Estimate of the Average Annual Cost for Disaster Financial Assistance Arrangements due to Weather Events

Table of Contents

Executive Summary

The Disaster Financial Assistance Arrangements (DFAA) program, created in 1970, reimburses the provinces and individuals (via the province) for expenses and damages resulting from disasters, natural or manmade. The program shares costs with the provinces on an increasing proportion up to the level reached at $15 multiplied by a province's population. Above this amount, the DFAA program pays 90 per cent of the costs.

For this report, PBO obtained historical DFAA payment data directly from Public Safety Canada (PSC) rather than using PSC's public disaster database. The public database is missing some disaster payments and some other listed payments are incorrect due to payment changes not being updated in the database. Therefore, the DFAA numbers used in this report are not the same as those found in the disaster database.

As shown in Summary Figure 1, over the past five years DFAA's liabilities have increased substantially because of a number of weather events that have caused heavy damage. As a result, DFAA's annual transfers to the provinces have been much higher than its nominal appropriation of $100 million (Summary Figure 2).

It is important to note that when a disaster occurs, DFAA in general books the liability in the year of the disaster recognizing its financial obligation. Yet, the actual transfers to the provinces for disasters can take place upwards of eight years after the event. This explains the large estimated transfers shown in Summary Figure 2 going out to fiscal year 2017-2018.

Summary Figure 1   **DFAA liabilities**
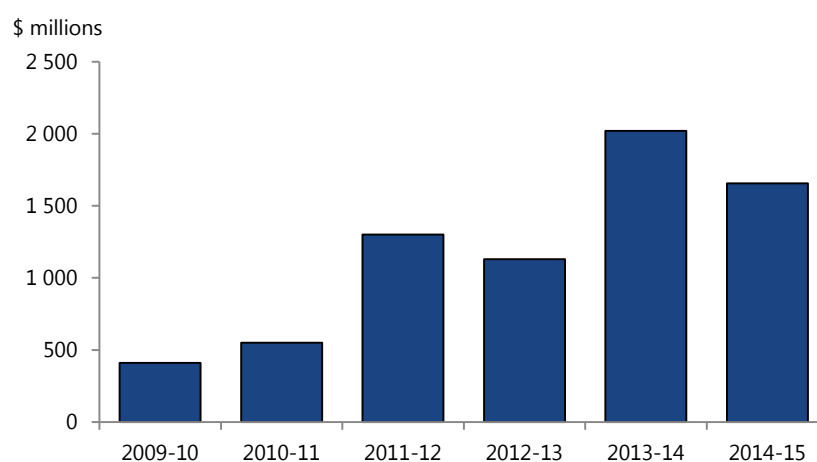
$ millions

Source: Public Safety.

Summary Figure 2   **DFAA annual transfers**
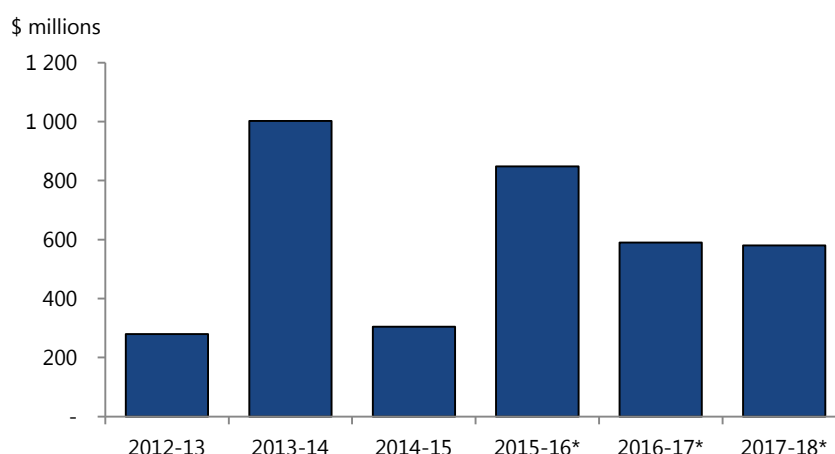
$ millions

Source: Public Safety.
Note: *Public Safety estimates.

In the fiscal year 2012-2013, DFAA transferred $280 million to the provinces; by 2013-2014, this had increased to $1.02 billion and $305 million in 2014-2015[1]. DFAA estimates its transfers resulting from previous events will be higher in subsequent years ($848 million in 2015-2016, $590 million in 2016-2017, and $580 million in 2017-2018).[2]

This report estimates the expected additional average annual cost to the DFAA program resulting from anticipated weather events (floods, hurricanes, convective storms, and winter storms) over the next five years.

PBO used data from numerous sources, including the Insurance Bureau of Canada (IBC), DFAA, Swiss Re, and Risk Management Solutions Inc. (RMS), to determine its estimate. For losses due to hurricanes, convective storms and winter storms, PBO used estimates provided by RMS. For losses due to flooding, PBO used estimates from IBC. RMS had Canadian specific models for hurricanes, convective storms and winter storms. The IBC flood estimate used a Canadian specific flood model based on Canadian flood extent and flood risk.

PBO estimates that over the next five years, on average, DFAA can expect annual costs of $229 million per year because of hurricanes, convective storms and winter storms. Using the IBC estimate for flood losses, PBO estimates that on average, DFAA can expect annual costs of $673 million for floods. Therefore, the total annual costs to the DFAA for weather events is estimated to be $902 million.

The results are listed in Summary Table 1 and Summary Figure 3 below. It is important to stress that these values are averages; in any given year, the losses can be much higher or much lower.

Summary Table 1

Estimated DFAA annual weather event costs[3]

$ millions	DFAA% of total event loss	Estimated annual total losses	DFAA portion
Hurricanes	19.20%	$98.7	$19.0
Convective storms	0.27%	$671	$1.83
Winter storms	12.12%	$1,720	$208
Floods	27.71%	$2,430	$673
Total	-	$4,920	$902

Sources: PBO; RMS; IBC; DFAA and Swiss Re.

Therefore, based on the estimated annual DFAA payments for future weather event shown in Summary Table 1, the DFAA will continue to require more than its nominal $100 million appropriation.

Summary Table 1 also shows that the DFAA costs resulting from floods are the largest of the weather events at $673 million and represent 75 per cent of DFAA's weather expenditures. This high value is partly due to the lack of flood insurance in Canada, as well as regulatory challenges in the Prairie Provinces. Over the past 10 years (2005-2014), Manitoba, Saskatchewan, and Alberta have accounted for 82 per cent of all DFAA weather event costs, almost all of which are a result of flooding.

The Prairie Provinces face regulatory challenges of reduced enforcement and compliance when floodplain management is the responsibility of municipalities.[4,5]

Summary Figure 3

Estimated DFAA annual weather event costs[6]

$ millions
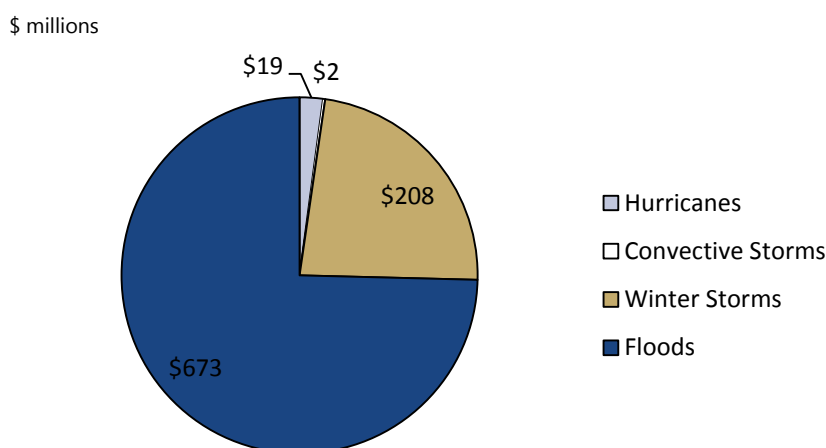
Sources: PBO; RMS; IBC; DFAA and Swiss Re.

Furthermore, Saskatchewan has unlicensed drainage of wetlands[7] that increases peak flows during floods[8] and Alberta appears to have inaccurate flood maps.[9] Furthermore, in creating flood maps, Alberta does not take into account rising groundwater[10] and debris floods on steep mountain creeks. [11]

One last consideration is interprovincial co-ordination of flood management. This currently does not exist in Canada even though it has been shown to be effective at reducing damages in other countries.[12] This is particularly important in the Prairie Provinces where rivers such as the Saskatchewan and its tributaries span all three provinces.

1. Introduction

The legislative mandate of the Parliamentary Budget Officer (PBO) includes providing independent analysis on the state of the nation's finances.[13] Consistent with this mandate, the objective of this report is to estimate the average annual cost of Public Safety Canada's (PSC) Disaster Financial Assistance Arrangements (DFAA) with the provinces for weather events.

For this analysis, weather events include hurricanes, floods, convective storms (hail, rain and wind), and winter storms. Wild fires, which can be a result of dry weather, are not included, as there are no wildfire models for Canada.[14] Wildfire models predict the likelihood of wildfires occurring in specific areas.

Over the last 20 years, the annual cost[15] for DFAA for weather events has been steadily increasing. Inflated to 2014 values using nominal gross domestic product (GDP)[16], the average DFAA cost from 1970 to 1994 amounted to $54 million per year; between 1995 and 2004, this annual average cost had risen to $291 million, and between 2005 and 2014,[17] it reached $410 million per year.

The increase in DFAA costs over the past 20 years is attributable to an increasing number of large weather events with greater intensity. In addition to a number of small events, over the past four years Canada has endured:

1. heavy rains in June 2014 in Saskatchewan (expected DFAA cost $160 million);

2. the Toronto ice storm of December 2013 (expected DFAA cost $120 million);

3. Southern Alberta and southeastern British Columbia flood of June 2013 (expected DFAA cost $1.347 billion), and;[18]

4. the Assiniboine River flood in Manitoba of 2011 which was contributed to by the flood that spring in Saskatchewan (expected DFAA cost $524 million for Manitoba and $245 million for Saskatchewan).[19]

Given the substantial increase in DFAA event costs over the past 20 years, PBO set out to determine if these high costs would increase further, stay the same or return to their previous levels.

The remainder of this report consists of three sections. The first provides background information about the DFAA program and a brief overview of the insurance industry with a description of flood insurance in Canada. The second section presents the methodology used to estimate the expected annual cost to the DFAA for weather events. The third section presents the results.

2. Background

2.1. DFAA program

The federal DFAA program, created in 1970, is currently administered by PSC. (A full description can be found on PSC's website.[20]) It is the responsibility of each province to administer disaster financial assistance for its jurisdiction. The federal program only deals with its provincial counterparts and does not handle individual claimants within each province.

Each province is responsible for submitting claims to the federal program. It is reimbursed if the cost exceeds a specific provincial threshold and the claim meets specific rules. Refer to the section *Proportion of loss DFAA covers* below for an explanation of the cost thresholds.

For each province, natural disaster relief payments are based on two sets of rules: federal rules (i.e. DFAA) and those set out by the province. The DFAA will only pay out according to the federal rules; the individual provincial rules can follow the federal rules, add further restrictions or be more generous.

Rules do vary from province to province. For example, Alberta covers 100% of primary residence damage, British Columbia covers only 80% of damage up to a total claim of $300,000, while Ontario requires that a disaster relief fund be created; it will match donations at a ratio of two to one.[21,22]

It is important to note that the DFAA does not cover expenses where "insurance coverage for a specific hazard for the individual, family, small business owner or farmer was available in the area at reasonable cost."[23] Consequently, DFAA coverage for individuals only applies to damage caused by overland flooding since reasonable cost insurance is available for the other perils (wind, hail, and winter storms). Box 2-1 provides an explanation of the different types of flooding. See below for a description of flood insurance in Canada.

In a simplified and abbreviated description, the federal DFAA program covers costs associated with:

1. the immediate disaster period such as rescue, transportation, shelter, health, food, and security;

2. the post disaster period for individuals such as damage to primary residences (not cottages), replacement of essential furnishing and clothing and assistance to small owner operated businesses, and;[24]

3. the cost of repairing public infrastructure such as roads, bridges, buildings, and sewer and water utilities.

Box 2-1: Different types of flooding

Not all flooding is the same. There are two broad categories of flooding: sewer backup and overland flooding.

Flooding caused by sewer backup is self-explanatory; it is flooding that occurs when an excess of flow through the sewer backs up into the basement of the home. Overland flooding occurs when water flows over the property and enters the home.

Overland flooding can be caused by storm surge, tidal wave, riverine, groundwater, ice jam or pluvial flooding.

Storm surge flooding occurs when high winds drive water inland from a large body of water.

Tidal wave flooding occurs when there has been an earthquake offshore causing a large wall of water (also known as tsunami) to come ashore.

Riverine flooding occurs when there is too much water flowing through a river or creek (the result of either rainfall or spring snowmelt runoff) such that it overflows it banks.

Groundwater flooding occurs when the water table rises above the ground level and flows into the property.

Ice jam flooding occurs in the spring when river ice breaks up and gets jammed in the river causing the river to back up and flood.

Pluvial flooding occurs when rainfall is so heavy that the drainage system cannot handle the volume and water starts to run overland. In an urban environment this occurs when the storm sewer system cannot handle the water volume. In rural environments this is generally caused by heavy rains on frozen ground such that the water flows overland rather than being absorbed. Snowmelt on frozen ground can also cause similar flooding.

Frequently, pluvial and riverine flooding occurs at the same time as sewer backup. See section 2.2 below for a discussion on how the insurance industry handles this from a coverage point of view.

Proportion of loss DFAA covers

A province or territory may request Government of Canada disaster financial assistance when eligible expenditures exceed an established initial threshold based on provincial or territorial population. The DFAA program reimburses provinces on a cost-share basis that changes as the cost increases. The thresholds for the payout proportion, which had been unchanged since 1970, were updated for the first time as of February 1, 2015. Annual inflation indexing of the thresholds was instituted at the same time.

When the DFAA program was established in 1970, it paid assistance according to Table 2-1 below. The threshold changes that took effect on February 1, 2015 are shown in Table 2-2 below.

Table 2-1   **DFAA assistance before February 1, 2015**

Expenditure per capita of provincial population	Federal share	Provincial share
$0 to $1	0%	100%
$1 to $3	50%	50%
$3 to $5	75%	25%
$5 plus	90%	10%

Source: Public Safety Canada.

For disasters greater than the maximum threshold, the province and federal government effectively share equally the cost up to the fourth threshold; from that point, the 10/90 split kicks in. For example, under the new plan, a province with a population of one million and a claim greater than $15 million would split equally the first $15 million in costs with the federal government; the federal government pays 90 per cent of the cost above $15 million.

Table 2-2   **DFAA assistance as of February 1, 2015**

Expenditure per capita of provincial population	Federal share	Provincial share
$0 to $3	0%	100%
$3 to $9	50%	50%
$9 to $15	75%	25%
$15 plus	90%	10%

Source: Public Safety Canada.

In order to estimate the material impact of the threshold changes going forward, PBO calculated the percentage difference between the previous payout thresholds and new ones using historical DFAA payments. The previous DFAA payouts for the period 2005-2014 were inflated to 2014 values using nominal GDP, then recalculated using the new payout thresholds.

With the new payout threshold, the DFAA will pay on average 9 per cent less for the same set of events. The difference is not substantial because large payout events dominate the overall total payout.

Therefore, even though a number of smaller events would no longer receive funds and each event would receive less, overall it does not make a large fiscal difference. For example, for a province with a population of one million

and a claim of $200 million, DFAA would pay $174 million versus $178 million, compared with the previous program.

Using the new payout thresholds, PBO determined that 35 of the 118 events in the 2005-2014 period would have had their DFAA payments reduced by 50 percent or more, with 11 events no longer receiving any DFAA funds. As an example, there was a spring flood in Bridgeport, Nova Scotia in May 2005 that received $510,000 from the DFAA that would receive $0 using the new thresholds.

Since the purpose of this report is to estimate the future average annual cost of the DFAA program in 2014 dollars, all past DFAA expenditures were converted using the following three steps:

1. The payment was increased to include the provincial share of the total according to the rules as shown in Table 2-1 above;

2. This value was then adjusted to 2014 nominal GDP using the method described in Appendix B section B.1 (i.e. using nominal GDP by province);

3. Lastly, the federal DFAA payment portion was recalculated using the rules as shown in Table 2-2 above.

2.2. Flood insurance in Canada

For an overview of insurance in general in Canada, refer to Box 2-2.

Box 2-2: Insurance in Canada

Because DFAA does not compensate claimants if insurance is available at reasonable cost, it is important to review what type of insurance is available to protect against these weather events, and how the industry provides it.

At a high-level, the insurance industry in Canada consists of six different players, each with a different responsibility. The six basic entity types are the Insurance Bureau of Canada (IBC), insurance companies, insurance brokers, reinsurance companies, reinsurance brokers, and catastrophe modeling firms. A brief description of each player is provided below.

From the IBC website: "IBC is the national trade association for the companies that insure the homes, cars and businesses of Canadians."[25] As such, IBC represents the insurance industry as a whole in Canada.

An insurance company is a firm that offers policies "in which an individual or entity receives financial protection or reimbursement against losses".[26] By pooling together multiple policies, the insurance company is able to reduce the cost of the individual policies.

Insurance brokers do not work for a particular insurance company, but rather work with the customer to find the best insurance policy from a range of insurance companies.

Reinsurance companies, for a fee paid by the insurance company, agree to assume a portion of the insurance company's risk. By purchasing reinsurance, an insurance company reduces its capital at risk, thereby allowing it to sell more insurance contracts. In addition to the placement of reinsurance as a method of risk transfer, Insurance-Linked Securities (ILS) and Insurance-Linked Warranties (ILW) are important elements of the insurance industry. Catastrophe bonds are an ILS that is sold by insurers and reinsurers to diversify their risk. These offer higher interest rates, but the investor loses the original investment (the bond) if the natural disaster for which the bond is sold occurs.

Box 2-2: Insurance in Canada (continued)

Reinsurance brokers are similar to insurance brokers but work as
intermediaries between insurers and reinsurers.

Catastrophe (Cat) modeling firms create computer models for various
types of catastrophes (hurricane, floods, convective storms such as
wind and hail, winter storms, wildfires, and earthquakes). Among
other uses, these models can estimate the likelihood of a building at
a specified location encountering a specific catastrophe and the
amount of damage the building is likely to sustain based on its
building characteristics.

Clearly, the amount of damage a building sustains depends on the
severity of the catastrophe. These models predict the likelihood of all
possible levels of severity, then estimate the average annual cost. Cat
models are commonly used throughout various segments of the
insurance industry to quantify catastrophe risk and inform
underwriting and portfolio management decisions.

Individual (i.e. private property) overland flood insurance at reasonable cost
currently does not exist in Canada. There have been some recent
announcements offering individual flood insurance. However, it is only
available in a couple of provinces, but not for properties at very high risk; nor
is it available at reasonable cost.

For example, an insurance company announced in February 2015 that it
would offer overland flood insurance in Ontario and Alberta starting in
May.[27] This flood insurance would not be available to properties deemed at
very high risk, which is about 5 per cent of properties.[28] The excluded
properties are considerably more numerous than those that are located in
existing floodplains.

According to a presentation by Conservation Ontario, about two per cent of
Ontario's population lives in a floodplain.[29] Therefore, those who own
properties that are likely to be flooded are unable to obtain flood insurance.
One company does offer insurance for high-risk properties, but the cost is
high. For $1 million in coverage of the building only (not contents) and a
deductible of $100,000, the annual premium is $18,000.[30]

Flood insurance is expensive because of "adverse selection". Only those at
greatest risk will want to purchase coverage. This differs from fire insurance
where in general, the likelihood of your property burning down is very low
and random and virtually everyone purchases fire insurance.

For fire insurance, the overall annual loss can be amortized over a large
population and the loss is quite low compared to the total value of insured
properties. On the other hand, flood insurance would have much fewer

properties and the losses would be quite high compared to the total value of insured properties. This then requires much higher premiums.

This is why in countries where flood insurance for high-risk properties is offered, either the insurance is financially backed by the government or regulations require all property insurance holders to purchase flood insurance (cross subsidization).[31]

Another consideration for flood insurance occurs when overland flooding happens at the same time as sewer backup. The current wording of insurance contracts stipulates that if both occur simultaneously, the homeowner requires overland flood insurance in order to be compensated.

This policy wording has been in place in Quebec since the Saguenay flood of 1996, but it was not yet in place for the southern Alberta flood of 2013.[32] Therefore, the private insurance industry compensation for the southern Alberta flood was considerably higher than if that same flood was to occur now. This would have entailed an even higher DFAA payout than the current total estimate of $1.338 billion. For background on the 2013 southern Alberta flood, see Box 2-3 below.

Box 2-3: Southern Alberta flood of 2013

At the time of the southern Alberta flood, there were reports that it was a storm of a lifetime and an extremely rare event.[33] Though a flood of its nature had not occurred since 1932, four similarly sized floods had occurred from 1879 to 1932.[34]

Considering that five similar floods occurred in a 134-year time span, one would expect a similar flood more frequently, that is, more than once in a lifetime. Subsequent statistical modeling has estimated the flood to occur somewhere between every 30 and 41 years, depending on the method used, but with high uncertainty due to a mixture of processes causing flooding in the region.[35]

A contributing factor to the amount of damage that occurred during the flood was that control of building on the floodplain prior to the flood was the responsibility of each municipality.[36]

Unlike Ontario's conservation authorities which have authority over their respective floodplains[37], Alberta's watershed planning and advisory councils (WPACs) have no such authority and play only an advisory role.[38]

Subsequent to the 2013 flood, the Alberta government enacted "*the Flood Recovery and Reconstruction Act, Bill 27* which restricts new construction and development projects on floodplains."[39]

The regulations associated with this bill are currently being developed; for the moment, individual municipalities still retain building decisions on their floodplains.[40] Experts have recommended creating a management agency "with the ability to oversee land-use decisions".[41]

An upcoming test of any new regulations that Alberta adopts will be the proposed new arena and complex on the bank of Bow River in downtown Calgary.[42]

Flood management in Alberta (see section 4) presents a full description of the factors that contributed to the damage losses for the 2013 flood.

3. Methodology Summary

This section provides a brief summary of the methodology which was used to estimate the average annual cost of the DFAA program for the next five years. A full description is in Appendix B.

The steps that were followed are:

1. Obtain the history of payments that the DFAA has made for events over the previous 10 years (2005-2014) to determine the total amount paid for each of the four perils. Inflate the payments to 2014 values using nominal GDP and convert the payments to the new DFAA payment rules as of February 2015.[43]

2. Obtain the insured losses and total losses from IBC, Swiss Re and DFAA where available. Otherwise, impute values when missing. Sum these total losses for each of the four perils. Inflate losses to 2014 values using nominal GDP.

3. Divide each of the DFAA total payments for each peril type (step 1) by the summation of total loss for each peril type (step 2) to get the estimate of the proportion that DFAA pays for each peril.

4. Obtain estimated future average annual insurance losses for three of the perils from Risk Management Solutions Inc. (RMS). RMS is a catastrophe modeling firm contracted by PBO to estimate the future annual losses for hurricanes, convective storms and winter storms. An estimate of future annual residential property flood loss was obtained from the Insurance Bureau of Canada (IBC).

5. Increase the RMS estimates to account for uninsured losses including public infrastructure losses. Increase the IBC estimated losses to include total commerical and public infrastructure losses. See Appendix B for further details.

6. Multiply the estimated annual loss for each peril (step 5) by the proportion that DFAA pays for each peril (step 3) to get the annual average estimated DFAA payment for each peril.

7. Add the four results from step 6 to get an estimate of the average total annual DFAA payments for the four types of weather events.

4. Results

Because of copyright issues associated with the weather event data, it is not possible to present a listing of all the weather events and their insured and total losses that were included in this analysis. A copy of all the DFAA payments can be found on PBO's website.

4.1. Estimate of average annual DFAA expenditures

As described in the previous section, all weather events from 2005 to 2014 were included in the analysis. This resulted in 118 events: 77 floods, 31 convective storms, six hurricane/tropical storms, and four winter storms. As mentioned in Appendix B, the ice storm of January 1998 was included to increase the winter storm sample size. Also, the dominant peril type assigned to each event is based on the DFAA claims payout for that event.

The results of the analysis are shown in Table 4-1 below. Over the 10-year analysis period, the total loss from floods amounted to just over $12.5 billion, the largest of all the perils. It was also by far the largest expense for the DFAA.

The winter storm payment total for the DFAA amounted to just under $1.3 billion. However, if 1998 ice storm was not included, this payment amounted to just $77 million.[44] That would make convective storms the second largest total loss at just over $7.3 billion during the decade-long period.

Table 4-1   **Cumulative losses, DFAA and insurance payments 2005 through 2014**

$ millions in 2014	Floods	Convective storms	Hurricanes	Winter storms*
DFAA	$3,465	$20	$138	$1,267**
Insurance	$4,982	$5,726	$436	$3,552
Total loss*	$12,505	$7,314	$718	$10,452
% DFAA	27.71%	0.27%	19.20%	12.12%
% by insurance	39.84%	78.29%	60.66%	33.98%

Source: PBO.
Notes: * Includes 1998 ice storm; ** $0.77 billion without 1998 ice storm and
      *** Includes amounts not covered by DFAA or insurance.

In looking at the relative proportions paid by DFAA and insurance for floods and convective storms, it is apparent which one has better insurance coverage. For floods, DFAA paid 27.7 per cent of the total loss, while

insurance paid 39.8 per cent. In contrast, DFAA paid only 0.27 per cent of total loss for convective storms compared with 78.3 per cent paid by insurance.

Even though there is not residential flood insurance, the insurance payouts for floods are as high as they are because of commercial flood insurance, as well as residential sewer backup insurance that made payments before the insurance contract wording was changed.

For example, included in the insurance payments for floods in Table 4-1 are the losses from the 2013 southern Alberta flood. As described earlier (see section 2.2 above), it is likely that these losses included higher insurance payments than would be realized in the future and in other provinces that resulted from changes to the wording of insurance contracts. Also mentioned in the same section was the recent availablity of flood insurance for certain properties that if purchased would make payments in these scenarios.

The percentage insurance coverage for hurricane losses was nearly as high as that for convective storms because, unlike flooding, wind is covered by insurance.

The RMS and IBC estimates for the average annual losses over the next five years for each of the four weather perils are shown in Table 4-2 below.[45] Hurricanes, convective storms and winter storms are for insured losses only while the IBC flood value is missing both commercial and public infrastructure losses (therefore, total residential only).

Table 4-2   **RMS and IBC estimated average annual catastrophe losses for 2016 to 2020**

$ millions	Average annual loss	Standard deviation
Hurricanes (RMS)**	$59.9	$499
Convective storms (RMS)**	$525	$470
Winter storms (RMS)**	$584	$706
Floods (IBC)***	$1,200	*

Source: RMS (See Appendix A for a disclaimer) and IBC.
Notes: *Standard deviation not available. **Only insured losses.
           ***Total economic residential loss.

The next step in the estimation is to increase the RMS estimated catastrophe losses for hurricanes, convective storms and winter storms to take into account uninsured losses and public sector losses. This is accomplished by scaling the RMS estimates using the percentage of total loss which insurance covers for each of these perils as shown in Table 4-1 above. Using hurricanes as an example, this is done by dividing the $59.9 million by 0.6066 to get $98.7 million as shown in Table 4-3 below.

The IBC flood esitmate for residential losses ($1.2B) needs to be increased to include commercial and public infrastructure losses. As shown in Table B-1 in Appendix B, residential sector losses represent an estimated 49.42 per cent of the total losses. Therefore, the estimates in Table 4-2 must be multiplied by 2.023 (that is, 1/(0.4942)) to account for public sector and commercial losses. The scaled flood value is shown in Table 4-3 below.

An estimate of DFAA's average annual payment for the next five years is obtained by multiplying the estimated DFAA event type payout ratios in Table 4-1 by the average event type estimated total economic losses in Table 4-3. The results are shown in Table 4-4 below.

Table 4-3 **Estimated average annual losses scaled to include total economic losses for 2016 to 2020**

$ millions	Scaled average annual loss
Hurricanes	$98.7
Convective storms	$671
Winter storms	$1,720
Floods	$2,430
Total	$4,920

Sources: RMS, IBC and PBO.

Table 4-4 **Estimated DFAA average annual payments for 2016 to 2020**

$ millions	Estimated DFAA average annual payments
Hurricanes	$19.0
Convective storms	$1.83
Winter storms	$208
Floods	$673
Total	$902

Sources: RMS, IBC and PBO.

The estimated annual DFAA payments for hurricanes and convective storms seem reasonable. By multiplying the values in Table 4-4 by 10 (to scale to 10 years), the results are close to the DFAA payments in Table 4-1 which are for the 10-year period 2005-2014.

In the case of winter storms, multiplying the value by 17 (1998-2014 because of the inclusion of the 1998 ice storm) results in $3.54 billion, which is three times the value in Table 4-1. Therefore the modeling predicts that winter storm losses will increase over the next five years.

For DFAA flood costs, the estimate is almost double the previous 10-year average ($673 million/year versus $347 million/year). However, the estimated DFAA annual flood loss is much closer to the previous five year average (2010-2014) of $569 million (calculation not shown). With the effects of climate change, such as extreme weather events on the Prairies (see end of next section), the previous five years might be more representative of future weather events than the previous 10 or 20 year period.

It is important to note that these annual estimated losses assume that no new mitigation measures are implemented. If such measures are implemented, it is reasonable to expect that average annual losses will be reduced.

4.2.   Analysis of historical DFAA payments

The previous section determined an estimate of the annual average costs for the next five years to the DFAA program because of weather catastrophes. This was the primary purpose of the paper.

This section analyses the DFAA historical payments to determine if there were any trends or patterns in the payments. Further analysis was then performed to determine if there were reasons for the observed trends or patterns.

The first analysis investigated how the costs have evolved over each decade since the DFAA program inception in 1970. The second analysis investigated DFAA payments based on province.

Table 4-5 and Figure 4-1 below present an historical overview of the DFAA payments for all four weather catastrophes combined, as well as separated by decade and catastrophe type. All values have been inflated to 2014 using nominal GDP. Since the program has been in place for 45 years, which is not evenly divisible by 10, the first five years are in their own group, with each subsequent decade as a group.

Table 4-5   Historical DFAA payments by catastrophe

$ millions in 2014	All years	1970-1974	1975-1984	1985-1994	1995-2004	2005-2014
Total all events	8,358	511	465	379	2,907	4,096
Total flood	6,517	458	399	263	1,595	3,803
Flood as % of total	78%	90%	86%	69%	55%	93%
Total convective	213	38	46	116	0	13
Convective as % of total	3%	7%	10%	31%	0%	0%
Total hurricane	222	15	0	0	51	156
Hurricane as % of total	3%	3%	0%	0%	2%	4%
Total winter	1,406	0	20	0	1,260	125
Winter as % of total	17%	0%	4%	0%	43%	3%

Sources: DFAA and PBO.

The results show that over the duration, floods have consistently been the largest cost. In the 1995-2004 period, the cost of floods as a percentage of the total DFAA payment fell because of the ice storm of 1998.

The 1985-1994 period was relatively quiet for weather catastrophes. A tornado in Edmonton in 1987 was the largest single event during this period. DFAA paid $20 million in 1987, which amounts to $116 million when inflated to 2014 values. This explains the jump to 31 percent for convective storms as a percentage of total payments during that period.

The next aspect investigated was an attempt to understand if any underlying factors, other than the weather, contributed to the flood losses. The DFAA payments were separated by province for all payments since its inception, as well as for the last 10 years. The results of this analysis are shown in Table 4-6 and Figure 4-2 below.

Figure 4-1 **Historical DFAA payments by catastrophe from 1970-2014**

$ millions in 2014
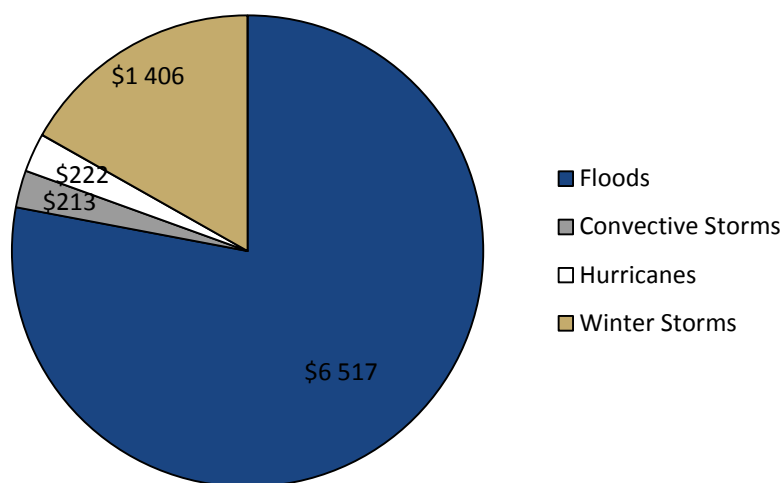
Sources: PBO and DFAA.

Table 4-6 **DFAA payments by province and territory***

$ millions in 2014

| Province	$ all years	% of total	Per capita	2005-2014	% of total	Per capita
NL	296	4%	561	174	4%	329
PE	32	0%	220	3	0%	21
NS	134	2%	143	16	0%	17
NB	269	3%	357	87	2%	115
QC	2,062	25%	251	166	4%	20
ON	387	5%	28	125	3%	9
MB	1,505	18%	1,174	767	19%	598
SK	914	11%	812	812	20%	722
AB	2,325	28%	564	1,758	43%	427
BC	391	5%	84	162	4%	35
NT	9	0%	200	6	0%	131
YT	25	0%	693	12	0%	332

Sources: DFAA and PBO.
Notes: Per capita is based on 2014 population.
*Nunavut isn't included in this analysis since it was only created in 1999 and only has had one event ($5.3 million flood in 2008)

Figure 4-2   **DFAA payments by province and territory* from 1970-2014**

$ millions in 2014
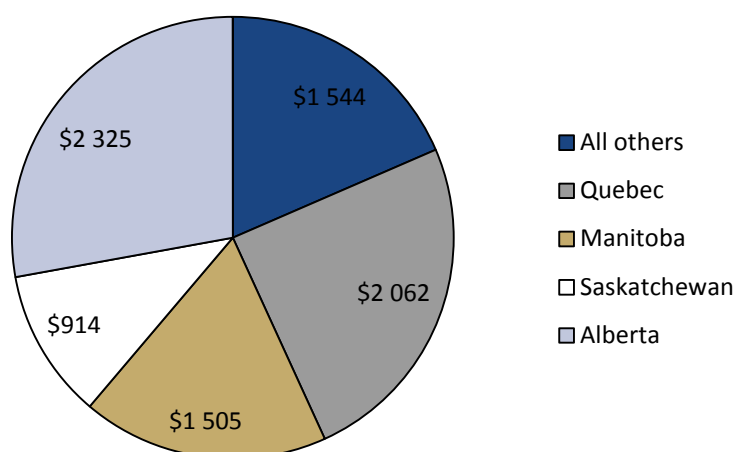
Sources: PBO and DFAA.
Note: *Nunavut isn't included

In Table 4-6, some trends do appear. Over the 45-year history of the DFAA program, a majority of the provinces and territories have exhibited a consistent, relatively low use of the program. These were: Newfoundland and Labrador, Prince Edward Island, Nova Scotia, New Brunswick, Ontario, British Columbia, Northwest Territories, and Yukon.

In contrast, the Prairie Provinces (Manitoba, Saskatchewan, and Alberta) have exhibited consistently high use of the program. In the case of Saskatchewan and Alberta, their use has proportionally increased over the past 10 years because of a number of large flood events; Manitoba's use has remained relatively constant.

Like Alberta and Saskatchewan, the overwhelming majority of Manitoba's claims were due to floods. Prior to 2005, Quebec's use had been quite high as a result of the 1996 Saguenay flood and the 1998 ice storm.

What was behind the consistently high use of the program by the Prairie Provinces? PBO interviewed various stakeholders in each of the Prairie Provinces, as well as in Ontario, to determine if any differences other than the weather could have contributed to the high DFAA use.

The primary finding is that floodplain regulatory environments in each of the Prairie Provinces were markedly different than that in Ontario. Flood management practices for the four provinces (Ontario, Manitoba, Saskatchewan, and Alberta) are discussed in the following four sections.

Flood management in Ontario

From a regulatory perspective, Ontario is considerably different from the Prairie Provinces. Ontario has conservation authorities that are responsible for 36 different watersheds encompassing 90 per cent of Ontario's population.[46] Because of the extreme damage and 81 deaths caused by Hurricane Hazel in and around Toronto in 1954, Ontario's conservation authorities subsequently mapped and prohibited construction in Ontario's flood zones.[47]

For determining flood zones, Ontario uses either a one in 100-year magnitude flood or the highest observed flood for the area, whichever is greater.[48] For most of southwestern Ontario, Hurricane Hazel is the standard and for northeastern Ontario, it is the Timmins' flood of 1961.[49]

Both Hurricane Hazel and the Timmins flood are considered to be greater than 200-year events.[50] As the conservation authorities are responsible for floodplain management, municipalities do not have responsibility for building decisions on floodplains within their boundaries.

Flood management in Manitoba

In Manitoba, the Red River flood of 1950 prompted the creation of the Red River flood control project of which the Red River Floodway around Winnipeg is the most well-known feature.[51] Because of the 1997 flood, a floodway expansion was completed in 2010, enabling it to withstand an estimated one-in-700 year flood.[52]

The Red River Flood zone, which includes Winnipeg, is the only flood zone within Manitoba that has strict and enforced building regulations similar to that of Ontario's conservation authorities. For the remainder of the province, each municipality is responsible for its own regulation and enforcement. This results in less consistent floodplain management because of a lack of enforcement with respect to such projects as new construction in areas with flood risk.[53]

An important recommendation from the task force that investigated the 2011 flood supports this view. It read: "Implement clear policy measures to ensure future development does not knowingly occur on land subject to flooding without appropriate mitigation".[54]

Flood management in Saskatchewan

Saskatchewan has some similar and some different issues to those of Manitoba. Like Manitoba, Saskatchewan's regulatory environment is inconsistent.

Up until 2013, all municipalities retained control of regulation and enforcement of construction on the floodplain within their jurisdiction. In

2013, floodplain regulation and control for rural municipalities were taken over by the province, although urban municipalities are still responsible for their floodplain management.

Another issue affecting Saskatchewan is that a vast majority of the southern half of the province is imperfectly drained (technically known as non-contributing).[55] Non-contributing means that water from the land does "not normally contribute runoff to streamflow."[56] Therefore, the water stays on the land and does not drain away into the river system. This non-draining is what creates the wetlands and sloughs for which Saskatchewan is famous.

In an effort to increase farmland and productivity, wetland drainage in Saskatchewan has been extensive. This wetland drainage has had an effect on flooding. It is estimated that the wetland drainage from 1958-2008 increased the 2011 flood peak by 32 per cent and the 2011 yearly streamflow volume by 29 per cent.[57]

Since 2008, wetland drainage has accelerated in Saskatchewan. Though there has been a policy in place to license wetland drainage, it does not seem to have been effectively enforced; there are an estimated 200,000 unlicensed drainage changes.[58] Increased drainage raises peak flood volumes as well as yearly streamflow volumes.

It is estimated that complete drainage of existing wetlands would have increased the 2011 flood peak by 78 per cent and the 2011 yearly volume of streamflow by 32 per cent.[59]

When drainage changes are unlicensed, they are likely not managed by the rural municipalities. Managed drainage changes can have culvert gates that can be closed during periods of high run off (either snow melt and/or heavy rain), thereby reducing flood peaks in streams and rivers.[60] The compensation cost of flooding agricultural land is considerably less expensive than flooding residential areas.[61]

From a DFAA perspective, if unlicensed drainage is increasing the peak volumes of floods, it is possible that these peaks will be above historical flood levels so that the damages will be eligible for DFAA payments. The DFAA will make payments to damages that occur outside the documented floodplain.

One final consideration for Saskatchewan flooding is the management of its reservoirs. An example of this is Lake Diefenbaker, which was created by the building of the Gardiner and the Qu'Appelle Dams on the South Saskatchewan River. Depending on how the level of the reservoir is managed, it can influence the duration and area of the flooding downstream from the dams as was found in the floods of 2005, 2011 and 2103.[62]

Key to managing reservoir levels is the prediction of inflows, which today is based on historical precipitation data.[63] Given the greater variability in the

weather, it is argued that probabilistic weather models, using medium term weather and snowmelt forecasts, would give a better prediction of inflows, resulting in better reservoir management.[64]

Flood management in Alberta

Over time, each province appears to have an event that changes how it manages floods. For Ontario, it was Hurricane Hazel in 1954. For Manitoba, it was the Red River flood of 1950 and, to a lesser extent, the Red River flood of 1997. Alberta's event could be the southern Alberta flood of 2013.

Unfortunately for Alberta, the big flood occurred much further along in the province's economic development than in either Ontario or Manitoba, so that much more development had occurred in flood-prone areas.

As previously discussed in Box 2-3 above, there are two primary issues affecting floodplain management in Alberta: seeminly inaccurate flood maps and inconsistent regulation/enforcement.

Since the DFAA makes payments based on whether a property is in a designated floodplain, it is important that floodplain maps accurately represent the floodplain.

The floodplain designation in Alberta is supposed to represent the one-in-100-year flood (also known as a 1 per cent risk or a return period of 100 years).[65] The 2013 Alberta flood was somewhere between a one-in-30 and one-in-41-year flood [66], yet neighbourhoods in Calgary which were supposedly outside the designated floodplain (one-in-100-year), such as the neighborhood of Bowness, still flooded. [67] This seems to indicate that the existing floodplain maps are not accurate.

When considering floodplain designation, the choice of the return period, 100-year, 200-year or higher, clearly affects the likelihood of a building getting flooded. A building constructed at the 200-year floodplain boundary is less likely to get flooded than one built at the 100-year floodplain boundary.

A 100-year threshold is considered to be the lowest level of protection[68] and results in a likelihood of 63 per cent of that size of flood occurring in 100 years. A 200-year threshold reduces the likelihood to 39 per cent in 100 years.

Although Alberta currently follows a 100-year floodplain protection level, most urban areas in Canada use a 200-year return period.[69] For example, British Columbia follows a 200-year protection level[70], Saskatchewan has a 500-year standard[71], while Ontario follows the worst storm of record or the predicted 100-year level.[72]

As described earlier, for Toronto and a large part of southern Ontario, Hurricane Hazel is the criteria; it is considered greater than 200-year protection.[73] In addition, Manitoba has selected 700-year protection for the Red River through Winnipeg.[74]

From a regulation and enforcement perspective, after the 2005 flood, a provincial legislature committee did make a number of recommendations, which were published in the Groeneveld (2006) report. Unfortunately, the report wasn't released until 2012, which was too late for any actions to be taken prior to the 2013 flood.[75]

Among other things, the report recommended updating flood maps, prohibiting the sale of Crown lands in designated floodplains. It is also recommended that "Flood Risk Management Guidelines for Location of New Facilities Funded By Alberta Infrastructure" be followed for provincially-funded new facilities.[76] If the recommendations of this report had been acted upon, the damage from the 2013 flood would have been reduced.[77]

Yet another consideration is the effect that groundwater can have during a flood. Groundwater flooding can cause significant damage to basements located close to rivers.[78] Unfortunately, levees and berms do not stop groundwater from entering buildings behind them.[79]

During the 2013 flood, ground-water flooding did occur behind berms in Canmore and other communities.[80] Alberta currently does not take this type of flooding into account.[81] This likely increases DFAA payments since homes behind berms or levees are considered to be protected.

One last contributor to damage costs for the 2013 flood was debris floods. These occur on steep creeks in the mountains after a heavy rain or a failed dam. The high volume of water picks up trees, rocks, and other sediment, increasing the level of damage.[82] The analysis of debris floods is different than that of water floods (also known as clearwater floods) because they are more closely related to landslides than floods.

During the 2013 flood, debris floods were estimated to have caused $100 million in damage.[83] One example was Cougar Creek, which flows into the Bow River at Canmore. The Cougar Creek debris flood resulted in the closure of Highway 1[84] plus substantial bank erosion that endangered homes along the creek and in the path of the debris flood.[85]

The risks of debris floods need to be accounted for in land-use planning, in addition to only clearwater flooding, in order to reduce damage claims during extreme rain events.[86]

Co-ordinated flood management

Research has shown that an area-wide coordinated response to flood management works more effectively than at a local level.[87] Currently, Alberta

does not have a co-ordinated watershed planning authority,[88] which has reduced damages from floods in other jurisdictions, for example Conservation Ontario.

Furthermore, successful flood management for water that flows between provinces, states or countries requires management at a level that encompasses all the affected regions.[89]

The South Saskatchewan River flows from Alberta to Saskatchewan then to Manitoba. Each province manages its section of the river separately. Currently there is no agreement among the provinces to share costs if it makes more sense to flood farmland in one province to protect buildings in another.[90]

This lack of overall coordination results in higher damage costs. In the United States, co-ordination between states has proven successful in reducing damage.[91]

General mitigation

Another factor that would reduce DFAA payments is mitigation. This includes the previously discussed topics of accurate floodplain maps combined with regulation and enforcement.

Mitigation also includes floodways, reservoirs, and specific building codes for buildings built on the floodplain. For example, a common sight in the Mississippi delta is houses built on stilts; when a flood occurs, the homes are not affected.

The parallel has been made between disaster damage reduction now and the fire reduction in the mid-20th century. In the early 1900s, there were major fires in Canada's large cities. By the adoption of new building codes, large urban fires no longer occur.

Adopting the same approach for natural disasters as was followed for fires in the last century would reduce damage costs. [92]

Flood forecasting

Flood forecasting is another type of mitigation. By providing advanced warning of an impending flood, allows measures to be taken, such as sandbagging, reservoir management, and evacuations, that reduce damages and injuries. In the case of the 2013 southern Alberta flood, the flood warning for some areas occurred after they had been flooded.[93] Better flood forecasting is possible. As it turns out, the southern Alberta flood of 2013 was predicted 10 days in advance by the European Centre for Medium Range Weather Forecasts.[94] The Centre did not communicate the warnings "to officials in Alberta because there was no formal network in place to circulate alerts".[95]

Effects of Climate Change

One last factor, which is likely affecting the intensity of floods in the Prairie Provinces, is climate change. The warming in the arctic has been associated with persistent weather systems in the mid-latitudes[96] as well as extreme weather events[97]. Consistent with this, multiple-day rain events have significantly increased in the Prairie Provinces[98] and in the Rockies.[99] The recent record setting multiple-day rainfalls in south-eastern Saskatchewan in 2010 and 2014 are likely examples.[100]

Appendix A: RMS Disclaimer

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Appendix B: Detailed Methodology

This appendix provides the detailed methodology that was used to determine the estimated annual costs of weather events for the next five years for the DFAA.

To estimate the expected average annual cost of the DFAA program because of weather events, two pieces of information are required:

1. an estimate of DFAA's average percentage contribution to the losses from each of the four weather perils (hurricanes, convective storms, winter storms, and floods), and;

2. an estimate of the average annual total loss resulting from these four weather perils.

Before performing these two estimations, it is necessary to inflate the historical catastrophe costs used in the estimates to current values. As explained in the following section, it is not accurate to inflate catastrophe costs by the Consumer Price Index (CPI).

The section on inflating historical costs is followed by sections describing the methodology used to estimate the percentage of DFAA's contribution to each type of catastrophe and the estimated annual loss by each catastrophe respectively.

B.1   Inflating using nominal GDP

To compare the costs of weather catastrophes from different years, it is necessary to convert the losses to current year dollars. Typically, the change in the CPI would be used to achieve this since it captures general inflation. For the case of losses resulting from natural disasters, inflation is not the only contributor to increased losses. There are two additional factors.

The first is population growth. If the same disaster hits an area at two different times and the population has increased, more people will be affected. As a result, losses will be greater.

The second factor is the increase in the standard of living. As real GDP per capita increases, people purchase more goods and assets, such as larger houses. This increases the losses in a natural disaster.

Real GDP captures increases in production resulting from population growth, as well as increases in productivity, while it excludes increases from inflation. Nominal GDP includes both real GDP and inflation.

So to recap, nominal GDP is a good inflator for disaster losses since it captures the effects of inflation, population growth, and accumulation of individual assets over time. Furthermore, by adjusting this way any change in the costs of weather catastrophes reflect the change in the frequency or the intensity of weather events.

Using nominal GDP assumes that the rise in the value of assets is the same in both urban and rural areas. This is not likely to be the case, as Canada's large urban municipalities grow at a faster rate than the rural ones. Nevertheless, since the largest losses generally occur in urban areas, this assumption is unlikely to skew the overall results.

Based on the province the catastrophe occurred in, Statistics Canada data for expenditure-based, province specific nominal GDP were used to convert the event costs to 2014 values.

B.2   Estimating the proportion that DFAA pays

As is shown in the results section, it is important to separate out DFAA's contribution based on each of the four weather perils since the proportion it pays varies significantly based on the peril.

To estimate the proportion that DFAA contributes for each weather event, it is necessary to obtain an historical record of the total losses for each weather event and the payments DFAA made for them. PBO obtained a complete history of DFAA's payments since its creation from Public Safety Canada.

Obtaining the total losses for each of the events was more challenging since Public Safety did not track this information. Several possible sources for total loss information were investigated.

One option was Property Claim Services (PCS), a subsidiary of Verisk Analytics Inc.[101] PCS has been operating in Canada since 2009 and tracks the total insurance losses for each natural disaster. There were two issues with using PCS data: it only covered six years and it did not have total losses, only total insurance losses.

Another option was using the Swiss Re Sigma annual reports on the cost of natural catastrophes and man-made disasters in the world.[102] Only 10 years of these Sigma reports were available; however, 10 years contained a sufficient number of events to perform the estimation.

Unlike the PCS loss reports, Swiss Re in most cases reported both the insurance loss as well as the total loss. Therefore, the analysis for this report covered the 10-year period from 2005 through 2014. The one exception to this was the inclusion of the ice storm of 1998. This was because there are very few winter storms in the dataset (only four including the 1998 ice storm).

The one issue with the Swiss Re data was that the reports covered catastrophes for the whole world and therefore used a cut-off of about $50 million for an event to be listed. As a result, smaller events were not included. On average, three Canadian events were missing each year.

PBO was able to obtain insured loss values for most of these missing events by using a table of historical catastrophe insurance losses that IBC had given to the PBO for a previous project. The IBC data had 25 events that were not in the Swiss Re reports.

The IBC data covered events from 1983 to mid-2013. Like the PCS data, the IBC data had insurance losses but not total losses. Furthermore, even though the IBC data listed all events from 1983 on, some loss values from 2009 on were not provided (though the event date and type were provided) because of data copyright restrictions.

A total of eight events were missing from Swiss Re (because of the $50 million cutoff) for which IBC did not have insured loss values (due to post-2008 data copyright). For these events, the missing loss values were imputed using the averages of the missing Swiss Re events for which IBC did have insured loss values. In 2014 dollars, the average insured loss for these missing smaller floods and convective storms was $47 million and $46 million, respectively.

Since IBC publishes total annual catastrophe losses in media releases each year, it was possible to validate the resulting yearly total of insurance losses that contained imputed values. There were three years that required imputed insurance loss values (2009, 2010, and 2013). For two of these three years (2010 and 2013) IBC had published total losses due to severe weather.

The PBO yearly totals containing imputed values were on average only 1% higher than the published IBC yearly totals. This small difference provided confidence in the imputation methodology.

For those events where IBC and Swiss Re both had values, the values were not always the same. In these cases, the averages of the two values were used.

For the 25 events that Swiss Re did not have (17 where IBC had insured losses and eight that were imputed) plus other events where Swiss Re or DFAA did not have total losses (only insured losses), it was then necessary to impute the total loss. Total losses are higher than insured losses. In any catastrophe, insurance does not cover all losses. There are several reasons for this:

1. Some people do not have insurance.
2. There are insurance deductibles that the insured has to pay.
3. There is not insurance for some perils, for example, residential flooding.

4. Some people are underinsured such that their insurance does not cover all their losses.

5. Damage to public infrastructure (roads, bridges, schools, public buildings, etc.) is not covered by insurance since public infrastructure is self-insured.

The missing total losses were imputed by scaling each event's insured loss. A separate scalar was developed for floods and convective storms, since floods have a greater uninsured amount that is partly due to the lack of flood insurance. The scalars were created by taking the average percentage increase for those events that had both an insured and a total loss value.

For floods, eight total loss values were imputed using the average of nine flood events that had both an insured loss and a total loss. The three largest flood events were not used in the scalar calculation, since the ratio of insured loss to total loss is much higher for larger than smaller floods, and it was smaller floods that required total loss imputing. The average increase of total loss over the insured loss for floods was 51%.

For convective storms, total losses for 20 events were imputed using the average of the nine convective storm events that had both an insured loss and a total loss. There were no exceptionally large convective storm events and the individual ratios were less variable than those for flooding were. The average increase of total loss over the insured loss for convective storms was 30 per cent.

There were also hurricane and winter storm events that required imputation to obtain total losses. Since there were very few events for either peril that could be used to derive a scalar (three for hurricanes and two for winter storms), the scalars developed for floods and convective storms were used.

In the case of hurricanes, the flood scalar was used, since the rain and storm surge portion of hurricanes is closer to that of floods. For winter storms, the convective storm scalar was used since much of the smaller winter storm damage (only small winter storms needed total loss imputing) is covered by insurance similar to that of convective storms.

There are many instances in the dataset where insurance makes payments for an event and there is no DFAA payment. These entailed 42 events: 11 floods, 27 convective storms, two hurricanes, and two winter storms.

Conversely, there are many instances where the DFAA makes payments and the insurance industry does not record any losses. These entailed 49 events: 44 floods, one convective storm, four hurricanes, and no winter storms.

For the events where there were only DFAA payments and no insurance payments on record, the total loss was assumed to be the federal DFAA payment plus the provincial DFAA payment. The provincial payment was calculated using the formula presented in Table 2-1 above.

As described in section B.3 below, the insurance industry when developing insurance loss models separates out the flood loss portion of hurricanes and convective storms and assigns it to flood losses. For example, for a tornado that is accompanied by flash flooding, the cost of the tornado damage is assigned to the convective storm costs and the flash flooding damage is assigned to flooding costs.

Unfortunately, the insurance industry and the DFAA in their payment data do not separate out which portion is for flooding and which portion is for other damage (for example, wind and hail). Given this, it was necessary to determine on an event-by-event basis whether flooding or the type of weather event (convective storm, hurricane, or winter storm) was the largest contributor to the overall damage cost (not on an individual property basis).

The largest contributor was then assigned the total cost. Determining the largest cost contributor was accomplished by reading the brief IBC event description, Swiss Re description, and/or the DFAA event description, whichever were available.

B.3   Estimating annual average peril total loss

PBO investigated two potential methods for estimating the average annual total losses for the four perils:

1.   tail matching, and;
2.   catastrophe modeling.

Tail matching

Tail matching uses the knowledge that catastrophes are "fat tailed". This term means that the likelihood of a large and expensive event occurring is not normally distributed in such a fashion that large events are more likely to occur than a normal distribution would predict.

If there were enough large event data points, it would be possible to fit a Pareto distribution to the tail that could then be used to determine an average total loss. Unfortunately, there are not enough data points available to accurately model the tail; as a result, this method could not be used.

Catastrophe modeling

Since tail matching was not a viable option, catastrophe modeling was chosen. PBO obtained an estimate of future average annual insurance losses in Canada for hurricanes, convective storms, and winter storms based on Canadian specifc models from Risk Management Solutions (RMS).[103] PBO obtained an estimate of future annual total residential flood losses from the

Insurance Bureau of Canada (IBC) that came from a Canadian specific flood model.

Probabilistic catastrophe modeling as a concept has been around since the late 1960s. However, it did not become commercially available until the late 1980s as computing power increased sufficiently to support it.[104] Figure B-1 below illustrates the modules that make up a catastrophe model. A brief explanation of each of the modules follows. The following diagram and accompanying descriptions are from a document by Muir-Wood (2012).

Figure B-1   **Probabilistic Catastrophe Model Components**
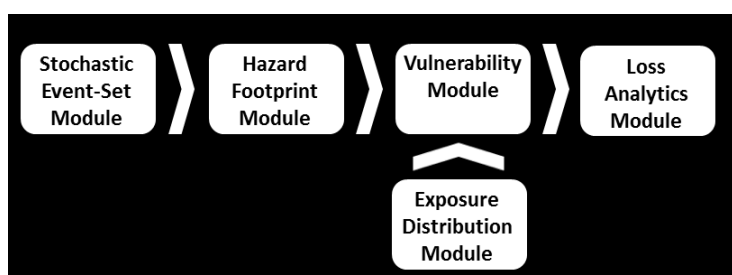
Source: (Muir-Wood, 2012).

The stochastic event-set module provides the set of all possible events weighted by their likelihood of occurrence (for example, all possible hurricanes and their track paths). Weighting is accomplished by how frequently the event occurs within the dataset.

The hazard footprint module provides the detailed map of the event along with the strength of the effect at every location. For a hurricane, this would be the various wind speeds along the hurricane's path, taking into account that wind speeds would be higher at the centre and lower toward the edges. For floods, this would be the water level at all points.

The exposure module is a detailed inventory of all the buildings and their location in the path of the event. For each building, there is information on its size and type of construction. Exposure modules can also contain infrastructure such as roads, bridges, culverts, and underpasses.

The vulnerability module defines how much each item in the exposure module is affected by the hazard. For example, for a building this would be the amount of damage expected at various wind speeds, and water levels, or at different levels of shaking.

The loss analytics module takes the output of the vulnerability and exposure modules for all the events in the stochastic event-set module to generate the estimated average annual loss.

IBC flood modelling details

IBC contracted JBA Risk Management to create Canadian specific flood extent and flood risk models, accounting for both riverine and pluvial flood risk using current geospatial and climatic data. The data enabled modeling at the property level. This is the equivalent of the hazard footprint and stochastic event-set in Figure B-1 above. The lower bound for flood events was a frequency of one in 20 years. IBC then had LexisNexis Risk Solutions run the analysis using exposure data (building replacement cost) from Brookfield RPS. The flood model assumes current rainfall and climate data and uses asset values as of the second quarter 2015. The model did not include potential increases due to climate change. The estimate only includes residential stock and therefore needed to be increased to account for both commercial buildings and public infrastructure. This is explained below in the section titled "Scaling modelled estimates".

RMS modelling details

RMS offers probabilistic models in Canada for three of the four weather perils that PBO required. RMS models hurricanes, winter storms and convective storms in Canada, but have not yet produced a Canadian Flood model.[105]

The estimated loss outputs of the hurricane, winter storm and convective storm probabilistic models separate out the losses due to flooding on a sub-peril basis. For example, when a weather event such as a hurricane or a convective storm has a rain component that causes flooding in addition to its other damaging elements (for example, wind for a hurricane, hail and wind for a convective storm), the catastrophe model utilizes hazard defined by sub-peril type to quantify costs due to flooding separate from the primary peril.

As previously described in section B.2 above, this has to be taken into account when classifying an event as a flood, convective storm or hurricane. The event is assigned to the peril that caused the most damage.

The RMS view of hurricane risk in North America considers a medium term perspective which emphasizes the five-year forecast horizon. The RMS North Atlantic Hurricane model also provides for post loss amplification that accounts for the increase in rebuilding costs following a catastrophe. For example, rebuilding costs increase as a result of the surge in local demand with many reconstructions happening simultaneously.

Similar to that of the IBC estimates, the RMS estimates need to be scaled as well. Specifically, the hurricane, winter storm and convective storm estimates are based on existing insurance penetration rates and therefore need to be scaled to account for full insurance penetration as well as public infrastructure (final number equalling full economic loss). The following

section explains how the estimates were scaled to account for total economic losses.

Scaling modelled estimates

The method for estimating DFAA's annual payments is based on the percentage which it has historically paid of the total economic loss. Total economic loss represents the total financial loss caused by a catastrophe and includes all residential, commercial and public infrastructure losses (both insured and uninsured). As mentioned above, the modelled estimates from both IBC and RMS need to be scaled up to account for total economic loss.

Since the IBC flood estimate only included total residential loss, it had to be scaled to account for both commercial and public infrastructure loss.

PBO was unable to find any rules of thumb used by the insurance industry to account for commercial and public infrastructure losses. In the absence of any insurance industry guidelines, it was decided that the IBC flood loss estimate would be increased by the proportion of public sector and commercial fixed assets in the overall economy.

The proportion of government and commercial fixed assets to total fixed assets (government + industrial + residential) was determined using Statistics Canada tables (table 031-0008 fixed residential capital and table 031-0006 fixed non-residential capital).[106]

The categories of health care and social assistance, educational services, and government sector were included as public infrastructure. Values assigned to intellectual property products were not included in the totals.

The results are shown in Table B-1 below. Public sector fixed assets represent 13 percent and commercial (industry) represent 38 percent of Canada's total assets. The IBC annual loss estimate for floods was increased by 100.2 percent (that is, 1/(1-0.5058) to account for these additional losses. This assumes that public and commercial infrastructure are equally likely to get damaged as residential infrastructure.

Table B-1   Proportion of public sector fixed assets

$ millions	Public sector	Industry	Residential
Asset value	$490,109	$1,450,849	$1,896,573
% of total	13%	38%	49%

Sources: Statistics Canada and PBO.

Since the RMS hurricane, winter storm and convective storm loss estimates assume current insurance penetration, it is then possible to scale them to total economic loss by using the proportion of the total economic loss which insurance has historically paid for each of these catastrophes (see Table 4-1).

Therefore, from table 4-1, the convective storm estimate was scaled by dividing by 0.7829, the hurricane estimate was scaled by dividing by 0.6066 and the winter storm estimate was scaled by dividing by 0.3398.

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Notes

1. Public Safety Canada (2015a).

2. Public Safety Canada (2015b).

3. The estimated annual total losses in this table are based on data from RMS and are subject to the disclaimer in Appendix A.

4. Exceptions are Winnipeg and the Red River floodway and in 2013, the Saskatchewan provincial government took control of flood plain management for its rural municipalities.

5. Shrubsole (2000), Kovacs and Sandink (2013), Manitoba 2011 Flood Review Task Force Report (2013).

6. The estimated annual total losses in this table are based on data from RMS and are subject to the disclaimer in Appendix A.

7. PBO sources.

8. Pomeroy, Shook, Fang, Dumanski, Westbrook and Brown (2014).

9. Pomeroy, Stewart and Whitfield (2015), Ferguson (2015), Alberta Environment and Parks (2015a).

10. Buttle, Allen, Caissie, Davison, Maske, Peters, Pomeroy, Simonovic, St-Hilarie and Whitfield (2015), WaterSMART Solutions Ltd. (2014).

11. Jakob, Clague and Church (2015), Pomeroy, Stewart and Whitfield (ibid.), Franklin and Schmidt (2013), Jakob (2014).

12. Jakob and Holm (2013), Pomeroy, Stewart and Whitfield (2015), WaterSMART Solutions Ltd. (2014).

13. Parliament of Canada Act (2007).

14. Wildfire models exist for parts of the United States (e.g. California).

15. Cost here refers to the sum of the payments due to all weather events that occurred in a particular year. The actual payments to provinces can occur several years after the actual event.

16. Refer to section B.1 for a discussion on why nominal GDP is an appropriate inflator for insurance costs.

17. Some of the values included in the 2005 to 2014 average are estimates since all costs and their eligibility for some events have not been determined.

18. The flood originated in the mountain headwaters of the Elk, Bow, Red Deer, Oldman river basins – the last three basins combine to form the South Saskatchewan River basin and flood damage extended along this river to Manitoba.

19. All expected DFAA costs are from the DFAA's internal accounts and are in current year dollars.

20. Public Safety Canada (2015c).

21. KPMG (2012).

22. On August 17, 2015, Ontario announced that it would be changing its disaster assistance program in early 2016 removing the donations requirement. Ministry of Municipal Affairs and Housing (2015).

23. Public Safety Canada (2015d) p. 14.

24. While flood insurance coverage at reasonable rates does not exist for private homes, it is available for commercial buildings.

25. Insurance Bureau of Canada (2015b).

26. (I) Investopedia (2015).

27. Nelson (2015).

28. Ibid.

29. Pearson (2007).

30. Cryderman (2014).

31. Insurance Bureau of Canada (2015a).

32. Insurance Industry Representatives (2015).

33. Rushworth (2014).

34. WaterSMART Solutions Ltd. (2013).

35. Pomeroy, Stewart and Whitfield (2015).

36. WaterSMART Solutions Ltd. (2013).

37. Conservation Ontario (2013).

38. Alberta Environment and Parks (2015b).

39. WaterSMART Solutions Ltd. (2014) p. 8.

40. Alberta Municipal Affairs (2015).

41. WaterSMART Solutions Ltd. (2014) p. 8.

42. Derworiz (2015).

43. The original annual budget for the DFAA program in 1970 was $10 million. The average annual growth rate for nominal expenditure GDP from 1970 to 2014 was 7.3 per cent. Inflated to 2014 values, the original $10 million budget would be $222 million. This is considerably more than the current $100 million annual appropriation.

44. With the 1998 ice storm removed the only other DFAA winter storm payment is the $120 million estimated payment for the 2013 Toronto ice storm. This is lowered to $77 million under the new DFAA payment rules.

45. See Appendix A for a disclaimer regarding the RMS results.

46. Conservation Ontario (2015).

47. Sandink, Kovacs, Oulahen and McGillivray (2010).

48. Ibid.

49. Ibid.

50. Water Resources Section (2002), Cumming Cockburn Limited (2000).

51. Wikipedia (2015b).

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53. Shrubsole (2000), PBO Sources.

54. Manitoba 2011 Flood Review Task Force Report (2013).

55. Dumanski, Pomeroy and Westbrook (2015).

56. Ibid. p 3895.

57. Pomeroy, Shook, Fang, Dumanski, Westbrook and Brown (2014).

58. PBO sources.

59. Pomeroy, Shook, Fang, Dumanski, Westbrook and Brown (2014).

60. Dumanski, Pomeroy and Westbrook (2015).

61. Jakob and Holm (2013).

62. Shook and Pomeroy (2015).

63. Ibid.

64. Ibid.

65. Pomeroy, Stewart and Whitfield (ibid.).

66. Ibid.

67. Ferguson (2015), Alberta Environment and Parks (2015a), Pomeroy, Stewart
    and Whitfield (2015).

68. Pomeroy, Stewart and Whitfield (2015).

69. Jakob and Church (2011 ibid.).

70. Professional Engineers and Geoscientists of BC (2012).

71. Kovacs and Sandink (2013).

72. Water Resources Section (2002).

73. Ibid., Cumming Cockburn Limited (2000).

74. Wikipedia (2015a).

75. Jakob and Holm (2013).

76. Groeneveld (2006) p. 11.

77. Shook (2015), Jakob and Holm (2013), Kovacs and Sandink (2013).

78. Buttle, Allen, Caissie, Davison, Maske, Peters, Pomeroy, Simonovic, St-Hilarie
    and Whitfield (2015).

79. Ibid.

80. Pomeroy, Stewart and Whitfield (ibid.).

81. WaterSMART Solutions Ltd. (2014).

82. Jakob, Clague and Church (2015).

83. Ibid., Pomeroy, Stewart and Whitfield (ibid.).

84. Franklin and Schmidt (2013), Jakob, Clague and Church (2015).

85. Jakob (2014).

86. Ibid.

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88. WaterSMART Solutions Ltd. (2014), Pomeroy, Stewart and Whitfield (2015).

89. Jakob and Holm (2013), Pomeroy, Stewart and Whitfield (2015).

90. PBO sources.

91. Pomeroy, Stewart and Whitfield (2015).

92. Kovacs (2011).

93. McClure and Howell (2013).

94. McClure (2014).

95. Ibid.

96. Francis and Skific (2015).

97. Tang, Zhang and Francis (2014).

98. Shook and Pomeroy (2012).

99. Harder, Pomeroy and Westbrook (2015 ibid).

100. Flooding, highway closures as heavy rain pounds Prairies (2014), Flood
     emergency declared in Yorkton, Sask. (2010).

101. Verisk Analytics Inc provides a wide variety of information about risk to both
     the insurance industry and businesses that have a risk management
     component.

102. For an example see Bevere, Orwig and Sharan (2015).

103. RMS is one of several firms that provide probabilistic catastrophe models to
     the insurance industry. Besides the four weather catastrophe models the PBO
     required, the industry has catastrophe models for earthquake, windstorm,
     wild fire, terrorism, pandemic, and longevity and mortality. Not all models
     are available in all countries.

104. Woo (2002).

105. The PBO also contracted RMS to provide a flood loss estimate. RMS didn't
     have a Canadian specific flood model and instead performed a relativity-
     based analysis that leveraged the flood modeling capabilities of their global
     flood model product suite and their existing set of Canadian exposure data.
     Given that some of the stochastic processes which cause flooding in Canada
     are different than that found in a global model, the results of this modeling
     are expected to have a greater degree of uncertainty than if a flood model

specific to Canada was available. Late in the analysis, PBO was able to obtain a flood loss estimate from IBC based on a Canadian specific model and this estimate was used instead.

106. Government fixed assets includes roads and bridges.