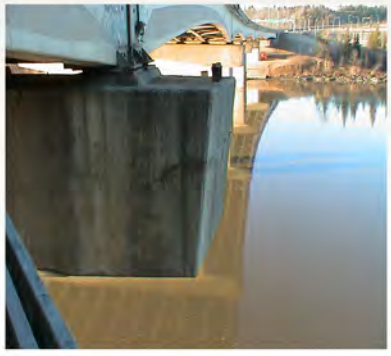

Adapting to Climate Change

Canada's First National Engineering Vulnerability Assessment

of

Public Infrastructure

April 2008

Appendix B-1
Poratage la Prairie, Manitoba

Canada PIEVC CVIIP engineerscanada ingénieurscanada

City of Portage La Prairie
Water Resources Infrastructure Assessment
Phase II - Pilot Study

Prepared for:
The City of Portage la Prairie

and
PIEVC

Submitted by:
GENIVAR

in association with
Tetr*ES* Consultants INC.

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November 2007

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0.0 Executive Summary

0.1 Introduction

The design of infrastructure systems and components is based upon conditions defined by historical climate data in addition to operation performance goals. Mounting evidence suggests that climate has changed, and will continue to change, creating situations where typical climate design ranges for a given location are no longer representative. Expanded climate ranges and increased frequency of extreme weather events have the potential to create vulnerability in the performance of engineered systems due to insufficient design capacity.

Engineers Canada, the business name of the Canadian Council of Professional Engineers, established the Public Infrastructure Engineering Vulnerability Committee (PIEVC) in order to oversee the planning and execution of a national engineering assessment of the vulnerability of Canadian Public Infrastructure to changing climatic conditions. The PIEVC has concluded that potential water resources infrastructure failure can have common impacts and that there are examples of water resources vulnerability across Canada. Consequently, PIEVC has identified water resources infrastructure vulnerability as one of four priority areas to be reviewed as part of the first National Engineering Assessment. The other areas include buildings, roads and associated structures e.g. bridges, and stormwater and wastewater systems.

This report constitutes the final documentation regarding the Pilot Project that constituted the second phase of a 3-phase project undertaken by PIEVC known as "Water Resources Infrastructure Assessment – Phase II Pilot Study". The complete project phasing is as follows:

- Phase 1 – Scoping Study, including development of a formal draft protocol for assessment of vulnerability of infrastructure in response to climate change events (completed prior to this assignment).
- Phase 2 – Pilot Study to conduct an engineering vulnerability assessment using the draft protocol.
- Phase 3 – Canada-wide National Engineering Vulnerability Assessment.

The facility selected by PIEVC for this Pilot Study was the water resource infrastructure of the City of Portage la Prairie located in the Province of Manitoba (Figure 1), including the water works system and drinking water treatment plant. The Portage la Prairie water resources infrastructure served as the Pilot for assessing the applicability of the Protocol developed in Phase 1. Phase 2 (this assignment) of the Infrastructure Assessment involves understanding the Draft Protocol, applying the Draft Drotocol to the Portage la Prairie water resources infrastructure and assessing the applicability and effectiveness of the Protocol in conducting assessments of vulnerability due to climate change.

Figure 1: Location of Portage la Prairie

0.2 Methodology

Summary of Protocol Approach

The Protocol is a procedure to sift through the data to develop relevant information on the specific elements of the climate and the specific attributes of the infrastructure that interact to create vulnerability. Climate data is used to design infrastructure and under climate change, historical climate data as the basis of operational design may not be appropriate. These factors may create vulnerabilities in the infrastructure due to the fact that the existing infrastructure may not have the resiliency required to accommodate the "real climate extremes" brought about by climate change effects. Furthermore, new infrastructure may not be designed with sufficient load and adaptive capacity to function at required performance levels under extreme events driven by climate change. The PIEVC has illustrated the relationship between climate elements, infrastructure attributes and relevant response of infrastructure to climate as the Venn Diagram shown in Figure 2.

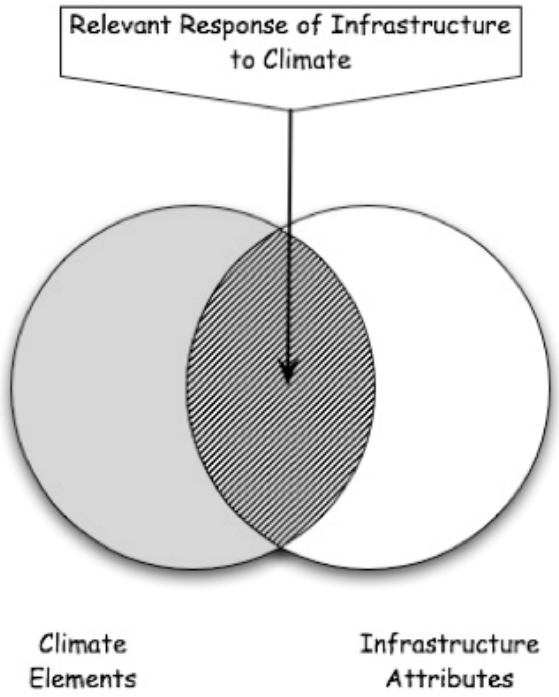


Figure 2: Relevant Interactions between Climate and Infrastructure (Source: PIEVC 2007)

The Draft Protocol consists of 5 steps, with the flow between steps illustrated in Figure 3.

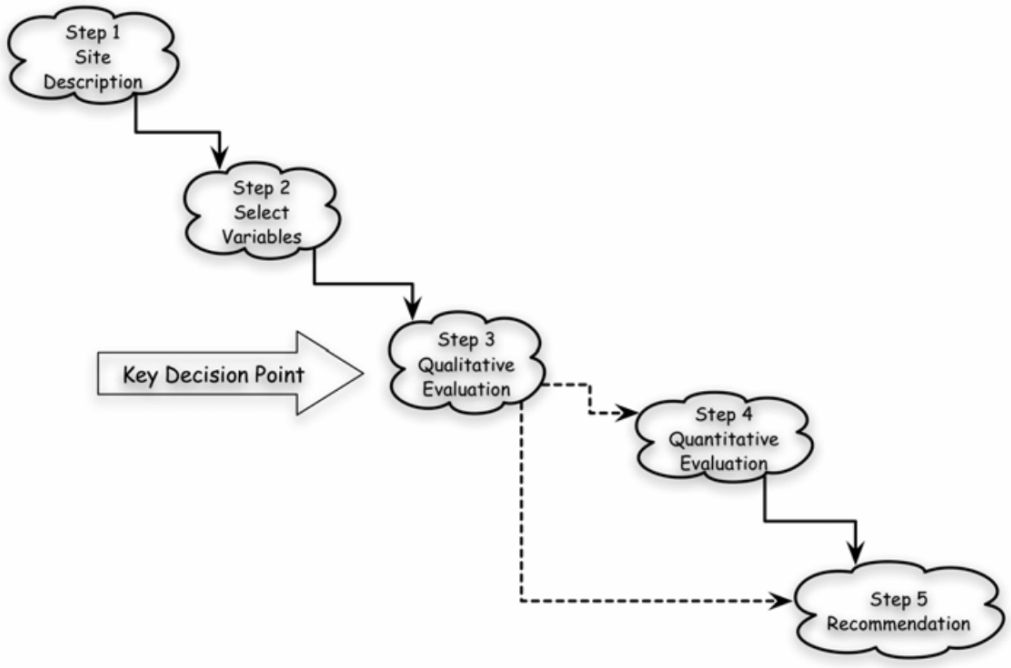


Figure 3: Overview of Draft PIEVC Protocol (Source: PIEVC 2007)

The steps in the Draft Protocol are summarized as follows:

0.2.1 Step 1: Project Definition

Step 1 involves general description of the following as part of the assessment:

- The infrastructure;
- The location;
- Historical climate;
- The load on the infrastructure;
- The age of the infrastructure;
- Other relevant factors; and
- Identification of major documents and information sources.

In this step, the boundary conditions for the vulnerability assessment are defined to set the limits for the application of the Protocol.

0.2.2 Step 2: Data Gathering and Sufficiency

The Protocol requires more information and additional detail regarding:

1) Which parts of the infrastructure will be assessed; and
2) The particular climate factors that will be considered.

Step 2 is comprised of two key activities:

1. Identify the specific features of the infrastructure that will be considered in the assessment:
    - Physical elements of the infrastructure;
    - Number of physical elements;
    - Location;
    - Other relevant engineering/technical considerations:
    - Material of construction;
    - Age;
    - Importance within the region;
    - Physical condition;
    - Operations and maintenance practices;
    - Performance measures used to operate/manage the infrastructure;
    - Insurance considerations;
    - Policies;
    - Guidelines;
    - Regulations; and
    - Legal considerations.

2. Identify applicable climate information. Sources of climate information include, but are not limited to:

    - The National Building Code of Canada, Appendix C, Climate Information;
    - Intensity - Duration – Frequency (IDF) curves for precipitation as rain;
    - Flood plain mapping;
    - Regionally specific climatic modeling;
    - Heat units (i.e. degree-days) (i.e. for agriculture, HVAC, energy use, etc.); and
    - Others, as appropriate.

The Protocol requires the practitioner to exercise professional judgment based on experience and training. Step 2 is an interdisciplinary process requiring engineering, climatological, operations, maintenance, and management expertise. The Protocol requires the practitioner to ensure that the right combination of expertise is represented either on the assessment team or through consultations with other professionals during the execution of the assessment.

0.2.3 Step 3: Qualitative Evaluation

In Step 3 the Protocol requires the practitioner to identify the relationships between the infrastructure, the climate and other factors that could lead to vulnerability. These include:

- Specific infrastructure components;
- Specific climate change parameter values;
- Specific performance goals; and
- Other change parameter values.

The Protocol requires the practitioner to identify which elements of the infrastructure are likely to be sensitive to changes in particular climate parameters. They will be required to evaluate this sensitivity in the context of the performance expectations and other demands that are placed on the infrastructure. Infrastructure performance may be influenced by a variety of factors and the Protocol directs the practitioner to consider the overall environment that encompasses the infrastructure.

Depending on the number of components and relationships involved, the Protocol requires the practitioner to prioritize the relationships.

At this point in the Protocol the practitioner will perform a qualitative assessment of the infrastructure's vulnerability. The relationships identified will be evaluated based on the professional judgment of the assessment team. The prioritization exercise will identify areas of key concern.

The practitioner will identify those relationships that need further quantitative evaluation. The assessment process does not require that all relationships be assessed quantitatively. Some relationships may clearly present no vulnerability. Some relationships may clearly

indicate a need for immediate action. Those relationships that do not yield a clear answer regarding vulnerability should be subjected to the quantitative assessment process outlined in Step 4.

At this stage of the Protocol the practitioner must also assess data availability and quality. If professional judgment identifies a potential vulnerability that requires data that is not available to the assessment team, the Protocol requires that the practitioner revisit Step 1 and/or Step 2 to acquire and refine the data to a level sufficient for quantitative analysis. The practitioner may determine that this process requires additional work outside of the scope of the assessment. Such a finding must be identified in the recommendations outlined in Step 5.

This is a key decision point in the Protocol. The practitioner is required to determine:

- Which relationships should be quantified;
- Where data refinement is required; and
- Initial recommendations about:
  - New research;
  - Immediate remedial action; or
  - Non-vulnerable infrastructure.

At the completion of Step 3, the Study Team conducted a Workshop for PIEVC and affiliated stakeholders for the purposes of reviewing the Protocol as it was applied to Steps 1 through 3 in the process. The Protocol considers the conclusion of Step 3 to be a "Key Decision Point" and so the timing of the Workshop was selected to offer a forum to discuss progress, challenges and paths forward in the Vulnerability Assessment. The Workshop consisted of a guided tour of the Portage la Prairie Water Treatment Plant (Figure 4), review and discussion of the Protocol as it was applied to the Portage la Prairie facility (Figure 5), review and discussion of Ouranos' climatic projection data gathering and modeling processes (Figure 6), break-out sessions for workshop participants to participate in their own "table-top" qualitative vulnerability assessment (Figure 7), and discussion of potential optimization opportunities within the Protocol itself.

Figure 4: Workshop water treatment plant tour

PIEVC Committee Members and Stakeholders participate in Water Treatment Plant Tour portion of the Study Team's Workshop in Portage la Prairie, Manitoba.

Figure 5: Workshop presentation

Study Team Members presented review of the Protocol as it was applied at the Portage la Prairie Water Treatment Plant.

Figure 6: Workshop climate data discussion

Participants from Ouranos present Workshop discussion relating to the gathering and processing of climate data in preparation of their climatic projection products.

Figure 7: Workshop tabletop exercise

Workshop Facilitators circulated between breakout groups comprised of PIEVC Committee Members and Stakeholders (including Portage Water Treatment Plant Managers and

Operators) as they conducted "table-top" qualitative assessment during a review of Step 3 of the Protocol.

0.2.4 Step 4: Quantitative Evaluation

In Step 4 the practitioner quantifies the vulnerability resulting from the relationships identified in Step 3 as requiring further analysis.

The Protocol sets out generic equations that direct the practitioner to numerically assess:

- The total load on the infrastructure, comprising:
  - The current load on the infrastructure;
  - Climate change effects on the infrastructure; and
  - Other change effects on the infrastructure.
- The total capacity of the infrastructure, comprising:
  - The existing capacity;
  - The maturing change in capacity; and
  - Additional changes in capacity.

Based on the numerical analysis:

- A vulnerability exists when Total Load exceeds Total Capacity; and
- Adaptive capacity exists when Total Load is less than Total Capacity.

At this stage of the Protocol the practitioner must make one final assessment about data availability and quality. If, in the professional judgment of the practitioner, the data quality or statistical error does not support clear conclusions from the quantitative evaluation, the Protocol will direct the practitioner to revisit Step 1 and/or Step 2 to acquire and refine the data to a level sufficient for quantitative analysis. The practitioner may determine that this process requires additional work outside of the scope of the assessment. Such a finding must be identified in the recommendations outlined in Step 5.

0.2.5 Step 5: Recommendations

In Step 5 the practitioner is directed to provide recommendations based on the work completed in Steps 1 through 4. Generally, the recommendations will fall into four major categories:

- Remedial action is required to upgrade the infrastructure;
- Management action is required to account for changes in the infrastructure capacity;
- No further action is required; and/or
- There are gaps in data availability or data quality that require further work.

The practitioner may identify additional conclusions or recommendations regarding the veracity of the assessment, the need for further work or areas that were excluded from the current assessment.

0.3 Project Findings

Climate may cause a number of different forms of vulnerability to infrastructure. Application of the Draft Protocol resulted in identification of infrastructure components with potential for an adverse Performance Response in several key areas of facility operation. The Draft Protocol lists possible anticipated performance responses as:

- Structural integrity;
- Serviceability;
- Functionality;
- Operations and maintenance;
- Emergency response risks;
- Insurance considerations;
- Policies and procedures;
- Economics;
- Public health and safety; and
- Environmental effects.

A summary of these identified performance response categories and the infrastructure components with potential sensitivities in these categories are summarized in Table 1.

Table 1: Performance response of infrastructure components to be considered

Infrastructure Components		Performance Response									
		Structural Integrity	Serviceability	Functionality	Operations & Maintenance	Emergency Response Risk	Insurance Considerations	Policies & Procedures	Economics	Public Health & Safety	Environmental Effects
Administration/ Operations	Personnel				3	3	3	3		3	
	Facilities/Equipment (WTP)	3	3	3	3	3	3	3		3	3
	Records				3	3	3	3		3	
Source Water	Shellmouth Dam / Reservoir	3	3			3		3		3	3
	Assiniboine River System				3	3		3			3

Infrastructure Components		Performance Response									
		Structural Integrity	Serviceability	Functionality	Operations & Maintenance	Emergency Response Risk	Insurance Considerations	Policies & Procedures	Economics	Public Health & Safety	Environmental Effects
	Portage Diversion	3	3		3	3	3	3		3	3
	Control Dam Structure	3	3		3	3	3	3		3	3
	Intake Well / Pumps	3	3	3	3	3	3	3		3	3
Treatment	Pretreatment (Actiflo)		3	3	3	3		3		3	3
	Softening/Clarification		3	3	3	3		3		3	3
	Filtration (Granular/GAC)		3	3	3	3		3		3	3
	Disinfection (Ozone/Chlorine)		3	3	3	3		3		3	3
	Storage		3	3	3	3		3		3	3
	Chemical Feed Systems		3	3	3	3		3		3	3
	Chemical Storage/Hazardous Materials		3	3	3	3		3		3	3
	Valves / pipelines (on site)	3	3	3	3	3		3		3	
Distribution	Pump stations (WTP/McKay)	3	3	3	3	3	3	3		3	3
	Pipelines, valves	3	3	3	3	3		3		3	
	Pipe Materials	3	3	3	3	3		3		3	3
Electric power	Substations / Transformers	3	3	3		3	3	3		3	
	Transmission lines	3	3	3		3	3	3		3	
	Standby generators	3	3	3	3	3	3	3		3	3
Transportation	Vehicles		3	3	3	3	3	3			
	Maintenance facilities	3	3	3	3	3	3	3		3	
	Supplies		3	3	3	3	3	3		3	
	Roadway infrastructure	3	3	3	3	3	3	3		3	
Communications	Telephone		3	3	3	3		3			
	Two-way radio		3	3	3	3		3			
	Telemetry	3	3	3	3	3		3		3	

Scale factors for the probability of infrastructure component response to climatic events and also for the severity of the infrastructure response were determined for each of the individual infrastructure components capable of a climatic effect response. The results were then assembled in a matrix to allow for overall system review. This matrix identified which performance responses where applicable to each infrastructure component. When

applying the severity scale factor, only one severity scale factor was applied using judgment on which performance response was critical for each infrastructure-climate relationship. Engineering judgment, engineering experience with Portage la Prairie's water supply infrastructure, and the local knowledge of the operators were used to determine appropriate scale factors.

After an infrastructure-climate relationship was assigned a probability scale factor and severity scale factor, the priority of that relationship was determined using the formula

$$P_C = S_C \times S_R$$

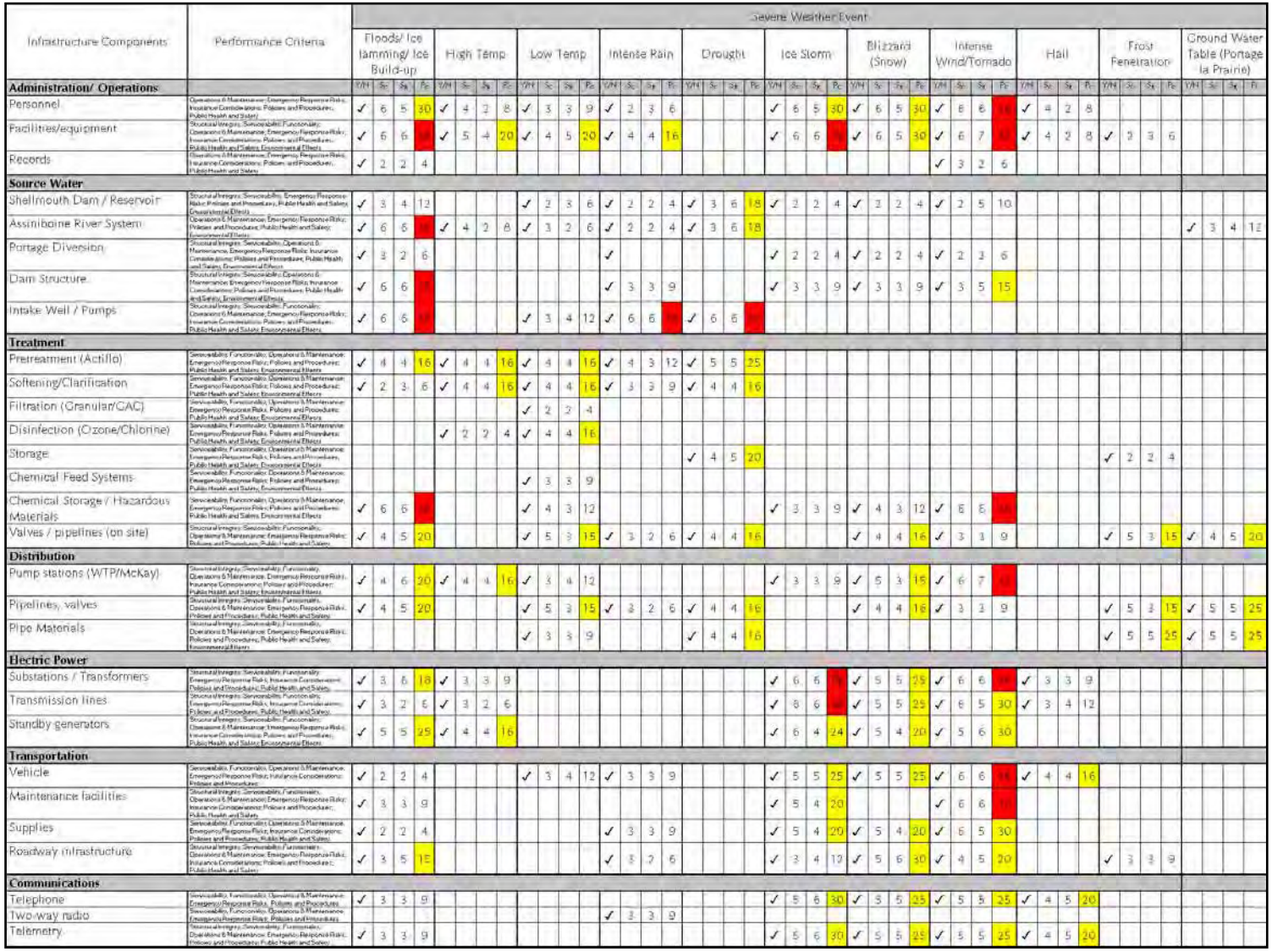
where: P_C is the priority of the climate effect,
S_C is the probability scale factor for the climate effect, and
S_R is the severity scale factor for the performance response.

Figure 8 shows the study team's results after applying the above equation to all infrastructure-climate relationships where a climate-event response relationship was judged to exist. Figure 8 is color coded to highlight the relationships where a vulnerability was identified to exist, or where one may exist. Red boxes highlight where the relationship had a priority of 36 or higher, and yellow boxes highlight relationships with priorities between 12 and 36. Once the priority of the relationships was calculated, the Protocol specified the course of action by the following criteria:

- Any relationship with a priority of 12 or less, or with either scale factor having a value of 2 or less, is discarded from further analysis.

- Any relationship that is determined to have a priority greater than or equal to 36 represents a vulnerability that requires attention and is reported directly in Step 5 with appropriate recommendations to address the identified vulnerability.

- Relationships with priority between 12 and 36 represent potential vulnerabilities. These infrastructure-climate relationships require further numerical analysis in Step 4 if there is sufficient data to quantify the vulnerability with more precision than the qualitative assessment alone could provide.



Infrastructure Components	Performance Criteria	Severe Weather Event: Floods/ Ice Jamming/ Ice Build-up				High Temp				Low Temp				Intense Rain				Drought				Ice Storm				Blizzard (Snow)				Intense Wind/Tornado				Hail				Frost Penetration				Ground Water Table (Portage la Prairie)			
		Y/N	S_C	S_R	P_C	Y/N	S_C	S_R	P_C	Y/N	S_C	S_R	P_C	Y/N	S_C	S_R	P_C	Y/N	S_C	S_R	P_C	Y/N	S_C	S_R	P_C	Y/N	S_C	S_R	P_C	Y/N	S_C	S_R	P_C	Y/N	S_C	S_R	P_C	Y/N	S_C	S_R	P_C	Y/N	S_C	S_R	P_C
Administration/ Operations																																											
Personnel	Operations & Maintenance; Emergency Response Risks; Insurance Considerations; Policies and Procedures; Public Health and Safety	✓	6	5	30	✓	4	2	8	✓	3	3	9	✓	2	3	6					✓	6	5	30	✓	6	5	30	✓	6	6	36	✓	4	2	8								
Facilities/equipment	Structural Integrity; Serviceability; Functionality; Operations & Maintenance; Emergency Response Risks; Insurance Considerations; Policies and Procedures; Public Health and Safety; Environmental Effects	✓	6	6	36	✓	5	4	20	✓	4	5	20	✓	4	4	16					✓	6	6	36	✓	6	5	30	✓	6	7	42	✓	4	2	8	✓	2	3	6				
Records	Operations & Maintenance; Emergency Response Risks; Insurance Considerations; Policies and Procedures; Public Health and Safety; Structural Integrity	✓	2	2	4																									✓	3	2	6										
Source Water																																											
Shellmouth Dam / Reservoir	Structural Integrity; Serviceability; Emergency Response Risks; Policies and Procedures; Public Health and Safety; Environmental Effects	✓	3	4	12					✓	2	3	6	✓	2	2	4	✓	3	6	18	✓	2	2	4	✓	3	2	4	✓	2	5	10										
Assiniboine River System	Operations & Maintenance; Emergency Response Risks; Policies and Procedures; Public Health and Safety; Environmental Effects	✓	6	6	36	✓	4	2	8	✓	3	2	6	✓	2	2	4	✓	3	6	18																	✓	3	4	12
Portage Diversion	Structural Integrity; Serviceability; Operations & Maintenance; Emergency Response Risks; Insurance Considerations; Policies and Procedures; Public Health and Safety; Environmental Effects	✓	3	2	6									✓								✓	2	2	4	✓	2	2	4	✓	2	3	6										
Dam Structure	Structural Integrity; Serviceability; Operations & Maintenance; Emergency Response Risks; Insurance Considerations; Policies and Procedures; Public Health and Safety; Environmental Effects	✓	6	6	36									✓	3	3	9					✓	3	3	9	✓	3	3	9	✓	3	5	15										
Intake Well / Pumps	Structural Integrity; Serviceability; Functionality; Operations & Maintenance; Emergency Response Risks; Insurance Considerations; Policies and Procedures; Public Health and Safety; Environmental Effects	✓	6	6	36					✓	3	4	12	✓	6	6	36	✓	6	6	36																						
Treatment																																											
Pretreatment (Actiflo)	Serviceability; Functionality; Operations & Maintenance; Emergency Response Risks; Policies and Procedures; Public Health and Safety; Environmental Effects	✓	4	4	16	✓	4	4	16	✓	4	4	16	✓	4	3	12	✓	5	5	25																						
Softening/Clarification	Serviceability; Functionality; Operations & Maintenance; Emergency Response Risks; Policies and Procedures; Public Health and Safety; Environmental Effects	✓	2	3	6	✓	4	4	16	✓	4	4	16	✓	3	3	9	✓	4	4	16																						
Filtration (Granular/GAC)	Serviceability; Functionality; Operations & Maintenance; Emergency Response Risks; Policies and Procedures; Public Health and Safety; Environmental Effects									✓	2	2	4																														
Disinfection (Ozone/Chlorine)	Serviceability; Functionality; Operations & Maintenance; Emergency Response Risks; Policies and Procedures; Public Health and Safety; Environmental Effects					✓	2	2	4	✓	4	4	16																														
Storage	Serviceability; Functionality; Operations & Maintenance; Emergency Response Risks; Policies and Procedures; Public Health and Safety; Environmental Effects																	✓	4	5	20																	✓	2	2	4				
Chemical Feed Systems	Serviceability; Functionality; Operations & Maintenance; Emergency Response Risks; Policies and Procedures; Public Health and Safety; Environmental Effects									✓	3	3	9																														
Chemical Storage / Hazardous Materials	Serviceability; Functionality; Operations & Maintenance; Emergency Response Risks; Policies and Procedures; Public Health and Safety; Environmental Effects	✓	6	6	36					✓	4	3	12									✓	3	3	9	✓	4	3	12	✓	6	6	36										
Valves / pipelines (on site)	Structural Integrity; Serviceability; Functionality; Operations & Maintenance; Emergency Response Risks; Policies and Procedures; Public Health and Safety	✓	4	5	20					✓	5	3	15	✓	3	2	6	✓	4	4	16					✓	4	4	16	✓	3	3	9					✓	5	3	15	✓	4	5	20
Distribution																																											
Pump stations (WTP/McKay)	Structural Integrity; Serviceability; Functionality; Operations & Maintenance; Emergency Response Risks; Insurance Considerations; Policies and Procedures; Public Health and Safety; Environmental Effects	✓	4	6	20	✓	4	4	16	✓	3	4	12									✓	3	3	9	✓	5	3	15	✓	6	7	42										
Pipelines, valves	Structural Integrity; Serviceability; Functionality; Operations & Maintenance; Emergency Response Risks; Policies and Procedures; Public Health and Safety	✓	4	5	20					✓	5	3	15	✓	3	2	6	✓	4	4	16					✓	4	4	16	✓	3	3	9					✓	5	3	15	✓	5	5	25
Pipe Materials	Structural Integrity; Serviceability; Functionality; Operations & Maintenance; Emergency Response Risks; Policies and Procedures; Public Health and Safety; Environmental Effects									✓	3	3	9					✓	4	4	16																	✓	5	5	25	✓	5	5	25
Electric Power																																											
Substations / Transformers	Structural Integrity; Serviceability; Functionality; Emergency Response Risks; Insurance Considerations; Policies and Procedures; Public Health and Safety	✓	3	6	18	✓	3	3	9													✓	6	6	36	✓	5	5	25	✓	6	6	36	✓	3	3	9						
Transmission lines	Structural Integrity; Serviceability; Functionality; Emergency Response Risks; Insurance Considerations; Policies and Procedures; Public Health and Safety	✓	3	2	6	✓	3	2	6													✓	6	6	36	✓	5	5	25	✓	6	5	30	✓	3	4	12				
Standby generators	Structural Integrity; Serviceability; Functionality; Operations & Maintenance; Emergency Response Risks; Insurance Considerations; Policies and Procedures; Public Health and Safety; Environmental Effects	✓	5	5	25	✓	4	4	16													✓	6	4	24	✓	5	4	20	✓	5	6	30								
Transportation																																										
Vehicle	Serviceability; Functionality; Operations & Maintenance; Emergency Response Risks; Insurance Considerations; Policies and Procedures	✓	2	2	4					✓	3	4	12	✓	3	3	9					✓	5	5	25	✓	5	5	25	✓	6	6	36	✓	4	4	16				
Maintenance facilities	Structural Integrity; Serviceability; Functionality; Operations & Maintenance; Emergency Response Risks; Insurance Considerations; Policies and Procedures; Public Health and Safety	✓	3	3	9																	✓	5	4	20					✓	6	6	36								
Supplies	Serviceability; Functionality; Operations & Maintenance; Emergency Response Risks; Insurance Considerations; Policies and Procedures; Public Health and Safety	✓	2	2	4									✓	3	3	9					✓	5	4	20	✓	5	4	20	✓	6	5	30								
Roadway infrastructure	Structural Integrity; Serviceability; Functionality; Operations & Maintenance; Emergency Response Risks; Insurance Considerations; Policies and Procedures; Public Health and Safety	✓	3	5	15									✓	3	2	6					✓	3	4	12	✓	5	6	30	✓	4	5	20					✓	3	3	9
Communications																																										
Telephone	Serviceability; Functionality; Operations & Maintenance; Emergency Response Risks; Policies and Procedures	✓	3	3	9																	✓	5	6	30	✓	5	5	25	✓	5	5	25	✓	4	5	20				
Two-way radio	Serviceability; Functionality; Operations & Maintenance; Emergency Response Risks; Policies and Procedures													✓	3	3	9																								
Telemetry	Structural Integrity; Serviceability; Functionality; Operations & Maintenance; Emergency Response Risks; Policies and Procedures; Public Health and Safety	✓	3	3	9																	✓	5	6	30	✓	5	5	25	✓	5	5	25	✓	4	5	20				

Figure 8: Completed Relationship Priority Matrix

Table 2 summarizes the infrastructure-climate effect relationships that had a relationship priority reaching the threshold value of 36 or more. The relationships are identified as vulnerabilities of the infrastructure to climate. The Protocol indicated that for these relationships, no further analysis is required and these relationships will be transferred to Step 5: Recommendations, where appropriate recommendations to address the vulnerability will be made.

Table 2: Relationships with priority above threshold value of 36

Infrastructure Component	Climate Variable	Priority of Relationship
Personnel	Intense Wind/Tornado	36
Facilities/equipment	Floods/Ice Jamming/Ice Buildup	36
	Ice Storm	36
	Intense Wind/Tornado	42
Assiniboine River System	Floods/Ice Jamming/Ice Buildup	36
Dam Structure	Floods/Ice Jamming/Ice Buildup	36
Intake Well / Pumps	Floods/Ice Jamming/Ice Buildup	36
	Intense Rain	36
	Drought	36
Chemical Storage / Hazardous Materials	Floods/Ice Jamming/Ice Buildup	36
	Intense Wind/Tornado	36
Pump stations (WTP/McKay)	Intense Wind/Tornado	42
Substations / Transformers	Ice Storm	36
	Intense Wind/Tornado	36
Transmission lines (Hydro)	Ice Storm	36
Vehicle	Intense Wind/Tornado	36
Maintenance facilities	Intense Wind/Tornado	36

The next class of relationship is defined as relationships with a Priority Value in the range of greater than 12 and less than 36 (Table 3). The Protocol considers these Priority Values to represent relationships that may or may not be vulnerable to climate change. To determine if vulnerability exists, the Protocol requires that these relationships undergo further analysis in Step 4: Quantitative Evaluation, as long as sufficient data exists to conduct the Quantitative Evaluation. The climate change data will be converted into loads and added to existing loads on the infrastructure to determine if the infrastructure components have enough adaptive capacity to withstand the changes in climate.

Table 3: Relationships with priorities between 12 and 36

Infrastructure Component	Climate Variable	Priority of Relationship
Personnel	Floods/Ice Jamming/Ice Buildup	30
	Ice Storm	30
	Blizzard	30

Infrastructure Component	Climate Variable	Priority of Relationship
Facilities/equipment	High Temp	20
	Low Temp	20
	Intense Rain	16
	Blizzard	30
Shellmouth Dam/Reservoir	Drought	18
Assiniboine River System	Drought	18
Dam Structure	Intense Wind/Tornado	15
Pretreatment	Floods/Ice Jamming/Ice Buildup	16
	High Temp	16
	Low Temp	16
	Drought	25
Softening	High Temp	16
	Low Temp	16
	Drought	16
Disinfection	Low Temp	16
Storage	Drought	20
Valves Pipelines (on WTP site)	Floods/Ice Jamming/Ice Buildup	20
	Low Temp	15
	Drought	16
	Blizzard	16
	Frost Penetration	15
	Ground Water Table	20
Pump stations (WTP/McKay)	Floods/Ice Jamming/Ice Buildup	20
	High Temp	16
	Blizzard	15
Pipelines and Valves	Floods/Ice Jamming/Ice Buildup	20
	Low Temp	15
	Drought	16
	Blizzard	16
	Frost Penetration	15
	Ground Water Table	25
Pipe Materials	Drought	16
	Frost Penetration	25
	Ground Water Table	25
Substations / Transformers	Floods/Ice Jamming/Ice Buildup	18
	Blizzard	25
Transmission lines (Hydro)	Blizzard	25
	Intense Wind/Tornado	30
Standby Generators	Floods/Ice Jamming/Ice Buildup	25
	High Temp	16
	Ice Storm	24
	Blizzard	20

Infrastructure Component	Climate Variable	Priority of Relationship
	Intense Wind/Tornado	30
Vehicle	Ice Storm	25
	Blizzard	25
	Hail	16
Maintenance Facilities	Ice Storm	20
Supplies	Ice Storm	20
	Blizzard	20
	Intense Wind/Tornado	30
Roadway Infrastructure	Floods/Ice Jamming/Ice Buildup	15
	Blizzard	30
	Intense Wind/Tornado	20
Telephone	Ice Storm	30
	Blizzard	25
	Intense Wind/Tornado	25
	Hail	20
Telemetry	Ice Storm	30
	Blizzard	25
	Intense Wind/Tornado	25
	Hail	20

Lastly, there is a third class of infrastructure components and climate effects that yield Priority Values of 12 or less, or have a probability or severity scale factor of 2 or less. These relationships are essentially screened out from the assessment by the Protocol, and do not undergo further assessment. The Protocol considers relationships in this final category to have little or no vulnerability and consequently are discarded from further analysis. Relationships in this category are shown in the Relationship Priority Matrix (Figure 8).

0.4 Assessment Conclusions and Recommendations

The results of the Protocol as it has been applied to the Portage la Prairie water resource infrastructure were derived by Qualitative and Quantitative Assessment and summarized in the results reported for Steps 3 and 4 of the Protocol. Conclusions reached from the assessment are summarized in the following sections. GENIVAR/TetrES' assessment has yielded recommendations that fall into four major categories:

1. **Remedial action is required to upgrade the infrastructure:** Vulnerabilities falling into this category represent critical issues that, if allowed to remain unmitigated, could result in unacceptable consequences in the form of unacceptable interruption of water supply/service and/or danger to life, health and property;
2. **Management action is required to account for changes in the infrastructure capacity:** Vulnerabilities that create reduced capacity in infrastructure such that it may fail to meet the minimum intended needs of the community it serves;
3. **No further action is required:** Vulnerabilities that are negligible in nature and have

no measurable impact on system performance; and/or

4. **Additional data and study are required:** There are gaps in data availability or data quality that require further work.

0.4.1 Identification of the Vulnerabilities of the Infrastructure Components

For the main infrastructure components of the Portage la Prairie water resources infrastructure, the following vulnerabilities and associated recommendations related to changing climate conditions are noted (cf. Table 4 and Table 5 for summary):

0.4.1.1 Administration / Operations

City Personnel

Potential vulnerabilities of the City personnel related to floods, ice jams, ice build-up and ice storms were noted. Based on the existing capacity of the City personnel to adapt to these events, no additional vulnerability exists and therefore no further action by the City is recommended.

Potential vulnerabilities of the City personnel related to intense winds and tornadoes were also noted and management action is recommended. The City should review their emergency preparedness requirements for intense wind and tornado events to ensure that proper plans are in place for personnel related to the operation of the infrastructure.

Facilities / Equipment

Potential vulnerabilities of the water treatment plant facilities and equipment related to high temperature, floods, ice jams, ice build-up and ice storms, intense winds and tornadoes were noted.

For high temperature climate variables, no action is recommended. High temperature changes resulted in slight system vulnerability in the extended climate change projection to 2080. This timeframe is well beyond the expected service life of the existing facilities and equipment, and it is expected that the future system will adapt to these changes. The climate projections associated with 20 and 40-year projections did not yield infrastructure responses sufficient to cause system vulnerabilities.

For floods, ice jams and ice build-up, management action is recommended. The City should review the level of flood protection related to each facility and prepare an action plan in the case of flooding. In the case where infrastructure is highly vulnerable, remedial flood protection work works should be completed.

For ice storms, remedial action is recommended. The City should review their emergency preparedness requirements to ensure that proper plans are in place related to the operation of the infrastructure. In addition, the City should review installing full standby power or

back-up facilities at the water treatment plant to reduce power vulnerability generally associated with ice storm events.

For intense winds and tornadoes, management action is recommended. The City should review their emergency preparedness requirements for intense wind and tornado events to ensure that proper plans are in place for the operation and protection of the infrastructure.

0.4.1.2 Source Water

Shellmouth Dam / Reservoir

The vulnerability of the Shellmouth Dam/ Reservoir to drought was assumed by engineering judgment to be very high. Data was not available to confirm this assumption. Additional study is required to assess the vulnerability of Shellmouth Dam to drought.

Assiniboine River System

The vulnerability of the Assiniboine River system to drought was assumed by engineering judgment to be very high. Data was not available to confirm this assumption. Additional study is required to assess the vulnerability of the Assiniboine River due to drought.

Potential Vulnerabilities of the Assiniboine River System related to floods, ice jams and ice build-up were noted and management action is recommended. The City should work with the Province of Manitoba to review flood related vulnerabilities for the Assiniboine River at Portage la Prairie to further assess the impacts to the water resources infrastructure.

Control Dam Structure

Potential vulnerabilities of the control dam structure related to floods, ice jams and ice build-up were noted and management action is recommended. The City should review the level of flood protection related to the dam and prepare an action plan in the case of flooding. In the case where infrastructure is highly vulnerable, remedial works should be completed. In the case of ice jamming (blinding off the intake), the City should prepare an action plan to remedy the blockage.

Intake Well / Pumps

Potential vulnerabilities of the intake well and pumps at the dam related to floods, ice jams, ice build-up, intense rain and drought were noted.

For floods, ice jams, ice build-up and intense rain, management action is recommended. The City should review the level of flood protection related to the intake well and prepare an action plan in the case of flooding. In the case where infrastructure is highly vulnerable, remedial works should be completed. In the case of ice jamming (blinding off the intake), the City should prepare an action plan to remedy the blockage.

For drought, additional study is required. The vulnerability of the intake well to drought was assumed by engineering judgment to be very high. Data was not available to confirm this assumption. The City should also review drought related issued with the Province of Manitoba to establish water rights priorities in the event of drought on the Assiniboine River. The City should also request that the Province further study the Assiniboine River watershed for climate change effects.

0.4.1.3 Treatment

Pretreatment (Actiflo)

Potential vulnerabilities of the pretreatment facilities and equipment related to high temperature, floods, ice jams, ice build-up and drought were noted.

For high temperature climate variables, no action is recommended. Using professional judgment due to insufficient data, it is not expected that greater vulnerability exists due to future changes of high temperatures and related effect on water quality. It is assumed that the range of water quality changes under these events will not exceed current seasonal spikes in water quality variables. Based on this assumption, the infrastructure has existing capability.

For floods, ice jams and ice build-up, no action is recommended. Using professional judgment due to insufficient data, it is not expected that greater vulnerability exists due to future changes of floods, ice jams and ice build-up and related effect on water quality. It is assumed that the range of water quality changes under these events will not exceed current seasonal variations. Based on this assumption, the infrastructure has existing capability.

For drought, additional study is required. The vulnerability of the pretreatment system to drought was assumed by engineering judgment to be very high. Data was not available to confirm this assumption. The City should review drought related issues with the Province of Manitoba to establish water rights priorities in the event of drought on the Assiniboine River. The City should also request that the Province further study the Assiniboine River watershed for climate change effects.

Softening / Clarification

Potential vulnerabilities of the Softening/ Clarification equipment related to high temperature and drought were noted.

For high temperature climate variables, no action is recommended. Using professional judgment due to insufficient data, it is not expected that greater vulnerability exists due to future changes of high temperatures and related effect on water quality. It is assumed that the range of water quality changes under these events will not exceed current seasonal

spikes and water quality variables. Based on this assumption, the infrastructure has existing capability.

For drought, additional study is required. The vulnerability of the softening/ clarification system to drought was assumed by engineering judgment to be very high. Data was not available to confirm this assumption. The City should review drought related issues with the Province of Manitoba to establish water rights priorities in the event of drought on the Assiniboine River. The City should also request that the Province further study the Assiniboine River watershed for climate change effects.

Storage

Vulnerability of the treated water storage related to drought was noted and additional study is required. The vulnerability of treated water storage for drought was assumed by engineering judgment to be very high. Data was not available to confirm this assumption. The City should review drought related issues with the Province of Manitoba to establish water rights priorities in the event of drought on the Assiniboine River. The City should also request that the Province further study the Assiniboine River watershed for climate change effects.

Chemical Storage / Hazardous Materials

Potential vulnerabilities of the chemical storage and hazardous materials stored at the facilities related to floods, ice jams, ice build-up, intense winds and tornadoes were noted.

For floods, ice jams, ice build-up, management action is recommended. The City should review the level of flood protection related to bulk chemical and other hazardous material and prepare an action plan in the case of flooding. In the case where infrastructure is highly vulnerable, remedial works should be completed.

For intense winds and tornadoes, management action is recommended. The City should review their emergency preparedness requirements for intense wind and tornado events to ensure that proper plans are in place for the operation and protection of the infrastructure.

Valves / Pipelines at the Water Treatment Plant

Potential vulnerability of the valves and piping at the water treatment plant site was noted related to floods, ice jams and ice build-up and no action is recommended. Using professional judgment due to insufficient data, it is not expected that greater vulnerability exists due to future changes of these climate variables. It is assumed that the infrastructure has existing capability.

0.4.1.4 Distribution

Pumping Stations (Water Treatment Plant and McKay)

Potential vulnerabilities of the pumping stations at the water treatment plant site and at the McKay Reservoir related to high temperature, floods, ice jams, ice build-up, intense winds and tornadoes were noted.

For floods, ice jams, ice build-up, additional study is recommended. The City should review the level of flood protection related to the pump stations and prepare an action plan in the case of flooding. In the case where infrastructure is highly vulnerable, remedial works should be completed.

For high temperature climate variables, no action is recommended. High temperature changes resulted in slight system vulnerability in the extended climate change projection to 2080. This timeframe is well beyond the expected service life of the existing facilities and equipment, and it is expected that the future system will adapt to these changes. The climate projections associated with 20 and 40-year projections did not yield infrastructure responses sufficient to cause system vulnerabilities.

For intense winds and tornadoes, management action is recommended. The City should review their emergency preparedness requirements for intense wind and tornado events to ensure that proper plans are in place for the operation and protection of the infrastructure.

Pipelines / Valves

Potential vulnerability of the valves and piping in the distribution system related to floods, ice jams and ice build-up were noted, and no action is recommended. Using professional judgment due to insufficient data, it is not expected that greater vulnerability exists due to future changes of these climate variables. It is assumed that the infrastructure has existing capability.

0.4.1.5 Electric Power

Substations / Transformers

Potential vulnerabilities of the substations/ transformers supplying power to the water treatment plant and pumping stations related to high temperature, floods, ice jams, ice build-up and ice storms, intense winds and tornadoes were noted.

For floods, ice jams, ice build-up, additional study is recommended. Using professional judgment due to insufficient data, it is not expected that greater vulnerability exists due to future changes of floods, ice jamming and ice build-up. It is assumed that the utility infrastructure is reasonably flood proofed. Assuming this, the infrastructure has existing capability. Additional study is required to confirm this assumption.

For ice storms, remedial action is recommended. The City should review their emergency preparedness requirements on ice storms. In addition, the City should review installing full standby power at the water treatment plant to reduce power vulnerability generally associated with ice storm events.

For intense winds and tornadoes, remedial action is recommended. Using professional judgment due to insufficient data, but with comments from Ouranos related to extreme wind and tornadoes, it is possible that greater vulnerability exists due to future climate changes. The City should review their emergency preparedness requirements on tornadoes as well as working with Manitoba Hydro to bury as many transmission lines as possible to reduce the vulnerability.

Standby Generators

Potential vulnerabilities of the standby generators supplying back-up power to the water treatment plant and pumping stations related to floods, ice jams, ice build-up, high temperatures, ice storms, intense winds and tornadoes were noted.

For floods, ice jams, ice build-up, additional study is recommended. Using professional judgment due to insufficient data, it is not expected that greater vulnerability exists due to future changes of floods, ice jamming and ice build-up. It is assumed that the utility infrastructure is reasonably flood proofed. Assuming this, the infrastructure has existing capability. Additional study is required to confirm this assumption.

For high temperature climate variables, no action is recommended. High temperature changes resulted in slight system vulnerability in the extended climate change projection to 2080. This timeframe is well beyond the expected service life of the existing facilities and equipment, and it is expected that the future system will adapt to these changes. The climate projections associated with 20 and 40-year projections did not yield infrastructure responses sufficient to cause system vulnerabilities.

For ice storms, additional study is required. Additional study is required to determine the frequency of ice storms and the need for standby power during these extreme events.

For intense winds and tornadoes, remedial action is recommended. Using professional judgment due to insufficient data, but with comments from Ouranos related to extreme wind and tornadoes, it is possible that greater vulnerability exists due to future climate changes. The City should review their emergency preparedness requirements on tornadoes as well as working with Manitoba Hydro to bury as many transmission lines as possible to reduce the vulnerability and determine the extent back-up power requirements.

Transmission Lines

Potential vulnerabilities of power transmission lines related to ice storms was noted and remedial action is recommended. The City should review their emergency preparedness requirements on ice storms. In addition, the City should review installing full standby power at the water treatment plant to reduce power vulnerability generally associated with ice storm events.

0.4.1.6 Transportation

Service Vehicles

Potential vulnerabilities of City service vehicles related to ice storms, hail and intense wind and tornadoes were noted.

For ice storms, additional study is required to determine the frequency of ice storms and its effects on service vehicles.

For hail, no further action is recommended. Climate change projections were not available related to this climate variable. Although additional data specific to hail is required, the vulnerability of service vehicles based on a hail event is low.

For intense winds and tornadoes, management action is recommended. The City should review their emergency preparedness requirements for intense wind and tornado events to ensure that proper plans are in place for the operation and protection of the infrastructure.

Maintenance Facilities

Potential vulnerabilities of City service vehicles related to ice storms, intense wind and tornadoes were noted.

For ice storms, additional study is required to determine the frequency of ice storms and its effects on maintenance facilities.

For intense winds and tornadoes, management action is recommended. The City should review their emergency preparedness requirements for intense wind and tornado events to ensure that proper plans are in place for the operation and protection of the infrastructure.

Supplies

Potential vulnerabilities of supplies related to ice storms, intense winds and tornadoes were noted.

For ice storms, additional study is required to determine the frequency of ice storms and its effects on supplies.

For intense winds and tornadoes, remedial action is recommended. Using professional judgment due to insufficient data, but with comments from Ouranos related to extreme wind and tornadoes, it is possible that greater vulnerability exists due to future climate changes. The City should review their emergency preparedness requirements on tornadoes. Back-up/ alternate sources of supplies should be considered.

Roadway Infrastructure

Potential vulnerabilities of the roadway infrastructure related to floods, ice jams, ice build-up, intense winds and tornadoes were noted.

For floods, ice jams, ice build-up, additional study is recommended. Using professional judgment due to insufficient data, it is not expected that greater vulnerability exists due to future changes of floods, ice jamming and ice build-up. It is assumed that the utility infrastructure is reasonably protected from flooding. Assuming this, the infrastructure has existing capability. Additional study is required to confirm this assumption.

For intense winds and tornadoes, remedial action is recommended. Using professional judgment due to insufficient data, but with comments from Ouranos related to extreme wind and tornadoes, it is possible that greater vulnerability exists due to future climate changes. The City should review their emergency preparedness requirements on tornadoes. Alternate means of access to critical infrastructure should be reviewed.

0.4.1.7 Communications

Telephone

Potential vulnerabilities of the telephone network to ice storms, hail and intense wind and tornadoes were noted.

For ice storms, additional study is required. Additional study is required to determine the frequency of ice storms and its effect on telephone services.

For hail, no further action is recommended. Climate change projections were not available for this climate variable. Although additional data specific to hail is required, the vulnerability of the telephone network to a hail event is low.

For intense winds and tornadoes, remedial action is recommended. Using professional judgment due to insufficient data, but with comments from Ouranos related to extreme wind and tornadoes, it is possible that greater vulnerability exists due to future climate changes. The City should review their emergency preparedness requirements on tornadoes. The City should also consider burying telephone lines to the greatest extent possible or having back-up wireless communication.

Telemetry

Vulnerabilities of the City's telemetry network to ice storms, hail and intense wind and tornadoes were noted.

For ice storms, additional study is required. Additional study is required to determine the frequency of ice storms and its effect on telephone services.

For hail, no further action is recommended. Climate change projections were not available related to this climate variable. Although additional data specific to hail is required, the vulnerability of the telemetry equipment due to a hail event is low.

For intense winds and tornadoes, remedial action is recommended. Using professional judgment due to insufficient data, but with comments from Ouranos related to extreme wind and tornadoes, it is possible that greater vulnerability exists due to future climate changes. The City should review their emergency preparedness requirements on tornadoes. The City should also consider burying communication lines to the greatest extent possible or having back-up wireless communication.

Table 4: Step 5 Recommendations (relationships with Priorities between 12 and 36)

Infrastructure Component	Climate Variable	Data Source	Forward to STEP 5 Recommendation Evaluation Y/N	Recommendations	Recommendation Comments
Personnel	Floods/ Ice Jamming/ Ice Build-up	Data not available	3	No Further Action	Using professional judgment due to insufficient data, it is not expected that greater vulnerability exists due to future changes of Floods/Ice Jamming/Ice Build-up. It is assumed that the personnel have existing capability or adaptive capabilities.
	Ice Storm	Data not available	3	No Further Action	Using professional judgment due to insufficient data, it is not expected that greater vulnerability exists due to future changes of Floods/Ice Jamming/Ice Build-up. It is assumed that the personnel have existing capability or adaptive capabilities.
Facilities/ Equipment	High Temp	Temperature: Annual Max (Deg. C)			
		2080	3	No Further Action	Although a slight vulnerability exists, the 2080 horizon is well beyond the remaining service life of the equipment. Expected that replacement equipment will have a higher rating nearing 2080.
Shellmouth Dam/ Reservoir	Drought	Rain: Avg Total Rain, Annual Plus Snow: Avg Total, Annual (mm)			
		2020	3	Additional Study Required	Further Study is required on climate impacts to the Assiniboine Watershed Infrastructure.
		2050	3	Additional Study Required	Further Study is required on climate impacts to the Assiniboine Watershed Infrastructure.
		2080	3	Additional Study Required	Further Study is required on climate impacts to the Assiniboine Watershed Infrastructure.

Infrastructure Component	Climate Variable	Data Source	Forward to STEP 5 Recommendation Evaluation Y/N	Recommendations	Recommendation Comments
Assiniboine River System	Drought	Rain: Avg Total Rain, Annual Plus Snow: Avg Total, Annual (mm)			
		2020	3	Additional Study Required	Further Study is required on climate impacts to the Assiniboine Watershed Infrastructure.
		2050	3	Additional Study Required	Further Study is required on climate impacts to the Assiniboine Watershed Infrastructure.
		2080	3	Additional Study Required	Further Study is required on climate impacts to the Assiniboine Watershed Infrastructure.
Pre-treatment	Floods/ Ice Jamming/ Ice Build-up	Data not available	3	No further Action	Using professional judgment due to insufficient data, it is not expected that greater vulnerability exists due to future changes of Floods/Ice Jamming/Ice Build-up. It is assumed that the range of water quality changes under these events will not exceed current seasonal spikes. Assuming this, the infrastructure has existing capability.
	High Temp	Temperature: Annual Max (Deg. C)			
		2080	3	No Further Action	Although a slight vulnerability exists, the 2080 horizon is well beyond the remaining service life of the equipment. Using professional judgment due to insufficient data, it is not expected that greater vulnerability exists due to future changes of high temperatures and related water quality. It is assumed that the range of water quality changes under these events will only slightly exceed current seasonal spikes. Assuming this, the infrastructure has existing capability.
	Drought	Rain: Avg Total Rain, Annual Plus Snow: Avg Total, Annual (mm)			
		2020	3	Additional Study Required	Further Study is required on climate impacts to the Assiniboine Watershed Infrastructure.
		2050	3	Additional Study Required	Further Study is required on climate impacts to the Assiniboine Watershed Infrastructure.
		2080	3	Additional Study Required	Further Study is required on climate impacts to the Assiniboine Watershed Infrastructure.
Softening	High Temp	Temperature: Annual Max (Deg. C)			
		2080	3	No Further Action	Although a slight vulnerability exists, the 2080 horizon is well beyond the remaining service life of the equipment. Using professional judgment due to insufficient data, it is not expected that greater vulnerability exists due to future changes of high temperatures and related water quality. It is assumed that the range of water quality changes under these events will only slightly exceed current seasonal spikes. Assuming this, the infrastructure has existing capability.
	Drought	Rain: Avg Total Rain, Annual Plus Snow: Avg Total, Annual (mm)			
		2020	3	Additional Study Required	Further Study is required on climate impacts to the Assiniboine Watershed Infrastructure.
		2050	3	Additional Study Required	Further Study is required on climate impacts to the Assiniboine Watershed Infrastructure.
		2080	3	Additional Study Required	Further Study is required on climate impacts to the Assiniboine Watershed Infrastructure.

Infrastructure Component	Climate Variable	Data Source	Forward to STEP 5 Recommendation Evaluation Y/N	Recommendations	Recommendation Comments
Storage	Drought	Rain: Avg Total Rain, Annual Plus Snow: Avg Total, Annual (mm)			
		2020	3	Additional Study Required	Further Study is required on climate impacts to the Assiniboine Watershed Infrastructure.
		2050	3	Additional Study Required	Further Study is required on climate impacts to the Assiniboine Watershed Infrastructure.
		2080	3	Additional Study Required	Further Study is required on climate impacts to the Assiniboine Watershed Infrastructure.
Valves Pipelines (on WTP site)	Floods/ Ice Jamming/ Ice Build-up	Data not available	3	No Further Action	Using professional judgment due to insufficient data, it is not expected that greater vulnerability exists due to future changes of Floods/Ice Jamming/Ice Build-up. It is assumed that the infrastructure has existing capability.
Pump Stations (WTP/ McKay)	Floods/ Ice Jamming/ Ice Build-up	Data not available	3	Additional Study Required	Using professional judgment due to insufficient data, a greater vulnerability may exist due to future changes of Floods/Ice Jamming/Ice Build-up. Additional study is required.
	High Temp	Temperature: Annual Max (Deg. C)			
		2080	3	No Further Action	Although a slight vulnerability exists, the 2080 horizon is well beyond the remaining service life of the equipment. Expected that replacement equipment will have a higher rating nearing 2080.
Pipelines and Valves	Floods/ Ice Jamming/ Ice Build-up	Data not available	3	No Further Action	Using professional judgment due to insufficient data, it is not expected that greater vulnerability exists due to future changes of Floods/Ice Jamming/Ice Build-up. It is assumed that the infrastructure has existing capability.
Substations / Transformers	Floods/ Ice Jamming/ Ice Build-up	Data not available	3	Additional Study Required	Using professional judgment due to insufficient data, it is not expected that greater vulnerability exists due to future changes of Floods/Ice Jamming/Ice Build-up. It is assumed that the utility infrastructure is reasonably flood proofed and that future events will not exceed current seasonal spikes. Assuming this, the infrastructure has existing capability. Additional study is required to confirm this assumption.
	Intense Wind/Tornado	Data not available	3	Remedial Action	Using professional judgment due to insufficient data, but with comments from Ouranos related to extreme wind and tornadoes, it is possible that greater vulnerability exists due to future climate changes. The City should review their emergency preparedness requirements on tornadoes as well as working with Manitoba hydro to bury as many transmission lines as possible to reduce the vulnerability.
Standby Generators	Floods/ Ice Jamming/ Ice Build-up	Data not available	3	Additional Study Required	Using professional judgment due to insufficient data, it is not expected that greater vulnerability exists due to future changes of Floods/Ice Jamming/Ice Build-up. It is assumed that the utility infrastructure is reasonably protected from flooding. Assuming this, the infrastructure has existing capability. Additional study is required to confirm this assumption.
	High Temp	Temperature: Annual Max (Deg. C)			
		2080	3	No Further Action	Although a slight vulnerability exists, the 2080 horizon is well beyond the remaining service life of the equipment. Expected that replacement equipment will have a higher temperature rating nearing 2080.
	Ice Storm	Data not available	3	Additional Study Required	Additional study is required to determine the frequency of ice storms and the need for standby power during this extreme event.

Infrastructure Component	Climate Variable	Data Source	Forward to STEP 5 Recommendation Evaluation Y/N	Recommendations	Recommendation Comments
	Intense Wind/Tornado	Data not available	3	Remedial Action	Using professional judgment due to insufficient data, but with comments from Ouranos related to extreme wind and tornadoes, it is possible that greater vulnerability exists due to future climate changes. The City should review their emergency preparedness requirements on tornadoes. In addition the City should review installing full standby power at the water treatment plant to reduce power vulnerability.
Vehicle	Ice Storm	Data not available	3	Additional Study Required	Additional study is required to determine the frequency of ice storms and its effect on service vehicles.
	Hail	Data not available	3	No Further Action	Climate change projections were not available related to this climate variable. Although additional data specific to hail is required, the vulnerability of service vehicles based on a hail event is low. No further action is required.
Maintenance Facilities	Ice Storm	Data not available	3	Additional Study Required	Additional study is required to determine the frequency of ice storms and its effect on maintenance facilities.
Supplies	Ice Storm	Data not available	3	Additional Study Required	Additional study is required to determine the frequency of ice storms and its effect on supply services.
	Intense Wind/Tornado	Data not available	3	Remedial Action	Using professional judgment due to insufficient data, but with comments from Ouranos related to extreme wind and tornadoes, it is possible that greater vulnerability exists due to future climate changes. The City should review their emergency preparedness requirements on tornadoes. Back-up/ Alternate sources of supplies should be considered.
Roadway Infrastructure	Floods/ Ice Jamming/ Ice Build-up	Data not available	3	Additional Study Required	Using professional judgment due to insufficient data, it is not expected that greater vulnerability exists due to future changes of Floods/Ice Jamming/Ice Build-up. It is assumed that the utility infrastructure is reasonably protected from flooding. Assuming this, the infrastructure has existing capability. Additional study is required to confirm this assumption.
	Intense Wind/Tornado	Data not available	3	Remedial Action	Using professional judgment due to insufficient data, but with comments from Ouranos related to extreme wind and tornadoes, it is possible that greater vulnerability exists due to future climate changes. The City should review their emergency preparedness requirements on tornadoes. Alternate means of access to critical infrastructure should be reviewed.
Telephone	Ice Storm	Data not available	3	Additional Study Required	Additional study is required to determine the frequency of ice storms and its effect on telephone services.
	Intense Wind/Tornado	Data not available	3	Remedial Action	Using professional judgment due to insufficient data, but with comments from Ouranos related to extreme wind and tornadoes, it is possible that greater vulnerability exists due to future climate changes. The City should review their emergency preparedness requirements on tornadoes. The City should also consider burying telephone lines to the greatest extent possible or having back-up wireless communication.
	Hail	Data not available	3	No Further Action	Climate change projections were not available related to this climate variable. Although additional data specific to hail is required, the vulnerability of telephone service due to a hail event is low. No further action is required.
Telemetry	Ice Storm	Data not available	3	Additional Study Required	Additional study is required to determine the frequency of ice storms and its effect on telemetry.
	Intense Wind/Tornado	Data not available	3	Remedial Action	Using professional judgment due to insufficient data, but with comments from Ouranos related to extreme wind and tornadoes, it is possible that greater vulnerability exists due to future climate changes. The City should review their emergency preparedness requirements on tornadoes. The City should also consider burying communication lines to the greatest extent possible or having back-up wireless communication.
	Hail	Data not available	3	No Further Action	Climate change projections were not available related to this climate variable. Although additional data specific to hail is required, the vulnerability of the telemetry equipment due to a hail event is low. No further action is required.

Table 5: Step 5: Recommendations (Relationships with priorities equal to or greater than 36)

Infrastructure Component	Climate Variable	Recommendations	Recommendation Comments
Personnel	Intense Wind/Tornado	Management Action	The City should review their emergency preparedness requirements on tornadoes relating to personnel.
Facilities / equipment	Floods/Ice Jamming/Ice Build-up	Management Action	The City should review the level of flood protection related to each facility and prepare an action plan in the case of flooding. In the case where infrastructure is highly vulnerable, remedial flood protection work works should be completed. Data was not available to determine if a greater vulnerability of these event s exists due to climate change.
	Ice Storm	Remedial Action	The City should review their emergency preparedness requirements on Ice Storms. In addition the City should review installing full standby power at the water treatment plant to reduce power vulnerability generally associated with ice storm events.
	Intense Wind/Tornado	Management Action	The City should review their emergency preparedness requirements on tornadoes relating to faculties and equipment.
Assiniboine River System	Floods/Ice Jamming/Ice Build-up	Management Action	The City should work with the Province of Manitoba to review flood related vulnerabilities related to the Assiniboine River and the Dam at this location. The City should review the Provinces policies related to managing these events.
Dam Structure	Floods/Ice Jamming/Ice Build-up	Management Action	The City should review the level of flood protection related to the dam and intake works and prepare an action plan in the case of flooding. In the case where infrastructure is highly vulnerable, remedial works should be completed. In the case of ice jamming (blinding off the intake), the City should prepare an action plan to remedy the blockage.
Intake Well / Pumps	Floods/Ice Jamming/Ice Build-up	Management Action	The City should review the level of flood protection related to the intake works and prepare an action plan in the case of flooding. In the case where infrastructure is highly vulnerable, remedial works should be completed. In the case of ice jamming (blinding off the intake), the City should prepare an action plan to remedy the blockage.
	Intense Rain	Management Action	The City should review the level of flood protection related to an intense rainfall event.
	Drought	Additional Study Required	The City should review drought related issued with the Province of Manitoba to establish water rights priorities in the event of drought on the Assiniboine River. The City should also request that the Province further study the Assiniboine River watershed for climate change effects.
Chemical Storage / Hazardous Materials	Floods/Ice Jamming/Ice Build-up	Management Action	The City should review the level of flood protection related to each the bulk chemical and other hazardous material and prepare an action plan in the case of flooding. In the case where infrastructure is highly vulnerable, remedial works should be completed. In the case of ice jamming (blinding off the intake), the City should prepare an action plan to remedy the blockage.
	Intense Wind/Tornado	Management Action	The City should review their emergency preparedness requirements on tornadoes relating to chemical storage and hazardous materials.
Pump stations (WTP/McKay)	Intense Wind/Tornado	Management Action	The City should review their emergency preparedness requirements on tornadoes relating to faculties and equipment.
Substations / Transformers	Ice Storm	Remedial Action	The City should review their emergency preparedness requirements on Ice Storms. In addition the City should review installing full standby power at the water treatment plant to reduce power vulnerability generally associated with ice storm events.
Transmission lines	Ice Storm	Remedial Action	The City should review their emergency preparedness requirements on Ice Storms. In addition the City should review installing full standby power at the water treatment plant to reduce power vulnerability generally associated with ice storm events. The City should also consider burying hydro lines to the greatest extent possible.
Vehicle	Intense Wind/Tornado	Management Action	The City should review their emergency preparedness requirements on tornadoes relating to faculties and equipment.
Maintenance facilities	Intense Wind/Tornado	Management Action	The City should review their emergency preparedness requirements on tornadoes relating to faculties and equipment.

0.4.2 Protocol Review Summary

This assessment constitutes a Pilot-application of a Draft Protocol for Assessment of Public Water Supply, Treatment and Distribution Infrastructure serving the City of Portage la Prairie. As the Study Team conducted the assessment, it documented issues and potential optimization opportunities for applying the Draft Protocol. These points of Protocol Review are summarized below for the consideration of the PIEVC Committee Members in their continued evolution of their Draft Protocol.

Step 1 Project Definition: The steps itemized in this phase of the Protocol were clearly detailed and were consistent with most typical data gathering efforts in defining the setting and related global project parameters. The Study Team does suggest that the general guidelines provided within Step 1 of the Draft Protocol be amended to include specific reference to typical categories of information that the assessor should gather as a starting point. It is recommended that an explicit list of such information be added for guidance to future users of the Protocol. Suggested information sources that could be appended to the Protocol's guidance in Step 1 include:

- P&ID (Process and Instrumentation) Drawings
- CAD Files
- Water Infrastructure Component Capacity and Performance Specifications where available for key components
- Operator Interviews
- Watershed Management Zone details (available in some jurisdictions, helpful in identifying watershed geographical limits, water supply management issues, regional demand/supply considerations, etc.)

Step 2 Data Gathering and Sufficiency: The steps in this phase of the Protocol were clearly defined and the suggested guidance was helpful to the assessors. In the application of the Draft Protocol in this assignment, the Study Team utilized Ouranos for development of the climatic projection estimates, which were calculated by Ouranos based upon historical meteorological parameters and regional climate models.

The Study Team suggests that if an entity such as Ouranos is relied upon for climate change trending information, the project schedule should allow for adequate time to prepare and review the results of the data request and preparation. In order to streamline the data supply by agencies like Ouranos, the Study Team recommends that the Protocol be modified to move the gathering of climate change data parameters and other change variables useful in performing quantitative analysis to a stage following the Qualitative Assessment (Step 3) stage of the Protocol. The Study Team believes that the Qualitative Assessment (Step 3) yields substantial understanding of the potential sensitivities and vulnerabilities of a given infrastructure system, allowing significant refinement in both the types of data being requested from Ouranos and the sets of data that need to be assembled in order to feed Ouranos' climate change projection models. Of additional consideration is the fact that the provision of the climate change projection data can be fairly costly, and

the structure of the protocol could require municipalities and other facility owners to allocate excessive funds to the climate change projection data request exercise. The City of Portage commented that they would reconsider spending these funds for future studies. The Study Team suggests that PIEVC consider the option of delaying climate change projection data requests until after the Qualitative Assessment (Step 3) is completed and the assessor is in possession of the results. This will provide increased understanding of a given facility's true sensitivities to climate change in terms of which climatic factors might be major factors in system vulnerability and which factors can be dismissed as minor. The effect of "triaging" the climatic change factors of importance could be benefits such as:

1. Reduced costs to the assessor due to savings realized through ordering only data simulations of significance to a given facility. Step 1 and 2 appear too early in the Protocol process to make this determination.

2. Reducing the overall data request load on agencies such as Ouranos through refinement of individual data requests. If potential end-users are warned that Ouranos data will be a governing factor in terms of workstream schedule (data turnaround is apparently at least 8 weeks), there may be efficiencies afforded if the majority of data requests made of Ouranos are pre-screened to allow for Ouranos production of essential climate change factors only.

In addition to the climatic change factor simulation data recommendations above, the Study Team also believes there is substantial benefit to the assessors if they undertake a mandatory site visit/ tour in conjunction with meetings with the owners and operators of a facility. These meetings were very fruitful for the Study Team and provide the assessors with an opportunity to obtain valued practical insight from the people who make the facility operational on a day-to-day basis. These personnel have strong site-specific knowledge of making their facilities operate smoothly and in satisfaction of their defined performance standards and goals through a wide range of conditions. Their expertise and history with a given facility provides the assessor with deep insight into some of the site-specific nuances of a particular plant or infrastructure.

Step 3 Qualitative Assessment: The Protocol provides good detail and background regarding the general framework of its Prioritization Methodologies, however, the Study Team believes there could be additional structure offered to the assessor in terms of conducting a stepwise risk assessment and itemizing the factors that should be considered in identifying and characterizing vulnerabilities and other risks. The Study Team recommends that PIEVC consider the addition of an accepted general risk assessment framework for integration into the Step 3 guidance. There are numerous examples of functional and practical qualitative risk assessment procedures that could be adapted for this purpose, including the American Water Works Association's (AWWA) Risk Assessment Methodology for Water Utilities or equivalents. Mention has also been made of confusion in interpretation of the Probability Scale Factor as discussed in Section 3.3.1 of the Protocol. Several Workshop participants interpreted this scale factor to represent the probability of a severe climatic event's occurrence; however the Protocol intends this value

to represent the probability of a climatic event EFFECT on a given component of infrastructure. The Protocol in its current form is not explicit on how it wishes the assessor to consider complex interactions such as cumulative effects and environmental effects of the scenarios leading to climatic change vulnerabilities. Cumulative effects could arise from multiple climatic severe events occurring simultaneously and or multiple cascading component failures occurring within a given event. The Study Team recommends considering the addition of specific guidance to assist the assessor in incorporating cumulative and environmental effects into their assessment. Participants in the workshop also indicated they would find it more functional in executing the Protocol's Step 3 if they were guided by the steps to group longer-duration climatic events such as drought, severe frost and groundwater together during the analysis.

Step 4: Quantitative Analysis: The Protocol calls for Quantitative Analysis of identified prioritized relationships above the level considered "insignificant" (Priority Value $\leq$12) and below a level considered "immediate action required" (Priority Value $\geq$36). For most facilities, the set of vulnerabilities residing in the range requiring further assessment through quantification is a smaller subset of the larger set of prioritized vulnerability relationships. When the Protocol is applied by individuals with sufficient design, operations and local setting knowledge, it can be argued that the additional precision garnered by quantification may not yield results whose value will justify the expense and time required to obtain the data required for the Quantitative Assessment. In the event of data being readily available, this concern would be less of an issue as the assessor could proceed with calculations if in possession of data necessary to conduct quantitative assessment. However, if that required data is not readily available, it could be argued that the effort required to generate or obtain the needed data would not provide significant additional understanding of a given vulnerability due to the fact that most of the required data will be predictive-based estimates on climate change projections. It may be argued that an accepted and peer-reviewed regional data set could be generated for major zones within Canada and these regional data sets could be generated periodically by an organization such as Ouranos. In this manner, costs and efforts required to obtain this data would be reduced significantly.

Step 5: Recommendations: The Protocol provides clear and practical instruction in terms of assisting the assessor in packaging their recommendations for further action. It is suggested that the Protocol be modified to include a specific built-in timeframe for facility operators and management to revisit the Recommendations and assess progress of implementation of any critical remedial efforts.

1.0 Introduction

The design of infrastructure systems and components are based upon conditions defined by historical climate data in addition to operation performance goals. Mounting evidence suggests that climate has changed, and will continue to change, creating situations where typical climate design ranges for a given location are no longer representative. Expanded climate ranges and increased frequency of extreme weather events have the potential to create vulnerability in the performance of engineered systems due to insufficient design capacity.

Engineers Canada, the business name of the Canadian Council of Professional Engineers, established the Public Infrastructure Engineering Vulnerability Committee (PIEVC) in order to oversee the planning and execution of a national engineering assessment of the vulnerability of Canadian Public Infrastructure to changing climatic conditions. The PIEVC has concluded that potential water resources infrastructure failure can have common impacts and that there are examples of water resources vulnerability across Canada. Consequently, PIEVC has identified water resources infrastructure vulnerability as one of four priority areas to be reviewed as part of the first National Engineering Assessment. The other areas include buildings, roads and associated structures e.g. bridges, and stormwater and wastewater systems.

This report constitutes the final documentation regarding the Pilot Project that constituted the second phase of a 3-phase project undertaken by PIEVC known as "Water Resources Infrastructure Assessment – Phase II Pilot Study". The complete project phasing is as follows:

- Phase 1 – Scoping Study, including development of a formal draft protocol for assessment of vulnerability of infrastructure in response to climate change events (completed prior to this assignment).
- Phase 2 – Pilot Study to conduct and engineering vulnerability assessment using the draft protocol.
- Phase 3 – Canada-wide National Engineering Vulnerability Assessment.

1.1 Phase II Pilot Study and Infrastructure Selection for Pilot Study

The Pilot Study phase of the Assessment project is the subject of this report. The Pilot Study is intended to evaluate and refine the parameters and boundary conditions for the National Engineering Assessment of the Vulnerability of Public Infrastructure to Climate Change by examining a water resources system.

The pilot study will:

a) Develop and refine methodologies or protocols, specifically for water resources infrastructure, designed to identify areas at risk from extreme climate events.

b) Examine the characteristics of water resources systems that make them more or less vulnerable to climate change. These can include, but are not limited to: age of the infrastructure, rate at which system is replaced or upgraded, system characteristics (e.g. combined sewer systems and separate storm sewer systems), geographical limitations on the system, other factors affecting sustainability of the current system (e.g. population growth), the variation in design standards across the country, and other factors that the Consultant identifies through this study.

c) Identify gaps in current and historical engineering standards that will need to be reviewed in depth to ensure that water resources infrastructure is designed, operated and maintained, while addressing the risk due to chronic and acute climate change factors.

d) Explore regional differences in climate change vulnerability, and provide an initial assessment of the chronic and acute climate change risk to water resources systems by region.

The municipalities considered for the pilot study were to be selected based on the literature review and analysis conducted in Phase I of this study and the most appropriate combination of the following factors:

- Weather/meteorological/climatic factors:
  - Located on a flood plain;
  - Exposed to storm surge;
  - Recently experienced extreme weather events where critical water resources infrastructure proved vulnerable;
  - Other weather/meteorological/climatic factors identified as high priority from the Consultant's assessment completed in Phase I
- Regional coverage:
  - Coastal;
  - Inland;
  - Northern;
  - Other factors that contribute to regional differences in the design, management, maintenance and operation of water resources systems as identified by the Consultant's assessment completed in Phase I.
- System design:
  - Average age of infrastructure;
  - Size of water resources system;
  - Rate of growth of the water resources system;
  - Other factors that contribute to system design differences as identified by a separate Consultant's assessment completed in Phase I.

The facility selected by PIEVC for this Pilot Study was the water resource infrastructure of the City of Portage la Prairie located in the Province of Manitoba. The Portage la Prairie water resource infrastructure served as a Pilot for assessing the applicability of the Protocol

developed in Phase 1. Phase 2 (this assignment) of the Assessment project involves understanding the Draft Protocol, applying the Draft Protocol to the Portage la Prairie infrastructure and assessing the applicability and effectiveness of the protocol in conducting assessments of vulnerability due to climate change.

2.0 Draft PIEVC Protocol for Climate Change Infrastructure Vulnerability Assessment

This section provides a brief overview of the Draft PIEVC Engineering Protocol for Climate Change Infrastructure Vulnerability Assessment (the Protocol). The Draft Protocol used for this study is provided in Appendix A in its entirety.

In May 2007, the PIEVC released a Draft PIEVC Engineering Protocol for Climate Change Infrastructure Vulnerability Assessment. This Engineering Protocol was furnished as a working draft for application in specific Pilot Studies. The Protocol is a document that a practitioner can use as a step-by-step guide to assess the impact of climate change on infrastructure. Assessing infrastructure's vulnerability to climate change is intended to develop information that infrastructure owners and operators can use to effectively incorporate climate change adaptation into the design, development, and management of infrastructure.

Many infrastructure components or systems are designed using climate data. Designs based on historical data may not be appropriate as the local climate changes due to global climate change. These factors may create vulnerabilities in the infrastructure due to the fact that the existing infrastructure may not have the resiliency required to accommodate the "real climate extremes" brought about by climate change effects. Furthermore, new infrastructure may not be designed with sufficient load and adaptive capacity to function at required performance levels under extreme events driven by climate change. Figure 9 demonstrates the interaction of climate and infrastructure. The Protocol provides the process to identify and assess the portion of the diagram where climate elements interact with the infrastructure attributes. Not all infrastructure or climate data that is available is required to assess the infrastructure. The initial stages of the Protocol help the practitioner to define the study boundaries and sift through the data to determine the relevant infrastructure and climate data.

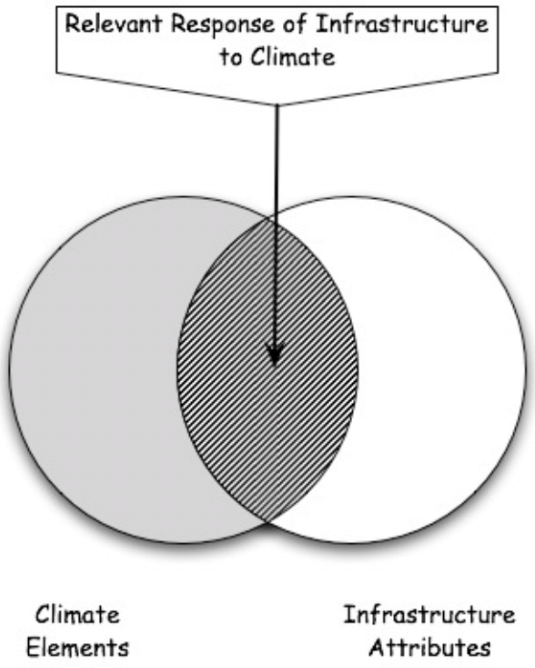


Figure 9: Venn diagram of climate and infrastructure interaction

To assess infrastructure's vulnerability to climate change, the practitioner must consider:

- The infrastructure;
- The climate (historical, recent, and projected); and
- Historical and projected response of the infrastructure to the climate.

The Protocol is organized into a 5-step process. Figure 10 illustrates flow of the Protocol's 5 steps.

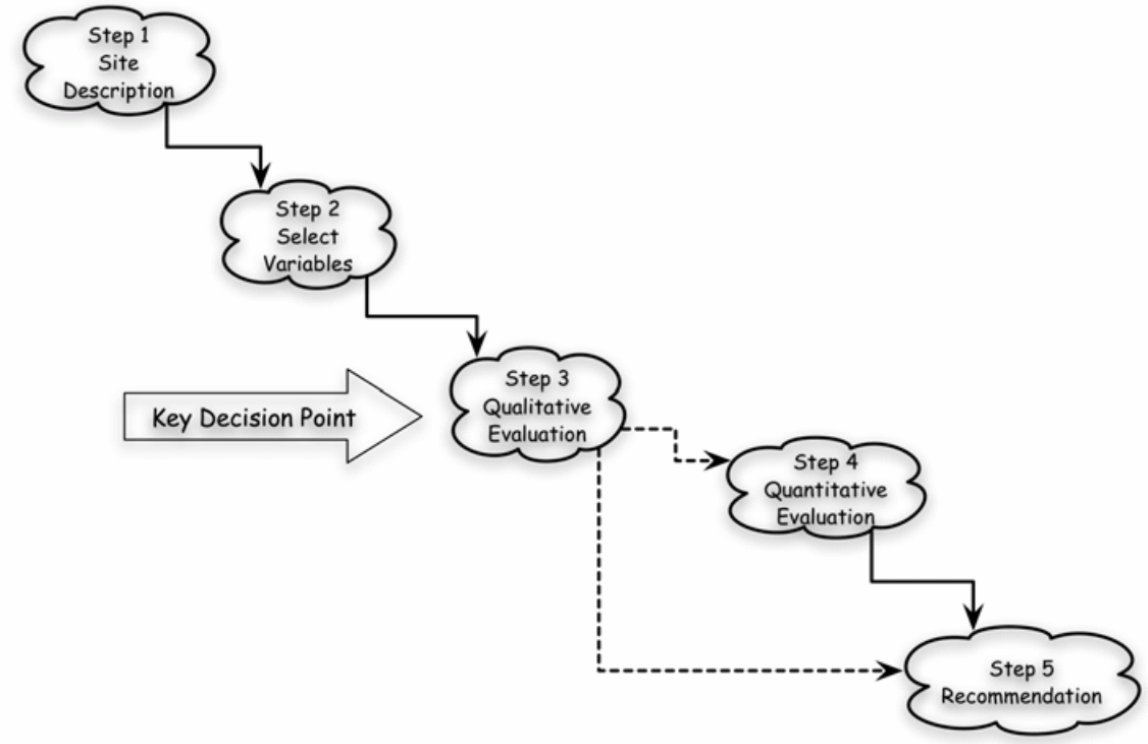


Figure 10: Flow diagram of Draft Protocol's 5 steps

The 5 steps of the protocol are:

- Step 1: Project Definition;
- Step 2: Data Gathering and Sufficiency;
- Step 3: Qualitative Evaluation;
- Step 4: Quantitative Evaluation; and
- Step 5: Recommendations.

2.1 Step 1: Project Definition

In the first step of the Protocol the practitioner defines the global project parameters. This includes identifying

- The infrastructure;
- The location;
- Historical climate;
- The load on the infrastructure;
- The age of the infrastructure;
- Other relevant factors; and
- Identification of major documents and information sources.

Brief descriptions or lists of these items are made and information sources are identified. Step 1 allows the practitioner to narrow their focus to allow for efficient data acquisition in Step 2.

Data sufficiency is assessed at the end of Step 1. This includes identifying assumptions proposed for the assessment and their rational. In places where insufficient information is available, this is documented and a process to develop the data is identified. If the data cannot be developed, the data gap is identified as a finding is Step 5: Recommendations.

The process flow chart of Step 1 is shown in Figure 11.

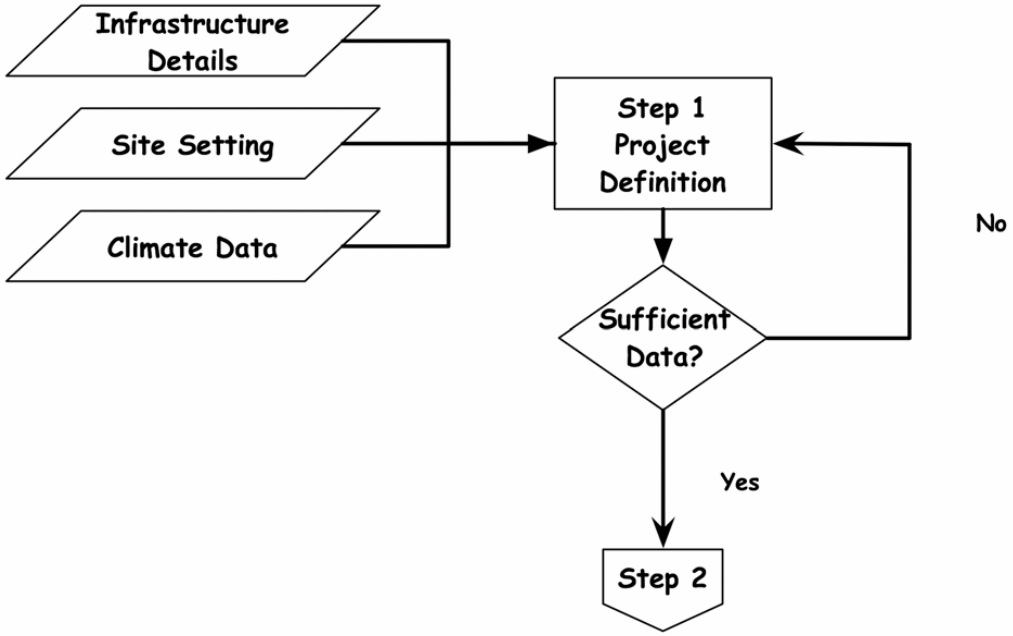


Figure 11: Step 1 flow chart

2.2 Step 2: Data Gathering and Sufficiency

In Step 2 the practitioner provides further definition regarding the infrastructure and the particular climate effects that are considered in the evaluation. The data is acquired from the sources identified in Step 1 and assessed for sufficiency. Data may be identified as insufficient if:

- It is of poor quality;
- Has high levels of uncertainty; or
- There is a lack of data altogether.

Identifying an area where data is required allows the practitioner to reevaluate sources of data or methods to infill the data gap. Activities to provide data where data is insufficient or missing are undertaken in Step 2. Where data cannot be developed, the data gap is identified in Step 5.

The process flow chart of Step 2 is shown in Figure 12.

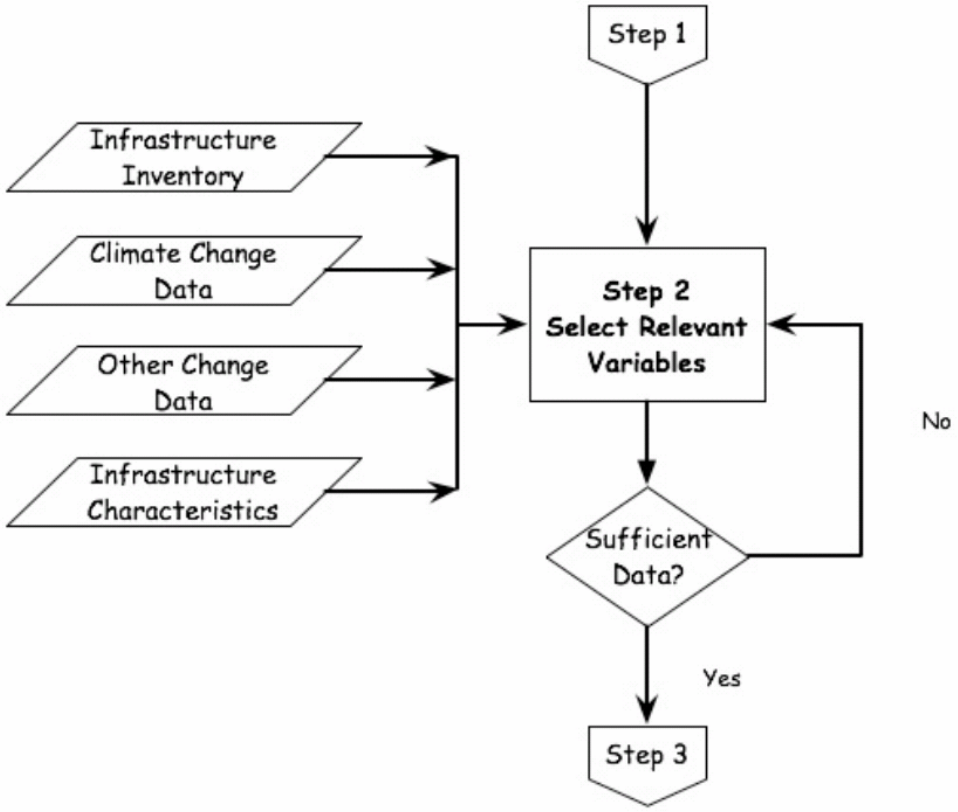


Figure 12: Step 2 flow chart

The infrastructure components, climate factors, time frame, geography, and jurisdictional considerations are described in sufficient detail to proceed to Step 3. Infrastructure inventory lists each component of the infrastructure systems to be assessed and includes details such as:

- Physical elements of the infrastructure;
- Number of physical elements;
- Location;
- Other relevant engineering/technical considerations;
- Material of construction;
- Age;
- Importance within the region;
- Physical condition;
- Operations and maintenance practices;
- Performance measures used to operate/manage the infrastructure;
- Insurance considerations;
- Policies;
- Guidelines;
- Regulations; and
- Legal considerations.

The climate baseline and climate change assumptions are stated and assessed for relevancy to the infrastructure. Information can be gathered from the following sources:

- The National Building Code of Canada, Appendix C, Climate Information;
- Intensity – Duration – Frequency (IDF) curves for precipitation as rain;
- Flood plain mapping;
- Regionally specific climatic modeling;
- Heat units (i.e. degree-days) (i.e. for agriculture, heating, ventilation and air conditioning (HVAC), energy use, etc.);
- Water elevation; and
- Other sources as appropriate.

The Protocol requires the practitioner to exercise professional judgment based on experience and training. Step 2 is an interdisciplinary process requiring engineering, climatological, operations, maintenance, and management expertise. The Protocol requires the practitioner to ensure that the right combination of expertise is represented either on the assessment team or through consultations with other professionals during the execution of the assessment.

2.3 Step 3: Qualitative Evaluation

In Step 3 the Protocol requires the practitioner to identify the relationships between the infrastructure, the climate and other factors that could lead to vulnerability. These include:

- Specific infrastructure components;
- Specific climate change parameter values;
- Specific performance goals; and
- Other change parameter values.

The process flow chart for Step 3 is shown in Figure 13.

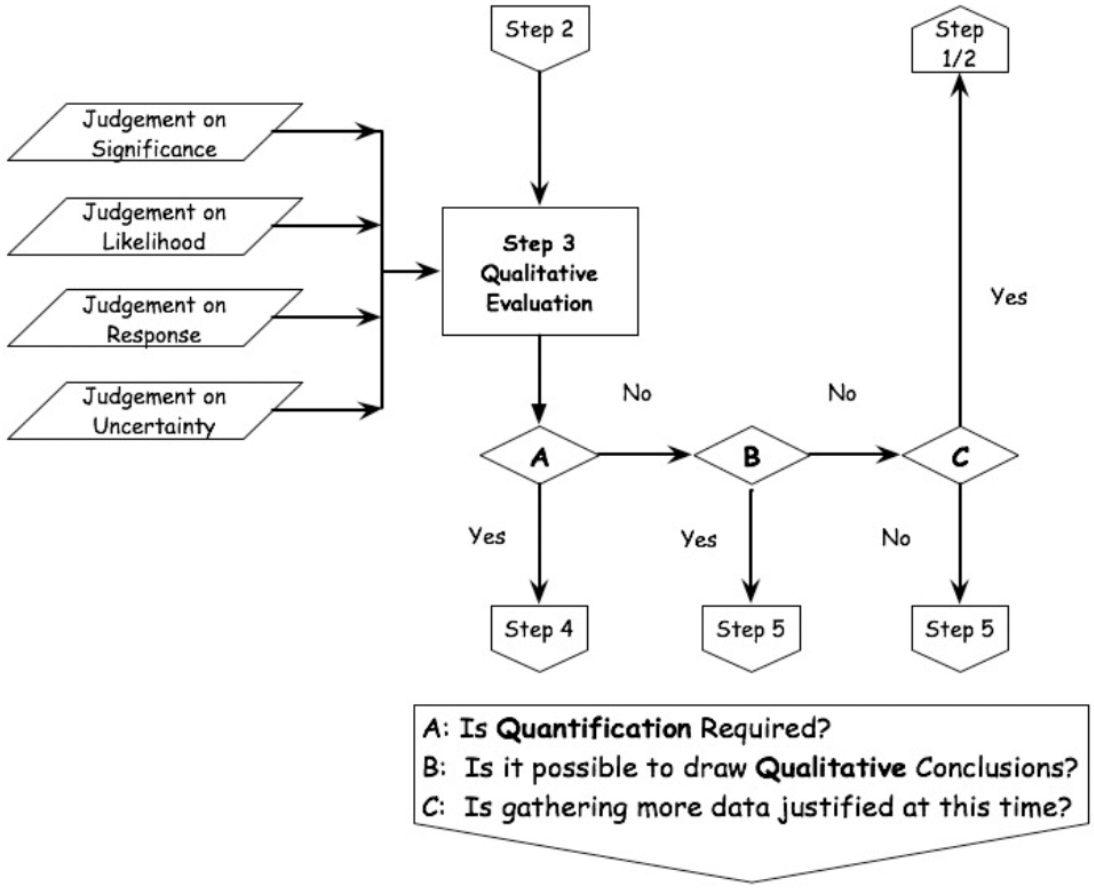


Figure 13: Step 3 flow chart

To prioritize infrastructure-climate relationships the practitioner assigns scale factors both to the probability of climate effects, and the severity of performance outcome for the infrastructure. Both scale factors use a system based on a scale of 1 to 7. The practitioner may select an alternative prioritization methodology. If a different prioritization methodology is selected, the practitioner is required to substantiate and document their choice of alternative methodology in the project report.

The probability scale factors to be applied to the climate effects are shown in Table 6. There are three available methods to select the probability scale factors. The practitioner is free to choose any of the three methods. Documentation of which method was chosen should be provided and the same method should be applied for the entire assessment. The severity scale factors to be assigned to the infrastructure performance response to the climate effects are shown in Table 7. Two methods are available to select severity scale factors. Again, the practitioner is free to choose between the methods, but consistency in applying that method and documentation of the chosen method are required. The performance response of the infrastructure for each of the infrastructure components are based on anticipated effects of climate and other effects, such as:

- Structural integrity;
- Serviceability;
- Functionality;
- Operations and maintenance;
- Emergency response risks;
- Insurance considerations;
- Policies and procedures;
- Economics;
- Public health and safety; and
- Environmental effects.

Table 6: Probability Scale Factors (S_c)

Scale	Probability		
	Method A	**Method B**	**Method C**
0	negligible or not applicable	<0.1 % <0.1 / 20	negligible or not applicable
1	improbable / highly unlikely	5 % 1 / 20	improbable 1:1 000 000
2	remote	20 % 4 / 20	remote 1:100 000
3	occasional	35 % 7 / 20	occasional 1:10 000
4	moderate / possible	50 % 10 / 20	moderate 1:1 000
5	often	65 % 13 / 20	probable 1:100
6	probable	80 % 16 / 20	frequent 1:10
7	certain / highly probable	>95 % >19 / 20	continuous 1:1

a) Choose Method A, Method B or Method C to select the priority.
b) Record in project documentation the Method that was used.
c) Use the same Method for all probability prioritization in the evaluation.

Table 7: Severity Scale Factors (S_R)

Scale	Magnitude	Severity of Consequences and Effects
	Method D	**Method E**
0	no effect	negligible or not applicable
1	measurable 0.0125	very low / unlikely / rare / measurable change
2	minor 0.025	low / seldom / marginal / change in serviceability
3	moderate 0.050	occasional loss of some capability
4	major 0.100	moderate loss of some capacity
5	serious 0.200	likely regular / loss of capacity and loss of some function
6	hazardous 0.400	major / likely / critical / loss of function
7	catastrophic 0.800	extreme/ frequent/ continuous / loss of asset

d) Choose Method D or Method E to select the priority.
e) Record in project documentation the Method that was used.
f) Use the same Method for all magnitude prioritization in the evaluation.

The scale factors are applied to the relationships using the engineering judgment of the study team, and rely on strong multidisciplinary content within the study team. After an infrastructure-climate relationship has had a probability scale factor and severity scale factor applied, the priority of that relationship can be determined as

$$P_C = S_C \times S_R$$

where: P_C is the priority of the climate effect,
S_C is the probability scale factor for the climate effect, and
S_R is the severity scale factor for the performance response.

Any relationship with a priority of 12 or less, or with either scale factor having a value of 2 or less, is discarded from further analysis. A relationship that is determined to have a priority greater than 36 represents a vulnerability that requires attention and is reported directly in Step 5 with appropriate recommendations to address the identified vulnerability. Relationships with priority between 12 and 36 represent potential vulnerabilities. These infrastructure-climate relationships require further numerical analysis in Step 4.

The same prioritization methodology can be repeated for other effects on the infrastructure identified in Step 2. The priority of the relationship of the infrastructure and other effects would be calculated as:

$$P_O = S_O \times S_R,$$

where: P_O is the priority of the other effect,
S_O is the probability scale factor for the other effect, and
S_R is the severity scale factor for the performance response.

A review of data sufficiency is required throughout the process of Step 3. If data gaps are present, the practitioner can return to Step 1 or Step 2 to either obtain the require data, or identify the data gap as a finding in Step 5.

This is a key decision point in the Protocol. The practitioner is required to determine:

- Which relationships should be quantified;
- Where data refinement is required; and
- Initial recommendations about:
  - New research;
  - Immediate remedial action; or
  - Non-vulnerable infrastructure.

2.4 Step 4: Quantitative Evaluation

In Step 4 the practitioner determines the relationship between the performance response loads placed on the infrastructure and its capacity. Vulnerability exists when infrastructure has insufficient capacity to withstand the effects placed on it. Resiliency exists when the infrastructure has sufficient capacity to withstand increasing climate change effects.

The process flow chart of Step 4 is shown in Figure 14.

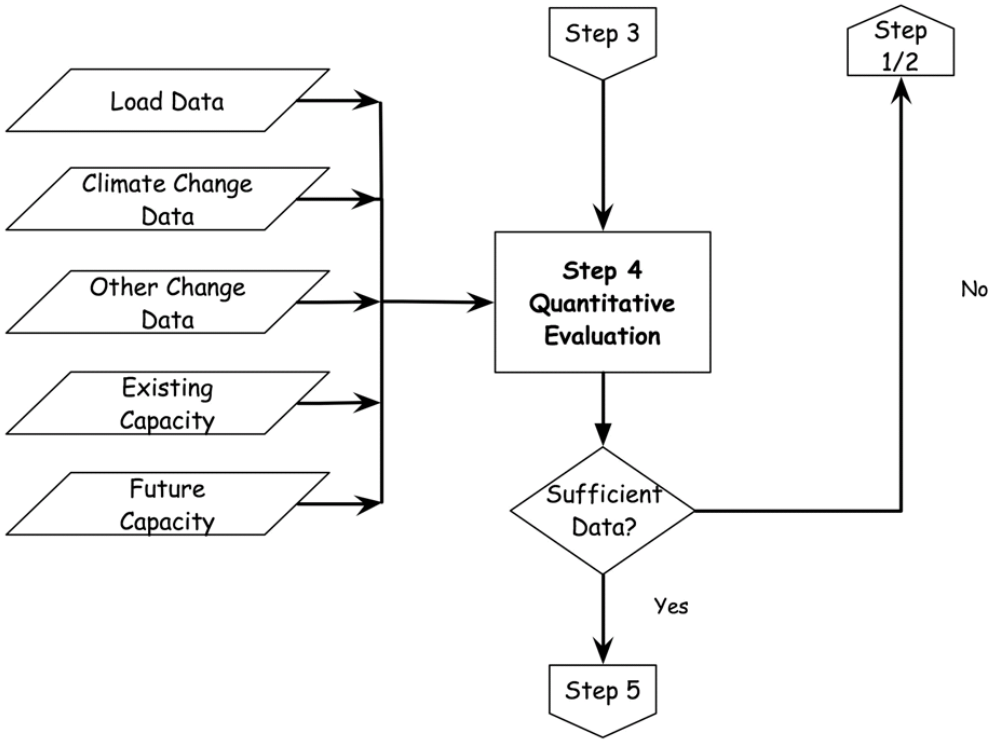


Figure 14: Step 4 flow chart

Each of the infrastructure-climate relationships identified for quantitative analysis will be assessed based on the loads added to the infrastructure from climate change and the capacity of the infrastructure component. Analysis includes calculating the total load on the infrastructure, L_T, as a summation of:

- The existing load;
- Load resulting from climate change; and
- Loads resulting from other changes, such as socioeconomic factors,

using the formula:

$$L_T = L_E + L_C + L_O,$$

where: L_T is the total load on the infrastructure;
L_E is the existing load on the infrastructure;
L_C is the load on the infrastructure resulting from climate change; and
L_O is the load on the infrastructure resulting from other changes.

The total capacity, C_T, of the infrastructure will also be calculated as a summation of:

- The existing capacity;
- Changes in capacity as the infrastructure ages; and
- Additional capacity that may be added,

by using the formula,

$$C_T = C_E + C_M + C_A,$$

where: C_T is the total capacity of the infrastructure;
C_E is the existing capacity of the infrastructure;
C_M is the maturing capacity of the infrastructure; and
C_A is the other additional capacity of the infrastructure of the study time frame.

The values of total load and total capacity are used to calculate three important indices; the vulnerability ratio V_R, the adaptive capacity ratio A_R, and the capacity deficit C_D, as follows:

$$V_R = \frac{L_T}{C_T},$$

$$A_R = \frac{C_T}{L_T}, \text{ and}$$

$$C_D = L_T - C_T.$$

These three indices determine which infrastructure components are vulnerable, and how much capacity must be added to address the vulnerability. Vulnerabilities occur when V_R is greater than 1 and A_R is less than 1. The capacity deficit is the required amount of capacity that must be added to the infrastructure to mitigate the vulnerability.

Data sufficiency is assessed to determine where there is insufficient information available to complete a particular portion of the assessment. If an area of insufficient data is found, the practitioner is directed to Step 1 or Step 2 to either obtain the require data, or identify the data gap as a finding in Step 5.

2.5 Step 5: Recommendations

In Step 5 the practitioner summarizes the limitations and findings of the study. The process flow chart of Step 5 is shown in Figure 15.

Relevant limitations of the evaluation are declared and commented on, included in these limitations are:

- The availability of infrastructure information and sources;
- Available climate change information and sources;
- Available other change information and sources;
- The use of generic data or specific examples to represent populations;
- Uncertainty and related concepts; and
- Any other limitations, if they exist.

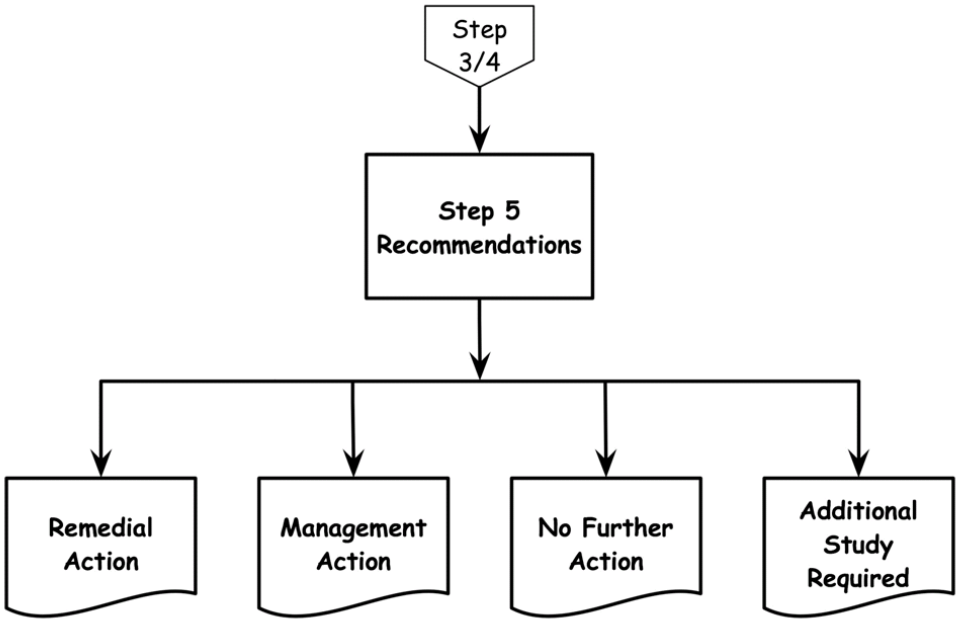


Figure 15: Step 5 flow chart

The specific recommendations for the activities completed in Steps 1 through 4, include:

- Infrastructure components that have been assessed to be vulnerable;
- Identification of appropriate initial recommendations regarding possible:
  - Remedial engineering actions; or
  - Management actions;
- Infrastructure components that have been assessed to have adaptive capacity and require no further action at this time;
- Reporting of data gaps and uncertainty requiring additional work or studies;
- Identification of screened, prioritized, yet to be evaluated combinations that require further action;
- Reporting of the other conclusions, trends, insights, and limitations; and
- Prioritized recommendations (where appropriate).

3.0 Portage la Prairie Water Resources Infrastructure Assessment

3.1 Step 1: Project Definition

In the first step of the Protocol the global project parameters were defined. This included identifying the infrastructure, climate factors of interest, time frame, geography, and jurisdictional considerations. Brief descriptions or lists of these items were made and information sources are identified.

3.1.1 Identify the Infrastructure

The potable water supply system for Portage la Prairie was assessed for vulnerabilities to climate change. All infrastructure components contributing to the delivery of potable water to the customers were included; from the source of raw water, to the treatment and distribution of potable water to customers.

Portage la Prairie is a city with a population of slightly greater than 13,000. It is located approximately 100 km west of Winnipeg as seen in Figure 16. Water users in Portage la Prairie include residential, commercial and industrial users. The potato processing industry has two large processing plants that demand high volumes of water, using more than 50% of the total water produced at the plant.

Portage la Prairie's source of raw water is the Assiniboine River. Major water control infrastructures that exist on the river are included in the study. The water treatment plant building envelope and the treatment processes inside the treatment plant are also assessed. Pumping stations and the distribution system that transports water to the consumers are also included in the assessment.

Figure 16: Location of Portage la Prairie

Sources of information for infrastructure data include:

- Past engineering reports:
  - Feasibility Study for City of Portage la Prairie Water Treatment Plant Upgrading, Cochrane Engineering Ltd., November 1999.
  - City of Portage la Prairie Water Treatment Plant Upgrading Functional Design, Cochrane Engineering Ltd., February 2001.
  - City of Portage la Prairie Water Network Analysis Final Report, Reid Crowther & Partners Ltd., March 1999.
- Engineering Drawings:
  - Portage la Prairie Water Treatment Plant Upgrading – Contract 1, Cochrane Engineering Ltd., September 2001.
  - Portage la Prairie Water Treatment Plant Upgrading – Contract 2, Cochrane Engineering Ltd., May 2004.
- Past Engineering Experience:
  - GENIVAR (formerly Cochrane Engineering Ltd.) designed recent major upgrades for the Portage la Prairie water treatment plant.
- Personal Communication with managers and operators:
  - Communication with managers and operators of the water resource infrastructure provide details regarding the infrastructure, as well as insight into the relationships the infrastructure has with the local climate.

3.1.2 Identify Climate Factors of Interest

Portage la Prairie's geographic location has a wide range of climate conditions. In the winter months temperatures can drop below –40°C and in the summer months rise to close to 40°C, a range of 80°C. Convective storms can produce 100 mm of rain in a single event, while a winter blizzard can reduce visibility to nearly zero and accumulate more than 30 cm of snow.

A list of climate factors that may contribute to infrastructure vulnerability was created. The climate factors to be considered in the assessment were chosen from Appendix B of the Draft Protocol. Some climate factors not included in the Draft Protocol, but determined to be important to the infrastructure, were added to the list. The list of climate elements and associated changes in those factors to be considered are detailed in Table 8.

Ouranos Consortium located in Montreal, Quebec, was designated by the PIEVC as the provider of climate data for the study. Ouranos is a group of scientists who specialize in regional climate change and adaptation to climate change. Ouranos generates data by downscaling the Canadian global climate model (CGCM3.1) using the Canadian regional climate model (CRCM 4.1.1).

The variables in Table 8 comprised the data request to Ouranos in Step 2 of the Protocol. From early communication with Ouranos, it was evident that the data request would not be able to be fully satisfied as they are not able to produce some of the variables with their models. Also, if historical weather station data cannot be provided to Ouranos from Environment Canada, Ouranos cannot calculate the future values of variables without this baseline information.

Literature providing information on current trends and changes of weather variables due to global climate change was researched in Step 2.

Another valuable source of climate information was incident reports provided by the City of Portage la Prairie. Incident reports from logbooks of the operators provide useful information of past infrastructure/climate relationships that have caused serviceability problems due to extreme climate events. Examples of incidents due to climate may be power outages, local flooding around the water treatment plant, ice jams, water main breaks, etc. The availability of such reports for assessments may vary from assessment to assessment based on the availability and accessibility of the information. Portage la Prairie staff reported that retrieving the information was difficult and time consuming.

Table 8: Climate Effects and Potential Change Factors

Climate Elements	Potential Change Factors
Temperature	• Rate of change • Mean values • Extremes – High summer – Low winter
Precipitation as Rain	• Frequency (One-Day, Short Duration Less than 24 hours, Multi-Day) • Total annual/seasonal precipitation and rain • Intensity of rain events (One-Day, Short Duration Less than 24 hours) • Proportion of annual and seasonal precipitation as rainfall • Drought conditions
Precipitation as Snow	• Frequency • Total annual/seasonal precipitation and snow • Magnitude of snow events • Frequency and intensity of rapid snow melt events • Rain on snow events
Wind Speed	• Mean values (one hour mean winds) – Monthly – Seasonal – Annual • Extremes/gusts • Thunderstorm winds • Changes in hurricane and/or tornado event frequency/intensity
Ice	• River or lake ice build up
Hail	• Frequency of events • Magnitude of events
Frost	• Freeze thaw cycles • Change in frost season
Ice Accretion	• Change in frequency/intensity of ice storm events • Ice build up on infrastructure elements
Other	• Degree days • Albedo • Streamflow on the Assiniboine River – Extremes

3.1.3 Identify the Time Frame

The design life of the individual infrastructure components vary greatly. Generally water treatment plants have significant upgrades every 20 to 30 years as populations grow and new treatment technology becomes available. Larger infrastructure such as the Shellmouth Dam and control structures for the Portage Diversion have a much longer life expectancy, 100 years or more is not unreasonable to expect for those components to remain in service. The piping in the distribution system also has a long serviceable life. Random breaks may cause pieces to fail before their life expectancy is achieved, but under normal conditions piping could be expected to exceed 80 years of service.

The timeframe for climate change data is in the same order as the life expectancy of the infrastructure components. The climate change data supplied by Ouranos was presented at three time horizons; 2020 (2011-2040), 2050 (2041-2070) and 2080 (2071-2100).

3.1.4 Identify the Geography

The City of Portage la Prairie is located in the Assiniboine River Drainage Basin. The Assiniboine River basin extends into large areas of Saskatchewan and North Dakota and covers a large portion of southwest Manitoba. The Assiniboine Rivers continues west after Portage la Prairie and ends at a confluence with the Red River in Winnipeg.

The wide range of flow variability has led to the construction of water control infrastructure on the River. The two most significant of these are the Shellmouth Dam located near Russell, MB, and the Portage Diversion which diverts flood water from near Portage la Prairie to Lake Manitoba through a 29 km long channel.

Information on the Assiniboine River system can be found from the following sources:

- Manitoba Water Stewardship:
  - Assiniboine River Water Management Model Documentation (Draft), Manitoba Water Stewardship, February 2007.
  - Inter-relationship of the Assiniboine Delta Aquifer and the Assiniboine River, 56th Canadian Geotechnical Conference, Bob Harrison and Duane Kelln, October 2003.

3.1.5 Identify Jurisdictional Considerations

The following government agencies have jurisdictional control over the infrastructure included in the assessment:

- City of Portage la Prairie:
  - Water treatment plant operation and maintenance
  - Distribution system operation and maintenance
- Province of Manitoba:

  - Operation of Shellmouth Dam
  - Operation of the Portage Diversion
  - Water rights licensing
  - Water quality standards
  - Facility licensing
- Government of Canada:
  - Water quality standards
- Rural Municipality of Portage la Prairie:
  - Plant located in Rural Municipality of Portage la Prairie

3.1.6 Assess Data Sufficiency

3.1.6.1 Infrastructure Data

There was no indication that any data gaps were present in the infrastructure data. Many sources of information were identified, some of which are in GENIVAR's possession, some of which had to be requested from Portage la Prairie.

3.1.6.2 Climate Data

One data gap was identified early in the process. Historical streamflow data was available for the Assiniboine River, but data was not directly available for climate change projections. Ouranos stated that in the past, for other clients they have developed a climate change data set tailor made for the client's hydrological model. The client is then able to develop stream flow data using their own hydrological model. Developing hydrological model that would allow the Study Team to generate streamflow under climate change conditions is beyond the scope of this study. Other climate change variables, such precipitation and temperature, were used to make judgments on future streamflow availability.

3.1.7 Protocol Review and Assessment

The following are the Study Team's comments regarding the Draft Protocol and general project observations:

- The Kickoff meeting on June 13th, 2007 was a successful start to the project. The different members of the working group were introduced along with their specific interest in the project.

- Due to the expected turnaround time for Ouranos data, for the data to be provided within the timeframe of this study it became clear that our initial data request needed to be fully formulated as there would be no time to refine this climatic data request later on with Ouranos. This made formulating the climate data request very important to getting a start to the project. Forming a list of climate data needs overshadowed the Engagement Plan in the early stages of the project. It was

decided to begin Step 1 immediately rather than wait for Engagement Plan approval.

- A workshop was proposed in the GENIVAR/TetrES proposal. The Workshop was recommended to occur between Step 3/Step 4 of the Protocol. The idea of a Workshop was a favorable idea in the working group discussions.

- It was decided to meet regularly by teleconference. This helped the Client track progress made by GENIVAR/TetrES and allowed for group discussion for issues that arose over the course of the project.

- Another early communication issue was the distribution of information with the Study Team and stakeholders. It was suggested at the beginning of the project that information be transferred though Portage la Prairie to the working group. It was soon realized that this created a bottleneck in information flow and information pertinent to the working group would be distributed directly to the entire working group.

- Streamflow data under climate change conditions was identified as a climate variable that Ouranos would not be able to provide. The climate models do not include detailed hydrological processes such as streamflow. As an alternative, Ouranos is able to tailor a data set into input for an existing hydrologic model if their clients have a model. Developing or modifying a hydrologic model was beyond the scope of this study, however, this may be an important service Ouranos can provide to other water resource assessments.

3.2 Step 2: Data Gathering and Sufficiency

In Step 2 further definition regarding the infrastructure and the particular climate effects that are considered in the evaluation are provided. Where available, the data specified in Step 1 was acquired from the sources identified. The data was assessed for sufficiency and comments regarding data gaps and insufficient data are provided.

3.2.1 State Infrastructure Components

The general components of the infrastructure affecting or directly involved in supplying potable water in Portage la Prairie were outlined in Step 1. A breakdown of the major systems into individual components is provided in Table 9.

Table 9: Infrastructure Inventory

System	Components
Administration/Operations	Personnel
	Facilities/Equipment (WTP)
	Records
Source Water	Shellmouth Dam / Reservoir
	Assiniboine River System
	Portage Diversion
	Control Dam Structure
	Intake Well / Pumps
Treatment	Pretreatment (Actiflo)
	Softening/Clarification
	Filtration (Granular/GAC)
	Disinfection (Ozone/Chlorine)
	Storage
	Chemical Feed Systems
	Chemical Storage / Hazardous Materials
	Valves / pipelines (on site)
Distribution	Pump stations (WTP/McKay)
	Pipelines, valves
	Pipe Materials
Electric power	Substations / Transformers
	Transmission lines
	Standby generators
Transportation	Vehicles
	Maintenance facilities
	Supplies
	Roadway infrastructure
Communications	Telephone
	Two-way radio
	Telemetry

3.2.1.1 Administration / Operations

The administration and operations were broken into three subcomponents; personnel, the facility and equipment of the water treatment plant, and records related to the infrastructure.

The personnel include the City of Portage la Prairie employees responsible for the management, operation and maintenance of the infrastructure. This includes the:

- Director of operations,
- Engineering manager,
- Water treatment plant facility manager,
- Distribution systems manager,
- Water treatment plant operations staff,
- Maintenance field staff, and
- Support services.

Figure 17: Control center for the water treatment plant

The ability of the personnel to safely and effectively operate the infrastructure during severe weather is critical to the operation of the infrastructure as a complete system.

The facility and equipment subcategory includes the water treatment plant substructure and superstructure, as in the foundation, roof, building envelope, etc., and also all process related equipment housed in the water treatment plant facility.

Records refer to all hard copy of electronically stored documents related to the operations of the infrastructure, including but not limited to:

- Plans and specifications,

- Operation and maintenance manuals,
- Best management practices and procedures,
- Water quality records,
- Water flow records, and
- Maintenance schedules.

3.2.1.2 Source Water

The Assiniboine River is Portage la Prairie's raw water source. Assiniboine River has a large watershed extending throughout southwestern Manitoba and into southeastern Saskatchewan and northern North Dakota. The river system has large annual and seasonal variations in flow. Due to this fact, large water control infrastructure is present on the River to modify flows during floods and drought, namely the Shellmouth Dam and Reservoir, and the Portage Diversion.

A summary of water quality parameters of raw Assiniboine River water, along with post treatment water quality objectives are provided in Table 10.

Table 10: Assiniboine River water quality characteristics

Parameter	Data Collected	Average Value +/- Standard Deviation	GCDWQ (2007)
Arsenic (mg/L)	Jan 86 - Jul 98	0.01 +/- 0.017	0.01 (IMAC)
Boron (mg/L)	Jan 86 - Sep 95	0.2 +/- 0.05	5 (IMAC)
Cadmium (mg/L)	Jan 86 - Apr 98	0.002 +/- 0.0003	0.005 (IMAC)
Copper (mg/L)	Jan 86 - July 98	0.01 +/- 0.011	1 (AO)
Chloride (mg/L)	Jan 86 - Apr 97	31 +/- 13.8	250 (AO)
Colour (mg/L)	Jan 86 - Mar 99	20 +/- 13	5 (AO)
Hardness (mg/L) as $CaC0_3$ Calcium (mg/L) Magnesium (mg/L)	May 96 - Mar 99 Jan 86 - Mar 99 Jan 86 - Mar 99	350 +/- 56.2 82 +/-56.2 43 +/- 27.1	150* - -
Iron (mg/L)	Jan 86 - Jun 98	1.9 +/- 6.24	0.3 (AO)
Lead (mg/L)	Jan 86 - Jul 98	0.003 +/- 0.0034	0.01 (AO)
Manganese (mg/L)	Jan 86 - Sep 95	0.3 +/- 1.11	0.05 (AO)
Nitrate (mg/L)	Jan 86 - Dec 91	0.3 +/- 0.30	45 (MAC)
pH	Jan 86 - Mar 99	8.2 +/- 0.30	6.5 – 8.5(AO)
Sodium (mg/L)	Jan 86 - Jun 98	65 +/- 25.9	200 (AO)
Sulphate (mg/L)	Jan 86 - Apr 97	208 +/- 65.0	500 (AO)
TDS (mg/L)	Jan 86 - Mar 99	594 +/- 148.2	500 (AO)
Total Coliform (MPN/100 mL)	May 73 - Dec 77	474 +/- 550.2	0 (MAC)
TOC (mg/L)	Jan 86 - Mar 99	12 +/- 6.6	5*
Turbidity (NTU)	May 96 - Mar 99	60 +/- 72.2 (spikes over 2000)	0.3
Zinc (mg/L)	Jan 86 - Sept 95	0.02 +/- 0.003	5 (IMAC)

The raw water intake from the river is located in the control dam structure seen in Figure 18. A detailed cross section of the intake structure is shown in Figure 19. Three 100 HP vertical turbine pumps withdraw the water from the well in the control dam and propel it to the treatment plant via two raw water mains.

Figure 18: Location of infrastructure surrounding the treatment plant

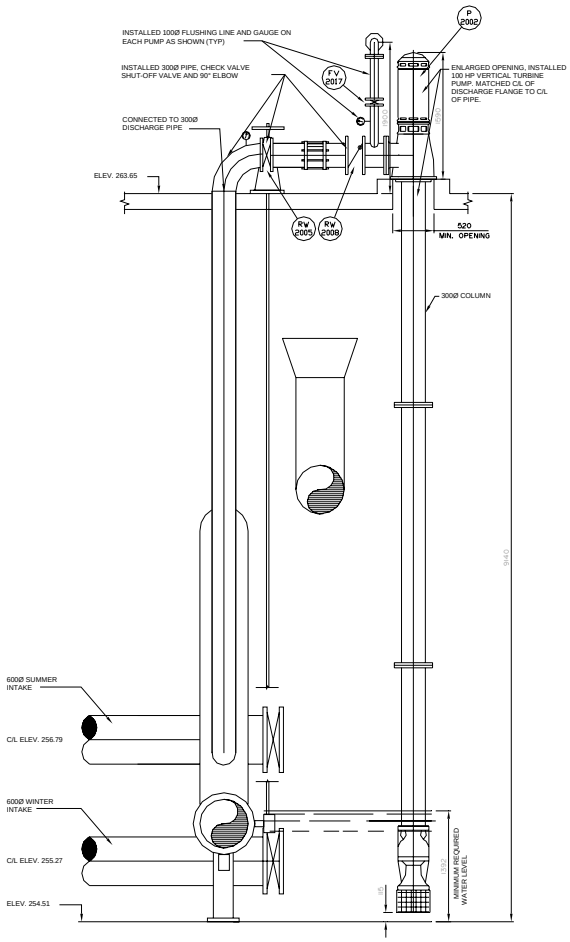


Figure 19: Intake well design

3.2.1.3 Treatment

The Portage la Prairie water treatment process flow is shown in Figure 22. The main treatment processes assessed in the study are as follows:

Pretreatment
The first treatment process is a ballasted flocculation process called Actiflo. This pre-clarification step provides a buffer to remove seasonal spikes in turbidity before clarification. Pre-clarification also removes colour, organics and algae. A separate building houses the pre-clarification process.

Softening/Clarification
After pre-clarification the water goes through clarification and softening. The plant has three clarifiers, two 11 ML/day units and one 20 ML/day units. Lime is added to the water as the softening agent. One of the clarifiers is shown in Figure 20. After softening, the water is recarbonated to adjust the pH.

Figure 20: Water treatment plant clarifier

Filtration
After clarification the water is filtered. The first filters are dual media gravity filters utilizing anthracite and crushed quartz sand. The water is then filtered using granular activated carbon (GAC). The GAC filters use adsorption to remove organics to improve taste and colour.

Disinfection (Ozone/Chlorine)
The water is disinfected using ozone contactors and chlorine. The chlorine provides residual protection while the water is in storage and the distribution system.

Storage
Water is stored on site in an 8 ML (megalitre) storage facility at the water treatment plant site.

Chemical Feed Systems
The chemical feed systems include those systems responsible for batching and pumping treatment chemicals to the appropriate treatment process. Chemicals include:

- Lime,
- Polymer,
- Chlorine,
- Potassium permanganate,

- Caustic soda,
- Ferric chloride, and
- Ozone gas.

Chemical Storage / Hazardous Materials

Bulk storage of chemicals occurs at the water treatment plant site. A large silo, prominently visible on the main treatment building, is used for the storage of lime. The pretreatment building is also used for chemical storage, as seen in Figure 21.

Figure 21: Chemical storage in pretreatment building

Valves / pipelines (on site)

This includes the two raw water pipes from the intake to the pretreatment building, pipes to the main treatment building and storage facility, and all other piping and valves on the water treatment plant site.

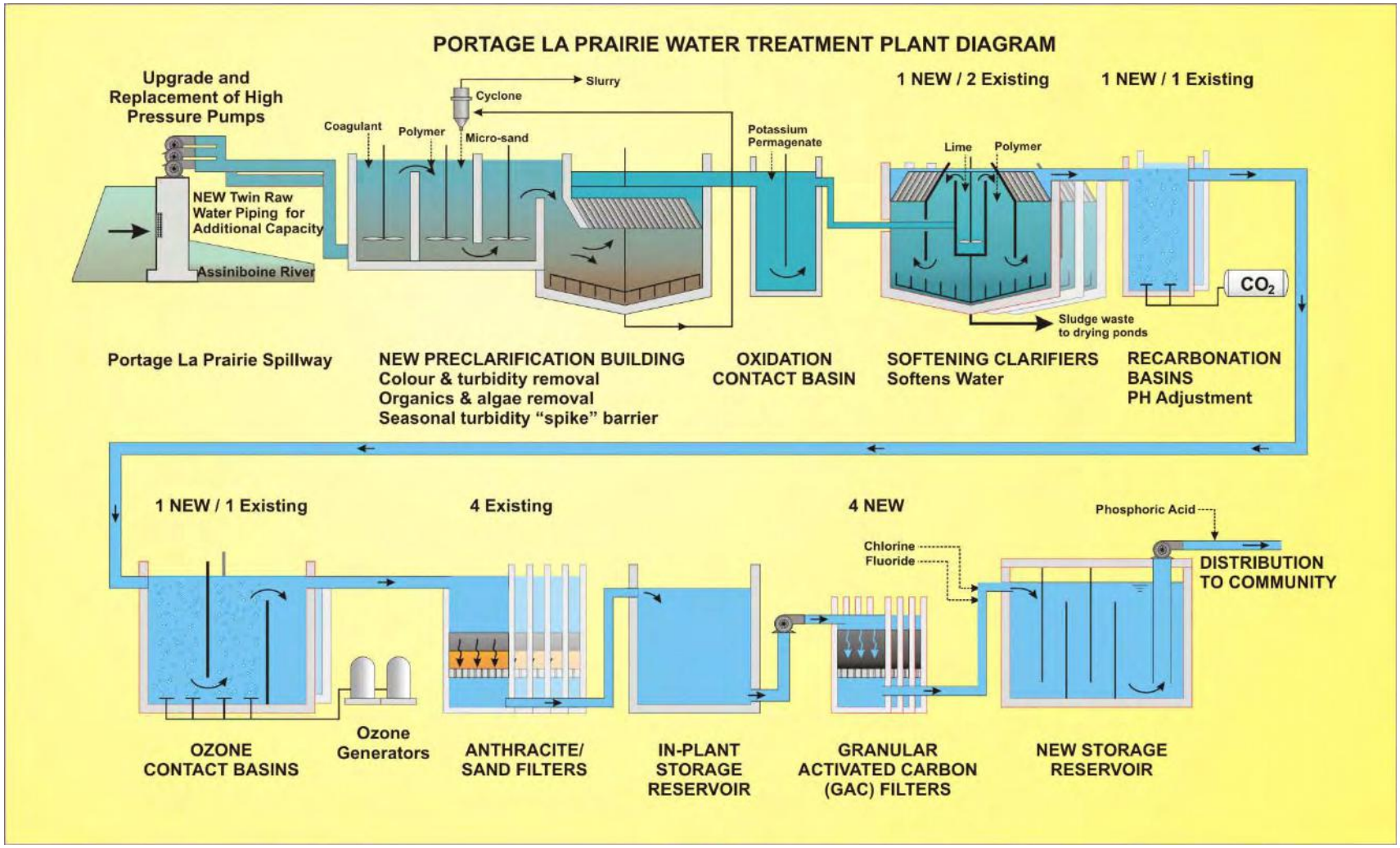


Figure 22: Portage la Prairie water treatment plant flow schematic

3.2.1.4 Distribution

The components of the distribution system assessed include pump stations, pipelines and values, and pipe materials.

There are two main pump stations in the distribution system. One is at the water treatment plant and the other is the McKay Pumphouse. The pump station at the water treatment plant contains four Peerless hi-lift pumps rated at 5,455 litres per minute at 36.57 m of head. The McKay pumphouse supplies flow and pressure to most of the distribution system and is located at the corner of McKay Avenue and Fifteenth St. N.W. The pumphouse contains eight vertical centrifugal pumps, each with a capacity of 2,839 litres per minute at 45.7 m of head.

The distribution system contains pipes of a wide variety of size, material and age. Installation of pipes that are still in service date back to 1905. Ages range from over 100 years to pipes recently installed.

Figure 23: Water Main Construction

Since different flow rates are required through different parts of the distribution system, there are a wide variety in the sizes of pipes to maintain flow and pressure. Sizes of pipe range from as small as 100 mm, to feeder lines as large as 600 mm. There are approximately 92 km of pipe in the system. The approximate length of each size of pipe is shown in Table 11.

Table 11: Size distribution of pipes in distribution system

Size (mm)	Length (km)
100	5.0
150	58.6
200	10.2
250	3.5
300	6.6
350	2.3
400	0.6
450	2.9
600	2.2

The materials the pipes are made of include cast iron, ductile iron and PVC. Pipes installed prior to 1978 and generally cast iron, pipes installed between 1978 and 1987 are ductile iron, and pipes installed after 1987 are PVC. Pipe material was considered as a separate infrastructure component in the analysis of infrastructure-climate relationships as different materials respond differently to climate factors such as frost penetration and changes in the ground water table.

3.2.1.5 Electric Power

The electrical power assessment focused on the Manitoba Hydro power grid providing power to the water treatment plant and pumpstations and the standby generators that service the plant during power outages.

The power utility was broken into subcategories as substations and transformers, and power lines. Power lines are underground on the water treatment plant site, however other parts of the grid servicing the plant are above ground lines exposed to the climate elements. The intake pumps are serviced from a separate power supply than the water treatment plant.

When a power outage occurs, three separate standby generators are required to keep the plant fully functional. The pump station at the water treatment plant has a permanent diesel powered standby generator. The intake structure has enough standby generation capacity to maintain 50% of the flow capacity of the pumps by operating one of the three intake pumps. The water treatment plant and intake each have power receptacles which a portable standby generator can be plugged into. A standby generator is able to keep these components operational. One potential vulnerability to the power supply of the treatment

plant may be created due to the fact that the City of Portage la Prairie owns only one standby generator. This generator is stored and used at the Portage la Prairie wastewater treatment plant. If the single standby generator was used for water treatment purposes, it could only be used to generate power for the intake pumps, or the treatment plant, but not both concurrently.

3.2.1.6 Transportation

The transportation related to the operation and maintenance of the infrastructure refers to:

- Vehicles:
  - Personal vehicles used by employees;
  - City owed and operated vehicles; and
  - Heavy equipment such as excavators or snowplows.
- Maintenance facilities, the maintenance yard is used for:
  - Storage of vehicles and heavy equipment; and
  - Repair and maintenance of vehicles and heavy equipment.
- Supplies:
  - This subcomponent refers to the ability of delivery personnel to provide equipment, parts, and chemicals to the treatment plant or others as necessary.

3.2.1.7 Communications

Communications were assessed as the methods that personnel communicate, and also electronic information transferred between sensors and computers. These systems include landlines, two-way radio, and telemetry.

3.2.2 State Climate Baseline

The study team provided Ouranos with the list of climate variables stated in Table 8 in Section 3.1.2 for the geographical area shown in Figure 24. The data request was submitted to Ouranos on July 5th, 2007, and the final report was received from Ouranos September 12th, 2007. Ouranos compiled a list of weather station variables that met selection criteria such as:

- Minimum data series length of 20 years;
- Less than 10% missing data; and
- A final year beginning no earlier than 1995.

Their search resulted in 13 weather stations in the geographical region used to calculate temperature indices, 12 to calculate precipitation indices and 10 stations to calculate wind indices. Only 3 stations met the required criteria for the “snow on the ground” and “rain on snow events”. The complete data request form can be seen in Appendix C, the report received from Ouranos can be viewed in Appendix D.

Ouranos included means and indexes of historical station data in their report. This historical data provides most of the baseline conditions for the study. Significant amounts of baseline information were also researched and gathered from literature specific to the Canadian Prairies, particularly for historical extreme event occurrence.

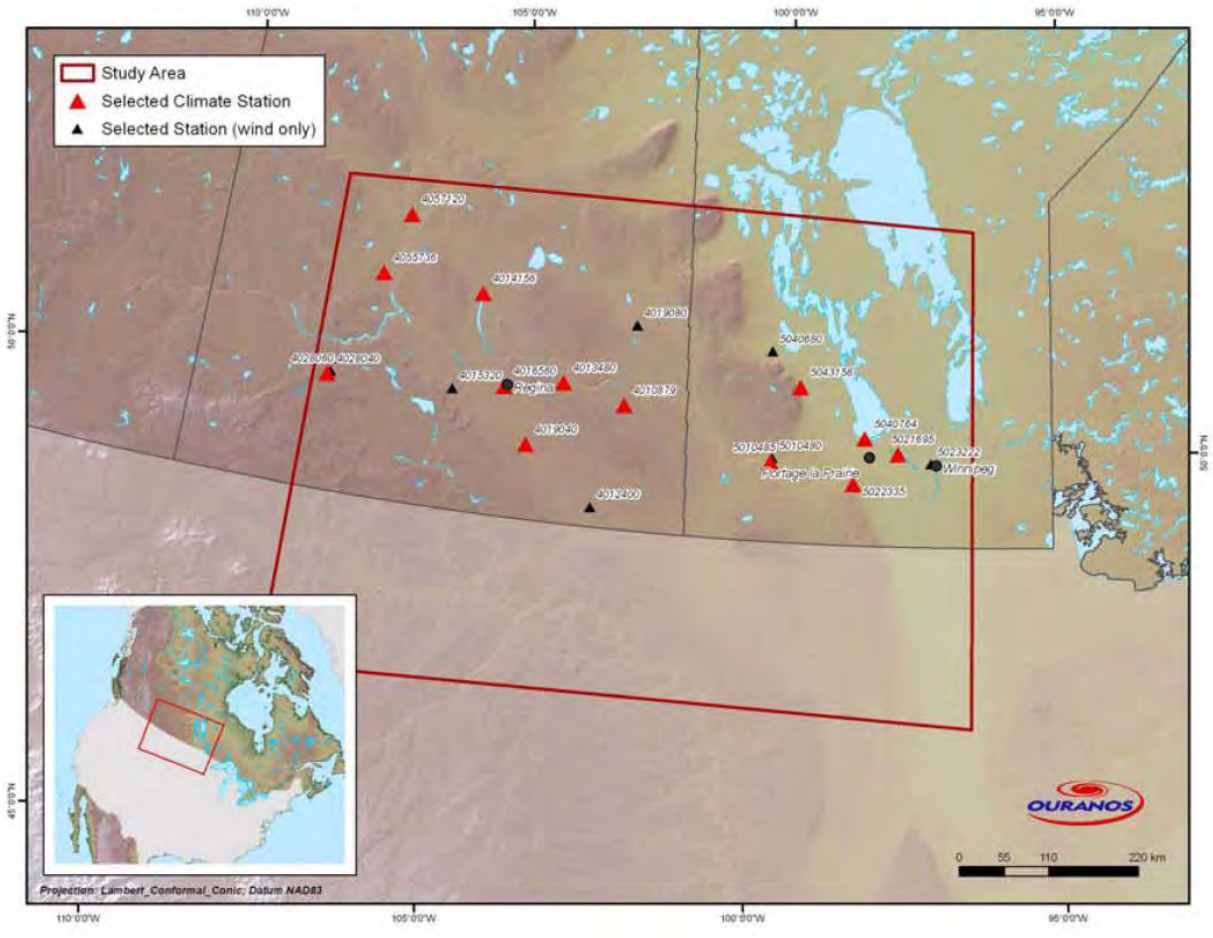


Figure 24: Geographical area of climate data request

3.2.2.1 Temperature

The baseline conditions for temperature indices can be viewed in Table 12. Monthly means of maximum and minimum temperature are provided, as well as the average in the annual maximum and minimum temperatures.

Table 12: Temperature baseline conditions

Month	Temperature Index (°C)			
	Monthly AVG TMAX	Monthly AVG TMIN	Average Annual MAX	Average Annual MIN
Jan	-11.156	-21.788	35.17	-37.75
Feb	-7.6304	-18.597		
Mar	-0.9664	-11.76		
Apr	10.081	-2.447		
May	18.06	4.0999		
Jun	22.545	9.529		
Jul	25.583	11.972		
Aug	24.826	10.555		
Sep	18.545	5.1376		
Oct	10.954	-1.1785		
Nov	-0.1839	-9.7971		
Dec	-7.843	-17.874		

3.2.2.2 Precipitation

The baseline condition information for precipitation can be seen in Table 13 through to Table 16.

Table 13: Precipitation event frequency baseline

Cutoff (mm)	Observed Frequency of Events		
	6 Hour Rainfall Frequency	1 Day Rainfall Frequency	1 Day Snowfall Frequency
5	0.0107	0.0507	0.0171
10	0.0043	0.0251	0.005
20	0.0009	0.0086	0.0007

Table 14: Maximum precipitation baseline

Duration (days)	Observed Maximum Rainfall (mm)	Observed Maximum Snowfall (mm)
1	40.8	15.326
2	49.5	18.869
5	60.8	22.638

Table 15: Annual and seasonal precipitation accumulation baseline

Period	Observed Rainfall (mm)	Observed Snowfall (mm)
Annual	324	112.04
DJF	1.37	55.077
MAM	67.6	31.76
JJA	194	0.0379
SON	59.9	24.145

Table 16: Dry spell/wet spell baseline

	Observed (days)
Avg MAX Dryspell	45.167
Avg MAX Wetspell	8.3333

3.2.2.3 Wind

The baseline condition for wind speeds can be viewed in Table 17.

Table 17: Wind speed baseline

Month	Observed (m/s)	Annual Max 6 h (m/s)
Jan	5.11	16.21
Feb	5.05	
Mar	5.06	
Apr	5.26	
May	5.32	
Jun	4.87	
Jul	4.31	
Aug	4.34	
Sep	4.88	
Oct	5.10	
Nov	5.00	
Dec	5.11	

3.2.2.4 Extreme Climate Events

The following is an identification of recent (the last 25 years) extreme weather events for Manitoba in which infrastructure proved vulnerable. Information was compiled from the Canadian Disaster Database (accessed at; http://publicsafety.gc.ca/res/em/cdd/search-en.asp), and Environment Canada Summer Severe Weather (accessed at; http://www.pnr-rpn.ec.gc.ca/air/summersevere/ae00s04.en.html). The data suggest that flooding was the

most frequent extreme event in Manitoba, though violent summer storms were of similar frequency. Flooding was related to the spring thaw and to summer storm events. Hail, and tornadoes were also associated with summer storms.

Floods:

- June 2, 2005. Western Manitoba. 100 to 175 mm rain
- July 21, 2004. The Pas, Manitoba.
- June 11, 2002. Southeast Manitoba. 240 mm rain
- April, 2001. Southern Manitoba. Spring thaw
- July 7-14, 2000. Southern Manitoba.
- April, 1999. Melita, Manitoba. Spring thaw
- May, 1997. Southern Manitoba. Spring thaw
- April/May,1996. Southern Manitoba. Spring thaw
- April, 1995. Southwest Manitoba. Spring thaw
- July 25-Aug 14, 1993. Winnipeg. Rain
- July 4, 1993. Swan River, Manitoba. Rain
- April 1, 1988. Duck Mountain/Swan River. Spring thaw, rain
- April-Jun, 1986. Icelandic and Fisher Rivers. Spring thaw.
- April-May, 1984. Manitoba

Storms:

- June 22/23, 2007. Tornadoes, hail, thunderstorm, Southwest Manitoba
- September 5, 1996. Thunderstorm, Southern Manitoba
- July 16, 1996. Hailstorm Winnipeg, Manitoba
- July 30, 1995. Southern Manitoba
- August 27, 1994. Hailstorm Southern Manitoba
- August 1, 1994. Hailstorm Southwest Manitoba
- May 18, 1994. Southern Manitoba
- June 24, 1992. Tornadoes, hail, Southern Manitoba
- July 6, 1987. Tornado. Winnipeg
- November 7, 1986. Snowstorm. Winnipeg
- April 27/28, 1984. Snow, freezing rain, wind. Central and Western Manitoba
- March 6, 1983. Freezing rain. Southern Manitoba

Severe cold snaps:

- Summer 1992. Prairie Provinces
- Dec/Jan 1990. Prairie Provinces
- Jan. 30 1989. Prairie Provinces

Drought:

- 1992. Prairie Provinces
- 1991. Prairie Provinces
- 1990. Prairie Provinces

- 1989. Prairie Provinces
- 1988. Prairie Provinces
- 1986. Prairie Provinces
- 1985. Prairie Provinces
- 1984. Prairie Provinces
- 1983. Prairie Provinces

Heat wave:

- June-July, 1988. Prairie Provinces

3.2.2.5 Ice (ice build-up, ice accretion, freezing rain)

Limited baseline data is available for these variables. Ouranos provided the average frost season length for the region as 144.55 days. No data was gathered that described the ice buildup or ice accretion variables. Freezing rain baseline data was also not available. Freezing rain events have not caused significant damages in the Portage la Prairie area.

3.2.3 State the Climate Change Assumptions

For future climate projections the Study Team relied upon the data received from Ouranos. The climate data report received from Ouranos can be seen in its entirety in Appendix D.

Ouranos generated the change in climate variables in the using the Canadian Regional Climate model (CRCM4). The model produced data for the local weather stations by downscaling the Canadian Global Climate Model (CGCM3.1). Details on why the use of the regional model to downscale the global model is necessary can be found in Ouranos' report. Ouranos provided the results from two runs of the IPCC SRES A2 greenhouse gas emission scenario, which assumes a higher greenhouse gas concentration by 2100 than most other scenarios.

Ouranos provided a cautionary note that only evaluating one emission scenario, from one GCM, downscaled using one method, does not provide the full spectrum of plausible changes in the future climate. A more robust analysis would include more emission scenarios, climate data from more than one GCM, and downscaled using a variety of methods. However, at this time, producing an ensemble of future climate change scenarios would be very costly and require a prohibitive amount of time to create. As the science of climate change forecasting improves, future evaluation may be able to employ a broader range of climate change data sets.

The results of Ouranos' report regarding changes from the baseline conditions are provided below for each of the two models runs; CRCM 4.1.1 ACU and CRCM 4.1.1 ADC.

3.2.2.1 Temperature

The assumed changes for temperature variables are shown in Table 18 through to Table 20. The data shows that the monthly average of daily maximum temperature will rise throughout the year, slightly more in the winter months. The change in the monthly average daily minimum temperature follows a similar, but slightly exaggerated trend as the maximum temperatures. The average annual maximum temperature and minimum temperature are expected to increase as well. Overall, both minimum and maximum temperatures are shown to be increasing in the future.

Table 18: Future change of monthly average maximum temperature

Month	Observed (°C)	Future Change ACU			Future Change ADC		
		2020 (°C)	2050 (°C)	2080 (°C)	2020 (°C)	2050 (°C)	2080 (°C)
Jan	-11.156	2.0282	3.6279	6.1173	2.2511	4.4165	5.9024
Feb	-7.6304	2.6772	4.2763	3.7222	2.7863	6.183	5.6297
Mar	-0.9664	0.9218	2.5799	3.6791	1.4705	1.5081	3.7007
Apr	10.081	0.4718	1.3975	2.7914	1.1059	1.0233	2.0281
May	18.06	1.4710	1.9014	4.4477	1.2636	1.9455	3.3918
Jun	22.545	1.7319	2.752	4.9652	1.8911	3.1178	4.3727
Jul	25.583	1.2351	2.9952	5.8823	3.4389	4.0202	6.3037
Aug	24.826	1.6656	3.1717	6.5294	2.7831	3.5029	6.2694
Sep	18.545	1.3506	3.8852	6.5807	2.4305	4.5885	5.7393
Oct	10.954	2.7449	3.9799	4.9277	2.5246	3.5081	5.4935
Nov	-0.1839	1.2742	1.4226	2.7500	1.5708	2.5262	2.5338
Dec	-7.8430	2.6064	3.8736	6.2622	2.9507	5.3276	6.4125

Table 19: Future change of monthly average minimum temperature

Month	Observed (°C)	Future Change ACU			Future Change ADC		
		2020 (°C)	2050 (°C)	2080 (°C)	2020 (°C)	2050 (°C)	2080 (°C)
Jan	-21.788	2.6803	4.6735	7.9629	2.852	5.4639	7.8183
Feb	-18.597	3.7665	6.1589	6.0426	3.5452	8.0437	7.7993
Mar	-11.76	2.1673	4.2426	5.2302	1.9474	2.494	5.1549
Apr	-2.447	0.5378	1.4238	2.4868	0.8081	1.2085	1.7999
May	4.0999	1.3001	1.9052	4.0649	0.8596	2.6956	4.0478
Jun	9.529	1.4609	2.6097	4.3117	1.4897	2.9326	4.5011
Jul	11.972	1.7551	3.5123	5.1745	1.9465	3.0554	4.9929
Aug	10.555	1.7231	3.5248	5.1353	1.7508	3.0128	4.9328
Sep	5.1376	1.7019	3.2395	5.3304	1.7884	3.9093	5.4061
Oct	-1.1785	1.9561	3.0146	3.8304	1.8262	2.4226	4.6505
Nov	-9.7971	1.6557	2.1577	3.7011	1.7923	2.9434	3.4871
Dec	-17.874	3.1769	5.0014	8.1784	3.5802	6.4542	8.2749

Table 20: Future change in annual maximum and minimum temperature

	Observed (°C)	Future Change ACU			Future Change ADC		
		2020 (°C)	2050 (°C)	2080 (°C)	2020 (°C)	2050 (°C)	2080 (°C)
Annual Max	35.175	1.5886	3.2532	6.003	2.805	3.7331	6.0165
Annual Min	-37.746	3.4118	4.8178	7.74	2.8926	6.6777	9.3112

3.2.2.2 Precipitation

The assumed changes in precipitation variables, both precipitation as rain and as snow, are shown in Table 21 through to Table 29.

The data shows that accumulations during rainfall events of durations 6 hours to 5 days will increase. Overall, the region will have more rainfall and less snowfall. The decrease in snowfall can be attributed to the shortened frost season. The net result of the changes in season precipitation is that the area will receive slightly more precipitation that it currently does. The change in the average maximum wet and dry spells is insignificant.

The precipitation data results are more variable than that of the temperature results. Contradictions are present in places between the model runs, Table 27 for example has the ACU model run showing increased frequencies of snowfall event frequencies, while the ADU model run show a decrease in the same variables.

Table 21: Future change in 6 hour rainfall accumulation frequencies

Cutoff (mm)	Observed (frequency)	Future Change ACU			Future Change ADC		
		2020 (ratio)	2050 (ratio)	2020 (ratio)	2050 (ratio)	2020 (ratio)	2050 (ratio)
5	0.0107	1.10	1.22	1.18	0.94	1.18	1.26
10	0.0043	1.19	1.42	1.32	0.94	1.36	1.50
20	0.0009	1.35	1.91	1.64	0.77	1.70	1.86

Table 22: Future change in one day rainfall frequencies

Cutoff (mm)	Observed (frequency)	Future Change ACU			Future Change ADC		
		2020 (ratio)	2050 (ratio)	2020 (ratio)	2050 (ratio)	2020 (ratio)	2050 (ratio)
5	0.0507	1.05	1.12	1.07	0.92	1.07	1.12
10	0.0251	1.10	1.21	1.15	0.96	1.19	1.25
20	0.0086	1.19	1.42	1.36	1.06	1.46	1.57

Table 23: Future change in average maximum rainfall

Period (days)	Observed (mm)	Future Change ACU			Future Change ADC		
		2020 (ratio)	2050 (ratio)	2020 (ratio)	2050 (ratio)	2020 (ratio)	2050 (ratio)
1	40.8	1.05	1.12	1.10	0.98	1.13	1.16
2	49.5	1.05	1.11	1.10	0.98	1.13	1.16
5	60.8	1.05	1.10	1.08	0.97	1.10	1.14

Table 24: Future change in average total rainfall

Total Rain	Observed (mm)	Future Change ACU			Future Change ADC		
		2020 (ratio)	2050 (ratio)	2020 (ratio)	2050 (ratio)	2020 (ratio)	2050 (ratio)
Annual	324	1.05	1.11	1.08	0.97	1.09	1.13
DJF	1.37	2.09	3.9	5.94	2.01	3.92	5.78
MAM	67.6	1.01	1.1	1.26	1.04	1.34	1.35
JJA	194	1.03	1.08	0.94	0.89	0.92	0.92
SON	59.9	1.16	1.16	1.23	1.22	1.32	1.56

Table 25: Future change in average maximum wet spell/dry spell length

	Observed (days)	Future Change ACU			Future Change ADC		
		2020 (days)	2050 (days)	2080 (days)	2020 (days)	2050 (days)	2080 (days)
Avg MAX Dryspell	45.167	-0.5	0.31	0.9	0.43	1.38	0.4
Avg MAX Wetspell	8.3333	-0.2	-0.9	-0.2	-0.5	-1.4	-1.2

Table 26: Future change in one day snow fall accumulation frequency

SWE cutoff (mm)	Observed (frequency)	Future Change ACU			Future Change ADC		
		2020 (ratio)	2050 (ratio)	2020 (ratio)	2050 (ratio)	2020 (ratio)	2050 (ratio)
5	0.0171	1.01	1.07	1.17	1.01	1.11	0.95
10	0.005	0.92	1.07	1.33	0.88	1.04	0.84
20	0.0007	0.95	1.44	1.29	0.74	1.11	0.62

Table 27: Future change in average maximum snowfall accumulation

Period (days)	Observed (mm)	Future Change ACU			Future Change ADC		
		2020 (ratio)	2050 (ratio)	2020 (ratio)	2050 (ratio)	2020 (ratio)	2050 (ratio)
1	15.326	0.99	1.08	1.11	0.96	1.04	0.93
2	18.869	1	1.08	1.15	0.98	1.04	0.92
5	22.638	1.02	1.08	1.15	0.98	1.04	0.96

Table 28: Future change in average total snow accumulation

Total SNOWFALL (SWE) (mm)	Observed (mm)	Future Change ACU			Future Change ADC		
		2020 (ratio)	2050 (ratio)	2080 (ratio)	2020 (ratio)	2050 (ratio)	2080 (ratio)
Annual	112.04	0.96	0.92	0.92	0.93	0.96	0.85
DJF	55.08	1.00	1.05	1.17	1.01	1.16	1.06
MAM	31.76	1.05	0.77	0.67	1.00	0.99	0.74
JJA	0.038	0.16	0.03	0.00	0.21	0.09	0.06
SON	24.15	0.8	0.83	0.74	0.75	0.64	0.60

Table 29: Future change in rain on snow events

Rainfall Cutoff (mm)	Observed (frequency)	Future Change ACU			Future Change ADC		
		2020 (ratio)	2050 (ratio)	2020 (ratio)	2050 (ratio)	2020 (ratio)	2050 (ratio)
1	0.0028	0.9	0.93	0.97	0.97	1.01	1.026
5	0.0005	0.84	0.89	0.97	0.95	1.12	1.081
10	9E-05	0.87	0.92	1.05	1.00	1.32	1.17

3.2.2.3 Wind

The assumed changes in wind are shown in Table 30 and Table 31. The data shows that the mean monthly wind speeds are expected to remain close to those of the current climate. The model results for the maximum annual 6 hour gust are inconsistent between the model runs and show no conclusive trend.

Table 30: Future change in monthly average wind (6 hour)

Month	Observed (m/s)	Future Change ACU			Future Change ADC		
		2020 (ratio)	2050 (ratio)	2020 (ratio)	2050 (ratio)	2020 (ratio)	2050 (ratio)
Jan	5.1078	0.9751	1.008	1.071	1.0113	1.0304	1.032
Feb	5.0487	0.9981	1.0053	0.9771	1.0422	1.0819	0.9837
Mar	5.0567	1.0498	1.0687	1.0457	1.0575	1.0344	1.0253
Apr	5.2598	0.9714	1.0266	1.0731	1.0012	1.0412	1.0048
May	5.3178	1.0311	1.0051	1.0521	1.0438	1.0674	1.0529
Jun	4.8709	1.0045	1.0368	1.0104	1.0069	1.0351	1.0136
Jul	4.306	0.957	0.9657	0.9293	0.9731	0.9755	0.9821
Aug	4.3377	0.995	0.9485	0.9521	0.9577	0.9342	0.923
Sep	4.8802	1.0059	1.003	0.9615	1.0154	0.994	0.9729
Oct	5.0952	0.9785	1.0008	0.9827	0.9859	1.003	1.0034
Nov	4.9994	1.0027	1.0423	1.0411	1.0421	1.0341	1.0497
Dec	5.1101	0.9946	1.0515	1.0621	1.1438	1.2038	1.1655

Table 31: Future Change in average annual maximum 6 hour gust

Observed (m/s)	Future Change ACU			Future Change ADC		
	2020 (ratio)	2050 (ratio)	2020 (ratio)	2050 (ratio)	2020 (ratio)	2050 (ratio)
16.21	0.980	1.016	0.985	1.012	1.021	1.010

3.2.2.4 Extreme Climate Events

The climate models were not able to produce data for extreme climate events such as intense convective storms, tornadoes and ice storms. These events required a finer resolution than even regional climate models are able to provide.

Ouranos provided some comments gathered from literature regarding severe events. Results from other models suggest that the atmosphere over mid-latitude land areas could become more unstable in the future, suggesting that an increase in convective activity is quite probable. To this date, researchers have not identified significant increases in overall severe storm activity as measured in the intensity or frequency of thunderstorms, hail events, tornadoes and winter storm activity in North America.

3.2.2.5 Ice (ice build-up, ice accretion, freezing rain)

The variables related to ice had insufficient data to draw conclusions regarding the intensity or frequency of future events. The shortened frost season, as seen in Table 32, could lead to less ice buildup on rivers and lakes, however this is also dependent on the depth of snowfall in a given season.

Table 32: Future Change in frost season length

Observed (days)	Future Change ACU			Future Change ADC		
	2020 (days)	2050 (days)	2020 (days)	2050 (days)	2020 (days)	2050 (days)
144.55	-12.72	-20.92	-31.83	-11.58	-19.48	-27.80

Very few studies regarding future changes in severity or frequency of freezing rain or ice storm events have been conducted. At present, Ouranos concludes that it remains unknown how climate change could affect the frequency and severity of freezing rain and ice storm events.

3.2.4 State the Time Frame

The general time frame of the design life of the infrastructure was identified to be 30 years for the treatment facility and 80 to 100 years for the distribution system and large control structures. Table 33 provides the design life of the infrastructure components in greater detail.

Table 33: Design Life of Infrastructure Components

Infrastructure Component	Time (Years)
Personell/ Operations	N/A
Shellmouth Dam	100
Assiniboine River System	N/A
Potage Diversion	100
Control Dam Structure	100
Intake Well	100
Water Treatment Plant Facility	30
Water Treatment Plant Processes	30
Pump Stations	30
Pipelines/Valves	100
Electrical Power Supply	N/A
Transportation	N/A
Communications	N/A

The water treatment facility and associated treatment processes received major upgrades in 2002. Capacity of the plant was increase to 34 ML per day. Upgrades to the plant included but were not limited to: addition of the pretreatment facility, the addition of a third clarifier, addition of granular activated filters and reconfigured ozone disinfection. The site the treatment plant is located on has room for additional upgrades, such as a fourth clarifier. The useful remaining life of the treatment plant is approximately 30 years as it is today. With room for upgrades, the water treatment plant could be located at the current site for more than 60 years into the future.

3.2.5 State the Geography

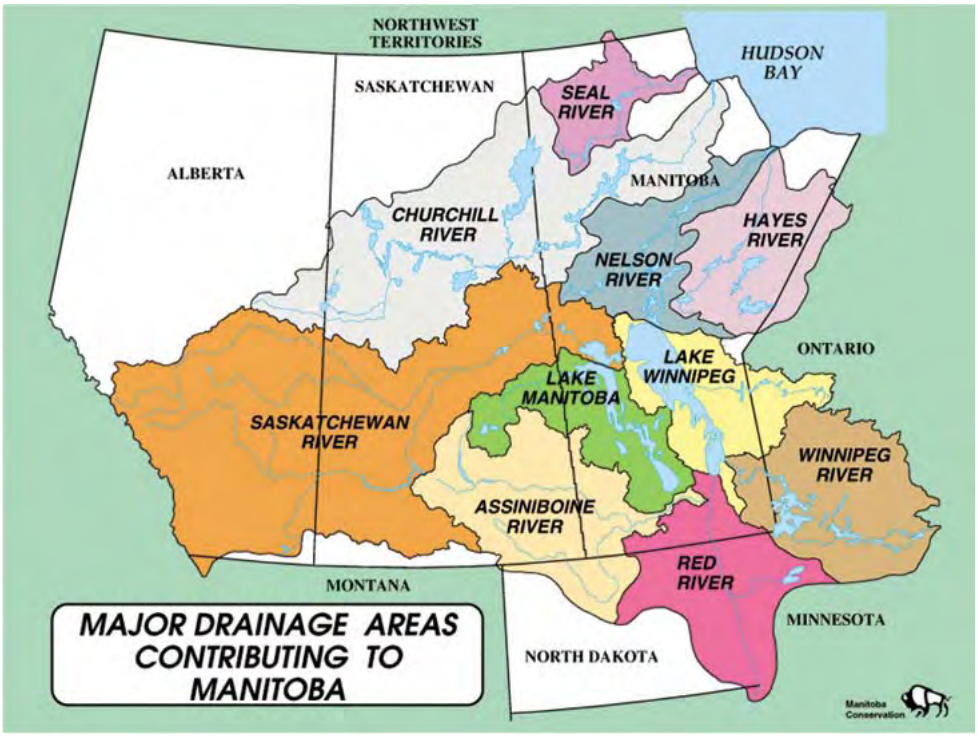
The following is a detailed description of the Assiniboine River system and the associated water control infrastructure identified in Step 1.

3.2.5.1 Assiniboine River System

The Assiniboine River Drainage Basin covers approximately 163,000 km^2 in Manitoba, Saskatchewan and North Dakota. The river passes through many populated areas including three of Manitoba's largest urban centers; Brandon, Portage la Prairie and Winnipeg. The direction of flow is generally southeast. The Assiniboine River joins the larger northward flowing Red River close to downtown Winnipeg. This confluence has long historical roots and is known as "The Forks".

The two major tributaries of the Assiniboine are the Qu'Appelle River and the Souris River. The Assiniboine River also receives a significant contribution from the Assiniboine Delta Aquifer, particularly in drier years. Table 34 provides a breakdown of the area of each sub-basin and the percentage of flow contributed for average, dry and drought conditions. The

Upper Assiniboine sub-basin is the portion of the Assiniboine River upstream of the Shellmouth Dam.



(http://www.gov.mb.ca/waterstewardship)

Figure 25: Major Drainage basins of Manitoba Rivers and Lakes

Table 34: Assiniboine River Flow Sources

Sub-basin	Drainage Area (km^2)	% of Drainage Area	% Flow Sources		
			Average[1]	Dry[2]	Drought[3]
Qu'Appelle River	**58,900**	36	15	10	5
Souris River	61,000	38	15	10	3
Upper Assiniboine	19,000	12	23	24	28
Manitoba Local Tributaries					
- upstream Brandon	15,800	10	28	26	16
- downstream Brandon	7,900	4	9	14	24
- total			37	40	40
Assiniboine Delta Aquifer	3,900	---	10	16	25

(Harrison, 2007)

Note: Unregulated conditions without Shellmouth Dam and Portage Diversion

1. Median Conditions
2. 1:10 year conditions
3. 1:50 year conditions

The hydrology of the basin is typical of prairie river systems. There is a large variability in annual stream flows. Peak flows occur during the spring melt of snow and low flows are experienced in fall and winter. Stream flow has been monitored on the Assiniboine River since the early 1900's at Brandon, Portage la Prairie and a community just to the west of Winnipeg called Headingley. An average annual flow at Headingley is approximately 1,200,000 dam^3. The largest runoff recorded at Headingley was during 1955 with a total annual volume of 3,500,000 dam^3. The driest year on record was 1940, with a total annual flow at Headingley of 230,000 dam^3 (Harrison, 2007).

3.2.5.2 Water Control Infrastructure

Due to the large natural variability in stream flow and high peak flows during the spring melt, large water control infrastructure has been constructed to provide flood and drought protection. The large amount of damage cause by the 1950 flood was the cause for a study that led to the construction of the Shellmouth dam near Russell, and the Portage Diversion at Portage la Prairie.

Shellmouth Dam

The Shellmouth Dam was designed and constructed by PFRA at a cost of $10.8 million. Construction was completed in 1970 and the dam was in full operation in 1971. The dam is 22 m high with a crest length of 1,270 m. Outflow from the dam is controlled by a 4.6 m reinforced concrete conduit. An ungated concrete chute spillway is designed to pass the 1:1000 year flow.

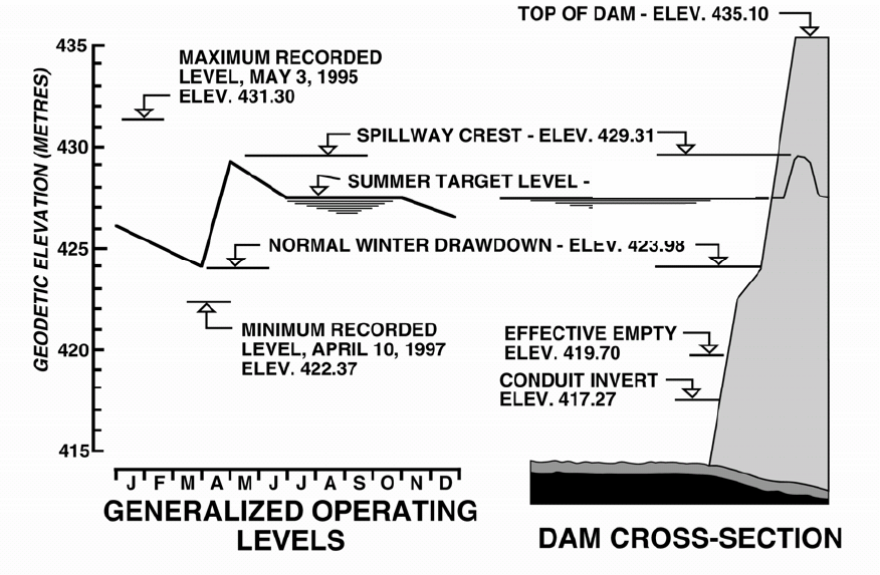
(http://whatiscivilengineering.csce.ca)

Figure 26: Shellmouth Dam and Lake of the Prairies

The dam's reservoir is named Lake of the Prairies and extends approximately 60 km northwest. The storage capacity of the lake is 370,000 dam^3 at the normal summer water level of 427.5 m, and 477,000 dam^3 at the spillway crest elevation of 429.31 m. It has been proposed to increase the storage capacity of the lake by adding gates to the spillway.

Figure 27 shows the general water levels in the lake throughout the year. The lake is drawn down throughout the winter to provide capacity for the spring melt runoff. As melt waters cause the water level to rise, maximum outflow is maintained at 45.3 m^3/s to minimize local flooding. If the water level approaches the crest of the spillway the outflow may be increased to minimize the eventual peak outflow in the event that the water rises above the spillway. The water level is dropped to a summer target level of 427.48 m to optimize recreation and fishery conditions. If dry conditions are anticipated, the summer level can be increased to augment flows later in the season. During periods of heavy summer rainfall the reservoir storage can be used to reduce or prevent flooding along the river downstream of the dam. If the summer lake level rises above 428.25 m, outflows can be increased to prevent the flooding of recreation facilities on the lake and reduce the probability that the spillway is overtopped.

The primary consideration for determining outflow from the reservoir is maintaining adequate downstream flow rates to meet water allocation commitments to licensed users and instream flow needs for healthy river ecosystems. Release rates are varied to maintain minimum target flows of 0.71 m^3/s directly below the dam and 5.67 m^3/s at Headingley.



(Harrison, 2007)

Figure 27: General Operating Levels of Lake of the Prairies

In most years, the Assiniboine River has sufficient flow to meet demands and the Shellmouth Dam is not operated to augment flows. The dam is operated to maintain the target summer level. However, in approximately 1 in 10 years, the flow from Assiniboine tributaries does not maintain the minimum target flows and releases from Shellmouth Dam are used to augment the flows and maintain the minimum target flows. During drought lasting several years where spring runoff is not capable of refilling the reservoir, maintaining the minimum downstream flows has severe impacts on lake levels.

Portage Diversion

The Portage Diversion was constructed in 1970 at a cost of $20.5 million. The diversion was constructed to help alleviate flooding between Portage la Prairie and Winnipeg. This reach of the river is naturally prone to widespread flooding because the area was once part of the floor of Glacial Lake Agassiz and very flat. The banks of the river are actually higher than much of the surrounding floodplain. The construction of the Portage Diversion in combination with construction of dyking along the river has alleviated much of the flooding.

The infrastructure constructed to divert water into the diversion channel can be seen in Figure 18. The water is forced into the diversion channel by a control dam at the Assiniboine River and an adjustable spillway on the entrance to the diversion channel. The diversion channel conveys water 29 km north into the south end of Lake Manitoba.

The control structure maintains a summer water surface elevation of 264.87 m. When flooding conditions exist downstream of the control structure the spillway gates are operated to allow up to 700 m^3/s of water to flow into the channel.

3.2.6 State Specific Jurisdictional Considerations

The following government agencies have jurisdictional control over the infrastructure included in the assessment:

- City of Portage la Prairie:
  - Water treatment plant operation and maintenance
  - Distribution system operation and maintenance
- Province of Manitoba:
  - Operation of Shellmouth Dam
  - Operation of the Portage Diversion
  - Water rights licensing
  - Water quality standards
  - Facility licensing
- Government of Canada:
  - Water quality standards
- Rural Municipality of Portage la Prairie:
  - Plant located in Rural Municipality of Portage la Prairie

3.2.7 State Other Potential Changes that Affect the Infrastructure

Other potential changes that may affect the infrastructure in the design life of the infrastructure components are:

- Population growth
  - Portage la Prairie stated that their population growth has been slow and steady.
- Industrial growth
  - The industrial growth in the area is mostly agriculture related. McCain and Simplot have large potato processing plants serviced by the Potage la Prairie water distribution system. Since a large amount of the industrial water demand is linked to agriculture that is dependent on climate, this portion of demand on the infrastructure is tied to the local climate. During drought conditions the raw potatoes are of poorer quality and require more water to process. Many of the producers use irrigation to continue production, therefore industrial demand is more likely to increase during drought. Also, in the case of a severe drought, the processing plants would be in competition for water rights with the producers using irrigation.
- Water quality standards
  - More stringent water quality standards may require process upgrades.

3.2.8 Assess Data Sufficiency

3.2.8.1 Infrastructure Data

A sufficient amount of infrastructure data was gathered to complete the assessment. There were no data gaps to report and the data appeared to be of good quality and accuracy.

3.2.8.2 Climate Data

GENIVAR/TetrES identified twenty-seven "Potential Climate Change Factors" as important to the project in its formed request for data from Ouranos (Appendix C). GENIVAR/TetrES requested that Ouranos supply historical data and future climate scenario projections. Ouranos produced climate scenario projections for nine of ten first priority factors, and two of three second priority factors. However, due to insufficient historical weather station data to validate the model outputs, Ouranos was unable to provide climate scenario projections for eleven of the remaining fourteen factors, many of which were related to the probability of extreme events.

The most recent IPCC report indicates that, "The uncertainty associated with RCM projections of climate change over North America remains large despite the investments made in increasing horizontal resolution." (Christensen et al. 2007, Chapter 11. Regional Climate Projections, P. 887). Because of this uncertainty, GENIVAR/TetrES considered that

confidence in climate projections developed from climate scenarios could be increased through comparison of projections with existing identified historical trends.

The trends-to-date clearly indicate that on the Canadian Prairies through the 20th century there has been a significant increase of approximately 0.5°C to 1.5°C in the annual mean temperature, primarily due to warmer nights in the winter months. These data indicate that Southern Canada has become less cold rather than warmer (Trenberth et al. 2007, Vincent and Mekis 2006; Khandekar 2002; Zhang et al. 2000). The temperature indices of the climate projections supplied by Ouranos do indicate that the winter months will warm the most, but also indicate that warming will be almost equal through the day. This is inconsistent with the trends observed in the historical data.

The data clearly indicate that on the Canadian Prairies through the 20th Century there has been a significant increase of approximately 10% in the annual amount of precipitation, and a significant increase of 5 to 10% in the annual number of days with measurable precipitation (Trenberth et al. 2007; Vincent and Mekis 2006; Khandekar 2002; Zhang et al 2001; Akinremi and McGinn 1999). The results presented by Ouranos are consistent with these historical data. However, Ouranos also indicated that the Rain Simple Day Intensity Index will increase in the future. This is inconsistent with recent research that has actually shown a significant decrease in the Rainfall Intensity Index (Vincent and Mekis 2006).

While necessity demands utilization of the available information developed through modeling climate change scenarios, lack of consistency between these climate projections and trends-to-date (Table 35) are worrisome in terms of ability to quantify specific climate changes in the future.

Table 35: Summary of IPCC trend analyses of average and extreme events, compared to actual historical trend data for the Canadian Prairies.

Phenomenon	Future Trend[1]	Likelihood[1]	Trend to date on Canadian Prairie[2]
Mean Temperature	Warming of both days and nights	Virtually certain	Warming of nights, some warming of days
Heat waves	Increased frequency	Very likely	No empirical evidence
Cold spells	Decreased frequency	N/A	Drastic decrease, particularly in winter
Precipitation	Upward linear trend	Very likely	Increase of ~12%
Heavy precipitation events	Increased frequency	Very likely	No trend, but daily intensity has significantly decreased
Drought	Increased area	Likely	No empirical evidence of a trend
Storms	Net increase	Likely	No empirical evidence of a trend
Severe weather	Insufficient data	N/A	No empirical evidence of a trend

Notes:
1. The direction of trend and likelihood of phenomena are for IPCC Special Report on Emissions Scenarios (SRES) projections of climate change (p. 14/15, Table SPM-2, IPCC WGII Fourth Assessment Report), from Table 3.8 (p. 315, IPCC WG1 Fourth Assessment Report), and from Chapter 11.5 (p. 887, IPCC WG1 Fourth Assessment Report).
2. Various region specific publications (see reference section).

3.2.9 Protocol Review and Assessment

Obtaining climate data quickly became a bottleneck in the project. The turn around time for data from Ouranos was indicated to be 5 to 7 weeks. Ouranos required 2 to 3 weeks to receive data from Environment Canada and another 3 to 4 weeks to perform there climate modeling. This delayed the scheduling of tasks. The most notable delay was the Workshop scheduled for August 1st, 2007 was postponed to a later date.

Touring the infrastructure facilities and talking to the operators aided in developing understanding of how the infrastructure functions and the relationships that exist with the local climate variations. Examples of climate/infrastructure relationships that were identified during the tour are silt deposits near the inlet and power supply vulnerability during intense storms.

Discussion were held between the GENIVAR/TetrES study team and Ouranos to determine how the weather variables should be summarized to make the use of them as efficient as possible. For precipitation it was suggested that intensity-duration-frequency (IDF) curves would efficiently describe the rainfall intensity for different return periods for different durations. However, Ouranos reported to the PIEVC that the post processing of the precipitation data would add extra cost to the supply of data. PIEVC recommended that the cost of the data processing was excessively high and that for this assignment, GENIVAR/TetrES should continue without IDF curves and a decision could be made later if they were found to be necessary.

3.3 Step 3: Qualitative Analysis

In Step 3 the infrastructure's response to the most relevant climate effects were identified. Infrastructure relationships that are identified as vulnerable, and relationships that require further analysis, are identified for quantitative evaluation in Step 4.

This analysis required the input of a number of judgments of significance that feed into the Qualitative Evaluation. These included judgments on:

- Significance
- Likelihood
- Response
- Uncertainty

as related to the infrastructure components. The protocol forms were used as guidance in conducting the Qualitative Analysis. The overall structure of the Qualitiative Evaluation took the form of an informal Hazards and Operability Analysis (HazOps) as prescribed in AWWA's Risk Assessment Methodology for Water Utilities (AWWA Research Foundation and Sandia National Laboratories 2002). The steps prescribed in most HazOps processes and also in the AWWA Risk Assessment Methodology for Water Utilities are as follows:

Risk Assessment Methodology Step 1: Identify Major System Components

In this step, the analysts identify the major system components for the water infrastructure. The major system components were categorized into the following groupings:

a) Administration and Operations: personnel, equipment, records, etc.
b) Source Water: watersheds and surface water sources, reservoirs and dams
c) Transmission System: intake structures, aqueducts, pump stations, pipelines and valves, appurtenances
d) Treatment Facilities: buildings, basins and tanks, controls, pumps, chemicals
e) Storage: Tanks, valves, piping
f) Distribution System: Pipelines, pump stations, hydrants, materials
g) Electric Power: substations, transformers, transmission lines, standby generators
h) Transportation: vehicles, maintenance facilities, roadways, supplies. and;
i) Communications: telephone, radios, telemetry

Risk Assessment Methodology Step 2: Determine Effects of Probable Disaster Hazards on System Components

In this step, the analysts considered extreme weather events driven by climate change and also other change parameters. For each infrastructure component, a performance response was evaluated in terms of anticipated effects on the infrastructure arising from the climate and other change parameters. The qualitative analysis was aided by general effects categories indicated on Form No. 3.3.2 in the Protocol, namely:

- Structural integrity
- Serviceability
- Functionality
- Operations and Maintenance
- Emergency Response Risk
- Insurance Considerations
- Policies and Procedures
- Economics
- Public Health and Safety
- Environmental Effects
- Other

Examples of extreme event effects for various water infrastructure systems and components include the following:

- Personnel Shortages: events may cause damage to homes of staff, preventing reporting to work. Transportation outages due to blocked roads or accidental chemical (i.e. chlorine) release disable operators.
- Contamination of Water Sources: any material in concentrations that could produce nuisance, process interruption or failure. Examples include sediments due to wildfires or flooding associated with extreme climatic events
- Contamination of Air: accidental chemical release either onsite (chlorine) or off-site by other industry
- Well and Pump Damage: flood events can cause mudding and other damage to pumps
- Other situations: pipeline breaks. Severe freezing temperatures, structural damage from high winds, piping damages due to differential settlement

Risk Assessment Methodology Step 3: Establish Performance Goals and Acceptable Levels of Service for the System

In order to plan for maintaining a given water utility's acceptable levels of service, it is important to establish these performance goals and define acceptable levels of service for the system. Impacts that prevent the facility from delivering a pre-defined level of performance and/or maintaining specific goals would require additional scrutiny in the form of possible mitigation, emergency response planning or other preparedness planning.

Goals that are common to a number of water infrastructure facilities include the following goals in a few main categories:

Life Safety: Above all else, the plant must preserve the life and safety of plant personnel while providing sufficient quantities of safe, clean water to the public. Meeting this goal should be a continuous function of the system before, during and after a disaster or extreme event. Examples of potentially life-threatening situations include:

- Failure of distribution system
- Failure of a dam
- Distribution of contaminated water
- Release of hazardous materials, especially chlorine
- Failure of structures

Fire Suppression: Fire fighting is an essential service that depends on a potable water supply to function. Loss of available water supply for the purposes of fire suppression could create secondary impacts (uncontrolled fires) in an affected community.

Public Health Needs: Every community has a minimum level of basic medical services that it needs to maintain during emergencies and other extreme events. These include hospitals

which have a constant need for potable water, dialysis patients requiring access to potable water within 24 hours, and personal hygiene/waste disposal activities that can typically practically function up to 72 hours without potable water supply.

Commercial and Business Users: Some commercial/industrial processes cannot operate without potable water. Certain processes may become critical without water, creating more impacts for emergency responders to manage. In the case of Portage la Prairie, two major food processing industries constitute a large component of the water supply demand for Portage la Prairie, therefore interruption of this water supply could lead to significant economic disruption to the operations of these water-intensive industries.

It is important to consider the full range of water demands and the criticality of each need in sustaining essential services and considering which industrial processes could "go critical" and spawn new emergencies in the absence of water. Setting the priority of these various needs is an important part of the process to define performance goals and establishing acceptable levels of service for the system.

Risk Assessment Methodology Step 4: Identify Critical Components

In this step the assessors must consider each extreme event scenario or potential disaster scenario and focus on system components whose failure renders the water supply system inoperative or unable to meet the acceptable levels of service defined in the previous step. These system components with a potential to fail are considered critical components, as they are most vulnerable to failure or partial failure due to an upset condition or extreme event scenario. Failure of a critical component WILL reduce a system's ability to meet minimum performance goals.

3.3.1 Prioritization Methodology

The Prioritization Methodology is in accordance with generally accepted qualitative Hazards and Operability Analyses procedures in that the assessor must consider both the probability of a given adverse effect in response to a climatic event on a component of the infrastructure (probability scale factor) and the anticipated severity of this effect on the infrastructure's ability to perform and provide critical levels of service to its users (severity scale factor). The methodology allows the assessor to assign pragmatic values for probability and severity for relationships between critical infrastructure components and climatic events which are capable of creating impacts to the infrastructure. Once the probability and severity scale factors are assigned, these factors are multiplied together to calculate a Priority of Climate Effect (P_C) value. The P_C value is compared to specific numeric threshold values to categorize a given infrastructure/climatic event response as negligible, in need of additional (quantitative) assessment, or in need of immediate remedial action.

To prioritize the infrastructure-climate relationships the Draft Protocol used a default scale of 1 to 7 for both the probability scale factors and the severity scale factors. Larger scale

factors correspond to a more probable or severe event. This scale was determined to be reasonable and adopted for the study.

The Study Team selected **Method A** from Table 36 as the Probability Scale Factor Method throughout application of the Protocol. Method A was selected due to the fact that its non-numerical basis meshed well with the qualitative nature of this portion of the assessment. Method A is also used often in the screening-level stage of a typical industrial Hazards and Operability Analysis (HazOps) process, however the use of Method B or C would have provided similar results and the selection of Probability Scale Factor Method was not considered critical to the outcome of the assessment. The Study Team selected and applied **Method E** from Table 37 for all severity of consequences and effects characterizations.

Table 36: Probability Scale Factors (S_c)

Scale	Probability*		
	Method A	**Method B**	**Method C**
0	negligible or not applicable	<0.1 % <0.1 / 20	negligible or not applicable
1	improbable / highly unlikely	5 % 1 / 20	improbable 1:1 000 000
2	remote	20 % 4 / 20	remote 1:100 000
3	occasional	35 % 7 / 20	occasional 1:10 000
4	moderate / possible	50 % 10 / 20	moderate 1:1 000
5	often	65 % 13 / 20	probable 1:100
6	probable	80 % 16 / 20	frequent 1:10
7	certain / highly probable	>95 % >19 / 20	continuous 1:1

*

g) Choose Method A, Method B or Method C to select the priority.
h) Record in project documentation the Method that was used.
i) Use the same Method for all probability prioritization in the evaluation.

Table 37: Severity Scale Factors (S_R)

Scale	Magnitude	Severity of Consequences and Effects
	Method D	**Method E**
0	~~no effect~~	negligible or not applicable
1	~~measurable 0.0125~~	very low / unlikely / rare / measurable change
2	~~minor 0.025~~	low / seldom / marginal / change in serviceability
3	~~moderate 0.050~~	occasional loss of some capability
4	~~major 0.100~~	moderate loss of some capacity
5	~~serious 0.200~~	likely regular / loss of capacity and loss of some function
6	~~hazardous 0.400~~	major / likely / critical / loss of function
7	~~catastrophic 0.800~~	extreme/ frequent/ continuous / loss of asset

*

j) Choose Method D or Method E to select the priority.
k) Record in project documentation the Method that was used.
l) Use the same Method for all magnitude prioritization in the evaluation.

The qualitative assessment results were recorded in a matrix format instead of separate instances of worksheet Form 3.3.2 as provided in the Protocol. Rather than repeated use of individual tables as provided in the Worksheets, a matrix was constructed as shown in Figure 28. The matrix was constructed with infrastructure components as rows and severe climate effects as columns. The matrix made the presentation and organization of the scale factors and relationship priorities simpler and much more compact. The matrix also offered the ability to review the collection of components as a complete system, and to review vulnerabilities on a system-wide basis.

In the relationship priority matrix, each infrastructure-climate relationship had four cells. The first cell was used as a prescreening step to identify the relationships where a relationship between the infrastructure components and climate effects existed. If a relationship may exist, a check was placed in the cell, if a relationship did not exist the cell was left blank and no further assessment was required for that infrastructure-climate

intersection. The second and third where the probability scale factors, S_C, and severity scale factors, S_R, chosen from Table 36 and Table 37 respectively. The fourth column was the priority of the relationship, P_C.

Infrastructure Components	Severe Weather Event																																			
	Floods/ Ice Jamming/ Ice Build-up				High Temp				Low Temp				Intense Rain				Drought				Ice Storm				Blizzard (Snow)				Intense Wind/Tornado				Hail				Frost Penetration				Ground Water Table (Portage la Prairie)			
Administration/operations	Y/N	S_C	S_R	P_C	Y/N	S_C	S_R	P_C	Y/N	S_C	S_R	P_C	Y/N	S_C	S_R	P_C	Y/N	S_C	S_R	P_C	Y/N	S_C	S_R	P_C	Y/N	S_C	S_R	P_C	Y/N	S_C	S_R	P_C	Y/N	S_C	S_R	P_C	Y/N	S_C	S_R	P_C	Y/N	S_C	S_R	P_C
Personnel																																											
Facilities/equipment																																											
Records																																											
Source Water																																											
Shellmouth Dam / Reservoir																																											
Assiniboine River System																																											
Portage Diversion																																											
Dam Structure																																											
Intake Well / Pumps																																											
Treatment																																											
Pretreatment (Actiflo)																																											
Softening/Clarification																																											
Filtration (Granular/GAC)																																											
Disinfection (Ozone/Chlorine)																																											
Storage																																											
Chemical Feed Systems																																											
Chemical Storage / Hazardous Materials																																											
Valves / pipelines (on site)																																											
Distribution																																											
Pump stations (WTP/McKay)																																											
Pipelines, valves																																											
Pipe Materials																																											
Electric power																																											
Substations / Transformers																																											
Transmission lines																																											
Standby generators																																											
Transportation																																											
Vehicle																																											
Maintenance facilities																																											
Supplies																																											
Roadway infrastructure																																											
Communications																																											
Telephone																																											
Two-way radio																																											
Telemetry																																											

Figure 28: Relationship Priority Matrix

3.3.2 Scale the Performance Response of the Infrastructure Components

Climate may cause a number of different forms of vulnerability to infrastructure. The Draft Protocol lists possible anticipated performance responses as:

- Structural integrity,
- Serviceability,
- Functionality,
- Operations and maintenance,
- Emergency response risks,
- Insurance considerations,
- Policies and procedures,
- Economics,
- Public health and safety, and
- Environmental effects.

Rather than assessing the severity scale factor of each performance response criteria for each individual infrastructure component, a table was constructed that identified which performance responses were applicable to each infrastructure component. When applying the severity scale factor, only one severity scale factor was applied using judgment on which performance response was most critical for each infrastructure-climate relationship. The table of performance responses considered for each infrastructure component is shown below as Table 38.

Engineering judgment, engineering experience with Portage la Prairie's water supply infrastructure, and the local knowledge of the operators were used to assign appropriate scale factors. The scale factors applied to infrastructure-climate relationships can be viewed in Figure 29.

Table 38: Performance response of infrastructure components to be considered

Infrastructure Components		Performance Response									
		Structural Integrity	Serviceability	Functionality	Operations & Maintenance	Emergency Response Risk	Insurance Considerations	Policies & Procedures	Economics	Public Health & Safety	Environmental Effects
Administration/ operations	Personnel				3	3	3	3		3	
	Facilities/Equipment (WTP)	3	3	3	3	3	3	3		3	3
	Records				3	3	3	3		3	
Source Water	Shellmouth Dam / Reservoir	3	3			3		3		3	3
	Assiniboine River System				3	3		3			3
	Portage Diversion	3	3		3	3	3	3		3	3
	Control Dam Structure	3	3		3	3	3	3		3	3
	Intake Well / Pumps	3	3	3	3	3	3	3		3	3
Treatment	Pretreatment (Actiflo)		3	3	3	3		3		3	3
	Softening/Clarification		3	3	3	3		3		3	3
	Filtration (Granular/GAC)		3	3	3	3		3		3	3
	Disinfection (Ozone/Chlorine)		3	3	3	3		3		3	3
	Storage		3	3	3	3		3		3	3
	Chemical Feed Systems		3	3	3	3		3		3	3
	Chemical Storage/Hazardous Materials		3	3	3	3		3		3	3
	Valves / pipelines (on site)	3	3	3	3	3		3		3	
Distribution	Pump stations (WTP/McKay)	3	3	3	3	3	3	3		3	3
	Pipelines, valves	3	3	3	3	3		3		3	
	Pipe Materials	3	3	3	3	3		3		3	3
Electric power	Substations / Transformers	3	3	3		3	3	3		3	
	Transmission lines	3	3	3		3	3	3		3	
	Standby generators	3	3	3	3	3	3	3		3	3
Transportation	Vehicles		3	3	3	3	3	3			
	Maintenance facilities	3	3	3	3	3	3	3		3	
	Supplies		3	3	3	3	3	3		3	
	Roadway infrastructure	3	3	3	3	3	3	3		3	

Infrastructure Components		Performance Response									
		Structural Integrity	Serviceability	Functionality	Operations & Maintenance	Emergency Response Risk	Insurance Considerations	Policies & Procedures	Economics	Public Health & Safety	Environmental Effects
Communications	Telephone		3	3	3	3		3			
	Two-way radio		3	3	3	3		3			
	Telemetry	3	3	3	3	3		3		3	

3.3.3 Scale the Climate Effects

The probability scale factor determination provides a qualitative judgment of the likelihood of an adverse reaction (effect) in the performance of a process component if it is placed in a situation where it is exposed to a severe or unanticipated operating condition. The probability scale factors were applied to those relationships where climate was judged to have a relationship with the infrastructure. The probability scale factors were chosen from Table 36, Method A, using engineering judgment, engineering experience with Portage la Prairie's water supply infrastructure, and the local knowledge of gained from the operators.

It is important to note that the probability scale factors in Table 5 are applied as probabilities of an infrastructure response (i.e. an effect) and **not probabilities of a particular climatic extreme event.** For example, if one was to consider the case of a system component and its vulnerability to an ice storm, then the Probability Scale Factor is assigned on the basis of the **likelihood of an effect on that infrastructure component**, therefore the assigned probability does not represent the likelihood of an ice storm event itself. **It is crucial in this step of the qualitative assessment to proceed on the basis that Probability Scale Factors are assigned to describe the likelihood of infrastructure performing sub-optimally when exposed to a given climatic or other change effect. It is not the probability of the change effect event occurring itself.** In the Study Team's Workshop, it was noted that breakout groups participating in "tabletop" exercises debated different interpretations of the Protocol in terms of the probability scale factor. Some groups believed the probability scale factor represented the probability of a climatic event occurrence (i.e. the probability of an ice storm) and assessors worked to correct this interpretation so that Workshop participants conducting "tabletop" Qualitative Assessment applied to proper context to the probability factor.

3.3.4 Scale Other Change Effects

No other change effects were considered as part of the analysis. The useful life remaining of the infrastructure, due to either its capacity or age, was considered, but not as a scaled effect.

3.3.5 Prioritize Climate Effect and Performance Response Relationships

After an infrastructure-climate relationship was assigned a priority scale factor and severity scale factor, the priority of that relationship was determined using the formula:

$$P_C = S_C \times S_R,$$

where: P_C is the priority of the climate effect,
S_C is the probability scale factor for the climate effect, and
S_R is the severity scale factor for the performance response.

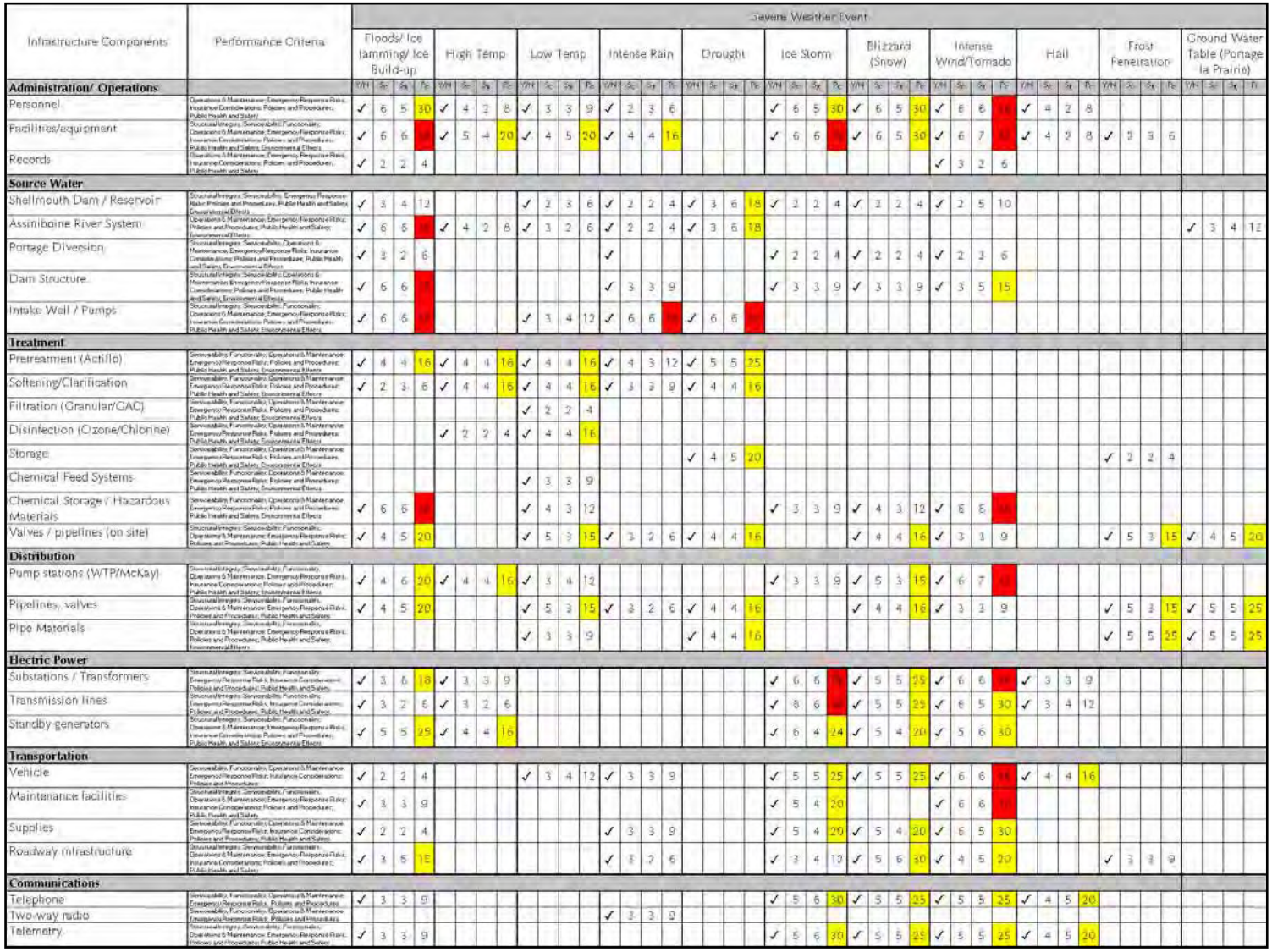
Figure 29 shows the Study Team's results after applying the above equation to all infrastructure-climate relationships where a vulnerable relationship was judged to exist. Once the priority of the relationship was calculated, the Protocol specified that the course of action by the following criteria:

- Any relationship with a priority of 12 or less, or with either scale factor having a value of 2 or less, is discarded from further analysis.

- Any relationship that is determined to have a priority greater than or equal to 36 represents a vulnerability that requires attention and is reported directly in Step 5 with appropriate recommendations to address the identified vulnerability.

- Relationships with priority between 12 and 36 represent potential vulnerabilities. These infrastructure-climate relationships require further numerical analysis in Step 4 if there is sufficient data to quantify the vulnerability with more precision than the qualitative assessment alone could provide.

Figure 29 is color coded to highlight the relationships where a vulnerability was identified to exist, or where one may exist. Red boxes highlight where the relationship had a priority above 36, and yellow boxes highlight relationships with priorities between 12 and 36.



Infrastructure Components	Performance Criteria	Severe Weather Event: Floods/ Ice Jamming/ Ice Build-up				High Temp				Low Temp				Intense Rain				Drought				Ice Storm				Blizzard (Snow)				Intense Wind/Tornado				Hail				Frost Penetration				Ground Water Table (Portage la Prairie)			
		Y/N	S_C	S_K	P_C	Y/N	S_C	S_K	P_C	Y/N	S_C	S_K	P_C	Y/N	S_C	S_K	P_C	Y/N	S_C	S_K	P_C	Y/N	S_C	S_K	P_C	Y/N	S_C	S_K	P_C	Y/N	S_C	S_K	P_C	Y/N	S_C	S_K	P_C	Y/N	S_C	S_K	P_C	Y/N	S_C	S_K	P_C
Administration/ Operations																																												
Personnel	Operations & Maintenance; Emergency Response Risks; Insurance Considerations; Policies and Procedures; Public Health and Safety	✓	6	5	30	✓	4	2	8	✓	3	3	9	✓	2	3	6					✓	6	5	30	✓	6	5	30	✓	6	6	36	✓	4	2	8								
Facilities/equipment	Structural Integrity; Serviceability; Functionality; Operations & Maintenance; Emergency Response Risks; Insurance Considerations; Policies and Procedures; Public Health and Safety; Environmental Effects	✓	6	6	36	✓	5	4	20	✓	4	5	20	✓	4	4	16					✓	6	6	36	✓	6	5	30	✓	6	7	42	✓	4	2	8	✓	2	3	6				
Records	Operations & Maintenance; Emergency Response Risks; Insurance Considerations; Policies and Procedures; Public Health and Safety; Structural Integrity	✓	2	2	4																									✓	3	2	6												
Source Water																																												
Shellmouth Dam / Reservoir	Structural Integrity; Serviceability; Emergency Response Risks; Policies and Procedures; Public Health and Safety; Environmental Effects	✓	3	4	12					✓	2	3	6	✓	2	2	4	✓	3	6	18	✓	2	2	4	✓	3	2	4	✓	2	5	10												
Assiniboine River System	Operations & Maintenance; Emergency Response Risks; Policies and Procedures; Public Health and Safety; Environmental Effects	✓	6	6	36	✓	4	2	8	✓	3	2	6	✓	2	2	4	✓	3	6	18																			✓	3	4	12
Portage Diversion	Structural Integrity; Serviceability; Operations & Maintenance; Emergency Response Risks; Insurance Considerations; Policies and Procedures; Public Health and Safety; Environmental Effects	✓	3	2	6									✓								✓	2	2	4	✓	2	2	4	✓	2	3	6												
Dam Structure	Structural Integrity; Serviceability; Operations & Maintenance; Emergency Response Risks; Insurance Considerations; Policies and Procedures; Public Health and Safety; Environmental Effects	✓	6	6	36									✓	3	3	9					✓	3	3	9	✓	3	3	9	✓	3	5	15												
Intake Well / Pumps	Structural Integrity; Serviceability; Functionality; Operations & Maintenance; Emergency Response Risks; Insurance Considerations; Policies and Procedures; Public Health and Safety; Environmental Effects	✓	6	6	36					✓	3	4	12	✓	6	6	36	✓	6	6	36																								
Treatment																																												
Pretreatment (Actiflo)	Serviceability; Functionality; Operations & Maintenance; Emergency Response Risks; Policies and Procedures; Public Health and Safety; Environmental Effects	✓	4	4	16	✓	4	4	16	✓	4	4	16	✓	4	3	12	✓	5	5	25																								
Softening/Clarification	Serviceability; Functionality; Operations & Maintenance; Emergency Response Risks; Policies and Procedures; Public Health and Safety; Environmental Effects	✓	2	3	6	✓	4	4	16	✓	4	4	16	✓	3	3	9	✓	4	4	16																								
Filtration (Granular/GAC)	Serviceability; Functionality; Operations & Maintenance; Emergency Response Risks; Policies and Procedures; Public Health and Safety; Environmental Effects									✓	2	2	4																																
Disinfection (Ozone/Chlorine)	Serviceability; Functionality; Operations & Maintenance; Emergency Response Risks; Policies and Procedures; Public Health and Safety; Environmental Effects					✓	2	2	4	✓	4	4	16																																
Storage	Serviceability; Functionality; Operations & Maintenance; Emergency Response Risks; Policies and Procedures; Public Health and Safety; Environmental Effects																	✓	4	5	20																	✓	2	2	4				
Chemical Feed Systems	Serviceability; Functionality; Operations & Maintenance; Emergency Response Risks; Policies and Procedures; Public Health and Safety; Environmental Effects									✓	3	3	9																																
Chemical Storage / Hazardous Materials	Serviceability; Functionality; Operations & Maintenance; Emergency Response Risks; Policies and Procedures; Public Health and Safety; Environmental Effects	✓	6	6	36					✓	4	3	12									✓	3	3	9	✓	4	3	12	✓	6	6	36												
Valves / pipelines (on site)	Structural Integrity; Serviceability; Functionality; Operations & Maintenance; Emergency Response Risks; Policies and Procedures; Public Health and Safety	✓	4	5	20					✓	5	3	15	✓	3	2	6	✓	4	4	16					✓	4	4	16	✓	3	3	9					✓	5	3	15	✓	4	5	20
Distribution																																												
Pump stations (WTP/McKay)	Structural Integrity; Serviceability; Functionality; Operations & Maintenance; Emergency Response Risks; Insurance Considerations; Policies and Procedures; Public Health and Safety; Environmental Effects	✓	4	6	20	✓	4	4	16	✓	3	4	12									✓	3	3	9	✓	5	3	15	✓	6	7	42												
Pipelines, valves	Structural Integrity; Serviceability; Functionality; Operations & Maintenance; Emergency Response Risks; Policies and Procedures; Public Health and Safety	✓	4	5	20					✓	5	3	15	✓	3	2	6	✓	4	4	16					✓	4	4	16	✓	3	3	9					✓	5	3	15	✓	5	5	25
Pipe Materials	Structural Integrity; Serviceability; Functionality; Operations & Maintenance; Emergency Response Risks; Policies and Procedures; Public Health and Safety; Environmental Effects									✓	3	3	9					✓	4	4	16																	✓	5	5	25	✓	5	5	25
Electric Power																																												
Substations / Transformers	Structural Integrity; Serviceability; Functionality; Emergency Response Risks; Insurance Considerations; Policies and Procedures; Public Health and Safety	✓	3	6	18	✓	3	3	9													✓	6	6	36	✓	5	5	25	✓	6	6	36	✓	3	3	9								
Transmission lines	Structural Integrity; Serviceability; Functionality; Emergency Response Risks; Insurance Considerations; Policies and Procedures; Public Health and Safety	✓	3	2	6	✓	3	2	6													✓	6	6	36	✓	5	5	25	✓	6	5	30	✓	3	4	12								
Standby generators	Structural Integrity; Serviceability; Functionality; Operations & Maintenance; Emergency Response Risks; Insurance Considerations; Policies and Procedures; Public Health and Safety; Environmental Effects	✓	5	5	25	✓	4	4	16													✓	6	4	24	✓	5	4	20	✓	5	6	30												
Transportation																																												
Vehicle	Serviceability; Functionality; Operations & Maintenance; Emergency Response Risks; Insurance Considerations; Policies and Procedures	✓	2	2	4					✓	3	4	12	✓	3	3	9					✓	5	5	25	✓	5	5	25	✓	6	6	36	✓	4	4	16								
Maintenance facilities	Structural Integrity; Serviceability; Functionality; Operations & Maintenance; Emergency Response Risks; Insurance Considerations; Policies and Procedures; Public Health and Safety	✓	3	3	9																	✓	5	4	20					✓	6	6	36										
Supplies	Serviceability; Functionality; Operations & Maintenance; Emergency Response Risks; Insurance Considerations; Policies and Procedures; Public Health and Safety	✓	2	2	4									✓	3	3	9					✓	5	4	20	✓	5	4	20	✓	6	5	30										
Roadway infrastructure	Structural Integrity; Serviceability; Functionality; Operations & Maintenance; Emergency Response Risks; Insurance Considerations; Policies and Procedures; Public Health and Safety	✓	3	5	15									✓	3	2	6					✓	3	4	12	✓	5	6	30	✓	4	5	20					✓	3	3	9				
Communications																																												
Telephone	Serviceability; Functionality; Operations & Maintenance; Emergency Response Risks; Policies and Procedures	✓	3	3	9																	✓	5	6	30	✓	5	5	25	✓	5	5	25	✓	4	5	20								
Two-way radio	Serviceability; Functionality; Operations & Maintenance; Emergency Response Risks; Policies and Procedures													✓	3	3	9																											
Telemetry	Structural Integrity; Serviceability; Functionality; Operations & Maintenance; Emergency Response Risks; Policies and Procedures; Public Health and Safety	✓	3	3	9																	✓	5	6	30	✓	5	5	25	✓	5	5	25	✓	4	5	20								

Figure 29: Completed Relationship Priority Matrix

Table 39 summarizes the infrastructure-climate effect relationships with a calculated priority value of 36 or more. The relationships are identified as vulnerabilities of the infrastructure to climate. The Protocol indicated that for these relationships, no further analysis was required and these relationships were transferred to Step 5: Recommendations, where appropriate recommendations to address the vulnerability were made.

Table 39: Relationships with Priorities equal to or greater than Threshold Value of 36

Infrastructure Component	Climate Variable	Priority of Relationship
Personnel	Intense Wind/Tornado	36
Facilities/equipment	Floods/Ice Jamming/Ice Buildup	36
	Ice Storm	36
	Intense Wind/Tornado	42
Assiniboine River System	Floods/Ice Jamming/Ice Buildup	36
Dam Structure	Floods/Ice Jamming/Ice Buildup	36
Intake Well / Pumps	Floods/Ice Jamming/Ice Buildup	36
	Intense Rain	36
	Drought	36
Chemical Storage / Hazardous Materials	Floods/Ice Jamming/Ice Buildup	36
	Intense Wind/Tornado	36
Pump stations (WTP/McKay)	Intense Wind/Tornado	42
Substations / Transformers	Ice Storm	36
	Intense Wind/Tornado	36
Transmission lines	Ice Storm	36
Vehicle	Intense Wind/Tornado	36
Maintenance facilities	Intense Wind/Tornado	36

The next class of relationship was defined as relationships with a priority value in the range of greater than 12 and less than 36. Table 40 summarizes the relationships that had a priority above 12 and below 36. The Protocol considers these Priority Values to represent relationships that may or not be vulnerable to climate change. To determine if vulnerability exists, the Protocol required that these relationships under go further analysis in Step 4: Quantitative Evaluation, as long as sufficient data existed to conduct the Quantitative Evaluation. The climate change data was converted into loads and added to existing loads on the infrastructure to determine if the infrastructure components have enough adaptive capacity to withstand the changes in climate.

Table 40: Relationships with Priorities between 12 and 35

Infrastructure Component	Climate Variable	Priority of relationship
Personnel	Floods/Ice Jamming/Ice Buildup	30
	Ice Storm	30
	Blizzard	30
Facilities/equipment	High Temp	20
	Low Temp	20
	Intense Rain	16
	Blizzard	30
Shellmouth Dam/Reservoir	Drought	18
Assiniboine River System	Drought	18
Dam Structure	Intense Wind/Tornado	15
Pretreatment	Floods/Ice Jamming/Ice Buildup	16
	High Temp	16
	Low Temp	16
	Drought	25
Softening	High Temp	16
	Low Temp	16
	Drought	16
Disinfection	Low Temp	16
Storage	Drought	20
Valves Pipelines (on WTP site)	Floods/Ice Jamming/Ice Buildup	20
	Low Temp	15
	Drought	16
	Blizzard	16
	Frost Penetration	15
	Ground Water Table	20
Pump stations (WTP/McKay)	Floods/Ice Jamming/Ice Buildup	20
	High Temp	16
	Blizzard	15
Pipelines and Valves	Floods/Ice Jamming/Ice Buildup	20
	Low Temp	15
	Drought	16
	Blizzard	16
	Frost Penetration	15
	Ground Water Table	25
Pipe Materials	Drought	16
	Frost Penetration	25
	Ground Water Table	25
Substations / Transformers	Floods/Ice Jamming/Ice Buildup	18
	Blizzard	25

Infrastructure Component	Climate Variable	Priority of relationship
Transmission lines (Hydro)	Blizzard	25
	Intense Wind/Tornado	30
Standby Generators	Floods/Ice Jamming/Ice Buildup	25
	High Temp	16
	Ice Storm	24
	Blizzard	20
	Intense Wind/Tornado	30
Vehicle	Ice Storm	25
	Blizzard	25
	Hail	16
Maintenance Facilities	Ice Storm	20
Supplies	Ice Storm	20
	Blizzard	20
	Intense Wind/Tornado	30
Roadway Infrastructure	Floods/Ice Jamming/Ice Buildup	15
	Blizzard	30
	Intense Wind/Tornado	20
Telephone	Ice Storm	30
	Blizzard	25
	Intense Wind/Tornado	25
	Hail	20
Telemetry	Ice Storm	30
	Blizzard	25
	Intense Wind/Tornado	25
	Hail	20

Lastly, there is a third class of infrastructure components and climate effects that yield Priority Values of 12 or less, or have a probability or severity scale factor of 2 or less. These relationships were essentially screened out from the assessment by the Protocol, and did not undergo further assessment. The Protocol considers relationships in this final category to have little or no vulnerability and consequently should be discarded from further analysis. Relationships in this category are shown in Figure 29.

3.3.6 Prioritize Other Effect and Performance Response Relationships

No other change effects were incorporated in to the study as scaled change effects, and therefore no prioritization of other change effects was warranted.

3.3.7 Assess Data Sufficiency

The data available for use in the qualitative assessment was sufficient for non-numerical, engineering judgment-based screening purposes.

3.3.8 Portage la Prairie Workshop

3.3.8.1 Workshop Review

A Workshop was held on August 30th, 2007 at Canad Inns in Portage la Prairie, to discuss the Water Resources Infrastructure Assessment progress up to this point and also to familiarize the workshop participants with both the Portage la Prairie Water Treatment Plant and the mechanics of applying the Protocol itself. The timing of the Workshop was intended to coincide with the conclusion of Step 3 of the Protocol, which constitutes a key decision point in the overall application of the Protocol.

Twenty-three people attended the Workshop. Participants included the members of the GENIVAR/TetrES study team, members of the Pilot Project Advisory Group, observers of the project, managers and operators of the Portage Water Treatment Plant and distribution system, and representatives from Ouranos.

The purpose of the Workshop was to review the following key aspects of the project:

- **Protocol effectiveness, functionality and data workflow.** At the time of the workshop the Study Team had worked through steps 1 through 3 of the Protocol. This experience with the Protocol provided opportunity to brief the Workshop Participants on the Protocol's effectiveness and functionality thus far.
- **Climate data availability, data suitability and data applicability**. Explaining the basic concepts of global climate change, global and regional climate models and application of climate data was important for understanding the climate data requirements of the assessment. Understanding the contribution made by Ouranos to the study was also important for future assessments.
- **Applicability of the Protocol itself**. An important component of the application of this Protocol is to document the effectiveness and usability of the Protocol as it is applied to water infrastructure.
- **Vulnerability assessment rationale**. It was important to walk the Workshop Participants through the process of qualitative vulnerability assessment in order for the participants to understand the logic behind the assessment results, and also to obtain the feedback from the Plant Operators and Managers themselves who could verify or correct any preliminary findings reviewed from the Qualitative Assessment.

GENIVAR/TetrES presented overviews of the Draft Protocol, Portage la Prairie's water distribution system, and climate change principles. A review of progress made by GENIVAR/TetrES in applying the Draft Protocol was also presented with questions encouraged throughout the workshop. Representatives from Ouranos provided an overview of the climate modeling procedure used to create the climate data contribution for the study. The Workshop also included a tour of the control structure and water treatment plant. A portion of the afternoon session of the Workshop was dedicated to having groups work through a tabletop exercise involving examples of the qualitative analysis process using matrices. The assessment exercise undertaken by the Workshop

participants was based upon parts of the Water Treatment Plant that they toured in the morning portion of the workshop. The results of this exercise were gathered for GENIVAR/TetrES to compare their analysis to the analysis of the work groups. The agenda for the Workshop was ambitious for a single day, but Participants assisted in efficiently covering the full range of planned topics for the day's agenda. The Workshop schedule was as follows:

- Introductions
- Workshop Overview
- Review of PIEVC Protocol and Vulnerability Assessment Principles
- Water Treatment Plant Tour
- Climate Change Primer
- Ouranos: Data delivery overview
- Qualitative Vulnerability Assessment Principles
- Yes/No Climatic Impact Matrix Review
- Lunch Break
- Vulnerability Assessment Breakout Session
- Breakout Results Discussion
- Discussion of Study Team Vulnerability Assessment Results
  - Screening out vulnerabilities
  - Issues for Quantitative Assessment
  - Issues for Recommendations
- Protocol Assessment
- Open Discussion and Wrap-Up

3.3.8.2 Tabletop Activity Results

The results from each of the three groups can be seen in Figure 31. From the wide range of results it is clear that applying the scale factors is a subjective process. In some cases one group may have prioritized a relationship as being critical, while another group may have identified it as having low priority or no priority at all.

Figure 30: Workshop Tabletop Activity

An important part of the tabletop activity was the inclusion of a water treatment plant operator and a distribution system operator in each of the groups. The operators' first hand working knowledge of the infrastructure was a valuable asset when groups were discussing how the infrastructure is affected by climate.

The Workshop benefited those who will be involved in the infrastructure vulnerability assessments, such as the City of Calgary, Ouranos, PIEVC and Engineers Canada members by illustrating what is involved in an assessment. The Workshop offered participants the ability to gain experience in applying the Protocol and in understanding the different contributions to the assessment from plant managers, plant operators and other personnel associated with maintaining the function of the infrastructure. Overall, the Workshop provided very good discussion regarding the application of the Draft Protocol.

Group 1 Results:

Infrastructure Components	Performance Criteria	Severe Weather Event																																					
		Floods/ Ice Jamming/ Ice Buildup				High Temp				Low Temp				Intense Rain / *Lightening*				Drought / *Fire*				Ice Storm				Blizzard (Snow)				Intense Wind/Tornado				Hail				Frost Penetration				Ground Water Table (Portage laPrairie)			
Administration/operations		Y/N	S_C	S_R	P_C	Y/N	S_C	S_R	P_C	Y/N	S_C	S_R	P_C	Y/N	S_C	S_R	P_C	Y/N	S_C	S_R	P_C	Y/N	S_C	S_R	P_C	Y/N	S_C	S_R	P_C	Y/N	S_C	S_R	P_C	Y/N	S_C	S_R	P_C	Y/N	S_C	S_R	P_C	Y/N	S_C	S_R	P_C
Personnel	; Serviceability; Functionality; Operations & Maintenance; Emergency Response Risks; ; Policies and Procedures; Public Health and Safety;	Y	5/1.	1/6.	5/6.	Y	6/1.	5/3.	30/3.	Y	6/1.	4/2.	24/2.	Y	2/1.	2/0.	4/0.					Y	1/1.	2/5.	2/5.	Y	7/5.	2/2.	14/10.	Y	1/1.			Y	1/1.			Y	1/1.			Y	1/1.		
Facilities/equipment *chlorine gas leak*	Structural Integrity; Serviceability; Functionality; Operations & Maintenance; ; Insurance Considerations; Economics; Public Health and Safety; Environmental Effects	Y	4	6	24	Y	1			Y	1			Y	1							Y	1			Y	1			Y	1			Y	1			Y	2	3	6	Y	2	3	6
Source Water																																												
Intake Well / Pumps	Structural Integrity; Serviceability; Functionality; Operations & Maintenance; ; Insurance Considerations; Economics; Public Health and Safety;	Y	5	5	25					Y	2	2	4					Y	1	6																							
Treatment																																												
Softening/Clarification	; Operations & Maintenance; ; ; Policies and Procedures;	Y	2	1	2	n				y	7	1	7	y	6	1	6	y	3	3	9	y	2	4	8	n				y	2	6	12	n				n				n			
Distribution																																												
Pipelines, valves *one feedermain section*	Structural Integrity; Serviceability; Functionality; Operations & Maintenance; Emergency Response Risks; Insurance Considerations; Policies and Procedures; Economics; Public Health and Safety; Environmental Effects	y	1	6	6	n				y	7	5	35	y	1	2	2	n				n				n				n				n				y	7	5	35	y	7	5	35
Electric power																																												
Substations / Transformers *off-site*	Structural Integrity; Serviceability; Functionality; Operations & Maintenance; Emergency Response Risks; ; Policies and Procedures; Economics; Public Health and Safety;	y	1	6	6	n				y	7	2	14	y	7	6	42	y	2	6	12	y	4	6	24	y	7	1	7	y	3	6	18	n				n				n			
Transportation																																												
Roadway infrastructure *supply of resources/chemicals*	Structural Integrity; Serviceability; Functionality; Operations & Maintenance; Emergency Response Risks; Policies and Procedures; Economics; Public Health and Safety;	y	2	6	12	n				n				y	2	1	2	n				y	4	2	8	y	7	2	14	n				n				n				n			
Communications																																												
Telemetry *telephone / cell / broadband-data / radio-communication*	Structural Integrity; Serviceability; Functionality; Operations & Maintenance; Emergency Response Risks; Policies and Procedures; Economics; Public Health and Safety; Environmental Effects	n				n				n				y	7	3	21	y	2	3	6	y	4	2	8	y	7	1	7	y	3	6	18	n				n				n			

Group 2 Results:

Infrastructure Components	Performance Criteria	Severe Weather Event																																					
		Floods/ Ice Jamming/ Ice Buildup				High Temp				Low Temp				Intense Rain				Drought				Ice Storm				Blizzard (Snow)				Intense Wind/Tornado				Hail				Frost Penetration				Ground Water Table (Portage laPrairie)			
Administration/operations		Y/N	S_C	S_R	P_C	Y/N	S_C	S_R	P_C	Y/N	S_C	S_R	P_C	Y/N	S_C	S_R	P_C	Y/N	S_C	S_R	P_C	Y/N	S_C	S_R	P_C	Y/N	S_C	S_R	P_C	Y/N	S_C	S_R	P_C	Y/N	S_C	S_R	P_C	Y/N	S_C	S_R	P_C	Y/N	S_C	S_R	P_C
Personnel	Serviceability; Functionality; Operations & Maintenance; Emergency Response Risks; Insurance Considerations; Policies and Procedures; Public Health and Safety;	Y	3	3	9	Y	2	1	2	Y	7	1	7	Y	7	1	7					Y	2	3	6	Y	6	3	18	Y	2	6	12	Y	6	1	6								
Facilities/equipment	Structural Integrity; Serviceability; Functionality; Operations & Maintenance; Emergency Response Risks; Insurance Considerations; Policies and Procedures; Economics; Public Health and Safety; Environmental Effects	Y	5	5	25	Y	1	0	0	Y	7	1	7	Y	7	2	14					Y	2	4	8	Y	3	5	15	Y	2	7	14	Y	2	2	4	Y	1	1	1	Y	1	1	1
Source Water																																												
Intake Well / Pumps	Structural Integrity; Serviceability; Functionality; Operations & Maintenance; Emergency Response Risks; Insurance Considerations; Policies and Procedures; Economics; Public Health and Safety; Environmental Effects	Y	6	5	30	Y	1	6	6	Y	6	6	36					Y	2	6	12	Y	1	6	6																				
Treatment																																												
Softening/Clarification	Structural Integrity; Serviceability; Functionality; Operations & Maintenance; Emergency Response Risks; Insurance Considerations; Policies and Procedures; Economics; Public Health and Safety; Environmental Effects	Y	7	2	14	Y	7	2	14	Y	7	2	14	Y	6	2	12	Y	1	7	7																						
Distribution																																												
Pipelines, valves	Structural Integrity; Serviceability; Functionality; Operations & Maintenance; Emergency Response Risks; Insurance Considerations; Policies and Procedures; Economics; Public Health and Safety; Environmental Effects	Y	2	1	2									Y	5	2	10																					Y	7	4	28	Y	6	2	12
Electric power																																												
Substations / Transformers	Structural Integrity; Serviceability; Functionality; Operations & Maintenance; Emergency Response Risks; Insurance Considerations; Policies and Procedures; Economics; Public Health and Safety; Environmental Effects	Y	1	6	6	Y	7	5	35	Y	6	5	30	Y	6	5	30					Y	1	6	6	Y	2	7	14																
Transportation																																												
Roadway infrastructure	Structural Integrity; Serviceability; Functionality; Operations & Maintenance; Emergency Response Risks; Policies and Procedures; Public Health and Safety	Y	4	6	24									Y	5	2	10					Y	2	3	6	Y	6	4	24	Y	2	2	4					Y	6	1	6				
Communications																																												
Telemetry	Structural Integrity; Serviceability; Functionality; Operations & Maintenance; Emergency Response Risks; Insurance Considerations; Policies and Procedures; Economics; Public Health and Safety; Environmental Effects	Y	1	3	3									Y	6	2	12					Y	2	2	4	Y	6	4	24	Y	2	2	4												

Group 3 Results:

Infrastructure Components	Performance Criteria	Severe Weather Event																																					
		Floods/ Ice Jamming/ Ice Buildup				High Temp				Low Temp				Intense Rain / *Lightening*				Drought / *Fire*				Ice Storm				Blizzard (Snow)				Intense Wind/Tornado				Hail				Frost Penetration				Ground Water Table (Portage laPrairie)			
Administration/operations		Y/N	Sc	SR	Pc	Y/N	Sc	SR	Pc	Y/N	Sc	SR	Pc	Y/N	Sc	SR	Pc	Y/N	Sc	SR	Pc	Y/N	Sc	SR	Pc	Y/N	Sc	SR	Pc	Y/N	Sc	SR	Pc	Y/N	Sc	SR	Pc	Y/N	Sc	SR	Pc	Y/N	Sc	SR	Pc
Personnel	; Serviceability; Functionality; Operations & Maintenance; Emergency Response Risks; ; Policies and Procedures; Public Health and Safety;	Y	5/1.	1/6.	5/6.	Y	6/1.	5/3.	30/3.	Y	6/1.	4/2.	24/2.	Y	2/1.	2/0.	4/0.					Y	1/1.	2/5.	2/5.	Y	7/5.	2/2.	14/10.	Y	1/1.			Y	1/1.			Y	1/1.			Y	1/1.		
Facilities/equipment *chlorine gas leak*	Structural Integrity; Serviceability; Functionality; Operations & Maintenance; ; Insurance Considerations; Economics; Public Health and Safety; Environmental Effects	Y	4	6	24	Y	1			Y	1			Y	1							Y	1			Y	1			Y	1			Y	1			Y	2	3	6	Y	2	3	6
Source Water																																													
Intake Well / Pumps	Structural Integrity; Serviceability; Functionality; Operations & Maintenance; ; Insurance Considerations; Economics; Public Health and Safety;	Y	5	5	25					Y	2	2	4					Y	1	6																							
Treatment																																												
Softening/Clarification	; Operations & Maintenance; ; ; Policies and Procedures;	Y	2	1	2	n				y	7	1	7	y	6	1	6	y	3	3	9	y	2	4	8	n				y	2	6	12	n				n				n			
Distribution																																												
Pipelines, valves *one feedermain section*	Structural Integrity; Serviceability; Functionality; Operations & Maintenance; Emergency Response Risks; Insurance Considerations; Policies and Procedures; Economics; Public Health and Safety; Environmental Effects	y	1	6	6	n				y	7	5	35	y	1	2	2	n				n				n				n				n				y	7	5	35	y	7	5	35
Electric power																																												
Substations / Transformers *off-site*	Structural Integrity; Serviceability; Functionality; Operations & Maintenance; Emergency Response Risks; ; Policies and Procedures; Economics; Public Health and Safety;	y	1	6	6	n				y	7	2	14	y	7	6	42	y	2	6	12	y	4	6	24	y	7	1	7	y	3	6	18	n				n				n			
Transportation																																												
Roadway infrastructure *supply of resources/chemicals*	Structural Integrity; Serviceability; Functionality; Operations & Maintenance; Emergency Response Risks; Policies and Procedures; Economics; Public Health and Safety;	y	2	6	12	n				n				y	2	1	2	n				y	4	2	8	y	7	2	14	n				n				n				n			
Communications																																												
Telemetry *telephone / cell / broadband-data / radio-communication*	Structural Integrity; Serviceability; Functionality; Operations & Maintenance; Emergency Response Risks; Policies and Procedures; Economics; Public Health and Safety; Environmental Effects	n				n				n				y	7	3	21	y	2	3	6	y	4	2	8	y	7	1	7	y	3	6	18	n				n				n			

Figure 31: Workshop tabletop activity results

3.3.8.3 Workshop Participant Feedback and Discussion

The Workshop participants provided interesting and valuable feedback and also asked specific questions for consideration in the review of the execution of the Protocol. A summary of workshop participant feedback is provided below:

- Questions or Comments in the Workshop's morning presentations:
  - Pam Kertland said we should justify why we gave each piece of infrastructure a higher or lower rating for each climate effect. The Study Team replied that it would make for a cumbersome report if we provided a justification for each number. The report will include some discussion of methodologies, but will not contain discussion of detail pertaining to each single number.
  - Darryl Danyluk asked if there are common things that can be crossed off in the vulnerabilities? The Study Team replied that they started by considering everything, even things that they knew probably wouldn't be considered vulnerable, and let them screen themselves out as the Protocol was applied. Different systems will have different features, and different areas will have different climates and climate changes, so the approach should be not to exclude infrastructure components of climate events from consideration base on prejudgment of the results of our assessment.
  - Brian Kyle asked if the Protocol accounts for cumulative effects? Is there a way to account for consecutive weather events, or effects of one piece of infrastructure on other parts? The Study Team replied that there is not an explicit way for the Protocol to address these types of vulnerabilities. These could be implicitly accounted for using engineering judgment while assessing the individual components. Addition of cumulative effects is a recommended consideration for the Draft Protocol.

- Protocol Tabletop Activity (Workshop Afternoon Session):
  - Different groups applied the Protocol differently. Relationships that were determined to be of high or critical vulnerabilities by one group may have been given low or no priority by another group. This was in part due to different interpretation of the probability scale factors
  - There was confusion regarding the application of probability scale factors. People were confused to whether it was the probability of the climate event occurrence or the probability of the climate event affecting the climate effect. The Protocol dictates that probability scale factor represents the probability of a climate effect on the infrastructure component, not the probability of a weather event itself.

- **Group 1 General Commentary:**
  - Split flooding and ice jams into two separate categories.
  - Split field staff into field staff and plant staff
  - Added fire to the drought category
  - Considered the feeder line as a separate component from the rest of the distribution system
  - Found the terminology in "Method E" confusing, definitions describing the difference between the terms could be useful.
  - Table 7 could include environmental effects

- **Group 2 General Commentary:**
  - Added lightning to the "Intense Rain" weather event
  - For telemetry, some considered the presence of alternate solutions if one system failed, this created potential for a reduced severity of a given event.
  - This group debated whether the probability scale factors should be consistent for each component, or whether different probabilities should be applied to each infrastructure component. They tried it both ways and found that they had to apply different probabilities to different infrastructure components to get reasonable results.
  - The group suggested having tighter criteria for the yes/no part of the matrix.
  - The group found that the most important climate events were flooding/ice jamming (Facility), and low temperature (Intake wells/softening/electrical power because of demand), blizzards
  - Overall, they felt that the plant was quite resilient

- **Group 3 General Commentary:**
  - This group identified 26 infrastructure component relationships affected by potential climatic events, of which 3 of these had a Priority Value requiring advancement to Step 5 of the Protocol, 6 relationships relegated to Step 4 for further analysis and 17 relationships scoring low enough in their Priority Value to be discarded from further assessment. However, some of the low priorities had high severity and low probability, and members of this group felt there may still be risk associated with these relationships.
  - Overall, the operators felt that their operations and system components were quite resilient.
  - This group found that the pipelines and valve components were at risk and required more info for these areas
  - Most of the relationships identified were associated with infrastructure response by system components affected by events involving ice jams, ice storms, or tornadoes.

- Other comments noted during exercise:
  - Darryl Danyluk thought that since drought, frost and groundwater were longer duration events, the information could be better organized if theses longer duration event scenarios were placed together in the table.
  - David Lapp thought that assessors could streamline the data request process by ordering climatic data after the qualitative analysis was completed, this could provide the assessor with a more refined view of the climatic parameters of significance to a given facility and would potentially save you from ordering data that was not needed.
  - David Lapp also asked that the final report comment on the transferability of the Protocol to the other sectors; waste water treatment plant, roads, and buildings. i.e. for assessing roads, would you assess a 60 km stretch or a 6 km stretch?

- After the Workshop:

  – Kelly Braden raised the concern of the duration of an event such as a power outage at the plant or an ice jam at the intake. The longer duration events would be less probable, but have a higher severity factor. Brent Burton commented that an intense storm caused turbidity problems for Greater Vancouver's source watershed, where a shorter duration storm might not have.
  – David Lapp brought up the probability and impact of a combination of severe weather events. Is the protocol set up to handle this type of evaluation and if not, what changes would be needed? Could these be considered in the current evaluation?

3.3.9 Protocol Review and Assessment

A matrix was used in place of the suggested worksheet forms. The Protocol was executed in its intended manner, the matrix provided an easier platform to work with.

3.4 Step 4: Quantitative Analysis

As specified earlier in the Protocol, infrastructure components possessing relationship priority values greater than 12 and less than 36 were relegated to Step 4 of the Protocol. Step 4 requires the assessor to determine the relationship between the performance response loads placed on the infrastructure and its capacity. Vulnerability exists when infrastructure has insufficient capacity to withstand the effects placed on it. Resiliency of the infrastructure exists when a given component has sufficient capacity to withstand increasing climate change effects without experiencing effects that compromise the ability of the infrastructure to perform sufficiently to meet its performance goals.

Quantitative analysis results are presented in Table 41 for the Portage la Prairie infrastructure components.

3.4.1 Calculate the Existing Load (L_E)

Determination of the existing load on the infrastructure was based upon a set of relevant facility information including:

- Definitions;
- Direct measurements;
- Engineering calculations; or
- Assumptions based upon professional judgment.

3.4.2 Calculate Climate Change Load (L_C)

The Protocol required the assessor to calculate the climate change load placed on infrastructure components that were classified, based upon their relationship priority values, to require Step 4: Quantitative Assessment. These scenarios were represented by calculated priority values above 12 and less than 36. Values below 12 were considered to have negligible effects and values of 36 and above are considered to require immediate remedial attention for the preparedness of the facility. The Protocol dictated that climate change load on the infrastructure is determined on the basis of the following:

- Definitions;
- Direct measurements;
- Engineering calculations; or
- Assumptions based upon professional judgment.

3.4.3 Calculate Other Change Loads (L_O)

The Protocol required consideration of other Change Loads as appropriate into the determination of total load. Other relevant change loads were considered based on the following:

- Definitions;
- Direct measurements;
- Engineering calculations; or
- Assumptions based upon professional judgment.

3.4.4 Calculate Total Load (L_T)

The basis of determination of all loads is specified in the master Step 4 Table (Table 41). Once the infrastructure, climate and other change loads were determined, the Protocol required these to be summed to represent the total load where:

$$L_T = L_E + L_C + L_O,$$

where: $L_{T=}$ = Total load on the infrastructure
L_E = Existing load on the infrastructure
L_C = Load on the infrastructure resulting from climate change
L_O = Load on the infrastructure resulting from other changes.

3.4.5 Calculate the Existing Capacity (C_E)

The existing capacity of the infrastructure components selected for quantitative analysis was determined through a combination of sources, including:

- Definitions;
- Direct measurements;
- Engineering calculations; or
- Assumptions based on professional judgment.

3.4.6 Calculate the Maturing Change in Existing Capacity (C_M)

The Protocol required consideration of other maturing changes in existing capacity, as determined using the following information sources:

- Definitions;
- Direct measurements;
- Engineering calculations; or
- Assumptions based on professional judgment.

3.4.7 Calculate Additional Capacity (C_A)

The Protocol required consideration of other additional capacity as it may exist within a given infrastructure system, as determined using the following information sources:

- Definitions;
- Direct measurements;
- Engineering calculations; or
- Assumptions based on professional judgment.

3.4.8 Calculate the Total Capacity (C_T)

The basis of determination of all capacities is specified in the master Step 4 Table (Table 41). Once the capacities were determined, the Protocol required these to be summed to represent Total Capacity of the Infrastructure such that:

$$C_T = C_E + C_M + C_A,$$

where: $C_{T=}$ = Total capacity on the infrastructure

C_E= Existing capacity of the infrastructure
C_M= Maturing capacity of the infrastructure
C_A = Additional capacity of the infrastructure.

3.4.9 Evaluate Vulnerability

The vulnerability of the infrastructure components that were selected for quantitative analysis was calculated using the ratio:

$$V_R = \frac{L_T}{C_T},$$

where: V_R= Vulnerability Ratio
L_T= Total Load on the Infrastructure
C_T= Total Capacity of the infrastructure.

Where $V_R < 1$, the infrastructure component was vulnerable.

3.4.10 Evaluate Adaptive Capacity

Adaptive capacity of the infrastructure for components selected for analysis in Step 4 was determined using the ratio

$$A_R = \frac{C_T}{L_T},$$

where: A_R= Adaptive Capacity Ratio
C_T= Total Capacity of the Infrastructure
L_T= Total Load on the infrastructure.

Where $A_R > 1$, the infrastructure component had adaptive capacity.

3.4.11 Calculate Capacity Deficit

The Protocol required calculation of a capacity deficit for the infrastructure components that were subjected to quantitative analysis as part of Step 4. The capacity deficit is calculated via the following equation:

$$C_D = L_T - C_T$$

$$= L_T - (C_E + C_M + C_A),$$

where: C_D= Capacity deficit of the infrastructure component
L_T= Total load on the infrastructure component

C_E = Existing capacity of the infrastructure component
C_M = Maturing capacity of the infrastructure component
C_A = Additional capacity of the infrastructure component.

The capacity deficit is the amount of capacity that must be added to the infrastructure component to address the vulnerability identified in the application of the protocol.

3.4.12 Assess Data Sufficiency

Throughout the completion of Step 4 of the Protocol, the assessors are required to document where there is insufficient information currently available to complete a quantification of particular vulnerabilities of interest. Where data was found to be insufficient to conduct a quantitative analysis, the data deficiency was identified and stated in Table 41, summarizing the Step 4 analysis results.

3.4.13 Protocol Review and Assessment

A strong emphasis was placed on formulating climate data requirements due to the Protocol's requirement for Quantitative Analyses in Step 4 of the assessment. The importance of getting a data request list formulated and finalized was our first priority and was completed prior to the Study Team's finalizing of its Engagement Plan due to concerns that the Study Team would not have the ability to control the timing of delivery for our requested climatic data. This concern was justified, as the required data did not arrive during the course of the assessment period, rather preliminary data arrived just prior to the commencement of the Portage Workshop with draft final reports issued in September 2007.

Table 41: Quantitative analysis results

Infrastructure Component	Climate Variable	Data Source	Calculation of Total Load (L_T)				Calculation of Total Capacity (C_T)				Vulnerability (V_R)	STEP 5	Adaptive Capacity (A_R)	Capacity Deficit (C_D)	Comments/ Data Sufficiency
			Existing Load L_E	Climate Load L_C	Other Load L_O	Total Load L_E= L_E+L_C+L_O	Existing Capacity C_E	Maturing Capacity C_M	Additional Capacity C_A	Total Capacity C_T= C_E+C_M+C_A	V_R=L_T/C_T	Y/N	A_R=C_T/L_T	C_D=L_T-C_T	
Personnel	Floods/ Ice Jamming/ Ice Build-up	Data not available	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	3	n/a	n/a	Climate change projections were not available related to this climate variable. Other variables (snow, rain, temperature) have been used to provide a general indication of possible change.
			Assumption related to engineering judgment												
	Ice Storm	Data not available	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	3	n/a	n/a	Climate change projections were not available related to this climate variable. Additional data specific to Ice Storms is required.
			Assumption related to engineering judgment												
	Blizzard	Snow: 1 Day Frequency (20mm)													
		2020	0.001	-0.00015	0	0.00085	n/a	n/a	n/a	n/a	<1		>1	0	Data indicates less possibility of heavy snowfall and assumed related blizzards. It is assumed that the personnel have existing capability or adaptive capabilities.
		2050	0.001	0.00028	0	0.00128	n/a	n/a	n/a	n/a	<1		>1	0	Data indicates minor increase in the possibility of heavy snowfall and assumed related blizzards. It is assumed that the personnel have existing capability or adaptive capabilities.
		2080	0.001	-0.00004	0	0.00096	n/a	n/a	n/a	n/a	<1		>1	0	Data indicates less possibility of heavy snowfall and assumed related blizzards. It is assumed that the personnel have existing capability or adaptive capabilities.

Infrastructure Component	Climate Variable	Data Source	Calculation of Total Load (L_T)				Calculation of Total Capacity (C_T)				Vulnerability (V_R)	STEP 5	Adaptive Capacity (A_R)	Capacity Deficit (C_D)	Comments/ Data Sufficiency
			Existing Load L_E	Climate Load L_C	Other Load L_O	Total Load L_T= L_E+L_C+L_O	Existing Capacity C_E	Maturing Capacity C_M	Additional Capacity C_A	Total Capacity C_T= C_E+C_M+C_A	V_R=L_T/C_T	Y/N	A_R=C_T/L_T	C_D=L_T-C_T	
				Ratio based calculation - Lc=(ratio-1)Le			Assumption related to engineering judgment								
Facilities/ Equipment	High Temp	Temperature: Annual Max (Deg. C)													Electrical and controls equipment are the most vulnerable component for analysis.
		2020	35.2	2.2	0	37.4	40	0	0	40	0.935		1.0695187	0	
		2050	35.2	3.5	0	38.7	40	0	0	40	0.9675		1.0335917	0	
		2080	35.2	6	0	41.2	40	0	0	40	1.03	3	0.9708738	0	
			Annual Max Temperature	Change in Temperature (avg. ACU/ADC)			Electrical systems rated to 40 deg. C.								
	Low Temp	Temperature: Annual Min (Deg. C)													HVAC system is capable of keeping the building heated to min 10 deg. C. at -40 Deg. C. exterior temp.
		2020	-37.8	3.2	0	-34.6	-40	0	0	-40	0.865		1.1560694	0	
		2050	-37.8	5.8	0	-32	-40	0	0	-40	0.8		1.25	0	
		2080	-37.8	8.5	0	-29.3	-40	0	0	-40	0.7325		1.3651877	0	
							HVAC system rating								
	Intense Rain	Rain: Avg Max Rain 1 Day (mm)													
		2020	40.8	0.816	0	41.616	64.8	0	0	64.8	0.642222222		1.5570934		Typical drainage/ storm water design standard - 5 year storm.
		2050	40.8	5.304	0	46.104	64.8	0	0	64.8	0.711481481		1.405518		Typical drainage/ storm water design standard - 5 year storm.
		2080	40.8	5.304	0	46.104	64.8	0	0	64.8	0.711481481		1.405518		Typical drainage/ storm water design standard - 5 year storm.
				Ratio based calculation - Lc=(ratio-1)Le			Environment Canada IDF curve 5 years return period, 24 hrs.								
	Blizzard	Snow: 1 Day Frequency (20mm)													

Infrastructure Component	Climate Variable	Data Source	Calculation of Total Load (L_T)				Calculation of Total Capacity (C_T)				Vulnerability (V_R)	STEP 5	Adaptive Capacity (A_R)	Capacity Deficit (C_D)	Comments/ Data Sufficiency
			Existing Load L_E	Climate Load L_C	Other Load L_O	Total Load L_T= L_E+L_C+L_O	Existing Capacity C_E	Maturing Capacity C_M	Additional Capacity C_A	Total Capacity C_T= C_E+C_M+C_A	V_R=L_T/C_T	Y/N	A_R=C_T/L_T	C_D=L_T-C_T	
		2020	0.001	-0.00015	0	0.00085	n/a	n/a	n/a	n/a	<1		>1	0	Data indicates less possibility of heavy snowfall and assumed related blizzards. It is assumed that the facilities have existing capability or adaptive capabilities.
		2050	0.001	0.00028	0	0.00128	n/a	n/a	n/a	n/a	<1		>1	0	Data indicates minor increase in the possibility of heavy snowfall and assumed related blizzards. It is assumed that the facilities have existing capability or adaptive capabilities.
		2080	0.001	-0.00004	0	0.00096	n/a	n/a	n/a	n/a	<1		>1	0	Data indicates less possibility of heavy snowfall and assumed related blizzards. It is assumed that the facilities have existing capability or adaptive capabilities.
				Ratio based calculation - Lc=(ratio-1)Le			Assumption related to engineering judgment								
Shellmouth Dam/ Reservoir	Drought	Rain: Avg Total Rain, Annual Plus Snow: Avg Total, Annual (mm)													
		2020	436	-2.88	0	433.12	n/a	n/a	n/a	n/a	<1	3	>1	0	Climate change projections were not available related to this climate variable. Additional data specific to drought and related stream flow on the Assiniboine is required.
		2050	436	25.7	0	461.7	n/a	n/a	n/a	n/a	<1	3	>1	0	Climate change projections were not available related to this climate variable. Additional data specific to drought and related stream flow on the Assiniboine is required.
		2080	436	21.16	0	457.16	n/a	n/a	n/a	n/a	<1	3	>1	0	Climate change projections were not available related to this climate variable. Additional data specific to drought and related stream flow on the Assiniboine is required.
				Ratio based calculation - Lc=(ratio-1)Le			Assumption related to engineering judgment								

Infrastructure Component	Climate Variable	Data Source	Calculation of Total Load (L_T)				Calculation of Total Capacity (C_T)				Vulnerability (V_R)	STEP 5	Adaptive Capacity (A_R)	Capacity Deficit (C_D)	Comments/ Data Sufficiency
			Existing Load L_E	Climate Load L_C	Other Load L_O	Total Load $L_T = L_E+L_C+L_O$	Existing Capacity C_E	Maturing Capacity C_M	Additional Capacity C_A	Total Capacity $C_T = C_E+C_M+C_A$	$V_R=L_T/C_T$	Y/N	$A_R=C_T/L_T$	$C_D=L_T-C_T$	
Assiniboine River System	Drought	Rain: Avg Total Rain, Annual Plus Snow: Avg Total, Annual (mm)													
		2020	436	-2.88	0	433.12	n/a	n/a	n/a	n/a	<1	3	>1	0	Climate change projections were not available related to this climate variable. Additional data specific to drought and related stream flow on the Assiniboine is required.
		2050	436	25.7	0	461.7	n/a	n/a	n/a	n/a	<1	3	>1	0	Climate change projections were not available related to this climate variable. Additional data specific to drought and related stream flow on the Assiniboine is required.
		2080	436	21.16	0	457.16	n/a	n/a	n/a	n/a	<1	3	>1	0	Climate change projections were not available related to this climate variable. Additional data specific to drought and related stream flow on the Assiniboine is required.
				Ratio based calculation - Lc=(ratio-1)Le			Assumption related to engineering judgment								
Dam Structure	Intense Wind/ Tornado	Data not available	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	3	n/a	n/a	Climate change projections were not available related to this climate variable. Other variables were also not sufficient to provide general indication of possible change.
			Assumption related to engineering judgment												
Pre-treatment	Floods/ Ice Jamming/ Ice Build-up	Data not available	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	3	n/a	n/a	Climate change projections were not available related to this climate variable. Other variables (snow, rain, temperature) have been used to provide a general indication of possible change. Data related to water quality in the event of Floods/ Ice Jamming/ Ice Build-up is required.
			Assumption related to engineering judgment												

Infrastructure Component	Climate Variable	Data Source	Calculation of Total Load (L_T)				Calculation of Total Capacity (C_T)				Vulnerability (V_R)	STEP 5	Adaptive Capacity (A_R)	Capacity Deficit (C_D)	Comments/ Data Sufficiency
			Existing Load L_E	Climate Load L_C	Other Load L_O	Total Load $L_T = L_E+L_C+L_O$	Existing Capacity C_E	Maturing Capacity C_M	Additional Capacity C_A	Total Capacity $C_T = C_E+C_M+C_A$	$V_R=L_T/C_T$	Y/N	$A_R=C_T/L_T$	$C_D=L_T-C_T$	
		Temperature: Annual Max (Deg. C)													Electrical and controls equipment are the most vulnerable component for analysis.
		2020	35.2	2.2	0	37.4	40	0	0	40	0.935		1.0695187	0	
		2050	35.2	3.5	0	38.7	40	0	0	40	0.9675		1.0335917	0	
		2080	35.2	6	0	41.2	40	0	0	40	1.03	3	0.9708738	0	Climate change projections were not available related to climate variable for raw water temperatures which was the basis of the vulnerability assumption. Data related to water quality in the event of high temperatures and elevated raw water temperatures is required.
			Annual Max Temperature	Change in Temperature (avg. ACU/ADC)			Process equipment treatability rating (assumption)								
	Low Temp	Temperature: Annual Min (Deg. C)													Climate change projections were not available related to climate variable for raw water temperatures which was the basis of the vulnerability assumption. Other variables (ambient air low temperature) have been used to provide a general indication of possible change. Based on this assumption and the trend to less extreme low temperatures, a lower vulnerability exists.
		2020	-37.8	3.2	0	-34.6	-40	0	0	-40	0.865		1.1560694	0	
		2050	-37.8	5.8	0	-32	-40	0	0	-40	0.8		1.25	0	
		2080	-37.8	8.5	0	-29.3	-40	0	0	-40	0.7325		1.3651877	0	
							Process equipment treatability rating (assumption)								

Infrastructure Component	Climate Variable	Data Source	Calculation of Total Load (L_T)				Calculation of Total Capacity (C_T)				Vulnerability (V_R)	STEP 5	Adaptive Capacity (A_R)	Capacity Deficit (C_D)	Comments/ Data Sufficiency
			Existing Load L_E	Climate Load L_C	Other Load L_O	Total Load $L_T = L_E+L_C+L_O$	Existing Capacity C_E	Maturing Capacity C_M	Additional Capacity C_A	Total Capacity $C_T = C_E+C_M+C_A$	$V_R=L_T/C_T$	Y/N	$A_R=C_T/L_T$	$C_D=L_T-C_T$	
	Drought	Rain: Avg Total Rain, Annual Plus Snow: Avg Total, Annual (mm)													
		2020	436	-2.88	0	433.12	n/a	n/a	n/a	n/a	<1	3	>1	0	Climate change projections were not available related to this climate variable. Additional data specific to drought and related stream flow on the Assiniboine is required.
		2050	436	25.7	0	461.7	n/a	n/a	n/a	n/a	<1	3	>1	0	Climate change projections were not available related to this climate variable. Additional data specific to drought and related stream flow on the Assiniboine is required.
		2080	436	21.16	0	457.16	n/a	n/a	n/a	n/a	<1	3	>1	0	Climate change projections were not available related to this climate variable. Additional data specific to drought and related stream flow on the Assiniboine is required.
				Ratio based calculation - Lc=(ratio-1)Le			Assumption related to engineering judgment								
Softening	High Temp	Temperature: Annual Max (Deg. C)													Electrical and controls equipment are the most vulnerable component for analysis.
		2020	35.2	2.2	0	37.4	40	0	0	40	0.935		1.0695187	0	
		2050	35.2	3.5	0	38.7	40	0	0	40	0.9675		1.0335917	0	
		2080	35.2	6	0	41.2	40	0	0	40	1.03	3	0.9708738	0	Climate change projections were not available related to climate variable for raw water temperatures which was the basis of the vulnerability assumption. Data related to water quality in the event of high temperatures and elevated raw water temperatures is required.
			Annual Max Temperature	Change in Temperature (avg. ACU/ADC)			Process equipment treatability rating (assumption)								

Infrastructure Component	Climate Variable	Data Source	Calculation of Total Load (L_T)				Calculation of Total Capacity (C_T)				Vulnerability (V_R)	STEP 5	Adaptive Capacity (A_R)	Capacity Deficit (C_D)	Comments/ Data Sufficiency
			Existing Load L_E	Climate Load L_C	Other Load L_O	Total Load $L_T = L_E+L_C+L_O$	Existing Capacity C_E	Maturing Capacity C_M	Additional Capacity C_A	Total Capacity $C_T = C_E+C_M+C_A$	$V_R=L_T/C_T$	Y/N	$A_R=C_T/L_T$	$C_D=L_T-C_T$	
	Low Temp	Temperature: Annual Min (Deg. C)													Climate change projections were not available related to climate variable for raw water temperatures which was the basis of the vulnerability assumption. Other variables (ambient air low temperature) have been used to provide a general indication of possible change. Based on this assumption and the trend to less extreme low temperatures, a lower vulnerability exists.
		2020	-37.8	3.2	0	-34.6	-40	0	0	-40	0.865		1.1560694	0	
		2050	-37.8	5.8	0	-32	-40	0	0	-40	0.8		1.25	0	
		2080	-37.8	8.5	0	-29.3	-40	0	0	-40	0.7325		1.3651877	0	
							Process equipment treatability rating (assumption)								
	Drought	Rain: Avg Total Rain, Annual Plus Snow: Avg Total, Annual (mm)													
		2020	436	-2.88	0	433.12	n/a	n/a	n/a	n/a	<1	3	>1	0	Climate change projections were not available related to this climate variable. Additional data specific to drought and related stream flow on the Assiniboine is required.
		2050	436	25.7	0	461.7	n/a	n/a	n/a	n/a	<1	3	>1	0	Climate change projections were not available related to this climate variable. Additional data specific to drought and related stream flow on the Assiniboine is required.
		2080	436	21.16	0	457.16	n/a	n/a	n/a	n/a	<1	3	>1	0	Climate change projections were not available related to this climate variable. Additional data specific to drought and related stream flow on the Assiniboine is required.
				Ratio based calculation - Lc=(ratio-1)Le			Assumption related to engineering judgment								

Infrastructure Component	Climate Variable	Data Source	Calculation of Total Load (L_T)				Calculation of Total Capacity (C_T)				Vulnerability (V_R)	STEP 5	Adaptive Capacity (A_R)	Capacity Deficit (C_D)	Comments/ Data Sufficiency
			Existing Load L_E	Climate Load L_C	Other Load L_O	Total Load $L_T = L_E+L_C+L_O$	Existing Capacity C_E	Maturing Capacity C_M	Additional Capacity C_A	Total Capacity $C_T = C_E+C_M+C_A$	$V_R=L_T/C_T$	Y/N	$A_R=C_T/L_T$	$C_D=L_T-C_T$	
Disinfection	Low Temp	Temperature: Annual Min (Deg. C)													Climate change projections were not available related to climate variable for raw water temperatures which was the basis of the vulnerability assumption. Other variables (ambient air low temperature) have been used to provide a general indication of possible change. Based on this assumption and the trend to less extreme low temperatures, a lower vulnerability exists. Low water temperatures reduce the effectiveness of disinfection.
		2020	-37.8	3.2	0	-34.6	-40	0	0	-40	0.865		1.1560694	0	
		2050	-37.8	5.8	0	-32	-40	0	0	-40	0.8		1.25	0	
		2080	-37.8	8.5	0	-29.3	-40	0	0	-40	0.7325		1.3651877	0	
							Process equipment treatability rating (assumption)								
Storage	Drought	Rain: Avg Total Rain, Annual Plus Snow: Avg Total, Annual (mm)													
		2020	436	-2.88	0	433.12	n/a	n/a	n/a	n/a	<1	3	>1	0	Climate change projections were not available related to this climate variable. Additional data specific to drought and related stream flow on the Assiniboine is required.
		2050	436	25.7	0	461.7	n/a	n/a	n/a	n/a	<1	3	>1	0	Climate change projections were not available related to this climate variable. Additional data specific to drought and related stream flow on the Assiniboine is required.
		2080	436	21.16	0	457.16	n/a	n/a	n/a	n/a	<1	3	>1	0	Climate change projections were not available related to this climate variable. Additional data specific to drought and related stream flow on the Assiniboine is required.
				Ratio based calculation - Lc=(ratio-1)Le			Assumption related to engineering judgment								

Infrastructure Component	Climate Variable	Data Source	Calculation of Total Load (L_T)				Calculation of Total Capacity (C_T)				Vulnerability (V_R)	STEP 5	Adaptive Capacity (A_R)	Capacity Deficit (C_D)	Comments/ Data Sufficiency
			Existing Load L_E	Climate Load L_C	Other Load L_O	Total Load $L_T = L_E+L_C+L_O$	Existing Capacity C_E	Maturing Capacity C_M	Additional Capacity C_A	Total Capacity $C_T = C_E+C_M+C_A$	$V_R=L_T/C_T$	Y/N	$A_R=C_T/L_T$	$C_D=L_T-C_T$	
Valves Pipelines (on WTP site)	Floods/ Ice Jamming/ Ice Build-up	Data not available	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	3	n/a	n/a	Climate change projections were not available related to this climate variable. Other variables (snow, rain, temperature) have been used to provide a general indication of possible change.
			Assumption related to engineering judgment												
	Low Temp	Temperature: Annual Min (Deg. C)													Data indicates that less extreme low temperatures are projected reducing the load on the infrastructure from its current baseline. It is assumed that the existing piping and appurtenances have existing capability or adaptive capabilities.
		2020	-37.8	3.2	0	-34.6	-40	0	0	-40	0.865		1.1560694	0	
		2050	-37.8	5.8	0	-32	-40	0	0	-40	0.8		1.25	0	
		2080	-37.8	8.5	0	-29.3	-40	0	0	-40	0.7325		1.3651877	0	
							Infrastructure system rating (assumption)								
	Drought	Rain: Avg Total Rain, Annual Plus Snow: Avg Total, Annual (mm)													
		2020	436	-2.88	0	433.12	n/a	n/a	n/a	n/a	<1		>1	0	Data indicates slightly lower precipitation from its current baseline. It is assumed that the existing piping and appurtenances have existing capability or adaptive capabilities. The basis of the vulnerability review is the related soil moisture (from precipitation) affecting bedding of the piping systems and the piping structural integrity.

Infrastructure Component	Climate Variable	Data Source	Calculation of Total Load (L_T)				Calculation of Total Capacity (C_T)				Vulnerability (V_R)	STEP 5	Adaptive Capacity (A_R)	Capacity Deficit (C_D)	Comments/ Data Sufficiency
			Existing Load L_E	Climate Load L_C	Other Load L_O	Total Load $L_T = L_E+L_C+L_O$	Existing Capacity C_E	Maturing Capacity C_M	Additional Capacity C_A	Total Capacity $C_T = C_E+C_M+C_A$	$V_R=L_T/C_T$	Y/N	$A_R=C_T/L_T$	$C_D=L_T-C_T$	
		2050	436	25.7	0	461.7	n/a	n/a	n/a	n/a	<1		>1	0	Data indicates slightly higher precipitation from its current baseline. It is assumed that the existing piping and appurtenances have existing capability or adaptive capabilities. The basis of the vulnerability review is the related soil moisture (from precipitation) affecting bedding of the piping systems and the piping structural integrity.
		2080	436	21.16	0	457.16	n/a	n/a	n/a	n/a	<1		>1	0	Data indicates slightly higher precipitation from its current baseline. It is assumed that the existing piping and appurtenances have existing capability or adaptive capabilities. The basis of the vulnerability review is the related soil moisture (from precipitation) affecting bedding of the piping systems and the piping structural integrity.
				Ratio based calculation - Lc=(ratio-1)Le			Assumption related to engineering judgment								
	Blizzard	Snow: 1 Day Frequency (20mm)													
		2020	0.001	-0.00015	0	0.00085	n/a	n/a	n/a	n/a	<1		>1	0	Data indicates less possibility of heavy snowfall and assumed related blizzards. It is assumed that the infrastructure has existing capability or adaptive capabilities.
		2050	0.001	0.00028	0	0.00128	n/a	n/a	n/a	n/a	<1		>1	0	Data indicates minor increase in the possibility of heavy snowfall and assumed related blizzards. It is assumed that the infrastructure has existing capability or adaptive capabilities.
		2080	0.001	-0.00004	0	0.00096	n/a	n/a	n/a	n/a	<1		>1	0	Data indicates less possibility of heavy snowfall and assumed related blizzards. It is assumed that the infrastructure has existing capability or adaptive capabilities.
				Ratio based calculation - Lc=(ratio-1)Le			Assumption related to engineering judgment								

Infrastructure Component	Climate Variable	Data Source	Calculation of Total Load (L_T)				Calculation of Total Capacity (C_T)				Vulnerability (V_R)	STEP 5	Adaptive Capacity (A_R)	Capacity Deficit (C_D)	Comments/ Data Sufficiency
			Existing Load L_E	Climate Load L_C	Other Load L_O	Total Load $L_T = L_E+L_C+L_O$	Existing Capacity C_E	Maturing Capacity C_M	Additional Capacity C_A	Total Capacity $C_T = C_E+C_M+C_A$	$V_R=L_T/C_T$	Y/N	$A_R=C_T/L_T$	$C_D=L_T-C_T$	
	Frost Penetration	Frost: Season Length (Days)													
		2020	144.5	-12.15	0	132.35	n/a	n/a	n/a	n/a	<1		>1	0	Data indicates a shorter frost season with increased precipitation (snow plus rain), which may lead to reduced frost penetration. It is assumed that the infrastructure has existing capability or adaptive capabilities.
		2050	144.5	-20.2	0	124.3	n/a	n/a	n/a	n/a	<1		>1	0	Data indicates a shorter frost season with increased precipitation (snow plus rain), which may lead to reduced frost penetration. It is assumed that the infrastructure has existing capability or adaptive capabilities.
		2080	144.5	-29.82	0	114.68	n/a	n/a	n/a	n/a	<1		>1	0	Data indicates a shorter frost season with increased precipitation (snow plus rain), which may lead to reduced frost penetration. It is assumed that the infrastructure has existing capability or adaptive capabilities.
				(avg. ACU/ADC)			Assumption related to engineering judgment								
	Ground Water Table	Rain: Avg Total Rain, Annual Plus Snow: Avg Total, Annual (mm)													
		2020	436	-2.88	0	433.12	n/a	n/a	n/a	n/a	<1		>1	0	Data indicates slightly lower precipitation from its current baseline. It is assumed that the existing piping and appurtenances have existing capability or adaptive capabilities. The basis of the vulnerability review is the groundwater table (from precipitation) affecting bedding of the piping systems and the piping structural integrity.

Infrastructure Component	Climate Variable	Data Source	Calculation of Total Load (L_T)				Calculation of Total Capacity (C_T)				Vulnerability (V_R)	STEP 5	Adaptive Capacity (A_R)	Capacity Deficit (C_D)	Comments/ Data Sufficiency
			Existing Load L_E	Climate Load L_C	Other Load L_O	Total Load L_T= L_E+L_C+L_O	Existing Capacity C_E	Maturing Capacity C_M	Additional Capacity C_A	Total Capacity C_T= C_E+C_M+C_A	V_R=L_T/C_T	Y/N	A_R=C_T/L_T	C_D=L_T-C_T	
		2050	436	25.7	0	461.7	n/a	n/a	n/a	n/a	<1		>1	0	Data indicates slightly higher precipitation from its current baseline. It is assumed that the existing piping and appurtenances have existing capability or adaptive capabilities. The basis of the vulnerability review is the groundwater table (from precipitation) affecting bedding of the piping systems and the piping structural integrity.
		2080	436	21.16	0	457.16	n/a	n/a	n/a	n/a	<1		>1	0	Data indicates slightly higher precipitation from its current baseline. It is assumed that the existing piping and appurtenances have existing capability or adaptive capabilities. The basis of the vulnerability review is the groundwater table (from precipitation) affecting bedding of the piping systems and the piping structural integrity.
Pump Stations (WTP/ McKay)	Floods/ Ice Jamming/ Ice Build-up up	Data not available	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	3	n/a	n/a	Climate change projections were not available related to this climate variable. Other variables (snow, rain, temperature) have been used to provide a general indication of possible change.
			Assumption related to engineering judgment												
	High Temp	Temperature: Annual Max (Deg. C)													Electrical and controls equipment are the most vulnerable component for analysis.
		2020	35.2	2.2	0	37.4	40	0	0	40	0.935		1.0695187	0	
		2050	35.2	3.5	0	38.7	40	0	0	40	0.9675		1.0335917	0	
		2080	35.2	6	0	41.2	40	0	0	40	1.03	3	0.9708738	0	
			Annual Max Temperature	Change in Temperature (avg. ACU/ADC)			Electrical systems rated to 40 deg. C.								
	Blizzard	Snow: 1 Day Frequency (20mm)													

Infrastructure Component	Climate Variable	Data Source	Calculation of Total Load (L_T)				Calculation of Total Capacity (C_T)				Vulnerability (V_R)	STEP 5	Adaptive Capacity (A_R)	Capacity Deficit (C_D)	Comments/ Data Sufficiency
			Existing Load L_E	Climate Load L_C	Other Load L_O	Total Load $L_T = L_E+L_C+L_O$	Existing Capacity C_E	Maturing Capacity C_M	Additional Capacity C_A	Total Capacity $C_T = C_E+C_M+C_A$	$V_R=L_T/C_T$	Y/N	$A_R=C_T/L_T$	$C_D=L_T-C_T$	
		2020	0.001	-0.00015	0	0.00085	n/a	n/a	n/a	n/a	<1		>1	0	Data indicates less possibility of heavy snowfall and assumed related blizzards. It is assumed that the facilities have existing capability or adaptive capabilities.
		2050	0.001	0.00028	0	0.00128	n/a	n/a	n/a	n/a	<1		>1	0	Data indicates minor increase in the possibility of heavy snowfall and assumed related blizzards. It is assumed that the facilities have existing capability or adaptive capabilities.
		2080	0.001	-0.00004	0	0.00096	n/a	n/a	n/a	n/a	<1		>1	0	Data indicates less possibility of heavy snowfall and assumed related blizzards. It is assumed that the facilities have existing capability or adaptive capabilities.
				Ratio based calculation - Lc=(ratio-1)Le			Assumption related to engineering judgment								
Pipelines and Valves	Floods/ Ice Jamming/ Ice Build-up up	Data not available	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	3	n/a	n/a	Climate change projections were not available related to this climate variable. Other variables (snow, rain, temperature) have been used to provide a general indication of possible change.
			Assumption related to engineering judgment												
	Low Temp	Temperature: Annual Min (Deg. C)													Data indicates that less extreme low temperatures are projected reducing the load on the infrastructure from its current baseline. It is assumed that the existing piping and appurtenances have existing capability or adaptive capabilities.
		2020	-37.8	3.2	0	-34.6	-40	0	0	-40	0.865		1.1560694	0	
		2050	-37.8	5.8	0	-32	-40	0	0	-40	0.8		1.25	0	
		2080	-37.8	8.5	0	-29.3	-40	0	0	-40	0.7325		1.3651877	0	

Infrastructure Component	Climate Variable	Data Source	Calculation of Total Load (L_T)				Calculation of Total Capacity (C_T)				Vulnerability (V_R)	STEP 5	Adaptive Capacity (A_R)	Capacity Deficit (C_D)	Comments/ Data Sufficiency
			Existing Load L_E	Climate Load L_C	Other Load L_O	Total Load L_T= L_E+L_C+L_O	Existing Capacity C_E	Maturing Capacity C_M	Additional Capacity C_A	Total Capacity C_T= C_E+C_M+C_A	V_R=L_T/C_T	Y/N	A_R=C_T/L_T	C_D=L_T-C_T	
							Infrastructure system rating (assumption)								
	Drought	Rain: Avg Total Rain, Annual Plus Snow: Avg Total, Annual (mm)													
		2020	436	-2.88	0	433.12	n/a	n/a	n/a	n/a	<1		>1	0	Data indicates slightly lower precipitation from its current baseline. It is assumed that the existing piping and appurtenances have existing capability or adaptive capabilities. The basis of the vulnerability review is the related soil moisture (from precipitation) affecting bedding of the piping systems and the piping structural integrity.
		2050	436	25.7	0	461.7	n/a	n/a	n/a	n/a	<1		>1	0	Data indicates slightly higher precipitation from its current baseline. It is assumed that the existing piping and appurtenances have existing capability or adaptive capabilities. The basis of the vulnerability review is the related soil moisture (from precipitation) affecting bedding of the piping systems and the piping structural integrity.
		2080	436	21.16	0	457.16	n/a	n/a	n/a	n/a	<1		>1	0	Data indicates slightly higher precipitation from its current baseline. It is assumed that the existing piping and appurtenances have existing capability or adaptive capabilities. The basis of the vulnerability review is the related soil moisture (from precipitation) affecting bedding of the piping systems and the piping structural integrity.
				Ratio based calculation - Lc=(ratio-1)Le			Assumption related to engineering judgment								

Infrastructure Component	Climate Variable	Data Source	Calculation of Total Load (L_T)				Calculation of Total Capacity (C_T)				Vulnerability (V_R)	STEP 5	Adaptive Capacity (A_R)	Capacity Deficit (C_D)	Comments/ Data Sufficiency
			Existing Load L_E	Climate Load L_C	Other Load L_O	Total Load $L_T = L_E+L_C+L_O$	Existing Capacity C_E	Maturing Capacity C_M	Additional Capacity C_A	Total Capacity $C_T = C_E+C_M+C_A$	$V_R = L_T/C_T$	Y/N	$A_R = C_T/L_T$	$C_D = L_T-C_T$	
	Blizzard	Snow: 1 Day Frequency (20mm)													
		2020	0.001	-0.00015	0	0.00085	n/a	n/a	n/a	n/a	<1		>1	0	Data indicates less possibility of heavy snowfall and assumed related blizzards. It is assumed that the infrastructure has existing capability or adaptive capabilities.
		2050	0.001	0.00028	0	0.00128	n/a	n/a	n/a	n/a	<1		>1	0	Data indicates minor increase in the possibility of heavy snowfall and assumed related blizzards. It is assumed that the infrastructure has existing capability or adaptive capabilities.
		2080	0.001	-0.00004	0	0.00096	n/a	n/a	n/a	n/a	<1		>1	0	Data indicates less possibility of heavy snowfall and assumed related blizzards. It is assumed that the infrastructure has existing capability or adaptive capabilities.
				Ratio based calculation - Lc=(ratio-1)Le			Assumption related to engineering judgment								
	Frost Penetration	Frost: Season Length (days)													
		2020	144.5	-12.15	0	132.35	n/a	n/a	n/a	n/a	<1		>1	0	Data indicates a shorter frost season with increased precipitation (snow plus rain), which may lead to reduced frost penetration. It is assumed that the infrastructure has existing capability or adaptive capabilities.
		2050	144.5	-20.2	0	124.3	n/a	n/a	n/a	n/a	<1		>1	0	Data indicates a shorter frost season with increased precipitation (snow plus rain), which may lead to reduced frost penetration. It is assumed that the infrastructure has existing capability or adaptive capabilities.
		2080	144.5	-29.82	0	114.68	n/a	n/a	n/a	n/a	<1		>1	0	Data indicates a shorter frost season with increased precipitation (snow plus rain), which may lead to reduced frost penetration. It is assumed that the infrastructure has existing capability or adaptive capabilities.

Infrastructure Component	Climate Variable	Data Source	Calculation of Total Load (L_T)				Calculation of Total Capacity (C_T)				Vulnerability (V_R)	STEP 5	Adaptive Capacity (A_R)	Capacity Deficit (C_D)	Comments/ Data Sufficiency
			Existing Load L_E	Climate Load L_C	Other Load L_O	Total Load L_T= L_E+L_C+L_O	Existing Capacity C_E	Maturing Capacity C_M	Additional Capacity C_A	Total Capacity C_T= C_E+C_M+C_A	V_R=L_T/C_T	Y/N	A_R=C_T/L_T	C_D=L_T-C_T	
				(avg. ACU/ADC)			Assumption related to engineering judgment								
	Ground Water Table	Rain: Avg Total Rain, Annual Plus Snow: Avg Total, Annual (mm)													
		2020	436	-2.88	0	433.12	n/a	n/a	n/a	n/a	<1		>1	0	Data indicates slightly lower precipitation from its current baseline. It is assumed that the existing piping and appurtenances have existing capability or adaptive capabilities. The basis of the vulnerability review is the groundwater table (from precipitation) affecting bedding of the piping systems and the piping structural integrity.
		2050	436	25.7	0	461.7	n/a	n/a	n/a	n/a	<1		>1	0	Data indicates slightly higher precipitation from its current baseline. It is assumed that the existing piping and appurtenances have existing capability or adaptive capabilities. The basis of the vulnerability review is the groundwater table (from precipitation) affecting bedding of the piping systems and the piping structural integrity.
		2080	436	21.16	0	457.16	n/a	n/a	n/a	n/a	<1		>1	0	Data indicates slightly higher precipitation from its current baseline. It is assumed that the existing piping and appurtenances have existing capability or adaptive capabilities. The basis of the vulnerability review is the groundwater table (from precipitation) affecting bedding of the piping systems and the piping structural integrity.
Pipe Materials	Drought	Rain: Avg Total Rain, Annual Plus Snow: Avg Total, Annual (mm)													

Infrastructure Component	Climate Variable	Data Source	Calculation of Total Load (L_T)				Calculation of Total Capacity (C_T)				Vulnerability (V_R)	STEP 5	Adaptive Capacity (A_R)	Capacity Deficit (C_D)	Comments/ Data Sufficiency
			Existing Load L_E	Climate Load L_C	Other Load L_O	Total Load $L_T = L_E+L_C+L_O$	Existing Capacity C_E	Maturing Capacity C_M	Additional Capacity C_A	Total Capacity $C_T = C_E+C_M+C_A$	$V_R=L_T/C_T$	Y/N	$A_R=C_T/L_T$	$C_D=L_T-C_T$	
		2020	436	-2.88	0	433.12	n/a	n/a	n/a	n/a	<1		>1	0	Data indicates slightly lower precipitation from its current baseline. It is assumed that the existing piping and appurtenances have existing capability or adaptive capabilities. The basis of the vulnerability review is the related soil moisture (from precipitation) affecting bedding of the piping systems and the piping structural integrity. Ductile and cast iron piping is more vulnerable to soil moisture changes.
		2050	436	25.7	0	461.7	n/a	n/a	n/a	n/a	<1		>1	0	Data indicates slightly higher precipitation from its current baseline. It is assumed that the existing piping and appurtenances have existing capability or adaptive capabilities. The basis of the vulnerability review is the related soil moisture (from precipitation) affecting bedding of the piping systems and the piping structural integrity. Ductile and cast iron piping is more vulnerable to soil moisture changes.
		2080	436	21.16	0	457.16	n/a	n/a	n/a	n/a	<1		>1	0	Data indicates slightly higher precipitation from its current baseline. It is assumed that the existing piping and appurtenances have existing capability or adaptive capabilities. The basis of the vulnerability review is the related soil moisture (from precipitation) affecting bedding of the piping systems and the piping structural integrity. Ductile and cast iron piping is more vulnerable to soil moisture changes.
				Ratio based calculation - Lc=(ratio-1)Le			Assumption related to engineering judgment								
	Frost Penetration	Frost: Season Length (days)													
		2020	144.5	-12.15	0	132.35	n/a	n/a	n/a	n/a	<1		>1	0	Data indicates a shorter frost season with increased precipitation (snow plus rain), which may lead to reduced frost penetration. It is assumed that the infrastructure has existing capability or adaptive capabilities.

Infrastructure Component	Climate Variable	Data Source	Calculation of Total Load (L_T)				Calculation of Total Capacity (C_T)				Vulnerability (V_R)	STEP 5	Adaptive Capacity (A_R)	Capacity Deficit (C_D)	Comments/ Data Sufficiency
			Existing Load L_E	Climate Load L_C	Other Load L_O	Total Load $L_T = L_E+L_C+L_O$	Existing Capacity C_E	Maturing Capacity C_M	Additional Capacity C_A	Total Capacity $C_T = C_E+C_M+C_A$	$V_R=L_T/C_T$	Y/N	$A_R=C_T/L_T$	$C_D=L_T-C_T$	
		2050	144.5	-20.2	0	124.3	n/a	n/a	n/a	n/a	<1		>1	0	Data indicates a shorter frost season with increased precipitation (snow plus rain), which may lead to reduced frost penetration. It is assumed that the infrastructure has existing capability or adaptive capabilities.
		2080	144.5	-29.82	0	114.68	n/a	n/a	n/a	n/a	<1		>1	0	Data indicates a shorter frost season with increased precipitation (snow plus rain), which may lead to reduced frost penetration. It is assumed that the infrastructure has existing capability or adaptive capabilities.
				(avg. ACU/ADC)			Assumption related to engineering judgment								
	Ground Water Table	Rain: Avg Total Rain, Annual Plus Snow: Avg Total, Annual (mm)													
		2020	436	-2.88	0	433.12	n/a	n/a	n/a	n/a	<1		>1	0	Data indicates slightly lower precipitation from its current baseline. It is assumed that the existing piping and appurtenances have existing capability or adaptive capabilities. The basis of the vulnerability review is the groundwater table (from precipitation) affecting bedding of the piping systems and the piping structural integrity.
		2050	436	25.7	0	461.7	n/a	n/a	n/a	n/a	<1		>1	0	Data indicates slightly higher precipitation from its current baseline. It is assumed that the existing piping and appurtenances have existing capability or adaptive capabilities. The basis of the vulnerability review is the groundwater table (from precipitation) affecting bedding of the piping systems and the piping structural integrity.

Infrastructure Component	Climate Variable	Data Source	Calculation of Total Load (L_T)				Calculation of Total Capacity (C_T)				Vulnerability (V_R)	STEP 5	Adaptive Capacity (A_R)	Capacity Deficit (C_D)	Comments/ Data Sufficiency
			Existing Load L_E	Climate Load L_C	Other Load L_O	Total Load $L_T = L_E+L_C+L_O$	Existing Capacity C_E	Maturing Capacity C_M	Additional Capacity C_A	Total Capacity $C_T = C_E+C_M+C_A$	$V_R=L_T/C_T$	Y/N	$A_R=C_T/L_T$	$C_D=L_T-C_T$	
		2080	436	21.16	0	457.16	n/a	n/a	n/a	n/a	<1		>1	0	Data indicates slightly higher precipitation from its current baseline. It is assumed that the existing piping and appurtenances have existing capability or adaptive capabilities. The basis of the vulnerability review is the groundwater table (from precipitation) affecting bedding of the piping systems and the piping structural integrity.
Substations / Transformers	Floods/ Ice Jamming/ Ice Build-up	Data not available	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	3	n/a	n/a	Climate change projections were not available related to this climate variable. Other variables (snow, rain, temperature) have been used to provide a general indication of possible change. Data related to overland flooding is required.
			Assumption related to engineering judgment												
	Blizzard	Snow: 1 Day Frequency (20mm)													
		2020	0.001	-0.00015	0	0.00085	n/a	n/a	n/a	n/a	<1		>1	0	Data indicates less possibility of heavy snowfall and assumed related blizzards. It is assumed that the infrastructure has existing capability or adaptive capabilities.
		2050	0.001	0.00028	0	0.00128	n/a	n/a	n/a	n/a	<1		>1	0	Data indicates minor increase in the possibility of heavy snowfall and assumed related blizzards. It is assumed that the infrastructure has existing capability or adaptive capabilities.

Infrastructure Component	Climate Variable	Data Source	Calculation of Total Load (L_T)				Calculation of Total Capacity (C_T)				Vulnerability (V_R)	STEP 5	Adaptive Capacity (A_R)	Capacity Deficit (C_D)	Comments/ Data Sufficiency
			Existing Load L_E	Climate Load L_C	Other Load L_O	Total Load $L_T = L_E+L_C+L_O$	Existing Capacity C_E	Maturing Capacity C_M	Additional Capacity C_A	Total Capacity $C_T = C_E+C_M+C_A$	$V_R=L_T/C_T$	Y/N	$A_R=C_T/L_T$	$C_D=L_T-C_T$	
		2080	0.001	-0.00004	0	0.00096	n/a	n/a	n/a	n/a	<1		>1	0	Data indicates less possibility of heavy snowfall and assumed related blizzards. It is assumed that the infrastructure has existing capability or adaptive capabilities.
				Ratio based calculation - Lc=(ratio-1)Le			Assumption related to engineering judgment								
Transmission lines	Blizzard	Snow: 1 Day Frequency (20mm)													
		2020	0.001	-0.00015	0	0.00085	n/a	n/a	n/a	n/a	<1		>1	0	Data indicates less possibility of heavy snowfall and assumed related blizzards. It is assumed that the infrastructure has existing capability or adaptive capabilities.
		2050	0.001	0.00028	0	0.00128	n/a	n/a	n/a	n/a	<1		>1	0	Data indicates minor increase in the possibility of heavy snowfall and assumed related blizzards. It is assumed that the infrastructure has existing capability or adaptive capabilities.
		2080	0.001	-0.00004	0	0.00096	n/a	n/a	n/a	n/a	<1		>1	0	Data indicates less possibility of heavy snowfall and assumed related blizzards. It is assumed that the infrastructure has existing capability or adaptive capabilities.
				Ratio based calculation - Lc=(ratio-1)Le			Assumption related to engineering judgment								
	Intense Wind/ Tornado	Data not available	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	3	n/a	n/a	Climate change projections were not available related to this climate variable. Other variables were also not sufficient to provide general indication of possible change.
			Assumption related to engineering judgment												

Infrastructure Component	Climate Variable	Data Source	Calculation of Total Load (L_T)				Calculation of Total Capacity (C_T)				Vulnerability (V_R)	STEP 5	Adaptive Capacity (A_R)	Capacity Deficit (C_D)	Comments/ Data Sufficiency
			Existing Load L_E	Climate Load L_C	Other Load L_O	Total Load $L_T = L_E+L_C+L_O$	Existing Capacity C_E	Maturing Capacity C_M	Additional Capacity C_A	Total Capacity $C_T = C_E+C_M+C_A$	$V_R=L_T/C_T$	Y/N	$A_R=C_T/L_T$	$C_D=L_T-C_T$	
Standby Generators	Floods/ Ice Jamming/ Ice Build-up	Data not available	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	3	n/a	n/a	Climate change projections were not available related to this climate variable. Other variables (snow, rain, temperature) have been used to provide a general indication of possible change. Data related to overland flooding is required.
			Assumption related to engineering judgment												
	High Temp	Temperature: Annual Max (Deg. C)													Electrical and controls equipment are the most vulnerable component for analysis.
		2020	35.2	2.2	0	37.4	40	0	0	40	0.935		1.0695187	0	
		2050	35.2	3.5	0	38.7	40	0	0	40	0.9675		1.0335917	0	
		2080	35.2	6	0	41.2	40	0	0	40	1.03	3	0.9708738	0	
			Annual Max Temperature	Change in Temperature (avg. ACU/ADC)			Electrical systems rated to 40 deg. C.								
	Ice Storm	Data not available	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	3	n/a	n/a	Climate change projections were not available related to this climate variable. Additional data specific to Ice Storms is required.
			Assumption related to engineering judgment												
	Blizzard	Snow: 1 Day Frequency (20mm)													
		2020	0.001	-0.00015	0	0.00085	n/a	n/a	n/a	n/a	<1		>1	0	Data indicates less possibility of heavy snowfall and assumed related blizzards. It is assumed that the infrastructure has existing capability or adaptive capabilities.
		2050	0.001	0.00028	0	0.00128	n/a	n/a	n/a	n/a	<1		>1	0	Data indicates minor increase in the possibility of heavy snowfall and assumed related blizzards. It is assumed that the infrastructure has existing capability or adaptive capabilities.

Infrastructure Component	Climate Variable	Data Source	Calculation of Total Load (L_T)				Calculation of Total Capacity (C_T)				Vulnerability (V_R)	STEP 5	Adaptive Capacity (A_R)	Capacity Deficit (C_D)	Comments/ Data Sufficiency
			Existing Load L_E	Climate Load L_C	Other Load L_O	Total Load $L_T = L_E+L_C+L_O$	Existing Capacity C_E	Maturing Capacity C_M	Additional Capacity C_A	Total Capacity $C_T = C_E+C_M+C_A$	$V_R=L_T/C_T$	Y/N	$A_R=C_T/L_T$	$C_D=L_T-C_T$	
		2080	0.001	-0.00004	0	0.00096	n/a	n/a	n/a	n/a	<1		>1	0	Data indicates less possibility of heavy snowfall and assumed related blizzards. It is assumed that the infrastructure has existing capability or adaptive capabilities.
				Ratio based calculation - Lc=(ratio-1)Le			Assumption related to engineering judgment								
	Intense Wind/ Tornado	Data not available	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	3	n/a	n/a	Climate change projections were not available related to this climate variable. Other variables were also not sufficient to provide general indication of possible change.
			Assumption related to engineering judgment												
Vehicle	Ice Storm	Data not available	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	3	n/a	n/a	Climate change projections were not available related to this climate variable. Additional data specific to Ice Storms is required.
			Assumption related to engineering judgment												
	Blizzard	Snow: 1 Day Frequency (20mm)													
		2020	0.001	-0.00015	0	0.00085	n/a	n/a	n/a	n/a	<1		>1	0	Data indicates less possibility of heavy snowfall and assumed related blizzards. It is assumed that the infrastructure has existing capability or adaptive capabilities.
		2050	0.001	0.00028	0	0.00128	n/a	n/a	n/a	n/a	<1		>1	0	Data indicates minor increase in the possibility of heavy snowfall and assumed related blizzards. It is assumed that the infrastructure has existing capability or adaptive capabilities.
		2080	0.001	-0.00004	0	0.00096	n/a	n/a	n/a	n/a	<1		>1	0	Data indicates less possibility of heavy snowfall and assumed related blizzards. It is assumed that the infrastructure has existing capability or adaptive capabilities.

Infrastructure Component	Climate Variable	Data Source	Calculation of Total Load (L_T)				Calculation of Total Capacity (C_T)				Vulnerability (V_R)	STEP 5	Adaptive Capacity (A_R)	Capacity Deficit (C_D)	Comments/ Data Sufficiency
			Existing Load L_E	Climate Load L_C	Other Load L_O	Total Load $L_T = L_E+L_C+L_O$	Existing Capacity C_E	Maturing Capacity C_M	Additional Capacity C_A	Total Capacity $C_T = C_E+C_M+C_A$	$V_R=L_T/C_T$	Y/N	$A_R=C_T/L_T$	$C_D=L_T-C_T$	
				Ratio based calculation - Lc=(ratio-1)Le			Assumption related to engineering judgment								
	Hail	Data not available	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	3	n/a	n/a	Climate change projections were not available related to this climate variable. Although additional data specific to hail is required, the vulnerability of service vehicles based on a hail event is low.
			Assumption related to engineering judgment												
Maintenance Facilities	Ice Storm	Data not available	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	3	n/a	n/a	Climate change projections were not available related to this climate variable. Additional data specific to Ice Storms is required.
			Assumption related to engineering judgment												
Supplies	Ice Storm	Data not available	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	3	n/a	n/a	Climate change projections were not available related to this climate variable. Additional data specific to Ice Storms is required.
			Assumption related to engineering judgment												
	Blizzard	Snow: 1 Day Frequency (20mm)													
		2020	0.001	-0.00015	0	0.00085	n/a	n/a	n/a	n/a	<1		>1	0	Data indicates less possibility of heavy snowfall and assumed related blizzards. It is assumed that the infrastructure has existing capability or adaptive capabilities.
		2050	0.001	0.00028	0	0.00128	n/a	n/a	n/a	n/a	<1		>1	0	Data indicates minor increase in the possibility of heavy snowfall and assumed related blizzards. It is assumed that the infrastructure has existing capability or adaptive capabilities.

Infrastructure Component	Climate Variable	Data Source	Calculation of Total Load (L_T)				Calculation of Total Capacity (C_T)				Vulnerability (V_R)	STEP 5	Adaptive Capacity (A_R)	Capacity Deficit (C_D)	Comments/ Data Sufficiency
			Existing Load L_E	Climate Load L_C	Other Load L_O	Total Load $L_T = L_E+L_C+L_O$	Existing Capacity C_E	Maturing Capacity C_M	Additional Capacity C_A	Total Capacity $C_T = C_E+C_M+C_A$	$V_R=L_T/C_T$	Y/N	$A_R=C_T/L_T$	$C_D=L_T-C_T$	
		2080	0.001	-0.00004	0	0.00096	n/a	n/a	n/a	n/a	<1		>1	0	Data indicates less possibility of heavy snowfall and assumed related blizzards. It is assumed that the infrastructure has existing capability or adaptive capabilities.
				Ratio based calculation - Lc=(ratio-1)Le			Assumption related to engineering judgment								
	Intense Wind/ Tornado	Data not available	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	3	n/a	n/a	Climate change projections were not available related to this climate variable. Other variables were also not sufficient to provide general indication of possible change.
			Assumption related to engineering judgment												
Roadway Infrastructure	Floods/ Ice Jamming/ Ice Build-up	Data not available	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	3	n/a	n/a	Climate change projections were not available related to this climate variable. Other variables (snow, rain, temperature) have been used to provide a general indication of possible change. Data related to overland flooding is required.
			Assumption related to engineering judgment												
	Blizzard	Snow: 1 Day Frequency (20mm)													
		2020	0.001	-0.00015	0	0.00085	n/a	n/a	n/a	n/a	<1		>1	0	Data indicates less possibility of heavy snowfall and assumed related blizzards. It is assumed that the infrastructure has existing capability or adaptive capabilities.
		2050	0.001	0.00028	0	0.00128	n/a	n/a	n/a	n/a	<1		>1	0	Data indicates minor increase in the possibility of heavy snowfall and assumed related blizzards. It is assumed that the infrastructure has existing capability or adaptive capabilities.
		2080	0.001	-0.00004	0	0.00096	n/a	n/a	n/a	n/a	<1		>1	0	Data indicates less possibility of heavy snowfall and assumed related blizzards. It is assumed that the infrastructure has existing capability or adaptive capabilities.

Infrastructure Component	Climate Variable	Data Source	Calculation of Total Load (L_T)				Calculation of Total Capacity (C_T)				Vulnerability (V_R)	STEP 5	Adaptive Capacity (A_R)	Capacity Deficit (C_D)	Comments/ Data Sufficiency
			Existing Load L_E	Climate Load L_C	Other Load L_O	Total Load $L_T = L_E+L_C+L_O$	Existing Capacity C_E	Maturing Capacity C_M	Additional Capacity C_A	Total Capacity $C_T = C_E+C_M+C_A$	$V_R=L_T/C_T$	Y/N	$A_R=C_T/L_T$	$C_D=L_T-C_T$	
				Ratio based calculation - Lc=(ratio-1)Le			Assumption related to engineering judgment								
	Intense Wind/ Tornado	Data not available	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	3	n/a	n/a	Climate change projections were not available related to this climate variable. Other variables were also not sufficient to provide general indication of possible change.
			Assumption related to engineering judgment												
Telephone	Ice Storm	Data not available	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	3	n/a	n/a	Climate change projections were not available related to this climate variable. Additional data specific to Ice Storms is required.
			Assumption related to engineering judgment												
	Blizzard	Snow: 1 Day Frequency (20mm)													
		2020	0.001	-0.00015	0	0.00085	n/a	n/a	n/a	n/a	<1		>1	0	Data indicates less possibility of heavy snowfall and assumed related blizzards. It is assumed that the infrastructure has existing capability or adaptive capabilities.
		2050	0.001	0.00028	0	0.00128	n/a	n/a	n/a	n/a	<1		>1	0	Data indicates minor increase in the possibility of heavy snowfall and assumed related blizzards. It is assumed that the infrastructure has existing capability or adaptive capabilities.
		2080	0.001	-0.00004	0	0.00096	n/a	n/a	n/a	n/a	<1		>1	0	Data indicates less possibility of heavy snowfall and assumed related blizzards. It is assumed that the infrastructure has existing capability or adaptive capabilities.
				Ratio based calculation - Lc=(ratio-1)Le			Assumption related to engineering judgment								

Infrastructure Component	Climate Variable	Data Source	Calculation of Total Load (L_T)				Calculation of Total Capacity (C_T)				Vulnerability (V_R)	STEP 5	Adaptive Capacity (A_R)	Capacity Deficit (C_D)	Comments/ Data Sufficiency
			Existing Load L_E	Climate Load L_C	Other Load L_O	Total Load $L_T = L_E+L_C+L_O$	Existing Capacity C_E	Maturing Capacity C_M	Additional Capacity C_A	Total Capacity $C_T = C_E+C_M+C_A$	$V_R=L_T/C_T$	Y/N	$A_R=C_T/L_T$	$C_D=L_T-C_T$	
	Intense Wind/ Tornado	Data not available	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	3	n/a	n/a	Climate change projections were not available related to this climate variable. Other variables were also not sufficient to provide general indication of possible change.
			Assumption related to engineering judgment												
	Hail	Data not available	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	3	n/a	n/a	Climate change projections were not available related to this climate variable. Although additional data specific to hail is required, the vulnerability of telephone service due to a hail event is low.
			Assumption related to engineering judgment												
Telemetry	Ice Storm	Data not available	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	3	n/a	n/a	Climate change projections were not available related to this climate variable. Additional data specific to Ice Storms is required.
			Assumption related to engineering judgment												
	Blizzard	Snow: 1 Day Frequency (20mm)													
		2020	0.001	-0.00015	0	0.00085	n/a	n/a	n/a	n/a	<1		>1	0	Data indicates less possibility of heavy snowfall and assumed related blizzards. It is assumed that the infrastructure has existing capability or adaptive capabilities.
		2050	0.001	0.00028	0	0.00128	n/a	n/a	n/a	n/a	<1		>1	0	Data indicates minor increase in the possibility of heavy snowfall and assumed related blizzards. It is assumed that the infrastructure has existing capability or adaptive capabilities.
		2080	0.001	-0.00004	0	0.00096	n/a	n/a	n/a	n/a	<1		>1	0	Data indicates less possibility of heavy snowfall and assumed related blizzards. It is assumed that the infrastructure has existing capability or adaptive capabilities.

Infrastructure Component	Climate Variable	Data Source	Calculation of Total Load (L_T)				Calculation of Total Capacity (C_T)				Vulnerability (V_R)	STEP 5	Adaptive Capacity (A_R)	Capacity Deficit (C_D)	Comments/ Data Sufficiency
			Existing Load L_E	Climate Load L_C	Other Load L_O	Total Load $L_T = L_E+L_C+L_O$	Existing Capacity C_E	Maturing Capacity C_M	Additional Capacity C_A	Total Capacity $C_T = C_E+C_M+C_A$	$V_R=L_T/C_T$	Y/N	$A_R=C_T/L_T$	$C_D=L_T-C_T$	
				Ratio based calculation - Lc=(ratio-1)Le			Assumption related to engineering judgment								
	Intense Wind/ Tornado	Data not available	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	3	n/a	n/a	Climate change projections were not available related to this climate variable. Other variables were also not sufficient to provide general indication of possible change.
			Assumption related to engineering judgment												
	Hail	Data not available	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	3	n/a	n/a	Climate change projections were not available related to this climate variable. Although additional data specific to hail is required, the vulnerability of telephone service due to a hail event is low.
			Assumption related to engineering judgment												

3.5 Step 5: Recommendations

3.5.1 Limitations

Ouranos was unable to provide the study team with projections in the occurrence or magnitude of extreme weather events. Sufficient weather station data is simply unavailable from Environment Canada. Considering that extreme events have the greatest potential for serious acute damage to infrastructure, it may be prudent to explore additional data sources for the identification of trends in the magnitude and/or frequency of these rare events.

There were inconsistencies, for even the most basic indices, between trends observed in historical data and future trends projected in model simulations. This is worrisome, especially considering the acknowledged large uncertainty in climate change projections that have been developed for North America. It is feasible that the uncertainty of this data may render the quantification results to be speculative in nature, with minimal incremental precision beyond the understanding of infrastructure response gained for a detailed qualitative HazOps-style process.

3.5.2 Recommendations

Quantitative analysis recommendations are presented in Table 42 and Table 43 for the Portage la Prairie infrastructure components.

Table 42: Step 5 Recommendations (Relationships with Priorities between 12 and 36)

Infrastructure Component	Climate Variable	Data Source	Forward to STEP 5 Recommendation Evaluation Y/N	Recommendations	Recommendation Comments
Personnel	Floods/ Ice Jamming/ Ice Build-up	Data not available	3	No Further Action	Using professional judgment due to insufficient data, it is not expected that greater vulnerability exists due to future changes of Floods/Ice Jamming/Ice Build-up. It is assumed that the personnel have existing capability or adaptive capabilities.
	Ice Storm	Data not available	3	No Further Action	Using professional judgment due to insufficient data, it is not expected that greater vulnerability exists due to future changes of Floods/Ice Jamming/Ice Build-up. It is assumed that the personnel have existing capability or adaptive capabilities.
Facilities/ Equipment	High Temp	Temperature: Annual Max (Deg. C)			
		2080	3	No Further Action	Although a slight vulnerability exists, the 2080 horizon is well beyond the remaining service life of the equipment. Expected that replacement equipment will have a higher rating nearing 2080.
Shellmouth Dam/ Reservoir	Drought	Rain: Avg Total Rain, Annual Plus Snow: Avg Total, Annual (mm)			
		2020	3	Additional Study Required	Further Study is required on climate impacts to the Assiniboine Watershed Infrastructure.
		2050	3	Additional Study Required	Further Study is required on climate impacts to the Assiniboine Watershed Infrastructure.
		2080	3	Additional Study Required	Further Study is required on climate impacts to the Assiniboine Watershed Infrastructure.

Infrastructure Component	Climate Variable	Data Source	Forward to STEP 5 Recommendation Evaluation Y/N	Recommendations	Recommendation Comments
Assiniboine River System	Drought	Rain: Avg Total Rain, Annual Plus Snow: Avg Total, Annual (mm)			
		2020	3	Additional Study Required	Further Study is required on climate impacts to the Assiniboine Watershed Infrastructure.
		2050	3	Additional Study Required	Further Study is required on climate impacts to the Assiniboine Watershed Infrastructure.
		2080	3	Additional Study Required	Further Study is required on climate impacts to the Assiniboine Watershed Infrastructure.
Pre-treatment	Floods/ Ice Jamming/ Ice Build-up	Data not available	3	No further Action	Using professional judgment due to insufficient data, it is not expected that greater vulnerability exists due to future changes of Floods/Ice Jamming/Ice Build-up. It is assumed that the range of water quality changes under these events will not exceed current seasonal spikes. Assuming this, the infrastructure has existing capability.
	High Temp	Temperature: Annual Max (Deg. C)			
		2080	3	No Further Action	Although a slight vulnerability exists, the 2080 horizon is well beyond the remaining service life of the equipment. Using professional judgment due to insufficient data, it is not expected that greater vulnerability exists due to future changes of high temperatures and related water quality. It is assumed that the range of water quality changes under these events will only slightly exceed current seasonal spikes. Assuming this, the infrastructure has existing capability.
	Drought	Rain: Avg Total Rain, Annual Plus Snow: Avg Total, Annual (mm)			
		2020	3	Additional Study Required	Further Study is required on climate impacts to the Assiniboine Watershed Infrastructure.
		2050	3	Additional Study Required	Further Study is required on climate impacts to the Assiniboine Watershed Infrastructure.
		2080	3	Additional Study Required	Further Study is required on climate impacts to the Assiniboine Watershed Infrastructure.
Softening	High Temp	Temperature: Annual Max (Deg. C)			
		2080	3	No Further Action	Although a slight vulnerability exists, the 2080 horizon is well beyond the remaining service life of the equipment. Using professional judgment due to insufficient data, it is not expected that greater vulnerability exists due to future changes of high temperatures and related water quality. It is assumed that the range of water quality changes under these events will only slightly exceed current seasonal spikes. Assuming this, the infrastructure has existing capability.
	Drought	Rain: Avg Total Rain, Annual Plus Snow: Avg Total, Annual (mm)			
		2020	3	Additional Study Required	Further Study is required on climate impacts to the Assiniboine Watershed Infrastructure.
		2050	3	Additional Study Required	Further Study is required on climate impacts to the Assiniboine Watershed Infrastructure.
		2080	3	Additional Study Required	Further Study is required on climate impacts to the Assiniboine Watershed Infrastructure.

Infrastructure Component	Climate Variable	Data Source	Forward to STEP 5 Recommendation Evaluation Y/N	Recommendations	Recommendation Comments
Storage	Drought	Rain: Avg Total Rain, Annual Plus Snow: Avg Total, Annual (mm)			
		2020	3	Additional Study Required	Further Study is required on climate impacts to the Assiniboine Watershed Infrastructure.
		2050	3	Additional Study Required	Further Study is required on climate impacts to the Assiniboine Watershed Infrastructure.
		2080	3	Additional Study Required	Further Study is required on climate impacts to the Assiniboine Watershed Infrastructure.
Valves Pipelines (on WTP site)	Floods/ Ice Jamming/ Ice Build-up	Data not available	3	No Further Action	Using professional judgment due to insufficient data, it is not expected that greater vulnerability exists due to future changes of Floods/Ice Jamming/Ice Build-up. It is assumed that the infrastructure has existing capability.
Pump Stations (WTP/ McKay)	Floods/ Ice Jamming/ Ice Build-up	Data not available	3	Additional Study Required	Using professional judgment due to insufficient data, a greater vulnerability may exist due to future changes of Floods/Ice Jamming/Ice Build-up. Additional study is required.
	High Temp	Temperature: Annual Max (Deg. C)			
		2080	3	No Further Action	Although a slight vulnerability exists, the 2080 horizon is well beyond the remaining service life of the equipment. Expected that replacement equipment will have a higher rating nearing 2080.
Pipelines and Valves	Floods/ Ice Jamming/ Ice Build-up	Data not available	3	No Further Action	Using professional judgment due to insufficient data, it is not expected that greater vulnerability exists due to future changes of Floods/Ice Jamming/Ice Build-up. It is assumed that the infrastructure has existing capability.
Substations / Transformers	Floods/ Ice Jamming/ Ice Build-up	Data not available	3	Additional Study Required	Using professional judgment due to insufficient data, it is not expected that greater vulnerability exists due to future changes of Floods/Ice Jamming/Ice Build-up. It is assumed that the utility infrastructure is reasonably flood proofed and that future events will not exceed current seasonal spikes. Assuming this, the infrastructure has existing capability. Additional study is required to confirm this assumption.
	Intense Wind/Tornado	Data not available	3	Remedial Action	Using professional judgment due to insufficient data, but with comments from Ouranos related to extreme wind and tornadoes, it is possible that greater vulnerability exists due to future climate changes. The City should review their emergency preparedness requirements on tornadoes as well as working with Manitoba hydro to bury as many transmission lines as possible to reduce the vulnerability.
Standby Generators	Floods/ Ice Jamming/ Ice Build-up	Data not available	3	Additional Study Required	Using professional judgment due to insufficient data, it is not expected that greater vulnerability exists due to future changes of Floods/Ice Jamming/Ice Build-up. It is assumed that the utility infrastructure is reasonably protected from flooding. Assuming this, the infrastructure has existing capability. Additional study is required to confirm this assumption.
	High Temp	Temperature: Annual Max (Deg. C)			
		2080	3	No Further Action	Although a slight vulnerability exists, the 2080 horizon is well beyond the remaining service life of the equipment. Expected that replacement equipment will have a higher temperature rating nearing 2080.
	Ice Storm	Data not available	3	Additional Study Required	Additional study is required to determine the frequency of ice storms and the need for standby power during this extreme event.
	Intense Wind/Tornado	Data not available	3	Remedial Action	Using professional judgment due to insufficient data, but with comments from Ouranos related to extreme wind and tornadoes, it is possible that greater vulnerability exists due to future climate changes. The City should review their emergency preparedness requirements on tornadoes. In addition the City should review installing full standby power at the water treatment plant to reduce power vulnerability.

Infrastructure Component	Climate Variable	Data Source	Forward to STEP 5 Recommendation Evaluation Y/N	Recommendations	Recommendation Comments
Vehicle	Ice Storm	Data not available	3	Additional Study Required	Additional study is required to determine the frequency of ice storms and its effect on service vehicles.
	Hail	Data not available	3	No Further Action	Climate change projections were not available related to this climate variable. Although additional data specific to hail is required, the vulnerability of service vehicles based on a hail event is low. No further action is required.
Maintenance Facilities	Ice Storm	Data not available	3	Additional Study Required	Additional study is required to determine the frequency of ice storms and its effect on maintenance facilities.
Supplies	Ice Storm	Data not available	3	Additional Study Required	Additional study is required to determine the frequency of ice storms and its effect on supply services.
	Intense Wind/Tornado	Data not available	3	Remedial Action	Using professional judgment due to insufficient data, but with comments from Ouranos related to extreme wind and tornadoes, it is possible that greater vulnerability exists due to future climate changes. The City should review their emergency preparedness requirements on tornadoes. Back-up/ Alternate sources of supplies should be considered.
Roadway Infrastructure	Floods/ Ice Jamming/ Ice Build-up	Data not available	3	Additional Study Required	Using professional judgment due to insufficient data, it is not expected that greater vulnerability exists due to future changes of Floods/Ice Jamming/Ice Build-up. It is assumed that the utility infrastructure is reasonably protected from flooding. Assuming this, the infrastructure has existing capability. Additional study is required to confirm this assumption.
	Intense Wind/Tornado	Data not available	3	Remedial Action	Using professional judgment due to insufficient data, but with comments from Ouranos related to extreme wind and tornadoes, it is possible that greater vulnerability exists due to future climate changes. The City should review their emergency preparedness requirements on tornadoes. Alternate means of access to critical infrastructure should be reviewed.
Telephone	Ice Storm	Data not available	3	Additional Study Required	Additional study is required to determine the frequency of ice storms and its effect on telephone services.
	Intense Wind/Tornado	Data not available	3	Remedial Action	Using professional judgment due to insufficient data, but with comments from Ouranos related to extreme wind and tornadoes, it is possible that greater vulnerability exists due to future climate changes. The City should review their emergency preparedness requirements on tornadoes. The City should also consider burying telephone lines to the greatest extent possible or having back-up wireless communication.
	Hail	Data not available	3	No Further Action	Climate change projections were not available related to this climate variable. Although additional data specific to hail is required, the vulnerability of telephone service due to a hail event is low. No further action is required.
Telemetry	Ice Storm	Data not available	3	Additional Study Required	Additional study is required to determine the frequency of ice storms and its effect on telemetry.
	Intense Wind/Tornado	Data not available	3	Remedial Action	Using professional judgment due to insufficient data, but with comments from Ouranos related to extreme wind and tornadoes, it is possible that greater vulnerability exists due to future climate changes. The City should review their emergency preparedness requirements on tornadoes. The City should also consider burying communication lines to the greatest extent possible or having back-up wireless communication.
	Hail	Data not available	3	No Further Action	Climate change projections were not available related to this climate variable. Although additional data specific to hail is required, the vulnerability of the telemetry equipment due to a hail event is low. No further action is required.

Table 43: Step 5: Recommendations (Relationships with priorities equal to or greater than 36)

Infrastructure Component	Climate Variable	Recommendations	Recommendation Comments
Personnel	Intense Wind/Tornado	Management Action	The City should review their emergency preparedness requirements on tornadoes relating to personnel.
Facilities / equipment	Floods/Ice Jamming/Ice Build-up	Management Action	The City should review the level of flood protection related to each facility and prepare an action plan in the case of flooding. In the case where infrastructure is highly vulnerable, remedial flood protection work works should be completed. Data was not available to determine if a greater vulnerability of these event s exists due to climate change.
	Ice Storm	Remedial Action	The City should review their emergency preparedness requirements on Ice Storms. In addition the City should review installing full standby power at the water treatment plant to reduce power vulnerability generally associated with ice storm events.
	Intense Wind/Tornado	Management Action	The City should review their emergency preparedness requirements on tornadoes relating to faculties and equipment.
Assiniboine River System	Floods/Ice Jamming/Ice Build-up	Management Action	The City should work with the Province of Manitoba to review flood related vulnerabilities related to the Assiniboine River and the Dam at this location. The City should review the Provinces policies related to managing these events.
Dam Structure	Floods/Ice Jamming/Ice Build-up	Management Action	The City should review the level of flood protection related to the dam and intake works and prepare an action plan in the case of flooding. In the case where infrastructure is highly vulnerable, remedial works should be completed. In the case of ice jamming (blinding off the intake), the City should prepare an action plan to remedy the blockage.
Intake Well / Pumps	Floods/Ice Jamming/Ice Build-up	Management Action	The City should review the level of flood protection related to the intake works and prepare an action plan in the case of flooding. In the case where infrastructure is highly vulnerable, remedial works should be completed. In the case of ice jamming (blinding off the intake), the City should prepare an action plan to remedy the blockage.
	Intense Rain	Management Action	The City should review the level of flood protection related to an intense rainfall event.
	Drought	Additional Study Required	The City should review drought related issued with the Province of Manitoba to establish water rights priorities in the event of drought on the Assiniboine River. The City should also request that the Province further study the Assiniboine River watershed for climate change effects.
Chemical Storage / Hazardous Materials	Floods/Ice Jamming/Ice Build-up	Management Action	The City should review the level of flood protection related to each the bulk chemical and other hazardous material and prepare an action plan in the case of flooding. In the case where infrastructure is highly vulnerable, remedial works should be completed. In the case of ice jamming (blinding off the intake), the City should prepare an action plan to remedy the blockage.
	Intense Wind/Tornado	Management Action	The City should review their emergency preparedness requirements on tornadoes relating to chemical storage and hazardous materials.
Pump stations (WTP/McKay)	Intense Wind/Tornado	Management Action	The City should review their emergency preparedness requirements on tornadoes relating to faculties and equipment.
Substations / Transformers	Ice Storm	Remedial Action	The City should review their emergency preparedness requirements on Ice Storms. In addition the City should review installing full standby power at the water treatment plant to reduce power vulnerability generally associated with ice storm events.
Transmission lines	Ice Storm	Remedial Action	The City should review their emergency preparedness requirements on Ice Storms. In addition the City should review installing full standby power at the water treatment plant to reduce power vulnerability generally associated with ice storm events. The City should also consider burying hydro lines to the greatest extent possible.
Vehicle	Intense Wind/Tornado	Management Action	The City should review their emergency preparedness requirements on tornadoes relating to faculties and equipment.
Maintenance facilities	Intense Wind/Tornado	Management Action	The City should review their emergency preparedness requirements on tornadoes relating to faculties and equipment.

4.0 Protocol Review Summary

This assessment constitutes a Pilot-application of a Draft Protocol for Assessment of Public Water Supply, Treatment and Distribution Infrastructure serving the City of Portage la Prairie. As the Study Team conducted the assessment, it documented issues and potential optimization opportunities for applying the Draft Protocol to water resources infrastructure. These points of Protocol Review are summarized below for the consideration of the PIEVC Committee Members in their continued evolution of their Draft Protocol.

Step 1 Project Definition: The steps itemized in this phase of the Protocol were clearly detailed and were consistent with most typical data gathering efforts in defining the setting and related global project parameters. The Study Team does suggest that the general guidelines provided within Step 1 of the Draft Protocol be amended to include specific reference to typical categories of information that the assessor should gather as a starting point. It is recommended that an explicit list of such information be added for guidance to future users of the Protocol. Suggested information sources that could be appended to the Protocol's guidance in Step 1 include:

- P&ID (Process and Instrumentation) Drawings
- CAD Files
- Water Infrastructure Component Capacity and Performance Specifications where available for key components
- Operator Interviews
- Watershed Management Zone details (available in some jurisdictions, helpful in identifying watershed geographical limits, water supply management issues, regional demand/supply considerations, etc.)

Step 2 Data Gathering and Sufficiency: The steps in this phase of the Protocol were clearly defined and the suggested guidance was helpful to the assessors. In the application of the Draft Protocol for this assignment, the Study Team utilized Ouranos for development of the climate projection estimates. Ouranos appears to be the sole source or preferred provider of regional climate change data for this process, therefore Ouranos became a critical participant in the execution of the Protocol.

The Study Team placed a strong priority on consultations with Ouranos to ensure that all information requested from Ouranos was fully developed and well understood by Ouranos personnel. This care was taken to reduce the likelihood of erroneous or false interpretation of our data request occurring within the compressed timeframe of this assessment.

The Study Team suggests that if an entity such as Ouranos is relied upon for climate change trending data, that their ability to provide these data sets on a wide-scale basis and in a timely manner be assessed. In this assignment, our Study Team constituted one application of a Draft Protocol. In the future, once the Draft Protocol is issued as a final protocol, it is highly conceivable that scores of these Infrastructure Vulnerability Assessments will be conducted throughout Canada simultaneously. The Study Team is

concerned that the volume of assessments will create a time-sensitive demand for climate change projection data that cannot be met within the window of need for conducting the various assessments.

In order to streamline the data supply burden on agencies like Ouranos, the Study Team recommends that the Protocol be modified to move the gathering of climate change data parameters and other change variables useful in performing quantitative analysis to a stage following the Qualitative Assessment (Step 3) stage of the Protocol. The Study Team believes that the Qualitative Assessment (Step 3) yields substantial understanding of the potential sensitivities and vulnerabilities of a given infrastructure system, allowing significant refinement in both the types of data being requested from Ouranos and the sets of data that need to be assembled in order to feed Ouranos' climate change projection models.

As the Draft Protocol exists now, the turn-around time for Ouranos data created a concern that the assessors needed to ensure all potential parameters of interest were ordered in advance of a later stage in the Protocol where increased understanding of the infrastructure's responses could offer chances to streamline or refine the data request to a more manageable package for Ouranos. Of additional consideration is the fact that the provision of the climate change projection data can be fairly costly, and the structure of the protocol as it exists now could require municipalities and other facility owners to allocate excessive funds to the climate change projection data request exercise. The Study Team suggest that PIEVC consider the option of delaying climate change projection data requests until after Step 3 has been conducted when the Qualitative Assessment is completed and the assessor is in possession of results from Step 3 that will provide increased understanding of a given facility's true sensitivities to climate change in terms of which climatic factors might be major factors in system vulnerability and which factors can be dismissed as minor. The effect of "triaging" the climatic change factors of importance could be benefits such as:

- Reduced costs to the assessor due to savings realized through ordering only data simulations of significance to a given facility. Step 1 and 2 appear too early in the Protocol process to make this determination.
- Reducing the overall data request load on agencies such as Ouranos through refinement of individual data requests. If potential end-users are warned that Ouranos data will be a governing factor in terms of workstream schedule (data turnaround is currently at least 8 weeks), there may be efficiencies afforded if the majority of data requests made of Ouranos are pre-screened to allow for Ouranos production of essential climate change factors only.
- Discussion were held between the GENIVAR/TetrES study team and Ouranos to determine how the weather variables should be summarized to make the use of them as efficient as possible. For precipitation it was suggested that intensity-duration-frequency (IDF) curves would efficiently described the rainfall intensity for different return periods for different durations. However, Ouranos reported to the PIEVC that the post processing of the precipitation data would add extra cost to the

supply of data. PIEVC recommended that the cost of the data processing was excessively high for this assignment and that GENIVAR/TetrES should continue without IDF curves and a decision could be made later if they were found to be necessary. The timing of the eventual delivery of data from Ouranos eliminated the possibility of deciding if additional data could be ordered through them at a later stage of the assessment.

It could be argued that the Draft Protocol as it exists now places an un-necessarily heavy burden on the assessor to assemble or generate climate change data where the need for most of this data may functionally be screened out as the Qualitative Assessment is concluded anyway. In reality, even if data from Ouranos became hypothetically readily available and instantaneously accessible, the results flowing from the Qualitative Assessment generate Priority Rankings that will reduce the set of relationships requiring quantitative assessment to a much smaller set of scenarios requiring Ouranos projection datasets.

In addition to the climatic change factor simulation data recommendations above, the Study Team also believes there is substantial benefit to the assessors if they undertake a mandatory site visit or tour in conjunction with meetings with the owners and operators of a facility. These meetings were very fruitful for the Study Team and provide the assessors with an opportunity to obtain valued practical insight from the people who make the facility operational on a day-to-day basis. These personnel have strong site-specific knowledge of making their facilities operate smoothly and in satisfaction of their defined performance standards and goals through a wide range of conditions. Their expertise and history with a given facility provides the assessor with deep insight into some of the site-specific nuances of a particular plant or infrastructure.

Step 3 Qualitative Assessment: The Protocol provides good detail and background regarding the general framework of its Prioritization Methodologies however the Study Team believes there could be additional structure offered to the assessor in terms of conducting a stepwise risk assessment and itemizing the factors that should be considered in identifying and characterizing vulnerabilities and other risks. The Study Team recommends that PIEVC consider the addition of an accepted general risk assessment framework for integration into the Step 3 guidance. There are numerous examples of functional and practical qualitative risk assessment procedures that could be adapted for this purpose, including the American Water Works Association's (AWWA) Risk Assessment Methodology for Water Utilities or equivalents. Mention has also been made of confusion in interpretation of the Probability Scale Factor as discussed in Section 3.3.1 of the Protocol. Several Workshop participants interpreted this scale factor to represent the Probability of a Severe Climatic Event's occurrence; however the Protocol intends this value to represent the Probability of a climatic event EFFECT on a given component of infrastructure. The Protocol in its current form is not explicit on how it wishes the assessor to consider complex interactions such as Cumulative Effects and Environmental Effects of the scenarios leading to climatic change vulnerabilities. Cumulative effects could arise from multiple climatic severe events occurring simultaneously and/or multiple cascading

component failures occurring within a given event. The Study Team recommends considering the addition of specific guidance to assist the assessor in incorporating cumulative and environmental effects into their assessment. Participants in the workshop also indicated they would find it more functional in executing the Protocol's Step 3 if they were guided by the steps to group longer-duration climatic events such as drought, severe frost and groundwater together during the analysis.

Step 4: Quantitative Analysis: The Protocol calls for Quantitative Analysis of identified prioritized relationships above the level considered "insignificant" (Priority Value $\leq$12) and below a level considered "immediate action required" (Priority Value $\geq$36). For most facilities, the set of vulnerabilities residing in the range requiring further assessment through quantification is a smaller subset of the larger set of prioritized vulnerability relationships. When the Protocol is applied by individuals with sufficient design, operations and local setting knowledge, it can be argued that the additional precision garnered by Quantification may not yield results which will justify the expense and time required to obtain the data required for the Quantitative Assessment. In the event of data being readily available, this concern would be less of an issue as the assessor could proceed with calculations if in possession of data necessary to conduct quantitative assessment. However if that required data is not readily available, it could be argued that the effort required to generate or obtain the needed data would not provide significant additional understanding of a given vulnerability due to the fact that most of the required data will be predictive-based estimates on climate change projections. It may be argued that an accepted and peer-reviewed regional data set could be generated for major zones within Canada and these regional data sets could be generated periodically by an organization such as Ouranos. In this manner, costs and efforts required to obtain this data would be reduced significantly.

Step 5: Recommendations: The Protocol provides clear and practical instruction in terms of assisting the assessor in packaging their recommendations for further action. It is suggested that the Protocol be modified to include a specific built-in timeframe for facility operators and management to revisit the Recommendations to assess progress of implementation in any critical remedial efforts identified as necessary as a product of the Assessment.

5.0 Conclusion

The results of the Protocol as it has been applied to the water resource infrastructure of Portage la Prairie were derived by Qualitative and Quantitative Assessment and summarized in the results reported for Steps 3 and 4 of the Protocol. Conclusions reached from the assessment can be summarized on an infrastructure component basis as follows:

5.1 Administration / Operations

City Personnel

Potential vulnerabilities of the City personnel related to floods, ice jams, ice build-up and ice storms were noted. Based on the existing capacity of the City personnel to adapt to these events, no additional vulnerability exists and therefore no further action by the City is recommended.

Vulnerabilities of the City personnel related to intense winds and tornadoes were also noted and management action is recommended. The City should review their emergency preparedness requirements for intense wind and tornado events to ensure that proper plans are in place for personnel related to the operation of the infrastructure.

Facilities / Equipment

Potential vulnerabilities of the water treatment plant facilities and equipment related to high temperature, floods, ice jams, ice build-up and ice storms, intense winds and tornadoes were noted.

For high temperature climate variables, no action is recommended. High temperature changes resulted in slight system vulnerability in the extended climate change projection to 2080. This timeframe is well beyond the expected service life of the existing facilities and equipment it is expected that the future system will adapt to these changes. The climate projections associated with 20 and 40-year projections did not yield infrastructure responses sufficient to cause system vulnerabilities.

For floods, ice jams and ice build-up, management action is recommended. The City should review the level of flood protection related to each facility and prepare an action plan in the case of flooding. In the case where infrastructure is highly vulnerable, remedial flood protection work works should be completed.

For ice storms, remedial action is recommended. The City should review their emergency preparedness requirements to ensure that proper plans are in place related to the operation of the infrastructure. In addition the City should review installing full standby power or back-up facilities at the water treatment plant to reduce power vulnerability generally associated with ice storm events.

For intense winds and tornadoes, management action is recommended. The City should review their emergency preparedness requirements for intense wind and tornado events to ensure that proper plans are in place for the operation and protection of the infrastructure.

5.2 Source Water

Shellmouth Dam / Reservoir

The vulnerability of the Shellmouth Dam and Reservoir to drought was assumed by engineering judgment to be very high. Data was not available to confirm this assumption. Additional study is required to assess the vulnerability of the Shellmouth Dam to drought.

Assiniboine River System

The vulnerability of the Assiniboine River system to drought was assumed by engineering judgment to be very high. Data was not available to confirm this assumption. Additional study is required to assess the vulnerability of the Assiniboine River to drought.

Potential vulnerabilities of the Assiniboine River System related to floods, ice jams and ice build-up were noted and management action is recommended. The City should work with the Province of Manitoba to review flood related vulnerabilities for the Assiniboine River at Portage la Prairie to further assess the impacts to the water resources infrastructure.

Control Dam Structure

Potential vulnerabilities of the control dam structure related to floods, ice jams and ice build-up were noted and management action is recommended. The City should review the level of flood protection related to the dam and prepare an action plan in the case of flooding. In the case where infrastructure is highly vulnerable, remedial works should be completed. In the case of ice jamming (blinding off the intake), the City should prepare an action plan to remedy the blockage.

Intake Well / Pumps

Potential vulnerabilities of the intake well and pumps at the dam related to floods, ice jams, ice build-up, intense rain and drought were noted.

For floods, ice jams, ice build-up and intense rain, management action is recommended. The City should review the level of flood protection related to the intake well and prepare an action plan in the case of flooding. In the case where infrastructure is highly vulnerable, remedial works should be completed. In the case of ice jamming (blinding off the intake), the City should prepare an action plan to remedy the blockage.

For drought, additional study is required. The vulnerability of the intake well to drought was assumed by engineering judgment to be very high. Data was not available to confirm

this assumption. The City should also review drought related issued with the Province of Manitoba to establish water rights priorities in the event of drought on the Assiniboine River. The City should also request that the Province further study the Assiniboine River watershed for climate change effects.

5.3 Treatment

Pretreatment (Actiflo)

Potential vulnerabilities of the pretreatment facilities and equipment related to high temperature, floods, ice jams, ice build-up and drought were noted.

For high temperature climate variables, no action is recommended. Using professional judgment due to insufficient data, it is not expected that greater vulnerability exists due to future changes of high temperatures and related effect on water quality. It is assumed that the range of water quality changes under these events will not exceed current seasonal spikes and water quality variables. Based on this assumption, the infrastructure has existing capability.

For floods, ice jams and ice build-up, no action is recommended. Using professional judgment due to insufficient data, it is not expected that greater vulnerability exists due to future changes of floods, ice jams and ice build-up and related effect on water quality. It is assumed that the range of water quality changes under these events will not exceed current seasonal variations. Based on this assumption, the infrastructure has existing capability.

For drought, additional study is required. The vulnerability of the pretreatment system to drought was assumed by engineering judgment to be very high. Data was not available to confirm this assumption. The City should review drought related issued with the Province of Manitoba to establish water rights priorities in the event of drought on the Assiniboine River. The City should also request that the Province further study the Assiniboine River watershed for climate change effects.

Softening / Clarification

Potential vulnerabilities of the Softening/ Clarification equipment related to high temperature and drought were noted.

For high temperature climate variables, no action is recommended. Using professional judgment due to insufficient data, it is not expected that greater vulnerability exists due to future changes of high temperatures and related effect on water quality. It is assumed that the range of water quality changes under these events will not exceed current seasonal spikes and water quality variables. Based on this assumption, the infrastructure has existing capability.

For drought, additional study is required. The vulnerability of the softening/ clarification system to drought was assumed by engineering judgment to be very high. Data was not available to confirm this assumption. The City should review drought related issued with the Province of Manitoba to establish water rights priorities in the event of drought on the Assiniboine River. The City should also request that the Province further study the Assiniboine River watershed for climate change effects.

Storage

Vulnerability of the treated water storage related to drought was noted and additional study is required. The vulnerability of treated water storage for drought was assumed by engineering judgment to be very high. Data was not available to confirm this assumption. The City should review drought related issued with the Province of Manitoba to establish water rights priorities in the event of drought on the Assiniboine River. The City should also request that the Province further study the Assiniboine River watershed for climate change effects.

Chemical Storage / Hazardous Materials

Potential vulnerabilities of the chemical storage and hazardous materials stored at the facilities related to floods, ice jams, ice build-up, intense winds and tornadoes were noted.

For floods, ice jams, ice build-up, management action is recommended. The City should review the level of flood protection related to each the bulk chemical and other hazardous material and prepare an action plan in the case of flooding. In the case where infrastructure is highly vulnerable, remedial works should be completed.

For intense winds and tornadoes, management action is recommended. The City should review their emergency preparedness requirements for intense wind and tornado events to ensure that proper plans are in place for the operation and protection of the infrastructure.

Valves / Pipelines at the Water Treatment Plant

Potential vulnerability of the valves and piping at the water treatment plant site was noted related to floods, ice jams and ice build-up and no action is recommended. Using professional judgment due to insufficient data, it is not expected that greater vulnerability exists due to future changes of these climate variables. It is assumed that the infrastructure has existing capability.

5.4 Distribution

Pumping Stations (Water Treatment Plant and McKay)

Potential vulnerabilities of the pumping stations at the water treatment plant site and at the McKay Reservoir related to high temperature, floods, ice jams, ice build-up, intense winds and tornadoes were noted.

For floods, ice jams, ice build-up, additional study is recommended. The City should review the level of flood protection related to the pump stations and prepare an action plan in the case of flooding. In the case where infrastructure is highly vulnerable, remedial works should be completed.

For high temperature climate variables, no action is recommended. High temperature changes resulted in slight system vulnerability in the extended climate change projection to 2080. This timeframe is well beyond the expected service life of the existing facilities and equipment it is expected that the future system will adapt to these changes. The climate projections associated with 20 and 40-year projections did not yield infrastructure responses sufficient to cause system vulnerabilities.

For intense winds and tornadoes, management action is recommended. The City should review their emergency preparedness requirements for intense wind and tornado events to ensure that proper plans are in place for the operation and protection of the infrastructure.

Pipelines / Valves

Potential vulnerability of the valves and piping in the distribution system were noted related to floods, ice jams and ice build-up and no action is recommended. Using professional judgment due to insufficient data, it is not expected that greater vulnerability exists due to future changes of these climate variables. It is assumed that the infrastructure has existing capability.

5.5 Electric Power

Substations / Transformers

Potential vulnerabilities of the substations/ transformers supplying power to the water treatment plant and pumping stations related to high temperature, floods, ice jams, ice build-up and ice storms, intense winds and tornadoes were noted.

For floods, ice jams, ice build-up, additional study is recommended. Using professional judgment due to insufficient data, it is not expected that greater vulnerability exists due to future changes of floods, ice jamming and ice build-up. It is assumed that the utility infrastructure is reasonably flood proofed. Assuming this, the infrastructure has existing capability. Additional study is required to confirm this assumption.

For ice storms, remedial action is recommended. The City should review their emergency preparedness requirements on Ice Storms. In addition the City should review installing full standby power at the water treatment plant to reduce power vulnerability generally associated with ice storm events.

For intense winds and tornadoes, remedial action is recommended. Using professional judgment due to insufficient data, but with comments from Ouranos related to extreme wind and tornadoes, it is possible that greater vulnerability exists due to future climate changes. The City should review their emergency preparedness requirements on tornadoes as well as working with Manitoba Hydro to bury as many transmission lines as possible to reduce the vulnerability.

Standby Generators

Potential vulnerabilities of the standby generators supplying back-up power to the water treatment plant and pumping stations related to floods, ice jams, ice build-up, high temperatures, ice storms, intense winds and tornadoes were noted.

For floods, ice jams, ice build-up, additional study is recommended. Using professional judgment due to insufficient data, it is not expected that greater vulnerability exists due to future changes of floods, ice jamming and ice build-up. It is assumed that the utility infrastructure is reasonably flood proofed. Assuming this, the infrastructure has existing capability. Additional study is required to confirm this assumption.

For high temperature climate variables, no action is recommended. High temperature changes resulted in slight system vulnerability in the extended climate change projection to 2080. This timeframe is well beyond the expected service life of the existing facilities and equipment it is expected that the future system will adapt to these changes. The climate projections associated with 20 and 40-year projections did not yield infrastructure responses sufficient to cause system vulnerabilities.

For ice storms, additional study is required. Additional study is required to determine the frequency of ice storms and the need for standby power during these extreme events.

For intense winds and tornadoes, remedial action is recommended. Using professional judgment due to insufficient data, but with comments from Ouranos related to extreme wind and tornadoes, it is possible that greater vulnerability exists due to future climate changes. The City should review their emergency preparedness requirements on tornadoes as well as working with Manitoba Hydro to bury as many transmission lines as possible to reduce the vulnerability and determine the extent back-up power requirements.

Transmission Lines

Potential vulnerabilities of power transmission lines related to ice storms were noted and remedial action is recommended. The City should review their emergency preparedness requirements on ice storms. In addition, the City should review installing full standby power at the water treatment plant to reduce power vulnerability generally associated with ice storm events.

5.6 Transportation

Service Vehicles

Potential vulnerabilities of City service vehicles related to ice storms, hail and intense wind and tornadoes were noted.

For ice storms, additional study is required to determine the frequency of ice storms and its effects on service vehicles.

For hail, no further action is recommended. Climate change projections were not available related to this climate variable. Although additional data specific to hail is required, the vulnerability of service vehicles based on a hail event is low.

For intense winds and tornadoes, management action is recommended. The City should review their emergency preparedness requirements for intense wind and tornado events to ensure that proper plans are in place for the operation and protection of the infrastructure.

Maintenance Facilities

Potential vulnerabilities of City service vehicles related to ice storms, intense wind and tornadoes were noted.

For ice storms, additional study is required to determine the frequency of ice storms and its effects on maintenance facilities.

For intense winds and tornadoes, management action is recommended. The City should review their emergency preparedness requirements for intense wind and tornado events to ensure that proper plans are in place for the operation and protection of the infrastructure.

Supplies

Potential vulnerabilities of supplies related to related to ice storms, intense winds and tornadoes were noted.

For ice storms, additional study is required to determine the frequency of ice storms and its effects on supplies.

For intense winds and tornadoes, remedial action is recommended. Using professional judgment due to insufficient data, but with comments from Ouranos related to extreme wind and tornadoes, it is possible that greater vulnerability exists due to future climate changes. The City should review their emergency preparedness requirements on tornadoes. Back-up/ alternate sources of supplies should be considered.

Roadway Infrastructure

Potential vulnerabilities of the roadway infrastructure related to floods, ice jams, ice build-up, intense winds and tornadoes were noted.

For floods, ice jams, ice build-up, additional study is recommended. Using professional judgment due to insufficient data, it is not expected that greater vulnerability exists due to future changes of floods, ice jamming and ice build-up. It is assumed that the utility infrastructure is reasonably protected from flooding. Assuming this, the infrastructure has existing capability. Additional study is required to confirm this assumption.

For intense winds and tornadoes, remedial action is recommended. Using professional judgment due to insufficient data, but with comments from Ouranos related to extreme wind and tornadoes, it is possible that greater vulnerability exists due to future climate changes. The City should review their emergency preparedness requirements on tornadoes. Alternate means of access to critical infrastructure should be reviewed.

5.7 Communications

Telephone

Vulnerabilities of the telephone network to ice storms, hail and intense wind and tornadoes were noted.

For ice storms, additional study is required. Additional study is required to determine the frequency of ice storms and its effect on telephone services.

For hail, no further action is recommended. Climate change projections were not available related to this climate variable. Although additional data specific to hail is required, the vulnerability of the telephone network to a hail event is low.

For intense winds and tornadoes, remedial action is recommended. Using professional judgment due to insufficient data, but with comments from Ouranos related to extreme wind and tornadoes, it is possible that greater vulnerability exists due to future climate changes. The City should review their emergency preparedness requirements on tornadoes. The City should also consider burying telephone lines to the greatest extent possible or having back-up wireless communication.

Telemetry

Vulnerabilities of the City's telemetry network to ice storms, hail and intense wind and tornadoes were noted.

For ice storms, additional study is required. Additional study is required to determine the frequency of ice storms and its effect on telephone services.

For hail, no further action is recommended. Climate change projections were not available related to this climate variable. Although additional data specific to hail is required, the vulnerability of the telemetry equipment due to a hail event is low.

For intense winds and tornadoes, remedial action is recommended. Using professional judgment due to insufficient data, but with comments from Ouranos related to extreme wind and tornadoes, it is possible that greater vulnerability exists due to future climate changes. The City should review their emergency preparedness requirements on tornadoes. The City should also consider burying communication lines to the greatest extent possible or having back-up wireless communication.

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7.0 Acknowledgements

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Caroline Larrivée - Ouranos

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8.0 Limitations

The findings and recommendations provided in this report were prepared by GENIVAR in association with TetrES Consultants Inc. (the Consultants) in accordance with generally accepted professional engineering principles and practices. The information contained in this report represents the professional opinion of the Consultant and their best judgment under the natural limitations imposed by the Scope of Work.

This report is limited in scope to only those items that are specifically referenced in this report. There may be existing conditions that were not recorded in this report. Such conditions were not apparent to the Consultants due to the limitations imposed by the scope of work. The Consultants, therefore, accept no liability for any costs incurred by the Client for subsequent discovery, manifestation or rectification of such conditions.

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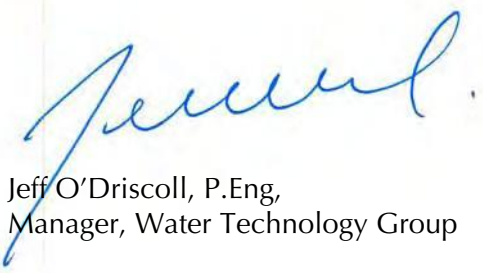
The report has been written to be read in its entirety, do not use any part of this report as a separate entity.

All files, notes, source data, test results and master files are retained by GENIVAR/TetrES and remain the property of the Consultants.

Respectfully Submitted:

GENVIAR



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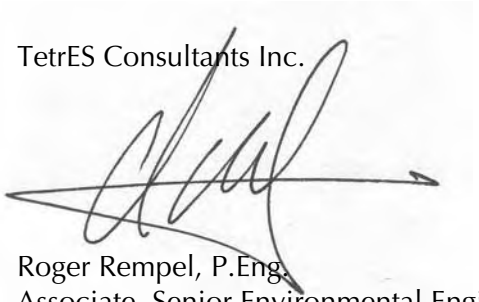

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Worksheet 3 Qualitative Assessment

In this section the practitioner will identify the infrastructure's response to the most relevant climate effects. This will be done by developing prioritized lists of relevant parameters which are then grouped to expose detrimental system responses. The grouped parameters, or relationships, are combinations of:

- Infrastructure component performance response;
- Climate effects; and/or
- Other Change effects.

3.3.1 Prioritization Methodology

The practitioner is required to prioritize a number of climate-infrastructure interactions, or relationships. The default prioritization system is based on a scale of **1 to 10. The** practitioner is directed to select a scale value based on either probability or severity of outcomes. The procedure directs the practitioner to select the scale values from either Figure 6 or Figure7 based on whether the scale factor is based on probability or severity.

Figure 6: Probability Scale Factors

Scale	Probability*		
	Method A	**Method B**	**Method C**
0	negligible or not applicable	~~<0.1 % <0.1 / 20~~	~~negligible or not applicable~~
1	improbable / highly unlikely	~~5 % 1 / 20~~	~~improbable 1:1 000 000~~
2	remote	~~20 % 4 / 20~~	~~remote 1:100 000~~
3	occasional	~~35 % 7 / 20~~	~~occasional 1:10 000~~
4	moderate / possible	~~50 % 10 / 20~~	~~moderate 1:1 000~~
5	often	~~65 % 13 / 20~~	~~probable 1:100~~
6	probable	~~80 % 16 / 20~~	~~frequent 1:10~~
7	certain / highly probable	~~>95 % >19 / 20~~	~~continuous 1:1~~

*****

a) Choose Method A, Method B or Method C to select the priority.
b) Record in project documentation the Method that was used.
c) Use the same Method for all probability prioritization in the evaluation.

Figure 7: Severity Scale Factors

Scale	Magnitude	Severity of Consequences and Effects
	Method D	**Method E**
0	~~no effect~~	negligible or not applicable
1	~~measurable 0.0125~~	very low / unlikely / rare / measurable change
2	~~minor 0.025~~	low / seldom / marginal / change in serviceability
3	~~moderate 0.050~~	occasional loss of some capability
4	~~major 0.100~~	moderate loss of some capacity
5	~~serious 0.200~~	likely regular / loss of and loss of some function
6	~~hazardous 0.400~~	major / likely / critical / loss of function
7	~~catastrophic 0.800~~	extreme/ frequent/ / loss of asset

*****

d) Choose Method D or Method E to select the priority.
e) Record in project documentation the Method that was used.
f) Use the same Method for all magnitude prioritization in the evaluation.

As appropriate, the practitioner may select an alternative prioritization methodology.

If the practitioner selects an alternative prioritization methodology they are directed to substantiate and document this choice in the project report.

3.3.2 Performance Response of Infrastructure Components to Climate Change **(Reference Appendix C Example Performance Responses)**		
Generally anticipated affects on the infrastructure arising from the climate and other change parameters	**Infrastructure Component**	**SCALE** **(use Figure 7)**
Structural Integrity		
Serviceability		
Functionality		
Operations and Maintenance		
Emergency response risk		
Insurance Considerations		
Policies and Procedures		
Economics		
Public Health and Safety		
Environmental Effects		
Other		
Transfer infrastructure components with Performance Response score of 3 or more onto section 3.3.5 & 3.3.6 below for combination relationship evaluation. **If Practitioner choose to use a different cut-off value other then >2, document the rationale for the decision in this section.**		
Scale factor used, if different: **The scale factors used were the same as the Protocol suggests, however, a scale factor was not applied to each individual affect performance response. A table of which performance responses are affected for each infrastructure, seen below. When applying scale factors, each infrastructure component-climate relationship was assigned one scale factor representing the worst case out of the performance responses.**		

Infrastrucure Components		Performance Response									
		Structural Integrity	Serviceability	Functionality	Operations & Maintenance	Emergency Response Risk	Insurance Considerations	Policies and Procedures	Economics	Public Health & Safety	Environmental Effects
Administration/ operations	Personnel				✓	✓	✓	✓		✓	
	Facilities/Equipment (WTP)	✓	✓	✓	✓	✓	✓	✓		✓	✓
	Records				✓	✓	✓	✓		✓	
Source Water	Shellmouth Dam / Reservoir	✓	✓			✓		✓		✓	✓
	Assiniboine River System				✓	✓		✓			✓
	Portage Diversion	✓	✓		✓	✓	✓	✓		✓	✓
	Control Dam Structure	✓	✓		✓	✓	✓	✓		✓	✓
	Intake Well / Pumps	✓	✓	✓	✓	✓	✓	✓		✓	✓
Treatment	Pretreatment (Actiflow)		✓	✓	✓	✓		✓		✓	✓
	Softening/Clarification		✓	✓	✓	✓		✓		✓	✓
	Filtration (Granular/GAC)		✓	✓	✓	✓		✓		✓	✓
	Disinfection (Ozone/Chlorine)		✓	✓	✓	✓		✓		✓	✓
	Storage		✓	✓	✓	✓		✓		✓	✓
	Chemical Feed Systems		✓	✓	✓	✓		✓		✓	✓
	Chemical Storage/Hazardous Materials		✓	✓	✓	✓		✓		✓	✓
	Valves / pipelines (on site)	✓	✓	✓	✓	✓		✓		✓	
Distribution	Pump stations (WTP/McKay)	✓	✓	✓	✓	✓	✓	✓		✓	✓
	Pipelines, valves	✓	✓	✓	✓	✓		✓		✓	
	Pipe Materials	✓	✓	✓	✓	✓		✓		✓	✓
Electric power	Substations / Transformers	✓	✓	✓		✓	✓	✓		✓	
	Transmission lines	✓	✓	✓		✓	✓	✓		✓	
	Standby generators	✓	✓	✓	✓	✓	✓	✓		✓	✓
Transportation	Vehicles		✓	✓	✓	✓	✓	✓			
	Maintenance facilities	✓	✓	✓	✓	✓	✓	✓		✓	
	Supplies		✓	✓	✓	✓	✓	✓		✓	
	Roadway infrastructure	✓	✓	✓	✓	✓	✓	✓		✓	
Communications	Telephone		✓	✓	✓	✓		✓			
	Two-way radio		✓	✓	✓	✓		✓			
	Telemetry	✓	✓	✓	✓	✓		✓		✓	

3.3.3 Scale the Climate Effects	
Relevant Climate Effects (from Worksheet 2 – section 3.2.2)	**SCALE (use Figure 6)**
Transfer Climate Parameter with Probability factor of 3 or more onto section 3.3.5 below for combination relationship evaluation. If Practitioner choose to use a different cut-off value other then >2, document the rationale for the decision in this section.	
Scale factor used, if different: **The same scale factors are used, but each climate effect was assigned a different probability scale factor dependent on the infrastructure-climate effect relationship. See the matrix below.**	

Infrastructure Components	Performance Criteria	Severe Weather Event																																					
		Floods/ Ice Jamming/ Ice Build-up				High Temp				Low Temp				Intense Rain				Drought				Ice Storm				Blizzard (Snow)				Intense Wind/Tornado				Hail				Frost Penetration				Ground Water Table (Portage la Prairie)			
Administration/ Operations		Y/N	S_C	S_R	P_C	Y/N	S_C	S_R	P_C	Y/N	S_C	S_R	P_C	Y/N	S_C	S_R	P_C	Y/N	S_C	S_R	P_C	Y/N	S_C	S_R	P_C	Y/N	S_C	S_R	P_C	Y/N	S_C	S_R	P_C	Y/N	S_C	S_R	P_C	Y/N	S_C	S_R	P_C	Y/N	S_C	S_R	P_C
Personnel	Operations & Maintenance; Emergency Response Risks; Insurance Considerations; Policies and Procedures; Public Health and Safety	✓	6	5	30	✓	4	2	8	✓	3	3	9	✓	2	3	6					✓	6	5	30	✓	6	5	30	✓	6	6	36	✓	4	2	8								
Facilities/equipment	Structural Integrity; Serviceability; Functionality; Operations & Maintenance; Emergency Response Risks; Insurance Considerations; Policies and Procedures; Public Health and Safety; Environmental Effects	✓	6	6	36	✓	5	4	20	✓	4	5	20	✓	4	4	16					✓	6	6	36	✓	6	5	30	✓	6	7	42	✓	4	2	8	✓	2	3	6				
Records	Operations & Maintenance; Emergency Response Risks; Insurance Considerations; Policies and Procedures; Public Health and Safety	✓	2	2	4																								✓	3	2	6												
Source Water																																												
Shellmouth Dam / Reservoir	Structural Integrity; Serviceability; Emergency Response Risks; Policies and Procedures; Public Health and Safety; Environmental Effects	✓	3	4	12					✓	2	3	6	✓	2	2	4	✓	3	6	18	✓	2	2	4	✓	2	2	4	✓	2	5	10												
Assiniboine River System	Operations & Maintenance; Emergency Response Risks; Policies and Procedures; Public Health and Safety; Environmental Effects	✓	6	6	36	✓	4	2	8	✓	3	2	6	✓	2	2	4	✓	3	6	18																					✓	3	4	12
Portage Diversion	Structural Integrity; Serviceability; Operations & Maintenance; Emergency Response Risks; Insurance Considerations; Policies and Procedures; Public Health and Safety; Environmental Effects	✓	3	2	6									✓								✓	2	2	4	✓	2	2	4	✓	2	3	6												
Dam Structure	Structural Integrity; Serviceability; Operations & Maintenance; Emergency Response Risks; Insurance Considerations; Policies and Procedures; Public Health and Safety; Environmental Effects	✓	6	6	36									✓	3	3	9					✓	3	3	9	✓	3	3	9	✓	3	5	15												
Intake Well / Pumps	Structural Integrity; Serviceability; Functionality; Operations & Maintenance; Emergency Response Risks; Insurance Considerations; Policies and Procedures; Public Health and Safety; Environmental Effects	✓	6	6	36					✓	3	4	12	✓	6	6	36	✓	6	6	36																								
Treatment																																												
Pretreatment (Actiflo)	Serviceability; Functionality; Operations & Maintenance; Emergency Response Risks; Policies and Procedures; Public Health and Safety; Environmental Effects	✓	4	4	16	✓	4	4	16	✓	4	4	16	✓	4	3	12	✓	5	5	25																								
Softening/Clarification	Serviceability; Functionality; Operations & Maintenance; Emergency Response Risks; Policies and Procedures; Public Health and Safety; Environmental Effects	✓	2	3	6	✓	4	4	16	✓	4	4	16	✓	3	3	9	✓	4	4	16																								
Filtration (Granular/GAC)	Serviceability; Functionality; Operations & Maintenance; Emergency Response Risks; Policies and Procedures; Public Health and Safety; Environmental Effects									✓	2	2	4																																
Disinfection (Ozone/Chlorine)	Serviceability; Functionality; Operations & Maintenance; Emergency Response Risks; Policies and Procedures; Public Health and Safety; Environmental Effects					✓	2	2	4	✓	4	4	16																																
Storage	Serviceability; Functionality; Operations & Maintenance; Emergency Response Risks; Policies and Procedures; Public Health and Safety; Environmental Effects																	✓	4	5	20																	✓	2	2	4				
Chemical Feed Systems	Serviceability; Functionality; Operations & Maintenance; Emergency Response Risks; Policies and Procedures; Public Health and Safety; Environmental Effects									✓	3	3	9																																
Chemical Storage / Hazardous Materials	Serviceability; Functionality; Operations & Maintenance; Emergency Response Risks; Policies and Procedures; Public Health and Safety; Environmental Effects	✓	6	6	36					✓	4	3	12									✓	3	3	9	✓	4	3	12	✓	6	6	36												
Valves / pipelines (on site)	Structural Integrity; Serviceability; Functionality; Operations & Maintenance; Emergency Response Risks; Policies and Procedures; Public Health and Safety	✓	4	5	20					✓	5	3	15	✓	3	2	6	✓	4	4	16					✓	4	4	16	✓	3	3	9					✓	5	3	15	✓	4	5	20
Distribution																																												
Pump stations (WTP/McKay)	Structural Integrity; Serviceability; Functionality; Operations & Maintenance; Emergency Response Risks; Insurance Considerations; Policies and Procedures; Public Health and Safety; Environmental Effects	✓	4	6	20	✓	4	4	16	✓	3	4	12									✓	3	3	9	✓	5	3	15	✓	6	7	42												
Pipelines, valves	Structural Integrity; Serviceability; Functionality; Operations & Maintenance; Emergency Response Risks; Policies and Procedures; Public Health and Safety	✓	4	5	20					✓	5	3	15	✓	3	2	6	✓	4	4	16					✓	4	4	16	✓	3	3	9					✓	5	3	15	✓	5	5	25
Pipe Materials	Structural Integrity; Serviceability; Functionality; Operations & Maintenance; Emergency Response Risks; Policies and Procedures; Public Health and Safety; Environmental Effects									✓	3	3	9					✓	4	4	16																	✓	5	5	25	✓	5	5	25
Electric Power																																												
Substations / Transformers	Structural Integrity; Serviceability; Functionality; Emergency Response Risks; Insurance Considerations; Policies and Procedures; Public Health and Safety;	✓	3	6	18	✓	3	3	9													✓	6	6	36	✓	5	5	25	✓	6	6	36	✓	3	3	9								
Transmission lines	Structural Integrity; Serviceability; Functionality; Emergency Response Risks; Insurance Considerations; Policies and Procedures; Public Health and Safety;	✓	3	2	6	✓	3	2	6													✓	6	6	36	✓	5	5	25	✓	6	5	30	✓	3	4	12								
Standby generators	Structural Integrity; Serviceability; Functionality; Operations & Maintenance; Emergency Response Risks; Insurance Considerations; Policies and Procedures; Public Health and Safety; Environmental Effects	✓	5	5	25	✓	4	4	16													✓	6	4	24	✓	5	4	20	✓	5	6	30												
Transportation																																												
Vehicle	Serviceability; Functionality; Operations & Maintenance; Emergency Response Risks; Insurance Considerations; Policies and Procedures;	✓	2	2	4					✓	3	4	12	✓	3	3	9					✓	5	5	25	✓	5	5	25	✓	6	6	36	✓	4	4	16								
Maintenance facilities	Structural Integrity; Serviceability; Functionality; Operations & Maintenance; Emergency Response Risks; Insurance Considerations; Policies and Procedures; Public Health and Safety	✓	3	3	9																	✓	5	4	20					✓	6	6	36												
Supplies	Serviceability; Functionality; Operations & Maintenance; Emergency Response Risks; Insurance Considerations; Policies and Procedures; Public Health and Safety	✓	2	2	4									✓	3	3	9					✓	5	4	20	✓	5	4	20	✓	6	5	30												
Roadway infrastructure	Structural Integrity; Serviceability; Functionality; Operations & Maintenance; Emergency Response Risks; Insurance Considerations; Policies and Procedures; Public Health and Safety	✓	3	5	15									✓	3	2	6					✓	3	4	12	✓	5	6	30	✓	4	5	20					✓	3	3	9				
Communications																																												
Telephone	Serviceability; Functionality; Operations & Maintenance; Emergency Response Risks; Policies and Procedures	✓	3	3	9																	✓	5	6	30	✓	5	5	25	✓	5	5	25	✓	4	5	20								
Two-way radio	Serviceability; Functionality; Operations & Maintenance; Emergency Response Risks; Policies and Procedures													✓	3	3	9																											
Telemetry	Structural Integrity; Serviceability; Functionality; Operations & Maintenance; Emergency Response Risks; Policies and Procedures; Public Health and Safety	✓	3	3	9																	✓	5	6	30	✓	5	5	25	✓	5	5	25	✓	4	5	20								

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3.3.4 Scale Other Change Effects

Relevant Climate Effects (from Worksheet 2 – section 3.2.7)	SCALE (use Figure 7)

Transfer Other Change Effects with Magnitude Scale factor of 3 or more onto section 3.3.6 below for combination relationship evaluation.
If Practitioner choose to use a different cut-off value other then >2, document the rationale for the decision in this section.

Scale factor used, if different:

3.3.5 Prioritize Climate Effects & Performance Response Relationship

$P_C = S_C \times S_R$ **Where:** P_C = Priority of Climate Effect; S_C = Scale factor for Climate Effect; S_R = Scale factor for Performance Response

Selected Climate Change Effect (from 3.3.3 above)	S_C	Selected Performance Responses (from 3.3.2 above)	S_R	Priority of Climate Effects ($P_C = S_C \times S_R$)
SEE ABOVE MATRIX		*SEE ABOVE MATRIX*		

Transfer Climate Parameter with Priority of 36 or more, Go immediately to STEP 5 (Section 3.5.2 in Work Sheet 5) and assess appropriate recommendations to address the identified vulnerability.
List the Infrastructure Components transferred to STEP 5 below:

Infrastructure Component	Climate Variable	Priority of Relationship
Personnel	Intense Wind/Tornado	36
Facilities/equipment	Floods/Ice Jamming/Ice Buildup	36
	Ice Storm	36
	Intense Wind/Tornado	42
Assiniboine River System	Floods/Ice Jamming/Ice Buildup	36
Dam Structure	Floods/Ice Jamming/Ice Buildup	36
Intake Well / Pumps	Floods/Ice Jamming/Ice Buildup	36
	Intense Rain	36
	Drought	36
Chemical Storage / Hazardous Materials	Floods/Ice Jamming/Ice Buildup	36
	Intense Wind/Tornado	36
Pump stations (WTP/McKay)	Intense Wind/Tornado	42
Substations / Transformers	Ice Storm	36
	Intense Wind/Tornado	36
Transmission lines	Ice Storm	36
Vehicle	Intense Wind/Tornado	36
Maintenance facilities	Intense Wind/Tornado	36

For relationships with calculated Priority between 12 and 36, categorize the Relationship for further numerical analysis in Step 4 (Section 3.4.4 and 3.4.8 in Worksheet 4)

Infrastructure Component	Climate Variable	Priority of relationship
Personnel	Floods/Ice Jamming/Ice Buildup	30

	Ice Storm	30
	Blizzard	30
Facilities/equipment	High Temp	20
	Low Temp	20
	Intense Rain	16
	Blizzard	30
Shellmouth Dam/Reservoir	Drought	18
Assiniboine River System	Drought	18
Dam Structure	Intense Wind/Tornado	15
Pretreatment	Floods/Ice Jamming/Ice Buildup	16
	High Temp	16
	Low Temp	16
	Drought	25
Softening	High Temp	16
	Low Temp	16
	Drought	16
Disinfection	Low Temp	16
Storage	Drought	20
Vales Pipelines (on WTP site)	Floods/Ice Jamming/Ice Buildup	20
	Low Temp	15
	Drought	16
	Blizzard	16
	Frost Penetration	15
	Ground Water Table	20
Pump stations (WTP/McKay)	Floods/Ice Jamming/Ice Buildup	20
	High Temp	16
	Blizzard	15
Pipelines and Valves	Floods/Ice Jamming/Ice Buildup	20
	Low Temp	15
	Drought	16
	Blizzard	16
	Frost Penetration	15
	Ground Water Table	25
Pipe Materials	Drought	16
	Frost Penetration	25
	Ground Water Table	25
Substations / Transformers	Floods/Ice Jamming/Ice Buildup	18
	Blizzard	25
Transmission lines	Blizzard	25
	Intense Wind/Tornado	30

Standby Generators	Floods/Ice Jamming/Ice Buildup	25
	High Temp	16
	Ice Storm	24
	Blizzard	20
	Intense Wind/Tornado	30
Vehicle	Ice Storm	25
	Blizzard	25
	Hail	16
Maintenance Facilities	Ice Storm	20
Supplies	Ice Storm	20
	Blizzard	20
	Intense Wind/Tornado	30
Roadway Infrastructure	Floods/Ice Jamming/Ice Buildup	15
	Blizzard	30
	Intense Wind/Tornado	20
Telephone	Ice Storm	30
	Blizzard	25
	Intense Wind/Tornado	25
	Hail	20
Telemetry	Ice Storm	30
	Blizzard	25
	Intense Wind/Tornado	25
	Hail	20

If Practitioner choose to use a different cut-off value other then 36, state the chosen value and document the rationale for the decision in this section.

Scale factor used, if different:

3.3.6 Prioritize Other Effects & Performance Response Relationship

$P_O = S_C \times S_R$ **Where:** P_C = Priority of Climate Effect; S_C = Scale factor for Climate Effect; S_R = Scale factor for Performance Response

Selected Climate Change Effect (from 3.3.4 above)	S_O	Selected Performance Responses (from 3.3.2 above)	S_R	Priority of Climate Effects ($P_O = S_O \times S_R$)

Transfer Climate Parameter with Priority of 36 or more, Go immediately to STEP 5 (Section 3.5.2 in Work Sheet 5) and assess appropriate recommendations to address the identified vulnerability.
List the Infrastructure Components transferred to STEP 5 below:

1.
2.
3.
4.
5.
6.

For relationships with calculated Priority between 12 and 36, categorize the Relationship for further numerical analysis in Step 4 (Section 3.4.4 & 3.4.8 in Worksheet 4)

1.
2.
3.
4.
5.
6.

If Practitioner choose to use a different cut-off value other then 36, state the chosen value and document the rationale for the decision in this section.
Scale factor used, if different:

3.3.7 Data Sufficiency	
Identify process to develop data, Where insufficient	
Data Needed	**Process**
See Report section 3.3.7	
Where data cannot be developed, identify the data gap as a finding in Step 5 of the Protocol – Recommendations. **List Data Gap as findings to be sent to STEP 5 (Worksheet 5: Section 3.5.2)**	
1.	
2.	
3.	
4.	
5.	
6.	

Worksheet 4 Quantitative Assessment

In this step the practitioner will determine the relationship between the Performance Responses loads placed on the infrastructure and its capacity. Vulnerability exists when infrastructure has insufficient capacity to withstand the effects placed on it. Resiliency exits when the infrastructure has sufficient capacity to withstand increasing climate change effects.

3.4.4 Calculation of Total Load (L_T)				
Basis of Determination: • **Definitions;** • **Direct measurements;** • **Engineering calculations; or** • **Assumptions based on professional judgement.**				
Infrastructure Component (from 3.3.5 from Work Sheet 3)	**3.4.1 Existing Load** State Basis of Determination **L_E**	**3.4.2 Climate Load** State Basis of Determination **L_C**	**3.4.3 Other Load** State Basis of Determination **L_O**	**Total Load** **$L_T = L_E+L_C+L_O$**
1. Facility/pump stations – High temp	35.2'C	+ 2.2'C (2020) + 3.5'C (2050) + 6.0'C (2080)	N/A	37.4 (2020) 38.7 (2050) 41.2 (2080)
EXAMPLE – SEE REPORT FOR COMPLETE ANALYSIS	Basis of Determination Average annual max temperature	Basis of Determination change in annual max temperature	Basis of Determination	
2.				
	Basis of Determination	Basis of Determination	Basis of Determination	
3.				
	Basis of Determination	Basis of Determination	Basis of Determination	

3.4.4 Calculation of Total Load (L_T)

Basis of Determination:

- **Definitions;**
- **Direct measurements;**
- **Engineering calculations; or**
- **Assumptions based on professional judgement.**

Infrastructure Component (from 3.3.5 from Work Sheet 3)	**3.4.1 Existing Load** State Basis of Determination **L_E**	**3.4.2 Climate Load** State Basis of Determination **L_C**	**3.4.3 Other Load** State Basis of Determination **L_O**	**Total Load** **$L_T = L_E+L_C+L_O$**
4.				
	Basis of Determination	Basis of Determination	Basis of Determination	
5.				
	Basis of Determination	Basis of Determination	Basis of Determination	
6.				
	Basis of Determination	Basis of Determination	Basis of Determination	
7.				
	Basis of Determination	Basis of Determination	Basis of Determination	
8.				
	Basis of Determination	Basis of Determination	Basis of Determination	

3.4.4 Calculation of Total Load (L_T)

Basis of Determination:

- **Definitions;**
- **Direct measurements;**
- **Engineering calculations; or**
- **Assumptions based on professional judgement.**

Infrastructure Component (from 3.3.5 from Work Sheet 3)	**3.4.1 Existing Load** State Basis of Determination **L_E**	**3.4.2 Climate Load** State Basis of Determination **L_C**	**3.4.3 Other Load** State Basis of Determination **L_O**	**Total Load** **$L_T = L_E+L_C+L_O$**

3.4.8 Calculation of Total Capacity (C_T)

$C_T = C_E + C_M + C_A$

Where: **C_T = Total capacity of the infrastructure**
C_E = Existing capacity of the infrastructure
C_M = Maturing capacity of the infrastructure
C_A = Additional capacity of the infrastructure

Basis of Determination

- **Definitions;**
- **Direct measurements;**
- **Engineering calculations; or**
- **Assumptions based on professional judgement**.

Infrastructure Component (from 3.3.5 & 3.3.6 from Work Sheet 3)	**3.4.5 Existing Capacity** State Basis of Determination **C_E**	**3.4.6 Maturing Capacity** State Basis of Determination **C_M**	**3.4.7 Additional Capacity** State Basis of Determination **C_A**	**Total Capacity** **$C_T = C_E+C_M+C_A$**
1. Facility/pump stations – High temp	40'C	N/A	N/A	40'C
	Basis of Determination Most electrical systems designed to sustain 40'C. This is the limiting factor.	Basis of Determination	Basis of Determination	

3.4.8 Calculation of Total Capacity (C_T)

$C_T = C_E + C_M + C_A$

Where: **C_T = Total capacity of the infrastructure**
C_E = Existing capacity of the infrastructure
C_M = Maturing capacity of the infrastructure
C_A = Additional capacity of the infrastructure

Basis of Determination
- **Definitions;**
- **Direct measurements;**
- **Engineering calculations; or**
- **Assumptions based on professional judgement**.

Infrastructure Component (from 3.3.5 & 3.3.6 from Work Sheet 3)	**3.4.5 Existing Capacity** State Basis of Determination **C_E**	**3.4.6 Maturing Capacity** State Basis of Determination **C_M**	**3.4.7 Additional Capacity** State Basis of Determination **C_A**	**Total Capacity** **$C_T = C_E+C_M+C_A$**
2.				
	Basis of Determination	Basis of Determination	Basis of Determination	
3.				
	Basis of Determination	Basis of Determination	Basis of Determination	
4.				
	Basis of Determination	Basis of Determination	Basis of Determination	
5.				
	Basis of Determination	Basis of Determination	Basis of Determination	
6.				
	Basis of Determination	Basis of Determination	Basis of Determination	

3.4.8 Calculation of Total Capacity (C_T)

$C_T = C_E + C_M + C_A$

Where: **C_T = Total capacity of the infrastructure**
C_E = Existing capacity of the infrastructure
C_M = Maturing capacity of the infrastructure
C_A = Additional capacity of the infrastructure

Basis of Determination
- **Definitions;**
- **Direct measurements;**
- **Engineering calculations; or**
- **Assumptions based on professional judgement**.

Infrastructure Component (from 3.3.5 & 3.3.6 from Work Sheet 3)	**3.4.5 Existing Capacity** State Basis of Determination **C_E**	**3.4.6 Maturing Capacity** State Basis of Determination **C_M**	**3.4.7 Additional Capacity** State Basis of Determination **C_A**	**Total Capacity** **$C_T = C_E+C_M+C_A$**
7.				
	Basis of Determination	Basis of Determination	Basis of Determination	
8.				
	Basis of Determination	Basis of Determination	Basis of Determination	
9.				
	Basis of Determination	Basis of Determination	Basis of Determination	

3.4.9 Evaluate Vulnerability (V_R)

3.4.9 Evaluate Vulnerability (V_R)

$$V_R = \frac{L_T}{C_T}$$

Where:

V_R = Vulnerability Ratio
L_T = Total load on the infrastructure
C_T = Total capacity of the infrastructure

Infrastructure Component	Total Load (from 3.4.4)	Total Capacity (from 3.4.8)	Vulnerability $V_R = \frac{L_T}{C_T}$
1. Facility/pump stations – High temp	37.4 (2020) 38.7 (2050) 41.2 (2080)	40'C	0.935 (2020) 0.9675 (2050) 1.03 (2080)
1.			
2.			
3.			
4.			
5.			
6.			
7.			

When V_R < 1, the infrastructure component is vulnerable

3.4.9 Evaluate Vulnerability (V_R)
Infrastructure Component showing vulnerability should be forwarded to Section 3.5.2 in Work Sheet 5 for STEP 5 Recommendation Evaluation. **List Infrastructure Components forwarded to Section 3.5.2 of Work Sheet 5 for Recommendation Assessment below:**
Facility/pump stations – High temp have V_R < 1 for the 2080 horizon, this is well beyond the remaining service life of the plant and may not represent a vulnerability at this time.

3.4.10 Adaptive Capacity (A_R)

$$A_R = \frac{C_T}{L_T}$$

Where:

A_R = Adaptive Capacity Ratio
C_T = Total capacity of the infrastructure
L_T = Total load on the infrastructure

Infrastructure Component	Total Capacity (from 3.4.8)	Total Load (from 3.4.4)	Vulnerability $A_R = \frac{C_T}{L_T}$
1. Facility/pump stations – High temp	37.4 (2020) 38.7 (2050) 41.2 (2080)	40'C	1.0695187 (2020) 1.0335917 (2050) 0.9708738 (2080)
1.			
2.			
3.			
4.			
5.			
6.			
7.			

When $A_R < 1$, the infrastructure component does not have adaptive capacity

3.4.10 Adaptive Capacity (A_R)
Infrastructure Component Lacking in Adaptive Capacity should be forwarded to Section 3.5.2 in Work Sheet 5 for STEP 5 Recommendation Evaluation. **List Infrastructure Components forwarded to Section 3.5.2 of Work Sheet 5 for Recommendation Assessment below:**

3.4.11 Calculate Capacity Deficit (C_D)

$C_D = L_T - C_T$

$= L_T - (C_E + C_M + C_A)$

Where:
C_D = Capacity deficit of the infrastructure component
L_T = Total load on the infrastructure component
C_E = Existing capacity of the infrastructure component
C_M = Maturing capacity of the infrastructure component
C_A = Additional capacity of the infrastructure component

Infrastructure Component	Total Load (from 3.4.4)	Total Capacity (from 3.4.8)	Capacity Deficit $C_D = L_T - C_T$
1.			
2.			
3.			
4.			
5.			
6.			
7.			
8.			

Clarification
The Capacity Deficit is the amount of capacity that must be added to the infrastructure component to address the vulnerability identified by this procedure. The capacity deficit may be addressed by capacity addition projects or through infrastructure management practices.

3.4.12 Data Sufficiency	
Identify process to develop data, Where insufficient	
Data Needed	**Process**
SEE REPORT	
Where data cannot be developed, identify the data gap as a finding in Step 5 of the Protocol – Recommendations. **List Data Gap as findings to be sent to STEP 5 (Worksheet 5: Section 3.5.2)**	
1.	
2.	
3.	
4.	
5.	
6.	

Worksheet 5 Recommendations

3.5.1 State Limitations	
Available infrastructure information and sources	
Available climate and information	• Extreme events not able to be modelled • Turnaround time for data 10 weeks
Available Other Change Information and sources	
Use of Generic/specific examples to represent population	
Uncertainty and related concepts	The modelling procedure of using only one emission scenario, simulated with a single GCM, downscaled by a single methodology, for only 2 model runs does not represent the full ensemble of possible climate change scenarios
Other	

3.5.2 Recommendations

Infrastructure Component • **Showing Vulnerability from Combination Relationship Assessments** **(from Work Sheet 3: 3.3.5 & 3.3.6, Priority values > 36)** • **Showing Vulnerability from Quantitative Assessment** **(from Work Sheet 4: 3.4.9, V_R >1)** • **Lack of Adaptive Capacity** **(from Work Sheet 4: 3.4.10, A_R<1)** • **Report on Data Gaps (from Worksheets 1-4: 3.1.2, 3.2.8, 3.3.7, 3.4.12)**	**Remedial Engineering Action**	**Management Actions**	**No further Action**	**Recommendation Priority** **(User defined)**	**Comments**
SEE TABLE BELOW					

Infrastructure Component	Climate Variable	Data Source	Forward to STEP 5 Recommendation Evaluation Y/N	Recommendations	Recommendation Comments
Personnel	Floods/ Ice Jamming/ Ice Build-up	Data not available	✓	No Further Action	Using professional judgement due to insufficient data, it is not expected that greater vulnerability exists due to future changes of Floods/Ice Jamming/Ice Build-up. It is assumed that the personnel have exiting capability or adaptive capabilities.
	Ice Storm	Data not available	✓	No Further Action	Using professional judgement due to insufficient data, it is not expected that greater vulnerability exists due to future changes of Floods/Ice Jamming/Ice Build-up. It is assumed that the personnel have exiting capability or adaptive capabilities.
Facilities/ Equipment	High Temp	Temperature: Annual Max (Deg. C)			
		2080	✓	No Further Action	Although a slight vulnerability exists, the 2080 horizon is well beyond the remaining service life of the equipment. Expected that replacement equipment will have a higher rating nearing 2080.
Shellmouth Dam/ Reservoir	Drought	Rain: Ave Total Rain, Annual Plus Snow: Ave Total, Annual (mm)			
		2020	✓	Additional Study Required	Further Study is required on climate impacts to the Assiniboine Watershed Infrastructure.
		2050	✓	Additional Study Required	Further Study is required on climate impacts to the Assiniboine Watershed Infrastructure.
		2080	✓	Additional Study Required	Further Study is required on climate impacts to the Assiniboine Watershed Infrastructure.
Assiniboine River System	Drought	Rain: Ave Total Rain, Annual Plus Snow: Ave Total, Annual (mm)			
		2020	✓	Additional Study Required	Further Study is required on climate impacts to the Assiniboine Watershed Infrastructure.
		2050	✓	Additional Study Required	Further Study is required on climate impacts to the Assiniboine Watershed Infrastructure.
		2080	✓	Additional Study Required	Further Study is required on climate impacts to the Assiniboine Watershed Infrastructure.
Pre-treatment	Floods/ Ice Jamming/ Ice Build-up	Data not available	✓	Additional Study Required	Using professional judgement due to insufficient data, it is not expected that greater vulnerability exists due to future changes of Floods/Ice Jamming/Ice Build-up. It is assumed that the range of water quality changes under these events will not exceed current seasonal spikes. Assuming this, the infrastructure has exiting capability.
	High Temp	Temperature: Annual Max (Deg. C)			

Infrastructure Component	Climate Variable	Data Source	Forward to STEP 5 Recommendation Evaluation Y/N	Recommendations	Recommendation Comments
		2080	✓	No Further Action	Although a slight vulnerability exists, the 2080 horizon is well beyond the remaining service life of the equipment. Using professional judgement due to insufficient data, it is not expected that greater vulnerability exists due to future changes of high temperatures and related water quality. It is assumed that the range of water quality changes under these events will only slightly exceed current seasonal spikes. Assuming this, the infrastructure has exiting capability.
	Drought	Rain: Ave Total Rain, Annual Plus Snow: Ave Total, Annual (mm)			
		2020	✓	Additional Study Required	Further Study is required on climate impacts to the Assiniboine Watershed Infrastructure.
		2050	✓	Additional Study Required	Further Study is required on climate impacts to the Assiniboine Watershed Infrastructure.
		2080	✓	Additional Study Required	Further Study is required on climate impacts to the Assiniboine Watershed Infrastructure.
Softening	High Temp	Temperature: Annual Max (Deg. C)			
		2080	✓	No Further Action	Although a slight vulnerability exists, the 2080 horizon is well beyond the remaining service life of the equipment. Using professional judgement due to insufficient data, it is not expected that greater vulnerability exists due to future changes of high temperatures and related water quality. It is assumed that the range of water quality changes under these events will only slightly exceed current seasonal spikes. Assuming this, the infrastructure has exiting capability.
	Drought	Rain: Ave Total Rain, Annual Plus Snow: Ave Total, Annual (mm)			
		2020	✓	Additional Study Required	Further Study is required on climate impacts to the Assiniboine Watershed Infrastructure.
		2050	✓	Additional Study Required	Further Study is required on climate impacts to the Assiniboine Watershed Infrastructure.
		2080	✓	Additional Study Required	Further Study is required on climate impacts to the Assiniboine Watershed Infrastructure.
Storage	Drought	Rain: Ave Total Rain, Annual Plus Snow: Ave Total, Annual (mm)			
		2020	✓	Additional Study Required	Further Study is required on climate impacts to the Assiniboine Watershed Infrastructure.
		2050	✓	Additional Study Required	Further Study is required on climate impacts to the Assiniboine Watershed Infrastructure.
		2080	✓	Additional Study Required	Further Study is required on climate impacts to the Assiniboine Watershed Infrastructure.

Infrastructure Component	Climate Variable	Data Source	Forward to STEP 5 Recommendation Evaluation Y/N	Recommendations	Recommendation Comments
Vales Pipelines (on WTP site)	Floods/ Ice Jamming/ Ice Build-up	Data not available	✓	No Further Action	Using professional judgement due to insufficient data, it is not expected that greater vulnerability exists due to future changes of Floods/Ice Jamming/Ice Build-up. It is assumed that the infrastructure has exiting capability.
Pump Stations (WTP/ McKay)	Floods/ Ice Jamming/ Ice Build-up	Data not available	✓	Additional Study Required	Using professional judgement due to insufficient data, a greater vulnerability may exists due to future changes of Floods/Ice Jamming/Ice Build-up. Additional study is required.
	High Temp	Temperature: Annual Max (Deg. C)			
		2080	✓	No Further Action	Although a slight vulnerability exists, the 2080 horizon is well beyond the remaining service life of the equipment. Expected that replacement equipment will have a higher rating nearing 2080.
Pipelines and Valves	Floods/ Ice Jamming/ Ice Build-up	Data not available	✓	No Further Action	Using professional judgement due to insufficient data, it is not expected that greater vulnerability exists due to future changes of Floods/Ice Jamming/Ice Build-up. It is assumed that the infrastructure has exiting capability.
Substations / Transformers	Floods/ Ice Jamming/ Ice Build-up	Data not available	✓	Additional Study Required	Using professional judgement due to insufficient data, it is not expected that greater vulnerability exists due to future changes of Floods/Ice Jamming/Ice Build-up. It is assumed that the utility infrastructure is reasonably flood proofed and that future events will not exceed current seasonal spikes. Assuming this, the infrastructure has exiting capability. Additional study is required to confirm this assumption.
	Intense Wind/Tornado	Data not available	✓	Remedial Action	Using professional judgement due to insufficient data, but with comments from Ouranos related to extreme wind and tornados, it is possible that greater vulnerability exists due to future climate changes. The City should review their EMO requirements on tornados as well as working with Manitoba hydro to bury as many transmission lines as possible to reduce the vulnerability.
Standby Generators	Floods/ Ice Jamming/ Ice Build-up	Data not available	✓	Additional Study Required	Using professional judgement due to insufficient data, it is not expected that greater vulnerability exists due to future changes of Floods/Ice Jamming/Ice Build-up. It is assumed that the utility infrastructure is reasonably protected from flooding. Assuming this, the infrastructure has exiting capability. Additional study is required to confirm this assumption.
	High Temp	Temperature: Annual Max (Deg. C)			
		2080	✓	No Further Action	Although a slight vulnerability exists, the 2080 horizon is well beyond the remaining service life of the equipment. Expected that replacement equipment will have a higher temperature rating nearing 2080.
	Ice Storm	Data not available	✓	Additional Study Required	Additional study is required to determine the frequency of ice storms and the need for standby power during this extreme event.

Infrastructure Component	Climate Variable	Data Source	Forward to STEP 5 Recommendation Evaluation Y/N	Recommendations	Recommendation Comments
	Intense Wind/Tornado	Data not available	✓	Remedial Action	Using professional judgement due to insufficient data, but with comments from Ouranos related to extreme wind and tornados, it is possible that greater vulnerability exists due to future climate changes. The City should review their EMO requirements on tornados. In addition the City should review installing full standby power at the water treatment plant to reduce power vulnerability.
Vehicle	Ice Storm	Data not available	✓	Additional Study Required	Additional study is required to determine the frequency of ice storms and its effect on service vehicles.
	Hail	Data not available	✓	No Further Action	Climate change projections were not available related to this climate variable. Although additional data specific to hail is required, the vulnerability of service vehicles based on a hail event is low. No further action is required.
Maintenance Facilities	Ice Storm	Data not available	✓	Additional Study Required	Additional study is required to determine the frequency of ice storms and its effect on maintenance facilities.
Supplies	Ice Storm	Data not available	✓	Additional Study Required	Additional study is required to determine the frequency of ice storms and its effect on supply services.
	Intense Wind/Tornado	Data not available	✓	Remedial Action	Using professional judgement due to insufficient data, but with comments from Ouranos related to extreme wind and tornados, it is possible that greater vulnerability exists due to future climate changes. The City should review their EMO requirements on tornados.
Roadway Infrastructure	Floods/ Ice Jamming/ Ice Build-up	Data not available	✓	Additional Study Required	Using professional judgement due to insufficient data, it is not expected that greater vulnerability exists due to future changes of Floods/Ice Jamming/Ice Build-up. It is assumed that the utility infrastructure is reasonably protected from flooding. Assuming this, the infrastructure has exiting capability. Additional study is required to confirm this assumption.
	Intense Wind/Tornado	Data not available	✓	Remedial Action	Using professional judgement due to insufficient data, but with comments from Ouranos related to extreme wind and tornados, it is possible that greater vulnerability exists due to future climate changes. The City should review their EMO requirements on tornados.
Telephone	Ice Storm	Data not available	✓	Additional Study Required	Additional study is required to determine the frequency of ice storms and its effect on telephone services.
	Intense Wind/Tornado	Data not available	✓	Remedial Action	Using professional judgement due to insufficient data, but with comments from Ouranos related to extreme wind and tornados, it is possible that greater vulnerability exists due to future climate changes. The City should review their EMO requirements on tornados.
	Hail	Data not available	✓	No Further Action	Climate change projections were not available related to this climate variable. Although additional data specific to hail is required, the vulnerability of telephone service due to a hail event is low. No further action is required.
Telemetry	Ice Storm	Data not available	✓	Additional Study Required	Additional study is required to determine the frequency of ice storms and its effect on telemetry.
	Intense Wind/Tornado	Data not available	✓	Remedial Action	Using professional judgement due to insufficient data, but with comments from Ouranos related to extreme wind and tornados, it is possible that greater vulnerability exists due to future climate changes. The City should review their EMO requirements on tornados.

Infrastructure Component	Climate Variable	Data Source	Forward to STEP 5 Recommendation Evaluation Y/N	Recommendations	Recommendation Comments
	Hail	Data not available	✓	No Further Action	Climate change projections were not available related to this climate variable. Although additional data specific to hail is required, the vulnerability of the telemetry equipment due to a hail event is low. No further action is required.

3.5.2.f
Report on the other conclusions, trends, insights and limitations

APPENDIX C

Data Request Forms

Provision of Climatic Data and Climate Change Scenarios
National Engineering Vulnerability Assessment (NEVA) Project

Data Request Form

Issued by :

Canadian Council of Professional Engineers (CCPE), doing business as Engineers Canada
1100-180 Elgin Street
Ottawa, (ON) K2P 2K3
613-232-2474
Attention: D. Lapp, P.Eng. or M. Carter, P.Eng.
PIEVC Secretariat

Issued to :

Ouranos inc.
550 Sherbrooke Street West, 19th floor West Tower
Montréal (QC) H3A 1B9
514-282-6464
Attention: A. Bourque or C. Larrivée

Reference Standing Offer Agreement:

Standing Offer Agreement between CCPE and Ouranos, dated June 28, 2007.
Call-Up #: _____

Requirement :

Provide historic climatic data and climate change scenarios for Portage-la-Prairie to the Public infrastructure Engineering Vulnerability Committee (PIEVC) Secretariat from the list of climatic elements listed in Table 1.

Name of location	Portage la Prairie, Manitoba
Infrastructure categories under assessment	Water Resources
Contact person	Jeff O'Driscoll, P.Eng.
Contact information	GENIVAR 600 – 5 Donald Street Winnipeg, Manitoba R3L 2T4

	telephone 204.477.6650 *fax* 204.474.2864
	email jeff.odriscoll@genivar.com *ftp site (if available)* n/a
Date of request	July 5, 2007
Requested date for delivery	ASAP
Climatic Elements Requested for Historical Data	Reference Table 1 (1-highest priority)
Climatic Elements Requested for Climatic Scenarios	Reference Table 1

Specified Geographical Boundaries	Assiniboine River Watershed: South / West Corner : N 47° 00', W 108° 00' North / East Corner : N 52° 30', W 96° 30'
Additional Comments (e.g. specify priorities for processing)	

Authorized: _____ Date _____

Request Accepted: _____ Date _____

Table 1 – List of Potential Climatic Elements
DRAFT PIEVC Engineering Protocol – Version 4

Potential Climate Elements and Change Factors		**Data requirements** *(indicate variables needed by order of priority)*	
Climate Elements	**Potential Change Factor**	Historical data	Climate scenarios
Temperature	○ Rate of change	2	2
	○ Mean values	2	2
	○ Extremes	2	2
	• High summer		
	• Low winter	2	2
Precipitation as Rain	○ Frequency (One-Day, Short Duration Less than 24 hours, Multi-Day)	1	1
	○ Total annual/seasonal precipitation and rain	1	1
	○ Intensity of rain events (One-Day, Short Duration Less than 24 hours)	1	1
	○ Proportion of annual and seasonal precipitation as rainfall	1	1
	○ Drought conditions	1	1
Precipitation as Snow	○ Frequency	1	1
	○ Total annual/seasonal precipitation and snow	1	1
	○ Magnitude of snow events	1	1
	○ Frequency and intensity of rapid snow melt events	1	1
	○ Rain on snow events	1	1
Wind Speed	○ Mean values (one hour mean winds)	3	3
	• Monthly	3	3
	• Seasonal	3	3
	• Annual		
	○ Extremes/gusts	3	3
	○ Thunderstorm winds	3	3
	○ Changes in hurricane and/or tornado event frequency/intensity	3	3
		3	3
Sea (Water) Level Elevation		N/A	N/A
Fog		N/A	N/A

Potential Climate Elements and Change Factors		**Data requirements** *(indicate variables needed by order of priority)*	
Climate Elements	**Potential Change Factor**	Historical data	Climate scenarios
Ice	○ River or lake ice build up	4	4
Hail	○ Frequency of events ○ Magnitude of events	6	6
		6	6
Frost	○ Freeze thaw cycles ○ Change in frost season	7	7
		7	7
Ice Accretion	○ Change in frequency/intensity of ice storm events ○ Ice build up on infrastructure elements	4	4
		4	4
Other	○ Degree days ○ Albedo ○ Streamflow on the Assiniboine River • Extremes	8	8
		8	8
		8	8
		8	8

Infrastructure Data Request List

Assiniboine River and Inlet Structure:

- Frequency of ice jams
- Frequency of silt removal
- Age and remaining life expectancy of the current inlet structure, i.e. room for pumping expansion, plans for upgrades
- Any historical years where high/low water level on the Assiniboine River created problems

Water Treatment Plant:

- Water quality summaries
- Incident reports - any climate related problems experienced by the plant, Doug mentioned that the plant experiences power outages, the cause and frequency of these might be important

Distribution System:

- Incident reports - any problems that can be attributed to climate, especially any breaks due to freeze/thaw cycles, a high/low water table, or sink holes
- Piping statistics - General statistics regarding size, material, condition and age
- City standards for construction specs - i.e. depth of cover, backfill, etc
- Water distribution model report

Other Factors:

- Future water demand:
    - Population trends and predictions
    - Future potential for wet industry development
    - Future rural distribution expansion

APPENDIX D

Ouranos Climate Data Report and Other Data

Climate change in Canada:
Climate scenarios for the public infrastructure vulnerability assessment

Portage-la-Prairie Water Resources Infrastructure Assessment Pilot Study

Produced for the *Public Infrastructure Engineering Vulnerability Committee* (PIEVC)

By Ouranos
www.ouranos.ca

September 2007

Ouranos, a research consortium on regional climatology and adaptation to climate change, is a joint initiative of the Government of Québec, Hydro-Québec, and the Meteorological Service of Canada with the participation of UQAM, Université Laval, McGill University, and the INRS. Valorisation Recherche Québec collaborated on the establishment and financing of Ouranos. The opinions and results presented in this publication are the sole responsibility of Ouranos and do not reflect in any way those of the aforementioned organizations.

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September 2007

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1. Introduction

The Canadian Council of Professional Engineers set up the Public Infrastructure Engineering Vulnerability Committee (PIEVC) to examine the vulnerability of public infrastructure to climate change across the nation. A series of pilot studies serve to test and validate the engineering vulnerability protocol proposed in Phase 1 of the PIEVC initiative. The current study is located in Portage-la-Prairie (Manitoba) and focuses on water resources infrastructure.

The draft engineering protocol requires information on a variety of climatic elements to use as input towards estimating the vulnerability of infrastructure to climate change. Estimates of climatic elements enable numerical estimations of the exposure of the infrastructure and help identify which changes in climatic conditions will have the most impact on its vulnerability.

In order to provide coherent results for all of the pilot projects, the vulnerability analyses must be based on plausible and comparable scenarios of climate change for the various regions of the country. Ouranos has been mandated to provide this data.

This report provides historical climate data and climate change scenarios for the Portage-la-Prairie pilot study on the vulnerability of the City's water resources infrastructure.

The data provided in this report is intended for the use of this pilot project only and should not be used for any other purpose because the results are specific to the characteristics of this project (location, timeframe, etc.).

2. Methodology

2.1. Selection of climate stations

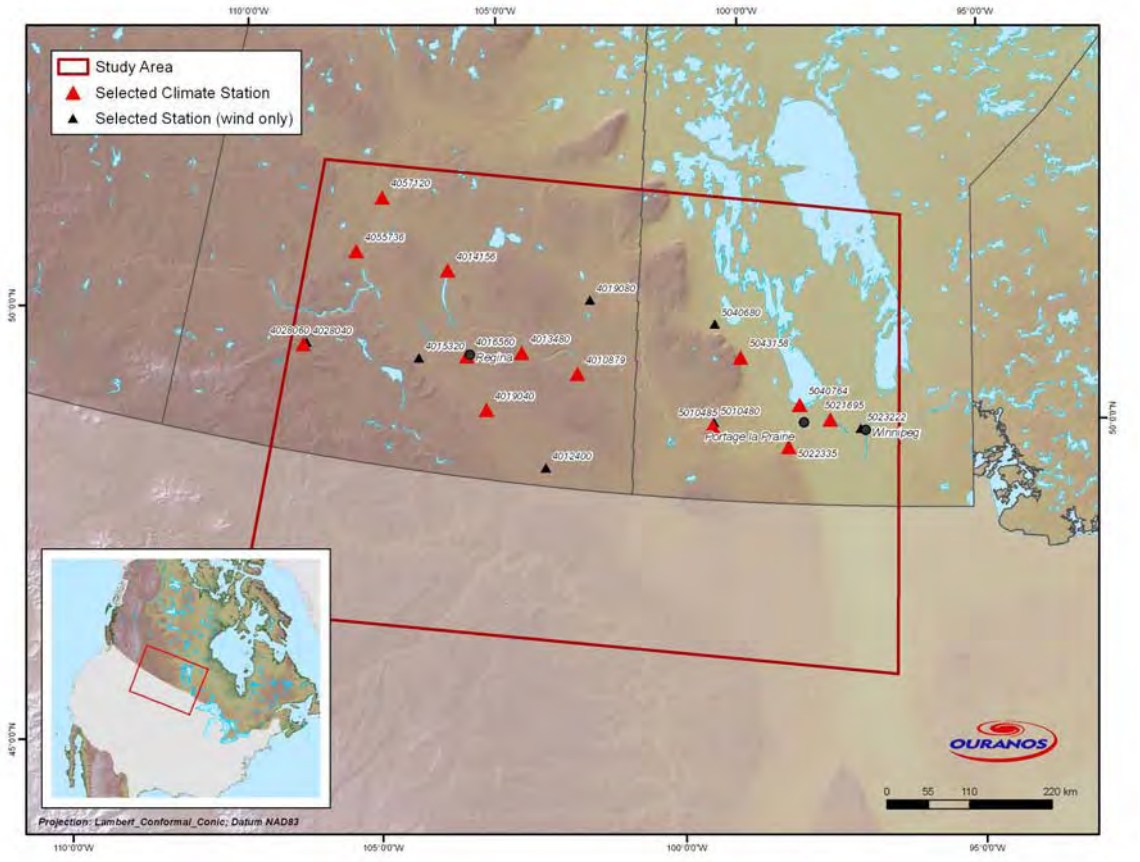
Observed weather station data was obtained from Environment Canada's national archives for the area of interest. Archived data were screened in order to select stations deemed to have a sufficiently long/complete record. Selection criteria included: a data series minimum length of 20 years, with less than 10% missing data and a final year being no earlier than 1995. A summary of the selected stations is presented in Table 2.1. The distribution of the stations within the study region is shown in Figure 2.1.

The number of climate stations available for the calculation of climate indices was dependant on the variable of interest. Table 2.1 shows that 13 stations were used to calculate temperature indices (variables TMAX and TMIN). For precipitation indices, the majority of indices were calculated using data from 12 climate stations. Wind indices were calculated using data from 10 stations. However, only 3 stations met required criteria for the variable of 'snow on the ground'. As such, observed 'Rain on snow events' were limited to these 3 stations.

Table 2.1 Selected Environment Canada station data for variables of Temperature, Precipitation, Snow and Wind
(Selection was based on the criteria of a minimum record length of 20 years and a maximum of 10% missing data, and final year no earlier than 1995).

Station ID	**Climate variables**					
	TMAX	TMIN	RAIN	SNOWFALL	SNOW on GROUND	WIND
4010879	yes	yes	yes	yes	no	yes
4013480	yes	yes	no	no	no	no
4014156	yes	yes	yes	yes	no	no
4016560	yes	yes	yes	yes	yes	yes
4019040	yes	yes	yes	yes	no	no
4028060	yes	yes	yes	yes	yes	no
4055736	yes	yes	yes	yes	no	no
4057120	yes	yes	yes	yes	yes	yes
5010485	yes	yes	yes	yes	no	no
5021695	yes	yes	yes	yes	no	no
5022335	yes	yes	yes	yes	no	no
5040764	yes	yes	yes	yes	no	no
5043158	yes	yes	yes	yes	no	no
5010480	no	no	no	no	no	yes
5023222	no	no	no	no	no	yes
5040680	no	no	no	no	no	yes
4012400	no	no	no	no	no	yes
4015320	no	no	no	no	no	yes
4019080	no	no	no	no	no	yes
4028040	no	no	no	no	no	yes

Figure 2.1 Location of selected climate stations within the study area.



2.2. Choice of climate model

Impact and adaptation projects should, in a best-case scenario, be based on projections of multiple climatic simulations in order to ensure that uncertainty of future climate projections is fully explored and incorporated in decision-making processes. Furthermore, in a regional context, such as the current PIEVC pilot project, downscaling of coarse resolution Global Circulation Model (GCM) output is desirable. Regional climate modeling employing the commonly termed approach of dynamical downscaling is one area of expertise covered by the Ouranos consortium and its research partners. Ouranos has contributed to the development of the Canadian Regional Climate Model (CRCM; Caya and Laprise, 1999) which, like other regional climate models (RCMs), uses principles of conservation of energy, mass and movement to generate temporal series of *physically coherent climatic variables*. Developed using the same physical principles as GCMs, RCMs concentrate on a portion of the globe and allow production of simulations at higher spatial resolution (approximately 45km for the CRCM compared to the several hundred kilometres seen with typical GCMs). Dynamical downscaling can have a particular advantage in simulating meso-scale weather events when compared with global models. As such, extreme events (particularly for precipitation) are typically better reproduced by regional modeling efforts.

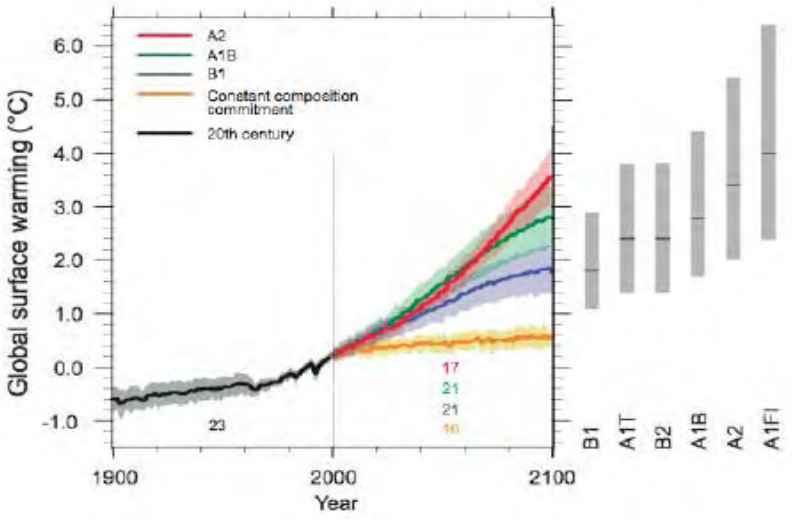
In general, the majority of CRCM simulations produced by Ouranos for impacts and adaptation purposes focus on the future period of 2041-2070 (termed horizon 2050). However, due to increasing demand for climatic scenarios for different future periods a small number of continuous simulations have been produced for the period 1961-2100. Two of these simulations have been selected for use in this pilot study. The simulations were produced using the Canadian Regional Climate Model, version 4.1.1 (CRCM 4.1.1) (Music and Caya, 2007, in press; Plummer *et al.* 2006). This selection was based on the advantages of having increased spatial resolution (compared to GCMs), the availability of continuous future series for the period 1961-2100 (the future horizons of interest in the pilot study being horizons 2020, 2050 and 2080). The choice was also due to the time constraints imposed for the completion of the project.

It is important to note that, due to the restricted number of simulations, caution is required in the interpretation of any modeling effort or analysis based on the scenarios provided. Use of only 2 simulations is sufficient for sensitivity analyses but lacks the robustness provided by the use of a large ensemble of simulations (recommended for decision-making or policy planning; see Conclusion - section 4 of this report).

The two simulations (CRCM 4.1.1 ACU; CRCM4.1.1 ADC) were carried out for a domain centred over Québec and covering an area of approximately 5,050 km by 4,000 km with a horizontal grid-size mesh of 45 km (true at 60 degrees north latitude) for the period 1961-2100. The simulations were driven at their boundaries by atmospheric fields taken from simulation output of the 4th and 5th members of the third generation coupled Canadian Global Climate Model (CGCM3) (Scinocca and MacFarlane, 2004). Both global and regional simulations were performed using the IPCC SRES A2 greenhouse gas (GHG) and aerosol projected evolution[1]. Figure 2.2 shows the simulated mean global temperature evolution according to the multiple GCM output grouped under various SRES different scenarios. It is interesting to note that the emissions scenarios diverge very little before approximately 2050.

[1] "The A2 storyline and scenario family describes a very heterogeneous world. The underlying theme is self-reliance and preservation of local identities. Fertility patterns across regions converge very slowly, which results in continuously increasing population. Economic development is primarily regionally oriented and per capita economic growth and technological change more fragmented and slower than other storylines." (Nakicenovic *et al.*, 2000)

Figure 2.2 Mean global temperature evolution according to the multiple GCM output grouped under various SRES different scenarios.

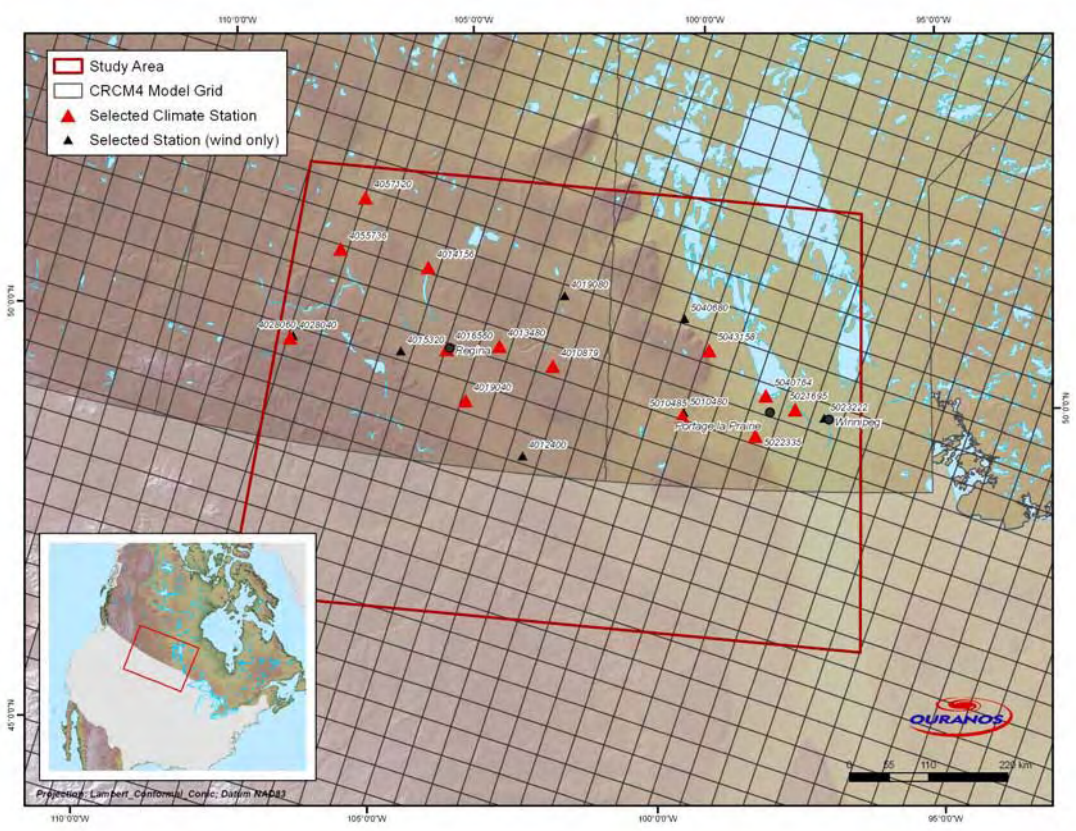


2.3. Climate model simulations and time periods

A total of 248 CRCM grid cells fell within the study area boundaries (see Figure 2.3). Corresponding grid cell data from the two CRCM 4.1.1 simulations described in section 2.2 (ACU and ADC) were extracted and used to calculate the climate indices listed in section 2.4. Future changes in indices were determined for three future periods or horizons: **horizon 2020** (2011 – 2040); **horizon 2050** (2041-2070); and **horizon 2080** (2071-2100) with respect to the present period (**1961-1990**).

Changes (or deltas) in indices are calculated as either the difference or ratio between simulated future conditions and simulated present day conditions. Deltas can then be applied to calculated observed values either through addition (difference) or multiplication (ratio).

Figure 2.3 Canadian Regional Climate Model (CRCM4) grid and location of selected climate stations within the study area.



2.4. Description of climate indices

The choice and priority of climate indices was made in consultation with the client in terms of specific project needs as well as in terms of the limitations of the climate model simulations. Calculated indices were chosen from those having been known and used in the climate literature in the past.

Temperature indices

a. Monthly average maximum temperature (Monthly AVG TMAX):
   - *Average daily maximum temperature for a given month over the time period*

b. Monthly average minimum temperature (Monthly AVG TMIN):
   - *Average daily minimum temperature for a given month over the time period*

c. Average annual daily maximum temperature (annual_max):

$$annual_\max = \left(\sum_{i=1}^{I} (t\max 365i) \right) / I$$

Calculated as the sum of $t\max 365i$ for years *i* through *I* divided by the number of years. Where $t\max 365i$ is the highest daily temperature for a given year *i*

d. Average annual daily minimum temperature (annual_min):

$$annual_\min = \left(\sum_{i=1}^{I} (t\min 365i) \right) / I$$

Calculated as the sum of $t\min 365i$ for years *i* through *I* divided by the number of years. Where $t\min 365i$ is the lowest daily temperature for a given year *i*

Rain indices

Rain indices refer in all cases to precipitation in **liquid form*

a. Rainfall frequency 6 hour (6h_frequency)
   - *cutoff values of 5, 10 and 20 mm*
   - *frequency of events that are greater than cutoff(s)*

b. Rainfall frequency 1 day (1day_frequency)
   - *cutoff values of 5, 10 and 20 mm*
   - *frequency of events that are greater than cutoff(s)*

c. Yearly Max. Rainfall (annual_max_rain):
   - *average maximum yearly rainfall event for 1, 2 and 5-day periods*

$$annual_\max_rain = \left(\sum_{i=1}^{I} (rain365ix) \right) / I$$

Calculated as the sum of $rain365ix$ for years *i* through *I* divided by the number of years. Where $rain365ix$ is the highest rainfall amount for a given year *i summed over period of x days.*

d. Average total annual / seasonal rainfall (Avg_total_rain)
   - *average sum of liquid precipitation for the year and 4 seasons (DJF, MAM, JJA, SON)*

e. Simple Daily Intensity Index (SDII)
   - *Mean rainfall amount per wet day (wet day > 1mm)*

f. Drought : Average maximum annual dryspell length (Avg_max_dryspell
   - *average yearly maximum number of consecutive 'no rain days' (< 1mm) for the season April 1 – Oct. 31st.*

$$Avg_MAX_dryspell = \left(\sum_{i=1}^{I} (dSPELLi) \right) / I$$

Calculated as the sum of $dSPELLi$ for years *i* through *I* divided by the number of years. Where $dSPELLi$ is the maximum dryspell length for a given year *i.*

g. Average maximum annual wetspell length (Avg_max_wetspell)
- Average yearly maximum number of consecutive 'rain days' (> 1 mm) for the season April 1 – Oct. 31st.

$$Avg_MAX_wetspell = \left(\sum_{i=1}^{I} (wSPELLi) \right) / I$$

Calculated as the sum of $wSPELLi$ for years *i* through *I* divided by the number of years. Where $wSPELLi$ is the maximum wetspell length for a given year *i.*

Snow indices

**Snow index values in mm indicate values of Snow Water Equivalent (SWE) in all cases.*

***Observed snowfall values from EC stations had units of cm of snow and were converted to SWE using an assumed conversion ratio of 10:1 (i.e. 10 mm of fresh snow = 1mm SWE)*

a. Snowfall frequency 1 day (1-day_frequency)
- *cutoff values of 5, 10 and 20 mm*
- *frequency of events that are greater than cutoff(s)*

b. Yearly maximum snowfall (annual_max_snow):
- *average maximum yearly snowfall event for 1, 2 and 5-day periods*

$$annual_\max_snow = \left(\sum_{i=1}^{I} (snow365ix) \right) / I$$

Calculated as the sum of $snow365ix$ for years *i* through *I* divided by the number of years. Where $snow365ix$ is the highest snowfall amount for a given year *i summed over period of x days.*

c. Average total annual / seasonal snowfall (Avg_total)
- *average sum of solid precipitation for the year and 4 seasons (DJF, MAM, JJA, SON)*

d. Simple Daily Intensity Index (SDII)
- *mean snowfall amount per wet day (wet day > 1mm)*

e. Rain on snow events
- occurrence defined as presence liquid precipitation > 1mm combined with presence of snow on ground (> 0)
- cutoff values of 1, 5 and 10 mm
- frequency of events that are greater than cutoff(s) over 1-day period

Wind indices

**Wind index values in m/s indicate values of average wind speed over a 6h period.*
***NB – A 6hour timestep was used as this is the minimum timestep available for analysis for the CRCM4 data.*

a. Monthly average 6h windspeed (Monthly AVG WIND6h):
- average 6h windspeed for a given month over the time period

b. Yearly maximum 6hour Wind (*Avg annual MAX6h*):
- average maximum yearly 6h Wind

$$Avg_annual_MAX6h = \left(\sum_{i=1}^{I} (wind365i) \right) / I$$

Calculated as the sum of $wind365i$ for years *i* through *I* divided by the number of years. Where $wind365i$ is the highest 6h mean windspeed for a given year *i.*

Frost indices

a. Frost Season (fr_seas_dys)
- average annual maximum length in days that the 30-day moving average of daily average temperature remains consecutively below 0°C

b. Freeze-Thaw cycles (frz_thw_freq)
- frequency of days where Tmax > 0°C and Tmin < 0°C

2.5. Regionalization of climate indices

Climate indices listed in section 3.1 were calculated for each climate station and each RCM grid cell individually. A regional value for each index is then determined by taking the average of all stations (grid points) within the study area. These regional values are presented in the results section of the report.

3. Results

3.1. Climate scenarios for Temperature, Rain, Snow, Wind and Frost indices

TEMPERATURE indices

TEMPERATURE : Monthly AVG TMAX							
month	*Observed (°C)*	*Future Change ACU*			*Future Change ADC*		
		2020 *(°C)*	***2050*** *(°C)*	***2080*** *(°C)*	***2020*** *(°C)*	***2050*** *(°C)*	***2080*** *(°C)*
January	-11.16	2.03	3.63	6.18	2.25	4.42	5.90
February	-7.63	2.68	4.28	3.72	2.79	6.18	5.63
March	-0.97	0.92	2.58	3.68	1.47	1.51	3.70
April	10.08	0.47	1.40	2.79	1.16	1.02	2.03
May	18.06	1.47	1.90	4.45	1.26	1.94	3.39
June	22.54	1.73	2.75	4.96	1.89	3.12	4.37
July	25.58	1.23	2.99	5.88	3.44	4.02	6.30
August	24.83	1.67	3.17	6.53	2.78	3.50	6.27
September	18.54	1.35	3.88	6.58	2.43	4.59	5.74
October	10.95	2.74	3.98	4.93	2.52	3.51	5.49
November	-0.18	1.27	1.42	2.75	1.57	2.53	2.53
December	-7.84	2.61	3.87	6.26	2.95	5.33	6.41

TEMPERATURE : Monthly AVG TMIN							
month	*Observed (°C)*	*Future Change ACU*			*Future Change ADC*		
		2020 *(°C)*	***2050*** *(°C)*	***2080*** *(°C)*	***2020*** *(°C)*	***2050*** *(°C)*	***2080*** *(°C)*
January	-21.79	2.68	4.67	7.96	2.85	5.46	7.82
February	-18.60	3.77	6.16	6.04	3.54	8.04	7.80
March	-11.76	2.17	4.24	5.23	1.95	2.49	5.15
April	-2.45	0.54	1.42	2.49	0.81	1.21	1.80
May	4.10	1.30	1.90	4.06	0.86	2.70	4.05
June	9.53	1.46	2.61	4.31	1.49	2.93	4.50
July	11.97	1.75	3.51	5.17	1.95	3.05	4.99
August	10.55	1.72	3.52	5.13	1.75	3.01	4.93
September	5.14	1.70	3.24	5.33	1.79	3.91	5.41
October	-1.18	1.96	3.01	3.83	1.83	2.42	4.65
November	-9.80	1.66	2.16	3.70	1.79	2.94	3.49
December	-17.87	3.18	5.00	8.18	3.58	6.45	8.27

TEMPERATURE : annual max /annual min							
month	*Observed (°C)*	*Future Change ACU*			*Future Change ADC*		
		2020 *(°C)*	***2050*** *(°C)*	***2080*** *(°C)*	***2020*** *(°C)*	***2050*** *(°C)*	***2080*** *(°C)*
annual maximum	35.17	1.59	3.25	6.00	2.80	3.73	6.02
annual minimum	-37.75	3.41	4.82	7.74	2.89	6.68	9.31

RAIN indices

RAIN : 6h_Frequency							
cutoff (mm)	*Observed (frequency)*	*Future Change ACU*			*Future Change ADC*		
		2020 *(ratio)*	***2050*** *(ratio)*	***2080*** *(ratio)*	***2020*** *(ratio)*	***2050*** *(ratio)*	***2080*** *(ratio)*
5	0.0107	1.10	1.22	1.18	0.94	1.18	1.26
10	0.0043	1.19	1.42	1.32	0.94	1.36	1.50
20	0.0009	1.35	1.91	1.64	0.77	1.70	1.86

RAIN : 1day_Frequency							
cutoff (mm)	*Observed (frequency)*	*Future Change ACU*			*Future Change ADC*		
		2020 *(ratio)*	***2050*** *(ratio)*	***2080*** *(ratio)*	***2020*** *(ratio)*	***2050*** *(ratio)*	***2080*** *(ratio)*
5	0.0507	1.05	1.12	1.07	0.92	1.07	1.12
10	0.0251	1.10	1.21	1.15	0.96	1.19	1.25
20	0.0086	1.19	1.42	1.36	1.06	1.46	1.57

RAIN: Avg_Max_rain							
period (days)	*Observed (mm)*	*Future Change ACU*			*Future Change ADC*		
		2020 *(ratio)*	***2050*** *(ratio)*	***2080*** *(ratio)*	***2020*** *(ratio)*	***2050*** *(ratio)*	***2080*** *(ratio)*
1	40.8	1.05	1.12	1.10	0.98	1.13	1.16
2	49.5	1.05	1.11	1.10	0.98	1.13	1.16
5	60.8	1.05	1.10	1.08	0.97	1.10	1.14

RAIN : Avg_total_rain							
Total rain	*Observed (mm)*	*Future Change ACU*			*Future Change ADC*		
		2020 *(ratio)*	***2050*** *(ratio)*	***2080*** *(ratio)*	***2020*** *(ratio)*	***2050*** *(ratio)*	***2080*** *(ratio)*
Annual	324.00	1.05	1.11	1.08	0.97	1.09	1.13
DJF	1.37	2.09	3.90	5.94	2.01	3.92	5.78
MAM	67.60	1.01	1.10	1.26	1.04	1.34	1.35
JJA	194.00	1.03	1.08	0.94	0.89	0.92	0.92
SON	59.90	1.16	1.16	1.23	1.22	1.32	1.56

RAIN : Simple Daily Intensity Index (SDII)						
Observed (mm/day)	*Future Change ACU*			*Future Change ADC*		
	2020 *(ratio)*	***2050*** *(ratio)*	***2080*** *(ratio)*	***2020*** *(ratio)*	***2050*** *(ratio)*	***2080*** *(ratio)*
7.49	1.02	1.06	1.03	1.01	1.05	1.05

RAIN : Dry spells / Wet_spells							
	Observed (days)	*Future Change ACU*			*Future Change ADC*		
		2020 *(days)*	***2050*** *(days)*	***2080*** *(days)*	***2020*** *(days)*	***2050*** *(days)*	***2080*** *(days)*
Avg MAX Dryspell	45.2	-0.50	0.31	0.90	0.43	1.38	0.40
Avg MAX Wetspell	8.3	-0.20	-0.90	-0.20	-0.50	-1.40	-1.20

SNOW indices

SNOW : 1day_Frequency							
SWE cutoff (mm)	*Observed (frequency)*	*Future Change ACU*			*Future Change ADC*		
		2020 *(ratio)*	***2050*** *(ratio)*	***2080*** *(ratio)*	***2020*** *(ratio)*	***2050*** *(ratio)*	***2080*** *(ratio)*
5	0.017	1.01	1.07	1.17	1.01	1.11	0.95
10	0.005	0.92	1.07	1.33	0.88	1.04	0.84
20	0.001	0.95	1.44	1.29	0.74	1.11	0.62

SNOW`: Avg_Max_snow							
period (days)	*Observed (days)*	*Future Change ACU*			*Future Change ADC*		
		2020 *(ratio)*	***2050*** *(ratio)*	***2080*** *(ratio)*	***2020*** *(ratio)*	***2050*** *(ratio)*	***2080*** *(ratio)*
1	15.3	0.99	1.08	1.11	0.96	1.04	0.93
2	18.9	1.01	1.08	1.15	0.98	1.04	0.92
5	22.6	1.02	1.08	1.15	0.98	1.04	0.96

SNOW : Avg_total_snow							
Total snowfall (SWE) (mm)	*Observed (mm)*	*Future Change ACU*			*Future Change ADC*		
		2020 *(ratio)*	***2050*** *(ratio)*	***2080*** *(ratio)*	***2020*** *(ratio)*	***2050*** *(ratio)*	***2080*** *(ratio)*
Annual	112.04	0.96	0.92	0.92	0.93	0.96	0.85
DJF	55.08	1.00	1.05	1.17	1.01	1.16	1.06
MAM	31.76	1.05	0.77	0.67	1.00	0.99	0.74
JJA	0.04	0.16	0.03	0	0.21	0.09	0.05
SON	24.14	0.80	0.83	0.74	0.75	0.64	0.60

SNOW : Simple Daily Intensity Index (SDII)						
Observed (mm/day)	*Future Change ACU*			*Future Change ADC*		
	2020 *(ratio)*	***2050*** *(ratio)*	***2080*** *(ratio)*	***2020*** *(ratio)*	***2050*** *(ratio)*	***2080*** *(ratio)*
4.19	1.01	1.07	1.12	1.03	1.07	1.04

SNOW : Rain_on_Snow_events							
Rain cutoff (mm)	*Observed (frequency)*	*Future Change ACU*			*Future Change ADC*		
		2020 *(ratio)*	***2050*** *(ratio)*	***2080*** *(ratio)*	***2020*** *(ratio)*	***2050*** *(ratio)*	***2080*** *(ratio)*
1	0.0028	0.90	0.93	0.97	0.97	1.01	1.03
5	0.0005	0.84	0.89	0.97	0.95	1.12	1.08
10	0.0001	0.87	0.92	1.05	1.00	1.32	1.17

WIND indices

WIND : Monthly AVG WIND6h							
Month	*Observed (m/s)*	*Future Change ACU*			*Future Change ADC*		
		2020 *(ratio)*	***2050*** *(ratio)*	***2080*** *(ratio)*	***2020*** *(ratio)*	***2050*** *(ratio)*	***2080*** *(ratio)*
January	5.11	0.97	1.01	1.07	1.01	1.03	1.03
February	5.05	1.00	1.00	0.98	1.04	1.08	0.98
March	5.06	1.05	1.07	1.05	1.06	1.03	1.02
April	5.26	0.97	1.03	1.07	1.00	1.04	1.00
May	5.32	1.03	1.00	1.05	1.04	1.07	1.05
June	4.87	1.00	1.04	1.01	1.01	1.03	1.01
July	4.31	0.96	0.97	0.93	0.97	0.98	0.98
August	4.34	0.99	0.95	0.95	0.96	0.93	0.92
September	4.88	1.01	1.00	0.96	1.01	0.99	0.97
October	5.09	0.98	1.00	0.98	0.99	1.00	1.00
November	5.00	1.00	1.04	1.04	1.04	1.03	1.05
December	5.11	0.99	1.05	1.06	1.14	1.20	1.16

WIND : Avg_annual_MAX6h						
Observed (m/s)	*Future Change ACU*			*Future Change ADC*		
	2020 *(ratio)*	***2050*** *(ratio)*	***2080*** *(ratio)*	***2020*** *(ratio)*	***2050*** *(ratio)*	***2080*** *(ratio)*
16.21	0.98	1.02	0.98	1.01	1.02	1.01

FROST indices

FROST SEASON LENGTH : fr_seas_dys						
Observed (days)	*Future Change ACU*			*Future Change ADC*		
	2020 *(days)*	***2050*** *(days)*	***2080*** *(days)*	***2020*** *(days)*	***2050*** *(days)*	***2080*** *(days)*
144.55	-12.72	-20.92	-31.83	-11.58	-19.48	-27.80

FREEZE THAW EVENTS : fr_thw_freq						
Observed (frequency)	*Future Change ACU*			*Future Change ADC*		
	2020 *(ratio)*	***2050*** *(ratio)*	***2080*** *(ratio)*	***2020*** *(ratio)*	***2050*** *(ratio)*	***2080*** *(ratio)*
0.22	1.01	1.01	0.99	0.99	1.01	0.95

3.2. Literature review for other climate indices

Although the climate scenarios for temperature changes and changes in precipitation patterns are quite reliable, there is far greater uncertainty linked to projections for relatively small-scale or localized atmospheric phenomena. Most authors agree that GHG concentrations do have an effect on these events; however, it remains difficult to find reliable projections that indicate future trends of intensity, direction or frequency for events such as storms, intense winds or other extreme events (Maarten, 2006). Climate scenarios are therefore difficult to produce for certain very localized events (wind gusts, tornadoes, thunderstorms) or events where processes are complex and depend on a number of factors (hurricanes, ice storms). The observed data is insufficient to validate the model outputs for these events.

Moreover, any seemingly apparent trend stemming from the observed data must be interpreted carefully as an increase could result from such factors as:

- increased weather station coverage
- improved quality of the data collected
- changes in land use (and corresponding increases in damage claims).

Consequently, among the list of climate elements that were requested for the Portage-la-Prairie project, it is not possible to provide sound numerical climate scenarios that could be used for the infrastructure vulnerability assessment. The following is the list of climate variables that fall under this category with a review of the literature explaining possible changes.

WIND (hurricanes, tornadoes, thunderstorms, winds gusts)

According to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC, 2007), it is “more likely than not” that the observed trend of hurricane intensification since the 1970s is linked to human-induced greenhouse gas emissions. The report also claims that “it is likely that future tropical cyclones (typhoons and hurricanes) will become more intense, with larger peak wind speeds and more heavy precipitation associated with ongoing increases of tropical sea surface temperatures.” However, there is no clear trend in terms of the frequency of tropical cyclones. Although some authors claim that there has been an increase in the frequency of hurricanes, namely in the North Atlantic (Holland *et al.* 2007, Webster *et al.* 2005), there remains much debate as to the possible mechanisms explaining this.

Research indicates that hurricane activity is linked to sea surface temperature (Holland *et al.* 2007; Emanuel, 2005), but changes in wind strength and direction can inhibit the formation of hurricanes (Knuston *et al.* 2004). It therefore seems theoretically probable that hurricanes would increase in intensity (more category 4 and 5 events). However, it remains unclear whether the frequency of events will increase and which trajectory these storms will follow. The Prairies are not however significantly affected by these storm systems.

Results from some model simulations suggest that the atmosphere over mid-latitude land areas could become more unstable in the future, suggesting that an increase in

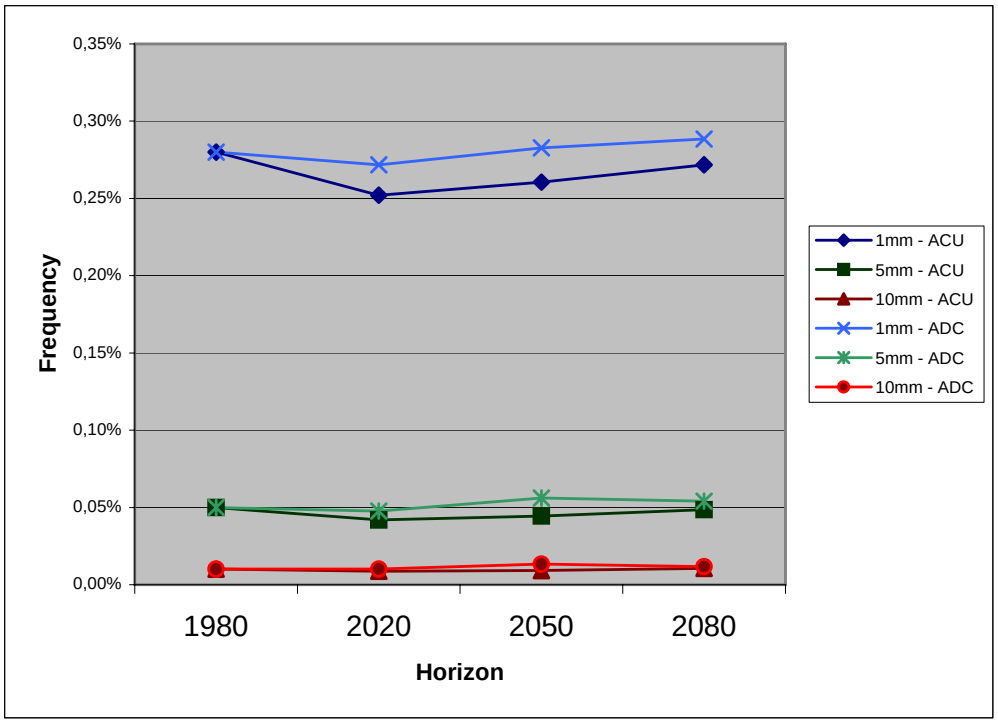
convective activity is quite probable (Balling *et al.* 2003). However, researchers have been unable to identify significant increases in overall severe storm activity as measured in the magnitude and/or frequency of thunderstorms, hail events, tornadoes, hurricanes, and winter storm activity in North America. Increasing trends in damages caused by these events seem to be more closely linked to changes in demography and land use (Balling *et al.* 2003)

ICE (ice build-up, ice accretion, freezing rain)

Ice build-up, caused by melting blocks of ice that accumulate and obstruct water ways or pile up around infrastructure components, can be triggered by:
- rapid melt events when there is a significant accumulation of snow and ice
- heavy precipitation events in spring when there is still a cover of ice
- heavy rain on snow events

Warmer average temperatures throughout the year (see climate scenarios in section 3.1) suggest that the length and severity of the cold season will decrease. However, depending on precipitation patterns, this could mean either an increase or decrease in river or lake ice build-up, because of the nature of the precipitation as well as the intensity of the events that cause ice build-up. For example, results from the Rain-on-snow indices scenarios (presented in section 3.1) suggest that there will be very little change in terms of the frequency of this type of event in future climate compared to the present average frequency. Figure 3.1 illustrates this for events of 1, 5 and 10mm of rainfall when there is snow on the ground.

Figure 3.1 Frequency of rain on snow events for 1980, 2020, 2050 and 2080.



Very few studies have been conducted on the possible impacts of climate change on freezing rain events and ice storms. A study conducted over northern and eastern Ontario (Cheng *et al.* 2007) suggests that freezing rain events could move further north as the boundary between snowfall and rainfall shifts northward. However, as the temperatures increase in the Fall and Spring (beginning and end of the winter season), freezing rain events could decrease since precipitation falling as freezing rain could fall as liquid rain under warmer conditions. At present, it remains unknown how climate change could affect the frequency and severity of freezing rain events and ice storms (Irland, 2000, Cheng *et al.* 2007).

SNOW (rapid melt events)

Variations and trends in temperature significantly influence snow covered areas, namely by determining whether precipitation falls as snow or rain and determining snowmelt (IPCC, 2007). However rapid snowmelt events are difficult to predict because they depend on a number of factors, including:
- temperature and precipitation conditions at the time of the melt
- total amount of snow on the ground

Because these events occur as the result of a combination of factors and can be very localized (in both time and space), it is difficult to establish reliable scenarios of change in future climate conditions. Moreover, the inherent variability of the climate makes it difficult to predict whether this type of event will occur more frequently or more intensely, as a change in only one of the determining factors can determine whether rapid snowmelt will happen or not.

Nevertheless, it is recognized that changes in average temperature will impact precipitation and wind patterns and influence the change in probability distributions of many atmospheric processes. Indeed, a warmer atmosphere increases the chances for convective activity. This is already the case in warmer regions of the world during warmer seasons (Balling *et al.* 2003). This will impact the frequency, intensity, duration and direction of extreme events such as tornadoes, hailstorms, thunderstorms. However, it remains difficult to determine quantitatively precisely how these events will change.

Climate change will also influence the variability of the climate, including inter-annual events such as El Nino. However, climate scenarios on this type of climate phenomenon or event have not yet been developed.

To assess the vulnerability of infrastructure to changes in these parameters where numerical scenarios are not reliable, it can be useful to conduct “what if” scenarios, using a plausible factor of change to add to historical trend data and local knowledge of climate events. These sensitivity analyses help to determine at what threshold the infrastructure can become vulnerable to climatic events and estimate the likelihood of such events happening based on the physics of climate change and on local observations of climate events.

4. Conclusion

The pilot projects conducted within the PIEVC initiative to test a protocol to assess infrastructure vulnerability to climate change require plausible and reliable climate scenarios based on similar methodologies in order to compare the relative vulnerability of various infrastructure throughout the country.

This report provides historical climate data and climate change scenarios for the Portage-la-Prairie pilot study on the vulnerability of the City's water resources infrastructure.

Prudence is required in the interpretation of analyses based on the future scenarios provided. Climate scenario production was limited to the use of only 2 simulations. Furthermore, these simulations were produced by the same regional model (CRCM 4.1.1), driven by two runs of the same GCM (CGCM3) and the same GHG emissions scenario (SRES A2). In short, the predicted changes cover only a small portion of the spectrum or envelope of changes that would be produced via the use of multiple SRES scenarios and multiple driving models (or even multiple RCMs). **As such, it is recommended that any decision or policy making activities be based on an expanded version of the present pilot project.**

At present, large ensemble analyses using strictly RCM output are very difficult to achieve as the high resolution simulations are very costly and time consuming to produce. RCM simulations continue to be produced by Ouranos but time costs prohibit a realistic inclusion of a large number of RCM simulations in the near future. However, inclusion of GCM output from a large number of simulations (multiple models and GHG emissions scenarios) from the IPCC's Fourth Assessment Report (IPCC, 2007) would be beneficial in order to assess future climate change uncertainty. Further research continues to be needed in climate modeling and climate scenarios in order to provide reliable data for climate change vulnerability and impacts assessments.

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Infrastructure Data Request List

Assiniboine River and Inlet Structure:

- Frequency of ice jams – Yearly in the Spring – Varies with depth of ice and thaw conditions – Can cause low water supply for short period of time(5-6 Hours) until control gates are raised to float upstream ice.
- Frequency of silt removal-Every second to third year with sand and tree removal.
- Age and remaining life expectancy of the current inlet structure, i.e. room for pumping expansion, plans for upgrades- 20 years – no upgrades pending- Could install higher capacity pumps.
- Any historical years where high/low water level on the Assiniboine River created problems –In 1983 an ice jam with ice up to 6-8 feet thick broke from an upstream ice jam and pushed over the dam structure and took out all hydro power and trees. Hydro cables had to be run overland to restore power to the dam structure and raw water intake areas. Since that time underground cables were installed. An ice jam downstream of the Water Treatment Plant caused water to come within several meters of the facility in the mid 1990's.

Water Treatment Plant:

- Water quality summaries- ALS Labs in Winnipeg- Robert Kittler- Water Treatment Plant code 171. I have talked to Robert Kittler and we will try to generate all major tests groups for the treated and raw water for whatever years that can be found. Robert or myself will forward the information to you.
- Incident reports - any climate related problems experienced by the plant, Doug mentioned that the plant experiences power outages, the cause and frequency of these might be important. The power outages are usually from electrical storms. The number of electrical storms will vary from year to year. Winter ice on lines and trees has caused outages in the power supply over the last 5 years. The power outage is usually 1-3 hours on major and ½ hour on most of the minor ones.

Distribution System:

- Incident reports - any problems that can be attributed to climate, especially any breaks due to freeze/thaw cycles, a high/low water table, or sink holes
- Piping statistics - General statistics regarding size, material, condition and age
- City standards for construction specs - i.e. depth of cover, backfill, etc
- Water distribution model report

Other Factors:

- Future water demand:
  - Population trends and predictions Slow steady population growth
  - Future potential for wet industry development Ongoing
  - Future rural distribution expansion Ongoing but limited

APPENDIX E

Summary of Draft Final Report Review Comments

Portage-la- Prairie Pilot Project
Draft Final Report – Genivar/Tetres

Comments and Suggestions for the Project Advisory Group
October 5, 2007

1. First we wish to compliment Genivar and Tetres for a job well done and the quality and thoroughness of the work. The addition of a workshop with the Advisory Group and the system operators was very worthwhile and a welcome addition to the overall process. We believe the content of the report is complete and fully meets the requirements of the work statement. some re-wording, summarizing and re-packaging of the findings, conclusions and recommendations is needed to make the document clear for decision-makers and PIEVC.

2. Many of our comments below relate to the packaging and presentation of the material, since this report, and particularly the Executive Summary, will be widely circulated to different audiences.

3. There should be a "CEO" version of the Executive Summary that is targeted to someone without a strong technical background. It should be not more than 4-5 pages with the target audience being the Portage City Council and the Mayor. It would not discuss the protocol except to perhaps mention that a protocol was used and would not reference to PIEVC, scale factors or anything else. A focus on the specific actions to reduce vulnerability that needs to be taken or budgeted for without the full background on the protocol and the assessment would suffice.

   It should focus on the components of their water works system that have higher vulnerabilities as well as the suggested remedial actions to address them. We suggest you work with Kelly Braden on the format that will suit his needs but whatever is finalized, it would become an addition to the front part of the final report as a separate stand-alone section.

4. The Executive Summary should articulate the conclusions and recommendations into three categories: 1) identification of the vulnerabilities of the infrastructure components (and for recommendations what key corrective or remedial actions could be taken to address them); 2) review of the protocol – its ability to do the vulnerability assessment and recommendations on how to improve it, and 3) the process for using the protocol.

5. For the vulnerabilities, the conclusions and recommendations should be presented by infrastructure component and not summarized by climate variable and which infrastructure components they affect. This would present the information better from an "end-user" perspective.

6. References to the timeliness and utility of the Ouranos data and climate scenarios and their utility/timeliness are certainly appropriate, but it is mentioned more often than it needs to be. We would like some general commentary and guidance on the application of the climate scenarios for other vulnerability assessments. As well, some comments on the appropriate place to apply the climate data/scenarios (i.e. after completing Step 3 of the protocol would be helpful). Explain the contribution of

the climate data and scenarios within the protocol step 4 for Portage and project it to other assessments.

7. Provide an answer to the question – did the protocol work and explain why, in your view, did it work.

8. Explain the importance of getting the input of managers and operators of the system, which was very valuable.

9. The “extended” Executive Summary will be an important document for us to use to promote the project and to secure additional partners for assessment projects. It will tell them “what they can get” out of such a project. Keep this in mind as you revise it to address these comments

10. A proposed schedule for the corrections and completing the project would be as follows:

    October 5 – Written comments from Engineers Canada (sorry they are late!)
    October 11 (end of business day)- Genivar/Tetres submit revised Executive Summary and CEO Summary that would be included in the PIEVC Agenda Book
    October 19 – Genivar/Tetres submit the final report in Word and pdf formats to Engineers Canada
    October 23 – Genivar (Jeff O’Driscoll) and Tetres (R. Rempel) attend PIEVC meeting in Ottawa and give a presentation on the project

Prepared by:

David Lapp, P.Eng.
PIEVC Secretariat on behalf of Project Advisory Group
October 5, 2007