As stated in *Moving Forward on Climate Change: A Plan for Honouring our Kyoto Commitment* [www.climatechange.gc.ca/English/], the Government's working assumption is that the *Canadian Environmental Protection Act, 1999* (CEPA 1999) will be chosen as the legislative vehicle for implementing a regulatory system for emissions of the Kyoto Greenhouse Gases (GHGs) from Large Final Emitters. The plan notes that the Government would regulate under Parts 5 and 11 of CEPA 1999 and that in order to do so, GHGs would first have to be added to the list of substances in Schedule 1 to the Act.

Addition to Schedule 1 is a decision of the Governor-in-Council (the federal Cabinet). The Governor in Council may, if satisfied that a substance meets the criteria set out in section 64 of CEPA, on the recommendation of the Ministers of Environment Canada and Health Canada, make an order adding a substance to Schedule 1.

The criteria set out in Section 64 of CEPA are that a substance is entering or may enter the environment in a quantity or concentration or under conditions that:

(a) have or may have an immediate or long-term harmful effect on the environment or its biological diversity;
(b) constitute or may constitute a danger to the environment on which life depends; or
(c) constitute or may constitute a danger in Canada to human life or health.

Therefore, the first step is to demonstrate that a substance meets at least one of these criteria. In *Moving Forward on Climate Change* it is noted that international science clearly demonstrates that GHGs meet the second criterion for listing, namely that they constitute a danger to the environment on which life depends.

This report provides a summary of international science from the Third Assessment Report of the Intergovernmental Panel on Climate Change (IPCC) in order to determine whether the Kyoto Protocol greenhouse gases (GHGs) (namely, carbon dioxide (CO2), methane (CH4), nitrous oxide (N2O), sulfur hexafluoride (SF6), hydrofluorocarbons (HFCs), and perfluorocarbons (PFCs)) meet one or more of the criteria set out in section 64 of the Canadian Environmental Protection Act (CEPA, 1999). Material from the IPCC Third Assessment Report has been used exclusively since the findings of the Report are recent and are accepted by scientists and governments worldwide as representing the current scientific consensus on climate change. It is important to note that the IPCC is a UN body that developed the science that forms the basis of the Kyoto Protocol. The scientific literature published since 2001, which will be included in the Fourth Assessment Report of the IPCC (to be produced in 2007), is expected to strengthen the conclusions of the Third Assessment Report. The evidence supports a conclusion that GHGs are entering or may enter the environment in a quantity or concentration or under conditions that constitute or may constitute a danger to the environment on which life depends, and thus meet the criterion of Section 64b.

The Ministers of Environment Canada and Health Canada intend to present this evidence to the Governor in Council in late summer or early fall and recommend that GHGs be added to Schedule 1. With the concurrence of the Governor in Council, a draft order to add GHGs to Schedule 1 and this report would be published in Canada Gazette 1 for a 60 day comment period.

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The Kyoto Protocol Greenhouse Gases (GHGs) and the Canadian Environmental Protection Act: A synthesis of relevant science from the IPCC* Third Assessment Report in the context of CEPA Section 64.

* Intergovernmental Panel on Climate Change

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1. INTRODUCTION

1.1 Purpose of the Report

The purpose of this Report is to determine whether the greenhouse gases (GHGs) addressed by the Kyoto Protocol (and not others) (namely, carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), sulfur hexafluoride (SF_6), hydrofluorocarbons (HFCs), and perfluorocarbons (PFCs)) meet one or more of the criteria set out in section 64 of the Canadian Environmental Protection Act (CEPA, 1999). This Report examines the relevance of the scientific information presented in the Third Assessment Report of the Intergovernmental Panel on Climate Change (IPCC TAR) to the criteria set out in Section 64 of CEPA.

1.2 Scope of the Report

This Report is divided in four sections. This first section (the Introduction) sets the stage for consideration of the relevant science in the sections that follow. The purpose and scope of the report are described, and the rationale for relying on science from the IPCC Third Assessment Report is provided. The second section (IPCC conclusions on current and future climate change) presents the main conclusions from the IPCC TAR on the issues of observed climate change and its causes and future climate change. In that section, evidence is presented on the role of human emissions of GHGs in climate change, a conclusion which then justifies a subsequent discussion of whether or not GHGs meet the criteria set out in Section 64 of CEPA.

The third section (Assessment of GHGs within the context of CEPA Section 64) presents particular lines of evidence from the IPCC TAR that are considered to be most relevant to CEPA Section 64. The final section provides a conclusion on whether the information, as documented in the IPCC TAR and summarized in this report, would support a recommendation by the Ministers to Governor in Council to add GHGs to Schedule 1 of CEPA 1999 pursuant to the criteria set out in Section 64.

1.3 The IPCC Third Assessment Report (TAR)

As stated above, the approach used in this report is to consider the lines of evidence on the consequences of climate change, as assessed by the IPCC TAR, within the context of Section 64 of CEPA 1999. The IPCC TAR included four reports: Climate Change 2001: The Scientific Basis (Contribution of Working Group I), Climate Change 2001: Impacts, Adaptation and Vulnerability (Contribution of Working Group II), Climate Change 2001: Mitigation (Contribution of Working Group III), Climate Change 2001: Synthesis Report. All of these except the report on mitigation are relevant to the issue at hand. It is not the objective of this report to provide a comprehensive summary of IPCC findings on the science and impacts of climate change. Rather, the intent of this report is to provide sufficient coverage to enable a decision regarding whether or not there is evidence that GHGs meet any of the criteria under Section 64 of CEPA 1999.

The IPCC was established by UN agencies in 1988 to undertake periodic comprehensive assessments of the available scientific and socio-economic information on climate change and its impacts and on options for mitigating and adapting to the risks posed by climate change. To date, the IPCC has issued comprehensive assessments in 1990, 1996 and 2001. Preparation of a fourth assessment report is underway. The IPCC is often called on to advise the Conference of the Parties, and other bodies to the UN Framework Convention on Climate Change.

Preparation of IPCC assessment reports is undertaken with the help of several thousand experts from around the world. Canadian experts have been substantively involved in each of the three assessments produced to date and are similarly making significant contributions to the preparation of the fourth assessment report. The individual IPCC WG reports are based on an assessment of published, peer-reviewed technical literature available at the time of preparation of the report. The TAR, published in 2001, was therefore based on available science up to and including 2001. (Papers that were accepted for publication but not yet in print were included in the literature base for the TAR.)

The IPCC assessment reports themselves undergo a very extensive and open peer review process involving hundreds of government and non-government experts. The completed assessment reports are finalized and then accepted at Sessions of the respective Working Groups. Plenary Sessions of the IPCC, attended by representatives of some 120 Nations, then accept the decisions of the Working Groups regarding their final reports and approve the Summaries for Policymakers that accompany each technical report. The contributions of the three Working Groups to the TAR were accepted, and the Summaries for Policymakers approved, at the 17th Session of the IPCC. The 18th Session of the IPCC adopted the Synthesis Report and approved its Summary for Policymakers.

The value of the IPCC Assessments is in their assessment of a vast and complex technical literature than reaches across many scientific and social disciplines. It is also in the process of consensus building that occurs during the preparation of IPCC reports. This is a fundamental component of any scientific assessment process; to establish, based on existing knowledge, what can be agreed upon, how confident scientists are in these conclusions, and what areas of uncertainty remain. The consensus that forms does not mean that there is unanimity of opinion among scientific experts but rather that the weight of evidence from the scientific literature, at that point in time, supports the conclusions drawn.. Individual papers and individual scientists may disagree with the conclusions but the conclusions are consistent with and a fair representation of the larger body of literature that exists. The level of agreement among scientists is in any case reflected in the confidence and likelihood statements that are attached to particular results (and the IPCC has a well established lexicon for articulating such things (see Section 2.3 of this report)).

As a result of the processes used to prepare IPCC reports, the IPCC is widely recognized as the international authority on climate change science. Following release of the TAR, 17 National Academies of Science[1], from many countries of the world, endorsed its conclusions and the process used to prepare its reports. In addition, a special committee of the US National Research Council advised the American President George Bush that the full IPCC Working Group I report of the Third Assessment (dealing with climate system science and predictions) was an "admirable summary of research activities in climate change"[2]. These reports have thus been accepted internationally as authoritative statements of the current state of scientific knowledge on climate change.

For these reasons, additional science reviews have not been undertaken by Environment Canada and Health Canada for the purpose of considering whether GHGs meet the criteria set out in section 64 of CEPA 1999. The Departments have used material from the IPCC TAR exclusively. The findings of the TAR are recent and have already been accepted by scientists and governments worldwide. Furthermore, the scientific literature published since 2001, which will be included in the Fourth Assessment Report of the IPCC (to be produced in 2007), is expected to strengthen the conclusions of the TAR.

2. IPCC CONCLUSIONS ON CURRENT AND FUTURE CLIMATE CHANGES OF RELEVANCE TO CEPA

By the operation of Sections 64 and 90 of CEPA, a substance can be recommended for addition to Schedule 1, thus allowing the enactment of preventative or control measures, if it is entering or may enter the environment in a quantity or concentration or under conditions that:

a. have or may have an immediate or long-term harmful effect on the environment or its biodiversity;
b. constitute or may constitute a danger to the environment on which life depends; or
c. constitute or may constitute a danger in Canada to human life or health.

The question then is whether human emissions of GHGs have consequences that meet one or more of the criteria above.

GHGs, upon being emitted to the atmosphere, alter its composition, thereby affecting its chemical and physical properties. The radiative properties of GHGs, and the role GHGs play in the energy balance of the Earth, are well established. GHGs in the atmosphere produce a “greenhouse effect” which describes the role of the atmosphere in insulating the planet from heat loss. Indeed, without the natural greenhouse effect produced by GHGs of natural origin, the average temperature of the Earth would be approximately 33 °C colder than it is. The term ‘enhanced greenhouse effect’ is the term used to describe the augmentation of atmospheric concentrations of GHGs as a result of human activity.

This report will determine whether human emissions of GHGs, by enhancing the natural greenhouse effect, are harmful according to the criteria set out in Section 64 of CEPA.

If it can be shown that the climate of the Earth has changed recently and that human emissions of GHGs have been a contributing factor, then it will be determined whether or not these changes have been harmful as defined by the criteria set out in CEPA 1999 Section 64. If it can also be shown that continuing human emissions of GHGs will lead to further climate change, then it will be determined whether or not there will be harmful or dangerous consequences in the future as defined by the criteria set out in Section 64 of CEPA 1999.

Collectively, the body of evidence that responds in great detail to these questions is contained within the full technical reports of Working Groups I (Science) and II (Impacts, Adaptation and Vulnerability) of the IPCC[3]. The evidence is synthesized and presented in question and answer format in the IPCC Synthesis Report[4]. Below, a summary is presented of the conclusions from the IPCC TAR that responds to the issues of observed climate change and its causes, and future climate change. In Section 3 of this report, evidence from the IPCC TAR, on the impacts of climate change, will be presented that is most relevant within the context of CEPA Section 64.

2.1 Observed Climate Change and its Causes

The detailed supporting evidence for this summary is presented in Tables 1 and 3 of Annex A.

The Earth's climate has changed since the pre-industrial era. Over the 20th century, the global average surface temperature has increased by 0.6 °C with a very likely[*] confidence range of 0.4-0.8 °C. It is very likely that the 1990s was the warmest decade, and 1998 the warmest year, of the instrumental record. It is likely that the 20th century warming, at least that of the Northern Hemisphere, is unprecedented during the past 1000 years. The warming has been accompanied by a suite of other changes in the climate system that, together, give a collective picture of a warming world. Most of the warming of the past 50 years is likely to have been due to increases in greenhouse gas concentrations. Concentrations of atmospheric GHGs and their radiative forcings have generally increased over the 20th century as a result of human activities. The rates of increase for carbon dioxide and methane are unprecedented.

On the basis of these conclusions, and for the purpose of considering GHGs under CEPA Section 64, it is valid, as will be done in Section 3, to consider whether there is any evidence of harm from *current* impacts, arising from recent climatic changes.

2.2 Future Climate Change

The detailed supporting evidence for this summary is presented in Table 2 of Annex A.

It is clearly demonstrated that the amount of future global warming will be dependent on the amount of greenhouse gas from human activity that is emitted in the future. The aggregate quantity of emissions in the future will be influenced by development choices made by individual countries worldwide. That said, carbon dioxide concentrations, globally averaged surface temperature and sea level are projected to increase under all IPCC emission scenarios during the 21st century[5]. The projected warming of 1.4 – 5.8°C over the period 1990 to 2100 is very likely to be without precedent during the last 10,000 years. Global mean sea level is projected to rise between 10 and 90 cm by the end of this century. There will be regional differences in warming, but it is very likely that nearly all land areas will warm more rapidly than the global average, and that high latitudes will warm the most. The earth's cryosphere (snow, ice and permafrost) will continue to

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[*] See discussion of IPCC lexicon on confidence and likelihood statements at the end of this section.

respond to the warming. The widespread retreat of glaciers and ice caps is projected to continue, as is the decrease in snow cover, permafrost and sea-ice extent.

On the basis of these conclusions, and for the purpose of considering GHGs under CEPA section 64, it is valid, as will be done in Section 3, to consider whether there is any threat of harm from *future* impacts arising from future climate change.

2.3 IPCC Lexicon for Statements of Confidence and Likelihood

Given that the evidence presented in the following sections has been extracted from the Third Assessment Report of the Intergovernmental Panel on Climate Change, knowledge of the IPCC lexicon around likelihood and confidence statements is necessary. The likelihood descriptors were used by IPCC WGI while the Confidence Descriptors were used by IPCC WGII. The IPCC lexicon is as follows:

LIKELIHOOD DESCRIPTOR	% CHANCE THAT STATEMENT IS TRUE
Virtually certain	>99%
Very likely	90-99%
Likely	66-90%
Medium likelihood	33-66%
Unlikely	10-33%
Very Unlikely	1-10%
Exceptionally unlikely	<1%
CONFIDENCE DESCRIPTOR	% CONFIDENCE
Very high	95% or greater
High	67-95%
Medium	33-67%
Low	5-33%
Very Low	5% or less

The decision to assign a level of probability or confidence to a finding represented the collective judgment of the IPCC authors, based on the observational evidence, modeling results and theory that were examined. In this report, where these terms are used in findings attributed to the IPCC, the criteria above should be assumed to apply.

3. ASSESSMENT OF THE IMPACTS OF CLIMATE CHANGE WITHIN THE CONTEXT OF CEPA 1999, SECTION 64

The material presented in the following sections was selected as being most relevant to Section 64 of CEPA 1999. Even so, the material is to be considered illustrative of the much more extensive body of work contained in the IPCC reports. References to sections in the underlying reports from which material has been extracted are provided for those wishing to read the more comprehensive material.

3.1 Impacts on Natural Systems

The IPCC TAR summary material most relevant to the issue of the impacts of climate change on the Earth's natural systems is listed in the Table below. References to sections of the full WGII report can be found within the Technical Summary references provided. A summary description of the impacts of climate change on natural systems is presented here. More detailed supporting evidence is provided in Tables 1 and 2 in Annex B to this report.

Report	Section Ref.	Section Heading
WGII Summary for Policymakers	2.1	Recent regional climate changes, particularly temperature increases, have already affected many physical and biological systems
	2.3	Natural systems are vulnerable to climate change, and some will be irreversibly damaged.
	3.1	(Effects on Vulnerability of) Hydrology and Water Resources
	3.3	(Effects on Vulnerability of) Terrestrial and Freshwater Ecosystems
	3.4	(Effects on Vulnerability of) Coastal and Marine Ecosystems
	4	Vulnerability Varies Across Regions
WGII Technical Summary	4.1	Water Resources
	4.3	Terrestrial and Freshwater Ecosystems
	4.4	Coastal and Marine Ecosystems
	5	Regional Analysis
	5.6	North America
	5.7	Polar Regions
	7.1	Detection of Climate Change Impacts
	7.2.1	Unique and Threatened Systems

There is high confidence that the collective evidence supports a conclusion that recent regional changes in temperature have had discernible impacts on many physical and biological systems. Examples of observational changes with linkages to climate change include shrinkage of glaciers; thawing of permafrost; shifts in ice freeze and break-up dates on rivers and lakes; increases in rainfall and rainfall intensity in most mid- and high latitudes of the Northern Hemisphere; lengthening of growing seasons; and earlier flowering dates of trees, emergence of insects, and egg-laying in birds. In about 80% of the biological cases and about 99% of the physical cases the changes are consistent with well-established relationships between temperature and physical and biological processes. The observed changes indicate a sensitivity in these systems to climate changes of a magnitude much smaller than those projected for the coming century.

There is also high confidence that diversity in ecological systems will continue to be affected by climate change and sea-level rise in the future, with an increased risk of extinction for some species currently listed as “critically endangered” and of currently “endangered” or “vulnerable” species becoming even rarer in the 21st century. Recent modeling studies continue to show potential for significant disruption of ecosystems under climate change (high confidence). As a class of ecosystems, inland waters are particularly vulnerable to climate change. Within these systems, the impacts for which there is high or very high confidence include reduction and loss of lake and river ice, loss of habitat for coldwater fish, and increases in extinctions and invasions of exotics. These impacts are of particular relevance to Canada with its large number of inland freshwater ecosystems. Other natural ecosystems at risk include coral reefs, mangroves, and other coastal wetlands; montane ecosystems that are restricted to the upper 200-300 m of mountainous areas; prairie wetlands; remnant native grasslands; ecosystems overlying permafrost; and ice edge ecosystems that provide habitat for polar bears and penguins. Many of these ecosystems at risk exist and occupy large areas within Canada.

The Arctic region is extremely vulnerable to climate change, and major physical and ecological impacts are expected to appear rapidly there as warming in northern high latitudes is expected to be greater than the global average. There will be increasing melting of Arctic glaciers, substantial loss of sea ice, different species compositions on land and sea, poleward shifts in species assemblages, and severe disruptions for communities of people who lead traditional lifestyles.

3.2 Impacts to Systems on which Human Life Depends

THE IPCC TAR presents evidence on the impacts of climate change on many different human systems. However, not all of these are equally relevant within the context of CEPA section 64. For the purposes of this discussion, the impacts of climate change that would seem most applicable are:

1. Impacts on water resources
2. Impacts on agriculture
3. Impacts arising from changes in extreme events
4. Impacts arising from sea level rise
5. Impacts arising from abrupt climatic and ecological changes

Direct impacts of climate change on water resources and agriculture include changes to precipitation patterns, timing of snowmelt, glacier retreat, evaporation of soil moisture and surface water, and changes in crop yields. In terms of human need, and the needs of other living things, it is not just the availability of food and water that is an issue, but rather access to these resources. Many socio-economic and natural factors will impact on access to adequate supplies of food and clean water but consideration of such issues is beyond the scope of this assessment. Here we will focus on the available evidence for climate change impacts to the production and availability of food and the availability of water.

Changes in extreme events and sea-level rise are arguably the most significant consequences of climate change for humans in the near term. The vulnerability of human societies and ecosystems to climate extremes is demonstrated by the damage, hardship and death caused by events such as droughts, floods, heat waves, avalanches, and storms, hurricanes and cyclones. Often, the impacts from these events fall disproportionately upon the poor. The vulnerability of human settlements along low-lying coastlines to the combined effects of sea-level rise and storm surges is a matter of these settlements, and the coastal resources they depend on, being threatened with flooding, wave damage and permanent inundation.

In the long term, the risk of large-scale, possibly abrupt and potentially irreversible (on human time scales) changes to critical components of the Earth's climate system is of most relevance to the safety and security of life on Earth. Examples of such changes include significant slowing of the thermohaline circulation, which will impact on ocean biochemistry and on climates of the North Atlantic region, large reductions in the Greenland and West Antarctic Ice Sheets, which would lead to global sea level rise measured in metres rather than centimetres; and accelerated global warming resulting from changes to the global carbon cycle with strong positive feedbacks to the climate system (e.g. release of stored carbon from arctic permafrost and release of methane hydrates from ocean sediments). If such changes were to occur, their impacts would be widespread and sustained. Depending on the rate and magnitude of such changes, the capacity for human and natural systems to adapt could be exceeded with substantial impacts resulting.

The IPCC TAR summary material most relevant to the issue of impacts on systems on which human life depends is listed below. References to sections of the full WGII report can be found within the Technical Summary references provided. A summary description of the impacts of climate change on human systems is provided here. More detailed supporting evidence is presented in Tables 3a and b of Annex B.

Report	Section Ref.	Section Heading
WGII Summary for Policymakers	2.4	Many human systems are sensitive to climate changes, and some are vulnerable.
	2.5	Projected changes in climate extremes could have major consequences
	2.6	The potential for large-scale and possibly irreversible impacts poses risks that have yet to be reliably quantified.
	3.1	(Effects on Vulnerability of) Hydrology and Water Resources
	3.2	(Effects on Vulnerability of) Agriculture and Food Security
	3.4	(Effects on Vulnerability of) Coastal Zones and Marine Ecosystems
	3.6	(Effects on Vulnerability of) Human Settlements, Energy and Industry
	4	Vulnerability Varies across Regions
WGII Technical Summary	4.1	Water Resources
	4.2	Agriculture and Food Security
	4.4	Coastal and Marine Ecosystems

	4.5	Human Settlements, Energy and Industry
	5	Regional Analysis
	5.6	North America
	5.7	Polar Regions
	7.2	Reasons for Concern
	7.2.3	Distribution of Impacts
	7.2.4	Extreme Weather Events
	7.2.5	Large-scale, Singular Events

A large proportion of the world's population is living under conditions of water scarcity now. Demand for water is generally increasing as a result of population and economic growth. Climate change would exacerbate water shortage and quality problems in many water-scarce areas of the world. Approximately 1.7 billion people, one-third of the world's population, presently live in countries that are water-stressed. This number is projected to increase to approximately 5 billion by 2025 depending on the rate of population growth. It is projected that streamflow and groundwater recharge will be reduced in many parts of the world (medium confidence). The retreat of glaciers has already begun in North America which will affect regional water resources by changing (probably decreasing) water supply from glacial melt during the summer season.

Degradation of soil and water resources is one of the major future challenges for global agriculture. It is established with high confidence that those processes are likely to be intensified by adverse changes in temperature and precipitation. It is established with high confidence also that some crops would benefit from modest warming and increases in CO_2 but effects would vary among crops and regions. Some declines will occur due to drought in some areas, including parts of the Canadian Prairies (medium confidence). Overall climate change is likely to tip agriculture production in favour of well-to-do and well-fed regions – which either benefit, under moderate warming, or suffer less severe losses – at the expense of less-well-to-do and less well-fed regions. By the 2080s, the additional number of people at risk of hunger as a result of climate change is estimated to be about 80 million.

The frequency and magnitude of many extreme climate events increase even with a small temperature increase and will become greater at higher temperatures (high confidence). Increases in extreme events can cause critical design or natural thresholds to be exceeded, beyond which the magnitude of impacts increases rapidly (high confidence). The amplitude and frequency of extreme precipitation events is very likely to increase over many areas and the return periods for extreme precipitation events are expected to decrease. This would lead to more frequent floods and landslides with attendant loss of life and other health impacts, property damage, and loss to infrastructure and settlements.

Global mean sea level is projected to rise between 10 and 90 cm by the end of this century. People living in coastal zones will generally be negatively affected by sea-level rise. Highly diverse and productive coastal ecosystems, coastal settlements, and island states will continue to be exposed to pressures whose impacts are expected to be largely negative and potentially disastrous in some instances. Projected sea-level rise will increase the average annual number of people flooded in coastal storm surges (high confidence.) Tens of millions of people living in deltas, in low-lying coastal areas, and on small islands will face risk of displacement.

Greenhouse gas forcing in the 21st century could set in motion large-scale, high impact, non-linear, and potentially abrupt changes in the Earth's physical and biological systems that could have severe consequences at regional or global scales. Although the probabilities of triggering such events are poorly understood they should not be ignored, given the severity of their consequences. Some of these changes have low probability of occurrence during the 21st century; however, greenhouse gas forcing in the 21st century could set in motion changes that could lead to such transitions in subsequent centuries and some of these changes could be irreversible over centuries to millennia.. Events of this type that might be triggered include complete or partial shutdown of the North Atlantic and Antarctic Deep Water formation, disintegration of the West Antarctic and Greenland Ice Sheets, and major perturbations of biosphere-regulated carbon dynamics.

3.3 Impacts on Human Life

The IPCC TAR summary material most relevant to the issue of the impacts of climate change on human life is listed below. References to sections of the full WGII report can be found within the Technical Summary references provided below. A summary description of the impacts of climate change on human life and health is presented, while more detailed supporting evidence is provided in Table 4 of Annex B.

Report	Section	Section Heading
WGII Summary for Policymakers	2.4	Many human systems are sensitive to climate change and some are vulnerable
	2.5	Projected changes in climate extremes could have major consequences
	3.5	(Effects on and Vulnerability of) human health
	4	Vulnerability varies across regions
WGII Technical Summary	4.5	Human settlements, energy and industry
	4.7	Human health
	5.6	North America
	5.7	Polar Regions

If heat waves increase in frequency and intensity, as they are very likely to do, the risk of death and serious illness would increase, principally in older age groups and the urban poor (high confidence). The greatest increases in thermal stress are forecast for mid- to high-latitude (temperate) cities, especially in populations that have limited resources. The effects of an increase in heat waves often would be exacerbated by increased humidity and urban air pollution**.** There is medium to high confidence of expansion of areas of potential transmission of malaria and dengue by 2050 to 2100. There is medium confidence that there will be an increase in deaths, injuries, and infections associated with extreme weather such as floods and storms.

In Canada, the projected increased frequency and severity of heat waves may lead to an increase in illness and death, particularly among young, elderly and frail people, especially in large urban areas. Acclimatization may be slower than the rate of ambient temperature change. Vector-borne diseases, including malaria and dengue fever, may expand their ranges in the United States and may develop in Canada.

3.4 Additional Weight-of-Evidence on the Consequences of Climate Change

The impacts described above, and others, were all addressed by the IPCC WGII in their synthesis of the key impacts of climate change into five global Reasons for Concern[6]. The effort to provide such a synthesis was motivated by the need to provide advice to policymakers on what would constitute "dangerous interference with the climate system" in the context of Article 2 of the United Nations Framework Convention on Climate Change (to which Canada is a signatory). The five Reasons for Concern are:

1. Risks to unique and threatened systems
2. Risks from extreme climate events
3. Distribution of impacts (among people, regions and sectors)
4. Aggregate (worldwide) impacts
5. Risks from large-scale discontinuities

Summary conclusions about the impacts of climate change on these Five Reasons for Concern were presented in Box 3-2 of the IPCC Synthesis Report and in Figure SPM-2 of the WGII Summary for Policymakers. These results are reproduced in this report as Table 5 and Figure 1 in Annex B.

The body of evidence regarding climate change impacts on these five Reasons for Concern supported the following conclusion[7]:

> "At a small increase in global mean temperature (0- 2°C)[*] some of the reasons for concern show the potential for negative impacts, whereas others show little adverse impact or risk. At higher temperature increases, all lines of evidence show a potential for adverse impacts, with impacts in each reason for concern becoming more negative at increasing temperature. There is high confidence in this general relationship between impacts and temperature change, but confidence generally is low in estimates of temperature change thresholds at which different categories of impacts would happen."

[*] 0-2°C is at the lower end of the projected temperature changes over the next century. [WGI Technical Summary Section F: The Projections of the Earth's Future Climate]

4. CONCLUSION

Given that:

- the radiative properties of GHGs, and the role GHGs play in the energy balance of the Earth, are well established;
- concentrations of atmospheric GHGs and their radiative forcings have generally increased over the 20th century as a result of human activities;
- the Earth's climate system has demonstrably changed on both global and regional scales since the pre-industrial era, with some of these changes attributable to human activities, including human emissions of GHGs;
- the global average surface temperature has increased over the 20th century by 0.6˚C (±-.2˚C)
- most of the warming of the past 50 years is likely to have been due to increases in greenhouse gas concentrations;
- the vulnerability of human societies and ecosystems to climate extremes is demonstrated by the damage, hardship and death caused by events such as droughts, floods, heat waves, avalanches, and storms, hurricanes and cyclones;
- the general relationship between impacts and temperature change has been established;

and furthermore, given that:

- the amount of future global warming will be dependent on the amount of greenhouse gases from human activity that are emitted in the future;
- the projected warming for the 21st century is very likely to be without precedent during the last 10,000 years and sea level is projected to rise significantly;
- the frequency and magnitude of many extreme climate events increase with a small temperature increase and will become greater at higher temperatures;
- GHG forcing in the 21st century could set in motion large-scale, high-impact, non-linear, and potentially abrupt changes in physical and biological systems over the coming decades to millennia;
- diversity in ecological systems will continue to be affected by climate change and sea-level rise in the future, with an increased risk of extinction for some species currently listed as "critically endangered" and of currently "endangered or vulnerable" species becoming even rarer in the 21st century;
- there are threats to humans and ecosystems from an increase in sea level rise, extreme events and abrupt climate and ecological changes;
- the Arctic region is extremely vulnerable to climate change, and major physical and ecological impacts are expected to appear rapidly there as warming in northern high latitudes is expected to be greater than the global average;
- vector-borne diseases, including malaria and dengue fever, may expand their ranges in the United States and may develop in Canada; and
- adverse impacts will become increasingly negative with increasing temperature:

It is proposed that greenhouse gases, including CO_2, CH_4, N_2O, SF_6, Hydrofluoroarbons and Perfluorocarbons, meet criterion b as set out in CEPA 1999 Section 64.

ENDNOTES

In the endnotes below, IPCC reports will be referred to simply as IPCC 2001: WGI, WGII, and Synthesis Report, as appropriate. The full references for these reports are given here:

IPCC 2001 WG1 Report:
IPCC 2001: Climate Change 2001: The Scientific Basis. Contribution of Working Group 1 to the Third Assessment Report of the Intergovernmental Panel on Climate Change. Houghton, J.T., Ding, Y., Griggs, D.J., Noguer, M., Van der Linden, P.J., Dai, X., Maskell, K. and Johnson, C.A. (Eds.). Cambridge University Press. Cambridge, UK and New York, USA. 881 pp.

IPCC 2001 WGII Report:
IPCC 2001:Climate Change 2001: Impacts, Adaptation, and Vulnerability. Contribution of Working Group 2 to the Third Assessment report of the Intergovernmental Panel on Climate Change. McCarthy, J.J., Canziani, O.F., Leary, N.A., Dokken, D.J. and White, K.S. (Eds.). Cambridge University Press. Cambridge, UK and New York, USA. 1032 pp.

IPCC 2001 Synthesis Report:
IPCC 2001:Climate Change 2001: Synthesis Report. Contributions of Working Groups 1, 2 and 3 to the Third Assessment report of the Intergovernmental Panel on Climate Change. Watson, R.T. et al. (Eds.). Cambridge University Press. Cambridge, UK and New York, USA. 397 pp.

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[1] Joint Statement by 17 National Academies of Science. Science Vol 292 Number 5520 (May 18) pp1261.
[2] National Research Council. 2001. Climate Change Science: An Analysis of Some Key Questions. Committee on the Science of Climate Change. Division of earth and Life Sciences. National Research Council. National Academy Press. Washington, D.C.
[3] IPCC 2001: WGI Report. IPCC 2001: WGII Report.
[4] IPCC 2001: Synthesis Report.
[5] The IPCC emissions scenarios referred to are the so-called SRES scenarios of the IPCC Special Report on Emission Scenarios. Nakicenovic, N.J. et al. 2000. Emission Scenarios. A Special report of Working Group III of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge, U.K.
[6] The underlying reference for this discussion on Reasons for Concern is Chapter 19 of the IPCC WGII Report.
[7] WGII Report Technical Summary Section 7.2.

ANNEXES

ANNEX A

Supporting Evidence for Sections 2.1 and 2.2 of this Report

Table 1: Supporting Evidence for observed climate change and its causes

Reference to IPCC Synthesis Report	**Supporting Evidence**	**References to TAR provided in IPCC Synthesis Report**
2.2	"The Earth's climate system has demonstrably changed on both global and regional scales since the pre-industrial era, with some of these changes attributable to human activities".	
2.3	"Emissions of greenhouse gases and aerosols due to human activities continue to alter the atmosphere in ways that are expected to affect the climate (see Table 2-1)." *(Table 2.1 is reproduced in this report as Table 3 of Annex A.)*	
2.4	"Concentrations of atmospheric greenhouse gases and their radiative forcings have generally increased over the 20th century as a result of human activities. Almost all greenhouse gases reached their highest recorded levels in the 1990s and continue to increase. From the years 1750 to 2000, the concentration of CO_2 increased by 31±4%, and that of CH_4 rose by 151±25% ……These rates of increase are unprecedented."	WGI TAR Chapters 3 &4, and SRAGA (Special Report on Aviation and the Global Atmosphere).
2.6	"An increasing body of observations gives a collective picture of a warming world and other changes in the climate system (see Table 2-1)." *(Table 2.1 is reproduced in this report as Table 3 of Annex A.)*	
2.7	"The global average surface temperature has increased from the 1860s to the year 2000, the period of instrumental record. Over the 20th century this increase was 0.6°C with a *very likely* confidence range of 0.4-0.8°C. It is very likely that the 1990s was the warmest decade, and 1998 the warmest year, of the instrumental record. Extending the instrumental record with proxy data for the Northern Hemisphere indicates that over the past 1,000 years the 20th century increase in temperature is likely to have been the largest of any century, and the 1990s was likely the warmest decade."	WGI TAR SPM & WGI TAR Sections 2.2.2, 2.3.2 and 2.7.2.

2.9	"There is new and stronger evidence that most of the warming observed over the last 50 years is attributable to human activities."	
2.10	"The observed warming over the 20th century is unlikely to be entirely natural in origin. The increase in surface temperatures over the last 100 years is very unlikely to be due to internal variability alone. Reconstructions of climate data for the last 1,000 years also indicate that this 20th century warming was unusual and unlikely to be the response to natural forcing alone: That is, volcanic eruptions and variation in solar irradiance do not explain the warming in the latter half of the 20th century but they may have contributed to the observed warming in the first half."	WGI TAR SPM & WGI TAR chapter 12.
2.11	"In the light of new evidence and taking into account the remaining uncertainties, most of the observed warming over the last 50 years is likely to have been due to the increase in greenhouse gas concentrations. Detection and attribution studies (including greenhouse gases and sulfate aerosols as anthropogenic forcing) consistently find evidence for an anthropogenic signal in the climate record of the last 35 to 50 years, despite uncertainties in forcing due to anthropogenic sulfate aerosols and natural factors (volcanoes and solar irradiance). The sulfate and natural forcings are negative over this period and cannot explain the warming; whereas most of these studies find that, over the last 50 years, the estimated rate and magnitude of warming due to increasing greenhouse gases alone are comparable with, or larger than, the observed warming. The best agreement for the 1860-2000 record is found when the above anthropogenic and natural forcing factors are combined."	WGI TAR SPM & WGI TAR Chapter 12
2.12	"Changes in sea level, snow cover, ice extent, and precipitation are consistent with a warming climate near the Earth's surface (see Table 2-1*).(Reproduced as Table 3 in Annex A)* Some of these changes are regional and some may be due to internal climate variations, natural forcings, or regional human activities rather than attributed solely to global human influence."	WGI TAR SPM & WGII TAR Section 4.3.11
2.13	"It is very likely that the 20th century warming has contributed significantly to the observed rise in global average sea level and increase in ocean-heat content. Warming drives sea-level rise through thermal expansion of seawater and widespread loss of land ice. Based on tide gauge records, after correcting for land movements, the average annual rise was between 1 and 2 mm during the 20th century. The very few long records show that it was less during the 19th century. Within present uncertainties, observations and models are both consistent with a lack of significant acceleration of sea-level rise during	WGI TAR sections 2.2.2.5, 11.2, & 11.3.2.

	the 20th century. The observed rate of sea-level rise during the 20th century is consistent with models. Global ocean-heat content has increased since the late 1950s, the period with adequate observations of subsurface ocean temperatures.”	

Table 2: Supporting evidence for future climate changes

Reference to IPCC Synthesis Report	Supporting Evidence	References to TAR provided in IPCC Synthesis Report
3.2	"Carbon dioxide concentrations, globally averaged surface temperature, and sea level are projected to increase under all IPCC emissions scenarios during the 21st century."	
3.3	"All SRES emissions scenarios result in an increase in the atmospheric concentration of CO_2. For the six illustrative SRES scenarios, the projected concentrations of CO_2 -- the primary anthropogenic greenhouse gas -- in the year 2100 range from 540 to 970 ppm, compared to about 280 ppm in the pre-industrial era and about 368 ppm in the year 2000. These projections include the land and ocean climate feedbacks."	WGI TAR Section 3.7.3.3
3.4	"Model calculations of the concentrations of the primary non-CO_2 greenhouse gases by year 2100 vary considerably across the six illustrative SRES scenarios."	WGI TAR Section 4.4.5 & WGI TAR Box 9.1
3.5	"The SRES scenarios include the possibility of either increases or decreases in anthropogenic aerosols, depending on the extent of fossil-fuel use and policies to abate polluting emissions......sulfate aerosol concentrations are projected to fall below present levels by 2100 in all six illustrative SRES scenarios. This would result in warming relative to present day. In addition, natural aerosols (e.g., sea salt, dust, and emissions leading to sulfate and carbon aerosols) are projected to increase as a result of changes in climate."	WGI TAR Section 5.5 & SRES (Special report on Emission Scenarios) Section 3.6.4
3.6	"The globally averaged surface temperature is projected to increase by 1.4 to 5.8°C over the period 1990 to 2100. This is about two to ten times larger than the central value of observed warming over the 20th century and the projected rate of warming is very likely to be without precedent during at least the last 10,000 years, based on paleoclimate data...... These results are for the full range of 35 SRES scenarios, based on a number of climate models."	WGI TAR Section 9.3.3
3.8	"Globally averaged annual precipitation is projected to increase during the 21st century. Globally averaged water vapor and evaporation are also projected to increase."	WGI TAR Section 9.3.1
3.9	"Global mean sea level is projected to rise by 0.09 to 0.88 m between the years 1990 and 2100, for the full range of SRES scenarios.....This is due primarily to thermal expansion and loss of mass from glaciers and ice caps."	WGI TAR Section 11.5.1

3.10	"Substantial differences are projected in regional changes in climate and sea level, compared to the global mean change**."**	
3.11	"It is very likely that nearly all land areas will warm more rapidly than the global average, particularly those at northern high latitudes in winter. Most notable of these is the warming in the northern regions of North America, and northern and central Asia, which exceeds global mean warming in each model by more than 40%."	WGI TAR Section 10.3.2
3.14	"Glaciers and ice caps are projected to continue their widespread retreat during the 21st century. Northern Hemisphere snow cover, permafrost, and sea-ice extent are projected to decrease further. The Antarctic ice sheet is likely to gain mass because of greater precipitation, while the Greenland ice sheet is likely to lose mass because the increase in runoff will exceed the precipitation increase."	WGI TAR Section 11.5.4

Table 3: Table 2.1 of the IPCC Synthesis Report

20th century changes in the Earth's atmosphere, climate, and biophysical system.[a]	
Indicator	***Observed Changes***
Concentration indicators	
Atmospheric concentration of CO_2	280 ppm for the period 1000-1750 to 368 ppm in year 2000 (31±4% increase). [WGI TAR Chapter 3]
Terrestrial biospheric CO_2 exchange	Cumulative source of about 30 Gt C between the years 1800 and 2000; but during the 1990s, a net sink of about 14±7 Gt C. [WG1 TAR Chapter 3 & SRLULUCF (Special Report on Land Use, Land Use Change, and Forestry)]
Atmospheric concentration of CH_4	700 ppb for the period 1000-1750 to 1,750 ppb in year 2000 (151±25% increase). [WGI TAR Chapter 4]
Atmospheric concentration of N_2O	270 ppb for the period 1000-1750 to 316 ppb in year 2000 (17±5% increase). [WGI TAR Chapter 4]
Tropospheric concentration of O_3	Increased by 35±15% from the years 1750 to 2000, varies with region. [WGI TAR Chapter 4]
Stratospheric concentration of O_3	Decreased over the years 1970 to 2000, varies with altitude and latitude. [WGI TAR Chapters 4 & 6]
Atmospheric concentrations of HFCs, PFCs, and SF_6	Increased globally over the last 50 years. [WGI TAR Chapter 4]
Weather indicators	
Global mean surface temperature	Increased by 0.6±0.2°C over the 20th century; land areas warmed more than the oceans (*very likely*). [WGI TAR Section 2.2.2.3]
Northern Hemisphere surface temperature	Increased over the 20th century greater than during any other century in the last 1,000 years; 1990s warmest decade of the millennium (*likely*). [WGI TAR Chapter 2 Executive Summary & Section 2.3.2.2]
Diurnal surface temperature range	Decreased over the years 1950 to 2000 over land: nighttime minimum temperatures increased at twice the rate of daytime maximum temperatures (*likely*). [WGI TAR Section 2.2.2.1]
Hot days / heat index	Increased (*likely*). [WGI TAR Section 2.7.2.1]
Cold / frost days	Decreased for nearly all land areas during the 20th century (*very*

	likely). [WGI TAR Section 2.7.2.1]
Continental precipitation	Increased by 5-10% over the 20th century in the Northern Hemisphere (*very likely*), although decreased in some regions (e.g., north and west Africa and parts of the Mediterranean). [WGI TAR Chapter 2 Executive Summary & Section 2.5.2]
Heavy precipitation events	Increased at mid- and high northern latitudes (*likely*). [WGI TAR Section 2.7.2.2]
Frequency and severity of drought	Increased summer drying and associated incidence of drought in a few areas (*likely*). In some regions, such as parts of Asia and Africa, the frequency and intensity of droughts have been observed to increase in recent decades. [WGII TAR Sections 10.1.3 & 11.1.2]
Biological and physical indicators	
Global mean sea level	Increased at an average annual rate of 1 to 2 mm during the 20th century. [WGI TAR Chapter 11]
Duration of ice cover of rivers and lakes	Decreased by about 2 weeks over the 20th century in mid- and high latitudes of the Northern Hemisphere (*very likely*). [WGI TAR Chapter 2 Executive Summary & Section 2.2.5.5, & WGII TAR Sections 5.7 & 16.1.3.1]
Arctic sea-ice extent and thickness	Thinned by 40% in recent decades in late summer to early autumn (*likely*) and decreased in extent by 10-15% since the 1950s in spring and summer. [WGI TAR Section 2.2.5.2 & WGII TAR Section 16.1.3.1]
Non-polar glaciers	Widespread retreat during the 20th century. [WGI TAR Section 2.2.5.4 & WGII TAR Section 4.3.11]
Snow cover	Decreased in area by 10% since global observations became available from satellites in the 1960s (*very likely*). [WGI TAR Section 2.2.5.1]
Permafrost	Thawed, warmed, and degraded in parts of the polar, sub-polar, and mountainous regions. [WGI TAR Sections 2.2.5.3 & 11.2.5, & WGII TAR Section 16.1.3.1]
El Niño events	Became more frequent, persistent, and intense during the last 20 to 30 years compared to the previous 100 years. [WGI TAR Section 7.6.5]
Growing season	Lengthened by about 1 to 4 days per decade during the last 40 years in the Northern Hemisphere, especially at higher latitudes. [WGII TAR Section 5.2.1]
Plant and animal ranges	Shifted poleward and up in elevation for plants, insects, birds, and fish. [WGII TAR Sections 5.2, 5.4, 5.9, & 16.1.3.1]
Breeding, flowering, and migration	Earlier plant flowering, earlier bird arrival, earlier dates of breeding season, and earlier emergence of insects in the Northern Hemisphere. [WGII TAR Sections 5.2.1 & 5.4.3]

Coral reef bleaching	Increased frequency, especially during El Niño events. [WGII TAR Section 6.3.8]
Economic indicators	
Weather-related economic losses	Global inflation-adjusted losses rose an order of magnitude over the last 40 years (see Q2 Figure 2-7). Part of the observed upward trend is linked to socio-economic factors and part is linked to climatic factors. [WGII TAR Sections 8.2.1 & 8.2.2]
a. This table provides examples of key observed changes and is not an exhaustive list. It includes both changes attributable to anthropogenic climate change and those that may be caused by natural variations or anthropogenic climate change. Confidence levels are reported where they are explicitly assessed by the relevant Working Group. An identical table in the Synthesis Report contains cross-references to the WGI and WGII reports.	

ANNEX B

Supporting Evidence for Sections 3.1 to 3.4 of this Report

Table 1: Current impacts on natural systems

"From the collective evidence, there is high confidence that recent regional climate changes in temperature have had discernible impacts on many physical and biological systems". (WGll SPM Section 2.1 pg.223 SynRpt*)*
"Observational evidence indicates that climate changes in the 20th century already have affected a diverse set of physical and biological systems. Examples of observed changes with linkages to climate include shrinkage of glaciers; thawing of permafrost; shifts in ice freeze and break-up dates on rivers and lakes; increases in rainfall and rainfall intensity in most mid- and high latitudes of the Northern Hemisphere; lengthening of growing seasons; and earlier flowering dates of trees, emergence of insects, and egg-laying in birds. Statistically significant associations between changes in regional climate and observed changes in physical and biological systems have been documented in freshwater, terrestrial, and marine environments on all continents."] [WGll TechSumm 7.1 pg. 282 SynRpt.]
"The presence of multiple causal factors (e.g. land use change, pollution) makes attribution of many observed impacts to regional climate change a complex challenge. Nevertheless, studies of systems subjected to significant regional climate change – and with known sensitivities to that change – find changes that are consistent with well-established relationships between climate and physical or biological processes (e.g. shifts in the energy balance of glaciers, shifts in the ranges of animals and plants when temperatures exceed physiological thresholds) in about 80% of biological cases and about 99% of physical cases." [WGll TechSumm 7.1 p. 282 SynRpt.]
"Based on observed changes, there is high confidence that 20th century climate changes have had a discernible impact on many physical and biological systems. Changes in biota and physical systems observed in the 20th century indicate that these systems are sensitive to climatic changes that are small relative to changes that have been projected for the 21st century. High sensitivity of biological systems to long-term climatic change also is demonstrated by paleorecords." [WGll TechSumm 7.1 p. 282 SynRpt.]
"…there is high confidence that observations of widespread accelerated glacier retreat and shifts in the timing of streamflow from spring toward winter in many areas are associated with observed increases in temperature."[WGll TechSumm 4.1]

Table 2: Future impacts on natural systems

"Diversity in ecological systems is expected to be affected by climate change and sea level rise, with an increased risk of extinction of some vulnerable species (high confidence)." (Synthesis Report Result 3.18 p. 68)
"Without adaptation, some species that currently are classified as "critically endangered" will become extinct, and the majority of those labeled "endangered or vulnerable" will become much rarer in the 21st century (high confidence)" [WGII TechSumm 4.3]
"Small increases in global average temperature may cause significant and irreversible damage to some systems and species, including possible local, regional, or global loss. Some plant and animal species, natural systems, and human settlements are highly sensitive to climate and are likely to be adversely affected by climate changes associated with scenarios of <1ºC mean global warming. Adverse impacts to species and systems would become more numerous and more serious for climatic changes that would accompany a global mean warming of 1-2ºC and are highly likely to become even more numerous and serious at higher temperatures. The greater the rate and magnitude of temperature and other climatic changes, the greater the likelihood that critical thresholds of systems would be surpassed" (WGII TechSumm 7.2.1)
"Species that may be threatened with local or global extinction by changes in climate that may accompany a small mean global temperature increase include critically endangered species generally, species with small ranges and low population densities, species with restricted habitat requirements, and species for which suitable habitat is patchy in distribution, particularly if under pressure from human land-use and land-cover change." [WGII TechSumm 7.2.1 p. 285]
"Natural systems that may be threatened include coral reefs, mangroves, and other coastal wetlands; montane ecosystems that are restricted to the upper 200-300 m of mountainous areas; prairie wetlands; remnant native grasslands; coldwater and some coolwater fish habitat; ecosystems overlying permafrost; and ice edge ecosystems that provide habitat for polar bears and penguins." [WGII TechSumm 7.2.1 p. 285]
"Climate change will lead to poleward movement of the southern and northern boundaries of fish distributions, loss of habitat for cold- and coolwater fish, and gain in habitat for warmwater fish (high confidence). As a class of ecosystems, inland waters are vulnerable to climatic change and other pressures owing to their small size and position downstream from many human activities (high confidence). The most vulnerable elements include reduction and loss of lake and river ice (very high confidence), loss of habitat for coldwater fish (very high confidence), increases in extinctions and invasions of exotics (high confidence), and potential exacerbation of existing pollution problems such as eutrophication, toxics, acid rain, and UV-B radiation (medium confidence)." [WGII Tech Summ 4.3]
"Vegetation distribution models since the SAR (Second Assessment Report) suggest that mass ecosystem or biome movement is most unlikely to occur because of different climatic tolerance of the species involved, different migration abilities, and the effects of invading species. Species composition and dominance will change, resulting in ecosystem types that may be quite different from those we see today. These changes will lag the changes in climate by years to decades to centuries (high confidence)…. Recent modeling studies continue to show potential for significant disruption of

ecosystems under climate change (high confidence).” [WGll TechSumm 4.3]
“Climate change in the polar region is expected to be among the greatest of any region on Earth. Twentieth century data for the Arctic show a warming trend of as much as 5°C over extensive land areas (very high confidence), while precipitation has increased (low confidence). There are some areas of cooling in eastern Canada. The extent of sea ice has decreased by 2.9% per decade, and it has thinned over the 1978-1996 period (high confidence). There has been a statistically significant decrease in spring snow extent over Eurasia since 1915 (high confidence). The area underlain by permafrost has been reduced and has warmed (very high confidence). The layer of seasonally thawed ground above permafrost has thickened in some areas, and new areas of extensive permafrost thawing have developed.” [WGll TechSumm 5.7 p. 276 SynRpt]
“Permafrost currently underlies 24.5% of the exposed land area of the Northern Hemisphere. Under climate warming, much of this terrain would be vulnerable to subsidence, particularly in areas of relatively warm, discontinuous permafrost. The area of the Northern Hemisphere occupied by permafrost could eventually be reduced by 12 to 22% of its current extent and could eventually disappear from half of the present-day Canadian permafrost region” [SynRpt 4.16. p. 84.]
”Some wetlands will be replaced by forests or heathlands, and those overlying permafrost are likely to be disrupted as a result of thawing of permafrost (high confidence). Most wetland processes are dependent on catchment-level hydrology; thus, adaptations for projected climate change may be practically impossible. Arctic and subarctic ombrotrophic bog communities on permafrost, as well as more southern depressional wetlands with small catchment areas, are likely to be most vulnerable to climate change”. [WGll TechSumm 4.3]]
“Peak streamflow will move from spring to winter in many areas where snowfall currently is an important component of the water balance (high confidence). …..Glacier retreat will continue, and many small glaciers may disappear (high confidence). The rate of retreat will depend on the rate of temperature rise.….[WGll TechSumm 4.1].
“Climate change is expected to increase the areal extent and productivity of forests over the next 50-100 years (medium confidence). However, climate change is likely to cause changes in the nature and extent of several "disturbance factors" (e.g., fire, insect outbreaks) (medium confidence).” [WGll TechSumm 5.6.5]

Table 3a: Impacts on water resources and food production

Water Shortages:
"Projected climate change would exacerbate water shortage and quality problems in many water-scarce areas of the world, but alleviate it in some other areas. …Climate change is projected to reduce streamflow and groundwater recharge in many parts of the world but to increase it in some other areas (medium confidence)….Several hundred million to a few billion people are projected to suffer a supply reduction of 10% or more by the year 2050 for climate change projections corresponding to 1% per year increase in CO_2 emissions." [SynRpt 3.22 p. 72]
"Approximately 1.7 billion people, one-third of the world's population, presently live in countries that are water-stressed (i.e., using more than 20% of their renewable water supply—a commonly used indicator of water stress). This number is projected to increase to about 5 billion by 2025, depending on the rate of population growth." [WGII TechSumm 4.1]
"Retreat of mountain glaciers already has begun in North America and in other regions of the world…..On a regional scale, the retreat of glaciers will affect water resources by changing (probably decreasing) water supply from glacial melt during the summer or changing the spatial location of the melt source….." WGII Report 15.2.2.2.1.
Food Production:
"By the 2080s, the additional number of people at risk of hunger as a result of climate change is estimated to be about 80 million." [WGII Report 5.3.6.2 p. 270].
The risk of hunger is not apportioned equitably within populations but will fall disproportionately on the urban poor, displaced people, rural smallholder producers, among others.[WGII Report 5.3.6.2 p. 270]"
"Degradation of soil and water resources is one of the major future challenges for global agriculture. It is established with high confidence that those processes are likely to be intensified by adverse changes in temperature and precipitation."[WGII TechSumm 4.2]
"Models of cereal crops indicate that in some temperate areas potential yields increase for small increases in temperature but decrease with larger temperature changes (medium to low confidence). In most tropical and subtropical regions potential yields are projected to decrease for most projected increases in temperature (medium confidence)."[SynRpt 3.21 p. 71]
"Some crops would benefit from modest warming accompanied by increasing CO2 but effects would vary among crops and regions (high confidence), including declines due to drought in some areas of Canada's Prairies and the U.S. Great Plains, potential increased food production in areas of Canada north of current production areas, and increased warm-temperature mixed forest production (medium confidence). However, benefits for crops would decline at an increasing rate and possibly become a net loss with further warming (medium confidence). [WGII SPM Table SPM-2 P. 235 Syn Rpt]

Table 3b: Impacts arising from changes in extreme events, sea level rise and abrupt changes

Extreme Events:
"The frequency and magnitude of many extreme climate events increase even with a small temperature increase and will become greater at higher temperatures (high confidence). Extreme events include, for example, floods, soil moisture deficits, tropical cyclones, storms, high temperatures, and fires. The impacts of extreme events often are large locally and could strongly affect specific sectors and regions. Increases in extreme events can cause critical design or natural thresholds to be exceeded, beyond which the magnitude of impacts increases rapidly (high confidence)." [WGII Tech Summ 7.2.4] ….
"The duration, location, frequency and intensity of extreme weather and climate events are likely, to very likely, to change, and would result in mostly adverse impacts on biophysical systems." [SynRpt 4.3 p. 80]
"More hot days and heat waves and fewer cold days and frost days are very likely over nearly all land areas. The changes in temperature extremes are likely to result in increased crop and livestock losses….. and increased human morbidity and heat stress-related mortality". [SynRpt 4.5 p. 80]
"Increased incidence of death and serious illness in older age groups and urban poor; increased heat stress in livestock and wildlife; increased risk of damage to a number of crops (all high confidence of occurrence in some areas)" [SynRpt Table 4-1 p. 82]
"The amplitude and frequency of extreme precipitation events is very likely to increase over many areas and the return periods for extreme precipitation events are expected to decrease. This would lead to more frequent floods and landslides with attendant loss of life, health impacts (e.g. epidemics, infectious diseases, food poisoning), property damage, loss to infrastructure and settlements... amongst others." [SynRpt 4.6 p. 80]
"Increased flood, landslide, avalanche and mudslide damage; increased soil erosion (all high confidence of occurrence in some areas)." [SynRpt Table 4-1 p. 82]
"Increased summer drying over most mid-latitude continental interiors and associated risk of drought (likely)…(projected impacts include)…."decreased crop yields; decreased water resource quantity and quality; increased risk of forest fire (all high confidence of occurrence in some areas)" [SynRpt Table 4-1. p. 82]
"Flood magnitude and frequency are likely to increase in most regions, and low flows are likely to decrease in many regions. …. The general increase in flood magnitude and frequency is a consequence of a projected general increase in the frequency of heavy precipitation events, although the effect of a given change in precipitation depends on catchment characteristics. Changes in low flows are a function of changes in precipitation and evaporation. Evaporation generally is projected to increase, which may lead to lower low flows even where precipitation increases or shows little change." [WGII TechSumm 4.1]
Sea Level Rise:
"Many coastal areas already are experiencing increased levels of sea flooding, accelerated coastal erosion, and seawater intrusion into freshwater sources; these processes will be exacerbated by climate change and sea-level rise. Sea-level rise in particular has contributed to erosion of sandy and gravel beaches and barriers; loss of coastal dunes and wetlands; and drainage problems in many low-lying, mid-latitude coastal areas. Highly diverse and productive coastal ecosystems, coastal settlements,

and island states will continue to be exposed to pressures whose impacts are expected to be largely negative and potentially disastrous in some instances." [WGII TechSumm 4.4]
"Few studies have examined potential changes in prevailing ocean wave heights and directions and storm waves and surges as a consequence of climate change. Such changes can be expected to have serious impacts on natural and human-modified coasts because they will be superimposed on a higher sea level than at present." [WGII TechSumm 4.4]
"Tens of millions of people live in the settlements potentially flooded. For example, estimates of the mean annual number of people who would be flooded by coastal storm surges increase several-fold (by 75 million to 200 million people, depending on adaptive responses) for mid-range scenarios of a 40-cm sea-level rise by the 2080s relative to scenarios with no sea-level rise." [WGII Tech Summ 4.5]
"Populations that inhabit small islands and/or low-lying coastal areas are at particular risk of severe social and economic effects from sea-level rise and storm surges. Many human settlements will face increased risk of coastal flooding and erosion, and tens of millions of people living in deltas, in low-lying coastal areas, and on small islands will face risk of displacement. Resources critical to island and coastal populations such as beaches, freshwater, fisheries, coral reefs and atolls, and wildlife habitat would also be at risk." [SPM SynRpt p. 12]
"Projected sea-level rise will increase the average annual number of people flooded in coastal storm surges (high confidence)……Significant portions of many highly populated coastal cities are also vulnerable to permanent land submergence and especially to more frequent coastal flooding superimposed on surge heights, due to sea-level rise. These estimates assume no change in the frequency or intensity of storms, which could exacerbate the effects of sea-level rise on flooding risk in some areas." [SynRpt 3.24 p. 74]
"Low-latitude tropical and subtropical coastlines, particularly in areas where there is significant human population pressure, are highly susceptible to climate change impacts. These impacts will exacerbate many present-day problems.….For instance, human activities have increased land subsidence in many deltaic regions by increasing subsurface water withdrawals, draining wetland soils, and reducing or cutting off riverine sediment loads. Problems of inundation, salinization of potable groundwater, and coastal erosion will all be accelerated with global sea-level rise superimposed on local submergence. Especially at risk are large delta regions of Asia and small islands whose vulnerability was recognized more than a decade ago and continues to increase." [WGII TechSumm 4.4]
"High-latitude (polar) coastlines also are susceptible to climate warming impacts, although these impacts have been less studied. Except on rock-dominated or rapidly emerging coasts, a combination of accelerated sea-level rise, more energetic wave climate with reduced sea-ice cover, and increased ground temperatures that promote thaw of permafrost and ground ice (with consequent volume loss in coastal landforms) will have severe impacts on settlements and infrastructure and will result in rapid coastal retreat." [WGII TechSumm 4.4]
"Sea-level rise would result in enhanced coastal erosion, coastal flooding, loss of coastal

wetlands, and increased risk from storm surges (in North America), particularly in Florida and much of the U.S. Atlantic coast (high confidence).” [WGII SPM Table SPM-2 p. 235 SynRpt]
Abrupt climatic and ecological changes:
“Greenhouse gas forcing in the 21st century could set in motion large-scale, high impact, non-linear, and potentially abrupt changes in physical and biological systems over the coming decades to millennia, with a wide range of associated likelihoods.” [IPCC SynRpt 4.9 p. 81]
“Human-induced climate change has the potential to trigger large-scale changes in Earth systems that could have severe consequences at regional or global scales. The probabilities of triggering such events are poorly understood but should not be ignored, given the severity of their consequences. Events of this type that might be triggered include complete or partial shutdown of the North Atlantic and Antarctic Deep Water formation, disintegration of the West Antarctic and Greenland Ice Sheets, and major perturbations of biosphere-regulated carbon dynamics. …. Large temperature increases have the potential to lead to large-scale discontinuities in the climate system (medium confidence).” [WGII TechSumm 7.2.5]
“The likelihood of many of these changes in Earth systems is not well-known, but it is probably very low; however, their likelihood is expected to increase with the rate, magnitude and duration of climate change….If these changes in Earth Systems were to occur, their impacts would be widespread and sustained.” [WGII SPM p. 225 SynRpt]
“Many natural and managed ecosystems may change abruptly or non-linearly during the 21st century. The greater the magnitude and rate of change, the greater the risk of adverse impacts.” [SynRpt 4.17 p. 84]
“Changes in climate could increase the risk of abrupt and non-linear changes in many ecosystems, which would affect their biodiversity, productivity and function.” [SynRpt 4.18 p. 84-5]
“In the Antarctic, projected climate change will generate impacts that will be realized slowly (high confidence*).* Because the impacts will occur over a long period, however, they will continue long after GHG emissions have stabilized. For example, there will be slow but steady impacts on ice sheets and circulation patterns of the global ocean, which will be irreversible for many centuries into the future and will cause changes elsewhere in the world, including a rise of sea level. Further substantial loss of ice shelves is expected around the Antarctic Peninsula.” [WGII TechSumm 5.7]
“The Arctic is extremely vulnerable to climate change…..In developed areas of the Arctic and where the permafrost is ice-rich, special attention will be required to mitigate the detrimental impacts of thawing, such as severe damage to buildings and transport infrastructure (very high confidence)” [WGII TechSumm 5.7]

Table 4: Impacts on human life

"If heat waves increase in frequency and intensity, the risk of death and serious illness would increase, principally in older age groups and the urban poor (high confidence). The effects of an increase in heat waves often would be exacerbated by increased humidity and urban air pollution. The greatest increases in thermal stress are forecast for mid- to high-latitude (temperate) cities, especially in populations with non-adapted architecture and limited air conditioning" [WGII TechSumm 4.7]
"More hot days and heat waves are very likely over nearly all land areas." [WG1 Report TechSumm F.5 p.208 SynRpt.]
(In North America) "increased frequency and severity of heat waves may lead to an increase in illness and death, particularly among young, elderly and frail people, especially in large urban areas. Acclimatization may be slower than the rate of ambient temperature change."[WGII Report: CH. 15 (North America) Executive Summary p.738]
"Higher temperatures, changes in precipitation, and changes in climate variability would alter the geographic ranges and seasonality of transmission of vector-borne infectious diseases— extending the range and season for some infectious diseases and contracting them for others." [WGII TechSumm. 4.7].
"Expansion of areas of potential transmission of malaria and dengue (is projected with) medium to high confidence." [Table 3-1 Section 3.17 IPCC Synthesis Report.]
"Vector-borne diseases, including malaria and dengue fever, may expand their ranges in the United States and may develop in Canada. Tick-borne Lyme disease may also expand its range in Canada…..Diseases associated with water may increase with warming of air and water temperatures, combined with heavy runoff events from agricultural and urban surfaces." [WGII Report: CH. 15 (N.A.) Executive Summary p.738; also WGII TechSumm 5.6.6] [15.2.4]
"Climate change will decrease air quality in urban areas with air pollution problems (medium confidence). An increase in temperature (and, in some models, ultraviolet radiation) increases the formation of ground-level ozone, a pollutant with well-established adverse effects on respiratory health." [WGII TechSumm 4.7]
(In North America) "respiratory disorders may be exacerbated by warming-induced increases in the frequency of smog (ground-level ozone) events, acidic deposition, and particulate air pollution." [WGII Report: CH. 15 (North America.) Executive Summary p.738]
"Any increases in the frequency and intensity of extreme events such as storms, floods, droughts, and cyclones would adversely impact human health through a variety of pathways. These natural hazards can cause direct loss of life and injury and can affect health indirectly through loss of shelter, population displacement, contamination of water supplies, loss of food production (leading to hunger and malnutrition), increased risk of infectious disease epidemics (including diarrhoeal and respiratory disease), and damage to infrastructure for provision of health services (very high confidence)" [WGII TechSumm 4.7]
"The frequency of extreme precipitation events is projected to increase almost everywhere. There is projected to be a general drying of the mid-continental areas during summer." [WG1 TechSumm F.5 p. 208 SynRpt.]

"The Arctic is extremely vulnerable to climate change, and major physical, ecological, and economic impacts are expected to appear rapidly. …. There will be different species compositions on land and sea, poleward shifts in species assemblages, and severe disruptions for communities of people who lead traditional lifestyles. For indigenous communities who follow traditional lifestyles, opportunities for adaptation to climate change are limited (very high confidence)" [WGII TechSumm 5.7].

Table 5: Concerns about the risks from climate change rise with temperature (Box 3-2 IPCC Synthesis Report.)
"***Unique and threatened systems****:* Some changes in species and systems have already been associated with observed changes in climate, and some highly vulnerable species and systems may be at risk of damage or even loss for very small changes in climate. Greater warming would intensify the risks to these species and systems, and place additional ones at risk. "
"***Extreme climate events****:* Increased frequencies and intensities of some extreme events have already been observed and are likely to increase with further warming, as would the risks to human life, property, crops, livestock, and ecosystems. These risks increase where development is occurring in inherently dynamic and unstable zones (e.g., river floodplains and low-lying coastal regions)."
"***Uneven distribution of impacts****:* In general, developing countries are at greater risk of adverse impacts from climate change than are developed countries, of which some of the latter may experience market sector benefits for warming less than a few °C. For greater warming, most regions are at risk of predominantly negative effects from climate change. But developing countries generally would continue to be more severely impacted than developed countries. Within countries, vulnerability varies and the poorest populations often have higher exposure to impacts that threaten their lives and livelihoods. "
"***Global aggregate impacts****:* Globally aggregated market sector impacts may be positive or negative up to a few °C, though the majority of people may be negatively affected. With greater warming, the risk of negative global market sector impacts increases, and impacts would be predominantly negative for most people. "
"***Large-scale, high-impact events****:* The probability of large-scale, high-impact events within a 100- year time horizon such as shutdown of the thermohaline circulation or collapse of the West Antarctic ice sheet is very low for warming less than a few °C. The risk, which is a product of the probabilities of these events and the magnitude of their consequences, is largely unquantified. For greater warming, and over a time horizon longer than 100 years, the probabilities and the risks increase, but by an amount that cannot now be estimated."

Figure 1 Annex B: Figure SPM-2 IPCC WGII Summary for Policymakers.

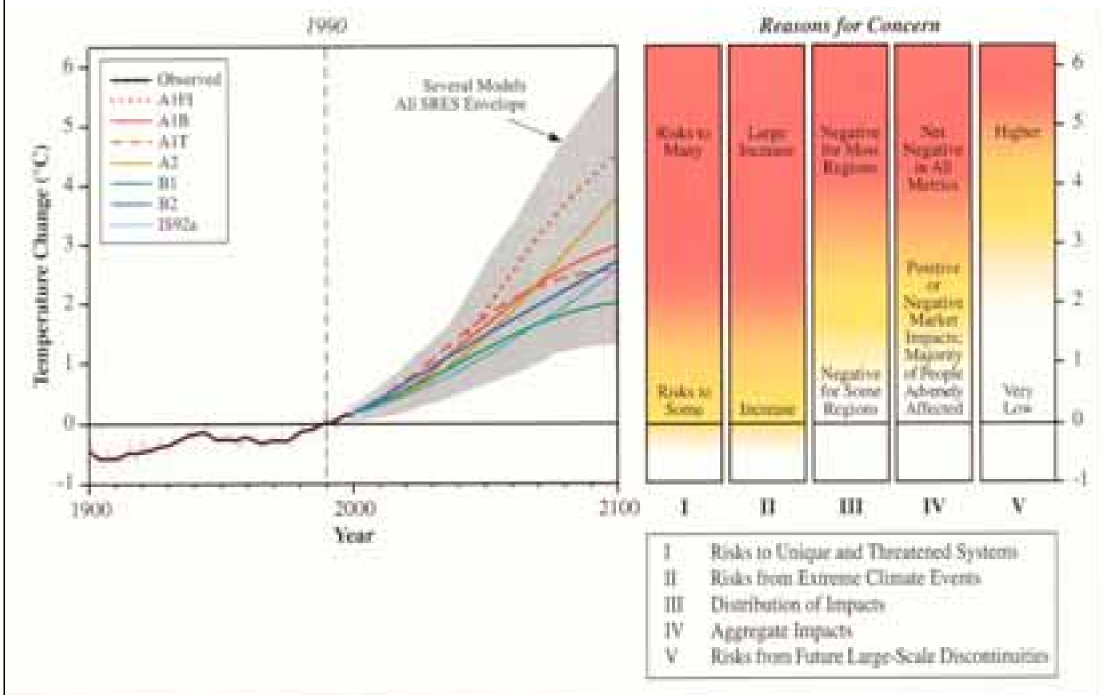

Figure SPM-2: Reasons for concern about projected climate change impacts. The risks of adverse impacts from climate change increase with the magnitude of climate change. The left part of the figure displays the observed temperature increase relative to 1990 and the range of projected temperature increase after 1990 as estimated by Working Group I of the IPCC for scenarios from the Special Report on Emissions Scenarios. *(Inserted Note: The coloured lines represent average projections of global temperature from several climate models that result from different scenarios of future GHG and aerosol emissions. The grey shadowy area encompasses the full range of projections from the model*s.) The right panel displays conceptualizations of five reasons for concern regarding climate change risks evolving through 2100. White indicates neutral or small negative or positive impacts or risks, yellow indicates negative impacts for some systems or low risks, and red means negative impacts or risks that are more widespread and/or greater in magnitude. The assessment of impacts or risks takes into account only the magnitude of change and not the rate of change. Global mean annual temperature change is used in the figure as a proxy for the magnitude of climate change, but projected impacts will be a function of, among other factors, the magnitude and rate of global and regional changes in mean climate, climate variability and extreme climate phenomena, social and economic conditions, and adaptation.