Using RSD to Develop a Sampling Methodology For Estimating the Emissions Contribution of Heavy-Duty Drayage Trucks In The Port of Houston

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Carl Fulper[1], Constance Hart[1], David Hawkins[1], Robert Giannelli[1], Cheryl Caffrey[1], James Warila[1], Sandeep Kishan[2], Timothy DeFries[2], Michael Sabisch[2], Alan Stanard[2] , Hugh Williamson[3]

[1]U.S. EPA, Office of Transportation and Air Quality,
[2] Eastern Research Group (ERG)
[3] CACI Intl, Inc.

Sponsors & Project Team

- U.S. EPA's Office of Transportation & Air Quality (OTAQ)
- Houston-Galveston Area Council (HGAC)
- Texas Commission on Environmental Quality (TCEQ)
- Port of Houston Authority
- Contractors: Eastern Research Group, Sensors Inc., University of Denver

Houston Port Study

- **Objective: Characterize activity and emissions of HD "drayage" trucks in Houston**
  - Improve Houston inventory/transportation modeling
  - Pilot project for users to expand MOVES to better reflect local situation
- **Measurement Targets:**
  - Portable Emissions: ≅ 8 hours (24 – 30 trucks)
  - Portable Activity: ≅ 7 days (additional 24 trucks)
  - Trucks selected based on RSD screening
- **Port entry records provide fleet data**

Customizing MOVES

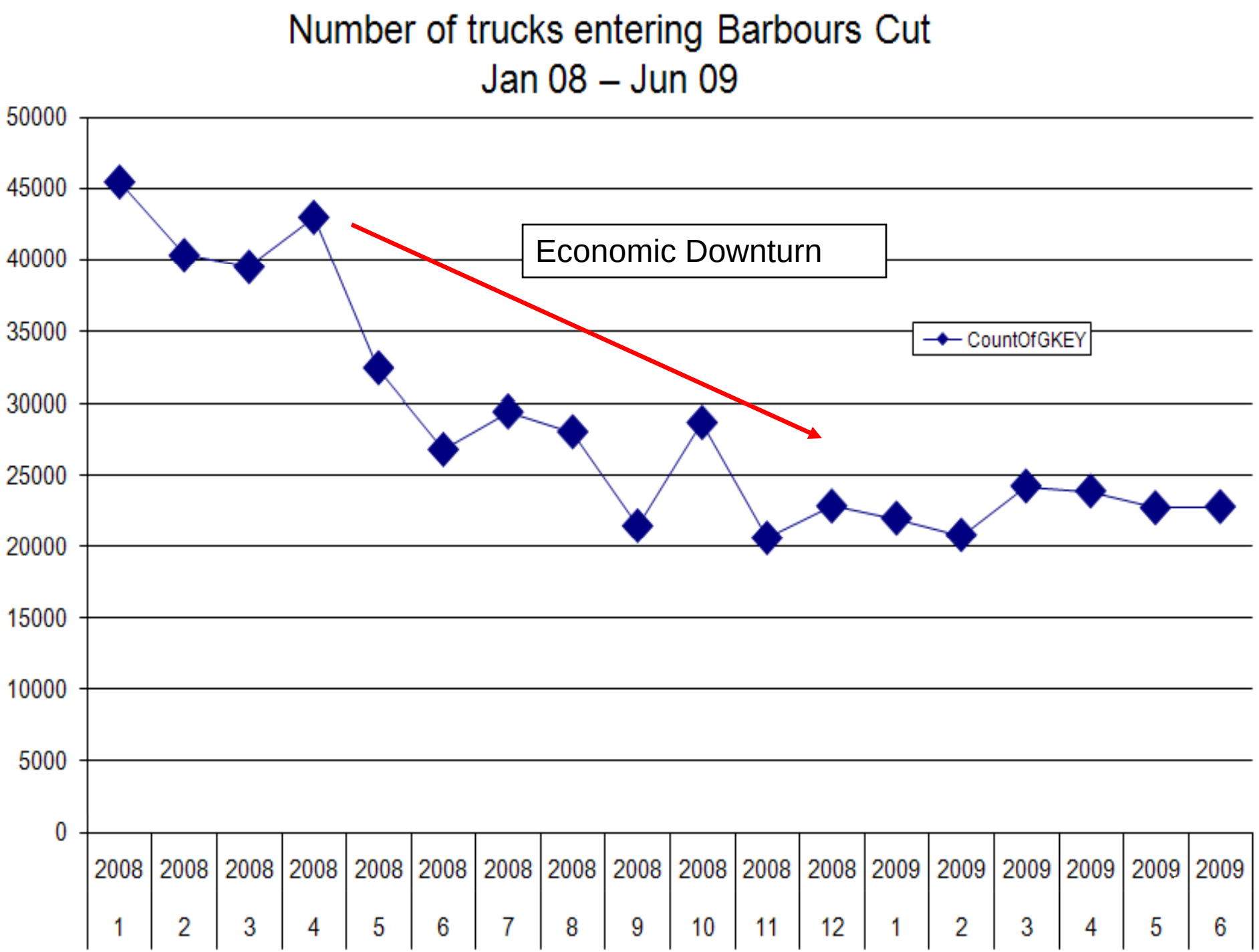
- **Over 100 database tables store default data**
  - National default emission, fleet & activity data
  - County level fuel & meteorology data
  - Vehicle classes, road types also table driven
- **User encouraged to customize with local data**
  - "Data Managers" allow easy customization of more common inputs (VMT, age distribution, speed distribution etc).
  - Focus of EPA's current technical guidance
- **User can also make more fundamental changes**
  - E.g., can add vehicle classes and road types with supporting data
  - This study is a pilot on how to do this

Adding Drayage Trucks to MOVES – Data Required

Data Type	Data Source	Key MOVES MySQL Tables
Population	Port Data, Registration Records	SourceTypeYear, SourceTypeAgeDistribution
Activity	PAMS, PEMS	RoadTypeDistribution
Drive Cycle	PAMS, PEMS	AvgSpeedDistribution, DriveScheduleSecond
Temporal Allocation	PAMS, PEMS	Day/Month/HourVMTFraction
Emissions	PEMS, RSD	EmissionRatebyAge

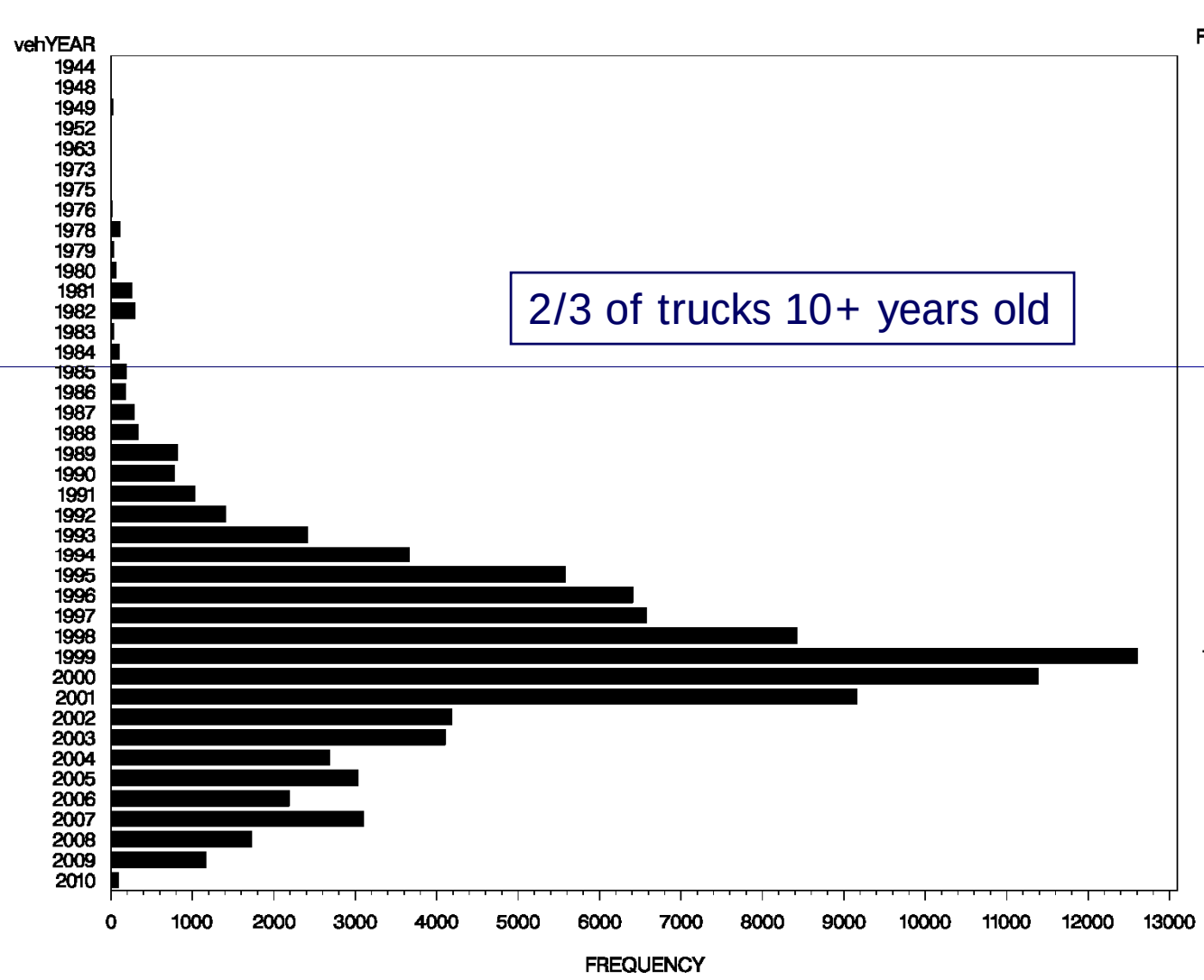
Major Activities Conducted

- **Analyzed 18 months of Port Entry data (June ’09)**
- **RSD screening study (July ‘09)**
- **Analysis of RSD data (August - December ‘09)**
- **Develop Sampling Methodology (Oct ‘09)**
- **Develop Recruitment Methodology (Oct ‘09)**
- **Mockups & Develop Testing Procedures (Nov ‘09)**
- **Recruitment & Preliminary Visits (Nov ‘09)**
- **Field Testing (December ‘09 – March ‘10)**
  - Portable Emissions (37 trucks) 1-2 day each vehicle
  - Portable Activity (23 trucks) 1 week/vehicle


Number of trucks entering Barbours Cut
Jan 08 – Jun 09
50000
45000
40000
35000
30000
25000
20000
15000
10000
5000
0
Economic Downturn
CountOfGKEY
2008 1
2008 2
2008 3
2008 4
2008 5
2008 6
2008 7
2008 8
2008 9
2008 10
2008 11
2008 12
2009 1
2009 2
2009 3
2009 4
2009 5
2009 6

Model Year Distribution from Port Entry Data

January – June 2009



2/3 of trucks 10+ years old

vehYEAR	FREQ.	CUM. FREQ.	PCT.	CUM. PCT.
1944	1	1	0.00	0.00
1948	7	8	0.01	0.01
1949	17	25	0.02	0.03
1952	1	26	0.00	0.03
1963	1	27	0.00	0.03
1973	1	28	0.00	0.03
1975	3	31	0.00	0.03
1976	8	39	0.01	0.04
1978	108	147	0.11	0.16
1979	31	178	0.03	0.19
1980	55	233	0.06	0.25
1981	259	492	0.27	0.52
1982	295	787	0.31	0.83
1983	29	816	0.03	0.86
1984	95	911	0.10	0.97
1985	185	1096	0.20	1.16
1986	177	1273	0.19	1.35
1987	283	1556	0.30	1.65
1988	328	1884	0.35	2.00
1989	811	2695	0.86	2.86
1990	778	3473	0.82	3.68
1991	1032	4505	1.09	4.77
1992	1403	5908	1.49	6.26
1993	2409	8317	2.55	8.81
1994	3661	11978	3.88	12.69
1995	5579	17557	5.91	18.60
1996	6408	23965	6.79	25.39
1997	6572	30537	6.96	32.36
1998	8419	38956	8.92	41.28
1999	12605	51561	13.36	54.64
2000	11388	62949	12.07	66.70
2001	9159	72108	9.71	76.41
2002	4184	76292	4.43	80.84
2003	4099	80391	4.34	85.19
2004	2685	83076	2.85	88.03
2005	3028	86104	3.21	91.24
2006	2183	88287	2.31	93.55
2007	3101	91388	3.29	96.84
2008	1729	93117	1.83	98.67
2009	1167	94284	1.24	99.91
2010	88	94372	0.09	100.00

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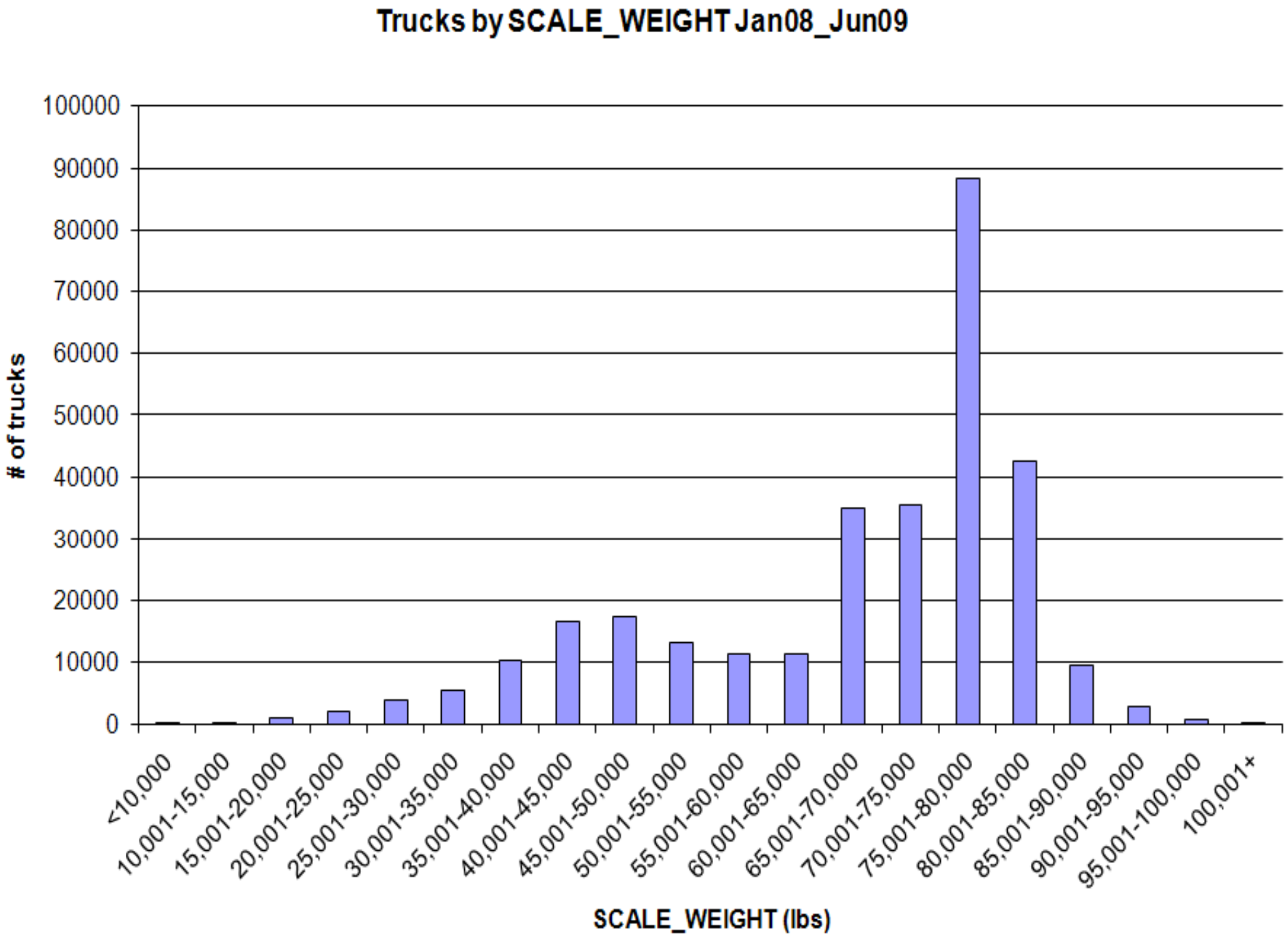
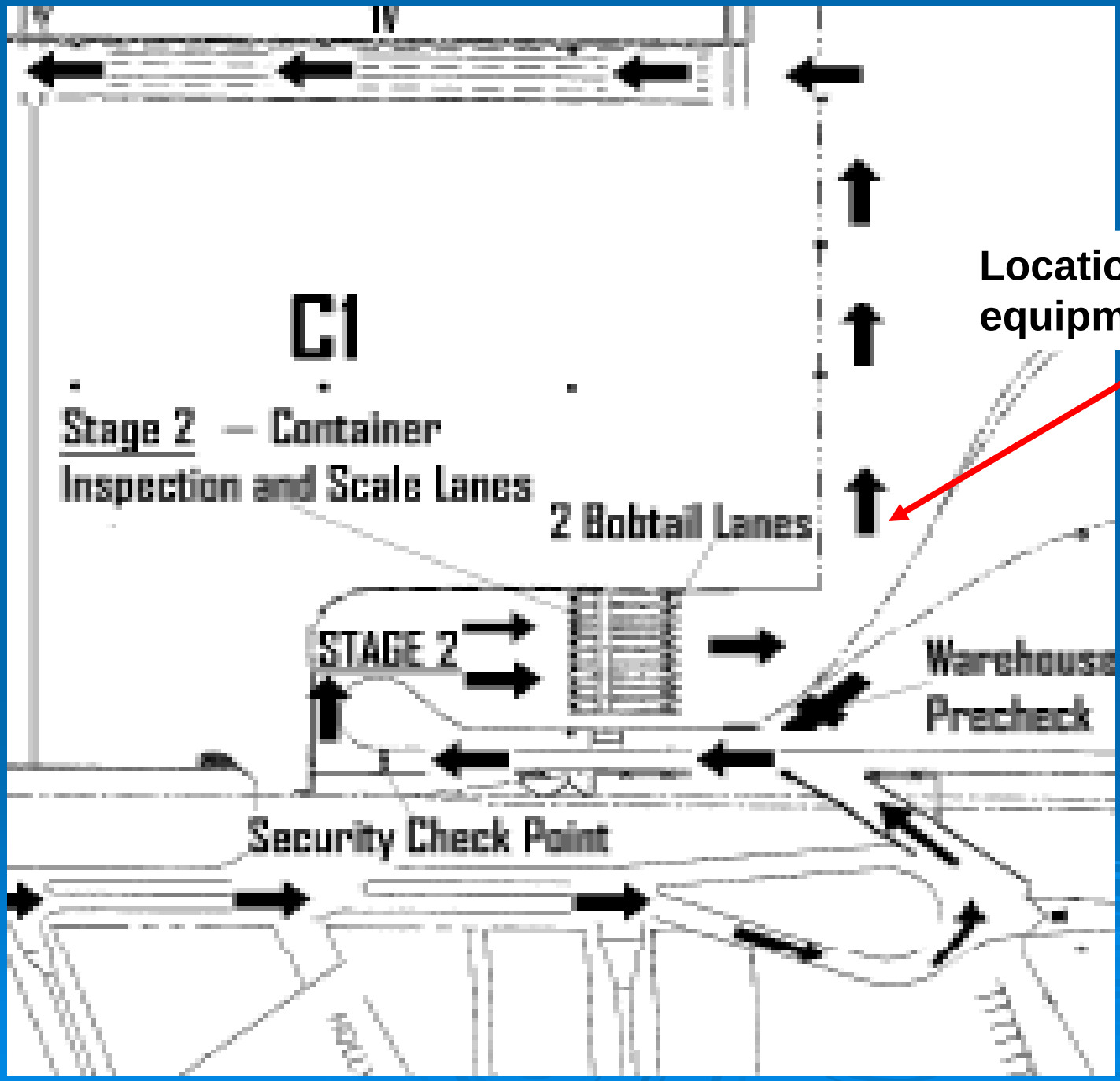

Trucks by SCALE_WEIGHT Jan08_Jun09
# of trucks
100000
90000
80000
70000
60000
50000
40000
30000
20000
10000
0
<10,000
10,001-15,000
15,001-20,000
20,001-25,000
25,001-30,000
30,001-35,000
35,001-40,000
40,001-45,000
45,001-50,000
50,001-55,000
55,001-60,000
60,001-65,000
65,001-70,000
70,001-75,000
75,001-80,000
80,001-85,000
85,001-90,000
90,001-95,000
95,001-100,000
100,001+
SCALE_WEIGHT (lbs)

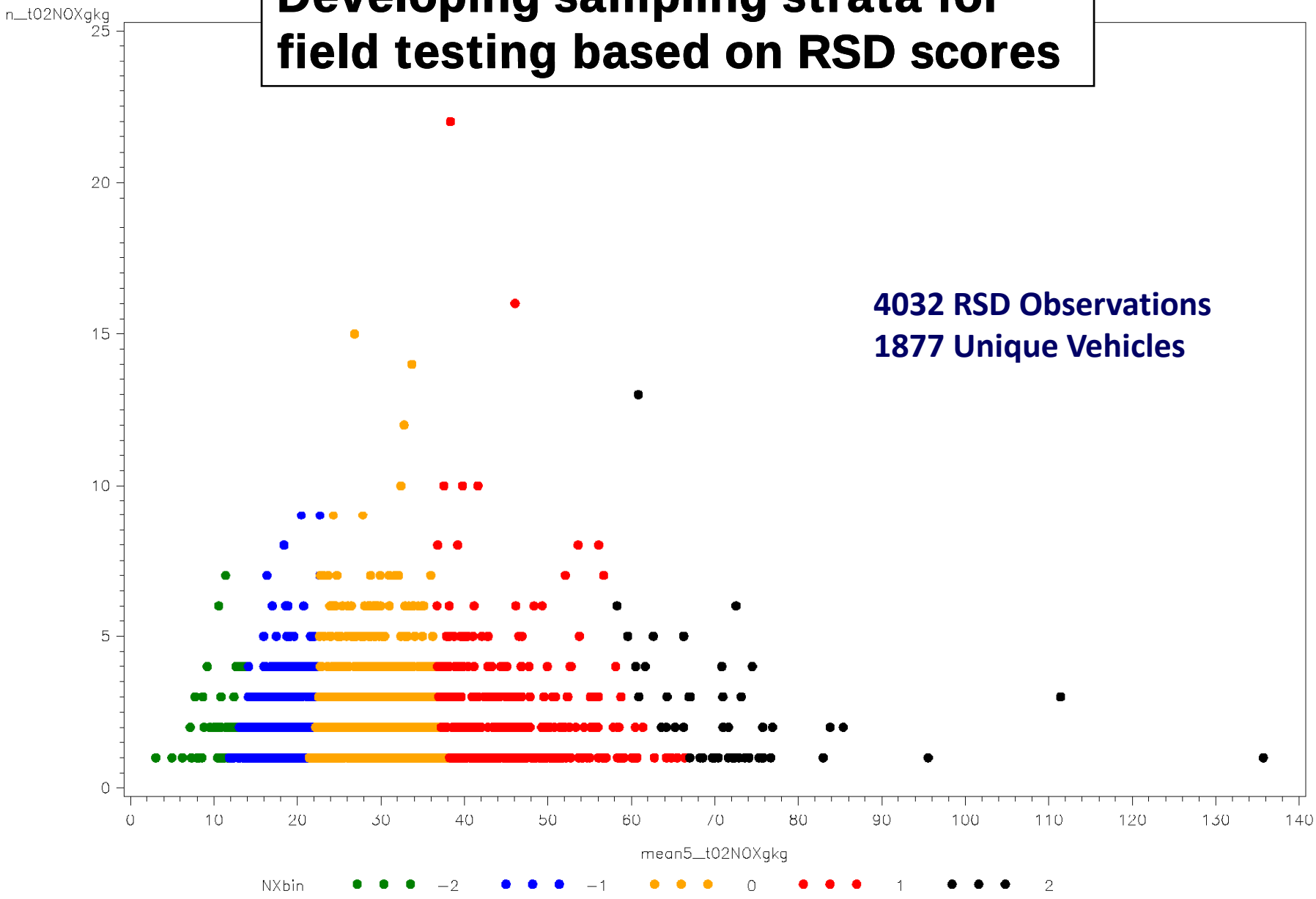
RSD Screening Study

- Conducted by University of Denver
- 2 weeks in July 2009
- Gaseous pollutants (CO2, CO, THC & NOx)
- Measured at entry gate of Barbour's Cut port
- Matched license plates to TX DOT database
- RSD readings: 4,032
- Unique vehicles: 1,877


C1
Stage 2 — Container
Inspection and Scale Lanes
2 Bobtail Lanes
STAGE 2
Warehouse
Precheck
Security Check Point
Location of RSD equipment

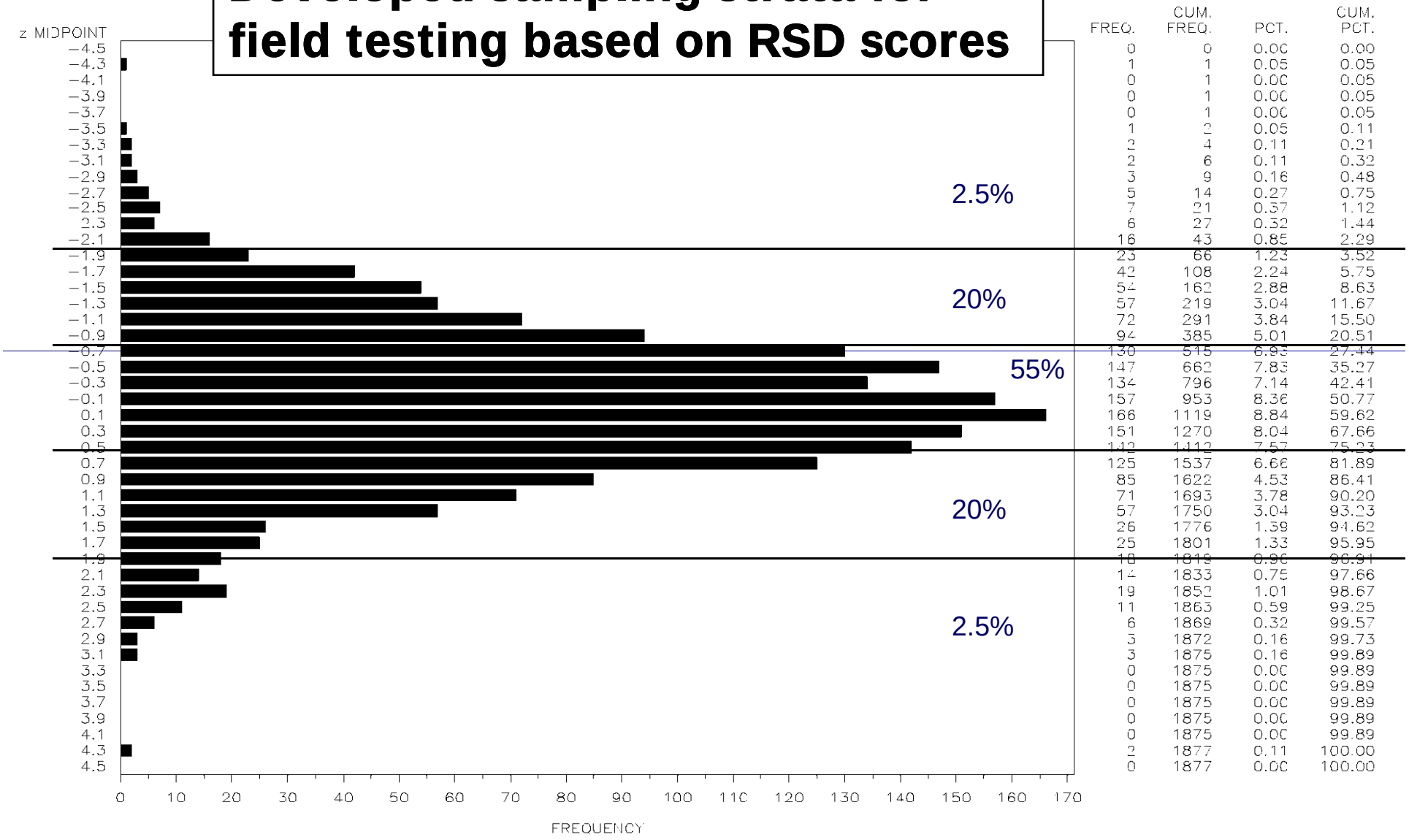
RSD Equipment

Developing sampling strata for field testing based on RSD scores



4032 RSD Observations
1877 Unique Vehicles

Developed sampling strata for field testing based on RSD scores



Developed Model Year and NOx Bins for Field Set and Desired Stratified Sample

Field Set

	NXbin					
	-2	***-1***	***0***	***1***	***2***	
1978-1993	8	23	69	20	2	**122**
1994-1997	1	34	259	175	25	**494**
1998-2003	11	234	636	168	16	**1065**
2004-2006	11	65	43	8	4	**131**
2007-2010	15	20	26	4	0	**65**
	46	**376**	**1033**	**375**	**47**	***1877***

Proportional

	NXbin					
	-2	***-1***	***0***	***1***	***2***	
1978-1993	0.1	0.4	1.2	0.3	0.0	**2.1**
1994-1997	0.0	0.6	4.4	3.0	0.4	**8.4**
1998-2003	0.2	4.0	10.8	2.9	0.3	**18.2**
2004-2006	0.2	1.1	0.7	0.1	0.1	**2.2**
2007-2010	0.3	0.3	0.4	0.1	0.0	**1.1**
	0.8	**6.4**	**17.6**	**6.4**	**0.8**	***32***

Stratified

	NXbin					
	-2	***-1***	***0***	***1***	***2***	
1978-1993	1	1	1	1	1	**5**
1994-1997	0	1	2	2	2	**7**
1998-2003	1	2	3	2	2	**10**
2004-2006	1	2	1	1	1	**6**
2007-2010	1	1	1	1	0	**4**
	4	**7**	**8**	**7**	**6**	***32***

Preliminary Field Results

Measurement Equipment

- **Portable Emissions - SEMTECH DS**
  - Gaseous pollutants (CO2, CO, THC, NO & NO2), with exhaust flow
  - GPS, RPM and engine parameters
  - Teflon membrane filters (PM) @ 47 C
- **Portable Activity**
  - Isaac data loggers
  - GPS and RPM (older vehicles)
  - GPS & engine parameters (J1708 & J1939)

Testing Summary

- **Portable Emissions Tests (≈ 1 day)**
  - Gaseous & PM: 22 Tests
  - Gaseous-only: 24 Tests
  - Total: 46 Tests on 37 Trucks
- **Portable Activity Tests (≈ 1 week)**
  - Total: 23 Tests on 23 Trucks
  - Some trucks received both PEMS and PAMS

Count of Trucks Tested, by RSD Bin, Model Year Group & Test Type

NOX Emission BINS

Model Year Groups	-2	-1	0	1	2	No RSD
2007 - 2010	1 0	1 0	1 0	1 0	0 0	
2004 - 2006	1 0	2 2	1 1	1 0	1 1	(2)
1998 - 2003	1 0	2 2 (2)	3 2 (8)	2 2	2 0	(4)
1994 - 1997	0 0	1 0 (1)	2 1 (1)	2 3	2 0	(2)
1978 - 1993	1 0	1 1	1 1	1 1	1 0	

Shaded cells = completed bins

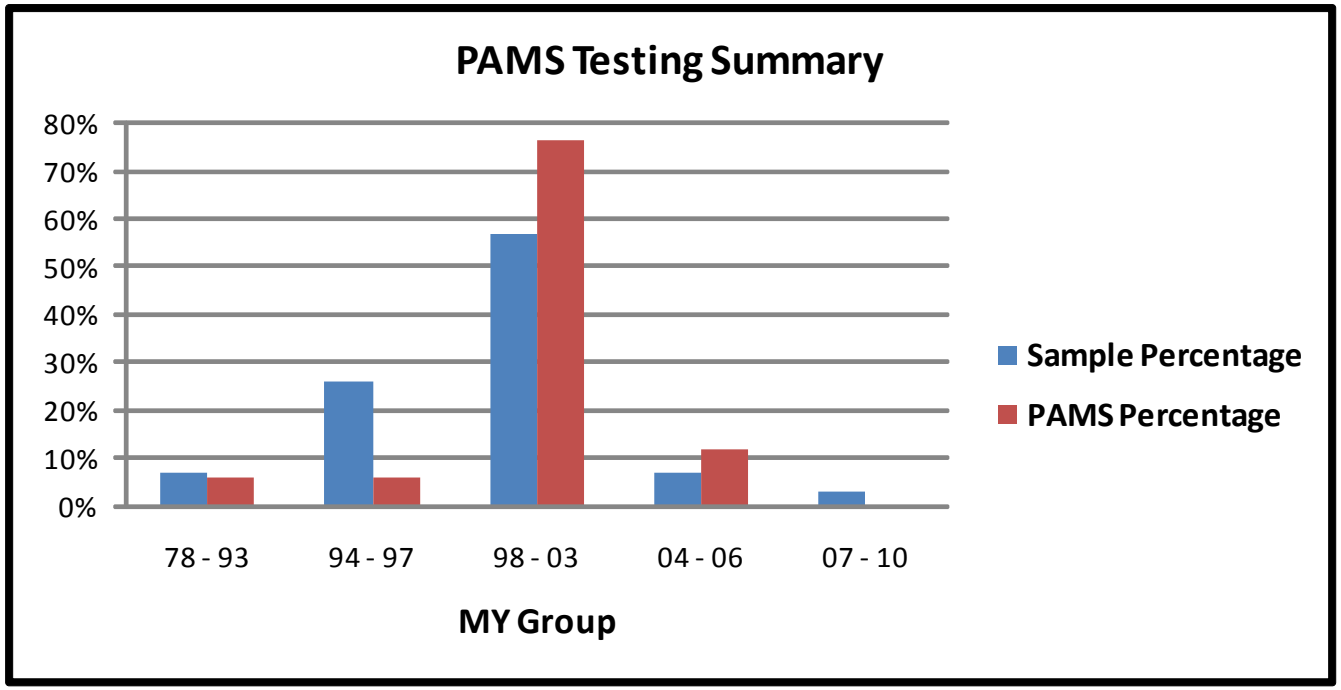
Green numbers = bin targets.

Red numbers = trucks which received full PM and Gaseous tests

(Black numbers) = trucks which received gaseous oversample tests

Count PAMS Tests Conducted, by Model Year Group

MY Group	78 - 93	94 - 97	98 - 03	04 - 06	07 - 10
# in Sample	122	494	1065	131	65
Sample %	7%	26%	57%	7%	3%
PAMS Count	1	3	17	2	0
PAMS %	6%	6%	76%	12%	0%



PEMS Vehicle Example

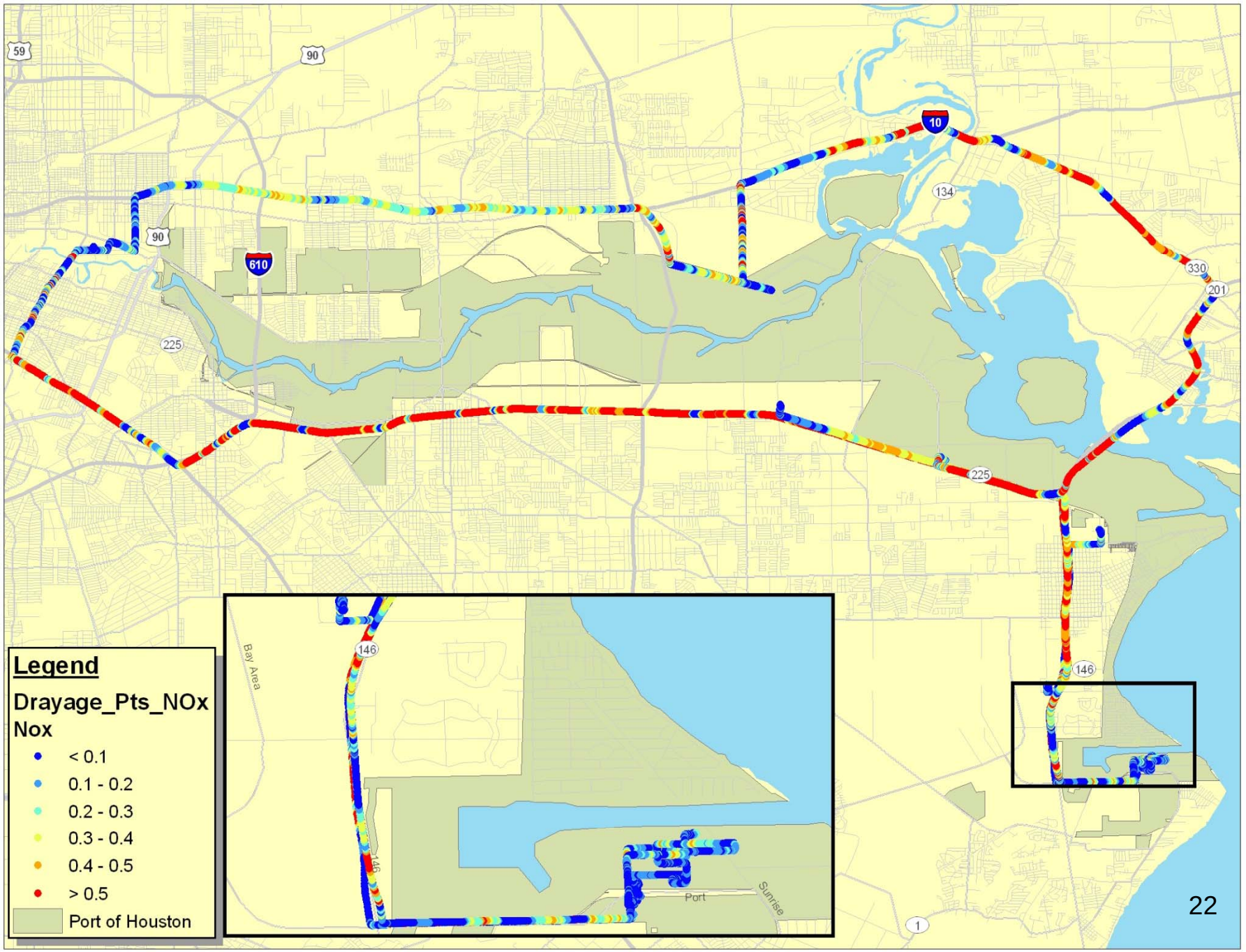
- MY 1994 Freightliner

PM Filters

Semtech_DS

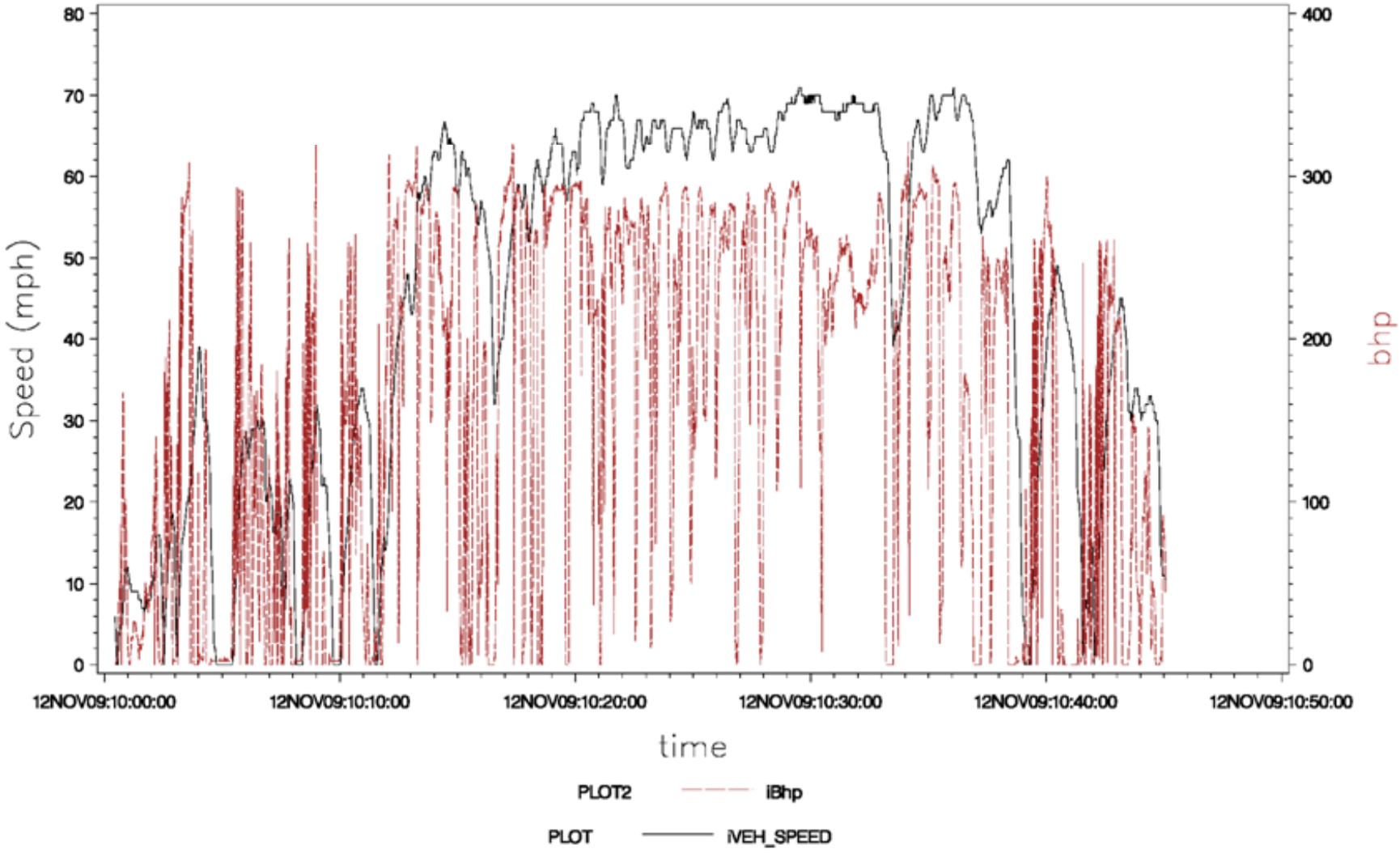
PM Proportional Sampler System

Exhaust System


Legend
Drayage_Pts_NOx
Nox
< 0.1
0.1 - 0.2
0.2 - 0.3
0.3 - 0.4
0.4 - 0.5
> 0.5
Port of Houston
59
90
610
10
134
330
201
225
146
Bay Area
Port
Sunrise
1

Speed and BHP by Sequence

1994 Freightliner Non Port Activity



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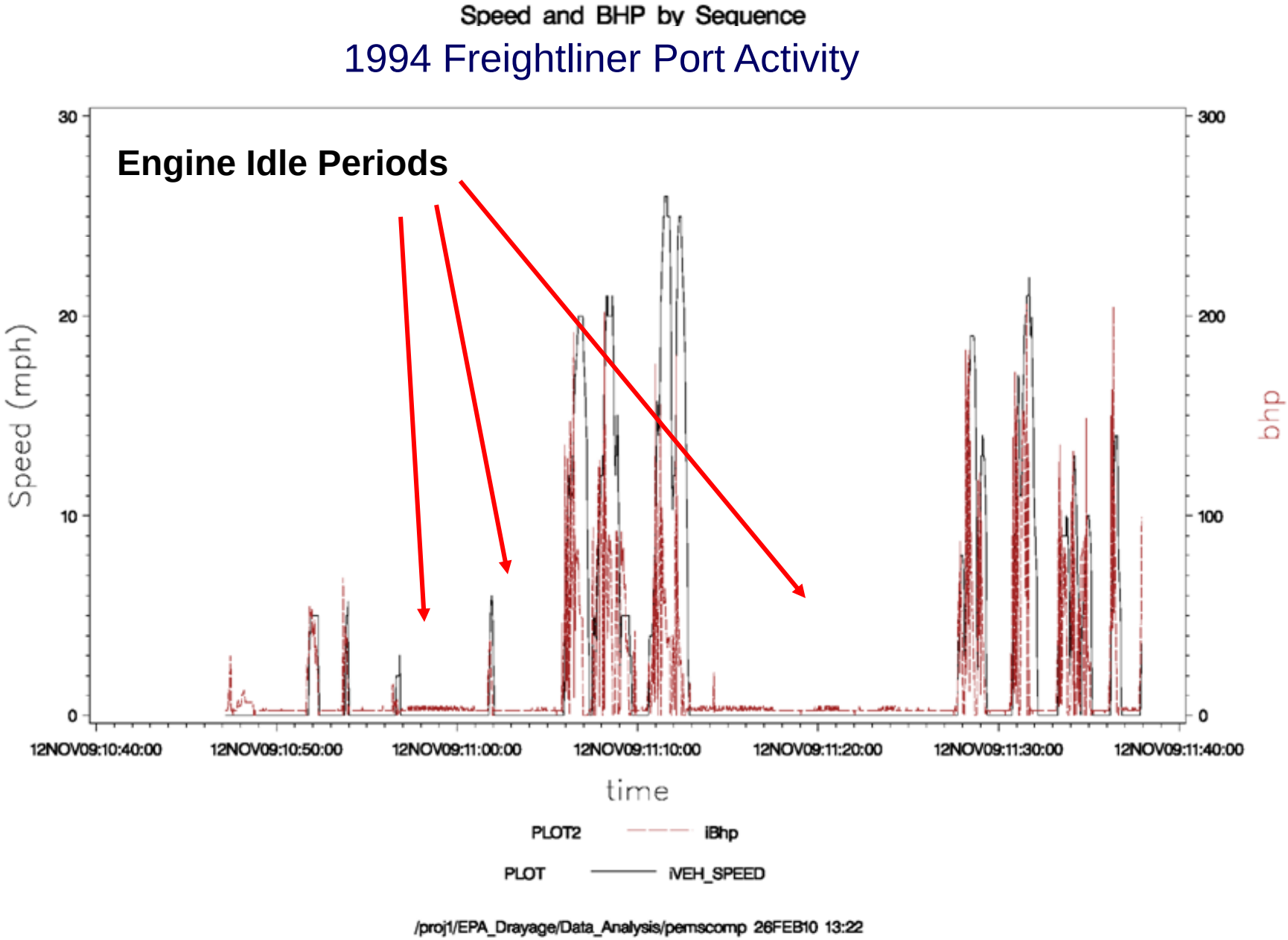
Speed and BHP by Sequence
1994 Freightliner Port Activity
Engine Idle Periods
Speed (mph)
bhp
30
20
10
0
300
200
100
0
12NOV09:10:40:00
12NOV09:10:50:00
12NOV09:11:00:00
12NOV09:11:10:00
12NOV09:11:20:00
12NOV09:11:30:00
12NOV09:11:40:00
time
PLOT2 iBhp
PLOT iVEH_SPEED
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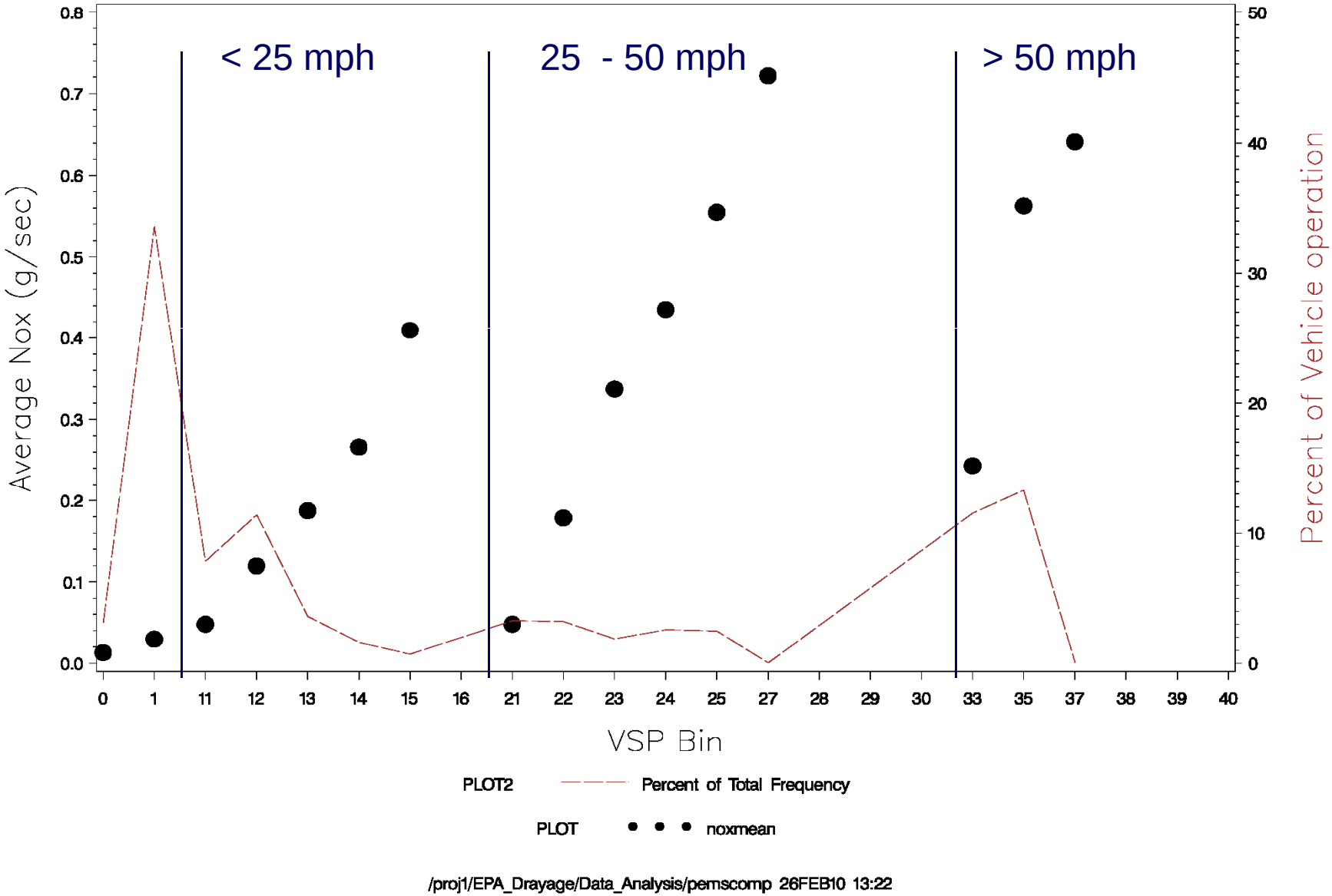
Port vs. Non-Port (Onroad) Activity & Emissions

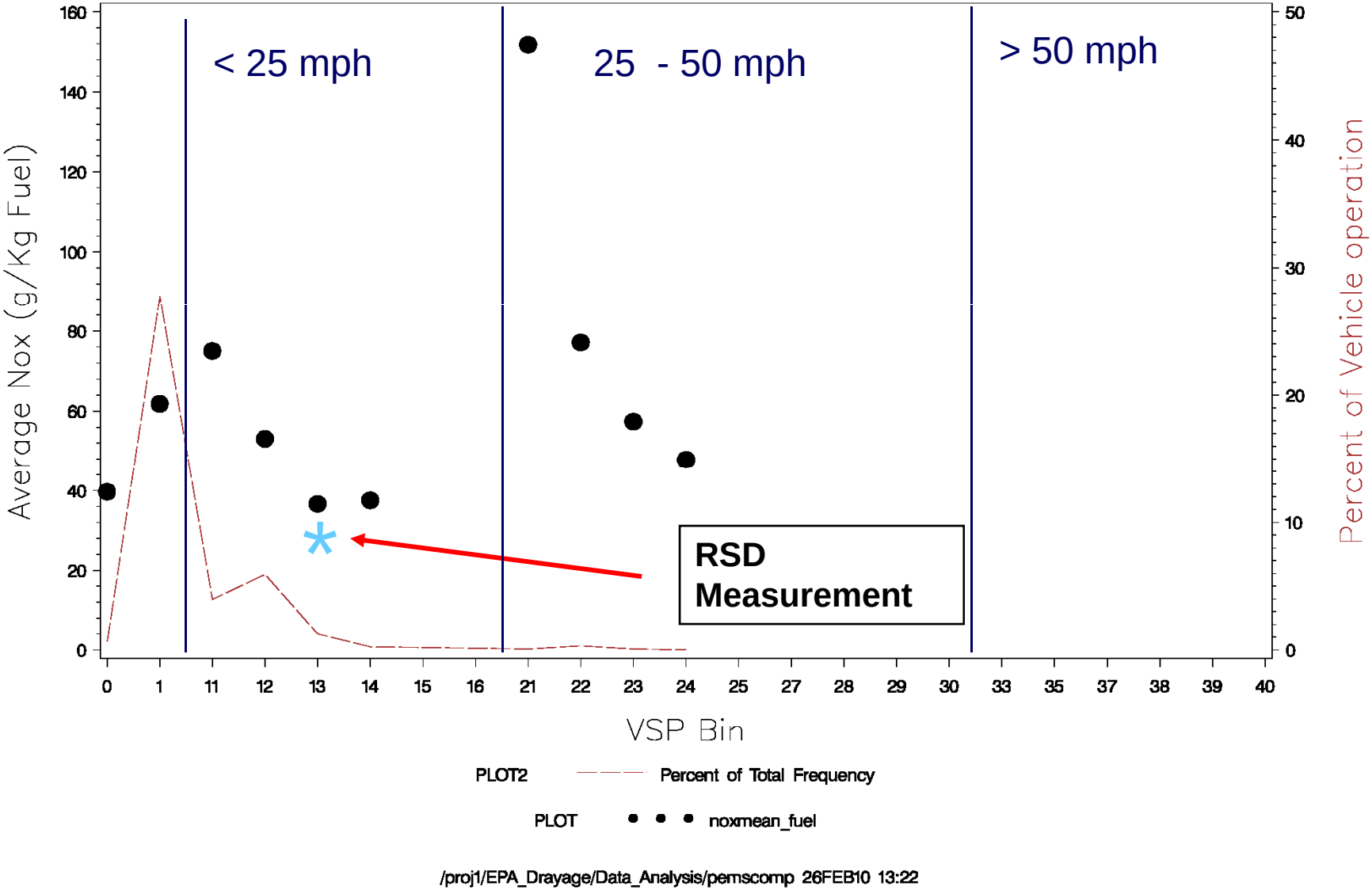
(1994 Freightliner)

		Contrast of Non Port and Port Activity/Emissions					
	Time (min)	Idle (%)	Distance (miles)	Total PM (g)	Total Nox (g)	Total CO (g)	Total HC (g)
Non Port	155	10.0%	99	31	2517	602	598
Port	104	69.0%	6	14	331	199	288

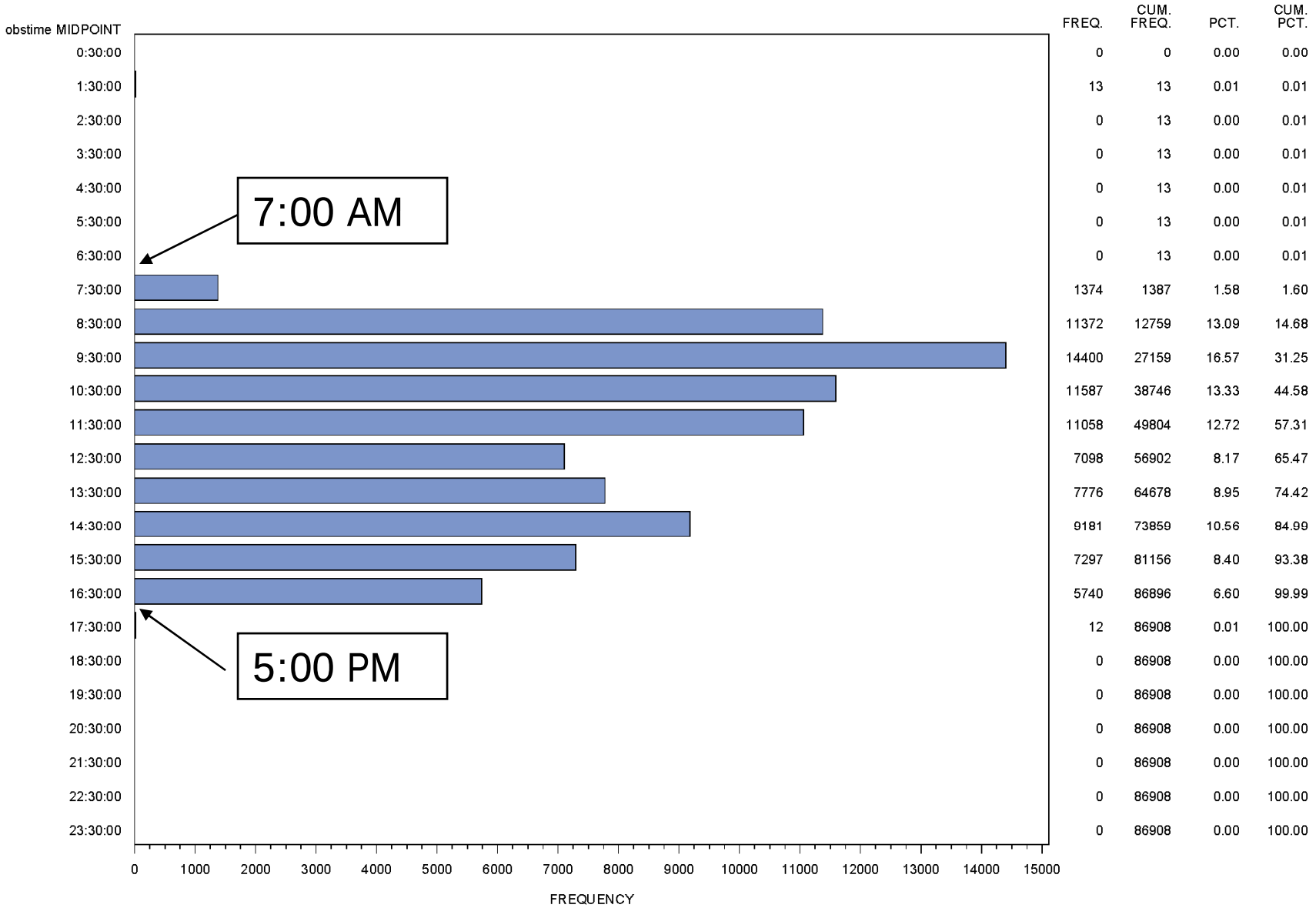
1994 Freightliner NOx Emissions & Activity by MOVES Vehicle Specific Power (VSP) Bin – Non port



1994 Freightliner NOx / Fuel Ratio by VSP Bin for Port Operation



Distribution of Time in Operation



obstime MIDPOINT	FREQ.	CUM. FREQ.	PCT.	CUM. PCT.
0:30:00	0	0	0.00	0.00
1:30:00	13	13	0.01	0.01
2:30:00	0	13	0.00	0.01
3:30:00	0	13	0.00	0.01
4:30:00	0	13	0.00	0.01
5:30:00	0	13	0.00	0.01
6:30:00	0	13	0.00	0.01
7:30:00	1374	1387	1.58	1.60
8:30:00	11372	12759	13.09	14.68
9:30:00	14400	27159	16.57	31.25
10:30:00	11587	38746	13.33	44.58
11:30:00	11058	49804	12.72	57.31
12:30:00	7098	56902	8.17	65.47
13:30:00	7776	64678	8.95	74.42
14:30:00	9181	73859	10.56	84.99
15:30:00	7297	81156	8.40	93.38
16:30:00	5740	86896	6.60	99.99
17:30:00	12	86908	0.01	100.00
18:30:00	0	86908	0.00	100.00
19:30:00	0	86908	0.00	100.00
20:30:00	0	86908	0.00	100.00
21:30:00	0	86908	0.00	100.00
22:30:00	0	86908	0.00	100.00
23:30:00	0	86908	0.00	100.00

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Conclusions

- Areas can take advantage of MOVES flexibility using available local data and targeted field work
- RSD screening very useful for improving sampling in portable emissions/activity measurement studies
- Preliminary data shows that in-port emissions are important to quantify
- State, Local and Federal collaboration is key for comprehensive field studies

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