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Memo

To:	Léa-Marie Bowes-Lyon, TMAC Katsky Venter, TMAC	**Client:**	TMAC Resources Inc.
From:	Victor Munoz, SRK	**Project No:**	1CT022.001
Cc:	Maritz Rykaart, SRK	**Date:**	March 28, 2014
Subject:	Water Cover Design for Tail Lake – Climate Change Update		

1 Introduction

The Doris North Project is a mining and milling undertaking of TMAC Resources Inc. Tailings will be deposited sub-aqueously in Tail Lake, which will be contained by two dams (North and South Dams). SRK Consulting (Canada) Inc. completed a design for the minimum water cover required to prevent re-suspension of tailings and prevent subsequent water quality effects (SRK 2011, 2005).

The water cover analysis utilized historical meteorological information obtained from the Cambridge Bay meteorological station. This memorandum complements previous work by way of performing a sensitivity analysis around meteorological parameters, based on outputs from global climate models.

This memorandum is expected to be read in conjunction with the SRK (2011) memorandum "Tail Lake Water Cover Design: Motivation to Reduce Water Cover Thickness".

2 Supporting Information

2.1 Climate Change Modelling

The Intergovernmental Panel on Climate Change (IPCC) is a scientific intergovernmental body associated with the United Nations, and has produced numerous models depicting future climate change. These models are based on varying concentrations of atmospheric greenhouse gases, in combination with a range of cases for economic growth, energy sources, population growth, land use and hydrocarbon usage.

Climate change scenarios based on the IPCC climate models are available through various websites. Two Canadian websites that provide this data are the Pacific Climate Impacts Consortium (PCIC) and the Canadian Climate Change Scenarios Network (CCCSN) available at http://www.pacificclimate.org/ and http://www.cccsn.ca/ respectively.

2.2 Minimum Water Cover Requirements

The 2011 SRK memorandum presented two approaches for calculating the minimum water cover at Tail Lake:

- Ice entrainment, and
- Wave action.

This memo discusses updates made to each of these calculations through consideration of climate change.

3 Methodology

3.1 Ice Entrainment Approach

Ice entrainment was previously estimated based on decay models from Bilello (1980). This model was calibrated based on available ice thickness measurements at the site. Bilello's methodology is a lineal equation composed of a coefficient alpha, which is multiplied by the accumulated degree days for a full year. In this expression, higher average temperatures will produce a reduction in the ice thickness measurements.

For the climate change temperature estimations, a tool from CCCSN was used, which provides climate change data based on weather station locations. Three "ensemble-mean" models can be used to predict climate change. The website recommends using the ensemble models as they are able to distinguish climate change from natural system variations (CCCSN 2014).

The CCCSN approach uses combinations of several experimental models in its results, as previously discussed. For this purpose, the CCCSN method was analyzed with the Cambridge Bay station temperature values. A total temperature increase is predicted for the Cambridge Bay and Tail Lake area as summarized in Table 1.

Table 1: Annual, Winter and Summer Mean Temperature Change in Cambridge Bay between 2020 and 2080 relative to the 1971-2000 Baseline

Ensemble Mean Scenario	Change Relative to the 1971-2000 baseline [Temp ˚C]								
	Annual			Winter			Summer		
	Max	Average	Min	Max	Average	Min	Max	Average	Min
SR-A2	+8.0	+4.7	+1.3	+12.0	+6.8	+1.6	+5.4	+2.8	+0.1
SR-A1B	+7.1	+4.2	+1.3	+10.2	+6.0	+1.8	+4.7	+2.5	+0.2
SR-B1	+4.7	+3.0	+1.2	+6.7	+4.2	+1.6	+3.5	+1.9	+0.2

Source: CCCSN, 2014

Based on this assessment from CCCSN, temperatures are expected to increase, and as a result the ice thickness would be expected to decrease over time. A conservative approach, in this case, will be to continue to use the previous estimation of ice thickness at Tail Lake, which was defined to be 2.05 m (SRK 2011).

3.2 Wave Action Approach

The concept of the wave action approach is to estimate the water depth threshold to ensure the tailings are not re-suspended during closure. As a part of the estimations, several environmental parameters are required, including fetch length, wind speed and wind direction.

In this analysis, it is assumed that fetch length and wind direction will remain constant over time, and therefore will not be affected by climate change estimations. SRK (2014) (Attachment 1) estimates that the hourly wind speed could increase to a maximum of 31.8 m/s, based respectively on the results of 95% of the CCCSN models for the time period spanning between the years 2011 to 2100.

To model this increase in wind speed, the 2011 SRK analysis has been updated to generate design parameters under a “realistic” case and “conservative” case. The “realistic” case represents the mostly likely set of design parameters, while the “conservative” case presents the most conservative range of design parameters. Design parameters that are updated include threshold velocity and maximum wind speed.

3.2.1 Threshold Velocity

The threshold velocity was updated based on the increase in the wind speed. Three methods were used to estimate threshold velocity, including Dingler (1979), Komar and Miller (1975), and MEND (1998). The MEND method is based on the median particle size, and is therefore not affected by the change in maximum wind speed. Table 2 presents an update of threshold velocities for both cases and each methodology.

Table 2: Threshold velocity expressions for Tail Lake

Method	Realistic Case				Conservative Case			
	Median Particle Size (mm)	Fetch (m)	Max. Wind Speed (m/s)	Particle Density (kg/m³)	Median Particle Size (mm)	Fetch (m)	Max. Wind Speed (m/s)	Particle Density (kg/m³)
	0.080	290	***28.1 (50%)***	2,850	0.076	626	***31.8 (95%)***	2,760
Komar and Miller (1975)	***0.761 m/s***				***0.800 m/s***			
Dingler (1979)	***0.491 m/s***				***0.533 m/s***			
MEND (1998)	0.063 m/s				0.065 m/s			
Suggested Design Value (Minimum)	0.063 m/s				0.065 m/s			

From Table 2, the minimum threshold velocity is from the MEND methodology. Since the MEND approach is independent of wind speed, the suggested design value for threshold velocity is not affected by climate change.

3.2.2 Design Criteria

Table 3 compiles a summary of the design criteria updates used to calculate the Tail Lake water cover in accordance with the methods by MEND (1998) and Lawrence (1991).

Table 3: Summary of design parameters for Tail Lake water cover design – Climate Change Update

Parameter	Realistic Case (Case 1)	Conservative Case (Case 2)
Fetch (m)	290	626
Maximum Wind Speed (m/s)	***28.1***	***31.8***
Median Particle Size (mm)	0.080	0.076
Threshold Velocity (m/s)	0.063	0.065
Particle Density (kg/m³)	2,850	2,760
Wave Height Ratio (dimensionless)	1.0	1.0
Ice Thickness (m)	2.01	2.05

3.2.3 Results

The water cover, as calculated using the Lawrence et al. (1991) and MEND (1998) methodologies, assumes that wave development is consistent with deep water wave theory. Deep water wave theory applies when the ratio of water depth over wavelength is less than 0.5, which is typically not met for shallow water covers (typically less than 5 m deep). Under such circumstances, shallow water wave theory must be applied, which results in calculating smaller significant wave heights and shorter significant wave periods.

Both Lawrence *et al*. (1991) and MEND (1998) design procedures suggest that the water cover design does not apply if the deep water wave condition cannot be met; however, they do not propose a solution to overcome this problem. Shore Protection Manual of the U.S. Army Coastal Engineering Research Center (CERC 1984) does provide a procedure to calculate the significant wave height and period using shallow wave theory.

This memorandum prepares a similar sensitivity analysis as prepared by SRK (2011), comparing water cover results for deep water wave theory as well as shallow wave theory. Table 4 shows the results considering climate change updates.

Table 4: Water cover design update including deep and shallow water wave theory

Author		**Deep Water Wave**	**Shallow Water Wave**	**Variation [ΔX]**
Lawrence et al (1991)	Case 1	1.07 m	1.03 m	0.04 m
	Case 2	2.05 m	2.00 m	0.05 m
MEND (1998)	Case 1	0.19 m	0.20 m	0.01 m
	Case 2	0.44 m	0.46 m	0.02 m

The minimum water cover, based on shallow and deep water wave action and including a climate change sensitivity analysis, is between 1.03 m and 2.05 m, depending on the methodology used (this assumes a correction for the shallow wave theory). Lawrence's expression results in the most conservative water cover design.

Based on the results presented in Table 4, the recommended minimum water cover due to wave action is 2.05 m.

4 Conclusion

Water cover is estimated based on the maximum result from the ice entrainment methodology and the wave action methodology.

The original design (SRK, 2011) suggests the critical methodology is the ice entrainment design, resulting in a water cover of 2.05 m. With the additional consideration of climate change impacts to temperature and ice thickness, the water cover could be reduced based on ice entrainment.

The wave action criteria, however, could experience an increase, based on the potential increase in maximum hourly wind speed at the site. The minimum water cover based on the wave action criteria is now 2.05 m, over the 1.78 m design estimated in the previous study (SRK 2011).

Based on these results, the impact of climate change to water cover design is that the limit is now governed by the wave action criteria instead of the ice entrainment criteria.

Table 5: Tail Lake water requirement comparison

	SRK 2011	**SRK 2014 Including Effects of Climate Change**
Minimum water cover required to prevent Ice Scour	2.05 m	< 2.05 m
Minimum water cover required to account for wave action	0.12 to 1.78 m	1.03 to 2.05 m
Minimum water cover considered in the design	2.05 m	2.05 m
Allowance required allowing for undulation in tailings surface	0.25 m	0.25 m
Allowance required to allow for severe drought conditions	0 m	0 m
Total Water Cover At Tail Lake	**2.30 m**	**2.30 m**

Based on Table 5, the original water cover design provided in the SRK 2011 report is sufficient to allow for potential changes due to climate change. The recommended total water cover at Tail Lake is 2.30 m.

Disclaimer

“This report and the opinions and conclusions contained herein (“Report”) contains the expression of the professional opinion of SRK Consulting (Canada) Inc. (“SRK”) as to the matters set out herein, subject to the terms and conditions of the agreement dated [HBML.BOC-CM.PSA.003, September 30, 2008] (the “Agreement”) between Consultant and Hope Bay Mining Ltd., as assigned to TMAC Resources Inc. (“TMAC”), the methodology, procedures and sampling techniques used, SRK’s assumptions, and the circumstances and constraints under which Services under the Agreement were performed by SRK. This Report is written solely for the purpose stated in the Agreement, and for the sole and exclusive benefit of TMAC, whose remedies are limited to those set out in the Agreement. This Report is meant to be read as a whole, and sections or parts thereof should thus not be read or relied upon out of context. In addition, this report is based in part on information not within the control of SRK. Accordingly, use of such report shall be at the user's sole risk. Such use by users other than TMAC and its corporate affiliates shall constitute a release and agreement to defend and indemnify SRK from and against any liability (including but not limited to liability for special, indirect or consequential damages) in connection with such use. Such release from and indemnification against liability shall apply in contract, tort (including negligence of SRK whether active, passive, joint or concurrent), strict liability, or other theory of legal liability; provided, however, such release, limitation and indemnity provisions shall be effective to, and only to, the maximum extent, scope or amount allowable by law.”.

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Attachment 1

Tail Lake Climate Change Memorandum

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Memo

To:	Katsky Venter, TMAC Léa-Marie Bowes-Lyon, TMAC	**Client:**	TMAC Resources Inc.
From:	Victor Munoz, SRK	**Project No:**	1CT022.001.310
Cc:	Maritz Rykaart, SRK	**Date:**	March 28, 2014
Subject:	Climate change evaluation of monthly wind velocities at Tail Lake		

1 Introduction

SRK Consulting (Canada) Inc. was retained by TMAC Resources Inc. to assess the impact of climate change on wind velocities across Tail Lake for a 100 year return period.

As part of this study, SRK evaluated various climate models, and compared the results in terms of percent change of wind velocities. The result of this analysis is a range of predicted maximum hourly wind velocities with a 100 year return period, that can be expected between now and the year 2100.

Notwithstanding the analysis results presented, SRK believes that reliance on contingencies rather than predictions is consistent with current best practices. For example, NRCAN (2004) states:

> *"Given the complexity of these systems, uncertainty is unavoidable, and is especially pronounced at the local and regional levels where many adaptation decisions tend to be made. Nonetheless, there are ways to deal with uncertainty in a risk management context, and most experts agree that present uncertainties do not preclude our ability to initiate adaptation"* and

> *"In all sectors, adaptation has the potential to reduce the magnitude of negative impacts and take advantage of possible benefits. Researchers recommend focusing on actions that enhance our capacity to adapt and improve our understanding of key vulnerabilities. These strategies work best when climate change is integrated into larger decision-making frameworks"*

2 Supporting Information

Climate is a complex system of highly independent natural forces, including ocean circulation and solar intensity, as well as anthropogenic factors such as population, economic growth, and fuel consumption. These complexities result in a high level of uncertainty in predictions of long term future climate. As a result, the Intergovernmental Panel on Climate Change (IPCC) provides a wide range of climate change predictions to 2100.

2.1 IPCC Climate Models

The IPCC models are generated based on varying concentrations of atmospheric greenhouse gases, in combination with a range of cases for economic growth, energy sources, population growth, land use, and hydrocarbon usage.

> *“There is no single central or "best guess" scenario, and probabilities or likelihood are not assigned to individual scenarios. None of the [models] represent an estimate of a central tendency for all driving forces or emissions, such as the mean or median, and none should be interpreted as such. The distribution of the [models] provides a useful context for understanding the relative position of a [model] but does not represent the likelihood of its occurrence”* (IPCC, 2000).

Climate change models based on the IPCC climate models are available through various websites. Two Canadian websites that provide this data are the Pacific Climate Impacts Consortium (PCIC) and the Canadian Climate Change Scenarios Network (CCCSN).

The PCIC provides a regional analysis tool to obtain climate prediction values for specific regions along the pacific coast. Regional climate data is available by province, territory, or for custom regions and can be defined by drawing a region on the website map. The climate change data available is relative to the 1971-2000 baseline.

The Canadian Climate Change Scenarios Network (CCCSN) supports climate change impact and adaptation research in Canada through the provision of global climate models and regional climate models with the full support of Environment Canada (EC). CCCSN provides climate change data based on global climate models from the IPCC’s second (SAR), third (TAR) and fourth (AR4) assessment reports. Tables 1, 2, and 3 present the assessment reports available on the CCCSN website. Each model is characterized by different meteorological parameters including air temperature, sea level, total precipitation, and wind speed. This information is presented in monthly, seasonal, and annual time steps.

CCCSN suggests that a variety of models be used in order to represent an average and/or extreme scenario for the location of interest. The analysis performed for the project site as presented in this memo incorporated all of the global climate models which include wind speed.

3 Methodology

The desired outcome of the climate change analysis is peak hourly wind velocities for a 100 year return period. However, the outputs from the climate models are monthly average wind velocities. A relationship was therefore established to convert maximum monthly average wind velocities to peak hourly velocities. The following methodology describes the comparison between climate model outputs and the transition from monthly values to hourly values.

3.1 Climate Model Outputs

Each model presents predicted monthly average wind velocities for three time frames, over a period of 30 years, which span from 2011 to 2040, 2041 to 2070, and 2071 to 2100. For each time period, the climate model generates a baseline record, from 1961 to 1990 or 1971 to 2000, depending on the source of the assessment report (second, third, or fourth edition). In other words, the output from the climate models was the baseline record and a predicted record, for each time period.

Table 4 presents the number of available climate change models for each time period, from each revision of the CCCSN report.

3.2 Frequency Analysis for Maximum Monthly Average Wind Velocities

For each time period within each model, two frequency analyses were performed to establish the maximum monthly average wind velocities with a 100 year return period under baseline conditions and under the predicted changed conditions.

The frequency analyses were performed on wind data from the open water season months (June through September) from each year of record for both the baseline and predicted conditions.

The outcomes for each time period are a baseline maximum monthly average velocity with a 100 year return period ($V_{Baseline}$), and a predicted maximum monthly average velocity with a 100 year return period ($V_{Predicted}$).

3.3 Percent Change

Each model is based on different underlying assumptions and boundary conditions, which results in variations in the baseline data as well as the predicted data. In order to compare the results between models, a percent change term was established for each model and time period, based on the baseline wind velocities, as expressed in Equation 3.3.

$$Percent\ change\ [\%] = \frac{Velocity_{Predicted} - Velocity_{Baseline}}{Velocity_{Baseline}} \quad \text{(Eq.3.3)}$$

From Eq. 3.3, a positive percent change corresponds to an increase in the 100 year return period wind velocity after climate change, and a negative percent change corresponds to a reduction in the 100 year return period wind velocity after climate change, relative to the baseline 100 year return period wind velocities. By calculating the percent change for each model and time period, all of the results can be compared on equal terms.

The percent change results for each model have been calculated for each of the three time periods.

3.4 Predicted Maximum Monthly Average Wind Velocities

Using the percent change terms generated from Section 3.3, the predicted maximum monthly average velocity is calculated using the historical data from 1971 - 2000, using Equation 3.4:

$$Velocity_{Predicted} = Percent\ Change\ [\%]\ \times\ Velocity_{Baseline} \qquad \text{(Eq. 3.4)}$$

In each case, the baseline velocity for a 100 year return period maximum monthly average wind velocity is equal to 7.95 m/s, which was determined from a frequency analysis of historical data from Cambridge Bay. Equation 3.4 was applied to the data for each time period to obtain the predicted velocity corresponding to each percent change term.

3.5 Predicted Maximum Hourly Wind Velocities

Historical hourly wind velocities for Cambridge Bay exist from 1953 to 2010. This data was used to generate a relationship between maximum monthly average velocities and maximum hourly velocities.

In order to establish a relationship, the historical record was converted into two data sets. The first data set consists of the annual maximum of the monthly average velocities, between 1953 and 2010, during the open water season. The second data set consists of the annual maximum hourly velocities, over the same time period. The data sets were compared on a graph, and a linear envelope curve was generated, as shown in Figure 6, to capture the maximum hourly velocities.

The equation of the envelope curve allowed for the conversion of maximum monthly average velocities to maximum hourly velocities.

4 Results

4.1 Percent Change for Maximum Monthly Average Wind Velocity

Figure 1 presents the percent change term for the maximum monthly average wind velocity during the open water season with a return period of 100 years for each model in the first predictive time period, which spans from 2011 to 2040. Figure 2 presents the same results, but for the predictive time period from 2041 to 2070 and Figure 3 shows the results from 2071 to 2100. In these figures, the x-axis presents the models, and the y-axis presents the predicted percent change term.

From the results shown in Figures 1 through 3, the climate change models exhibit significant amounts of variation between predicted percent change terms. In order to understand the trends in these results, each time period was examined separately.

Figure 4 was generated to show the model results, sorted from lowest to highest. The x-axis shows the percentage of all models whose results agree that the percent change to wind velocities will be less than or equal to a given value. For example, 50% on the x-axis indicates that 50% of the models predict that the percent change will be less than 4% for the 2071-2100 time period, less than 3% for the 2041-2070 time period, and less than 1% for the 2011-2040 time period. In other words, 50% of all the models suggest that the 100 year return maximum monthly average wind velocity will not increase by more than 4% before the year 2100.

Similarly, 95% of the models agree that the percent change of the maximum monthly average wind velocity will be less than or equal to 24% before 2100. Or in other words, only 5% of the models expect the wind velocity statistic to increase by more than 24%.

One trend observed in Figure 4 shows the models predict the percent change to wind velocities will increase over time. This is denoted by the fact that the 2071-2100 time frame line is above the 2041-2070, and the 2041-2070 line is above the 2011-2040 time frame line. A second observation is that the percent change to wind velocities may be somewhere between -14% and 24% in the next 100 years. A negative percentage change corresponds to a decrease in wind velocities.

Table 5 presents the average and extreme wind velocity percent change results for three percentiles (5, 50, and 95) from Figure 4. The Low 5th percentile signifies that less than 5% of the models expect wind velocities to decrease by more than 14% before the year 2100. The Median percentile signifies that 50% of the models expect wind velocities to increase by less than 4% before the year 2100; and the High 95th percentile signifies that less than 5% of the models expect wind velocities to increase by more than 24% before 2100.

4.2 Predicted Maximum Monthly Average Wind Velocities

Equation 3.4 was used to convert percentage change into the predicted maximum monthly average wind velocities. This conversion was completed for each percent change presented in Figure 4. Figure 5 shows the model percentage versus the predicted maximum monthly average wind velocities.

Similarly to Figure 4, the x-axis shows the percentage of all models whose results agree that the predicted wind velocity will be less than or equal to a given value. For example, 50% on the x-axis means that 50% of the models predict that the maximum velocity be less than 8.3 m/s in the 2071-2100 time frame, less than 8.2 m/s in the 2041-2070 time frame, and less than 8 m/s in the 2011-2040 time frame. In other words, 50% of all the climate scenarios modelled suggest that the maximum monthly average wind velocity will not exceed 8.3 m/s for the 100 year return period, before the year 2100.

Table 5 shows the predicted maximum monthly average velocity corresponding to the three pre-defined percentiles, as described in Section 4.1. The table shows the range of wind velocities that can be expected in each percentile, as well as the baseline velocities, for comparative purposes.

4.3 Predicted Maximum Hourly Wind Velocities

The relationship between historical maximum monthly average velocities and maximum hourly velocities was generated and presented in Figure 6, and the expression for the envelope curve is given by Equation 4.3.

$$Velocity_{Maximum\ Hourly} = 2.48 \times Velocity_{Max\ of\ Monthly\ Average} + 7.5 \qquad \text{(Eq. 4.3)}$$

Equation 4.3 can be applied to any maximum monthly average velocity to define the corresponding maximum hourly velocity. The envelope curve was used instead of a line of best fit to capture the maximum values.

The predicted maximum monthly average velocities for the 3 model percentiles, from Table 5, were converted to predicted maximum hourly velocities using Equation 4.3.

5 Summary

SRK used a combination of climate models in order to estimate a range of predicted hourly wind velocities with a 100 year return period on Tail Lake. This range is denoted by three percentiles; Low 5th percentile, Median percentile, and High 95th percentile. The results are expressed as maximum hourly wind velocities for the 100 year return period, as follows:

- The baseline maximum hourly wind velocity with a 100 year return period is 27.1 m/s, from the historical Cambridge Bay record.
- The Low (95% Exceedance) percentile signifies that less than 5% of the models expect maximum hourly wind velocities to go below 24.5 m/s, (or decrease by more than 14%), before the year 2100.
- The Median (50% Exceedance) percentile signifies that 50% of the models expect maximum hourly wind velocities to be less than 28.1 m/s, (or increase by less than 4%), before the year 2100.
- The High (5% Exceedance) percentile signifies that less than 5% of the models expect maximum hourly wind velocities to exceed 31.8 m/s, (or increase by more than 24%), before the year 2100.

Disclaimer

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Tables

Table 1: Models from the IPCC's Second Assessment Report (IS92a experiment) and their basic characteristics, i.e., domain and resolution (horizontal and vertical) and scenarios available at CCCSN webpage

CENTRE	MODEL	RESOLUTION	SCENARIO
Center for Climate Research Studies (CCSR) and National Institute for Environmental Studies (NIES), Japan	CCSRNIES	T21 L20 (5.6° lat x 5.6° long)	GGA1, GSA1
Canadian Centre for Climate Modelling and Analysis (CCCma)	CGCM1 (IS92a)	T32 L10 (3.7° lat x 3.7° long)	GGA1, GSA1, GSA2, GSA3
Australia's Commonwealth Scientific and Industrial Research Organization (CSIRO)	CSIROMk2b (IS92a)	R21 L9 (3.2° lat x 5.6° long)	GGA1, GSA1
Deutsches Klimarechenzentrum (DKRZ), Germany	ECHAM3	T21	GGA1, GSA1, GSA2
Deutsches Klimarechenzentrum (DKRZ), Germany	ECHAM4	T42 L19 (2.8° lat x 2.8° long)	GGA1, GSA1, GSA2
Geophysical Fluid Dynamics Laboratory (GFDL), USA	GFDLR15	R15 (4.5° lat x 7.5° long)	GGA1, GSA1
Hadley Centre for Climate Prediction and Research (HCCPR), UK	HADCM2	T42 (2.5° lat x 3.75° long)	GGA1, GGA2, GGA3, GGA4, GSD1, GSD2, GSD3, GSD4, GGS1, GGS2, GGS3, GGS4, GSA1, GSA2, GSA4
Hadley Centre for Climate Prediction and Research (HCCPR), UK	HADCM3	T42 L19 (2.5° lat x 3.75° long)	GGA1, PAA
National Center for Atmospheric Research (NCAR), USA	NCARPCM (IS92a)	T42 L18 (2.8° lat x 2.8° long)	BAU

Table 2: Models from the IPCC's Third Assessment Report (TAR) and their basic characteristics, i.e. domain and resolution (horizontal and vertical), and scenarios available at CCCSN webpage

CENTRE	MODEL	RESOLUTION	SCENARIO
Center for Climate Research Studies (CCSR) and National Institute for Environmental Studies (NIES), Japan	CCSRNIES	T21 L20 (5.6° lat x 5.6° long)	SR-A1, SR-A1F1, SR-A1T, SR-A2, SR-B1, SR-B2
Canadian Centre for Climate Modelling and Analysis (CCCma)	CGCM1	T32 L10 (3.7° lat x 3.7° long)	SR-A2, SR-B2
Australia's Commonwealth Scientific and Industrial Research Organisation (CSIRO)	CSIROMk2b	R21 L9 (3.2° lat x 5.6° long)	SR-A1, SR-A2, SR-B1 SR-B2
Geophysical Fluid Dynamics Laboratory (GFDL), USA	GFDLR30	R30 L14 (2.25° lat x 3.75° long)	SR-A2, SR-B2
Hadley Centre for Climate Prediction and Research (HCCPR), UK	HADCM3	T42 L19 (2.5° lat x 3.75° long)	SR-A2, SRA2B, SRA2C, SR-B2
National Center for Atmospheric Research (NCAR), USA	NCARPCM	T42 L18 (2.8° lat x 2.8° long)	SR-A2, SR-B2

Source: CCCSN webpage

Table 3: Models from the IPCC's Fourth Assessment Report (AR4), and scenarios available at CCCSN webpage

CENTRE	MODEL	SCENARIO
Beijing Climate Center	BCCCM1	1PTO2X, 1PTO4X
Bjerknes Centre for Climate	BCM2.0	SR-A2, SR-B1
Canadian Centre for Climate Modelling and Analysis (CCCma)	CGCM3T47	1PTO2X, 1PTO4X, SR-A1B, SR-A2, SR-B1
	(T47 resolution)	
Canadian Centre for Climate Modelling and Analysis (CCCma)	CGCM3	SR-A1B, SR-B1
	(T63 resolution)	
Centre National de Recherches Meteorologiques	CNRMCM3	1PTO2X, 1PTO4X, COMMIT, SR-A1B, SR-A2, SR-B1
Australia's Commonwealth Scientific and Industrial Research Organisation (CSIRO)	CSIROMk3	1PTO2X, SR-A2, SR-B1
Max Planck Institute für Meteorologie	ECHAM5OM	1PTO2X, 1PTO4X, SR-A1B, SR-A2, SR-B1
Meteorological Institute, University of Bonn Meteorological Research Institute of KMA Model and Data Groupe at MPI-M	ECHO-G	1PTO2X
Geophysical Fluid Dynamics Laboratory (GFDL), USA	GFDLCM2.0	COMMIT, SR-A1B, SR-A2, SR-B1
Geophysical Fluid Dynamics Laboratory (GFDL), USA	GFDLCM2.1	COMMIT, SR-A1B, SR-A2, SR-B1
GISS	GISSE-H	1PTO2X, SR-A1B
GISS	GISSE-R	1PTO2X, 1PTO4X, SR-A1B, SR-A2, SR-B1
UK Met. Office	HADCM3	SR-A1B, SR-A2, SR-B1
UK Met. Office	HADGEM1	SR-A1B, SR-A2
INGV, National Institute of Geophysics and Volcanology, Italy (2)	INMCM3.0	1PTO2X, 1PTO4X, 2XCO2, AMIP, COMMIT, SLAB, SR-A1B, SR-A2, SR-B1
Institute for Numerical Mathematics	INMCM3.0	1PTO2X, 1PTO4X, 2XCO2, AMIP, COMMIT, SLAB, SR-A1B, SR-A2, SR-B1
Institut Pierre Simon Laplace	IPSLCM4	1PTO2X, 1PTO4X, COMMIT, PDCTL, SR-A1B, SR-A2, SR-B1
National Institute for Environmental Studies	MIROC3.2 hires	SR-A1B, SR-B1, Extremes (AMIP, SR-A1B, SR-B1)
Meteorological Research Institute, Japan Meteorological Agency, Japan	MRI-CGCM2.3.2	SR-A2, SR-A1B, SR-B1
National Institute for Environmental Studies	MIROC3.2 medres	SR-A1B, SR-A2, SR-B1, Extremes (AMIP, COMMIT, SR-A1B, SR-A2, SR-B1)
National Center for Atmospheric Research (NCAR), USA	NCARPCM	COMMIT, SR-A1B, SR-A2, SR-B1
National Center for Atmospheric Research (NCAR), USA	NCARCCSM3	SR-A1B, SR-A2, SR-B1

Source: CCCSN webpage

Table 4: Number of scenarios on CCCSN site, by assessment report and climate change time frame.

Assessment Report by IPCC	Time frame		
	2011-2040	2041-2070	2071-2100
4th (2007)	56	56	56
3th (2001)	20	18	18
2th (1995)	13	10	10
Total Scenarios	89	84	84

Source: \\Van-svr0\projects\01_SITES\Hope.Bay\1CT022.001_2014 Hope Bay Ongoing Support\310_Response to Information Requests\Responses to IR's\EC_MPD&EPOD_ES #6\Compilation climate change 2020-2050-2080s.xlsx

Table 5: Range of changes predicted for maximum monthly average wind velocity and maximum hourly wind velocity.

Model Percentiles[1]	Worst-Case Percent Change[2]	Baseline monthly wind velocity from Historical Record [m/s][3]	Predicted Maximum Monthly Average Wind Velocity[4] up to the year 2100 [m/s]	Baseline Maximum Hourly Wind Velocity from Historical Record[5] [m/s]	Predicted Maximum Hourly Wind Velocity[6] up to the year 2100 [m/s]
Low 5th	-14%	7.95	6.84	27.1	24.5
Median	+4%	7.95	8.27	27.1	28.1
High 5th	+24%	7.95	9.86`	27.1	31.8

Source: \\Van-svr0\projects\01_SITES\Hope.Bay\1CT022.001_2014 Hope Bay Ongoing Support\310_Response to Information Requests\Responses to IR's\EC_MPD&EPOD_ES #6\Compilation climate change 2020-2050-2080s.xlsx

Notes:

1. Percentile of scenarios which predict a percent change that is less than or greater than the worst-case percent change, presented in column 2.
2. Largest rate of change in magnitude from the three time frames (2011-2040, 2041-2070, 2071-2100)
3. Calculated from Cambridge Bay historical record of maximum monthly average velocities, from 1953-2010.
4. Calculated based on Equation 3.4, based on the baseline monthly wind velocity. These values represent the maximum monthly average wind velocities during the open water season for a return period of 100 years .
5. Calculated from Cambridge Bay historical record of maximum hourly velocities, from 1953-2010.
6. Calculated based on Equation 4.3, from relationship between maximum monthly average velocities and maximum hourly velocities. These values represent the maximum hourly wind velocities during the open water season for a return period of 100 years .

Figures

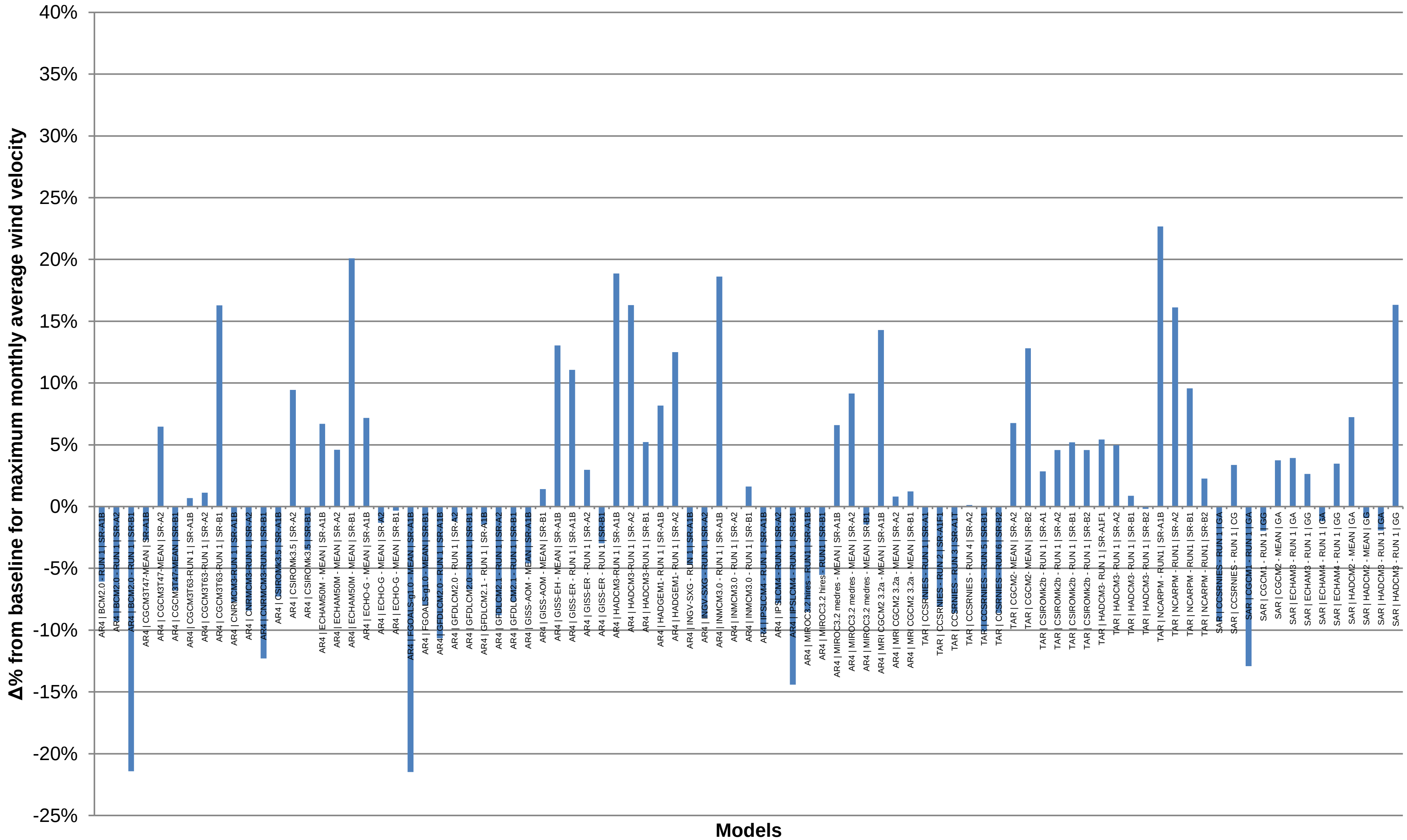

Figure 1: Rate of change between baseline and 2011-2040 conditions for maximum monthly average wind velocities during open water season for a return period of 100 years

Source: \\Van-svr0\projects\01_SITES\Hope.Bay\1CT022.001_2014 Hope Bay Ongoing Support\310_Response to Information Requests\Responses to IR's\EC_MPD&EPOD_ES #6\Compilation climate change 2020-2050-2080s.xlsx

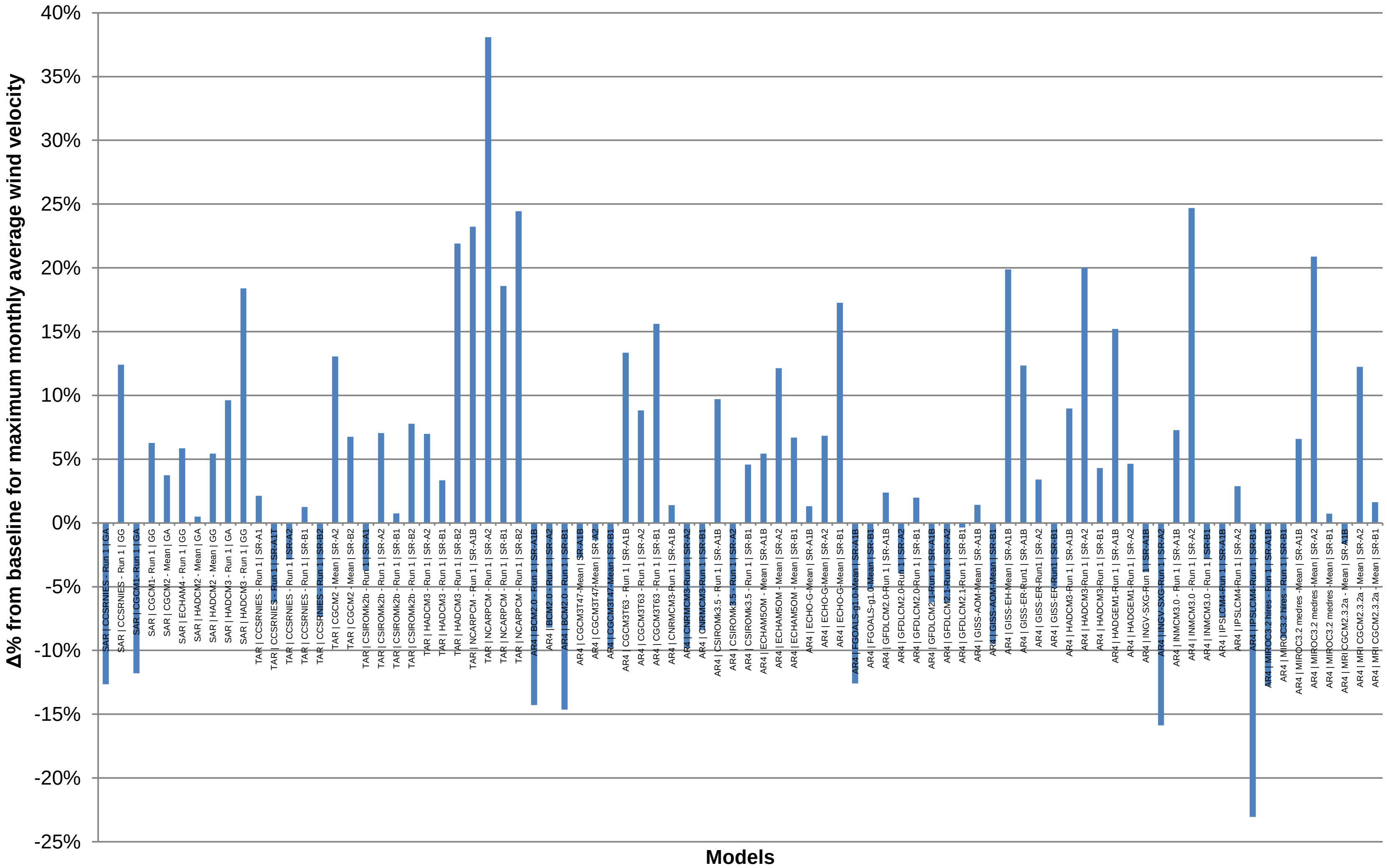

Figure 2: Rate of change between baseline and 2041-2070 conditions for annual maximum wind velocities during open water season for a return period of 100 years.

Source: \\Van-svr0\projects\01_SITES\Hope.Bay\1CT022.001_2014 Hope Bay Ongoing Support\310_Response to Information Requests\Responses to IR's\EC_MPD&EPOD_ES #6\Compilation climate change 2020-2050-2080s.xlsx

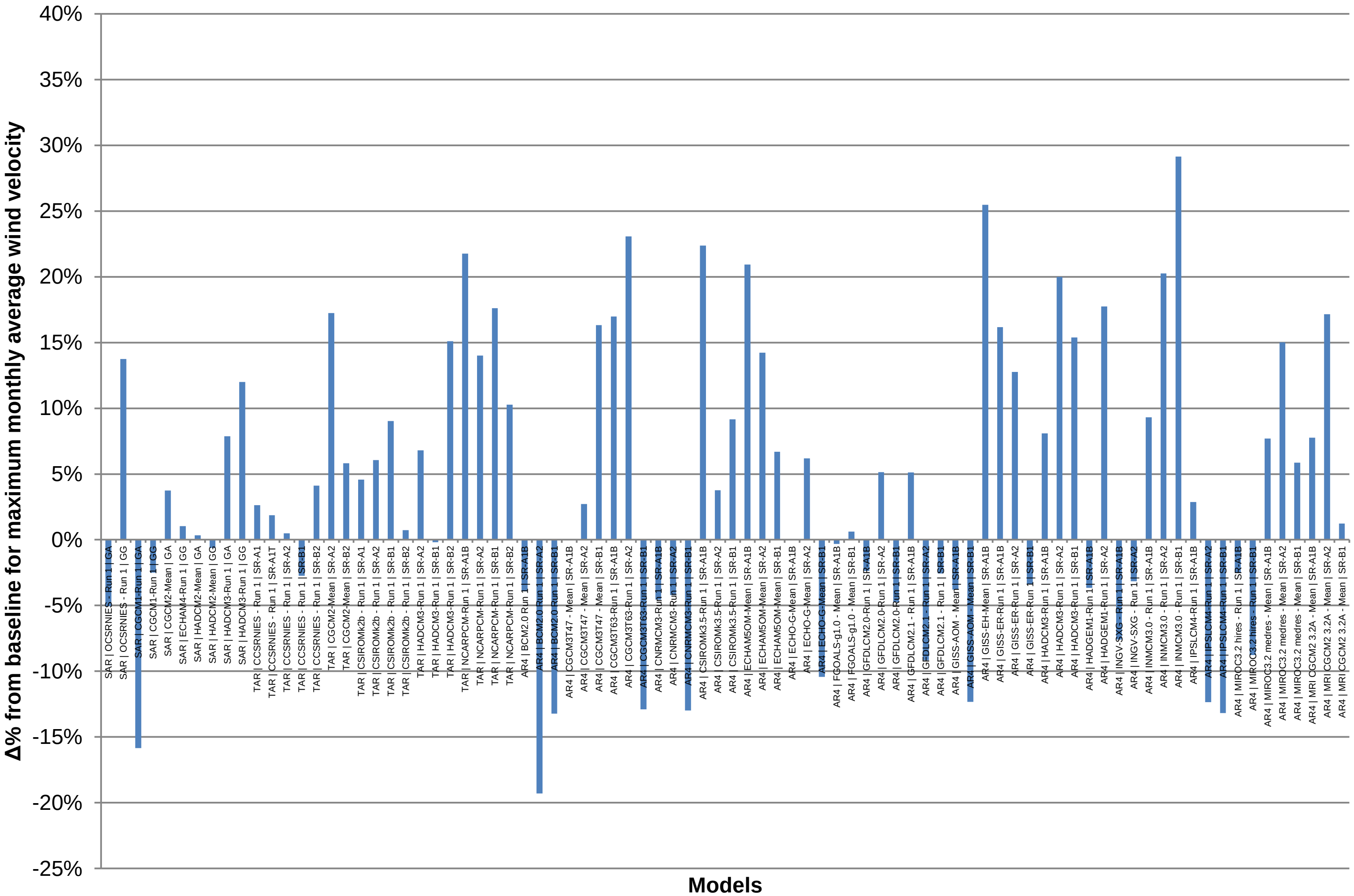

Figure 3: Rate of change between baseline and 2071-2100 conditions for annual maximum wind velocities during open water season for a return period of 100 years.

Source: \\Van-svr0\projects\01_SITES\Hope.Bay\1CT022.001_2014 Hope Bay Ongoing Support\310_Response to Information Requests\Responses to IR's\EC_MPD&EPOD_ES #6\Compilation climate change 2020-2050-2080s.xlsx

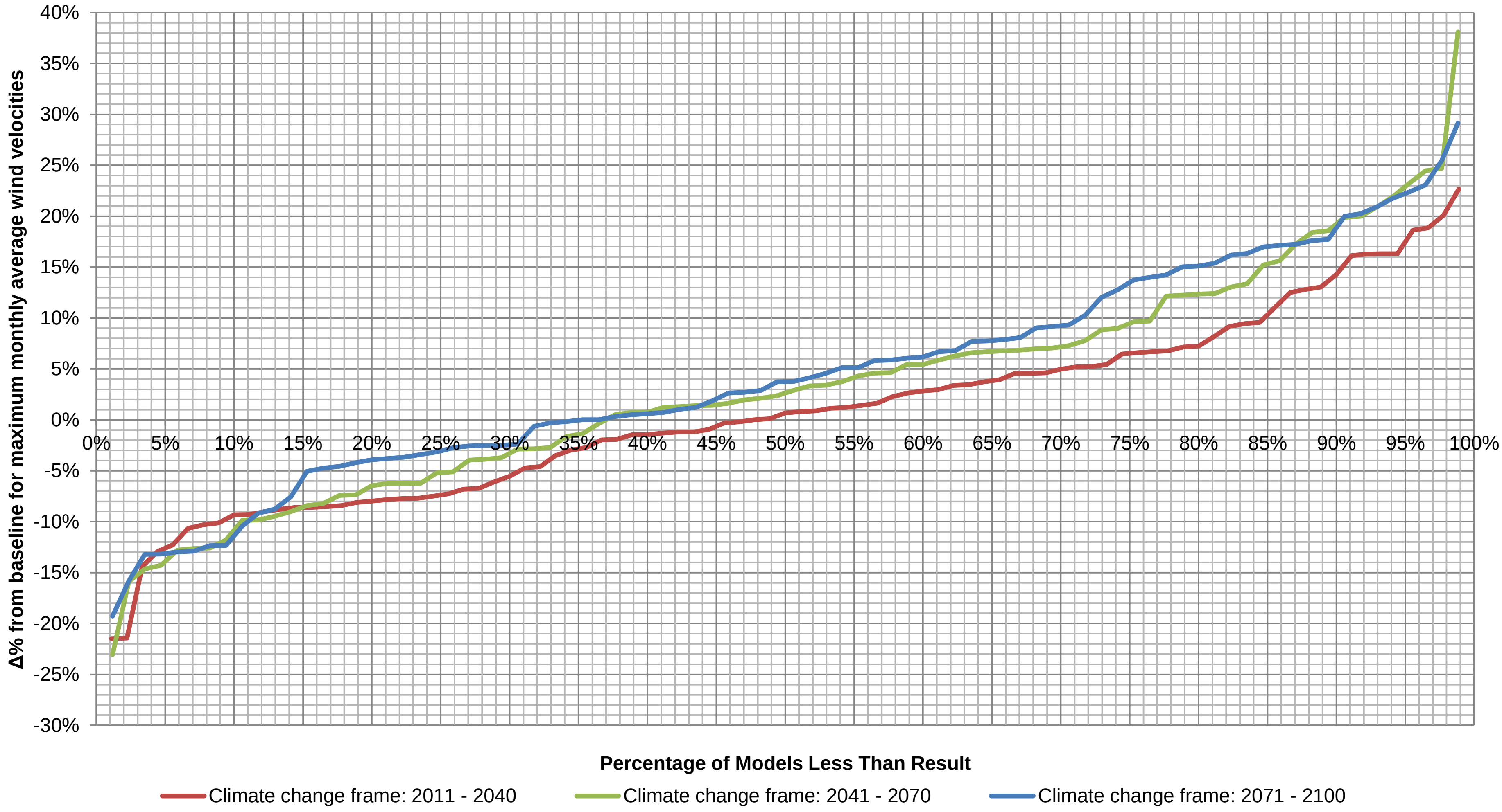

Figure 4: Percent Change from baseline versus percentage of models in agreement for maximum monthly average wind velocity during open water season for a return period of 100 years.

Source: \\Van-svr0\projects\01_SITES\Hope.Bay\1CT022.001_2014 Hope Bay Ongoing Support\310_Response to Information Requests\Responses to IR's\EC_MPD&EPOD_ES #6\Compilation climate change 2020-2050-2080s.xlsx

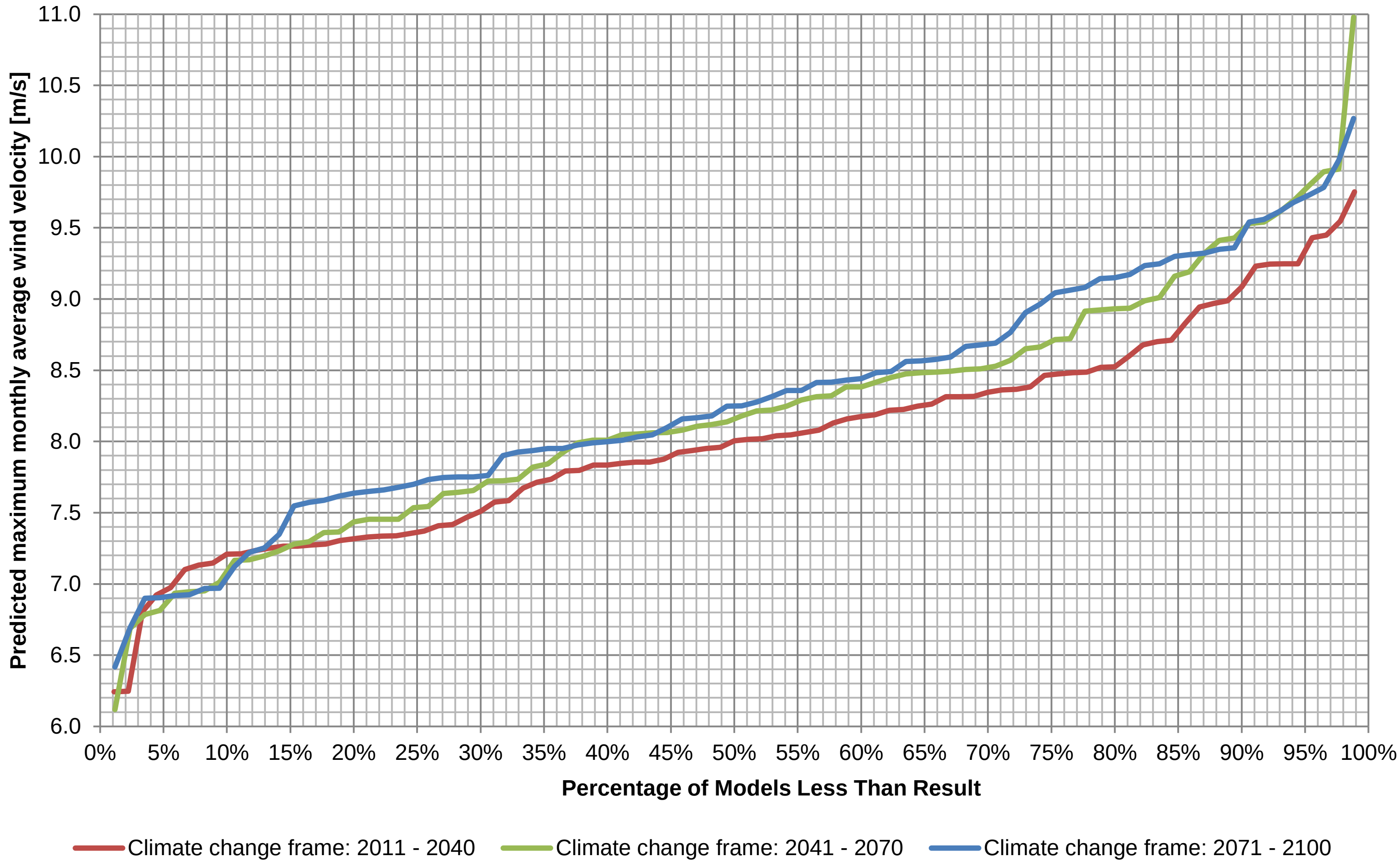

Figure 5: Predicted maximum monthly average velocity versus percentage of models in agreement during open water season for a return period of 100 years

Source: \\Van-svr0\projects\01_SITES\Hope.Bay\1CT022.001_2014 Hope Bay Ongoing Support\310_Response to Information Requests\Responses to IR's\EC_MPD&EPOD_ES #6\Compilation climate change 2020-2050-2080s.xlsx

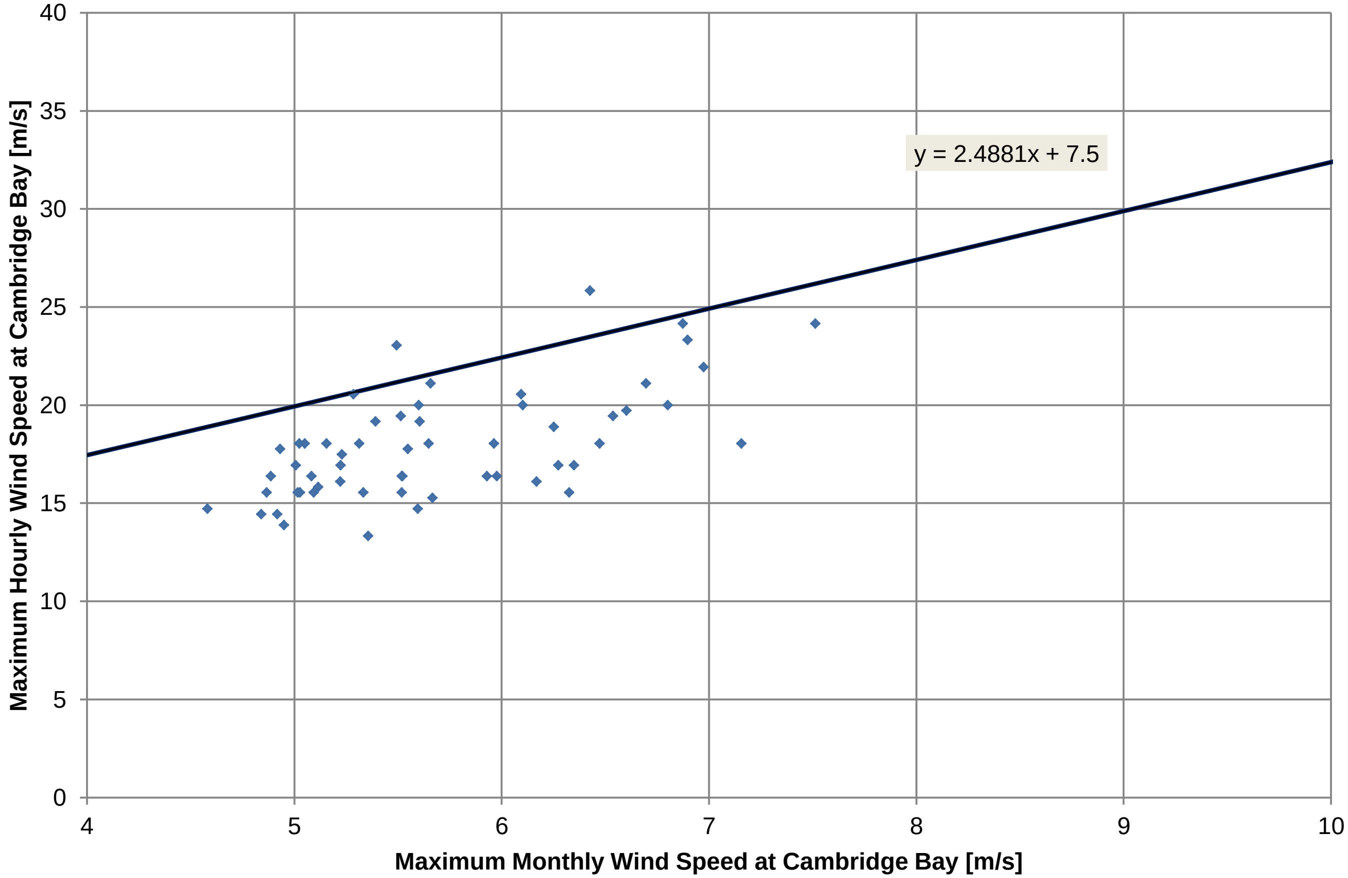

Figure 6: Envelope curve for historical information between maximum monthly average wind speed and maximum hourly wind speed at Cambridge bay during the open water season.

Source: Z:\01_SITES\Hope.Bay\1CT022.001_2014 Hope Bay Ongoing Support\310_Response to Information Requests\Responses to IR's\EC_MPD&EPOD_ES #6\GRPextractor_cambridgebay-winds_01092010_112828_SB.xlsx