State of Oregon
Department of
Environmental
Quality

KLAMATH FALLS, OREGON
$PM_{2.5}$ PARTICULATE SITE VALIDATION STUDY

2000 - 2001

Conducted By

The Oregon Department Of Environmental Quality

Laboratories And Applied Research Division

Air Quality Monitoring Section

Sampling by: Pegeen Fitzpatrick

Report by: Mark Hansen, and Jeff Smith

August, 2001

Review by:_____ **Date:** _____

Review by:_____ **Date:** _____

Review by:_____ **Date:** _____

WORK PLAN

1. PURPOSE:

This study is being conducted in conjunction with the establishment of a new Federal Reference Method (FRM) $PM_{2.5}$ particulate sampling site in Klamath Falls on Clinton Street at Peterson Elementary School. Data from this fine particulate study will help determine if the FRM $PM_{2.5}$ sampler is optimally placed to characterize neighborhood scale $PM_{2.5}$ levels in Klamath Falls. If the study validates the selection of the Peterson School site $PM_{2.5}$ measurements from there will be used to determine if the Klamath Falls area air shed meets the new National Ambient Air Quality Standard (NAAQS) for $PM_{2.5}$ particulates.

2. HOW ACCOMPLISHED:

The study will begin in mid-Spring 2000 and continue for one year. The survey samplers have been successfully tested and their sampling precision and accuracy documented. Two types of $PM_{2.5}$ survey samplers are available for use in this study. Both samplers are low volume devices using an inertial greased impactor as the particulate size separation method. Both use the same 47 mm diameter Teflon filter. One is a battery powered sampler, the "Mini-Vol", operating at 5 lpm (liters per minute). The filter attaches to the top of the sampler by means of a special fitting. The other samplers uses a 110 VAC pump to pull 15 lpm of ambient air through the filter. The filter is "Quik" connected to a 2 meter piece of PVC pipe which is attached to the pump with tygon tubing. Both types of samplers have been used in many studies in the past and both have been recently re-tested at selected sites for their precision and accuracy. Test results are on file at the ODEQ laboratory. The AC powered 15 lpm samplers will be used in the Klamath Falls, primarily due to their more reliable operation during cold weather and their better precision results.

The samplers will run on the national EPA every 6^{th} day schedule, the same as other particulate samplers located statewide. Sites will be serviced by the Portland DEQ Lab air monitoring staff as required. The filters will be returned to the Oregon DEQ laboratory for analysis and determination of their $PM_{2.5}$ mass loadings.

3. SITE SELECTION:

Survey sites have been located to the north, south, east and west of the FRM $PM_{2.5}$ benchmark sampler at Peterson School with surroundings approximately similar to the FRM site and to each other. Effort was made to select sites with no known major fine particulate point sources nearby. The survey sites are within 1-2 kilometers of the benchmark FRM site.

See the site photos and network map (figure 1) below for more information about the sites.

Klamath Falls PM2.5
Survey Sites.

BENCHMARK SITE
Peterson Elementary School
4856 Clinton Street
Lat./Long. 42° 11’ 42.4” / 121° 43’ 54.47”
Site ID# 10118

NORTH
Klamath Falls – Hope Street
2326 Hope Street
Lat./Long 42° 12’ 22” / 121° 43’ 44”
Site ID #: 10119

WEST
Stearns Elementary School
3641 Crest Street
Lat./Long 42° 11’ 35.91” / 121° 44’ 28.87”
Site ID #: 23733

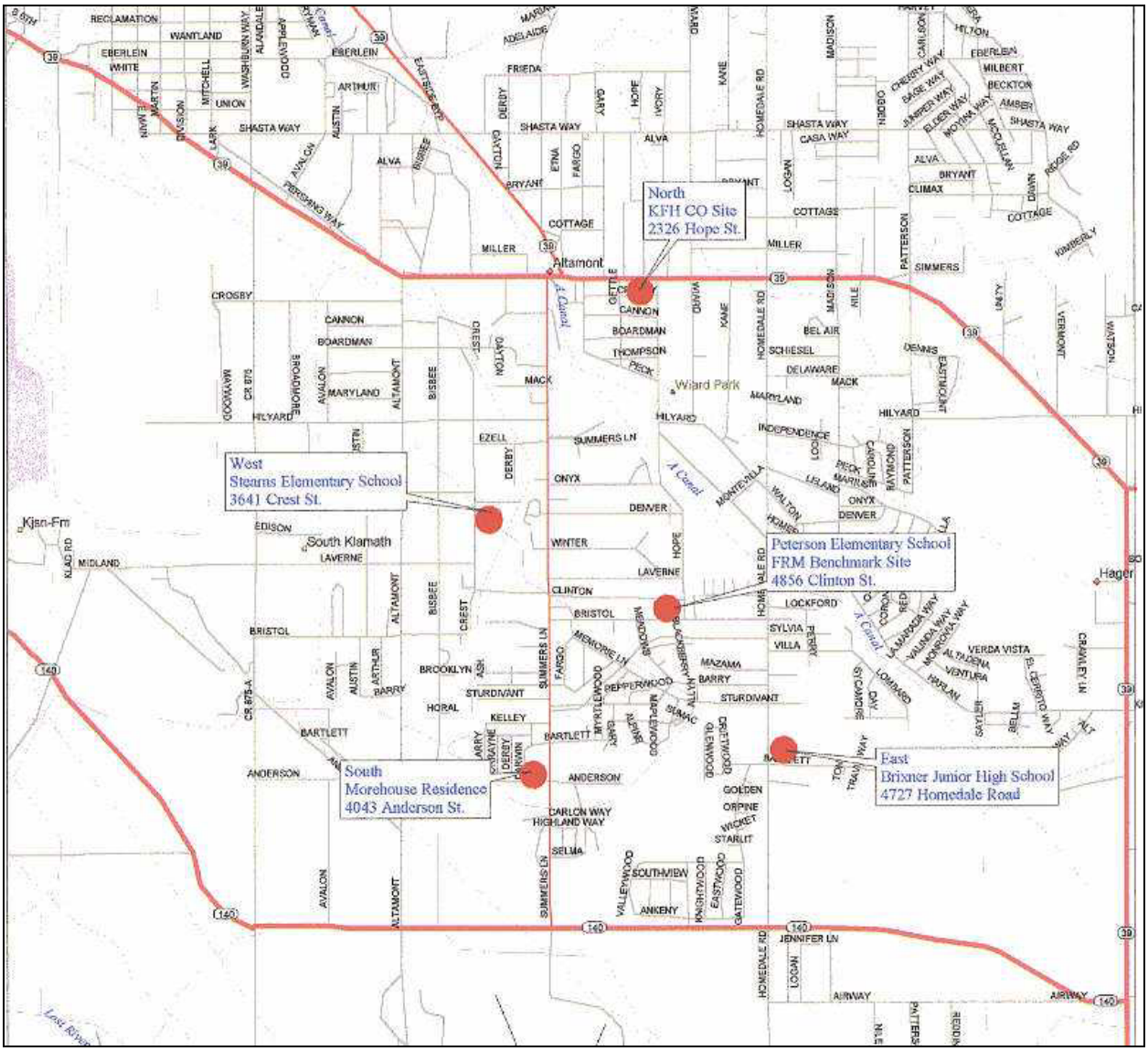
SOUTH
Morehouse Residence
4043 Anderson Street
Lat./Long 42° 10’ 52.24” / 121° 44’ 19.2”
Site ID #: 23735

EAST
Brixner Junior High School
4727 Homedale Road
Lat./Long 42° 10’ 57.77” / 121° 43’ 15.58
Site ID #: 23734

KLAMATH FALLS $PM_{2.5}$ SURVEY SITES MAP

Figure 1

↑North



4. NETWORK QA/QC:

The Rupprecht & Patashnick (R&P) model 2025 sequential FRM $PM_{2.5}$ sampler is an EPA certified reference method sampler for the measurement of $PM_{2.5}$. It is a proven and reliable method of measuring fine particulate and will be the benchmark device for this study. It samples at the Peterson School benchmark site. Two $PM_{2.5}$ survey samplers will be co-located at the benchmark site where they will provide data used to determine the precision and accuracy of the study results.

All of the survey samplers will be subjected to periodic independent flow audits performed by DEQ Lab staff during regularly scheduled (monthly) network reviews. The performance of the local operator will also be reviewed during these visits.

The operator will maintain a "journal" of the project, noting significant events (equipment problems, unusual weather, etc.), and document the required cleaning and regreasing of the $PM_{2.5}$ impactor inlets.

Additional standard Quality Control activities will occur at the laboratory during the review of the samples, field data sheets, and analytical mass determination.

5. FUND CODE:

This study is part of the calendar year 2000 work plan for the state wide $PM_{2.5}$ network. It is funded under an EPA 103 grant. The internal DEQ Lab fund code is 9811.

6. SUMMARY AND REPORT:

A report detailing the results of this study will be generated at the end of the one year project. The report will include all of the sampling data from all 5 sites. The data from the co-located survey samplers (primary and duplicate) at the benchmark site will be analyzed to determine the precision of the survey samplers. The accuracy of the survey method will be determined by comparing the results of the co-located survey and FRM samplers. The results of the 4 survey sites will be compared to that of the benchmark site. A conclusion will be made as to the suitability of the current $PM_{2.5}$ siting in Klamath Falls.

7. PROJECT SCHEDULE:

Activity	Date
Develop work plan.	January, 2000
Site search and procurement.	February-March, 2000
Equipment preparation and testing.	April, 2000
Begin sampling.	May, 2000
End sampling.	June 2001
Final report.	August 2001

PROJECT IMPLEMENTATION

1. NETWORK QA/QC:

All sampler and flow orifices used in the survey were calibrated at the ODEQ Lab using a National Institute of Standards and Technology (NIST) traceable roots meter.

Prior to startup of the actual survey, the 15 lpm inlets were tested as a group at a site in Portland. Three 24 hour samples were collected. This was to test each sampler's operation as well as to compare the performance of the $PM_{2.5}$ inlets used in the survey. Results of the group testing showed that the inlets compared favorably to one another although they tended to over-collect $PM_{2.5}$ as compared to the reference method sampler (FRM). The results of this test are on file at the ODEQ laboratory.

Network Quality Control (QC) audits were performed on 7/2/00, 8/7/00, 8/27/00, 9/26/00, 10/30/00, 12/6/00, 1/11/01, 2/8/01, 3/7/01, 4/4/01 and 5/2/01. A review of audit records indicated that, with only one marginal exception, all of the samplers operated within 10% of the ideal design flow (assuring a proper particulate size cut by the inlets). The one exception was a single audit of one sampler that showed a flow slightly below the 10% limit. This flow was corrected. The operator's flow orifice used for the survey was also regularly audited and found to be well within the 10% limit. According to the operator's records all of the $PM_{2.5}$ impactor inlets were cleaned at their regularly scheduled (monthly) intervals during the survey.

The benchmark $PM_{2.5}$ FRM sampler was subject to regular monthly QC audits. All sensor and flow audits performed during the duration of the survey were within EPA established limits. Additional quarterly Quality Assurance (QA) audits of the $PM_{2.5}$ FRM sampler performed by the DEQ Laboratory QA section were all within EPA limits, confirming these results.

As a result of all of these efforts, we believe that the data quality objectives for this project were met and are confident in the quality of the data generated by this survey.

2. RESULTS:

Results of the Klamath Falls $PM_{2.5}$ survey are shown in the following tables and graphs. Table 1 contains all of the survey sampling data from the study. At the bottom of Table 1 is the key for the codes used to indicate missing samples. Table 2 is a summary of the data. Figure 1 is a graph of all the results for the entire project.

The precision and accuracy (P&A) of the R&P $PM_{2.5}$ FRM sampler was not tested as part of this study. P&A data for this sampler is routinely developed at a number of regular $PM_{2.5}$ sampling sites across the state. This information is available from the DEQ Lab and from EPA.

Data on the precision of the survey samplers was generated by co-locating (primary and duplicate) samplers at the benchmark site. This data is displayed in Table 3 and its accompanying graph. The statistical correlation between the two was 0.9914. The corresponding R squared value is 0.9829. The average difference between the primary and duplicate samplers was 0.35 ug/m3 with a maximum difference of 4.7 ug/m3. The sigma value between the two was 1.43. This data is based on only 51 of the possible 62 valid matched filter pairs. Of the eleven missing sample pairs, six were due to the operator's failure to remove the inlet impactor stages from a damaged inlet housing and install them in the replacement housing.

Fortunately, this occurred during the last six samples of the survey when PM2.5 levels were near their lowest.

Survey sampler accuracy is determined by comparing the average of the co-located survey samplers against the benchmark PM2.5 FRM sampler. In instances where either the primary or duplicate survey sample is missing, the single good value is used to represent the survey sampler average. This data is displayed in Table 4 and its accompanying graph. The survey samplers tended to over collect particulate as compared to the benchmark FRM sampler by an average of 1.5 ug/m3 with a maximum difference of 7.7 ug/m3. The correlation between the two was 0.9699 (R squared value of 0.9407). The sigma value between the two was 2.46. Note, the linear curve fit of the accuracy data has a slope of .936, which would indicate that the FRM collects more PM than does the survey sampler. This contrary conclusion is the result of a single data pair at the high end of the curve that is skewing the fit.

All of the survey sites generated varied but consistent results. The data is displayed as a graph in figure 1. Survey averages from the five sites ranged from 10.4 to 13.6 ug/m3. The North site had the highest, and the East and South sites the lowest survey averages. The results from the survey samplers at the current FRM benchmark site (KFP) were comfortably in the middle of the range. These annual average values are comfortably below the annual $PM_{2.5}$ NAAQS of 15 ug/m3.

The highest single value from the entire survey was 54.2 ug/m3 and occurred at the West site on 12-8-00, followed by 51.9 ug/m3 at the South site on the same date. These are both below the NAAQS 24 hour standard of 65 ug/m3.

3. CONCLUSIONS:

The survey results indicate that the current $PM_{2.5}$ monitoring station at the Peterson School site is suitably located to characterize neighborhood scale $PM_{2.5}$ levels in Klamath Falls. When comparing the survey averages from each site, the Peterson School site ranks virtually tied for second with the West site. Its PM values are right between the values from the highest and lowest sites. The North site generated the highest individual survey average, and on days of elevated PM2.5 levels, one or two of the other sites would occasionally report values exceeding those from the Peterson School site. The North site at Hope Street, was much closer to the Hwy. 39 corridor and business district. This may explain it's higher readings. Conversely, the two lowest survey averages (East and South sites) were further removed from the business district and in more residential settings.

Although three years of monitoring data are required in order to determine compliance with the new PM2.5 NAAQS, based on the results of this one year survey it is reasonable to project that Klamath Falls has a good chance of complying with these standards.

Table 1. Klamath Falls PM2.5 Survey Results (all values in ug/m^3)

Date	North Hope St	East Brixner	South Morehouse	West Stearns	KFP Prim	KFP Dupe	KFP P&D avg	KFP FRM
7-Jun-00	5.0	5.2	5.5	4.8	3.9	5.5	4.7	3.5
11-Jun-00	3.7	3.3	2.6	4.2	2.8	2.6	2.7	3.2
17-Jun-00	6.5	4.2	3.9	4.3	3.4	3.4	3.4	2.6
23-Jun-00	6.6	5.1	4.6	6.7	5.7	5.0	5.4	3.9
29-Jun-00	7.6	9.1	11.0	8.7	8.5	8.5	8.5	10.2
5-Jul-00	3.7	2.6	7.6	5.1	3.6	2.7	3.2	2.7
11-Jul-00	7.3	5.2	6.7	6.9	6.4	**OE**	6.4	5.6
17-Jul-00	7.7	6.5	7.4	3.8	6.2	6.9	6.6	6.1
23-Jul-00	5.3	4.7	4.4	5.7	4.2	5.7	5.0	3.9
29-Jul-00	6.7	4.8	4.9	6.3	5.0	5.1	5.1	4.7
4-Aug-00	6.7	7.6	7.0	6.5	6.5	6.5	6.5	**IM**
10-Aug-00	7.4	4.7	4.6	5.5	5.9	4.7	5.3	4.6
16-Aug-00	9.6	5.8	6.5	6.2	5.4	6.0	5.7	5.6
22-Aug-00	10.0	**IM**	9.1	9.5	9.2	9.4	9.3	8.2
28-Aug-00	5.4	7.3	5.4	6.4	7.6	4.7	6.2	3.8
3-Sep-00	4.5	3.2	3.2	3.3	5.5	4.4	5.0	2.0
9-Sep-00	6.5	7.3	4.4	6.2	4.4	5.6	5.0	3.3
15-Sep-00	6.9	4.4	6.2	7.9	4.4	4.3	4.4	5.3
21-Sep-00	5.0	4.6	4.9	3.4	3.7	3.7	3.7	4.3
27-Sep-00	10.0	8.6	8.4	10.7	8.9	8.5	8.7	8.1
3-Oct-00	7.3	7.2	6.2	6.6	7.0	6.9	7.0	6.6
9-Oct-00	7.2	7.9	6.3	8.4	**IM**	7.0	7.0	6.9
15-Oct-00	13.8	11.4	16	18.8	**IM**	**IM**	12	16.9
17-Oct-00	**NA**	**NA**	**NA**	**NA**	12.2	11.7	12.0	12.9
21-Oct-00	3.5	2.7	4.0	5.2	3.4	2.7	3.1	2.9
27-Oct-00	11.5	10.5	13.1	14.4	12.5	11.6	12.1	14.6
2-Nov-00	21.2	10.7	14.8	15.5	18.6	14.2	16.4	16.2
8-Nov-00	8.2	6.2	6.7	5.0	5.4	5.8	5.6	5.9
14-Nov-00	19.8	13.2	13.7	18.3	19.0	19.0	19.0	19.8
20-Nov-00	36.4	27.9	28.1	30.1	30.2	29.8	30.0	32.4
26-Nov-00	17.4	14.6	20.5	20.0	21.4	20.7	21.1	21.8
2-Dec-00	34.7	21.2	23.1	20.8	23.7	23.5	23.6	24.4
8-Dec-00	40.8	39.8	51.9	54.2	48.7	47.4	48.1	53.6
14-Dec-00	10.7	6.7	8.1	6.9	7.1	7.8	7.5	6.4
20-Dec-00	22.8	23.9	25.9	29.4	22.9	22.9	22.9	24.7
26-Dec-00	32.6	23.8	19.9	25.1	29.9	27.1	28.5	21.8
1-Jan-01	42.5	39.2	32.1	33.8	40.0	41.0	40.5	36.7
7-Jan-01	24.3	14.1	12.8	12.5	17.8	17.6	17.7	11.6
13-Jan-01	13.7	6.5	7.0	8.7	10.0	10.2	10.1	7.8
19-Jan-01	35.3	**OE**	26.4	29.3	35.1	30.4	32.8	26.9
25-Jan-01	11.1	5.0	9.9	8.0	6.9	6.3	6.6	4.5
31-Jan-01	39.1	31.4	31.8	34	34.3	31.4	32.9	31.9
6-Feb-01	16.3	8.3	6.3	4.6	6.0	6.6	6.3	2.7
12-Feb-01	14.3	7.2	14.5	12.1	11.2	11.5	11.4	10.3
18-Feb-01	4.0	3.1	3.7	2.8	3.0	2.9	3.0	1.9
24-Feb-01	12.9	10.8	17.5	12.9	19.4	16.0	17.7	13.0

Date	North Hope St	East Brixner	South Morehouse	West Stearns	KFP Prim	KFP Dupe	KFP P&D avg	KFP FRM
2-Mar-01	16.9	7.1	12.4	8.1	11.8	11.3	11.6	IM
8-Mar-01	**FC**	8.2	8.3	13.6	9.0	8.9	9.0	7.5
14-Mar-01	24	11.0	15.0	18.5	17.8	20.8	19.3	11.6
20-Mar-01	14.8	10.4	12.6	13.8	14.1	14.1	14.1	11.0
26-Mar-01	12.4	7.7	9.7	14.5	11.3	10.7	11.0	8.8
1-Apr-01	11	9.4	8.5	9.3	7.3	9.6	8.5	6.3
7-Apr-01	9.1	3.7	3.9	6.6	5.5	5.8	5.7	1.8
13-Apr-01	10.0	7.5	6.6	7.5	7.9	7.7	7.8	4.6
19-Apr-01	7.3	4.3	5.7	5.2	**IBO**	**IBO**		2.9
25-Apr-01	10.9	9.3	10.0	11.4	8.8	**IM**	8.8	6.5
1-May-01	8.5	6.0	6.0	**OE**	9.3	**OE**	9.3	3.1
7-May-01	12.0	10.6	10.1	10.9	11.1	**OE**	11.1	7.0
13-May-01	12.4	9.3		11.7	11.0	**OE**	11	5.9
19-May-01	10.6	14.2	7.9	8.0	9.7	**OE**	9.7	6.0
25-May-01	11.5	13.9	9.4	9.4	10.0	**OE**	10.0	7.1
31-May-01	8.9	8.1	6.0	6.7	5.5	**OE**	5.5	3.0
Average	13.6	10.1	11.2	11.9	12.0	12.0	11.8	10.3
Count	60	59	60	60	59	52	60	60

Code key for missing samples:

IM	instrument malfunction
OE	operator error
FC	filter contaminated
PD	power disconnected
IBO	instrument blown over
NA	not a sample day

Table 2. Summary of Results

Site	# samples (62 possible)	Survey Avg ug/m3	Highest ug/m3	Days > 15 ug/m3
North	60	13.6	42.5	15
East	59	10.4	39.8	7
South	60	11.2	51.9	11
West	60	11.8	54.2	13
KFP-P	59	12.0	48.7	14
KFP-D	52	12.0	47.4	12
Avg of P&D *	60	11.7	48.1	14
KFP FRM	60	10.3	53.6	11

* using available numbers when either Pri or Dup sample is missing

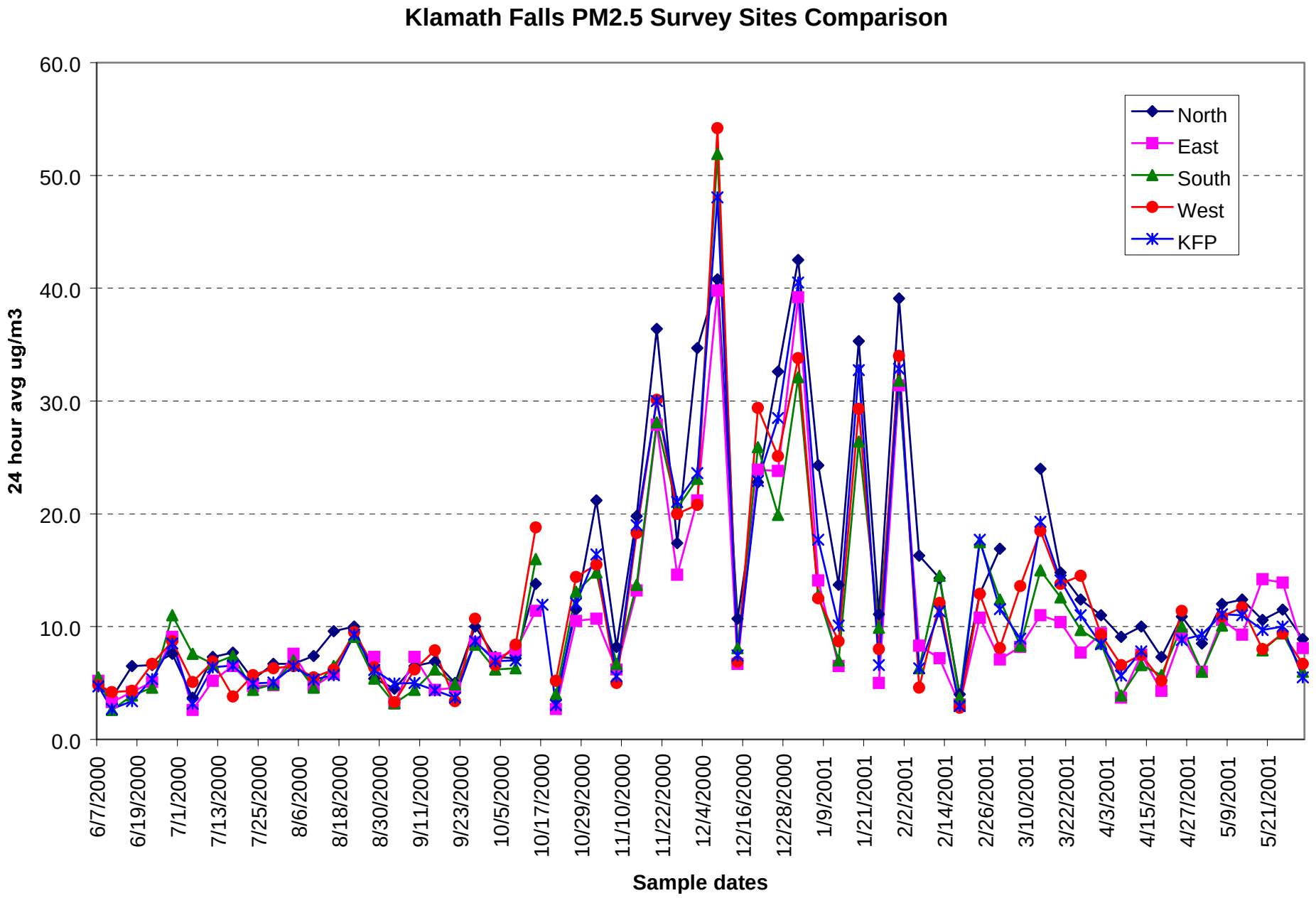

Klamath Falls PM2.5 Survey Sites Comparison
24 hour avg ug/m3
60.0
50.0
40.0
30.0
20.0
10.0
0.0
North
East
South
West
KFP
6/7/2000
6/19/2000
7/1/2000
7/13/2000
7/25/2000
8/6/2000
8/18/2000
8/30/2000
9/11/2000
9/23/2000
10/5/2000
10/17/2000
10/29/2000
11/10/2000
11/22/2000
12/4/2000
12/16/2000
12/28/2000
1/9/2001
1/21/2001
2/2/2001
2/14/2001
2/26/2001
3/10/2001
3/22/2001
4/3/2001
4/15/2001
4/27/2001
5/9/2001
5/21/2001
Sample dates

Figure 1

Table 3. Precision Data: Co-Located survey samplers at the Benchmark Site

All values in ug/m3.

Date	Pri	Dup	Pri - Dup
7-Jun-00	3.9	5.5	-1.6
11-Jun-00	2.8	2.6	0.2
17-Jun-00	3.4	3.4	0
23-Jun-00	5.7	5	0.7
29-Jun-00	8.5	8.5	0
5-Jul-00	3.6	2.7	0.9
17-Jul-00	6.2	6.9	-0.7
23-Jul-00	4.2	5.7	-1.5
29-Jul-00	5	5.1	-0.1
4-Aug-00	6.5	6.5	0
10-Aug-00	5.9	4.7	1.2
16-Aug-00	5.4	6	-0.6
22-Aug-00	9.2	9.4	-0.2
28-Aug-00	7.6	4.7	2.9
3-Sep-00	5.5	4.4	1.1
9-Sep-00	4.4	5.6	-1.2
15-Sep-00	4.4	4.3	0.1
21-Sep-00	3.7	3.7	0
27-Sep-00	8.9	8.5	0.4
3-Oct-00	7	6.9	0.1
17-Oct-00	12.2	11.7	0.5
21-Oct-00	3.4	2.7	0.7
27-Oct-00	12.5	11.6	0.9
2-Nov-00	18.6	14.2	4.4
8-Nov-00	5.4	5.8	-0.4
14-Nov-00	19	19	0
20-Nov-00	30.2	29.8	0.4
26-Nov-00	21.4	20.7	0.7

Date	Pri	Dup	Pri - Dup
2-Dec-00	23.7	23.5	0.2
8-Dec-00	48.7	47.4	1.3
14-Dec-00	7.1	7.8	-0.7
20-Dec-00	22.9	22.9	0
26-Dec-00	29.9	27.1	2.8
1-Jan-01	40	41	-1
7-Jan-01	17.8	17.6	0.2
13-Jan-01	10	10.2	-0.2
19-Jan-01	35.1	30.4	4.7
25-Jan-01	6.9	6.3	0.6
31-Jan-01	34.3	31.4	2.9
6-Feb-01	6	6.6	-0.6
12-Feb-01	11.2	11.5	-0.3
18-Feb-01	3	2.9	0.1
24-Feb-01	19.4	16	3.4
2-Mar-01	11.8	11.3	0.5
8-Mar-01	9	8.9	0.1
14-Mar-01	17.8	20.8	-3
20-Mar-01	14.1	14.1	0
26-Mar-01	11.3	10.7	0.6
1-Apr-01	7.3	9.6	-2.3
7-Apr-01	5.5	5.8	-0.3
13-Apr-01	7.9	7.7	-0.2
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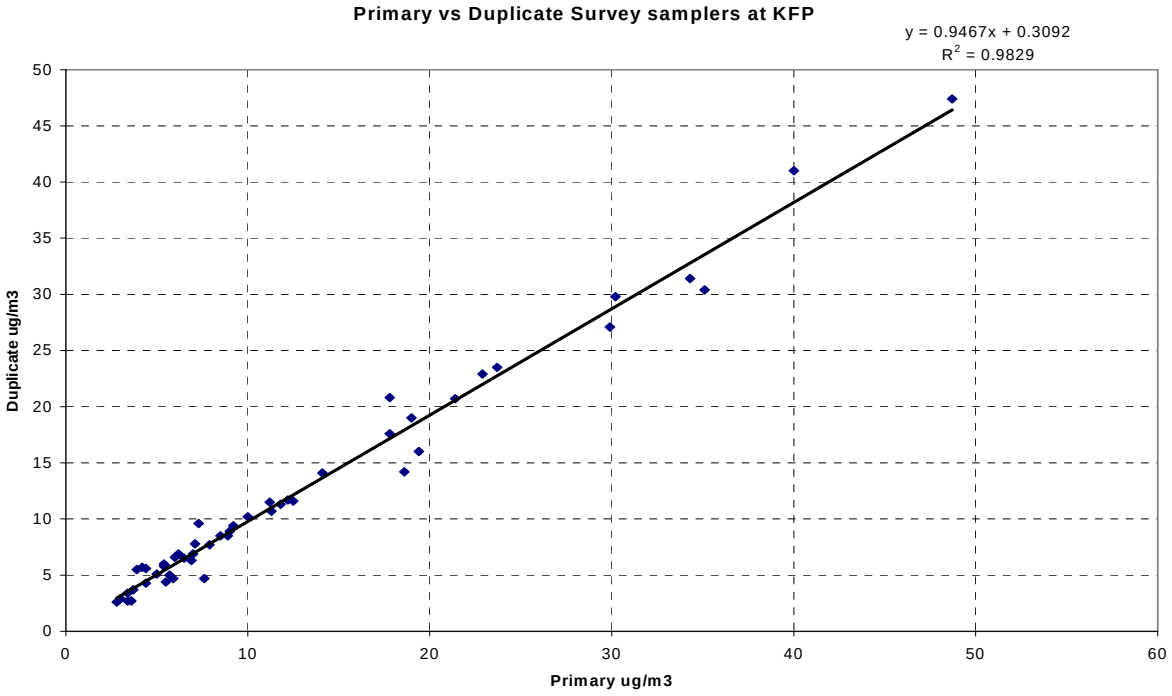

Table 4. Accuracy Data: FRM versus Survey at Benchmark Site (KFP)

All values in ug/m3.

Date	FRM	P&D Avg	FRM-Avg
7-Jun-00	3.5	4.7	-0.8
11-Jun-00	3.2	2.7	0.5
17-Jun-00	2.6	3.4	-0.8
23-Jun-00	3.9	5.4	-1.5
29-Jun-00	10.2	8.5	1.7
5-Jul-00	2.7	3.2	-0.5
11-Jul-00	5.6	6.4	-0.8
17-Jul-00	6.1	6.6	-0.5
23-Jul-00	3.9	4.2	-0.3
29-Jul-00	4.7	5.1	-0.4
10-Aug-00	4.6	5.3	-0.7
16-Aug-00	5.6	5.7	-0.1
22-Aug-00	8.2	9.3	-1.1
28-Aug-00	3.8	6.2	-2.4
3-Sep-00	2	5	-3
9-Sep-00	3.3	5	-1.7
15-Sep-00	5.3	4.4	-0.9
21-Sep-00	4.3	3.7	0.6
27-Sep-00	8.1	8.7	-0.6
3-Oct-00	6.6	7	-0.4
9-Oct-00	6.9	7	-0.1
17-Oct-00	12.9	12	0.9
21-Oct-00	2.9	3.1	-0.2
27-Oct-00	14.6	12.1	2.5
2-Nov-00	16.2	16.4	-0.2
8-Nov-00	5.9	5.6	0.3
14-Nov-00	19.8	19	0.8
20-Nov-00	32.4	30	2.4
26-Nov-00	21.8	21.1	0.8
2-Dec-00	24.4	23.6	0.8
8-Dec-00	53.6	48.1	5.5
14-Dec-00	6.4	7.5	-1.1
20-Dec-00	24.7	22.9	1.8
26-Dec-00	21.8	28.5	-6.7
1-Jan-01	36.7	40.5	-3.8
7-Jan-01	11.6	17.7	-6.1
13-Jan-01	7.8	10.1	-2.3
19-Jan-01	26.9	32.8	-5.9
25-Jan-01	4.5	6.6	-2.1
31-Jan-01	31.9	32.9	-1
6-Feb-01	2.7	6.3	-3.6
12-Feb-01	10.3	11.4	-1.1
18-Feb-01	1.9	3	-1.1
24-Feb-01	13	17.7	-4.7
8-Mar-01	7.5	9	-1.5
14-Mar-01	11.6	19.3	-7.7
20-Mar-01	11	14.1	-3.1
26-Mar-01	8.8	11	-2.2
1-Apr-01	6.3	8.5	-2.2
7-Apr-01	1.8	5.7	-3.9
13-Apr-01	4.6	7.8	-3.2
25-Apr-01	6.5	8.8	-2.3
1-May-01	3.1	9.3	-6.2
7-May-01	7	11.1	-4.1
13-May-01	5.9	11	-5.2
19-May-01	6	9.7	-3.7
25-May-01	7.1	10	-2.9
31-May-01	3	5.5	-2.5
Average =	10.34	11.85	-1.51
Count =			58
Correlation =			0.9699
Sigma =			2.46
Max diff =			7.7