Cycle Path Condition Monitoring Techniques

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ERPUG 2023
Athens, Greece
October 27, 2023

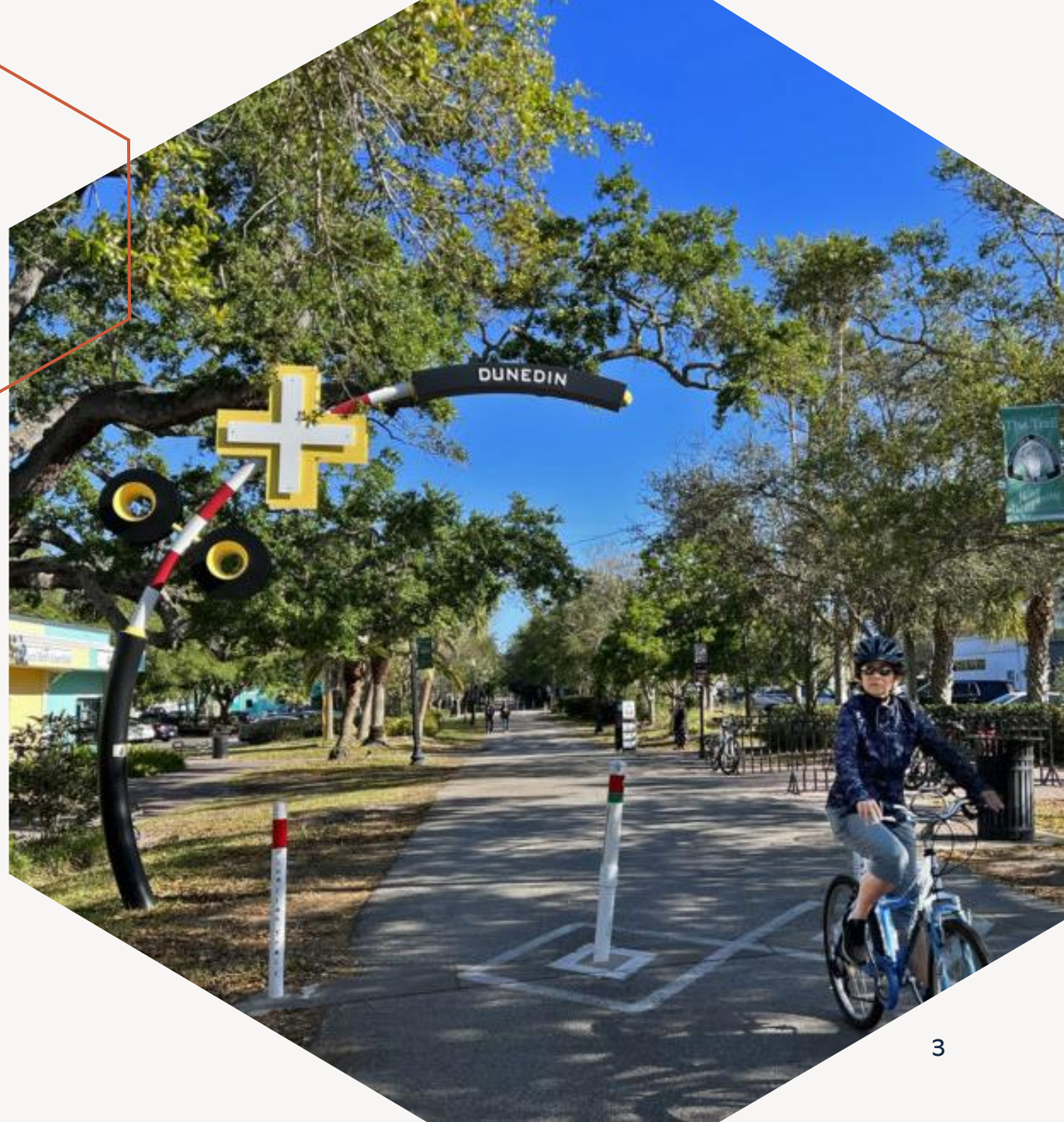
Agenda


Cycle Paths in USA and Canada
Measurement Needs
Introducing the SST
Profile Processing
Condition Rating
Analysis Results
Conclusions

Cycle Paths

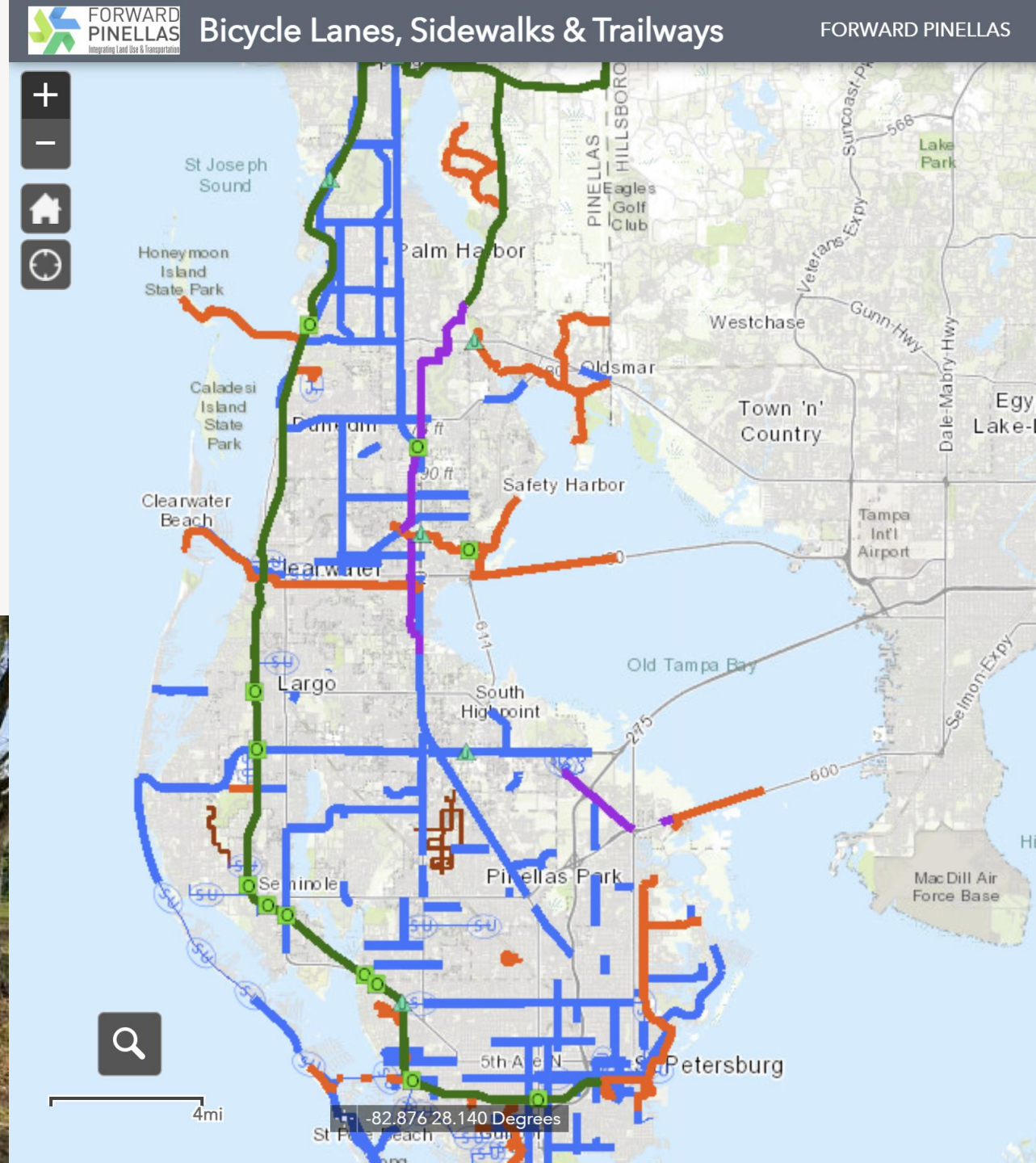
In the USA and Canada, cycle paths are primarily used for recreational purposes.

Condition monitoring and active management are required to ensure **safety** and **comfort** for users, as well as to **protect the investment**.



Florida Example

- The Pinellas Trail, built over an old rail line near Tampa, Florida, is **76 km** long.
- Uses: cycling, walking, and jogging.
- It is currently being extended to **121 km** (the project is about 60% complete)



Measurement Needs

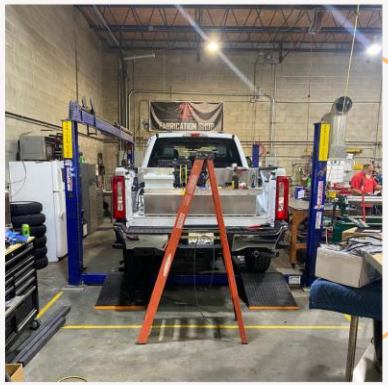
- Faults and Tripping Hazards
- Obstructions and Protrusions (Trees, Poles, Vegetation, etc.)
- Gaps and Cracks
- Asphalt and Concrete Distresses
- Smoothness and Ride Quality

Sidewalk Surface Tester (SST)

- Introducing the new SST for sidewalk and trail surveys
- Platform testing and selection
- Designed and built in 2023
- Based on same Drive platform as ICC's Iris family of collection vehicles








Vehicle Platform

- Trailerable, lightweight, narrow, 100% electric, golf-cart style vehicle
- Optimized for bicycle paths, walking trails, and sidewalks
- Length: 2.1 m
- Width: 1.0 m
- Mass: 220 kg
- Maximum Speed: 24 km/h
- Motor: 3000W 36V High Torque
- Vehicle Battery: Lithium Ion 36V, 60 Ah, 2160 Watt hours (Wh)
- Vehicle Run Time: 6-8 hours (per battery)
- Vehicle Charge Time: 4-6 hours
- Second Vehicle Battery included, drop-in field-replaceable
- System Battery: Lithium Ion 12V, 200 Ah, 2400 Watt hours (Wh)
- System Run Time: ~24 hours
- System Charge Time: 4-6 hours
- Passenger Capacity: 1

Subsystems

- 3x Gocator point lasers
- 2x 12MP Basler cameras (front and rear)
- 5g Accelerometers
- 250 Hz MEMS IMU
- Hemisphere DGPS
- 5,000 CPR wheel encoder
- Target sensor
- Drive collection system (fanless computer and ADAS in environmentally-sealed enclosure)
- High contrast monitor
- Event keyboard

Measurements

- Front and rear right-of-way images at 1.5 m intervals (captured at fixed interval)
- Laser Elevations at 0.5 or 1.0 mm longitudinal spacing (captured at fixed interval)
- Pitch, Heading, and Roll at 250 Hz
- All data synchronized to DMI and GPS to 0.0001 s (0.1 ms)

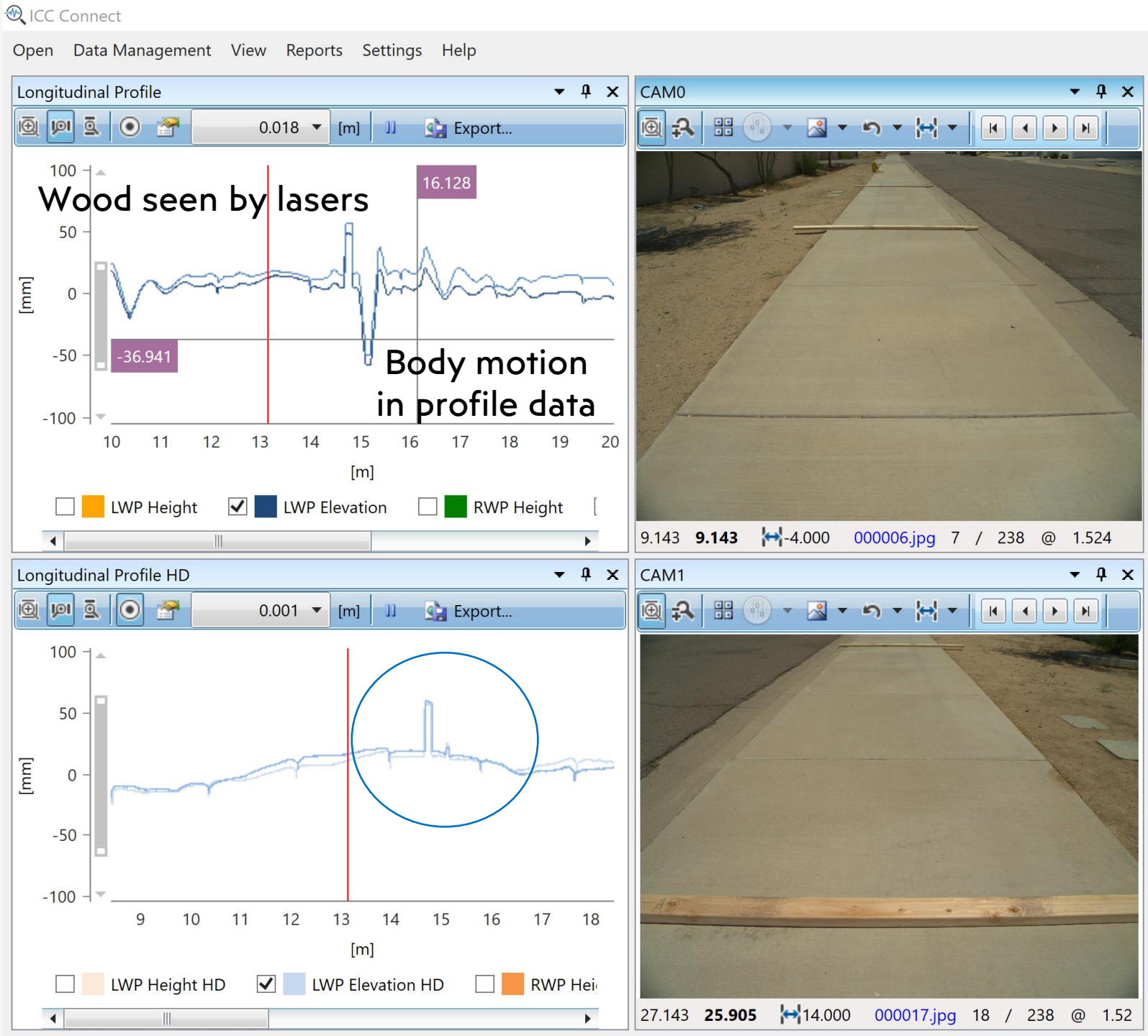
Measurements (cont.)

- Raw and high-pass filtered Longitudinal Profile data
  - Roughness parameters including International Roughness Index (IRI) and Rolling Straight Edge (RSE)
  - Texture parameters including Mean Profile Depth (MPD), Root Mean Square (RMS), and Ridge-Valley Depth (RVD)
  - Obstruction Height (e.g. Fault, Tripping Hazard)
  - Vertical Separation (e.g. Gap Width, Crack Width)
- Crossfall
- Grade

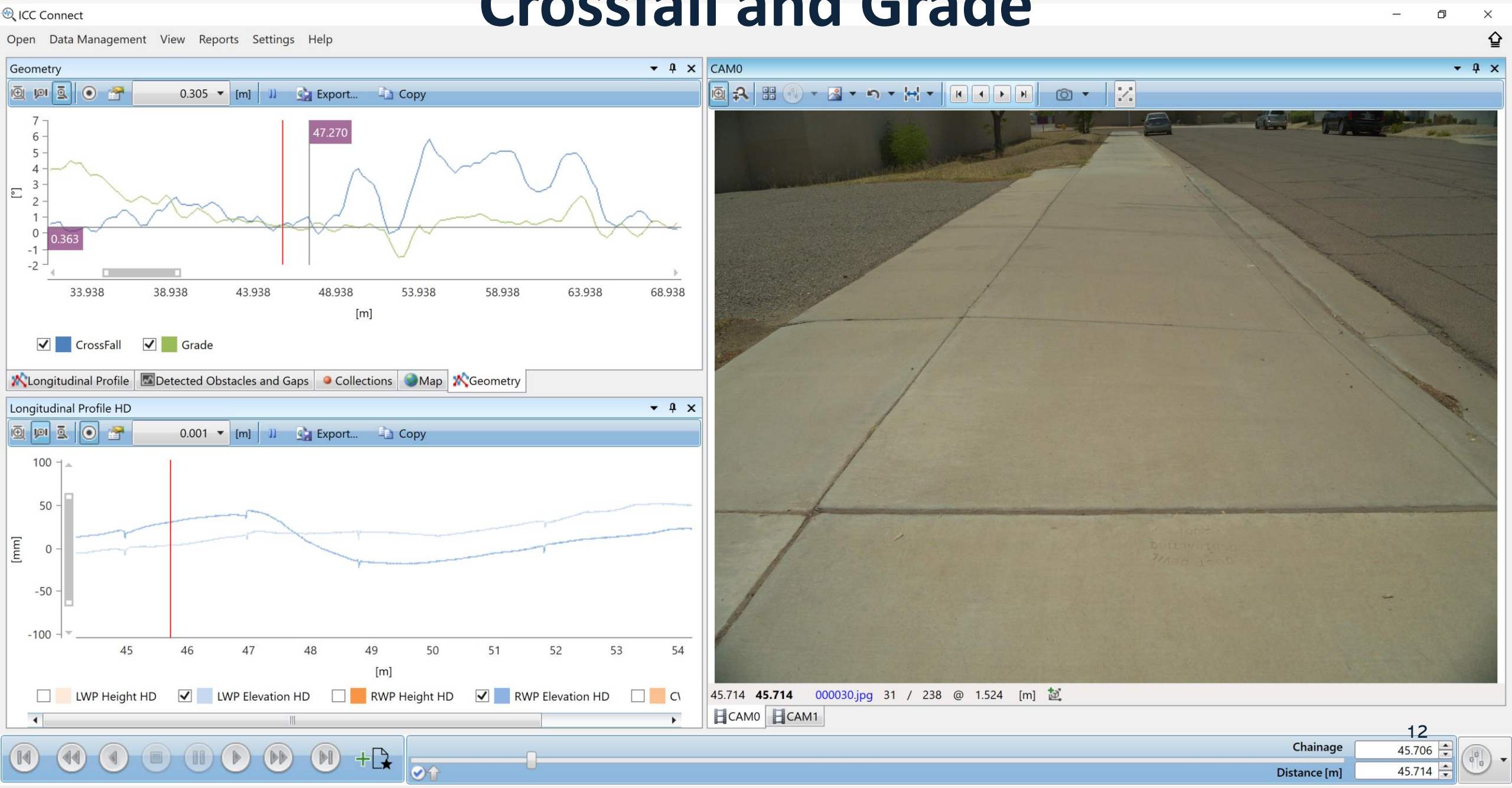
Further work is required to develop or adopt smoothness metrics that are suitable for characterizing safety and comfort on cycle paths and trails.

Profile Processing

- Longitudinal profile calculated from laser and accelerometer data (as in traditional inertial profiler) is insufficient
- Vehicle body motion is visible in the profile
- Accelerometer data processing is changed and supplemented with IMU data to subtract body motion from laser data
- The resulting HD profile is cleaner and can be used for further processing

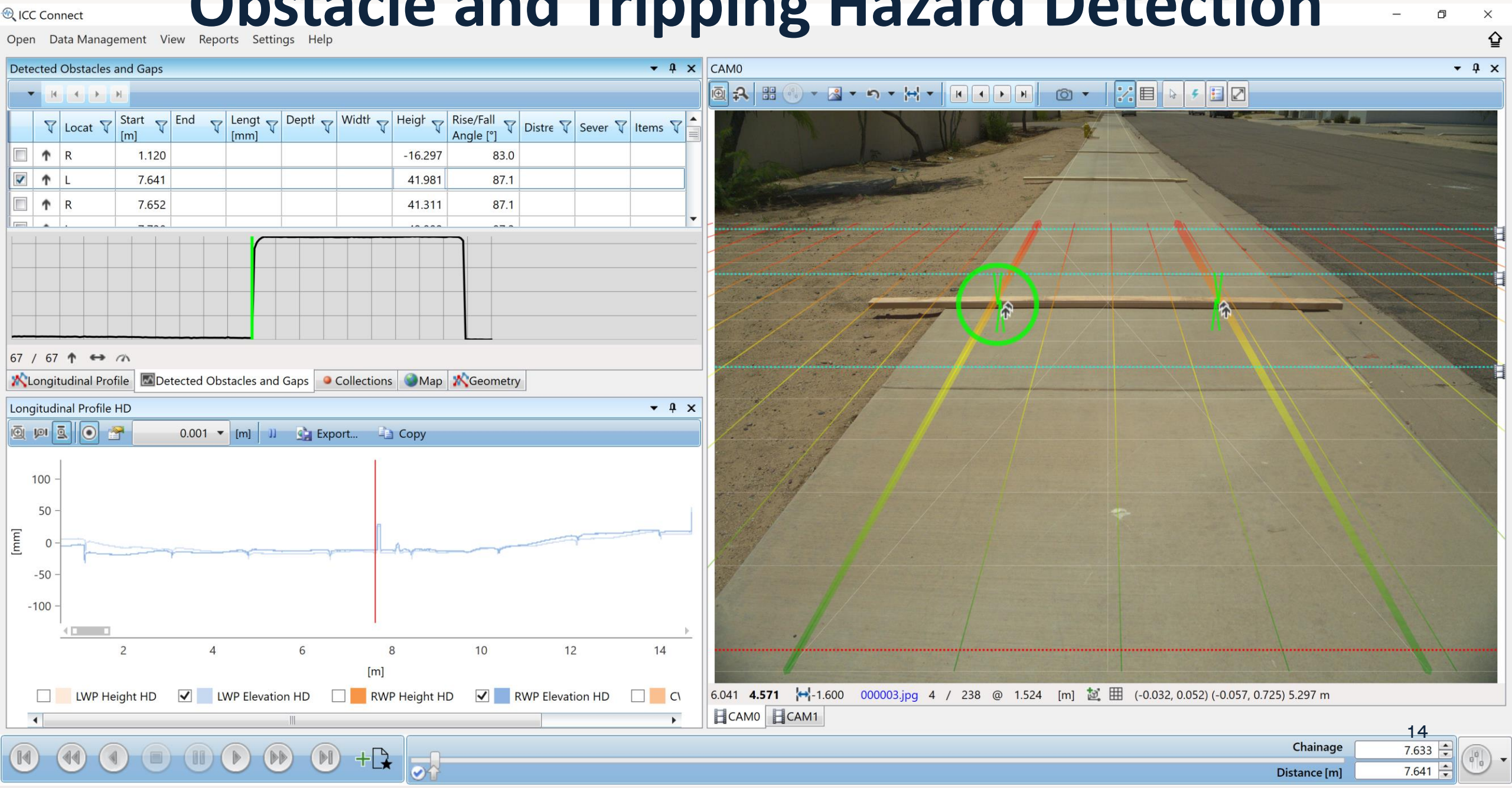


Crossfall and Grade



HD Profile shows Joints and Texture

Obstacle and Tripping Hazard Detection

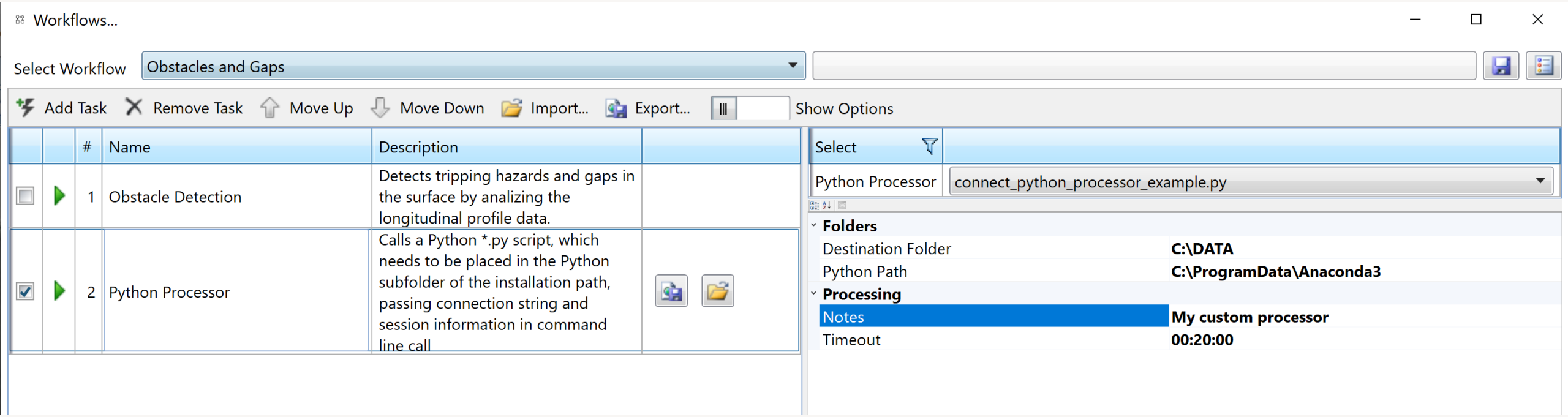


Gap Detection

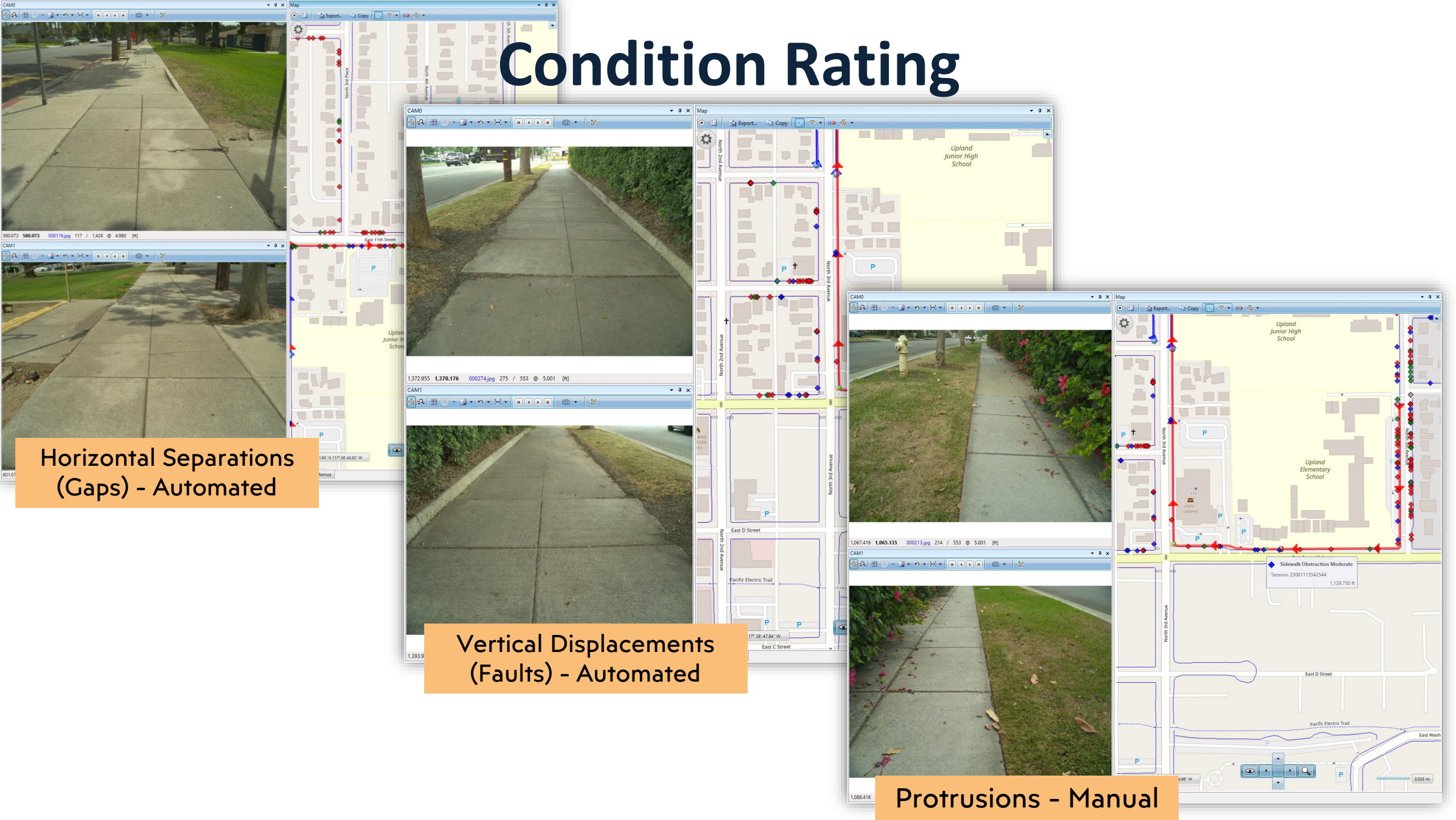
Highly Distressed Section

Custom Code Integration

- New processing algorithms developed by agencies and research institutes can be put into production easily
- The Python integration in Connect™ allows your code to be run alongside standard processors
- Your code has access to data via **read/write API** plus **direct database access** and **raw data access**
- Processor runs on one session at a time; batch processing is handled by the workflow engine

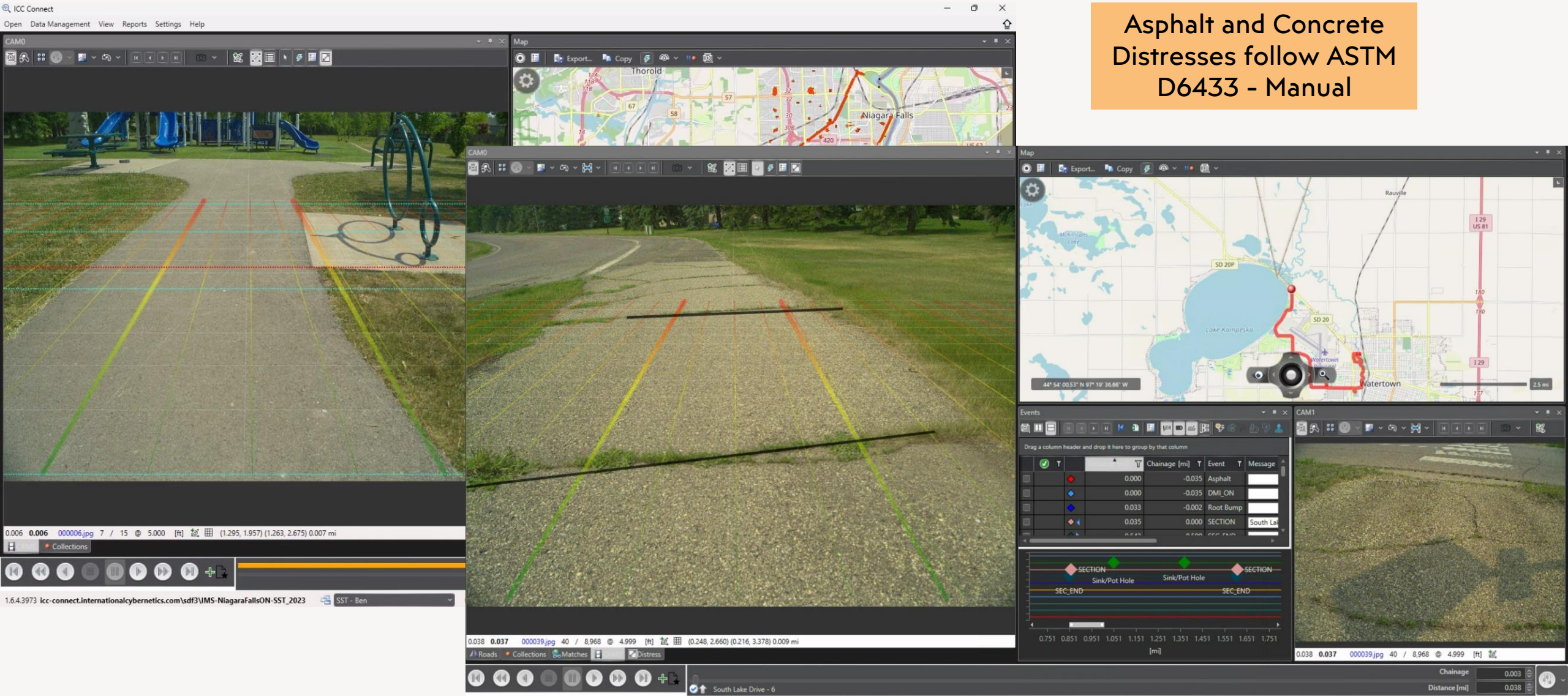


Condition Rating



Niagara Falls, Ontario, Canada

Asphalt and Concrete Distresses follow ASTM D6433 - Manual



Typical Deliverables

- Condition Data GIS Layers
- Condition Index Calculation
- ArcGIS Dashboard or Story Map
- Easy Sidewalk Analysis (ESA)

Data Dictionary

- Distress survey produces PCI for each trail segment

IMS Infrastructure Management Services

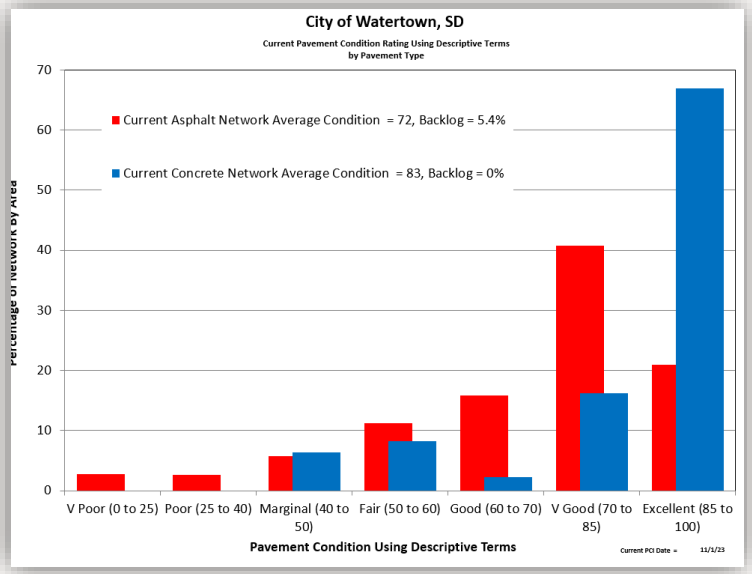
City of Niagara Falls, Canada

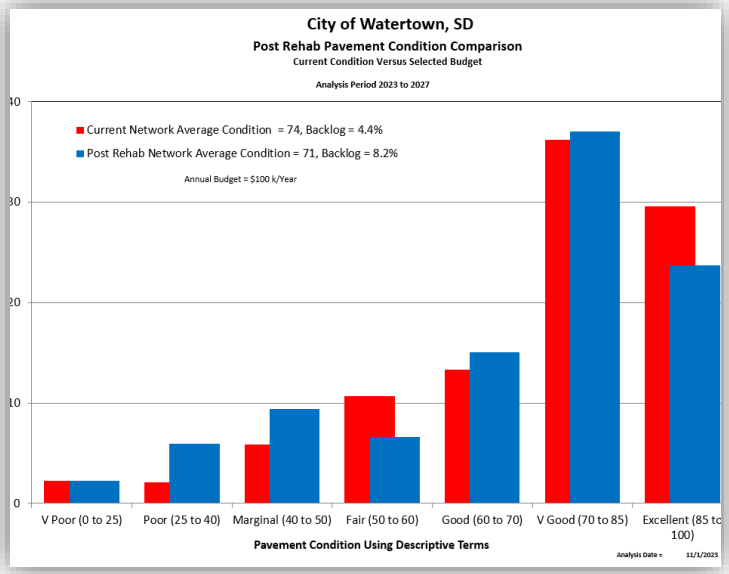
Asset	Code	Asset Type	Measurement	Definition
Trail	**TRA**	Linear	Meters	An identification of the start and end of definable trail structures. If no structure exists, no entry will be made. Driveway ap same construction method is used beyond the driveway apron. Intersections will cause the structures to be interrupted, ev intersection.

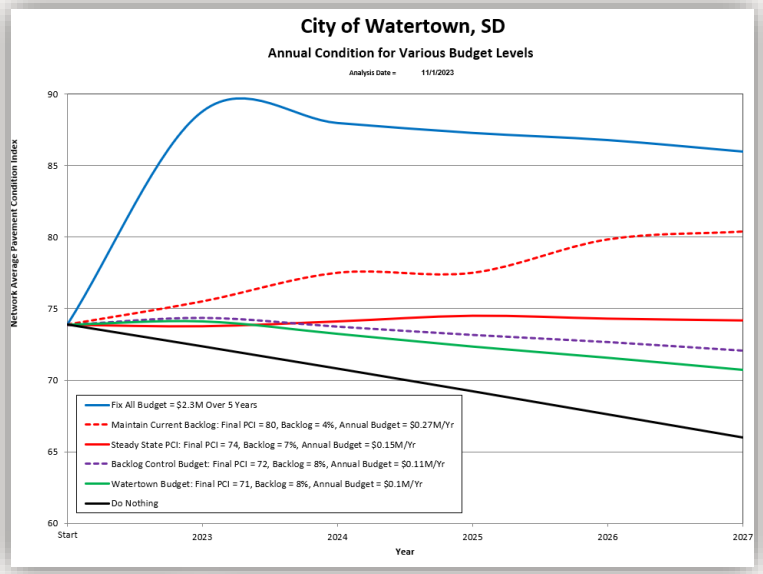
Attribute	Code	Reponses	Representation	Definition
TRA_SlabCount		Count slabs	Numeric - Count	If material type is concrete, this point should be dropped for each slab to obtain the total slab count
TRA_Distress_Asphalt - Rutting		Asphalt - Rutting	Numeric - Area	Area quantity of rutting that is visible on asphalt trails
TRA_Distress_Asphalt - Longitudinal Cracking		Asphalt - Longitudinal Cracking	Numeric - Length	Length quantity of longitudinal cracking that is visible on asphalt trails
TRA_Distress_Asphalt - Transverse Cracking		Asphalt - Transverse Cracking	Numeric - Length	Length quantity of transverse cracking that is visible on asphalt trails
TRA_Distress_Asphalt - Alligator Cracking		Asphalt - Alligator Cracking	Numeric - Area	Area quantity of alligator cracking that is visible on asphalt trails
TRA_Distress_Asphalt - Block Cracking		Asphalt - Block Cracking	Numeric - Area	Area quantity of block cracking that is visible on asphalt trails
TRA_Distress_Asphalt - Edge Cracking		Asphalt - Edge Cracking	Numeric - Length	Length quantity of edge cracking that is visible on asphalt trails
TRA_Distress_Asphalt - Distortions		Asphalt - Distortions	Numeric - Area	Area quantity of distortions that are visible on asphalt trails
TRA_Distress_Asphalt - Bleeding		Asphalt - Bleeding	Numeric - Area	Area quantity of bleeding that is visible on asphalt trails
TRA_Distress_Asphalt - Raveling		Asphalt - Raveling	Numeric - Area	Area quantity of raveling that is visible on asphalt trails
TRA_Distress_Asphalt - Patching		Asphalt - Patching	Numeric - Area	Area quantity of patching that is visible on asphalt trails
TRA_Distress_Asphalt - Potholes		Asphalt - Potholes	Numeric - Count	Count of potholes that are visible on asphalt trails
TRA_Distress_Concrete - Linear Cracking		Concrete - Linear Cracking	Numeric - Slab Count	Slab Count of linear cracking that is visible on concrete trails
TRA_Distress_Concrete - Divided Slab		Concrete - Divided Slab	Numeric - Slab Count	Slab Count of divided slabs that are visible on concrete trails
TRA_Distress_Concrete - Corner Break		Concrete - Corner Break	Numeric - Slab Count	Slab Count of corner breaks that are visible on concrete trails
TRA_Distress_Concrete - Joint Spalling		Concrete - Joint Spalling	Numeric - Slab Count	Slab Count of joint spalling that is visible on concrete trails
TRA_Distress_Concrete - Faulting		Concrete - Faulting	Numeric - Slab Count	Slab Count of faulting that is visible on concrete trails
TRA_Distress_Concrete - Polished Aggregate		Concrete - Polished Aggregate	Numeric - Slab Count	Slab Count of polished aggregate that is visible on concrete trails
TRA_Distress_Concrete - Scaling		Concrete - Scaling	Numeric - Slab Count	Slab Count of scaling that is visible on concrete trails
TRA_Distress_Concrete - Patching		Concrete - Patching	Numeric - Slab Count	Slab Count of patching that is visible on concrete trails
TRA_Distress_Concrete - Punchouts		Concrete - Punchouts	Numeric - Slab Count	Slab Count of punchouts that are visible on concrete trails
TRA_Severity			Text	Severity observation for each LAD and Excessive Cross Slope - see SEVERITIES tab for details
	1	Moderate		See Distress Severity tab for definitions

Easy Sidewalk Analysis (ESA)

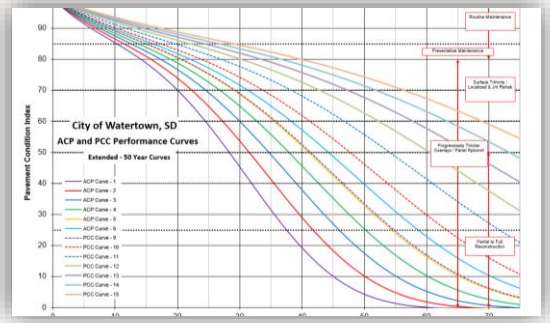
Estimate Maintenance Costs and Plan Work





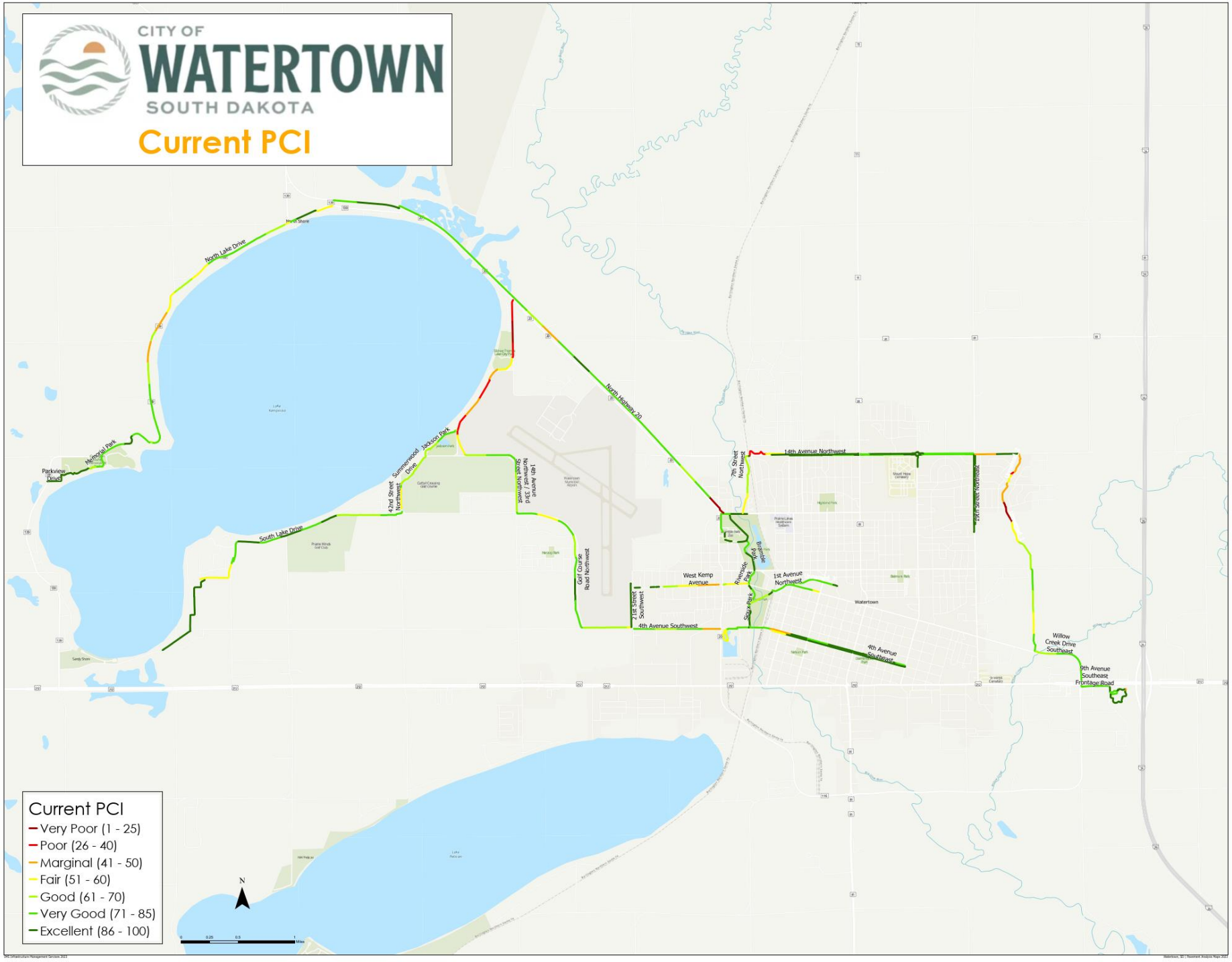


	GISID	Direction	Street Number	Block Number	On Street	FunCL Code	Functional Class	Pavetype Code	Pavetype	Pvmnt Width (ft)	Pvmnt Length (ft)	Add Area (yd2)	Pvmnt Area (yd2)	IRI (mm/m)	Deflection Results	Rutting (ACP Only)	L&T Crk / Linear Crk	Alligator Crk / Divided Slab	Map Crk (Block Crk)/ Cnnr Brk	Edge Crk / Jnt Spall	Distortions / Faulting	Bleeding / Polished Agg	Raveling / Scaling	Patches / Potholes	Surface Distress Index (SDI)	Roughness Index (RI)	Structural Index (SI)	Pvmnt Condition Index (PCI)	PCI Survey Date (mm/dd/yyyy)	Strength Code	Strength Rating	Condition Rating	LADD	NLAD
8	153		1000	1	11th Street Northeast	1	Trail	2	Concrete	3.5	501	28	585	0.0	0	10.0	10.0	10.0	10.0	9.9	10.0	10.0	10.0	10.0	99	100	60	99	6/14/2023	2	Mod	Excellent	0	0
9	103	Eastbound	1010	1	14th Avenue Northwest	1	Trail	1	Asphalt	8.8	1,000	56	1,167	0.0	0	10.0	6.9	8.0	8.8	9.0	10.0	9.8	10.0	9.1	30	100	80	30	6/14/2023	3	Strng	Poor	38	32
0	104	Eastbound	1010	2	14th Avenue Northwest	1	Trail	1	Asphalt	5.8	1,000	56	1,167	0.0	0	10.0	5.7	3.3	10.0	10.0	10.0	10.0	10.0	10.0	58	100	80	58	6/14/2023	3	Strng	Fair	7	35
1	105	Eastbound	1010	3	14th Avenue Northwest	1	Trail	2	Concrete	5.8	32	2	37	0.0	0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	100	100	60	100	6/14/2023	2	Mod	Excellent	0	0
2	106	Eastbound	1010	4	14th Avenue Northwest	1	Trail	1	Asphalt	5.9	1,000	56	1,167	0.0	0	10.0	9.1	10.0	10.0	10.0	10.0	10.0	10.0	10.0	93	100	60	93	6/14/2023	2	Mod	Excellent	0	7
3	107	Eastbound	1010	5	14th Avenue Northwest	1	Trail	1	Asphalt	5.9	1,000	56	1,167	0.0	0	10.0	8.2	10.0	10.0	10.0	10.0	10.0	10.0	10.0	86	100	60	86	6/14/2023	2	Mod	Excellent	0	14
4	108	Eastbound	1010	6	14th Avenue Northwest	1	Trail	1	Asphalt	5.9	1,000	56	1,167	0.0	0	10.0	8.5	9.4	10.0	10.0	10.0	10.0	10.0	10.0	82	100	60	82	6/14/2023	2	Mod	V Good	6	12
5	109	Eastbound	1010	7	14th Avenue Northwest	1	Trail	1	Asphalt	5.9	178	10	208	0.0	0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	100	100	60	100	6/14/2023	2	Mod	Excellent	0	0
6	110	Eastbound	1010	8	14th Avenue Northwest	1	Trail	1	Asphalt	7.5	1,000	56	1,167	0.0	0	9.8	8.5	10.0	10.0	10.0	10.0	10.0	9.2	10.0	82	100	60	82	6/14/2023	2	Mod	V Good	2	16
7	111	Eastbound	1010	9	14th Avenue Northwest	1	Trail	1	Asphalt	6.2	1,000	56	1,167	0.0	0	10.0	8.3	10.0	10.0	10.0	10.0	10.0	8.5	9.9	76	100	60	76	6/14/2023	2	Mod	V Good	2	22
8	112	Eastbound	1010	10	14th Avenue Northwest	1	Trail	1	Asphalt	6	303	17	354	0.0	0	10.0	8.5	10.0	10.0	10.0	10.0	10.0	10.0	10.0	88	100	60	88	6/14/2023	2	Mod	Excellent	0	12
9	113	Eastbound	1010	11	14th Avenue Northwest	1	Trail	2	Concrete	5.9	557	31	650	0.0	0	10.0	10.0	10.0	10.0	8.6	10.0	10.0	10.0	10.0	94	100	60	94	6/14/2023	2	Mod	Excellent	0	0
0	114	Eastbound	1010	12	14th Avenue Northwest	1	Trail	1	Asphalt	7.7	1,000	56	1,167	0.0	0	10.0	8.6	10.0	10.0	10.0	10.0	10.0	9.3	10.0	85	100	60	85	6/14/2023	2	Mod	V Good	0	15
1	115	Eastbound	1010	13	14th Avenue Northwest	1	Trail	1	Asphalt	7.7	1,000	56	1,167	0.0	0	10.0	8.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	84	100	60	84	6/14/2023	2	Mod	V Good	0	16
2	116	Eastbound	1010	14	14th Avenue Northwest	1	Trail	1	Asphalt	7.7	371	21	433	0.0	0	10.0	7.8	10.0	10.0	10.0	10.0	10.0	9.2	10.0	78	100	60	78	6/14/2023	2	Mod	V Good	0	22
3	127	Eastbound	1010	15	14th Avenue Northwest	1	Trail	2	Concrete	5	1	0	1	0.0	0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	100	100	60	100	6/14/2023	2	Mod	Excellent	0	0
4	125	Eastbound	1010	16	14th Avenue Northwest	1	Trail	1	Asphalt	5.5	1,000	56	1,167	0.0	0	9.7	5.0	10.0	10.0	9.5	10.0	10.0	9.2	9.8	48	100	80	49	6/14/2023	3	Strng	Marginal	8	44
5	126	Eastbound	1010	17	14th Avenue Northwest	1	Trail	2	Concrete	5.2	1,000	56	1,167	0.0	0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	100	100	60	100	6/14/2023	2	Mod	Excellent	0	0
6	154	Westbound	1020	1	14th Avenue Northwest	1	Trail	1	Asphalt	6.3	1,000	56	1,167	0.0	0	10.0	8.5	10.0	10.0	10.0	10.0	10.0	9.1	10.0	83	100	60	83	6/14/2023	2	Mod	V Good	0	17
7	155	Westbound	1020	2	14th Avenue Northwest	1	Trail	1	Asphalt	6.3	1,000	56	1,167	0.0	0	10.0	8.5	10.0	10.0	10.0	10.0	10.0	9.1	10.0	83	100	60	83	6/14/2023	2	Mod	V Good	0	17



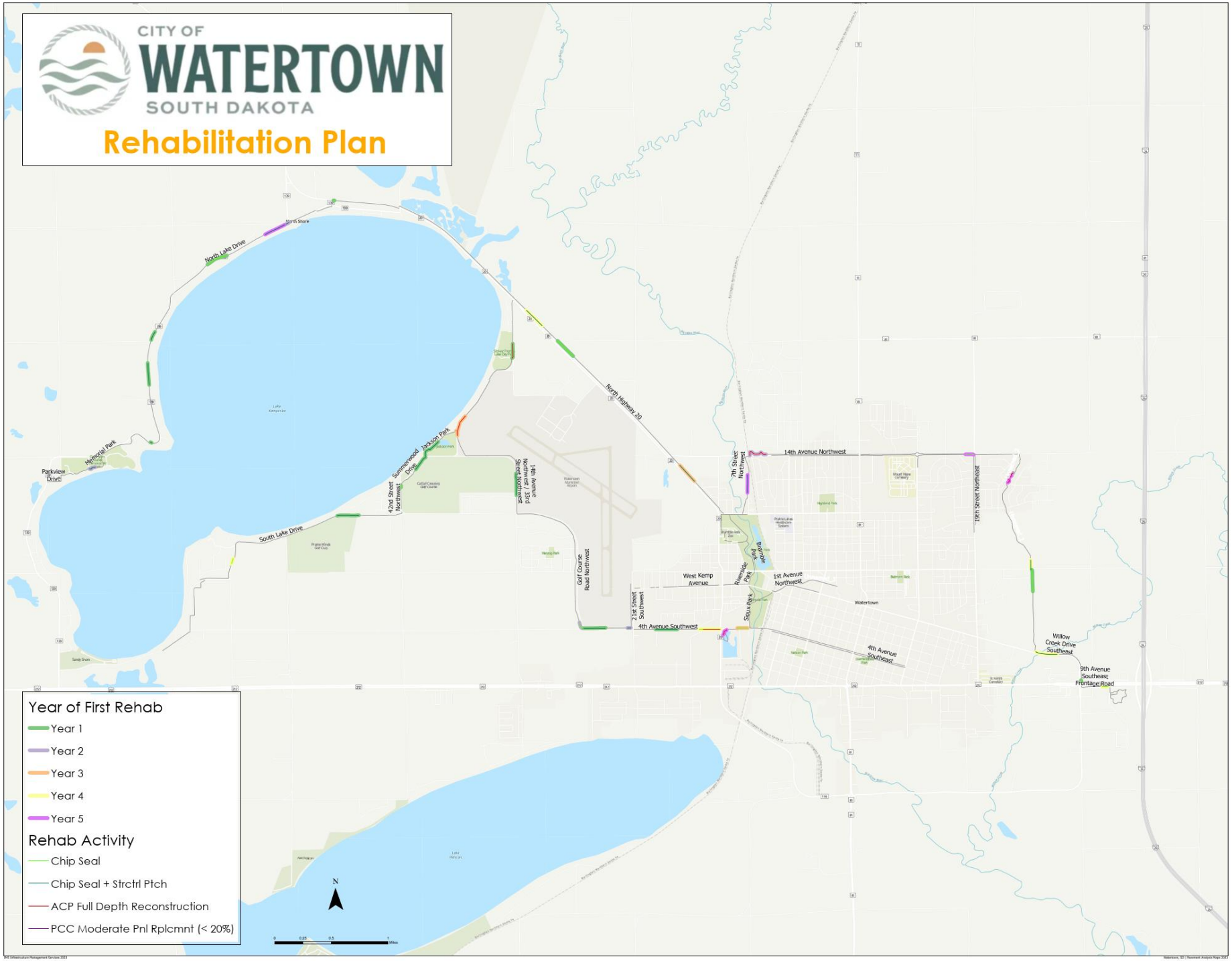
Condition

- Data is linked with Client's GIS and Asset Management Solution
- User-defined intervals, e.g. 2 m, 10 m, 100 m, segment-level



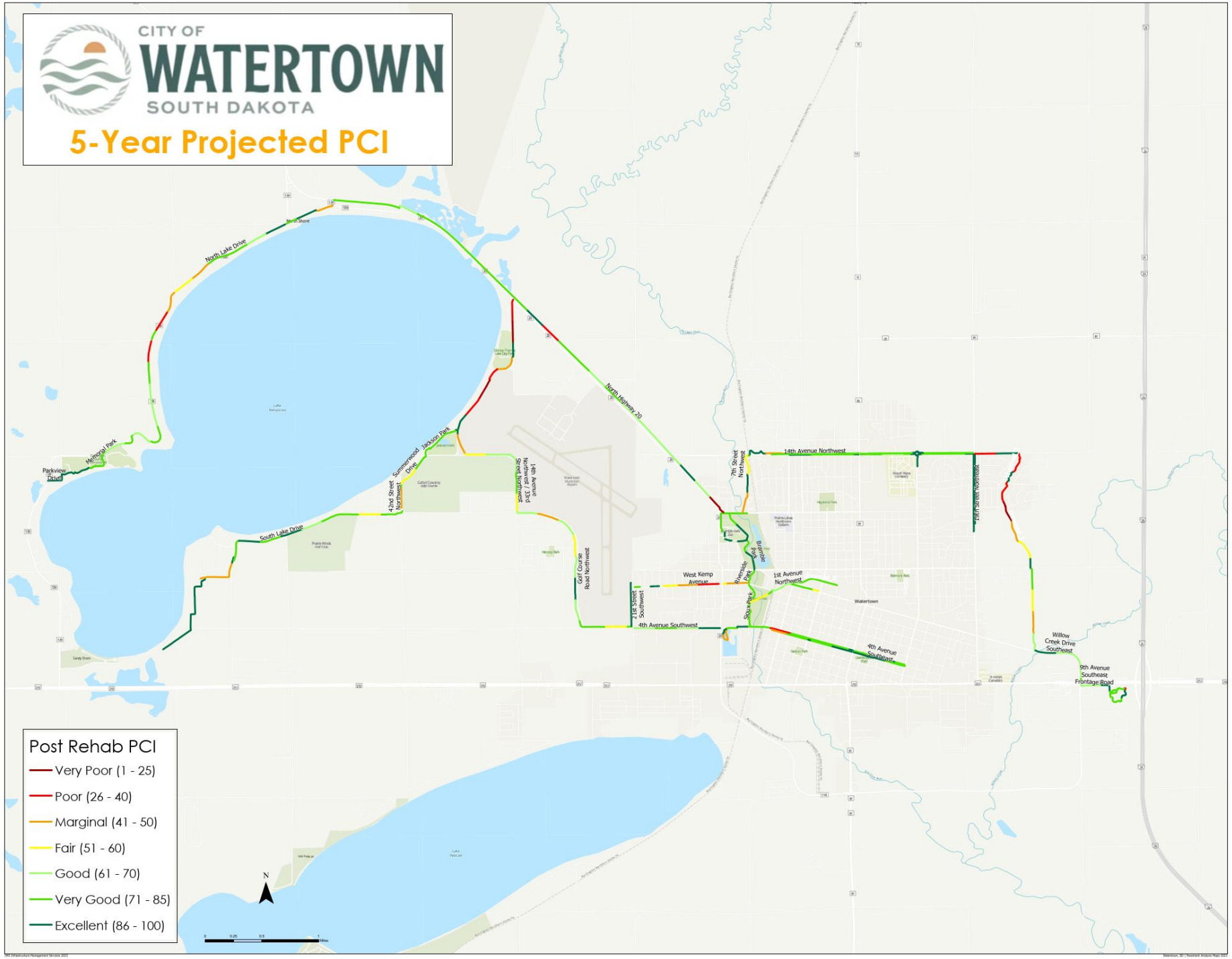
Rehabs

- 5-year rehab plan based on ESA optimization and client's budget and treatment types is presented as GIS layer



Projection

- Future condition after 5 years is projected assuming the recommended rehab plan is followed



Conclusions

- Cost-effective cycle path surveys can be done with a combination of automated and manual efforts
- High degree of variation in conditions and defect types may make implementation of AI more challenging as it requires large training data sets
- Further work is required to develop or adopt metrics that are suitable for characterizing safety and comfort on cycle paths and trails
- Software that has an open architecture and is extendable can allow agencies and research institutes to develop and test algorithms more rapidly




Thank You

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