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1991 Air Quality Data Summary

for the counties

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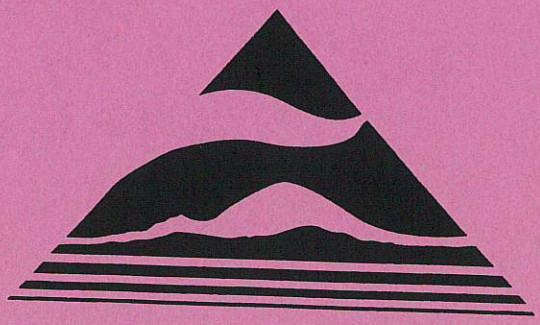

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PUGET SOUND AIR POLLUTION CONTROL AGENCY

Serving King, Kitsap, Pierce and Snohomish Counties

1991 AIR QUALITY DATA SUMMARY

Contents

Reference copies of this summary have been placed in public and college libraries within the Puget Sound Region. Copies are available at the Puget Sound Air Pollution Control Agency Seattle headquarters office. A single copy picked up at the Seattle office is free; otherwise the price for each copy is: $4.00 (plus $2.00 postage and handling if mailed).

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EXECUTIVE SUMMARY

Introduction

This twentieth annual data summary reviews 1991 air quality and meteorological data for the Puget Sound Region. The report begins with sampling network tables providing the address and type of sampling at each location. Summaries of pollutant measurements and information to assist in interpretation appear within the report. Sections near the back summarize air pollution episodes and "impaired air quality" periods and provide meteorological analyses consisting of wind speed averages and wind roses.

Air pollution consists of a complex mixture of compounds that are often difficult to quantify. National ambient air quality standards have been established for the six common pollutants known as carbon monoxide, particulate matter, ozone, sulfur dioxide, lead and nitrogen dioxide. For these pollutants Federal law requires meeting the national primary standards that protect health and establishes deadlines for states to develop and implement plans to achieve the air quality standards.

The Washington Department of Ecology and the Puget Sound Air Pollution Control Agency have established state and local ambient air quality standards for the same six pollutants that are at least as stringent as the national standards. The state and the local ambient sulfur dioxide standard pre-dates the national standard and is also more stringent than the national standard. A table of all these ambient air quality standards and a discussion of the characteristics and effects of each of those air pollutants appear on the last two facing pages of this report.

In specific areas, the Puget Sound Region has been designated out of compliance with the standards for the pollutants carbon monoxide, ozone and particulate matter. The Region is in attainment of the standards for sulfur dioxide, lead and nitrogen dioxide.

Daily Air Quality

The Agency uses the national Pollutant Standards Index to report daily air quality. The Index value is calculated directly from pollutant measurements, and the report includes a descriptive term for the daily Index value.

These terms describe the air quality (in progressively more polluted stages) as "Good", "Moderate", "Unhealthful", or "Very Unhealthful". Any pollutant measurement exceeding the short term national primary standard causes the Index value to be in the Unhealthful or a worse category.

The daily Pollutant Standards Index values provide a way to summarize the air quality for the entire year. In 1991:

Everett had 188 Good, 176 Moderate, and 1 Unhealthful days;
Seattle had 256 Good, 109 Moderate, and zero Unhealthful days;
Tacoma had 282 Good, 82 Moderate, and 1 Unhealthful days.

Carbon Monoxide

The carbon monoxide nonattainment area includes Everett, Seattle, Bellevue and Tacoma. During 1991, only the station in downtown Everett and the station in downtown Tacoma measured carbon monoxide values that exceeded the level of the primary (health related) standard of 9 ppm averaged over eight hours. These cases for Everett and Tacoma are summarized below.

Location	Number of Days 8 hr Avg Exceeded 9 ppm	Highest 8 hr Avg (ppm)
Everett, Broadway	1	10.2
Tacoma, 1101 Pacific	1	9.6

Particulate Matter

The particulate matter standards adopted by the U. S. EPA in July 1987 measure only PM_{10} (particles 10 micrometers or less in diameter). The

levels for the national primary and secondary PM_{10} standards are 150 $\mu g/m^3$ for a 24 hour average and 50 $\mu g/m^3$ for an annual arithmetic mean. Washington State and Puget Sound Region PM_{10} standards were established at the same level as the national PM_{10} standards.

For 1991, none of the daily or annual average PM_{10} values exceeded the level of the standard. The following table summarizes the maximum daily PM_{10} value and the annual PM_{10} arithmetic average by monitoring location for the year 1991.

1991 PM_{10} Summary

Location	Maximum Daily PM_{10} Value ($\mu g/m^3$)	Annual PM_{10} Arith Avg ($\mu g/m^3$)
Marysville, City Hall	123	27.8
Marysville, Jr Hi School	103	---
Everett, Hoyt & 26th	57	24.9
Bellevue, Bellevue Wy NE	82	22.8
Lake Forest Pk, City Hall	135	28.3
Seattle, Harbor Is	116	35.6
Seattle, Duwamish	143	37.0
Seattle, South Park	89	27.1
Kent, James & Central	146	32.1
Puyallup, South Hill	68	---
NE Tacoma, 27th & 54th	82	30.4
Tacoma, Taylor Way	94	30.5
Tacoma, Alexander	99	29.4
Tacoma, E 11th St	130	35.4
Kitsap County, Meadowdale	65	---

None of the annual PM_{10} values for the past three calendar years exceeded the annual PM_{10} standard of 50 $\mu g/m^3$, so the Puget Sound Region is in compliance with the annual PM_{10} standard.

The last three years of data must also be used to determine compliance with the 24 hour average PM_{10} standard. The U. S. EPA requires attainment to be determined by statistically adjusting for days without data and then calculating the average number of days per year exceeding the standard at a particular location for the last three years. If this "expected" number of days above the standard exceeds one, then the PM_{10} standard has not been attained.

Through 1991 there were no locations within the Puget Sound Region where the "expected" number of days above the standard exceeded one per year. The following table shows the only monitoring location where the "expected" number of days per year with daily values exceeding 150 $\mu g/m^3$ is more than zero.

Location	Number of Days Expected to Exceed 150 $\mu g/m^3$
Tacoma, E 11th St	0.3

To determine if wood smoke was threatening the PM_{10} standard in some residential areas, the Puget Sound Air Pollution Control Agency installed fully instrumented PM_{10} monitoring stations in the following wood smoke impacted areas beginning during the months as shown below. None of the PM_{10} values have exceeded the national PM_{10} standard since monitoring began in these locations.

Location	Sampling began	Max Daily PM_{10} value since beginning ($\mu g/m^3$)
Marysville, City Hall/JHS	Nov 89	123
Lake Forest Pk, City Hall	Jun 89	135
Puyallup, South Hill	Dec 91	68
Kitsap County, Meadowdale	Nov 91	65

Ozone

Ozone is a photochemical pollutant with highest levels measured on hot days from mid May to mid September. In 1987 the Puget Sound Region attained the ozone standard, but monitoring data during the summer of 1990 resulted again in a designation as out of compliance with this standard.

If a particular location shows more than one (1.0) daily maximum hour per year, averaged over the last three years, with a concentration greater than 0.12 ppm, then the ozone standard has been violated. At the Enumclaw monitoring location, for the three year period ending with 1991, the "expected" number of days per year with an hourly average above 0.12 ppm calculated to be 1.3 days; all other ozone monitoring locations showed 1.0 or fewer days.

The following table summarizes the maximum 1 hour average ozone value during 1991 for each ozone monitoring site.

1991 Ozone Summary

Location	Maximum 1 hr Avg (ppm)
Lake Sammamish State Park	0.109
Ravensdale	0.101
Enumclaw, Highway 410	0.112
La Grande, Pack Forest	0.099

Weather and Air Quality

One of the variables that influences the air quality on a given day is the weather. Weather never causes high pollutant levels, but sometimes under stable conditions the pollutants emitted from human activities are not quickly dispersed.

Poor dispersion exists on about one-third of the days during nighttime and early morning hours, but the weather effectively disperses pollutants by afternoon on most of these days. A few times during the months of January, February, October, November or December each year, poor dispersion persists for 24 or more hours and may result in the declaration of an "air pollution episode" or local "impaired air quality". These cases are often associated with the higher pollutant levels.

During 1991, the Department of Ecology declared the "Forecast" stage of an air pollution episode that included the Puget Sound Region during the following periods:

10:00 am, Tuesday, January 22 -
3:00 pm, Thursday, January 24;

10:00 am, Monday, December 16 -
4:00 pm, Tuesday, December 17.

Beginning in the fall of 1990, revisions to the Washington Clean Air Act changed the criteria for determining "impaired air quality" as well as defining two stages of "impaired air quality". During 1991, the Puget Sound Air Pollution Control Agency declared a local condition of "impaired air quality" resulting in a burn ban on four occasions effective during the following periods:

2:30 pm, Saturday, January 5 -
9:30 am, Sunday, January 6;

2:30 pm, Monday, January 21 -
3:00 pm, Thursday, January 24;

2:30 pm, Tuesday, January 29 -
8:30 am, Thursday, January 31;

2:30 pm, Sunday, December 15 -
2:30 pm, Tuesday, December 17.

Other Information Sources

All data collected are reported to the Washington State Department of Ecology; some of it is forwarded from there to the Aerometric Information Retrieval System maintained by the U. S. EPA. The Department of Ecology conducts air monitoring within the Puget Sound Region along with that done by our Agency. The Department publishes an annual summary of data for the entire state. Requests for the state summary should be directed to the Washington Department of Ecology - PV11, Air Program, Olympia, WA 98504-8711.

The current daily Pollutant Standards Index is available toll free from the Puget Sound Air Pollution Control Agency by dialing 1-800-433-2215.

1991 SAMPLING NETWORK

Location	*Type of Sampling*			
City Hall, 514 Delta Ave, Marysville, Wa (discontinued Sep 25)	PM_{10}	$(PM_{10})_{eq}$		
Marysville JHS, 1605 7th St, Marysville, Wa (began Sep 27)	PM_{10}	$(PM_{10})_{eq}$		Wind
Hoyt Ave & 26th St, Everett, Wa	PM_{10}			b_{sp}, SO_2, Wind
* Broadway & Hewitt Ave, Everett, Wa			CO	
* 622 Bellevue Way NE, Bellevue, Wa			CO	
* 504 Bellevue Way NE, Bellevue, Wa	PM_{10}			
* 20050 SE 56th, Lake Sammamish State Park, Wa (seasonal)				O_3
17711 Ballinger Way NE, Lake Forest Park, Wa	PM_{10}	$(PM_{10})_{eq}$		b_{sp}, Wind
* Northgate, 310 NE Northgate Way, Seattle, Wa			CO	
* Sand Point, 7600 Sand Pt Way NE, Seattle, Wa				Wind, Temp, dT
* 5701 8th Ave NE, Seattle, Wa				TSP/Pb
* University Dist, 1307 NE 45th St, Seattle, Wa			CO	
* 1424 4th Ave, Seattle, Wa			CO	
* 5th Ave & James St, Seattle, Wa			CO	
* Beacon Hill, 15th S & Charlestown, Seattle, Wa				Wind, Temp
Harbor Island, 2555 13th Ave SW, Seattle, Wa				TSP/Pb
Harbor Island, 3400 13th Ave SW, Seattle, Wa	PM_{10}			
Duwamish, 4752 E Marginal Way S, Seattle, Wa	PM_{10}			$PM_{2.5}$, b_{sp}, SO_2, Wind

Notes- (1) *Type of Sampling*:

PM_{10}	=	Particulate Matter ≤ 10 micrometers (reference method)	b_{sp}	=	Atmospheric Particles (by nephelometer)
$(PM_{10})_{eq}$	=	Particulate Matter ≤ 10 micrometers (equivalent method)	O_3	=	Ozone
CO	=	Carbon Monoxide	SO_2	=	Sulfur Dioxide
$PM_{2.5}$	=	Particulate Matter ≤ 2.5 micrometers	TSP/Pb	=	Total Suspended Particulates and Lead
Wind	=	Wind Direction & Speed	Temp	=	Air Temperature
			dT	=	delta Temperature

(2) * Station operated by Washington State Department of Ecology.

1991 SAMPLING NETWORK

Location	*Type of Sampling*		
South Park, 723 S Concord St, Seattle, Wa	PM_{10}		
James St & Central Ave, Kent, Wa	PM_{10}	$(PM_{10})_{eq}$	$PM_{2.5}$, b_{sp}, Wind
* Ravensdale, Wa (seasonal)			O_3
* Highway 410, 2 miles east of Enumclaw, Wa (seasonal)			O_3
* Charles L Pack Forest, La Grande, Wa (seasonal)			O_3
South Hill, 9616 128th St E, Puyallup, Wa (began Dec 7)	PM_{10}	$(PM_{10})_{eq}$	Wind
* 5233 Circle Drive NE, Northeast Tacoma, Wa (began Sep 24)			Wind, Temp
27th St NE & 54th Ave NE, Northeast Tacoma, Wa	PM_{10}		b_{sp}, SO_2, Wind
2340 Taylor Way, Tacoma, Wa	PM_{10}		
2301 Alexander Ave, Tacoma, Wa	PM_{10}		SO_2, Wind
Fire Station #12, 2316 E 11th St, Tacoma, Wa	PM_{10}		$PM_{2.5}$, b_{sp}, Wind
* 1101 Pacific Ave, Tacoma, Wa		CO	
Meadowdale, 7252 Blackbird Dr NE, Kitsap Co, Wa (began Nov 23)	PM_{10}	$(PM_{10})_{eq}$	Wind

Notes- (1) *Type of Sampling*:

PM_{10}	=	Particulate Matter ≤ 10 micrometers (reference method)	b_{sp}	=	Atmospheric Particles (by nephelometer)
$(PM_{10})_{eq}$	=	Particulate Matter ≤ 10 micrometers (equivalent method)	O_3	=	Ozone
CO	=	Carbon Monoxide	SO_2	=	Sulfur Dioxide
$PM_{2.5}$	=	Particulate Matter ≤ 2.5 micrometers	Temp	=	Air Temperature
Wind	=	Wind Direction & Speed			

(2) * Station operated by Washington State Department of Ecology.

POLLUTANT STANDARDS INDEX

The Pollutant Standards Index (PSI) provides a nationally uniform method to report daily air quality levels. In cooperation with the Washington State Department of Ecology, the Puget Sound Air Pollution Control Agency began reporting the PSI in 1980 for the Everett, Seattle, and Tacoma areas.

Measured pollutant levels during each day convert to a scale that shows if there are potential health effects. This Index scale, ranging from zero to 500, categorizes air quality by the following descriptions:

from	0	to	50,	Good;
from	51	to	100,	Moderate;
from	101	to	199,	Unhealthful;
from	200	to	299,	Very Unhealthful;
from	300	to	500,	Hazardous.

The table below shows the pollutant concentration and the averaging period associated with each PSI value that is a break-point between Index categories. PSI values for pollutant concentrations between break-points are determined by linear interpolation.

Whenever the PSI is greater than 100, a measured pollutant level has exceeded the national primary air quality standard established to protect health. An index value of 200 means the pollutant concentration has reached the "Alert" level in the Washington Episode Avoidance Plan.

For each day, the pollutant levels within the cities of Everett, Seattle and Tacoma convert to the PSI value. The daily Index value for each city comes from the pollutant with the highest value on the PSI scale. The highest values usually occur near congested traffic or an industrial area.

Since high ozone levels occur some distance downwind of Everett, Seattle or Tacoma on hot summer afternoons, the Agency reports the ozone PSI value in a downwind area during the months from May through September. For 1991, the maximum ozone PSI value of 93 occurred near Enumclaw on July 2.

Tables that follow summarize the daily PSI values for Everett, Seattle, and Tacoma. The 1991 summary table shows for each month: the number of days in each PSI interval, the maximum Index, the date of the maximum and the pollutant determining the maximum value.

A 1980 through 1991 summary table shows annually the number of days in each air quality category and the number of days each pollutant determined the PSI. For all the unhealthful days each year (Index values greater than 100), this summary also tabulates the pollutant responsible. The right-hand columns list the highest PSI value for each year.

Pollutant Concentration for Each PSI Break-point Value

PSI Value	CO *8 hr Avg (ppm)*	PM10 *24 hr Avg ($\mu g/m^3$)*	SO_2 *24 hr Avg (ppm)*	O_3 *1 hr Avg (ppm)*
50	4.5	50	0.03	0.06
100	9.0	150	0.14	0.12
200	15.0	350	0.30	0.20
300	30.0	420	0.60	0.40
400	40.0	500	0.80	0.50
500	50.0	600	1.00	0.60

POLLUTANT STANDARDS INDEX

1991

EVERETT

Number of Days in Each PSI Interval during Each Month

AIR QUALITY	(PSI Interval)	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL
GOOD	(0 to 50)	17	15	19	17	18	15	18	17	9	9	19	15	188
MODERATE	(51 to 100)	14	13	12	13	13	15	13	14	21	22	11	15	176
UNHEALTHFUL	(101 to 199)	0	0	0	0	0	0	0	0	0	0	0	1	1
VERY UNHEALTHFUL	(200 to 299)	0	0	0	0	0	0	0	0	0	0	0	0	0
Maximum PSI each month		78	100	67	89	78	78	78	78	78	100	78	117	117
Date		29th	8th	1st#	19th	20th#	21st	12th	2nd#	4th#	4th	5th#	16th	Dec 16
Pollutant		CO	CO	CO	CO	CO	CO	CO	CO	CO	CO	CO	CO	CO

SEATTLE

Number of Days in Each PSI Interval during Each Month

AIR QUALITY	(PSI Interval)	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL
GOOD	(0 to 50)	10	10	16	23	30	29	29	30	25	19	23	12	256
MODERATE	(51 to 100)	21	18	15	7	1	1	2	1	5	12	7	19	109
UNHEALTHFUL	(101 to 199)	0	0	0	0	0	0	0	0	0	0	0	0	0
VERY UNHEALTHFUL	(200 to 299)	0	0	0	0	0	0	0	0	0	0	0	0	0
Maximum PSI each month		97	89	89	67	53	52	56	56	57	64	78	100	100
Date		21st	1st#	1st	1st	1st	6th	23rd	15th	16th#	11th	22nd	15th#	Dec 15#
Pollutant		PM	CO	CO	CO	PM	PM	CO	CO	PM	PM	CO	CO	CO

TACOMA

Number of Days in Each PSI Interval during Each Month

AIR QUALITY	(PSI Interval)	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL
GOOD	(0 to 50)	13	16	25	26	28	29	30	31	25	18	22	19	282
MODERATE	(51 to 100)	17	12	6	4	3	1	1	0	5	13	8	12	82
UNHEALTHFUL	(101 to 199)	1	0	0	0	0	0	0	0	0	0	0	0	1
VERY UNHEALTHFUL	(200 to 299)	0	0	0	0	0	0	0	0	0	0	0	0	0
Maximum PSI each month		117	100	67	59	55	66	58	44	58	89	78	68	117
Date		31st	6th	1st	18th	1st	5th	23rd	14th#	25th	11th	14th	15th	Jan 31
Pollutant		CO	CO	CO	PM	PM	PM	PM	PM	PM	CO	CO	PM	CO

PM = Particulate Matter; CO = Carbon Monoxide; SO2 = Sulfur Dioxide.

Earliest date of occurrence

POLLUTANT STANDARDS INDEX

1980 - 1991

EVERETT

	Days in Each Air Quality Category				Pollutant Determining the PSI						Highest Value		
					All Days			Unhealthful Days					
	Good	Moderate	Unhealthful	Very Unhealthful	PM	CO	SO2	PM	CO	SO2	PSI	Date	Pollutant
1980	340	19	0	0	356	-	3	0	-	0	60	Jan 23	PM
1981	350	11	0	0	340	-	21	0	-	0	62	Jan 16	PM
1982	334	30	1	0	277	70	18	0	1	0	117	Dec 30	CO
1983	308	56	1	0	191	150	24	0	1	0	117	Nov 30	CO
1984	309	57	0	0	105	217	44	0	0	0	92	Sep 28	PM
1985	300	64	1	0	152	166	47	0	1	0	117	Dec 11	CO
1986	324	41	0	0	169	148	48	0	0	0	89	Jan 25	CO
1987	203	158	3	0	96	250	18	0	3	0	117	Jun 26#	CO
1988	174	184	8	0	15	345	6	0	8	0	133	Sep 13#	CO
1989	150	213	2	0	26	338	1	0	2	0	133	Feb 10	CO
1990	166	197	2	0	29	335	1	0	2	0	117	Mar 2#	CO
1991	188	176	1	0	32	333	0	0	1	0	117	Dec 16	CO
Totals	3146	1206	19	0	1788	2352	231	0	19	0			

SEATTLE

	Days in Each Air Quality Category				Pollutant Determining the PSI						Highest Value		
					All Days			Unhealthful Days					
	Good	Moderate	Unhealthful	Very Unhealthful	PM	CO	SO2	PM	CO	SO2	PSI	Date	Pollutant
1980	73	275	18	0	95	270	1	1	17	0	194	Jan 23	PM
1981	69	267	28	1	109	254	2	5	24	0	213	Jan 15	CO
1982	86	268	10	1	96	264	5	1	10	0	214	Feb 6	PM
1983	98	258	9	0	101	261	3	0	9	0	183	Jan 28	CO
1984	146	218	2	0	111	242	13	2	0	0	103	Dec 6	PM
1985	150	202	10	3	156	206	3	6	7	0	204	Dec 12	PM
1986	130	226	8	1	113	246	6	1	8	0	206	Jan 7	PM
1987	120	238	7	0	119	246	0	3	4	0	184	Feb 6	PM
1988	215	146	5	0	67	298	1	2	3	0	150	Dec 3	CO
1989	231	134	0	0	129	233	3	0	0	0	100	Jan 19#	CO
1990	239	126	0	0	141	218	6	0	0	0	100	Jan 18	CO
1991	256	109	0	0	141	216	8	0	0	0	100	Dec 15#	CO
Totals	1813	2467	97	6	1378	2954	51	21	82	0			

TACOMA

	Days in Each Air Quality Category				Pollutant Determining the PSI						Highest Value		
					All Days			Unhealthful Days					
	Good	Moderate	Unhealthful	Very Unhealthful	PM	CO	SO2	PM	CO	SO2	PSI	Date	Pollutant
1980	83	271	12	0	256	107	3	4	8	0	160	Apr 12	PM
1981	74	278	10	3	222	137	6	1	12	0	227	Jan 12	CO
1982	119	242	4	0	255	101	9	0	4	0	167	Dec 30	CO
1983	140	222	3	0	228	128	9	1	2	0	137	Dec 23	PM
1984	162	198	6	0	207	149	10	0	6	0	117	Jan 19#	CO
1985	140	213	12	0	252	109	4	1	11	0	165	Dec 13	PM
1986	161	197	7	0	247	114	4	2	5	0	167	Oct 23	CO
1987	173	177	13	2	227	136	2	5	10	0	220	Feb 5	CO
1988	226	132	8	0	184	175	7	3	5	0	183	Jan 27	CO
1989	260	103	2	0	217	121	27	0	2	0	117	Nov 30#	CO
1990	289	75	1	0	237	87	41	1	0	0	118	May 5	PM
1991	282	82	1	0	268	85	12	0	1	0	117	Jan 31	CO
Totals	2109	2190	79	5	2800	1449	134	18	66	0			

Earliest date of occurrence

PARTICULATE MATTER

Introduction

Particulate Matter as a general term includes small particles of dust, soot, organic matter and compounds containing sulfur, nitrogen, and metals. In July 1987, the U. S. EPA changed the national particulate matter standards from Total Suspended Particulates (TSP) to only that portion of particulate matter with particle diameters smaller than or equal to 10 micrometers (PM_{10}). The levels for both the national primary and secondary standards are: 150 $\mu g/m^3$ for a 24 hour average and 50 $\mu g/m^3$ annual arithmetic mean. The PM_{10} standards also include calculation formulas to statistically determine if the standards are attained (40 CFR Part 50, Appendix K).

Particulate Sources and Air Quality

Particulates directly enter the air from industrial operations, from auto, bus and truck traffic, from fuel combustion including wood stoves and fireplaces, from construction, and from other sources. The emission levels change daily due to intermittent industrial operations, equipment upset or breakdown, traffic cycles and building heating requirements. Gaseous transformation products like sulfates, nitrates, and some organics are also components of particulate matter. When emitted to the air, the wind disperses and transports particulate matter. Ambient levels change from day to day in response to what enters the air and to the variations in weather.

Sampling Methods

Reference methods designated by the U. S. EPA to measure PM_{10} all draw outside air first through an inlet which traps particulates larger than 10 micrometers and then through a filter that collects the remaining particulate matter (PM_{10}). Sampling for a single measurement continues for 24 hours usually from midnight to midnight.

After sampling, the pre-weighed filter must be manually removed. Following conditioning in a controlled atmosphere for 24 hours to remove moisture effects, the sampled filter is weighed on a precise balance to calculate the weight of particulate matter collected. The volume of air sampled, corrected to standard temperature and pressure conditions, is calculated from the flow rate and sampling time. The ambient PM_{10} concentration is the weight (mass) of particulate collected divided by the volume of air sampled, and is reported in micrograms per standard cubic meter.

The U. S. EPA has designated three methods as *equivalent methods* for the measurement of PM_{10}; two use a measurement principle based on beta-ray attenuation; one uses a tapered element oscillating micro balance. All three equivalent methods are automated and continuous so that PM_{10} values may be immediately telemetered to a central computer. These methods also measure consecutive daily values without manual intervention.

During 1991, the Puget Sound Air Pollution Control Agency installed five equivalent method PM_{10} beta attenuation instruments at locations that receive impacts from wood smoke. These were collocated with at least one manual, reference method instrument to enable data comparison on some days.

An integrating nephelometer continuously measures the light scattering extinction coefficient. A component of the scattering coefficient due to dry particles, (b_{sp}), generally shows good correlation to PM_{10} values and to visibility. The b_{sp} values are reported as a scattering coefficient per meter times 10^{-4}. Operating a nephelometer at a site concurrent with a reference method enables development of a relationship between the two methods for that site.

Graphs and Summaries of Data

The following graphs and tables summarize PM_{10} data from both reference and equivalent methods and b_{sp} values from nephelometer measurements. Column graphs for selected stations present a PM_{10} history from the beginning of PM_{10} measurements. None of the annual PM_{10} values for the past six calendar years exceeded the annual PM_{10} standard of 50 $\mu g/m^3$. None of the daily PM_{10} values during 1991 exceeded the level of the 150 $\mu g/m^3$ standard. However, the tables document that PM_{10} values on a number of days for several stations did exceed the 75 $\mu g/m^3$ "impaired air quality" trigger level established in Washington State law.

PARTICULATE MATTER (PM10)
Micrograms per Standard Cubic Meter

Sampling Method: Reference - Hi Vol ANDERSEN/GMW 1200 Quartz Fiber filters

1991

Location	Number of Values	Quarterly Arithmetic Averages 1st	2nd	3rd	4th	Year Arith Mean
City Hall, 514 Delta Ave, Marysville, Wa	89	40.6	19.0	23.8		27.8
Marysville JHS, 1605 7th St, Marysville, Wa	32			-	33.5	-
Hoyt Ave & 26th St, Everett, Wa	60	29.5	19.5	23.7	26.7	24.9
504 Bellevue Way NE, Bellevue, Wa	342	26.9	17.8	21.1	25.3	22.8
17711 Ballinger Way NE, Lake Forest Park, Wa	315	42.9	17.7	19.2	33.2	28.3
Harbor Island, 3400 13th Ave SW, Seattle, Wa	57	44.5	28.4	30.6	38.9	35.6
Duwamish, 4752 E Marginal Way S, Seattle, Wa	356	47.0	28.3	32.4	40.2	37.0
South Park, 723 S Concord St, Seattle, Wa	60	33.2	18.9	25.5	30.6	27.1
James St & Central Ave, Kent, Wa	323	38.9	22.4	30.9	36.3	32.1
27th St NE & 54th Ave NE, Northeast Tacoma, Wa	60	29.0	25.4	34.6	32.4	30.4
2340 Taylor Way, Tacoma, Wa	57	36.8	22.1	28.6	34.4	30.5
2301 Alexander Ave, Tacoma, Wa	150	36.7	20.9	27.2	32.8	29.4
Fire Station #12, 2316 E 11th St, Tacoma, Wa	356	44.5	25.9	30.8	40.5	35.4

Notes
(1) Nationally scheduled particulate matter sampling occurs each sixth day. Quarterly averages are shown only when at least one data value exists for 75 percent or more of the six day intervals.
(2) Annual averages are shown only if there are at least three quarterly averages.

Summary of Maximum and 2nd High Observed Concentrations

Location	Jan 3 Thu	Jan 4 Fri	Jan 5 Sat	Jan 21 Mon	Jan 24 Thu	Jan 29 Tue	Jan 30 Wed	Jan 31 Thu	Feb 6 Wed	May 16 Thu	Jun 5 Wed	Oct 9 Wed	Oct 15 Tue	Oct 30 Wed	Dec 14 Sat
City Hall, 514 Delta Ave, Marysville, Wa	102	--	--	123		--		--	--	--		--	--	--	--
Marysville JHS, 1605 7th St, Marysville, Wa	--	--	--	--	--	--	--	--	--	--	--			76	78
Hoyt Ave & 26th St, Everett, Wa	--	--	--	--		--	56	--	--	--			57	--	
504 Bellevue Way NE, Bellevue, Wa				82						82					
17711 Ballinger Way NE, Lake Forest Park, Wa		135	131		--		--								
Harbor Island, 3400 13th Ave SW, Seattle, Wa	--	--	--	--	68	--	116	--	--	--				--	
Duwamish, 4752 E Marginal Way S, Seattle, Wa				143					127	--					
South Park, 723 S Concord St, Seattle, Wa	--	--	--	--		--	89	--	--	--		71		--	
James St & Central Ave, Kent, Wa		146		115											
27th St NE & 54th Ave NE, Northeast Tacoma, Wa	--	--	--	--		--		--	--	--	82	82		--	
2340 Taylor Way, Tacoma, Wa	--	--	--	--		--	94	--	--	--		78		--	
2301 Alexander Ave, Tacoma, Wa		--		--		99	--	85	--		--	--		--	
Fire Station #12, 2316 E 11th St, Tacoma, Wa		129		130											

-- Indicates no sample on specified day

PARTICULATE MATTER (PM10)
Micrograms per Standard Cubic Meter

Sampling Method: Reference - Hi Vol ANDERSEN/GMW 1200 Quartz Fiber filters

Jan - Feb, 1991

Summary of Observations Equal To or Greater Than 75

Location	Jan 2 Wed	Jan 3 Thu	Jan 4 Fri	Jan 5 Sat	Jan 19 Sat	Jan 21 Mon	Jan 23 Wed	Jan 25 Fri	Jan 26 Sat	Jan 27 Sun	Jan 29 Tue	Jan 30 Wed	Jan 31 Thu	Feb 6 Wed	Feb 7 Thu	Feb 8 Fri	Feb 22 Fri
City Hall, 514 Delta Ave, Marysville, Wa	--	102	--	--	--	123	--	--	--	89	--	78	--	--	--		--
Marysville JHS, 1605 7th St, Marysville, Wa	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
504 Bellevue Way NE, Bellevue, Wa						82											
17711 Ballinger Way NE, Lake Forest Park, Wa	83	126	135	131	75	109	102	87	88	85	96	--					
Harbor Island, 3400 13th Ave SW, Seattle, Wa	--	--	--	--	--	--	--	--	--	--	--	116	--	--	--	--	--
Duwamish, 4752 E Marginal Way S, Seattle, Wa			88			143	86				117	116		127	111	78	75
South Park, 723 S Concord St, Seattle, Wa	--	--	--	--	--	--	--	--	--	--	--	89	--	--	--	--	--
James St & Central Ave, Kent, Wa			146	94		115					96	78					
27th St NE & 54th Ave NE, Northeast Tacoma, Wa	--	--	--	--	--	--	--	--	--	--	--		--	--	--	--	--
2340 Taylor Way, Tacoma, Wa	--	--	--	--	--	--	--	--	--	--	--	94	--	--	--	--	--
2301 Alexander Ave, Tacoma, Wa	--		--	80		--	--	--		--	99	--	85	--	80	--	--
Fire Station #12, 2316 E 11th St, Tacoma, Wa			129	95		130					114	99	78	87	93		

-- Indicates no sample on specified day

Feb - Dec, 1991

Summary of Observations Equal To or Greater Than 75

Location	Feb 25 Mon	Feb 26 Tue	Feb 27 Wed	Feb 28 Thu	Mar 31 Sun	May 16 Thu	Jun 5 Wed	Oct 3 Thu	Oct 9 Wed	Oct 11 Fri	Oct 16 Wed	Oct 30 Wed	Oct 31 Thu	Dec 14 Sat	Dec 15 Sun	Dec 16 Mon	Dec 17 Tue
City Hall, 514 Delta Ave, Marysville, Wa	--	83	--	--		--		--	--	--	--	--	--	--	--	--	--
Marysville JHS, 1605 7th St, Marysville, Wa	--	--	--	--	--	--	--			--	--	76	--	78	--	--	
504 Bellevue Way NE, Bellevue, Wa		--				82				--	--						
17711 Ballinger Way NE, Lake Forest Park, Wa					78										--	79	
Harbor Island, 3400 13th Ave SW, Seattle, Wa	--	--	--	--		--				--	--	--	--		--	--	--
Duwamish, 4752 E Marginal Way S, Seattle, Wa		79	113	95		--				78					87	80	104
South Park, 723 S Concord St, Seattle, Wa	--	--	--	--		--				--	--	--	--		--	--	--
James St & Central Ave, Kent, Wa								105							--		
27th St NE & 54th Ave NE, Northeast Tacoma, Wa	--	--	--	--		--	82		82	--	--	--	--		--	--	--
2340 Taylor Way, Tacoma, Wa	--	--	--	--		--			78	--	--	--	--		--	--	--
2301 Alexander Ave, Tacoma, Wa	--		--		--		--		--	--	--	--	75		--	--	
Fire Station #12, 2316 E 11th St, Tacoma, Wa	79	100	91	80						101	84		81		85	77	77

-- Indicates no sample on specified day

PARTICULATE MATTER (PM10)
Micrograms per Standard Cubic Meter

Sampling Method: Equivalent -BetaAtten ANDERSEN FH62I-N Glass Fiber strip

1991

Location	Number of Values	Quarterly Arithmetic Averages 1st	2nd	3rd	4th	Year Arith Mean
City Hall, 514 Delta Ave, Marysville, Wa	234	32.0	19.2	27.4		26.2
Marysville JHS, 1605 7th St, Marysville, Wa	96			-	31.4	-
17711 Ballinger Way NE, Lake Forest Park, Wa	244		-	19.5	28.4	-
James St & Central Ave, Kent, Wa	232		-	32.3	31.3	-

Notes
(1) Nationally scheduled particulate matter sampling occurs each sixth day. Quarterly averages are shown only when at least one data value exists for 75 percent or more of the six day intervals.
(2) Annual averages are shown only if there are at least three quarterly averages.

1991

Summary of Maximum and 2nd High Observed Concentrations

Location	Jan 25 Fri	Jan 29 Tue	Oct 3 Thu	Dec 2 Mon	Dec 15 Sun	Dec 16 Mon	Dec 31 Tue
City Hall, 514 Delta Ave, Marysville, Wa	84	94	--	--	--	--	--
Marysville JHS, 1605 7th St, Marysville, Wa	--	--			103	85	
17711 Ballinger Way NE, Lake Forest Park, Wa	--	--			68	77	
James St & Central Ave, Kent, Wa	--	--	109		88		
South Hill, 9616 128th St E, Puyallup, Wa	--	--	--	--	68		54
Meadowdale, 7252 Blackbird Dr NE, KitsapCo, Wa	--	--	--	53	65		

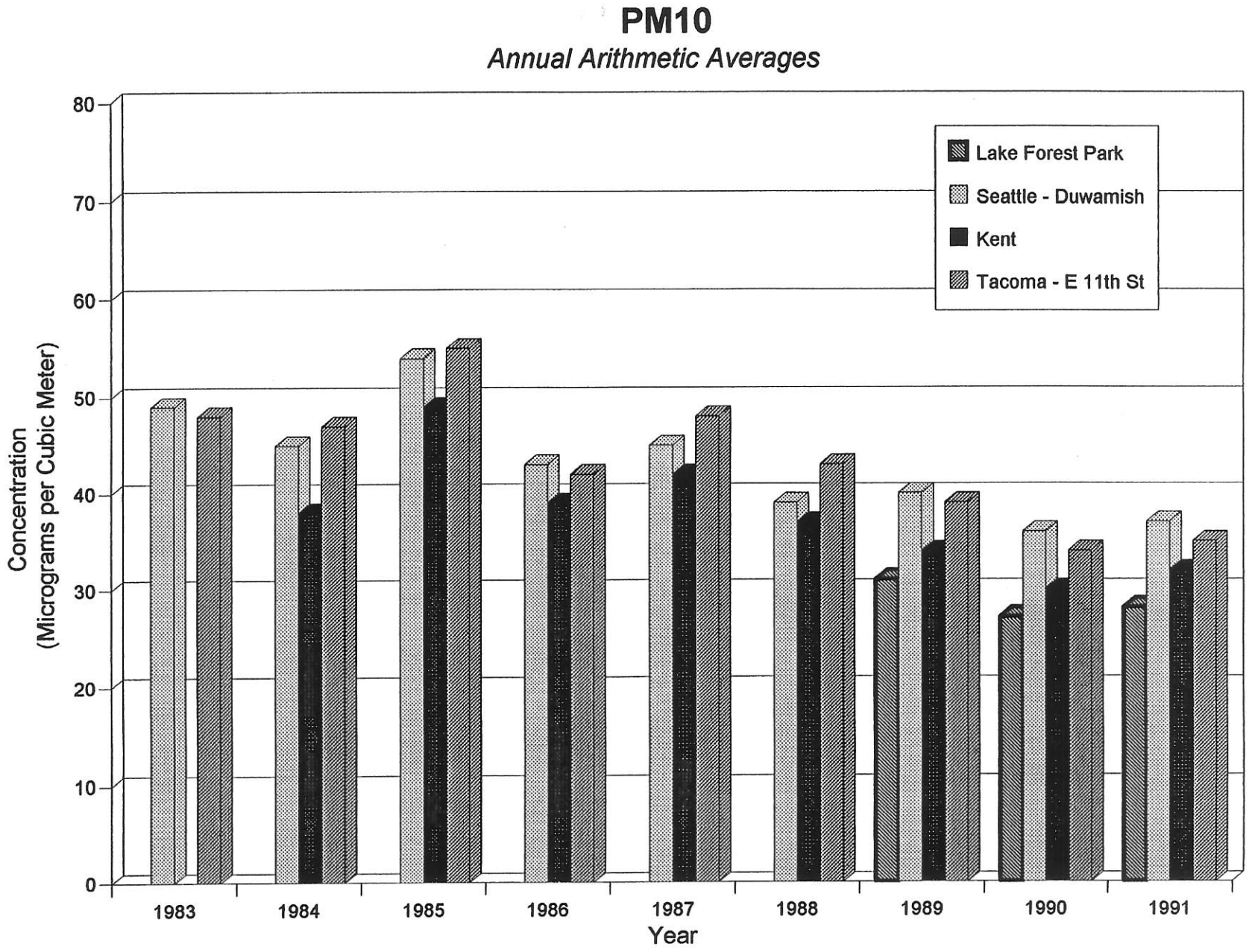
-- Indicates no sample on specified day

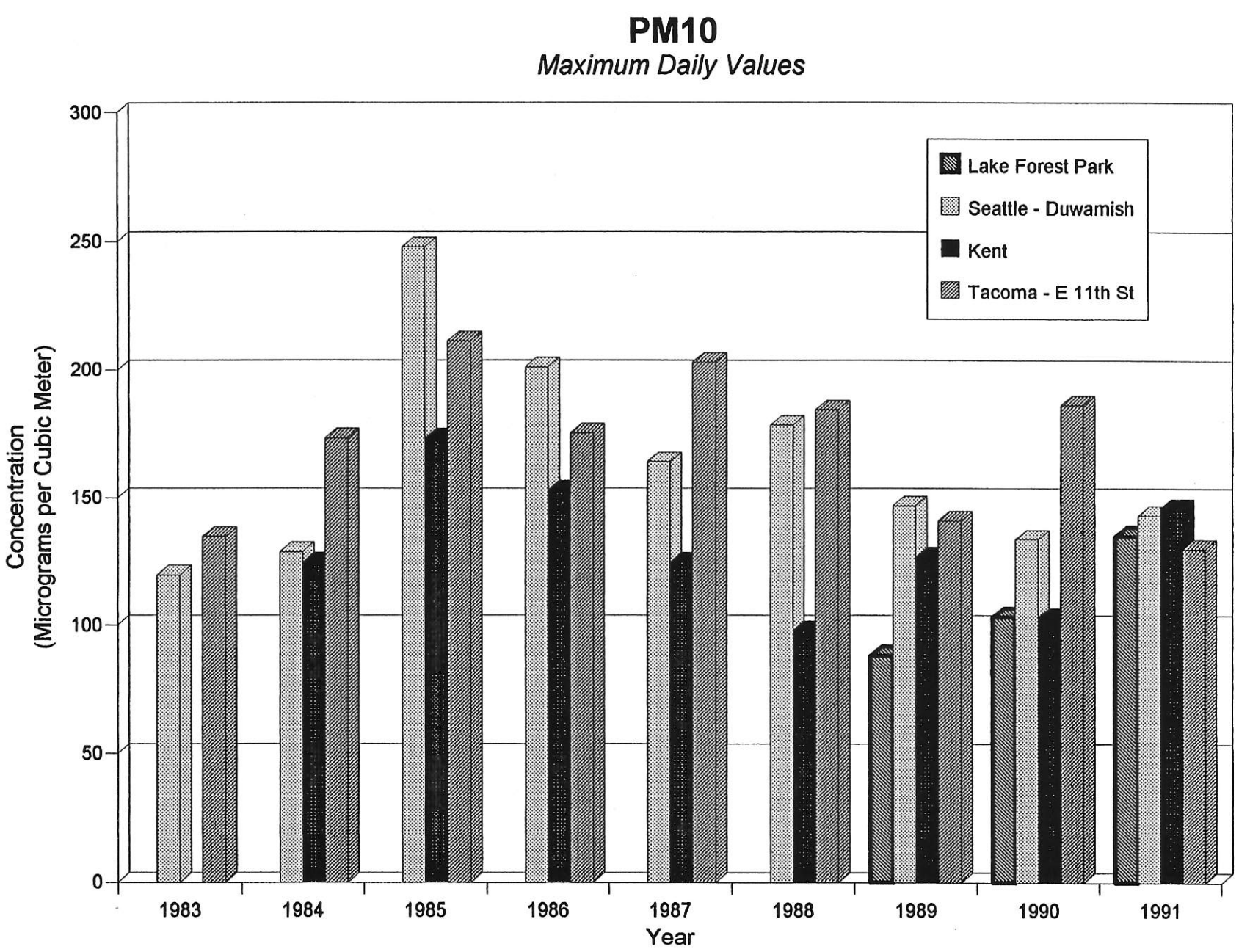
1991

Summary of Observations Equal To or Greater Than 75

Location	Jan 25 Fri	Jan 27 Sun	Jan 29 Tue	Oct 3 Thu	Dec 15 Sun	Dec 16 Mon
City Hall, 514 Delta Ave, Marysville, Wa	84	77	94	--	--	--
Marysville JHS, 1605 7th St, Marysville, Wa	--	--	--		103	85
17711 Ballinger Way NE, Lake Forest Park, Wa	--	--	--			77
James St & Central Ave, Kent, Wa	--	--	--	109	88	

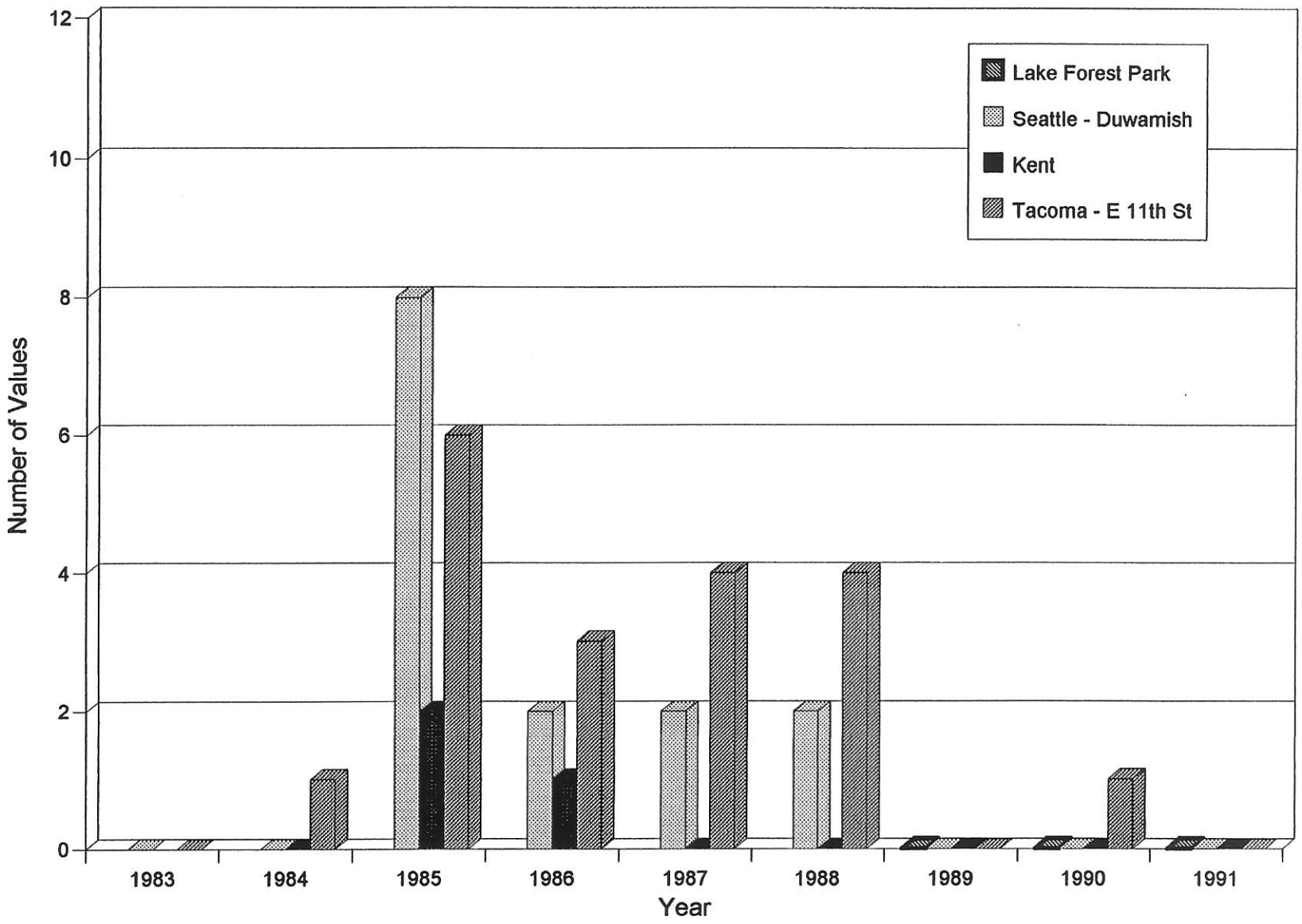
-- Indicates no sample on specified day


PM10
Annual Arithmetic Averages
Concentration
(Micrograms per Cubic Meter)
80
70
60
50
40
30
20
10
0
Lake Forest Park
Seattle - Duwamish
Kent
Tacoma - E 11th St
1983
1984
1985
1986
1987
1988
1989
1990
1991
Year


PM10
Maximum Daily Values
Concentration
(Micrograms per Cubic Meter)
300
250
200
150
100
50
0
1983
1984
1985
1986
1987
1988
1989
1990
1991
Year
Lake Forest Park
Seattle - Duwamish
Kent
Tacoma - E 11th St

PM10

Number of Daily Values Greater than 150 micrograms per cubic meter



ATMOSPHERIC PARTICLES
(bsp (X 10 Exp-4)/M)
1991

Location	Monthly Arithmetic Averages												No. of 1 Hour Samples	Year Arith Mean
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec		
Hoyt Ave & 26th St, Everett, Wa	.84	.62	.53	.47	.38	.28	.37	.38	.59	.80	.53	.64	8657	.54
17711 Ballinger Way NE, Lake Forest Park, Wa	1.39	.83	.64	.46	.40	.23		.34	.52	.81	.75	.95	8360	.64
Duwamish, 4752 E Marginal Way S, Seattle, Wa	.94	.86	.51	.53	.39	.29	.35	.45	.62	.80	.63	.87	8703	.60
James St & Central Ave, Kent, Wa	1.10	.88	.53	.49	.37	.28	.39	.49	.67	.85	.69	.95	8619	.64
27th St NE & 54th Ave NE, Northeast Tacoma, Wa	.78	.61	.40	.40	.31	.24	.31	.36	.49	.67	.63	.71	8645	.49
Fire Station #12, 2316 E 11th St, Tacoma, Wa	1.36	.93	.52	.50	.37	.28	.38	.43	.64	.85	.78	1.08	8477	.67

1991

Statistical Summary

Location	No. of 1 Hour Samples	Frequency Distribution - Percent												1 Hour Max	Arith Mean	Arith Std Dev
		5	10	20	30	40	50	60	70	80	90	95	99			
Hoyt Ave & 26th St, Everett, Wa	8657	.1	.2	.2	.3	.3	.4	.5	.6	.8	1.1	1.4	2.1	3.48	.54	.43
17711 Ballinger Way NE, Lake Forest Park, Wa	8360	.1	.2	.2	.3	.3	.4	.5	.7	.9	1.4	2.0	3.8	7.21	.64	.72
Duwamish, 4752 E Marginal Way S, Seattle, Wa	8703	.2	.2	.3	.3	.4	.4	.5	.7	.8	1.2	1.6	2.6	5.10	.60	.52
James St & Central Ave, Kent, Wa	8619	.1	.2	.2	.3	.4	.5	.6	.7	.9	1.4	1.8	3.2	5.70	.64	.60
27th St NE & 54th Ave NE, Northeast Tacoma, Wa	8645	.1	.1	.2	.2	.3	.3	.4	.5	.7	1.1	1.5	2.2	4.67	.49	.46
Fire Station #12, 2316 E 11th St, Tacoma, Wa	8477	.1	.2	.2	.3	.4	.4	.6	.7	1.0	1.5	2.1	3.2	5.40	.67	.65

PM_{10} SITE SPECIFIC RELATIONSHIPS and ANALYSIS FOR DAYS WITH THE HIGHEST PM_{10} VALUES

Introduction

All the *reference methods* designated by the U. S. EPA to measure PM_{10} collect particulate matter on a filter for a 24 hour period. The actual PM_{10} value is not available until sampling ends and each sampled filter is manually removed, transported to the Seattle laboratory, conditioned for at least 24 hours and then processed. Since this may not be completed for several days, the PM_{10} reference methods provide only historic data.

Measuring the PM_{10} value for the daily Pollutant Standards Index requires a continuous, real-time method since the Federal Regulations indicate the Index should be based on data obtained during the 24 hour period immediately preceding the time of the report. Additionally, under the Washington Clean Air Act and Department of Ecology implementing regulations, real-time PM_{10} values are needed to declare an "impaired air quality" condition. The declaration of "impaired air quality" prohibits outdoor fires and bans most indoor burning.

The U. S. EPA has recently certified three different continuous PM_{10} monitors as *equivalent methods* for the measurement of PM_{10}. When sited and operated according to approved procedures, these new monitors directly measure PM_{10} values that are immediately available to report the daily Index or determine a condition of "impaired air quality".

For other real-time monitoring techniques, site specific relationships may be developed to provide a real-time estimate of the 24 hour average PM_{10} value at specific locations. This procedure has been used in the Puget Sound Region for over eleven years and currently provides real-time estimates of the PM_{10} value from locations where it would not otherwise be available.

Site Specific Relationships

The Federal Regulations (40 CFR Part 58, Appendix G) provide that particulate measurements from samplers other than reference or equivalent method samplers may be included in Pollutant Standards Index calculations, if such measurements can be quantitatively related to reference or equivalent method measurements. The Puget Sound Air Pollution Control Agency used multiple linear regression to quantitatively relate continuous nephelometer particulate measurements of dry particle light scattering (b_{sp}) to the PM_{10} measurements during 1991 for specific sites in Everett, Lake Forest Park, Seattle-Duwamish, Kent, Northeast Tacoma and the Tacoma tide flats.

A summary of the 1991 statistics and results of the multiple regression analysis appears in the table subtitled, "Site Specific PM_{10}, b_{sp} Statistics and Equations". Review of the partial correlation coefficients for all the sites reveals correlation from .70 to .91 between the collocated continuous particulate measurement (b_{sp}) and the PM_{10} value. As documented in the table, two other independent variables, precipitation and day of week, are not correlated to the PM_{10} value, but when included in the multiple regression analysis the resulting equation predicts a PM_{10} value that correlates to the actual PM_{10} value even better than if based on the continuous particulate measurement alone. The multiple correlation coefficient improves to within a range of .81 to .92 for all the sites.

Four of the sites obtained over 300 paired observations providing a significant statistical basis for the multiple regression relationships developed for these locations. The table presents an equation for each site that estimates the actual PM_{10} value as a function of the 24 hour average dry particle light scattering measured by nephelometer (b_{sp}), the logarithm of the 24 hour precipitation (LPR) and the day of week variable (DAY).

For real-time use, the 24 hour average PM_{10} estimate at each site may be calculated for any 24 hour period from the appropriate equation, given the real-time nephelometer measurement and values for the precipitation and day of week variables. Since the most weight in each equation comes from the b_{sp} value, b_{sp} is measured at each site. The precipitation value is obtained from an official National Weather Service station representing the entire area.

Analysis for Days of Highest PM_{10} Values

Periods of stagnant weather that sometimes result in a condition of "impaired air quality" occur during fall and winter, primarily during the months of January, February, November and December. The higher PM_{10} values also occur most often during the fall and winter, except that industrial monitoring locations affected by local industrial emissions do measure higher PM_{10} values during other times of the year.

For the four stations with the most daily PM_{10} values during 1991, all the dates when the PM_{10} value was 75 $\mu g/m^3$ or greater are included in tables showing January on one page and February to December on the following page. Also included are all the dates during which an "impaired air quality" condition and/or the "Forecast" stage of an air pollution episode was in effect. Revisions in the Washington Clean Air Act lowered the PM_{10} value for determining "impaired air quality" from 90 $\mu g/m^3$ to 75 $\mu g/m^3$ beginning in the fall of 1990.

Review of the data shows that none of the measured values exceeded the level of the 24 hour average PM_{10} standard that is established at 150 $\mu g/m^3$. Further, nearly all the measured values exceeding 75 $\mu g/m^3$ during 1991 occurred during the months of January, February, October and December.

As shown in these tables, most of the PM_{10} estimates that differed from the actual PM_{10} values by more than 25 percent are cases where the estimate is low compared to the measured value. This may result from a distribution of particles versus size on those dates that varies from usual for the site.

The nephelometer (b_{sp}) measurement is more responsive to the particles smaller than 2.5 micrometers referred to as "fine" particulates. The actual PM_{10} measurement includes all particles up to the size of 10 micrometers. The component of PM_{10} of size from 2.5 to 10 micrometers is referred to as "coarse" particulates. The coarse component of PM_{10} commonly consists of crustal material (road and fugitive dust) and plant pollens, whereas combustion particles (from wood smoke for example) are primarily fine particulates.

If on a given day the coarse particle component increases compared to the fine particle component, the nephelometer based PM_{10} estimates would likely be low compared to the measured PM_{10} value. For example general industrial activity or construction activity may produce fugitive dust rich in coarse particles. This might occur irregularly throughout the year. Another example that may increase fugitive dust for days (maybe weeks) is that created by the traffic upon roads sanded during snow and freezing temperature.

The tables show that in 1991, underprediction in the PM_{10} estimates occurred at all stations during the first part of January. This followed a two week period of snow and freezing temperatures in late December of 1990. It is also notable that maximum measured PM_{10} values for all these stations also occurred during January.

Second, the tables show that underprediction in the PM_{10} estimates during other months occurred most frequently at the Seattle site and the Tacoma site. Both of these sites are industrial locations. The case on October 3 at Kent documents a situation caused by fugitive dust from site preparation for a construction project about 300 feet northwest of the monitoring station.

In conclusion, reference method PM_{10} values are never available except for an historic review such as done here. Reporting the daily Pollutant Standards Index and managing the "impaired air quality" program require real-time PM_{10} values. The new equivalent method PM_{10} monitors and the nephelometer based PM_{10} site specific relationships provide needed PM_{10} values continuously and in real-time.

PARTICULATE MATTER (PM_{10})

Site Specific PM_{10}, b_{sp} Statistics and Equations
(Developed from Data Collected During Calendar Year 1991)

Sta	Partial Correlation Coefficients: PM_{10} b_{sp}	PM_{10} LPR	PM_{10} DAY	b_{sp} LPR	Mult Corr Coef: PM_{10} all	No. Obs	Equation	Std Err Est
EVT	.90	-.39	.09	-.28	.92	60	$PM_{10} = 2.4 + \mathbf{30.1}\ b_{sp} - \mathbf{1.7}\ LPR + \mathbf{2.6}\ DAY$	5.0
LFP	.91	-.28	-.04	-.22	.92	301	$PM_{10} = 0.7 + \mathbf{34.7}\ b_{sp} - \mathbf{1.6}\ LPR + \mathbf{2.2}\ DAY$	8.1
DWM	.81	-.30	.35	-.17	.87	356	$PM_{10} = 0.4 + \mathbf{35.5}\ b_{sp} - \mathbf{3.3}\ LPR + \mathbf{12.2}\ DAY$	9.7
KNT	.84	-.45	.12	-.25	.89	318	$PM_{10} = -0.6 + \mathbf{30.1}\ b_{sp} - \mathbf{4.5}\ LPR + \mathbf{5.9}\ DAY$	8.6
TNE	.70	-.55	.24	-.29	.81	59	$PM_{10} = -4.7 + \mathbf{34.0}\ b_{sp} - \mathbf{6.8}\ LPR + \mathbf{7.2}\ DAY$	10.6
TDF	.83	-.32	.24	-.14	.88	346	$PM_{10} = 0.0 + \mathbf{30.6}\ b_{sp} - \mathbf{4.2}\ LPR + \mathbf{9.3}\ DAY$	9.6

Abbreviations

- PM_{10} : 24 hour average particulate matter 10 micrometers or less in diameter ($\mu g/m^3$).
- b_{sp} : 24 hour average light scattering due to dry particles ($\times 10^{-4}$ per meter).
- LPR : the common logarithm of the 24 hour precipitation with .001 substituted for Zero and .005 substituted for Trace.
- DAY : set to 1 for Mon, Tue, Wed, Thu or Fri; set to 0 for Sat or Sun.
- No. Obs : number of collocated data observations in the regression analysis.

Station Addresses (Record Period during 1991)

- EVT : Hoyt Ave & 26th St, Everett (Jan - Dec)
- LFP : 17711 Ballinger Way NE, Lake Forest Park (Jan - Dec)
- DWM : Duwamish, 4752 E Marginal Way S, Seattle (Jan - Dec)
- KNT : James St & Central Ave, Kent (Jan - Dec)
- TNE : 27th St NE & 54th Ave NE, Northeast Tacoma (Jan - Dec)
- TDF : Fire Station #12, 2316 E 11th St, Tacoma (Jan - Dec)

PARTICULATE MATTER (PM_{10})

Site Specific Analysis for Days when any PM_{10} Value was 75 $\mu g/m^3$ or Greater
and for Episode or Impaired Air Quality Days

(Jan 1991)

			LkFrstPk (LFP)			Seattle (DWM)			Kent (KNT)			Tacoma (TDF)		
Day	Date		Est $\mu g/m^3$	Val $\mu g/m^3$	Err %	Est $\mu g/m^3$	Val $\mu g/m^3$	Err %	Est $\mu g/m^3$	Val $\mu g/m^3$	Err %	Est $\mu g/m^3$	Val $\mu g/m^3$	Err %
	Jan 91													
Wed	02		47	**83**	-43	49	**43**	14	43	**45**	-4	53	**48**	10
Thu	03		57	**126**	-55	43	**69**	-38	42	**64**	-34	40	**52**	-23
Fri	04		91	**135**	-33	51	**88**	-42	90	**146**	-38	85	**129**	-34
Sat	05	I	106	**131**	-19	56	**74**	-24	69	**94**	-27	90	**95**	-5
Sun	06	I	62			25	**33**	-24	29	**39**	-26	51	**59**	-14
Sat	19		58	**75**	-23	29	**34**	-15	37	**46**	-20	27	**33**	-18
Mon	21	I	98	**109**	-10	122	**143**	-15	118	**115**	3	118	**130**	-9
Tue	22	I,E	91			133						110		
Wed	23	I,E	65	**102**	-36	82	**86**	-5		**72**		73	**64**	14
Thu	24	I,E	73			67	**72**	-7	58	**70**	-17	61	**64**	-5
Fri	25		72	**87**	-17	51	**73**	-30	45	**50**	-10	47	**56**	-16
Sat	26		97	**88**	10	41	**62**	-34	62	**74**	-16	65	**71**	-8
Sun	27		109	**85**	28	72	**64**	13	81	**71**	14	64	**58**	10
Tue	29	I	105	**96**	9	92	**117**	-21	82	**96**	-15	95	**114**	-17
Wed	30	I	70			88	**116**	-24	66	**78**	-15	94	**99**	-5
Thu	31	I	30	**34**	-12	58	**59**	-2	65	**67**	-3	78	**78**	0

Notes

I: A condition of "impaired air quality" was in effect during the following times in King, Kitsap, Pierce and Snohomish counties . . . .

2:30 pm, Sat, **Jan 5** - 9:30 am, Sun, **Jan 6**;
2:30 pm, Mon, **Jan 21** - 3:00 pm, Thu, **Jan 24**;
2:30 pm, Tue, **Jan 29** - 8:30 am, Thu, **Jan 31**.

E: The Department of Ecology declared the "Forecast" stage of an air pollution episode effective during the following time . . . .

10:00 am, Tue, **Jan 22** - 3:00 pm, Thu, **Jan 24**.

Est: Estimated 24 hour average PM_{10} using the site specific equation.

Val: 24 hour average PM_{10} value measured by a reference method.

Err: Error in PM_{10} estimate compared to measured value.

PARTICULATE MATTER (PM_{10})

Site Specific Analysis for Days when any PM_{10} Value was 75 $\mu g/m^3$ or Greater
and for Episode or Impaired Air Quality Days
(Feb - Dec 1991)

Day	Date		LkFrstPk (LFP) Est $\mu g/m^3$	LkFrstPk (LFP) Val $\mu g/m^3$	LkFrstPk (LFP) Err %	Seattle (DWM) Est $\mu g/m^3$	Seattle (DWM) Val $\mu g/m^3$	Seattle (DWM) Err %	Kent (KNT) Est $\mu g/m^3$	Kent (KNT) Val $\mu g/m^3$	Kent (KNT) Err %	Tacoma (TDF) Est $\mu g/m^3$	Tacoma (TDF) Val $\mu g/m^3$	Tacoma (TDF) Err %
Feb 91														
Wed	06		56	**68**	-18	78	**127**	-39	54	**67**	-19	69	**87**	-21
Thu	07		59	**66**	-11	73	**111**	-34	50	**67**	-25	73	**93**	-22
Fri	08		40	**39**	3	69	**78**	-12	55	**69**	-20	55	**72**	-24
Fri	22		50	**50**	0	58	**75**	-23	58	**62**	-6		**71**	
Mon	25		41	**48**	-15	51	**66**	-23	51	**59**	-14	56	**79**	-29
Tue	26		44	**52**	-15	52	**79**	-34	48	**67**	-28	48	**100**	-52
Wed	27		49	**62**	-21	63	**113**	-44	62	**74**	-16	61	**91**	-33
Thu	28		46	**49**	-6	69	**95**	-27	57	**63**	-10	61	**80**	-24
Mar 91														
Sun	31		39	**78**	-50	39	**39**	0	42	**42**	0	38	**41**	-7
Oct 91														
Thu	03		30	**24**	25	57	**42**	36	48	**105**	-54	48	**44**	9
Fri	11		41	**35**	17	72	**78**	-8	52	**59**	-12	72	**101**	-29
Wed	16		15	**17**	-12	25	**40**	-38	16	**23**	-30	22	**84**	-74
Thu	31		59	**50**	18	76	**63**	21	58	**52**	12	80	**81**	-1
Dec 91														
Sun	15	I	97			110	**87**	26	129			110	**85**	29
Mon	16	I,E	94	**79**	19	93	**80**	16	111	**74**	50	111	**77**	44
Tue	17	I,E	70	**73**	-4	114	**104**	10	83	**58**	43	91	**77**	18

Notes

I: A condition of "impaired air quality" was in effect during the following times in King, Pierce and Snohomish counties . . . .

2:30 pm, Sun, **Dec 15** - 2:30 pm, Tue, **Dec 17.**

E: The Department of Ecology declared the "Forecast" stage of an air pollution episode effective during the following time . . . .

10:00 am, Mon, **Dec 16** - 4:00 pm, Tue, **Dec 17.**

Est: Estimated 24 hour average PM_{10} using the site specific equation.

Val: 24 hour average PM_{10} value measured by a reference method.

Err: Error in PM_{10} estimate compared to measured value.

LEAD

The ambient air quality standard for lead is 1.5 $\mu g/m^3$ averaged over one calendar quarter. Lead emissions to the air in urban areas come principally from automobile exhaust. In some places localized industrial emissions of lead come from stationary sources such as primary and secondary nonferrous smelters. As shown below, lead concentrations measured in the Puget Sound Region during 1991 were lower than the ambient standard. These current ambient lead levels are significantly lower than levels existing during the 70's due primarily to the phase down of lead in gasoline. The lead levels at the Harbor Island station still document some effect from the nearby site of a secondary lead smelter that ceased operation several years ago.

LEAD
Micrograms per Standard Cubic Meter

Sampling Method: Standard High Volume Quartz Fiber filters

1991

Location	Monthly Arithmetic Averages												No. Of Obs.	Year Arith Mean
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec		
5701 8th Ave NE, Seattle, Wa	.05	.05	.04	.04	.04	.04	.04	.04	.06	.06	.03	.05	47	.04
Harbor Island, 2555 13th Ave SW, Seattle, Wa	.21	.21	.15	.18	.53	.54	.12	.37	.25	.59	.60	.48	58	.35

Location	Quarterly Arithmetic Averages			
	1st	2nd	3rd	4th
5701 8th Ave NE, Seattle, Wa	.05	.04	.05	.05
Harbor Island, 2555 13th Ave SW, Seattle, Wa	.19	.42	.25	.56

Summary of Individual 24 Hour Average Lead Values

Location	Highest Value		Values Higher than .50	
	Value	Date	Value	Date
5701 8th Ave NE, Seattle, Wa	.09	9 Oct		
Harbor Island, 2555 13th Ave SW, Seattle, Wa	2.17	20 Nov	2.17	20 Nov
			1.68	11 Jun
			1.35	21 Oct
			1.06	30 May
			1.03	15 Oct
			.97	2 Dec
			.87	6 May
			.78	27 Sep
			.62	28 Aug
			.57	30 Jan
			.54	24 Apr
			.51	16 Aug

SULFUR DIOXIDE

Sulfur dioxide is a common air pollutant regulated under a national standard. Local sulfur dioxide standards have been in effect since 1968. The national, state and local sulfur dioxide standards are summarized on page 44. Sulfur dioxide enters the air mainly from industrial processes and from the combustion of sulfur-containing fuels such as coal and oil. In the Puget Sound Region, the four main industrial areas with sulfur dioxide point sources are the Everett Port area, Seattle Harbor Island-Duwamish Valley area, Tacoma Port area and the Bremerton Naval Shipyard. Reactions in the air partially convert sulfur dioxide to other sulfur compounds such as sulfuric acid and various sulfate salts. The tables below summarize sulfur dioxide data collected during 1991.

SULFUR DIOXIDE
(Parts per Million)
1991

Location	Monthly Arithmetic Averages												No. of 1 Hour Samples	Year Arith Mean
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec		
Hoyt Ave & 26th St, Everett, Wa	.004	.007	.006	.007	.005	.006	.009	.008	.009	.007	.005	.004	8633	.006
Duwamish, 4752 E Marginal Way S, Seattle, Wa	.008	.010	.011	.010	.012	.006	.007	.009	.011	.011	.008	.012	8629	.010
27th St NE & 54th Ave NE, Northeast Tacoma, Wa		.010	.008	.007	.005	.005	.006	.008	.008	.010	.010		7622	.008
2301 Alexander Ave, Tacoma, Wa	.009	.010	.008	.006	.005	.005	.006	.007	.009	.010	.008	.009	8670	.008

Summary of Maximum and Second Highest Concentrations
for Various Averaging Periods

Location / Continuous Sampling Period(s)	1 Hour Average			3 Hour Average			24 Hour Average		
	Value	Date	End Time	Value	Date	End Time	Value	Date	End Time
Hoyt Ave & 26th St, Everett, Wa	.083	5 Jun	1300	.047	25 Feb	1700	.018	26 Feb	1000
1 Jan-31 Dec	.060	26 Aug	1500	.047	5 Jun	1300	.017	20 Apr	1200
Duwamish, 4752 E Marginal Way S, Seattle, Wa	.158	24 May	2200	.093	7 Dec	1500	.036	25 May	1100
1 Jan-31 Dec	.139	7 Dec	1400	.086	5 Mar	1800	.032	8 Dec	0900
27th St NE & 54th Ave NE, Northeast Tacoma, Wa	.095	11 Oct	1000	.078	11 Oct	1200	.031	7 Feb	1400
29 Jan-6 Dec; 19 Dec-31 Dec	.081	7 Feb	0500	.069	5 Sep	1000	.027	11 Oct	2200
2301 Alexander Ave, Tacoma, Wa	.110	7 Jul	0800	.072	5 Sep	1100	.024	7 Feb	1400
1 Jan-31 Dec	.102	5 Sep	1000	.063	7 Feb	1400	.022	11 Oct	2300

Notes
(1) Ending times are reported in Pacific Standard Time.
(2) For equal concentration values the date and time refer to the earliest occurrences.
(3) Continuous sampling periods are those with fewer than 10 consecutive days of missing data.
(4) At all stations sulfur dioxide was measured using the continuous ultraviolet fluorescence method.

OZONE

Introduction

The principal oxidant found in photochemical smog is ozone, a very reactive form of oxygen. Most photochemical oxidants result from sunlight driven chemical reactions in the ambient air between nitrogen oxides and volatile organic compounds (VOC).

The highest ozone levels occur on hot summer afternoons since this is the period of most intense radiant energy from sunlight. However, even with strong sunlight, ozone levels would be low without the precursor nitrogen oxide and VOC pollutants emitted from human activities.

On any given day the photochemical reactions continue for several hours and generally produce maximum ozone levels between noon and early evening at locations several miles away from the sources of nitrogen oxides and VOC. Each day after nightfall the high ozone levels diminish because the photochemical effect ends. However, the photochemical smog is such a complex mixture that significant ozone levels sometimes continue for hours into the night.

In the Puget Sound Region the highest ozone levels occur from mid May to mid September on the few days favorable for significant photochemical activity. These high values develop when urban area emissions are trapped beneath a nighttime and morning temperature inversion followed during the day by very high temperatures. Light northerly winds often develop on these hot days. As a result, the highest ozone values normally occur south to southeast of the major cities or source areas.

Ozone Standard and Summary of Data

The U. S. EPA has set the level of the ozone standard at a value of 0.12 ppm. According to the Federal regulation (40 CFR Part 50), the standard is attained when the expected number of days per calendar year with a maximum hourly average concentration above 0.12 ppm is one day or less.

If an "exceedance" means a day on which the maximum 1 hour average is higher than 0.12 ppm, the standard is attained when the expected number of exceedances is equal to or less than one. If no data are missing, the expected number of exceedances is the average number of measured exceedances per year at a particular location for the last three years.

When some data for a given year are missing, the number of exceedances in that year must be adjusted to estimate the true number. The estimate is calculated using the number of measured exceedances, the number of required monitoring days, the number of days with a measured maximum value and the number of days determined to be less than the level of the standard. The required ozone monitoring season in Washington state is the period from April 1 through October 31 each year.

For each year the estimated number of exceedances is always equal to or greater than the measured number of exceedances. For stations where no exceedances are measured, the estimate is zero. The expected number of exceedances is then the average of the annual estimates for the last three years.

The 1991 ozone summary table on the following page lists the six highest daily maximum 1 hour averages for each monitoring location. For the three year period ending with 1991, the expected number of ozone exceedances calculates to be 1.3 days for the Enumclaw location; all other ozone monitoring locations calculate to be 1.0 or fewer days. In 1987 the Puget Sound Region attained the ozone standard, but monitoring data during the summer of 1990 resulted again in a designation as out of compliance with this standard.

Pollutant Standards Index

A one hour average ozone value of 0.12 ppm is equivalent to 100 on the Pollutant Standards Index scale. Since the high ozone levels occur some distance downwind of major cities, ozone never determines the Index for Everett, Seattle or Tacoma. At outlying locations such as Lake Sammamish, Enumclaw and La Grande, ozone occasionally causes unhealthful air quality, however for 1991, the maximum ozone level occurred July 2 and was described as "moderate" on the Index scale.

OZONE
(Parts per Million)
1991

Location / Continuous Sampling Period(s)	Six Highest Daily Maximum 1 Hour Averages			Estimated No. of Days Daily Maximum 1 Hour Average Exceeded .12 ppm			No. of Days Daily Maximum 1 Hour Average Expected To Exceed .12 ppm
	Value	Date	End Time	1989	1990	1991	
20050 SE 56th, Lake Sammamish State Park, Wa 1 Apr-31 Oct	.109	23 Jul	1400	0.0	1.0	0.0	0.3
	.100	17 Aug	1600				
	.091	2 Jul	1600				
	.086	18 Aug	1500				
	.082	12 Jul	1500				
	.078	15 Aug	1500				
Ravensdale, Wa 1 Apr-31 Oct	.101	17 Aug	1800		0.0	0.0	0.0
	.099	2 Jul	1600				
	.093	18 Aug	1600				
	.091	23 Jul	1400				
	.080	4 Aug	1700				
	.076	20 Aug	1700				
Highway 410, 2 miles east of Enumclaw, Wa 1 Apr-31 Oct	.112	2 Jul	1600	0.0	3.8	0.0	1.3
	.109	23 Jul	1500				
	.105	17 Aug	1700				
	.099	18 Aug	1600				
	.094	3 Aug	1600				
	.085	1 Jul	1700				
Charles L Pack Forest, La Grande, Wa 1 Apr-29 Oct	.099	23 Jul	1500	0.0	2.9	0.0	1.0
	.094	3 Jul	1700				
	.093	18 Aug	1400				
	.090	12 Jul	1700				
	.087	22 Jul	1700				
	.085	3 Aug	1600				

Notes
(1) All ozone stations operated by the Washington State Department of Ecology.
(2) Ending times are reported in Pacific Standard Time.
(3) For equal concentration values the date and time refer to the earliest occurrences.
(4) Continuous sampling periods are those with fewer than 10 consecutive days of missing data.
(5) At all stations ozone was measured using the continuous ultraviolet photometric detection method.

CARBON MONOXIDE

Introduction

As a group, motor vehicles emit more carbon monoxide than any other source. For Puget Sound Region cities, motor vehicles are the principal source of carbon monoxide causing the ambient levels to exceed air quality standards.

The occasions with high ambient levels of carbon monoxide occur mainly during autumn and winter months. The highest levels are measured near congested motor vehicle traffic present during late afternoon commuting and around shopping centers particularly during holiday periods.

Stable weather and light wind may be a contributing factor during some periods when levels are high. Such a condition temporarily reduces the means to disperse carbon monoxide that is emitted into the air.

Pollutant Standards Index and Washington State Episode Levels

The level of the 8 hour average standard is 9 parts per million (ppm), and this is equivalent to 100 on the Pollutant Standards Index scale. PSI values exceeding 100 are termed "Unhealthful". An 8 hour average of 15 ppm equals 200 on the PSI scale. Index values of 200 to 299 are described as "Very Unhealthful".

Episode criteria are specified in the Washington Episode Plan (Washington Administrative Code 173-435). The Alert stage is reached when the ambient carbon monoxide concentration reaches 15 ppm for an 8 hour average, and meteorological conditions are such that the carbon monoxide concentration can be expected to remain at or above that level for 12 or more hours, or to recur within 24 hours unless control actions are taken. Correspondingly, the carbon monoxide concentration for the Warning stage is 30 ppm for an 8 hour average, and for the Emergency stage is 40 ppm for an 8 hour average.

Summary of 1991 Data

The table on the next page summarizes the six highest 1 hour and 8 hour average carbon monoxide levels at each station during 1991. These data were obtained from Department of Ecology data summaries.

Only the stations in downtown Everett and downtown Tacoma measured carbon monoxide values that exceeded the level of the 8 hour average standard. Since this occurred only once at each location, none of the stations in the Puget Sound Region violated the 8 hour average standard during 1991.

Multi-Year Summary

Multi-year graphs following the 1991 summary table present column charts to show the historical trend. For the longest term sampling sites in the cities of Seattle, Everett, Bellevue and Tacoma, one chart shows the number of days on which the 8 hour average exceeded 9 ppm for each year from 1979 to 1991. A companion chart graphs the value that was the second high 8 hour average for each of those years.

As documented in previous annual data summaries, the first complete year of carbon monoxide data for the Seattle 5th Avenue and James Street station was 1972. The results at this station have improved from exceeding the primary standard 112 days in 1972 and 130 days in 1973, to zero exceedances during 1987 through 1991.

For all cities, the data acquired since 1979 show that carbon monoxide values have improved with some variability from year to year. The charts show that for the last three years the carbon monoxide levels have nearly achieved the standards.

To show the standard has been attained for any station, the U. S. EPA requires that the number of cases exceeding the level of the standard averaged over a two year period not exceed one per year. The significant improvement from levels in the mid 1970's is due mainly to the Federal emission standards for new motor vehicles and to the program requiring regular testing of vehicle emissions to assure compliance with these standards.

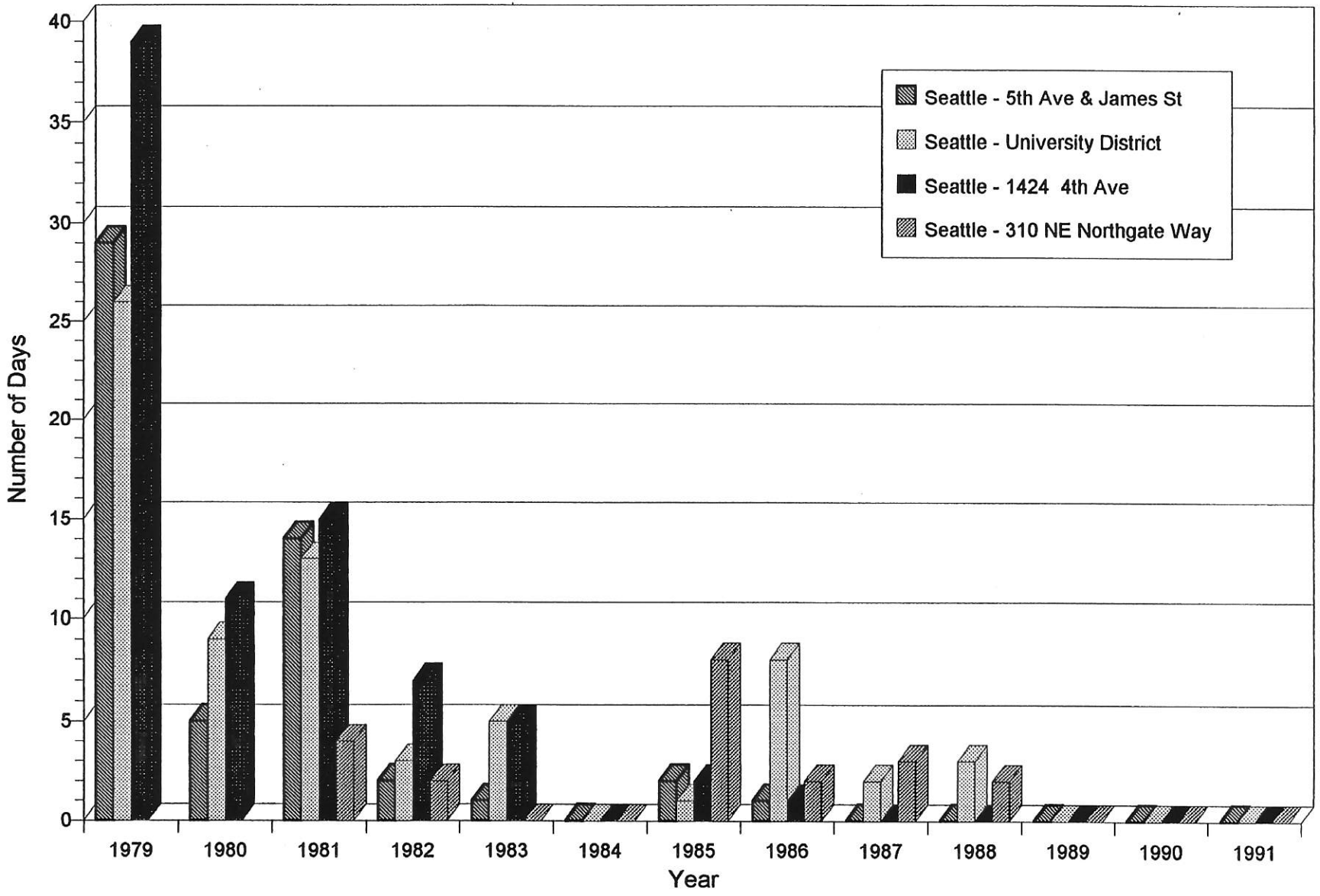
CARBON MONOXIDE
(Parts per Million)
1991

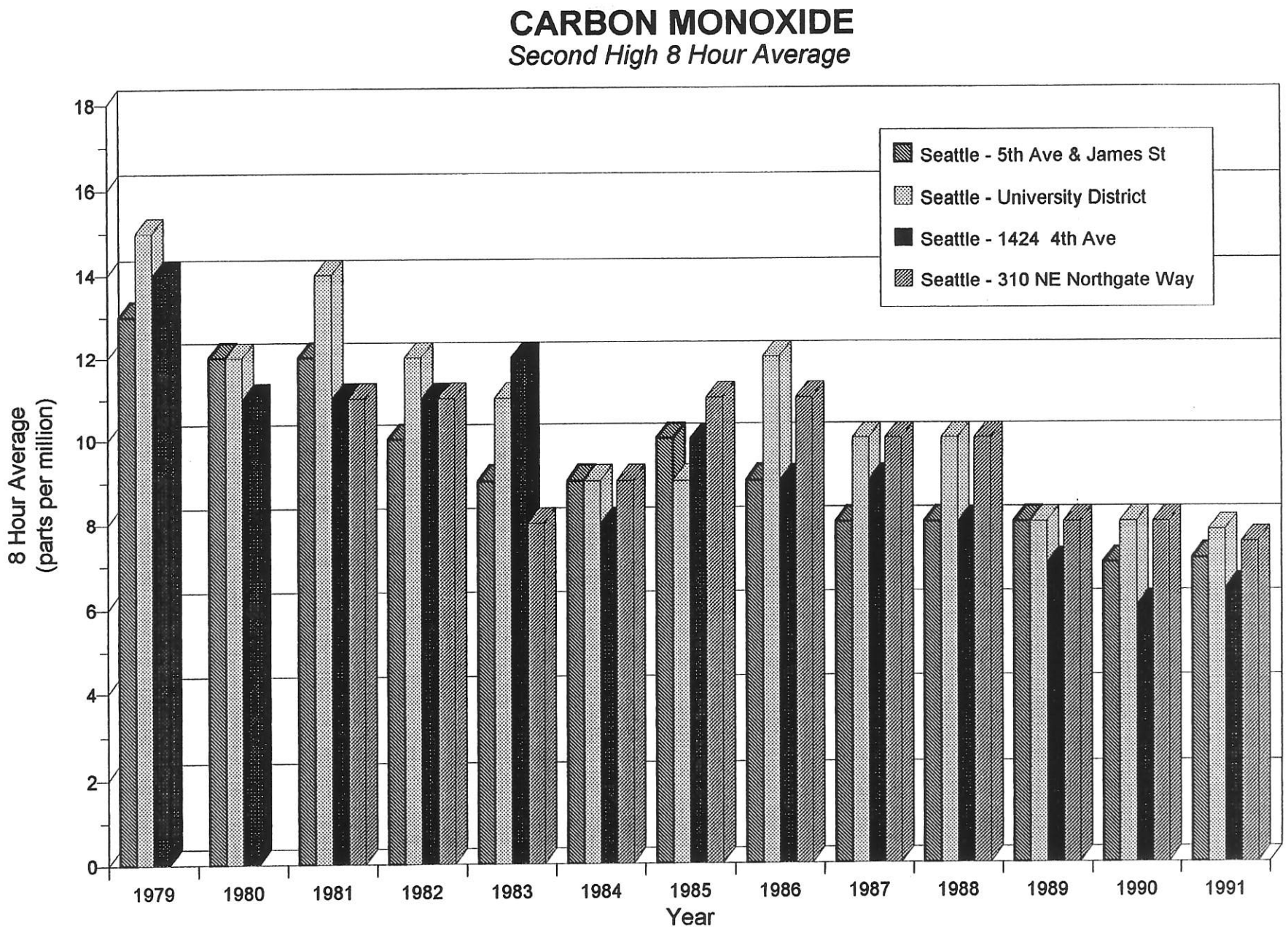
Location / Continuous Sampling Period(s)	Six Highest Concentrations						Number of 8 Hour Averages Exceeding 9 ppm	Number of Days 8 Hour Average Exceeded 9 ppm
	1 Hour Average			8 Hour Average				
	Value	Date	End Time	Value	Date	End Time		
Broadway & Hewitt Ave, Everett, Wa	17.0	16 Dec	1800	10.2	16 Dec	2300	1	1
1 Jan-31 Dec	15.4	16 Dec	1700	9.1	8 Feb	1900		
	14.6	16 Dec	1900	8.6	4 Oct	1900		
	13.5	6 Feb	1700	7.9	19 Apr	1800		
	13.0	29 Jan	1900	7.8	9 Oct	1900		
	12.7	30 Dec	1700	7.7	25 Feb	1800		
622 Bellevue Way NE, Bellevue, Wa	10.7	6 Feb	2000	7.5	7 Feb	0100	0	0
1 Jan-15 May; 28 May-31 Dec	9.2	6 Feb	1900	6.9	28 Dec	0100		
	9.0	6 Feb	2100	6.2	15 Dec	2400		
	8.7	14 Nov	1900	5.9	21 Jan	2400		
	8.4	27 Dec	2000	5.3	1 Feb	2000		
	8.3	31 Dec	1900	5.3	14 Nov	2200		
Northgate, 310 NE Northgate Way, Seattle, Wa	12.1	13 Dec	0900	8.9	16 Dec	0100	0	0
1 Jan-31 Dec	11.3	26 Feb	0800	7.5	21 Jan	2400		
	11.3	28 Feb	0800	7.1	16 Dec	1300		
	10.9	30 Dec	1900	6.9	13 Dec	1300		
	9.8	15 Dec	2100	6.8	17 Dec	2000		
	9.8	16 Dec	0900	6.7	30 Dec	2200		
University Dist, 1307 NE 45th St, Seattle, Wa	11.5	26 Jan	2300	7.9	6 Feb	2400	0	0
1 Jan-22 Apr; 19 Dec-31 Dec	11.2	6 Feb	1900	7.8	22 Jan	0100		
	11.2	14 Feb	1800	7.6	1 Mar	2000		
	10.2	8 Feb	1000	7.5	1 Feb	1900		
	10.0	31 Dec	1000	7.4	8 Feb	1500		
	9.7	21 Jan	2300	7.0	10 Jan	2000		
1424 4th Ave, Seattle, Wa	10.8	26 Nov	1500	6.5	22 Jan	0200	0	0
1 Jan-31 Dec	9.9	1 Feb	1800	6.4	22 Nov	1900		
	9.3	22 Nov	1800	6.0	27 Dec	2400		
	8.4	23 Dec	1600	5.9	15 Dec	2400		
	8.0	31 Oct	1800	5.6	16 Dec	1800		
	7.9	18 Dec	1800	5.6	23 Dec	2100		
5th Ave & James St, Seattle, Wa	11.6	22 Nov	1700	8.7	27 Dec	2400	0	0
1 Jan-31 Dec	10.8	27 Dec	2200	7.1	22 Jan	0300		
	10.6	27 Dec	2300	6.8	15 Dec	2400		
	10.1	22 Nov	1800	6.5	22 Nov	1900		
	9.0	27 Dec	2100	6.1	17 Dec	1800		
	8.9	6 Feb	1800	5.8	22 Jan	1100		
1101 Pacific Ave, Tacoma, Wa	15.5	31 Jan	1800	9.6	31 Jan	2000	1	1
1 Jan-28 Jun; 14 Aug-31 Dec	13.6	6 Feb	1800	8.7	6 Feb	2300		
	12.6	1 Feb	1800	7.9	11 Oct	1500		
	12.0	31 Jan	1700	7.7	1 Feb	1900		
	12.0	7 Feb	0800	7.7	7 Feb	1500		
	10.6	1 Mar	1700	6.5	5 Jan	0100		

Notes
(1) All carbon monoxide stations operated by the Washington State Department of Ecology.
(2) Ending times are reported in Pacific Standard Time.
(3) For equal concentration values the date and time refer to the earliest occurrences.
(4) Continuous sampling periods are those with fewer than 10 consecutive days of missing data.
(5) At all stations carbon monoxide was measured using the continuous nondispersive infrared method.

CARBON MONOXIDE

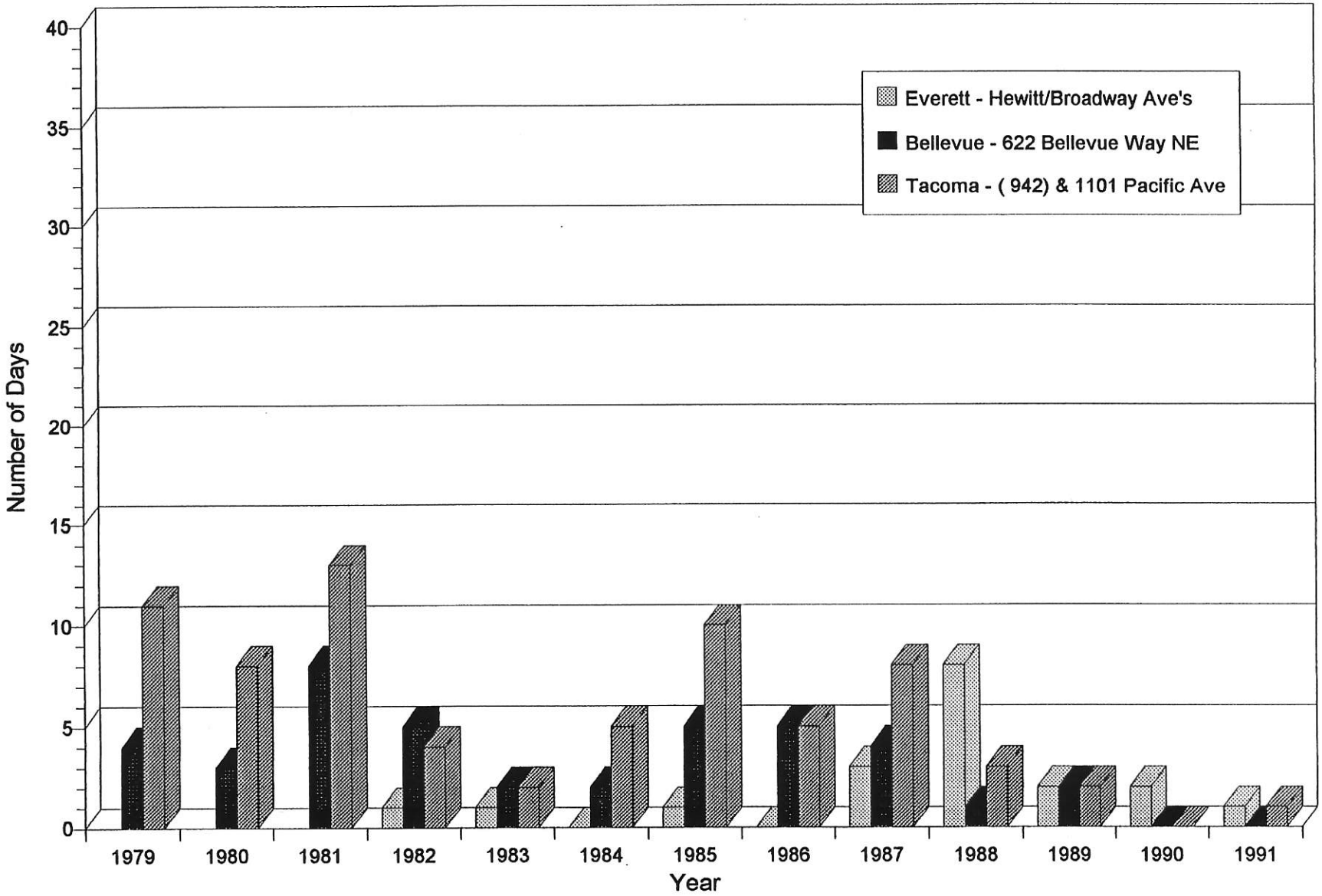
Number of Days 8 Hour Average Exceeded 9 ppm

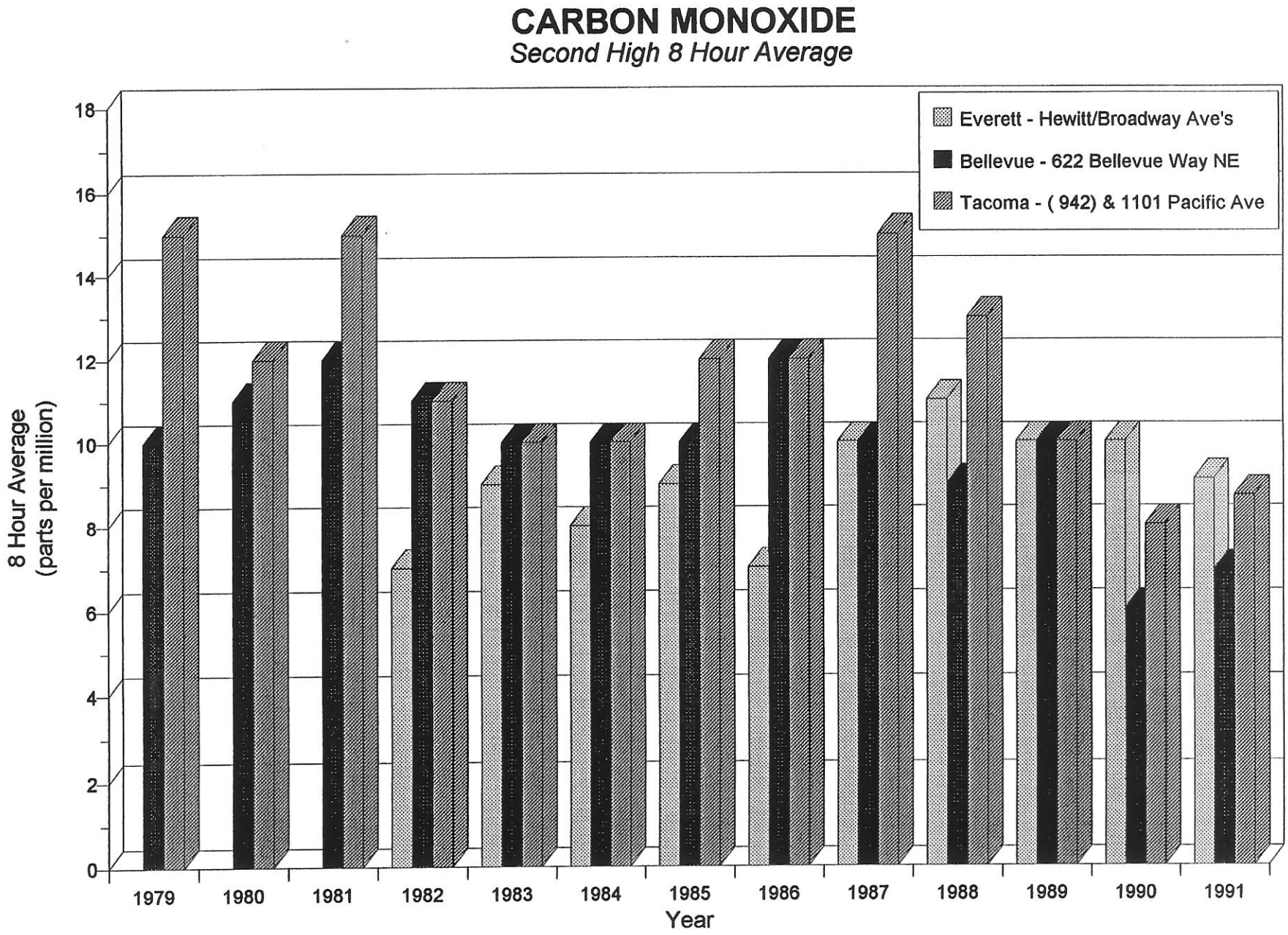



CARBON MONOXIDE
Second High 8 Hour Average
8 Hour Average
(parts per million)
0
2
4
6
8
10
12
14
16
18
1979
1980
1981
1982
1983
1984
1985
1986
1987
1988
1989
1990
1991
Year
Seattle - 5th Ave & James St
Seattle - University District
Seattle - 1424 4th Ave
Seattle - 310 NE Northgate Way

CARBON MONOXIDE

Number of Days 8 Hour Average Exceeded 9 ppm




CARBON MONOXIDE
Second High 8 Hour Average
Everett - Hewitt/Broadway Ave's
Bellevue - 622 Bellevue Way NE
Tacoma - (942) & 1101 Pacific Ave
8 Hour Average
(parts per million)
0
2
4
6
8
10
12
14
16
18
1979
1980
1981
1982
1983
1984
1985
1986
1987
1988
1989
1990
1991
Year

QUALITY ASSURANCE

Introduction

Quality Assurance (QA) includes all activities involved with obtaining valid data and documenting the quality of the data. Quality Assurance is an integral part of all monitoring activities. Some specific QA activities are: selection of methods and analyzers; installation of equipment; calibration; zero and span checks and adjustments; control checks, limits and corrective actions; maintenance; recording and validating data; and documentation of quality control information.

The Agency participates in audit programs conducted independently by the U. S. Environmental Protection Agency and the Washington State Department of Ecology. For the EPA, this consists of (1) Agency participation in EPA's national performance audits, and (2) occasional on-site audits of some Agency monitoring equipment by EPA or their designated representative. Each quarter the Department of Ecology also independently audits some Agency monitoring equipment on-site at various locations.

Precision and Accuracy Audits

The QA program requirements are established in Title 40, Code of Federal Regulations, Part 58. The important QA characteristics that the regulations require to be developed and reported are *precision* and *accuracy*. In simple terms, *precision* means the ability to repeat a measurement of the same, known sample at a different time; *accuracy* means the agreement between a measurement and the true value.

At a minimum, each instrument measuring a pollutant at a location must be audited for precision at least every two weeks and for accuracy at least once per year. For each audit, the percentage difference between the instrument indicated concentration and the true concentration is calculated.

Each calendar quarter the average and the standard deviation of these percentage differences are calculated. These two statistics are then pooled for all audits involving the same parameter.

Probability Limits

The Federal regulation requires summary of the precision and accuracy audit results by computing the 95 percent probability limits for each pollutant from the weighted average percentage difference, D, and the pooled standard deviation, S_a, as follows:

$$\text{Upper 95 Percent Probability Limit} = D + 1.96\,(S_a)$$

$$\text{Lower 95 Percent Probability Limit} = D - 1.96\,(S_a)$$

These upper and lower limits reflect data quality by establishing that, with 95 percent probability, the data values during the audit period fall within the limits. As an example, if the average of the percentage differences is zero and the standard deviation of the percentage differences is 4.1 percent, the upper and lower 95 percent probability limits are respectively +8 and -8 percent.

Agency Precision and Accuracy

For most Agency monitoring locations precision audits are performed each week and accuracy audits are completed each month or each quarter. The table following this page summarizes the precision and accuracy probability limits by quarter for all air quality data that the Agency originated in 1991. For each parameter, the type of audit, (accuracy or precision), is followed by a brief phrase description of the audit process or the actual measurement point that is audited. The number of audits and the lower and upper probability limits (of percent differences) are presented for each quarter.

Wind sensor audits appear in the table this year. This section of the table reports the quarterly audit of the direction system for the cardinal points and the quarterly audit of the speed system at one of the controlled rates of shaft rotation.

DATA QUALITY ASSESSMENT
1991

Lower and Upper 95 Percent Probability Limits
of Percent Differences

Parameter & Type of Audit	Number of Stations	Audit Results by Quarter: 1st No. of Audits	1st Prob. Limits Lwr (%)	1st Prob. Limits Upr (%)	2nd No. of Audits	2nd Prob. Limits Lwr (%)	2nd Prob. Limits Upr (%)	3rd No. of Audits	3rd Prob. Limits Lwr (%)	3rd Prob. Limits Upr (%)	4th No. of Audits	4th Prob. Limits Lwr (%)	4th Prob. Limits Upr (%)
Particulate Matter (PM10) (Reference Method)	13												
Accuracy													
Flow Rate		80	-3	+3	78	-3	+4	70	-4	+4	75	-5	+3
Precision													
Collocated Samples		45	-9	+5	23	-17	+4	23	-11	+4	21	-6	+2
Particulate Matter (PM10) (Equivalent Method)	5												
Accuracy													
Flow Rate								9	-2	+4	12	+2	+8
Sulfur Dioxide	4												
Accuracy													
Level 1		10	-11	+14	11	-3	+13	7	-2	+10	9	-4	+10
Level 2		10	-8	+13	11	-1	+10	7	+2	+6	9	-2	+10
Level 3		10	-7	+10	11	-2	+9	7	0	+7	9	-4	+9
Level 4		2	+3	+5	2	0	+6	2	+1	+4	2	-3	+7
Precision													
One point check		45	-3	+5	50	-3	+9	53	0	+7	58	-5	+10
Atmospheric Particles (Nephelometer)	6												
Precision													
One point check		79	-4	+8	77	-4	+6	77	-2	+6	82	-2	+6
Wind	10												
Direction													
Accuracy													
90 degrees (E)		7	-2	+4	7	-1	+1	7	-2	+1	9	-2	+2
180 degrees (S)		7	-1	+2	7	0	0	7	0	0	9	-1	0
270 degrees (W)		7	-1	+1	7	-1	+1	7	-1	+1	9	0	+1
360 degrees (N)		7	0	+1	7	0	0	7	0	0	9	0	0
Speed													
Accuracy													
11 mph (1000 rpm)		7	-1	1	7	-1	1	7	0	0	9	0	0

AIR POLLUTION EPISODES and IMPAIRED AIR QUALITY PERIODS

Introduction

The policy and rules for air pollution episode avoidance and for restrictions on the use of solid fuel burning devices during periods of "impaired air quality" are established by the Washington Clean Air Act and implemented by state and local regulations. Legislative amendments during 1990 significantly revised these rules effective in mid 1990.

Air Pollution Episodes

The Washington Clean Air Act defines air pollution episodes and the policy for establishing an avoidance plan in RCW 70.94.710 through 70.94.730. The Washington State Department of Ecology has adopted WAC 173-435 which implements an episode avoidance plan.

The "First" or "Forecast" stage of the Episode Plan may be declared by the Department of Ecology when an air stagnation advisory is issued by the National Weather Service or there is equivalent indication of stagnant atmospheric conditions and conditions are forecast to persist for 24 hours.

During 1991, the Department of Ecology declared the "Forecast" stage of an air pollution episode which included the Puget Sound Region during the following periods:

10:00 am, Tuesday, January 22 -
3:00 pm, Thursday, January 24;

10:00 am, Monday, December 16 -
4:00 pm, Tuesday, December 17.

Impaired Air Quality Periods

The Washington Clean Air Act defines two stages of "impaired air quality" in RCW 70.94.473. A *first stage* of "impaired air quality" is reached when PM_{10} is at an ambient level of 75 $\mu g/m^3$ measured on a 24 hour average or when carbon monoxide is at an ambient level of 8 ppm measured on an 8 hour average.

During a first stage of "impaired air quality", any person in a residence or commercial establishment which has an adequate source of heat without burning wood shall not burn wood in any solid fuel burning device except those certified as described in RCW 70.94.473 or a pellet stove either certified or issued an exemption by the U. S. Environmental Protection Agency.

A *second stage* of "impaired air quality" is reached when PM_{10} is at an ambient level of 105 $\mu g/m^3$ measured on a 24 hour average. When a second stage of "impaired air quality" is in effect, any person in a residence or commercial establishment which has an adequate source of heat without burning wood shall not burn wood in any solid fuel burning device.

During 1991, "impaired air quality" was in effect as follows in the counties of King, Pierce and Snohomish (Kitsap was included for all January cases but not in any December cases):

Stage	Dates
1	2:30 pm, Saturday, January 5 - 9:30 am, Sunday, January 6;
1	2:30 pm, Monday, January 21 - 9:30 am, Tuesday, January 22;
2	9:30 am, Tuesday, January 22 - 3:00 pm, Thursday, January 24;
1	2:30 pm, Tuesday, January 29 - 8:30 am, Thursday, January 31;
1	2:30 pm, Sunday, December 15 - 2:30 pm, Monday, December 16;
2	2:30 pm, Monday, December 16 - 9:30 am, Tuesday, December 17;
1	9:30 am, Tuesday, December 17 - 2:30 pm, Tuesday, December 17.

Along with the restrictions on the use of solid fuel burning devices as outlined above, all outdoor fires are prohibited during any period of "impaired air quality".

WIND ANALYSIS

Wind Data

Everyone has a qualitative sense of surface wind and some effects produced by the wind. The wind direction helps identify the sources or source areas affecting a specific location.

From an air pollution standpoint, low wind speed poorly dilutes pollutants and is therefore associated with higher air pollutant concentrations. During a stable, temperature inversion condition, the wind is often light or calm. When this condition persists, the natural process that effectively disperses pollutants is greatly diminished, and pollutant levels are higher near the source areas.

Wind Speed Averages

The table below presents monthly and annual average wind speed computed from hour average wind speed at various locations. These average values are sometimes used to compare locations or different months. Air stagnation episodes are not exposed by this analysis unless episode conditions predominate during most of a month.

Wind Roses

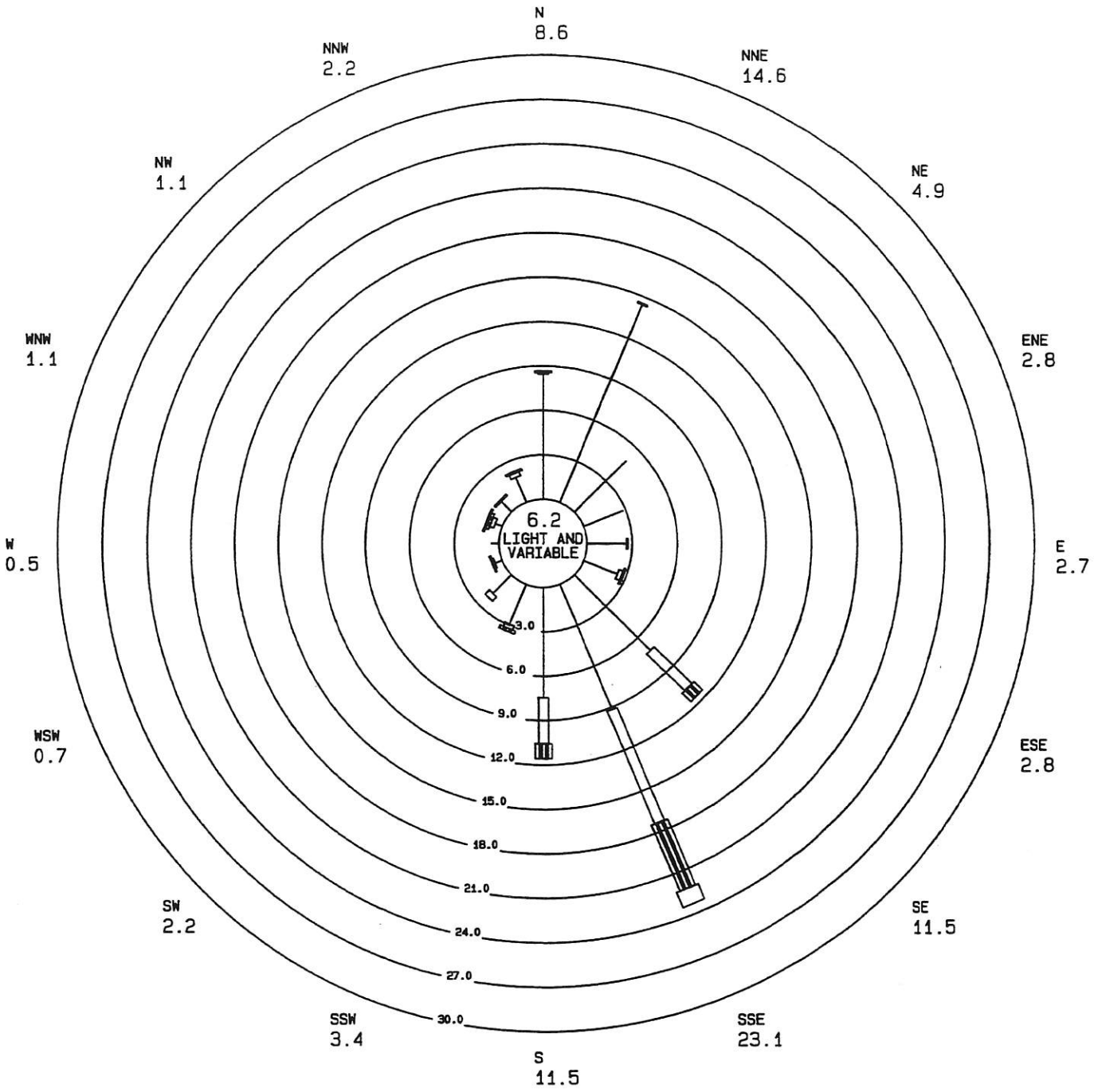
A wind rose is a quantitative graphical summary of the wind direction and speed for a given time. The following wind rose graphs show the number of observations or hours, expressed as a percentage, that had a particular direction and speed during the summary period.

The wind rose spokes or arms represent 16 points of the compass and are labeled by wind direction. The percentage of time the wind blew *from* a given direction (without regard to speed) is expressed numerically beneath that direction on the perimeter of each rose.

For a particular wind direction the length of each segment of a spoke represents the percentage of time the wind speed was within a specific speed interval. If summed for all wind directions, the result would provide the percentage of all hours the wind speed was measured within a particular interval. The percentage of time during which the wind was light and variable shows in the center of the rose.

WIND SPEED
(Miles per Hour)
1991

Location	Monthly Arithmetic Averages												No. of 1 Hour Samples	Year Arith Mean
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec		
Marysville JHS, 1605 7th St, Marysville, Wa											3.7	3.4	1516	
Hoyt Ave & 26th St, Everett, Wa	4.8	4.9	4.8	5.2	4.6	4.5	4.7	4.8	3.8	4.2	5.2	5.0	8727	4.7
17711 Ballinger Way NE, Lake Forest Park, Wa	2.5	2.7	3.3	3.6	3.3	3.0	2.6	2.7	2.1	2.2	2.8	2.7	8718	2.8
Duwamish, 4752 E Marginal Way S, Seattle, Wa	4.7	4.6	5.3	5.3	5.0	5.3	4.7	4.5	3.7	4.1	5.4	4.7	8729	4.8
James St & Central Ave, Kent, Wa	3.7	3.9	4.4	4.5	4.1	4.4	3.9	3.6	3.3	3.3	4.2	4.1	8721	3.9
South Hill, 9616 128th St E, Puyallup, Wa												2.4	609	
27th St NE & 54th Ave NE, Northeast Tacoma, Wa	4.2	4.4	4.5	4.1	3.4	3.8	3.7	3.4	3.7	3.7	3.6	3.7	8650	3.8
2301 Alexander Ave, Tacoma, Wa	4.1	4.5	5.5	5.8	5.4	5.8	5.4	5.0	4.2	4.6	4.6	4.7	8643	5.0
Fire Station #12, 2316 E 11th St, Tacoma, Wa	5.3	5.2	5.7	5.8	5.6	6.0	5.5	5.1	4.3	4.4	4.8	4.9	8726	5.2
Meadowdale, 7252 Blackbird Dr NE, KitsapCo, Wa												1.7	946	



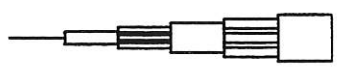
HOUR AVERAGE SURFACE WINDS

PERCENTAGE FREQUENCY OF OCCURRENCE

STATION LOCATION- PUGET SOUND AIR POLLUTION CONTROL AGENCY
Marysville JHS, 1605 7th St, Marysville, Wa

INCLUSIVE DATES- NOV, DEC, 1991

TOTAL OBSERVATIONS- 1,456

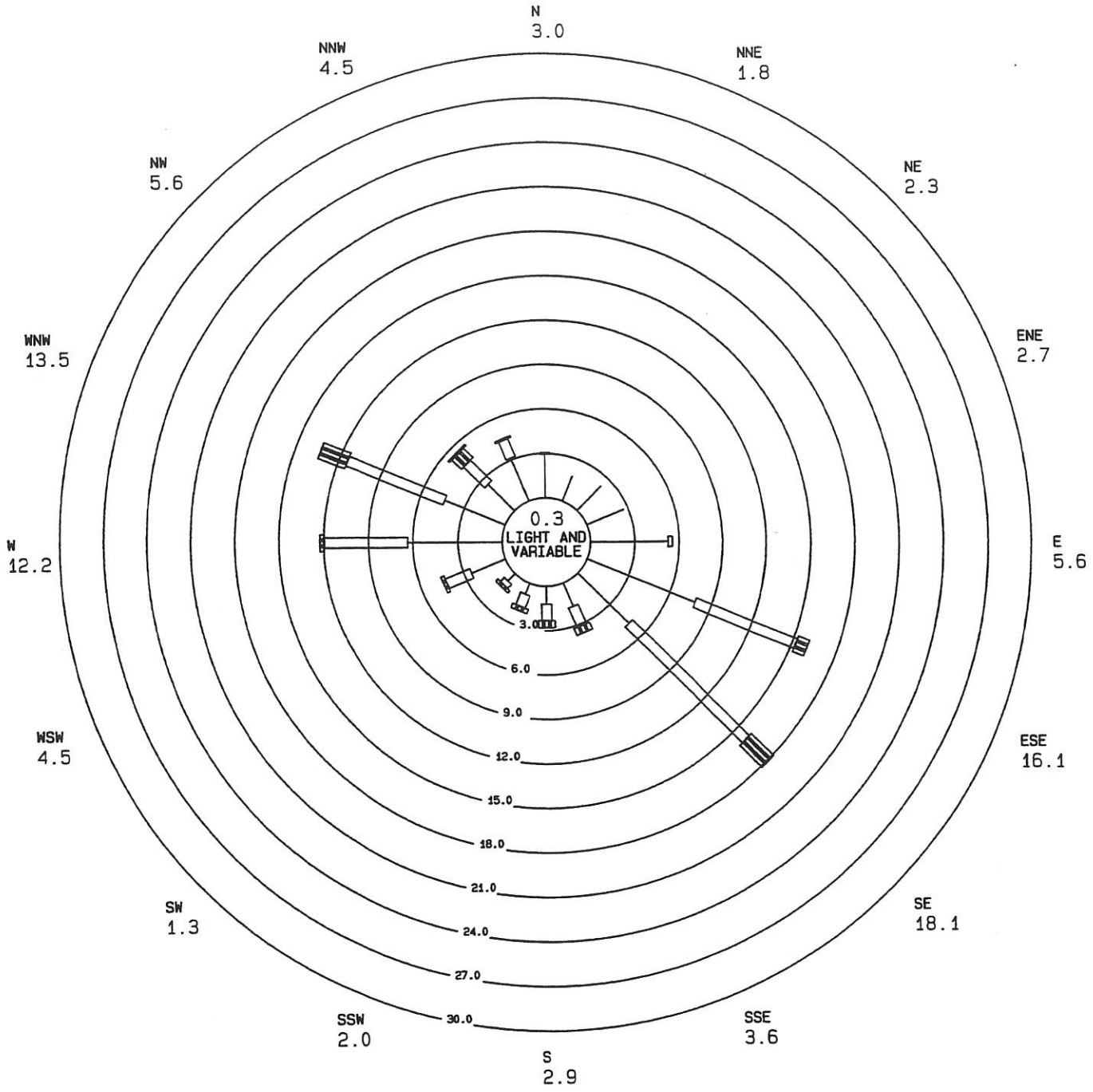


0.9-3.9	4.0-6.9	7.0-10.9	11.0-16.9	17.0-21.9	OVER 21.9

KNOTS

0.0 3.0 6.0 9.0 12.0 15.0

PERCENT



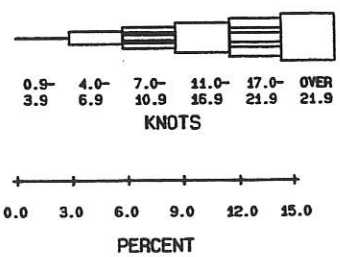
HOUR AVERAGE SURFACE WINDS

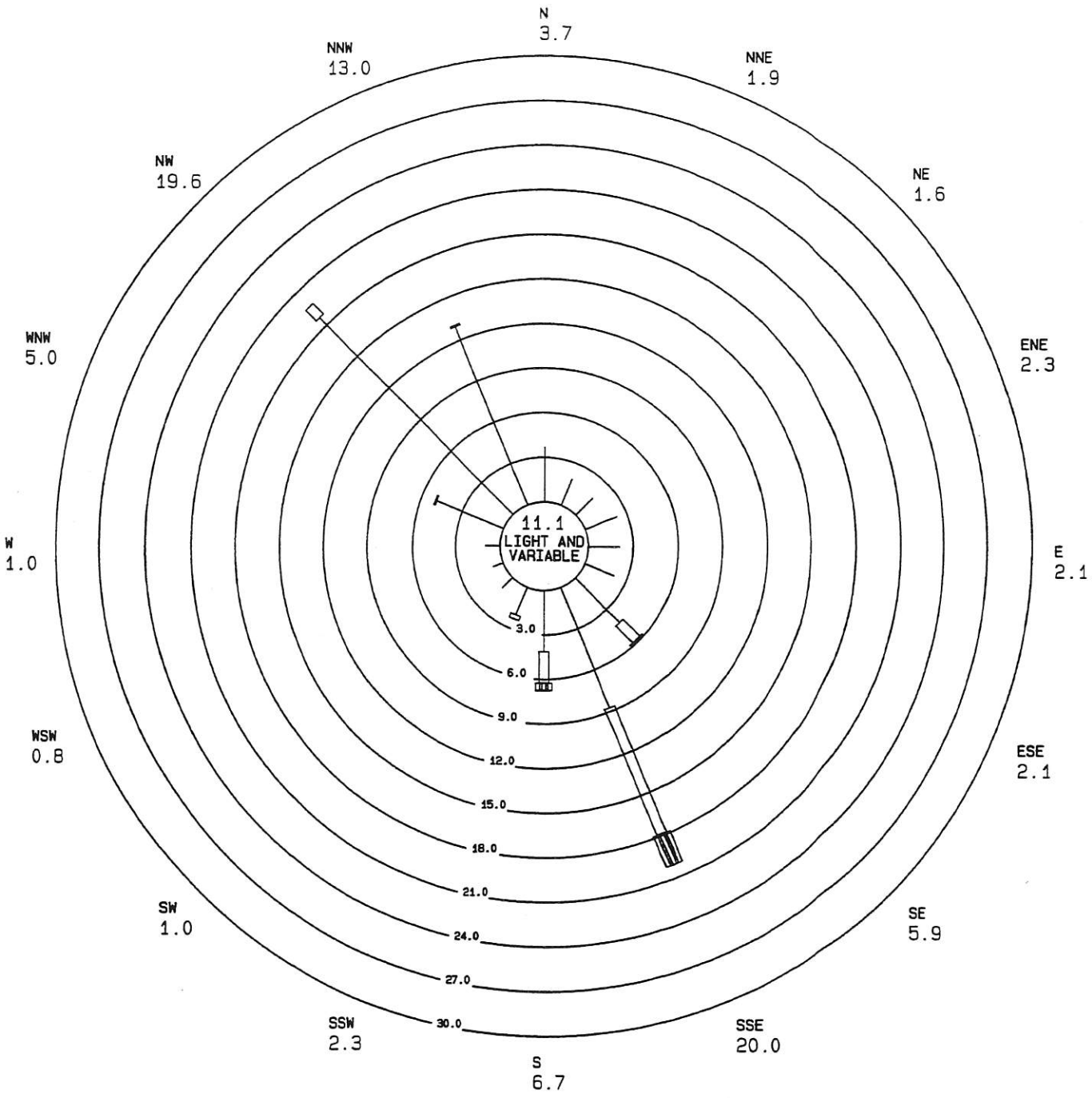
PERCENTAGE FREQUENCY OF OCCURRENCE

STATION LOCATION- PUGET SOUND AIR POLLUTION CONTROL AGENCY
Hoyt Ave & 26th St, Everett, Wa

INCLUSIVE DATES- ALL MONTHS 1991

TOTAL OBSERVATIONS- 8,727





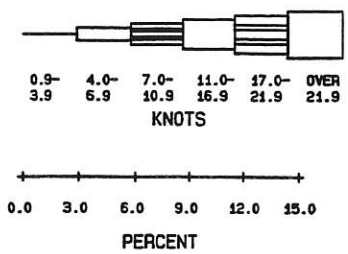
HOUR AVERAGE SURFACE WINDS

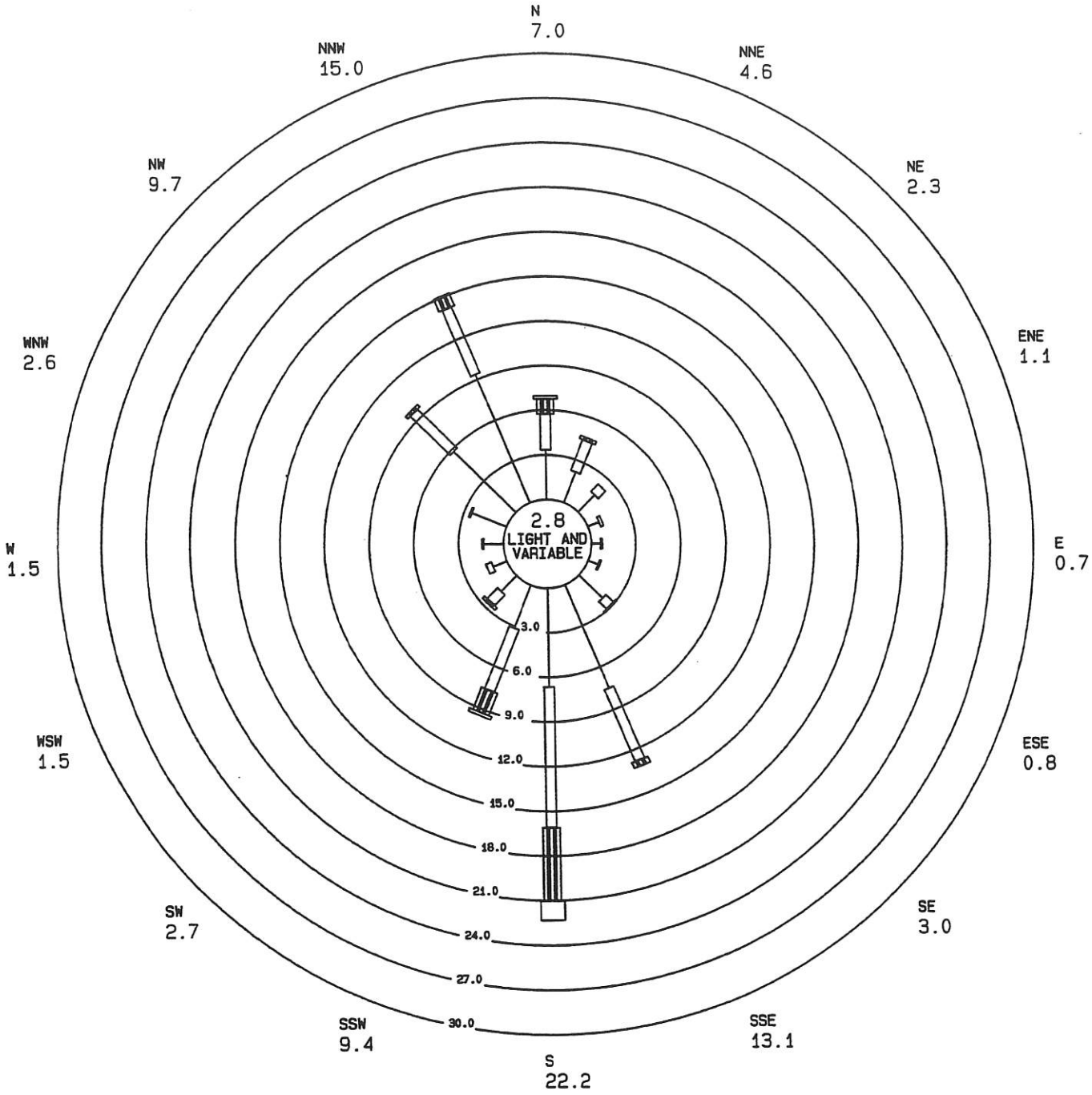
PERCENTAGE FREQUENCY OF OCCURRENCE

STATION LOCATION- PUGET SOUND AIR POLLUTION CONTROL AGENCY
17711 Ballinger Way NE, Lake Forest Park, Wa

INCLUSIVE DATES- ALL MONTHS 1991

TOTAL OBSERVATIONS- 8,718





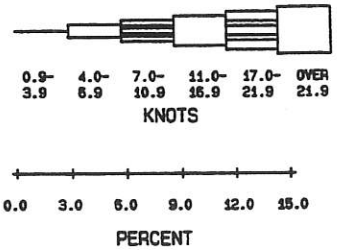
HOUR AVERAGE SURFACE WINDS

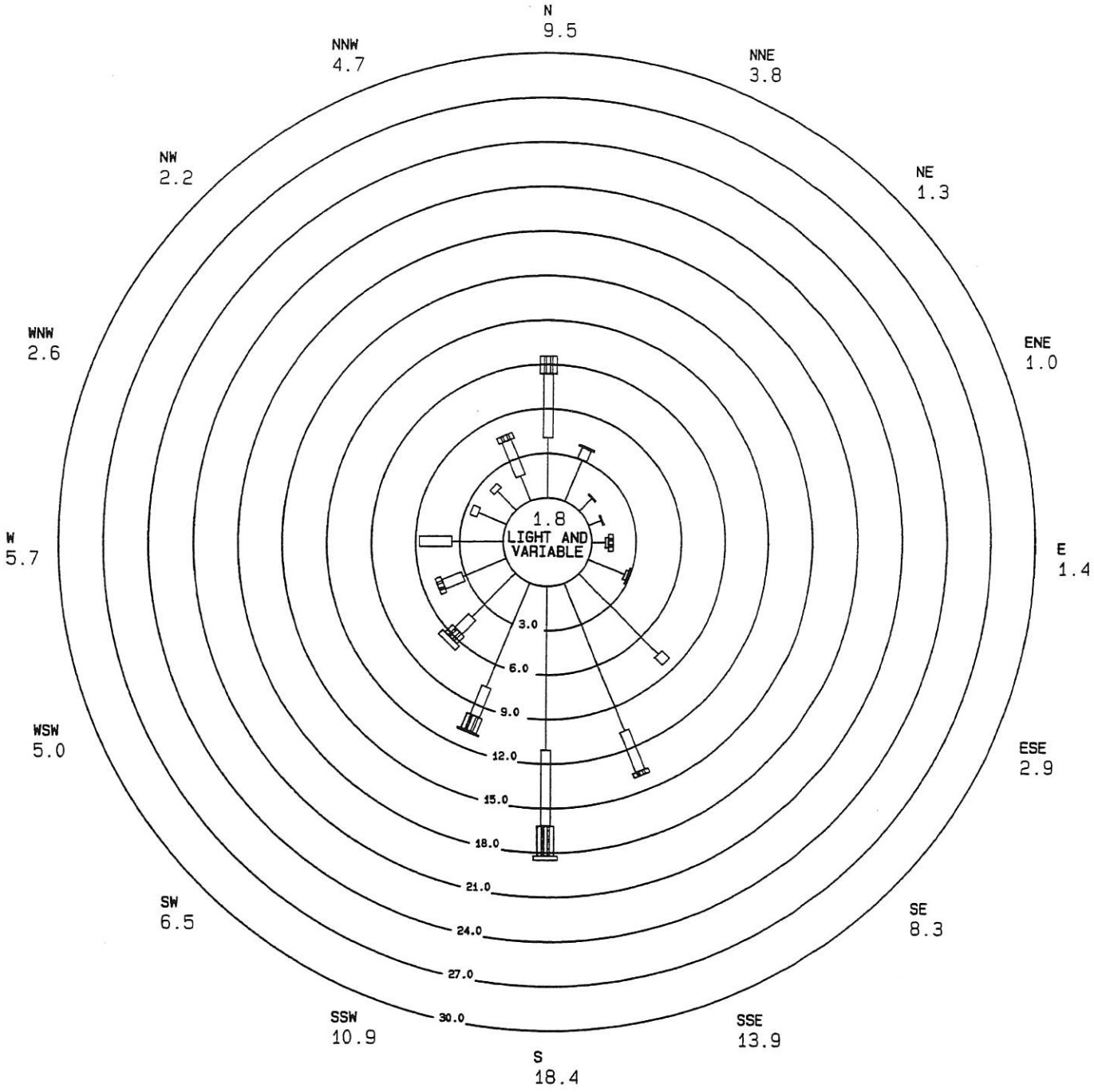
PERCENTAGE FREQUENCY OF OCCURRENCE

STATION LOCATION- PUGET SOUND AIR POLLUTION CONTROL AGENCY
Duwamish, 4752 E Marginal Way S, Seattle, Wa

INCLUSIVE DATES- ALL MONTHS 1991

TOTAL OBSERVATIONS- 8,729





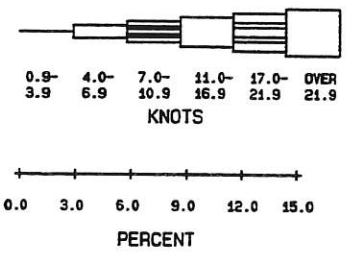
HOUR AVERAGE SURFACE WINDS

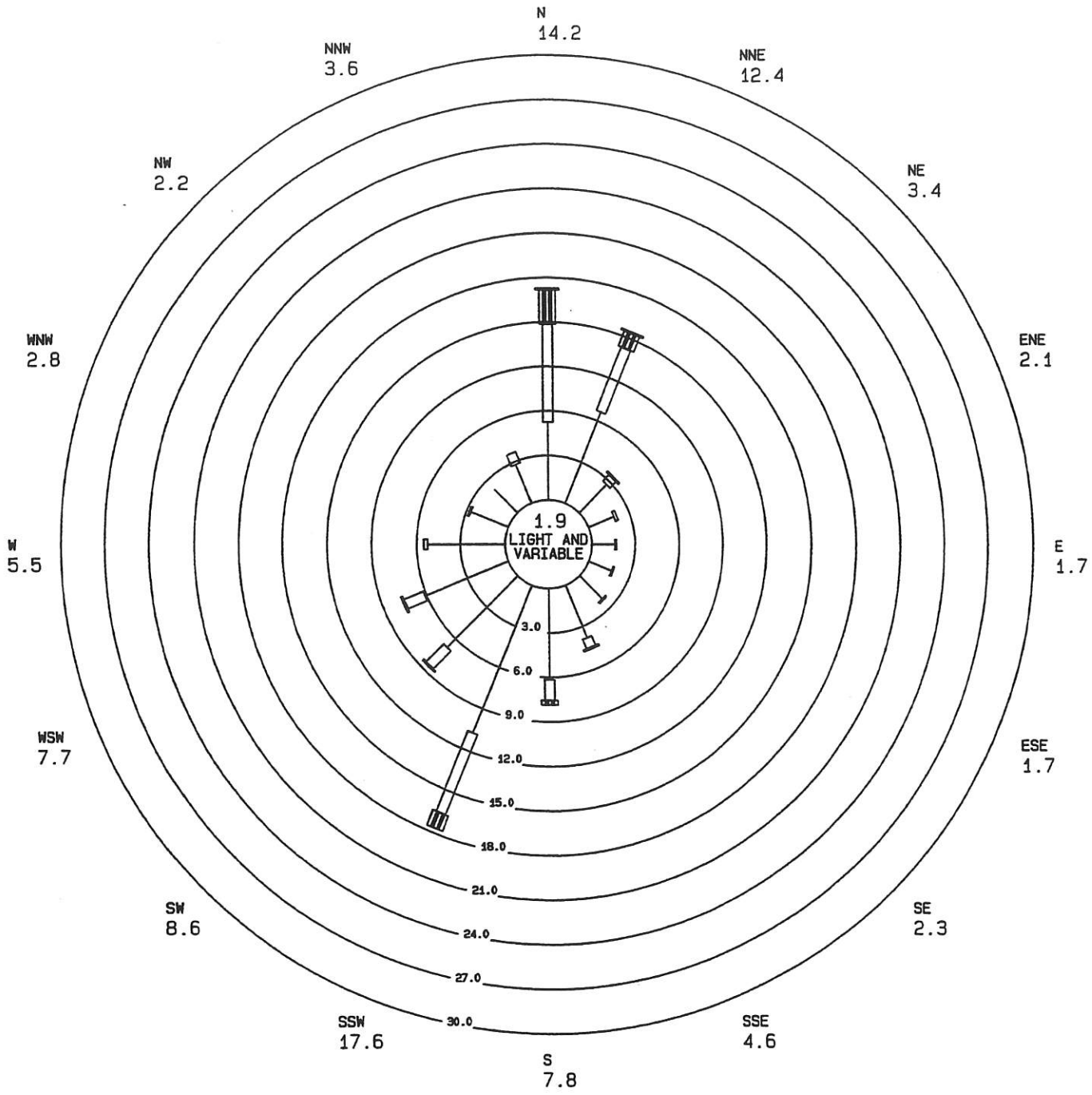
PERCENTAGE FREQUENCY OF OCCURRENCE

STATION LOCATION- PUGET SOUND AIR POLLUTION CONTROL AGENCY
James St & Central Ave, Kent, Wa

INCLUSIVE DATES- ALL MONTHS 1991

TOTAL OBSERVATIONS- 8,721





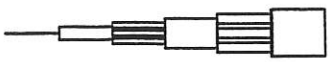
HOUR AVERAGE SURFACE WINDS

PERCENTAGE FREQUENCY OF OCCURRENCE

STATION LOCATION- PUGET SOUND AIR POLLUTION CONTROL AGENCY
27th St NE & 54th Ave NE, Northeast Tacoma, Wa

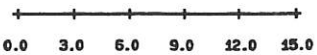
INCLUSIVE DATES- ALL MONTHS 1991

TOTAL OBSERVATIONS- 8,650

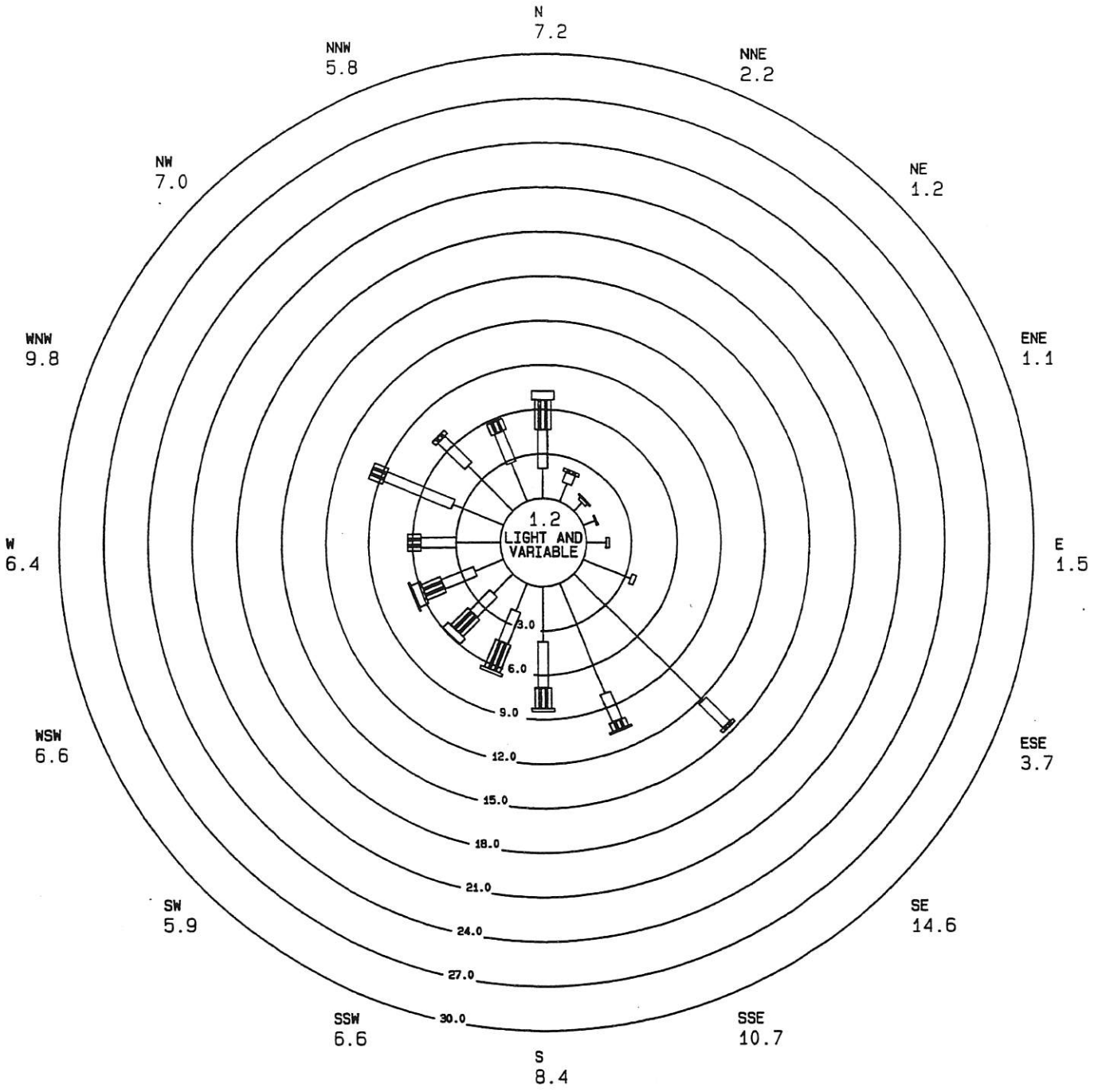


0.9- 3.9	4.0- 6.9	7.0- 10.9	11.0- 16.9	17.0- 21.9	OVER 21.9

KNOTS



PERCENT



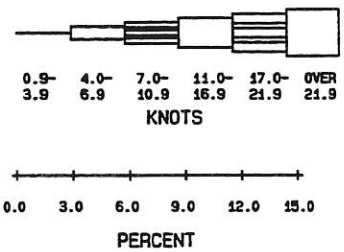
HOUR AVERAGE SURFACE WINDS

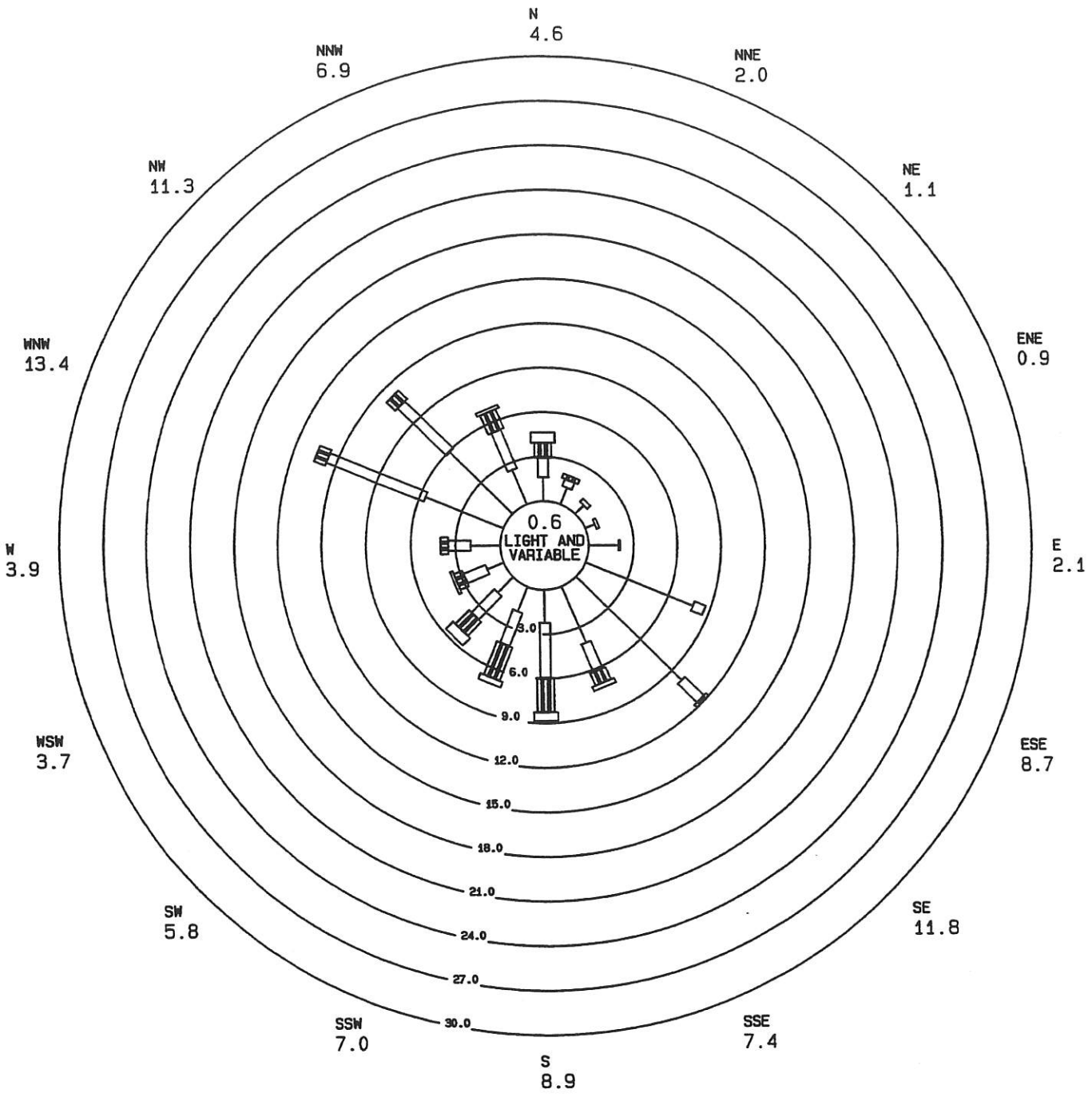
PERCENTAGE FREQUENCY OF OCCURRENCE

STATION LOCATION- PUGET SOUND AIR POLLUTION CONTROL AGENCY
2301 Alexander Ave, Tacoma, Wa

INCLUSIVE DATES- ALL MONTHS 1991

TOTAL OBSERVATIONS- 8,643





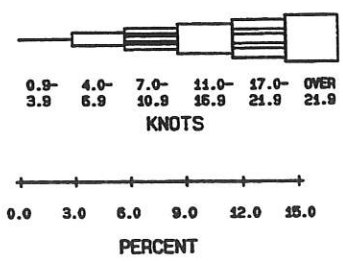
HOUR AVERAGE SURFACE WINDS

PERCENTAGE FREQUENCY OF OCCURRENCE

STATION LOCATION- PUGET SOUND AIR POLLUTION CONTROL AGENCY
Fire Station #12, 2316 E 11th St, Tacoma, Wa

INCLUSIVE DATES- ALL MONTHS 1991

TOTAL OBSERVATIONS- 8,726



AMBIENT AIR QUALITY STANDARDS

POLLUTANT	NATIONAL Primary	NATIONAL Secondary	WASHINGTON STATE	PUGET SOUND REGION
CARBON MONOXIDE				
8 Hour Average	9 ppm		9 ppm	9 ppm
1 Hour Average	35 ppm		35 ppm	35 ppm
PARTICULATE MATTER (PM10)				
Annual Arithmetic Average	50 $\mu g/m^3$	50 $\mu g/m^3$	50 $\mu g/m^3$	50 $\mu g/m^3$
24 Hour Average [a]	150 $\mu g/m^3$	150 $\mu g/m^3$	150 $\mu g/m^3$	150 $\mu g/m^3$
PARTICULATE MATTER (TSP)				
Annual Geometric Average			60 $\mu g/m^3$	60 $\mu g/m^3$
24 Hour Average			150 $\mu g/m^3$	150 $\mu g/m^3$
OZONE				
1 Hour Average [b]	0.12 ppm	0.12 ppm	0.12 ppm	0.12 ppm
SULFUR DIOXIDE				
Annual Average	0.03 ppm		0.02 ppm	0.02 ppm
30 Day Average				0.04 ppm
24 Hour Average	0.14 ppm		0.10 ppm	0.10 ppm [c]
3 Hour Average		0.50 ppm		
1 Hour Average [d]			0.25 ppm	0.25 ppm
1 Hour Average			0.40 ppm	0.40 ppm [c]
5 Minute Average [e]				1.00 ppm
LEAD				
Calendar Quarter Average	1.5 $\mu g/m^3$	1.5 $\mu g/m^3$		1.5 $\mu g/m^3$
NITROGEN DIOXIDE				
Annual Average	0.05 ppm	0.05 ppm	0.05 ppm	0.05 ppm

Notes

(1) ppm = parts per million.

(2) $\mu g/m^3$ = micrograms per cubic meter.

(3) Annual, Quarter and 30 Day standards never to be exceeded; shorter term standards not to be exceeded more than once per year unless noted.

a - Standard attained when expected number of days per year with a 24 hour concentration above 150 $\mu g/m^3$ is equal to one or less.

b - Standard attained when expected number of days per year with an hourly average above 0.12 ppm is equal to one or less.

c - Sulfur Dioxide short-term standard never to be exceeded.

d - Not to be exceeded more than twice in seven days.

e - Not to be exceeded more than once in eight hours.

CHARACTERISTICS AND EFFECTS OF AMBIENT AIR POLLUTANTS

Carbon Monoxide

Carbon monoxide is a colorless, odorless, toxic gas commonly formed when carbon-containing fuel is not burned completely. The automobile internal combustion engine is a principal source of carbon monoxide. Carbon monoxide chemically combines with the hemoglobin in the red blood cells to decrease the oxygen-carrying capacity of the blood. It also weakens the contractions of the heart, thus reducing the amount of blood pumped throughout the body. Additionally it can affect the functioning of the lungs and brain. People with heart disease and pregnant women are particularly at risk because of the effects of carbon monoxide.

Particulate Matter (PM_{10} and TSP)

Particulate matter consists of small discrete solid or aerosol particles dispersed in the air. Particulate matter with an aerodynamic diameter of less than or equal to 10 micrometers is referred to as PM_{10}. Total Suspended Particulates (TSP) includes PM_{10} and larger suspended particulates. Transportation, industrial activity and wood burning are major sources of particulate matter. Particulates one micrometer or less in diameter are especially associated with a variety of adverse effects on public health and welfare. The small particles can be breathed deeply into the lungs. Particulate in the respiratory tract may produce injury by itself, or it may act in conjunction with gases to increase the effect on the body. The elderly, those suffering from respiratory illness, and young children are especially prone to the deleterious effects of particulates. Soiling of buildings and other property, and reduced visibility are further results of high particulate matter levels.

Ozone

Ozone is a pungent-smelling, colorless gas produced in the atmosphere when nitrogen oxides and volatile organic compounds chemically react under the effect of strong sunlight. It is a pulmonary irritant that affects lung tissues and respiratory functions. Ozone impairs the normal function of the lung and, at concentrations between 0.15 and 0.25 ppm, causes lung tightness, coughing and wheezing. Other oxidants that often accompany ozone cause eye irritation. Persons with chronic respiratory problems, such as asthma, seem most sensitive to increases in ozone concentration. In contrast, ozone is beneficial when it occurs very high in the atmosphere, miles above the earth, where it protects us from harmful ultraviolet radiation.

Sulfur Dioxide

Sulfur dioxide is a colorless, corrosive gas, that has a bitter taste, but no appreciable smell between 0.3 to 1.0 ppm. Industrial sites such as smelters, paper mills, power plants and steel manufacturing plants are the main sources of sulfur dioxide pollution. The presence of sulfur dioxide in the ambient air has been associated with a variety of respiratory diseases and increased mortality rates. When sulfur dioxide is inhaled with small particles, the effect on health is increased. Inhalation of sulfur dioxide can cause increased airway resistance by constricting lung passages.

Lead

Lead particles or its compounds enter the air from vehicle exhaust and from industries that smelt or process the metal. Lead affects humans in numerous ways, but the greatest impacts appear to be on the blood-forming system, the nervous system, and the kidneys. It affects some people more than others. Young children from one to five years old are particularly sensitive to lead exposure. The standard for lead in air is intended to prevent most children from exceeding blood lead levels of 30 micrograms per deciliter of blood.

Nitrogen Dioxide

Nitrogen dioxide is a poisonous, brownish gas that, along with being a strong oxidizing agent, quickly reacts with water vapor to form corrosive nitric acid. Nitrogen dioxide is formed as the result of high temperature fuel combustion and subsequent atmospheric reactions. The presence of nitrogen dioxide in ambient air has been connected with a range of respiratory diseases. Further, nitrogen dioxide plays an essential role in the production of ozone.

AIR QUALITY UNITS CONVERSION TABLE

Air quality standards for gases are defined in terms of micrograms (µg) or milligrams (mg) per cubic meter as well as in parts per million (ppm). As this data summary expresses measurements for gaseous pollutants in terms of ppm, the following conversion table is for the convenience of those who wish to interpret our results in terms of µg/cubic meter or mg/cubic meter. These conversion factors from the Federal Register assume a pressure of 760 millimeters Hg and a temperature of 25 degrees C.

Pollutant	*Multiply ppm by*	*To Obtain*
Carbon Monoxide	1.145	mg/cubic meter
Ozone	1961	µg/cubic meter
Sulfur Dioxide	2619	µg/cubic meter
Nitrogen Dioxide	1880	µg/cubic meter