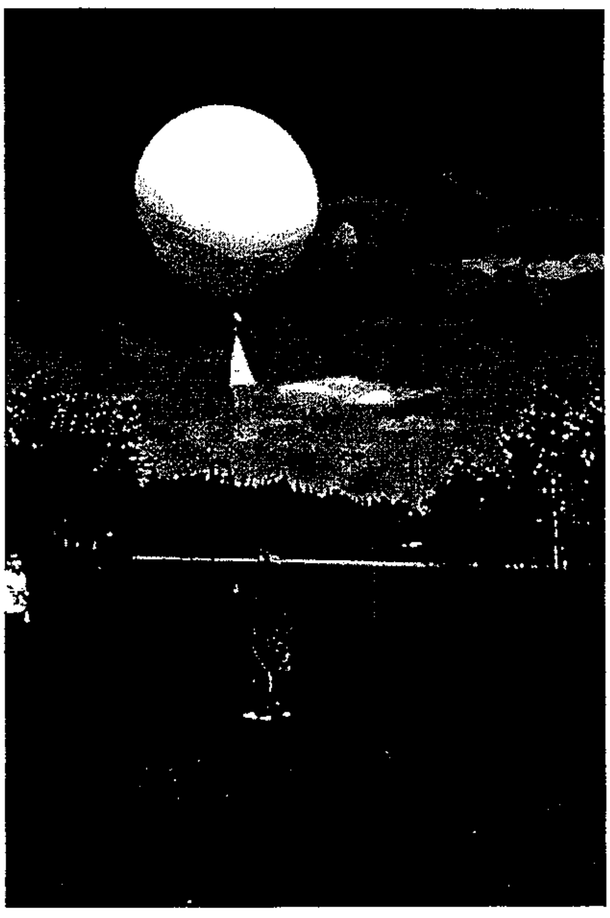

Figure 6.1 A radiosonde balloon release from Elk Island National Park, Alberta

Further evidence of a drop in the number of properly done soundings can be found in Appendix J.

In addition to the upper air network, MSC used to run a supplementary climate network in which numerous stations observed additional climate variables such as hours of bright sunshine, solar radiation, soil temperature and evaporation. With the removal of MSC observers in the 1990s, the supplementary network was decommissioned and the number of stations carrying out these types of measurements plummeted.

* The requirement used to be 200mb in the Arctic

7 The Volunteer Network

Canada has benefited over the years from the selfless work of thousands of unpaid volunteers who trudge out of doors twice a day to record temperatures, and in some cases precipitation amounts. Their faithfulness to these tasks is truly inspiring. Aside from service certificates and tokens of appreciation mailed to them from MSC, these volunteers have received very little for their trouble, other than knowing that they have contributed immensely to a treasure trove of data for others to use.

One of the biggest benefits provided by volunteer climate sites is continuity in what they observe, where they observe and the instruments they use. MSC sites have historically been located at airports and as airports have expanded, the observing sites have had to move. Changes in instrumentation have also occurred. Since airports are in cities or near cities, temperature trends have been affected by urban heat islands to varying extents. In contrast, many volunteer climate stations have stayed in the same family for years, in some cases for over 100 years. Their rain gauges and Stevenson screens (a shaded, louvered housing for thermometers) have stayed at the same spot since the station was created. Because of this consistency, data from volunteer observers can be better than data from official MSC sites for long term trending analysis.

Some of these observers (including some in remote areas) have received a letter from the regional office they have dealt with for years. This letter informs them that **unless they can move from sending in paper forms to submitting their data via telephone (ONTAP) or the Internet (COOLTAP), their observations will no longer be processed.** Not all observers have received or will receive this letter. It appears that paper forms from a few sites will continue to be accepted at MSC headquarters. These will be placed in storage and not processed unless resources are found to carry out the work of transferring the records to electronic form for insertion into the national archive.

The difficulty with the electronic methods MSC is insisting on is that the two options of data input (phone and Internet) require significantly more time and aggravation from the volunteers than the previous method of filling out a paper form and mailing it in. If the observers are comfortable with electronic input, this is not a factor. Some may even prefer it. However for many remote and rural stations the only connection to the Internet is via dial-up. For such sites, electronic submission can become an onerous chore, and may be the difference between stopping and continuing their observing program. Telephone data input faces even more challenges on the convenience front, especially if more than one day's worth of data needs to be submitted.

Preliminary results from those who have received the "letter" and responded, indicate that roughly 40 percent have agreed to electronic data submission. Approximately 25 percent have refused, and the remainder have indicated they could give it a try. Regional staff have little confidence that the latter group will continue with their observing programs.

Even in a best case scenario, it would appear that a significant portion of the volunteer network stations will shut down, and Canada will lose data that can never be replaced. Even if a new volunteer climate observer is found at a location in the same region after closure of an existing site, the continuity of the old station's long-term record will have been lost.

(See Appendix C for an acknowledgement of the importance of climate volunteer networks by the Ontario Climate Advisory Committee.)

8 Repairing the Damage and Reversing the Trend

Environment Canada carries out a climate program via the Meteorological Service of Canada. It was given this mandate because it has a national perspective. Governments need to do the things that are in the national interest, but that no one else can or will do. However, it is clear that MSC no longer has the ability to be all things to all people. Over a decade of sustained funding cuts has seen to that.

The May 2006 letter from the MSC-Ontario RDG to the Ontario Climate Advisory Committee (Appendix D) was written in response to Committee concerns over climate network and other climate related issues (Appendix C). It implicitly acknowledges that while worthwhile efforts are taking place in some areas of Environment Canada's climate program, MSC is simply unable to provide the level of service the province, Conservation Ontario and other Committee members are seeking, let alone re-establish the services that once existed. The language used in the reply to the Committee's letter indicates that MSC is open to discussing, recognizing, reviewing and assessing climate network concerns in Ontario. However, there is very little in the way of actual commitment to bring the existing network up to standards, let alone expand the network with trained observers. Emphasis is placed on the Data Management Framework (DMF) as a project to meet some of the concerns, but whether the DMF will ever be completed, let alone become what it was promised to be remains an open question. Automated QA/QC is far behind schedule, and even if it eventually works, will not prevent bad data from contaminating the climate archive (see Section 5.2).

In addition, the response letter from MSC frequently points to the existence of programs to assess climate and to communicate its effects to industry and the climate community, but makes no mention of the precarious state those programs are in, or how poorly they are funded. Programs with minimal resources devoted to them are continually battered by financial pressures, in some cases partway through the fiscal year. If MSC is truly client driven, then it must not only tell clients what is, but what is not. If the emperor has no clothes, users of climate data and climate products have a right to know that.

The response letter from EC was followed in 2006 and 2007 by invitations to EC's Weather and Environmental Monitoring and National Data Analysis and Archives sections to attend meetings of the Ontario Climate Advisory and Ontario Provincial Flood Forecasting Warning Committee for further discussions on the network issues. At these meetings, EC noted that the economic pressures that it is facing have, in some cases, dictated the decisions taken with respect to the networks and that it is sometimes easier to find funding for new projects than it is to obtain resources for ongoing maintenance of networks.

8.1 A New Management Mindset

We believe that senior management in EC and MSC needs to come to terms with three realities:

1) the present situation with respect to the climate network and climate data infrastructure cannot be allowed to continue. We contend that MSC is unable to fulfill its goal of ensuring the safety and security of Canadians. This is not a situation where this goal is simply threatened; in our opinion it is a situation where here and now, MSC is not able to carry out its mandated responsibilities.

2) The strategy of continued cuts to less visible portions of the EC/MSC infrastructure while maintaining the **appearance** of continuing service has permitted politicians to escape repercussions from Canadians. A more forthright termination of highly visible programs would have generated significantly

more demands for accountability and a discussion of the tradeoffs involved. This has become an issue of speaking truth to power **and** to the Canadian public.

3) If MSC wishes to be involved in a vigorous and useful national climate program, it will need to reach out to external agencies and partners for assistance. A national collaborative effort can reverse the degradation. Keeping the problem in-house, as has been done for the past 10-15 years, will only exacerbate it. We propose an approach to help resolve these problems. This approach will take a significant amount of work and political will but it can be done.

8.2 A Proposal for Recovery

1) Assess the current state of affairs in an atmosphere of openness.

- Hold a conference to which all users of Canadian climate data are invited (this includes members of the international community)
- Solicit input from attendees, potential partner agencies and the public about the state of the climate program
- Encourage the voices of MSC employees and former employees who care deeply about maintaining this precious Canadian heritage
- Bring in auditors from an independent agency such as the WMO to evaluate the current situation
- Publish the assessment on the EC website.

2) Design the climate network we wish to see.

- Complete a Climate Network Design Plan in cooperation with our partners. This recognizes that by working with partner agencies who can contribute valued climate data of their own, we can build a stronger integrated network that meets the needs of a diverse community
- In cooperation with users, partner agencies, and the WMO, establish achievable, concrete steps with timelines and deliverables for the building of a new **National Climate Network** and its associated infrastructure, including human quality control of climate data
- Publish the Plan on the EC website as well as those of our partners.

3) Build a climate infrastructure together with our partners.

- Establish a governing body external to government for the creation and maintenance of the National Climate Network and associated infrastructure. EC would be one partner among many in this national organization.
- Align current climate network funding commitments within MSC with the fiscal plan of the National Climate Network governing body. Align non-monetary resources with National Climate Network aims and objectives.
- Work to obtain signed agreements establishing multi-year funding from partner agencies. Obtain funding up front in order to protect the recovery program from political meddling and year to year or month to month financial pressures.
- Hold meetings every year to report to partners and all interested parties, and publish the actual progress on the various partners' websites as well as that of the National Climate Network.

(One possible structure for a new climate network is explored in Appendix K)

We look forward to working with EC and MSC management to bring this new and positive approach to fruition.

Appendices

Some of the following appendices have been edited for spelling and grammar. In some cases, they have been edited to remove references to individuals.

Appendix A

Excerpt from WMO Guide to Climatological Practices (Draft Third Edition)

1.5 National Climate Activities

In most countries, National Meteorological and Hydrological Services (NMHSs) have long held key responsibilities for national climate activities, including the making, quality control and storage of climate observations; the provision of climatological services; research on climate; and the applications of climate knowledge. Recent years have seen an increasing contribution to these activities from academia and private enterprise.

Some countries have within their NMHS a single division responsible for all climatological activities. In other countries the NMHS may find it beneficial to assign responsibilities for different climatological activities (such as observing, data management and research) to different units within the Service. This could be on the basis of commonality of skills, such as across synoptic analysis and climate observation or across research in objective (numerical) weather and climate prediction. Some countries establish area or branch offices to handle subnational activities, while in other cases the necessary pooling and retention of skills for some activities are achieved only through an office serving the needs of a group of countries.

Where there is a division of responsibility within a NMHS, it is essential that a close liaison exist between those applying the climatological data in research or services, and those responsible for the acquisition and management of the observations. This is of paramount importance in determining the adequacy of the networks and of the content and quality control of the observations. It is also essential that the staff receive training appropriate to their duties, so that the climatological aspects are handled as effectively as would be the case in an integrated climate centre or division. If data are handled in several places, it is important to establish a single coordinating authority to ensure there is no divergence among data sets.

Climatologists within an NMHS should be directly responsible for, or provide consultation and advice regarding:

- planning of networks of stations
- location or relocation of climatological stations
- care and security of the observing sites
- regular inspection of stations
- selection and training of observers
- instruments or observing systems to be installed so as to ensure that representative and homogeneous records are obtained (see Chapter 2).

Once data are observed, they must be managed. NMHS functions for managing the information from observing sites include data and metadata acquisition, quality control, storage, archiving, and access (see Chapter 3). Dissemination of the collected climatic information is another requirement of an NMHS. The NMHS must be able to anticipate, investigate and understand the needs of government departments, commerce, industry and the general public for climatological information; promote and market the use of the information; make available its expertise to interpret the data; and advise on the use of the data (see Chapter 6).

The NMHS should maintain a continuing research programme directly related to its climatological functions and operations. The research programme should consider new climate applications and products that increase user understanding and application of climate information. Studies should explore new and more efficient methods of managing an ever increasing volume of data, improving user access to the archived data, and migrating data to digital form. Quality assurance programmes for observations and summaries should be routinely evaluated with a goal of developing better and more timely techniques. The use of information dissemination platforms such as the Internet should also be developed.

The meeting of national and international responsibilities, and the building of NMHS capacity relevant to climate activities, can only be achieved with the availability of adequately trained staff. Thus, the NMHS should maintain and develop links with training and research establishments dealing with climatology and its applications. In particular, it should ensure that their staff attend training programmes that supplement general meteorological training with education and skills specific to climatology. The WMO Education and Training department fosters and supports international collaboration that includes the development of a range of mechanisms for continued training, such as fellowships, conferences, familiarisation visits, computer assisted learning, training courses and technology transfer to developing countries.

A successful national climate services programme must have a structure that works within a particular country to be successful. The structure must be one that allows the linkage of available applications, scientific research, technological capabilities and communications into a unified system. The essential components of a national climate services programme are:

- mechanisms to ensure the climate information and prediction needs of all users are recognized;
- collection of meteorological and environmental observations, management of data bases, and the provision of services;
- coordination of meteorological, oceanographic, hydrological and related scientific research to improve climate services;
- multidisciplinary studies to determine national risk, sectoral and community vulnerability related to climate variability and change, and to formulate appropriate response strategies and recommend national policies;
- development and provision of information and prediction services to meet user needs;
- linkages to other programmes with similar or related objectives.

It is important to realize that a national climate services programme is an ongoing process that may change in structure through time. An integral part of this process is the continual incorporation of user requirements and feedback in an effort to develop useful products and services. Gathering requirements specifications is vital in the process of programme development. Users may contribute in the evaluation of products, which invariably leads to refinements and the development of improved products. Measuring the benefits of the application of products is a difficult task, but interaction with users through workshops, training and other outreach activities can aid in this process. The justification for existence of a national climate services programme, or requests for international financial support for aspects of the programme, can be greatly strengthened by documented user requirements and positive feedback. The documented approval of the programme, by at least part of the user community, is very useful in helping to guide future operations and to assist in the advertising of the service as a successful entity.

Appendix B

Verification of Weather Forecasts and Warnings: Climate Stations in the BC Interior

An important aspect of providing accurate weather forecasts and warnings is post-event research to determine what in fact did happen. Problems need to be noted and improvements made by revising procedures and understanding. This is a continuous, iterative process. Needless to say, climate stations are a vital part of such study and improvement. While filled with technical terms and obscure station identifiers, this account by a PYR representative gives some insight into the climate station infrastructure required for appropriate verification of forecasts and warnings in one of the most meteorologically challenging areas of Canada, BC's mountainous interior.

B.1 Climate Stations for the Forecast Regions of the BC Interior

[Names in bold are BC Interior forecast regions. These are followed by a list of climate stations used to verify forecasts for those regions, as well as some comments. Principal climate stations, typically airport sites, have an "A" suffix. All station identifiers are three or four capitalized letters (e.g. WSL, CHKK). A map of these regions is on page B-2. Ed.]

Shuswap: Salmon Arm A [is] quite important because WSL doesn't report [precipitation] in the winter. There is however, a highway station just to the west. It would also be nice to have a station in Sicamous because it can sometimes snow [heavily] there and not in Salmon Arm.

North Okanagan: [We use] at least one station in the Vernon area: Vernon North, Vernon Swan Lake, Lumby or Vernon Bella Vista. The autostation WJV doesn't report [precipitation] in the winter. CHKK is just south of Vernon.

Central Okanagan: [We use] Kelowna UA or Kelowna Quails Gate, and Peachland. Kelowna airport (YLW) doesn't report snow on ground (SOG) and snow density, and there is no nearby highway station. Peachland and Westbank are important because a local effect can occur in this area where they receive [significantly] more snow than in Kelowna. [We] consider Winfield fairly important as well.

South Okanagan: [We use] Oliver or Oliver STP and Osoyoos West. WYY doesn't report [precipitation] in the winter and there is no highway station south of Penticton.

Similkameen: We will occasionally use Hedley N or Jellicoe to verify a warning.

Nicola: Merrit STP is very important as there are no precipitation observations in winter. CFME reports rain in the warm season if available.

Fraser Canyon: Lytton 2 is fairly important because WLY doesn't report snow density and SOG. Most people live in Lilloeet yet WKF only reports rainfall in the warm season.

South Thompson: Kamloops Pratt Road will give the snowfall amount over higher terrain in the winter. Lots of people live in Logan Lake which is much higher than YKA, yet there is no [observation].

West Columbia: Revelstoke Columbia Park is very important because town often receives a lot more [precipitation] than at YRV, and the auto station doesn't report snow density/SOG.

Yoho Kootenay Parks: Yoho NP Emerald Lake closed a while ago. This was the only station that reported [precipitation] in the winter. WYL only reports rainfall in the warm season.

North Thompson: [We use] Mclure, Vavenby or Darfield. There are no hourly manned [observations] in this region.

Boundary: [We use] Billings, Grand Forks and Midway. Grand Forks is closing this month and will be missed. There are no hourly [precipitation] obs in this region.

Arrow Slocan Lakes: [We use] Fauquier and New Denver. WNP doesn't report [precipitation] in the winter. It would be best to have a good [observation] in Nakusp.

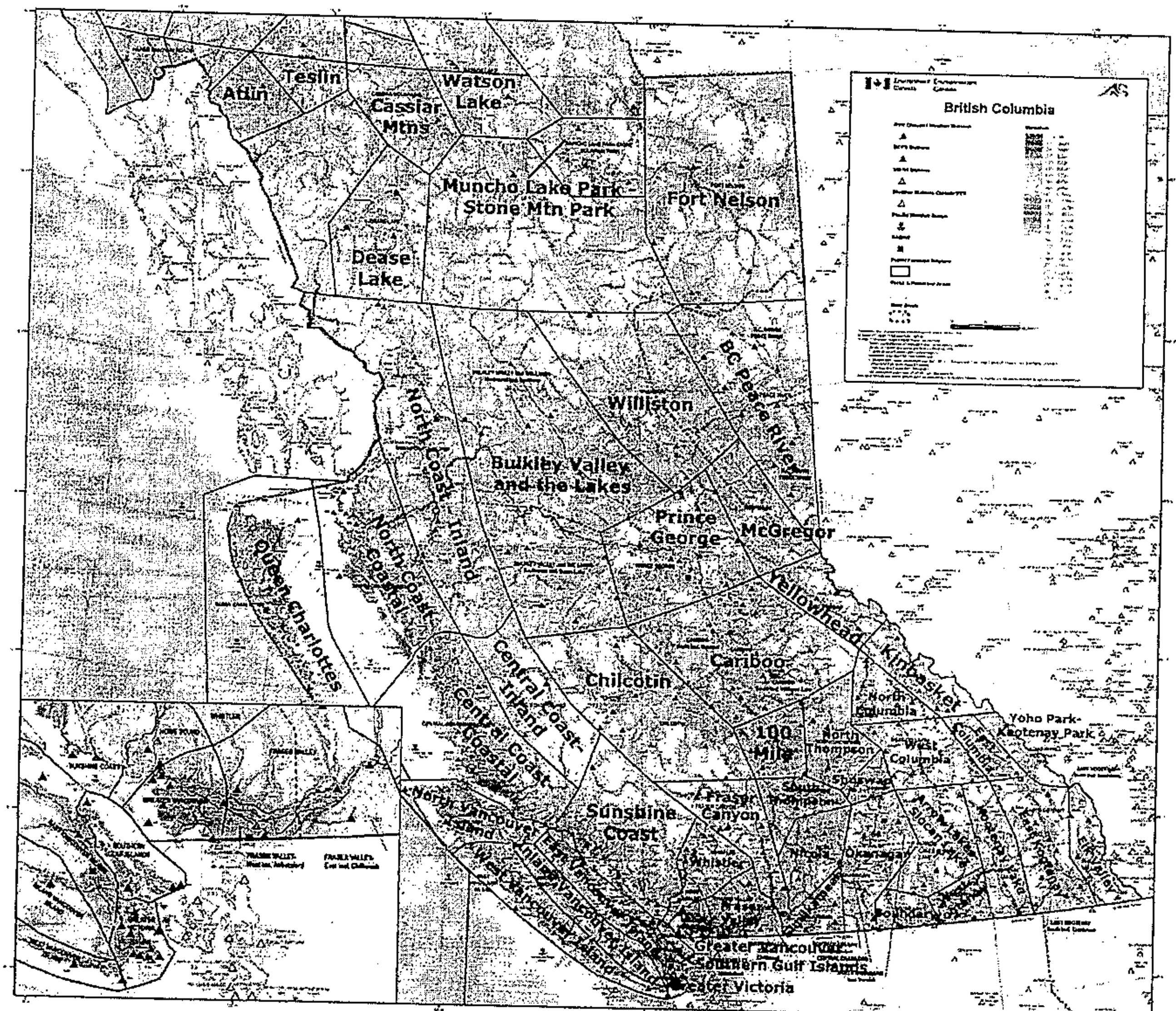

Figure 1. Map of Forecast Regions for British Columbia

West Kootenay: [We use] Nelson NE or Nelson Rixen Creek. Lots of people live in Rossland (500 m higher than YCG) yet there is no [observation] .

Kootenay Lake: [We use] Creston and Kaslo. WJR doesn't report [precipitation] in the winter. CHCF is a good station for the Crawford/Kootenay Bay area.

East Kootenay-South: Kimberley PCC is nice to have. Wasa isn't as important.

East Kootenay-North: Kootenay NP West Gate is somewhat important. There are a couple [of] highway stations in this region.

Elk Valley: Fernie is very important as the weather here is very different that in Sparwood. CHMR just to the south of Fernie usually receives a little less [precipitation] than Fernie.

100 Mile: 100 Mile House 6NE and maybe 108 Mile House Abel Lake are very important. WCL is not representative of 100 mile House. Many times subsidence extends past WCL but not to 100 Mile House. It would be nice to have an hourly [observation] here with an anemometer. They receive a lot more wind than at WCL. The other climate stations are not as important.

Chilcotin: Lunch Lake is important and indicates the spillover that can occur near the Coast Mountains. Kleena Kleene also receives heavy snow in very strong flows but they closed not long ago.

Cariboo: Climate stations are somewhat important here. There are highway [observations] and YWL. YQZ doesn't report snow density and SOG.

Prince George: [We use] Vanderhoof.

Yellowhead: McBride Elder Creek is closing soon. [We'll] really miss this one because there are no [observations] nearby in the winter. Valemount and Tete Jaune closed a while ago which [we] considered important observations. This region has poor coverage.

Bulkley Valley: [We use] Houston and Fraser Lake North Shore.

BC North Peace River: [There is] already a good [observation] at YXJ.

BC South Peace River: Dawson Creek auto (YDQ) doesn't report precipitation at all. It would be nice to have a climate observation here.

B.2 Summary

"*... [we] really depend on climate and highway observations. There are many hourly [observations] that are useless during the winter months. [We] find it's becoming more difficult to verify warning events with the closure of climate stations. Many of our autostations don't report precipitation in the winter, so without a climate report we'll never know if an event occurred. A climate report is a lot more dependable than a report from the public ... [we] also wish every autostation reported precipitation/SOG and that they reported every 10 minutes so [we'd] know right away that a significant wind gust or torrential rain [had] occurred. It would also be nice to increase the number of stations because there are many significantly sized towns without one. For example, WCL (Clinton) should not be used for 100 Mile House because the weather is often very different. Most people live in 100 Mile House and not Clinton yet the national verification uses WCL for the region.*"

Appendix C

Letter to Environment Canada from OCAC (Ontario Climate Advisory Committee)

Mr. Jim Abraham,
Acting Regional Director General,
Environment Canada, Ontario Region,
4905 Dufferin Street,
Downsview, Ontario,
M3H 5T4

July 21, 2005

Dear Mr. Abraham,

Climate Issues in Ontario

Background

Climate information is a fundamental need for government and private sector resource management program areas at all levels. The determination of design standards for public safety and their application in project and infrastructure design are dependent on climate data. The data are used on a daily basis to make short and long term decisions. Recent source water protection initiatives in Ontario are a good example of this. Climate data are fundamental components of the hydrologic cycle and the overall water budget, which is being examined as part of the source water protection program. Climate change is another example of a program that requires high-quality long-term climate data for assessing climatic trends. A third key area is weather radar: the science around weather radar is evolving and requires a robust ground-based rain gauge network for ground truthing purposes. Weather data will also be critical to the success of research at the new National Labs being created by Environment Canada.

Changes in federal program direction, technology, agencies collecting climate information and funding of the federal climate program have all had an impact on the overall Canadian, and specifically Ontario, climate program. A role of the Ontario Climate Advisory Committee is to make recommendations to Environment Canada, the lead agency for climate data collection in Ontario. The Climate Advisory Committee offers Environment Canada a unique opportunity to obtain input from practitioners and the user community. Not all regions of Canada have active Climate Advisory Committees. This emphasizes the unique opportunity for Ontario Region to be a leader in this area. **The purpose of this letter is to offer suggestions to Environment Canada from the Ontario Climate Advisory Committee for consideration with respect to the climate program in Ontario.**

The Ontario Climate Advisory Committee (OCAC) offers the following suggestions.

Climate Monitoring and Network Management

Historically, the climate network in Ontario could be characterized into two primary components: a network operated by Environment Canada staff and a volunteer observing network administered by Environment Canada. In recent years, the volunteer network has been diminishing due to attrition and there has been some additional downsizing of this network by Environment Canada for other reasons. Both of these factors have combined to reduce the overall network density.

Suggestion: This has resulted in a need for leadership by Environment Canada to take stock of where climate data are collected, to what standard and to identify gaps in the existing network.

Initiatives such as ICONO (described below) contribute to these goals.

Inventory of Climate Observing Networks in Ontario (ICONO)

The reduced density of observing sites supported by Environment Canada has been one factor that has resulted in more agencies such as the Ministry of Natural Resources, Conservation Authorities, Universities, Municipalities and private industry independently collecting climate data in Ontario. In order to manage change and facilitate network planning, the Climate Advisory Committee launched the Inventory of Climate Observing Networks in Ontario (ICONO) in 1999. This initiative was intended to provide an inventory of climate network information to avoid duplication and facilitate network planning. ICONO remains an important initiative valued by the user community. However to be useful the current ICONO database needs to be updated and expanded as required and continually maintained in a state to remain current and useful.

The current initiative to create a Web-Based system to facilitate user updates is fundamental and its support and funding by Environment Canada, MSC-Ontario Region, is appreciated by the OCAC. This inventory is fundamental to network planning, emergency response and event documentation and research.

Suggestion: The OCAC recommends that Environment Canada continue development of the web-based user interface to maintain the ICONO database and broadly communicate this initiative to the user community.

Network Density

While more agencies are collecting climate data, there remains a need to collect climate data to an Environment Canada standard to support scientific research and design standards. The OCAC recommends that EC complete a needs review and update its network. Recent attrition of volunteer observing stations has reduced the number of sites where climate normals are available due to the number of climate stations closed during the 1990s. Therefore, this issue will further manifest itself in the next climate normals update in 2010 and in detection of climate change/climate trends research.

Network density is also important with respect to validating radar data and improving rainfall-radar based products (i.e. QPE).

Suggestion: When reviewing the network density across Ontario, a risk based approach should be considered. Given the high population density and extensive infrastructure base in southern Ontario, as well as the climatological influence of the Great Lakes, it is expected that a higher network density may be required in southern Ontario than in northern Ontario. This approach should be monitored to determine if network densities need adjustment in northern regions, as climate change continues to manifest itself.

Suggestion: Where feasible, Environment Canada is also encouraged to proactively seek climate station volunteers in data sparse areas to expand the volunteer network in these regions.

Access to Information

The recent delivery of Climate Data Online and the continued publication of the Canadian Daily Climate Data CD by Environment Canada are very much appreciated by the user community. Access to information is very important. It is important that open access to information continues and is expanded as new information and products become available.

Suggestion: Environment Canada is encouraged to facilitate development of a framework to store and make available climate data from other agencies collecting climate information. The development of standards to classify information collected by different agencies, along with a process to include this information into an overall climate archive, are fundamental components to realizing this goal. The ICONO initiative is a key component to realizing this goal.

Modern computer modeling requires a range of climate parameters beyond traditional daily climate information such as precipitation and air temperature. Often this information is not available on-line.

Suggestion: Environment Canada is encouraged to:

1. expand the range of data available through Climate Data Online to include other data such as hourly precipitation and radiation/sunshine parameters, which have already been processed and are available in the Environment Canada National Climate Data and Information Archive
2. ensure that climate data such as hourly precipitation and radiation/sunshine parameters are processed in a timely fashion (i.e. decoded, QCd) for uploading to the Environment Canada National Climate Data and Information Archive, and Climate Data Online
3. investigate development of long-term continuous data sets at selected sites that could be used to support input requirements of modern-day modeling and research applications and be able to track climate change trends.

Climate Standards and Training

Climate standards and training remain an important component of the climate program in Ontario. Expertise in climate standards and training in the broader public arena will change over time. Environment Canada is recognized as providing vital ex pertise in these areas and needs to continue in the future. Training provided by Environment Canada staff to various user groups is very much appreciated. Support for standards development and training of climate observers are fundamental to the program.

Suggestion: Environment Canada is encouraged to continue to provide expertise in these areas. The OCAC wishes to organize more training sessions in the future, and hopes that Environment Canada will continue to support these requests for members of their staff to participate.

Event Documentation

Severe storm documentation is fundamental to assessing how our climate is changing, and how associated risks are changing. Severe event documentation supports design standards with respect to municipal infrastructure, public safety, flood management and the design of critical infrastructure including major dams, dykes, municipal water control infrastructure, electrical and communications systems. Documentation and evaluation of severe events and the subsequent use of this information to plan for future severe events are critical in the review of design standards, emergency preparedness and response planning with a fundamental goal of ensuring public safety. Environment Canada's documentation of the extreme rainfall events that occurred in southern and central Ontario in 2000, in Northwestern Ontario in 2002 and in southern and eastern Ontario in 2004, as well as Ice Storm '98, is greatly appreciated. It is hoped that knowledge gained from severe events will be incorporated into forecast models to improve severe event forecasts.

Suggestion: Environment Canada is encouraged to develop a process or protocol that can be used to assemble and efficiently document severe events. It is recognized that EC cannot and should not do this alone, but alternatively seek partnerships with other organizations to accomplish this goal.

Suggestion: An overall framework is needed and a custodian is required to maintain this information. OCAC recommends that EC develop a process or framework to accomplish this goal.

Development and Maintenance of Design Standards

Design standards such as rainfall Intensity-Duration-Frequency (IDF) Curves, or snow load designs are used on a daily basis to design infrastructure. There is concern that the full range of information needed to support these standards is not being updated and that the expertise needed to develop and maintain these standards is critically weak.

An additional concern with respect to design standards is how climate change may impact these standards. Infrastructure once designed must stand the test of time. If climate change is expected to radically change IDF curves, for example, this needs to be quantified and communicated to designers who rely on this information.

Suggestion: The OCAC recommends that EC review the data needs related to different design standards and develop a process to maintain critical design standards such as IDF curves on a current basis. EC is also encouraged to quantify and communicate the impacts of climate change in the design-life of critical infrastructure.

Climate Trends

Research into the impacts of climate phenomena such as El Niño need to be further studied along with trends and cycles in droughts and major floods. Funding through the Climate Change Adaptation Fund/ Climate Change Impacts and Adaptation Program to investigate synoptic typing of factors affecting climate is an important step in achieving this goal.

Suggestion: Environment Canada is encouraged to pursue further research into long-term climate trends and the factors influencing these trends.

Weather Radar

Weather radar holds great promise for the advancement of climate and weather science. Weather radar is still evolving and requires good quality climate data at a sufficient density to advance weather radar technology. The new National Nowcasting and Remote Sensing lab being established in Toronto offers an exciting new opportunity to advance this science in the area of real-time forecasting.

Suggestion: Environment Canada is encouraged to:

1. continue to advance weather radar technology and review the climate network required to support advancement of this technology
2. investigate partnering with other agencies collecting climate data to assist in support of weather radar research.

We respectively ask that you consider this advice. If you wish, either myself or other members of the OCAC would be happy to meet with you to discuss the comments and issues raised in this letter.

Yours truly,

Dr. David Yap
Chair of the Ontario Climate Advisory Committee

Appendix D

Response to OCAC from MSC-Ontario

May 15, 2006

Dr. David Yap
Chair of the Ontario Climate Advisory Committee
Ontario Ministry of the Environment
125 Resources Road
Toronto, Ontario
M9P 3V6

Dear Dr. Yap,

RE: Climate Issues in Ontario (letter received July, 2005)

I would like to thank you for your letter of July 21, 2005 on "Climate Issues in Ontario", in which the Ontario Climate Advisory Committee has provided a detailed assessment of climate observing networks, access to climate information, documentation of severe weather events, climate and radar research and other climate-related issues in Ontario.

The letter also provided 15 constructive suggestions or recommendations to Environment Canada on strengthening the observing, archiving and application of climate data. These suggestions have been reviewed within Environment Canada and detailed responses have been prepared which identify key areas where progress is underway or planned, as well as areas where challenges are still being faced (see attached).

My apologies for the delayed response and we look forward to continued cooperation with the OCAC on these issues.

Yours truly,

Pradeep Kharé
Regional Director General-Ontario

Climate Monitoring and Network Management

Suggestion 1 (page 2) : This [attrition and downsizing of the climate network] has resulted in a need for leadership by Environment Canada to take stock of where climate data are collected, to what standard and to identify gaps in the existing network.

The Environment Canada Reference Climate Stations, surface weather and volunteer climate networks are all georeferenced and observe and collect data according to World Meteorological Organizations protocols. The ability to accommodate external agency data collected to different observational standards is integral to the Department's new Data Management Framework (which is discussed under Suggestion 5).

Environment Canada has conducted a number of reviews of national climate networks to identify significant gaps (i.e. the 1992 Reference Climate Station network analysis) or to rationalize the network in a systematic fashion in response to budgetary pressures. The Department conducted a climate network analysis five years ago, to assess Canada's climate network in light of the standards for the Global Climate Observing System (GCOS) Surface Network. This assessment concluded that there were large geographic gaps in the Canadian North, which led to substantial investment in the installation of new Reference Climate Stations under the Action Plan 2000 program.

Environment Canada currently has a review of the national surface weather and climate networks underway. The Department's goal is to conduct a comprehensive, science-based review including consideration of user requirements. This review will risk assess our partnerships, and draw on spatial and statistical analyses to assess the gaps in the current surface networks as compared to the identified requirements.

Inventory of Climate Observing Networks in Ontario (ICONO)

Suggestion 2 (page 2): The OCAC recommends that Environment Canada continue development of the web-based user interface to maintain the ICONO database and broadly communicate this initiative to the user community.

Environment Canada has been supportive of ICONO since its launch by the OCAC in 1999, acting as custodian of the database and maintaining and managing the database since its inception. In 2004, OCAC members recommended that a web-based ICONO user interface be developed to ensure continued and timely maintenance of the ICONO database. In 2005, Environment Canada funded the development of a prototype of the web-based ICONO interface and automatic updating of the database within OMNR's LIO warehouse. Environment Canada will be reviewing its programs and projects in the new government organizational structure and will need to determine how the ICONO initiative will be supported. The Committee will be updated on the status of ICONO as details become available within Environment Canada.

Network Density

Suggestion 3 (page 2) : When reviewing the network density across Ontario, a risk based approach should be considered. Given the high population density and extensive infrastructure base in southern Ontario, as well as the climatological influence of the Great Lakes, it is expected that a higher network density may be required in southern Ontario than in northern Ontario. This approach should be monitored to determine if network densities need adjustment in northern regions, as climate change continues to manifest itself.

The spatial density of the present climate network is greater in southern than northern Ontario, taking into account the higher population base and specific climatological influences of southern Ontario. It is expected that this trend will continue into the future, especially as volunteer climate observers are generally easier to recruit in higher population density areas. However, on a per population basis, the network in southern Ontario is not as dense as it is in northern Ontario, and Environment Canada recognizes that ongoing and future network reviews will need to better assess population and infrastructure vulnerability and the influence of climate change in Ontario as well as the rest of Canada.

Suggestion 4 (page 3): Where feasible, Environment Canada is also encouraged to proactively seek climate station volunteers in data sparse areas to expand the volunteer network in these regions.

When an Ontario volunteer climate observer ends his/her observing services and the climate station is closed, Environment Canada's Ontario Climate Center and Air Monitoring Operations Division evaluate whether a replacement volunteer for this site should be found or if a site in the immediate area can be opened as a replacement. The decision is based primarily on the criteria of whether the station has had a long term period of record, if the station closure will result in an areal data sparsity and if the station was located in an area that has not been severely impacted by urbanization. (Long term climate stations in non-urbanized areas are valued for climate change/trend research and design standards calculations. Population is not presently considered to be a selection criterion.) Once identified as a location in which a climate station is needed, Environment Canada advises its station inspectors of the importance of having a site in this area, and makes attempts to "recruit" volunteer observers (i.e. advertising for volunteers in the local media). Such attempts have been successful in the past in reopening some sites.

There are limits to the number of new stations that, under current policy, can be added to the Ontario climate network, as the network is presently close to the specified station limit. However, the Meteorological Service of Canada is presently attempting to fill some climate station sparse areas and since fall 2005, ten new volunteer stations have been added to the network in southern and central Ontario. An additional four proposed stations are also being assessed: two in southern Ontario and two in northern Ontario.
Environment Canada is also willing to collaborate with partner agencies to discuss how it would be able to assist in helping establish climate stations in areas where it is collectively agreed that there is a need for these stations.

Access to Information

Suggestion 5: Environment Canada is encouraged to facilitate development of a framework to store and make available climate data from other agencies collecting climate information. The development of standards to classify information collected by different agencies, along with a process to include this information into an overall climate archive, are fundamental components to realizing this goal. The ICONO initiative is a key component to realizing this goal.

As described under Suggestion 7 below, Environment Canada is currently developing the Data Management Framework (DMF) which will include real-time and archive MSC operational data and metadata, and supplemental agency data where data sharing agreements are made. Co-operative sharing and archiving of climate data in Ontario is part of the DMF "vision". This project was initiated in 2004, with an expected implementation date of 2008, followed by continuous development and improvement of the system. Environment Canada will also continue to work with other partner organizations on the OCAC to ensure that, as part of the ICONO initiative, data standards are developed that meet the needs of all agencies.

Suggestion 6 (page 3): Environment Canada is encouraged to expand the range of data available through Climate Data Online to include other data such as hourly precipitation and radiation/sunshine parameters, which have already been processed and are available in the Environment Canada National Climate Data and Information Archive

Although there is presently no specific implementation date, Environment Canada is planning to expand Climate Data Online to include supplemental climate data such as hourly precipitation and radiation/ sunshine.

Suggestion 7 (page 3): Environment Canada is encouraged to ensure that climate data such as hourly precipitation and radiation/sunshine parameters are processed in a timely fashion (i.e. decoded, QCd) for uploading to the Environment Canada National Climate Data and Information Archive, and Climate Data Online

Quality control of climate data, including data received from data loggers, is completed by staff within the Ontario Climate Centre, before the data is sent for upload to the Environment Canada Digital Climate Archive. Staffing resources have been a limiting factor for the timely QCing of selected climate data, such as hourly rainfall. As of May 2006, quality control of Ontario hourly rainfall data has only been completed through 2003. The computer verification system for solar radiation data has become obsolete in recent years and the data is therefore not being ingested into the Archive.
Environment Canada is presently developing a Data Management Framework (DMF) which will include automation and near real time QCing of all climate data, including hourly rainfall and solar radiation. The DMF, or data infrastructure system, will automatically quality-control, store and provide near real-time and archive access to various raw and decoded data streams, including the MSC climate and solar radiation network data. This project was initiated in 2004, with an expected implementation date of 2008, followed by continuous development and improvement of the system.

Suggestion 8 (page 3): Environment Canada is encouraged to investigate development of long-term continuous data sets at selected sites that could be used to support input requirements of modern-day modeling and research application and be able to track climate change trends.

In 1992, Environment Canada established the Canadian Reference Climate network to address attrition and unevenness of the surface climate network. The intention was to secure and operate a suite of reliable, high quality, long-term climate stations for climate trend analysis and detection. The RCS network now consists of 302 stations. A total of 44 sites are protected within Ontario and 25 of these have already been modernized to RCS standards. Most of the remaining Ontario sites will be modernized to RCS within the next few years.

Initially the requirement was for stations to have a minimum of 30 years of quality data to be included in the network. Recently some stations with "RCS potential" have been added because although they have somewhat less than 30 years data, they are well sited and have excellent prospects to remain a reference station for many years to come. Environment Canada's goal is to sustain this set of stations and maintain them following life cycle management principles.

Climate Standards and Training

Suggestion 9 (page 4): Environment Canada is encouraged to continue to provide expertise in these areas [training of climate observers and standards development]. The OCAC wishes to organize more training sessions in the future, and hopes that Environment Canada will continue to support these requests for members of their staff to participate.

Environment Canada has standards for the installation and maintenance of several observing instruments and configurations including the Reference Climate Stations and the radar network, as well as a general installation guide for automatic weather stations. Environment Canada is in the process of instituting a continuous improvement program for its monitoring networks. This program will involve rounding out our existing installation and maintenance protocols and instituting continuous learning practices to drive ongoing program improvements.

Under the Meteorological Service of Canada's Focusing for the Future framework, air monitoring divisions across the country have limited resources available to train our own climate observers and no explicit funding to train observers in partner organizations. However, Environment Canada does have substantial expertise in this area and all Canadians benefit when high standards for climate observations are maintained by all organizations. Maintenance schedules for Environment Canada monitoring staff are quite demanding and are established months in advance. However, limited training of climate observers is still possible, especially if requests are received well in advance.

Event Documentation

Suggestion 10 (page 4): Environment Canada is encouraged to develop a process or protocol that can be used to assemble and efficiently document severe events. It is recognized that EC cannot and should not do this alone, but alternatively seek partnerships with other organizations to accomplish this goal.

Environment Canada also recognizes that there is a need for different types of studies to document different aspects of severe events. The Ontario Storm Prediction Centre maintains a severe weather event database for Ontario, and documents select events in forecast verification studies (i.e. Ice Storm '98, the recent August 2005 Toronto storm, tornado events). The science divisions of MSC-Ontario have in the past undertaken post-storm climatological/meteorological studies of severe events, with studies in recent years of Ice Storm '98, extreme rainfall events during the years 2000 and 2004, and a meteorological/hydrological study of the northwestern Ontario June 2002 storm. The radar research group of Environment Canada will also undertake case studies of extreme weather, with a focus on evaluating the performance of weather radar during the event. Partner agencies also carry out studies of extreme weather events, which will likely have a different focus again from Environment Canada's studies. Environment Canada agrees that a severe event documentation protocol needs to be established, and is willing to discuss with the OCAC and partner organizations how this can be achieved.

Suggestion 11 (page 4): An overall framework is needed and a custodian is required to maintain this information [severe event documentation]. OCAC recommends that EC develop a process or framework to accomplish this goal.

The importance of severe event documentation is recognized, as well as the need to co-ordinate with other agencies on this documentation. Environment Canada would welcome further discussions with the OCAC on the type of process that could be implemented to achieve this goal, and the role that it could play in ensuring that this is accomplished.

Development and Maintenance of Design Standards

Suggestion 12 (page 4/5): The OCAC recommends that EC review the data needs related to different design standards and develop a process to maintain critical design standards such as IDF curves on a current basis. EC is also encouraged to quantify and communicate the impacts of climate change in the design life-life of critical infrastructure.

Environment Canada recognizes the importance of design standards and that the National Building Code requires updating of its climatic parameters. However, in the last ten years Environment Canada has not been funded to develop new infrastructure standards on a national basis. Wind pressures and IDF curves have been updated for regional stations during this period only when external client funding has been made available. Within Ontario, provincial funding was provided to have IDFs updated through 2003. The Canadian Electrical Association Technologies (CEA) Inc. is currently funding Environment Canada-National Archives and Data Management to develop updated ice and wind loading maps for the CSA standard C22.3#1-01 for electrical transmission lines which should be published in 2006. However, the CEA work only addresses ice and wind loads, and there are 12 or more additional climate elements that require updating on a national basis, including IDF curves. A Memorandum to Cabinet is presently being drafted to seek funding to address these update issues.

One of the problems encountered in updating IDF curves is that Environment Canada has not been recently processing rate-of-rainfall data from TBRG charts. Funding has been made available to address this first hurdle in IDF updates. It is expected that a considerable amount of the data will be processed, QCd and available for analysis as IDF updates by the end of this fiscal year. Planning of the IDF updates will then follow. Additional IDF curves could be analysed if there is further data management work to acquire observational data from other agencies with climate networks.

The Adaptation and Impacts Research division and regional science units of MSC (including MSC-Ontario) play a key role in communicating the impacts of climate variability and change on infrastructure. This is accomplished through research study publications, presentations, and collaborative work with, for example, municipalities, provincial governments, Public Safety and Emergency Preparedness Canada, the Canadian Council of Professional Engineers, Canadian Standards Association and the Insurance Industry of Canada, as well as Conservation Authorities and Emergency Management Ontario within Ontario.

Climate Trends

Suggestion 13 (page 5): Environment Canada is encouraged to pursue further research into long-term climate trends and the factors influencing these trends.

Environment Canada is actively engaged in climate research, including the assessment of long-term climate trends and the factors influencing these trends. The Adaptation and Impacts Research Group, Climate Research Branch and regional science divisions of MSC (including MSC-Ontario) collectively conduct research to assess the current state of the climate, its variability and extreme events and understand the factors influencing these trends (i.e. ENSO, climate change), the impacts of a changing climate on Canada as well as the adaptation and mitigation options that will be required to respond to changes in climate. In the past several years, Climate Research Branch has produced homogeneous temperature, precipitation and wind datasets suitable for detailed time series and trend analyses. These datasets have been used in recent research on trends in important climatic indicators for temperature and precipitation at long-term stations across Canada. Environment Canada also recognizes the importance of communicating these results to the Canadian public and decision-makers. The "Atmospheric Hazards in Ontario" website developed by Environment Canada, in partnership with emergency Management Ontario, includes mapped and written information on trends in 20 of these climatic indicators for Ontario. Canadians continue to be informed of the historical perspective of current climate conditions through electronic publishing of the "Climate Trends and Variation Bulletin", and specifically, within Ontario, the electronic "Monthly Weather Review" produced by the Ontario Climate Centre.

Weather Radar

Suggestion 14: Environment Canada is encouraged to continue to advance weather radar technology and review the climate network required to support the advancement of this technology.

Environment Canada's weather radar programs continue to advance radar technology within Canada. The National Radar Project Radar completed the installation of 30 Dopplerized radars across Canada in 2004. Radar research continues to improve the reliability of Quantitative Precipitation Estimates from radar and characterize radar errors. Specifically, ongoing research initiatives within Environment Canada's Meteorological Research Division and Ontario's Nowcasting and Remote Sensing Meteorology Lab include:

- Improved quality control to remove artifacts (non-precipitation targets)
- Improved techniques for converting electromagnetic measurements aloft into surface precipitation
- Methods of automatically assessing data quality and passing this assessment information to users

Environment Canada's Canadian Precipitation Analysis Project focuses on developing a national precipitation analysis using Numerical Weather Prediction (NWP), rain gauge data and radar. The Project to date has focused on Quebec where the Environment Canada climate network is supplemented by a large number of gauges from cooperating agencies. The CaPA research team recommends that the Meteorological Service of Canada build on efforts to link with partner agencies and ensure co-operative sharing of climate data for research and documentation of severe weather events. Data exchange will have two-way benefits. Environment Canada acquires additional gauge data while supplying agencies get "value added" from the Quality Assessment that Environment Canada can provide.

Environment Canada recognizes the need for climate network reviews to consider the needs of the radar research program, and will strive to ensure that this is considered in ongoing and future reviews of the climate network.

Suggestion 15: Environment Canada is encouraged to investigate partnering with other agencies collecting climate data to assist in support of weather radar research.

Environment Canada recognizes the importance of having as dense a network as possible of quality surface rain gauge data to use in:

- assessing new radar techniques
- verifying calibration of new and existing Quantitative Precipitation Estimate technologies and
- developing new techniques for real time Quantitative Assessment and dynamic calibration assessment

It further recognizes that partner organizations' climate data networks are a valued supplement to the Environment Canada climate network. As noted above, Environment Canada's Meteorological Research Branch and National Labs are actively continuing research on weather radar, and in year 2000 and 2005 case studies within Ontario, the research has supplemented Environment Canada rain gauge data with a dense network of partner agencies' rain data. Recommendation from MSC-Ontario's recent studies of heavy rainfall events in southern and eastern Ontario during the years 2000 and 2004 include the importance of having a co-operative climate network where data and information is freely shared amongst agencies to document severe events and for weather radar research purposes. Environment Canada is presently partnering with the Toronto and Region Conservation Authority (TRCA), sharing information, radar and rain gauge data, in support of a radar research case study and other collaborative studies of the Toronto August 19, 2005 extreme rainfall event. The TRCA supplemented the 5 Environment Canada gauge data in the immediate Toronto area with data from an additional 90+ gauges collected by the Authority from a number of networks. As noted in Suggestion #8 above, Environment Canada in partnership with other agencies (Provincial, Federal, Municipal and Academia) is working to modernize the RCS network in Ontario. This modernization includes instrumentation which can be used to support weather radar research.

Appendix E

Letter to Environment Canada from the Ontario Provincial Flood Forecasting and Warning Committee (PFFWC)

Ministry of
Natural Resources

Natural Resource Management Division
Lands and Waters Branch
P.O. Box 7000, 300 Water Street
Peterborough, ON K9J 8M5
Telephone: (705) 755-1278
Fax: (705) 755-1267

Ministère des
Richesses naturelles

Division de la gestion des richesses naturelles
Direction des terres et eaux
C.P. 7000, 300, rue Water
Peterborough (Ontario) K9J 8M5
Téléphone : (705) 755-1278
Télécopie : (705) 755-1267

September 8, 2003

Roger Street
Regional Director
Environment Canada
4905 Dufferin Street
Downsview, ON
M3H 5T4

<u>Re: Ontario Heavy Rainfall Study for Spring and Summer, 2000</u>

Dear Mr. Street

On behalf of the Provincial Flood Forecasting and Warning Committee (PFFWC) I am writing to you to compliment M.S.C – Ontario Region, Environment Canada for their excellent work in the producing the Ontario Heavy Rainfall Study for Spring and Summer, 2000 report. Excellent work has been done by authors Joan Klaassen, Paul Ford, Guilong Li and Qian Li and other MSC staff in bringing together the data and information and performing the analysis necessary for this study.

The Provincial Flood Forecasting and Warning Committee recognize and appreciate the significant in-kind contribution by MSC to this study. The Committee also acknowledges Conservation Ontario and the Ontario Ministry of Natural Resources for initiating and funding the study.

The study is a testament to the principles of partnerships in which agencies work together towards a common goal. The success of studies such as these is largely due to a wealth of data and information collected and shared amongst our agencies, and the cooperative working arrangement that has been fostered over several years. The PFFWC recognizes this study as a success story demonstrating that our agencies must continue to cooperate and work together to achieve common goals in public safety.

Severe Weather Forecasting and Flood Forecasting are strongly linked. Both require timely, accurate knowledge of expected weather systems, a means of tracking weather systems, and a willingness to put resources into scientific investigation required to improve upon our capabilities. After reviewing this study the PFFWC has prepared a number of recommendations, extracted from the study (attached), which will further our common goals of public safety. The committee requests that you give these recommendations careful consideration as many of these recommendations are towards the MSC – Ontario Region. We propose that these recommendations be the subject of discussion at a future PFFWC meeting with the view towards establishing recommendation priorities, and fostering further cooperative working arrangements.

Yours truly,

Rob Messervey,
Manager Water Resources Section
Chair, PFFWC

<u>Ontario Heavy Rainfall Study for Spring and Summer 2000</u>

Provincial Flood Forecasting and Warning Committee Recommendations

<u>Conclusions</u>

Documentation of the severe events that occurred in 2000 could not have been undertaken without information from precipitation networks operated by Conservation Authorities, Ministry of Natural Resources, Municipalities and Environment Canada.

<u>Recommendations</u>

Integration of Severe Weather Forecasting with Provincial Flood Forecasting

1. Recommend MSC Ontario Region assign a representative from the Meteorological Science Group to sit as a member on the Provincial Flood Forecasting and Warning Committee. Representation from MSC is intended to foster integration of severe weather forecasting mandates with that of flood forecasting.

Severe Event Forecasting

2. Recommend MSC conduct a review of their severe event forecasts criteria to more fully recognize the mechanisms of flooding. Specific criteria for issuing rainfall warnings should consider antecedent precipitation and ground conditions entering into a rainfall event. These conditions should be considered when deciding whether to issue a warning.

3. Recommend method of real-time feed back of precipitation as it occurs should be supplied to the weather forecaster so forecasts can be refined as events develop.

Severe Event Reporting and Documentation

4. Recommend severe event reporting be recognized as beneficial to the public good and appropriate long-term resourcing for this type of work be included in the Meteorological Services of Canada Ontario Region base budget or an alternate means of delivering this service through competent professionals to a consistent standard be developed.

5. It is recommended that a committee be struck with representatives from the Province (MNR), the Federal Government (MSC), Association of Municipalities of Ontario and Conservation Ontario to develop a severe event reporting and documentation process.

Climate Monitoring Network

6. Recommend Environment Canada complete a network design to define the networks needed in Ontario, to describe climate normal statistics, IDF statistics and 1 to 30 day rainfall statistics. Special attention needs to be paid to the dynamic nature of climate in southern Ontario resulting from the effects of the Great Lakes. The increasing public risk also needs to be considered given the increasing population densities.

7. Recommend that after completion of a Network design that Environment Canada meet with representatives from Ministry of Natural Resources, Ministry of the Environment, Ontario Ministry of Agriculture and Food, Association of Municipalities of Ontario and Conservation Ontario to explore how the recommended network could be implemented in a co-operative manner.

Research

8. Recommend design storm distributions be reviewed. Specifically design storm distributions should be reviewed in the light of the need to reflect antecedent conditions. Consideration should be given to developing seasonal design storm distributions to reflect the seasonal differences between storms events. This recommendation would be best accomplished through EC or through a research project at a University specializing in climatology. This is pertinent to climate change, funding sources are available with respect to climate change, and these sources should be pursued.

9. Recommend Environment Canada develop a process to maintain and update Intensity Duration Frequency Curves across Ontario. This information is fundamental to managing risk associated with severe events. Implications with respect to climate change need to be considered when updating this information.

10. Recommend climate zones in Ontario be reviewed from the context of defining areas where there is a higher potential for severe storm events. This would best be accomplished through EC or through a research project at a University specializing in climatology. Historical radar, climate data and severe event history should be used to define these areas, For example the lake breeze zone in south western Ontario, what areas of southern Ontario have a higher potential for lake breeze events is an example.

11. It is recommended that Environment Canada and the Province seek potential private – public sector partnership with the insurance industry to fund research with respect to risk management related to severe events.

Radar

12. Encourage Environment Canada to continue research into improving the reliability of radar information to estimate the extent and amount of precipitation over areas where radar stations exist. Research should focus both on improving the real time reliability of radar and the post event application of radar to document historical events.

This committee looks forward to meeting/working with Environment Canada Ontario Region to implement recommendations and reduce public risk.

Appendix F

Letter to Marc-Denis Everell (Asst. Deputy Minister of EC at the time) from PNR climate staff, 2001

Integrity of the Canadian Climate Data Network

Mr. Everell,

We are writing to you today to express our concern regarding the integrity of the Canadian Climate network. This network in Canada is really an ensemble of sub networks. We have data coming from:

- MSC automatic weather stations
- Automatic weather stations from partners (DND, provinces, municipalities, etc.)
- Manned Observations from NavCanada Flight Service Station (FSS) sites
- Contractors
- MSC staffed weather stations
- 1800 Volunteer Climate Observers.

Historically, the MSC staffed offices were the backbone of the climate network providing high quality climate data. However, all but a few were eliminated during the cuts of Program Review 1 and 2. Many important programs such as snow cover, sunshine and evaporation were decimated to [their] current level of non-existence.

This void was to be filled by contractors and automation. Contractors have proven to be extremely [unpredictable] when it comes to [providing quality] climate data. Some contracts are excellent while others are totally unreliable. Automatic weather stations have done an excellent job of providing climate data in terms of temperature, wind and pressure. Unfortunately, the same cannot be said when it comes to precipitation. The [weighing] gauge, the main precipitation gauge on autostations, is subject to many problems such as wind pumping. On windy days, the wind shakes the gauge so much that it actually records precipitation. Lethbridge Airport is equipped with an AWOS automatic weather station and is located in a very windy part of the country. Drought conditions prevailed throughout the summer [of 2001] yet the [autostation] reported a total of 16.5 mm of rain [that] August... The quality assurance process found that no rain fell in Lethbridge in August. See Table 1.

Weighing gauges cannot measure snowfall. They can only measure melted snow and are very unreliable. Figure 1 compares the monthly total precipitation at Edmonton City Centre Airport between manned and weighing gauges and shows very well the great unreliability of the weighing gauge. Canadians are noticing the erroneous values produced by the automatic stations. [The] appendix shows a recent email that was sent to our office regarding the precipitation data produced by auto stations.

In light of the poor quality precipitation from the automatic stations, the data from the volunteer climate observers becomes our most trustworthy precipitation network in Canada. Without this network, it would become practically impossible to get an accurate picture of snow cover and snowfall. We appeal to you to maintain the Volunteer climate network. The only cost to MSC is the maintenance and the archiving of the data as the collection is done by volunteers. Proposals currently circulating suggest eliminating the network due to the cumbersome problems of paper archiving. We already have in place processes that allow the volunteer to submit their data electronically via the Internet.

In these days of climate change, widespread drought in many regions of Canada, we cannot afford to lose such important data. We hope you will consider these issues when decisions will be made regarding the Canadian Climate Data networks. Thank You.

Iqaluit			Lethbridge			Saskatoon		
October 2000			August 2001			April 2000		
Day	AWOS	Post QC	Day	AWOS	Post QC	Day	AWOS	Post QC
1	0.0	0.0	1	0.5	0.0	1	18.5	8.9
2	0.0	0.0	2	0.5	0.0	2	4.0	2.0
3	0.5	0.0	3	1.0	0.0	3	0.5	0.0
4	0.0	0.0	4	0.5	0.0	4	0.0	0.2
5	0.0	0.0	5	0.5	0.0	5	23.0	11.0
6	14.5	0.0	6	0.5	0.0	6	0.0	T
7	0.0	5.0	7	0.5	0.0	7	0.0	T
8	0.0	T	8	0.0	0.0	8	0.0	0.0
9	0.5	0.0	9	0.0	0.0	9	0.0	0.0
10	3.5	T	10	0.5	0.0	10	0.0	T
11	0.0	8.4	11	0.5	0.0	11	0.5	4.6
12	0.0	0.0	12	0.5	0.0	12	2.0	2.0
13	0.0	0.0	13	0.5	0.0	13	0.5	0.6
14	0.0	T	14	0.5	0.0	14	0.0	0.0
15	0.0	T	15	0.5	0.0	15	0.0	0.4
16	0.0	0.0	16	0.5	0.0	16	0.5	0.2
17	0.0	0.0	17	0.5	0.0	17	8.0	4.0
18	1.5	1.0	18	0.5	0.0	18	0.0	0.0
19	5.5	3.5	19	0.5	0.0	19	0.5	0.0
20	0.0	0.0	20	0.5	0.0	20	0.5	0.0
21	0.0	0.0	21	0.5	0.0	21	0.5	0.5
22	6.0	4.6	22	0.5	0.0	22	0.5	0.0
23	4.0	T	23	0.5	0.0	23	0.0	0.0
24	0.0	0.2	24	1.5	0.0	24	0.5	0.5
25	3.0	0.8	25	0.5	0.0	25	1.0	1.0
26	0.5	0.0	26	0.5	0.0	26	2.5	2.5
27	0.0	1.4	27	1.0	0.0	27	0.5	0.0
28	0.0	T	28	0.0	0.0	28	0.5	0.0
29	2.0	0.0	29	0.5	0.0	29	5.5	2.3
30	0.0	0.0	30	0.5	0.0	30	0.5	0.5
31	11.0	9.6	31	1.0	0.0			
Total	52.5	34.5	Total	16.5	0.0	Total	70.5	41.2

Table 1. Daily Total Precipitation Amounts at Selected Automatic Weather Stations (AWOS)
(T = trace amount of precipitation: i.e. < .2 mm)

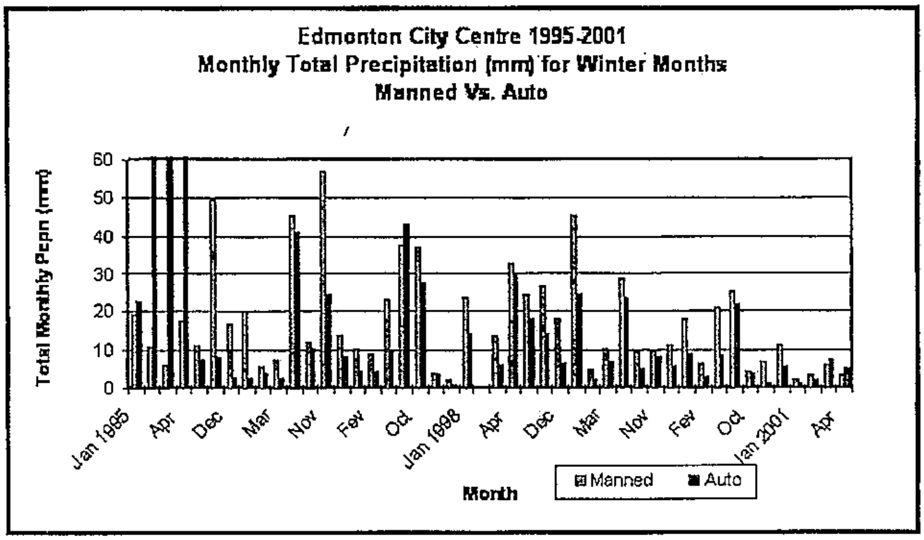

Figure 1. Monthly Winter Precipitation Comparison

[Everell Letter] Appendix

Canadians are noticing the bad values produced by automatic weather stations. Here is an email that was sent to our region recently by a resident of Regina.

```
"-----Original Message-----"
From: xxxxxx xxxxxx [mailto:xxxxxxxx@sk.sympatico.ca]
Sent: September 5, 2001 7:02 AM
To: meteo@ec.gc.ca
Subject: Other.PNR

Comments:  On the current conditions page for the City of Regina you list the
max, min and precip total for the day previous the current day.  I have no-
ticed that almost daily, .5 mm of precipitation is recorded, as is the case
again today, even though there wasn't a cloud in the sky all day.  Though .5
mm is not significant, if you register .5 mm each day of the year that greatly
skews the total precip for any given year.  That would mean that Regina re-
ceives at least 182 mm of precipitation without a drop falling from the sky.
Can you please tell me why this is?  Thanks"
```

The normal yearly precipitation total for Regina is 364.0 mm.

[The response letter to the climate staff from the ADM essentially said that better sensors and algorithms would solve these problems. This letter highlights that these issues have been pointed out to senior management well before this document was produced. Ed.]

Appendix G

Quality Control and Autostations

G.1 Snow Capping

Snow capping is a phenomenon which affects autostation precipitation weighing gauges. In essence, a snowstorm of sufficient intensity that dumps snow having a fairly high moisture content, can cover the intake of the precipitation gauge with a layer of snow. Although some snow makes it into the gauge during the storm, a significant amount is blocked from entering and "caps" the intake (Figure 1). This snow cap remains in place until ambient temperatures rise sufficiently to melt the cap, typically on a bright sunny day. The gauge then reports the melting snow as precipitation. Taken in isolation, the numbers, while a bit high, do not look out of place. Only manual QC which includes space checks, cross element checks and other data stream checks catches it.

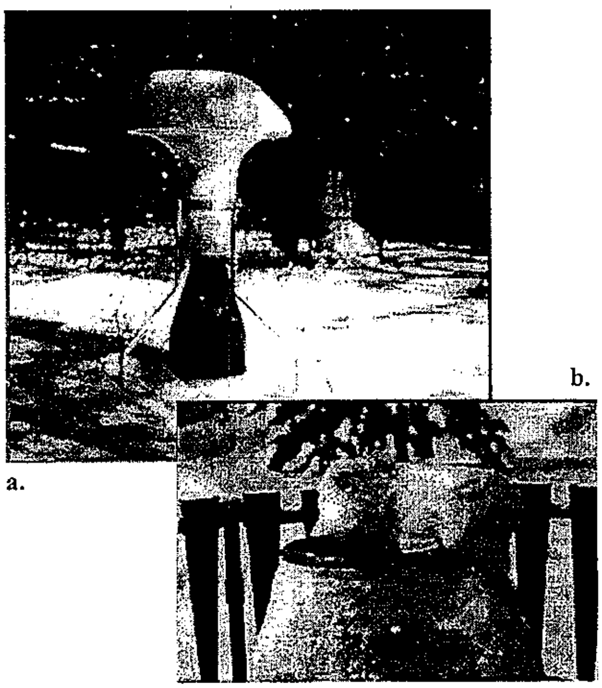

Figure 1. Complete (a.) and partial (b.) snow caps over precipitation weighing gauges

On March 24th, 2004, the autostation at Berens River, Manitoba reported 12.8 mm of precipitation. The hourly weather reports for Berens River (below) show temperatures rising from -3 degrees Celsius to +2 degrees over the space of three hours. Note the remarks highlighted in red that indicate precipitation starting as the temperatures rise to the freezing point.

```
WCF SA 1200 AUTO8 M M M 034/-06/-07/2206/M/
    3007 ?220MM?=
WCF SA 1300 AUTO8 M M M 040/-06/-07/2303/M/
    3015 ?219MM?=
WCF SA 1400 AUTO8 M M M 048/-05/-06/2301/M/
    3021 ?284MM?=
WCF SA 1500 AUTO8 M M M 059/-05/-07/3102/M/
    3025 ?260MM?=
WCF SA 1600 AUTO8 M M M 070/-03/-06/2605/
    M/0014 PCPN 1.4MM PAST HR 3030 ?32MM?=
WCF SA 1700 AUTO8 M M M 074/-02/-05/2605/
    M/0062 PCPN 4.8MM PAST HR 1026 ?60MM?=
WCF SA 1800 AUTO8 M M M 070/-01/-05/2705/
    M/0114 PCPN 5.2MM PAST HR /R11/ 0012
    ?28MM?=
WCF SA 1900 AUTO8 M M M 071/02/-04/2303/
    M/0014 PCPN 1.4MM PAST HR 3002 ?50MM?=
WCF SA 2000 AUTO8 M M M 071/04/-04/2206/
    M/0014 5001 ?67MM?=
WCF SA 2100 AUTO8 M M M 071/06/-03/2205/
    M/0014 1002 ?72MM?=
WCF SA 2200 AUTO8 M M M 071/07/-03/2107/
    M/0014 1001 ?83MM?=
WCF SA 2300 AUTO8 M M M 069/07/-04/1908/
    M/0014 8002 ?45MM?=
```

Without doing any cross data stream checks, this error would be in the archive and would appear in the monthly data as legitimate precipitation for that day (see Table 1 on the following page). These checks are no longer done on MSC climate data.

Monthly Summary for: BERENS RIVER CS

Year: 2004 Month:March

DATE	TEMPERATURE MAXIMUM °C	TEMPERATURE MINIMUM °C	TEMPERATURE MEAN °C (T)	PRECIPITATION HEATING DEGREE D. 18.0-T	PRECIPITATION RAINFALL mm	PRECIPITATION SNOWFALL cm	PRECIPITATION TOTAL PRECIP. mm	SNOW ON GROUND cm		BRIGHT SUNSHINE hours
1	0.5	-6.9	-3.2	21.2	Msg	Msg	0.0	Msg		Msg
2	-1.3	-18.7	-10.0	28.0	Msg	Msg	0.0	Msg		Msg
3	-14.1	-26.3	-20.2	38.2	Msg	Msg	0.0	Msg		Msg
4	-7.5	-27.9	-17.7	35.7	Msg	Msg	1.6	Msg		Msg
5	-3.5	-15.0	-9.3	27.3	Msg	Msg	1.4	Msg		Msg
6	-0.4	-12.0	-6.2	24.2	Msg	Msg	2.5	Msg		Msg
7	-6.4	-13.8	-10.1	28.1	Msg	Msg	0.0	Msg		Msg
8	-0.2	-10.9	-5.6	23.6	Msg	Msg	0.6	Msg		Msg
9	7.0	-12.9	-3.0	21.0	Msg	Msg	1.0	Msg		Msg
10	2.4	-21.6	-9.6	27.6	Msg	Msg	4.0	Msg		Msg
11	-17.0	-27.9	-22.5	40.5	Msg	Msg	0.7	Msg		Msg
12	-7.3	-17.0	-12.2	30.2	Msg	Msg	0.6	Msg		Msg
13	-1.0	-11.1	-6.1	24.1	Msg	Msg	3.4	Msg		Msg
14	-4.5	-21.9	-13.2	31.2	Msg	Msg	0.0	Msg		Msg
15	-1.9	-24.9	-13.4	31.4	Msg	Msg	0.0	Msg		Msg
16	-0.6	-4.7	-2.7	20.7	Msg	Msg	6.7	Msg		Msg
17	-2.4	-12.7	-7.6	25.6	Msg	Msg	1.4	Msg		Msg
18	-6.1	-19.1	-12.6	30.6	Msg	Msg	0.0	Msg		Msg
19	-2.9	-11.7	-7.3	25.3	Msg	Msg	9.6	Msg		Msg
20	-10.9	-22.7	-16.8	34.8	Msg	Msg	0.0	Msg		Msg
21	-7.8	-30.6	-19.2	37.2	Msg	Msg	0.0	Msg		Msg
22	-5.3	-25.1	-15.2	33.2	Msg	Msg	0.6	Msg		Msg
23	-2.1	-28.3	-15.2	33.2	Msg	Msg	0.7	Msg		Msg
24	7.4	-6.3	0.6	17.5	Msg	Msg	12.8	Msg		Msg
25	7.9	-17.0	-4.6	22.6	Msg	Msg	0.0	Msg		Msg
26	-5.5	-21.1	-13.3	31.3	Msg	Msg	0.0	Msg		Msg
27	2.1	-5.5	-1.7	19.7	Msg	Msg	37.3	Msg		Msg
28	1.4	-0.8	0.3	17.7	Msg	Msg	26.5	Msg		Msg
29	-0.8	-8.6	-4.7	22.7	Msg	Msg	0.0	Msg		Msg
30	4.9	-11.3	-3.2	21.2	Msg	Msg	0.7	Msg		Msg
31	8.2	-1.4	3.4	14.6	Msg	Msg	0.0	Msg		Msg
Sum	-67.7	-495.7	-281.7	839.7	Msg	Msg	112.1			-67.7
Mean	-2.2	-16.0	-9.1	27.1	Msg	Msg	3.6			-2.2
Normals	-2.8	-15.0	-8.9	834.2	4.3	21.9	23.2	15		-2.8
S.D.	6.0	8.4	6.6	6.6	Msg	Msg	8.2			6.0
Max	8.2	-0.8	3.4	40.5	Msg	Msg	37.3			8.2
Min	-17.0	-30.6	-22.5	14.6	Msg	Msg	0.0			-17.0

Table 1. Monthly climate data summary for Berens River with no QC performed to remove spurious precipitation.

G.2 Rapid Temperature Changes

Some precipitation gauges respond to temperature variations. On the 15th of January, 2003, a chinook hit southern Alberta resulting in a temperature rise of 7 degrees in 2 hours at Claresholm, Alberta. As shown in the accompanying table (Table 2 below), relative humidity decreased, indicating a drying of the air. Nevertheless, 0.7 mm of precipitation was recorded by the gauge. This value is bogus.

A similar incident occurred on the 26th of the month when temperatures rose 15 degrees in 3 hours. In this case 0.9 mm was recorded at 8 am and 10 am. Both values are bogus.

A check of a neighbouring station (Claresholm Meadow Creek - Table 3) showed no precipitation on either day. By no longer performing QC checks to catch occurrences such as this, MSC is changing the reported conditions associated with chinooks, and thereby effectively changing the climate. Chinooks which are known to bring dry warm conditions are according to this data bringing wet conditions. Will someone doing a scientific study in the future know that these numbers are imaginary?

Monthly Summary for: ***CLARESHOLM MEADOW CREEK***

Year: 2003 Month:January

DATE	TEMPERATURE MAXIMUM °C	MINIMUM °C	MEAN °C (T)	HEATING DEGREE D. 18.0-T	PRECIPITATION RAINFALL mm	SNOWFALL cm	TOTAL PRECIP. mm	SNOW ON GROUND cm		BRIGHT SUNSHINE hours
2					0.0	0.0	0.0			
14					0.0	2.0	2.0			
15					0.0	0.0	0.0			
16					0.0	0.0	0.0			
17					0.0	0.0	0.0			
18					0.0	0.0	0.0			
19					0.0	0.0	0.0			
20					T	20.0	20.0			
21					0.0	0.0	0.0			
22					0.0	1.0	1.0			
23					T	T	0.0			
24					0.0	0.0	0.0			
25					0.0	0.0	0.0			
26					0.0	0.0	0.0			
27					0.0	0.0	0.0			
31					0.0	0.0	0.0			
Sum	0.0	0.0	0.0	0.0	0.0	24.5	24.5			0.0
Mean	0.0	0.0	0.0	0.0	0.0	0.8	0.8			0.0
Normals					0.3	17.9	18.1	1		
S.D.	0.0	0.0	0.0	0.0	0.0	3.6	3.6			0.0
Max	0.0	0.0	0.0	0.0	0.0	20.0	20.0			0.0
Min	0.0	0.0	0.0	0.0	0.0	0.0	0.0			0.0

Table 3. Nearby station check: monthly climate data summary for Claresholm Meadow Creek indicating no precipitation on the days in question.

Temperature

DATE	00	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17	18	19	20	21	22	23
15	-16.1	-15.3	-16.4	-14.6	-13.3	-12.2	-12.2	-11.7	-9.8	-8.9	-7.2	-4.2	-0.2	-0.2	1.2	1.3	-2.4	-3.2	-10.4	-11.5	-9.8	-12.4	-13.8	-14.8
26	-18.2	-17.3	-16.6	-15.5	-14.7	-12.2	-10.1	2.1	5.5	5.3	7.9	7.9	11.1	11.4	12.5	12.5	11.6	10.0	8.7	7.3	6.6	5.1	5.5	5.2

Relative Humidity

DATE	00	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17	18	19	20	21	22	23
15	91	91	91	89	91	88	89	90	92	91	87	85	75	76	70	67	79	83	94	99	97	90	90	91
26	85	86	85	86	87	89	93	86	72	77	67	70	56	56	55	56	58	55	66	69	77	82	78	77

Weighing Gauge Output

DATE	00	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17	18	19	20	21	22	23
15	-	-	-	-	-	-	-	-	-	-	-	-	0.7	-	-	-	-	-	-	-	-	-	-	-
26	-	-	-	-	-	-	-	-	0.9	-	0.9	-	-	-	-	-	-	-	-	-	-	-	-	-

Table 2. Temperature, Relative Humidity and Precipitation Gauge output for January 15th and 26th from the autostation at Claresholm, Alberta.

G.3 Cumulative Errors

Errors such as those described in this appendix are frequently small. However, while they may not seem important, they add up. Table 4 below shows the effects of frequent small errors and occasional larger errors on monthly total precipitation figures for Iqaluit, Lethbridge and Saskatoon. The first column under each station is the day of the month, the middle column is the uncorrected autostation precipitation value, and the third column is the quality controlled value after various checks.

Notice the effects of QC: at Iqaluit there is a difference of 18.0 mm, at Lethbridge which was in drought and had zero precipitation for the entire month, the gauge created a fictitious 17.5 mm*, and at Saskatoon the gauge produced significantly more precipitation than actually fell during several episodes, for a difference of 29.3 mm.

With human QC gone, the autostation numbers are now the official EC numbers.

Iqaluit			Lethbridge			Saskatoon		
YFB October 2000			YQL August 2001			YXE April 2000		
	AWOS	Actual		AWOS	Actual		AWOS	Actual
1	0.0	0.0	1	0.5	0.0	1	18.5	8.9
2	0.0	0.0	2	0.5	0.0	2	4.0	2.0
3	0.5	0.0	3	1.0	0.0	3	0.5	0.0
4	0.0	0.0	4	0.5	0.0	4	0.0	0.2
5	0.0	0.0	5	0.5	0.0	5	23.0	11.0
6	14.5	0.0	6	0.5	0.0	6	0.0	T
7	0.0	5.0	7	0.5	0.0	7	0.0	T
8	0.0	T	8	0.5	0.0	8	0.0	0.0
9	0.5	0.0	9	0.5	0.0	9	0.0	0.0
10	3.5	T	10	0.5	0.0	10	0.0	T
11	0.0	8.4	11	0.5	0.0	11	0.5	4.6
12	0.0	0.0	12	0.5	0.0	12	2.0	2.0
13	0.0	0.0	13	0.5	0.0	13	0.5	0.6
14	0.0	T	14	0.5	0.0	14	0.0	0.0
15	0.0	T	15	0.5	0.0	15	0.0	0.4
16	0.0	0.0	16	0.5	0.0	16	0.5	0.2
17	0.0	0.0	17	0.5	0.0	17	8.0	4.0
18	1.5	1.0	18	0.5	0.0	18	0.0	0.0
19	5.5	3.5	19	0.5	0.0	19	0.5	0.0
20	0.0	0.0	20	0.5	0.0	20	0.5	0.0
21	0.0	0.0	21	0.5	0.0	21	0.5	0.5
22	6.0	4.6	22	0.5	0.0	22	0.5	0.0
23	4.0	T	23	0.5	0.0	23	0.0	0.0
24	0.0	0.2	24	1.5	0.0	24	0.5	0.5
25	3.0	0.8	25	0.5	0.0	25	1.0	1.0
26	0.5	0.0	26	0.5	0.0	26	2.5	2.5
27	0.0	1.4	27	1.0	0.0	27	0.5	0.0
28	0.0	T	28	0.0	0.0	28	0.5	0.0
29	2.0	0.0	29	0.5	0.0	29	5.5	2.3
30	0.0	0.0	30	0.5	0.0	30	0.5	0.5
31	11.0	9.6	31	1.0	0.0			
Total	52.5	34.5	Total	17.5	0.0	Total	70.5	41.2

Table 4. Autostation vs QC'd monthly precipitation values for several sites.

* Lethbridge's false precipitation amounts were due to an error known as wind pumping, whereby strong winds vibrate the gauge and generate spurious readings.

s.20(1)(c)
s.20(1)(d)

G.4 Missing Data

One of the major problems with autostations continues to be the high number of missing data episodes. It is not that the data doesn't exist, it simply has to be pursued and looked for using various means.

In addition to this, missing data occurrences increased after MSC staff were replaced by contractors in field offices. Replacement staff were typically less trained and were not inspected as frequently to ensure they were meeting required standards.

While Regional Climate centres existed, staff made a point of trying to retrieve missing data. As mentioned in this report, PNR typically had to look for data from 100 or so of its 1000 stations each month. Nobody in MSC tries to retrieve missing data anymore.

The graph below (Figure 2) shows the decreasing trend in amount of complete precipitation records at l

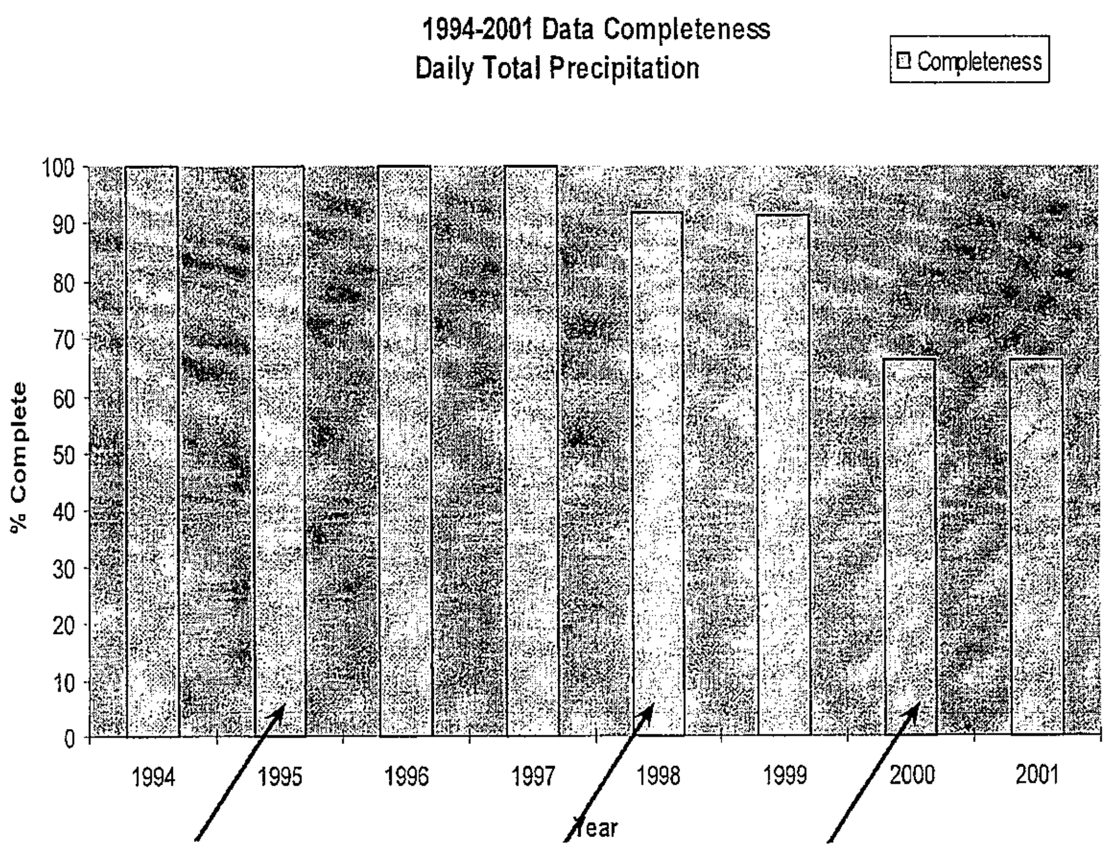

Figure 2. Completeness in Precipitation Data at from 1994-2001.

Appendix H

Orphaned Climate Programs and Databases within PNR

The disbanding of Prairie and Northern region's Climate Section has left several vital programs orphaned with no designated support or funding. Over the last four years, these systems have been supported on an ad-hoc basis by a handful of staff who have an understanding of the programs. This additional workload is outside their mandate and cannot be supported in the long term. A permanent solution is required or the department risks compromising access to its own data.

One program in particular, called Climate Manager, needs intervention. It is widely used internally in PNR as a source of historical data for development of techniques, and studies of impacts. It currently drives a number of forecast guidance tools and is often used as a source of climate data for internal and external clients. Climate Manager continues to operate but the ingest of new data has failed so there is nothing beyond June 2007. As a consequence there are growing demands to update the data and to add new stations.

In addition, the raw data currently collected from autostations are stored on two workstations. These data are not systematically backed up and are at risk of permanent loss. The archive files contain detailed information that is useful for post event research and method development. This archive contains such elements as:

- hourly precipitation amounts
- precipitation intensities
- 1 hour averages of various elements (temperature, wind, relative humidity)
- radiation
- 2 metre winds

Of all the old Climate Section archives, this one is the most precious, and the most at risk, as the data it contains does not exist anywhere else in Canada.

One critical point is that the data is currently in comma delimited files. In order to properly read it, one must also maintain the index files which indicate what element is in what column. As new sensors are added to stations, these index files change. Without a history of the index files, keeping the data files is useless. An archive of these index files must be maintained as well.

Appendix I

EC Pacific and Yukon Region (PYR) Report on Changes to the Climate Network

[*This report was prepared by Climate Services in PYR for distribution to EC climate scientists. Ed.*]

[PYR Climate Services (PYRCS)] have some serious concerns about the direction our National Climatic Network is going, and what [we] perceive to be a major deterioration in its usefulness to climate change research. [We] write this memo to outline some of those changes which you may or may not be aware of, and to get your opinion on whether or not the direction we are going will seriously impede your research.

Rainfall Intensity

It was, at least in part, a memo from [PYRCS] that prompted the Data Rescue Program where several years of TBRG data were rescued from boxes, processed, and are just now resulting in the first general update of IDF curves in about 15 years. The decision to stop processing TBRG data, and several other types of supplementary data in 1999 was a poor one both in terms of climate change research, and for the safety of the public.

To make matters worse, many of the TBRGs were shut down a few years after EC closed its Weather Offices in the mid-nineties, and had to start paying Nav Canada to operate them. These were, unfortunately, at airport locations where many of the longest running rainfall intensity records existed. Nanaimo, Tofino, Vancouver and Victoria are the only controlled airports in PYR currently operating a TBRG. All the rest stopped recording in 2002. Sunshine data stopped at about the same time at the same stations.

Overall the TBRG network for PYR has been reduced from 112 in 1985, to 71 stations at the turn of the century, to 36 stations now.

Volunteer Observers

[Our] greatest concern, however, is with the intentional dismantling of the Volunteer Climate Network, ostensibly, for lack of funding. There is lots of money for new auto-stations, but very little for Volunteers... The problem here is one of philosophy by management. They believe that the climate data produced by the Volunteer Network is basically a bunch of garbage – numbers mostly invented by QC technicians.

In some cases there is an element of truth there, for many an agency-operated station reports only 5 days a week, and some considerable work has to be done on them to make a complete report, including moving or spreading out accumulated temperatures and precip. These stations, and the few volunteer stations that tend to miss a lot of observations, are easy to spot as they have an abundant number of estimated values.

The majority of our Volunteer observers are very conscientious, and have very few missing values. [We] received an email last month from an observer at a station where three generations of one family have been operating for 49 years. Her children have gone off to college and she feared that she may miss an occasional observation, and wondered how to report a missed observation.

These stations are easy to spot too. If there are few or no "E"s (for Estimated) in the monthly means or totals, then you can assume the data are quite complete with little or no intervention by the QC technician.

A letter will soon be going out to volunteer observers not reporting by CoolTap (web-based electronic data reporting via the Internet), telling them to start reporting by CoolTap or they will be closed. There are many of our best and most valuable stations which will be put at risk of closing because of poor internet connections or other reasons. This includes: Chilliwack – with 100 years of history; Germansen Landing with 57 years of history, and the only station in the entire Omenica region of BC. Many good stations will be lost, but many weekday only agency operated stations will remain. They won't get the letter. We're keeping many of our worst stations.

Auto-stations

Management, unfortunately, believes that auto-station data are much better than volunteer data, and has been busy populating the Regional Climate Station (RCS) list with them. Auto-stations are a valuable part of the climate network, but when it comes to precipitation they are extremely limited. Their problems include:

- Intensity data are not easily available and probably won't be for years
- Many auto-stations don't compare well with co-located manned stations
- Most auto-stations have a short history
- All auto-stations have a limited life span
- Auto-station technology is continually evolving
- There is often little or no data to [compare with autostation data], as many manned stations were closed as soon as their auto-station was functioning.
- Auto-stations still can't measure, or accurately measure snowfall.

The worst problem is the last, which results in the fact that of the 23 autostations on the PYR RCS list, only one has more than 3 complete years of precipitation – Victoria Gonzales. When you remove that station from the equation the average number of complete years of precipitation becomes 0.5!

Some RCS stations are simply ridiculous. Check out Warfield and Cape St James in Climate Online.

There are no accessible rainfall intensity data available for auto-stations. [We are] told there will be, but [we're] not holding [our] breath. When it does become available it will not go back any further than the early to mid-nineties, and many will have no history at all. [We] believe most of the back data will be hourly and 6-hourly values only.

In the past two years many auto-stations in PYR have been upgraded (?!) to be able to measure rain, snow, total precipitation, and depth of snow on the ground. This should be a wonderful breakthrough in technology, unfortunately, if you look at the data, it frequently makes absolutely no sense.

[See Table 1 below. 19 cm of total snow but zero total precipitation for January 1 at Callaghan Valley; 3 cm of total snow January 3rd but somehow 21 mm of total precipitation – 3 cm of snow when melted typically yields in the neighbourhood of 3mm of water equivalent, although this can vary significantly if snow is dry or moist. Ed.]

Callaghan Valley Jan 2008

Daily Data Report for January 2008

Day	Max Temp °C	Min Temp °C	Mean Temp °C	Heat Deg Days °C	Cool Deg Days °C	Total Rain mm	Total Snow cm	Total Precip mm	Snow on Grnd cm	Dir of Max Gust 10's Deg	Spd of Max Gust Km/h
01†	-0.9	-7.9	-4.4	22.4	0.0	M	19.0	0.0	133		<31
02†	1.2	-2.4	-0.6	18.6	0.0	0.0	29.0	18.2	152		<31
03†	1.7	-1.7	0.0	18.0	0.0	0.0	3.0	21.0	157	13	33

Table 1. MSC Climate Online records for Callaghan Valley, BC.

Lest you think this is a coastal phenomenon:

Lytton RCS Dec 2007

Daily Data Report for December 2007											
Day	Max Temp °C	Min Temp °C	Mean Temp °C	Heat Deg Days °C	Cool Deg Days °C	Total Rain mm	Total Snow cm	Total Precip mm	Snow on Grnd cm	Dir of Max Gust 10's Deg	Spd of Max Gust Km/h
01†	-4.7	-9.8	-7.3	25.3	0.0	M	M	0.8	4	33	35
02†	-9.0	-10.2	-9.6	27.6	0.0	0.0	19.0	3.0	2		<31
03†	-1.3	-10.3	-5.8	23.8	0.0	0.0	20.0	31.8	32		<31
04†	6.7	-1.4	3.7	14.3	0.0	M	M	106.6	38	18	54

Table 2. MSC Climate Online records for Lytton, BC.

[*As shown in Table 2, on the 2nd of December, 19 cm of snow was reported at Lytton but only 2 cm of snow was measured on the ground; on the following day, only 20 cm of snow fell but 32 cm of snow was measured on the ground - 30 more than the day before; and on the 4th, total rain and total snow were missing, but somehow 106.6 mm of total precipitation was measured. Ed.*]

[We] have been told that this is not necessarily the final configuration for auto-stations. That's good and bad news; good because this configuration doesn't work very well, and bad because by the time they come up with one that appears to work, the volunteer networks will have been destroyed, and you will never really be able to properly QC the data or correlate it to any historical data.

It has always been our philosophy in PYR that if you change the way you QC the data, you change the data, and thereby change the climate. Obviously, if you change the way you measure the data, then you certainly change the data. To dismantle the volunteer climate network, or reduce it to a handful of stations in favour of a constantly evolving system with only a short-term history, [we] think, would be a nightmare scenario for you guys. [Are we] out to lunch here?

The volunteer network has been the only form of observing that has remained consistent over the past 100 years. To [our] way of thinking, that is priceless! That is data you can work with without an extraordinary amount of manipulation.

You may disagree and suggest that our professional observers (contract & Nav Canada) are consistent, but [we] have to tell you that that is not the case. The removal of all Environment Canada personnel from the observing field began a deterioration in the quality of climate observations that continues today, and is being accelerated by the fact that personnel are not being trained to the standards they once were. In fact, they may not be trained in climate observations at all, except by other observers.

Many of our airport stations are now measuring snowfall improperly. Just recently [we] sent out an email to half a dozen of them reminding them of how to measure snowfall as per MANOBS (*EC's Manual of surface weather Observations. Ed.*). They have been measuring the snowfall with a ruler regardless of whether or not melting has occurred. Consequently, you now get Snowfall Water Equivalents that greatly exceed Snowfall. This should rarely ever happen, and should never happen when melting has occurred.

In Table 3, Vancouver International Airport (YVR) reported a snowfall of 8.4 cm and a water equivalent of 15.2 mm on the 2nd [of] Dec, 2007. On the 22nd they report[ed] a snowfall of 4.0 cm and a water equivalent of 8.0 mm. This should never happen; not at a principal station, but it does all the time with increasing regularity and increasing absurdity.

Quality Control

Regional quality control of climate data will cease as of April 1st in favour of DMF QC, which, [we] believe is at least a year, maybe two from even beginning to function. Stopping regional QC will change the data. Also, without regional QC to ground-proof the QC done by DMF, you will introduce biases that may be impossible to identify. You will change the data, and hence, the climate.

Meaningful QC will be nearly impossible in the future as stations will be far too sparse. In a region where you can drive from rainforest to near desert conditions in an hour and a half, one climate station every couple hundred kms is not going to work very well.

Sunshine data

We, in PYR, have several years of sunshine data for as many as 33 stations in various formats. There seems to be little interest in getting those data into the archives, though it can be done without a great deal of expense or time.

[We] believe many of these changes will seriously impede your research into the effects of climate change on precipitation patterns. If [we are] out to lunch, please let [us] know and [we'll] apologize and stop whining.

Vancouver Intl Airport *Dec 2007*

Daily Data Report for December 2007

Day	Max Temp °C	Min Temp °C	Mean Temp °C	Heat Deg Days °C	Cool Deg Days °C	Total Rain mm	Total Snow cm	Total Precip mm	Snow on Grnd cm	Dir of Max Gust 10's Deg	Spd of Max Gust km/h
01†	0.3	-2.4	-1.1	19.1	0.0	0.0	4.4	3.2		10	52
02†	2.4	-2.3	0.1	17.9	0.0	10.6	8.4	25.8	2	10	41
22†	5.7	0.3	3.0	15.0	0.0	10.4	4.0	18.4	2	10	52

Table 3. MSC Climate Online records for Vancouver, BC.

Appendix J

The Cost of Contracting Out the Canadian Upper Air Data Network

[*This appendix is an analysis done by PNR climate staff sometime after 2003. Ed.*]

MSC currently operates just under 30 Upper Air radiosonde stations across Canada. Upper air data is not traditionally considered when one thinks of climate data. It is however of primary importance. From the beginning of the Upper Air Observing program in the 1950's up until about 1994, all upper air flights were performed by MSC staff. Starting in 1994, MSC started contracting out Upper Air Observing. Today, there are only three stations which are staffed by MSC personnel (Stony Plain, AB, Eureka, NT and Alert, NT). Depending on the region, the amount of training received by Contract Observers varies from a 2-3 week course to a few days of on the job training.

The implementation of contracting out has had negative effects on the archived Upper Air dataset. Table 1 on the following page shows the number of missing flights for the 10 years prior to contracting out (1984 to 1993), and the number of missing flights for contract years from 1994-2003. While 1994 might not be the exact date each station went from MSC staff to contract, it is still a good approximation. This analysis was done using the archived Upper Air dataset using elements 181 to 186. This analysis does not identify where the miss occurred. Was the flight not done? Was it done, but not archived? Was it archived, but not sent to Downsview? We have no way of knowing why the flight is missing from the archive, and it does not really matter why. What matters is that it is missing. For climate purposes, an non-archived observation is as bad as an observation not done.

Of the 23 contract sites analyzed, only 3 performed better during the contract years than they did during the MSC years:

Several instances of complete months missing were noted. While a problem even in the MSC days (33 station-months missing from 1984 to 1993), it grew dramatically in the contractor era. For the period from 1994 to 2003, 101 station-months were missing, an increase of over 300%. The total number of missed flights in the contract stations increased from 4,896 to 14,301 while the three remaining MSC sites actually saw a decrease of missed flights from 745 to 482. Figure 1 below shows a summary of all missed flights from 1984 to 2003 for all stations in Canada. s.20(1)(d) s.20(1)(c)

This analysis has identified four quality gaps in the Canadian Upper Air Network and Archive:

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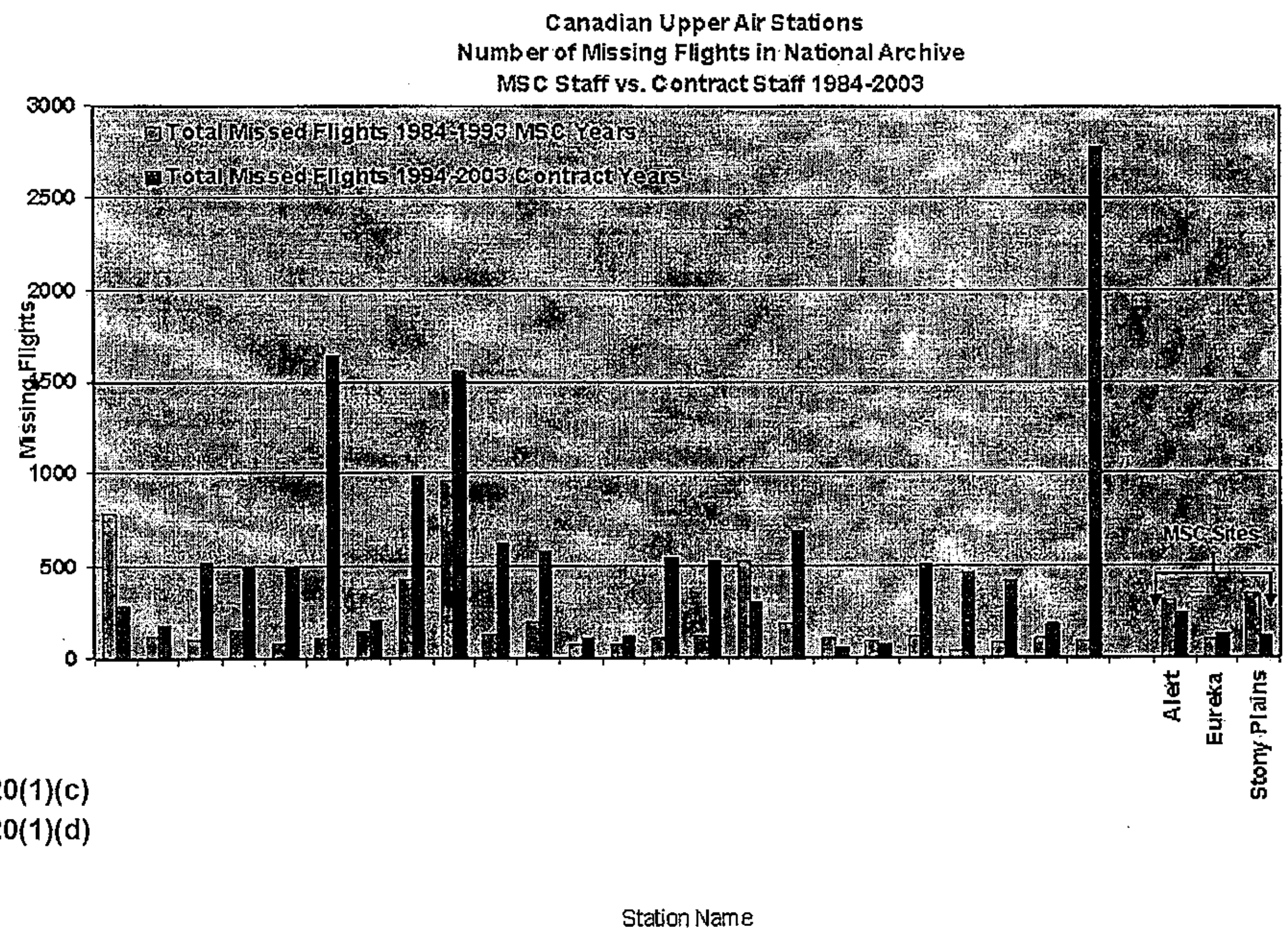
Recommendations:

- Create a National Monitoring Desk for Upper Air Flights.
- Impose a monetary penalty for contractors who miss flights.
- Review the archiving process of Upper Air Data to ensure that all flights do get archived.

Current Contract Sites	MSC Years	Whole Month Missing		Contract Years	Whole Month Missing		Difference Between No. of Missing Flights for each Period
	Total Missed Flights 1984-1993	No. of Missing Months	Missing Obs	Total Missed Flights 1994-2003	No. of Missing Months	Missing Obs	
	790	8	496	285	2	185	-505
	113	0		178	1	143	65
	94	0		511	5	294	417
	152	0		489	3	389	337
	77	0		497	5	455	420
	103	1	61	1638	25	1550	1535
	143	2	124	206	1	102	63
	424	3	249	984	10	779	560
	960	8	655	1559	9	1044	599
	131	1	68	628	7	456	497
	199	2	119	580	3	207	381
	69	1	51	105	0		36
	72	0		111	0		39
	105	0		542	6	397	437
	117	0		526	5	380	409
	532	5	323	304	2	158	-228
	185	2	145	689	7	515	504
	108	0		55	0		-53
	89	0		74	0		-15
	119	0		502	2	182	383
	42	0		465	3	181	423
	78	0		416	4	282	338
	102	0		184	1	112	82
	92	0		2773	43	2623	2681
Totals	4896	33	2291	14301	101	7811	9405
MSC Sites 1984-2003	**MSC Staff**	**Whole Month Missing**		**Msc Staff**	**Whole Month Missing**		**Difference Between No. of Missing Flights for each Period**
	Total Missed Flights 1984-1993	**No. of Missing Months**	**Missing Obs**	**Total Missed Flights 1994-2003**	**No. of Missing Months**	**Missing Obs**	
Alert	309	3	228	244	2	164	-65
Eureka	94	1	53	125	1	67	31
Stony Plains	342	4	244	113	1	61	-229
Totals	745	8	525	482	4	292	-263
Grand Total	5641	41	2816	14783	105	8103	

Table 1. Chart comparing missed upper air flights for MSC years and Contractor years



s.20(1)(c)
s.20(1)(d)

Figure 1. Graph comparing total missed upper air flights for MSC years and Contractor years for each upper air station in Canada.

Appendix K

One Possible Climate Network Configuration

Given an interagency recovery process such as that suggested in Chapter 8 ("Repairing the Damage and Reversing the Trend") and the political will to make it work, what might a future National Climate Network (NCN) look like in practice? One possibility is presented here.

Data Gathering

Everything depends on observations. Assuming that the recovery process has designed a climate observing network that meets the needs of participating agencies, what might those observing stations look like?

Multi-disciplinary stations. High quality stations that would have an extensive suite of sensors. The sensors would meet the needs not only of atmospheric science, but those of forestry, soil science, hydrology or agriculture. Such stations would contain the full array of sensors as laid out in the applicable WMO technical specifications for each discipline. They could also be locations where sensor testing would occur, and if so would likely have NCN employees onsite or nearby to carry out maintenance and calibration of sensors.

Central node stations. Designed to meet both realtime and long-term needs, these stations would have a NCN employee who would continuously monitor a number of remote stations. Datastreams and atmospheric conditions would be assessed in real time via telecommunications networks and remote cameras installed at the sites. The employee would be able to correct erroneous readings and supplement observations based on what cameras showed. Studies would need to be carried out to determine how many stations one individual could adequately monitor.

Auxiliary Sites. Auxiliary sites would come in a variety of flavours:

1) Cooperating agency stations. These would be stations such as those run by Nav Canada, provincial or county transportation departments, national or provincial park staff or municipalities. Such stations would have sensors that varied according to the facility and need, but the observers would be trained to a prescribed level of competence by NCN staff.

2) Volunteer stations. These would be the classic volunteer stations. They would receive training (perhaps remotely or via DVD), as well as incentive awards to encourage accuracy and reliability. Significant service awards might involve more substantial gifts, similar to those the government reward system provides to employees who perform to an outstanding level.

3) Autostations. These would consist of automatic weather stations whose sensors had been fully tested and field certified for accuracy.

4) Private weather stations. Many organizations and individuals own their own weather stations. Among these are television stations, academics with their own mesoscale networks for research purposes and farmers participating in networks purchased by organizations such as the Canadian Wheat Board.

5) Public observations. It would seem wise to harness the interest of individuals who do not

possess their own instruments, but who can nevertheless add valuable information from locations not normally monitored or where certain sensors do not exist. Such a system could resemble the CANWARN amateur radio station network in Canada or the Tornado Spotter program set up years ago in the U.S. This system would be created for Internet use, and target any type of weather. Persons who took the time to be trained, either online or via DVD, would be assigned a username and password, and would be allowed to submit public observations in real time, and consent to be contacted when necessary by NCN or forecast center staff if questions arose. A simple point and click page would indicate choices such as cloudy, sunny, snow, rain, lightning, strong winds, etc. This program would also serve as a valuable outreach tool for the NCN.

6) Satellite, radar and lightning networks. A significant amount of effort would be put into the calibration of satellite, radar and lightning networks in order to allow these sensor systems to reliably fill in gaps between observing sites, especially in remote areas of the country.

Quality Control and Technical Services

Located in central regional facilities (including the Yukon, Northwest Territories and Nunavut), these sites would perform the duties described in Chapter 5 including regular updates to IDF curves and processing of paper forms sent in by volunteers. Technical services staff would be on hand to handle regular maintenance and deal with equipment malfunctions.

Research

Located either in regional facilities or in the NCN central headquarters, scientists would continuously study sensor performance and carry out tests on new sensors. Ongoing studies would be undertaken in the science of climate monitoring and regular conferences held to exchange knowledge and experience with international colleagues. In addition, a significant amount of effort would be devoted to the recovery and/or quality control of data missing or not processed since the mid 1990s.

Information Storage and Data Dissemination

The computing facilities for ingesting and storing a continuous stream of climate data would be located both in regional facilities and the NCN headquarters. IT staff would maintain an online data warehouse for all NCN partners, industry, academia and the public, with special emphasis on ease of use. An extended hours help desk would assist clients in obtaining the data they needed. Given that the data entering the archive would vary significantly in terms of quality, it would be critical to maintain metadata together with the data it described, and allow users the opportunity to become informed about the quality of the data they were obtaining.