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Analysis of Sulfur Dioxide (SO_2) Monitoring Data and Meteorology at March and Cherry Points

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Technical Report

by

Air Quality Program

Air Quality Program
Washington State Department of Ecology
Olympia, Washington

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Executive Summary

The EPA (Environmental Protection Agency) established a sulfur dioxide (SO_2) standard in June 2010. High SO_2 levels are mostly caused by single, stationary sources. This Washington State Department of Ecology (Ecology) Air Quality Program (AQP) technical report describes analyses of SO_2 monitoring data and meteorological data collected at three facilities at March Point in Skagit County and three facilities at Cherry Point in Whatcom County.

Although these monitors are located within the respective SO_2 source facility fence lines and are not considered ambient air quality monitors, they provide a reasonable estimate of the impacts of the facilities' emissions to ambient air.

This review of March and Cherry Point's facilities' emissions, monitored values, and characteristics should not be construed as a formal determination of compliance status with the 2010 1-hr SO_2 ambient standard in these two areas.

March Point: The two refineries (Shell and Tesoro) discussed here have seen significant SO_2 emissions reductions in the past decade. Emissions from ChemTrade chemical company (formerly General Chemical) are relatively unchanged over this period. The 2008–2011 monitoring data from March Point show design values below the new SO_2 standard. Analysis of meteorological and SO_2 data suggests that monitors are appropriately situated to capture the highest concentrations associated with the respective facilities.

Cherry Point: SO_2 emissions at the two refineries [BP and Phillips 66 (formerly ConocoPhillips)] have trended down in recent years while emissions from Intalco (aluminum smelting facility) have increased. Design values measured at the monitors operated by the refineries are low while the monitor operated by Intalco shows design values that often exceed the 1-hr SO_2 standard.

There are siting concerns for all three monitors, in that they may not capture SO_2 concentrations associated with wintertime outflow winds from the Frazer River Valley. These stable winds could give rise to even higher SO_2 levels, southwest of the facilities. Even so, the meteorological analysis, combined with SO_2 monitoring data and emission trends from the refineries do not provide a compelling case for a possible National Ambient Air Quality Standard (NAAQS) exceedance around the two refineries due to their emissions of SO_2.

Intalco's present SO_2 monitoring concentrations are nearly twice those observed at the BP and Phillips 66 monitors. Due to operating characteristics of the Intalco facility that can coincide with the Fraser River Valley outflow winds, if a monitor were placed southwest of the facility, there is a possibility that it could regularly exceed the SO_2 standard unless the facility takes steps to reduce SO_2 emissions.

Background

In June 2010, the EPA revised the NAAQS, establishing a 1 hour (hr) sulfur dioxide ($SO_{2)}$ standard of 75 ppb. Unlike some other criteria pollutants (i.e., ozone), SO_2 is primarily the result of a single, stationary source of pollution. Because SO_2 is oxidized to sulfate aerosol over a period of hours to a few days, the highest concentrations tend to be relatively close their sources.

In an effort to understand ambient concentrations of SO_2 around the state, Ecology has looked at areas where SO_2 monitoring data are available. These areas include March Point in Skagit County and Cherry Point in Whatcom County (discussed in this document) as well as Longview – Kelso (Cowlitz County), Beacon Hill (King County), and Cheeka Peak (Clallam County). The latter three locations are discussed in a separate technical memorandum attached to a letter from Laurie Hulse-Moyer (Ecology AQP planner) to Ken Johnson (Weyerhaeuser) and Pat Ortiz (Longview Fibre) on February 15, 2013.

The SO_2 monitors in Skagit and Whatcom counties discussed in this document are associated with industrial point sources of SO_2, and are required by the facility's air quality permits and Northwest Clean Air Agency (NWCAA) rules. They are operated by the individual companies and audited by NWCAA. Although these compliance monitors are located within the respective facility fence line and are not considered ambient air quality monitors, they provide a reasonable estimate of impacts to ambient air.

In the two major sections below, the existing SO_2 and meteorology monitoring data are presented. The meteorological data is used to assess whether the monitored SO_2 concentrations are representative of the major ambient impacts from SO_2 emissions by the facilities. Emission trends from the facilities were examined. Most facilities discussed in this report have seen significant emission reductions during the past decade, and these are reflected in recent SO_2 monitoring data.

Disclaimer: Ecology is in the process of determining its approach to evaluating Washington's status with regard to the 2010 1-hr SO_2 NAAQS. This review of March and Cherry Point's facilities' emissions, monitored values, and characteristics should not be construed as a formal determination of these industrial facilities' compliance status with the 2010 1-hr SO_2 ambient standard. Existing permits may not have measures in place to ensure compliance with the new 1-hr SO_2 NAAQS. A specific source's compliance with the standard must be evaluated through New Source Review or other permit modification, or could be determined by other means and must be made on a case-by-case basis. A review of current permitted levels and potential to emit may be required to confirm the facilities' ability to comply with the standard at maximum permitted levels.

March Point, Skagit County, WA

Figure 1 shows portions of Fidalgo Island including March Point and the city of Anacortes. The largest sources of SO_2 at March Point are two refineries and one chemical plant. The Tesoro refinery is at the north end of March Point. Shell (sometimes referred to as the Puget Sound Refinery, PSR), and ChemTrade Logistics, Inc. (formerly General Chemical) are to the south and southeast of Tesoro, respectively. Each facility has an SO_2 monitor and there is an additional SO_2 monitor at the S. Texaco station located on Shell property. Monitoring sites are marked by pushpins—yellow for ambient monitors and purple for compliance monitors. Meteorological monitoring is co-located with the Shell SO_2 monitor.

The nearest city to these sources, Anacortes, is located across Fidalgo Bay on the main portion of Fidalgo Island to the west and northwest of March Point.

Figure 1. March Point Facilities and Monitoring Station Locations

March Point Monitored SO_2 Values

Monitored values of SO_2 obtained from the NWCAA are summarized below. One-hr average observations were available from 2008 through 2011 and were used in this analysis.

Table 1. Summary of Monitored 1-Hr SO_2 Values [ppb] at March Point, 2007–2013

Shell / PSR	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**
99th percentile of daily	18	25	24	21	23	22	20
Design Value[1]			22	23	23	22	22
Annual Average	3.1	3.8	2.9	1.9	2.7	2.9	1.9
Tesoro	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**
99th percentile of daily	63	46	30	25	16	23	23
Design Value[1]			46	34	24	21	21
Annual Average	2.3	1.5	0.5	0.4	0.5	0.6	0.5
Gen Chemical/ChemTrade	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**
99th percentile of daily	90	88	43	40	44	44	37
Design Value[1]			74	57	42	43	42
Annual Average	12.5	7.1	3.7	3.4	4.5	6.5	6.1
S. Texaco Station	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	
99th percentile of daily			17	10	15	14	17
Design Value[1]					14	13	15
Annual Average			2.2	2.6	2.2	2.5	2.1

[1] Running 3-year average of the 99th percentile of the daily maximum 1-hr concentration. There was no Federal 1-hr standard before 2010. If these were ambient air quality monitors, they would all demonstrate compliance with the 2010 1-hr SO_2 NAAQS of 75 ppb.

March Point Analysis

Although the monitored values and calculated design values of SO_2 shown in Table 1 are below the 1-hr SO_2 NAAQS of 75 ppb, meteorological data are required to determine whether the observations are representative of the highest SO_2 concentrations in the area. It also needs to be evaluated whether the monitors are measuring emissions from more than one source.

Four years of meteorological observations (2008–2011) from the Shell-PSR SO_2 and meteorological station were paired with concurrent concentrations from each of the three facility monitors for this analysis. The meteorology of March Point is complex with reports of visible plumes from the Tesoro and Shell stacks moving in significantly different directions at the same time. This wind direction variability over just a few kilometers (km) introduces uncertainty into the meteorological analysis.

SO_2 data from near the South Texaco ambient monitoring site are not discussed in this analysis because this monitor is located outside the Shell-PSR property boundary and has been recording very low design values.

Figure 2 shows March Point in greater detail with polar plots of maximum concentration by wind speed and wind direction plotted at the locations of the SO_2 monitors operated by Tesoro at the northern end of March Point, Shell south of Tesoro, and ChemTrade to the east of Shell. It should be noted that polar plots show the maximum concentrations for each combination of wind speed and wind direction.

It is apparent that the Tesoro monitor observes the highest concentrations when the winds are from the southeast at speeds between 10 and 25 miles per hour (mph). Southeast winds bring emissions from the catalyst regenerator/CO boiler stack to the monitor. The relatively high wind speeds observed with the highest concentrations are indicative of a plume being bent over and having a high impact relatively nearby.

The Shell monitor records elevated SO_2 concentrations with northerly winds, likely from Tesoro emissions. There is also a modest elevation of the maximum concentration with southeasterly winds which carry Shell emissions to the monitor. There is a very slight increase in concentrations with light easterly winds which may be from ChemTrade or some unidentified distant source.

The ChemTrade monitor, located almost due east of the Shell's PSR monitor and southeast of Tesoro, records relatively high maximum concentrations when the wind comes from the northwest at between 5 and 15 mph. Although the Tesoro refinery lies to the northwest, there are no corresponding high concentrations at Shell with northerly winds ruling out Tesoro as a contributor. Close examination of overhead images (not shown) reveals that ChemTrade has two stacks that lie almost directly in line with the direction of the maximum. The ChemTrade monitor also observes relatively high concentrations from a broad range of directions which cannot be assigned to any well-defined emission sources.

In the wind rose in the upper-right corner of Figure 2, the speed ranges associated with the maximum concentrations observed at the Tesoro and ChemTrade monitors are shown by orange (10 to 25 mph) and green (5 to 10 mph), respectively. The relatively strong southeasterly winds shown in the wind rose agree quite well with the polar plot at Tesoro, which shows the highest concentrations associated with 10 to 25 mph winds from the southeast. Except for a small number of west-southwest winds in the same speed range that may be expected to produce similar concentrations to the east-northeast of the refinery, this monitor seems well-located to observe the highest ground-level impact from Tesoro.

A comparison of the polar plot at the ChemTrade monitor with the wind rose shows that the 5 to 10 mph bin occurs frequently from the northwest. This supports the high concentrations observed with those wind speeds. However, there is also a much more frequent occurrence of those same wind speeds coming from the southwest. The northwest winds have an overwater trajectory that may be expected to be relatively stable and produce higher concentrations. The southwesterly winds, although also originating over Puget Sound, traverse somewhat rougher terrain before arriving at ChemTrade and may be expected to be slightly more turbulent and produce lower concentrations.

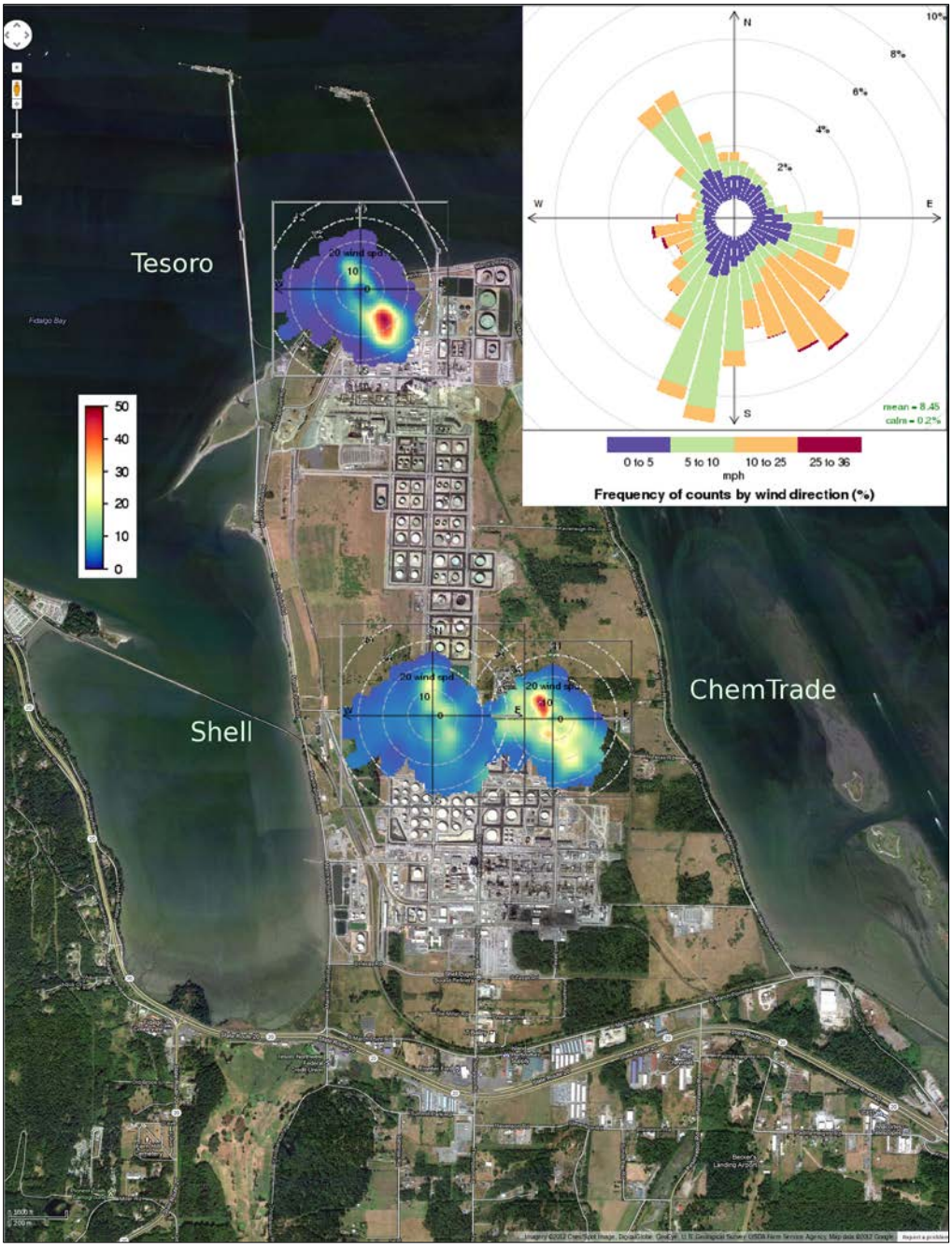

Figure 2. Polar Plots of Observed SO_2 Concentrations from March Points Sources

March Point Emission Trends

Figure 3 below shows emission trends for the three March Point facilities. Tesoro emissions are down significantly from 1980 and 2000 levels; emission values in 2007 are less than one-fifth of those in 2000. The low emissions in 1995 were part of a 6-year period when Tesoro emissions fluctuated between 2000 and 3200 tons per year. Shell emissions follow a similar trend. Emissions for both refineries plummeted responding to a combination of the lower fuel sulfur standards and additional controls. By the start of the Great Recession in December 2007, Tesoro and Shell emissions had already bottomed out. ChemTrade (previously known as General Chemical) emissions were historically much lower than Tesoro and Shell, and made some process changes in 2009, resulting in lowered SO_2 emissions. Emissions from all three facilities are currently in the range of hundreds of tons per year.

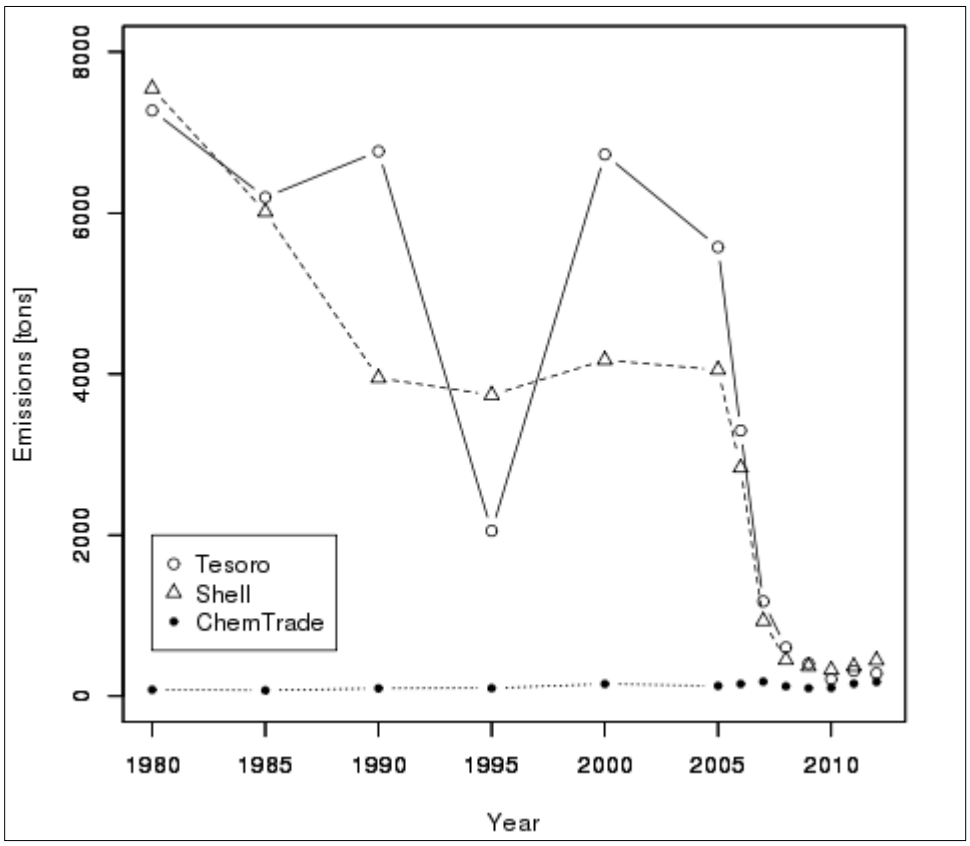

Figure 3. March Point Annual SO_2 Emissions, 1980–2012

March Point Summary

Based on the available information presented above, Ecology believes it is unlikely that there are violations of the 1-hr SO_2 NAAQS of 75ppb in the vicinity of March Point from current actual emissions. Monitored values are mostly well below the NAAQS, especially in recent years following significant emission reductions at the two refineries in the area.

Cherry Point, Whatcom County, WA

Figure 4 shows the Cherry Point and surrounding areas east to Ferndale, the closest city, and north to Custer. The three main sources of SO_2 at Cherry Point are the BP and Phillips 66 refineries, and Alcoa's aluminum smelter (Intalco). Monitoring sites are marked in Figure 4 by the blue pushpins to signify compliance sites. There is a meteorology tower at the BP site. As with the March Point SO_2 monitors, these compliance monitors are required by the source's permit and NWCAA rules to assure compliance at the fence line. They are not ambient monitors sited for determining compliance with NAAQS.

Figure 4. Cherry Point Facilities and Monitoring Sites

Cherry Point Monitored SO_2 Values

The BP monitor is located 1200 meters (m) north-northwest of the primary source of SO_2 at the BP refinery. Both SO_2 concentrations and meteorological parameters are recorded at this site. Alcoa operates an SO_2 monitor 800 m north of the Alcoa potlines. The Phillips 66 SO_2 monitor is located north of the refinery. A fourth SO_2 monitor is located 10 km to the northeast in Custer. It observes concentrations that are characteristic of background values except when southerly winds send emissions from a digester/internal combustion electric generator system located directly across the road toward the monitor. This analysis used data from Custer from January 2011 to August 2012.

Table 2 shows monitored SO_2 concentrations obtained from the NWCAA from 2007 through 2013 at these facility monitoring sites. At the time detailed data analyses were conducted, Ecology was able to obtain one-hr data for only the highlighted years.

Table 2. Summary of Monitored 1-Hr SO2 Values [ppb] at Cherry Point, 2007–2013

BP Cherry Point, Blaine	2007	2008	2009	2010	2011	2012	2013
99th percentile of daily max	37	39	15	23	32	29	16
Design Value (ppb)[1]			30	26	23	28	26
Average (ppb)	3.8	4.0	2.3	4.6	5.9	6.2	2.1
INTALCO/ALCOA, Ferndale	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**
99th percentile of daily max	48	51	70	76	102	92	76
Design Value (ppb)[1]			56	65	83	90	90
Average (ppb)	2.4	3.5	4.9	5.6	7.9	4.6	4.5
Conoco/Phillips66, Ferndale	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**
99th percentile of daily max	41	20	23	25	20	36	27
Design Value (ppb)[2]			28	23	23	27	28
Average (ppb)	2.1	2.4	2.6	2.9	2.9	3.2	2.7

[1] Running 3-yr average of the 99th percentile of the daily maximum 1-hr concentration. There was no Federal 1-hr standard before 2010. If these were ambient air quality monitors, they would all demonstrate compliance with the 2010 1-hr SO_2 NAAQS of 75 ppb.

[2] Running 3-yr average of the 99th percentile of the daily maximum 1-hr concentration. There was no Federal 1-hr standard before 2010.

Although not a NAAQS compliance monitor, concentrations at the Intalco monitor have been high enough that "Design Values" exceeded the standards value for 2011–2013. As mentioned above, because these are not ambient air monitors, they cannot be used to determine compliance with the SO_2 NAAQS. Measured SO_2 concentrations at the monitors operated by the refineries are in the 20 to low 30 ppb range---well below the 75 ppb level of the 2010 1-hr SO_2 standard.

Analysis of SO_2 concentrations at Cherry Point proved to be more complicated than at March Point, and required different analysis techniques.

Figure 5 shows percentile roses for each of the three compliance monitors and their relationship to the primary sources of SO_2. The percentile roses use wind direction from the meteorological tower located at the BP monitoring site and the concurrent hourly average SO_2 concentration from each compliance monitor and are plotted at the location of the monitor.

The boundaries between colors represent important levels in the distribution of concentrations as shown in the legend at lower right. The outer boundary of the red area shows the 99th percentile concentrations for each wind direction. Longer distances from the center represent higher concentrations. For clarity, the BP and Phillips 66 percentile roses are plotted at twice the scale of the Intalco percentile rose. Patterns point in the direction wind is coming from when indicated concentration was observed. Insets are standard wind roses for annual (lower left) and summer nights (upper right). The 3 to 12 mph wind speed range, which covers the range of wind speeds identified above as associated with the highest concentrations observed at BP and Intalco, is shaded yellow in the wind roses.

The annual wind rose in Figure 5 also shows that the conditions with the potential to produce high concentrations from Intalco emissions (yellow shaded portions) are not confined to only south and south-southwest wind directions but also occur more frequently with other directions (especially north-east).

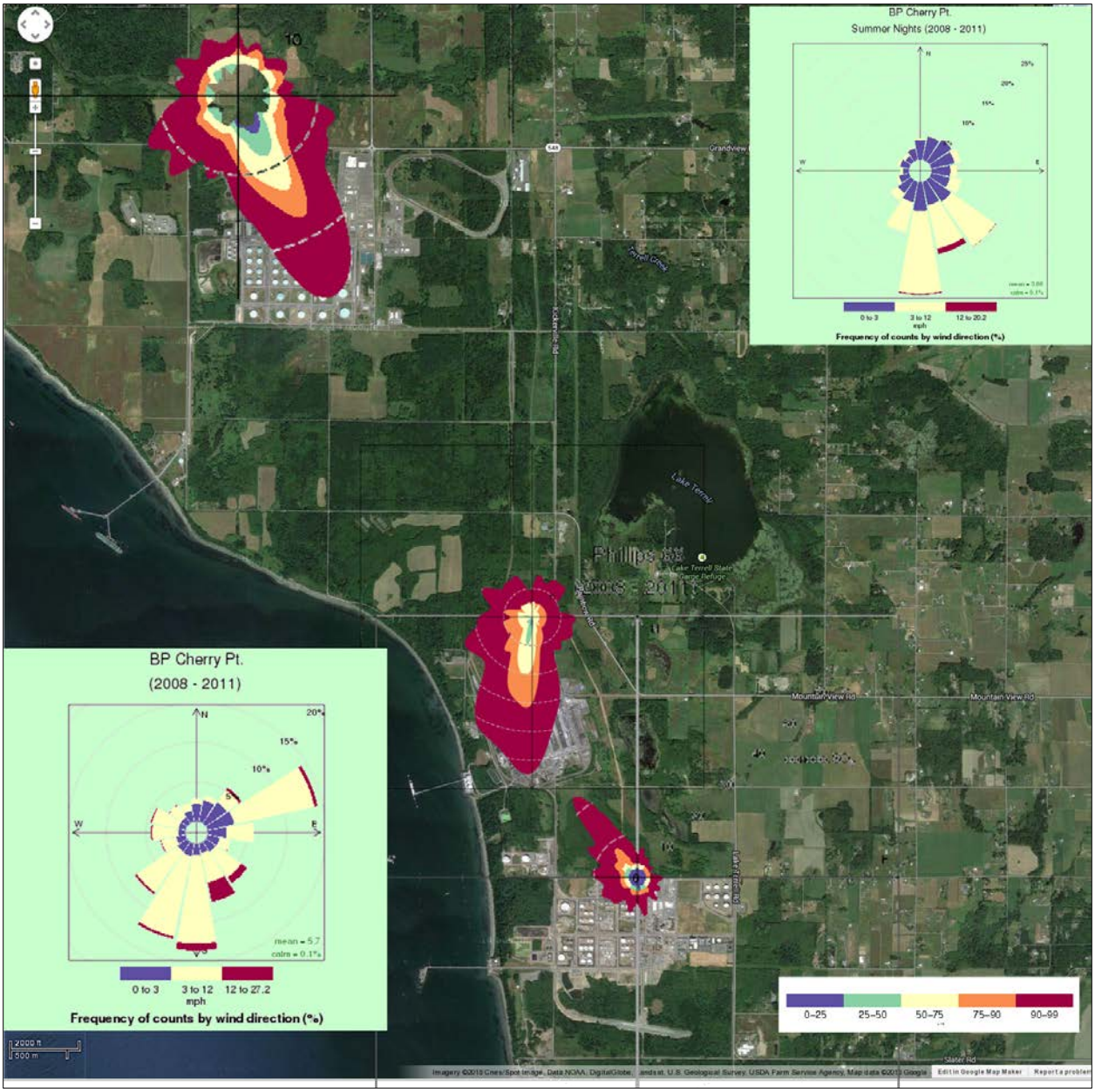

Figure 5. Percentile Roses for the 3 Source Operated Compliance Monitors at Cherry Point

Analysis of BP data

The percentile rose at BP (Figure 5) clearly shows that the highest concentrations are most frequently observed when the wind blows from the south-southeast or southeast to cross directly over the refinery on its way to the monitor.

Figure 6 is a seasonal polar frequency plot of the maximum SO_2 concentration by wind direction and wind speed as observed by the BP monitor. It clearly shows that the maximum observed SO_2 concentrations by the BP monitor occur in summer with wind speeds between 6 and 12 mph from the southeast. It also shows that similar winds in other seasons typically result in lower concentrations.

Except for the northeast winds of winter, most of the air arriving at the BP refinery crosses a combination of water and land surfaces. Summer winds appear to travel over the BP facility en

route to the monitor and thus capture the emissions (see wind rose on the top right of Figure 5). Since south-southeast winds also have the potential to also carry Intalco emissions to the monitor, it is likely that Intalco emissions contribute about 5 ppb to these high values in summer (see section on *"Analysis of Phillips 66 data"* for details).

Figure 7 clearly shows that the highest 1-hr SO_2 concentrations observed at the BP site occur in the middle of late spring and early summer nights.

Northeasterly winds, which occur during winter (see bottom left wind rose in Figure 5), are likely an outflow from the Fraser River Valley and will be more stable than southerly winds. Stable winds often result in higher pollutant concentrations downwind. Therefore, we cannot definitively conclude that the existing monitor has captured the maximum hourly concentrations. However, SO_2 design values at the BP monitor are roughly one-third of the 1-hr NAAQS; the stable northeast winds will need to substantially hinder dispersion in order to exceed the NAAQS.

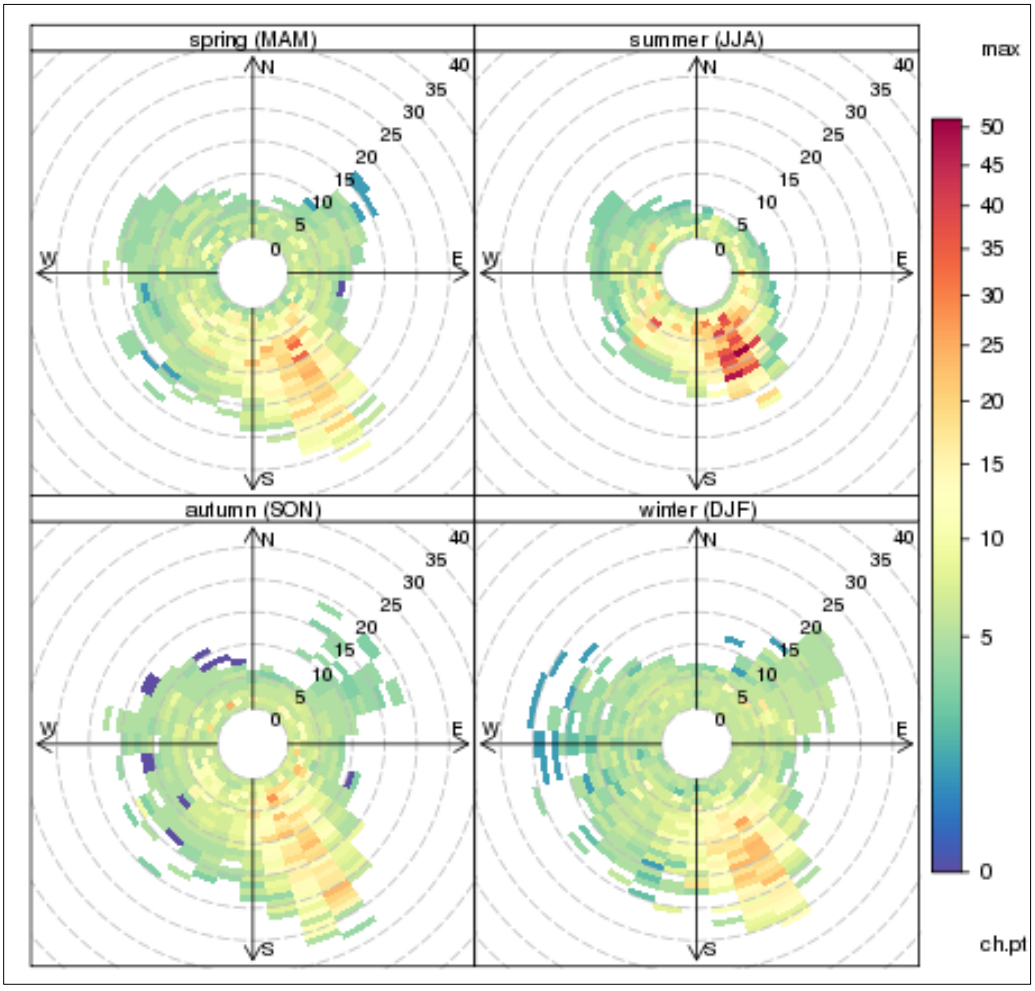

Figure 6. Polar Frequency Plot of Maximum 1-Hr SO_2 Concentrations at BP (2008–2011)

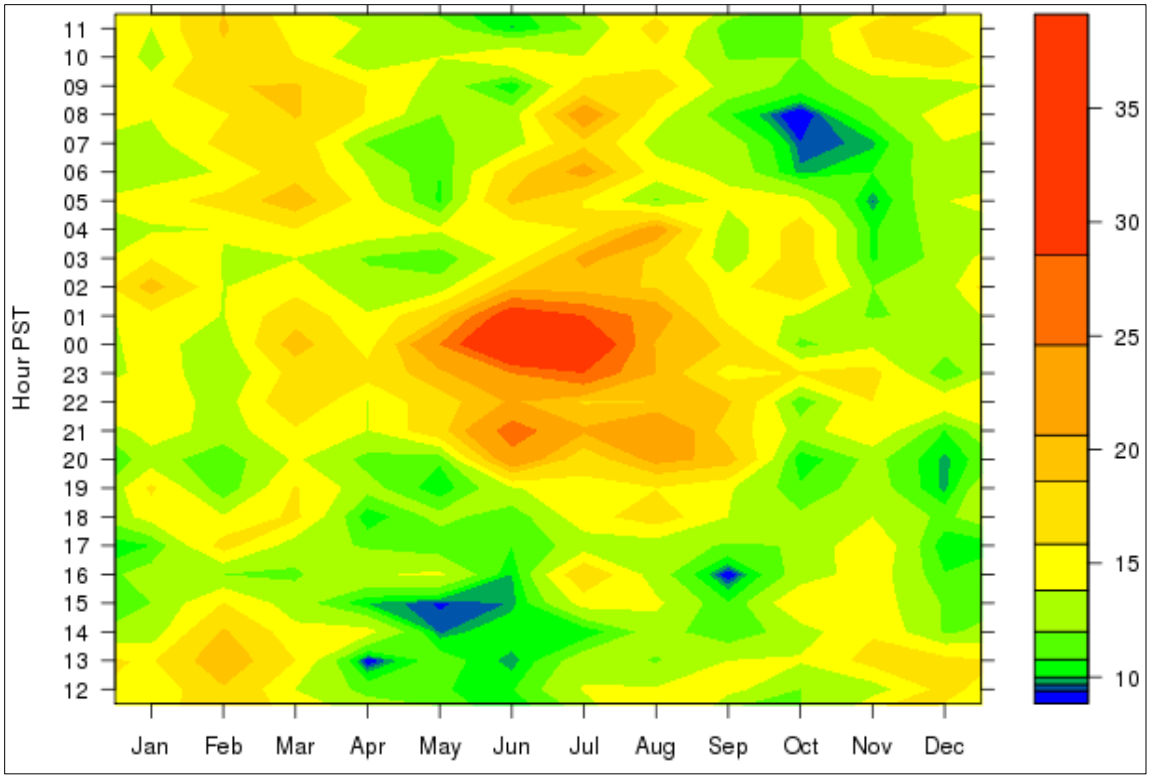

Figure 7. 99th Percentile of BP SO_2 Concentrations (ppb; 2008 – 2011) by Hour and Month

Analysis of Intalco data

The seasonal polar frequency plot in Figure 8 shows that high concentrations at the Intalco site are observed in all four seasons, at wind speeds between 6 and 15 mph. The existing monitor is well-located to sample Intalco emissions when the wind is only from the south or south-southwest, and the corresponding SO_2 levels sometimes exceed the 1-hr standard. Although the topography crossed by winds from most southerly directions share a similar mix of water and land surface characteristics and would be expected to produce similar concentrations, the northeasterly winds do not. Wintertime northeast winds are likely to be stable and result in less dispersion. The present SO_2 monitor will miss high concentrations during such events.

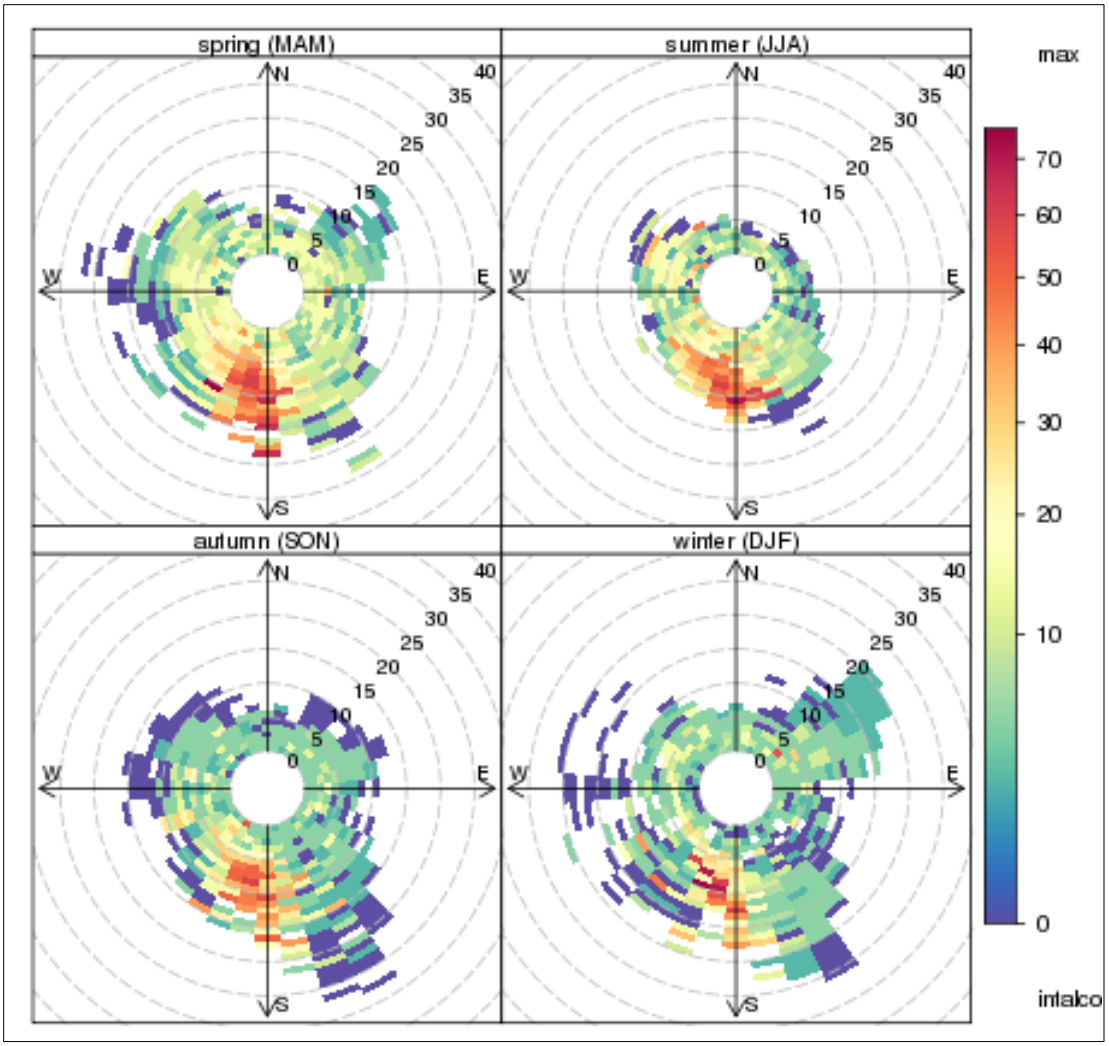

Figure 8. Maximum 1-Hr SO_2 Concentrations at Intalco (2007–2009)

Analysis of Phillips 66 data

The percentile rose for the Phillips monitor (Figure 5) seems to reflect the small contribution that the Phillips refinery makes to SO_2 concentrations. The 99th percentile concentrations for wind directions from east through south to west, which are required to carry Phillips refinery emissions to the monitor, remain below 10 ppb. However, there is a significant contribution from the northwest, often exceeding 20 ppb. The Intalco smelter is about 1700 m away and is likely the primary contributor when the wind comes from the northwest (see Figure 5).

If we assume that turbulent dispersion with northwest winds is similar to that with south-southeast winds we can make a linear scaling of concentration with distance (i.e., a 20 ppb SO_2 contribution from 1700 m away, as mentioned above) to estimate that Intalco emissions contribute about 5 ppb toward the 99th percentile SO_2 concentration observed six km away at BP.

The seasonal polar frequency plot in Figure 9 shows that a majority of high values occur year round during northwest winds (likely caused by Intalco emissions), although a few summertime high values occur during south winds. The latter are consistent with transport of Phillips 66 emissions, and mostly occur between 6-9PM during periods of light to moderate winds.

As with the other two sources, northeast winds could produce higher concentrations than observed by this monitor. However the low SO_2 levels measured by the Phillips 66 monitor suggest that a NAAQS exceedance is unlikely.

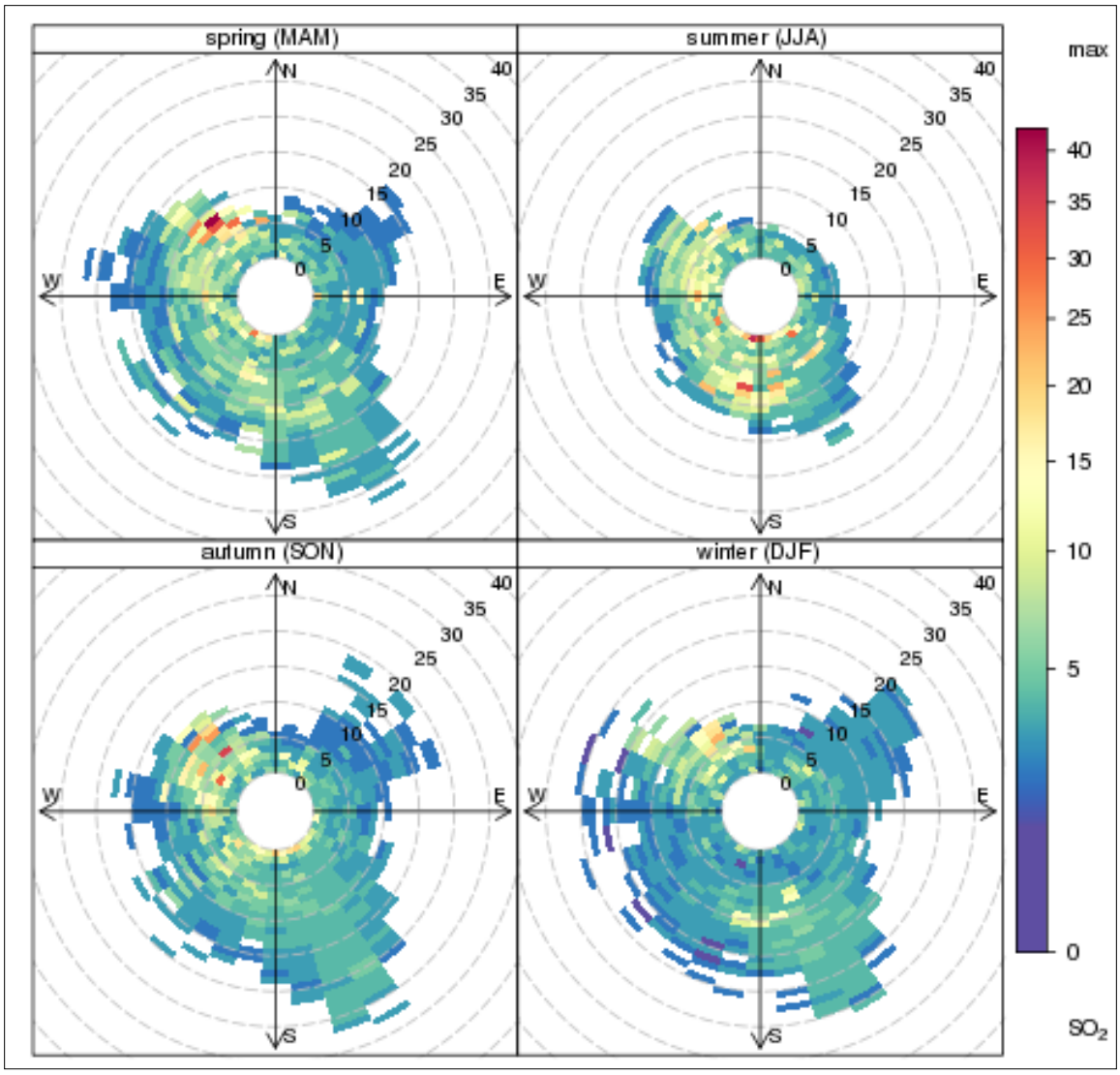

Figure 9. Maximum 1-Hr SO_2 Concentrations at Phillips 66 (2008–2011)

Cherry Point Emission Trends

Figure 10 shows emission trends from 2005 to 2012 for sources at Cherry Point. Emissions from the refineries have generally been on a downward trend in recent years. Intalco emissions have increased significantly as production rates have increased since the 2001–2002 period when the smelter ceased operation. The Intalco emitted 1,738 tons in 2005 and 4,679 tons just five years later in 2010 as production returned to near historic rates.

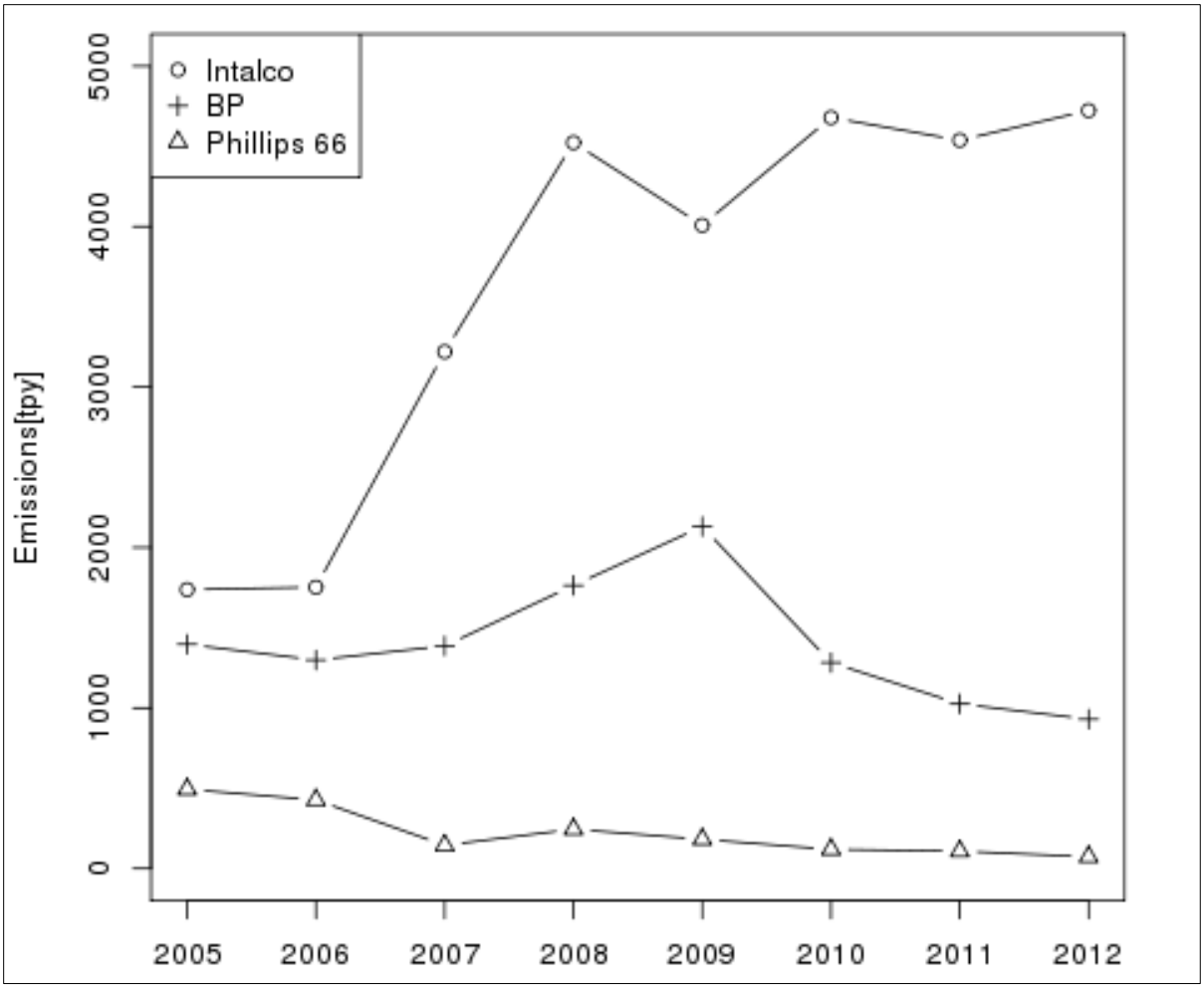

Figure 10. SO_2 Emission Trends at Cherry Point, 2005–2012 (tons per year)

Cherry Point Summary

Although the wintertime outflow from the Frazer River Valley will affect SO_2 concentrations measured at the BP and Phillip refineries, it is unlikely that the increased stability expected during these periods will increase the maximum concentration enough to threaten the NAAQS. The meteorological analysis, combined with SO_2 monitoring data and emission trends from the refineries do not provide a compelling reason to install additional SO_2 monitors to the southwest of the BP and Phillips 66 refineries.

Because Intalco concentrations are nearly twice those observed at BP and Phillips, the same analysis indicates that the single existing monitor associated with the Intalco facility is not likely to be measuring all or even a majority of high concentrations from this facility.