

Project SHA/UM/5-10 1st Quarter Meeting

Structural Assessment of Maryland Sign Structures based on AASHTO LTS-6 Strength and Fatigue Criteria



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@Hanover - OOTS / TDSD conference room
May 30, 2019



Agenda



1. Introduction
2. Task 1 - Study and evaluate SHA sign structure database
 - Step 1: Collect from SHA to sign structure database
 - Step 2: Categorize all MD sign structures
3. Task 2 - Take samples from categories and analyze sampling sign structures
 - Step 3: find subtotal numbers for the 5 major categories
 - Step 4: Adopt stratified sampling methodology based on 5 sub-populations.
4. Task 3 - Run selected sampled cases and verify SABRE results
 - Step 5: Verify SABRE program using STADD-Pro
 - Step 6: Establish SABRE model and run samples from 5 major categories

Agenda

5. Task 4 - Evaluate sampling sign structures
 - Step 7: Evaluate sampling sign structures based on AASHTO LTS-6 with fatigue consideration
6. Task 5 - Rank and prioritize the whole population based on the evaluation
 - Step 8: Rank all MD sign structures based on the evaluation.
 - Step 9: Prioritize all MD sign structures based on budget and risk
7. Task 6 - Summary and Report
 - Step 10: Summarize and draw conclusion of the study

1. Introduction



Status

- The SHA current sign structure standard is 2001-AASHTO LTS- 4
- Majority of MD sign structures are designed after 2001 with wind speed of 100 MPH
- The older Trichord and Square Tubular sign structures are designed for 90 MPH. This wind speed was only applicable for Group I-III load combinations
- Fatigue was not part of the design criteria on the 1994 AASHTO.

Purpose

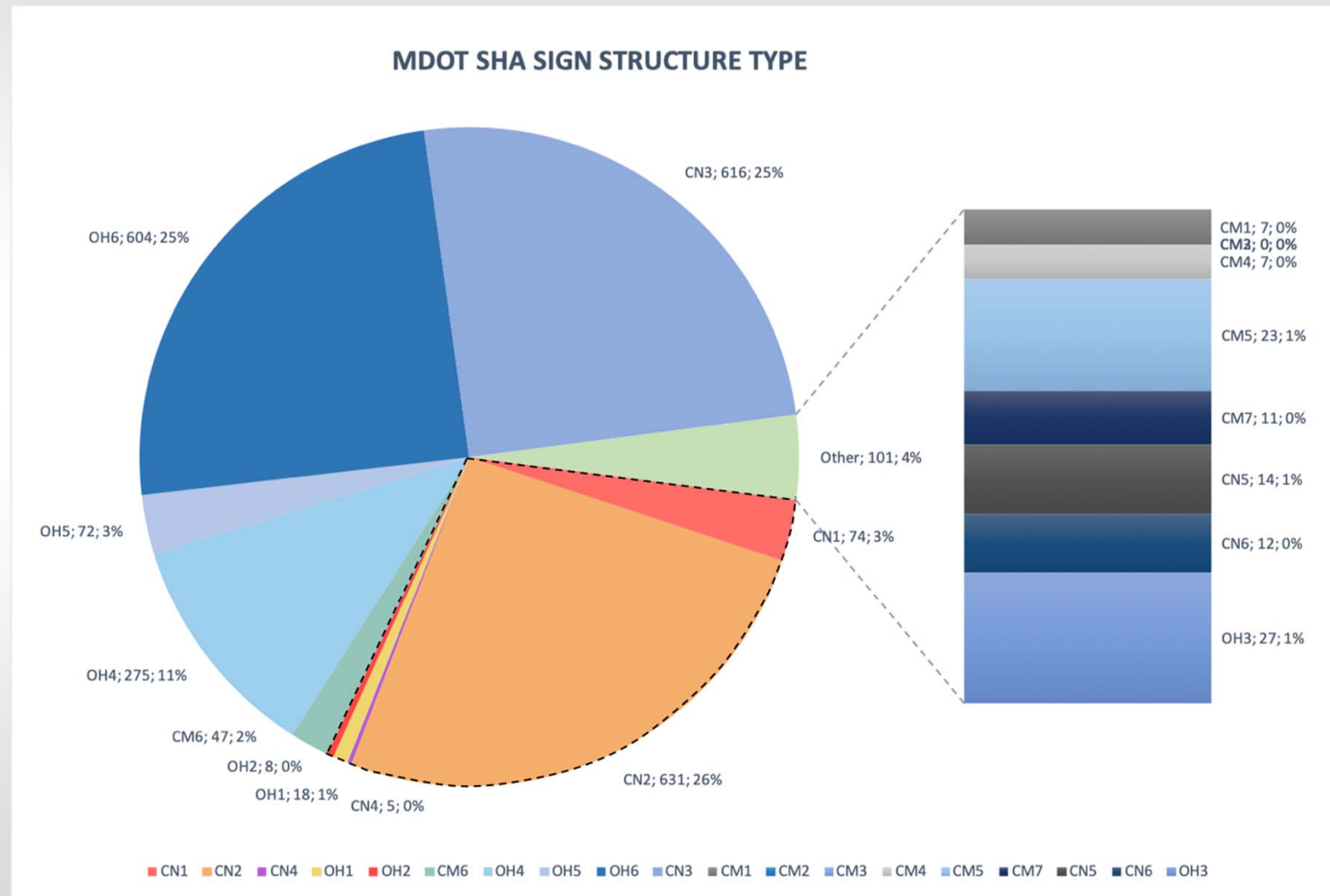
- To conduct structural assessment of Maryland sign structures based on AASHTO LTS- 6 strength and fatigue criteria

2. Task 1: Study and evaluate SHA sign structure database

Step 1: Collect from SHA to sign structure database - SHA categorized sign structures into 19 types. Total 2451 sign structures are shown by types in the table.

Type	Chord No.	Number	Ratio	Galloping	NW Gust	Truck Gust	Galloping	NW Gust	Truck Gust
CM1	Tri	7	0.29%	No	Yes	Yes	0	1	1
CM2	Tri	0	0.00%	No	Yes	Yes	0	1	1
CM3	Box	0	0.00%	No	Yes	Yes	0	1	1
CM4	Tri	7	0.29%	No	Yes	Yes	0	1	1
CM5	Box	23	0.94%	No	Yes	Yes	0	1	1
CM6	Box	47	1.92%	No	Yes	Yes	0	1	1
CM7	Tri	11	0.45%	No	Yes	Yes	0	1	1
CN1	Single	74	3.02%	Yes	Yes	Yes	1	1	1
CN2	Double	631	25.74%	Yes	Yes	Yes	1	1	1
CN3	Box	616	25.13%	No	Yes	Yes	0	1	1
CN4	Double	5	0.20%	Yes	Yes	Yes	1	1	1
CN5	Box	14	0.57%	No	Yes	Yes	0	1	1
CN6	Pedestal	12	0.49%	No	Yes	No	0	1	0
OH1	Single	18	0.73%	Yes	Yes	Yes	1	1	1
OH2	Double	8	0.33%	Yes	Yes	Yes	1	1	1
OH3	Tri	27	1.10%	No	Yes	Yes	0	1	1
OH4	Tri	275	11.22%	No	Yes	Yes	0	1	1
OH5	Tri	72	2.94%	No	Yes	Yes	0	1	1
OH6	Box	604	24.64%	No	Yes	Yes	0	1	1
5 Total		2451					736	2451	2439

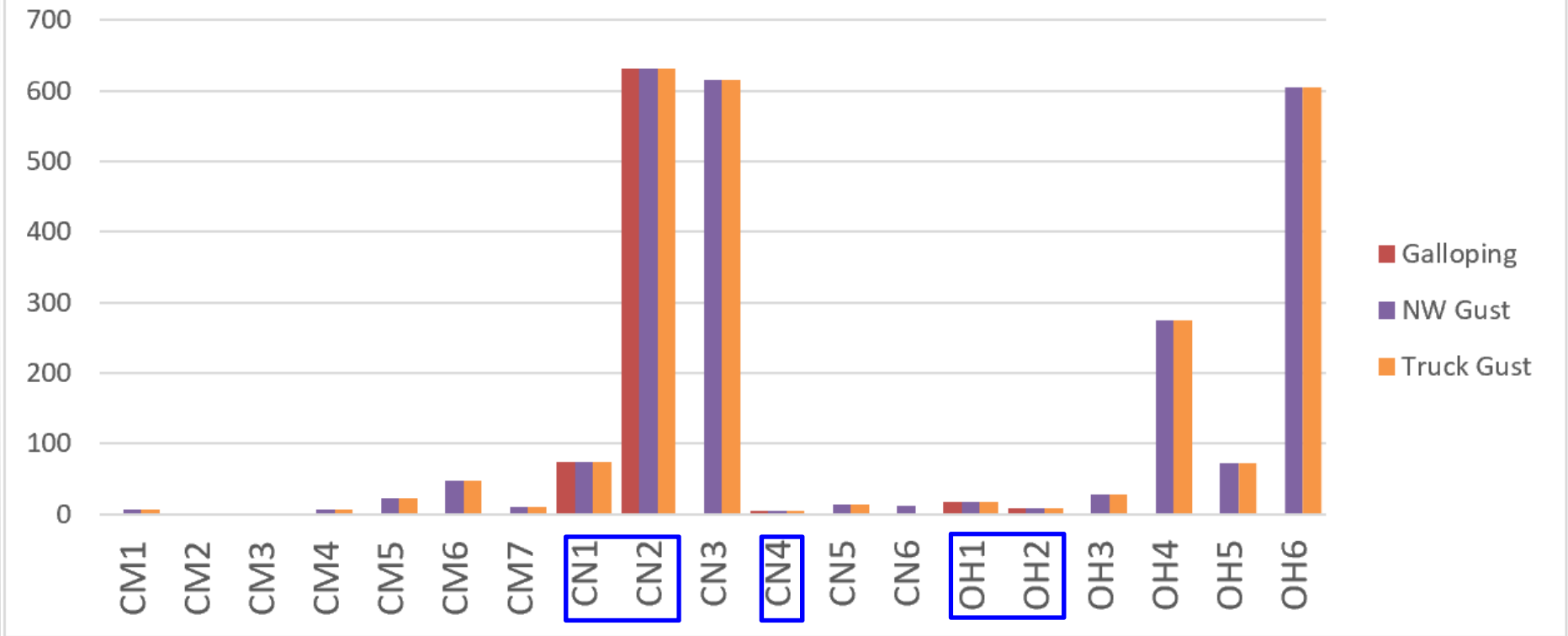
2. Task 1: Study and evaluate SHA sign structure database



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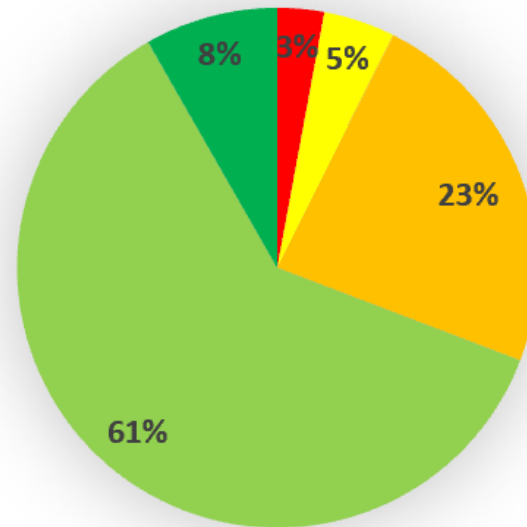


Number of structures influenced by wind load



2. Task 1: Study and evaluate SHA sign structure database

MDOT SHA SIGN STRUCTURE RATING



■ 1. Deficient
 ■ 2. Poor
 ■ 3. Fair
 ■ 4. Good
 ■ 5. Excellent

MDOT SHA Sign Structure Rating in Pie Chart.

SHA, by following the bridge rating, has rated the sign bridge in five categories.

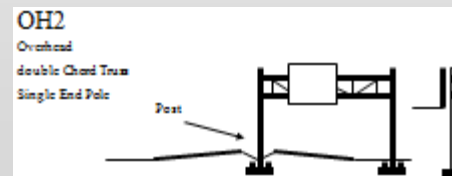
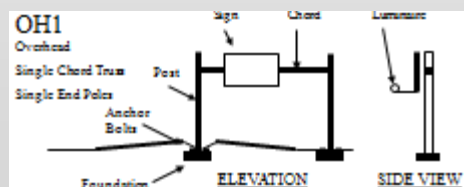
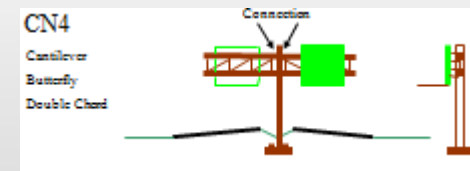
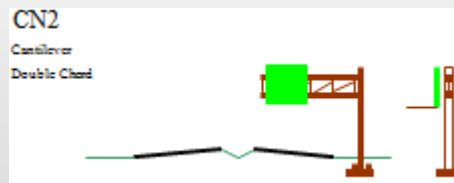
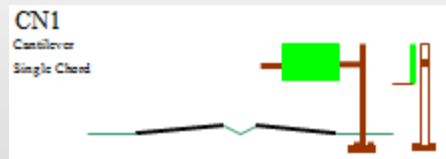
Rate	Deficient	Poor	Fair	Good	Excellent
	1	2	3	4	5
No.	70	107	564	1466	199
%	2.91%	4.45%	23.44%	60.93%	8.27%

2. Task 1: Study and evaluate SHA sign structure database

Step 2: Categorize all MD sign structures based on 5 major categories of

- (1) cantilever type (CN1-3),
- (2) butterfly type (CN4-5 may include 6),
- (3) span-cantilever type (CM1-3, may include 7),
- (4) double type (CM4-5, may include CM6),
- (5) overhead type (OH1-6).

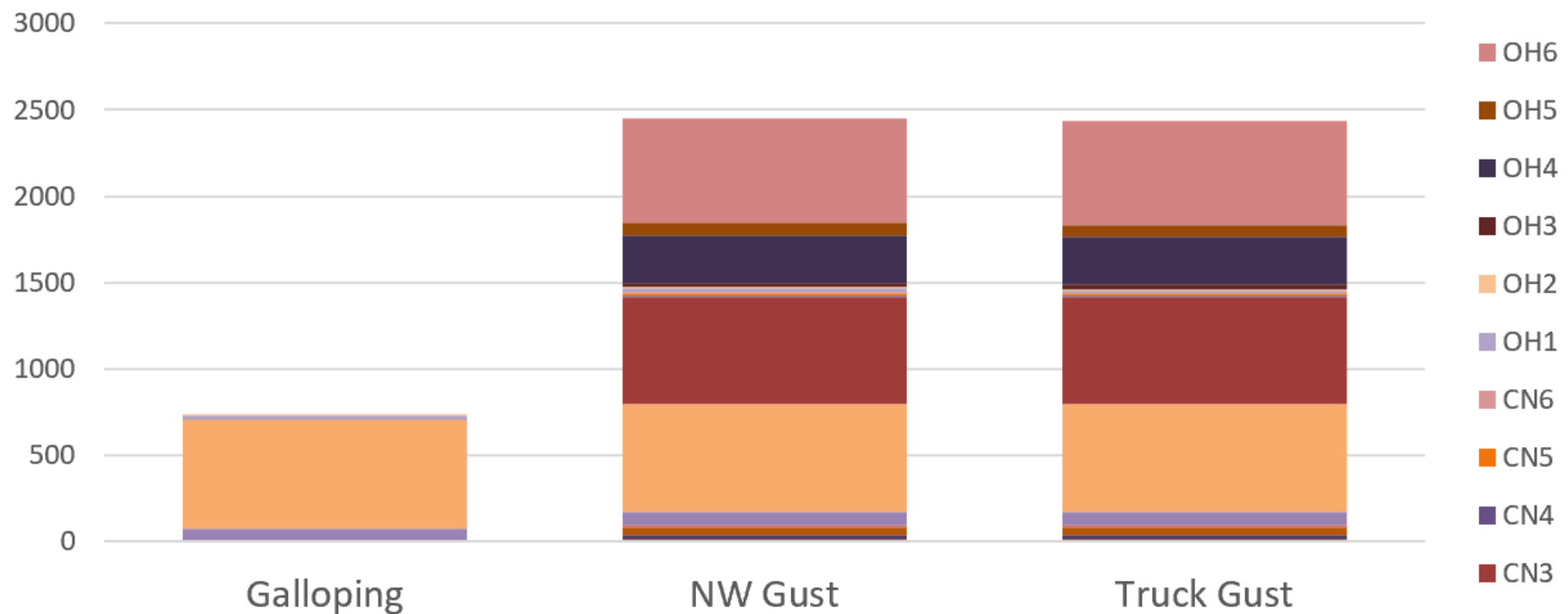
Prone for Gallop



2. Task 1: Study and evaluate SHA sign structure database



Number of structures influenced by wind load

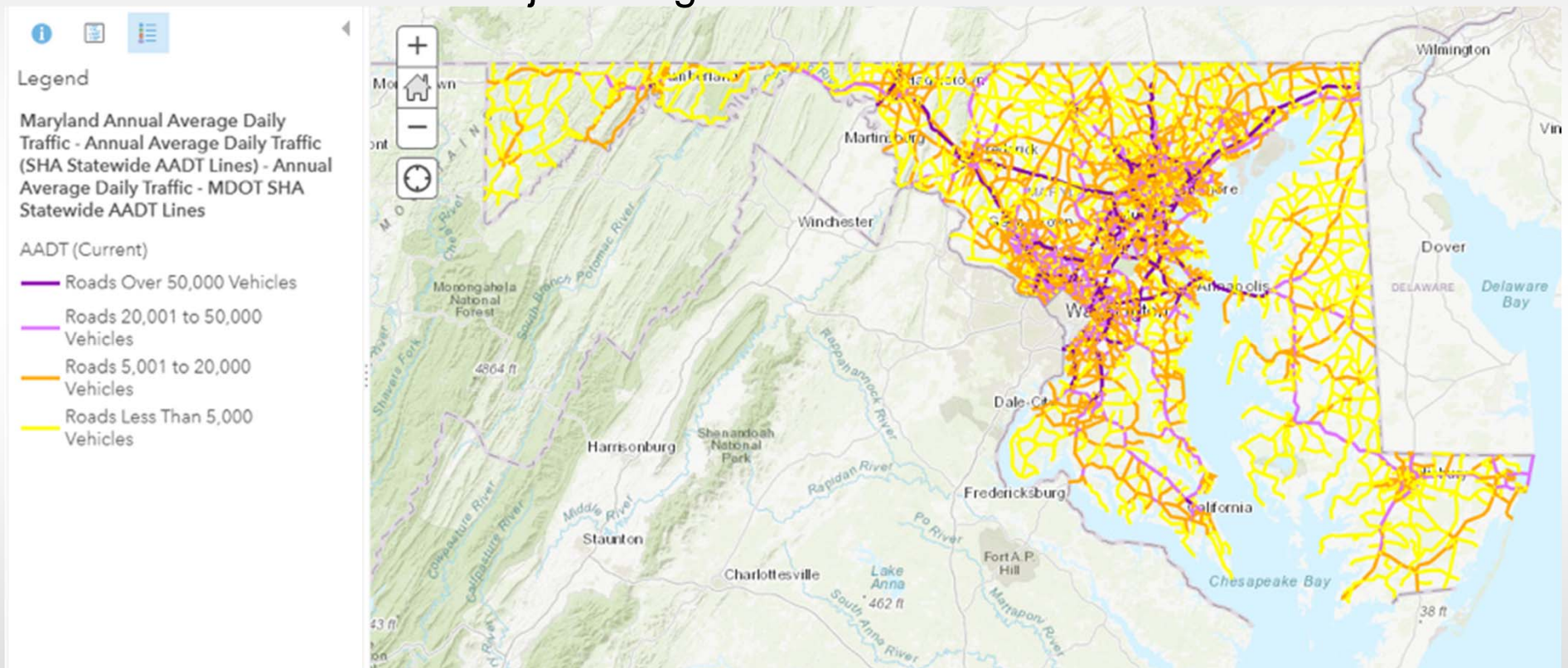


Numbers and Types of Structures Influenced by Three Fatigue Loads.

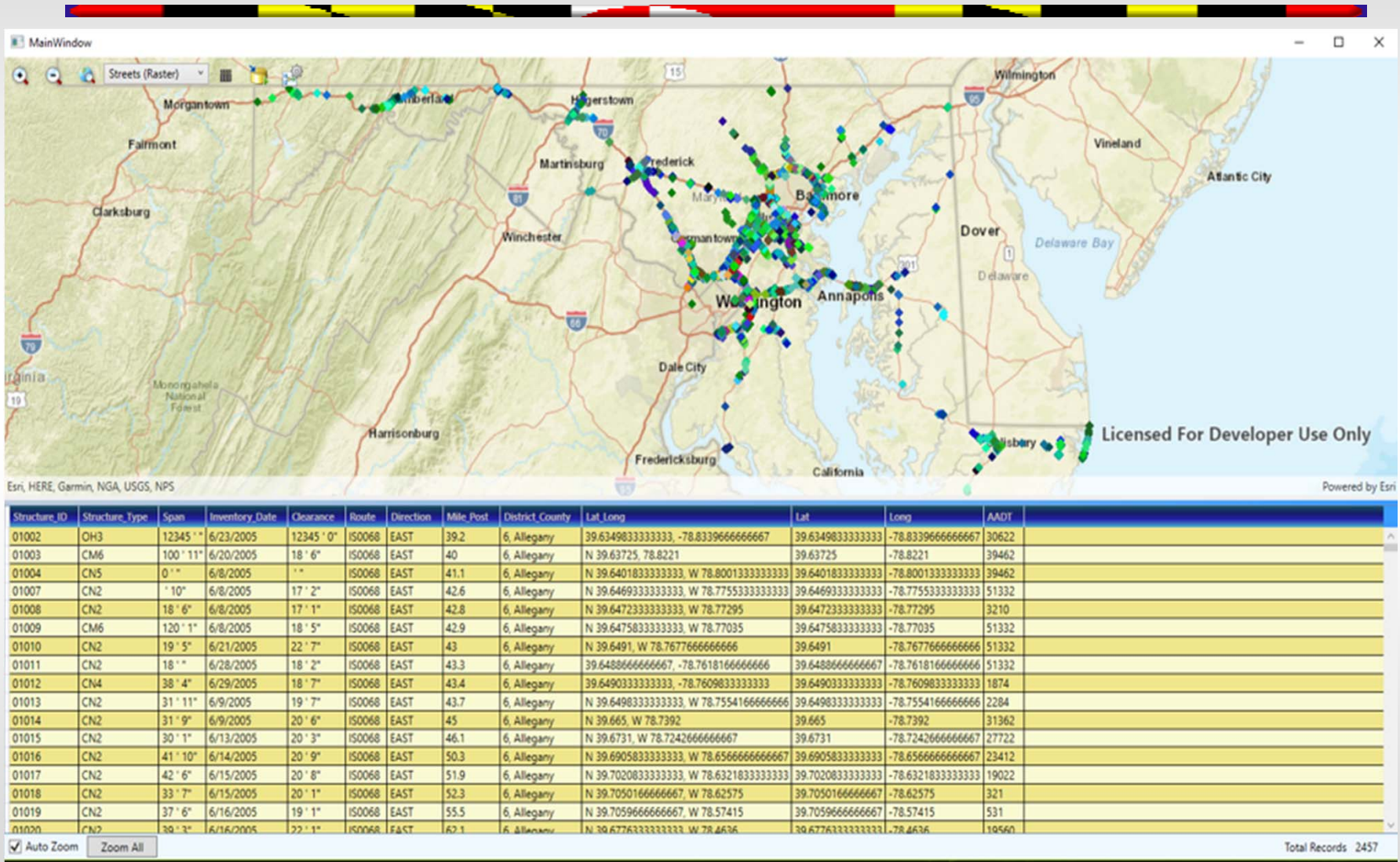
10 Galloping-influenced sign structures shown as bar 1, and bars 2 & 3 are for almost all the structures.

3. Task 2: Take samples from categories and analyze sampling sign structures

Step 3: Take total MD sign structure population and find subtotal numbers for the 5 major categories.

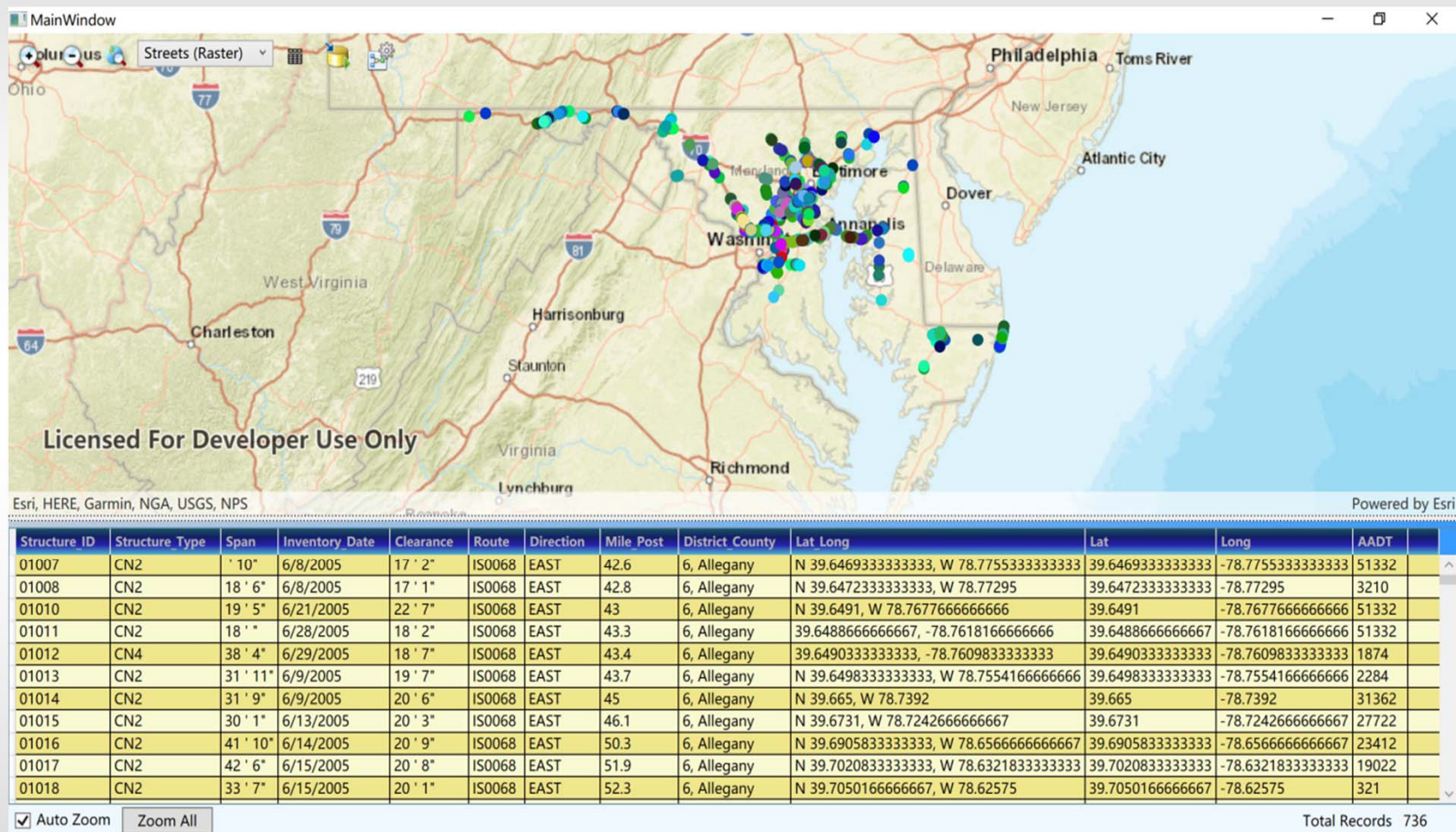


3. Task 2: Take samples from categories and analyze sampling sign structures



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It shows the main program with the whole structure information(2457 in total).

3. Task 2: Take samples from categories and analyze sampling sign structures



Only 5 out of 19 types for a total 736 galloping-influenced structures

13 are left for consideration. Those structures are shown in the Arc-GIS map by their categories.

3. Task 2: Take samples from categories and analyze sampling sign structures



Type	Before 2002	After 2002	Incorrect Info	N.I.S	Lack of Info	Total
CN1	13	13	2	10	36	74
CN2	344	101	13	112	61	631
CN4	3	0	2	0	0	5
OH1	2	0	1	9	6	18
OH2	2	2	0	2	2	8
SUM	364	116	18	133	105	736

Summarize the remaining structures to be considered according to their built years.

4. Task 3: Run selected sampled cases and verify SABRE results

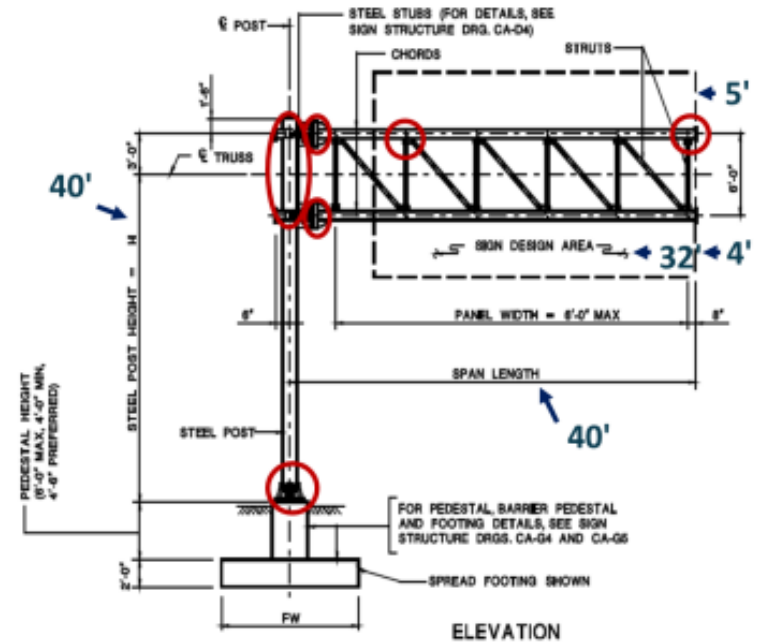
Two steps involved in this task on strength evaluation and fatigue evaluation:

Step 5: Verify SABRE program using STADD-Pro based on the examples adopted from NCHRP reports 796 and 718 and NJDOT report.

Step 6: Establish SABRE model and run samples from 5 major categories (for instance, 5 samples selected from category I, 3 from category II, and so on) for a total sample population say 30 (assumed) sign structures.

4. Task 3: Run selected sampled cases and verify SABRE results

Fatigue calibration with NJDOT Ex. 1
Overhead Cantilever Sign Structure – Flat Panel Sign Board



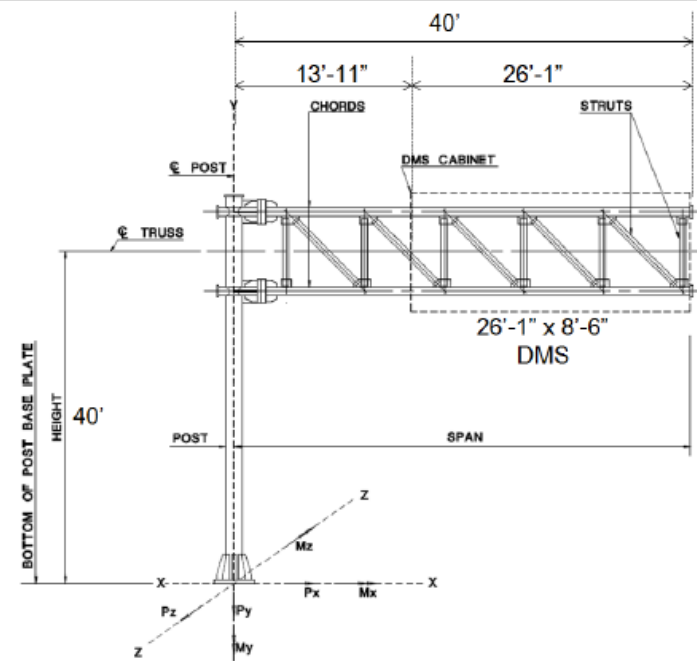
Example 1

Fatigue II		Sabre	Report hand check	Corrected Note	Staad (corrected)
Joint load (kips)	Gallop	7.056	7.056		7.056
	Natural.W	3.761	4.146	3.085 Cd=1.2	3.067
	NW sign	2.534	3.6048	2.545	
	NW chord	0.703			
	NW column	0.525	0.5401	0.5401	
	Truck.W	0.499	1.438	0.469	0.479
	TW sign	0.134	0.357	0.134	
	TW chord	0.365	1.0811	0.335 L=12ft	
Moment (K-ft)	Gallop	169.9	141.6		169.3
	Natural.W	63.6	81.9	57.65 L=12ft	61.1
	Truck.W	15.7	49.9	14.51	17

0.4%
4.1%
7.6%

4. Task 3: Run selected sampled cases and verify SABRE results

Fatigue calibration with NJDOT Ex. 2
 Cantilever Sign Structure Category I –
 VMS/DMS Sign Board



Example 2

Fatigue I		Sabre	Report	Corrected	Note	Staad (corrected)
Joint load (kips)	Gallop	4.655	4.655			4.641
	Natural.W	3.534		2.888		2.569
	NW sign	1.967	1.959			
	NW chord	0.929		0.293		
	NW column	0.639		0.636		
	Truck.W	1.489	3.373	1.838		1.686
	TW sign	1.083	3.0682	1.5341	double lane	
	TW chord	0.406	0.3048	0.1524	L=12ft	
		Sabre	Report SAP200 check			
Moment (K-ft)	Gallop	124.44	147.08			125
	Natural.W	54.67	131.33			52.7
	Truck.W	43.15	105.33			44

0.4%
3.7%
1.9%



4. Task 3: Run selected sampled cases and verify SABRE results Step 6

5 Cantilever box sign structural examples by SABRE

Cantilever box	Max CSR		Fatigue stress limit (ksi)		
	Pole	Arm	Galloping	Wind Gust	Truck Gust
c-35-30-f	0.728	0.683	2.43	1.43	0.08
c-35-34-e	0.873	0.806	2.88	1.75	0.07
c-40-34-e	0.662	0.852	2.79	1.48	0.08
c-45-32-f	0.616	0.596	3.29	1.65	0.16
c-45-34-a	0.815	0.69	3.38	1.39	0.13

Conclusion: Samples show CSR are all less than 0.9; Fatigue for gallop can be ignored and even the base hole sizes not qualified, by combining the statement in the new and old codes, it is reasonable to take the fatigue stress limit as 2.6ksi (Category E') for the member with concentration factor KI out of the ranges in Table 11.9.3.1.

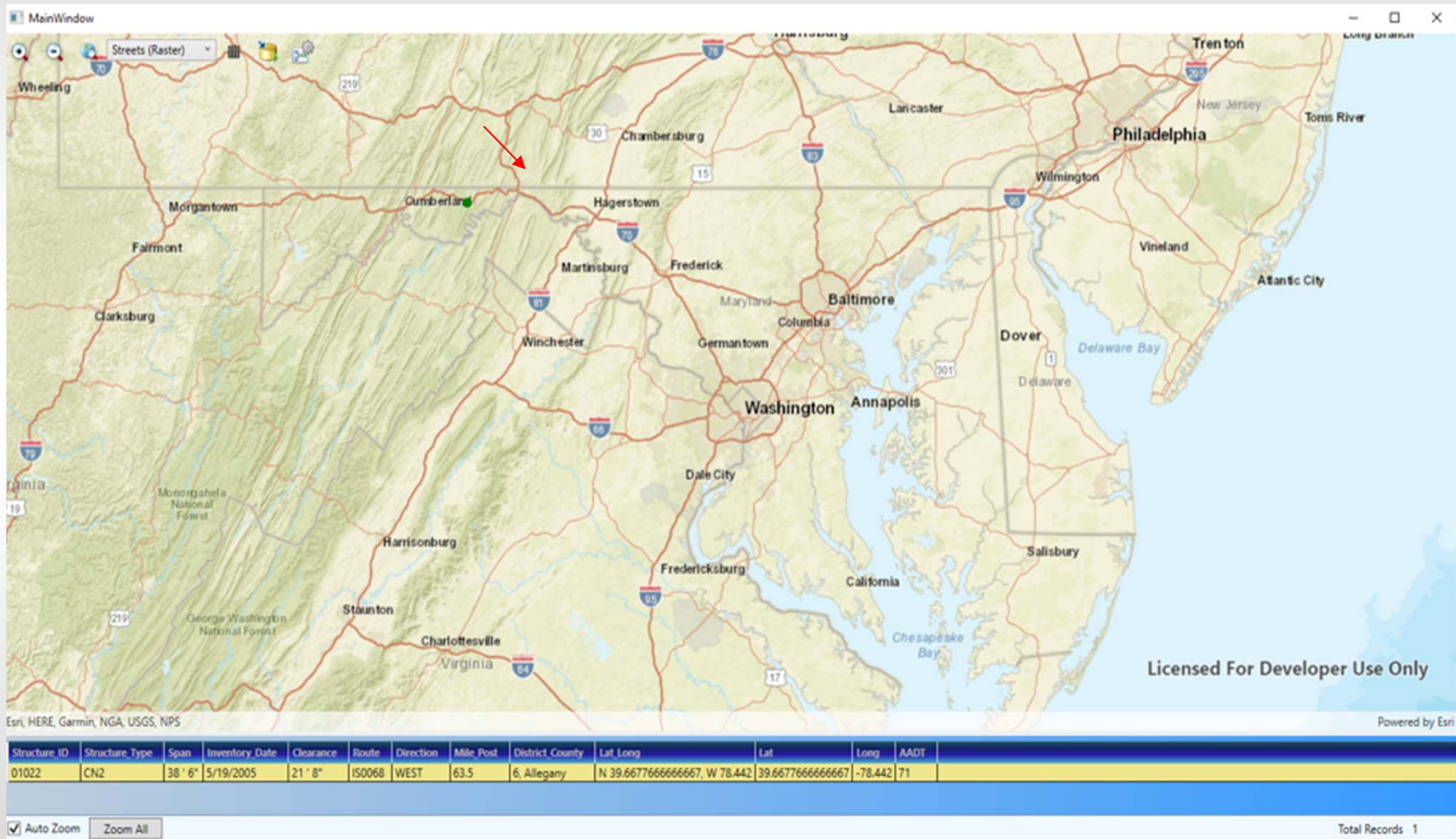
5. Task 4: Evaluate sampling sign structures

Table 3 – Risk Category by Traffic Volume (AASHTO-LRFD)

	Risk Category		
	Typical	High	Low
Traffic Volume	<35	N/A	N/A
ADT < 100	300	1,700	300
100 < ADT ≤ 1,000	700	1,700	300
1,000 < ADT ≤ 10,000	700	1,700	300
ADT > 10,000	1,700	1,700	300
Typical: Support failure could cross travelway.			
High: Support failure could stop a lifeline travelway.			
Low: Support failure could not cross travelway.			
Roadside sign supports: use 10-year MRI.			

It can be seen that ADT<100 can be considered Category 1, combining 100<ADT<1,000 and 1,000<ADT<10,000 can be considered Category 2, ADT>10,000 can be considered Category 3 or 4 where their corresponding maps are shown in Figs.8-11, respectively.

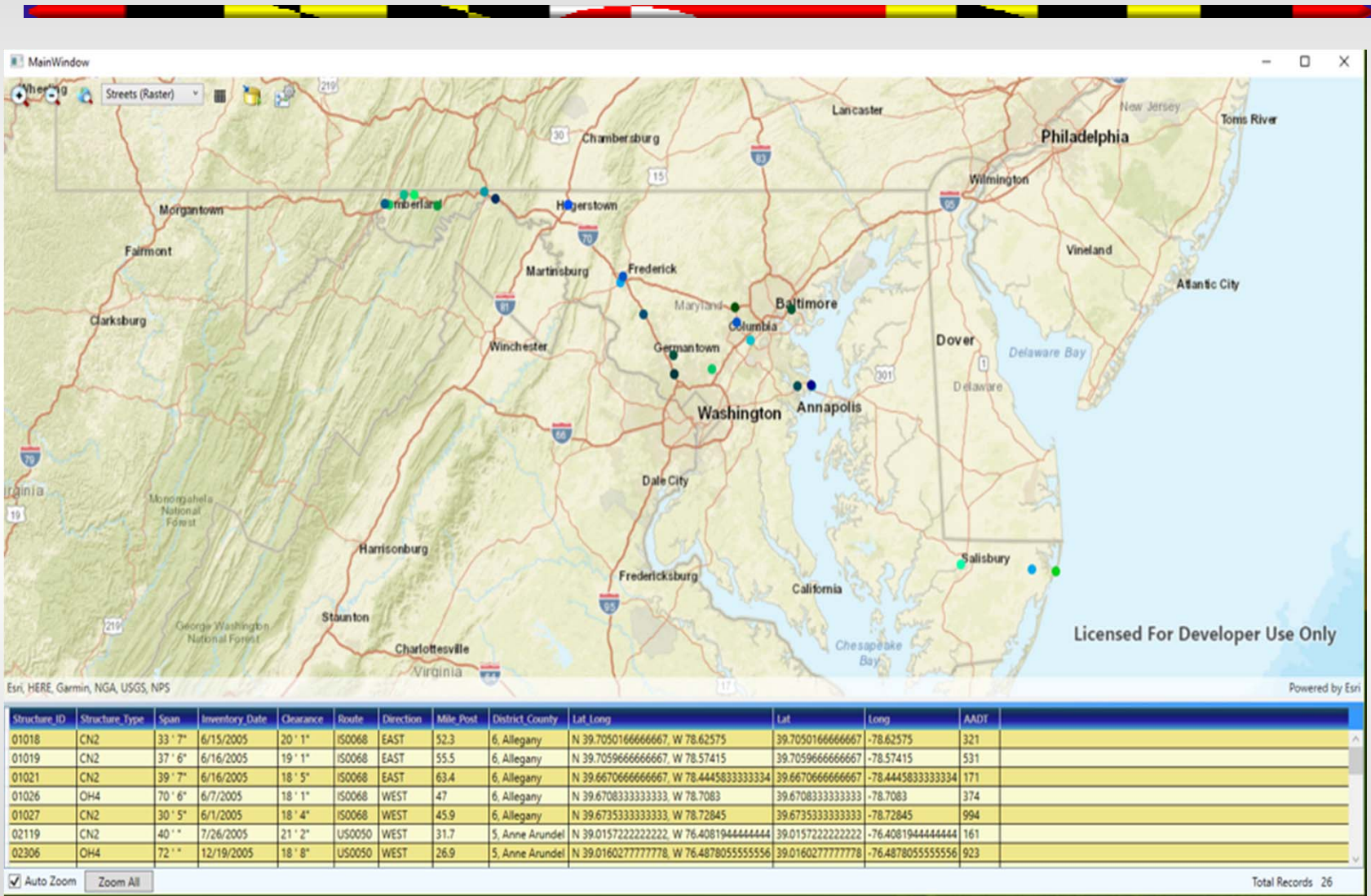
5. Task 4: Evaluate sampling sign structures



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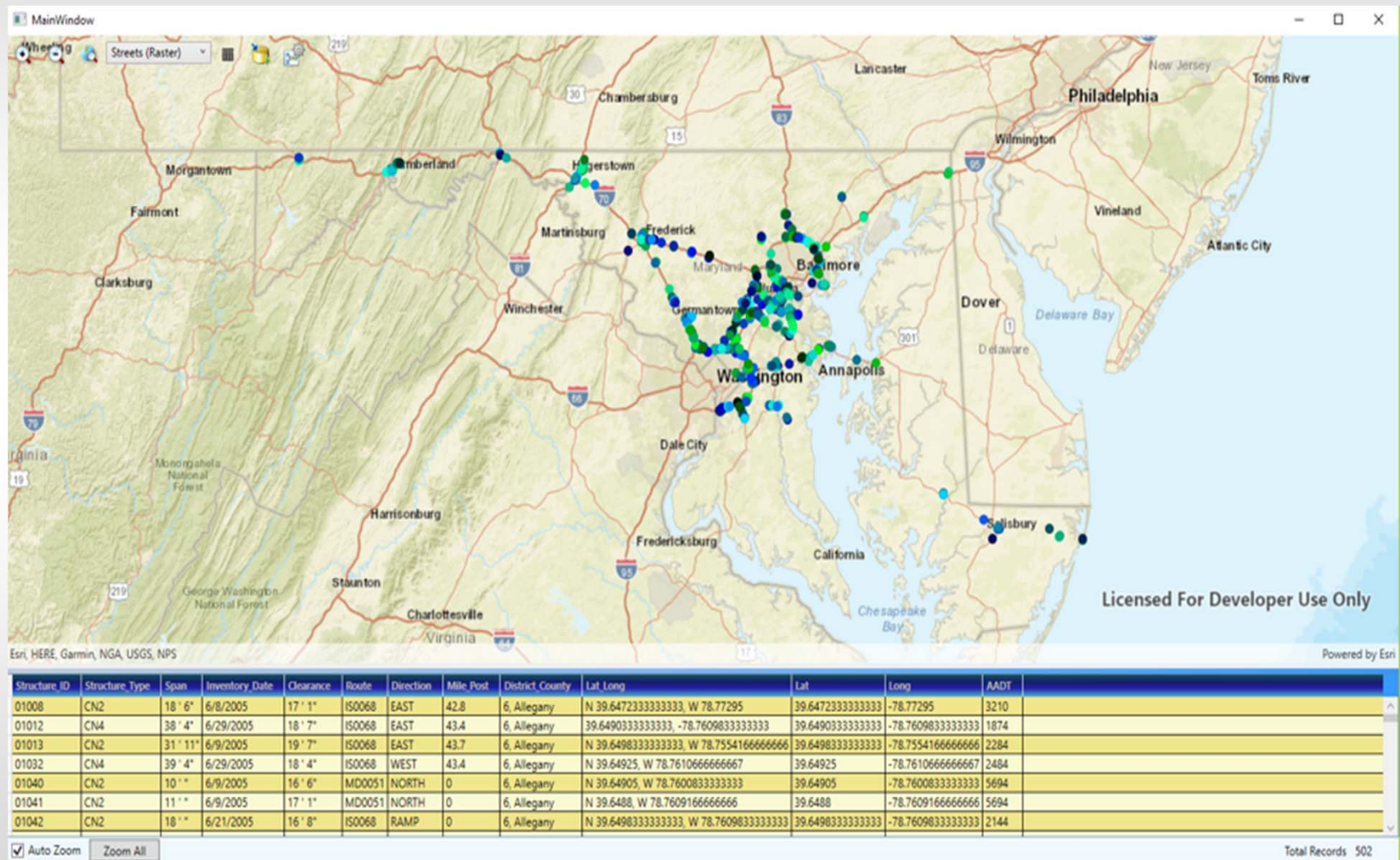
Structures with ADT less than 100 (Category 1), 1 in total

5. Task 4: Evaluate sampling sign structures

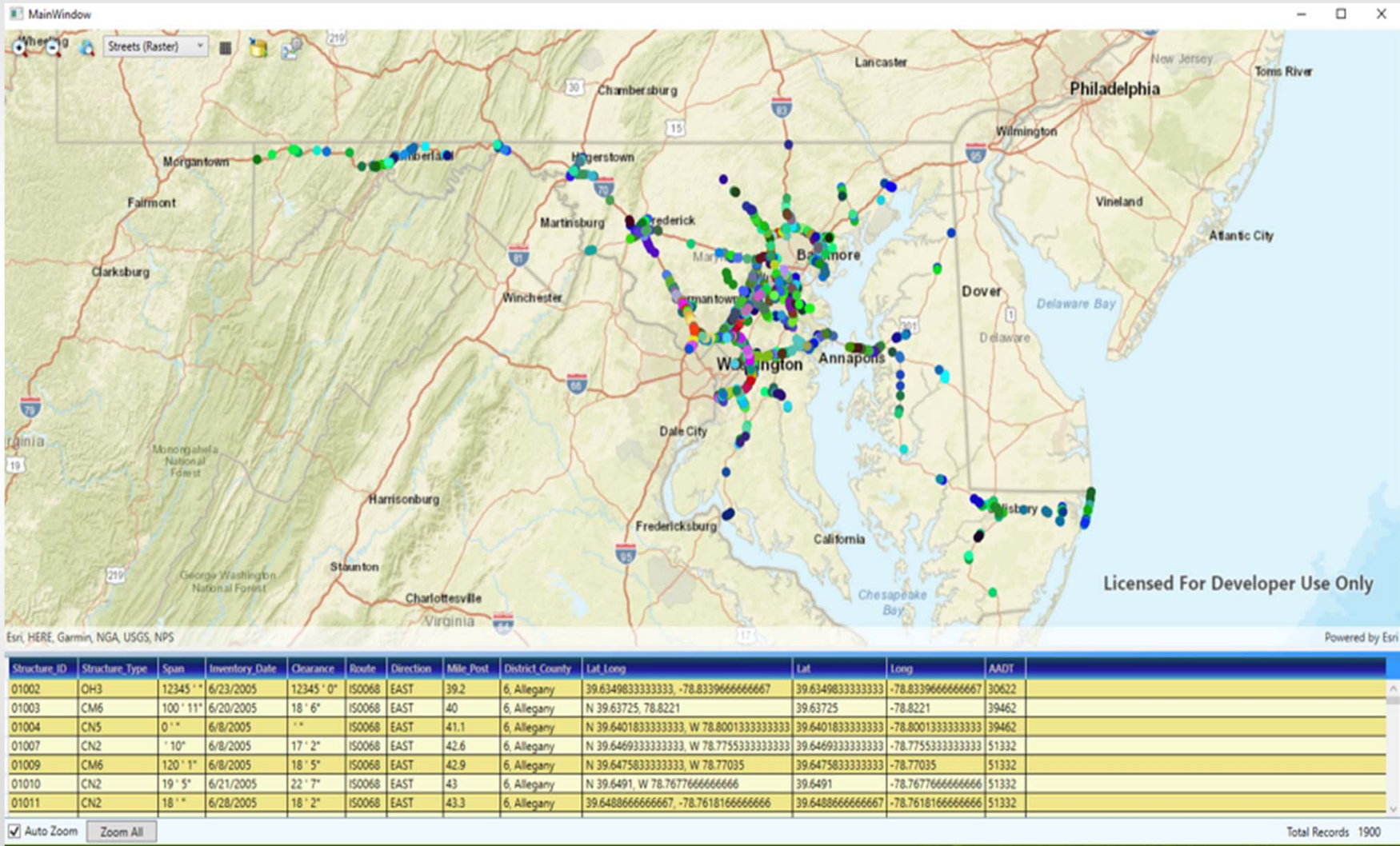


21 Structures with ADT between 100 and 1,000 (Category 2), 26 in total

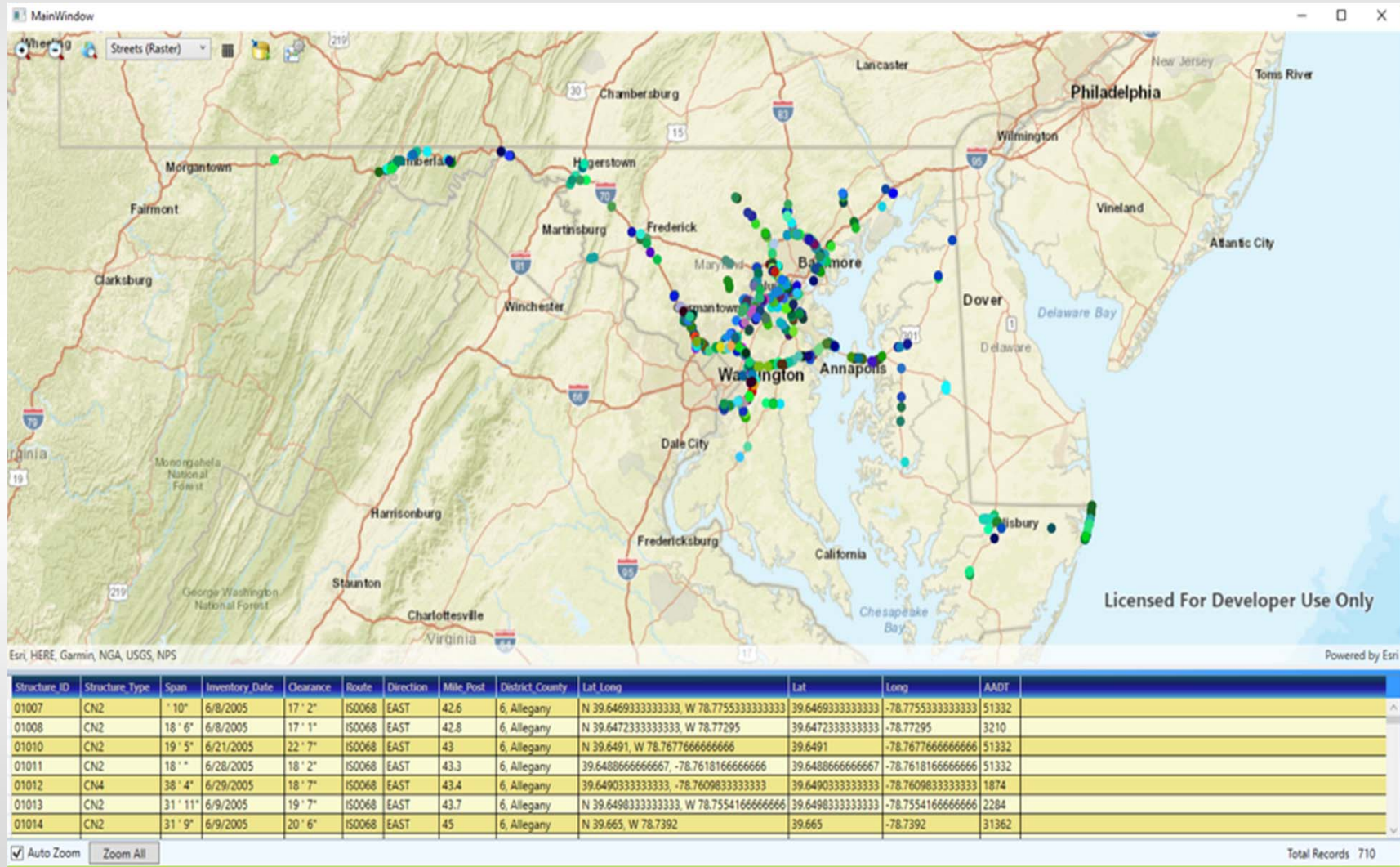
5. Task 4: Evaluate sampling sign structures



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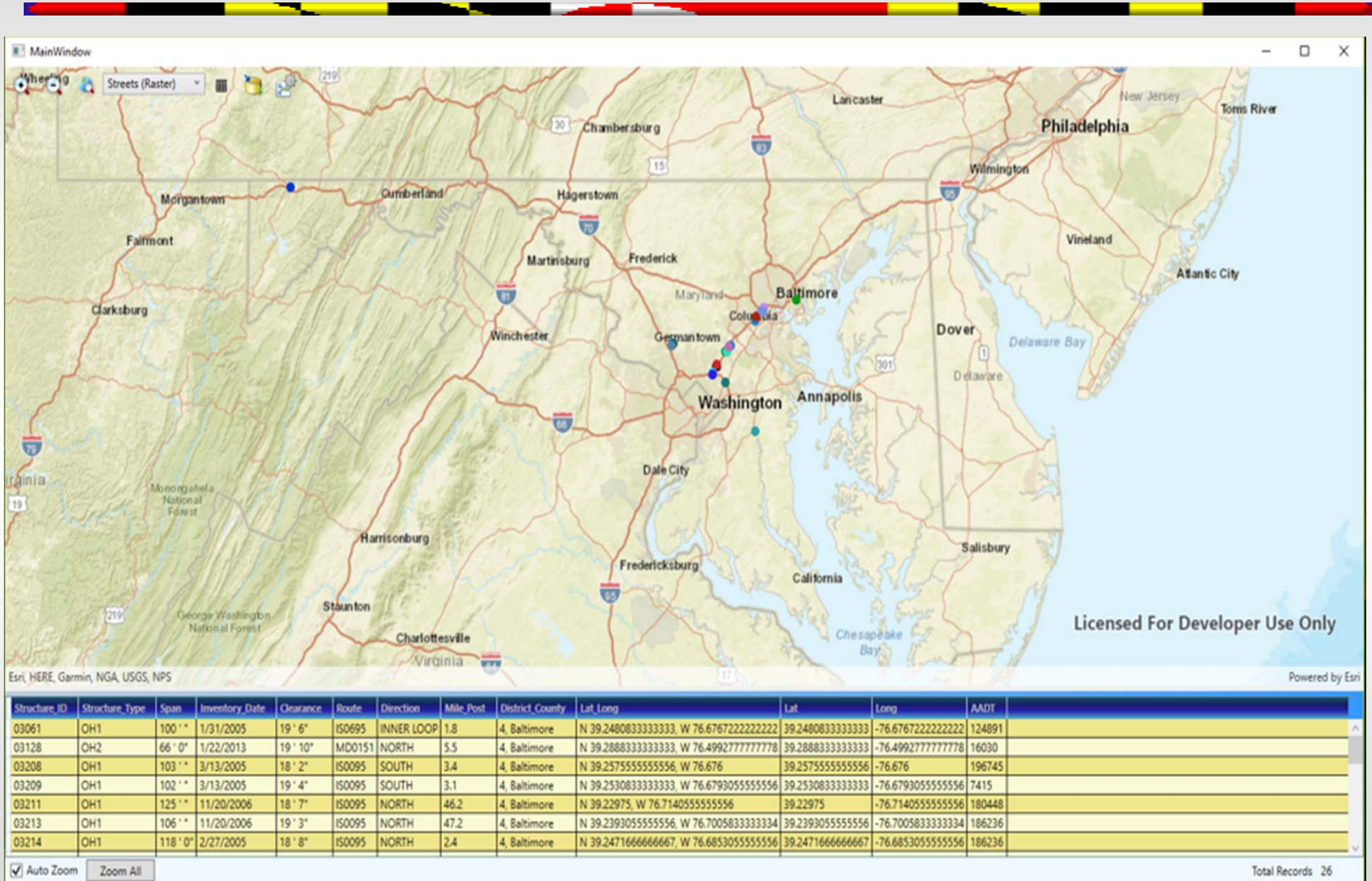


5. Task 4: Evaluate sampling sign structures



24 Galloping-influenced Structure Types CN1, CN2 and CN4 (710 in total)

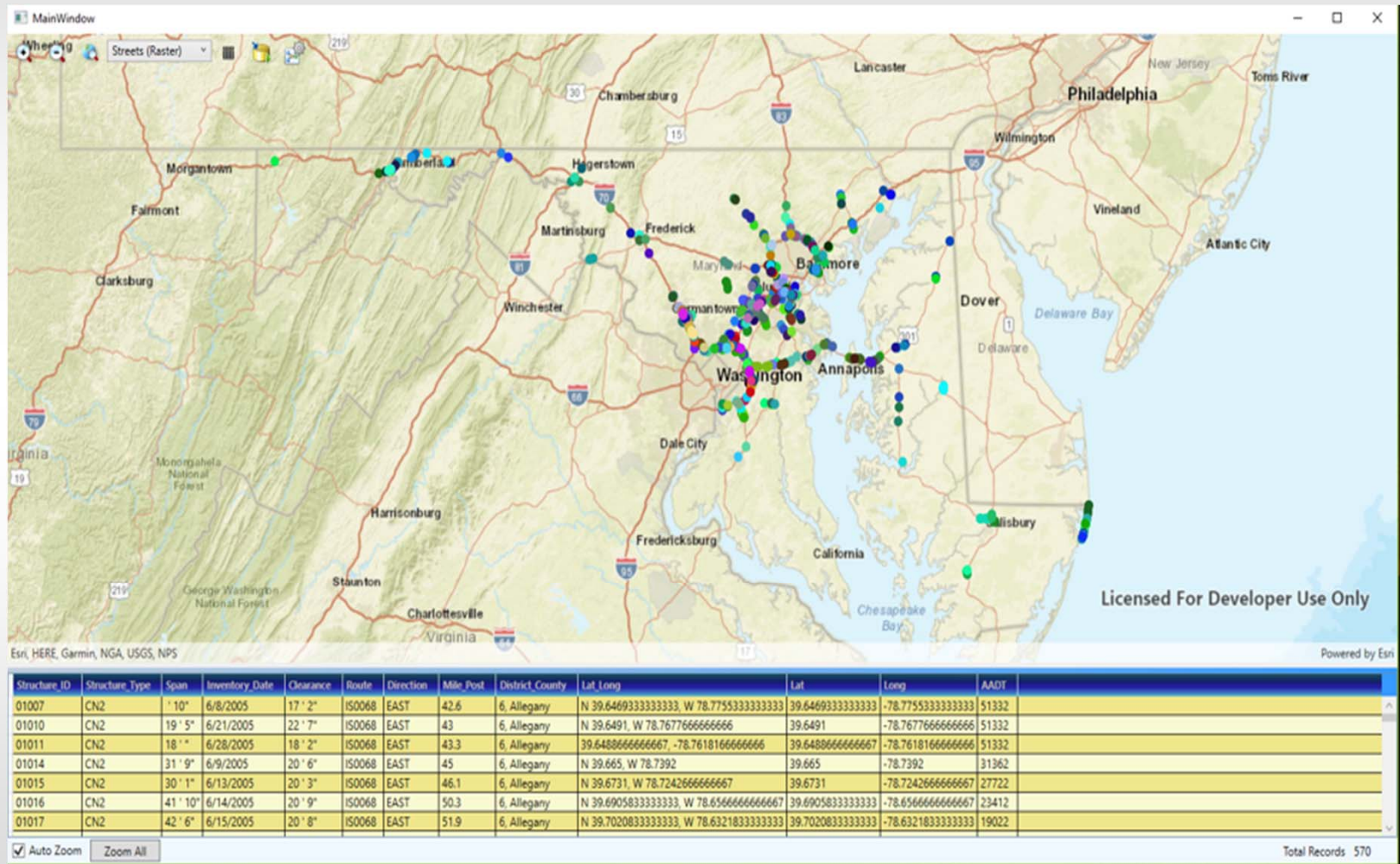
5. Task 4: Evaluate sampling sign structures



25 Galloping-influenced Structure Types OH1 and OH2 (26 in total)

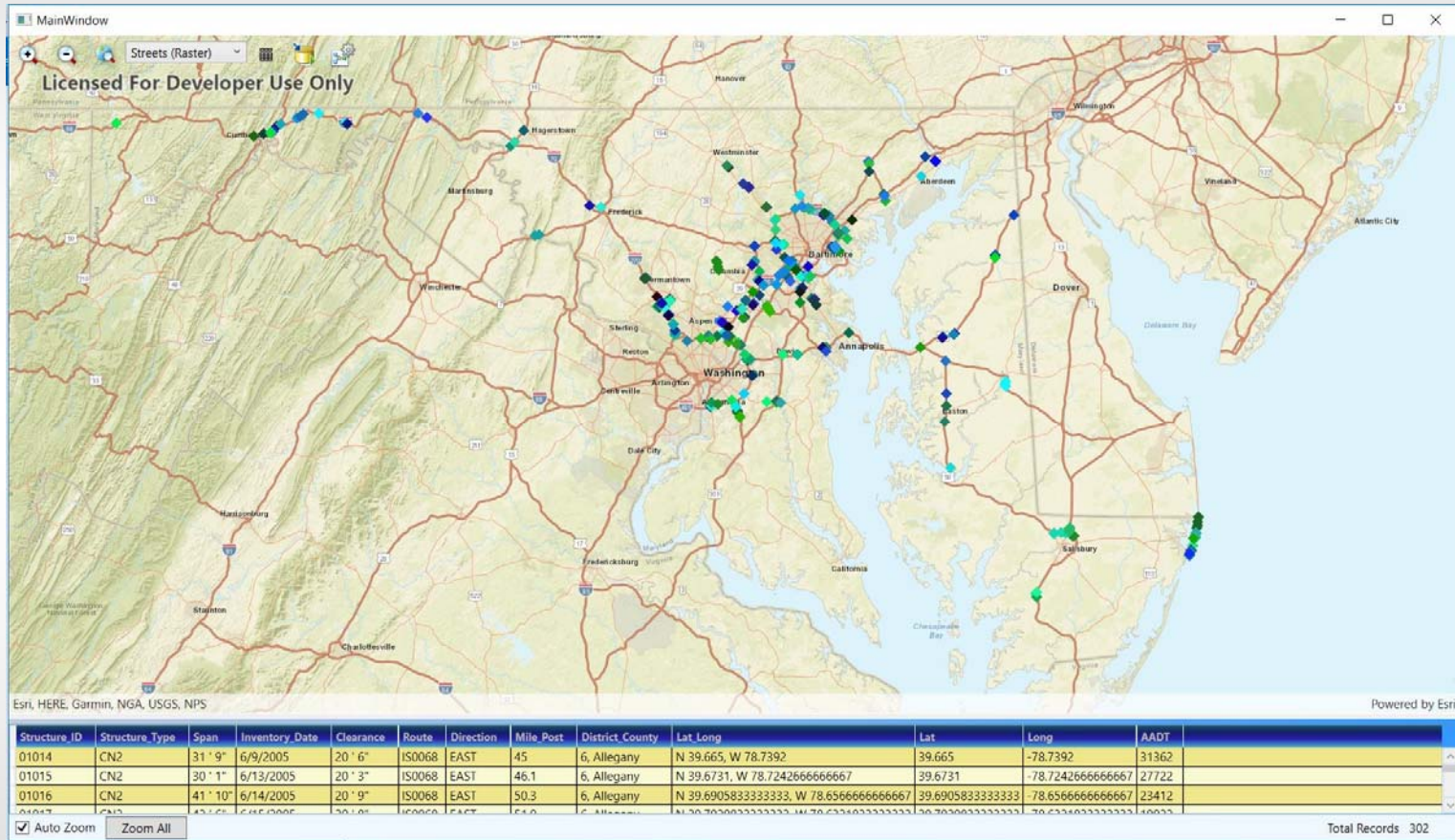


5. Task 4: Evaluate sampling sign structures



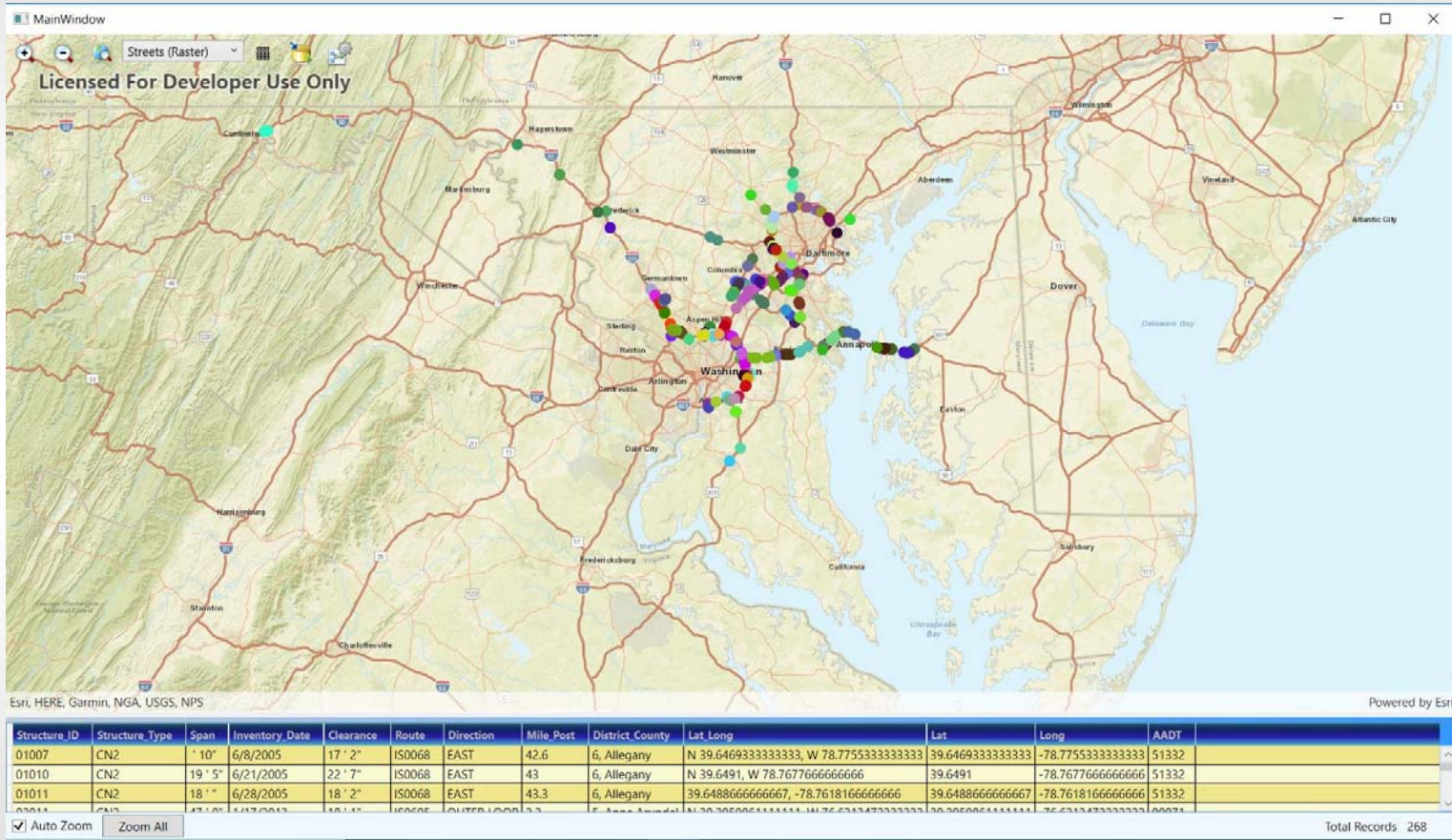
Galloping-influenced Structures in Types CN1, CN2, CN4, OH1 and OH2, ADT over 10,000 (original; 570 in total)

5. Task 4: Evaluate sampling sign structures



Galloping-influenced Structures in Types CN1, CN2, CN4, OH1 and OH2, ADT between 10,000 to 50,000 (recategorized; 302 in total)

5. Task 4: Evaluate sampling sign structures



Galloping-influenced Structures in Types CN1, CN2, CN4, OH1 and OH2, ADT over 50,000 (recategorized; 268 in total)

5. Task 4: Evaluate sampling sign structures

Structure ID	Structure Type	Span	Inventory Date	Clearance	Route	Direction	Mile Post	District County	Lat Long
01007	CN2	10"	6/8/2005	17' 2"	IS0068	EAST	42.6	6, Allegany	N 39.6469333333333, W 78.7755333333333
01008	CN2	18' 6"	6/8/2005	17' 1"	IS0068	EAST	42.8	6, Allegany	N 39.6472333333333, W 78.77295
01010	CN2	19' 5"	6/21/2005	22' 7"	IS0068	EAST	43	6, Allegany	N 39.6491, W 78.7677666666666
01011	CN2	18' 1"	6/28/2005	18' 2"	IS0068	EAST	43.3	6, Allegany	N 39.6488666666667, -78.7618166666666
01012	CN4	38' 4"	6/29/2005	18' 7"	IS0068	EAST	43.4	6, Allegany	39.6490333333333, -78.7609833333333
01013	CN2	31' 11"	6/9/2005	19' 7"	IS0068	EAST	43.7	6, Allegany	N 39.6498333333333, W 78.7541666666666
01014	CN2	31' 9"	6/9/2005	20' 6"	IS0068	EAST	45	6, Allegany	N 39.665, W 78.7392

Query Sign Structures

Available Structure Types: CM7, CN5, CN6, OH3, OH4, OH5
 Selected Structure Types: CN2, CN1, OH1, OH2, CN4

Available Routes: 0000, CO, CO Shady Grove F, CO0116
 Selected Routes: < >

Available Counties: 1, Dorcheste, 1, Somerset, 1, Wicomico, 1, Worcester, 2, Caroline, 2, Cecil
 Selected Counties: < >

ADT Range (Max=267232, Min=71) AADT From: 1000 AADT To: 267232

Customized Structure Type Symbologies

Type	Shape	Size	Color From	Color To	By AADT	By Rating
Type CN1	Circle	10	Green	Green	<input checked="" type="radio"/>	<input type="radio"/>
Type CN2	Cross	10	Purple	Purple	<input checked="" type="radio"/>	<input type="radio"/>
Type CN4	Diamond	10	Yellow	Yellow	<input checked="" type="radio"/>	<input type="radio"/>
Type OH1	X	10	Blue	Blue	<input checked="" type="radio"/>	<input type="radio"/>
Type OH2	Triangle	10	Red	Red	<input checked="" type="radio"/>	<input type="radio"/>

Galloping-influenced Structures in Types CN1, CN2, CN4, OH1 and OH2, ADT over 10,000 (with Symbology; 570 in total)

Task 5 - Rank and prioritize the whole population based on the evaluation



Two steps involved in this task:

- **Step 8:** Rank all MD sign structures based on the evaluation.
- **Step 9:** Prioritize all MD sign structures based on budget and risk.

The tentative factors considered in ranking and prioritizing are:

- Structure type
- Structure age (year built)
- Traffic Volume in AADT
- Structural analysis results, especially fatigue analysis
- Structural condition (rating) (ignored for the time being; future in-depth inspections for the at-risk structures)

Task 5 - Rank and prioritize the whole population based on the evaluation

One tentative factor considered in ranking and prioritizing for

- Structure type and Number of anchor bolts – **40%**)

		Risk Value for No. of Bolts			
		# of Anchor Bolts / Pole	4	6	8
Sign Structure Type	CN-1 (Mast Arms)	<input type="radio"/>	10	8	7
	CN-2	<input checked="" type="radio"/>	10	8	7
	CN-3	<input type="radio"/>	10	8	7
	CN-4	<input type="radio"/>	9	7	6
	CN-5	<input type="radio"/>	9	7	6
	CN-6	<input type="radio"/>	9	7	6
	OH-1	<input type="radio"/>	9	8	6
	OH-2	<input type="radio"/>	9	8	6
	OH-3	<input type="radio"/>	9	8	6
	OH-4	<input type="radio"/>	7	6	4
	OH-5	<input type="radio"/>	7	6	4
	OH-6	<input type="radio"/>	7	6	3
	CM-1	<input type="radio"/>	9	8	7
	CM-2	<input type="radio"/>	7	6	5
	CM-3	<input type="radio"/>	7	6	4
	CM-4	<input type="radio"/>	6	5	4
	CM-5	<input type="radio"/>	6	5	4
CM-6	<input type="radio"/>	9	8	6	
CM-7	<input type="radio"/>	8	7	5	

Task 5 - Rank and prioritize the whole population based on the evaluation

The tentative factors considered in ranking and prioritizing are:

- Structure age (year built) (**10%**)

AGE	Years Built	Risk Value	
	Years in Service	Risk Value	
	0 To 10		0
	10 To 20		2
	20 To 30		4
	30 To 40		6
	Above 40 / Unknown		10

Suggested

- Traffic Volume in AADT (**20%**)

AADT	Current AADT	Risk Value	
	AADT	Risk Value	
	Up to 10K		2
	10K To 25K		4
	25K To 50K		6
	50K To 100K		8
	100K or Higher		10

AADT	Current AADT	Risk Value	
	AADT	Risk Value	
	Up to 100		2
	100 To 1000		4
	1000 To 10000		6
	10000 To 50000		8
	50000 or Higher		10

Task 5 - Rank and prioritize the whole population based on the evaluation



The tentative factors considered in ranking and prioritizing are:

- Structural analysis results, especially fatigue analysis (**30%**)
 - Prior to 1983 – designed by Office of Structures; may not locate design files
 - Prior to 2002 – no design standard; check archive for possible design files by Office of Traffic and Safety
 - After 2002 – design standard is available; but only 1 of 5 types (631 out of 736) available for CN2
- Structural condition (rating) (ignored for the time being; future in-depth inspections for the at-risk structures)
- Risk Ratings & In-Depth Inspection Ratings equally (**50% - 50%**) to come with a “**Replacement Priority List**”.
- Risk or Reliability analysis? or both?**

Deliverables

"Structural Assessment of Maryland Sign Structures based on AASHTO LTS- 6 Strength and Fatigue Criteria"																
Task #	Task Items	1st	2nd	3rd	4th	5th	6th	7th	8th	9th	10th	11th	12th	13rd	14th	15th
1	Study and evaluate SHA sign structure database															
				100%												
2	Take samples from categories and analyze															
	sampling sign structures			40%												
3	Run selected sampled cases and verify SABRE															
	results					20%										
4	Evaluate sampling sign structures															
							20%									
5	Rank and priotize the whole population															
	based on the evaluation											10%				
6	Summary and report															
Milestone	Milestone Items															
a	Kick-off meeting	X														
b	Quarterly progress meeting				X			X			X			X		
c	Quarterly reports			X			X			X			X			
d	Final Report															X
e	Final project meeting/presentation															X

6. Research Plan/Deliverables

- **Anticipated Work for next Quarter**

- Complete and summarize the survey;
- Complete beta test for SPOLES program.
- Complete the numerical study on the mediation device for signal poles 50', 60', 70' and 75'.
- Get ready for the proposed validation of the numerical results by testing a single arm specimen;

- **Project Deliverables**

- Enhanced S-POLES;
- Excel for Fatigue Detail Evaluation;
- Quarterly reports
- Reports on literature review
- Draft report and two-page summary
- Final report