Addressing Climate Change and its Uncertainties in Impact Assessments

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Based on research report for R&D program of Canadian Environmental Assessment Agency

Planning for climate change

- At strategic level
- At project level:
  - Means to help adapt to climate change through design of project
  - Means to mitigate climate change through decision on project (choice of alternative)

Projects and climate change

- Effects of project on climate through GHG emissions
  - Directly (fossil fuel plants, hydroelectric project)
  - Indirectly (new highway, transit line)
- Effects of climate change on project
- Effects of climate change on impacts from project

Effects of climate change on project

- Streamflow ----> Hydroelectric plant
- Water levels -----> Marina
- Permafrost -----> Pipeline
- Rainfall ----> Stormwater collection system

Effects on impacts from project

- Quarry ----> Groundwater
- Dam ----> Fisheries ----> Food supply
- Irrigation Project ----> Agricultural Production ----> Jobs ----> Local Economy

Uncertainties

- Effects of GHGs emissions on global climate
- Effects on regional climate
- Effects on environment

Research project and presentation

- Methods for addressing uncertainties with illustrative example
- Methods for communicating the uncertainties
- Implications for development of guidelines

Methods to address uncertainties

- Scenario analysis
- Probabilistic analysis
- Sensitivity analysis
- Combinations of above

Scenario analysis

- Scenarios - sets of “futures”
- Developed by IPCC and other groups
- Use range of scenarios

Probabilistic analysis

- Scenarios do not address likelihoods
- Estimate probabilities of outcomes (impacts) given probabilities of inputs
- Monte Carlo (stochastic) simulation

Sensitivity analysis

Asks “what if” questions:

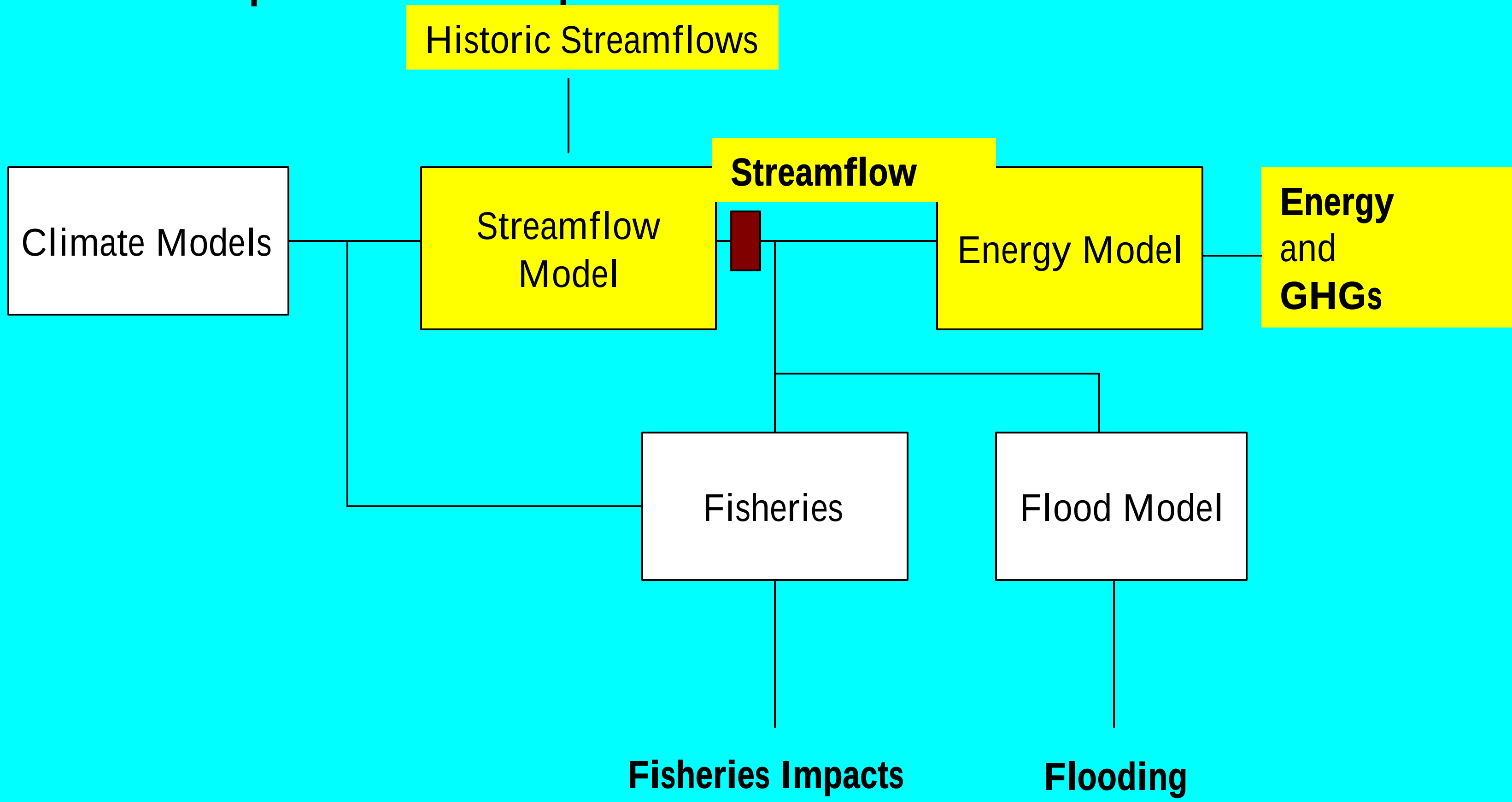
1. If parameter x changes by amount y, what would be the effect?
2. What change in parameter x would cause a certain level of impact?

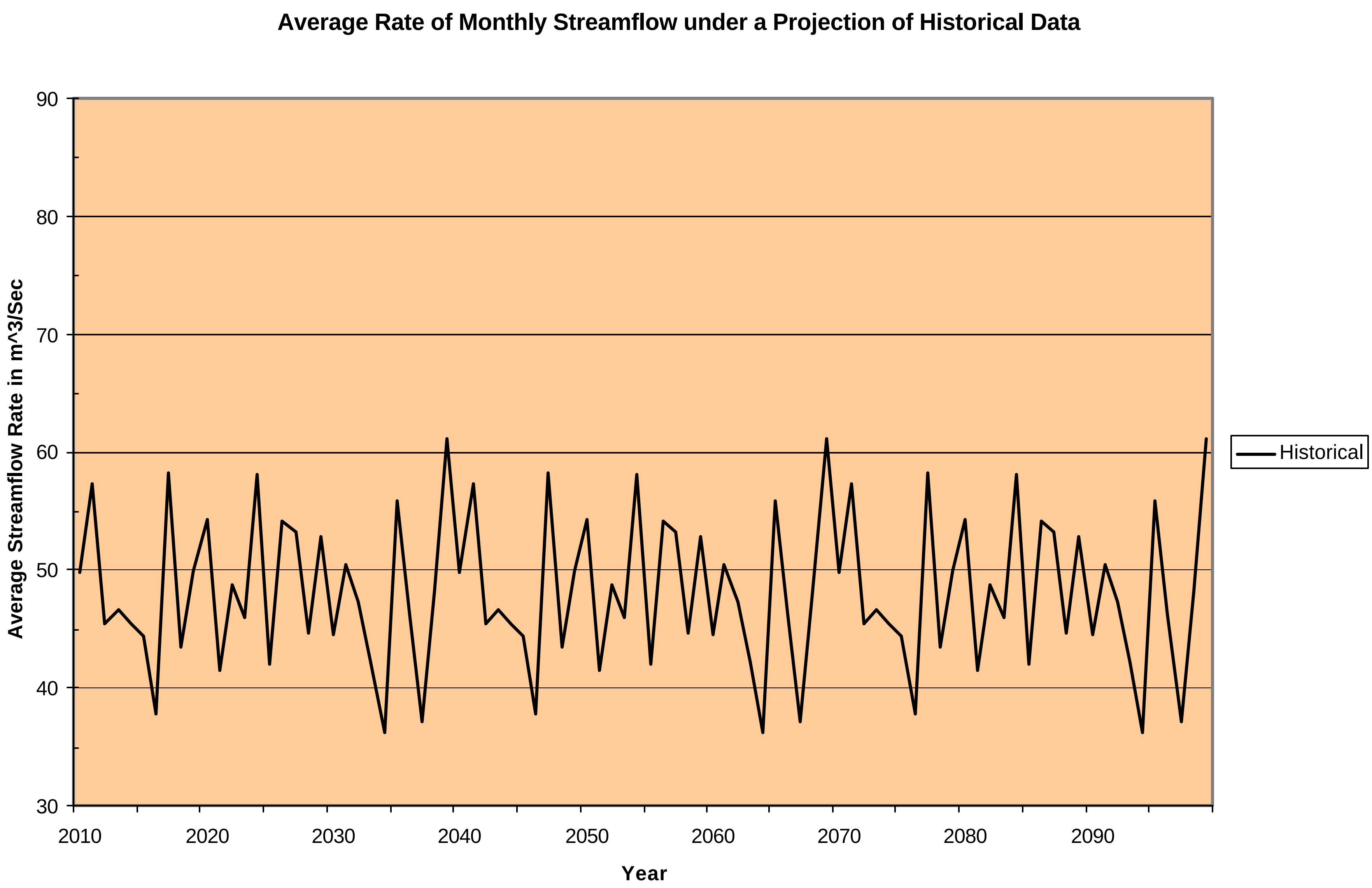
Use these results to judge whether and how climate change may be significant

Hypothetical example

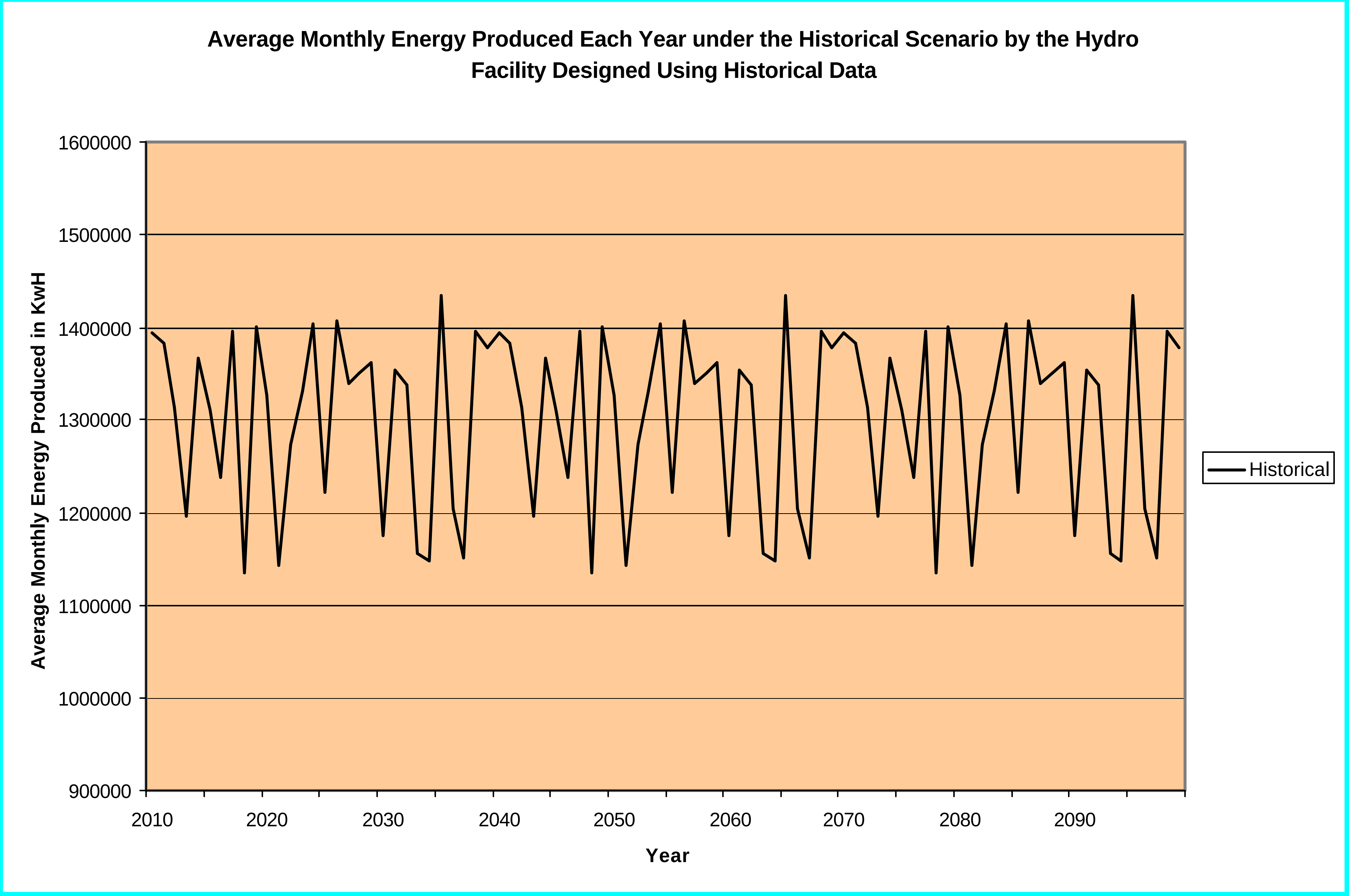
- Based on real case
- Proposed hydroelectric project in Ontario
- Climate change will affect streamflows

Hydro Example based upon Historic Data

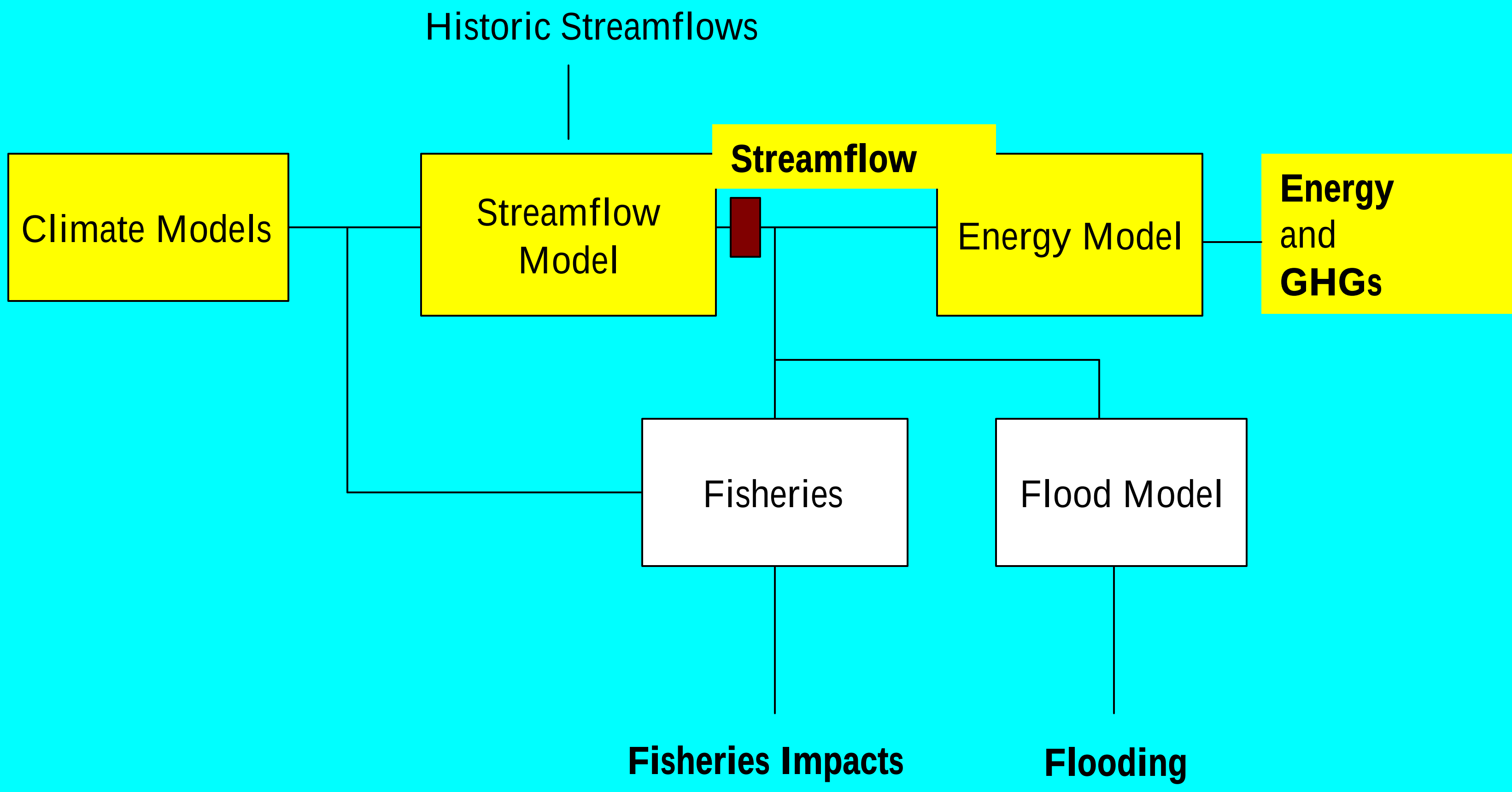




Average Rate of Monthly Streamflow under a Projection of Historical Data
Average Streamflow Rate in m^3/Sec
90
80
70
60
50
40
30
2010
2020
2030
2040
2050
2060
2070
2080
2090
Year
Historical

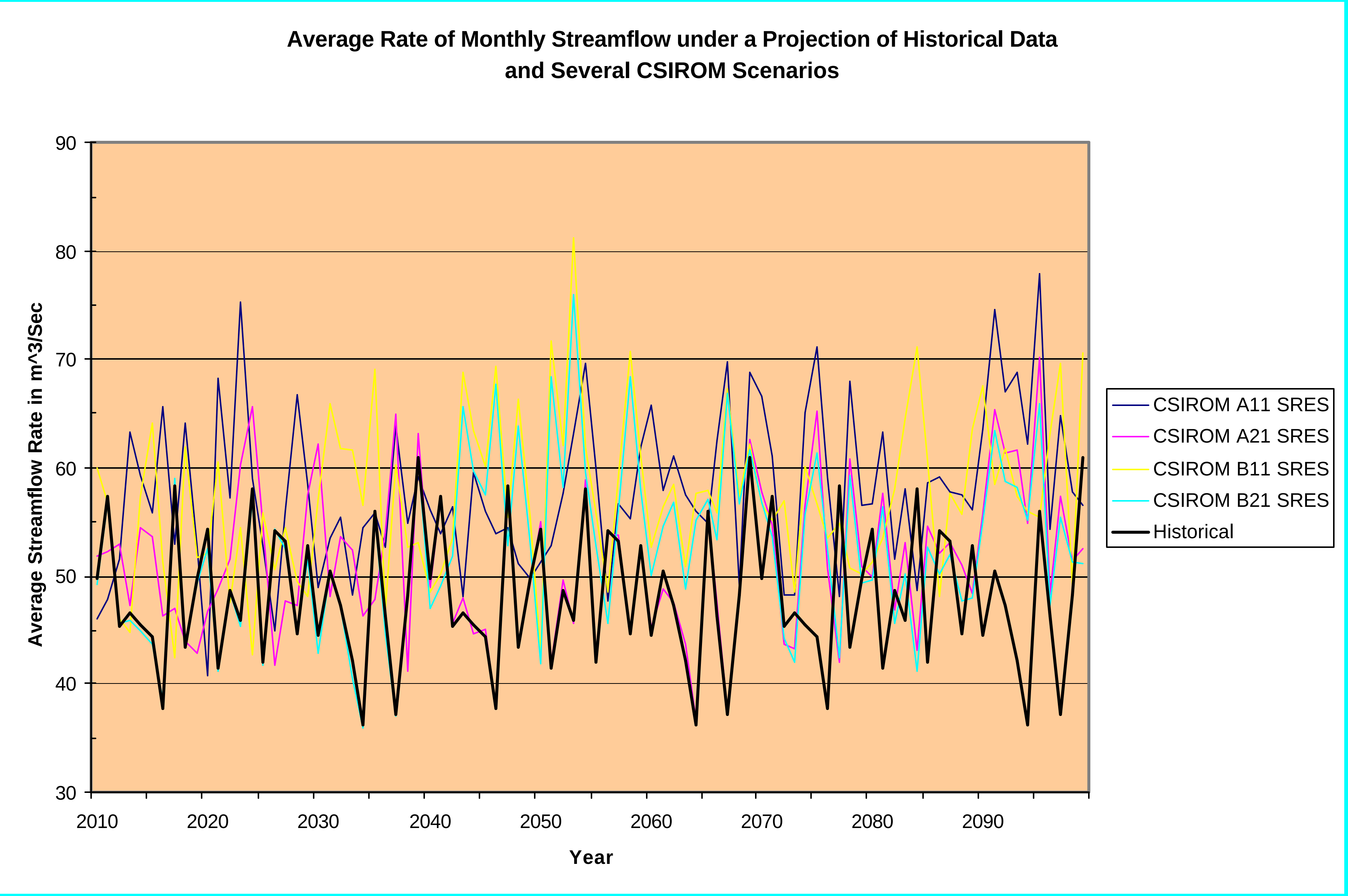

Average Monthly Energy Produced Each Year under the Historical Scenario by the Hydro Facility Designed Using Historical Data
Average Monthly Energy Produced in KwH
1600000
1500000
1400000
1300000
1200000
1100000
1000000
900000
2010
2020
2030
2040
2050
2060
2070
2080
2090
Year
Historical

Hydro Example based upon Climate Change Data



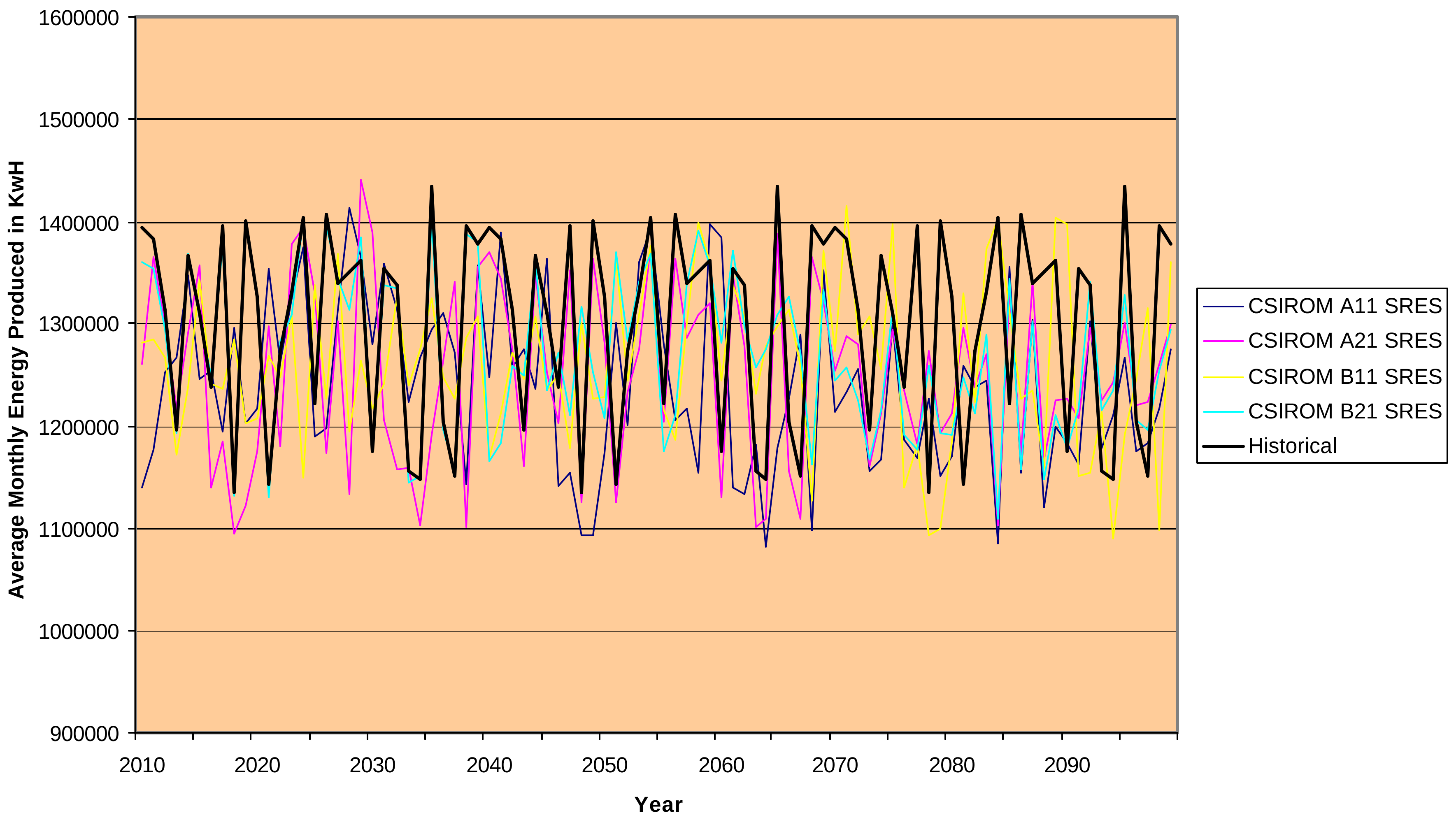
Scenario analysis: streamflows and energy

- Canadian Climate Impacts Scenarios
- Projection of HISTORICAL data into the period 2010-2099
- Capacity of facility based on historical data

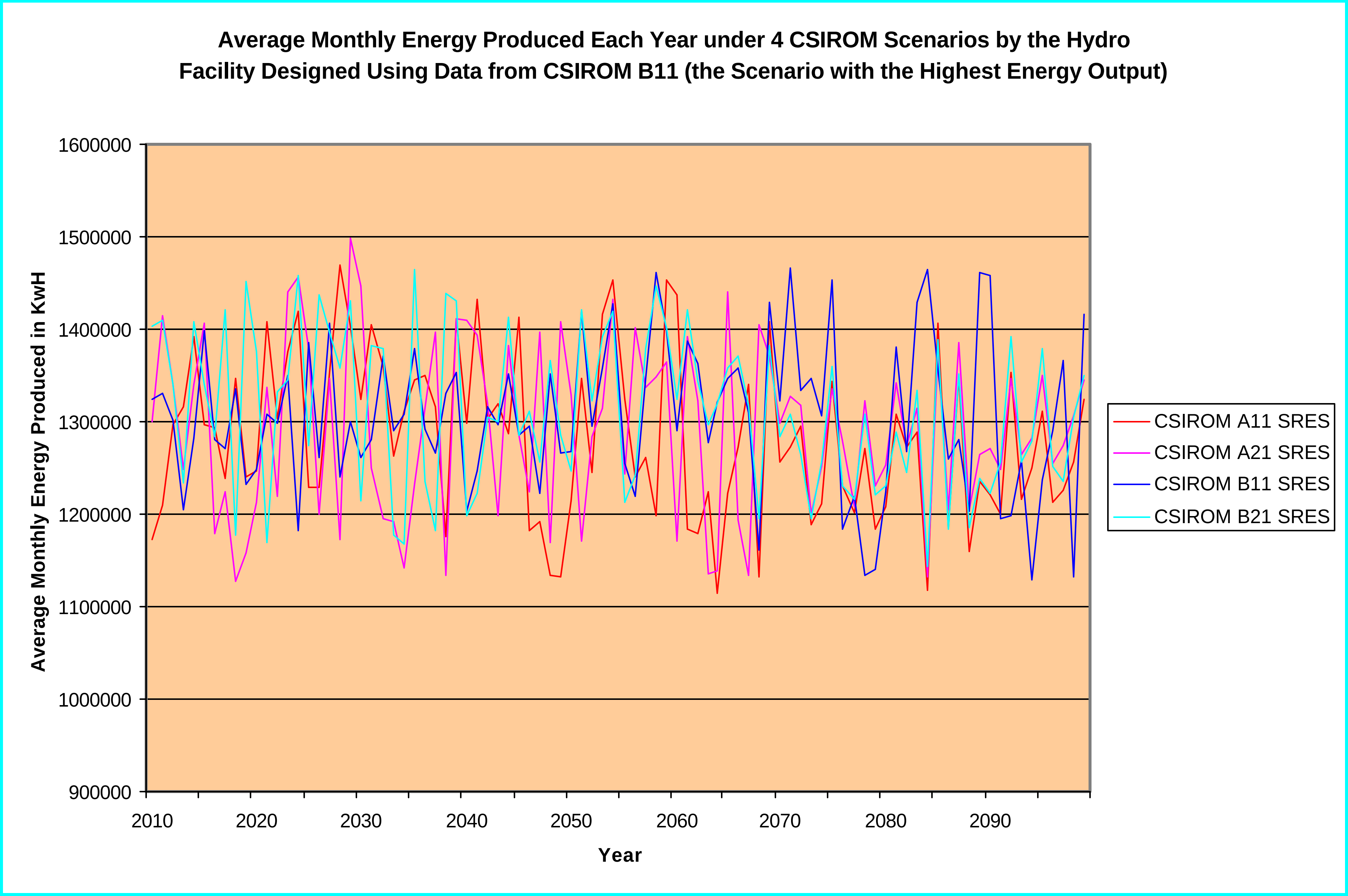


Average Rate of Monthly Streamflow under a Projection of Historical Data
and Several CSIROM Scenarios
90
80
70
60
50
40
30
2010
2020
2030
2040
2050
2060
2070
2080
2090
Year
Average Streamflow Rate in m^3/Sec
CSIROM A11 SRES
CSIROM A21 SRES
CSIROM B11 SRES
CSIROM B21 SRES
Historical

Average Monthly Energy Produced Each Year under the Historical and 4 CSIROM Scenarios by the Hydro Facility Designed Using Historical Data

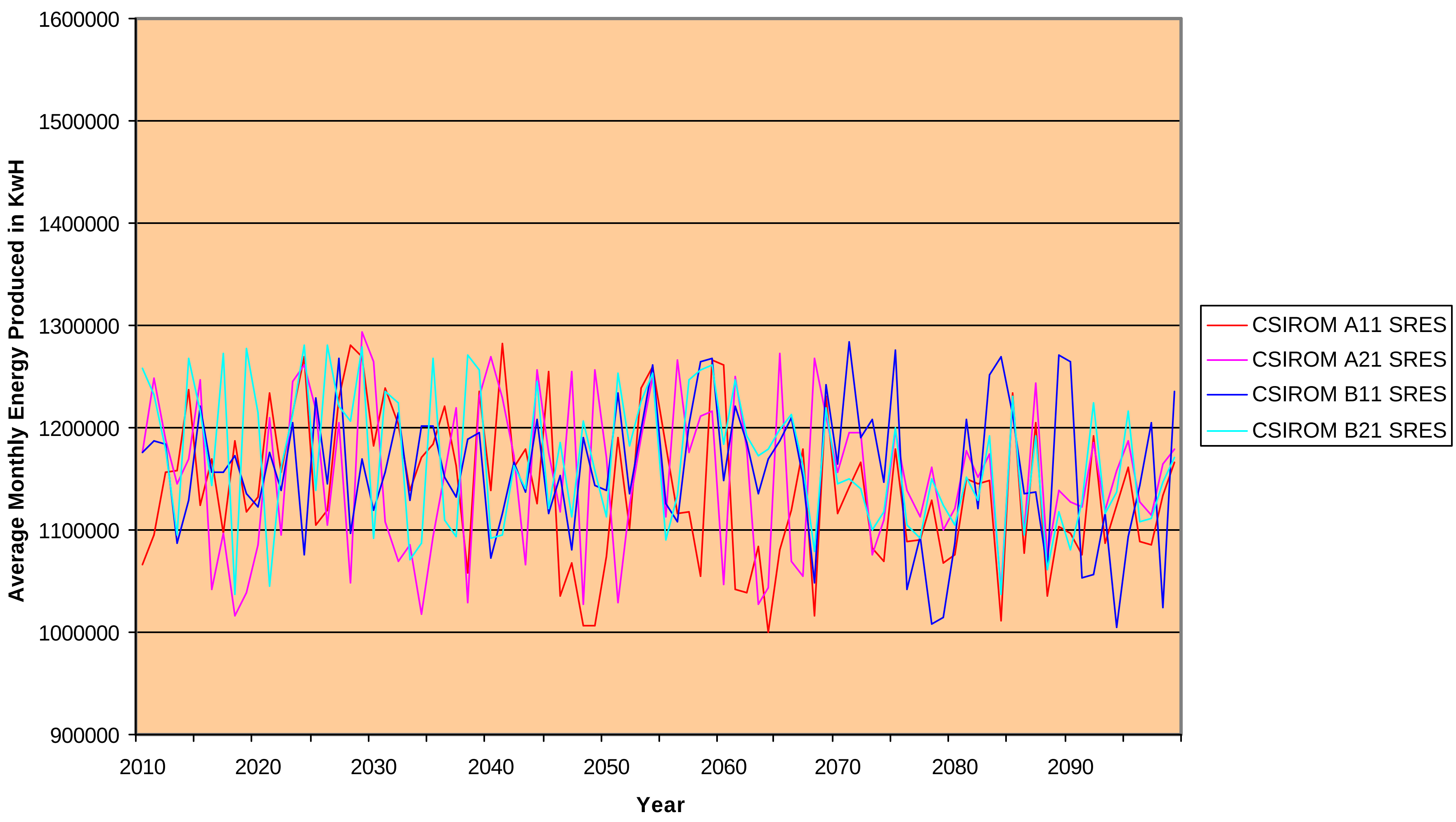


Expected Monthly Energy Production & GHG Reductions 2010-2099		
	Facility Capacity Based Upon Historical Data	
Scenario	Average Monthly Energy in Kwh	Annual Reduction in GHG Emissions in Tonnes CO_2
Historical	1,301,307	14,054
CSIROM A11	1,239,742	13,389
CSIROM A21	1,250,407	13,504
CSIROM B11	1,261,209	13,621
CSIROM B21	1,268,823	13,703



Average Monthly Energy Produced Each Year under 4 CSIROM Scenarios by the Hydro Facility Designed Using Data from CSIROM B11 (the Scenario with the Highest Energy Output)
Average Monthly Energy Produced in KwH
1600000
1500000
1400000
1300000
1200000
1100000
1000000
900000
2010
2020
2030
2040
2050
2060
2070
2080
2090
Year
CSIROM A11 SRES
CSIROM A21 SRES
CSIROM B11 SRES
CSIROM B21 SRES

Average Monthly Energy Produced Each Year under 4 CSIROM Scenarios by the Hydro Facility Designed Using Data from CSIROM B21 (the Scenario with the Lowest Energy Output)

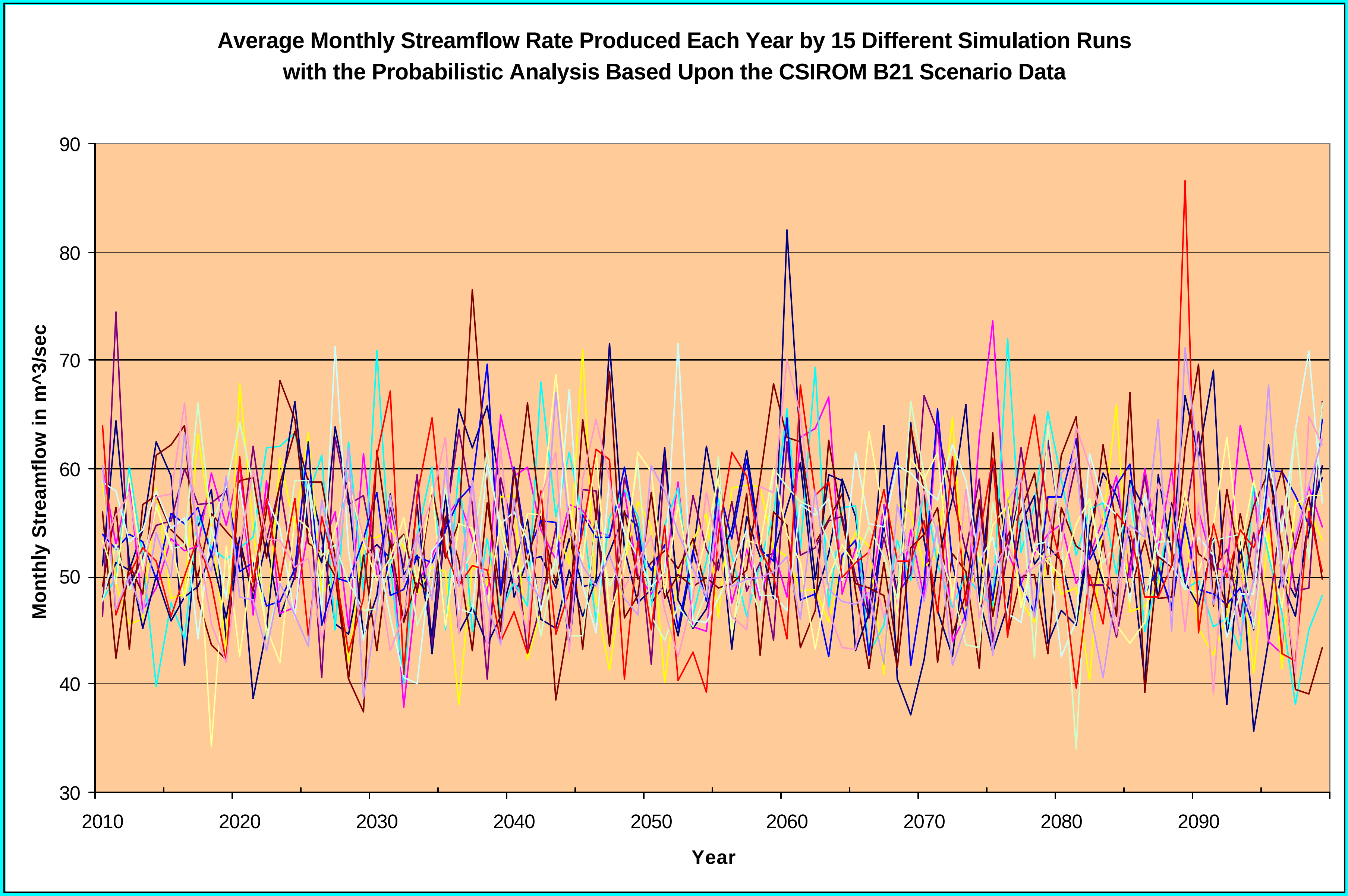


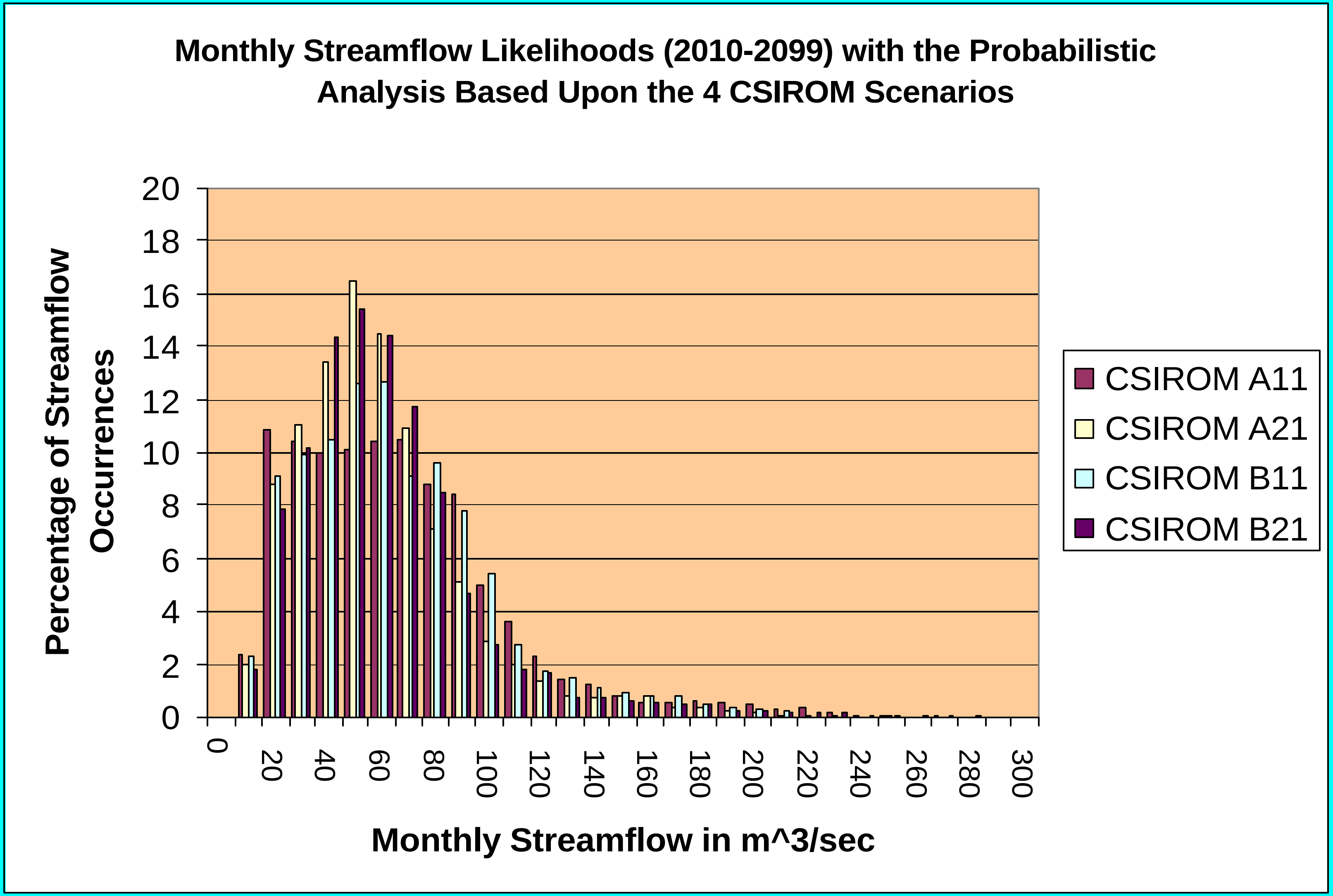
Expected Monthly Energy Production in Kwh for 2010-2099		
	Facility Capacity Design Based Upon Data From:	
Scenario	CSIROM B21 Scenario	CSIROM B11 Scenario
Historical	1,194,325	1,344,701
CSIROM A11	1,140,190	1,282,184
CSIROM A21	1,152,737	1,291,820
CSIROM B11	1,158,754	1,305,290
CSIROM B21	1,168,313	1,311,126

Expected Annual Reduction in GHG Emissions in tonnes of CO_2		
	Facility Capacity Design Based Upon Data From:	
Scenario	CSIROM B21 Scenario	CSIROM B11 Scenario
Historical	12,899	14,523
CSIROM A11	12,314	13,848
CSIROM A21	12,450	13,952
CSIROM B11	12,515	14,097
CSIROM B21	12,618	14,160

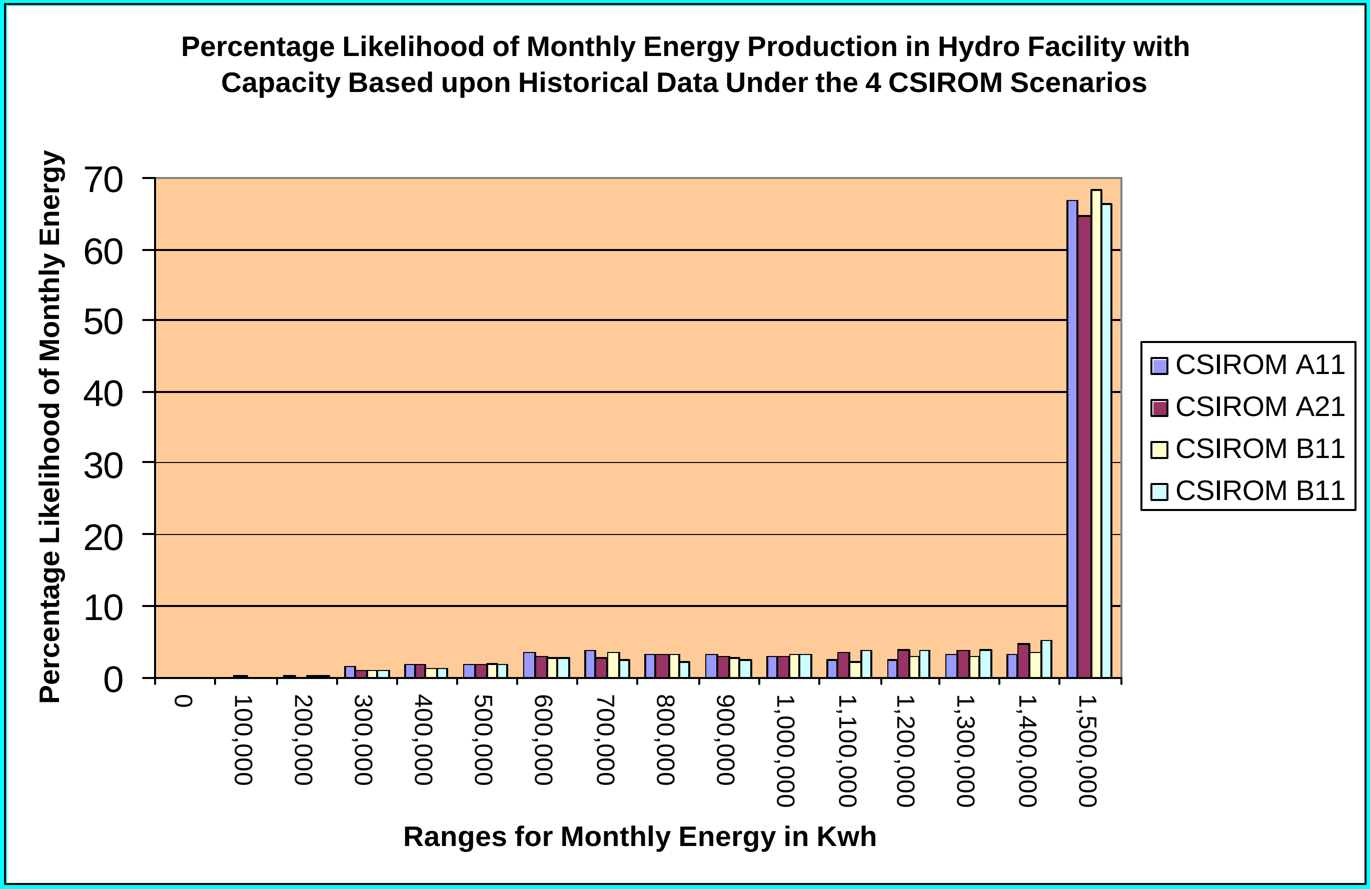
Probabilistic analysis

- Streamflows simulated using scenarios


Average Monthly Streamflow Rate Produced Each Year by 15 Different Simulation Runs
with the Probabilistic Analysis Based Upon the CSIROM B21 Scenario Data
Monthly Streamflow in m^3/sec
90
80
70
60
50
40
30
2010
2020
2030
2040
2050
2060
2070
2080
2090
Year



Monthly Streamflow Likelihoods (2010-2099) with the Probabilistic Analysis Based Upon the 4 CSIROM Scenarios
Percentage of Streamflow Occurrences
Monthly Streamflow in m^3/sec
CSIROM A11
CSIROM A21
CSIROM B11
CSIROM B21
0
2
4
6
8
10
12
14
16
18
20
0
20
40
60
80
100
120
140
160
180
200
220
240
260
280
300

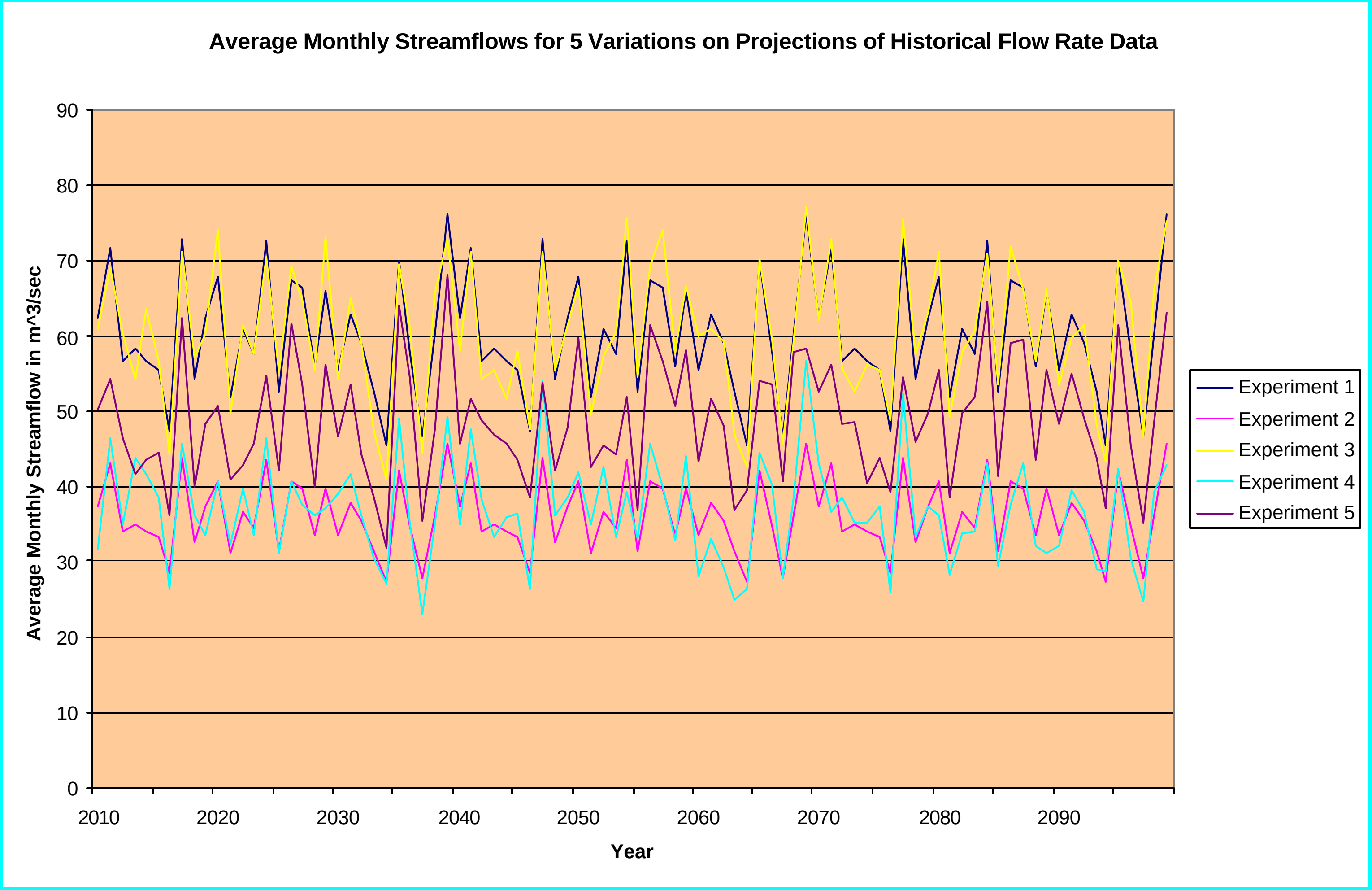


Percentage Likelihood of Monthly Energy Production in Hydro Facility with Capacity Based upon Historical Data Under the 4 CSIROM Scenarios
Percentage Likelihood of Monthly Energy
70
60
50
40
30
20
10
0
0
100,000
200,000
300,000
400,000
500,000
600,000
700,000
800,000
900,000
1,000,000
1,100,000
1,200,000
1,300,000
1,400,000
1,500,000
Ranges for Monthly Energy in Kwh
CSIROM A11
CSIROM A21
CSIROM B11
CSIROM B11

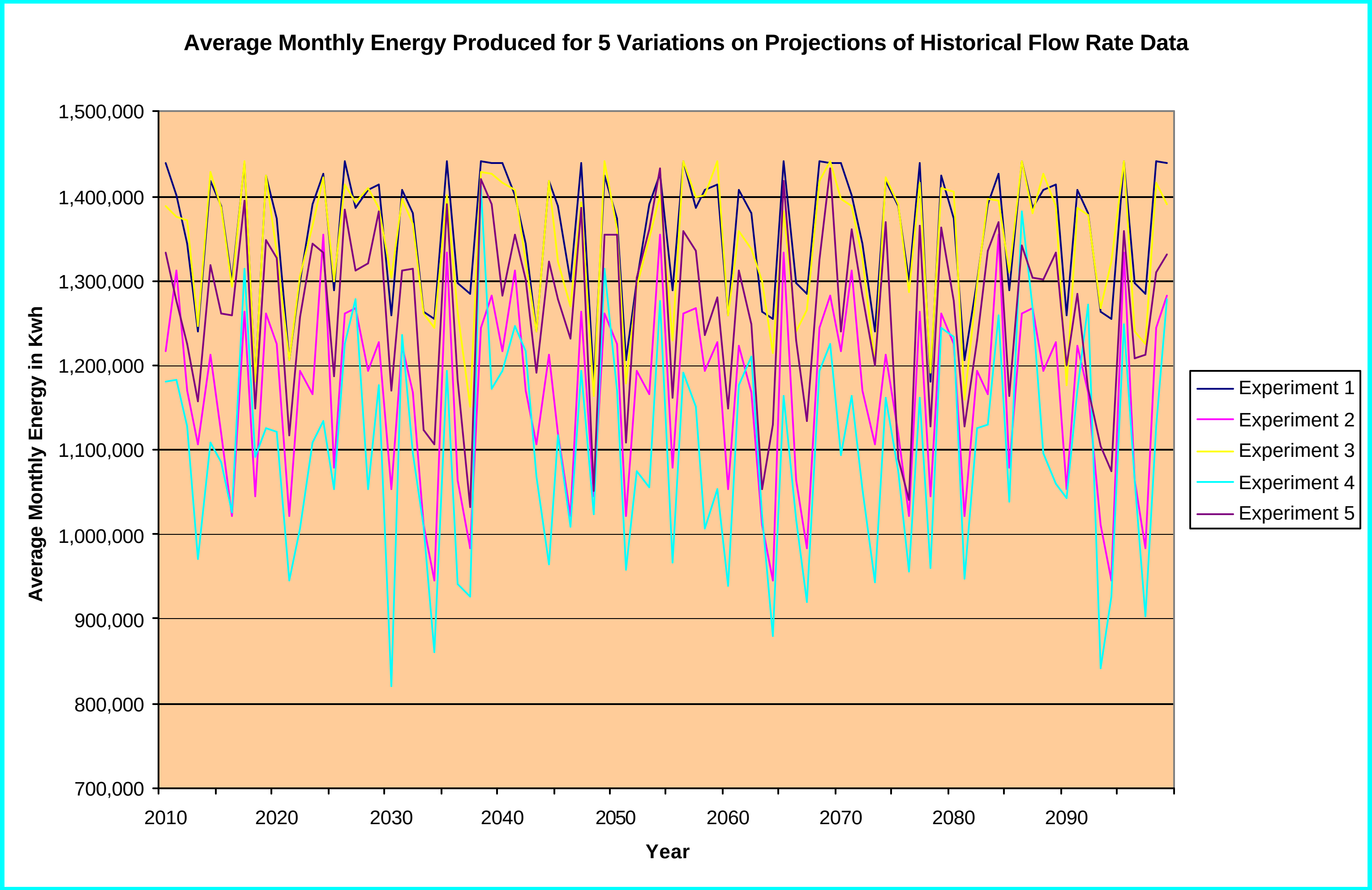
PROBABILISTIC OUTPUTS WITH CAPACITY BASED ON HISTORICAL DATA					
	Experiment				
	Historical	CSIROM A11	CSIROM A21	CSIROM B11	CSIROM B21
Mean Average Monthly Flow	48	58	51	57	53
Min Average Monthly Flow	9	2	2	2	5
Max Average Monthly Flow	108	294	290	276	291
Mean Average Monthly Energy	1,302,895	1,240,236	1,251,745	1,261,884	1,269,461
Min Average Monthly Energy	322,621	80,382	82,103	90,920	85,401
Max Average Monthly Energy	1,441,145	1,441,145	1,441,145	1,441,145	1,441,145
Mean Annual GHG Reduction	14,071	13,395	13,519	13,628	13,710

Sensitivity analysis

SENSITIVITY ANALYSIS EXPERIMENTS PERFORMED		
Experiment	**Change to Mean Historic Flow Rate**	**Change to Standard Deviation of Historic Flow Rate**
Experiment 1	15%	0%
Experiment 2	-15%	0%
Experiment 3	15%	25%
Experiment 4	-15%	25%
Experiment 5	0%	25%



Average Monthly Streamflows for 5 Variations on Projections of Historical Flow Rate Data
Average Monthly Streamflow in m^3/sec
Year
0
10
20
30
40
50
60
70
80
90
2010
2020
2030
2040
2050
2060
2070
2080
2090
Experiment 1
Experiment 2
Experiment 3
Experiment 4
Experiment 5



Average Monthly Energy Produced for 5 Variations on Projections of Historical Flow Rate Data
1,500,000
1,400,000
1,300,000
1,200,000
1,100,000
1,000,000
900,000
800,000
700,000
Average Monthly Energy in Kwh
2010
2020
2030
2040
2050
2060
2070
2080
2090
Year
Experiment 1
Experiment 2
Experiment 3
Experiment 4
Experiment 5

SENSITIVITY OF HISTORICAL VALUES TO 5 CHANGES IN HISTORICAL STREAMFLOW RATES						
	Historical	Experiment 1	Experiment 2	Experiment 3	Experiment 4	Experiment 5
Change to Mean	0%	15%	-15%	15%	-15%	0%
Change to STD	0%	0%	0%	25%	25%	25%
Monthly Energy (Kwh)	1,301,307	1,355,618	1,167,060	1,341,103	1,101,460	1,254,385
Annual GHG Reduction (tonnes CO2)	14,054	14,641	12,604	14,484	11,896	13,547
Maximum Monthly Flow (m^3/sec)	108	135	81	146	137	143

Flooding

1. Assess change in probability of flooding
2. Assess change in flood damages

Current Condition (based on daily streamflows):

- Low level of damage at 200-250 m3/s
  - Probability = 0.08 per year
- Medium level of damage at >250 m3/s
  - Probability = 0.02 per year

Flooding: sensitivity analysis

Annual Probability of Damage

Damage	Historic	With Increase in S.D. by: 15%	25%	22%	12%
Low	0.08	0.14	0.22	0.20	0.08
Medium	0.02	0.05	0.11	0.08	0.04

Flooding: scenario and probabilistic analyses

Probabilities of Occurrences for Daily Streamflows, 2010-2099

Streamflow (m^3/sec)	A11C	A21C	B11C	B21	Historic
200 to 210	0.042	0.009	0.026	0.017	0.025
210 to 220	0.033	0.010	0.020	0.017	0.021
220 to 230	0.025	0.004	0.010	0.013	0.015
230 to 240	0.017	0.004	0.010	0.011	0.013
240 to 250	0.018	0.009	0.000	0.011	0.006
	0.135	0.036	0.056	0.069	0.08
250 to 260	0.013	0.002	0.006	0.007	0.005
260 to 270	0.014	0.002	0.001	0.009	0.006
270 to 280	0.010	0.001	0.001	0.008	0.003
280 to 290	0.012	0.000	0.000	0.002	0.001
>290	0.019	0.002	0.005	0.004	0.005
	0.068	0.007	0.013	0.030	0.020

Fisheries: recreational fishing

Affected by changes in:

- Flows
- Temperature of water

Sensitivity analysis (1): fisheries

Ask Experts About:	Streamflow Changes by: -10%	+ 10%
Water Temp Changes by: -1.0C	Significant loss of warm water species	Minor loss loss of warm water species
+1.0C	Significant loss of warm and cold water species	Insignificant effects

Sensitivity analysis (2): fisheries

Ask expert:

What change in streamflow and water temperature would lead to threshold changes in quality of fisheries, e.g. collapse of warm water species?

How would this compare with what might occur with climate change?

Choice of method

Should depend on:

- Quality of the methods/models and data
  - Difficulty (e.g. expertise, data and cost)
  - Quality of information provided
- Importance of the impact studied

Choice of method

	Model and Data Availability		
Importance	Poor	Fair	Excellent
Low	None	Sensitivity	Sensitivity or Scenario
Medium	Sensitivity	Scenario	Scenario
High	Sensitivity	Scenario	Scenario and Probabilistic

Communicating results to decision makers and stakeholders

Need to clearly communicate:

- **Results** of the analyses
- Information about the **degree of belief** in the results

Presentation of uncertainties in quantitative results

- Range - extreme values

  0.98 to 1.60 Gwh/month

  10,600 to 17,300 tonnes CO2/year

  Annual probability of medium flood damage = 0.02 to 0.068
- Mean and confidence

  1.27 ± 0.65 Gwh/month (90% confidence)
- Full probability distribution
- Thresholds and vulnerability levels

In qualitative results

- Range

  "Low to medium"
- Central tendency and variation from it

  "Low with significant possibility of medium"
- Explain thresholds and vulnerabilities

  "Possible loss of significant game species"

Need to clearly define terms

Degree of belief/confidence

To assess beliefs in the results, explain:

- Models used
- Data sets employed
- Assumptions made
- Results achieved

Presentation on acceptability: scenario analysis for energy production

Model:	Source	IPCC/CICS	Consultant	Consultant
	Rep. of reality	Unknown	Medium	High
	Theory/Sch.of thought	School	Est. Theory	Est. Theory
	Peer review	Yes	No	No
	Acceptance	Variable	-	-
Data:	Source	Various	MNR	-
	Primary/Sec.	Primary	Primary	-
	Theory/Sch.of thought	-	-	-
Key Assumptions:				
	Rep. of reality	Medium	High	High
	Acceptance	Variable	High	High
Resulting Estimates:				
	Indep. review	Yes	No	No
	Acceptance by review	Medium	-	-
	Overall confidence	Medium	Low-Medium	Low-Medium

Guidelines

Basic issues to address:

- Identification of uncertainties about effects of:
  - Project on climate change and GHG emissions
  - Climate change on project
  - Climate change on impacts of project
- Scoping of above
- Method(s): Choice and Use
- Communication: Results and Acceptability

Recommended guidelines

Two sets:

1. Based on review of EAs
2. Based on the work reported here

Barrow and Lee (2003) report to CEAA

Acknowledgements and Reports

- Canadian Environmental Assessment Agency for funding

- Our report in a few months, and two CICS reports, available at:

  http://www.ceaa-acee.gc.ca/015/0002/index_e.htm