Ontario Reduced Load Period (RLP) Determination of Onset and Removal Dates

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Outline

Jurisdictional Scan: RLP Practices

Establish Ontario RLP zones

Method for Ontario RLP Start and End Date Model

Ontario RLP Model and Excel solution

Next Steps

Jurisdictional Scan
Surrounding Agencies RLP Practices

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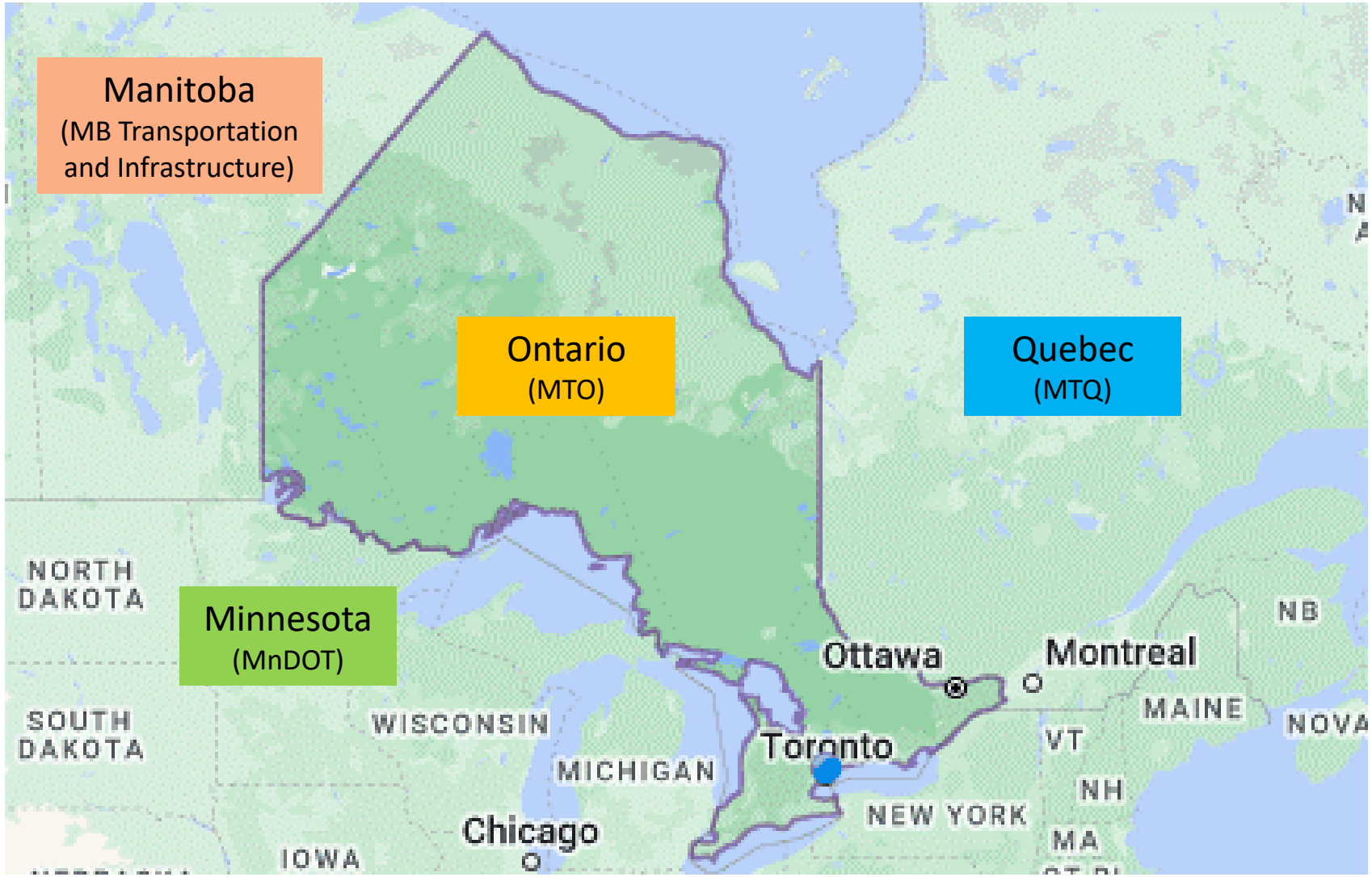
MTO and Surrounding Agencies: RLP Current Practices



Comparison

- Zones
- Advanced Notice to the Industry
- RLP Start Date Criteria
- RLP End Data Criteria
- Review for Consistency / Continuity

Current RLP Practices: Zones and Advance Notice to the Industry

Agencies	Zone	Advance Notice to the Industry
Ontario (MTO)	Current: 3 Schedule List NW, NE and Southern Ontario	Fixed dates 511 website
Minnesota (MnDOT)	6 RLP Zones	At least 3 days
Quebec (MTQ)	3 RLP Zones	At least one week
Manitoba (MB Transportation and Infrastructure)	4 RLP Zones	3 days

CTI algorithms for setting RLP Start and End Dates

What is CTI?

- **Cumulative Thawing Index (CTI) is the cumulative number of degree-days when air temperatures are above 0 °C**

CTI Equations

- Different agencies using Different CTI Equation to calculate CTI, but they all use the same Input Parameters

Input parameters

- Daily Air Temperature T_{Air} (measured and/or forecast)
- Reference Temperatures T_{Ref} (lookup table, values set by agency)

Benefits of CTI method

- Simple, only requires Daily Air and pre-set Reference Temperatures
- CTI algorithm is applicable for large geographical zone and can be customized for municipalities using local input data
- CTI algorithm has 7 days advance forecast capability of RLP onset and removal dates to facilitate timely notice and administration of RLP.

Current Jurisdictional Practices: SLP Start and End Date

Agencies	Start RLP	End RLP
Ontario (MTO)	• Freeze/thaw depth at SLA stations • Use CTI thresholds in NW and NE • Observation, historical date, temperature in Southern Ontario	• NE and NW CTI predictions, southern Ontario Fixed dates or site temperature and site observations • Approx. 5 to 10.6 weeks from the start of RLP
Minnesota (MnDOT)	• Use CTI threshold • Forecast of warmer temperature	• Complete thaw plus 3 weeks • Site Observations • Not longer than 8 weeks from start of RLP
Quebec (MTQ)	• 30% of stations in the zone reaching 30 cm thawing depth	• 50% of stations in the zone has reached 90 cm thaw, plus 5 weeks
Manitoba (MB Transportation and Infrastructure)	• Use CTI threshold and temperature continue to rise • Cannot be earlier than specific start date of the zone	• Use CTI threshold and temperature continue to rise • Not later than specified end date • Approx. 12 to 13 weeks from start of RLP

Ontario Reduced Load Period (RLP) Zones

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Ontario RLP Zone Development

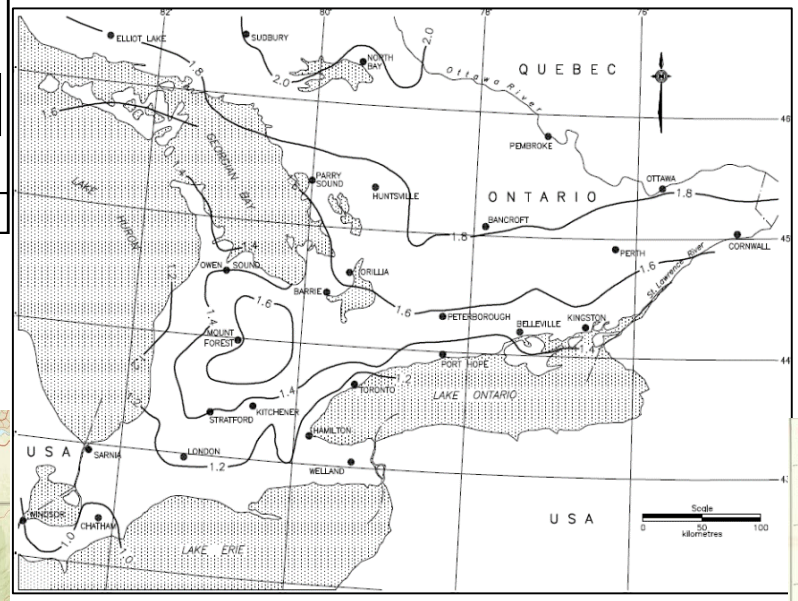
Factors for Ontario RLP Zone Determination:

- Vast geographical and climatic zones
- MTO PGAC Zone experience
- Pavement and Foundation Degree Freezing Index Days/Frost Depth Penetration data
- Dominant subgrade soils in Ontario
- Road Weather Information station (RWIS) and Seasonal Load Adjustment (SLA) Stations locations and coverage.
- Selection of SLA sites for zones calibration and verification using air temperature parameter.

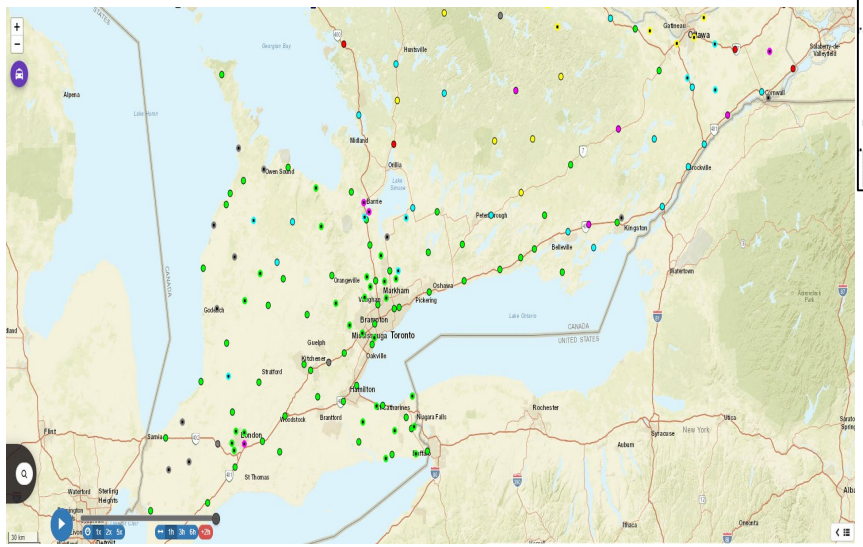
Factors considered for Ontario RLP Zones

PGAC Zones

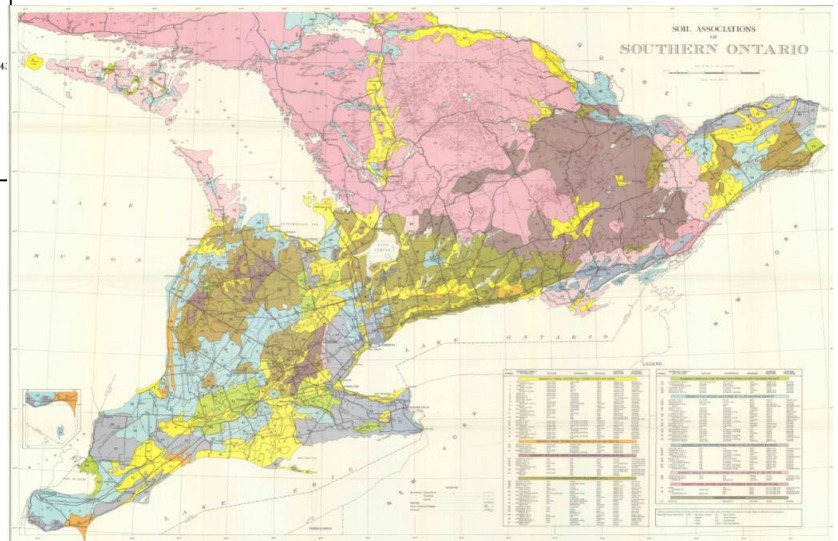
Frost Depth/ Degree Freezing Index



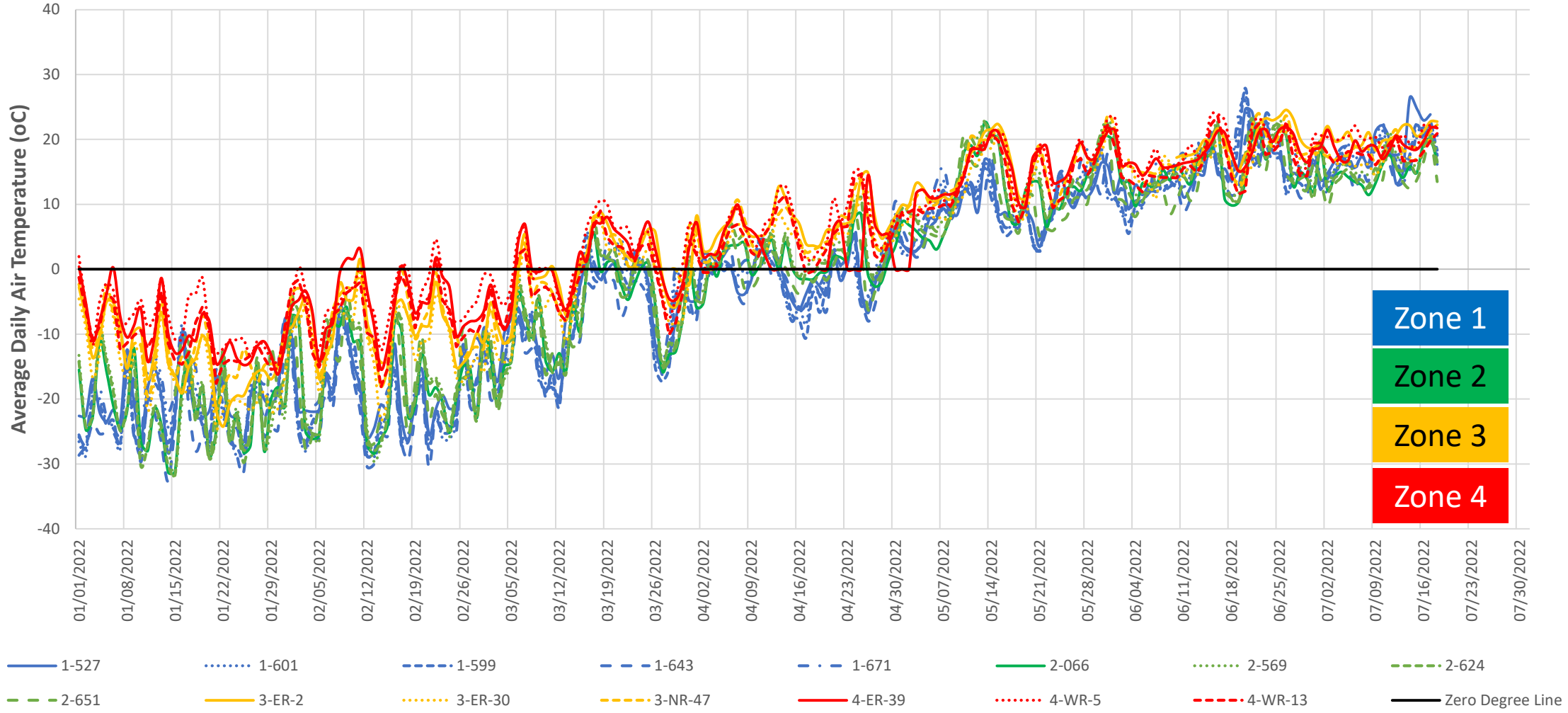
RWIS and SLA sites



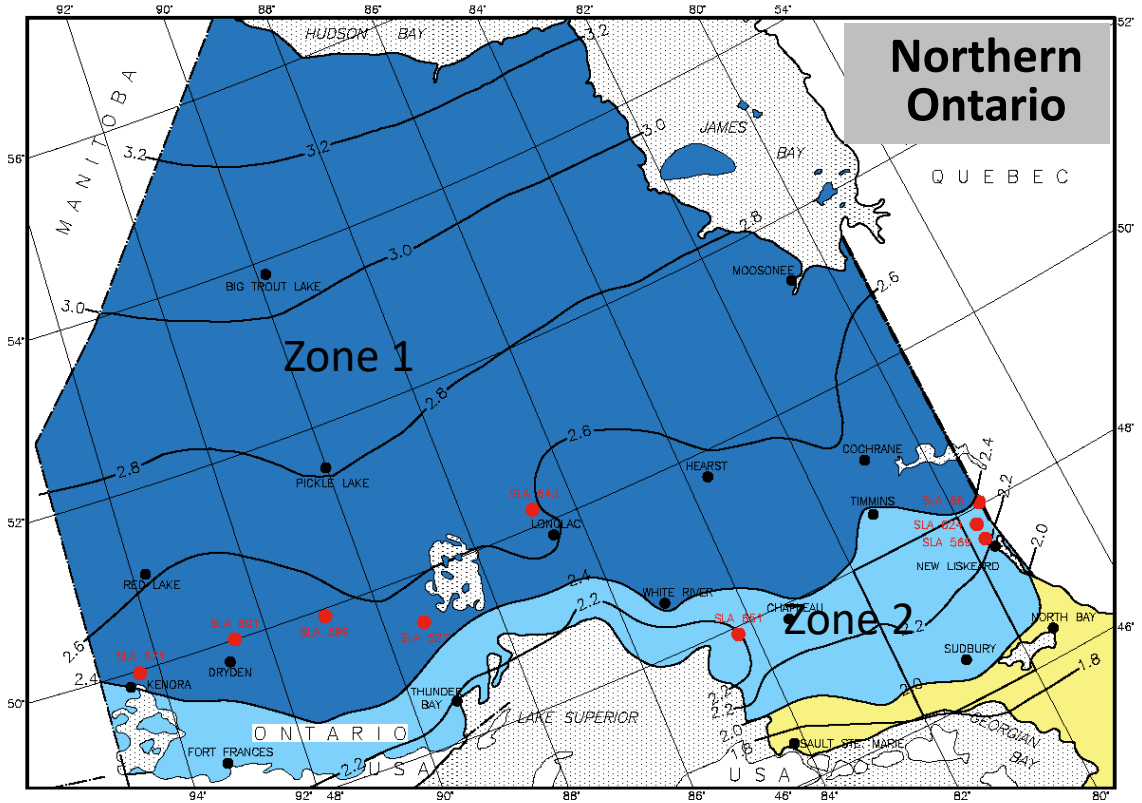
Ontario Surficial soils

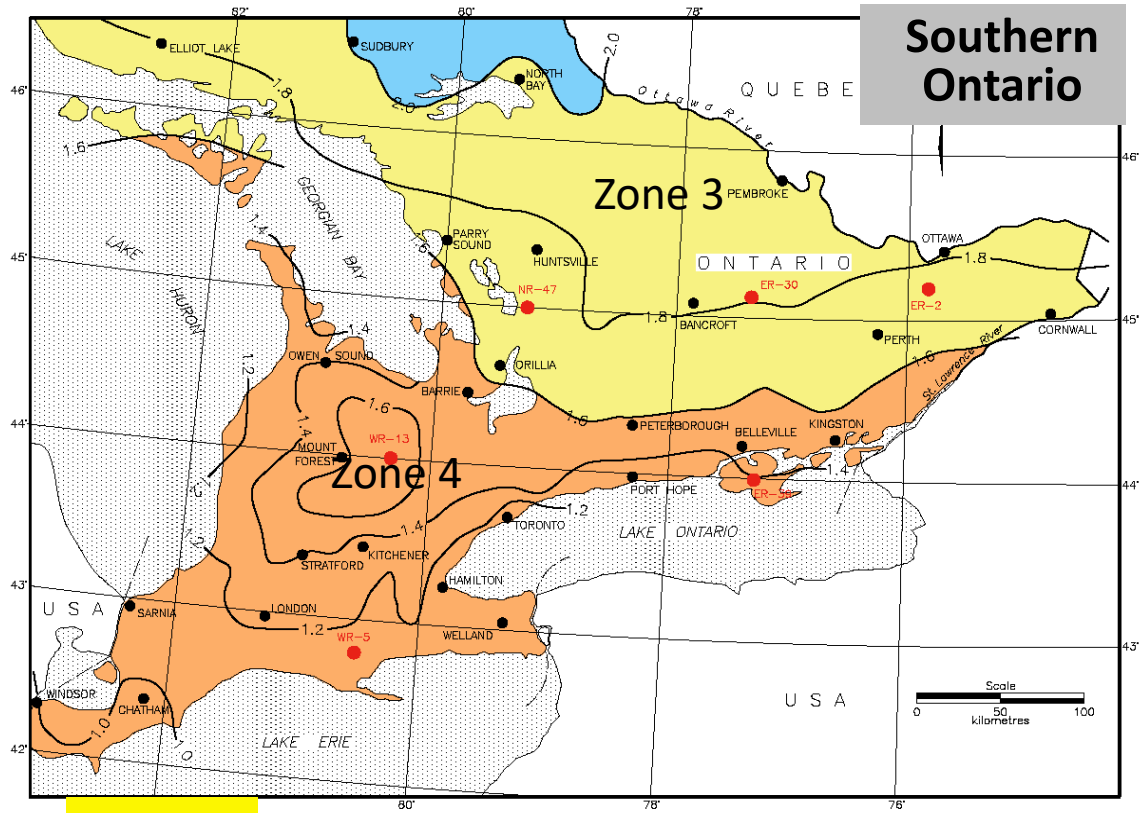


Average SLA Temperature Plots for each zone: Average Daily Air Temperatures (2022)



Ontario RLP Zones with selective SLA Sites





Zone 1	Frost Depth 2.4 m to 3.2 m with **5 SLA Sites**
Zone 2	Frost Depth 2.0 m to 2.4 m with **4 SLA Sites**
Zone 3	Frost Depth 1.6 m to 2.0 m with **3 SLA Sites**
Zone 4	Frost Depth 1.0 m to 1.6 m with **3 SLA Sites**

Ontario RLP Start and End Dates Model

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CTI Equations Reviewed:

- 4 CTI Equations were assessed in the analysis
  - MTO (NER)
  - MTO (NWR)
  - MnDOT
  - Manitoba
- Sample of CTI Equation and Input Parameters are Air Temperature and Reference Temperature

$$Cum.TI = \sum_{i=1}^{n} [TI_d - (0.5 \times FI_d)]$$

When $(T_{AIR} - T_{REF}) > 0°C$,

$$TI_d = [T_{AIR} - T_{REF}] \text{ and } FI_d = 0°C \cdot day$$

When $(T_{AIR} - T_{REF}) < 0°C$,

$$TI_d = 0°C \cdot day \text{ and } FI_d = [0°C - T_{AIR}]$$

Selection of RLP Start Date and End Date - Model and Criteria

RLP shall start

- **on or earlier than the date** that pavement strength starts decreasing (i.e., **strength decreasing**)
- Pavement starts weakening when:
  - ✓ thaw depth reaches the base granular layer
  - ✓ Increasing moisture in base granular layer
- RLP to start when any one of these conditions is met
- The RLP **Start Date – determine the CTI threshold value and model/algorithm that consistently predict the date when one or both of these strength weaking conditions are met with verification using moisture probe, FWD test and frost probe data**

RLP shall end

- **on or later than the date** that pavement strength achieved pre thaw strength (i.e., **strength recovering**)
- Pavement starts strength recovery when:
  - ✓ Resilient modulus of base granular and/or subgrade increased to or above level before thaw weakening
  - ✓ Base layer moisture decreasing
- Reduced Load Period to end at a date when these conditions are met
- The RLP **End Date – determine the CTI threshold criteria and model/algorithm that consistently predict the date when all these strength recovery conditions are met with verification by moisture probe, FWD test and frost probe data**

Data Collection 2022

15 SLA stations in 4 zones

RWIS Data

•Collect and extract air and subsurface temperatures, subsurface moisture content, and frost depth to determine thaw/frost front and draining conditions

Borehole Data

Collect borehole data to assess pavement structure (type and thickness) and subgrade information for use with FWD analysis and modules back calculation

FWD Testing Results

Perform Falling Weight Deflectometer (FWD) testing at various times around complete thaw period to determine pavement and subgrade strength recovery

RWIS Data (Example Zone 1 - Hwy 527)

- Air Temperature: Measured data interval at every 1 hour or every 10 minutes (site dependent)
- Subsurface Temperature: Typical 13 sensors below surface at depth between 5 cm to 255 cm (site dependent)
- Moisture Contents: Typical 3 moisture sensor below surface at depth 15, 45, and 100 cm (site dependent)

Time EDT	Air Temp (°C)	Subsurface Temperature (°C)													Subsurface Water Content (%)		
		5 cm	15 cm	30 cm	45 cm	60 cm	75 cm	90 cm	105 cm	135 cm	165 cm	195 cm	225 cm	255 cm	15 cm	45 cm	100 cm
03/18/2022 0:00	-2.5	-1.9	6.2	-4.1	-5.8	-6.6	-6.4	-6.1	-4.6	-4.2	-3.1	-2.2	0.6	3.1	11	8	8
03/18/2022 1:00	-3.9	-2.1	6.2	-4.1	-5.8	-6.6	-6.4	-6	-4.6	-4.1	-3.1	-2.2	0.6	3.1	11	8	8
03/18/2022 2:00	-5.5	-2.3	6.2	-4.1	-5.7	-6.6	-6.3	-6	-4.6	-4.2	-3.1	-2.2	0.6	3.1	11	8	8
03/18/2022 3:00	-6.2	-2.6	6.1	-4	-5.7	-6.6	-6.3	-6	-4.6	-4.1	-3.1	-2.2	0.6	3.1	11	8	8
03/18/2022 4:00	-7.3	-2.8	6.1	-4	-5.6	-6.6	-6.3	-6	-4.6	-4.1	-3.1	-2.2	0.6	3.1	11	8	8
03/18/2022 5:00	-8.2	-3.1	6	-4	-5.6	-6.5	-6.3	-6	-4.6	-4.1	-3.1	-2.2	0.6	3.1	11	8	8
03/18/2022 6:00	-9.3	-3.4	5.9	-4	-5.6	-6.5	-6.3	-6	-4.6	-4.1	-3.1	-2.2	0.6	3.1	11	8	8
03/18/2022 7:00	-9.8	-3.8	5.8	-4	-5.5	-6.5	-6.3	-6	-4.6	-4.1	-3.1	-2.2	0.6	3.1	11	8	8
03/18/2022 8:00	-10.8	-4.2	5.7	-4	-5.5	-6.5	-6.3	-6	-4.6	-4.1	-3.1	-2.2	0.6	3.1	11	8	8
03/18/2022 9:00	-10.3	-4.5	5.5	-4	-5.5	-6.4	-6.3	-6	-4.6	-4.1	-3.1	-2.2	0.6	3.1	11	8	8
03/18/2022 10:00	-6.1	-4.8	5.4	-4	-5.4	-6.4	-6.3	-6	-4.6	-4.1	-3.1	-2.2	0.6	3.1	11	8	8
03/18/2022 11:00	1.2	-4.9	5.2	-4	-5.4	-6.4	-6.2	-6	-4.6	-4.1	-3.1	-2.2	0.6	3.1	11	8	8
03/18/2022 12:00	2.8	-4.6	5.1	-4.1	-5.4	-6.4	-6.2	-6	-4.6	-4.1	-3.1	-2.2	0.6	3.1	11	8	8
03/18/2022 13:00	5.8	-3.8	5.1	-4.1	-5.4	-6.3	-6.2	-6	-4.6	-4.1	-3.1	-2.2	0.6	3.1	11	8	8
03/18/2022 14:00	7.2	-2.4	5.2	-4.2	-5.4	-6.3	-6.2	-6	-4.6	-4.1	-3.1	-2.2	0.6	3.1	11	8	8
03/18/2022 15:00	7.1	-1	5.4	-4.2	-5.4	-6.3	-6.2	-6	-4.6	-4.1	-3.1	-2.2	0.6	3.1	11	8	8
03/18/2022 16:00	7.5	0.3	5.6	-4.3	-5.3	-6.3	-6.2	-6	-4.6	-4.1	-3.1	-2.2	0.6	3.1	11	8	8
03/18/2022 17:00	7.7	1.5	6	-4.3	-5.3	-6.3	-6.2	-6	-4.6	-4.1	-3.1	-2.2	0.6	3.1	11	8	8
03/18/2022 18:00	7.2	2.2	6.5	-4.3	-5.3	-6.2	-6.1	-5.9	-4.5	-4.1	-3.1	-2.2	0.6	3.1	11	8	8
03/18/2022 19:00	6.6	2.2	6.9	-4.2	-5.3	-6.2	-6.1	-5.9	-4.5	-4.1	-3.1	-2.2	0.6	3.1	11	8	8
03/18/2022 20:00	2.6	1.6	7.1	-4.2	-5.3	-6.2	-6.1	-5.9	-4.5	-4.1	-3.1	-2.2	0.6	3.1	11	8	8
03/18/2022 21:00	-1.5	0.7	7.2	-4	-5.3	-6.2	-6.1	-5.9	-4.5	-4.1	-3.1	-2.2	0.6	3.1	11	8	8
03/18/2022 22:00	0.6	-0.1	7.1	-3.8	-5.3	-6.1	-6.1	-5.9	-4.5	-4.1	-3.1	-2.2	0.6	3.1	11	8	8
03/18/2022 23:00	-3.3	-0.7	7	-3.6	-5.2	-6.1	-6.1	-5.9	-4.5	-4.1	-3.1	-2.2	0.6	3.1	11	8	8

Zone : WR-5 Ostrander (2022 Data)

- Top-down and bottom-up thawing in Ontario
- Surficial freeze thaw cycles - 3 consecutive days above thaw check

2022																									
SLR Data							New Temp Probes																		
			SLR				-5	-15	-30	-45	-75	-90	-105	-135	-165	-195	-225	-255							
Date	T_{air}	T_{surf}	TI_a	FI_a	CTI	Place SLR?	5 cm Subsurface Temp	15 cm Subsurface Temp	30 cm Subsurface Temp P	45 cm Subsurface Temp	75 cm Subsurface Temp	90 cm Subsurface Temp	105 cm Subsurface Temp	135 cm Subsurface Temp	165 cm Subsurface Temp	195 cm Subsurface Temp	225 cm Subsurface Temp	255 cm Subsurface Temp	Date	Moisture (%) WCR @ 15 cm	Moisture (%) WCR @ 45 cm	Moisture (%) WCR @ 100 cm
2/4/2022	-10.50	-1.50	0.00	10.50	0	No	-4.2	-1.7	-1.7	-1.8	-0.7	-0.2	0.2	1.5	2.7	3.8	5.0	6.3	2/4/2022	3.6	2.8	3.0
2/5/2022	-12.45	-1.50	0.00	12.45	0	No	-5.6	-2.2	-2.2	-1.9	-0.5	-0.2	0.2	1.4	2.6	3.8	4.9	6.1	2/5/2022	4.0	3.0	3.0
2/6/2022	-6.75	-1.50	0.00	6.75	0	No	-4.6	-3.1	-3.1	-2.5	-0.6	-0.1	0.2	1.4	2.6	3.7	4.8	6.1	2/6/2022	4.0	3.0	3.0
2/7/2022	-6.05	-1.50	0.00	6.05	0	No	-3.3	-3.1	-3.1	-2.7	-0.8	-0.2	0.2	1.4	2.5	3.6	4.7	6.0	2/7/2022	7.3	3.0	3.0
2/8/2022	-5.10	-2.00	0.00	5.10	0	No	-2.5	-2.6	-2.6	-2.4	-0.8	-0.2	0.2	1.4	2.5	3.6	4.6	5.9	2/8/2022	4.2	3.0	3.0
2/9/2022	-2.90	-2.00	0.00	2.90	0	No	-2.1	-2.3	-2.3	-2.2	-0.7	-0.2	0.2	1.3	2.4	3.5	4.6	5.8	2/9/2022	3.3	3.3	3.0
2/10/2022	-2.75	-2.00	0.00	2.75	0	No	-0.8	-1.9	-1.9	-2.0	-0.6	-0.2	0.2	1.3	2.4	3.4	4.5	5.7	2/10/2022	8.4	3.1	3.0
2/11/2022	0.10	-2.00	2.10	0.00	2	No	-0.3	-1.5	-1.5	-1.8	-0.6	-0.1	0.2	1.3	2.4	3.4	4.4	5.7	2/11/2022	3.9	3.1	3.0
2/12/2022	-5.25	-2.00	0.00	5.25	0	No	-0.8	-1.3	-1.3	-1.6	-0.6	-0.1	0.2	1.3	2.3	3.3	4.4	5.6	2/12/2022	6.8	3.2	3.0
2/13/2022	-6.65	-2.00	0.00	6.65	0	No	-2.8	-1.2	-1.2	-1.4	-0.5	-0.1	0.2	1.3	2.3	3.3	4.3	5.5	2/13/2022	4.8	3.6	3.5
2/14/2022	-12.50	-2.00	0.00	12.50	0	No	-4.7	-1.6	-1.6	-1.4	-0.5	-0.1	0.2	1.3	2.3	3.3	4.3	5.5	2/14/2022	4.0	4.0	4.0
2/15/2022	-8.55	-2.50	0.00	8.55	0	No	-4.5	-2.4	-2.4	-1.7	-0.4	-0.1	0.2	1.2	2.2	3.2	4.2	5.4	2/15/2022	4.0	4.0	4.0
2/16/2022	-2.75	-2.50	0.00	2.75	0	No	-1.9	-2.3	-2.3	-2.0	-0.4	-0.1	0.2	1.2	2.2	3.2	4.2	5.4	2/16/2022	4.5	4.0	4.0
2/17/2022	0.70	-2.50	3.20	0.00	3	No	0.4	-1.7	-1.7	-1.8	-0.4	-0.1	0.2	1.3	2.2	3.2	4.1	5.3	2/17/2022	9.6	4.0	4.0
2/18/2022	-0.05	-2.50	2.45	0.00	6	No	-1.4	-1.2	-1.2	-1.6	-0.4	0.0	0.3	1.2	2.2	3.1	4.1	5.2	2/18/2022	8.1	3.9	4.0
2/19/2022	-7.50	-2.50	0.00	7.50	0	No	-2.5	-1.1	-1.1	-1.4	-0.4	0.0	0.3	1.2	2.2	3.1	4.1	5.2	2/19/2022	5.5	3.8	4.0
2/20/2022	-3.45	-2.50	0.00	3.45	0	No	-2.7	-1.2	-1.2	-1.2	-0.3	0.0	0.3	1.2	2.2	3.1	4.0	5.1	2/20/2022	4.8	4.0	4.0
2/21/2022	-1.10	-2.50	1.40	0.00	1	No	-0.5	-1.2	-1.2	-1.2	-0.3	0.0	0.3	1.2	2.2	3.1	4.0	5.1	2/21/2022	7.7	4.0	4.0
2/22/2022	4.60	-3.00	7.60	0.00	9	No	1.1	-1.0	-1.0	-1.2	-0.3	0.0	0.3	1.2	2.1	3.0	4.0	5.1	2/22/2022	11.9	4.0	4.0
2/23/2022	-0.95	-3.00	2.05	0.00	11	No	0.2	-0.5	-0.5	-1.1	-0.4	-0.1	0.3	1.3	2.1	3.0	3.9	5.0	2/23/2022	7.9	5.0	4.8
2/24/2022	-7.50	-3.00	0.00	7.50	0	No	-2.4	-0.5	-0.5	-0.9	-0.3	0.0	0.3	1.2	2.1	3.0	3.9	5.0	2/24/2022	5.1	5.0	4.5
2/25/2022	-8.10	-3.00	0.00	8.10	0	No	-2.2	-0.7	-0.7	-0.9	-0.2	0.1	0.3	1.2	2.1	3.0	3.9	4.9	2/25/2022	4.4	4.7	4.0
2/26/2022	-7.70	-3.00	0.00	7.70	0	No	-3.0	-1.1	-1.1	-0.9	-0.1	0.2	0.4	1.3	2.1	3.0	3.8	4.9	2/26/2022	4.1	4.3	4.0
2/27/2022	-6.10	-3.00	0.00	6.10	0	No	-2.6	-1.3	-1.3	-1.1	0.0	0.3	0.5	1.3	2.1	2.9	3.8	4.8	2/27/2022	4.4	4.0	4.0
2/28/2022	-4.85	-3.00	0.00	4.85	0	No	-2.5	-1.5	-1.5	-1.2	0.0	0.4	0.5	1.3	2.1	2.9	3.8	4.8	2/28/2022	5.0	4.0	4.0
3/1/2022	-0.90	-3.50	2.60	0.00	3	No	-1.0	-1.4	-1.4	-1.2	0.0	0.4	0.6	1.3	2.1	2.9	3.7	4.8	3/1/2022	5.6	4.0	4.0
3/2/2022	-0.90	-3.50	2.60	0.00	5	No	-0.4	-1.2	-1.2	-1.2	0.1	0.4	0.6	1.4	2.1	2.9	3.7	4.8	3/2/2022	6.9	4.0	4.0
3/3/2022	-3.95	-3.50	0.00	3.95	0	No	-1.4	-1.0	-1.0	-1.1	0.1	0.4	0.6	1.4	2.1	2.9	3.7	4.7	3/3/2022	7.5	4.1	4.0
3/4/2022	-5.55	-3.50	0.00	5.55	0	No	-2.1	-1.0	-1.0	-1.1	0.1	0.4	0.6	1.4	2.1	2.9	3.7	4.7	3/4/2022	5.1	4.1	4.0
3/5/2022	-2.55	-3.50	0.95	0.00	1	No	-0.6	-1.0	-1.0	-1.0	0.1	0.5	0.7	1.4	2.1	2.9	3.7	4.7	3/5/2022	5.5	4.0	4.0
3/6/2022	4.95	-3.50	8.45	0.00	9	No	5.1	-0.7	-0.7	-1.0	0.1	0.5	0.7	1.4	2.1	2.9	3.7	4.7	3/6/2022	7.7	4.7	4.0
3/7/2022	6.30	-3.50	9.80	0.00	19	Yes	1.0	0.0	0.0	-0.8	0.1	0.5	0.7	1.4	2.1	2.9	3.7	4.6	3/7/2022	6.8	5.5	4.0
3/8/2022	-1.30	-4.00	2.70	0.00	22	Yes	1.0	0.0	0.0	-0.5	0.3	0.6	0.7	1.4	2.1	2.8	3.6	4.6	3/8/2022	6.0	4.7	4.2
3/9/2022	0.05	-4.00	4.05	0.00	26	Yes	1.6	0.3	0.3	-0.1	0.5	0.8	0.8	1.4	2.1	2.8	3.6	4.6	3/9/2022	5.8	4.0	4.0
3/10/2022	0.15	-4.00	4.15	0.00	30	No	2.3	0.9	0.9	0.4	0.8	1.0	1.0	1.5	2.1	2.8	3.6	4.5	3/10/2022	5.8	4.0	4.0
3/11/2022	-0.25	-4.00	3.75	0.00	34	No	0.3	0.9	0.9	0.7	1.2	1.2	1.2	1.6	2.2	2.9	3.5	4.5	3/11/2022	8.2	3.9	4.0
3/12/2022	-4.90	-4.00	0.00	4.90	0	No	-1.2	0.3	0.3	0.4	1.3	1.4	1.4	1.8	2.3	2.9	3.5	4.5	3/12/2022	6.9	3.1	4.1
3/13/2022	-6.55	-4.00	0.00	6.55	0	No	-3.3	-0.5	-0.5	-0.1	1.1	1.4	1.4	1.8	2.3	2.9	3.5	4.5	3/13/2022	10.7	3.0	4.0
3/14/2022	-0.95	-4.00	3.05	0.00	3	No	0.1	-0.9	-0.9	-0.6	0.9	1.2	1.3	1.8	2.4	3.0	3.6	4.5	3/14/2022	3.3	2.3	4.0

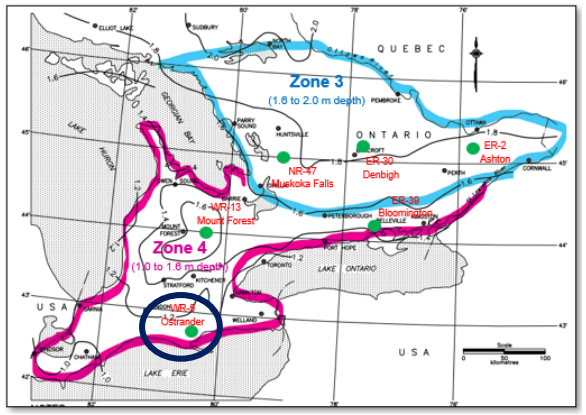
Top Down and Bottom Up Thawing

Computation of T_{Air}, FI, TI and CTI

Subsurface Temperature Reading and Color Code for Freezing/ Thawing Temperature

Moisture Probes

Frost Depth	105 cm
Thaw to 5 cm	March 6
Thaw to 30 cm	March 7
Thaw to 90 cm	March 10
Complete Thaw *Refreeze	March 10

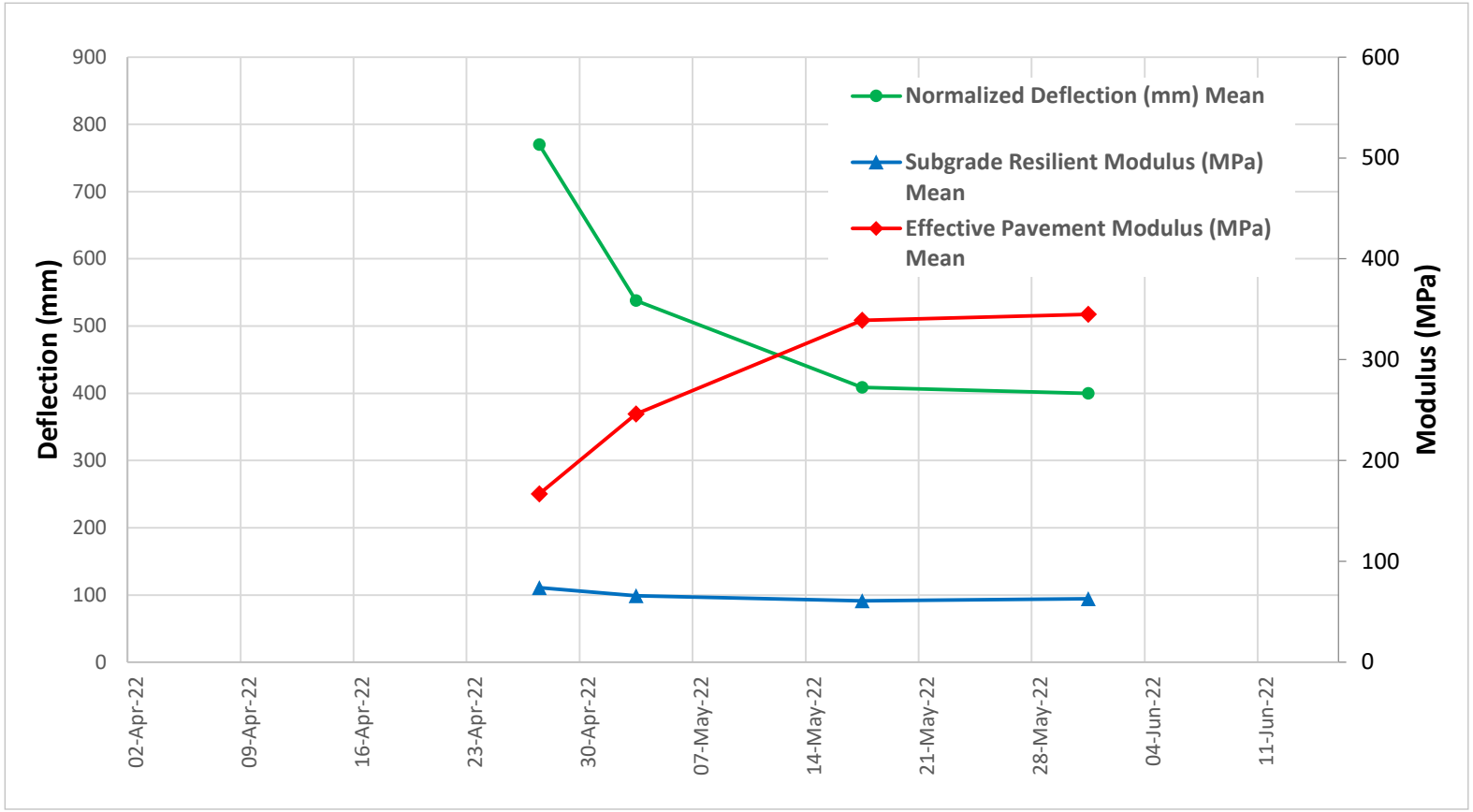


Borehole Data: Pavement Structure and Subgrade Information

RLP Zone	SLA Station	HMA (mm)	Surface Treated (mm)	Granular Base (mm)	SSM (mm)	HMA (mm)	SSM (mm)	Granular Subbase (mm)	Total Thickness (mm)	Subgrade Types
1	Hwy 527	60		200				740	1000	Sand with Silt and Gravel
	Hwy 599		25	300					325	Sand with Gravel/ Gravelly Sand
	Hwy 601		25	200				375	600	Silty Clay & Sand/Clay with Sand
	Hwy 643	45		150				305	500	Gravelly Sand/Sand with Gravel
	Hwy 671		20	200					220	Silty Sand/Sand and Silt
2	Hwy 66	230						200	430	Other + CL
	Hwy 569		25	230	355	50			660	CL-ML, CL
	Hwy 624		25	230		50	455		760	SM
	Hwy 651	50						865	915	Encounter BR or Boulders
3	ER-2 Ashton	250		180				260	690	Grey Sa tr Gr and Br Sa
	ER-30 Denbigh	90		190				250	530	Br Sa
	NR-47 Muskoka Falls	140			240	50		1370	1800	SM
4	ER-39 Bloomfield	110		300				500	910	Br Si Sa
	WR-5 Ostrander	325		175				> 1400	1900	Not Encountered within 2 m
	WR-13 Mount Forest	265		185				750	1200	Silty Sand

FWD Testing Results (Example Zone 1 - Hwy 527)

- FWD Testing Date: Typical 4 testing dates after complete thaw period (site dependent)
- Pavement Strength Recovering Indicator: Deflection decrease and Modulus increase
- Primary pavement strength weakening, and gain is in granular layers during spring thaw



Method to determine RLP Start Date
Select Best-Fit CTI Threshold and Algorithm

Data

- Select the closest subsurface temperature sensor to the base layer and find the first date that sensor's average daily temperature is >= 0 ^{o}C for 3 consecutive days to indicate onset of pavement weakening
- Find the daily maximum and minimum air temperature to calculate the daily CTI using different CTI Equations (Ontario NW & NE, MnDOT and Manitoba)
- Identify the corresponding CTI with the date for start of pavement weakening for each SLA station

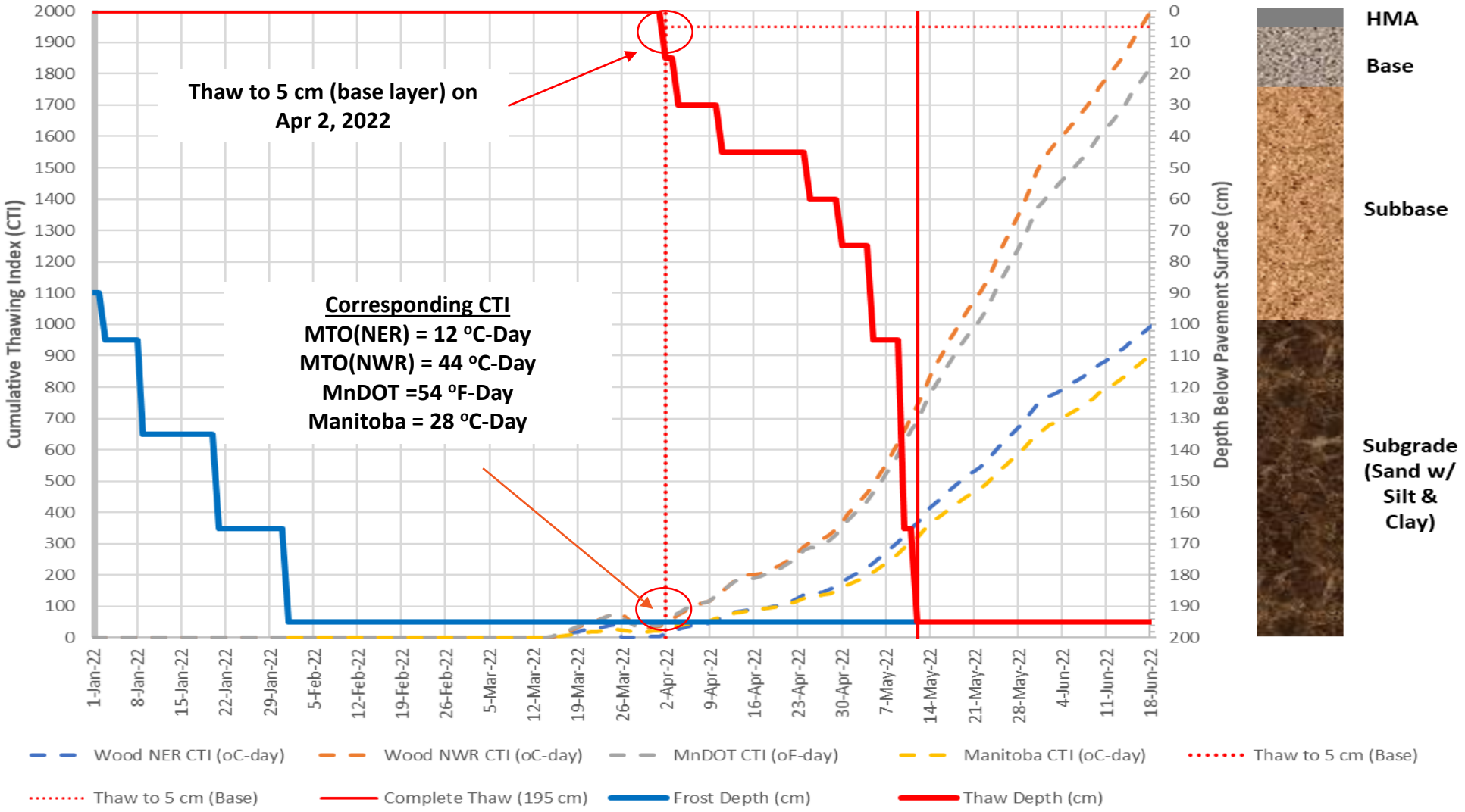
Analyze

- Analyze all CTIs for each zone and determine the initial CTI Start Date Threshold for each RLP zone
- Compare if the predicted RLP start date using Start Date CTI Threshold for the zone is on, earlier than, later than the actual date of pavement thaw weakening start date for each SLA site using 2022 and 2021 (Zone 1 and Zone 2 only)
- Compare results from all CTI Equations

Determine

- Review the results of predicted and actual date of strength weakening
- Recommend the **RLP Start Date CTI Threshold and best fit algorithm for each RLP zone**

Example: Cumulative Thawing Index & Frost/Thaw Depths (Zone 1 - Hwy 527)



RLP Start Date Analysis: Results and Recommendations

Results:

- RLP Start Date CTI thresholds are established for all RLP zones using different CTI Equations
  - MTO (NER), MTO (NWR), MnDOT, and Manitoba
- The selected thresholds predict the RLP start date very closely to the actual thaw weakening start date (i.e., on or later than actual)
- All CTI equations predicted the same RLP start date
- Except Zone 4, MTO (NWR) CTI Equation predicts start date much earlier for Zone 4
- In terms of the complexity among all CTI Equations, Manitoba's CTI Equation is relatively simpler

Recommendations:

- Use the following for Ontario RLP Start Date
  - ✓ **Calibrated Manitoba CTI Algorithm**
  - ✓ **RLP Start Date CTI Thresholds: 8 ^{o}C-Day for all Zones**

Method to determine RLP End Date - CTI Threshold and Best Fit Algorithm

Data

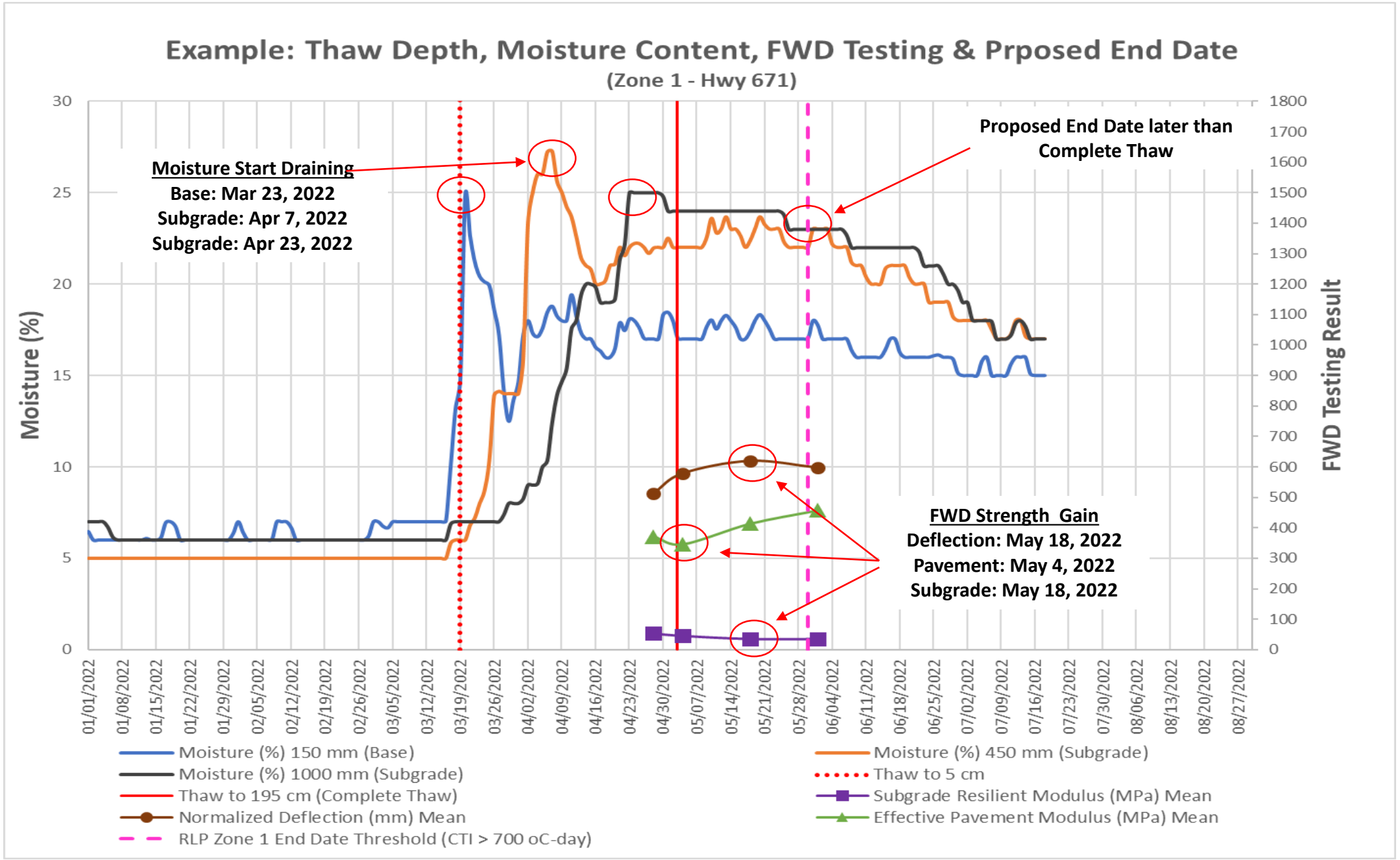
- Determine the date that the pavement strength gain reached level prior to initial pavement weakening based on FWD results
- Determine if the selected date that the subsurface (base/subbase/subgrade) are draining based on the subsurface moisture content readings
- Identify the CTI value that correspond to sufficient pavement strength recovery for each SLA in the zone

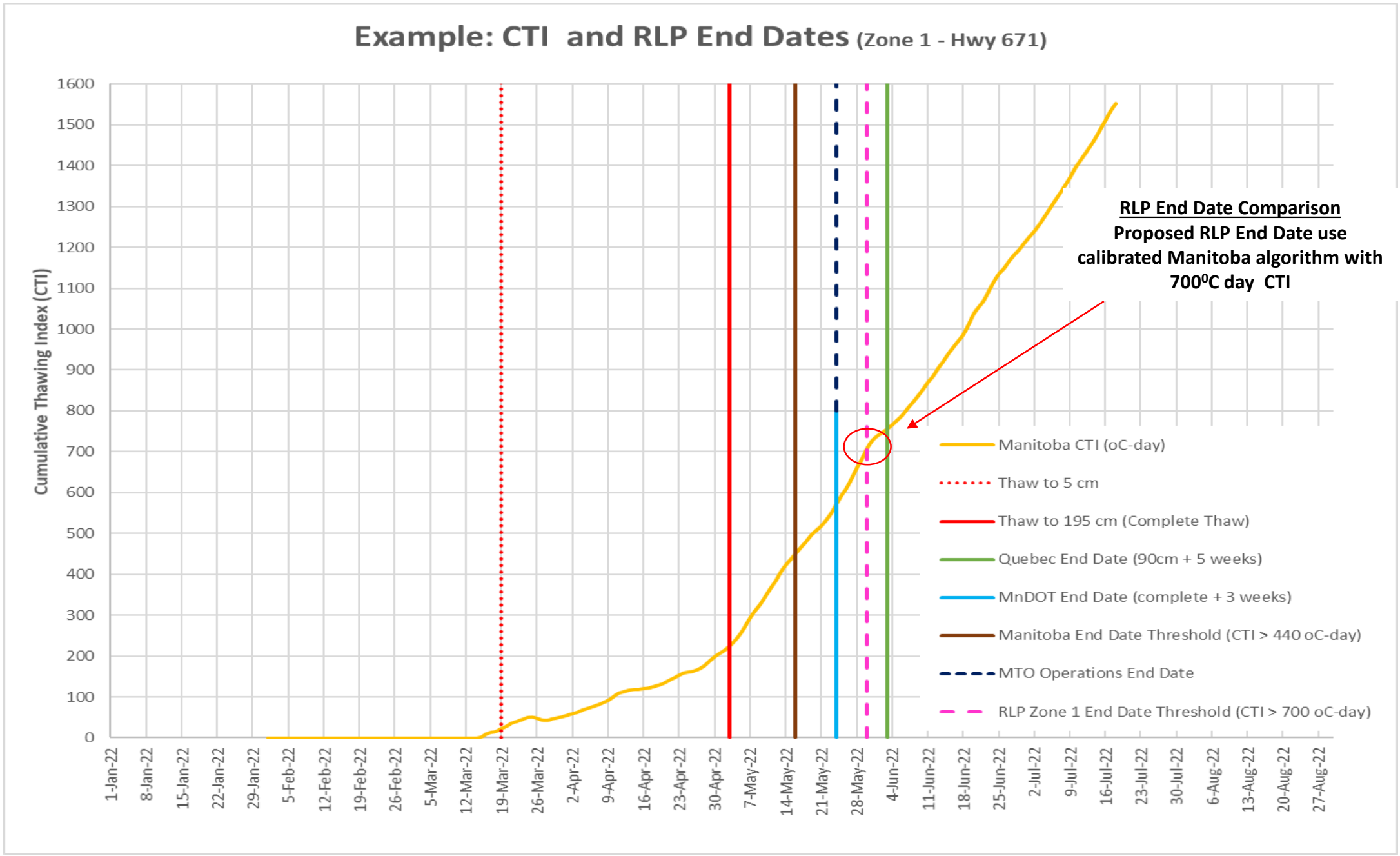
Analyze

- Analyze CTIs values and determine the removal CTI Threshold values for each RLP zone
- Compare the predicted RLP End Date with other jurisdiction algorithms and MTO Operations RLP end dates
- Determine the algorithm that provide best fit CTI prediction for all the sites in the zone

Determine

- Recommend the **RLP End Date - CTI Threshold and algorithm for each RLP zone**


Example: Thaw Depth, Moisture Content, FWD Testing & Prposed End Date
(Zone 1 - Hwy 671)
Moisture Start Draining
Base: Mar 23, 2022
Subgrade: Apr 7, 2022
Subgrade: Apr 23, 2022
Proposed End Date later than Complete Thaw
FWD Strength Gain
Deflection: May 18, 2022
Pavement: May 4, 2022
Subgrade: May 18, 2022
Moisture (%)
FWD Testing Result
Moisture (%) 150 mm (Base)
Moisture (%) 1000 mm (Subgrade)
Thaw to 195 cm (Complete Thaw)
Normalized Deflection (mm) Mean
RLP Zone 1 End Date Threshold (CTI > 700 oC-day)
Moisture (%) 450 mm (Subgrade)
Thaw to 5 cm
Subgrade Resilient Modulus (MPa) Mean
Effective Pavement Modulus (MPa) Mean


Example: CTI and RLP End Dates (Zone 1 - Hwy 671)
Cumulative Thawing Index (CTI)
1600
1500
1400
1300
1200
1100
1000
900
800
700
600
500
400
300
200
100
0
1-Jan-22
8-Jan-22
15-Jan-22
22-Jan-22
29-Jan-22
5-Feb-22
12-Feb-22
19-Feb-22
26-Feb-22
5-Mar-22
12-Mar-22
19-Mar-22
26-Mar-22
2-Apr-22
9-Apr-22
16-Apr-22
23-Apr-22
30-Apr-22
7-May-22
14-May-22
21-May-22
28-May-22
4-Jun-22
11-Jun-22
18-Jun-22
25-Jun-22
2-Jul-22
9-Jul-22
16-Jul-22
23-Jul-22
30-Jul-22
6-Aug-22
13-Aug-22
20-Aug-22
27-Aug-22
RLP End Date Comparison
Proposed RLP End Date use calibrated Manitoba algorithm with 700⁰C day CTI
Manitoba CTI (oC-day)
Thaw to 5 cm
Thaw to 195 cm (Complete Thaw)
Quebec End Date (90cm + 5 weeks)
MnDOT End Date (complete + 3 weeks)
Manitoba End Date Threshold (CTI > 440 oC-day)
MTO Operations End Date
RLP Zone 1 End Date Threshold (CTI > 700 oC-day)

RLP End Date Analysis: Results and Recommendations

Results:

- RLP End Date CTI thresholds are established for all RLP zones using calibrated Manitoba CTI Equation with borehole, FWD and SLA station data
- All predicted RLP end dates are:
  - Later than complete pavement structure thaw date
  - Pavement strength recovery increase to or above pre-initial thaw level
  - Pavement granular/subgrade with decreasing moisture trend
- On average, the selected best fit calibrated algorithm and threshold model predicted RLP End Date is slightly later than Manitoba and Minnesota CTI models but earlier than Quebec.

Recommendations:

- Analysis of selective SLA sites within each zone using calibrated Manitoba algorithm with the following Ontario RLP End Date thresholds:
  - ✓ **RLP End Date CTI Thresholds:** **Zone 1: 700 °C-Day****
    Zone 2: 700 °C-Day
    Zone 3: 560 °C-Day
    Zone 4: 290 °C-Day

**Zone 1 – Existing SLA sites are all in lower part of Zone 1. Additional 2 SLA sites near middle of the zone recommended for 2023.

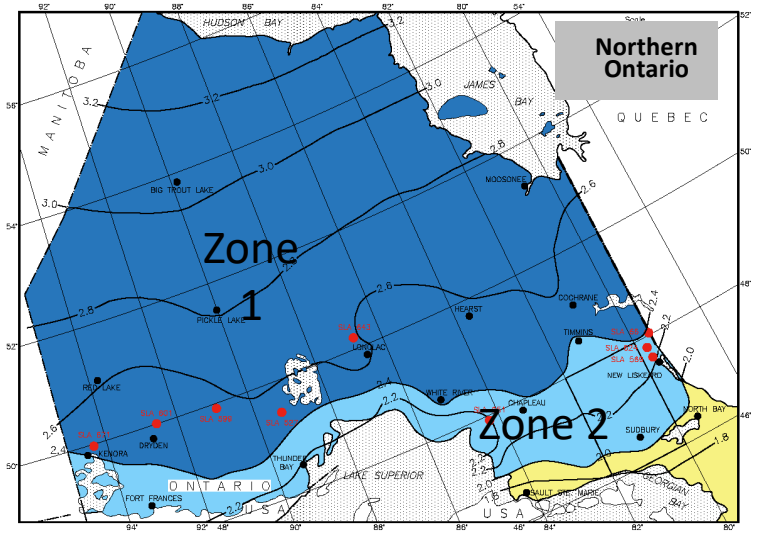
Recommended Ontario RLP Algorithm and Start and Removal Threshold Values

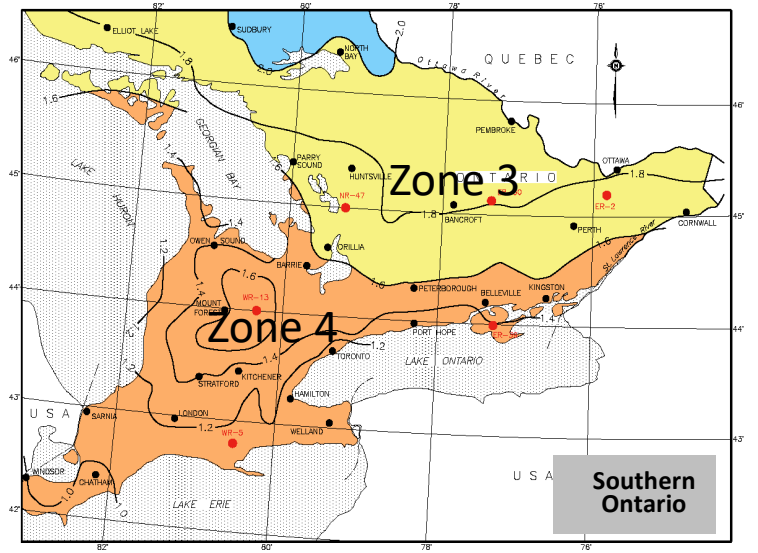
TIMD

Ministry of Transportation

Ontario

Recommended Ontario RLP Algorithms and Threshold values





Use 7 days forecast air temperatures to predict CTI seven days ahead

Recommended Start RLP when 3 consecutive days of CTI is greater than CTI threshold. Remove RLP when CTI threshold exceeded

Cumulative Thawing Index (CTI) Equation

Set $CTI = 0^oC\text{-}day$ on February 1 of each year, calculate the CTI on February 2 of each year as follow:

$$CTI_i = TI_{i-1} + TI_i$$

$$Reset\ CTI\ to\ 0^oC\text{-}day \quad when\ \ CTI < 0^oC\text{-}day$$

$$TI = (0.5 \times T_{Air}) + T_{Ref} \quad when\ \ T_{Air} < 0^oC$$

$$TI = T_{Air} + T_{Ref} \quad when\ \ T_{Air} \geq 0^oC$$

$$T_{Air} = \frac{T_{Max} + T_{Min}}{2}$$

$$T_{Ref} = 0.06^oC\ on\ February\ 1\ and\ increase\ by\ 0.06^oC\ daily\ until\ May\ 31$$

$$T_{Ref} = 0^oC\ from\ June\ 1\ to\ January\ 31$$

$$T_{Max} = Maximun\ Daily\ Air\ Temperature\ in\ Degree\ Celcius$$

$$T_{Min} = Minimum\ Daily\ Air\ Temperature\ in\ Degree\ Celcius$$

CTI Thresholds for	RLP Zones			
	1	2	3	4
Start Date	8 °C-day	8 °C-day	8 °C-day	8 °C-day
End Date	700 °C-day	700 °C-day	560 °C-day	290 °C-day

**An excel spreadsheet to calculate the CTI will be available*

Recommended RLP Models for Municipalities

MTO RLP

Municipalities can follow the RLP dates based on geographic region of the 4 MTO zones. MTO to update yearly the reference temperatures table for Excel Calculator for each zone

Update models, algorithms and CTI threshold values as required with ongoing monitoring of RWIS and SLA data

Provide technical support to OGRA and municipalities

OGRA/Municipalities -Site-specific RLP

•Municipalities as supported by OGRA use closest RWIS/air temperature data as input into the corresponding zone CTI Excel Calculator

Use ongoing and 7 days in advance temperatures to predict onset and removal of RLP dates using the CTI Excel Calculator to provide advance notice to industry

RLP Start Date

- Determine using CTI Excel Calculator using zone or local data

RLP Removal Date

- Determine using CTI Excel Calculator with the different CTI threshold values (290^0Cdays to 700^0C days) for the zones with SLA or local RWIS data

Excel CTI Zone Calculator

MTO - Reduced Load Period (RLP) Recommendation Table

RLP Zone 4		Enter RLP Year:	2022
		Start	End
CTI Threshold		8	290
Zone Specific		6-Mar-2022	24-Apr-2022
Site Specific		Start	End
1	SLA ER-39 Bloomfield	7-Mar-2022	20-Apr-2022
2	SLA WR-5 Ostrander	6-Mar-2022	15-Apr-2022
3	SLA WR-13 Mount Forest	7-Mar-2022	24-Apr-2022
4		--	--
5		--	--
6		--	--
7		--	--
8		--	--

Site Specific Table:	1
Enter Site/Hwy/Road ID:	SLA ER-39 Bloomfield
Enter GPS Coordinates:	43.988056, -77.250556

Day	Date	Daily Air Temperatures			Reference Temperature	Calculated Thawing Index	Calculated Cumulative Thawing Index	> CTI Start Date Threshold for 3 consecutive days on	> CTI End Date Threshold for 1 day on
		Enter Measured or Forecast		Calculated					
	Always Day 0 = Feb 1	Max (°C)	Min (°C)	Mean (°C)	Tref (°C)	TI (°C)	CTI (°C-Day)	7-Mar-2022	20-Apr-2022
0	1-Feb-2022	2	-14	-5.8	0.06	-2.8	0.0	No	No
27	28-Feb-2022	0	-16	-7.9	1.68	-2.2	0.0	No	No
28	1-Mar-2022	3	-16	-6.5	1.74	-1.5	0.0	No	No
29	2-Mar-2022	3	-8	-2.4	1.80	0.6	0.6	No	No
30	3-Mar-2022	1	-14	-6.4	1.86	-1.3	0.0	No	No
31	4-Mar-2022	-1	-18	-9.4	1.92	-2.8	0.0	No	No
32	5-Mar-2022	5	-18	-6.6	1.98	-1.3	0.0	No	No
33	6-Mar-2022	15	-7	4.1	2.04	6.1	6.1	No	No
34	7-Mar-2022	15	-1	7.0	2.10	9.1	15.2	Yes	No
35	8-Mar-2022	3	-3	0.0	2.16	2.2	17.4	Yes	No
36	9-Mar-2022	3	-3	-0.4	2.22	2.0	19.4	Yes	No
37	10-Mar-2022	3	-3	0.1	2.28	2.3	21.7	Yes	No

Next Steps

2023–2024

Additional year of data to refine the algorithms and threshold values used in the models, if applicable. Additional 2 SLA in NW Ontario to provide better coverage of Zone 1. Technical knowledge transfer and training sessions for OGRA and municipalities

2024-2025

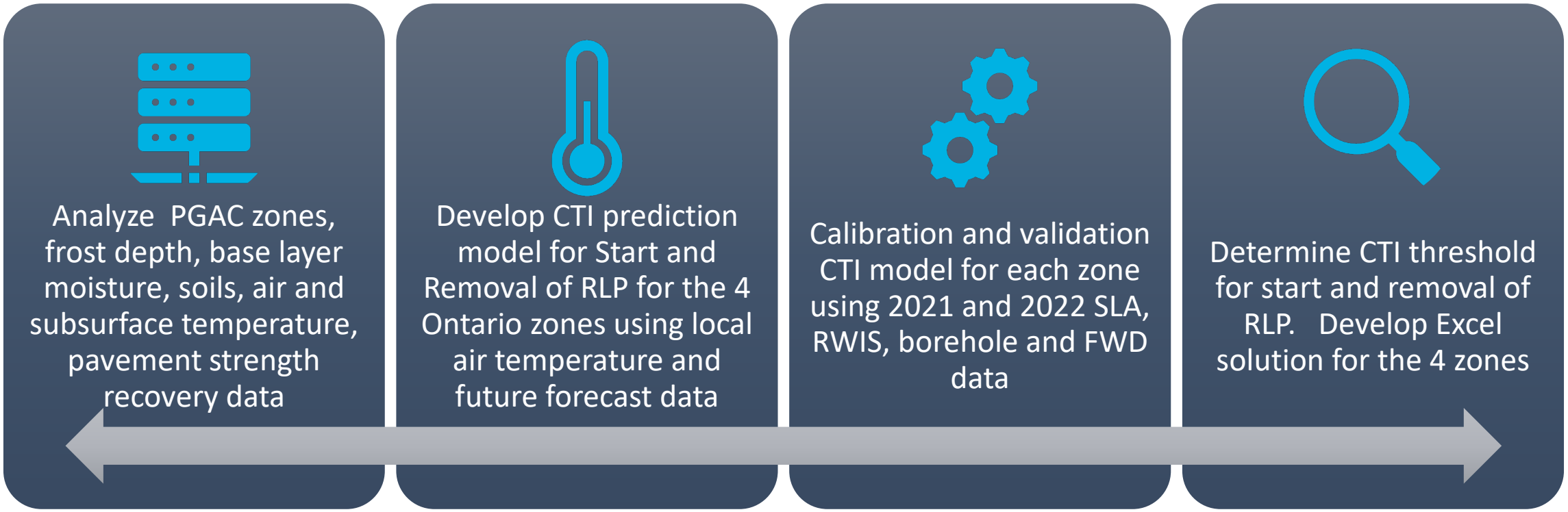
Supplementary information from HIIFP study to be completed in 2024/25. Further yearly data to refine the RLP algorithms and threshold values as required.

Summary

Determined RLP zones for use in Ontario

Perform jurisdictional scan of other agencies. Using 2021 and 2022 SLA, RWIS, borehole and FWD determine RLP model and threshold values for zones

Calibrate and validate start and removal RLP dates model for the 4 zones. Develop Excel solution for RLP period determination. Ongoing Technical transfer.



Ministry of Transportation
Standards and Contracts Branch

Thank You!

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