Climate Change Adaptation System Resilience

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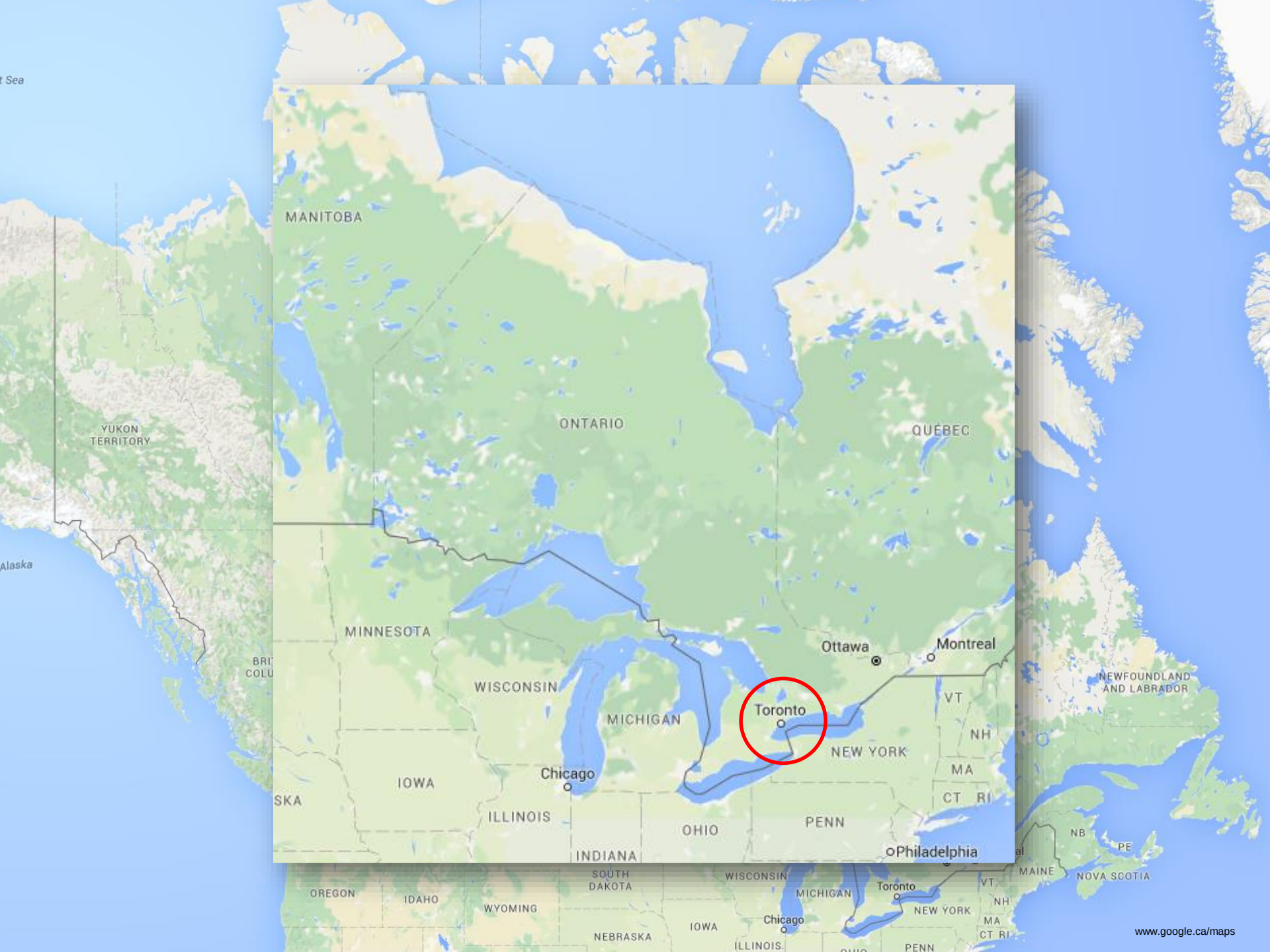
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- Population of 2.8 million
- Largest city in Canada
- Fourth largest city in North America
- Consistently ranked one of the world's most livable cities

Toronto has North America's largest continuous underground pedestrian system and shopping complex

PATH

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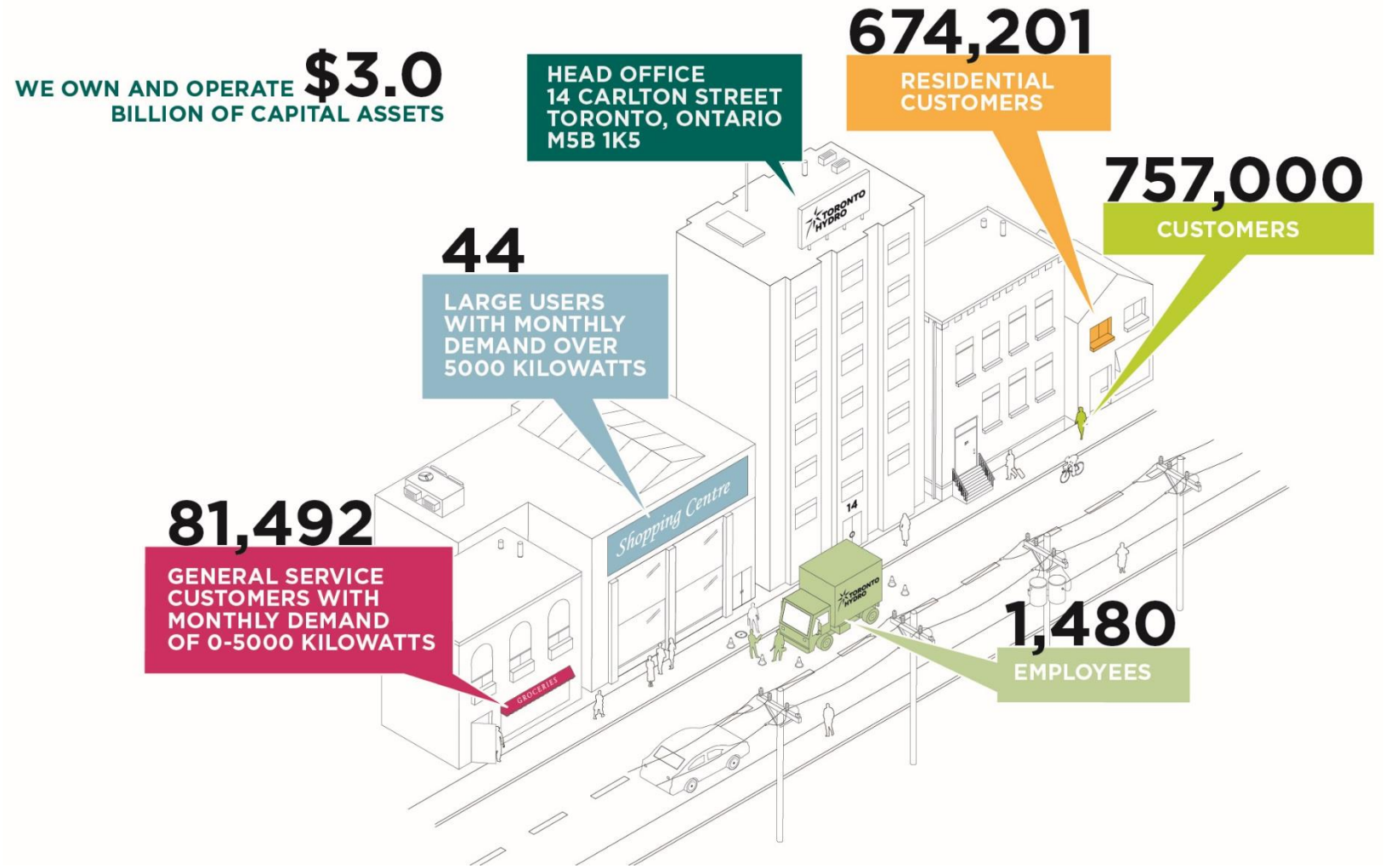

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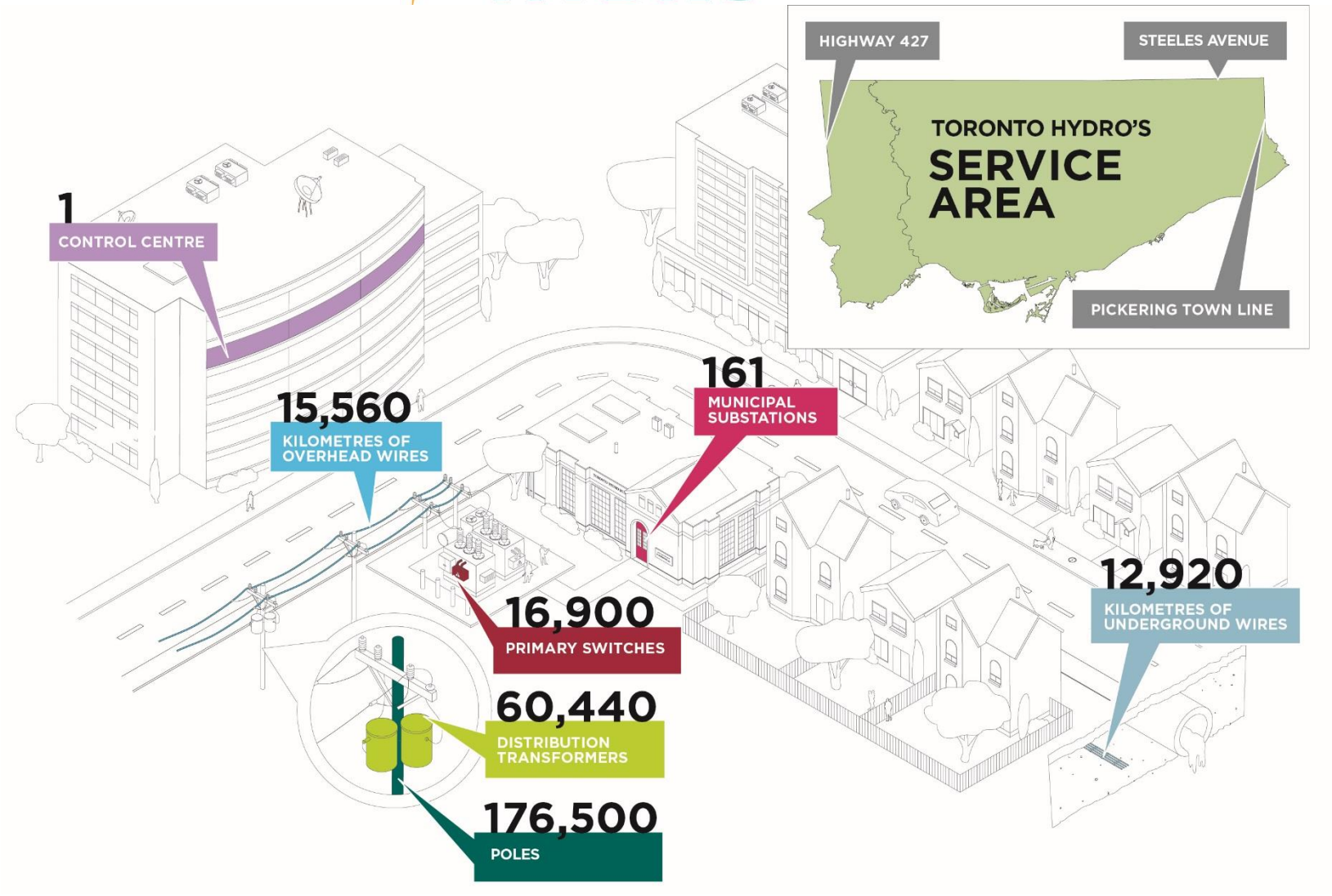
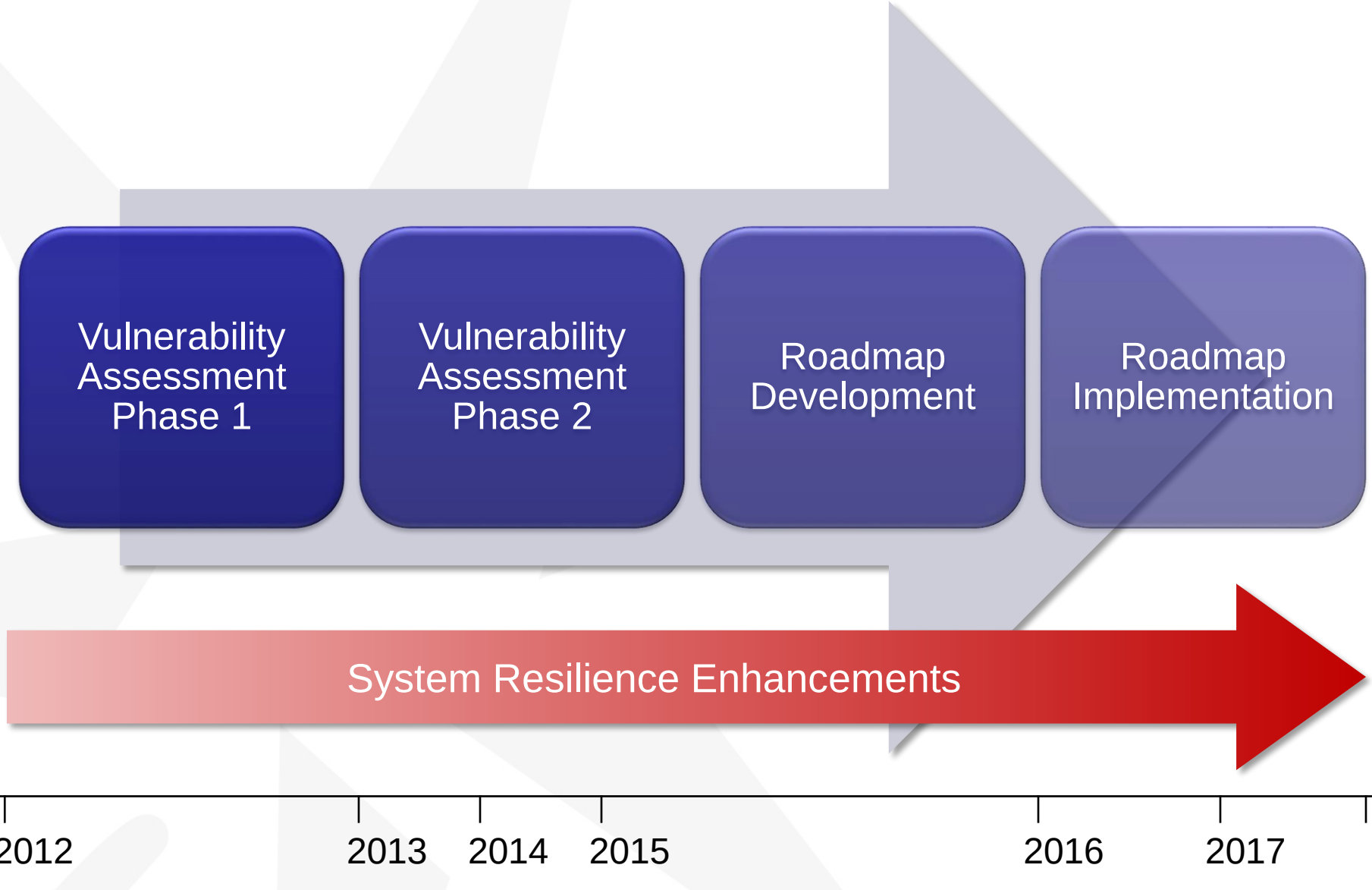


Climate Change Adaptation



Climate Change Adaptation

July 2013 – Extreme rainfall (126mm in 2 hrs)

325,000 customers impacted
Flooding of station control equipment

2012 2013 2014 2015 2016 2017

Climate Change Adaptation

December 2013 – Ice storm

300,000 customers impacted
Tree limbs falling on power lines

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2012 2013 2014 2015 2016 2017

Climate Change Vulnerability Assessment

- Engineers Canada's *Public Infrastructure Engineering Vulnerability Committee* (PIEVC) Engineering Protocol
- Consortium: AECOM, City of Toronto, Clean Air Partnership, Engineers Canada, Risk Sciences International…
- NRCan funding

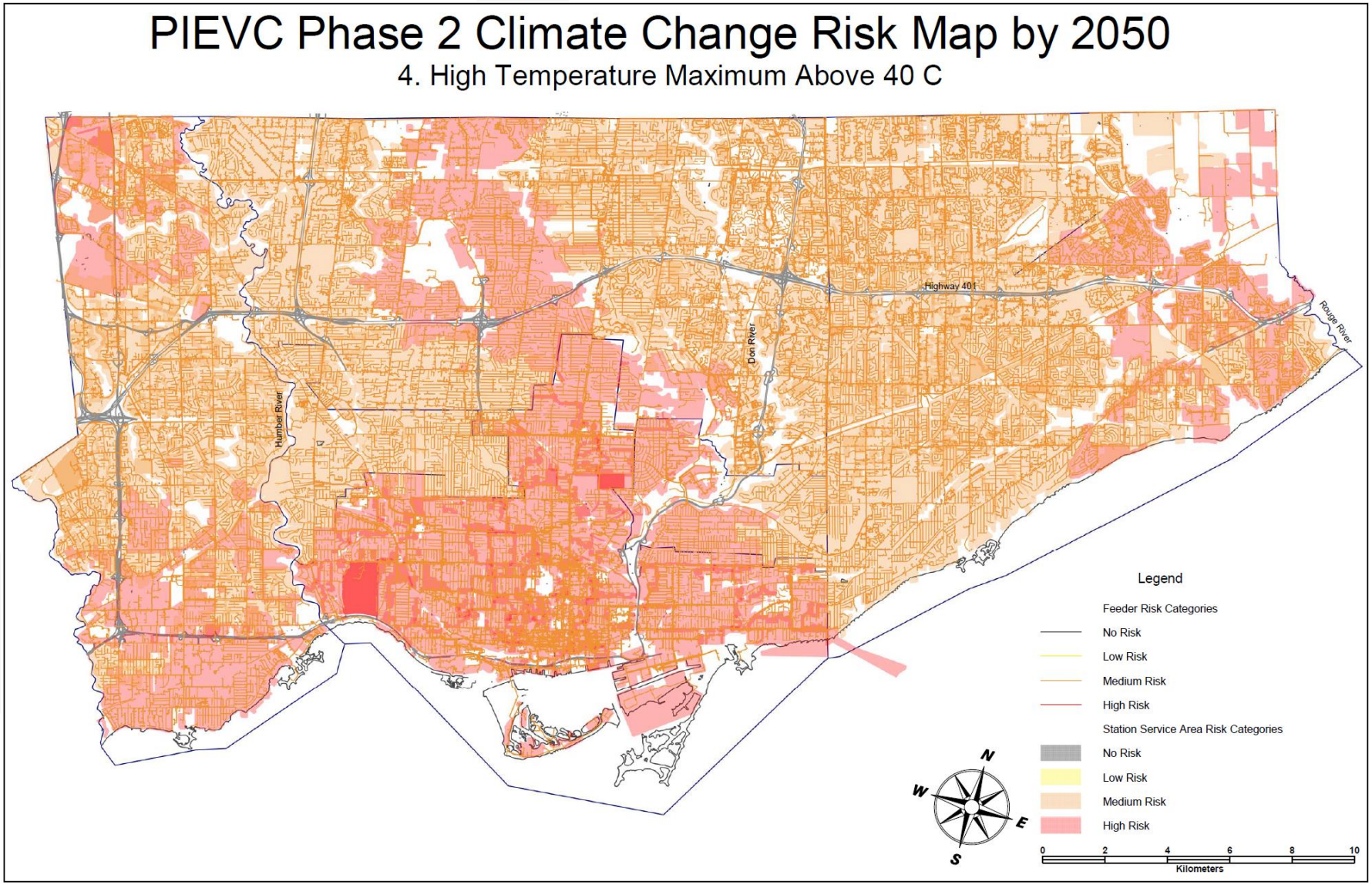
Phase 1	Phase 2
• Pilot case study • Current climate only • Small portion of distribution system • Completed Sept 2012	• 2010-2050, 20 climate parameters • Entire distribution system • Completed June 2015

Vulnerability Assessment Phase 2

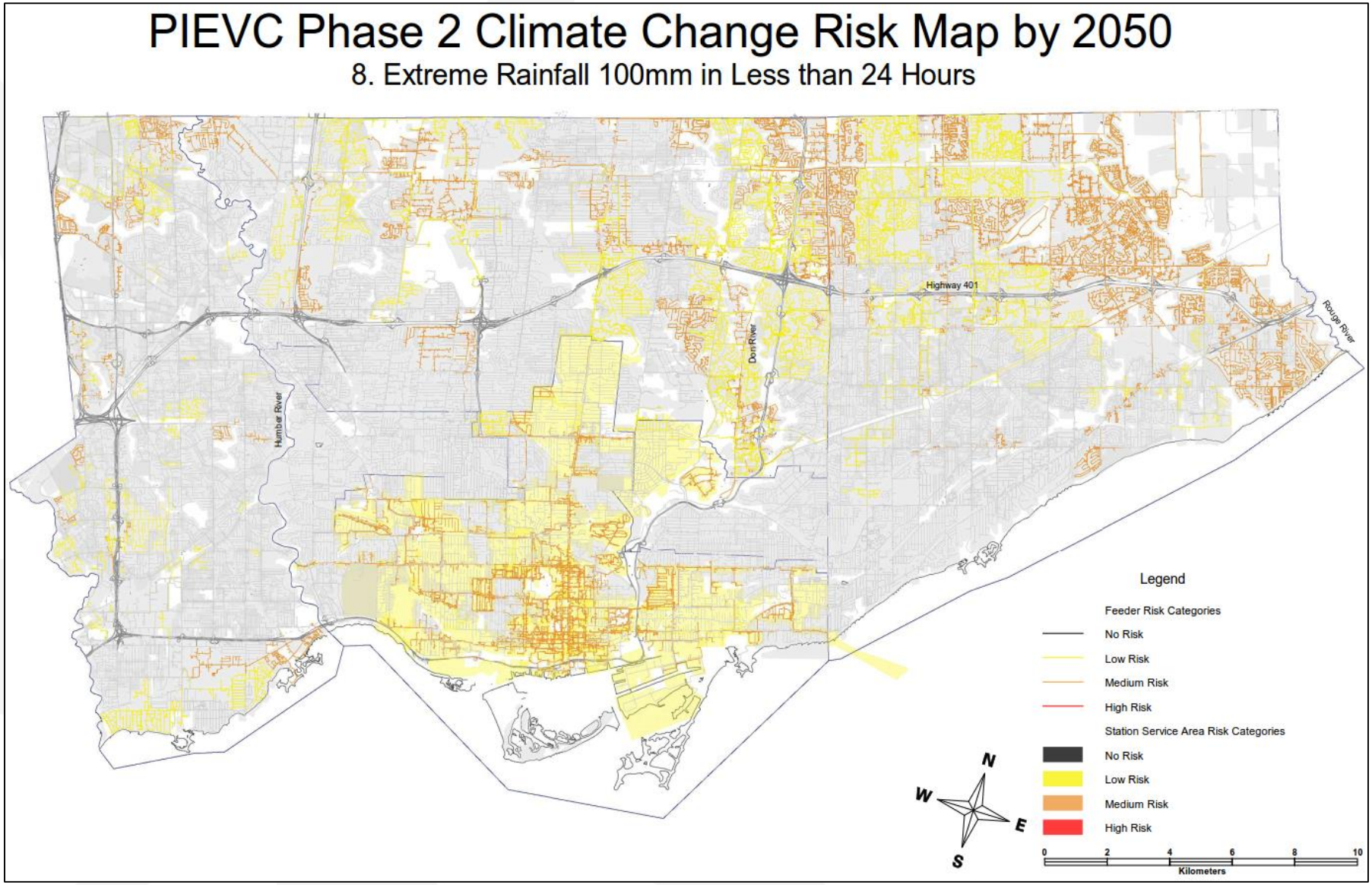
Table ES-1 Climate Parameters and Probability of Occurrence

Climate Parameter		Annual Probability (Historical; **Projected 2030's and *2050's***)	Probability of Occurrence Study Period (2015-2050)
Daily Maximum	25°C	66 per year; **84 per year**, ***106 per year***	100%
	30°C	16 per year; **26 per year**, ***47 per year***	100%
40°C		~0.01 per year; **0.3 to 2 days per year**, ***1-7 days per year***	
High Daily Avg. Temperature	30°C	0.07 per year; **N/A**, ***1.2 days per year***	~100%
Heat Wave	3 days max temp over 30°C	0.88 per year; **>1 for both**	100%
High Nighttime	Nighttime low >23°C	0.70 per year; **7 per year**, ***16 per year***	~100%
100 mm in <1 day + antecedent		0.04 per year; ***extreme precipitation expected ↑, percentage unknown***	
15 mm (tree branches)		0.11 per year; **>0.13 per year**, ***>0.16 per year***	
25 mm ≈ 12.5 mm radial		0.06 days per year; **>0.07 per year**, ***>0.09 per year***	
		Upper bound of estimate: 0.007 events per year; >0.008 per year; >0.01 per year	
70 km/h+ (tree branches)		21 days per year; **N/A**, ***24 to 26 per year***	
90 km/h		2 days per year; **N/A**, ***>2.5 per year***	
120 km/h		~0.05 days per year; ***likely ↑, but % unknown***	
Lightning	Flash density per km km^2	1.12 to 2.24 per year per km^2; ***Expected increase, % change unknown***	~50-70%(Lg); ~10-20% (Sm)
Snowfall	Days w/ >10 cm	1.5 days per year; ***Trend decreasing but highly variable***	100%
	Days w/ > 5cm	5 days per year; ***Trend decreasing but highly variable***	100%
Frost		229 frost free days; **249 frost free days**, ***273 frost free days***	100%

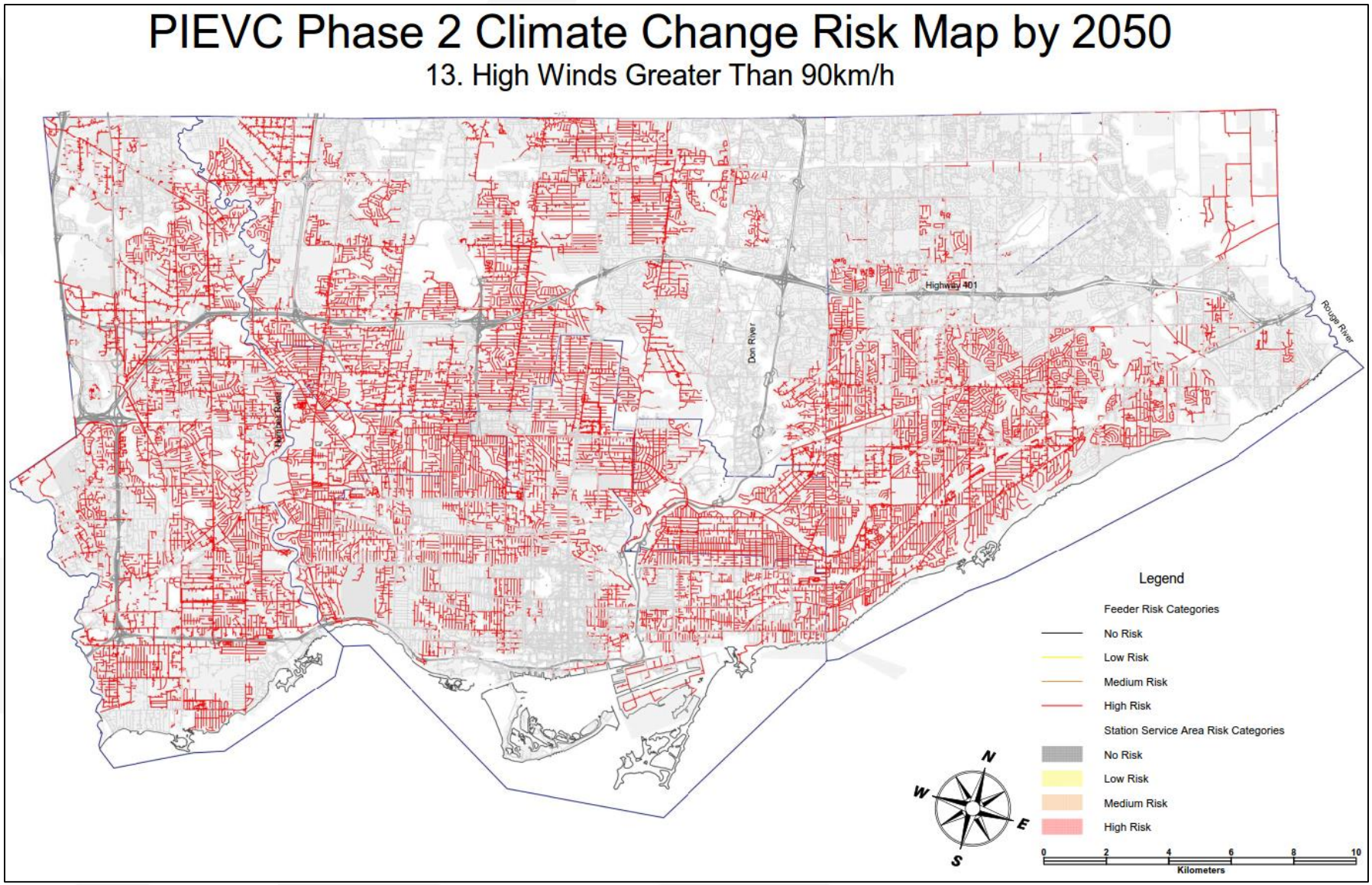
Vulnerability Assessment Phase 2



Vulnerability Assessment Phase 2



Vulnerability Assessment Phase 2

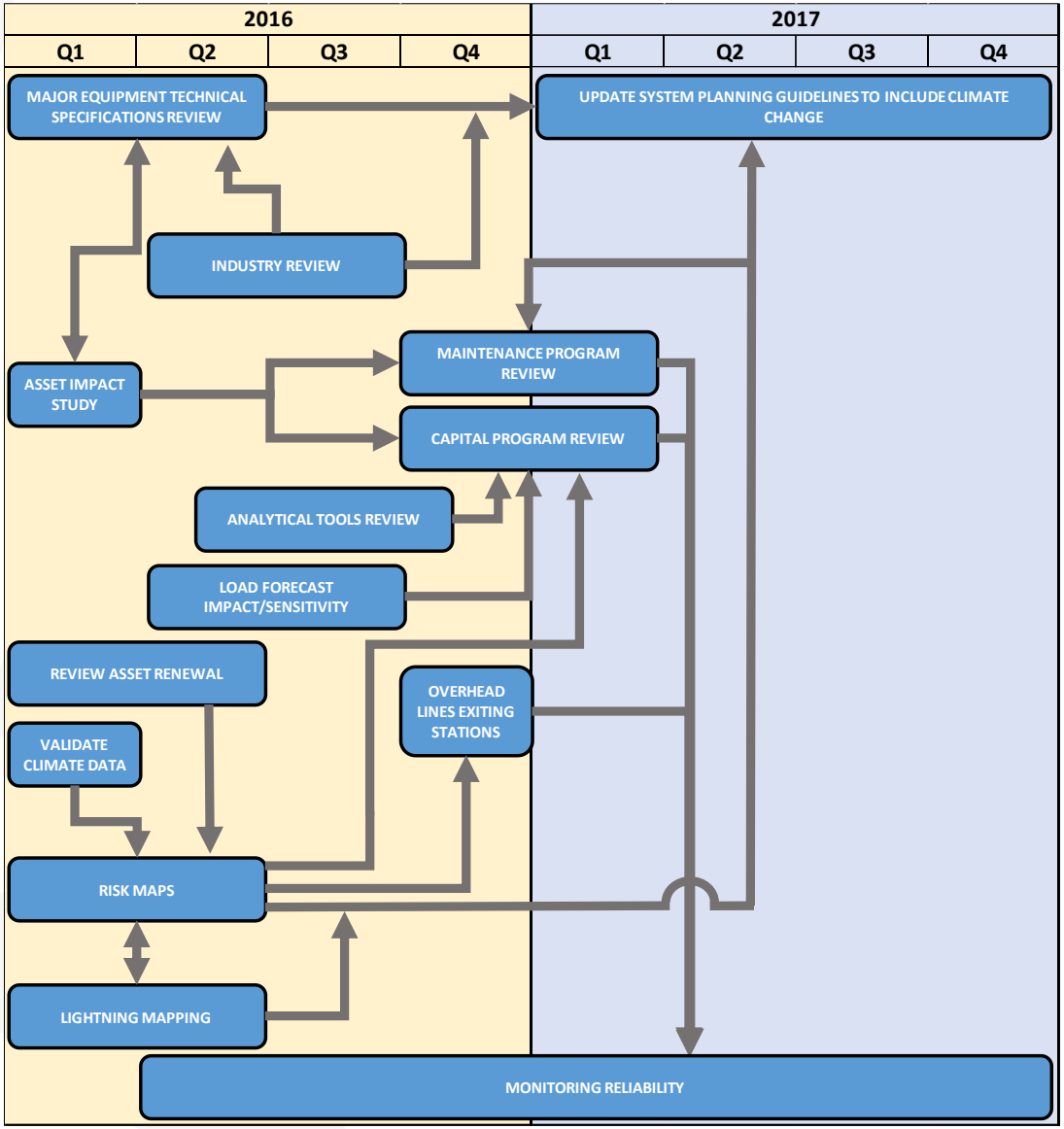


Vulnerability Assessment Adaptation Opportunities

- Infrastructure strengthening
- Capacity planning
- Inspection and maintenance programs
- Data collection and quality

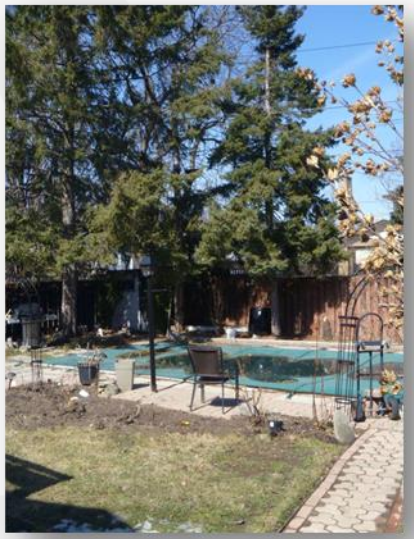
Climate Change Adaptation Roadmap

- Climate data validation
- Asset lifecycle
- Equipment specifications
- Capital and maintenance programs
- Planning data, tools, guidelines
- Design practices
- Construction standards



Ongoing System Resilience Enhancements
Capital & Maintenance Programs

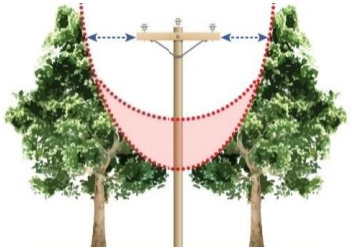
Rear Lot Conversion



Overhead Infrastructure Relocation

Tree Trimming Standards

Organization	Clearance from Bare Conductor (ft.)							
	1	2	3	4	5	6	7	8
City of Toronto (0.9 m = 3')	■	■	■					
Toronto Hydro (1.3 m = 4'2")	■	■	■	■				
Other Utilities (2.4 m - 3.7 m = 8' - 12')	■	■	■	■	■	■	■	■



Ongoing System Resilience Enhancements

New Technologies

Breakaway Connectors

Stainless Steel Submersible Transformers

Opportunities

- Common climate data source
- Accelerated industry standards adaptation
- Vulnerability interdependencies

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Questions