MEMORANDUM

SUBJECT: Investigation of How Distributions of Hourly Nitrogen Dioxide
Concentrations Have Changed Over Time in Six Cities

FROM: Michael Rizzo, Air Quality Analysis Group

TO: Nitrogen Dioxide NAAQS Review Docket (EPA–HQ–OAR–
2006–0922)

DATE: November 20, 2008

For the current review of the nitrogen dioxide (NO2) National Ambient Air Quality
Standards (NAAQS), I have compared the distributions of hourly NO2 concentration
values for years with low and high ambient air concentrations to determine how these
distributions have changed over time for six cities across the United States.
Understanding these historical changes is relevant to creating estimates of what air
quality for NO2 would be if air quality deteriorated or improved to just meet potential
NAAQS standards being analyzed in the risk and exposure analysis for NO2.

For each of the cities (Los Angeles, Atlanta, New York, Philadelphia, Denver and
Chicago), NO2 data for reference and equivalent air monitors were taken from the Air
Quality System (AQS) on September 10, 2008, years prior to and including 2007.   The
base year of 2007 was used as the low concentration year and compared to a high
concentration year which was selected from years prior to 2007 as described below.

Completeness criteria were applied to data from each year to determine which sites
within each city would be used in the analysis. Sites had to have at least 75% of the
hourly values within a sampled day to be valid. Each quarter had to have at least 75%
valid days to be complete and all four quarters had to be complete across the year to be
used. Any sites without complete data for 2007 were eliminated. Among the sites which
are complete for 2007, monitoring records were then examined to determine which sites
had complete data for each year prior to 1986. The earliest year in which all retained
sites had complete data was used as the high concentration year for that city. Thus, all
valid sites within a specific area utilized the same years of data for consistency purposes.

For each site within a city, pairs of points on the low and high year distributions were
selected at percentiles ranging from 0% to 100% with 1% increments. Figures 1 through
6 display these paired points by monitoring site, visualizing the relationship between the

low and high year distributions for complete sites within each city. A line representing the linear fit of the data is also displayed along with the correlation coefficient characterizing the quality of the fit.

Overall, the majority of sites across the six cities exhibit a strongly linear relationship between the low and high year distributions. In some cases, specific observations at individual sites deviate from linearity to varying degrees either at the extreme upper or lower ends of the distributions. Obviously noticeable deviations from the linear fit at most sites are limited to the extreme upper end of the distribution at values usually greater than the 98th percentile.

In the majority of the monitor cases, the y-intercept of the best fit line is positive, with only a few cases of a noticeable negative intercept. A positive intercept indicates a larger decline between high and low year concentrations in the upper end of the distribution than in the lower percentiles. The positive intercept adds a constant value to the proportionally reduced individual concentrations across the distribution. The size of that offset will be larger relative to the concentrations at the lower end of the distribution and smaller relative to the concentrations at the upper end of the distribution. Hence, a linear relationship with a positive intercept will cause concentrations on the distribution's upper end to be reduced more between the high and low years as opposed to concentrations on the lower end of the distribution.

Where an individual paired data point falls below the best fit line, it means that percentile point has declined even more strongly than the middle of the distribution. Most, although not all, of the 98th and higher percentile points that deviate from their best fit lines do fall below the line.

Figure 1. Comparison of low to high year concentration distributions for sites within the New York area

High Year: 1984 Low Year: 2007

Figure 2. Comparison of low to high year concentration distributions for sites within the Philadelphia area

High Year: 1985 Low Year: 2007

Figure 3. Comparison of low to high year concentration distributions for a site within the Atlanta area

Figure 4. Comparison of low to high year concentration distributions for a site within the Chicago area
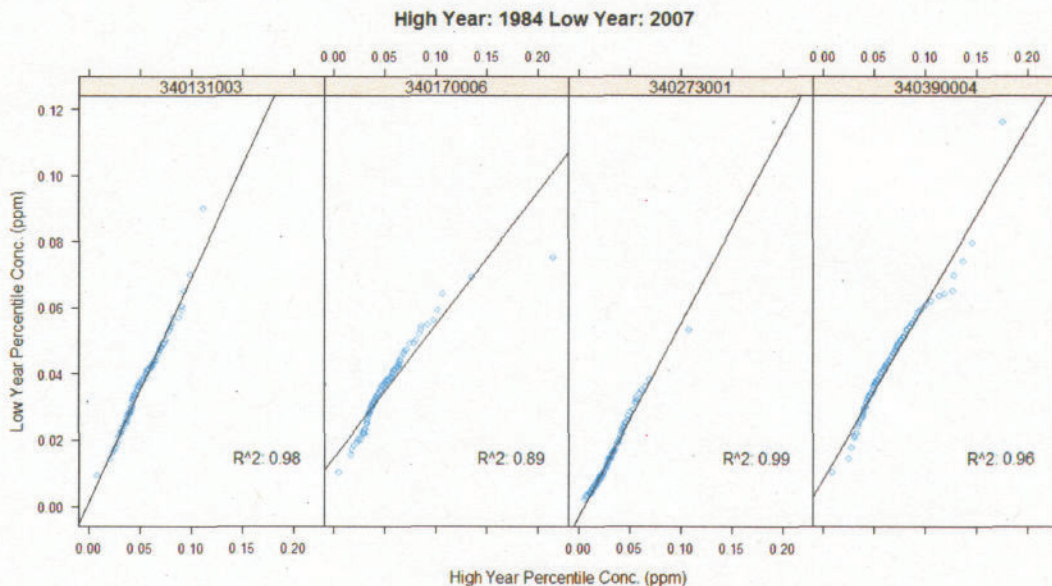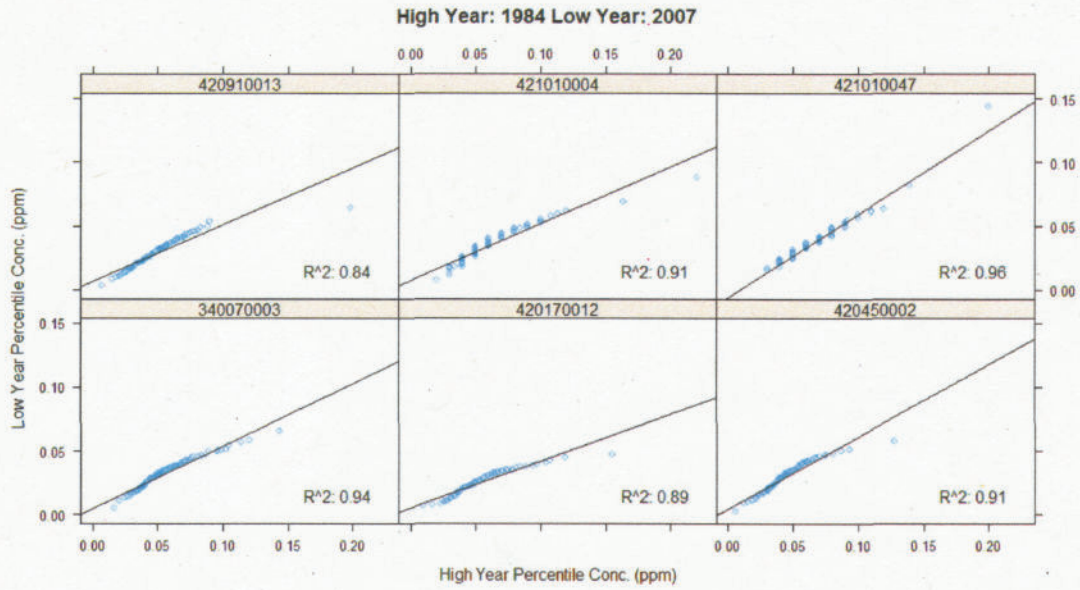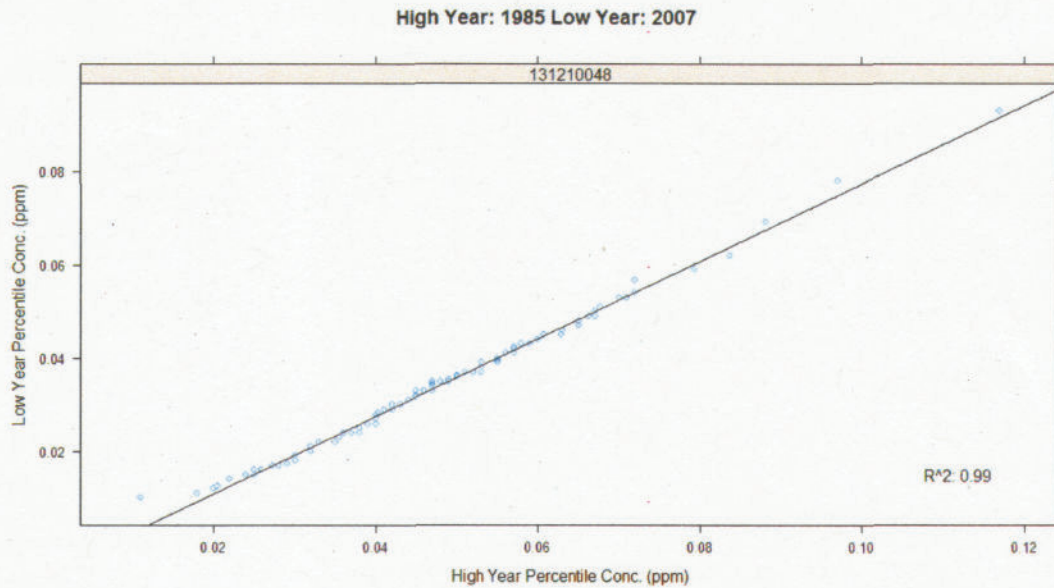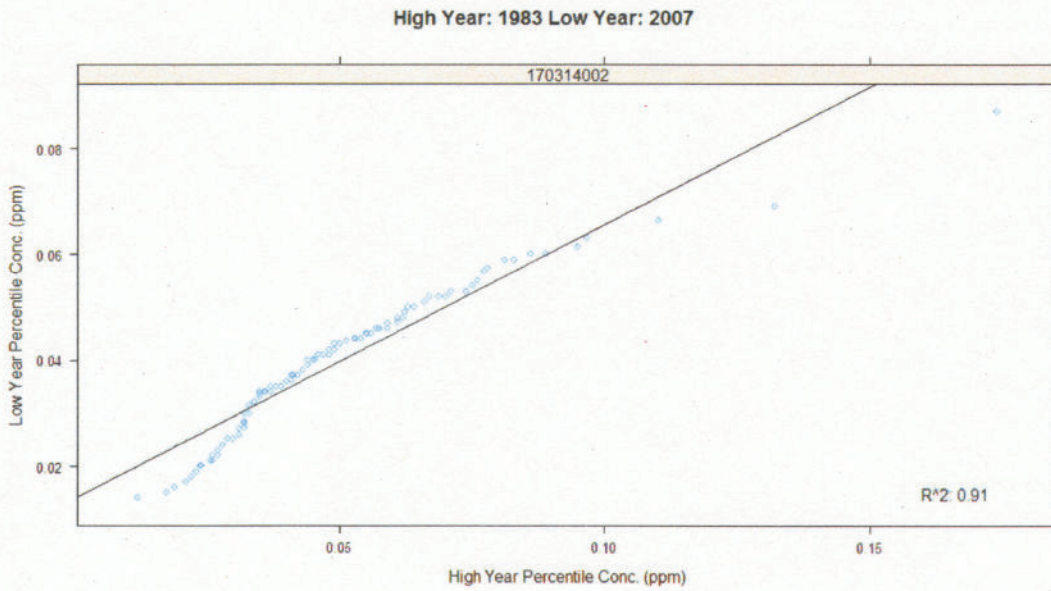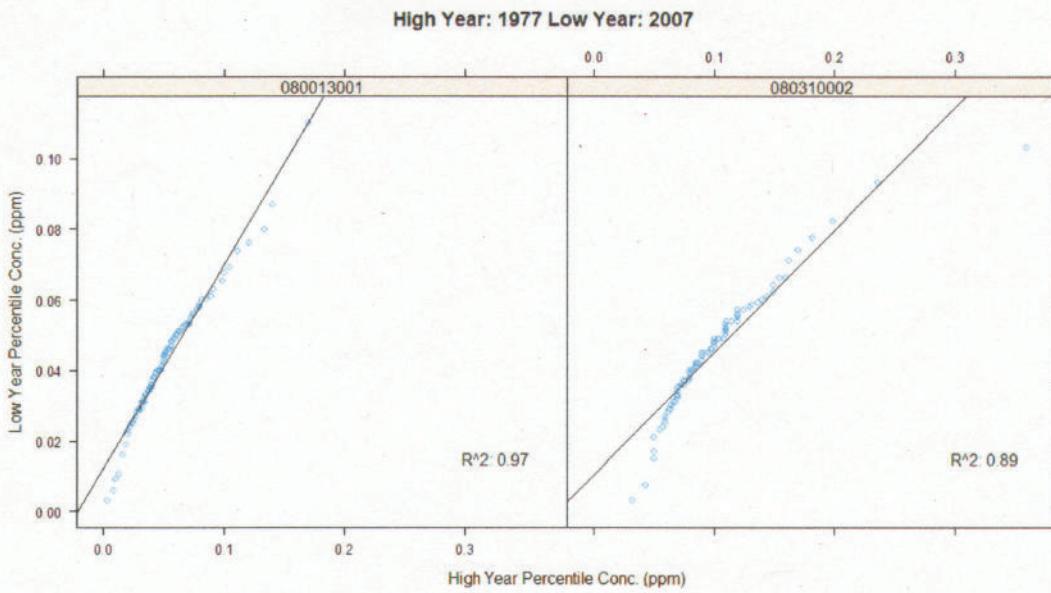
High Year: 1977 Low Year: 2007

Figure 5. Comparison of low to high year concentration distributions for sites within the Denver area
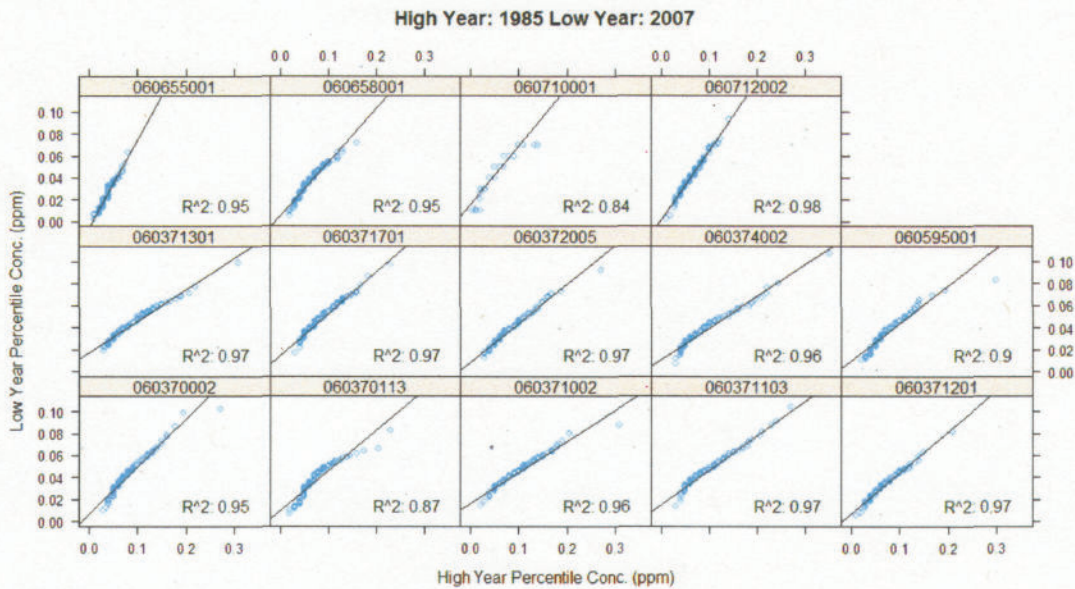
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Figure 6. Comparison of low to high year concentration distributions for sites within the Los Angeles area

An additional analysis was done to determine whether or not the relationship between high and low year NO_2 concentrations remained consistent when examining the distributions from a subset of high and low years for the sites analyzed above. The three most complete low concentration years and the three most complete high concentration years which were unique to each site were paired to give nine combinations of low to high year comparisons with each comparison fitted to a linear model. An example of the nine possible pairings is presented in Figure 7 for the site used in Atlanta, GA. The studentized residuals were computed and compared to a students t distribution at a significance level of 10%. Points significant at the 10% level for each site and pair of years are listed in tables 1 through 6. Highlighted sites within the tables correspond to site-year pairs appearing in Figures 1 through 6.

The corresponding R^2 for each comparison and the individual point's percent of the total error in the model are also listed. In general, an R^2 greater than 0.95 showed the data fit a linear model well across the entire span of the distribution. Values at the extreme upper and lower ends of the distribution tended to deviate more from linearity when the R^2 was between 0.9 and 0.94, while the middle part of the distribution remained linear. When the R^2 fell below 0.9, the relationship between the low and high year distributions appeared more curvilinear although in some cases outliers played a large role at specific sites in determining the R^2 with the remainder of the data being fit well by the linear model. The overall quality of the fit between the low and high years also appeared to be more dependent on the site rather than the area. Since attainment of the standard would probably be based on the monitor having the highest concentration within a geographic area, adjusting the data at individual sites through either "roll up" or "roll back" appears justified.

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Atlanta–Sandy Springs–Gainesville, GA–AL: 131210048
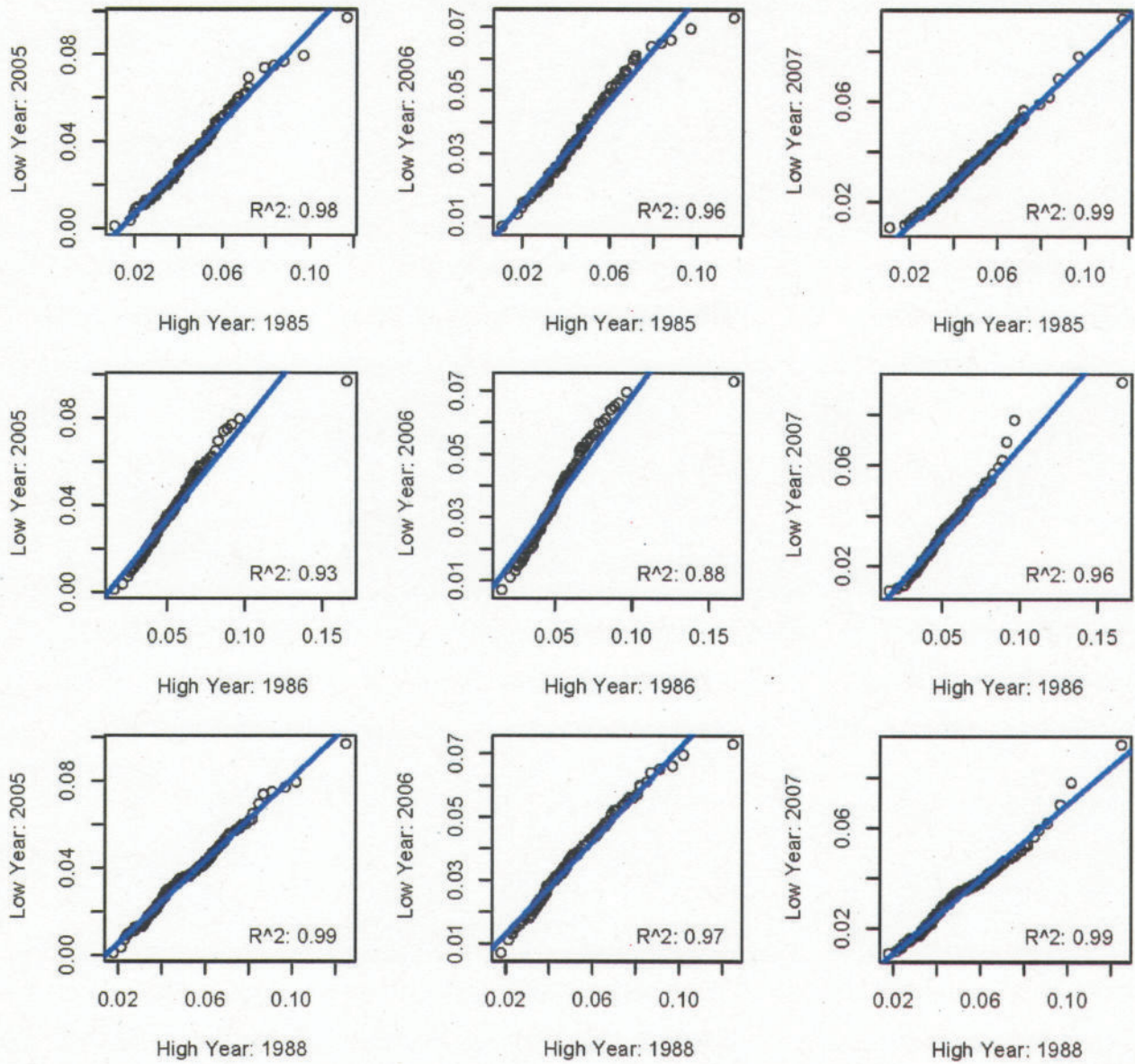
Figure 7. Example of the Low to High Year Comparisons for a Monitor within Atlanta, GA

Site	High Year	Low Year	R^2	Percentile	Percent of SSE
131210048	2005	1985	0.98	95	11
131210048	2005	1985	0.98	99	14
131210048	2005	1985	0.98	100	28
131210048	2005	1986	0.93	100	64
131210048	2005	1988	0.99	100	20
131210048	2006	1985	0.96	100	51
131210048	2006	1986	0.88	100	63
131210048	2006	1988	0.97	100	55
131210048	2007	1985	0.99	0	33
131210048	2007	1986	0.96	100	51
131210048	2007	1986	0.96	99	21
131210048	2007	1988	0.99	100	11
131210048	2007	1988	0.99	99	21

Site	High Year	Low Year	R^2	Percentile	Percent of SSE
170314002	2005	1983	0.91	100	42
170314002	2005	1985	0.86	100	55
170314002	2005	1987	0.99	0	13
170314002	2005	1987	0.99	98	10
170314002	2005	1987	0.99	100	27
170314002	2006	1983	0.93	100	26
170314002	2006	1985	0.90	100	50
170314002	2006	1987	0.98	97	14
170314002	2006	1987	0.98	98	16
170314002	2007	1983	0.91	99	11
170314002	2007	1983	0.91	100	19
170314002	2007	1985	0.89	100	45
170314002	2007	1987	0.97	97	10

Site	High Year	Low Year	R^2	Percentile	Percent of SSE
080013001	2005	1977	0.94	0	12
080013001	2005	1977	0.94	1	11
080013001	2005	1978	0.90	2	12
080013001	2005	1978	0.90	0	13
080013001	2005	1978	0.90	1	11
080013001	2005	1979	0.94	0	15
080013001	2005	1979	0.94	1	11
080013001	2005	1979	0.94	2	13
080013001	2006	1979	0.91	100	12
080013001	2007	1977	0.97	0	13
080013001	2007	1977	0.97	1	14
080013001	2007	1978	0.94	0	14
080013001	2007	1978	0.94	1	13
080013001	2007	1978	0.94	2	12
080013001	2007	1979	0.97	0	18
080013001	2007	1979	0.97	1	14
080013001	2007	1979	0.97	2	13
080310002	2004	1973	0.87	100	14
080310002	2004	1975	0.95	99	15
080310002	2004	1975	0.95	100	10
080310002	2005	1973	0.83	100	11
080310002	2005	1975	0.92	99	12
080310002	2007	1973	0.78	0	11
080310002	2007	1973	0.78	100	31
080310002	2007	1974	0.85	1	12
080310002	2007	1974	0.85	100	24
080310002	2007	1974	0.85	0	14
080310002	2007	1975	0.95	1	20
080310002	2007	1975	0.95	100	16

Site	High Year	Low Year	R^2	Percentile	Percent of SSE
060370002	2005	1970	0.96	100	41
060370002	2005	1971	0.97	100	27
060370002	2005	1972	0.95	100	39
060370002	2006	1970	0.97	0	18
060370002	2006	1970	0.97	100	27
060370002	2006	1971	0.98	100	15
060370002	2006	1972	0.96	0	14
060370002	2006	1972	0.96	100	27
060370002	2007	1970	0.97	100	43
060370002	2007	1971	0.97	100	27
060370002	2007	1972	0.95	100	39
060370113	2005	1985	0.92	0	10
060370113	2005	1985	0.92	99	10
060370113	2005	1985	0.92	100	12
060370113	2005	1986	0.93	0	11
060370113	2005	1986	0.93	100	13
060370113	2005	1987	0.90	0	11
060370113	2005	1987	0.90	100	31
060370113	2006	1985	0.92	99	12
060370113	2006	1987	0.90	100	21
060370113	2007	1985	0.87	99	13
060370113	2007	1987	0.85	100	18
060371002	2005	1970	0.99	0	42
060371002	2005	1970	0.99	1	13
060371002	2005	1970	0.99	100	10
060371002	2005	1971	0.98	0	23
060371002	2005	1971	0.98	99	10
060371002	2005	1971	0.98	100	17
060371002	2005	1974	0.99	0	28
060371002	2005	1974	0.99	1	18
060371002	2006	1970	0.97	0	21
060371002	2006	1970	0.97	1	13
060371002	2006	1970	0.97	100	10
060371002	2006	1971	0.96	0	21
060371002	2006	1971	0.96	1	13
060371002	2006	1974	0.96	0	14
060371002	2006	1974	0.96	1	15
060371002	2006	1974	0.96	100	14
060371002	2007	1970	0.98	0	29
060371002	2007	1970	0.98	1	17
060371002	2007	1971	0.97	0	22
060371002	2007	1971	0.97	1	13
060371002	2007	1974	0.98	0	22
060371002	2007	1974	0.98	1	21
060371103	2005	1980	0.97	1	12
060371103	2005	1980	0.97	98	20
060371103	2005	1980	0.97	99	11
060371103	2005	1981	0.96	0	12
060371103	2005	1981	0.96	1	14
060371103	2005	1981	0.96	99	16

Site	High Year	Low Year	R^2	Percentile	Percent of SSE
060371103	2005	1982	0.97	1	12
060371103	2005	1982	0.97	98	13
060371103	2006	1980	0.94	0	23
060371103	2006	1981	0.93	99	10
060371103	2006	1981	0.93	0	23
060371103	2006	1982	0.94	0	19
060371103	2006	1982	0.94	100	23
060371103	2007	1980	0.95	0	16
060371103	2007	1980	0.95	1	11
060371103	2007	1980	0.95	100	19
060371103	2007	1981	0.94	0	17
060371103	2007	1981	0.94	1	12
060371103	2007	1981	0.94	100	17
060371103	2007	1982	0.94	0	11
060371103	2007	1982	0.94	100	36
060371201	2005	1970	0.96	0	25
060371201	2005	1971	0.96	0	18
060371201	2005	1971	0.96	99	13
060371201	2005	1972	0.96	0	23
060371201	2005	1972	0.96	99	15
060371201	2006	1970	0.94	0	16
060371201	2006	1970	0.94	1	14
060371201	2006	1971	0.94	0	11
060371201	2006	1971	0.94	99	12
060371201	2006	1972	0.93	0	14
060371201	2006	1972	0.93	1	12
060371201	2006	1972	0.93	99	13
060371201	2006	1972	0.93	100	11
060371201	2007	1970	0.96	0	13
060371201	2007	1972	0.96	0	14
060371201	2007	1972	0.96	99	12
060371301	2005	1975	0.97	99	13
060371301	2005	1975	0.97	100	14
060371301	2005	1976	0.99	100	12
060371301	2005	1978	0.98	98	13
060371301	2005	1978	0.98	100	39
060371301	2006	1975	0.95	100	51
060371301	2006	1976	0.98	0	14
060371301	2006	1976	0.98	100	24
060371301	2006	1978	0.94	100	67
060371301	2007	1975	0.95	99	10
060371301	2007	1978	0.96	98	16
060371301	2007	1978	0.96	100	18
060371701	2005	1970	0.93	100	52
060371701	2005	1971	0.92	100	25
060371701	2005	1974	0.93	100	40
060371701	2006	1970	0.93	1	14
060371701	2006	1970	0.93	0	21
060371701	2006	1970	0.93	100	39
060371701	2006	1971	0.91	0	18

Site	High Year	Low Year	R^2	Percentile	Percent of SSE
060371701	2006	1971	0.91	1	16
060371701	2006	1971	0.91	100	17
060371701	2006	1974	0.92	0	22
060371701	2006	1974	0.92	1	15
060371701	2006	1974	0.92	100	26
060371701	2007	1970	0.97	0	15
060371701	2007	1970	0.97	100	39
060371701	2007	1971	0.96	0	11
060371701	2007	1971	0.96	98	11
060371701	2007	1971	0.96	100	9
060371701	2007	1974	0.97	0	17
060371701	2007	1974	0.97	100	23
060372005	2005	1983	0.93	99	9
060372005	2005	1983	0.93	100	23
060372005	2005	1985	0.98	0	18
060372005	2005	1985	0.98	100	15
060372005	2006	1983	0.95	99	18
060372005	2006	1984	0.97	100	29
060372005	2006	1985	0.98	0	11
060372005	2007	1983	0.92	100	28
060372005	2007	1985	0.97	100	29
060372005	2007	1985	0.97	0	10
060374002	2005	1970	0.96	100	76
060374002	2005	1971	0.94	99	10
060374002	2005	1971	0.94	100	55
060374002	2005	1974	0.94	100	74
060374002	2006	1970	0.99	0	33
060374002	2006	1970	0.99	98	22
060374002	2006	1971	0.95	0	24
060374002	2006	1971	0.95	98	10
060374002	2006	1974	0.98	0	34
060374002	2006	1974	0.98	98	11
060374002	2007	1970	0.99	0	11
060374002	2007	1970	0.99	2	17
060374002	2007	1971	0.95	0	12
060374002	2007	1974	0.98	0	14
060374002	2007	1974	0.98	100	14
060595001	2005	1970	0.97	100	13
060595001	2005	1972	0.92	100	39
060595001	2006	1970	0.98	100	21
060595001	2006	1971	0.97	100	11
060595001	2006	1972	0.93	100	49
060595001	2007	1970	0.96	100	21
060595001	2007	1971	0.95	100	12
060595001	2007	1972	0.89	100	40
060655001	2005	1972	0.93	100	27
060655001	2005	1981	0.92	100	12
060655001	2006	1972	0.95	99	13
060655001	2006	1974	0.92	100	24
060655001	2006	1981	0.93	100	14

Site	High Year	Low Year	R^2	Percentile	Percent of SSE
060655001	2007	1972	0.94	100	20
060658001	2005	1974	0.92	0	11
060658001	2005	1974	0.92	100	35
060658001	2005	1975	0.90	0	11
060658001	2005	1975	0.90	100	14
060658001	2005	1976	0.90	100	36
060658001	2006	1974	0.92	100	34
060658001	2006	1975	0.90	100	13
060658001	2006	1976	0.90	100	34
060658001	2007	1974	0.90	100	38
060658001	2007	1975	0.89	100	19
060658001	2007	1976	0.88	100	38
060710001	2005	1978	0.82	100	9
060710001	2005	1981	0.62	100	33
060710001	2006	1975	0.69	0	11
060710001	2006	1975	0.69	1	11
060710001	2006	1975	0.69	100	8
060710001	2006	1978	0.80	0	13
060710001	2006	1978	0.80	1	13
060710001	2006	1978	0.80	100	11
060710001	2006	1981	0.58	100	32
060710001	2007	1975	0.63	100	10
060710001	2007	1978	0.73	100	12
060710001	2007	1981	0.53	100	32
060712002	2005	1983	0.97	1	18
060712002	2005	1983	0.97	0	10
060712002	2005	1983	0.97	100	20
060712002	2005	1984	0.97	100	25
060712002	2006	1983	0.96	0	16
060712002	2006	1983	0.96	1	11
060712002	2006	1983	0.96	100	17
060712002	2006	1984	0.97	100	25
060712002	2006	1985	0.98	0	13
060712002	2007	1983	0.96	2	13
060712002	2007	1983	0.96	1	18
060712002	2007	1984	0.98	100	15
060712002	2007	1985	0.98	2	12

Site	High Year	Low Year	R^2	Percentile	Percent of SSE
340131003	2005	1983	0.98	1	11
340131003	2005	1984	0.95	100	53
340131003	2005	1985	0.90	100	40
340131003	2006	1983	0.96	100	29
340131003	2006	1985	0.78	100	39
340131003	2007	1983	0.98	0	13
340131003	2007	1983	0.98	1	11
340131003	2007	1984	0.98	100	49
340131003	2007	1985	0.85	100	37
340170006	2005	1984	0.94	100	41
340170006	2005	1985	0.96	100	42
340170006	2005	1986	0.98	99	14
340170006	2006	1984	0.96	99	24
340170006	2006	1985	0.96	99	33
340170006	2006	1986	0.94	100	21
340170006	2006	1986	0.94	99	30
340170006	2007	1984	0.89	100	48
340170006	2007	1985	0.90	100	49
340170006	2007	1986	0.95	100	33
340170006	2007	1986	0.95	0	14
340273001	2005	1984	0.96	100	55
340273001	2005	1985	0.90	100	45
340273001	2005	1986	0.93	100	46
340273001	2006	1984	0.98	100	20
340273001	2006	1985	0.95	100	33
340273001	2006	1986	0.96	100	21
340273001	2007	1984	0.99	100	34
340273001	2007	1985	0.95	100	38
340273001	2007	1986	0.96	100	28

Site	High Year	Low Year	R^2	Percentile	Percent of SSE
340070003	2004	1971	0.84	100	29
340070003	2004	1973	0.84	100	28
340070003	2004	1977	0.82	100	23
340070003	2006	1971	0.83	100	31
340070003	2006	1973	0.83	100	31
340070003	2006	1977	0.81	100	27
340070003	2007	1971	0.81	100	35
340070003	2007	1973	0.81	100	36
340070003	2007	1977	0.79	100	31
420170012	2005	1981	0.96	100	79
420170012	2005	1982	0.99	99	25
420170012	2005	1983	0.96	100	67
420170012	2006	1981	0.99	99	18
420170012	2006	1981	0.99	100	21
420170012	2006	1982	0.92	100	60
420170012	2006	1983	0.98	100	19
420170012	2007	1981	0.97	99	17
420170012	2007	1981	0.97	100	16
420170012	2007	1982	0.90	100	54
420170012	2007	1983	0.96	100	16
420450002	2003	1983	0.97	99	12
420450002	2003	1983	0.97	100	12
420450002	2003	1991	0.75	100	23
420450002	2003	1992	0.96	97	14
420450002	2003	1992	0.96	98	13
420450002	2003	1992	0.96	99	14
420450002	2003	1992	0.96	100	39
420450002	2004	1983	0.90	100	39
420450002	2004	1991	0.47	100	23
420450002	2004	1992	0.92	100	27
420450002	2007	1983	0.92	100	35
420450002	2007	1991	0.50	100	23
420450002	2007	1992	0.94	99	12
420450002	2007	1992	0.94	100	21
420910013	2005	1983	0.96	100	60
420910013	2005	1984	0.80	100	52
420910013	2005	1991	0.89	100	60
420910013	2006	1984	0.89	100	49
420910013	2006	1991	0.96	100	50
420910013	2007	1983	0.97	100	37
420910013	2007	1984	0.84	100	52
420910013	2007	1991	0.93	100	59
421010004	2004	1977	0.92	99	20
421010004	2006	1972	0.97	99	28
421010004	2006	1976	0.96	99	41
421010004	2006	1977	0.97	97	22
421010004	2007	1972	0.95	100	28
421010004	2007	1976	0.96	100	22
421010004	2007	1977	0.92	99	13
421010047	2004	1984	0.93	99	11

Site	High Year	Low Year	R^2	Percentile	Percent of SSE
421010047	2004	1986	0.94	100	22
421010047	2004	1988	0.94	0	11
421010047	2004	1988	0.94	99	18
421010047	2005	1984	0.96	99	10
421010047	2005	1986	0.92	100	47
421010047	2005	1988	0.96	100	12
421010047	2005	1988	0.96	99	14
421010047	2007	1984	0.96	100	39
421010047	2007	1986	0.83	100	63
421010047	2007	1988	0.93	100	56