Prevention of Significant Deterioration Application for Changes Related to 737 MAX Production and Capacity Increase

Prepared for

Boeing Commercial Airplanes - Renton

Submitted to:

Washington Department of Ecology

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Prepared by

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Contents

Figures

1. Project Description

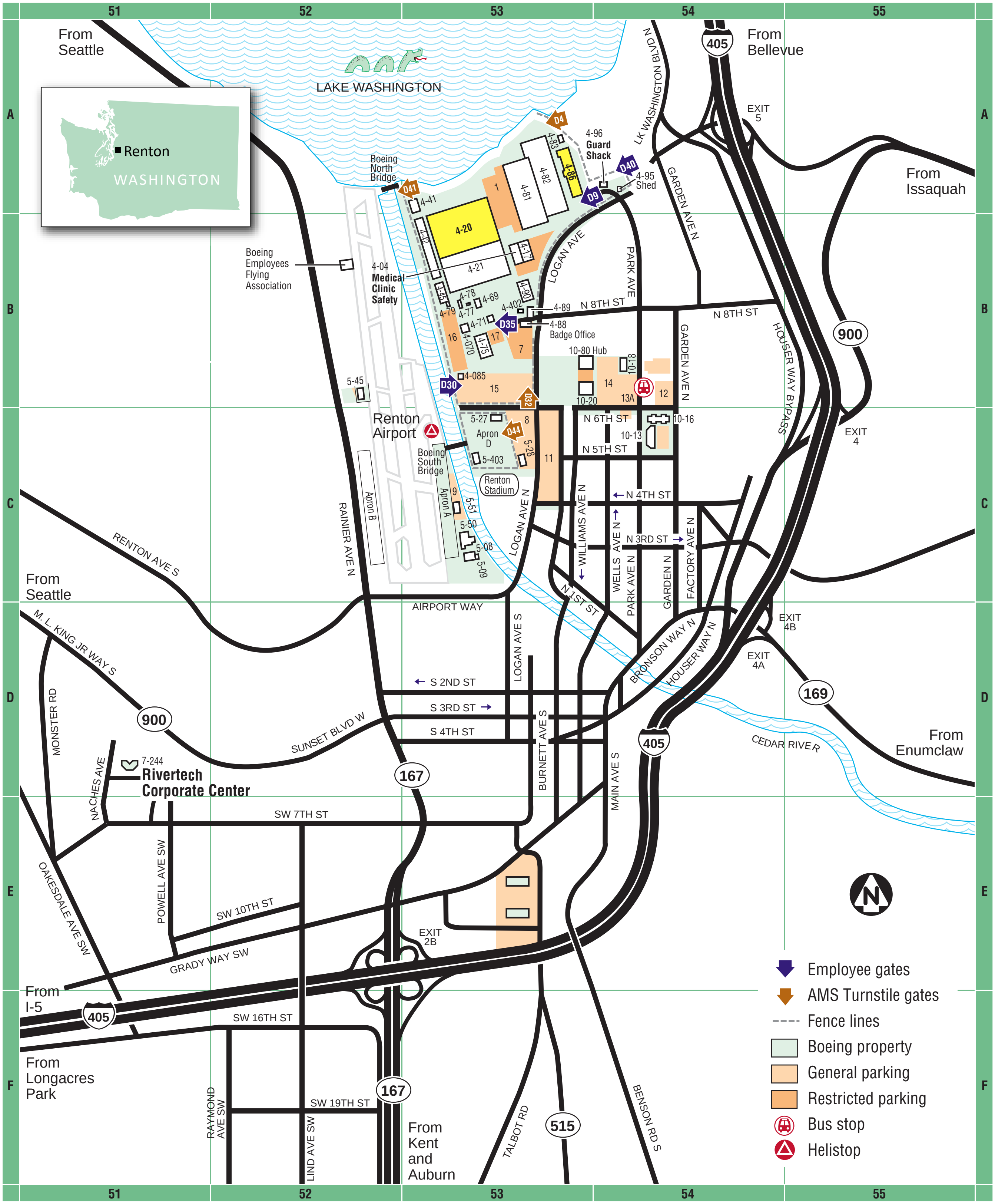
Boeing Commercial Airplanes' Renton facility (Boeing Renton) produces single-aisle airplanes and is located in Renton, King County, Washington (Figure 1-1). Boeing manufactures the 737 model airplane in Renton and proposes to make changes to the facility that will enable it to produce "737 MAX airplanes" (the newest planned 737 derivative) and increase production capacity. The current production rate for 737 Next Generation models (Models 700, 800, and 900) is approximately 420 airplanes per year. Changes permitted under Prevention of Significant Deterioration (PSD) No. 11-02 will enable production up to a maximum of about 504 737 Next Generation airplanes per year. This application is to amend Ecology issued PSD 08-01 Amendment 1 and permit new and/or modified paint booths in Building 4-86.

The proposed project involves two independent phases.[1] Because of production requirements, space limitations, and other factors, each phase consists of a series of events. For example, to make room for a new 737 MAX assembly line, existing manufacturing processes must be moved to a different building. Thereafter, new wing manufacturing and assembly tools and equipment for the 737 MAX must be installed and tested, and production techniques must be proven and certified before the equipment can be used for production airplanes.

Phase 1 of the project is comprised of two components. *The first component* is to make the changes to the facility necessary to develop the production technology and capability for the 737 MAX model while maintaining production of existing models at levels up to approximately 540 airplanes per year, consistent with PSD No. 11-02. The Boeing Company management has directed Boeing Renton to promptly undertake the necessary changes. The changes include creating new separate wing assembly capacity and airplane assembly line for the 737 MAX within the existing buildings. While this change will increase physical production capacity, Boeing will continue to comply with all current emission limitations and is not requesting an increase in allowable emissions for this phase of the project. *The second component* of Phase 1 would be an increase in overall production, utilizing the increased production capacity created in the first component of Phase 1 for the production of salable 737 MAX airplanes, and related emission increases. As mentioned, Boeing management has directed that the Phase 1 changes be promptly undertaken. This decision is independent of the future potential changes included in Phase 2. Similarly, the Phase 1 changes are physically and economically independent of the Phase 2 changes; the Phase 1 changes will be made regardless of whether or not the Phase 2 changes are made.

Phase 2, the second independent phase of this project, will be to make further changes to the facility in reaction to one or more future directives from Boeing management to increase overall 737 production capacity and thereafter, utilize some or all of that capacity to increase 737

[1] Although Boeing believes that these phases could be permitted as separate projects, Ecology also has the discretion to, at the request of Boeing, permit these independent phases together as contemplated by 40 CFR 52.21(j)(4) and (r)(2). *See* EPA, PSD Permit Modifications: Policy Statement on Changes to a Source, a Permit Application, or Issued Permit and on Extensions to Construction Scheduling (6/85 Draft) at p. 33; *See also* EPA, Permitting of Multi-Phase Construction Under Prevention of Significant Deterioration Regulations (August 20, 1979). Boeing hereby requests that Ecology permit these independent phases together, in order to expedite any necessary review prior to construction of Phase 2 and to eliminate any second-guessing regarding project segmentation. Boeing's use of the phrase "project" to describe the combined phases should not be construed as a position that these phases must be considered a single project for purposes of PSD.



North

0 0.5 1

Approximate scale in feet

FIGURE 1-1
Site Map
Boeing

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\\simba\Proj\TheBoeingCompany\418836\Graphics\ Fig1-1_SiteMap_31may11.ai production. No such rate directives have been issued at this time, but there is a reasonable possibility that future market conditions affecting 737 demand will support production beyond the capacity achieved through Phase 1. The changes necessary to achieve this would include creating additional wing assembly and painting capacity within the existing buildings, and increasing onsite final decorative coating capacity by the installation of an additional two position paint hangar. Phase 2 will require an increase in the allowable by the emissions under PSD 08-01 Amendment 1 for Buildings 4-20, 4-21, 4-81, and 4-82 from 118 tons per year (tpy) to 165 tpy.

Although the exact timing for each of the phases will depend in part on Boeing corporate directives, we anticipate that construction of Phase 1 will commence on or before November 15, 2013; and construction of Phase 2 will commence on or before July 15, 2016 and that there will not be more than 18 months between the end of Phase 1 and the beginning of Phase 2.

The Washington Department of Ecology (Ecology) has issued several PSD permits for Boeing Renton. These include the following:

- **PSD-11-02** for the Boeing Renton Site, Production Capacity Increase including four new replacement wing panel booths (Building 4-20) and one new and one modified wing paint booth (Building 4-86). These changes in part accommodate a 737 production increase to about 504 airplanes per year. Boeing is not seeking to change any approval conditions imposed by this permit.
- **PSD-08-01 Amendment 1** for the Boeing Renton Site, 5-50 Paint Hangar and Buildings 4-20, 4-21, 4-81, and 4-82. PSD-08-01 Amendment 1 limits the volatile organic compound (VOC) emissions from Buildings 4-20, 4-21, 4-81, and 4-82 to 118 tons per year (tpy). Boeing is seeking to change the VOC limit to 165 tpy for Buildings 4-20, 4-21, 4-81, and 4-82 with this application to allow for increased production. Boeing does not anticipate adding or modifying emission units to the buildings covered by PSD-08-01 Amendment 1, but does anticipate moving production and manufacturing equipment within the buildings, adding new manufacturing equipment such as new drilling and riveting equipment, and adding a new airplane assembly line**.**
- **PSD-97-2** for the Boeing Renton Site, Building 4-86. PSD-97-2 Condition 2 limits VOC emissions from Building 4-86 to 242 tpy. The project will result in physical and operational changes in Building 4-86 that include modifying existing wing paint booths and adding new wing paint booths in Phase 2; however, Boeing is not seeking to change that limit with this application.
- **PSD-88-4** for the Boeing Renton Site, 4-41 Paint Hangar. PSD-88-4 Condition 1 of that permit limits VOC emissions from Building 4-41 to 124 tpy. There will be no physical or operational changes to Building 4-41 because of this project and Boeing is not seeking any changes to the approval conditions imposed by this permit.

Model 737 assembly operations primarily occur in Buildings 4-20, 4-21, 4-42, 4-81, 4-82, and 4-86 and can be grouped as follows:

- **Wing Assembly Operations** include assembling the upper and lower wing panels. These operations primarily occur in Buildings 4-20 and 4-21.

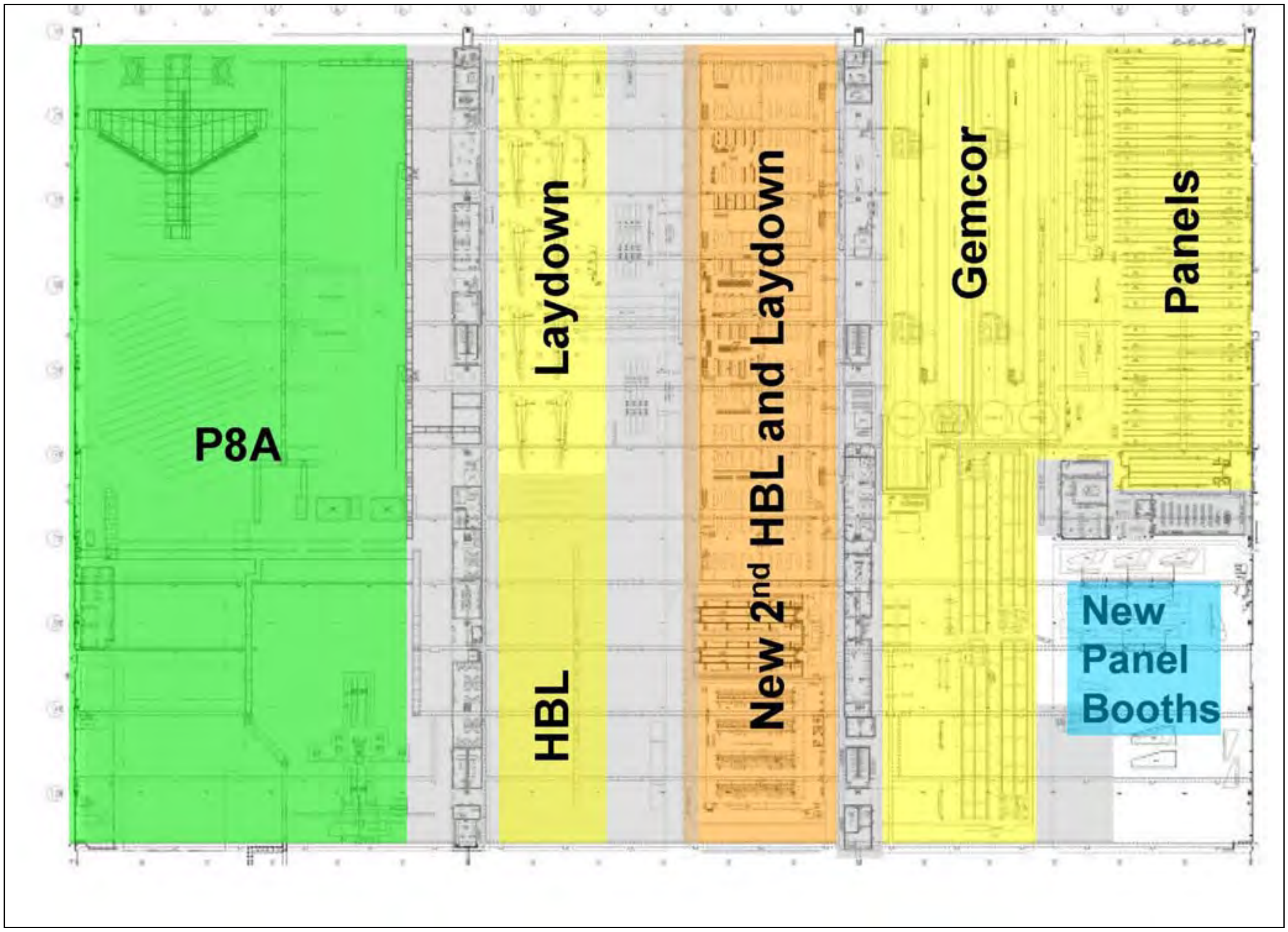
- **Wing Clean, Seal, Test, and Paint Operations** include cleaning the complete wing assemblies, sealing them including the interior surfaces of the fuel tank, applying corrosion inhibiting compounds, testing the fuel tank for leaks, correcting any leaks, and painting the exterior surfaces. These activities only occur in Building 4-86.
- **Final Assembly Operations** include joining the wings and tail assemblies to the fuselage and adding the necessary electrical systems, hydraulic systems, and interiors. These operations occur in Buildings 4-81 and 4-82.
- **Delivery Operations** include final painting, any necessary depainting, and preparing the airplane for delivery. These operations occur in Building 4-42 and the paint hangars. Some airplanes receive their final exterior coating in Building 4-41 Paint Hangar and some in the Building 5-50 paint hangar. Others are flown offsite because Renton does not have the capacity to apply the final exterior coating to all the airplanes produced in Renton. As discussed above, Phase 2 of this project includes the construction of a new two position paint hangar to increase Boeing Renton's on-site final exterior coating capacity.
- **Combustion Operations** include the boilers, heaters, and backup diesel generators. The boilers are located in Buildings 4-89 and 5-50.

These operations include the assembly of various sub-assemblies (e.g., wing spars and wings) from their component parts; the installation of various airplane systems (e.g., hydraulic, fuel, electrical) in the sub-assemblies; final assembly of a complete airplane structure and integration of the airplane systems; the installation of landing gear, engines, and interior components (e.g., seats, sidewalls, partitions); and functional testing. The main body sections (fuselages) are assembled in Kansas and are delivered to Boeing Renton by rail. Air emissions primarily occur from activities such as spray coating, sealing, hand-wipe and flush cleaning, and the use of miscellaneous adhesives, resins, and other products that contain volatile organic compounds.

As part of this project, in Phase 1, Boeing intends to move wing systems from Building 4-81 into Buildings 4-20 and 4-21 (Figure 1-2). In addition, both Phase 1 and Phase 2 of this project include the installation of new wing panel assembly tools and non-emission unit equipment (e.g., riveters), new automated spar assembly tools (ASATs), and other assorted tooling and non-emission-unit equipment in Buildings 4-20 and 4-21. No new or modified spray booths are planned, and no other emission units would be added or modified in Buildings 4-20 and 4-21 as part of this project.

In Building 4-86 (Figure 1-3), Boeing paints wings that are mostly assembled. There are four distinct operations that occur in Building 4-86, carried out in booths that are configured differently. These operations (and booth types) are:

1. **Pressure testing**, where the wing is cleaned, coated with a leak detection indicator, pressurized with ammonia, inspected, and cleaned.
2. **Horizontal wing painting**, where the spar cavities (leading and trailing edges) are hand-wipe cleaned, primed, and painted. This step also includes application of a Teflon-filled coating on abrasion-prone areas and the final interior fuel tank coating.



North

FIGURE 1-2
Future Building 4-20 Layout
Boeing

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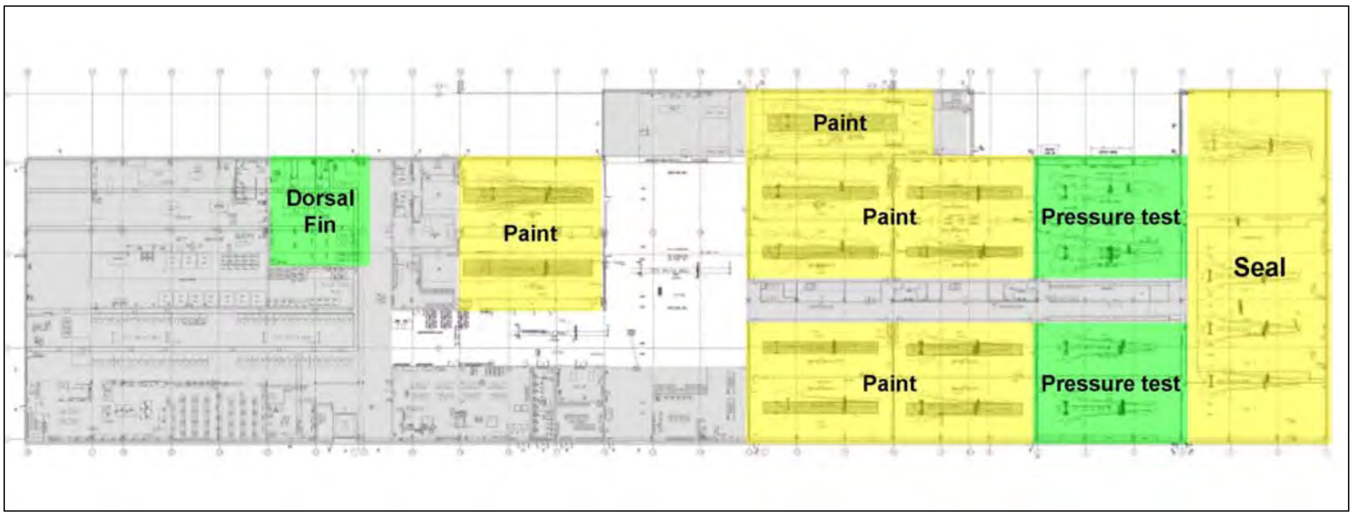

North

FIGURE 1-3
Building 4-86 Layout
Boeing

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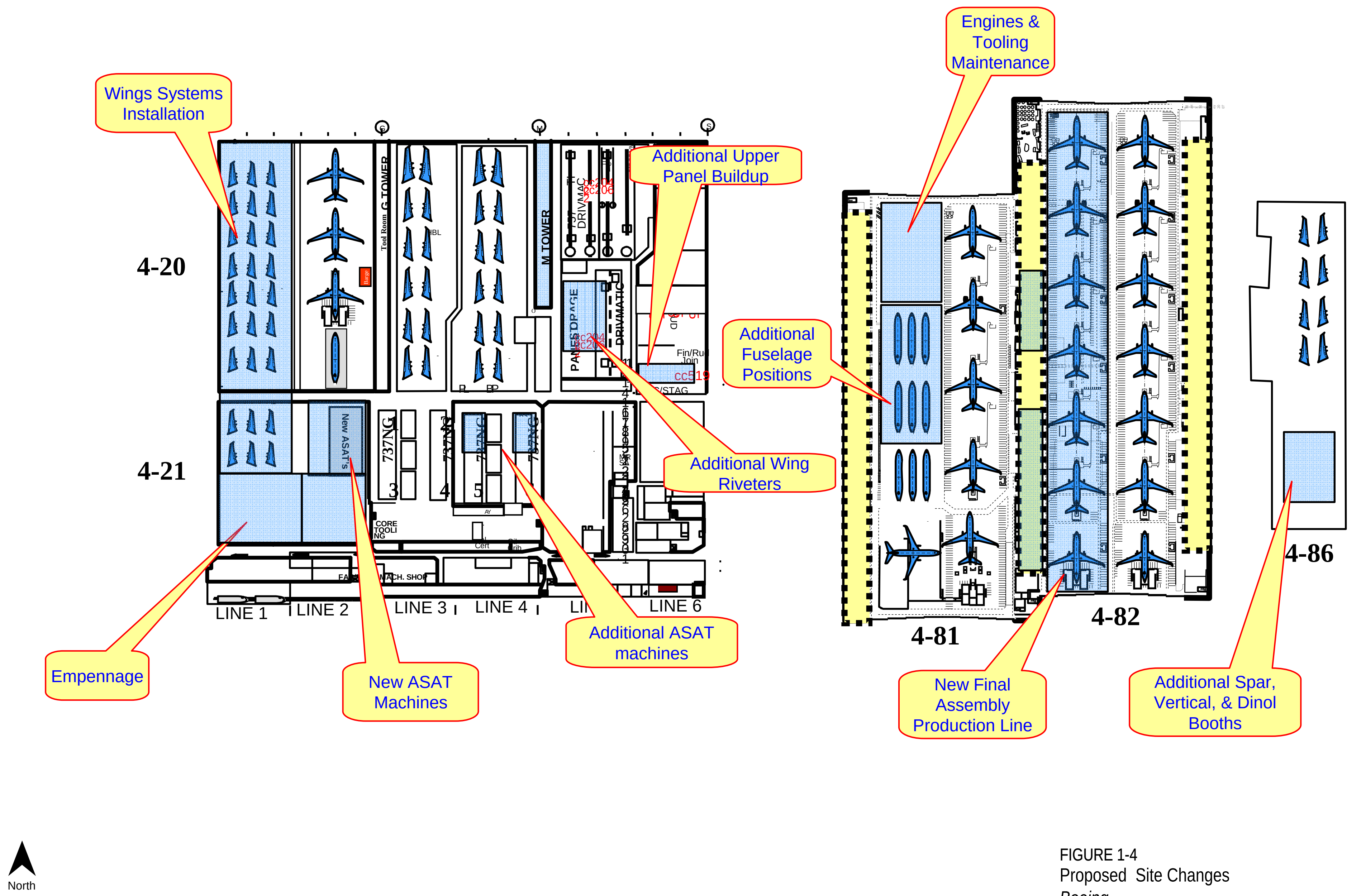

FIGURE 1-4
Proposed Site Changes
Boeing

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4. **Vertical wing painting**, where the upper and lower wing skins are cleaned, primed, and painted. The upper skins are primed with a standard urethane-compatible, corrosion-resistant primer, and the lower skins are primed with corrosion-resistant rubberized sealant.

5. Spar cavity **corrosion-inhibiting compound (CIC)** (with wings in the horizontal position), where paraffin-based material is sprayed onto exterior surfaces that are normally not in view.

There are currently four pressure testing booths, seven horizontal paint booths (four used for horizontal wing paint and three used for CIC application), and four vertical wing booths (inspar) in Building 4-86. PSD No 11-02 permitted the construction of an additional vertical booth and the modification of one of the existing vertical booths.

Boeing is considering two options for changes to wing coating operations in Building 4-86. Option 1 is the addition of three new horizontal booths dedicated to CIC coating, and the conversion of three horizontal booths (currently used for CIC) into vertical booths for inspar coating. Boeing is also considering constructing an additional vertical wing paint booth. Option 2 also includes the addition of three new horizontal booths dedicated to CIC coating, but instead of the conversion of the three horizontal booths from CIC to inspar painting, it includes three new vertical wing booths for inspar coating.

There will not be any physical or operational changes to Building 4-86's existing four horizontal wing paint booths or to its four existing or recently permitted (under PSD No 11-02) vertical wing paint booths.

Boeing also intends to build a new, approximately 90,000-square-foot paint hangar at the Renton facility in Phase 2. The new hangar will have two paint positions so that two 737s can be painted at the same time. Each position will have the ability to paint up to 121 airplanes per year, for a total of 242 airplanes per year. Each of the two paint positions in the new paint hangar will have potential VOC emissions of about 61 tpy, for total potential VOC emissions for the new paint hangar of about 122 tpy.

In addition to the changes described above, Boeing intends to make other changes to 737 assembly operations that are not expected to involve changes to spray booths or other emission units. These changes include, but may not be limited to:

- Installing another airplane assembly "moving" line in Building 4-82 and relocating some associated wing assembly operations to either Building 4-20 or Building 4-81;
- Adding engine buildup tooling and non-emission unit equipment to Building 4-82;
- Adding fuselage system installation positions to Building 4-81, and
- Other miscellaneous assembly tooling and non-emission unit equipment.

Boeing is also planning for potential additional warehouse space and parking structures. Table 1-1 summarizes the proposed actions for each building.

TABLE 1-1
Summary of Proposed Project

Building	Phase 1 Changes	Phase 2 Changes
4-20/4-21	Additional new wing panel assembly tooling and non-emission unit equipment Additional new ASATs Moving wing system installation tooling from Building 4-82 Other new miscellaneous assembly tooling and non-emission unit equipment	Additional new wing panel assembly tooling and non-emission unit equipment Additional new ASATs Other new miscellaneous assembly tooling non-emission unit equipment
4-86 Option 1	No changes	1 new vertical wing booth 3 new CIC wing booths Modifications (new fans, etc.) to 3 existing horizontal booths (currently used for CIC)
4-86 Option 2	No changes	3 new vertical wing booths 3 new CIC wing booths
4-81/4-82	Additional new final assembly (“moving”) line Additional / relocation of existing engine buildup tooling and non-emission unit equipment	Additional new systems installations tooling and non-emission unit equipment Additional / relocation of empennage tooling and non-emission unit equipment
4-41 & 5-50 Paint Hangars	No changes	No changes
New final decorative paint positions	No changes	Construction of new two position paint hangars (likely 1 building)

VOC emissions from all 737 assembly operations at Boeing Renton, including on-site painting of completed airplanes, average about one ton per airplane. The emissions are about equally divided between painting the initial coats on the airplane parts (such as the wings and internal surfaces) and painting the completed airplane with the final exterior coat.

2. Prevention of Significant Deterioration

The Prevention of Significant Deterioration (PSD) program is intended to protect current levels of air quality and to ensure that the air quality does not significantly deteriorate in areas that meet the National Ambient Air Quality Standards (NAAQS). The program requires certain major emissions sources and major modifications to undergo a specific review procedure. The federal PSD requirements are contained in 40 Code of Federal Regulations (CFR) 52.21; however, in Washington State the U.S. Environmental Protection Agency (EPA) has delegated the implementation of the program to the Washington Department of Ecology (Ecology). Ecology implements the PSD program under Washington Administrative Code (WAC) 173-400-720. Under 40 CFR 52.21(a)(2)(iv)(a), "a project is a major modification for a regulated NSR [New Source Review] pollutant if it causes two types of emissions increases—a significant emissions increase (as defined in paragraph (b)(40) of this section), and a significant net emissions increase (as defined in paragraphs (b)(3) and (b)(23) of this section)." The significant emissions increase analysis (often called Step 1) looks only at the emissions from the proposed project, and the significant net emissions increase (often called Step 2) looks at additional increases and decreases from "contemporaneous" projects at the source.

For the significant emissions increase analysis, the proposed project will involve both constructing new emissions units and modifying existing units. The PSD regulations require use of the Hybrid Test for projects that involve both the addition of new emission units and the modification of existing emission units (40 CFR 52.21(a)(2)(iv)(f)). Under the Hybrid Test, a significant emissions increase of a regulated NSR pollutant is projected to occur if the sum of the emissions increases for each emissions unit, using the Actual-to-Projected-Actual Applicability Test (40 CFR 52.21(a)(2)(iv)(c)) for modified units and the Actual-to-Potential Applicability Test (40 CFR 52.21(a)(2)(iv)(d)) for new units, equals or exceeds the significant amount for that pollutant (as defined in paragraph 40 CFR 52.21 (b)(23)). The Actual-to-Projected-Actual Applicability Test involves adding the projected (future) actual emissions from existing emission units that are modified as part of the project or that are expected to experience an emission increase as a result of the project, and then subtracting the past actual emissions (referred to as "baseline actual emissions") from those units. In lieu of projecting future actual emissions for a particular existing emission unit, an applicant can choose instead to use the unit's potential to emit as the unit's post-project emissions (40 CFR 52.21(b)(41)(ii)(d)). The Actual-to-Potential test, which is required for all new units being constructed as part of the project, involves totaling the potential emissions of the proposed new emission units, then subtracting past actual emissions of those units. A new unit that is being constructed as part of the project has a baseline of zero (40 CFR 52.21(b)(48)(iii)).

If the project would result in a significant emissions increase, then a significant net emissions increase analysis is often conducted. However, EPA has clearly stated that calculating a net emissions increase is at the source's option (see, for example, 67 Federal Register 80186, at 80197 [December 31, 2002]) and therefore a source may seek a PSD permit based on a calculated significant emission increase alone.

Because the Boeing Renton facility currently has the potential to emit more than 250 tpy of a regulated NSR pollutant (VOC), Boeing Renton is considered a "major stationary source" for PSD purposes, as defined by 40 CFR 52.21 (b)(1)(i).

The purposes of this project are to develop the production technology and methods to produce 737 MAX airplanes, to increase Boeing's ability to assemble Model 737 airplanes from the current permitted capacity of about 504 airplanes per year, and to increase Boeing Renton's on-site final exterior coating capacity.

At Boeing Renton, VOCs are emitted from cleaning, sealing, and coating operations primarily from six buildings (Buildings 4-20/21, 4-42, 4-81/82, 4-86, 4-41, and 5-50) with trace or negligible emissions from other buildings and the flight line. These emissions are briefly described as follows:

- **Building 4-20/21.** Buildings 4-20 and 4-21 are joined together with no separation, and for production purposes they are considered one building. Wings are assembled in this building using operations such as hand-wipe cleaning, drilling, riveting, and bolting. Some operations are manual, such as hand-wipe cleaning, while others are automated, such as with an ASAT that drills holes and sets rivets automatically. The building also contains six wing panel booths in which the wing upper and lower panels are cleaned, sealed, and coated before being joined together. In addition to wing assembly, the final assembly of P8A's occurs in Building 4-20/21. The P8A is a military airplane based on the Model 737. For several reasons, including International Traffic in Arms regulations, the P8A final assembly line is kept separate from the 737 production lines and kept secure. The P8A production rate is a small fraction of the total 737 production rate, but the emissions from the P8A production are included in the emissions calculations for 737 production in Building 4-20/21.
- **Building 4-86**. Wings are sealed, pressure tested, and painted in Building 4-86. Wing sealing is primarily a manual operation during which sealant is applied to the interior surfaces of the wing to ensure that fuel does not leak out of the wing. After sealing, the wings are pressure tested for leaks and any leaks are sealed. Next the wings are moved to a horizontal (spar) paint booth and the spar cavities on the leading and trailing edges are sprayed. The wing is then moved to a vertical (inspar) booth where the upper and lower wing surfaces are sprayed. Finally, the wings are moved back to a horizontal booth where paraffin-based corrosion-inhibiting compounds are sprayed into wing cavities and a final coat of fuel tank primer is applied inside the wing. From there the wings are transferred to Building 4-81/82 for wing systems installation. Building 4-86 is subject to a VOC annual limit of 242 tons per year under PSD 97-2.
- **Building 4-81/82.** Much like Building 4-20/4-21, Buildings 4-81 and 4-82 are joined together to form a single structure. In Building 4-81/82, the main components, such as the fuselage, wings, landing gear, and engines, are assembled together and the various electrical, hydraulic, and interior systems are installed and tested. Cleaning, sealing, and touchup operations also occur in these buildings. Final sealing and touchup manual operations are also conducted here, which usually involve minor emission sources such as tube application of sealant and aerosol can or brush application of touchup. The combined VOC emissions from wing buildup and final assembly operations in Buildings 4-20, 4-21, 4-81, and 4-82 shall not exceed 118 tons per year, under PSD 08-01 Amendment 1.

- **Buildings 4-41 and 5-50.** Buildings 4-41 and 5-50 are paint hangars where completed airplanes are cleaned and the final decorative paint coats are applied. Each paint hangar has a dedicated ventilation system that includes particulate filters. Spray gun cleaning also occurs in the paint hangars. Under PSD 88-4, the Building 4-41 Paint Hangar is subject to an annual emission limit of 124 tons of VOC per year, and under PSD 08-01 Amendment 1, the Building 5-50 Paint Hangar is subject to an annual VOC limit of 40.8 tons per year.
- **Flightline.** Final testing, touchup, and cleaning of completed airplanes occur on the flightline. These operations are manual and VOC emissions are negligible.
- **Boilers and other combustion sources.** Boilers in Buildings 4-89 and 5-50 support the Renton facility's operation. Other combustion sources include backup diesel generators.

From time to time, Boeing makes minor changes to the assembly operations to improve efficiency but does not fundamentally change the processes. For example, as part of this 737 MAX project, Boeing is proposing to move the wing systems installation operations currently in Building 4-81/82 to Building 4-20/21.

2.1 Significant Emissions Increase Analysis

As stated above, this project will involve both modifying existing emission units and constructing new emission units; therefore, a hybrid test is required under 40 CFR 52.21(a)(2)(iv)(f). The hybrid test involves using the Actual-to-Projected-Actual Applicability Test (40 CFR 52.21(a)(2)(iv)(c)) for modified units and debottlenecked units the Actual-to-Potential Applicability Test (40 CFR 52.21(a)(2)(iv)(d)) for new units to be constructed as part of the project.

2.1.1 Actual-to-Projected-Actual Applicability Test for Modified and Debottlenecked Emission Units

For existing emission units that are being modified or debottlenecked as part of the project, the PSD baseline emissions are the emissions averaged over any 24-consecutive-month period in the 10 years before Ecology receives a complete application for the project. For a regulated NSR pollutant, when a project involves more than one emission unit, only one 24-consecutive-month period may be used to determine the baseline actual emissions for all emission units being changed; however, a different 24-consecutive-month period can be used for each regulated NSR pollutant (40 CFR 52.21(b)(48)(ii)(d)). For this project, the 10-year period from which the baseline period may be selected for all NSR regulated pollutants begins in 2002 and includes the full calendar years 2002 through 2010. For "new" units constructed prior to the project (i.e., units that have been in operation for less than two years) baseline actual emissions are the units' potential to emit (40 CFR 52.21(b)(48)(iii)).

Table 2-1 presents the VOC emissions from 737 assembly operations and the number of 737s produced for the 6 years 2005 through 2010. The table does not include data from 2002 through 2004 because the maximum number of 737s produced during any 24-consecutive-month period from 2002 through 2004 that is part of the 10-year period is less than the number of 737s produced during any 24 consecutive months from 2005 through 2010. The table also does not include emissions from painting completed airplanes because not all 737's produced in Renton receive their final exterior coating in Renton and the paint hangars in Renton have been operating at or near capacity. Boeing has selected 2009 and 2010 calendar years as the baseline period for VOC emissions.

TABLE 2-1
Estimated VOC Emissions from 737 Assembly Operations for 2005 through 2010

Year	Number of 737s Produced	Estimated VOC Emissions (tons)	Estimated VOC Emissions per Airplane (tons)
2005	214	70	0.33
2006	302	115	0.38
2007	330	134	0.41
2008[a]	290	105	0.36
2009	372	136	0.37
2010	376	171	0.45

[a] A 2-month work stoppage occurred in 2008.

Note that the Building 5-50 paint hangar has recently become operational and was permitted under a recent PSD permit PSD-08-01 Amendment 1 issued by Ecology.

Increased 737 production enabled by the project would be expected to result in increased emissions from the 737 assembly operations and related combustion from boilers and heaters. Table 2-2 lists the projected actual emissions (at the maximum production rate) from the 737 assembly operations and from the related operations that would experience increased emissions as a result of increased production at the assembly operations under both Option 1 of installing three new horizontal booths dedicated to CIC coating and converting three horizontal booths (presently used for CIC) into vertical wing booths, and Option 2 of adding three new horizontal CIC booths and three new vertical wing booths. The increased emissions would primarily result from debottlenecking the assembly operations via the increased capacity of the wing assembly operations in Building 4-20/21 and Building 4-86 and the new two-position paint hangar. Details of the emission estimates are shown in Appendix A. Note that with the exception of combustion-related emissions, the emissions listed in Table 2-2 are specific to 737 production only. Because the combustion operations provide heat and energy to all operations at the Boeing Renton facility, including operations such as office buildings that are not directly related to production, emissions from combustion are treated differently than those from the other operations. The projected actual emission rate for combustion operations is the baseline rate for the entire Boeing Renton facility plus the expected additional heat that would be required to support production at the maximum potential production rate - based on an average heat usage of 873 million British thermal units (MMBtu) of natural gas per airplane and 31,550 gallons of oil. For natural gas, the average usage rate per airplane for 2009 was used. The maximum oil firing rate was estimated based on double the maximum amount of oil burned in any of the last 5 years; this would give an upper limit on the amount of oil burned. The emissions of greenhouse gases were estimated based on the maximum emission rate per airplane in the last 5 years for Scope 1 Stationary Sources combustion sources, at 71 tons of carbon dioxide equivalent (CO_2e) per airplane in 2008. Similarly, the manufacturing process resulted in emissions of 7.6 tons of CO_2e per airplane in 2008 in the form of hydrofluorocarbons (HFC).

Projected actual VOC emissions from the 4-41 Hangar and the 5-50 Hangar are based on current PSD permit limits. The projected actual emissions from existing wing coating operations in Building 4-86, are based on the current PSD permit limit for that building less the potential emissions from the new wing paint booths that are proposed for Building 4-86.

TABLE 2-2
Projected Actual Emissions of Regulated NSR Pollutants for Existing 737 Assembly Operations and Related Operations (tpy)

Operation	CO	NOx	PM[a]	SOx	Lead	VOC Option 1	VOC Option 2	CO_2e
Wing Assembly						125.1	125.1	
Wing Coating						217.6	194.0	
Final Assembly						28.9	28.9	
Flightline						4.4	4.4	
4-41 Hangar						49.3	49.3	
5-50 Hangar						40.8	40.8	
Non-combustion CO_2e								6,361
Combustion[b]	26.5	68.2	2.5	0.3	0.00018	1.8	1.8	58,662
Total	26.5	68.2	<3.5	0.3	0.00018	467.9	444.3	65,023

[a] PM emission from non-combustion sources will be less than 1 tpy
[b] All combustion-related emissions are accounted for in Combustion.
CO = carbon monoxide
NOx = nitrogen oxides
PM = particulate matter
SOx = sulfur oxides

During the baseline period, Boeing Renton did not operate above any legally enforceable emission limit and there are no new emission standards that affect these units or activities that have come into effect between the baseline period and the date of this application. Therefore, no adjustments are required under 40 CFR 52.21(b)(48)(ii)(b) or (c). Table 2-3 shows the difference between the baseline actual emissions from existing emission units and the projected actual emissions from the existing emission units (at the maximum potential production rate).

Table 2-3 shows the baseline actual emissions for calendar years 2009 and 2010 from the 737 assembly operations and related operations that are expected to experience an emission increase as a result of the increased 737 production enabled by the project, except that CO_2e is based on 2006 and 2007 which was the 2 year period with the greatest CO_2e production rate. During the baseline period the 5-50 Paint Hangar was permitted but it is considered a "new" unit because it was constructed prior to the project and has been in operation for less than 2 years. Therefore, as allowed by 40 CFR 52.21(b)(48)(iii), baseline actual emissions for the 5-50 Paint Hangar are equal to its potential to emit of 40.8 tpy. Table 2-4 shows the total emission increase from the existing emission units.

TABLE 2-3
Baseline Actual Emissions of Regulated NSR Pollutants for Existing 737 Assembly Operations and Related Operations (tpy in 2009-2010 except for CO_2e, which was in 2006-2007)

Operation	CO	NOx	PM[a]	SOx	Lead	VOC	CO_2e
Wing Assembly						61.9	
Wing Coating						76.0	
Final Assembly						14.3	
Flightline						2.2	
4-41 Hangar						34.0	
5-50 Hangar						40.8	
Non-combustion CO_2e							2,986
Combustion[b]	13.3	34.2	1.3	0.1	0.00008	0.9	24,243
Total	**13.3**	**34.2**	**≤2.3**	**0.1**	**0.00008**	**230.1**	**27,229**

[a] PM emissions from non-combustion sources were less than 1 tpy.
[b] All combustion-related emissions are accounted for in Combustion.

TABLE 2-4
Emissions Increases of Regulated NSR Pollutants for Existing 737 Assembly Operations and Related 737 Operations (tpy)

	CO	NOx	PM	SOx	Lead	VOC Option 1	VOC Option 2	CO_2e
Projected	26.5	68.2	<3.5	0.3	0.00018	467.9	444.3	65,023
Baseline	13.3	34.2	≤2.3	0.1	0.00008	230.1	230.1	27,229
Total Increase from Existing Sources	**13.2**	**34.0**	**≤1.2**	**0.2**	**0.00010**	**237.8**	**214.2**	**37,794**

2.1.2 Actual-to-Potential Test for Newly Constructed Emission Units

For emission units that will be newly constructed as part of the project, baseline emissions are zero and post-project emissions are the units' potential to emit. Thus, the emission increase from these units resulting from the project is their potential to emit. The only new potential emission units would be up to three new CIC booths in Building 4-86, a new vertical wing paint booth in Building 4-86, and a new two-position paint hangar. Three booths in Building 4-86 would be modified to allow for painting wings vertically (inspar), but the emissions from these modified booths are accounted for in the Actual-to-Projected Actual Applicability Test. Boeing Renton normally operates two production shifts per day and on a 5-day-a-week schedule. The new and modified booths will be physically capable of operating three shifts per day; therefore, the potential to emit for the new booths is based on operating three shifts per day, seven days per week. The potential emissions from all the new CIC booths would be a total of 12.6 tons per year, and the potential VOC emissions for each new vertical wing booth would be 11.8 tons per year (one new booth under Option 1 and three under Option 2). Finally, the potential VOC emissions for the new paint hangar would be about 122 tons per year. These emissions are shown in Table 2-5.

TABLE 2-5
Emissions Increases of Regulated NSR Pollutants for New Units (tpy)

	CO	NOx	PM	SOx	Lead	VOC Option 1	VOC Option 2	CO_2e
4-86 Vertical Wing						11.8	35.4	
4-86 CIC (3 booths)						12.6	12.6	
New Hangar						122.0	122.0	
Total for New Units						**146.4**	**170.0**	

2.1.3 Hybrid Total Emissions Increase

The total emission increase relating to the production capacity increase project is the sum of the increases from the existing units and the potential to emit from the newly constructed units and is presented in Table 2-6.

TABLE 2-6
Emissions Increases of Regulated NSR Pollutants for Existing and Newly Constructed Emission Units (tpy)

	CO	NOx	PM	SOx	Lead	VOC Option 1	VOC Option 2	CO_2e
Total for Existing Units	13.2	34.0	1.2	0.2	0.0001	237.8	214.2	37,794
Total for Newly Constructed Units						146.4	170.0	
Hybrid Total	13.2	34.0	1.2	0.2	0.0001	384.2	384.2	37,794
PSD Significant Rate	100	40	10	40	0.6	40	40	75,000
Significant	**No**	**No**	**No**	**No**	**No**	**Yes**	**Yes**	**No**

As shown in Table 2-6, only the VOC emissions increase from this project is above the PSD significant emission increase rate. Also note that both Option 1 and Option 2 result in the same Hybrid Total of 384.2 tons per year. This is because under both options the same number of airplanes and wings will be produced and painted. The difference between the two options is the number of new wing paint booths versus the number of modified wing paint booths.

The PSD rule (40 CFR 52.21(b)) defines "major modification" as follows:

> (2)(i) Major modification means any physical change in or change in the method of operation of a major stationary source that would result in: a significant emissions increase (as defined in paragraph (b)(40) of this section) of a regulated NSR pollutant (as defined in paragraph (b)(50) of this section); and a significant net emissions increase of that pollutant from the major stationary source.

The federal rule in 40 CFR 52.21 (b)(23) defines a significant increase to be equal to or exceeding any of the rates listed in Table 2-7.

TABLE 2-7
Pollutant and PSD Significant Emission Rates

Pollutant	Significant Emission Rate (tpy)
CO	100
NO_x	40
SO_2	40
PM	25
PM_{10}	15
$PM_{2.5}$	10
Ozone	40 (VOCs or NOx)[a]
Lead	0.6
Fluorides	3
Sulfuric Acid Mist	7
H_2S	10
Total Reduced Sulfur	10
Reduced Sulfur Compounds	10
Ozone-Depleting Substances	100[b]
Greenhouse Gases	75,000 (CO_2e)

Note: There are additional rates for municipal waste combustors and landfills; however, Boeing does not combust or landfill municipal waste at the Boeing Renton facility.
[a] VOC and NO_x are precursors of ozone.
[b] WAC 173-400-720(4)(b)(e)(B).

The project is not expected to emit measurable quantities of fluorides, hydrogen sulfide (H_2S), total reduced sulfur, or reduced sulfur compounds. The expected increase in ozone-depleting substances is about 3.2 tons per year.[2] As shown in Table 2-6, the emissions increases from the project will not exceed the significant emission rate of any regulated NSR pollutant except for VOCs; therefore, the project will only have a significant emissions increase for VOCs.

2.2 Significant Net Emissions Increase Analysis

As stated in 40 CFR 52.21(a)(2)(iv)(a), "If the project causes a significant emissions increase, then the project is a major modification only if it also results in a significant net emissions increase." The proposed project will result in a significant emissions increase only for VOC; therefore, the project will be subject to PSD for VOC and will be considered a major modification only if it also results in a significant net emissions increase of VOC. 40 CFR 52.21(b)(3)(i) outlines the steps necessary to calculate the net emissions increase. Although EPA has clearly stated that calculating a net emission increase is at the source's option (see, for example, 67 Federal Register 80186, at 80197 [December 31, 2002]) and therefore a source may seek a PSD permit based on a calculated significant emission increase alone, this section addresses the net emission increase associated with the project.

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[2] EPA has not established a significance level of ozone-depleting substances (ODS) in 40 CFR 52.21; however, in a March 19,1998, letter to Kevin Tubbs of American Standard, John Seitz of EPA stated that in 1996, EPA proposed a 100-ton-per-year threshold and did not receive any adverse comments. The letter went on to state that EPA would not object if a state did not require PSD review of ODS emissions less than 100 tons per year. See http://www.epa.gov/region7/air/nsr/nsrmemos/rfrigrnt.pdf.

The first step in calculating the net emission increase is to calculate the total emissions increase from the project (40 CFR 52.21(b)(3)(i)(a)); this is shown in Table 2-6 as the Hybrid Total of 384.2 tpy. Next, all creditable increases and decreases in actual emissions that are contemporaneous with the proposed change (i.e., occurring during the period beginning on the date 5 years before construction commences on the proposed project and ending on the date that the emission increase from the proposed project occurs) must be considered (see 40 CFR 52.21(b)(3)(ii)). Creditable increases do not include any increases that Ecology or EPA have relied on in issuing a PSD permit (see 40 CFR 52.21(b)(3)(iii)(*a*)). In the past 5 years, the following projects have or may have caused VOC emission increases:

- Reconfigure and refurbish existing Paint Hangar 1 (P1) in Building 5-50.
- Install additional automated spar assembly tools and metal shim wet milling machine in Building 4-21.
- Install an additional automatic wing fastener insertion system.
- Install additional assembly tooling and support equipment in Buildings 4-20/21 and 4-81/82.
- Install four wing panel booths, a new horizontal wing build line, a new wing-riveter, and miscellaneous assembly tools in Building 4-20.
- Install a new vertical wing booth, revert an existing spar (horizontal) booth to its original use as a vertical wing booth, and install new fans in an existing vertical wing booth in Building 4-86.

However, Ecology relied on the VOC emission increases from those changes listed above when it approved PSD-08-01 Amendment 1 and PSD 11-02, and Boeing Renton has complied with the emission requirements of that permit. (40 CFR (b)(3)(iii)(a)). Other increases in emissions over the past 5 years have been a result of increased utilization of existing capacity excluded from the definition of physical change or change in method of operation under 52.21(b)(2)(iii)(f) and changes occurring before the contemporaneous period that Ecology has approved under PSD-97-2 for Building 4-86 or PSD-88-4 for Building 4-41 Paint Hangar.

There have been no other increases in actual emissions at Boeing Renton that are contemporaneous with this particular change and are otherwise creditable. Boeing is not taking credit for any contemporaneous emissions decreases in this analysis. Therefore, the net emissions increase for this project is equal to the project's emission increase of 384.2 tpy as calculated by the Hybrid Test in Section 2.1.3. Since the project will result in both a significant emission increase (as defined by 40 CFR 52.21(b)(40)) and a significant net emission increase (as defined by 40 CFR 52.21(b)(3) and 40 CFR 52.21(b)(23)) the project is a major modification and subject to PSD review for VOC.

2.3 PSD Requirements

A PSD permit application must demonstrate that:

- Best available control technology will be used for each new emission unit that will emit the pollutant for which PSD is triggered, and will be used for each modified emission unit that will experience a net increase in emissions of the pollutant for which PSD is triggered as a result of the modification to that unit.

- Allowable emissions increases from the project will not cause or contribute to a violation of any ambient air quality standard or increment.
- The project will not significantly adversely impact air quality related values such as soils, vegetation, and visibility in Class I areas.

Sections 3, 4, and 5 address these requirements.

3. Best Available Control Technology Analysis

As required by 40 CFR 52.21(j)(3), a major modification shall apply best available control technology (BACT) for each regulated NSR pollutant for which it would result in a significant net emissions increase at the source. This requirement applies to each proposed new emission unit and each emissions unit at which a net emissions increase in the pollutant would occur as a result of a physical change or change in the method of operation in the unit. Thus, emission units that are not new units or modified units are not subject to BACT, regardless of whether such units will experience an increase in emissions of that pollutant as a result of the project. Further, new or modified units that are associated with a project but will not emit that pollutant (for new units), or will not experience a net increase in emissions of that pollutant "as a result of" the project (for modified units), are not subject to BACT.

40 CFR 52.21(b)(12) defines BACT as follows:

> Best available control technology means an emissions limitation (including a visible emission standard) based on the maximum degree of reduction for each pollutant subject to regulation under Act *[sic]* which would be emitted from any proposed major stationary source or major modification which the Administrator, on a case-by-case basis, taking into account energy, environmental, and economic impacts and other costs, determines is achievable for such source or modification through application of production processes or available methods, systems, and techniques, including fuel cleaning or treatment or innovative fuel combustion techniques for control of such pollutant. In no event shall application of best available control technology result in emissions of any pollutant that would exceed the emissions allowed by any applicable standard under 40 CFR parts 60 and 61. If the Administrator determines that technological or economic limitations on the application of measurement methodology to a particular emissions unit would make the imposition of an emissions standard infeasible, a design, equipment, work practice, operational standard, or combination thereof, may be prescribed instead to satisfy the requirement for the application of best available control technology. Such standard shall, to the degree possible, set forth the emissions reduction achievable by implementation of such design, equipment, work practice or operation, and shall provide for compliance by means which achieve equivalent results.

As discussed in Section 2 of this application, the only regulated NSR pollutant for which the project results in a plant-wide significant emission increase and net emissions increase is VOCs. There are up to six new VOC emission units and/or up to three modified emission units anticipated for the project in Building 4-86. In addition, Boeing is proposing a new two-position paint hangar at the Renton Facility as shown in Table 3-1. The table also shows the potential VOC emissions for each of the new or modified booths. Spray gun and line cleaning operations are included in the emissions for the 4-86 wing booths and the paint hangar because the paint containers and the spray guns are connected by long lines that need to be cleaned. For the purposes of the emissions estimates and this BACT analysis, all the gun and line cleaning solvent is assumed to be emitted through the booth or hangar. Gun cleaning for the Dinol CIC booth are not included because those operations will occur elsewhere in existing gun cleaning facilities.

TABLE 3-1
New and Modified Emission Units

Building	Booth Type	Maximum Quantity	New/Modified	VOC Emissions (tpy/booth or position)	Exhaust Rate (acfm)
New Paint Hangar	Two-Position Paint Hangar	2 Positions	New	61	165,000
Building 4-86	Vertical Wing Booth	3	Modified	24	140,000
	Vertical Wing Booth	3	New	24	140,000
	Dinol CIC Wing Booth	3	New	4.2	40,000

acfm = actual cubic feet per minute

This section presents a BACT analysis for these new and modified spray booths using the EPA top-down approach. This top-down approach includes the following steps:

- Identify pollution-control technology options available in the market.
- Evaluate the options and reject technically infeasible options.
- Rank remaining control technologies by control effectiveness.
- Evaluate effective controls considering energy, environmental, and economic impacts.
- Select BACT based on analysis.

This BACT analysis considers those technologies that reduce VOC emissions from the cleaning and coating operations that will take place in the new or modified units. BACT analysis was performed for each booth operating at the emission rates and exhaust flow rates listed in Table 3-1. Boeing currently uses a combination of low-VOC coatings, high-transfer-efficiency application techniques, and good work practices (such as keeping containers of coating closed when not in use) to minimize VOC emissions. The Aerospace National Emission Standard for Hazardous Air Pollutants (NESHAP) and/or PSCAA regulations require low-VOC coatings, high-transfer-efficiency coating techniques, and these good work practices; therefore these coatings, application techniques, and work practices are considered the base case for BACT.

The cleaning and coating operations that are planned for the new and modified vertical wing booths are as follows:

- **Wing cleaning and conversion coating** – Before the exterior of the wing can be coated, it first must be cleaned and prepped for priming.

- **Wing priming** – Priming provides corrosion protection and ensures the necessary bond between the surface of the wing and the topcoat.

- **Wing topcoat** – The topcoat is the final coating of the normally visible surfaces of the wing, top and bottom. The topcoat not only provides the final protection of the wing surface but also provides the decorative color to the top and bottom of the wing.

- **Wing corrosion-inhibiting compound** – Portions of the wing that are not normally visible often need a special coating to further protect them from corrosion. This corrosion-inhibiting compound is applied to the wing assembly before the wing is transported to the main assembly line for attachment to the fuselage of the airplane.
- **Spray equipment cleaning –** The spray equipment (such as guns and lines) used to perform the operations above is cleaned after each use. A small amount of solvent evaporates while cleaning the spray equipment.

The cleaning and coating operations that are planned for the new Dinol/CIC wing booths include cleaning the wings and applying corrosion-inhibiting compounds.

The cleaning and coating operations that are planned for the new paint hangar include cleaning the airplanes and applying primers and final decorative topcoats. Airplanes may also be depainted and repainted in the proposed new hangar.

3.1 Available Control Technologies

BACT databases from EPA (EPA, RACT/BACT/LAER Clearinghouse [RBLC]), California Air Resources Board (CARB), and South Coast Air Quality Management District (SCAQMD) were reviewed for possible control technologies that are both available on the market and proven practice in the aerospace or other industries with similar requirements for coating very large objects. The technologies reviewed are summarized in Table 3-2.

3.2 BACT Feasibility Review

The control technologies in Table 3-2 have been demonstrated and achieved in practice and therefore could be feasible technologies for implementation at Boeing Renton paint booth operations. Note that Boeing considers the use of low-VOC coating, high-transfer-efficiency spray equipment, and good work practices to minimize VOC emissions to be the base case for BACT.

3.3 Ranking of BACT by Control

The potential control options provided in Table 3-2 have been ranked in Table 3-3 based on the control efficiencies documented as being achieved in practice.

3.4 Cost-effectiveness Evaluation

Reputable vendors of paint operation and control technologies were identified based on contacts within the aerospace industry and were contacted to assess implementation of the different controls available in the marketplace (listed in Table 3-3). A similar BACT analysis for Renton was submitted in spring 2011 for Building 4-86 wing booth changes and approved by Ecology in PSD-11-02. Ecology also approved a similar analysis for the Building 5-50 Paint Hangar in PSD-08-01 Amendment 1. The BACT determinations from that analysis showed thermal oxidizer and thermal oxidizer with preheater were double the cost or greater than the carbon adsorption and regenerative thermal oxidizer (RTO) with concentrator technologies. All technologies were determined to be not cost-effective.

TABLE 3-2
BACT Review

Control Technology	Equipment Description	Company	Date Implemented	Pollutant Controlled	Control Efficiency	Emission Limit	Database Reference
Thermal oxidizer	Spray Booth	Watkins Manufacturing Corporation	10/28/2002	VOC	98.9%	95% control	CARB, BACT Clearinghouse
Regenerative thermal oxidizer	Spray Booth	Arcadia, Inc.	2/6/2001	VOC	99.3%	.89 lb/hr	CARB, BACT Clearinghouse SCAQMD Clearinghouse
Regenerative thermal oxidizer	Spray Booth	Huck International – Deutsch Operations	NA	VOC	90.6%	59 lb/day	CARB, BACT Clearinghouse SCAQMD Clearinghouse
Regenerative thermal oxidizer with concentrator	Spray Booth	Kal-Gard Coating & Mfg, E/M Corp.	8/14/2008	VOC	NA	2 tpy	CARB, BACT Clearinghouse
Regenerative thermal oxidizer with concentrator	Spray Booth	Douglas Production Division	3/30/1994	VOC	93.2%	341 gallons/ day	CARB, BACT Clearinghouse SCAQMD Clearinghouse
Carbon adsorption	Spray Booth	Lippert Components, Inc.	5/8/2002	VOC	99.3%	85.5% control	CARB, BACT Clearinghouse
Carbon adsorption	Spray Booth	Northrop-Grumman	2/25/1991	VOC	90%	414 lb/day	CARB, BACT Clearinghouse
Low-VOC coatings, HVLP coating gun, best management practices	Spray Booth	Time Aviation Services Inc.	6/18/1999	VOC	NA	3 gallons/ day	CARB, BACT Clearinghouse
Low-VOC coatings, HVLP coating gun, best management practices	Spray Booth	California Air National Guard, Fresno	1/22/1997	VOC	NA	5.23 lb VOC/ gallon coating	CARB, BACT Clearinghouse
Low-VOC coatings, HVLP coating gun, enclosed gun cleaner	Spray Booth	Toter	12/16/1999	VOC	NA	1.09 lb VOC/ gallon	CARB, BACT Clearinghouse

NA = not applicable
HVLP = high-volume low-pressure

TABLE 3-3
Ranking of Control Technologies

Type of Control Technology	Control Efficiency	Ranking
Regenerative thermal oxidizer	99.3%	1
Carbon adsorption	99.3%	2
Thermal oxidizer	98.9%	3
Regenerative thermal oxidizer with concentrator	93.2%	4
Low-VOC coatings, HVLP coating gun, best management practices	Not Applicable	5

For this BACT analysis, vendor quotes from 2011 were used to complete this analysis for thermal oxidizer and thermal oxidizer with preheater technologies. New vendor quotes for the carbon adsorption and regenerative thermal oxidizer with concentrator technologies were obtained because these technologies are expected to again be the more cost-effective options for Renton operations. Vendor quotes are summarized in the cost-effectiveness evaluation spreadsheets located in Appendixes B, C and D. Cost evaluations followed published EPA guidance for VOC control by incinerators and by carbon adsorption (EPA, 2002). Sections 3.4.1 through 3.4.6 discuss those results.

The cost-effectiveness analyses used the standard default values for construction as provided by EPA. Boeing Renton expects that the installation of any add-on control technology on any booths within the factory buildings would require complicated retrofit construction and expenses. The existing facility has limited space available for the footprint of additional equipment, which may require that any add-on controls be placed on the roof, in turn requiring additional structural support, stairs, and platform access. The existing natural gas lines would need to be upgraded to supply sufficient flow and pressure to operate the control equipment for the RTO and RTO with concentrator. Complicated retrofits like these can increase installation costs by a factor of 50 percent. Boeing normally uses a 10.5 percent annualized opportunity cost when considering capital investments; however, Ecology requested that a 7.0 percent annual interest rate also be used for the BACT evaluation.

3.4.1 Thermal Oxidizer

A thermal oxidizer introduces the VOC emissions in an air stream to a burner that destroys those emissions prior to release to the atmosphere through a stack. This control technology has been improved upon over the years to also include preheating the incoming air stream to obtain additional fuel efficiencies. Vendor information from Callidus and John Zink for thermal oxidizers with and without preheaters was considered. The equipment costs and operating parameters are provided in Appendixes B, C and D. The thermal oxidizer control technology overall cost-effectiveness in dollars per ton removed is listed in Tables 3-4, 3-5, and 3-6.

3.4.2 Carbon Adsorption

Carbon adsorption uses a filter bank of canisters that contain activated carbon, which adsorbs the VOC emissions as the air stream passes through before being released to the atmosphere.

Vendor information for the carbon adsorption technology was obtained from Thermal Recovery Systems. The equipment costs and operating parameters are provided in Appendixes B, C and D. The carbon adsorption control technology overall cost-effectiveness in dollars per ton removed is listed in Tables 3-4, 3-5, and 3-6.

3.4.3 Regenerative Thermal Oxidizer

A regenerative thermal oxidizer was ranked as one of the top control technologies available based on control efficiency. VOC emissions are burned inside an enclosed chamber. Heat from the exhaust gas is recovered in a heat exchanger, which allows for fuel efficiencies in sustaining the high burn temperature.

TABLE 3-4
Summary of Costs for Control Technologies for Building 4-86 Dinol Booths

		Total Cost per Ton of VOC Reduced	
Type of Control Technology	**Vendor Name**	**10.5% Opportunity Cost**	**7% Interest Rate**
Thermal oxidizer	Callidus	$236,495	$229,626
Thermal oxidizer with preheater	John Zink	$142,875	$130,810
Thermal oxidizer with preheater	Callidus	$174,841	$163,393
Carbon adsorption	Thermal Recovery Systems	$129,403	$128,056
Regenerative thermal oxidizer with concentrator	Anguil	$86,646	$77,294
Regenerative thermal oxidizer	Anguil	$63,387	$58,514

TABLE 3-5
Summary of Costs for Control Technologies for Building 4-86 Vertical Wing Booths

		Total Cost per Ton of VOC Reduced	
Type of Control Technology	**Vendor Name**	**10.5% Opportunity Cost**	**7% Interest Rate**
Thermal oxidizer	Callidus	$319,061	$316,005
Thermal oxidizer with preheater	John Zink	$231,303	$220,568
Thermal oxidizer with preheater	Callidus	$181,589	$175,477
Carbon adsorption	Thermal Recovery Systems	$225,641	$225,268
Regenerative thermal oxidizer	Anguil	$69,006	$62,956
Regenerative thermal oxidizer with concentrator	Anguil	$68,240	$61,852

TABLE 3-6
Summary of Costs for Control Technologies for New Paint Hangar

Type of Control Technology	Vendor Name	Total Cost per Ton of VOC Reduced 10.5% Opportunity Cost	Total Cost per Ton of VOC Reduced 7% Interest Rate
Thermal oxidizer	Callidus	$168,965	$168,374
Thermal oxidizer with preheater	John Zink	$104,958	$102,882
Thermal oxidizer with preheater	Callidus	$85,331	$84,148
Carbon adsorption	Thermal Recovery Systems	$114,339	$114,251
Regenerative thermal oxidizer	Anguil	$24,294	$22,964
Regenerative thermal oxidizer with concentrator	Anguil	$20,401	$18,929

Vendor information for the RTO technology was obtained from Anguil for the booths in Building 4-86. The equipment cost and operating parameters are provided in Appendixes B, C and D. The RTO control technology overall cost-effectiveness in dollars per ton removed is listed in Tables 3-4, 3-5, and 3-6.

3.4.4 Regenerative Thermal Oxidizer with Concentrator

This control technology augments the RTO methodology with the addition of a concentrator wheel. The wheel provides for a more concentrated VOC content in a smaller air stream for burning. Greater fuel efficiencies are obtained during operation. Vendor information for the RTO with concentrator control technology was obtained from Anguil. The equipment cost and operating parameters are provided in Appendixes B, C and D. The RTO with concentrator control technology overall cost-effectiveness in dollars per ton removed is listed in Tables 3-4, 3-5, and 3-6.

3.4.5 Low-VOC Coatings, High-Transfer-Efficiency Coating Techniques, and Good Work Practices

Boeing Renton already uses low-VOC coatings that meet specifications required for airplane coating operations. Boeing also uses high-transfer-efficiency coating techniques, such as HVLP spray guns, which provide a high transfer efficiency and reduce the overall amount of paint required to perform a job. In addition, Boeing uses good work practices to minimize VOC emissions, including storing coatings and solvents in closed containers, bagging solvent hand-wipe cleaning rags when not in use, and capturing and containing solvent used for cleaning spray equipment. The VOC emission standards for uncontrolled use of cleaning solvents and coatings as defined in 40 CFR 63 Subpart GG, Aerospace NESHAP, and PSCAA Regulation II, 3.09, will be applied in this operation. No cost analysis was performed because Boeing considers this to be the base case for BACT.

3.4.6 Summary of Cost-effectiveness Analysis

The costs of control technologies identified as available and technologically feasible for the new and modified spray booths are summarized in Tables 3-4, 3-5 and 3-6. These cost estimates are conservative (potentially underestimating the costs) and do not include the complicated retrofit installation expenses that Boeing Renton might incur except with respect to the new paint hangar.

3.5 Comparison with other Aerospace BACT Determinations

Because of the unique nature of Boeing's operations at this facility, comparison with other aerospace facilities is of limited usefulness. For example, Boeing is currently the only manufacturer of large commercial airplanes in the United States. A review of RBLC entries of the last 10 years for aerospace surface coatings (Process Type 41.001) shows only entries for Boeing commercial airplane operations in the Puget Sound area (Table 3-7). None of those entries indicates that add-on controls were considered BACT.

A further review of the RBLC entries for permits between 1990 and 2000 (Table 3-8) indicates some technology decisions for aerospace coating operations that required add-on controls. However, each of these operations was in an ozone non-attainment area at the time of permitting. For example, Huck International is located in Los Angeles, an ozone non-attainment area; CA-0881 issued in 1996 indicates "BACT-PSD," yet Permit CA-0980 issued to the same company a year earlier indicates that lowest achievable emissions rate (LAER) was required. Similar issues can be found with Kal-Gard Coating, also located in Los Angeles, permit ID numbers CA-0889, CA-1045, and CA-0977. For each of these RBLC entries, we believe that the control determinations were intended to implement LAER for those operations under nonattainment area New Source Review rather than BACT under the PSD program.

The RBLC also indicates that add-on controls have been installed at both Edwards Air Force Base (AFB) in California and Hill AFB in Utah. Edwards AFB is in an ozone non-attainment area and Hill AFB was in an ozone non-attainment or maintenance area at the time of permitting. Neither of these entries purports to reflect a BACT decision under PSD. Each of these decisions is discussed further below, based on information provided by CH2MHILL and Air Force personnel familiar with those operations.

Edwards AFB has two booths used to paint airplanes and parts; the booths have carbon adsorption systems installed. The first booth has an air flow of 111,000 cubic feet per minute (cfm) with 2.25 tpy of uncontrolled VOC emissions. The second booth is much larger (493,000 cfm) and has only 1.65 tpy of uncontrolled VOC emissions. The emissions from these Edwards AFB booths are much lower than those expected at the Boeing Renton booths. Both of the carbon systems were installed because the AFB believed a cost savings would be achieved while meeting nonattainment area requirements. These systems were supposed to be regenerative carbon systems, but soon after installation, the regenerative portion failed and was never repaired. Today, carbon is swapped out manually at great expense, albeit infrequently because of decreased VOC emissions over the years. The use of good work practices to reduce VOC emissions by using low-VOC paints and application methods has proved more cost-effective than maintaining the carbon VOC control system and running it. This VOC control system's efficiency is not achieved in practice as designed and listed in the EPA RBLC.

Hill AFB was in an ozone non-attainment or maintenance area at the time of permitting and installed a Zeolite adsorption system. This unit has not been operational at Hill AFB for an extended period of time. We have been unable to determine how long the unit operated or the reason it was taken out of operation. Because of this lack of information, we believe that no judgment can be made as to the feasibility of such a system for Boeing Renton.

TABLE 3-7
RBLC Aerospace Coating Entries Since 2000 (Process Type 41.001)

ID	Company	Permit Date	Process	Control Method Description	BACT
WA-0326	Boeing Commercial Airplanes Group	10/12/2005	Exterior Coating Operations		N/A
WA-0326	Boeing Commercial Airplanes Group	10/12/2005	Final Assembly		N/A
WA-0326	Boeing Commercial Airplanes Group	10/12/2005	Interiors Manufacturing		N/A
WA-0330	Boeing Commercial Airplanes Group	10/12/2005	Paint Hangar Final Exterior Coating	A BACT review was not required because Ecology determined that there was no physical change or change in the method of operation that causes or results in an emissions increase.	BACT-PSD
WA-0330	Boeing Commercial Airplanes Group	10/12/2005	787 Final Assembly	A BACT review was not required because Ecology determined that there was no physical change or change in the method of operation that causes or results in an emissions increase.	BACT-PSD
WA-0330	Boeing Commercial Airplanes Group	10/12/2005	Interiors Manufacturing	A BACT review was not required because Ecology determined that there was no physical change or change in the method of operation that causes or results in an emissions increase.	BACT-PSD
WA-0340	The Boeing Company	07/27/2007	Paint Hangar/Final Exterior Coating		Other Case-by-Case
WA-0344	Boeing Commercial Airplanes Group	10/07/2008	Paint Booth/Hangar	Compliance with 40 CFR Part 63, Subpart GG, and low-VOC vapor-pressure cleaning solvents and strippers with low-pressure applicators or manual application for depainting.	BACT-PSD

TABLE 3-8
RBLC Aerospace Coating Entries between 1990 and 2000

ID	Company	State	Permit Date	Process	Control Method Description	BACT
CA-0410	Northrop 3-2 Division	CA	05/03/1990	Paint Spray Facility In Hangar	Filter-type carbon adsorption panel over exhaust air vent.	BACT-PSD (Note Ozone NAA)
CA-0451	Tracor Flight Systems, Inc.	CA	10/23/1991	Coating Operation	Diagonal fan and filter cells w/ arrestor pads.	BACT-PSD
CA-0881	Huck International - Deutsch Operations	CA	02/29/1996	Four Spray Booths	BACT determination is Tellkamp Systems regenerative thermal oxidizer with a 1.6-MMBtu/hr natural gas burner and 3-MMBtu/hr stand-by burner. Permit limit is lb VOC/day limit.	BACT-PSD (Note Ozone NAA)
CA-0889	Kal-Gard Coating & Mfg., E/M Corp.	CA	01/06/1999	Spray Booths, Nine Brinks, Devilbiss; Blekker	BACT determination is use of Zeolite concentrator and thermal oxidizer. Permit limit is lb VOC/day facility limit.	BACT-PSD (Note Ozone NAA)
CA-0901	Time Aviation Services, Inc.	CA	06/18/1999	Spray Booths, Two Dry Filters	Permit limit is usage limit and use of SCAQMD Regulation XI compliant materials. Listings of VOC limits for individual aerospace coating types can be found at: www.aqmd.gov/rules/html/r1124.html.	BACT-PSD
CA-1045	Kal-Gard Coating & Mfg. E/M	CA	01/06/1999	Spray Booth	A Zeolite concentrator and thermal oxidizer	BACT-PSD (Note Ozone NAA)
WA-0283	Boeing Commercial Airplanes Group, Everett Div. Plant	WA	07/10/1991	Surface Coating	Solvent substitution and best management practices. HVLP, electrostatic airless, and modified high-efficiency air-assisted airless spray equipment. Baseline emission rate: 278 tpy.	BACT-PSD
WA-0284	Boeing Commercial Airplanes Group, Everett Div. Plant	WA	10/08/1992	Surface Coating	Best management practices, electrostatic air-assisted airless spray equipment. Baseline emissions: 237 tpy.	BACT-PSD
WA-0285	Boeing Commercial Airplanes Group	WA	11/26/1991	Surface Coating, Parts	Solvent substitute and best management practices. HVLP spray equipment. Baseline emission rate: 167 tpy.	BACT-PSD

TABLE 3-8
RBLC Aerospace Coating Entries between 1990 and 2000

ID	Company	State	Permit Date	Process	Control Method Description	BACT
WA-0286	Boeing Commercial Airplanes Group	WA	12/31/1990	Surface Coating	Control methods: low-VOC coatings and best management practices; electrostatic air-assisted spray equipment. Baseline emission rate: 182 tpy.	BACT-PSD
WA-0287	Boeing Commercial Airplanes - Everett Facility	WA	12/23/1991	Surface Coating, Corrosion Inhibitor	Best management practices. Electrostatic, air-assisted, or airless spray equipment. Baseline emission rate: 11.5 tpy. Control eff. 15-35%.	BACT-PSD
CA-0771	California Air National Guard, Fresno	CA	01/22/1997	HVLP Applicator Used To Coat Parts	Lowest available VOC content which meets military specifications.	LAER
CA-0977	Kal-Gard Coatings & Manufacturing	CA	05/28/1997	Metal Part Coating Operation	Zeolite concentrator and thermal oxidizer.	LAER
CA-0979	Douglas Products Division	CA	03/30/1994	Metal Parts Coating Operation	Concentrator and thermal oxidizer.	LAER
CA-0980	Huck International - Deutsch Operations	CA	03/09/1995	Metal Parts Coating Operation	Thermal oxidizer.	LAER
CA-0549	Edwards Air Force Base	CA	05/07/1993	Hangar-Sized Spray Booth For Aircraft Up To EC-18	Carbon adsorption filter bank w/ FID to detect breakthrough.	Other Case-by-Case
CA-0685	T.B.M. Inc.	CA	11/06/1995	Aircraft Refinishing Operation	Low-VOC coatings and Hercules GW/R enclosed gun.	Other Case-by-Case
UT-0058	Hill Air Force Base	UT	12/15/1997	Surface Coating, Military Operations	Zeolite adsorption system, M&W condesorb fob, 26 Zeolite adsorption cells, 100,000 acfm at 80 degrees Fahrenheit. Maximum loading 122 lb VOC/hr.	Other Case-by-Case
WA-0045	Heath Tecna Aerospace Co.	WA	03/27/1992	Spray Booth	Carbon adsorber (methylene chloride).	Other Case-by-Case

Ozone NAA = Non Attainment Area
FID = Flame Ionizing detector

In summary, we do not think that there are similar aerospace coating operations operated by other companies in the United States and could not find a recent BACT determination in EPA's RBLC that requires add-on controls for aerospace coating operations. The few older determinations that are listed as BACT were intended to implement LAER for those operations under nonattainment area New Source Review rather than BACT under the PSD program.

3.6 BACT Selection

Tables 3-4, 3-5, and 3-6 show that control costs per ton of VOC removed would exceed $60,000 for the Dinol booth, $30,000 for the vertical wing booths, and about $19,000 for the paint hangar, respectively. Boeing does not consider any of these add-on control technologies to be economically feasible for the Boeing Renton facility, especially in light of our understanding that the Puget Sound air shed is quite likely "NOx limited" with respect to ozone formation such that the destruction of VOC from these operations would not likely improve ozone concentrations.

Boeing will continue to implement the use of low-VOC coatings, high-transfer-efficiency coating equipment, and good work practices to minimize VOC emissions in compliance with the Aerospace NESHAP VOC emission standards in 40 CFR 63 Subpart GG and the PSCAA standards in Regulation II, Section 3.09. These requirements are listed in Table 3-9. This conclusion is consistent with other recent BACT determinations made by Ecology, PSCAA, and others for coating large aerospace parts and components.

TABLE 3-9
BACT Work Practice Limitations

Production Activity	Emission Standard
Low-VOC primers	General aviation rework: 4.5 pounds per gallon (lb/gal). Large commercial aircraft: 5.4 lb/gal. All other applications: 2.9 lb/gal as required by 40 CFR 63.745(c).
Low-VOC topcoats	General aviation rework: 4.5 lb/gal. All other applications: 3.5 lb/gal as required by 40 CFR 63.745(c).
Low-VOC vapor-pressure cleaning solvents	Less than 45 millimeters mercury (mm Hg) at 20^{o}C or Table 1 in 40 CFR 63.744.
High-transfer-efficiency coating equipment	65% or greater rated transfer efficiency as required by 40 CFR 63.745(f).
Bulk solvent application	Low-pressure applicators or manual application as required by 40 CFR 63.745(f).
Paint gun cleaning, waste solvents and rags	Capture and closed containment as required by 40 CFR 63.744.
Low-VOC vapor-pressure cleaning solvents and strippers	Less than 45 mm Hg at 20^{o}C or as specified in Table 1 of 40 CFR 63 Subpart GG.
Solvents and strippers application	Low-pressure applicators or manual application.

4. Air Quality Impact Analysis

4.1 Class I Areas

Because the proposed emission increase and net emission increase in VOC from the Boeing Renton 737 MAX project would exceed 100 tpy there must be a demonstration that the project would not cause or significantly contribute to a violation of any ambient air quality standard. Furthermore, PSD rules require an analysis of air quality related values (AQRVs) on federally designated Class I areas. Federally mandated Class I areas are defined in the Clean Air Act as having special national or regional value from a natural, scenic, recreational, or historic perspective. Class I areas include national parks over 6,000 acres and wilderness areas and memorial parks over 5,000 acres as of 1977. These areas are stringently regulated because they have remained relatively untouched by development. Therefore, in addition to stricter PSD increment standards for criteria air pollutants, additional analyses of air quality impacts on Class I areas are required. Class I areas within 200 kilometers (km) of the Boeing Renton facility are listed in Table 4-1.

TABLE 4-1
Class I Areas within 200 km of the Boeing Renton Facility

Area	Distance from Boeing Renton to Class I Area (km)	Net Emissions Increase (Quantity) Divided by Distance (Q/D) (tons VOC/km)	Increase in Allowed Emissions Divided by Distance (Q*/D) (tons VOC/km)
Alpine Lakes Wilderness Area	45.5	8.4	3.6
Mt. Rainier National Park	58.9	6.5	2.8
Olympic National Park	72.1	5.3	2.3
Glacier Peak Wilderness Area	94.5	4.1	1.7
Goat Rocks Wilderness Area	104	3.7	1.6
North Cascades National Park	139	2.8	1.2
Mt. Adams Wilderness Area	140	2.7	1.2

Air quality-related values include impacts on visibility, soil, flora, fauna, and aquatic resources within the Class I area. The FLM guidance on evaluating impact of major projects on Class I areas is the Federal Land Managers' Air Quality Related Values Work Group (FLAG) 2010 report. In FLAG, the federal lands managers (FLMs) have developed a tool to screen out projects that would not have a significant impact on AQRVs based on annual emissions and distance from a Class I area. This screening tool is called the Q/D Method, which is to divide the amount of emission increases in tons per year (Q) by the distance to a federal Class I area in kilometers (D). FLAG states that "The FLM role within the regulatory context consists of considering whether emissions from a new source, or emission increases from a modified source, may have an adverse impact on AQRVs and providing comments to permitting authorities (States or EPA).” and; “Therefore, the Agencies will consider a source locating greater than 50 km from a Class I area to have negligible impacts with respect to Class I AQRVs if its total SO_2, NO_x, PM_{10}, and H_2SO_4 annual emissions (in tons per year, based on 24-hour maximum allowable emissions), divided by the distance (in km) from the Class I area (Q/D) is 10 or less. The Agencies would not request any further Class I AQRV impact analyses from such sources.” For this project, the only pollutant that would have a significant increase is VOC. VOC is not among the pollutants that the FLMs recommend to be included in the calculation of Q. Furthermore, the FLAG guidance states that “current information indicates most FLM areas are NOx limited“ and “until there is enough information available for FLAG to determine whether ozone formation in each FLM area is primarily limited by NOx or VOC emissions, we will assume all FLM areas are NOx-limited and will focus on control of NOx emissions.” (FLAG Executive Summary & Section 3.4.5). Because there has not been a demonstration that ozone formation in the Puget Sound region’s Class I areas is not NOx limited and VOC is the only pollutant that is expected of have a significant increase as a result of this project, there is no need to perform the Q/D analysis and it can be presumed that the project would have no significant adverse impacts on Class I areas.[3]

As mentioned above, VOCs are a precursor to ozone. Boeing’s proposed increase and net emissions increase in VOC emissions are greater than 100 tpy and therefore require an analysis of the effect that the proposed increase in emission of VOCs would have on the area’s ozone levels. The analysis of the proposed project emission for ozone is described below.

EPA has set primary and secondary ozone standards to protect human health and welfare. On March 12, 2008, EPA revised the primary and secondary ozone standards to 0.075 ppm (8-hour average).

Ozone is formed in the troposphere when sunlight causes complex photochemical reactions involving oxides of nitrogen (NOx), VOCs, and carbon monoxide that originate chiefly from gasoline engines and burning of other fossil fuels. Woody vegetation is another major source of VOCs. Factors involved in ozone formation include terrain, meteorology, temperature, the ratio of VOC emissions to NOx emissions within the surrounding airshed, and the relative reactivities of the VOC species. NOx and VOCs can be transported long distances by regional weather patterns before they react to create ozone in the atmosphere, where it can persist for several weeks. Because ozone is a regional pollutant, precursor sources both near and far can contribute to ozone formation.

Breathing ozone can trigger a variety of health problems for humans, including chest pain, coughing, throat irritation, and congestion. It can worsen bronchitis, emphysema, and asthma. Additionally, elevated levels of ozone can also reduce lung function by inflaming the linings of the lungs. Repeated exposure to elevated concentrations of ozone may permanently scar lung tissue.

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[3] Nonetheless, for informational purposes the 737 MAX project’s Q/D for all Class I areas within 200 km are shown in Table 4-1 where Q is that annual emission rate of VOC. As shown, even if VOC emissions were considered in the calculation of Q, the ratio of Q/D would be less than 10 and according to the FLAG guidance it could be presumed that the project would have no significant adverse impacts on Class I areas.

Ozone is also phytotoxic, causing damage to a variety of vegetation (Ashmore et al. 2004). Ozone pollution has been shown to reduce plant growth, alter species composition, and predispose trees to insect and disease attack. Ozone also causes direct foliar injury to some plant species. Ozone-affected leaves are often marked with discoloration and lesions, and they age more rapidly than normal leaves (EPA 2007).

Ozone enters plants through leaf stomata, causing changes in biochemical and physiological processes. The mesophyll cells under the upper epidermis of leaves are the most sensitive to ozone, and those are the first cells to die. The adjacent epidermal cells then die, forming a small black or brown interveinal necrotic lesion that becomes visible on the upper surface of the leaf. These lesions, termed oxidant stipple, are quite specific indicators that the plant has been exposed to ozone. There are other plant symptoms that can result from exposure to ozone; however, these symptoms are non-specific for ozone since other stressors can also cause them to occur. In general, the most reliable indicator that ozone has impacted vegetation is oxidant stipple.

In addition to affecting individual plants, ozone can also affect entire ecosystems. Research shows that plants growing in areas with high exposure to ambient ozone may undergo natural selection for ozone tolerance (EPA 2007). The final result could be the elimination of the most ozone-sensitive genotypes from the area (FLAG 2010).

In the Class I areas closest to Boeing Renton, several species are known to be sensitive to ozone, including *Populus tremuloides* (quaking aspen), *Apocynum androsaemifolium* (spreading dogbane), *Abies lasiocarpa* (subalpine fir), *Populus trichocarpa* (black cottonwood), and *Pinus ponderosa* (ponderosa pine) (Brace et al. 1998). These sensitive species have been systematically evaluated and no ozone injury has been documented in the parks.

The purpose of this analysis is to determine whether the proposed increase of VOC emissions from the 737 MAX project would be a significant contributor to elevated ozone concentrations in the Pacific Northwest.

4.2 Modeling of Ozone Concentrations

This section summarizes an analysis of photochemical oxidant (principally ozone) that would result from the proposed increase in VOC emission from the 737 MAX project. A modeling study was undertaken to explore the likely effect on ambient ozone of varying levels of increased emissions of VOCs at two Boeing Airplane Company plants: Boeing Renton, where 737s are assembled, and North Boeing Field/Plant 2 in Seattle, where some 737s receive their final exterior coating. See Appendix F for the full study report. The modeling study was performed using the AIRPACT-3 model with two emission levels: the actual 2008 VOC emissions and a 750-tpy rate. The actual 2008 emission rates of 196 tpy for Renton and 100 tpy for North Boeing Field were selected because 2008 was the year with the highest measured ozone levels in the last 5 years. The 750-tpy rate for Renton also includes a 200-tpy rate for North Boeing Field, exceeding the proposed increases in this application and the proposed total allowable emissions from the two facilities. Hence, the 750-tpy rate represents a conservative estimate of impacts on ozone concentrations in the Puget Sound of the maximum allowable VOC increase area from the project.

The AIRPACT-3 model was used to simulate the two emissions cases for two different elevated ozone episodes in the Pacific Northwest: the week of June 24 through July 1, 2008, and the week of August 12 through 18, 2008. These two cases were handled differently in terms of emissions specifications in one significant way. The June 2008 case was set up to simulate a seven-days-per-week painting operation at the same daily rate as weekdays under the five-days-per-week painting schedule. The August 2008 case was set up as a five-days-per-week operation, which reflects the current Boeing paint operations, with no emissions on the weekend. The 5 day-a-week schedule reflects a greater daily emission rate.

The June 2008 ozone episode simulation shows very small increases in hourly concentrations of surface-level ozone with a 750-tpy emission rate. The maximum (high ozone day) difference (increase) in surface-level ozone from the actual 2008 emissions case to the 750-tpy emissions case was 0.38 parts per billion (ppb) (380 parts per trillion) on Sunday, June 29, 2008, about 75 miles southeast of the plant. Due to the seven-days-per-week emissions profile that was applied for the June episode, emission rates for each day of the week were the same.

The August 2008 simulation also showed very small increases in hourly concentrations of surface-level ozone. The maximum (high ozone day) difference (increase) in surface-level ozone, from the actual 2008 emissions case to the future 750-tpy emissions case, was 0.34 ppb (340 parts per trillion). The maximum differences in surface-level ozone were seen in results for Friday, August 15, 2008, about 75 miles southeast of the plant. Due to the five-days-per-week emissions profile that was applied for the August episode, the Saturday and Sunday concentrations returned to relative background rates.

The results for the simulations of both episodes indicated that the proposed changes in VOC emissions at the two Boeing plants will have a negligible effect on ambient ozone levels within the Pacific Northwest region. These results are consistent with the extremely small change in VOC emissions as a portion of total VOCs (anthropogenic and biogenic) emitted within the urban region of Puget Sound, and they agree with the results of another study that Boeing conducted for VOC emissions increases at Boeing's Everett facility.

4.3 Modeling Analysis Conclusions

Analysis of the AIRPACT-3 model results for the two cases for both episodes shows that the maximum hourly ozone increase for the most aggressive emissions case was only 0.38 ppb. This result was obtained for the June episode for the future emissions case. The results from both the June and August episodes agreed generally in showing that the maximum ozone differences between the current and future cases were less than 0.4 ppb (less than 0.5 percent of the NAAQS). The results for the simulation of both episodes indicate that the proposed changes in VOC emissions at the two Boeing plants will have a negligible effect upon ambient ozone levels within the western Washington region. These results are consistent with the extremely small change in VOC emissions as a portion of total VOCs (anthropogenic and biogenic) emitted within the urban region of Puget Sound. The Puget Sound Clean Air Agency 2005 emission inventory concluded that 148,100 tpy of VOCs were emitted within the Puget Sound Clean Air Agency's jurisdiction from anthropogenic (human caused) sources. The 737 MAX project VOC increase of 384 tpy of VOC is about 0.2 percent of the overall anthropogenic VOC emissions in the airshed. According to an EPA study, biogenic (natural emission) sources contribute about 46 percent of the VOCs in the Puget Sound airshed (http://www.epa.gov/pugetsound/transboundary/emissions.html). Thus, the 737 MAX project VOC increase is about 0.1 percent of overall anthropogenic and biogenic VOC emissions in the airshed.

The analysis above demonstrates that the total VOC emissions for the 737 MAX project are not expected to cause or significantly contribute to an exceedance of the ozone NAAQS anywhere in the Pacific Northwest region, including the nearby Class I areas.

5. Air Quality-Related Values

PSD regulations and guidance require an evaluation of the effects of the project's emissions on visibility, local soils, and vegetation in Class I and II areas; the effect of increased air pollutant concentrations on flora and fauna in the Class I areas; and the effect of the project on growth in the area surrounding the project. The analyses assess increment consumption (if applicable) and impacts on AQRVs in Class I areas. AQRVs include regional visibility or haze; the effects of primary and secondary pollutants on sensitive plants; the effects of pollutant deposition on soils and receiving water bodies; and other effects associated with secondary aerosol formation. The FLMs for the National Park Service (NPS), U.S. Fish and Wildlife Service (USFWS), and U.S. Forest Service (USFS) have the responsibility of ensuring AQRVs in the Class I areas are not adversely affected.

5.1 Local Impacts on Soils, Vegetation, and Animals

According to EPA guidance,[4] for most types of soils and vegetation, ambient concentrations of criteria pollutants below the secondary NAAQS will not result in harmful effects. Only the VOC emissions from the 737 MAX project are subject to PSD review. VOC is regulated as a precursor to ozone; however, ozone has no secondary NAAQS. Additionally, the expected VOC emissions from the 737 MAX project do not trigger a detailed ambient air quality impact analysis for Class I area as discussed above and the modeling as described in Section 4.2 shows no significant expected ozone increase as a result of the project. Consequently, the impacts on local soils, vegetation, and animals attributable to the 737 MAX project will be negligible.

FLAG guidance does not provide a specific VOC impact on vegetation in the Pacific Northwest. The National Park Service has established monitors for ozone in three Class I Areas in Washington State: Mount Rainer National Park, Olympic National Park, and North Cascades National Park. As discussed above, Boeing Renton estimated that the incremental increase in ozone concentrations directly attributable 737 MAX project would be less than 0.38 ppb on an hourly average, a very small fraction of the NAAQS of 75 ppb on an 8-hour average. Therefore, the increase in ozone from this project is not likely to harm vegetation or animals.

5.2 Construction and Growth Impacts

Employment at Boeing Renton is expected to increase by no more than 12 percent as a result of this project. Additionally, there will not be a significant increase in congestion on Washington's roads and highways as a result of the project. Therefore, the proposed project is not expected to cause adverse construction- and growth-related impacts.

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[4] Draft EPA New Source Review Workshop Manual, Chapter D, § IIC, EPA,1990.

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APPENDIX A

Detailed Emission Estimates

TABLE A-1
Annual Non-Paint Hangar VOC Emission Rates

	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Renton: VOC Tons	140	83	66	74	84	133	154	124	166	212
Aircraft produced 737 + 757	346	250	182	213	214	302	330	290	372	376
PSD-88-4 for the Boeing Renton Site, 4-41 Paint Hangar	18	12	1	3	14	18	20	19	30	42
Renton less paint hangar	122	71	65	71	70	115	134	105	136	170
2 yr ave, Tons VOC/yr		96.5	68.3	68.0	70.3	92.3	124.5	119.6	120.3	152.9
tons/plane	0.351	0.286	0.358	0.333	0.326	0.380	0.407	0.362	0.365	0.453

TABLE A-2
Combustion-Related Fuel Consumption

Fuel	Oil #6	Oil #2	Natural Gas - 10-100 MMBtu/Hr	Natural Gas - < 10 MMBtu/Hr	Natural Gas - > 100 MMBtu/Hr	Total Oil	Total Gas	Planes	Gas
	gal	gal	1000 Therms	1000 Therms	1000 Therms	MMBtu	MMBtu	Planes/yr	MMBtu/pl
2002		-	594	32	4,358	-	498,400	250	1,994
2003	800	60	452	22	3,318	120	379,200	182	2,084
2004	31,548	200	431	20	3,159	4,445	361,000	213	1,695
2005	16,000	500	403		2,743	2,310	314,600	214	1,470
2006	12,000	500	1,373		2,277	1,750	365,000	302	1,209
2007	16,312		1,361		2,082	2,284	344,300	330	1,043
2008	4,743	57	820		2,561	672	338,100	290	1,166
2009	5,154		1,055		2,194	722	324,900	372	873
						Two year total			
Fuel			Natural Gas - 10-100 MMBtu/Hr	Natural Gas - < 10 MMBtu/Hr	Natural Gas - > 100 MMBtu/Hr	NG <100 MMBtu/hr	NG> 100 MMBtu/hr		
			MMBtu	MMBtu	MMBtu				
2002			59,400	3,200	435,800				
2003			45,200	2,200	331,800	110,000	767,600		
2004			43,100	2,000	315,900	92,500	647,700		
2005			40,300	-	274,300	85,400	590,200		
2006			137,300	-	227,700	177,600	502,000		
2007			136,100	-	208,200	273,400	435,900		
2008			82,000	-	256,100	218,100	464,300		
2009			105,500	-	219,400	187,500	475,500		
Factors	140	MMBtu/1000 gal							
	100	MMBtu/ 1000 Therms							

TABLE A-3
Combustion Related Emissions

Combustion Emission Calculations

	Factors									
	Total Gas Used in Baseline Period:		6.63E+05	MMBtu/ 2-yr		3.32E+05	MMBtu/yr			
	Gas Used in Boilers 1-3 in Baseline Period:		1.88E+05	MMBtu/ 2-yr		9.38E+04	MMBtu/yr	28%		
	Gas Used in Boilers 4-6 in Baseline Period:		4.76E+05	MMBtu/ 2-yr		2.38E+05	MMBtu/yr	72%		
	Total Oil Used in Baseline Period:		9954	Gal/2-yr		4.977	1000 Gal/yr	140	MMBtu/1000 gal	
Baseline										
			CO	NOx <100 MMBtu	NOx > 100 MMBtu	NOx Total	PM	SO2	Lead	VOC
Gas	Emission Factor	lb/MMBtu (AP-42)	0.08	0.031	0.275		0.0075	0.00059	4.90E-07	0.00539
	Emissions	Ton/yr	13.26	1.47	32.63	34.10	1.24	0.10	0.0001	0.89
Oil	Emission Factor	lb/1000 gal (lb/MMBtu of GHG)	5	19	14		3.3	7.385	0.00126	0.2
	Emissions	Ton/yr	0.01	0.05	0.03	0.08	0.01	0.02	0.0000	0.00
	Total Baseline	Tons/yr	13.27	1.52	32.67	34.19	1.25	0.12	0.0001	0.89
			Gas			Oil increase:				Fraction of fuel burned in Boilers 1-3:
			873	MMBtu/plane						28%
			756	plane/yr						
			660,281	MMBtu/yr					Gas:	186,731
						32.62	1000 gal/yr		Oil:	9.23
			CO	NOx <100 MMBtu	NOx > 100 MMBtu	NOx Total	PM	SO2	Lead	VOC
Gas	Emission Factor	lb/MMBtu	0.08	0.031	0.275		0.0075	0.00059	4.90E-07	0.00539
	Emissions	Ton/yr	26.41	2.93	65.00	67.93	2.48	0.19	0.00016	1.78
Oil	Emission Factor	lb/1000 gal (lb/MMBtu of GHG)	5	19	14		3.3	7.385	0.00126	0.2
	Emissions	Ton/yr	0.08	0.09	0.16	0.25	0.05	0.12	0.00002	0.00
	Projected	Tons/yr	26.49	3.02	65.16	68.18	2.53	0.32	0.00018	1.78

TABLE A-4
Combustion-Related GHG Emissions

	2010	2009	2008	2007	2006	2005	2004	2003
Utilities	CO2e Metric ton	CO2e Metric ton	CO2e Metric ton	CO2e Metric ton	CO2e Metric ton	CO2e Metric ton	CO2e Metric ton	CO2e Metric ton
Electricity	32,327	34,139	32,266	34,867	36,879	36,210	39,758	42,081
Natural Gas	15,631	17,453	17,668	18,149	19,372	17,939	19,253	20,352
#6 Residual Fuel Oil	29	60	54	184	136	0	0	0
Purchased Steam	0	0	0	0	0	0	0	0
Total	47,988	51,652	49,988	53,201	56,387	54,149	59,011	62,432
Other Fuels	**2010**	**2009**	**2008**	**2007**	**2006**	**2005**	**2004**	**2003**
#1, #2 Petroleum Diesel (on-road - taxed)	1,552	1,400	1,315	1,064	1,490	1,448	0	0
#2 Petroleum Diesel (untaxed)	115	84	79	288	98	100	0	0
#1 Petroleum Diesel (untaxed)	0	0	0	0	0	0	0	0
#4 Petroleum Diesel (untaxed)	0	0	0	0	0	0	0	0
#5 Petroleum Residual Fuel Oil (untaxed)	0	0	0	0	0	0	0	0
Bio-diesel (on-road - taxed)	145	135	135	0	0	0	0	0
Bio-diesel (untaxed)	6	5	8	0	0	0	0	0
Motor Gasoline (on-road - taxed)	367	374	362	365	749	707	0	0
Motor Gasoline (untaxed)	308	363	337	377	0	0	0	0
Jet A / Jet Fuel (used in aircraft)	13,956	14,825	11,516	32,286	29,519	18,846	0	0
Jet A / Jet Fuel (used in stationary source)	0	0	0	0	0	0	0	0
Aviation Gasoline (mobile)	0	0	0	0	0	0	0	0
Propane (used in stationary source)	37	39	45	45	0	0	0	0
Propane (used in mobile source)	329	336	299	390	6	0	0	0
LPG	0	0	0	0	0	0	0	0
CNG	0	0	0	0	0	0	0	0
Total Scope 1	34,368	37,614	34,084	55,319	54,628	39,040	19,253	20,352
Total Scope 2	32,327	34,139	32,266	34,867	36,879	36,210	39,758	42,081
Total Stationary (scope 1)	18,096	20,544	20,457	21,214	22,864	18,039	19,253	20,352
Planes/yr	376	372	290	330	302	214	213	182
Tons/plane	48	55	71	64	76	84	90	112
2 Yr Ave	19,320	20,501	20,835	**22,039**	20,451	18,646	19,802	23,514
Total Mobile (scope 1)	16,349	17,069	13,627	34,105	31,764	21,001	0	0

	2010	2009	2008	2007	2006	2005	2004	2003
Other Direct / Fugitive Emissions	CO2e Metric ton	CO2e Metric ton	CO2e Metric ton	CO2e Metric ton	CO2e Metric ton	CO2e Metric ton	CO2e Metric ton	CO2e Metric ton
CO_2	0	0	0	0	0	0	0	0
CH_4	0	2	1	0	2	0	0	0
N_2O	0	0	0	0	0	0	0	0
SF_6	0	0	0	0	0	0	0	0
NF_3	0	0	0	0	0	0	0	0
HFC-23	0	0	111	106	231	0	0	0
HFC-32	7	0	0	0	0	0	0	0
HFC-41	0	0	0	0	0	0	0	0
HFC-43-10mee	16	35	6	0	0	0	0	0
HFC-125	85	14	0	13	31	0	0	0
HFC-134	0	0	0	0	0	0	0	0
HFC-134a	1,697	2,464	2,148	2,029	2,904	0	0	0
HFC-143	0	0	0	0	0	0	0	0
HFC-143a	86	21	0	22	50	0	0	0
HFC-152	0	0	0	0	0	0	0	0
HFC-152a	0	0	0	0	0	0	0	0
HFC-161	0	0	0	0	0	0	0	0
HFC-227ea	0	0	0	0	0	0	0	0
HFC-236cb	0	0	0	0	0	0	0	0
HFC-236ea	0	0	0	0	0	0	0	0
HFC-236fa	0	0	0	0	0	0	0	0
HFC-245ca	0	0	0	0	0	0	0	0
HFC-245fa	1	0	0	0	41	0	0	0
HFC-365mfc	0	4	0	0	0	0	0	0
Total	1,970	2,540	2,266	2,170	3,258	0	0	0
2 Yr Ave	2,255	2,403	2,218	2,714	1,629	0		
Tons/plane	6.0	6.5	7.6	8.2	5.4	0.0		
Total Stationary	21,575	22,904	23,054	24,753	22,081	18,646	19,802	23,514
Total Stationary Tons/plane	57.4	61.6	79.5	75.0	73.1	87.1	93.0	129.2
756 Tons/yr	43,379	46,546	60,098	56,707	55,274	65,871	70,284	97,675
Increase	21,804	23,643	37,045	31,954	33,194	47,225	50,482	74,160

TABLE A-5
Building 4-86 CIC Wing Panel Booths Emissions

Number of Booths	3			
Number of Planes/yr	1642.5			
Wings/Booth-yr	1095			
Spray time hr/wing	8			
Spray time hr/booth-	8760			
	Gallons/Airplane	lbs VOC/gallon	lbs VOC/plane	
Dinol (CIC)			12.27	
Total			12.27	
	lbs VOC	planes	lbs VOC/plane	
Gun and Line Cleaning				
Note: 1572 is for toluene and it's a 50/50 mix				
		Painting	**Cleaning**	**Total**
	Total VOC (lbs/airplane)	12.27	0	12.27
	Total VOC (tons per airplane)	0.0061	0.00	
	Total VOC (lbs/booth-yr)	6,720	-	
	Total VOC (tons per booth-yr)	3.36	0.00	3.36
Adjustment for changes in paints and wings, 25% (tons/booth-yr)		4.20	0.00	4.20
Adjustment for changes in paints and wings, 25% (pounds per plane)				15.3

TABLE A-6
Building 4-86: Adding 1 Booth

New Inspar (top and bottom of wing)				
Number of Booths	1			
Number of Planes/yr	182.5			
Wings/Booth-yr	365			
Spray time hr/wing	8			
Spray time hr/booth-yr	2920			

	Gallons/Airplane	lbs VOC/gallon	lbs VOC/plane
BMS 10-79 GD (10P20-44) Primer	2.5	2.3	5.75
BMS 5-95 spray seal	6	4.4	26.4
BMS 10-60 Enamel	8	3.5	28
Total			60.15

	Gallons/Airplane	lbs VOC/gallon	Fraction Emitted	lbs VOC/plane
B90 Semi-aqueous Cleaner	24	3.2	0.2	15.4
Gun and Line Cleaning	20	7	0.2	28.0
Total				43.4

Note: 1572 is for toluene and it's a 50/50 mix

		Painting	Cleaning	Total
	Total VOC (lbs/airplane)	60.2	43.4	104
	Total VOC (tons per airplane)	0.03	0.02	0.05
	Total VOC (lbs/booth-yr)	10,977	7,913	18,891
	Total VOC (tons per booth-yr)	5.49	3.96	9.45
Adjustment for changes in paints and wings, 25% (tons/booth-yr)		6.86	4.95	11.81

TABLE A-7.1
Emissions Increase, Option 1 (tpy)

Projected Actual Emissions of Regulated NSR Pollutants for Existing 737 Assembly Operations

Unit or Activity	CO	NOx	PM	SOx	Lead	VOC	CO_2e
Wing Assembly						125.1	
Wing Coating						217.6	
Final Assembly						28.9	
Flightline						4.4	
4-41 Hangar						49.3	
5-50 Hangar						40.8	
737 Assembly							6,361
Combustion	26.5	68.2	2.5	0.3	0.0002	1.8	58,662
Total	26.5	68.2	2.5	0.3	0.0002	467.9	65,023

Baseline Actual Emissions of Regulated NSR Pollutants for Existing 737 Assembly Operations

Unit or Activity	CO	NOx	PM	SOx	Lead	VOC	CO_2e
Wing Assembly						61.9	
Wing Coating						76.0	
Final Assembly						14.3	
Flightline						2.2	
4-41 Hangar						34.0	
5-50 Hangar						40.8	
737 Assembly							2,986
Combustion	13.3	34.2	1.3	0.1	0.0002	0.9	24,243
Total	13.3	34.2	1.3	0.1	0.0002	230.1	27,229

TABLE A-7.1
Emissions Increase, Option 1 (tpy) (continued)

Emission Increase of Regulated NSR Pollutants for 737 Assembly Operations from Existing Units and Related Activities

Net	CO	NOx	PM	SOx	Lead	VOC	CO_2e
Adjusted Project Actual	26.5	68.2	2.5	0.3	0.00018	467.9	65,023
Baseline Actual	13.3	34.2	1.3	0.1	0.00008	230.1	27,229
Difference	13.2	34.0	1.2	0.2	0.00010	237.8	37,794

Potential Emissions from New Units

Unit or Activity	CO	NOx	PM	SOx	Lead	VOC	CO_2e
4-86 Inspar						11.8	
4-86 CIC						12.6	
New Hangar						122.0	
Combustion							
Total	0.0	0.0	0.0	0.0	0.0	146.4	-
Total Hybrid	13.2	34.0	1.3	0.2	0.00010	384.2	37,794

TABLE A-7.2
Projected Actual Emissions, Option 2 (tpy)

Unit or Activity	CO	NOx	PM	SOx	Lead	VOC	CO_2e
Wing Assembly						125.1	
Wing Coating						194.0	
Final Assembly						28.9	
Flightline						4.4	
4-41 Hangar						49.3	
5-50 Hangar						40.8	
737 Assembly							6,361
Combustion	26.5	68.2	2.5	0.3	0.0002	1.8	58,662
Total	26.5	68.2	2.5	0.3	0.0002	444.3	65,023

Baseline Actual Emissions of Regulated NSR Pollutants for Existing 737 Assembly Operations

Unit or Activity	CO	NOx	PM	SOx	Lead	VOC	CO_2e
Wing Assembly						61.9	
Wing Coating						76.0	
Final Assembly						14.3	
Flightline						2.2	
4-41 Hangar						34.0	
5-50 Hangar						40.8	
737 Assembly							2,986
Combustion	13.3	34.2	1.3	0.1	0.00008	0.89	-
Total	13.3	34.2	1.3	0.1	0.00008	230.1	2,986

TABLE A-7.2
Emissions Increase, Option 2 (tpy) (continued)

Emission Increase of Regulated NSR Pollutants for 737 Assembly Operations from Existing Units and Related Activities

Net	CO	NOx	PM	SOx	Lead	VOC	CO_2e
Adjusted Project Actual	26.5	68.2	2.5	0.3	0.00018	444.3	65,023
Baseline Actual	13.3	34.2	1.3	0.1	0.00008	230.1	2,986
Difference	13.2	34.0	1.2	0.2	0.00010	214.2	62,037

Potential Emissions from New Units

Unit or Activity	CO	NOx	PM	SOx	Lead	VOC	CO_2e
4-86 Inspar						35.4	
4-86 CIC						12.6	
New Hangar						122.0	
Combustion							
Total	0.0	0.0	0.0	0.0	0.0	170.0	-
Total Hybrid	13.2	34.0	1.2	0.2	0.0001	384.2	62,037

APPENDIX B

Building 4-86 Dinol Booths BACT Costs

BACT Cost Estimation Spreadsheet
Dinol
Control Technology: Thermal Oxidizer - Callidus w/o preheater

Given Parameters

			Reference
Annual operating hours	2190	hrs	Boeing
Exhaust flow rate, Q	40,000	acfm	Boeing
Estimated uncontrolled emissions	4.2	tons/year	Boeing
Capital Project Opportunity Cost	10.5%		Boeing
Interest rate	7.0%		Ecology
Equipment lifetime	15	years	Callidus
Fuel requirement	36.0	MMBtu/hr	Callidus
Electricty requirement	26	kw	Callidus

Table 1. Capital Cost Estimate

			Cost	Reference
Purchased Equipment				
Basic equipment and auxillaries	A		$600,000	Callidus
Freight	.05A		$30,000	EPA
Sales Tax		9.5%	$59,850	
Total Purchased Equipment Cost	B		$689,850	
Direct Installation Cost				
Foundation and supports	.08B		$55,188	EPA
Erection and handling	.14B		$96,579	EPA
Electrical	.04B		$27,594	EPA
Piping	.02B		$13,797	EPA
Painting	.01B		$6,899	EPA
Insulation	.01B		$6,899	EPA
Building and site preparation not included				
Total Direct Installation Cost			$206,955	
Total Direct Cost			$896,805	
Indirect Cost				
Engineering and supervision	0.10B		$68,985	EPA
Construction and field expenses	0.05B		$34,493	EPA
Construction fee	0.10B		$68,985	EPA
Start-up	0.02B		$13,797	EPA
Performance test	0.01B		$6,899	EPA
Contingency	0.03B		$20,696	EPA
Total Indirect Cost			$213,854	
Total Capital Cost			**$1,110,659**	

BACT Cost Estimation Spreadsheet

Dinol

Control Technology: Thermal Oxidizer - Callidus w/o preheater

Table 2. Annual Cost

				Annual Cost		Reference
Direct Costs						
2-1	Operating labor		0.5 hrs/shift @ $102.63/hr	$14,047		Boeing/EPA
2-2	Supervisory labor		included in labor rate	$0		Boeing
2-3	Maintenance labor		0.5 hr/shift@$102.63/hr	$14,047		Boeing/EPA
2-4	Maintenance materials		100% of maintenance lbr	$14,047		EPA
Utilities						
	Electricty	$0.06	per kwh	$3,416		Boeing
	Fuel	$9	per MMBtu	$733,212		Boeing
Total Direct Cost				$778,771		
Indirect Costs						
	Administrative charges	0.02	of total capital cost	$22,213		EPA
	property tax	0.01	of total capital cost	$11,107		EPA
	Insurance	0.01	of total capital cost	$11,107		EPA
Total Annual Costs Excluding Capital Recovery				$823,197		
	Capital recovery			$150,214		10.5%
				$100,143		7.0%
	Capital Project Opport		10.5%			Boeing
	Interest rate		7.0%			Ecology
	Lifetime		15 years			Callidus
Total Annual Cost				$973,412		
Uncontrolled Emissions				3.84	lb/hr	
Control Efficiency				98%		Callidus
Emission Reduction				4.12	tons/year	
Cost Effectiveness				$236,495	$/ton	

References

EPA	EPA Capital Cost Factors for Thermal and Catalytic Incinerators
	EPA Air Pollution Control Cost Manual - Sixth Edition (EPA 452/B-02-001)
	Section 3 - VOC Controls
	Section 3.2 - VOC Destruction Controls
	Chapter 2 - Incinerators
Callidus	E-mail from Ania Guy, Callidus Technologies by Honeywell, 04/27/2011.
Boeing	Boeing capital project opportunity cost = 10.5%
	Boeing operating and maintenance labor cost = $102.63/hr
	Boeing projected natural gas = $9.30 per million Btu
	Boeing electricty cost = $0.06 per kwh

BACT Cost Estimation Spreadsheet
Dinol
Control Technology: Thermal Oxidizer - Callidus w/o preheater

Given Parameters

			Reference
Annual operating hours	2190	hrs	Boeing
Exhaust flow rate, Q	40,000	acfm	Boeing
Estimated uncontrolled emissions	4.2	tons/year	Boeing
Interest rate	7.0%		Ecology
Equipment lifetime	15	years	Callidus
Fuel requirement	36.0	MMBtu/hr	Callidus
Electricty requirement	26	kw	Callidus

Table 1. Capital Cost Estimate

		Cost	Reference
Purchased Equipment			
Basic equipment and auxillaries	A	$600,000	Callidus
Freight	.05A	$30,000	EPA
Sales Tax	9.5%	$59,850	
Total Purchased Equipment Cost	B	$689,850	
Direct Installation Cost			
Foundation and supports	.08B	$55,188	EPA
Erection and handling	.14B	$96,579	EPA
Electrical	.04B	$27,594	EPA
Piping	.02B	$13,797	EPA
Painting	.01B	$6,899	EPA
Insulation	.01B	$6,899	EPA
Building and site preparation not included			
Total Direct Installation Cost		$206,955	
Total Direct Cost		$896,805	
Indirect Cost			
Engineering and supervision	0.10B	$68,985	EPA
Construction and field expenses	0.05B	$34,493	EPA
Construction fee	0.10B	$68,985	EPA
Start-up	0.02B	$13,797	EPA
Performance test	0.01B	$6,899	EPA
Contingency	0.03B	$20,696	EPA
Total Indirect Cost		$213,854	
Total Capital Cost		**$1,110,659**	

BACT Cost Estimation Spreadsheet

Dinol

Control Technology: **Thermal Oxidizer - Callidus w/o preheater**

Table 2. Annual Cost

				Annual Cost		Reference
Direct Costs						
2-1	Operating labor		0.5 hrs/shift @ $102.63/hr	$14,047		Boeing/EPA
2-2	Supervisory labor		included in labor rate	$0		Boeing
2-3	Maintenance labor		0.5 hr/shift@$102.63/hr	$14,047		Boeing/EPA
2-4	Maintenance materials		100% of maintenance lbr	$14,047		EPA
Utilities						
	Electricty	$0.06	per kwh	$3,416		Boeing
	Fuel	$9	per MMBtu	$733,212		Boeing
Total Direct Cost				$778,771		
Indirect Costs						
	Administrative charges	0.02	of total capital cost	$22,213		EPA
	property tax	0.01	of total capital cost	$11,107		EPA
	Insurance	0.01	of total capital cost	$11,107		EPA
Total Annual Costs Excluding Capital Recovery				$823,197		
	Capital recovery			$121,944		
	Interest		7.0%			Ecology
	Lifetime		15 years			Callidus
Total Annual Cost				$945,142		
Uncontrolled Emissions				3.84	lb/hr	
Control Efficiency				98%		Callidus
Emission Reduction				4.12	tons/year	
Cost Effectiveness				$229,626	$/ton	

References

EPA	EPA Capital Cost Factors for Thermal and Catalytic Incinerators
	EPA Air Pollution Control Cost Manual - Sixth Edition (EPA 452/B-02-001)
	Section 3 - VOC Controls
	Section 3.2 - VOC Destruction Controls
	Chapter 2 - Incinerators
Callidus	E-mail from Ania Guy, Callidus Technologies by Honeywell, 04/27/2011.
Boeing	
	Boeing operating and maintenance labor cost = $102.63/hr
	Boeing projected natural gas = $9.30 per million Btu
	Boeing electricty cost = $0.06 per kwh

BACT Cost Estimation Spreadsheet
Dinol
Control Technology: Thermal Oxidizer w Preheater - John Zink

Given Parameters

			Reference
Annual operating hours	2190	hrs	Boeing
Exhaust flow rate, Q	40,000	acfm	Boeing
Estimated uncontrolled emissions	4.2	tons/year	Boeing
Interest rate	10.5%		Boeing
Equipment lifetime	20	years	John Zink
Fuel requirement	11.8	MMBtu/hr	John Zink
Electricty requirement	93	kw	John Zink

Table 1. Capital Cost Estimate

		Cost	Reference
Purchased Equipment			
Basic equipment and auxillaries	A	$1,000,000	John Zink
Freight	.05A	$50,000	EPA
Sales Tax	9.5%	$99,750	
Total Purchased Equipment Cost	B	$1,149,750	
Direct Installation Cost			
Foundation and supports	.08B	$91,980	EPA
Erection and handling	.14B	$160,965	EPA
Electrical	.04B	$45,990	EPA
Piping	.02B	$22,995	EPA
Painting	.01B	$11,498	EPA
Insulation	.01B	$11,498	EPA
Building and site preparation not included			
Total Direct Installation Cost		$344,925	
Total Direct Cost		$1,494,675	
Indirect Cost			
Engineering and supervision	0.10B	$114,975	EPA
Construction and field expenses	0.05B	$57,488	EPA
Construction fee	0.10B	$114,975	EPA
Start-up	0.02B	$22,995	EPA
Performance test	0.01B	$11,498	EPA
Contingency	0.03B	$34,493	EPA
Total Indirect Cost		$356,423	
Total Capital Cost		**$1,851,098**	

BACT Cost Estimation Spreadsheet

Dinol

Control Technology: Thermal Oxidizer w Preheater - John Zink

Table 2. Annual Cost

				Annual Cost		Reference
Direct Costs						
2-1	Operating labor		0.5 hrs/shift @ $102.63/hr	$14,047		Boeing/EPA
2-2	Supervisory labor		included in labor rate	$0		Boeing
2-3	Maintenance labor		0.5 hr/shift@$102.63/hr	$14,047		Boeing/EPA
2-4	Maintenance materials		100% of maintenance lbr	$14,047		EPA
Utilities						
	Electricty	$0.06	per kwh	$12,253		Boeing
	Fuel	$9.30	per MMBtu	$240,738		Boeing
Total Direct Cost				$295,133		
Indirect Costs						
	Administrative charges	0.02	of total capital cost	$37,022		EPA
	property tax	0.01	of total capital cost	$18,511		EPA
	Insurance	0.01	of total capital cost	$18,511		EPA
Total Annual Costs Excluding Capital Recovery				$369,177		
	Capital recovery			$224,896		
	Interest		10.5%			Boeing
	Lifetime		20 years			John Zink
Total Annual Cost				$594,073		
Uncontrolled Emissions				3.84	lb/hr	
Control Efficiency				99%		John Zink
Emission Reduction				4.16	tons/year	
Cost Effectiveness				$142,875	$/ton	

References

EPA	EPA Capital Cost Factors for Thermal and Catalytic Incinerators
	EPA Air Pollution Control Cost Manual - Sixth Edition (EPA 452/B-02-001)
	Section 3 - VOC Controls
	Section 3.2 - VOC Destruction Controls
	Chapter 2 - Incinerators
John Zink	E-mail from Carl Connally, John Zink, 04/26/2011.
Boeing	Boeing capital project opportunity cost = 10.5%
	Boeing operating and maintenance labor cost = $102.63/hr
	Boeing projected natural gas = $9.30 per million Btu
	Boeing electricty cost = $0.06 per kwh

BACT Cost Estimation Spreadsheet
Dinol
Control Technology: Thermal Oxidizer w Preheater - John Zink

Given Parameters

			Reference
Annual operating hours	2190	hrs	Boeing
Exhaust flow rate, Q	40,000	acfm	Boeing
Estimated uncontrolled emissions	4.2	tons/year	Boeing
Interest rate	7.0%		Ecology
Equipment lifetime	20	years	John Zink
Fuel requirement	11.8	MMBtu/hr	John Zink
Electricty requirement	93	kw	John Zink

Table 1. Capital Cost Estimate

		Cost	Reference
Purchased Equipment			
Basic equipment and auxillaries	A	$1,000,000	John Zink
Freight	.05A	$50,000	EPA
Sales Tax	9.5%	$99,750	
Total Purchased Equipment Cost	B	$1,149,750	
Direct Installation Cost			
Foundation and supports	.08B	$91,980	EPA
Erection and handling	.14B	$160,965	EPA
Electrical	.04B	$45,990	EPA
Piping	.02B	$22,995	EPA
Painting	.01B	$11,498	EPA
Insulation	.01B	$11,498	EPA
Building and site preparation not included			
Total Direct Installation Cost		$344,925	
Total Direct Cost		$1,494,675	
Indirect Cost			
Engineering and supervision	0.10B	$114,975	EPA
Construction and field expenses	0.05B	$57,488	EPA
Construction fee	0.10B	$114,975	EPA
Start-up	0.02B	$22,995	EPA
Performance test	0.01B	$11,498	EPA
Contingency	0.03B	$34,493	EPA
Total Indirect Cost		$356,423	
Total Capital Cost		**$1,851,098**	

BACT Cost Estimation Spreadsheet

Dinol

Control Technology: Thermal Oxidizer w Preheater - John Zink

Table 2. Annual Cost

				Annual Cost		Reference
Direct Costs						
2-1	Operating labor		0.5 hrs/shift @ $102.63/hr	$14,047		Boeing/EP/
2-2	Supervisory labor		included in labor rate	$0		Boeing
2-3	Maintenance labor		0.5 hr/shift@$102.63/hr	$14,047		Boeing/EP/
2-4	Maintenance materials		100% of maintenance lbr	$14,047		EPA
Utilities						
	Electricty	$0.06	per kwh	$12,253		Boeing
	Fuel	$9.30	per MMBtu	$240,738		Boeing
Total Direct Cost				$295,133		
Indirect Costs						
	Administrative charges	0.02	of total capital cost	$37,022		EPA
	property tax	0.01	of total capital cost	$18,511		EPA
	Insurance	0.01	of total capital cost	$18,511		EPA
Total Annual Costs Excluding Capital Recovery				$369,177		
	Capital recovery			$174,731		
	Interest		7.0%			Ecology
	Lifetime		20 years			John Zink
Total Annual Cost				$543,908		
Uncontrolled Emissions				3.84	lb/hr	
Control Efficiency				99%		John Zink
Emission Reduction				4.16	tons/year	
Cost Effectiveness				$130,810	$/ton	

References

EPA	EPA Capital Cost Factors for Thermal and Catalytic Incinerators
	EPA Air Pollution Control Cost Manual - Sixth Edition (EPA 452/B-02-001)
	Section 3 - VOC Controls
	Section 3.2 - VOC Destruction Controls
	Chapter 2 - Incinerators
John Zink	E-mail from Carl Connally, John Zink, 04/26/2011.
Boeing	
	Boeing operating and maintenance labor cost = $102.63/hr
	Boeing projected natural gas = $9.30 per million Btu
	Boeing electricty cost = $0.06 per kwh

BACT Cost Estimation Spreadsheet
Dinol
Control Technology: Thermal Oxidizer - Callidus w preheater

Given Parameters

			Reference
Annual operating hours	2190	hrs	Boeing
Exhaust flow rate, Q	40	acfm	Boeing
Estimated uncontrolled emissions	4.2	tons/year	Boeing
Interest rate	10.5%		Boeing
Equipment lifetime	15	years	Callidus
Fuel requirement	17.0	MMBtu/hr	Callidus
Electricty requirement	52	kw	Callidus

Table 1. Capital Cost Estimate

		Cost	Reference
Purchased Equipment			
Basic equipment and auxillaries	A	$1,000,000	Callidus
Freight	.05A	$50,000	EPA
Sales Tax	9.5%	$99,750	
Total Purchased Equipment Cost	B	$1,149,750	
Direct Installation Cost			
Foundation and supports	.08B	$91,980	EPA
Erection and handling	.14B	$160,965	EPA
Electrical	.04B	$45,990	EPA
Piping	.02B	$22,995	EPA
Painting	.01B	$11,498	EPA
Insulation	.01B	$11,498	EPA
Building and site preparation not included			
Total Direct Installation Cost		$344,925	
Total Direct Cost		$1,494,675	
Indirect Cost			
Engineering and supervision	0.10B	$114,975	EPA
Construction and field expenses	0.05B	$57,488	EPA
Construction fee	0.10B	$114,975	EPA
Start-up	0.02B	$22,995	EPA
Performance test	0.01B	$11,498	EPA
Contingency	0.03B	$34,493	EPA
Total Indirect Cost		$356,423	
Total Capital Cost		**$1,851,098**	

BACT Cost Estimation Spreadsheet

Dinol

Control Technology: **Thermal Oxidizer - Callidus w preheater**

Table 2. Annual Cost

				Annual Cost		Reference
Direct Costs						
2-1	Operating labor		0.5 hrs/shift @ $102.63/hr	$14,047		Boeing/EPA
2-2	Supervisory labor		included in labor rate	$0		Boeing
2-3	Maintenance labor		0.5 hr/shift@$102.63/hr	$14,047		Boeing/EPA
2-4	Maintenance materials		100% of maintenance lbr	$14,047		EPA
Utilities						
	Electricty	$0.06	per kwh	$6,862		Boeing
	Fuel	$9	per MMBtu	$346,239		Boeing
Total Direct Cost				$395,243		
Indirect Costs						
	Administrative charges	0.02	of total capital cost	$37,022		EPA
	property tax	0.01	of total capital cost	$18,511		EPA
	Insurance	0.01	of total capital cost	$18,511		EPA
Total Annual Costs Excluding Capital Recovery				$469,287		
	Capital recovery			$250,357		
	Interest		10.5%			Boeing
	Lifetime		15 years			Callidus
Total Annual Cost				$719,644		
Uncontrolled Emissions				3.84	lb/hr	
Control Efficiency				98%		Callidus
Emission Reduction				4.12	tons/year	
Cost Effectiveness				$174,841	$/ton	

References

EPA	EPA Capital Cost Factors for Thermal and Catalytic Incinerators
	EPA Air Pollution Control Cost Manual - Sixth Edition (EPA 452/B-02-001)
	Section 3 - VOC Controls
	Section 3.2 - VOC Destruction Controls
	Chapter 2 - Incinerators
Callidus	E-mail from Ania Guy, Callidus Technologies by Honeywell, 04/27/2011.
Boeing	Boeing capital project opportunity cost = 10.5%
	Boeing operating and maintenance labor cost = $102.63/hr
	Boeing projected natural gas = $9.30 per million Btu
	Boeing electricty cost = $0.06 per kwh

BACT Cost Estimation Spreadsheet
Dinol
Control Technology: Thermal Oxidizer - Callidus w preheater

Given Parameters

			Reference
Annual operating hours	2190	hrs	Boeing
Exhaust flow rate, Q	40	acfm	Boeing
Estimated uncontrolled emissions	4.2	tons/year	Boeing
Interest rate	7.0%		Ecology
Equipment lifetime	15	years	Callidus
Fuel requirement	17.0	MMBtu/hr	Callidus
Electricty requirement	52	kw	Callidus

Table 1. Capital Cost Estimate

		Cost	Reference
Purchased Equipment			
Basic equipment and auxillaries	A	$1,000,000	Callidus
Freight	.05A	$50,000	EPA
Sales Tax	9.5%	$99,750	
Total Purchased Equipment Cost	B	$1,149,750	
Direct Installation Cost			
Foundation and supports	.08B	$91,980	EPA
Erection and handling	.14B	$160,965	EPA
Electrical	.04B	$45,990	EPA
Piping	.02B	$22,995	EPA
Painting	.01B	$11,498	EPA
Insulation	.01B	$11,498	EPA
Building and site preparation not included			
Total Direct Installation Cost		$344,925	
Total Direct Cost		$1,494,675	
Indirect Cost			
Engineering and supervision	0.10B	$114,975	EPA
Construction and field expenses	0.05B	$57,488	EPA
Construction fee	0.10B	$114,975	EPA
Start-up	0.02B	$22,995	EPA
Performance test	0.01B	$11,498	EPA
Contingency	0.03B	$34,493	EPA
Total Indirect Cost		$356,423	
Total Capital Cost		**$1,851,098**	

BACT Cost Estimation Spreadsheet

Dinol

Control Technology: **Thermal Oxidizer - Callidus w preheater**

Table 2. Annual Cost

				Annual Cost		Reference
Direct Costs						
2-1	Operating labor		0.5 hrs/shift @ $102.63/hr	$14,047		Boeing/EPA
2-2	Supervisory labor		included in labor rate	$0		Boeing
2-3	Maintenance labor		0.5 hr/shift@$102.63/hr	$14,047		Boeing/EPA
2-4	Maintenance materials		100% of maintenance lbr	$14,047		EPA
Utilities						
	Electricty	$0.06	per kwh	$6,862		Boeing
	Fuel	$9	per MMBtu	$346,239		Boeing
Total Direct Cost				$395,243		
Indirect Costs						
	Administrative charges	0.02	of total capital cost	$37,022		EPA
	property tax	0.01	of total capital cost	$18,511		EPA
	Insurance	0.01	of total capital cost	$18,511		EPA
Total Annual Costs Excluding Capital Recovery				$469,287		
	Capital recovery			$203,241		
	Interest		7.0%			Ecology
	Lifetime		15 years			Callidus
Total Annual Cost				$672,528		
Uncontrolled Emissions				3.84	lb/hr	
Control Efficiency				98%		Callidus
Emission Reduction				4.12	tons/year	
Cost Effectiveness				$163,393	$/ton	

References

EPA	EPA Capital Cost Factors for Thermal and Catalytic Incinerators
	EPA Air Pollution Control Cost Manual - Sixth Edition (EPA 452/B-02-001)
	Section 3 - VOC Controls
	Section 3.2 - VOC Destruction Controls
	Chapter 2 - Incinerators
Callidus	E-mail from Ania Guy, Callidus Technologies by Honeywell, 04/27/2011.
Boeing	
	Boeing operating and maintenance labor cost = $102.63/hr
	Boeing projected natural gas = $9.30 per million Btu
	Boeing electricty cost = $0.06 per kwh

BACT Cost Estimation Spreadsheet
Dinol Booth
Control Technology: Thermal Recovery Systems - Carbon Adsorption

Given Parameters

			Reference
Annual operating hours	2016	hrs	Boeing
Exhaust flow rate, Q	40,000	acfm	Boeing
Estimated uncontrolled emissions	4.2	tons/year	Boeing
Interest rate	10.5%		Boeing
Equipment lifetime	5	years	EPA
Fuel requirement	0.0	MMBtu/hr	TRS
Electricty requirement	56	kw	EPA

Table 1. Capital Cost Estimate

		Cost	Reference
Purchased Equipment			
Basic equipment and auxillaries	A	$33,500	TRS
Freight	.05A	$1,675	EPA
Sales Tax	9.5%	$3,342	
Total Purchased Equipment Cost	B	$38,517	
Direct Installation Cost			
Foundation and supports	.08B	$3,081	EPA
Erection and handling	.14B	$5,392	EPA
Electrical	.04B	$1,541	EPA
Piping	.02B	$770	EPA
Painting	.01B	$385	EPA
Insulation	.01B	$385	EPA
Building and site preparation not included			
Total Direct Installation Cost		$11,555	
Total Direct Cost		$50,072	
Indirect Cost			
Engineering	0.10B	$3,852	EPA
Construction and field expenses	0.05B	$1,926	EPA
Construction fee	0.10B	$3,852	EPA
Start-up	0.02B	$770	EPA
Performance test	0.01B	$385	EPA
Contingency	0.03B	$1,155	EPA
Total Indirect Cost		$11,940	
Total Capital Cost		**$62,012**	

BACT Cost Estimation Spreadsheet
Dinol Booth

Control Technology: **Thermal Recovery Systems - Carbon Adsorption**

Table 2. Annual Cost

				Annual Cost		Reference
Direct Costs						
2-1	Operating labor		0.5 hrs/shift @ $102.63/hr	$12,931		Boeing/EPA
2-2	Supervisory labor		included in labor rate	$0		Boeing
2-3	Maintenance labor		0.5 hr/shift@$102.63/hr	$12,931		Boeing/EPA
2-4	Maintenance materials		100% Maintenance Labor	$12,931		TRS
	Replacement Parts, Carbon		22 carbon swaps/yr			TRS
	Carbon Replacement Labor		5hr @ $102.63/hr	$11,289		TRS/Boeing
	Carbon Replacement Costs		$19,840 per carbon swap	$436,480		TRS
Utilities						
	Electricty	$0.06	per kwh	$6,774		Boeing
	Fuel	$9.30	per MMBtu	$0		Boeing
Total Direct Cost				$493,337		
Indirect Costs						
	Administrative charges	0.02	of total capital cost	$1,240		EPA
	property tax	0.01	of total capital cost	$620		EPA
	Insurance	0.01	of total capital cost	$620		EPA
Total Annual Costs Excluding Capital Recovery				$495,818		
	Capital recovery			$16,568		
	Interest		10.5%			Boeing
	Lifetime		5 years			EPA
Total Annual Cost				$512,386		
Uncontrolled Emissions				4.17	lb/hr	
Control Efficiency				95%		TRS
Emission Reduction				3.99	tons/year	
Cost Effectiveness				$128,417	$/ton	

Assumptions
Carbon Replacement Labor Time Calculation:
1 units * 20 Filter Banks * 15 minutes swap time per filter bank = 5 hours of labor time per carbon swap
15 minutes swap time per filter bank from Phil Chapman

Number of Carbon Swaps

	Quantity	UOM
Carbon per filter	6	lbs
filters per bank	16	ea
filter banks per booth	20	ea
lbs of carbon per booth	1920	lb of carbon/booth
VOC adsorption rate from EPA	0.2	lb of VOC/lb of carbon
VOC adsorption capacity	384	lb of VOC/booth
VOC adsorption capacity	0.192	tons of VOC /booth
VOC emissions	4.2	tpy
Carbon swaps per year	21.9	carbon swaps per year per booth

References

EPA — EPA Capital Cost Factors for Thermal and Catalytic Incinerators
EPA Air Pollution Control Cost Manual - Sixth Edition (EPA 452/B-02-001)
Section 3 - VOC Controls
Section 3.1 - VOC Recapture Controls
Section 3.1 Carbon Adsorbers

TRS — E-mail from Phil Chapman, Thermal Recovery Systems, Inc. 02/17/12
Boeing — Boeing capital project opportunity cost = 10.5%
Boeing operating and maintenance labor cost = $102.63/hr
Boeing projected natural gas = $9.30 per million Btu
Boeing electricty cost = $0.06 per kwh

BACT Cost Estimation Spreadsheet
Dinol Booth
Control Technology: Thermal Recovery Systems - Carbon Adsorption

Given Parameters

			Reference
Annual operating hours	2016	hrs	Boeing
Exhaust flow rate, Q	40,000	acfm	Boeing
Estimated uncontrolled emissions	4.2	tons/year	Boeing
Interest rate	7.0%		Ecology
Equipment lifetime	5	years	EPA
Fuel requirement	0.0	MMBtu/hr	TRS
Electricty requirement	56	kw	EPA

Table 1. Capital Cost Estimate

		Cost	Reference
Purchased Equipment			
Basic equipment and auxillaries	A	$33,500	TRS
Freight	.05A	$1,675	EPA
Sales Tax	9.5%	$3,342	
Total Purchased Equipment Cost	B	$38,517	
Direct Installation Cost			
Foundation and supports	.08B	$3,081	EPA
Erection and handling	.14B	$5,392	EPA
Electrical	.04B	$1,541	EPA
Piping	.02B	$770	EPA
Painting	.01B	$385	EPA
Insulation	.01B	$385	EPA
Building and site preparation not included			
Total Direct Installation Cost		$11,555	
Total Direct Cost		$50,072	
Indirect Cost			
Engineering	0.10B	$3,852	EPA
Construction and field expenses	0.05B	$1,926	EPA
Construction fee	0.10B	$3,852	EPA
Start-up	0.02B	$770	EPA
Performance test	0.01B	$385	EPA
Contingency	0.03B	$1,155	EPA
Total Indirect Cost		$11,940	
Total Capital Cost		**$62,012**	

BACT Cost Estimation Spreadsheet
Dinol Booth
Control Technology: **Thermal Recovery Systems - Carbon Adsorption**

Table 2. Annual Cost

				Annual Cost		Reference
Direct Costs						
2-1	Operating labor		0.5 hrs/shift @ $102.63/hr	$12,931		Boeing/EPA
2-2	Supervisory labor		included in labor rate	$0		Boeing
2-3	Maintenance labor		0.5 hr/shift@$102.63/hr	$12,931		Boeing/EPA
2-4	Maintenance materials		100% Maintenance Labor	$12,931		TRS
	Replacement Parts, Carbon		22 carbon swaps/yr			TRS
	Carbon Replacement Labor		5hr @ $102.63/hr	$11,289		TRS/Boeing
	Carbon Replacement Costs		$19,840 per carbon swap	$436,480		TRS
Utilities						
	Electricty	$0.06	per kwh	$6,774		Boeing
	Fuel	$9.30	per MMBtu	$0		Boeing
Total Direct Cost				$493,337		
Indirect Costs						
	Administrative charges	0.02	of total capital cost	$1,240		EPA
	property tax	0.01	of total capital cost	$620		EPA
	Insurance	0.01	of total capital cost	$620		EPA
Total Annual Costs Excluding Capital Recovery				$495,818		
	Capital recovery			$15,124		
	Interest		7.0%			Ecology
	Lifetime		5 years			EPA
Total Annual Cost				$510,942		
Uncontrolled Emissions				4.17	lb/hr	
Control Efficiency				95%		TRS
Emission Reduction				3.99	tons/year	
Cost Effectiveness				$128,056	$/ton	

Assumptions

Carbon Replacement Labor Time Calculation:
1 units * 20 Filter Banks * 15 minutes swap time per filter bank = 5 hours of labor time per carbon swap
15 minutes swap time per filter bank from Phil Chapman

Number of Carbon Swaps

	Quantity	UOM
Carbon per filter	6	lbs
filters per bank	16	ea
filter banks per booth	20	ea
lbs of carbon per booth	1920	lb of carbon/booth
VOC adsorption rate from EPA	0.2	lb of VOC/lb of carbon
VOC adsorption capacity	384	lb of VOC/booth
VOC adsorption capacity	0.192	tons of VOC /booth
VOC emissions	4.2	tpy
Carbon swaps per year	21.9	carbon swaps per year per booth

References

EPA	EPA Capital Cost Factors for Thermal and Catalytic Incinerators
	EPA Air Pollution Control Cost Manual - Sixth Edition (EPA 452/B-02-001)
	Section 3 - VOC Controls
	Section 3.1 - VOC Recapture Controls
	Section 3.1 Carbon Adsorbers
TRS	E-mail from Phil Chapman, Thermal Recovery Systems, Inc. 02/17/12
Boeing	
	Boeing operating and maintenance labor cost = $102.63/hr
	Boeing projected natural gas = $9.30 per million Btu
	Boeing electricty cost = $0.06 per kwh

BACT Cost Estimation Spreadsheet
Dinol Booth
Control Technology: Regenerative Thermal Oxidizer w/ Zeolite Concentrator - Anguil

Given Parameters

			Reference
Annual operating hours	2016	hrs	Boeing
Exhaust flow rate, Q	40,000	acfm	Boeing
Estimated uncontrolled emissions	4.2	tons/year	Boeing
Interest rate	10.5%		Boeing
Equipment lifetime	10	years	Anguil
Fuel requirement	1.3	MMBtu/hr	Anguil
Electricty requirement	52	kw	Anguil

Table 1. Capital Cost Estimate

		Cost	Reference
Purchased Equipment			
Basic equipment and auxillaries	A	$710,000	Anguil
Freight	.05A	$35,500	EPA
Sales Tax	9.5%	$70,823	
Total Purchased Equipment Cost	B	$816,323	
Direct Installation Cost			
Foundation and supports	.08B	$65,306	EPA
Erection and handling	.14B	$114,285	EPA
Electrical	.04B	$32,653	EPA
Piping	.02B	$16,326	EPA
Painting	.01B	$8,163	EPA
Insulation	.01B	$8,163	EPA
Building and site preparation not included			
Total Direct Installation Cost		$244,897	
Total Direct Cost		$1,061,219	
Indirect Cost			
Engineering and supervision	0.10B	$81,632	EPA
Construction and field expenses	0.05B	$40,816	EPA
Construction fee	0.10B	$81,632	EPA
Start-up	0.02B	$16,326	EPA
Performance test	0.01B	$8,163	EPA
Contingency	0.03B	$24,490	EPA
Total Indirect Cost		$253,060	
Total Capital Cost		**$1,314,279**	

BACT Cost Estimation Spreadsheet
Dinol Booth
Control Technology: Regenerative Thermal Oxidizer w/ Zeolite Concentrator - Anguil

Table 2. Annual Cost

				Annual Cost		Reference
Direct Costs						
2-1	Operating labor		0.5 hrs/shift @ $102.63/hr	$12,931		Boeing/EPA
2-2	Supervisory labor		included in labor rate	$0		Boeing
2-3	Maintenance labor		0.5 hr/shift@$102.63/hr	$12,931		Boeing/EPA
2-4	Maintenance materials		100% of maintenance lbr	$12,931		EPA
Utilities						
	Electricty	$0.06	per kwh	$6,290		Boeing
	Fuel	$9	per MMBtu	$23,623		Boeing
Total Direct Cost				$68,708		
Indirect Costs						
	Administrative charges	0.02	of total capital cost	$26,286		EPA
	property tax	0.01	of total capital cost	$13,143		EPA
	Insurance	0.01	of total capital cost	$13,143		EPA
Total Annual Costs Excluding Capital Recovery				$121,279		
	Capital recovery			$218,509		
	Interest		10.5%			Boeing
	Lifetime		10 years			Anguil
Total Annual Cost				$339,787		
Uncontrolled Emissions				4.17	lb/hr	
Control Efficiency				95%		Anguil
Emission Reduction				3.99	tons/year	
Cost Effectiveness				$85,160	$/ton	

References

EPA
EPA Capital Cost Factors for Thermal and Catalytic Incinerators
EPA Air Pollution Control Cost Manual - Sixth Edition (EPA 452/B-02-001)
Section 3 - VOC Controls
Section 3.2 - VOC Destruction Controls
Chapter 2 - Incinerators

Anguil
E-mail from Jason Schueler, Anguil, 02/23/12

Boeing
Boeing capital project opportunity cost = 10.5%
Boeing operating and maintenance labor cost = $102.63/hr
Boeing projected natural gas = $9.30 per million Btu
Boeing electricty cost = $0.06 per kwh

BACT Cost Estimation Spreadsheet

Dinol Booth

Control Technology: Regenerative Thermal Oxidizer w/ Zeolite Concentrator - Anguil

Given Parameters

			Reference
Annual operating hours	2016	hrs	Boeing
Exhaust flow rate, Q	40,000	acfm	Boeing
Estimated uncontrolled emissions	4.2	tons/year	Boeing
Interest rate	7.0%		Ecology
Equipment lifetime	10	years	Anguil
Fuel requirement	1.3	MMBtu/hr	Anguil
Electricty requirement	52	kw	Anguil

Table 1. Capital Cost Estimate

		Cost	Reference
Purchased Equipment			
Basic equipment and auxillaries	A	$710,000	Anguil
Freight	.05A	$35,500	EPA
Sales Tax	9.5%	$70,823	
Total Purchased Equipment Cost	B	$816,323	
Direct Installation Cost			
Foundation and supports	.08B	$65,306	EPA
Erection and handling	.14B	$114,285	EPA
Electrical	.04B	$32,653	EPA
Piping	.02B	$16,326	EPA
Painting	.01B	$8,163	EPA
Insulation	.01B	$8,163	EPA
Building and site preparation not included			
Total Direct Installation Cost		$244,897	
Total Direct Cost		$1,061,219	
Indirect Cost			
Engineering and supervision	0.10B	$81,632	EPA
Construction and field expenses	0.05B	$40,816	EPA
Construction fee	0.10B	$81,632	EPA
Start-up	0.02B	$16,326	EPA
Performance test	0.01B	$8,163	EPA
Contingency	0.03B	$24,490	EPA
Total Indirect Cost		$253,060	
Total Capital Cost		**$1,314,279**	

BACT Cost Estimation Spreadsheet

Dinol Booth

Control Technology: **Regenerative Thermal Oxidizer w/ Zeolite Concentrator - Anguil**

Table 2. Annual Cost

				Annual Cost		Reference
Direct Costs						
2-1	Operating labor		0.5 hrs/shift @ $102.63/hr	$12,931		Boeing/EPA
2-2	Supervisory labor		included in labor rate	$0		Boeing
2-3	Maintenance labor		0.5 hr/shift@$102.63/hr	$12,931		Boeing/EPA
2-4	Maintenance materials		100% of maintenance lbr	$12,931		EPA
Utilities						
	Electricty	$0.06	per kwh	$6,290		Boeing
	Fuel	$9	per MMBtu	$23,623		Boeing
Total Direct Cost				$68,708		
Indirect Costs						
	Administrative charges	0.02	of total capital cost	$26,286		EPA
	property tax	0.01	of total capital cost	$13,143		EPA
	Insurance	0.01	of total capital cost	$13,143		EPA
Total Annual Costs Excluding Capital Recovery				$121,279		
	Capital recovery			$187,124		
	Interest		7.0%			Ecology
	Lifetime		10 years			Anguil
Total Annual Cost				$308,403		
Uncontrolled Emissions				4.17	lb/hr	
Control Efficiency				95%		Anguil
Emission Reduction				3.99	tons/year	
Cost Effectiveness				$77,294	$/ton	

References

EPA	EPA Capital Cost Factors for Thermal and Catalytic Incinerators
	EPA Air Pollution Control Cost Manual - Sixth Edition (EPA 452/B-02-001)
	Section 3 - VOC Controls
	Section 3.2 - VOC Destruction Controls
	Chapter 2 - Incinerators
Anguil	E-mail from Jason Schueler, Anguil, 02/23/12
Boeing	
	Boeing operating and maintenance labor cost = $102.63/hr
	Boeing projected natural gas = $9.30 per million Btu
	Boeing electricty cost = $0.06 per kwh

BACT Cost Estimation Spreadsheet
Dinol
Control Technology: Regenerative Thermal Oxidizer - Anguil

Given Parameters

			Reference
Annual operating hours	2190	hrs	Boeing
Exhaust flow rate, Q	40,000	acfm	Boeing
Estimated uncontrolled emissions	4.2	tons/year	Boeing
Interest rate	10.5%		Boeing
Equipment lifetime	15	years	Anguil
Fuel requirement	3.3	MMBtu/hr	Anguil
Electricty requirement	112	kw	Anguil

Table 1. Capital Cost Estimate

		Cost	Reference
Purchased Equipment			
Basic equipment and auxillaries	A	$430,000	Anguil
Freight	.05A	$21,500	EPA
Sales Tax	9.5%	$42,893	
Total Purchased Equipment Cost	B	$494,393	
Direct Installation Cost			
Foundation and supports	.08B	$39,551	EPA
Erection and handling	.14B	$69,215	EPA
Electrical	.04B	$19,776	EPA
Piping	.02B	$9,888	EPA
Painting	.01B	$4,944	EPA
Insulation	.01B	$4,944	EPA
Building and site preparation not included			
Total Direct Installation Cost		$148,318	
Total Direct Cost		$642,710	
Indirect Cost			
Engineering and supervision	0.10B	$49,439	EPA
Construction and field expenses	0.05B	$24,720	EPA
Construction fee	0.10B	$49,439	EPA
Start-up	0.02B	$9,888	EPA
Performance test	0.01B	$4,944	EPA
Contingency	0.03B	$14,832	EPA
Total Indirect Cost		$153,262	
Total Capital Cost		**$795,972**	

BACT Cost Estimation Spreadsheet

Dinol

Control Technology: **Regenerative Thermal Oxidizer - Anguil**

Table 2. Annual Cost

				Annual Cost		Reference
Direct Costs						
2-1	Operating labor		0.5 hrs/shift @ $102.63/hr	$14,047		Boeing/EPA
2-2	Supervisory labor		included in labor rate	$0		Boeing
2-3	Maintenance labor		0.5 hr/shift@$102.63/hr	$14,047		Boeing/EPA
2-4	Maintenance materials		100% of maintenance lbr	$14,047		EPA
Utilities						
	Electricty	$0.06	per kwh	$14,717		Boeing
	Fuel	$9	per MMBtu	$67,211		Boeing
Total Direct Cost				$124,070		
Indirect Costs						
	Administrative charges	0.02	of total capital cost	$15,919		EPA
	property tax	0.01	of total capital cost	$7,960		EPA
	Insurance	0.01	of total capital cost	$7,960		EPA
Total Annual Costs Excluding Capital Recovery				$155,909		
	Capital recovery			$107,654		
	Interest		10.5%			Boeing
	Lifetime		15 years			Anguil
Total Annual Cost				$263,563		
Uncontrolled Emissions				3.84	lb/hr	
Control Efficiency				99%		Anguil
Emission Reduction				4.16	tons/year	
Cost Effectiveness				$63,387	$/ton	

References

EPA	EPA Capital Cost Factors for Thermal and Catalytic Incinerators
	EPA Air Pollution Control Cost Manual - Sixth Edition (EPA 452/B-02-001)
	Section 3 - VOC Controls
	Section 3.2 - VOC Destruction Controls
	Chapter 2 - Incinerators
Anguil	E-mail from Scott Bayon, Anguil, 04/25/2011
Boeing	Boeing capital project opportunity cost = 10.5%
	Boeing operating and maintenance labor cost = $102.63/hr
	Boeing projected natural gas = $9.30 per million Btu
	Boeing electricty cost = $0.06 per kwh

BACT Cost Estimation Spreadsheet

Dinol

Control Technology: Regenerative Thermal Oxidizer - Anguil

Given Parameters

			Reference
Annual operating hours	2190	hrs	Boeing
Exhaust flow rate, Q	40,000	acfm	Boeing
Estimated uncontrolled emissions	4.2	tons/year	Boeing
Interest rate	7.0%		Ecology
Equipment lifetime	15	years	Anguil
Fuel requirement	3.3	MMBtu/hr	Anguil
Electricty requirement	112	kw	Anguil

Table 1. Capital Cost Estimate

		Cost	Reference
Purchased Equipment			
Basic equipment and auxillaries	A	$430,000	Anguil
Freight	.05A	$21,500	EPA
Sales Tax	9.5%	$42,893	
Total Purchased Equipment Cost	B	$494,393	
Direct Installation Cost			
Foundation and supports	.08B	$39,551	EPA
Erection and handling	.14B	$69,215	EPA
Electrical	.04B	$19,776	EPA
Piping	.02B	$9,888	EPA
Painting	.01B	$4,944	EPA
Insulation	.01B	$4,944	EPA
Building and site preparation not included			
Total Direct Installation Cost		$148,318	
Total Direct Cost		$642,710	
Indirect Cost			
Engineering and supervision	0.10B	$49,439	EPA
Construction and field expenses	0.05B	$24,720	EPA
Construction fee	0.10B	$49,439	EPA
Start-up	0.02B	$9,888	EPA
Performance test	0.01B	$4,944	EPA
Contingency	0.03B	$14,832	EPA
Total Indirect Cost		$153,262	
Total Capital Cost		**$795,972**	

BACT Cost Estimation Spreadsheet

Dinol

Control Technology: Regenerative Thermal Oxidizer - Anguil

Table 2. Annual Cost

				Annual Cost		Reference
Direct Costs						
2-1	Operating labor		0.5 hrs/shift @ $102.63/hr	$14,047		Boeing/EPA
2-2	Supervisory labor		included in labor rate	$0		Boeing
2-3	Maintenance labor		0.5 hr/shift@$102.63/hr	$14,047		Boeing/EPA
2-4	Maintenance materials		100% of maintenance lbr	$14,047		EPA
Utilities						
	Electricty	$0.06	per kwh	$14,717		Boeing
	Fuel	$9	per MMBtu	$67,211		Boeing
Total Direct Cost				$124,070		
Indirect Costs						
	Administrative charges	0.02	of total capital cost	$15,919		EPA
	property tax	0.01	of total capital cost	$7,960		EPA
	Insurance	0.01	of total capital cost	$7,960		EPA
Total Annual Costs Excluding Capital Recovery				$155,909		
	Capital recovery			$87,393		
	Interest		7.0%			Ecology
	Lifetime		15 years			Anguil
Total Annual Cost				$243,303		
Uncontrolled Emissions				3.84	lb/hr	
Control Efficiency				99%		Anguil
Emission Reduction				4.16	tons/year	
Cost Effectiveness				$58,514	$/ton	

References

EPA	EPA Capital Cost Factors for Thermal and Catalytic Incinerators
	EPA Air Pollution Control Cost Manual - Sixth Edition (EPA 452/B-02-001)
	Section 3 - VOC Controls
	Section 3.2 - VOC Destruction Controls
	Chapter 2 - Incinerators
Anguil	E-mail from Scott Bayon, Anguil, 04/25/2011
Boeing	
	Boeing operating and maintenance labor cost = $102.63/hr
	Boeing projected natural gas = $9.30 per million Btu
	Boeing electricty cost = $0.06 per kwh

APPENDIX C

Building 4-86 Vertical Wing Booths BACT Costs

BACT Cost Estimation Spreadsheet
Inspar
Control Technology: Thermal Oxidizer - Callidus w/o preheater

Given Parameters

			Reference
Annual operating hours	2190	hrs	Boeing
Exhaust flow rate, Q	140,000	acfm	Boeing
Estimated uncontrolled emissions	11.8	tons/year	Boeing
Interest rate	10.5%		Boeing
Equipment lifetime	15	years	Callidus
Fuel requirement	167.0	MMBtu/hr	Callidus
Electricty requirement	22	kw	Callidus

Table 1. Capital Cost Estimate

		Cost	Reference
Purchased Equipment			
Basic equipment and auxillaries	A	$750,000	Callidus
Freight	.05A	$37,500	EPA
Sales Tax	9.5%	$74,813	
<u>Total Purchased Equipment Cost</u>	B	$862,313	
Direct Installation Cost			
Foundation and supports	.08B	$68,985	EPA
Erection and handling	.14B	$120,724	EPA
Electrical	.04B	$34,493	EPA
Piping	.02B	$17,246	EPA
Painting	.01B	$8,623	EPA
Insulation	.01B	$8,623	EPA
Building and site preparation not included			
<u>Total Direct Installation Cost</u>		$258,694	
<u>Total Direct Cost</u>		$1,121,006	
Indirect Cost			
Engineering and supervision	0.10B	$86,231	EPA
Construction and field expenses	0.05B	$43,116	EPA
Construction fee	0.10B	$86,231	EPA
Start-up	0.02B	$17,246	EPA
Performance test	0.01B	$8,623	EPA
Contingency	0.03B	$25,869	EPA
<u>Total Indirect Cost</u>		$267,317	
Total Capital Cost		**$1,388,323**	

BACT Cost Estimation Spreadsheet

Inspar

Control Technology: **Thermal Oxidizer - Callidus w/o preheater**

Table 2. Annual Cost

				Annual Cost		Reference
Direct Costs						
2-1	Operating labor		0.5 hrs/shift @ $102.63/hr	$14,047		Boeing/EPA
2-2	Supervisory labor		included in labor rate	$0		Boeing
2-3	Maintenance labor		0.5 hr/shift@$102.63/hr	$14,047		Boeing/EPA
2-4	Maintenance materials		100% of maintenance lbr	$14,047		EPA
Utilities						
	Electricty	$0.06	per kwh	$2,891		Boeing
	Fuel	$9	per MMBtu	$3,401,289		Boeing
Total Direct Cost				$3,446,322		
Indirect Costs						
	Administrative charges	0.02	of total capital cost	$27,766		EPA
	property tax	0.01	of total capital cost	$13,883		EPA
	Insurance	0.01	of total capital cost	$13,883		EPA
Total Annual Costs Excluding Capital Recovery				$3,501,855		
	Capital recovery			$187,768		
	Interest		10.5%			Boeing
	Lifetime		15 years			Callidus
Total Annual Cost				$3,689,623		
Uncontrolled Emissions				10.78	lb/hr	
Control Efficiency				98%		Callidus
Emission Reduction				11.56	tons/year	
Cost Effectiveness				$319,061	$/ton	

References

EPA	EPA Capital Cost Factors for Thermal and Catalytic Incinerators
	EPA Air Pollution Control Cost Manual - Sixth Edition (EPA 452/B-02-001)
	Section 3 - VOC Controls
	Section 3.2 - VOC Destruction Controls
	Chapter 2 - Incinerators
Callidus	E-mail from Ania Guy, Callidus Technologies by Honeywell, 03/11/11
Boeing	Boeing capital project opportunity cost = 10.5%
	Boeing operating and maintenance labor cost = $102.63/hr
	Boeing projected natural gas = $9.30 per million Btu
	Boeing electricty cost = $0.06 per kwh

BACT Cost Estimation Spreadsheet
Inspar
Control Technology: Thermal Oxidizer - Callidus w/o preheater

Given Parameters

			Reference
Annual operating hours	2190	hrs	Boeing
Exhaust flow rate, Q	140,000	acfm	Boeing
Estimated uncontrolled emissions	11.8	tons/year	Boeing
Interest rate	7.0%		Ecology
Equipment lifetime	15	years	Callidus
Fuel requirement	167.0	MMBtu/hr	Callidus
Electricty requirement	22	kw	Callidus

Table 1. Capital Cost Estimate

		Cost	Reference
Purchased Equipment			
Basic equipment and auxillaries	A	$750,000	Callidus
Freight	.05A	$37,500	EPA
Sales Tax	9.5%	$74,813	
Total Purchased Equipment Cost	B	$862,313	
Direct Installation Cost			
Foundation and supports	.08B	$68,985	EPA
Erection and handling	.14B	$120,724	EPA
Electrical	.04B	$34,493	EPA
Piping	.02B	$17,246	EPA
Painting	.01B	$8,623	EPA
Insulation	.01B	$8,623	EPA
Building and site preparation not included			
Total Direct Installation Cost		$258,694	
Total Direct Cost		$1,121,006	
Indirect Cost			
Engineering and supervision	0.10B	$86,231	EPA
Construction and field expenses	0.05B	$43,116	EPA
Construction fee	0.10B	$86,231	EPA
Start-up	0.02B	$17,246	EPA
Performance test	0.01B	$8,623	EPA
Contingency	0.03B	$25,869	EPA
Total Indirect Cost		$267,317	
Total Capital Cost		**$1,388,323**	

BACT Cost Estimation Spreadsheet

Inspar

Control Technology: **Thermal Oxidizer - Callidus w/o preheater**

Table 2. Annual Cost

				Annual Cost		Reference
Direct Costs						
2-1	Operating labor		0.5 hrs/shift @ $102.63/hr	$14,047		Boeing/EPA
2-2	Supervisory labor		included in labor rate	$0		Boeing
2-3	Maintenance labor		0.5 hr/shift@$102.63/hr	$14,047		Boeing/EPA
2-4	Maintenance materials		100% of maintenance lbr	$14,047		EPA
Utilities						
	Electricty	$0.06	per kwh	$2,891		Boeing
	Fuel	$9	per MMBtu	$3,401,289		Boeing
Total Direct Cost				$3,446,322		
Indirect Costs						
	Administrative charges	0.02	of total capital cost	$27,766		EPA
	property tax	0.01	of total capital cost	$13,883		EPA
	Insurance	0.01	of total capital cost	$13,883		EPA
Total Annual Costs Excluding Capital Recovery				$3,501,855		
	Capital recovery			$152,430		
	Interest		7.0%			Boeing
	Lifetime		15 years			Callidus
Total Annual Cost				$3,654,286		
Uncontrolled Emissions				10.78	lb/hr	
Control Efficiency				98%		Callidus
Emission Reduction				11.56	tons/year	
Cost Effectiveness				$316,005	$/ton	

References

EPA	EPA Capital Cost Factors for Thermal and Catalytic Incinerators
	EPA Air Pollution Control Cost Manual - Sixth Edition (EPA 452/B-02-001)
	Section 3 - VOC Controls
	Section 3.2 - VOC Destruction Controls
	Chapter 2 - Incinerators
Callidus	E-mail from Ania Guy, Callidus Technologies by Honeywell, 03/11/11
Boeing	
	Boeing operating and maintenance labor cost = $102.63/hr
	Boeing projected natural gas = $9.30 per million Btu
	Boeing electricty cost = $0.06 per kwh

BACT Cost Estimation Spreadsheet
Inspar
Control Technology: Thermal Oxidizer w Preheater - John Zink

Given Parameters

			Reference
Annual operating hours	2190	hrs	Boeing
Exhaust flow rate, Q	140,000	acfm	Boeing
Estimated uncontrolled emissions	11.8	tons/year	Boeing
Interest rate	10.5%		Boeing
Equipment lifetime	20	years	John Zink
Fuel requirement	91.5	MMBtu/hr	John Zink
Electricty requirement	373	kw	John Zink

Table 1. Capital Cost Estimate

		Cost	Reference
Purchased Equipment			
Basic equipment and auxillaries	A	$2,500,000	John Zink
Freight	.05A	$125,000	EPA
Sales Tax	9.5%	$249,375	
Total Purchased Equipment Cost	B	$2,874,375	
Direct Installation Cost			
Foundation and supports	.08B	$229,950	EPA
Erection and handling	.14B	$402,413	EPA
Electrical	.04B	$114,975	EPA
Piping	.02B	$57,488	EPA
Painting	.01B	$28,744	EPA
Insulation	.01B	$28,744	EPA
Building and site preparation not included			
Total Direct Installation Cost		$862,313	
Total Direct Cost		$3,736,688	
Indirect Cost			
Engineering and supervision	0.10B	$287,438	EPA
Construction and field expenses	0.05B	$143,719	EPA
Construction fee	0.10B	$287,438	EPA
Start-up	0.02B	$57,488	EPA
Performance test	0.01B	$28,744	EPA
Contingency	0.03B	$86,231	EPA
Total Indirect Cost		$891,056	
Total Capital Cost		**$4,627,744**	

BACT Cost Estimation Spreadsheet

Inspar

Control Technology: **Thermal Oxidizer w Preheater - John Zink**

Table 2. Annual Cost

				Annual Cost		Reference
Direct Costs						
2-1	Operating labor		0.5 hrs/shift @ $102.63/hr	$14,047		Boeing/EPA
2-2	Supervisory labor		included in labor rate	$0		Boeing
2-3	Maintenance labor		0.5 hr/shift@$102.63/hr	$14,047		Boeing/EPA
2-4	Maintenance materials		100% of maintenance lbr	$14,047		EPA
Utilities						
	Electricty	$0.06	per kwh	$49,012		Boeing
	Fuel	$9.30	per MMBtu	$1,863,581		Boeing
Total Direct Cost				$1,954,735		
Indirect Costs						
	Administrative charges	0.02	of total capital cost	$92,555		EPA
	property tax	0.01	of total capital cost	$46,277		EPA
	Insurance	0.01	of total capital cost	$46,277		EPA
Total Annual Costs Excluding Capital Recovery				$2,139,845		
	Capital recovery			$562,240		
	Interest		10.5%			Boeing
	Lifetime		20 years			John Zink
Total Annual Cost				$2,702,085		
Uncontrolled Emissions				10.78	lb/hr	
Control Efficiency				99%		John Zink
Emission Reduction				11.68	tons/year	
Cost Effectiveness				$231,303	$/ton	

References

EPA	EPA Capital Cost Factors for Thermal and Catalytic Incinerators
	EPA Air Pollution Control Cost Manual - Sixth Edition (EPA 452/B-02-001)
	Section 3 - VOC Controls
	Section 3.2 - VOC Destruction Controls
	Chapter 2 - Incinerators
John Zink	E-mail from Carl Connally, John Zink, 03/08/11, 03/09/11 and 3/17/11.
Boeing	Boeing capital project opportunity cost = 10.5%
	Boeing operating and maintenance labor cost = $102.63/hr
	Boeing projected natural gas = $9.30 per million Btu
	Boeing electricty cost = $0.06 per kwh

BACT Cost Estimation Spreadsheet
Inspar
Control Technology: Thermal Oxidizer w Preheater - John Zink

Given Parameters

			Reference
Annual operating hours	2190	hrs	Boeing
Exhaust flow rate, Q	140,000	acfm	Boeing
Estimated uncontrolled emissions	11.8	tons/year	Boeing
Interest rate	7.0%		Ecology
Equipment lifetime	20	years	John Zink
Fuel requirement	91.5	MMBtu/hr	John Zink
Electricty requirement	373	kw	John Zink

Table 1. Capital Cost Estimate

		Cost	Reference
Purchased Equipment			
Basic equipment and auxillaries	A	$2,500,000	John Zink
Freight	.05A	$125,000	EPA
Sales Tax	9.5%	$249,375	
Total Purchased Equipment Cost	B	$2,874,375	
Direct Installation Cost			
Foundation and supports	.08B	$229,950	EPA
Erection and handling	.14B	$402,413	EPA
Electrical	.04B	$114,975	EPA
Piping	.02B	$57,488	EPA
Painting	.01B	$28,744	EPA
Insulation	.01B	$28,744	EPA
Building and site preparation not included			
Total Direct Installation Cost		$862,313	
Total Direct Cost		$3,736,688	
Indirect Cost			
Engineering and supervision	0.10B	$287,438	EPA
Construction and field expenses	0.05B	$143,719	EPA
Construction fee	0.10B	$287,438	EPA
Start-up	0.02B	$57,488	EPA
Performance test	0.01B	$28,744	EPA
Contingency	0.03B	$86,231	EPA
Total Indirect Cost		$891,056	
Total Capital Cost		**$4,627,744**	

BACT Cost Estimation Spreadsheet

Inspar

Control Technology: **Thermal Oxidizer w Preheater - John Zink**

Table 2. Annual Cost

				Annual Cost		Reference
Direct Costs						
2-1	Operating labor		0.5 hrs/shift @ $102.63/hr	$14,047		Boeing/EPA
2-2	Supervisory labor		included in labor rate	$0		Boeing
2-3	Maintenance labor		0.5 hr/shift@$102.63/hr	$14,047		Boeing/EPA
2-4	Maintenance materials		100% of maintenance lbr	$14,047		EPA
Utilities						
	Electricty	$0.06	per kwh	$49,012		Boeing
	Fuel	$9.30	per MMBtu	$1,863,581		Boeing
Total Direct Cost				$1,954,735		
Indirect Costs						
	Administrative charge:	0.02	of total capital cost	$92,555		EPA
	property tax	0.01	of total capital cost	$46,277		EPA
	Insurance	0.01	of total capital cost	$46,277		EPA
Total Annual Costs Excluding Capital Recovery				$2,139,845		
	Capital recovery			$436,826		
	Interest		7.0%			Boeing
	Lifetime		20 years			John Zink
Total Annual Cost				$2,576,671		
Uncontrolled Emissions				10.78	lb/hr	
Control Efficiency				99%		John Zink
Emission Reduction				11.68	tons/year	
Cost Effectiveness				$220,568	$/ton	

References

EPA	EPA Capital Cost Factors for Thermal and Catalytic Incinerators
	EPA Air Pollution Control Cost Manual - Sixth Edition (EPA 452/B-02-001)
	Section 3 - VOC Controls
	Section 3.2 - VOC Destruction Controls
	Chapter 2 - Incinerators
John Zink	E-mail from Carl Connally, John Zink, 03/08/11, 03/09/11 and 3/17/11.
Boeing	
	Boeing operating and maintenance labor cost = $102.63/hr
	Boeing projected natural gas = $9.30 per million Btu
	Boeing electricty cost = $0.06 per kwh

BACT Cost Estimation Spreadsheet
Inspar
Control Technology: Thermal Oxidizer - Callidus w preheater

Given Parameters

			Reference
Annual operating hours	2190	hrs	Boeing
Exhaust flow rate, Q	140,000	acfm	Boeing
Estimated uncontrolled emissions	11.8	tons/year	Boeing
Interest rate	10.5%		Boeing
Equipment lifetime	15	years	Callidus
Fuel requirement	77.0	MMBtu/hr	Callidus
Electricty requirement	22	kw	Callidus

Table 1. Capital Cost Estimate

			Cost	Reference
Purchased Equipment				
Basic equipment and auxillaries	A		$1,500,000	Callidus
Freight	.05A		$75,000	EPA
Sales Tax		9.5%	$149,625	
Total Purchased Equipment Cost	B		$1,724,625	
Direct Installation Cost				
Foundation and supports	.08B		$137,970	EPA
Erection and handling	.14B		$241,448	EPA
Electrical	.04B		$68,985	EPA
Piping	.02B		$34,493	EPA
Painting	.01B		$17,246	EPA
Insulation	.01B		$17,246	EPA
Building and site preparation not included				
Total Direct Installation Cost			$517,388	
Total Direct Cost			$2,242,013	
Indirect Cost				
Engineering and supervision	0.10B		$172,463	EPA
Construction and field expenses	0.05B		$86,231	EPA
Construction fee	0.10B		$172,463	EPA
Start-up	0.02B		$34,493	EPA
Performance test	0.01B		$17,246	EPA
Contingency	0.03B		$51,739	EPA
Total Indirect Cost			$534,634	
Total Capital Cost			**$2,776,646**	

BACT Cost Estimation Spreadsheet

Inspar

Control Technology: **Thermal Oxidizer - Callidus w preheater**

Table 2. Annual Cost

				Annual Cost		Reference
Direct Costs						
2-1	Operating labor		0.5 hrs/shift @ $102.63/hr	$14,047		Boeing/EPA
2-2	Supervisory labor		included in labor rate	$0		Boeing
2-3	Maintenance labor		0.5 hr/shift@$102.63/hr	$14,047		Boeing/EPA
2-4	Maintenance materials		100% of maintenance lbr	$14,047		EPA
Utilities						
	Electricty	$0.06	per kwh	$2,891		Boeing
	Fuel	$9	per MMBtu	$1,568,259		Boeing
Total Direct Cost				$1,613,292		
Indirect Costs						
	Administrative charges	0.02	of total capital cost	$55,533		EPA
	property tax	0.01	of total capital cost	$27,766		EPA
	Insurance	0.01	of total capital cost	$27,766		EPA
Total Annual Costs Excluding Capital Recovery				$1,724,358		
	Capital recovery			$375,536		
	Interest		10.5%			Boeing
	Lifetime		15 years			Callidus
Total Annual Cost				$2,099,894		
Uncontrolled Emissions				10.78	lb/hr	
Control Efficiency				98%		Callidus
Emission Reduction				11.56	tons/year	
Cost Effectiveness				$181,589	$/ton	

References

EPA	EPA Capital Cost Factors for Thermal and Catalytic Incinerators
	EPA Air Pollution Control Cost Manual - Sixth Edition (EPA 452/B-02-001)
	Section 3 - VOC Controls
	Section 3.2 - VOC Destruction Controls
	Chapter 2 - Incinerators
Callidus	E-mail from Ania Guy, Callidus Technologies by Honeywell, 03/11/11
Boeing	Boeing capital project opportunity cost = 10.5%
	Boeing operating and maintenance labor cost = $102.63/hr
	Boeing projected natural gas = $9.30 per million Btu
	Boeing electricty cost = $0.06 per kwh

BACT Cost Estimation Spreadsheet

Inspar

Control Technology: Thermal Oxidizer - Callidus w preheater

Given Parameters

			Reference
Annual operating hours	2190	hrs	Boeing
Exhaust flow rate, Q	140,000	acfm	Boeing
Estimated uncontrolled emissions	11.8	tons/year	Boeing
Interest rate	7.0%		Ecology
Equipment lifetime	15	years	Callidus
Fuel requirement	77.0	MMBtu/hr	Callidus
Electricty requirement	22	kw	Callidus

Table 1. Capital Cost Estimate

			Cost	Reference
Purchased Equipment				
Basic equipment and auxillaries	A		$1,500,000	Callidus
Freight	.05A		$75,000	EPA
Sales Tax		9.5%	$149,625	
Total Purchased Equipment Cost	B		$1,724,625	
Direct Installation Cost				
Foundation and supports	.08B		$137,970	EPA
Erection and handling	.14B		$241,448	EPA
Electrical	.04B		$68,985	EPA
Piping	.02B		$34,493	EPA
Painting	.01B		$17,246	EPA
Insulation	.01B		$17,246	EPA
Building and site preparation not included				
Total Direct Installation Cost			$517,388	
Total Direct Cost			$2,242,013	
Indirect Cost				
Engineering and supervision	0.10B		$172,463	EPA
Construction and field expenses	0.05B		$86,231	EPA
Construction fee	0.10B		$172,463	EPA
Start-up	0.02B		$34,493	EPA
Performance test	0.01B		$17,246	EPA
Contingency	0.03B		$51,739	EPA
Total Indirect Cost			$534,634	
Total Capital Cost			**$2,776,646**	

BACT Cost Estimation Spreadsheet

Inspar

Control Technology: **Thermal Oxidizer - Callidus w preheater**

Table 2. Annual Cost

				Annual Cost		Reference
Direct Costs						
2-1	Operating labor		0.5 hrs/shift @ $102.63/hr	$14,047		Boeing/EPA
2-2	Supervisory labor		included in labor rate	$0		Boeing
2-3	Maintenance labor		0.5 hr/shift@$102.63/hr	$14,047		Boeing/EPA
2-4	Maintenance materials		100% of maintenance lbr	$14,047		EPA
Utilities						
	Electricty	$0.06	per kwh	$2,891		Boeing
	Fuel	$9	per MMBtu	$1,568,259		Boeing
Total Direct Cost				$1,613,292		
Indirect Costs						
	Administrative charges	0.02	of total capital cost	$55,533		EPA
	property tax	0.01	of total capital cost	$27,766		EPA
	Insurance	0.01	of total capital cost	$27,766		EPA
Total Annual Costs Excluding Capital Recovery				$1,724,358		
	Capital recovery			$304,861		
	Interest		7.0%			Boeing
	Lifetime		15 years			Callidus
Total Annual Cost				$2,029,219		
Uncontrolled Emissions				10.78	lb/hr	
Control Efficiency				98%		Callidus
Emission Reduction				11.56	tons/year	
Cost Effectiveness				$175,477	$/ton	

References

EPA	EPA Capital Cost Factors for Thermal and Catalytic Incinerators
	EPA Air Pollution Control Cost Manual - Sixth Edition (EPA 452/B-02-001)
	Section 3 - VOC Controls
	Section 3.2 - VOC Destruction Controls
	Chapter 2 - Incinerators
Callidus	E-mail from Ania Guy, Callidus Technologies by Honeywell, 03/11/11
Boeing	
	Boeing operating and maintenance labor cost = $102.63/hr
	Boeing projected natural gas = $9.30 per million Btu
	Boeing electricty cost = $0.06 per kwh

BACT Cost Estimation Spreadsheet
Inspar
Control Technology: Thermal Recovery Systems - Carbon Adsorption

Given Parameters

			Reference
Annual operating hours	2190	hrs	Boeing
Exhaust flow rate, Q	140,000	acfm	Boeing
Estimated uncontrolled emissions	11.8	tons/year	Boeing
Interest rate	10.5%		Boeing
Equipment lifetime	5	years	EPA
Fuel requirement	0.0	MMBtu/hr	TRS
Electricty requirement	112	kw	EPA

Table 1. Capital Cost Estimate

		Cost	Reference
Purchased Equipment			
Basic equipment and auxillaries	A	$97,250	TRS
Freight	.05A	$4,863	EPA
Sales Tax	9.5%	$9,701	
Total Purchased Equipment Cost	B	$111,813	
Direct Installation Cost			
Foundation and supports	.08B	$8,945	EPA
Erection and handling	.14B	$15,654	EPA
Electrical	.04B	$4,473	EPA
Piping	.02B	$2,236	EPA
Painting	.01B	$1,118	EPA
Insulation	.01B	$1,118	EPA
Building and site preparation not included			
Total Direct Installation Cost		$33,544	
Total Direct Cost		$145,357	
Indirect Cost			
Engineering	0.10B	$11,181	EPA
Construction and field expenses	0.05B	$5,591	EPA
Construction fee	0.10B	$11,181	EPA
Start-up	0.02B	$2,236	EPA
Performance test	0.01B	$1,118	EPA
Contingency	0.03B	$3,354	EPA
Total Indirect Cost		$34,662	
Total Capital Cost		**$180,019**	

BACT Cost Estimation Spreadsheet
Inspar
Control Technology: **Thermal Recovery Systems - Carbon Adsorption**

Table 2. Annual Cost

				Annual Cost	Reference
Direct Costs					
2-1	Operating labor		0.5 hrs/shift @ $102.63/hr	$14,047	Boeing/EPA
2-2	Supervisory labor		included in labor rate	$0	Boeing
2-3	Maintenance labor		0.5 hr/shift@$102.63/hr	$14,047	Boeing/EPA
2-4	Maintenance materials		100% Maintenance Labor	$14,047	TRS
	Replacement Parts, Carbon		36 carbon swaps/yr		TRS
	Carbon Replacement Labor		17.5hr@$102.63/hr	$64,657	TRS/Boeing
	Carbon Replacement Costs		$69,440 per carbon swap	$2,352,627	TRS
Utilities					
	Electricty	$0.06	per kwh	$14,717	Boeing
	Fuel	$9.30	per MMBtu	$0	Boeing
Total Direct Cost				$2,474,143	
Indirect Costs					
	Administrative charges	0.02	of total capital cost	$3,600	EPA
	property tax	0.01	of total capital cost	$1,800	EPA
	Insurance	0.01	of total capital cost	$1,800	EPA
Total Annual Costs Excluding Capital Recovery				$2,481,344	
	Capital recovery			$48,097	
	Interest		10.5%		Boeing
	Lifetime		5 years		EPA
Total Annual Cost				$2,529,441	
Uncontrolled Emissions				10.78 lb/hr	
Control Efficiency				95%	TRS
Emission Reduction				11.21 tons/year	
Cost Effectiveness				$225,641 $/ton	

Assumptions
Carbon Replacement Labor Time Calculation:
1 units * 70 Filter Banks * 15 minutes swap time per filter bank = 17.5 hours of labor time per carbon swap
15 minutes swap time per filter bank from Phil Chapman

Number of Carbon Swaps

	Quantity	UOM
Carbon per filter	6	lbs
filters per bank	16	ea
filter banks per booth	70	ea
lbs of carbon per booth	6720	lb of carbon/booth
VOC adsorption rate[1]	0.2	lb of VOC/lb of carbon
VOC adsorption capacity	1344	lb of VOC/booth
VOC adsorption capacity	0.672	tons of VOC /booth
VOC emissions	24	tpy
Carbon swaps per year	35.7	carbon swaps per year per booth

[1] Reference: Island Clean Air website, 'Activated Carbon Explained', accessed 3/2/2012,
http://www.islandcleanair.com/pdf/Activated%20Carbon%20Explained.pdf

References

EPA — EPA Capital Cost Factors for Thermal and Catalytic Incinerators
EPA Air Pollution Control Cost Manual - Sixth Edition (EPA 452/B-02-001)
Section 3 - VOC Controls
Section 3.1 - VOC Recapture Controls
Section 3.1 Carbon Adsorbers

TRS — E-mail from Phil Chapman, Thermal Recovery Systems, Inc. 02/17/12
Boeing — Boeing capital project opportunity cost = 10.5%
Boeing operating and maintenance labor cost = $102.63/hr
Boeing projected natural gas = $9.30 per million Btu
Boeing electricty cost = $0.06 per kwh

BACT Cost Estimation Spreadsheet
Inspar
Control Technology: Thermal Recovery Systems - Carbon Adsorption

Given Parameters

			Reference
Annual operating hours	2190	hrs	Boeing
Exhaust flow rate, Q	140,000	acfm	Boeing
Estimated uncontrolled emissions	11.8	tons/year	Boeing
Interest rate	7.0%		Ecology
Equipment lifetime	5	years	EPA
Fuel requirement	0.0	MMBtu/hr	TRS
Electricty requirement	112	kw	EPA

Table 1. Capital Cost Estimate

		Cost	Reference
Purchased Equipment			
Basic equipment and auxillaries	A	$97,250	TRS
Freight	.05A	$4,863	EPA
Sales Tax	9.5%	$9,701	
Total Purchased Equipment Cost	B	$111,813	
Direct Installation Cost			
Foundation and supports	.08B	$8,945	EPA
Erection and handling	.14B	$15,654	EPA
Electrical	.04B	$4,473	EPA
Piping	.02B	$2,236	EPA
Painting	.01B	$1,118	EPA
Insulation	.01B	$1,118	EPA
Building and site preparation not included			
Total Direct Installation Cost		$33,544	
Total Direct Cost		$145,357	
Indirect Cost			
Engineering	0.10B	$11,181	EPA
Construction and field expenses	0.05B	$5,591	EPA
Construction fee	0.10B	$11,181	EPA
Start-up	0.02B	$2,236	EPA
Performance test	0.01B	$1,118	EPA
Contingency	0.03B	$3,354	EPA
Total Indirect Cost		$34,662	
Total Capital Cost		**$180,019**	

BACT Cost Estimation Spreadsheet
Inspar
Control Technology: **Thermal Recovery Systems - Carbon Adsorption**

Table 2. Annual Cost

				Annual Cost		Reference
Direct Costs						
2-1	Operating labor		0.5 hrs/shift @ $102.63/hr	$14,047		Boeing/EPA
2-2	Supervisory labor		included in labor rate	$0		Boeing
2-3	Maintenance labor		0.5 hr/shift@$102.63/hr	$14,047		Boeing/EPA
2-4	Maintenance materials		100% Maintenance Labor	$14,047		TRS
	Replacement Parts, Carbon		36 carbon swaps/yr			TRS
	Carbon Replacement Labor		17.5hr@$102.63/hr	$64,657		TRS/Boeing
	Carbon Replacement Costs		$69,440 per carbon swap	$2,352,627		TRS
Utilities						
	Electricty	$0.06	per kwh	$14,717		Boeing
	Fuel	$9.30	per MMBtu	$0		Boeing
Total Direct Cost				$2,474,143		
Indirect Costs						
	Administrative charges	0.02	of total capital cost	$3,600		EPA
	property tax	0.01	of total capital cost	$1,800		EPA
	Insurance	0.01	of total capital cost	$1,800		EPA
Total Annual Costs Excluding Capital Recovery				$2,481,344		
	Capital recovery			$43,905		
	Interest		7.0%			Boeing
	Lifetime		5 years			EPA
Total Annual Cost				$2,525,249		
Uncontrolled Emissions				10.78	lb/hr	
Control Efficiency				95%		TRS
Emission Reduction				11.21	tons/year	
Cost Effectiveness				$225,268	$/ton	

Assumptions

Carbon Replacement Labor Time Calculation:

1 units * 70 Filter Banks * 15 minutes swap time per filter bank = 17.5 hours of labor time per carbon swap

15 minutes swap time per filter bank from Phil Chapman

Number of Carbon Swaps

	Quantity	UOM
Carbon per filter	6	lbs
filters per bank	16	ea
filter banks per booth	70	ea
lbs of carbon per booth	6720	lb of carbon/booth
VOC adsorption rate[1]	0.2	lb of VOC/lb of carbon
VOC adsorption capacity	1344	lb of VOC/booth
VOC adsorption capacity	0.672	tons of VOC /booth
VOC emissions	24	tpy
Carbon swaps per year	35.7	carbon swaps per year per booth

[1] Reference: Island Clean Air website, 'Activated Carbon Explained', accessed 3/2/2012, http://www.islandcleanair.com/pdf/Activated%20Carbon%20Explained.pdf

References

EPA — EPA Capital Cost Factors for Thermal and Catalytic Incinerators
EPA Air Pollution Control Cost Manual - Sixth Edition (EPA 452/B-02-001)
Section 3 - VOC Controls
Section 3.1 - VOC Recapture Controls
Section 3.1 Carbon Adsorbers

TRS — E-mail from Phil Chapman, Thermal Recovery Systems, Inc. 02/17/12

Boeing

Boeing operating and maintenance labor cost = $102.63/hr
Boeing projected natural gas = $9.30 per million Btu
Boeing electricty cost = $0.06 per kwh

BACT Cost Estimation Spreadsheet

Inspar

Control Technology: Regenerative Thermal Oxidizer - Anguil

Given Parameters

			Reference
Annual operating hours	2190	hrs	Boeing
Exhaust flow rate, Q	140,000	acfm	Boeing
Estimated uncontrolled emissions	11.8	tons/year	Boeing
Interest rate	10.5%		Boeing
Equipment lifetime	15	years	Anguil
Fuel requirement	11.4	MMBtu/hr	Anguil
Electricty requirement	344	kw	Anguil

Table 1. Capital Cost Estimate

		Cost	Reference
Purchased Equipment			
Basic equipment and auxillaries	A	$1,500,000	Anguil
Freight	.05A	$75,000	EPA
Sales Tax	9.5%	$149,625	
Total Purchased Equipment Cost	B	$1,724,625	
Direct Installation Cost			
Foundation and supports	.08B	$137,970	EPA
Erection and handling	.14B	$241,448	EPA
Electrical	.04B	$68,985	EPA
Piping	.02B	$34,493	EPA
Painting	.01B	$17,246	EPA
Insulation	.01B	$17,246	EPA
Building and site preparation not included			
Total Direct Installation Cost		$517,388	
Total Direct Cost		$2,242,013	
Indirect Cost			
Engineering and supervision	0.10B	$172,463	EPA
Construction and field expenses	0.05B	$86,231	EPA
Construction fee	0.10B	$172,463	EPA
Start-up	0.02B	$34,493	EPA
Performance test	0.01B	$17,246	EPA
Contingency	0.03B	$51,739	EPA
Total Indirect Cost		$534,634	
Total Capital Cost		**$2,776,646**	

BACT Cost Estimation Spreadsheet

Inspar

Control Technology: **Regenerative Thermal Oxidizer - Anguil**

Table 2. Annual Cost

				Annual Cost		Reference
Direct Costs						
2-1	Operating labor		0.5 hrs/shift @ $102.63/hr	$14,047		Boeing/EPA
2-2	Supervisory labor		included in labor rate	$0		Boeing
2-3	Maintenance labor		0.5 hr/shift@$102.63/hr	$14,047		Boeing/EPA
2-4	Maintenance materials		100% of maintenance lbr	$14,047		EPA
Utilities						
	Electricty	$0.06	per kwh	$45,202		Boeing
	Fuel	$9	per MMBtu	$232,184		Boeing
Total Direct Cost				$319,528		
Indirect Costs						
	Administrative charges	0.02	of total capital cost	$55,533		EPA
	property tax	0.01	of total capital cost	$27,766		EPA
	Insurance	0.01	of total capital cost	$27,766		EPA
Total Annual Costs Excluding Capital Recovery				$430,594		
	Capital recovery			$375,536		
	Interest		10.5%			Boeing
	Lifetime		15 years			Anguil
Total Annual Cost				$806,130		
Uncontrolled Emissions				10.78	lb/hr	
Control Efficiency				99%		Anguil
Emission Reduction				11.68	tons/year	
Cost Effectiveness				$69,006	$/ton	

References

EPA	EPA Capital Cost Factors for Thermal and Catalytic Incinerators
	EPA Air Pollution Control Cost Manual - Sixth Edition (EPA 452/B-02-001)
	Section 3 - VOC Controls
	Section 3.2 - VOC Destruction Controls
	Chapter 2 - Incinerators
Anguil	E-mail from Scott Bayon, Anguil, 03/10/11 and 03/14/11
Boeing	Boeing capital project opportunity cost = 10.5%
	Boeing operating and maintenance labor cost = $102.63/hr
	Boeing projected natural gas = $9.30 per million Btu
	Boeing electricty cost = $0.06 per kwh

BACT Cost Estimation Spreadsheet
Inspar
Control Technology: Regenerative Thermal Oxidizer - Anguil

Given Parameters

			Reference
Annual operating hours	2190	hrs	Boeing
Exhaust flow rate, Q	140,000	acfm	Boeing
Estimated uncontrolled emissions	11.8	tons/year	Boeing
Interest rate	7.0%		Ecology
Equipment lifetime	15	years	Anguil
Fuel requirement	11.4	MMBtu/hr	Anguil
Electricty requirement	344	kw	Anguil

Table 1. Capital Cost Estimate

		Cost	Reference
Purchased Equipment			
Basic equipment and auxillaries	A	$1,500,000	Anguil
Freight	.05A	$75,000	EPA
Sales Tax	9.5%	$149,625	
Total Purchased Equipment Cost	B	$1,724,625	
Direct Installation Cost			
Foundation and supports	.08B	$137,970	EPA
Erection and handling	.14B	$241,448	EPA
Electrical	.04B	$68,985	EPA
Piping	.02B	$34,493	EPA
Painting	.01B	$17,246	EPA
Insulation	.01B	$17,246	EPA
Building and site preparation not included			
Total Direct Installation Cost		$517,388	
Total Direct Cost		$2,242,013	
Indirect Cost			
Engineering and supervision	0.10B	$172,463	EPA
Construction and field expenses	0.05B	$86,231	EPA
Construction fee	0.10B	$172,463	EPA
Start-up	0.02B	$34,493	EPA
Performance test	0.01B	$17,246	EPA
Contingency	0.03B	$51,739	EPA
Total Indirect Cost		$534,634	
Total Capital Cost		**$2,776,646**	

BACT Cost Estimation Spreadsheet

Inspar

Control Technology: Regenerative Thermal Oxidizer - Anguil

Table 2. Annual Cost

				Annual Cost		Reference
Direct Costs						
2-1	Operating labor		0.5 hrs/shift @ $102.63/hr	$14,047		Boeing/EPA
2-2	Supervisory labor		included in labor rate	$0		Boeing
2-3	Maintenance labor		0.5 hr/shift@$102.63/hr	$14,047		Boeing/EPA
2-4	Maintenance materials		100% of maintenance lbr	$14,047		EPA
Utilities						
	Electricty	$0.06	per kwh	$45,202		Boeing
	Fuel	$9	per MMBtu	$232,184		Boeing
Total Direct Cost				$319,528		
Indirect Costs						
	Administrative charges	0.02	of total capital cost	$55,533		EPA
	property tax	0.01	of total capital cost	$27,766		EPA
	Insurance	0.01	of total capital cost	$27,766		EPA
Total Annual Costs Excluding Capital Recovery				$430,594		
	Capital recovery			$304,861		
	Interest		7.0%			Boeing
	Lifetime		15 years			Anguil
Total Annual Cost				$735,455		
Uncontrolled Emissions				10.78	lb/hr	
Control Efficiency				99%		Anguil
Emission Reduction				11.68	tons/year	
Cost Effectiveness				$62,956	$/ton	

References

EPA	EPA Capital Cost Factors for Thermal and Catalytic Incinerators EPA Air Pollution Control Cost Manual - Sixth Edition (EPA 452/B-02-001) Section 3 - VOC Controls Section 3.2 - VOC Destruction Controls Chapter 2 - Incinerators
Anguil	E-mail from Scott Bayon, Anguil, 03/10/11 and 03/14/11
Boeing	Boeing operating and maintenance labor cost = $102.63/hr Boeing projected natural gas = $9.30 per million Btu Boeing electricty cost = $0.06 per kwh

BACT Cost Estimation Spreadsheet

Inspar

Control Technology: Regenerative Thermal Oxidizer w/ Zeolite Concentrator - Anguil

Given Parameters

			Reference
Annual operating hours	2190	hrs	Boeing
Exhaust flow rate, Q	140,000	acfm	Boeing
Estimated uncontrolled emissions	11.8	tons/year	Boeing
Interest rate	10.5%		Boeing
Equipment lifetime	10	years	Anguil
Fuel requirement	4.0	MMBtu/hr	Anguil
Electricty requirement	180	kw	Anguil

Table 1. Capital Cost Estimate

		Cost	Reference
Purchased Equipment			
Basic equipment and auxillaries	A	$1,620,000	Anguil
Freight	.05A	$81,000	EPA
Sales Tax	9.5%	$161,595	
Total Purchased Equipment Cost	B	$1,862,595	
Direct Installation Cost			
Foundation and supports	.08B	$149,008	EPA
Erection and handling	.14B	$260,763	EPA
Electrical	.04B	$74,504	EPA
Piping	.02B	$37,252	EPA
Painting	.01B	$18,626	EPA
Insulation	.01B	$18,626	EPA
Building and site preparation not included			
Total Direct Installation Cost		$558,779	
Total Direct Cost		$2,421,374	
Indirect Cost			
Engineering and supervision	0.10B	$186,260	EPA
Construction and field expenses	0.05B	$93,130	EPA
Construction fee	0.10B	$186,260	EPA
Start-up	0.02B	$37,252	EPA
Performance test	0.01B	$18,626	EPA
Contingency	0.03B	$55,878	EPA
Total Indirect Cost		$577,404	
Total Capital Cost		**$2,998,778**	

BACT Cost Estimation Spreadsheet
Inspar

Control Technology: **Regenerative Thermal Oxidizer w/ Zeolite Concentrator - Anguil**

Table 2. Annual Cost

				Annual Cost		Reference
Direct Costs						
2-1	Operating labor		0.5 hrs/shift @ $102.63/hr	$14,047		Boeing/EPA
2-2	Supervisory labor		included in labor rate	$0		Boeing
2-3	Maintenance labor		0.5 hr/shift@$102.63/hr	$14,047		Boeing/EPA
2-4	Maintenance materials		100% of maintenance lbr	$14,047		EPA
Utilities						
	Electricty	$0.06	per kwh	$23,652		Boeing
	Fuel	$9	per MMBtu	$80,653		Boeing
Total Direct Cost				$146,448		
Indirect Costs						
	Administrative charges	0.02	of total capital cost	$59,976		EPA
	property tax	0.01	of total capital cost	$29,988		EPA
	Insurance	0.01	of total capital cost	$29,988		EPA
Total Annual Costs Excluding Capital Recovery				$266,399		
	Capital recovery			$498,569		
	Interest		10.5%			Boeing
	Lifetime		10 years			Anguil
Total Annual Cost				$764,968		
Uncontrolled Emissions				10.78	lb/hr	
Control Efficiency				95%		Anguil
Emission Reduction				11.21	tons/year	
Cost Effectiveness				$68,240	$/ton	

References

EPA	EPA Capital Cost Factors for Thermal and Catalytic Incinerators
	EPA Air Pollution Control Cost Manual - Sixth Edition (EPA 452/B-02-001)
	Section 3 - VOC Controls
	Section 3.2 - VOC Destruction Controls
	Chapter 2 - Incinerators
Anguil	E-mail from Jason Schueler, Anguil, 02/23/12
Boeing	Boeing capital project opportunity cost = 10.5%
	Boeing operating and maintenance labor cost = $102.63/hr
	Boeing projected natural gas = $9.30 per million Btu
	Boeing electricty cost = $0.06 per kwh

BACT Cost Estimation Spreadsheet
Inspar
Control Technology: Regenerative Thermal Oxidizer w/ Zeolite Concentrator - Anguil

Given Parameters

			Reference
Annual operating hours	2190	hrs	Boeing
Exhaust flow rate, Q	140,000	acfm	Boeing
Estimated uncontrolled emissions	11.8	tons/year	Boeing
Interest rate	7.0%		Ecology
Equipment lifetime	10	years	Anguil
Fuel requirement	4.0	MMBtu/hr	Anguil
Electricty requirement	180	kw	Anguil

Table 1. Capital Cost Estimate

		Cost	Reference
Purchased Equipment			
Basic equipment and auxillaries	A	$1,620,000	Anguil
Freight	.05A	$81,000	EPA
Sales Tax	9.5%	$161,595	
Total Purchased Equipment Cost	B	$1,862,595	
Direct Installation Cost			
Foundation and supports	.08B	$149,008	EPA
Erection and handling	.14B	$260,763	EPA
Electrical	.04B	$74,504	EPA
Piping	.02B	$37,252	EPA
Painting	.01B	$18,626	EPA
Insulation	.01B	$18,626	EPA
Building and site preparation not included			
Total Direct Installation Cost		$558,779	
Total Direct Cost		$2,421,374	
Indirect Cost			
Engineering and supervision	0.10B	$186,260	EPA
Construction and field expenses	0.05B	$93,130	EPA
Construction fee	0.10B	$186,260	EPA
Start-up	0.02B	$37,252	EPA
Performance test	0.01B	$18,626	EPA
Contingency	0.03B	$55,878	EPA
Total Indirect Cost		$577,404	
Total Capital Cost		**$2,998,778**	

BACT Cost Estimation Spreadsheet
Inspar

Control Technology: **Regenerative Thermal Oxidizer w/ Zeolite Concentrator - Anguil**

Table 2. Annual Cost

				Annual Cost		Reference
Direct Costs						
2-1	Operating labor		0.5 hrs/shift @ $102.63/hr	$14,047		Boeing/EPA
2-2	Supervisory labor		included in labor rate	$0		Boeing
2-3	Maintenance labor		0.5 hr/shift@$102.63/hr	$14,047		Boeing/EPA
2-4	Maintenance materials		100% of maintenance lbr	$14,047		EPA
Utilities						
	Electricty	$0.06	per kwh	$23,652		Boeing
	Fuel	$9	per MMBtu	$80,653		Boeing
Total Direct Cost				$146,448		
Indirect Costs						
	Administrative charges	0.02	of total capital cost	$59,976		EPA
	property tax	0.01	of total capital cost	$29,988		EPA
	Insurance	0.01	of total capital cost	$29,988		EPA
Total Annual Costs Excluding Capital Recovery				$266,399		
	Capital recovery			$426,959		
	Interest		7.0%			Boeing
	Lifetime		10 years			Anguil
Total Annual Cost				$693,357		
Uncontrolled Emissions				10.78	lb/hr	
Control Efficiency				95%		Anguil
Emission Reduction				11.21	tons/year	
Cost Effectiveness				$61,852	$/ton	

References

EPA	EPA Capital Cost Factors for Thermal and Catalytic Incinerators
	EPA Air Pollution Control Cost Manual - Sixth Edition (EPA 452/B-02-001)
	Section 3 - VOC Controls
	Section 3.2 - VOC Destruction Controls
	Chapter 2 - Incinerators
Anguil	E-mail from Jason Schueler, Anguil, 02/23/12
Boeing	
	Boeing operating and maintenance labor cost = $102.63/hr
	Boeing projected natural gas = $9.30 per million Btu
	Boeing electricty cost = $0.06 per kwh

APPENDIX D

Paint Hangar BACT Costs

BACT Cost Estimation Spreadsheet
New Paint Hangar
Control Technology: Thermal Oxidizer - Callidus w/o preheater

Given Parameters

			Reference
Annual operating hours	6264	hrs	Boeing
Exhaust flow rate, Q	165,000	acfm	Boeing
Estimated uncontrolled emissions	61	tons/year	Boeing
Interest rate	10.5%		Boeing
Equipment lifetime	15	years	Callidus
Fuel requirement	167.0	MMBtu/hr	Callidus
Electricty requirement	22	kw	Callidus

Table 1. Capital Cost Estimate

		Cost	Reference
Purchased Equipment			
Basic equipment and auxillaries	A	$750,000	Callidus
Freight	.05A	$37,500	EPA
Sales Tax	9.5%	$74,813	
Total Purchased Equipment Cost	B	$862,313	
Direct Installation Cost			
Foundation and supports	.08B	$68,985	EPA
Erection and handling	.14B	$120,724	EPA
Electrical	.04B	$34,493	EPA
Piping	.02B	$17,246	EPA
Painting	.01B	$8,623	EPA
Insulation	.01B	$8,623	EPA
Building and site preparation not included			
Total Direct Installation Cost		$258,694	
Total Direct Cost		$1,121,006	
Indirect Cost			
Engineering and supervision	0.10B	$86,231	EPA
Construction and field expenses	0.05B	$43,116	EPA
Construction fee	0.10B	$86,231	EPA
Start-up	0.02B	$17,246	EPA
Performance test	0.01B	$8,623	EPA
Contingency	0.03B	$25,869	EPA
Total Indirect Cost		$267,317	
Total Capital Cost		**$1,388,323**	

BACT Cost Estimation Spreadsheet
New Paint Hangar
Control Technology: Thermal Oxidizer - Callidus w/o preheater

Table 2. Annual Cost

				Annual Cost		Reference
Direct Costs						
2-1	Operating labor		0.5 hrs/shift @ $102.63/hr	$40,180		Boeing/EPA
2-2	Supervisory labor		included in labor rate	$0		Boeing
2-3	Maintenance labor		0.5 hr/shift@$102.63/hr	$40,180		Boeing/EPA
2-4	Maintenance materials		100% of maintenance lbr	$40,180		EPA
Utilities						
	Electricty	$0.06	per kwh	$8,268		Boeing
	Fuel	$9	per MMBtu	$9,728,618		Boeing
Total Direct Cost				$9,857,426		
Indirect Costs						
	Administrative charges	0.02	of total capital cost	$27,766		EPA
	property tax	0.01	of total capital cost	$13,883		EPA
	Insurance	0.01	of total capital cost	$13,883		EPA
Total Annual Costs Excluding Capital Recovery				$9,912,959		
	Capital recovery			$187,768		
	Interest		10.5%			Boeing
	Lifetime		15 years			Callidus
Total Annual Cost				$10,100,727		
Uncontrolled Emissions				19.48	lb/hr	
Control Efficiency				98%		Callidus
Emission Reduction				59.78	tons/year	
Cost Effectiveness				$168,965	$/ton	

References

EPA	EPA Capital Cost Factors for Thermal and Catalytic Incinerators
	EPA Air Pollution Control Cost Manual - Sixth Edition (EPA 452/B-02-001)
	Section 3 - VOC Controls
	Section 3.2 - VOC Destruction Controls
	Chapter 2 - Incinerators
Callidus	E-mail from Ania Guy, Callidus Technologies by Honeywell, 03/11/11
Boeing	Boeing capital project opportunity cost = 10.5%
	Boeing operating and maintenance labor cost = $102.63/hr
	Boeing projected natural gas = $9.30 per million Btu
	Boeing electricty cost = $0.06 per kwh

BACT Cost Estimation Spreadsheet
New Paint Hangar
Control Technology: Thermal Oxidizer - Callidus w/o preheater

Given Parameters

			Reference
Annual operating hours	6264	hrs	Boeing
Exhaust flow rate, Q	165,000	acfm	Boeing
Estimated uncontrolled emissions	61	tons/year	Boeing
Interest rate	7.0%		Ecology
Equipment lifetime	15	years	Callidus
Fuel requirement	167.0	MMBtu/hr	Callidus
Electricty requirement	22	kw	Callidus

Table 1. Capital Cost Estimate

		Cost	Reference
Purchased Equipment			
Basic equipment and auxillaries	A	$750,000	Callidus
Freight	.05A	$37,500	EPA
Sales Tax	9.5%	$74,813	
<u>Total Purchased Equipment Cost</u>	B	$862,313	
Direct Installation Cost			
Foundation and supports	.08B	$68,985	EPA
Erection and handling	.14B	$120,724	EPA
Electrical	.04B	$34,493	EPA
Piping	.02B	$17,246	EPA
Painting	.01B	$8,623	EPA
Insulation	.01B	$8,623	EPA
Building and site preparation not included			
<u>Total Direct Installation Cost</u>		$258,694	
<u>Total Direct Cost</u>		$1,121,006	
Indirect Cost			
Engineering and supervision	0.10B	$86,231	EPA
Construction and field expenses	0.05B	$43,116	EPA
Construction fee	0.10B	$86,231	EPA
Start-up	0.02B	$17,246	EPA
Performance test	0.01B	$8,623	EPA
Contingency	0.03B	$25,869	EPA
<u>Total Indirect Cost</u>		$267,317	
Total Capital Cost		**$1,388,323**	

BACT Cost Estimation Spreadsheet

New Paint Hangar

Control Technology: Thermal Oxidizer - Callidus w/o preheater

Table 2. Annual Cost

				Annual Cost		Reference
Direct Costs						
2-1	Operating labor		0.5 hrs/shift @ $102.63/hr	$40,180		Boeing/EPA
2-2	Supervisory labor		included in labor rate	$0		Boeing
2-3	Maintenance labor		0.5 hr/shift@$102.63/hr	$40,180		Boeing/EPA
2-4	Maintenance materials		100% of maintenance lbr	$40,180		EPA
Utilities						
	Electricty	$0.06	per kwh	$8,268		Boeing
	Fuel	$9	per MMBtu	$9,728,618		Boeing
Total Direct Cost				$9,857,426		
Indirect Costs						
	Administrative charges	0.02	of total capital cost	$27,766		EPA
	property tax	0.01	of total capital cost	$13,883		EPA
	Insurance	0.01	of total capital cost	$13,883		EPA
Total Annual Costs Excluding Capital Recovery				$9,912,959		
	Capital recovery			$152,430		
	Interest		7.0%			Boeing
	Lifetime		15 years			Callidus
Total Annual Cost				$10,065,389		
Uncontrolled Emissions				19.48	lb/hr	
Control Efficiency				98%		Callidus
Emission Reduction				59.78	tons/year	
Cost Effectiveness				$168,374	$/ton	

References

EPA	EPA Capital Cost Factors for Thermal and Catalytic Incinerators
	EPA Air Pollution Control Cost Manual - Sixth Edition (EPA 452/B-02-001)
	Section 3 - VOC Controls
	Section 3.2 - VOC Destruction Controls
	Chapter 2 - Incinerators
Callidus	E-mail from Ania Guy, Callidus Technologies by Honeywell, 03/11/11
Boeing	
	Boeing operating and maintenance labor cost = $102.63/hr
	Boeing projected natural gas = $9.30 per million Btu
	Boeing electricty cost = $0.06 per kwh

BACT Cost Estimation Spreadsheet
New Paint Hangar
Control Technology: Thermal Oxidizer w Preheater - John Zink

Given Parameters

			Reference
Annual operating hours	6264	hrs	Boeing
Exhaust flow rate, Q	165,000	acfm	Boeing
Estimated uncontrolled emissions	61	tons/year	Boeing
Interest rate	10.5%		Boeing
Equipment lifetime	20	years	John Zink
Fuel requirement	91.5	MMBtu/hr	John Zink
Electricty requirement	373	kw	John Zink

Table 1. Capital Cost Estimate

		Cost	Reference
Purchased Equipment			
Basic equipment and auxillaries	A	$2,500,000	John Zink
Freight	.05A	$125,000	EPA
Sales Tax	9.5%	$249,375	
<u>Total Purchased Equipment Cost</u>	B	$2,874,375	
Direct Installation Cost			
Foundation and supports	.08B	$229,950	EPA
Erection and handling	.14B	$402,413	EPA
Electrical	.04B	$114,975	EPA
Piping	.02B	$57,488	EPA
Painting	.01B	$28,744	EPA
Insulation	.01B	$28,744	EPA
Building and site preparation not included			
<u>Total Direct Installation Cost</u>		$862,313	
<u>Total Direct Cost</u>		$3,736,688	
Indirect Cost			
Engineering and supervision	0.10B	$287,438	EPA
Construction and field expenses	0.05B	$143,719	EPA
Construction fee	0.10B	$287,438	EPA
Start-up	0.02B	$57,488	EPA
Performance test	0.01B	$28,744	EPA
Contingency	0.03B	$86,231	EPA
<u>Total Indirect Cost</u>		$891,056	
Total Capital Cost		**$4,627,744**	

BACT Cost Estimation Spreadsheet
New Paint Hangar
Control Technology: Thermal Oxidizer w Preheater - John Zink

Table 2. Annual Cost

				Annual Cost		Reference
Direct Costs						
2-1	Operating labor		0.5 hrs/shift @ $102.63/hr	$40,180		Boeing/EPA
2-2	Supervisory labor		included in labor rate	$0		Boeing
2-3	Maintenance labor		0.5 hr/shift@$102.63/hr	$40,180		Boeing/EPA
2-4	Maintenance materials		100% of maintenance lbr	$40,180		EPA
Utilities						
	Electricty	$0.06	per kwh	$140,188		Boeing
	Fuel	$9.30	per MMBtu	$5,330,351		Boeing
Total Direct Cost				$5,591,078		
Indirect Costs						
	Administrative charges	0.02	of total capital cost	$92,555		EPA
	property tax	0.01	of total capital cost	$46,277		EPA
	Insurance	0.01	of total capital cost	$46,277		EPA
Total Annual Costs Excluding Capital Recovery				$5,776,188		
	Capital recovery			$562,240		
	Interest		10.5%			Boeing
	Lifetime		20 years			John Zink
Total Annual Cost				$6,338,428		
Uncontrolled Emissions				19.48	lb/hr	
Control Efficiency				99%		John Zink
Emission Reduction				60.39	tons/year	
Cost Effectiveness				$104,958	$/ton	

References

EPA	EPA Capital Cost Factors for Thermal and Catalytic Incinerators
	EPA Air Pollution Control Cost Manual - Sixth Edition (EPA 452/B-02-001)
	Section 3 - VOC Controls
	Section 3.2 - VOC Destruction Controls
	Chapter 2 - Incinerators
John Zink	E-mail from Carl Connally, John Zink, 03/08/11, 03/09/11 and 3/17/11.
Boeing	Boeing capital project opportunity cost = 10.5%
	Boeing operating and maintenance labor cost = $102.63/hr
	Boeing projected natural gas = $9.30 per million Btu
	Boeing electricty cost = $0.06 per kwh

BACT Cost Estimation Spreadsheet

New Paint Hangar

Control Technology: Thermal Oxidizer w Preheater - John Zink

Given Parameters

			Reference
Annual operating hours	6264	hrs	Boeing
Exhaust flow rate, Q	165,000	acfm	Boeing
Estimated uncontrolled emissions	61	tons/year	Boeing
Interest rate	7.0%		Boeing
Equipment lifetime	20	years	John Zink
Fuel requirement	91.5	MMBtu/hr	John Zink
Electricty requirement	373	kw	John Zink

Table 1. Capital Cost Estimate

		Cost	Reference
Purchased Equipment			
Basic equipment and auxillaries	A	$2,500,000	John Zink
Freight	.05A	$125,000	EPA
Sales Tax	9.5%	$249,375	
Total Purchased Equipment Cost	B	$2,874,375	
Direct Installation Cost			
Foundation and supports	.08B	$229,950	EPA
Erection and handling	.14B	$402,413	EPA
Electrical	.04B	$114,975	EPA
Piping	.02B	$57,488	EPA
Painting	.01B	$28,744	EPA
Insulation	.01B	$28,744	EPA
Building and site preparation not included			
Total Direct Installation Cost		$862,313	
Total Direct Cost		$3,736,688	
Indirect Cost			
Engineering and supervision	0.10B	$287,438	EPA
Construction and field expenses	0.05B	$143,719	EPA
Construction fee	0.10B	$287,438	EPA
Start-up	0.02B	$57,488	EPA
Performance test	0.01B	$28,744	EPA
Contingency	0.03B	$86,231	EPA
Total Indirect Cost		$891,056	
Total Capital Cost		**$4,627,744**	

BACT Cost Estimation Spreadsheet

New Paint Hangar

Control Technology: Thermal Oxidizer w Preheater - John Zink

Table 2. Annual Cost

				Annual Cost		Reference
Direct Costs						
2-1	Operating labor		0.5 hrs/shift @ $102.63/hr	$40,180		Boeing/EPA
2-2	Supervisory labor		included in labor rate	$0		Boeing
2-3	Maintenance labor		0.5 hr/shift@$102.63/hr	$40,180		Boeing/EPA
2-4	Maintenance materials		100% of maintenance lbr	$40,180		EPA
Utilities						
	Electricty	$0.06	per kwh	$140,188		Boeing
	Fuel	$9.30	per MMBtu	$5,330,351		Boeing
Total Direct Cost				$5,591,078		
Indirect Costs						
	Administrative charges	0.02	of total capital cost	$92,555		EPA
	property tax	0.01	of total capital cost	$46,277		EPA
	Insurance	0.01	of total capital cost	$46,277		EPA
Total Annual Costs Excluding Capital Recovery				$5,776,188		
	Capital recovery			$436,826		
	Interest		7.0%			Boeing
	Lifetime		20 years			John Zink
Total Annual Cost				$6,213,014		
Uncontrolled Emissions				19.48	lb/hr	
Control Efficiency				99%		John Zink
Emission Reduction				60.39	tons/year	
Cost Effectiveness				$102,882	$/ton	

References

EPA	EPA Capital Cost Factors for Thermal and Catalytic Incinerators
	EPA Air Pollution Control Cost Manual - Sixth Edition (EPA 452/B-02-001)
	Section 3 - VOC Controls
	Section 3.2 - VOC Destruction Controls
	Chapter 2 - Incinerators
John Zink	E-mail from Carl Connally, John Zink, 03/08/11, 03/09/11 and 3/17/11.
Boeing	
	Boeing operating and maintenance labor cost = $102.63/hr
	Boeing projected natural gas = $9.30 per million Btu
	Boeing electricty cost = $0.06 per kwh

BACT Cost Estimation Spreadsheet
New Paint Hangar
Control Technology: Thermal Oxidizer - Callidus w preheater

Given Parameters

			Reference
Annual operating hours	6264	hrs	Boeing
Exhaust flow rate, Q	165,000	acfm	Boeing
Estimated uncontrolled emissions	61	tons/year	Boeing
Interest rate	10.5%		Boeing
Equipment lifetime	15	years	Callidus
Fuel requirement	77.0	MMBtu/hr	Callidus
Electricty requirement	22	kw	Callidus

Table 1. Capital Cost Estimate

		Cost	Reference
Purchased Equipment			
Basic equipment and auxillaries	A	$1,500,000	Callidus
Freight	.05A	$75,000	EPA
Sales Tax	9.5%	$149,625	
Total Purchased Equipment Cost	B	$1,724,625	
Direct Installation Cost			
Foundation and supports	.08B	$137,970	EPA
Erection and handling	.14B	$241,448	EPA
Electrical	.04B	$68,985	EPA
Piping	.02B	$34,493	EPA
Painting	.01B	$17,246	EPA
Insulation	.01B	$17,246	EPA
Building and site preparation not included			
Total Direct Installation Cost		$517,388	
Total Direct Cost		$2,242,013	
Indirect Cost			
Engineering and supervision	0.10B	$172,463	EPA
Construction and field expenses	0.05B	$86,231	EPA
Construction fee	0.10B	$172,463	EPA
Start-up	0.02B	$34,493	EPA
Performance test	0.01B	$17,246	EPA
Contingency	0.03B	$51,739	EPA
Total Indirect Cost		$534,634	
Total Capital Cost		**$2,776,646**	

BACT Cost Estimation Spreadsheet

New Paint Hangar

Control Technology: Thermal Oxidizer - Callidus w preheater

Table 2. Annual Cost

				Annual Cost		Reference
Direct Costs						
2-1	Operating labor		0.5 hrs/shift @ $102.63/hr	$40,180		Boeing/EPA
2-2	Supervisory labor		included in labor rate	$0		Boeing
2-3	Maintenance labor		0.5 hr/shift@$102.63/hr	$40,180		Boeing/EPA
2-4	Maintenance materials		100% of maintenance lbr	$40,180		EPA
Utilities						
	Electricty	$0.06	per kwh	$8,268		Boeing
	Fuel	$9	per MMBtu	$4,485,650		Boeing
Total Direct Cost				$4,614,458		
Indirect Costs						
	Administrative charges	0.02	of total capital cost	$55,533		EPA
	property tax	0.01	of total capital cost	$27,766		EPA
	Insurance	0.01	of total capital cost	$27,766		EPA
Total Annual Costs Excluding Capital Recovery				$4,725,524		
	Capital recovery			$375,536		
	Interest		10.5%			Boeing
	Lifetime		15 years			Callidus
Total Annual Cost				$5,101,060		
Uncontrolled Emissions				19.48	lb/hr	
Control Efficiency				98%		Callidus
Emission Reduction				59.78	tons/year	
Cost Effectiveness				$85,331	$/ton	

References

EPA	EPA Capital Cost Factors for Thermal and Catalytic Incinerators
	EPA Air Pollution Control Cost Manual - Sixth Edition (EPA 452/B-02-001)
	Section 3 - VOC Controls
	Section 3.2 - VOC Destruction Controls
	Chapter 2 - Incinerators
Callidus	E-mail from Ania Guy, Callidus Technologies by Honeywell, 03/11/11
Boeing	Boeing capital project opportunity cost = 10.5%
	Boeing operating and maintenance labor cost = $102.63/hr
	Boeing projected natural gas = $9.30 per million Btu
	Boeing electricty cost = $0.06 per kwh

BACT Cost Estimation Spreadsheet
New Paint Hangar
Control Technology: Thermal Oxidizer - Callidus w preheater

Given Parameters

			Reference
Annual operating hours	6264	hrs	Boeing
Exhaust flow rate, Q	165,000	acfm	Boeing
Estimated uncontrolled emissions	61	tons/year	Boeing
Interest rate	7.0%		Ecology
Equipment lifetime	15	years	Callidus
Fuel requirement	77.0	MMBtu/hr	Callidus
Electricty requirement	22	kw	Callidus

Table 1. Capital Cost Estimate

			Cost	Reference
Purchased Equipment				
Basic equipment and auxillaries	A		$1,500,000	Callidus
Freight	.05A		$75,000	EPA
Sales Tax		9.5%	$149,625	
Total Purchased Equipment Cost	B		$1,724,625	
Direct Installation Cost				
Foundation and supports	.08B		$137,970	EPA
Erection and handling	.14B		$241,448	EPA
Electrical	.04B		$68,985	EPA
Piping	.02B		$34,493	EPA
Painting	.01B		$17,246	EPA
Insulation	.01B		$17,246	EPA
Building and site preparation not included				
Total Direct Installation Cost			$517,388	
Total Direct Cost			$2,242,013	
Indirect Cost				
Engineering and supervision	0.10B		$172,463	EPA
Construction and field expenses	0.05B		$86,231	EPA
Construction fee	0.10B		$172,463	EPA
Start-up	0.02B		$34,493	EPA
Performance test	0.01B		$17,246	EPA
Contingency	0.03B		$51,739	EPA
Total Indirect Cost			$534,634	
Total Capital Cost			**$2,776,646**	

BACT Cost Estimation Spreadsheet
New Paint Hangar
Control Technology: **Thermal Oxidizer - Callidus w preheater**

Table 2. Annual Cost

				Annual Cost		Reference
Direct Costs						
2-1	Operating labor		0.5 hrs/shift @ $102.63/hr	$40,180		Boeing/EPA
2-2	Supervisory labor		included in labor rate	$0		Boeing
2-3	Maintenance labor		0.5 hr/shift@$102.63/hr	$40,180		Boeing/EPA
2-4	Maintenance materials		100% of maintenance lbr	$40,180		EPA
Utilities						
	Electricty	$0.06	per kwh	$8,268		Boeing
	Fuel	$9	per MMBtu	$4,485,650		Boeing
Total Direct Cost				$4,614,458		
Indirect Costs						
	Administrative charges	0.02	of total capital cost	$55,533		EPA
	property tax	0.01	of total capital cost	$27,766		EPA
	Insurance	0.01	of total capital cost	$27,766		EPA
Total Annual Costs Excluding Capital Recovery				$4,725,524		
	Capital recovery			$304,861		
	Interest		7.0%			Boeing
	Lifetime		15 years			Callidus
Total Annual Cost				$5,030,384		
Uncontrolled Emissions				19.48	lb/hr	
Control Efficiency				98%		Callidus
Emission Reduction				59.78	tons/year	
Cost Effectiveness				$84,148	$/ton	

References

EPA	EPA Capital Cost Factors for Thermal and Catalytic Incinerators
	EPA Air Pollution Control Cost Manual - Sixth Edition (EPA 452/B-02-001)
	Section 3 - VOC Controls
	Section 3.2 - VOC Destruction Controls
	Chapter 2 - Incinerators
Callidus	E-mail from Ania Guy, Callidus Technologies by Honeywell, 03/11/11
Boeing	
	Boeing operating and maintenance labor cost = $102.63/hr
	Boeing projected natural gas = $9.30 per million Btu
	Boeing electricty cost = $0.06 per kwh

BACT Cost Estimation Spreadsheet
New Paint Hangar
Control Technology: Thermal Recovery Systems - Carbon Adsorption

Given Parameters

			Reference
Annual operating hours	2190	hrs	Boeing
Exhaust flow rate, Q	165,000	acfm	Boeing
Estimated uncontrolled emissions	61	tons/year	Boeing
Interest rate	10.5%		Boeing
Equipment lifetime	5	years	EPA
Fuel requirement	0.0	MMBtu/hr	TRS
Electricty requirement	149	kw	EPA

Table 1. Capital Cost Estimate

		Cost	Reference
Purchased Equipment			
Basic equipment and auxillaries	A	$118,700	TRS
Freight	.05A	$5,935	EPA
Sales Tax	9.5%	$11,840	
Total Purchased Equipment Cost	B	$136,475	
Direct Installation Cost			
Foundation and supports	.08B	$10,918	EPA
Erection and handling	.14B	$19,107	EPA
Electrical	.04B	$5,459	EPA
Piping	.02B	$2,730	EPA
Painting	.01B	$1,365	EPA
Insulation	.01B	$1,365	EPA
Building and site preparation not included			
Total Direct Installation Cost		$40,943	
Total Direct Cost		$177,418	
Indirect Cost			
Engineering	0.10B	$13,648	EPA
Construction and field expenses	0.05B	$6,824	EPA
Construction fee	0.10B	$13,648	EPA
Start-up	0.02B	$2,730	EPA
Performance test	0.01B	$1,365	EPA
Contingency	0.03B	$4,094	EPA
Total Indirect Cost		$42,307	
Total Capital Cost		**$219,725**	

BACT Cost Estimation Spreadsheet
Paint Hangar

Control Technology: **Thermal Recovery Systems - Carbon Adsorption**

Table 2. Annual Cost

				Annual Cost	Reference
Direct Costs					
2-1	Operating labor		0.5 hrs/shift @ $102.63/hr	$14,047	Boeing/EPA
2-2	Supervisory labor		included in labor rate	$0	Boeing
2-3	Maintenance labor		0.5 hr/shift@$102.63/hr	$14,047	Boeing/EPA
2-4	Maintenance materials		100% Maintenance Labor	$14,047	TRS
	Replacement Parts, Carbon		76 carbon swaps/yr		TRS
	Carbon Replacement Labor		21hr@$102.63/hr	$163,797	TRS/Boeing
	Carbon Replacement Costs		$83,328 per carbon swap	$6,332,928	TRS
Utilities					
	Electricty	$0.06	per kwh	$19,579	Boeing
	Fuel	$9.30	per MMBtu	$0	Boeing
Total Direct Cost				$6,558,447	
Indirect Costs					
	Administrative charges	0.02	of total capital cost	$4,395	EPA
	property tax	0.01	of total capital cost	$2,197	EPA
	Insurance	0.01	of total capital cost	$2,197	EPA
Total Annual Costs Excluding Capital Recovery				$6,567,236	
	Capital recovery			$58,705	
	Interest		10.5%		Boeing
	Lifetime		5 years		EPA
Total Annual Cost				$6,625,941	
Uncontrolled Emissions				55.71 lb/hr	
Control Efficiency				95%	TRS
Emission Reduction				57.95 tons/year	
Cost Effectiveness				$114,339 $/ton	

Assumptions
Carbon Replacement Labor Time Calculation:
1 units * 84 Filter Banks * 15 minutes swap time per filter bank = 21 hours of labor time per carbon swap
15 minutes swap time per filter bank from Phil Chapman

Number of Carbon Swaps

	Quantity	UOM
Carbon per filter	6	lbs
filters per bank	16	ea
filter banks per booth	84	ea
lbs of carbon per booth	8064	lb of carbon/booth
VOC adsorption rate[1]	0.2	lb of VOC/lb of carbon
VOC adsorption capacity	1612.8	lb of VOC/booth
VOC adsorption capacity	0.8064	tons of VOC /booth
VOC emissions	61	tpy
Carbon swaps per year	75.6	carbon swaps per year per booth

[1] Reference: Island Clean Air website, 'Activated Carbon Explained', accessed 3/2/2012,
http://www.islandcleanair.com/pdf/Activated%20Carbon%20Explained.pdf

References

EPA	EPA Capital Cost Factors for Thermal and Catalytic Incinerators
	EPA Air Pollution Control Cost Manual - Sixth Edition (EPA 452/B-02-001)
	Section 3 - VOC Controls
	Section 3.1 - VOC Recapture Controls
	Section 3.1 Carbon Adsorbers
TRS	E-mail from Phil Chapman, Thermal Recovery Systems, Inc. 02/17/12
Boeing	Boeing capital project opportunity cost = 10.5%
	Boeing operating and maintenance labor cost = $102.63/hr
	Boeing projected natural gas = $9.30 per million Btu
	Boeing electricty cost = $0.06 per kwh

BACT Cost Estimation Spreadsheet
New Paint Hangar
Control Technology: Thermal Recovery Systems - Carbon Adsorption

Given Parameters

			Reference
Annual operating hours	2190	hrs	Boeing
Exhaust flow rate, Q	165,000	acfm	Boeing
Estimated uncontrolled emissions	61	tons/year	Boeing
Interest rate	7.0%		Ecology
Equipment lifetime	5	years	EPA
Fuel requirement	0.0	MMBtu/hr	TRS
Electricty requirement	149	kw	EPA

Table 1. Capital Cost Estimate

		Cost	Reference
Purchased Equipment			
Basic equipment and auxillaries	A	$118,700	TRS
Freight	.05A	$5,935	EPA
Sales Tax	9.5%	$11,840	
Total Purchased Equipment Cost	B	$136,475	
Direct Installation Cost			
Foundation and supports	.08B	$10,918	EPA
Erection and handling	.14B	$19,107	EPA
Electrical	.04B	$5,459	EPA
Piping	.02B	$2,730	EPA
Painting	.01B	$1,365	EPA
Insulation	.01B	$1,365	EPA
Building and site preparation not included			
Total Direct Installation Cost		$40,943	
Total Direct Cost		$177,418	
Indirect Cost			
Engineering	0.10B	$13,648	EPA
Construction and field expenses	0.05B	$6,824	EPA
Construction fee	0.10B	$13,648	EPA
Start-up	0.02B	$2,730	EPA
Performance test	0.01B	$1,365	EPA
Contingency	0.03B	$4,094	EPA
Total Indirect Cost		$42,307	
Total Capital Cost		**$219,725**	

BACT Cost Estimation Spreadsheet
Paint Hangar

Control Technology: **Thermal Recovery Systems - Carbon Adsorption**

Table 2. Annual Cost

				Annual Cost	Reference
Direct Costs					
2-1	Operating labor		0.5 hrs/shift @ $102.63/hr	$14,047	Boeing/EPA
2-2	Supervisory labor		included in labor rate	$0	Boeing
2-3	Maintenance labor		0.5 hr/shift@$102.63/hr	$14,047	Boeing/EPA
2-4	Maintenance materials		100% Maintenance Labor	$14,047	TRS
	Replacement Parts, Carbon		76 carbon swaps/yr		TRS
	Carbon Replacement Labor		21hr@$102.63/hr	$163,797	TRS/Boeing
	Carbon Replacement Costs		$83,328 per carbon swap	$6,332,928	TRS
Utilities					
	Electricty	$0.06	per kwh	$19,579	Boeing
	Fuel	$9.30	per MMBtu	$0	Boeing
Total Direct Cost				$6,558,447	
Indirect Costs					
	Administrative charges	0.02	of total capital cost	$4,395	EPA
	property tax	0.01	of total capital cost	$2,197	EPA
	Insurance	0.01	of total capital cost	$2,197	EPA
Total Annual Costs Excluding Capital Recovery				$6,567,236	
	Capital recovery			$53,589	
	Interest		7.0%		Boeing
	Lifetime		5 years		EPA
Total Annual Cost				$6,620,824	
Uncontrolled Emissions				55.71 lb/hr	
Control Efficiency				95%	TRS
Emission Reduction				57.95 tons/year	
Cost Effectiveness				$114,251 $/ton	

Assumptions

Carbon Replacement Labor Time Calculation:
1 units * 84 Filter Banks * 15 minutes swap time per filter bank = 21 hours of labor time per carbon swap
15 minutes swap time per filter bank from Phil Chapman

Number of Carbon Swaps

	Quantity	UOM
Carbon per filter	6	lbs
filters per bank	16	ea
filter banks per booth	84	ea
lbs of carbon per booth	8064	lb of carbon/booth
VOC adsorption rate[1]	0.2	lb of VOC/lb of carbon
VOC adsorption capacity	1612.8	lb of VOC/booth
VOC adsorption capacity	0.8064	tons of VOC /booth
VOC emissions	61	tpy
Carbon swaps per year	75.6	carbon swaps per year per booth

[1] Reference: Island Clean Air website, 'Activated Carbon Explained', accessed 3/2/2012,
http://www.islandcleanair.com/pdf/Activated%20Carbon%20Explained.pdf

References

EPA
EPA Capital Cost Factors for Thermal and Catalytic Incinerators
EPA Air Pollution Control Cost Manual - Sixth Edition (EPA 452/B-02-001)
Section 3 - VOC Controls
Section 3.1 - VOC Recapture Controls
Section 3.1 Carbon Adsorbers

TRS
E-mail from Phil Chapman, Thermal Recovery Systems, Inc. 02/17/12

Boeing
Boeing operating and maintenance labor cost = $102.63/hr
Boeing projected natural gas = $9.30 per million Btu
Boeing electricty cost = $0.06 per kwh

BACT Cost Estimation Spreadsheet
New Paint Hangar
Control Technology: Regenerative Thermal Oxidizer - Anguil

Given Parameters

			Reference
Annual operating hours	6264	hrs	Boeing
Exhaust flow rate, Q	165,000	acfm	Boeing
Estimated uncontrolled emissions	61	tons/year	Boeing
Interest rate	10.5%		Boeing
Equipment lifetime	15	years	Anguil
Fuel requirement	11.4	MMBtu/hr	Anguil
Electricty requirement	344	kw	Anguil

Table 1. Capital Cost Estimate

		Cost	Reference
Purchased Equipment			
Basic equipment and auxillaries	A	$1,500,000	Anguil
Freight	.05A	$75,000	EPA
Sales Tax	9.5%	$149,625	
Total Purchased Equipment Cost	B	$1,724,625	
Direct Installation Cost			
Foundation and supports	.08B	$137,970	EPA
Erection and handling	.14B	$241,448	EPA
Electrical	.04B	$68,985	EPA
Piping	.02B	$34,493	EPA
Painting	.01B	$17,246	EPA
Insulation	.01B	$17,246	EPA
Building and site preparation		$380,000	
Total Direct Installation Cost		$897,388	
Total Direct Cost		$2,622,013	
Indirect Cost			
Engineering and supervision	0.10B	$172,463	EPA
Construction and field expenses	0.05B	$86,231	EPA
Construction fee	0.10B	$172,463	EPA
Start-up	0.02B	$34,493	EPA
Performance test	0.01B	$17,246	EPA
Contingency	0.03B	$51,739	EPA
Total Indirect Cost		$534,634	
Total Capital Cost		**$3,156,646**	

BACT Cost Estimation Spreadsheet
New Paint Hangar
Control Technology: Regenerative Thermal Oxidizer - Anguil

Table 2. Annual Cost

				Annual Cost	Reference
Direct Costs					
2-1	Operating labor		0.5 hrs/shift @ $102.63/hr	$40,180	Boeing/EPA
2-2	Supervisory labor		included in labor rate	$0	Boeing
2-3	Maintenance labor		0.5 hr/shift@$102.63/hr	$40,180	Boeing/EPA
2-4	Maintenance materials		100% of maintenance lbr	$40,180	EPA
Utilities					
	Electricty	$0.06	per kwh	$129,289	Boeing
	Fuel	$9	per MMBtu	$664,109	Boeing
Total Direct Cost				$913,937	
Indirect Costs					
	Administrative charges	0.02	of total capital cost	$63,133	EPA
	property tax	0.01	of total capital cost	$31,566	EPA
	Insurance	0.01	of total capital cost	$31,566	EPA
Total Annual Costs Excluding Capital Recovery				$1,040,203	
	Capital recovery			$426,930	
	Interest		10.5%		Boeing
	Lifetime		15 years		Anguil
Total Annual Cost				$1,467,133	
Uncontrolled Emissions				19.48 lb/hr	
Control Efficiency				99%	Anguil
Emission Reduction				60.39 tons/year	
Cost Effectiveness				$24,294 $/ton	

References

EPA	EPA Capital Cost Factors for Thermal and Catalytic Incinerators
	EPA Air Pollution Control Cost Manual - Sixth Edition (EPA 452/B-02-001)
	Section 3 - VOC Controls
	Section 3.2 - VOC Destruction Controls
	Chapter 2 - Incinerators
Anguil	E-mail from Scott Bayon, Anguil, 03/10/11 and 03/14/11
Boeing	Boeing capital project opportunity cost = 10.5%
	Boeing operating and maintenance labor cost = $102.63/hr
	Boeing projected natural gas = $9.30 per million Btu
	Boeing electricty cost = $0.06 per kwh

BACT Cost Estimation Spreadsheet
New Paint Hangar
Control Technology: Regenerative Thermal Oxidizer - Anguil

Given Parameters

			Reference
Annual operating hours	6264	hrs	Boeing
Exhaust flow rate, Q	165,000	acfm	Boeing
Estimated uncontrolled emissions	61	tons/year	Boeing
Interest rate	7.0%		Ecology
Equipment lifetime	15	years	Anguil
Fuel requirement	11.4	MMBtu/hr	Anguil
Electricty requirement	344	kw	Anguil

Table 1. Capital Cost Estimate

		Cost	Reference
Purchased Equipment			
Basic equipment and auxillaries	A	$1,500,000	Anguil
Freight	.05A	$75,000	EPA
Sales Tax	9.5%	$149,625	
Total Purchased Equipment Cost	B	$1,724,625	
Direct Installation Cost			
Foundation and supports	.08B	$137,970	EPA
Erection and handling	.14B	$241,448	EPA
Electrical	.04B	$68,985	EPA
Piping	.02B	$34,493	EPA
Painting	.01B	$17,246	EPA
Insulation	.01B	$17,246	EPA
Building and site preparation		$380,000	
Total Direct Installation Cost		$897,388	
Total Direct Cost		$2,622,013	
Indirect Cost			
Engineering and supervision	0.10B	$172,463	EPA
Construction and field expenses	0.05B	$86,231	EPA
Construction fee	0.10B	$172,463	EPA
Start-up	0.02B	$34,493	EPA
Performance test	0.01B	$17,246	EPA
Contingency	0.03B	$51,739	EPA
Total Indirect Cost		$534,634	
Total Capital Cost		**$3,156,646**	

BACT Cost Estimation Spreadsheet

New Paint Hangar

Control Technology: **Regenerative Thermal Oxidizer - Anguil**

Table 2. Annual Cost

				Annual Cost		Reference
Direct Costs						
2-1	Operating labor		0.5 hrs/shift @ $102.63/hr	$40,180		Boeing/EPA
2-2	Supervisory labor		included in labor rate	$0		Boeing
2-3	Maintenance labor		0.5 hr/shift@$102.63/hr	$40,180		Boeing/EPA
2-4	Maintenance materials		100% of maintenance lbr	$40,180		EPA
Utilities						
	Electricty	$0.06	per kwh	$129,289		Boeing
	Fuel	$9	per MMBtu	$664,109		Boeing
Total Direct Cost				$913,937		
Indirect Costs						
	Administrative charges	0.02	of total capital cost	$63,133		EPA
	property tax	0.01	of total capital cost	$31,566		EPA
	Insurance	0.01	of total capital cost	$31,566		EPA
Total Annual Costs Excluding Capital Recovery				$1,040,203		
	Capital recovery			$346,583		
	Interest		7.0%			Boeing
	Lifetime		15 years			Anguil
Total Annual Cost				$1,386,786		
Uncontrolled Emissions				19.48	lb/hr	
Control Efficiency				99%		Anguil
Emission Reduction				60.39	tons/year	
Cost Effectiveness				$22,964	$/ton	

References

EPA — EPA Capital Cost Factors for Thermal and Catalytic Incinerators
EPA Air Pollution Control Cost Manual - Sixth Edition (EPA 452/B-02-001)
Section 3 - VOC Controls
Section 3.2 - VOC Destruction Controls
Chapter 2 - Incinerators

Anguil — E-mail from Scott Bayon, Anguil, 03/10/11 and 03/14/11

Boeing

Boeing operating and maintenance labor cost = $102.63/hr
Boeing projected natural gas = $9.30 per million Btu
Boeing electricty cost = $0.06 per kwh

BACT Cost Estimation Spreadsheet

New Paint Hangar

Control Technology: Regenerative Thermal Oxidizer w/ Zeolite Concentrator - Anguil

Given Parameters

			Reference
Annual operating hours	6264	hrs	Boeing
Exhaust flow rate, Q	165,000	acfm	Boeing
Estimated uncontrolled emissions	61	tons/year	Boeing
Interest rate	10.5%		Boeing
Equipment lifetime	10	years	Anguil
Fuel requirement	4.4	MMBtu/hr	Anguil
Electricty requirement	182	kw	Anguil

Table 1. Capital Cost Estimate

		Cost	Reference
Purchased Equipment			
Basic equipment and auxillaries	A	$1,725,000	Anguil
Freight	.05A	$86,250	EPA
Sales Tax	9.5%	$172,069	
Total Purchased Equipment Cost	B	$1,983,319	
Direct Installation Cost			
Foundation and supports	.08B	$158,666	EPA
Erection and handling	.14B	$277,665	EPA
Electrical	.04B	$79,333	EPA
Piping	.02B	$39,666	EPA
Painting	.01B	$19,833	EPA
Insulation	.01B	$19,833	EPA
Building and site preparation		$380,000	CH2M HILL
Total Direct Installation Cost		$974,996	
Total Direct Cost		$2,958,314	
Indirect Cost			
Engineering and supervision	0.10B	$198,332	EPA
Construction and field expenses	0.05B	$99,166	EPA
Construction fee	0.10B	$198,332	EPA
Start-up	0.02B	$39,666	EPA
Performance test	0.01B	$19,833	EPA
Contingency	0.03B	$59,500	EPA
Total Indirect Cost		$614,829	
Total Capital Cost		**$3,573,143**	

BACT Cost Estimation Spreadsheet
New Paint Hangar
Control Technology: **Regenerative Thermal Oxidizer w/ Zeolite Concentrator - Anguil**

Table 2. Annual Cost

				Annual Cost		Reference
Direct Costs						
2-1	Operating labor		0.5 hrs/shift @ $102.63/hr	$40,180		Boeing/EPA
2-2	Supervisory labor		included in labor rate	$0		Boeing
2-3	Maintenance labor		0.5 hr/shift@$102.63/hr	$40,180		Boeing/EPA
2-4	Maintenance materials		100% of maintenance lbr	$40,180		EPA
Utilities						
	Electricty	$0.06	per kwh	$68,403		Boeing
	Fuel	$9	per MMBtu	$256,323		Boeing
Total Direct Cost				$445,265		
Indirect Costs						
	Administrative charges	0.02	of total capital cost	$71,463		EPA
	property tax	0.01	of total capital cost	$35,731		EPA
	Insurance	0.01	of total capital cost	$35,731		EPA
Total Annual Costs Excluding Capital Recovery				$588,190		
	Capital recovery			$594,061		
	Interest		10.5%			Boeing
	Lifetime		10 years			Anguil
Total Annual Cost				$1,182,252		
Uncontrolled Emissions				19.48	lb/hr	
Control Efficiency				95%		Anguil
Emission Reduction				57.95	tons/year	
Cost Effectiveness				$20,401	$/ton	

References

EPA	EPA Capital Cost Factors for Thermal and Catalytic Incinerators
	EPA Air Pollution Control Cost Manual - Sixth Edition (EPA 452/B-02-001)
	Section 3 - VOC Controls
	Section 3.2 - VOC Destruction Controls
	Chapter 2 - Incinerators
Anguil	E-mail from Jason Schueler, Anguil, 02/23/12
Boeing	Boeing capital project opportunity cost = 10.5%
	Boeing operating and maintenance labor cost = $102.63/hr
	Boeing projected natural gas = $9.30 per million Btu
	Boeing electricty cost = $0.06 per kwh

BACT Cost Estimation Spreadsheet
New Paint Hangar
Control Technology: Regenerative Thermal Oxidizer w/ Zeolite Concentrator - Anguil

Given Parameters

			Reference
Annual operating hours	6264	hrs	Boeing
Exhaust flow rate, Q	165,000	acfm	Boeing
Estimated uncontrolled emissions	61	tons/year	Boeing
Interest rate	7.0%		Ecology
Equipment lifetime	10	years	Anguil
Fuel requirement	4.4	MMBtu/hr	Anguil
Electricty requirement	182	kw	Anguil

Table 1. Capital Cost Estimate

		Cost	Reference
Purchased Equipment			
Basic equipment and auxillaries	A	$1,725,000	Anguil
Freight	.05A	$86,250	EPA
Sales Tax	9.5%	$172,069	
Total Purchased Equipment Cost	B	$1,983,319	
Direct Installation Cost			
Foundation and supports	.08B	$158,666	EPA
Erection and handling	.14B	$277,665	EPA
Electrical	.04B	$79,333	EPA
Piping	.02B	$39,666	EPA
Painting	.01B	$19,833	EPA
Insulation	.01B	$19,833	EPA
Building and site preparation		$380,000	CH2M HILL
Total Direct Installation Cost		$974,996	
Total Direct Cost		$2,958,314	
Indirect Cost			
Engineering and supervision	0.10B	$198,332	EPA
Construction and field expenses	0.05B	$99,166	EPA
Construction fee	0.10B	$198,332	EPA
Start-up	0.02B	$39,666	EPA
Performance test	0.01B	$19,833	EPA
Contingency	0.03B	$59,500	EPA
Total Indirect Cost		$614,829	
Total Capital Cost		**$3,573,143**	

BACT Cost Estimation Spreadsheet
New Paint Hangar
Control Technology: **Regenerative Thermal Oxidizer w/ Zeolite Concentrator - Anguil**

Table 2. Annual Cost

				Annual Cost		Reference
Direct Costs						
2-1	Operating labor		0.5 hrs/shift @ $102.63/hr	$40,180		Boeing/EPA
2-2	Supervisory labor		included in labor rate	$0		Boeing
2-3	Maintenance labor		0.5 hr/shift@$102.63/hr	$40,180		Boeing/EPA
2-4	Maintenance materials		100% of maintenance lbr	$40,180		EPA
Utilities						
	Electricty	$0.06	per kwh	$68,403		Boeing
	Fuel	$9	per MMBtu	$256,323		Boeing
Total Direct Cost				$445,265		
Indirect Costs						
	Administrative charges	0.02	of total capital cost	$71,463		EPA
	property tax	0.01	of total capital cost	$35,731		EPA
	Insurance	0.01	of total capital cost	$35,731		EPA
Total Annual Costs Excluding Capital Recovery				$588,190		
	Capital recovery			$508,735		
	Interest		7.0%			Boeing
	Lifetime		10 years			Anguil
Total Annual Cost				$1,096,926		
Uncontrolled Emissions				19.48	lb/hr	
Control Efficiency				95%		Anguil
Emission Reduction				57.95	tons/year	
Cost Effectiveness				$18,929	$/ton	

References

EPA — EPA Capital Cost Factors for Thermal and Catalytic Incinerators
EPA Air Pollution Control Cost Manual - Sixth Edition (EPA 452/B-02-001)
Section 3 - VOC Controls
Section 3.2 - VOC Destruction Controls
Chapter 2 - Incinerators

Anguil — E-mail from Jason Schueler, Anguil, 02/23/12

Boeing

Boeing operating and maintenance labor cost = $102.63/hr
Boeing projected natural gas = $9.30 per million Btu
Boeing electricty cost = $0.06 per kwh

APPENDIX E

Detailed Emission Calculations

Baseline Emissions

Table E-1 shows the 2009 and 2010 volatile organic compound (VOC) emissions for each activity for the Boeing Renton site.

TABLE E-1
Baseline VOC Emissions (tons per year [tpy])

	2009	2010	Average Baseline
Wing Assembly	61.6	62.2	61.9
Wing Coating	59.0	93.1	76.0
Final Assembly	14.2	14.4	14.3
4-41 Paint Hangar	28.0	40.0	34.0
4-42/Flightline	2.3	2.1	2.2
Combustion	0.9	0.9	0.9
Total	165.9	212.6	189.3
Airplane production	372	376	374.0

Note that the average baseline wing coating emissions include emissions from applying corrosion-inhibiting compound (CIC) coatings to the wings. Boeing is proposing to move that operation to three new booths in the same building. Because the existing booths will continue to have the ability to be used for CIC coating application, the baseline emissions for wing coating operations do not need to be adjusted.

Projected Actual Total Emissions for Option 1

Boeing proposes to increase airplane production. This increase will be made possible in part by de-bottlenecking existing operations. The project's actual emission for existing emission units is the maximum annual rate, in tons per year, at which an existing emissions unit is projected to emit a regulated NSR pollutant in any one of the 5 years (12-month period) following the date the unit resumes regular operation after the project, or in any one of the 10 years following that date, if the project involves increasing the emissions unit's design capacity or its potential to emit that regulated NSR pollutant and full utilization of the unit would result in a significant emissions increase or a significant net emissions increase at the major stationary source, 40 CFR 52.21 (b)(41)(ii)(*a*). However, 40 CFR 52.21(b)(41)(ii)(*d*) also allows the use of the emissions unit's potential to emit, in tons per year, as defined at 40 CFR 52.21 (b)(4). Boeing Renton has existing PSD permit conditions limiting its VOC emissions in tons per year, and therefore those limits are used in calculating the projected actual emissions (Table E-2). The wing coating operations are in Building 4-86 and have a PSD limit of 242 tons of VOCs per year (PSD-97-2 Condition 2). In Building 4-86, as part of this project, Boeing is proposing to install three new Dinol CIC booths and modify three booths currently used for CIC to become vertical wing paint booths. Boeing is also proposing to install one new vertical wing paint booth in Building 4-86. Under the Hybrid Test for projects that involve multiple types of emission units, new units and existing units are treated separately. Therefore, to account for the emissions from the new booths that would be installed in Building 4-86 and subject to the 242 tpy limit, potential emissions from those new units (12.6 tpy for the Dinol CIC booths and 11.8 tpy for the new vertical wing booth) were subtracted from the 242 tpy limit (242 - 12.6 - 11.8 = 217.6).

The projected total emissions from the other de-bottlenecked activities were calculated by multiplying the baseline emissions by the ratio of increased production and shown in Table E-2.

TABLE E-2
Projected Actual VOC Emissions from Existing Emissions Units (tpy)

	Average Baseline	Projected Total	New Emission Units	Adjusted Projected Actual
Wing Assembly	61.9	125.1		125.1
Wing Coating	76.0	242[a]	24.4	217.6
Final Assembly	14.3	28.9		28.9
4-41 Paint Hangar	34.0	49.3		49.3
5-50 Paint Hangar		40.8*		40.8
4-42/Flightline	2.2	4.4		4.4
Combustion	0.9	1.8		1.8
Total	189.3	492.3	36.3	467.9

[a] Existing PSD emissions limits that are not being proposed to change.

Note that the projected emissions assume most of the final decorative exterior coating will be applied at the Renton facility. However, some of the planes will be flown offsite for final exterior coating.

Potential VOC Emissions from New Vertical Wing Booths

Boeing proposes to add up to three wing booths to be used for vertical coating operations, one under Option 1 and three under Option 2. The tops and bottoms of wing assembles will be cleaned, sealed, and coated in vertical wing booths. The new vertical wing booths will have the capacity of painting one wing per day, 365 wings per year. Table E-3 shows the estimated potential VOC emissions from each booth.

TABLE E-3

Potential VOC Emissions from New or Modified Vertical Wing Booth

Number of Booths	1
Number of Planes/yr	182.5
Wings/Booth/yr	365
Spray Time hr/wing	8
Spray Time hr/booth/yr	2,920

	Gallons/Airplane	lb VOC/gallon	lb VOC/Plane
BMS 10-79 GD (10P20-44) Primer	2.5	2.3	5.75
BMS 5-95 Spray Seal	6	4.4	26.4
BMS 10-60 Enamel	8	3.5	28
Total			60.15

	Gallons/Airplane	lb VOC/gallon	Fraction Emitted	lb VOC/Plane
B90 Semi-aqueous Cleaner	24	3.2	0.2	15.4
Gun and Line Cleaning	20	7	0.2	28.0
Total				43.4

	Painting	Cleaning	Total
Total VOC (lb/airplane)	60.2	43.4	104
Total VOC (tons per airplane)	0.03	0.02	0.05
Total VOC (lb/booth-yr)	10,977	7,913	18,891
Total VOC (tons per booth-yr)	5.49	3.96	9.45
Adjustment for changes in paints and wings, 25% (tons/booth-yr)	6.86	4.95	11.81

Boeing is proposing to construct up to three new CIC booths in Building 4-86. CIC is applied to surfaces of the wing to prevent corrosion. The new and modified CIC booths will have the capacity of painting as many as one wing per shift. Table E-4 shows the estimated potential VOC emissions from each booth.

TABLE E-4
Potential VOC Emissions from Dinol CIC Booths

Number of Booths			3
Number of Planes/yr			1,642.5
Wings/Booth-yr			1,095
Spray time hr/wing			8
Spray time hr/booth-yr			8,760
			lb VOC/Plane
Dinol (CIC)			12.27
Total			12.27
	lb VOC	**Planes**	**lb VOC/Plane**
Gun and Line Cleaning	N/A	N/A	N/A
	Painting	**Cleaning**	**Total**
Total VOC (lbs/airplane)	12.27	0	12.27
Total VOC (tons per airplane)	0.0061	0	.00061
Total VOC (lbs/booth-yr)	6,720	0	6,720
Total VOC (tons per booth-yr)	3.36	0	3.36
Adjustment for changes in paints and wings, 25% (tons/booth-yr)	4.20	0	4.20
Total for 3 booths (tons/yr)			12.6

Combustion Emissions

Baseline emissions for the combustion sources were based on the fuel consumption for 2008 and 2009 and either EPA emission factors or permit limits (Table E-5).

To estimate the future actual combustion emissions, first the amount of heat used to manufacture each airplane was determined. As shown in Table E-6, the most natural gas used in the last 5 years occurred in 2006. That was divided by the number of airplanes produced in 2006, 302, to determine the heat input for each plane, 1,209 million British thermal units (MMBtu) per plane, from natural gas.

Based on the 2009 average gas usage of 873 MMBtu/plane and a project actual production, a total projected heat input of natural gas of 660,281 MMBtu/yr was projected (Table E-7). Renton uses some boilers that have capacities of less than 100 MMBtu/hr and some boilers have capacities of greater than 100 MMBtu/hr. The emission factors for each are different. To account for the difference between boiler sizes, the historical percentages of 28 percent of the heat input going to the smaller boilers and 72 percent going to the larger boiler were assumed.

TABLE E-5
Baseline Combustion Emissions

Combustion Emission Calculations										
	Factors									
Total Gas Used in Baseline Period:			6.63E+05	MMBtu/ 2-yr		3.32E+05	MMBtu/yr			
Gas Used in Boilers 1-3 in Baseline Period:			1.88E+05	MMBtu/ 2-yr		9.38E+04	MMBtu/yr	28%		
Gas Used in Boilers 4-6 in Baseline Period:			4.76E+05	MMBtu/ 2-yr		2.38E+05	MMBtu/yr	72%		
Total Oil Used in Baseline Period:			9954	Gal/2-yr		4.977	1000 Gal/yr	140	MMBtu/1000 gal	
Baseline										
			CO	NOx <100 MMBtu	NOx > 100 MMBtu	NOx Total	PM	SO2	Lead	VOC
Gas	Emission Factor	lb/MMBtu (AP-42)	0.08	0.031	0.275		0.0075	0.00059	4.90E-07	0.00539
	Emissions	Ton/yr	13.26	1.47	32.63	34.10	1.24	0.10	0.0001	0.89
Oil	Emission Factor	lb/1000 gal (lb/MMBtu of GHG)	5	19	14		3.3	7.385	0.00126	0.2
	Emissions	Ton/yr	0.01	0.05	0.03	0.08	0.01	0.02	0.0000	0.00
	Total Baseline	Tons/yr	13.27	1.52	32.67	34.19	1.25	0.12	0.0001	0.89

TABLE E-6
Combustion Fuel Usage

Year	Oil #6 (gal)	Oil #2 (gal)	Natural Gas 10-100 MMBtu/Hr (1,000 Therms)	Natural Gas < 10 MMBtu/Hr (1,000 Therms)	Natural Gas > 100 MMBtu/Hr (1,000 Therms)	Total Oil (MMBtu)	Total Gas (MMBtu)	Gas (MMBtu/plane)
2002		-	594	32	4,358	-	498,400	1,994
2003	800	60	452	22	3,318	120	379,200	2,084
2004	31,548	200	431	20	3,159	4,445	361,000	1,695
2005	16,000	00	403		2,743	2,310	314,600	1,470
2006	12,000	500	1,373		2,277	1,750	365,000	1,209
2007	16,312		1,361		2,082	2,284	344,300	1,043
2008	4,743	57	820		2,561	672	338,100	1,166
2009	5,154		1,055		2,194	722	324,900	873

Similarly, 2007 used the most oil in the last 5 years, 16,312 gallons. To conservatively estimate the maximum oil burned in the future, this amount was doubled, to 32,620 gallons. The same 28:72 percent split between the small and large boilers was assumed to calculate the projected actual emissions from combustion.

These estimates of projected emissions are likely overestimates because most of the heat generated at the Renton facility goes to space heating and other activities that are not directly proportional to airplane production.

TABLE E-7
Projected Actual Combustion Emissions

			Gas			Oil increase:				Fraction of fuel burned in Boilers 1-3:
			873	MMBtu/plane						28%
			660,281	MMBtu/yr					Gas:	186,731
						32.62	1000 gal/yr		Oil:	9.23
			CO	NOx <100 MMBtu	NOx > 100 MMBtu	NOx Total	PM	SO2	Lead	VOC
Gas	Emission Factor	lb/MMBtu	0.08	0.031	0.275		0.0075	0.00059	4.90E-07	0.00539
	Emissions	Ton/yr	26.41	2.93	65.00	67.93	2.48	0.19	0.00016	1.78
Oil	Emission Factor	lb/1000 gal (lb/MMBtu of GHG)	5	19	14		3.3	7.385	0.00126	0.2
	Emissions	Ton/yr	0.08	0.09	0.16	0.25	0.05	0.12	0.00002	0.00
	Projected	Tons/yr	26.49	3.02	65.16	68.18	2.53	0.32	0.00018	1.78

Greenhouse Gas Emissions

The baseline greenhouse gas (GHG) emissions were based on 2006–2007 emissions. The GHG emissions are divided between those from combustion and those from other airplane assembly operations. As shown in Table A-4 (Appendix A), the greatest amount of stationary GHG emissions per plane in the last 5 years was 79.5 tonnes, which occurred in 2008. Therefore, the GHG emission rates for 2008 were scaled up from 290 planes per year to determine the projected actual GHG emissions. The emissions as shown in Table A-4 were also multiplied by 1.1 to convert from tonnes (metric tons) to U.S. “short” tons.

APPENDIX F

Ozone Modeling

Modeling Study of Ambient Ozone Changes Related to Aircraft Painting Operation Increases at Two Boeing Facilities: Renton and North Boeing Field/Plant 2

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September 2011

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Figure A5. Maximum surface layer ozone difference between CURRENT case and FUTURE case of 0.23 ppb occurs at two times. Shown here is 16 PST, August 14, 2008.

Figure A6. Maximum O3 in CURRENT case run for Friday August 15, 2008, is 103 ppb in the vicinity of Mt. Rainier National Park at 16 PST.

Figure A7. Maximum surface layer ozone difference between CURRENT case and ALLOWED case of 0.17 ppb occurs over three hours. Shown here is 16 PST on August 15, 2008.

Figure A8. Maximum surface layer ozone difference between CURRENT case and ALLOWED case of 0.17 ppb occurs over three hours. Shown here is 17 PST on August 15, 2008.

Figure A9. Maximum surface layer ozone difference between CURRENT case and FUTURE case of 0.34 ppb occurs over three hours. Shown here is 15 PST on August 15, 2008.

Figure A8. Maximum surface layer ozone difference between CURRENT case and ALLOWED case of 0.17 ppb occurs over three hours. Shown here is 17 PST on August 15, 2008.

Figure A9. Maximum surface layer ozone difference between CURRENT case and FUTURE case of 0.34 ppb occurs over three hours. Shown here is 15 PST on August 15, 2008.

Figure A10. Maximum surface layer ozone difference between CURRENT case and FUTURE case of 0.34 ppb occurs over three hours. Shown here is 17 PST on August 15, 2008.

Figure A11. Maximum O3 in CURRENT case run for Saturday August 16, 2008, is 140 ppb at 16 PST in the Portland area and nearby Columbia Gorge. Ozone is 80-90 ppb in the vicinity of the Mt. Rainier National Park.

Figure A12. Maximum surface layer ozone difference between CURRENT case and ALLOWED case of 0.02 ppb occurs in the earliest hours for Saturday August 16, 2008, basically just a remnant of the previous day.

Figure A13. Maximum surface layer ozone difference between CURRENT case and FUTURE case of 0.03 ppb occurs in the earliest hours for Saturday August 16, 2008, basically just a remnant of the previous day.

EXECUTIVE SUMMARY

A modeling study was undertaken to explore the likely effect on ambient ozone of varying levels of increased emissions of volatile organic compounds (VOCs) at two Boeing Aircraft Company plants, the Renton Plant and the North Boeing Field/Plant 2 in Seattle.

The modeling study was performed by applying the AIRPACT-3 modeling system with emissions processing modification to represent three emissions cases, as specified by CH2M HILL, representing: current emissions, presently allowed emissions (+97% over current), and future emissions (+220% over current). The AIRPACT-3 system was used to simulate these three emissions cases for two different elevated ozone episodes: the week of June 24 through July 1, 2008, and the week of August 12 through 18, 2008.

Analysis of the AIRPACT-3 model results for the three cases for both episodes shows that the maximum hourly ozone increase for the most aggressive emissions case was only 0.38 ppb ozone. This result was obtained for the June episode for the future emissions case. The maximum hourly ozone was modeled at 17 PST on June 29, 2008, to be 111 ppb in the Columbia Gorge and 80-90 ppb in the Mt. Rainier National Park. The maximum difference in ozone of 0.38 ppb was located at the Mt Rainier National Park but was offset a few hours earlier, when the park showed only 70-80 ppb ozone. The results from both the June and August episodes agreed generally in showing that the maximum ozone differences between the current and future cases were less than 1 ppb and were also not typically exactly collocated with the reported maximum ozone value, but rather were usually offset either in space or time, or both. The results for the simulation of both episodes indicate that the proposed changes in VOC emissions at the two Boeing plants will have a very small and negligible effect upon ambient ozone levels within the western Washington region. These results are consistent with the relatively small change in VOC emissions as a portion of total VOCs emitted within the urban region of Puget Sound.

INTRODUCTION

This report presents the methodology and results of a modeling study examining the expected effect on ambient ozone of emissions of volatile organic carbon compounds (VOCs) for three levels of painting operations at two Boeing facilities located at Renton, Washington, and at North Boeing Field/Plant 2, Seattle, Washington.

To explore the effects to be expected for specific emissions changes, this work applies a methodology that underlies most regional air quality modeling. This involves the use of regional simulated meteorology with a comprehensive emissions inventory, with appropriate modifications representing the emissions cases to be tested, to drive a numerical atmospheric chemical conversion and transport model (CCTM). This methodology has been developed and applied by the Laboratory for Atmospheric Research (LAR) at Washington State University, in cooperation with the Atmospheric Sciences Department at the University of Washington, in the AIRPACT regional air-quality forecasting system. The AIRPACT system has been forecasting air quality on a daily basis for the Puget Sound region since 2001.[1] The current version, AIRPACT-3, utilizes the state-of-the -art CCTM called the Community Multi-scale Model for Air Quality (CMAQ), version 4.6.[2] This version of the AIRPACT system has been applied by Drs. Vaughan and Lamb to explore the likely effects of anticipated changes in ambient ozone for Boeing VOC emission changes. Two weeks of 2008 during which ozone levels built to high values, one in June and one in August, were proposed by LAR for this modeling study; these two weeks were agreed to by CH2M HILL in consultation with Washington State Department of Ecology (Ecology). The next sections provide information on the domain, the AIRPACT-3 system, the cases (periods) selected for modeling, the Boeing emissions scenarios as specified by CH2M HILL, the emissions as provided to CMAQ, the simulated ambient ozone results, and conclusions.

---

[1] Vaughan, J., et al. (2004), A numerical daily air quality forecast system for the Pacific Northwest, *Bull. Am. Meteorol. Soc.*, 85, 549– 561.
[2] Chen, J., J. Vaughan, J. Avise, S. O'Neill, and B. Lamb (2008), Enhancement and evaluation of the AIRPACT ozone and PM2.5 forecast system for the Pacific Northwest, *J. Geophys. Res.*, 113, D14305, doi:10.1029/2007JD009554.

The AIRPACT-3 System

The AIRPACT-3 air quality modeling system components, as applied to the problem of simulating the effect of Boeing emissions changes, are documented in Table 1. Figure 1 shows the myriad components of the AIRPACT-3 forecasting system. The major components utilized in this study include:

- Numerical meteorological simulations from the University of Washington mesoscale modeling project Weather Research and Forecasting model (WRF version 3.1.1). (http://www.atmos.washington.edu/mm5rt/info.html)
- MCIP -- reprocesses WRF meteorology into CMAQ-required format files.
- BEIS-3 -- processes biogenic emissions for combination with other emissions via SMOKE .
- SMOKE (Sparse Matrix Optimized Kernel for Emissions) -- processes each type of emission and combines all emissions into CMAQ-required format files.
- CMAQ -- combines meteorology and emissions and calculates chemistry and wet and dry deposition, resulting in hourly, gridded forecast values for ozone and other air pollutant concentrations.

Table 1. AIRPACT-3 system as applied for the CH2M HILL - Boeing Project of 2011.

3-D Domain (Figure 2) Grid cells	95x95 12-km grid cells, 21 layers
Meteorology	WRF 12-km domain from UW
MCIP	v3.3
SMOKE	v2.7, except for LAYPOINT and SMKINVEN at v2.7_plus
CMAQ	v4.6
Mass adjustment option (CMAQ)	DENRATE
Anthropogenic Point Emissions	2007 and 2005 Emissions with corrections by Ecology, IDEQ, & ODEQ; **and with adjustments for Boeing Emission Scenarios**
Anthropogenic Emissions for Area, Mobile On-road, Mobile Nonroad	2005 Emissions as provided by Ecology, IDEQ, & ODEQ
Fire Emissions	None currently
Biogenic Emissions	BEIS-3

Typically, AIRPACT-3 results are post-processed using the PAVE visualization tool (not shown in Figure 1) to generate graphics for reporting via the web. Graphics in this report for emissions and ozone results were produced using PAVE.

AIRPACT-3 air quality modeling occurs on a domain of 12-km-square cells with the entire domain spanning 95 cells E-W and 95 cells N-S. The sub-domain (Figure 2) used for reviewing results in this report is 30 cells by 30 cells, or 360 km by 360 km. The Boeing Renton location is column 23, row 67; the North Boeing Field location is column 22, row 67. Three of the Class I Areas shown in Figure 2 are listed in Table 2.

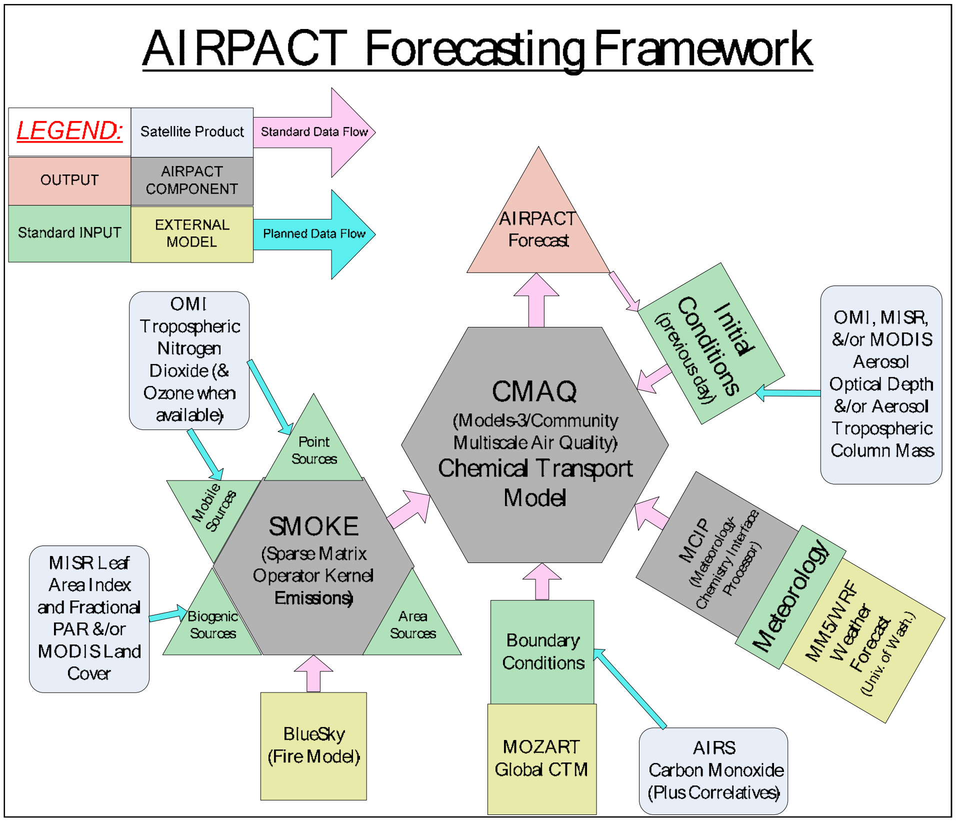

Figure 1. AIRPACT-3 System. Point sources were modified to reflect Boeing emissions scenarios. Satellite resources (light gray), used for system evaluation, were not applied for the CH2M HILL - Boeing study.

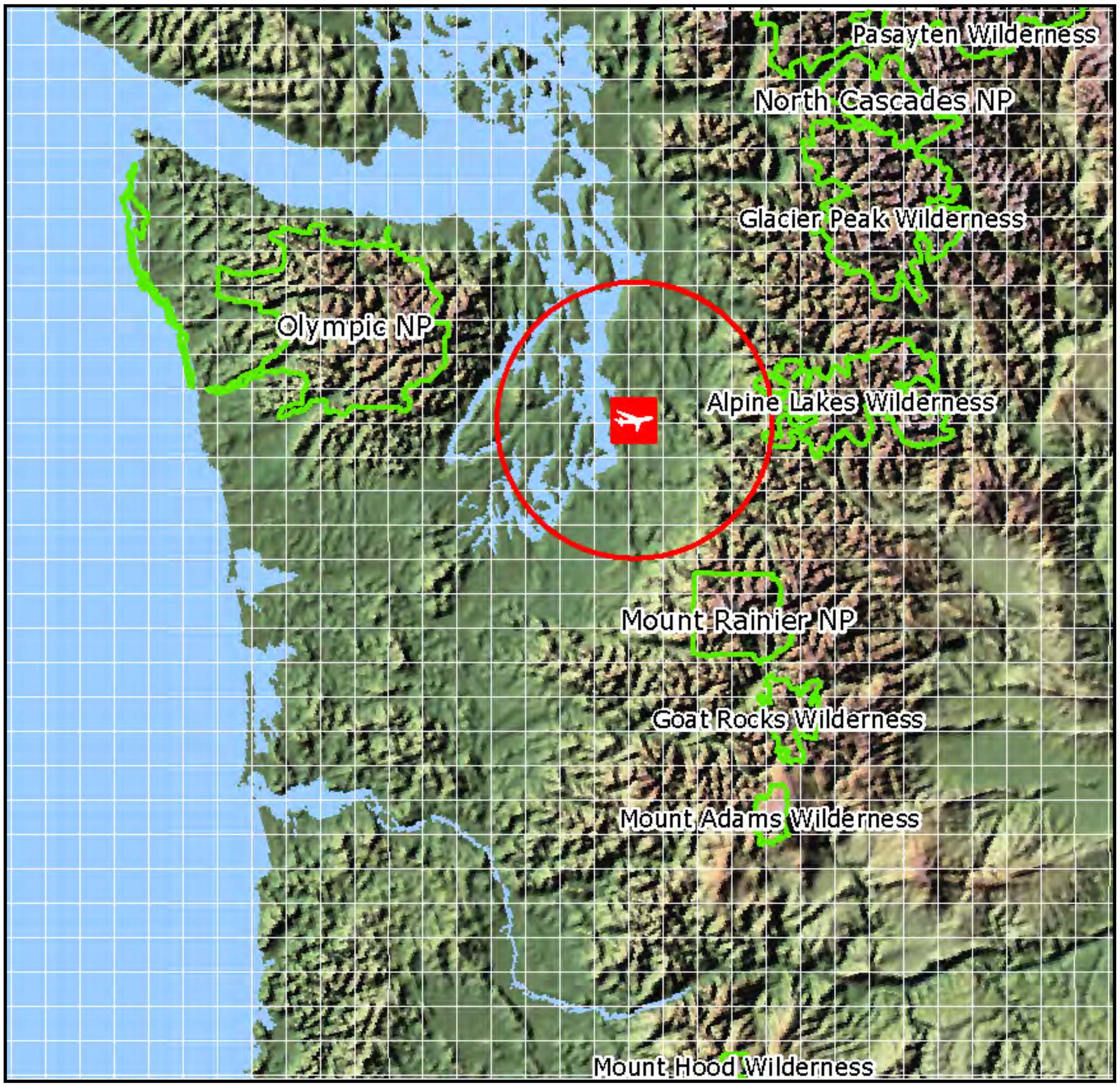

Figure 2. Terrain map of the 30-cell by 30-cell sub-domain showing the federal Class I areas of concern for Prevention of Significant Deterioration protection under the Clean Air Act (green outlines), and the location of the subject Boeing facilities (cells at column 22, row 67 and column 23, row 67) centered within a circle of radius ~50 km.

Table 2. Name, acreage, jurisdiction and approximate centroids for Federal Class I Areas within approximately 50 km of Renton, WA. (http://www.epa.gov/visibility/class1.html)

Area Name	Acres	Agency[a]	Reference Lat./Long.
Alpine Lakes Wilderness	303,508	USDA-FS	47.5655, -121.1783
Mount Rainier N.P.	235,239	USDI-NPS	46.85, -121.75
Olympic N.P.	892,578	USDI-NPS	47.9693, -123.4985
[a] USDA-FS = Forest Service; USDI-NPS = National Park Service			

Cases selected for modeling VOC emissions effect on O3

In consultation with CH2M HILL and Ecology, two weeks were selected for this modeling study, June 24-July 1, 2008, and August 12-18, 2008.

The June 2008 Case:

AIRPACT-3 model results are compared to available ozone and PM2.5 observations in Figure 3 for the Enumclaw Mud Mountain site for the period of June 24-July 1 (Tuesday through Monday). During this period, moderate ozone levels on the 24th through 26th increased to high levels on the 28th and 29th, and then decreased somewhat on June 30th and further on July 1st.

The August 2008 Case:

AIRPACT-3 performance charts are shown in Figure 4, showing AIRPACT-3 CMAQ forecast results and AIRNow (U.S. Environmental Protection Agency) monitoring data, for the Enumclaw Mud Mountain site, for ozone and PM2.5 for the period of August 12-18 (Tuesday through Sunday). In this case, moderate ozone levels on the 12th and 13th increased to high levels for the 14th through 16th, and then dropped again on the 17th and 18th.

Five- versus seven-day-week operations:

These two cases, June 2008 and August 2008, were handled differently in terms of emissions specification in one significant way. The June 2008 case was treated to simulate a seven-day-week painting operation at the same daily rate as weekdays under the five-day-week schedule would imply. The August 2008 case was treated as a five-day-week operation, as reflects the current Boeing paint operations, with no emissions on the weekend.

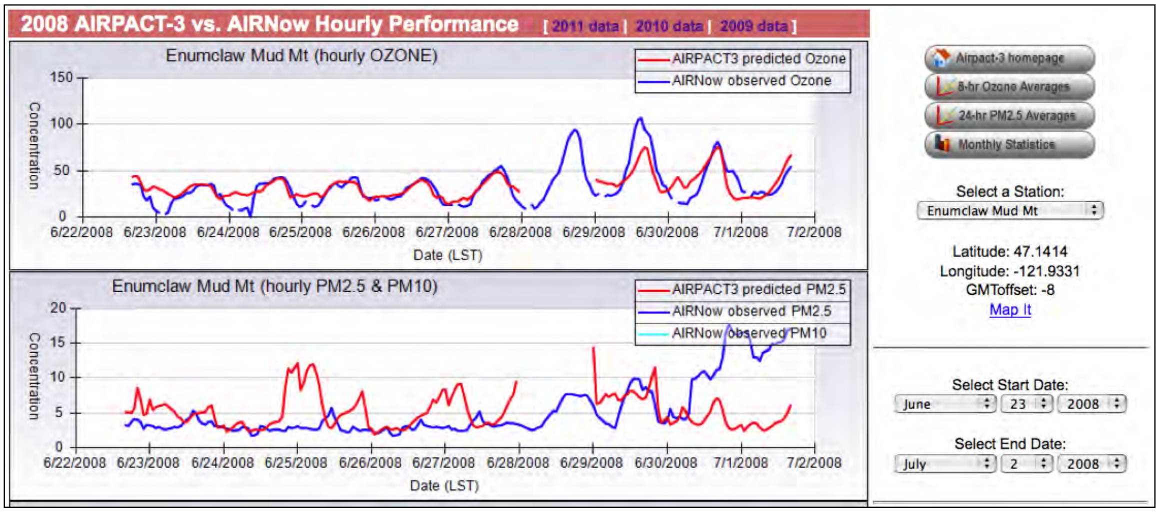

Figure 3. AIRPACT-3 performance charts for O3 and PM2.5 for June 24 through July 1, 2008 (Tues-Mon).

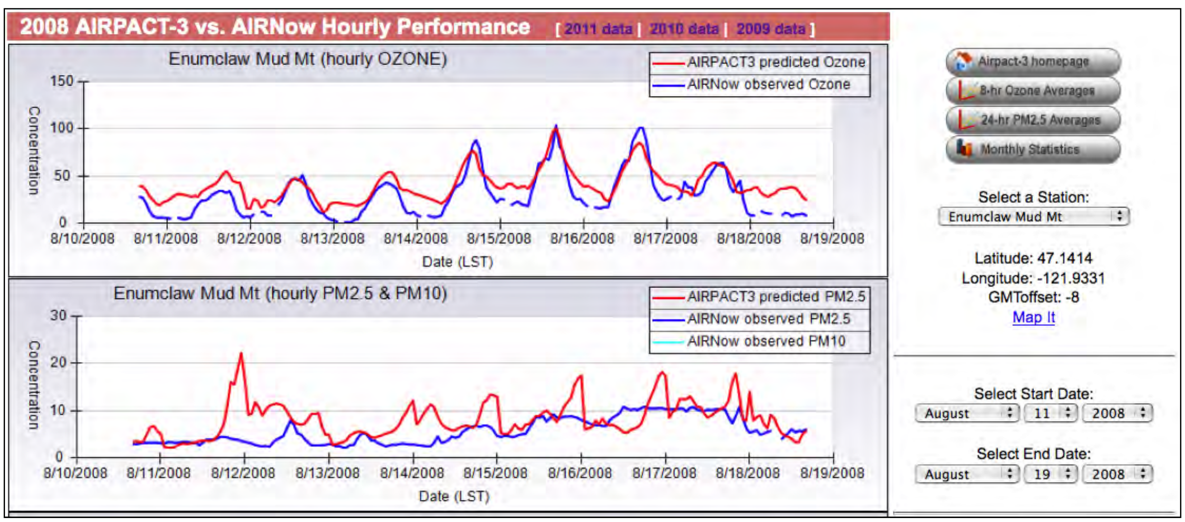

Figure 4. AIRPACT-3 performance charts for O3 and PM2.5 for August 12-18, 2008 (Tues-Mon).

Emissions treatment

The point source inventory used in this study is based on an updated inventory provided by Ecology for AIRPACT use and was modified for this project to represent the three Boeing emissions scenarios. The background on the point inventory from Ecology is described next. Then the calculations of the VOC and nitrogen oxide (NOx) emissions for the three emissions scenarios for the two cases (periods) are presented. The remainder of this section describes the CMAQ-ready emissions files as produced from running SMOKE using the results of the scenario and the case-specific values as calculated and shown below in the Boeing Emissions Scenario Calculations section (Tables 5, 6, 8, and 9).

AIRPACT point emissions

For AIRPACT, point sources are industrial, commercial, or institutional stationary sources whose emissions are individually tracked and located with geographic coordinates. Most of the point sources fall under the federal major source definition, although many sources counted in the point source inventory were smaller sources. Stationary sources that are not tracked individually are aggregated into the area sources inventory. The data elements required for the SMOKE point source file PTINV are shown in Table 3.

Table 3. Data elements for point source emissions required in SMOKE file PTINV.

o State/Province FIPS
o County/District FIPS
o Plant ID (Facility ID)
o Point ID (Emissions Unit ID)
o Stack ID (Emissions Release Point ID)
o Segment ID (Emissions Process ID, preferred but may leave blank)
o Plant Name (preferred but may leave blank)
o SCC Code
o Stack Height (ft)
o Stack Diameter (ft)
o Stack Temperature (degrees Fahrenheit)
o Stack Flow Rate (ft3/sec)
o Stack Velocity (ft/sec)
o SIC Code (must be 4-digit SIC)
o Stack Latitude (decimal degrees)
o Stack Longitude (decimal degrees)
o Pollutant Code
o Emissions (tons/yr preferred, but may be tons/day)

The inventories provided by the state and local air agencies were checked for missing data and geographic coordinate systems. If a process had PM10 emissions, but no PM2.5 emissions, the PM2.5 emissions were estimated as PM2.5 = PM10. If a process had PM2.5 emissions, but no PM10 emissions, the PM10 emissions were estimated as PM10

= PM2.5. If coordinates were not in lat-long, they were converted to lat-long (NAD83) using ArcGIS. Other minor changes and additions were made as necessary.

Each agency providing data is listed below:

- Idaho Department of Environmental Quality's (IDEQ) 2005 inventory was used. PM additions were made as described above. Coordinates were converted from UTM to lat-long.
- Oregon Department of Environmental Quality's (ODEQ) 2005 inventory was used. PM additions were made as described above. Several sources originally in ODEQ's nonpoint and nonroad files were treated as point sources since individual emissions and location coordinates had been provided. Sources included airports, confined animal feeding operations, and dry cleaners.
- Ecology's 2007 inventory was used. PM additions were made as described above. A few sources were missing lat-long coordinates. Some were filled in using historical database UTM coordinates converted to lat-long (NAD83). The remaining sources with missing coordinates were deleted from the dataset. None had very high emissions.
- Metro Vancouver's (Vancouver, BC) 2005 inventory was used. PM10 and PM2.5 emissions were included for all particulate sources; therefore, no augmentation was necessary. One source was missing coordinates. It was deleted from the dataset. It did not have high emissions.
- Emissions data for 2005 were available for some sources through the National Emissions Inventory (NEI), but were incomplete and inconsistent. The 2005 NEI effort was abbreviated in order to devote resources to re-engineering the NEI for the 2008 inventory cycle. The normal aggregation of data in common formats and databases was not done. It would have taken much processing time and follow-up with the states to process the 2005 data for modeling. The prior AIRPACT inventory (based on the 2002 NEI) was used without update. Pollutants new for this AIRPACT update are not part of these emissions files, and will be missing.

Boeing Emissions Scenario Calculations

Total Boeing painting operation VOC emissions were specified by CH2M HILL for the two Boeing plants for three scenarios. The three scenarios are identified as CURRENT (representing actual current operations), ALLOWED (representing the limits of the current permitting), and FUTURE (representing a putative future level of emissions, for consideration as a planning input).

For the two one-week cases simulated, two different assumptions about Boeing operations were applied. For the August 2008 case (August 12th through August 18th, Tuesday through Monday), it was assumed that Boeing would operate five days per week, three shifts per day. Thus for a given scenario, SMOKE was used to distribute the total VOC emissions over all weeks, for five days per week, evenly over all hours of the day. Saturday and Sunday VOC emissions for this August 2008 week for these processes were therefore zero. However, for the June 2008 case (June 24 through July 1), it was assumed that Boeing would operate seven days per week, three shifts per day, emitting at the same daily rate as obtained for weekdays in the treatment of August week. This amounted to a scaling up of emissions for the August case by a factor of 7/5 (or 1.4) simply by extending the number of days from 5 to 7 per week.

Emissions calculations for Boeing Renton:

Boeing Renton emissions were extracted from pt_wa_tpy.txt and analyzed in MS Excel (file Boeing_Rentox.xls). Totals of all VOC species for each of the Boeing Renton painting point sources (excluding boilers) were used to calculate the proportions of VOC by source. These proportions were then used to allocate the total VOC emissions as tons per year (TPY) as specified by CH2M HILL for each scenario (CURRENT, ALLOWED, and FUTURE). Allocation of these source-specific VOC totals into specific VOC chemical species was handled in subsequent SMOKE processing. For Renton sources, the total VOCs allocated by case in TPY specified by CH2M HILL are shown in Table 4. Allocation of the VOC totals according to paint operation source VOC proportions results are shown in Table 5; Table 5 shows the VOC emissions to be specified in the fundamental point emissions files for CURRENT, ALLOWED, and FUTURE scenarios, in TPY. Note that boiler operations are not scaled up with other paint operations unless paint operations are additionally expected to expand to weekend days. Table 6 shows same for NOx emissions.

Table 4. Renton scenario VOC emission totals, TPY.

CURRENT	ALLOWED	FUTURE
196	484	750

Emissions calculations for North Boeing Field/Plant 2:

North Boeing Field/Plant 2 (NBF) emissions were extracted from pt_wa_tpy.txt and analyzed in MS Excel (file Boeing_NBF_Plant_2.xls). Totals of all VOC species for each of the Boeing NBF painting point sources (excluding boilers) were used to calculate the proportions of VOC by source. These proportions were then used to allocate the total VOC emissions as TPY as specified by CH2M HILL for each scenario (CURRENT, ALLOWED, and FUTURE). Allocation of these source-specific VOC totals into specific (chemical species) VOCs was handled in subsequent SMOKE processing. For NBF sources, the total VOCs allocated by case in TPY specified by CH2M HILL are shown in Table 7. Allocation of the NBF VOC totals according to paint operation source VOC proportions results in Table 8, showing the VOC emissions in TPY to be specified in the fundamental point emissions files for CURRENT, ALLOWED, and FUTURE scenarios. Note that boiler operations are not scaled up with other paint operations unless paint operations are additionally expected to expand to weekend days. Table 9 shows the same results for NBF NOx emissions.

Table 5. Renton emissions scenario VOCs. Yellow section is for August 2008 case and orange is for June 2008 case. Note the grey section showing that the boiler VOC emissions were not scaled up for August 2008 case for increased painting in five-day-week treatment, but the orange section for boiler SCCs, because of additional two days of operation, the boiler VOCs are scaled up for the June 2008 case seven-day-week treatment.

VOCs	CASE: August 2008			CASE: June 2008		
SCC	CURRENT	ALLOWED	FUTURE	CURRENT	ALLOWED	FUTURE
Natual Gas >100 MMBtu/hr	1.0080E+00	1.0080E+00	1.0080E+00	1.4112E+00	1.4112E+00	1.4112E+00
10-100 MMBtu/hr	5.0000E-03	5.0000E-03	5.0000E-03	7.0000E-03	7.0000E-03	7.0000E-03
Miscellaneous Industrial	1.5473E+01	3.8209E+01	5.9209E+01	2.1663E+01	5.3493E+01	8.2892E+01
Cleaning Stripping	4.9349E-03	1.2186E-02	1.8884E-02	6.9089E-03	1.7061E-02	2.6437E-02
Adhesive Application	1.7148E+01	4.2346E+01	6.5619E+01	2.4008E+01	5.9284E+01	9.1866E+01
Prime Coating	1.2028E+01	2.9702E+01	4.6026E+01	1.6839E+01	4.1583E+01	6.4436E+01
Cleaning	1.3014E+02	3.2136E+02	4.9797E+02	1.8219E+02	4.4990E+02	6.9716E+02
Topcoat	2.1104E+01	5.2114E+01	8.0755E+01	2.9546E+01	7.2960E+01	1.1306E+02
Fugitive VOC	1.0418E-01	2.5727E-01	3.9866E-01	1.4585E-01	3.6017E-01	5.5812E-01
	Boilers unchanged across CASES			Boiler VOC and NOX scaled up by 1.4		

Table 6. Renton emissions scenario NOx. Yellow section is for August 2008 case and orange is for June 2008 case. Note the grey section showing that the boiler NOx emissions were not scaled up for August 2008 case for increased panting in five-day-week treatment, but in the orange section for boiler SCCs, because of additional two days of operation, the boiler NOx are scaled up for the June 2008 case seven-day-week treatment.

NOx	CASE: August 2008			CASE: June 2008		
SCC	CURRENT	ALLOWED	FUTURE	CURRENT	ALLOWED	FUTURE
Natual Gas >100 MMBtu/hr	3.00E+00	3.00E+00	3.00E+00	4.20E+00	4.20E+00	4.20E+00
10-100 MMBtu/hr	2.80E+01	2.80E+01	2.80E+01	3.92E+01	3.92E+01	3.92E+01
Miscellaneous Industrial	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Cleaning Stripping	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Adhesive Application	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Prime Coating	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Cleaning	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Topcoat	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Fugitive VOC	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Boilers unchanged across CASES			Boiler VOC and NOX scaled up by 1.4		

Table 7. North Boeing Field/Plant 2 scenario VOC emission totals, TPY.

CURRENT	**ALLOWED**	**FUTURE**
100	100	200

Table 8. North Boeing Field/Plant 2 emissions scenario VOCs. Yellow section is for August 2008 case and orange is for June 2008 case. Note the grey section showing that the boiler VOC emissions were not scaled up for August 2008 case for increased painting in five-day-week treatment, but the orange section for boiler SCCs, because of additional two days of operation, the boiler VOCs are scaled up for the June 2008 case seven-day-week treatment.

VOCs	CASE: August 2008			CASE: June 2008		
SCC	CURRENT	ALLOWED	FUTURE	CURRENT	ALLOWED	FUTURE
Cleaning	1.46E-01	1.46E-01	2.91E-01	2.04E-01	2.04E-01	4.08E-01
Natural Gas10-100	1.02E+00	1.02E+00	1.02E+00	1.42E+00	1.42E+00	1.42E+00
Petroleum Fugitive	1.50E+00	1.50E+00	3.01E+00	2.11E+00	2.11E+00	4.21E+00
Miscellaneous Coating	2.72E+00	2.72E+00	5.45E+00	3.81E+00	3.81E+00	7.63E+00
Adhesive	1.31E-02	1.31E-02	2.62E-02	1.83E-02	1.83E-02	3.67E-02
Primer	2.10E-03	2.10E-03	4.19E-03	2.94E-03	2.94E-03	5.87E-03
CleaningStripping	1.05E+00	1.05E+00	2.10E+00	1.47E+00	1.47E+00	2.94E+00
Miscellaneous	6.81E+00	6.81E+00	1.36E+01	9.53E+00	9.53E+00	1.91E+01
Natural Gas10-100	3.50E-03	3.50E-03	3.50E-03	4.90E-03	4.90E-03	4.90E-03
Jet Engine	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Gen eric	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Adhesive	6.18E-02	6.18E-02	1.24E-01	8.66E-02	8.66E-02	1.73E-01
Petroleum Fugitive	1.22E+00	1.22E+00	2.44E+00	1.71E+00	1.71E+00	3.41E+00
Miscellaneous	5.29E+00	5.29E+00	1.06E+01	7.40E+00	7.40E+00	1.48E+01
Topcoat	3.20E+01	3.20E+01	6.39E+01	4.47E+01	4.47E+01	8.95E+01
Plane Clearning	4.51E+01	4.51E+01	9.01E+01	6.31E+01	6.31E+01	1.26E+02
Primer	4.15E+00	4.15E+00	8.29E+00	5.80E+00	5.80E+00	1.16E+01
	Boilers, Turbine and generic			Boilers, Turbine and generic		
	VOC unchanged across scenarios			VOC unchanged acros scenarios		

Table 9. North Boeing Field #2 emissions scenario NOx. Yellow section is for August 2008 case and orange is for June 2008 case. Note the grey sections showing that the boiler and turbine and generic NOx emissions were not scaled up for August 2008 case for increased painting in five-day-week treatment, but in the orange section for boiler SCCs, because of additional two days of operation, the NOx are scaled up by a factor of 1.4 for the June 2008 case seven-day-week treatment.

SCC	CURRENT	ALLOWED	FUTURE	CURRENT	ALLOWED	FUTURE
Cleaning	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Natural Gas 10-100	2.10E+01	2.10E+01	2.10E+01	2.94E+01	2.94E+01	2.94E+01
Petroleum Fugitive	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Miscellaneous Coating	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Adhesive	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Primer	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Cleaning Stripping	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Miscellaneous	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Natural Gas 10-100	5.00E+00	5.00E+00	5.00E+00	7.00E+00	7.00E+00	7.00E+00
Jet Engine	1.00E+00	1.00E+00	1.00E+00	1.40E+00	1.40E+00	1.40E+00
Gen eric	1.00E+00	1.00E+00	1.00E+00	1.40E+00	1.40E+00	1.40E+00
Adhesive	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Petroleum Fugitive	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Miscellaneous	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Topcoat	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Plane Clearning	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Primer	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Boilers, Turbine and generic NOx unchanged across scenarios			Boilers, Turbine and generic NOx scaled up by 1.4		

CMAQ -ready SMOKE-processed emissions:

In this section plots are included to illustrate how emissions passed to the CMAQ model are specified to vary across the three emissions scenarios: 1) CURRENT estimated emissions, 2) ALLOWED emissions under current permit terms, and 3) some putative FUTURE emissions. Emissions are shown for ARO1, a VOC contributing to ozone production. In specifying the emissions for the three cases {CURRENT, ALLOWED, and FUTURE}, different bulk VOC annual emissions were specified for the Boeing sources of concern at both Renton and NBF facilities. The ARO1 emissions being shown herein were calculated by the SMOKE (Sparse Matrix Optimization Kernel for Emissions) software when it applied a profile for redistributing bulk VOCs into emissions of the specific chemical species treated by the SAPRC chemistry mechanism utilized in CMAQ. The plots included show:

For June 2008 case:

- CURRENT CASE column-total point ARO1 emissions for representative hours on Thursday June 26th and Saturday June 28th, 2008 (Figures E1 and E2);
- ALLOWED case less CURRENT case differences for column-total point ARO1 emissions for representative hours on Thursday June 26th and Saturday June 28th, 2008 (Figures E3 and E4); and
- FUTURE case less CURRENT case differences for column-total point ARO1 emissions for representative hours on Thursday June 26th and Saturday June 28th, 2008 (Figures E5 and E6);

For August 2008:

- CURRENT CASE column-total point ARO1 emissions for representative hours on Thursday August 14th and Saturday August 16th, 2008 (Figures E7 and E8);
- ALLOWED case less CURRENT case differences for column-total point ARO1 emissions for representative hours on Thursday August 14th and Saturday August 16th, 2008 (Figures E9 and E10); and
- FUTURE case less CURRENT case differences for column-total point ARO1 emissions for representative hours on Thursday August 14th and Saturday August 16th, 2008 (Figures E11 and E12).

These emissions plots demonstrate differences among CURRENT, ALLOWED, and FUTURE emissions cases. In this section ARO1 is shown as a representative VOC species to demonstrate that the SMOKE speciation mentioned above occurs and also to demonstrate that the intended emissions changes in time and space are being applied. June 2008 scenario emissions shown in Figures E1 through E6 demonstrate the manipulation of Boeing Renton and NBF paint operation VOCs, according to a seven-days-per-week, three-shifts-per-day (24 hours per day) operation schedule. A single representative VOC species, ARO1, which is driven by specification of the bulk annual VOC specified as TPY by SMOKE, is shown. Emissions shown in Figures E7 through E12 demonstrate the manipulation of Boeing Renton and NBF paint operation VOCs, according to a five-days-per-week, three-shifts-per-day (24 hours per day) operation schedule. Again, only ARO1 is shown.

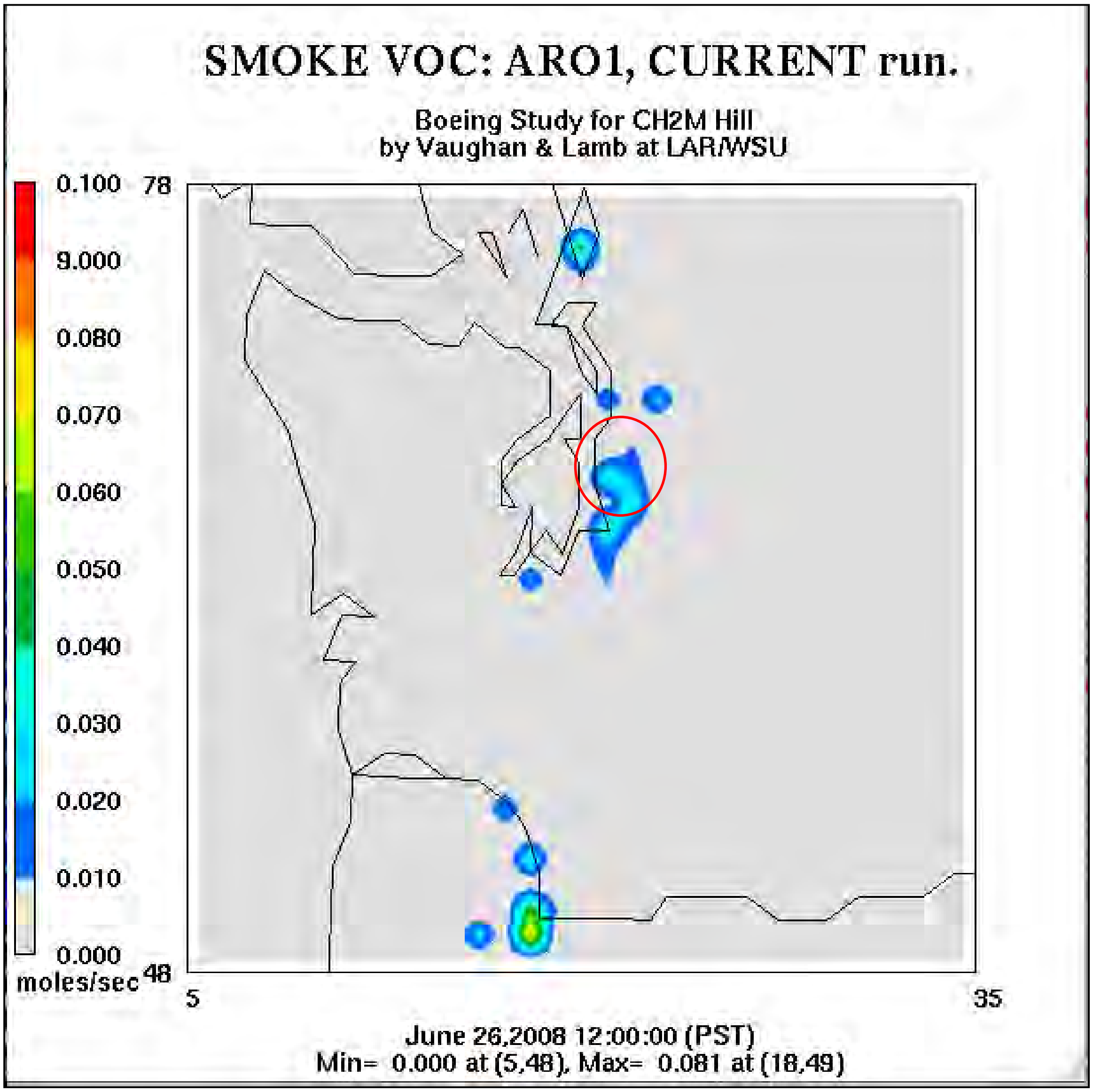

Figure E1. Vertical column-totaled ARO1 emissions within the sub-domain for the CURRENT emissions case for June 26, 2008. The red circle encloses the area of the Boeing emissions being manipulated.

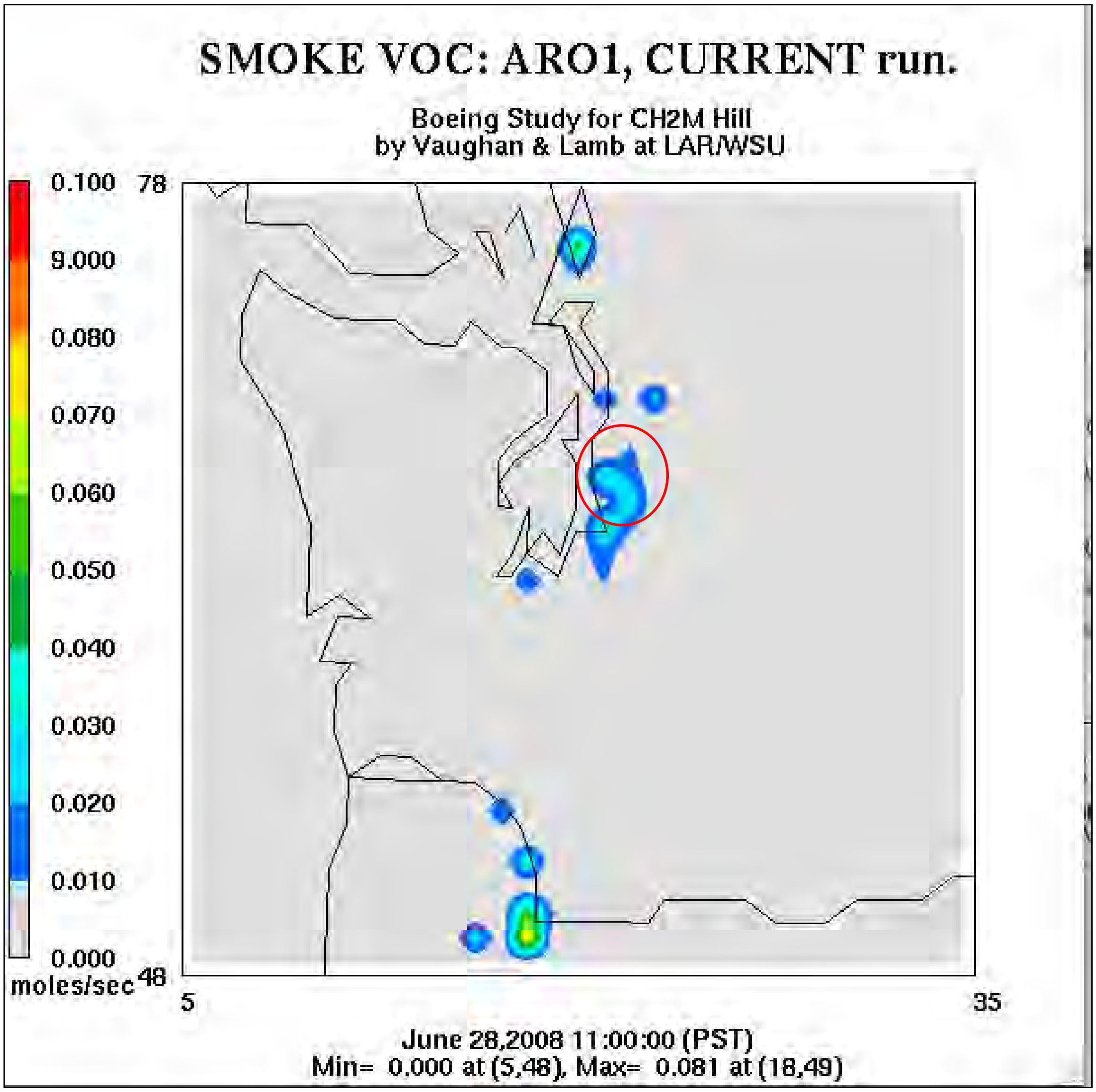

Figure E2. Vertical column-totaled ARO1 emissions within the sub-domain for the CURRENT emissions case for Saturday June 28, 2008. The red circle encloses the area of the Boeing emissions being manipulated. Note that the weekend emissions are the same as the weekday emissions in episode because all the Boeing VOC emissions are being specified with 24-hour operation for seven days a week, so weekday and weekend emissions are equal.

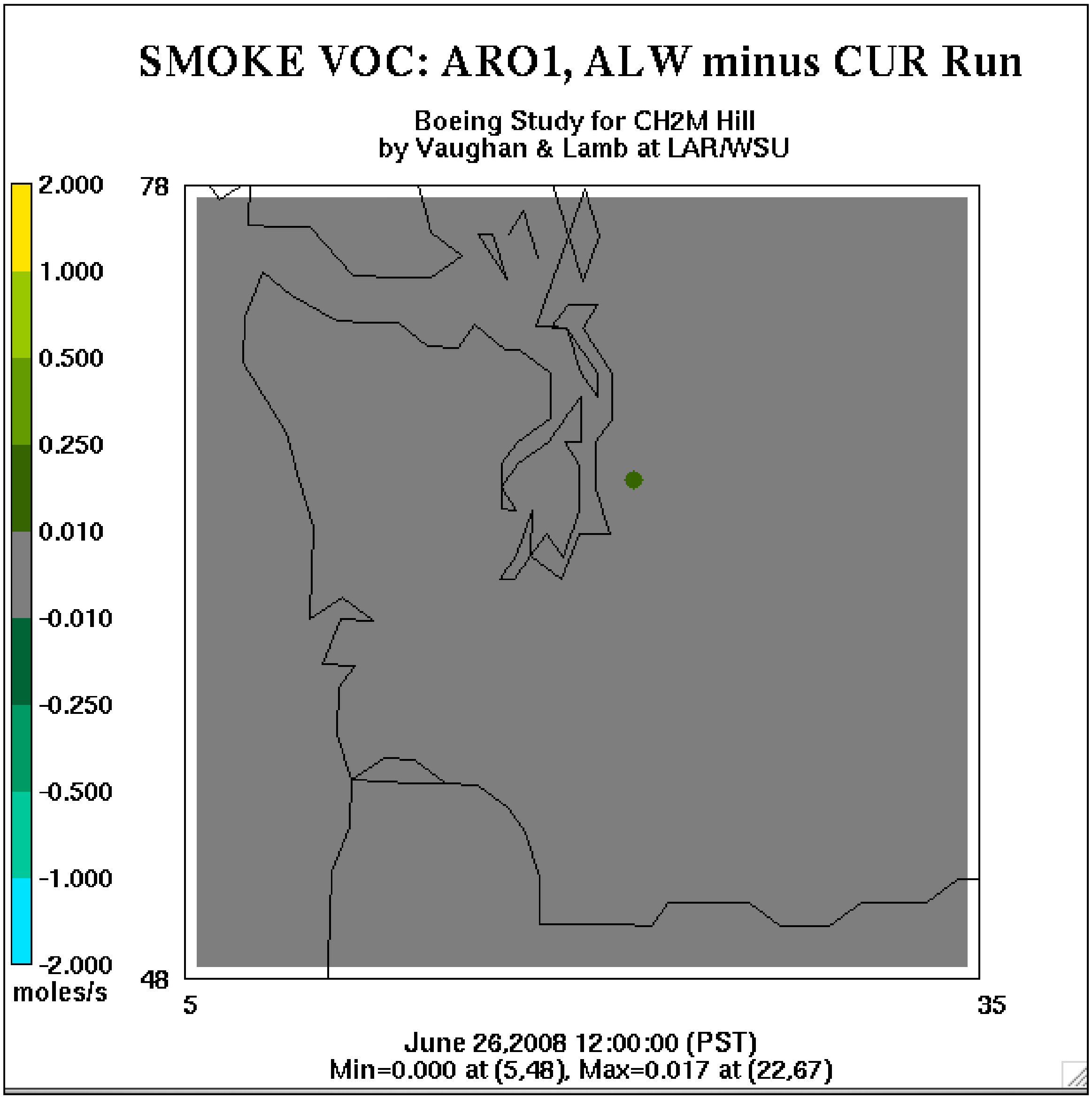

Figure E3. Differences in vertical column-totaled ARO1 emissions within the sub-domain between the CURRENT and ALLOWED emissions cases for June 26, 2008. This shows the effect of the increase of 97% from CURRENT case to ALLOWED case emissions, all of which increase occurs at the Renton facility.

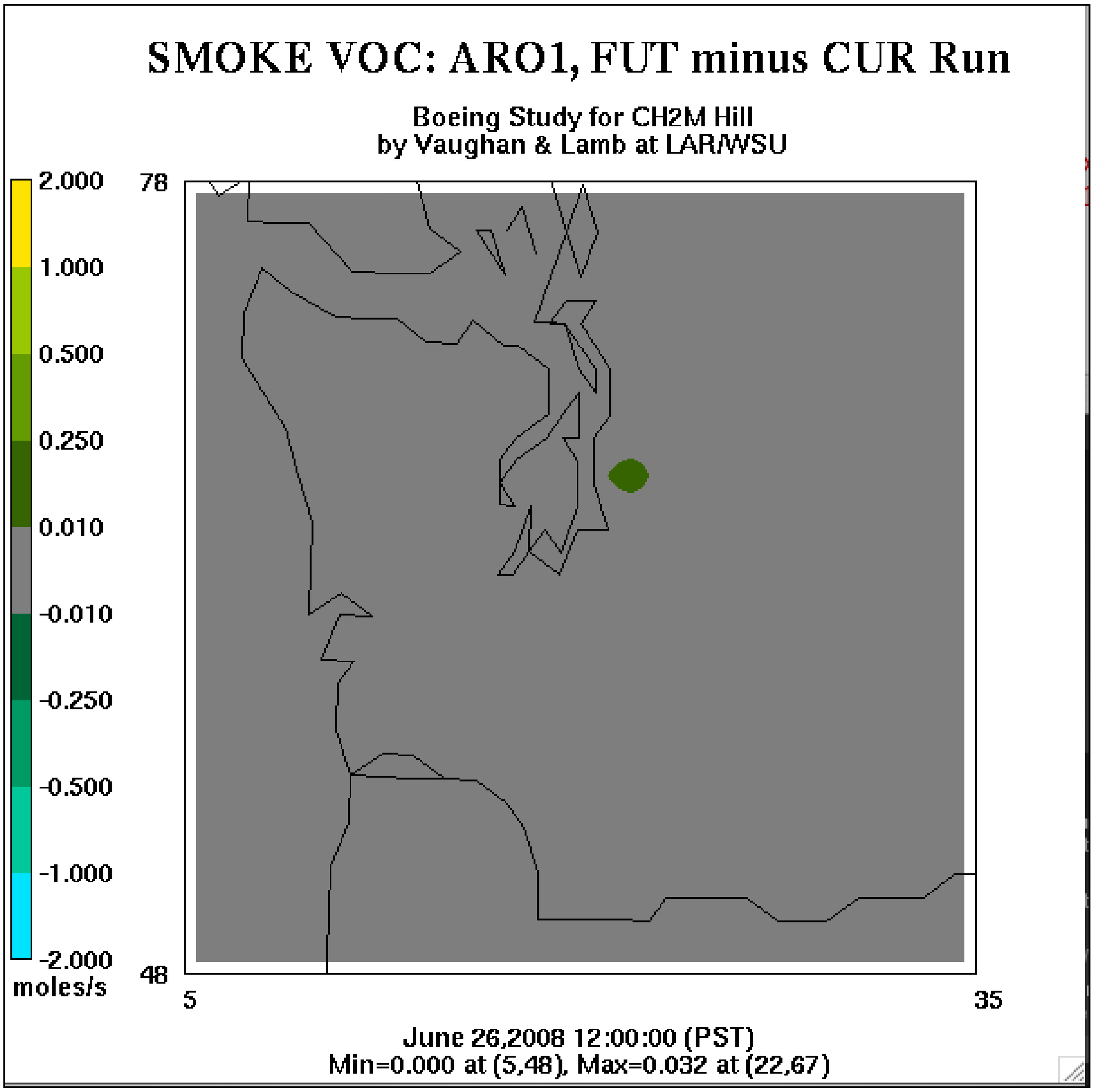

Figure E4. Differences in vertical column-totaled ARO1 emissions within the sub-domain between the CURRENT and FUTURE emissions cases for June 26, 2008. Note the growth of the green area; this shows the effect of increased emissions at North Boeing Field in addition to the increased emissions at Renton, reflecting the fact that the FUTURE case includes increases at both facilities beyond the ALLOWED case. The increase over CURRENT case is 220% and occurs at both facilities.

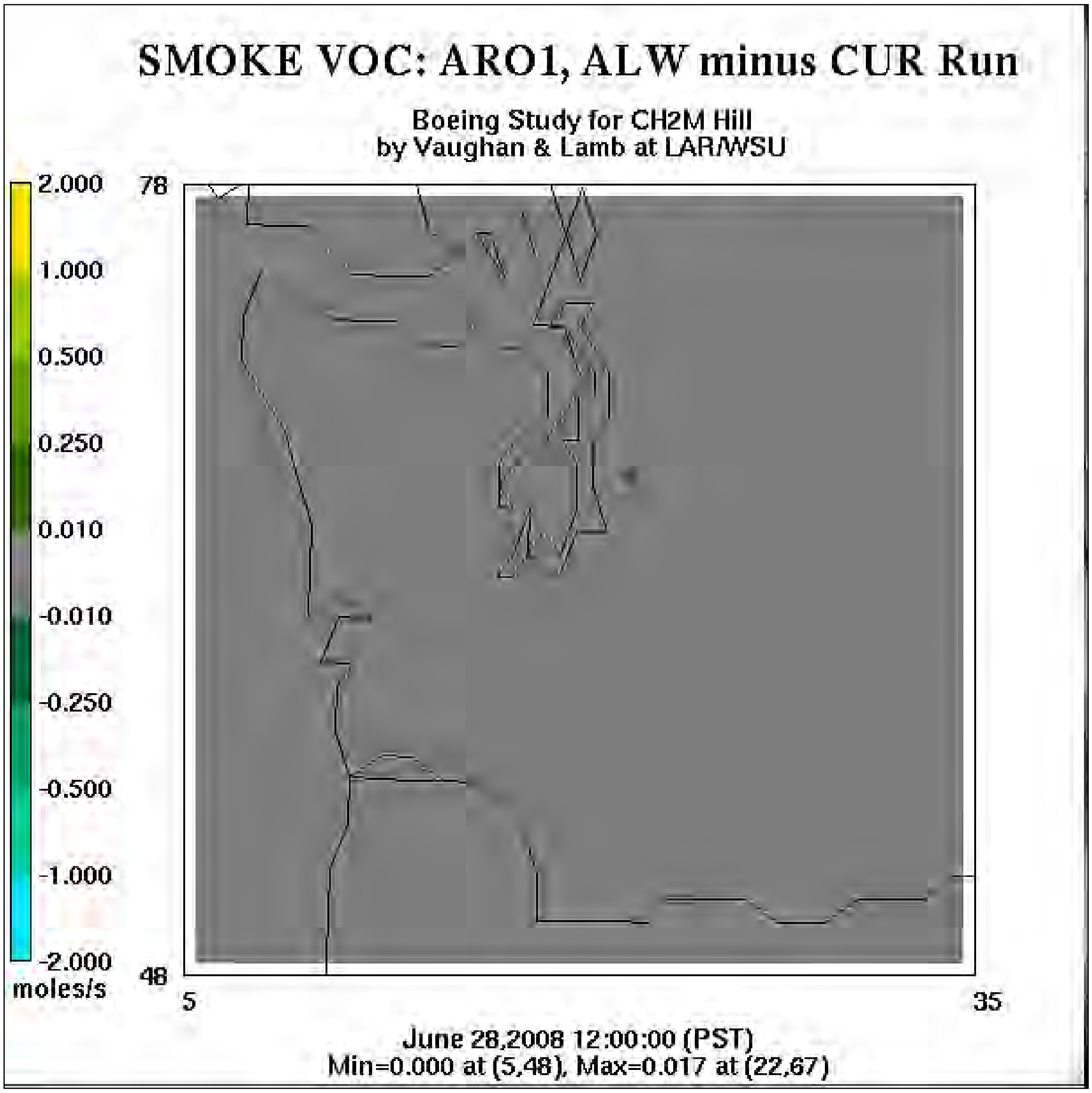

Figure E5. Differences in vertical column-totaled ARO1 emissions within the sub-domain between the CURRENT and ALLOWED emissions cases for June 28, 2008.

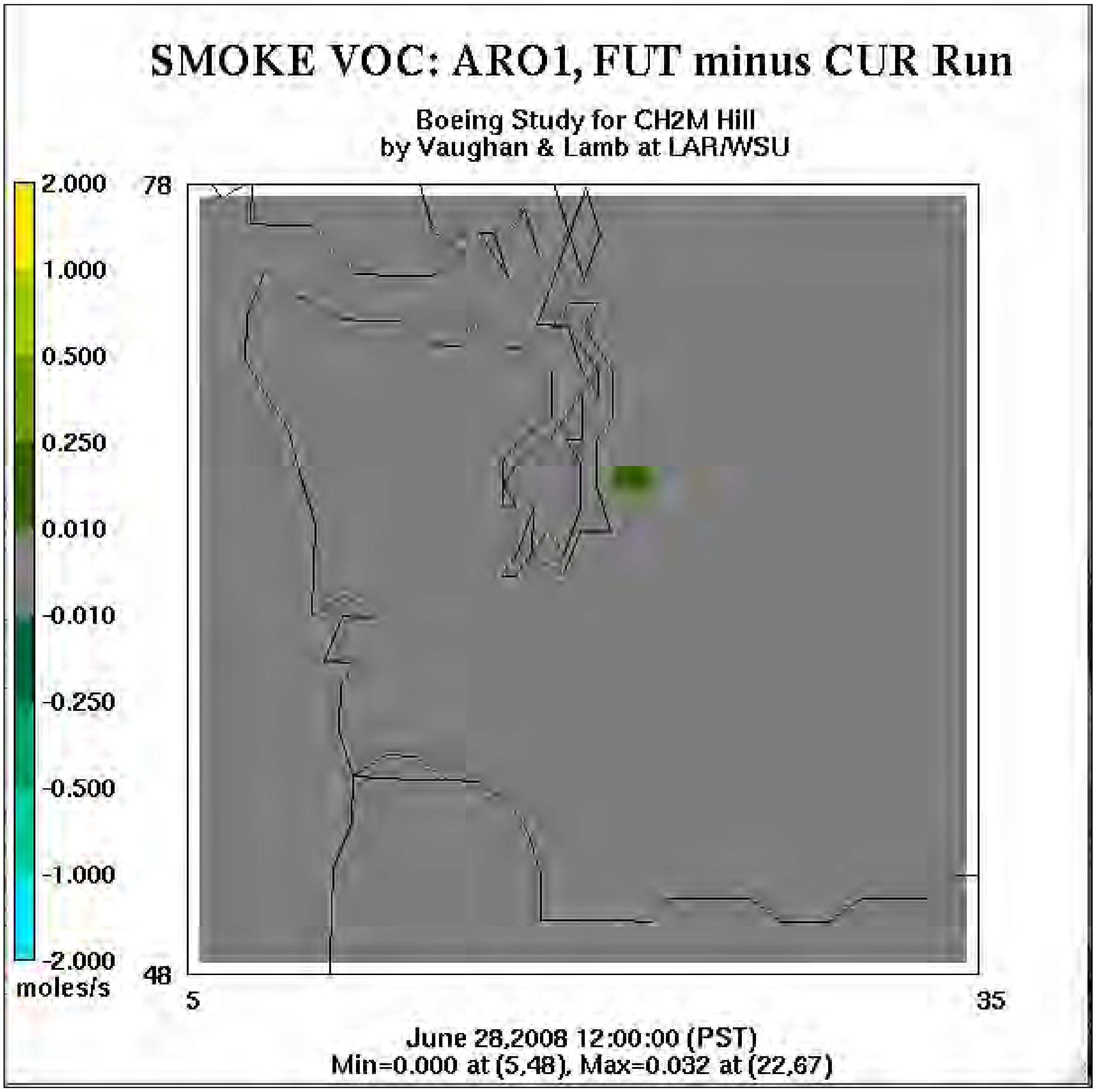

Figure E6. Differences in vertical column-totaled ARO1 emissions within the sub-domain between the CURRENT and FUTURE emissions cases for June 28, 2008.

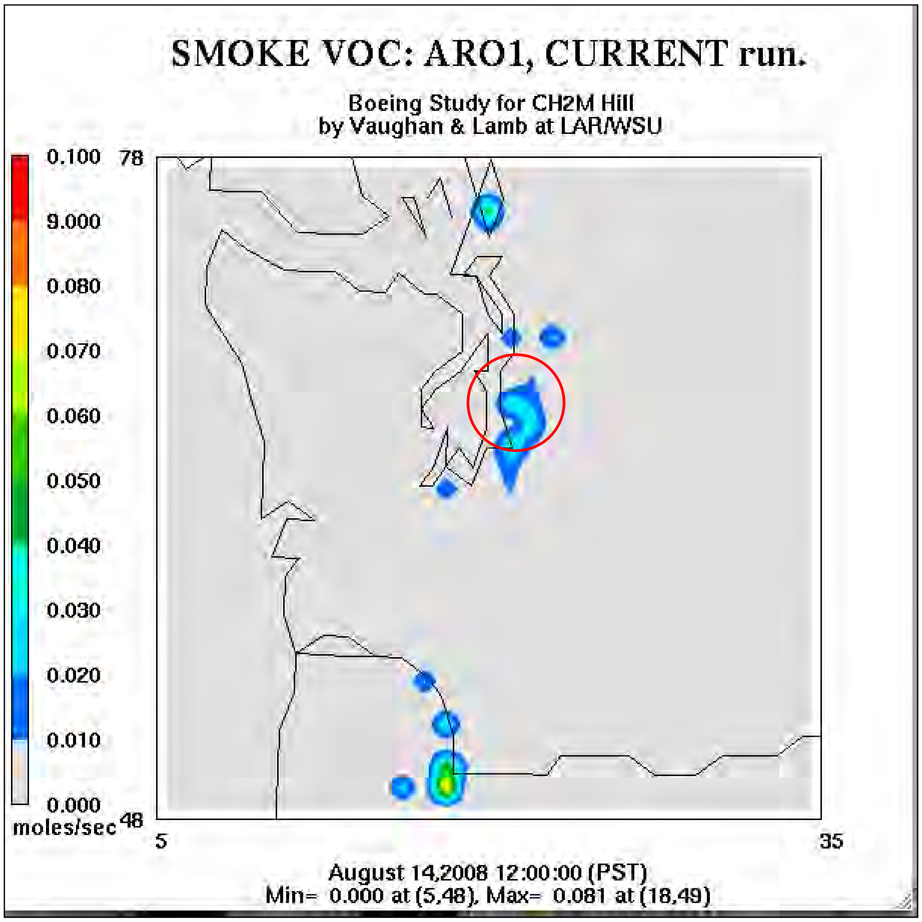

Figure E7. Vertical column-totaled ARO1 emissions within the sub-domain for the CURRENT emissions case for August 14, 2008. The red circle encloses the area of the Boeing emissions being manipulated.

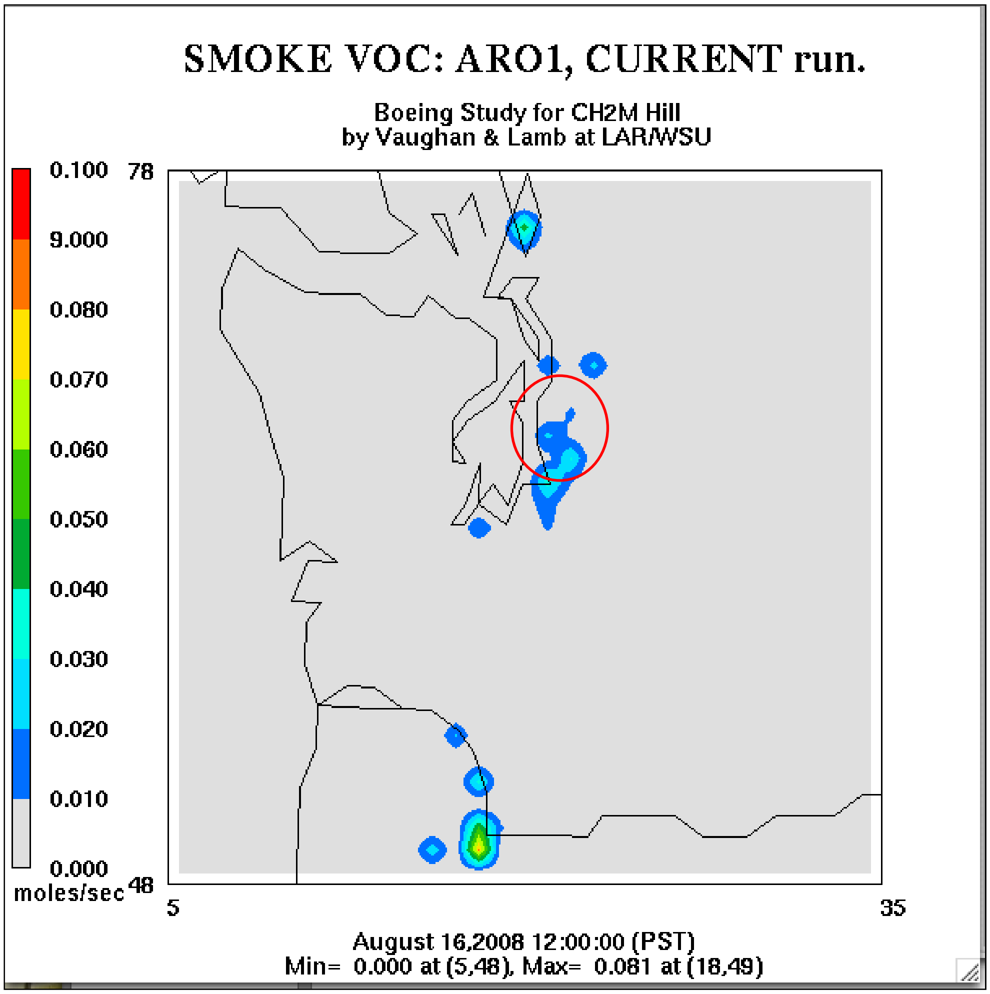

Figure E8. Vertical column-totaled ARO1 emissions within the sub-domain for the CURRENT emissions case for Saturday August 16, 2008. The red circle encloses the area of the Boeing emissions being manipulated. Note that the weekend emissions are less than the weekday emissions in this episode because all the Boeing VOC emissions are being specified with 24-hour operation for five days a week, but no emissions on weekend days.

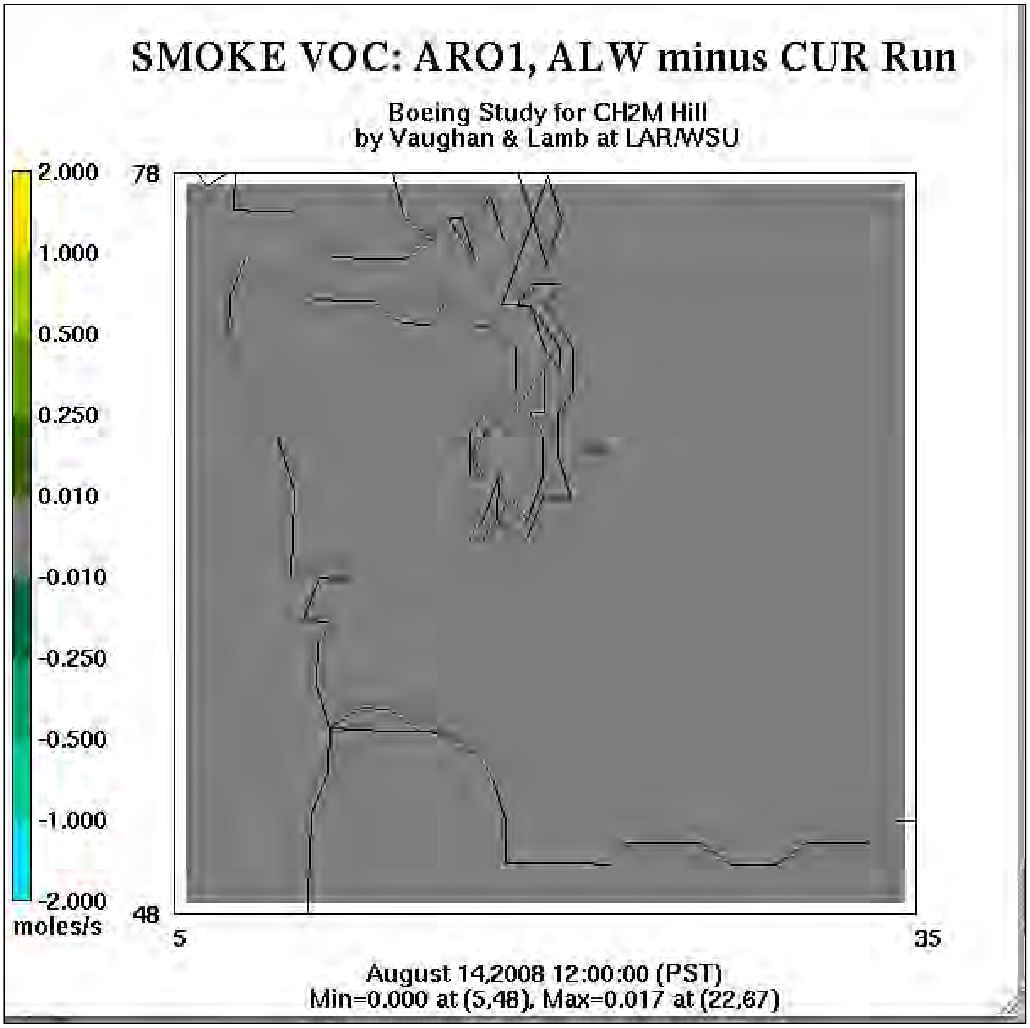

Figure E9. Differences in vertical column-totaled ARO1 emissions within the sub-domain between the CURRENT and ALLOWED emissions cases for August 14, 2008. This shows the effect of the increase of 97% from CURRENT case to ALLOWED case emissions, all of which increase occurs at the Renton facility.

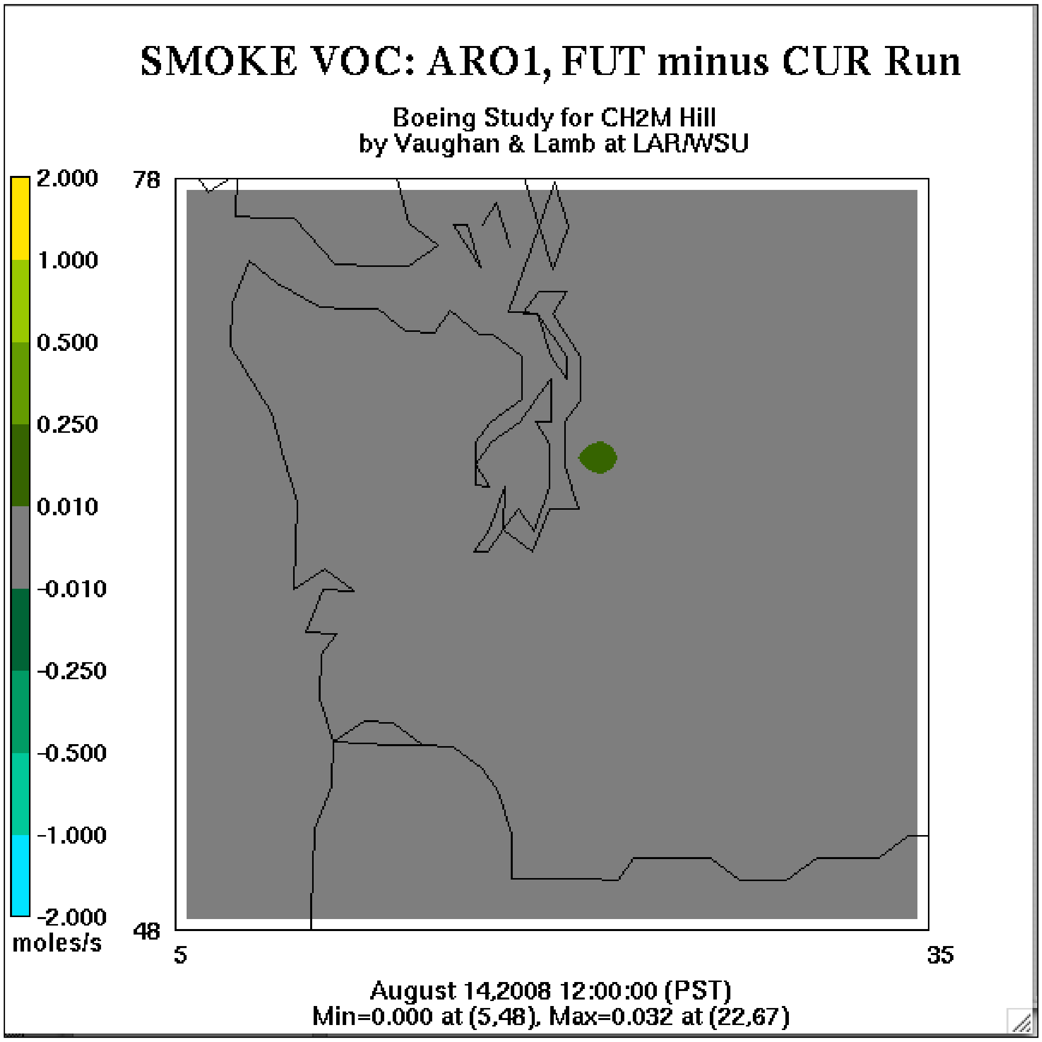

Figure E10. Differences in vertical column-totaled ARO1 emissions within the sub-domain between the CURRENT and FUTURE emissions cases for August 14, 2008. Note the growth of the green area; this shows the effect of increased emissions at North Boeing Field in addition to the increased emissions at Renton, reflecting the fact that the FUTURE case includes increases at both facilities beyond the ALLOWED case. The increase over CURRENT case is 220% and occurs at both facilities.

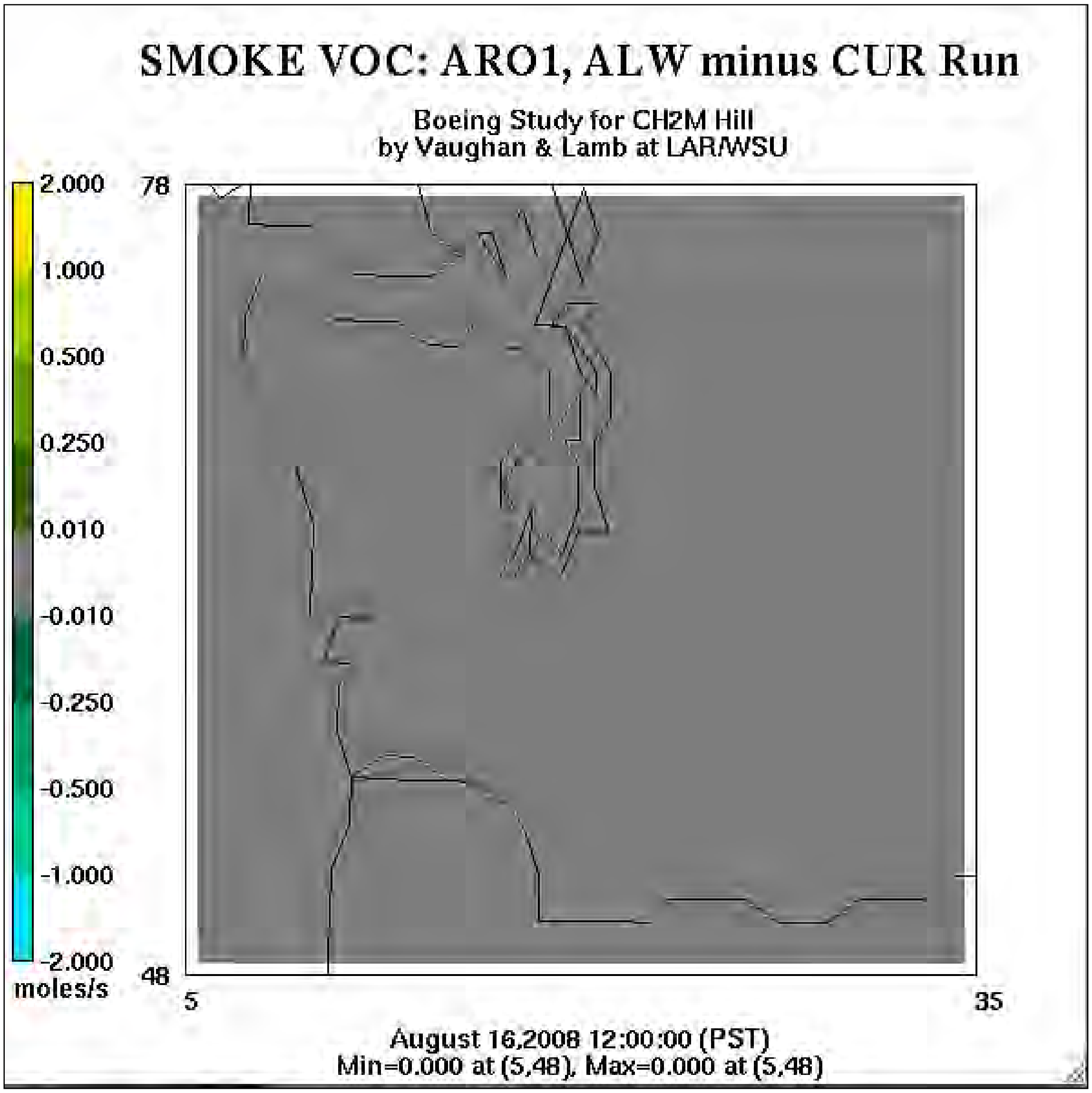

Figure E11. Differences in vertical column-totaled ARO1 emissions within the sub-domain between the CURRENT and ALLOWED emissions cases for Saturday August 16, 2008. Note that because all the Boeing VOC emissions being manipulated are being specified with 24-hour operation for five days a week, but no emissions on weekend days, that the changes between emissions cases are zero fields on the weekend days.

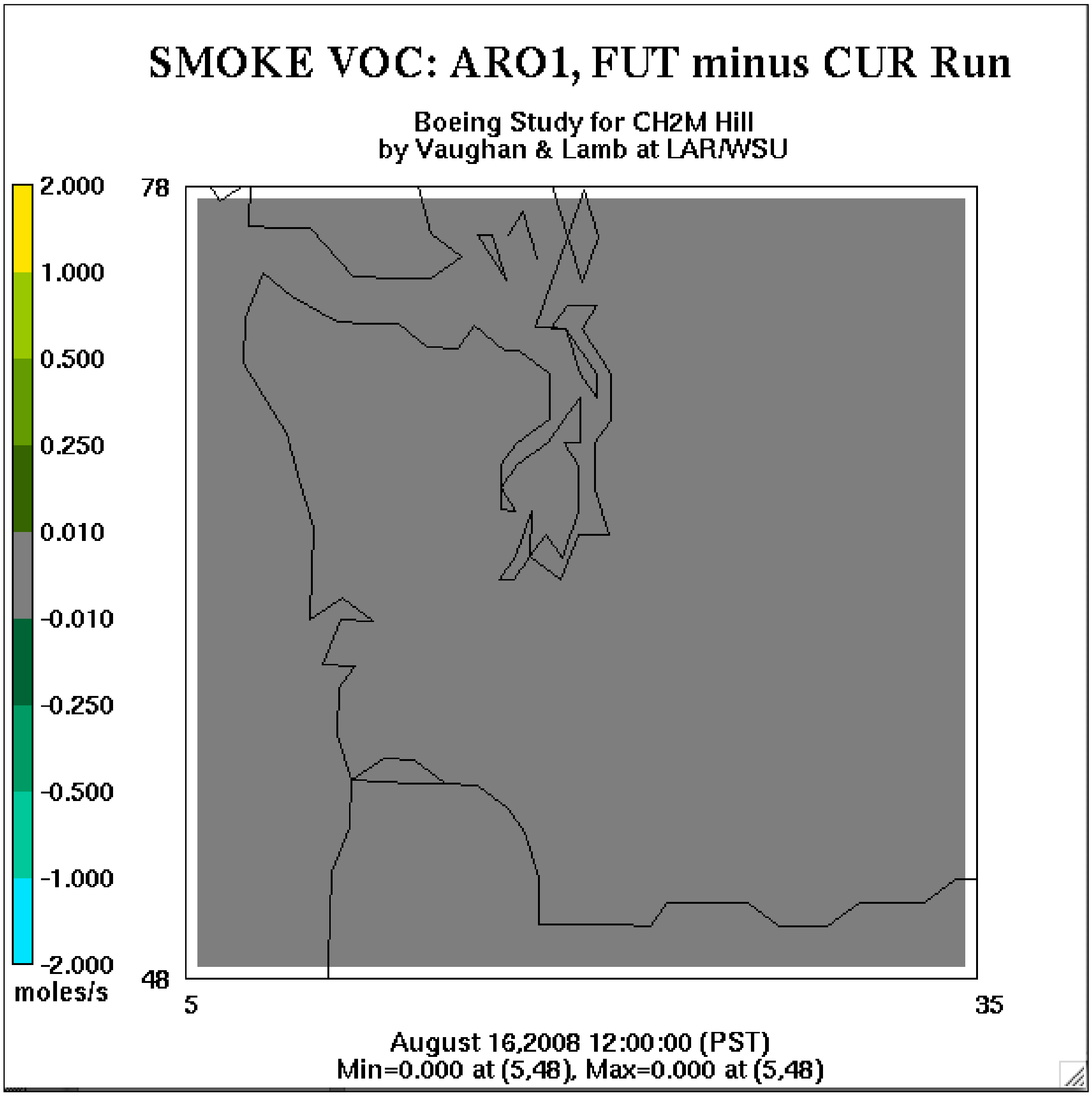

Figure E12. Differences in vertical column-totaled ARO1 emissions within the sub-domain between the CURRENT and FUTURE emissions cases for Saturday August 16, 2008. Note that because all the Boeing VOC emissions being manipulated are being specified with 24-hour operation for five days a week, but no emissions on weekend days, that the changes between emissions cases are zero fields on the weekend days.

OZONE

Air quality modeling is an imperfect practice, and while realistic simulation results are always assiduously sought, the most reliable guidance available from these models is by comparison of results in a relative manner. Therefore, we are more interested in what the model results say in terms of differences, in a relative sense, than in absolute numbers.

In this section, surface-level concentration model results are shown for ozone (O3), as mixing ratio, expressed as parts per billion (volume). Ozone results are shown for the CMAQ runs for both episodes. For days with elevated ozone as seen in Figure 3, the maps of maximum hourly modeled ozone are shown, along with plots showing the differences between emissions cases (CURRENT vs. ALLOWED and CURRENT vs. FUTURE) for the hour of maximum ozone (based on CURRENT run) and/or the hour of maximum positive difference from CURRENT case to other cases.

Results for episode of June 24-July 1, 2008:

- CURRENT CASE surface layer ozone maximum for Saturday June 28th (Figure J1) and Sunday June 29th (Figure J4);
- ALLOWED case less CURRENT case maximum differences for surface layer ozone for Saturday June 28th (Figure J2) and Sunday June 29th (Figure J5), and
- FUTURE case less CURRENT case maximum differences for surface layer ozone for Saturday June 28th (Figure J3) and Sunday June 29th (Figure J6).

Results for episode of August 12-18, 2008:

- CURRENT CASE surface layer ozone maximum for Thursday August 14th (Figure A1), Friday August 15th (Figure A6), and Saturday August 16th (Figure A11);
- ALLOWED case less CURRENT case maximum differences for surface layer ozone for Thursday August 14th (Figures A2 and A3), Friday August 15th (Figures A7 and A8), and Saturday August 16th (Figure A12); and
- FUTURE case less CURRENT case maximum differences for surface layer ozone for Thursday August 14th (Figures A4 and A5), Friday August 15th (Figures A9 and A10), and Saturday August 16th (Figure A13).

JUNE 28 OZONE

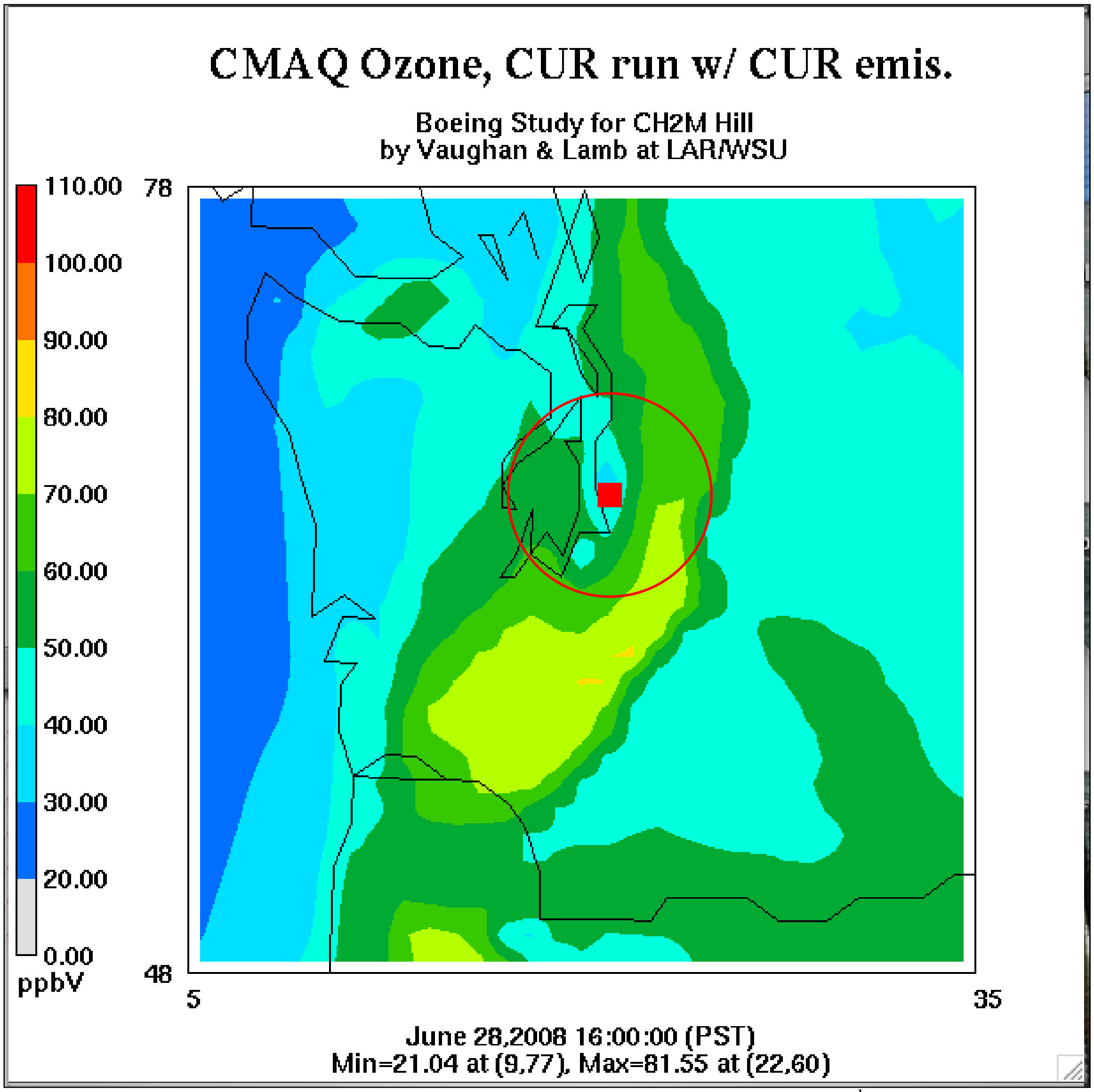

Figure J1. Maximum O3 in CURRENT case run for Saturday June 28th, 2008, is 81 ppb in the vicinity of Mt. Rainier National Park at 16 PST. Also shown is the location of the subject Boeing facilities (cells at column 22, row 67 and column 23, row 67) centered within a circle of radius ~50 km.

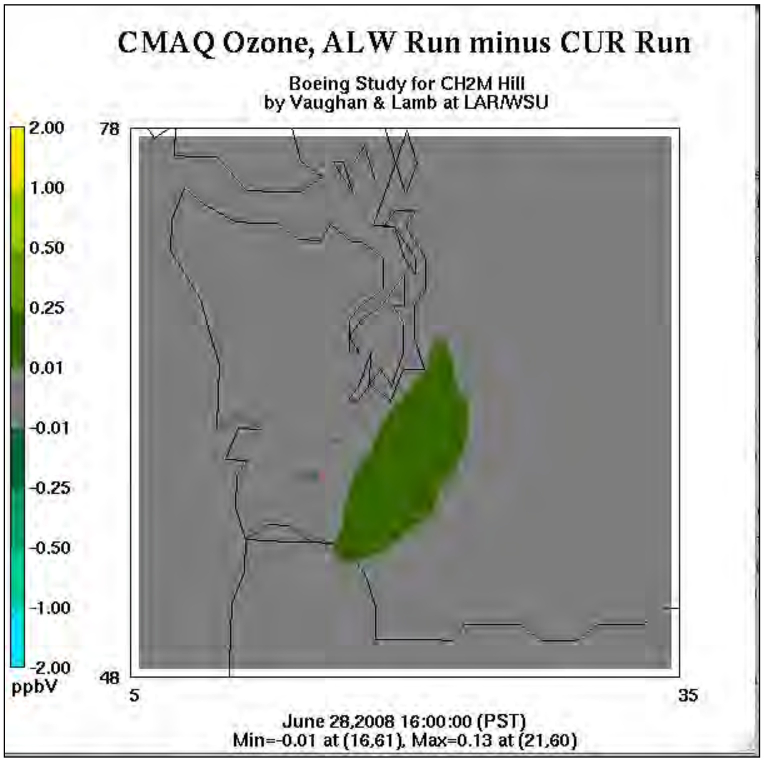

Figure J2. Maximum surface layer ozone difference between CURRENT case and ALLOWED case of 0.13 ppb occurs at 16 PST on June 28th, 2008.

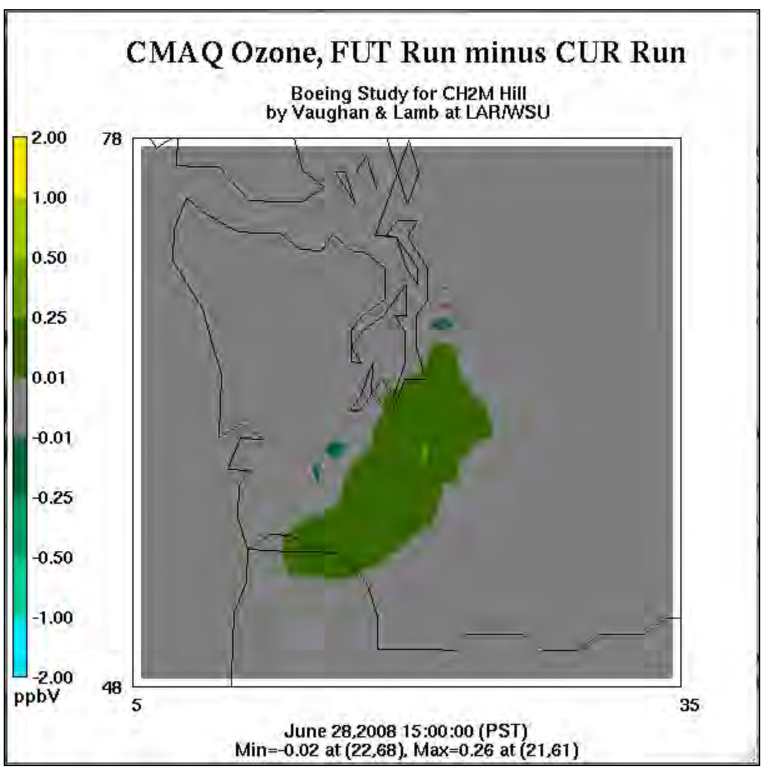

Figure J3. Maximum surface layer ozone difference between CURRENT case and FUTURE case of 0.26 ppb occurs at 15 PST on June 28th, 2008.

JUNE 29 OZONE

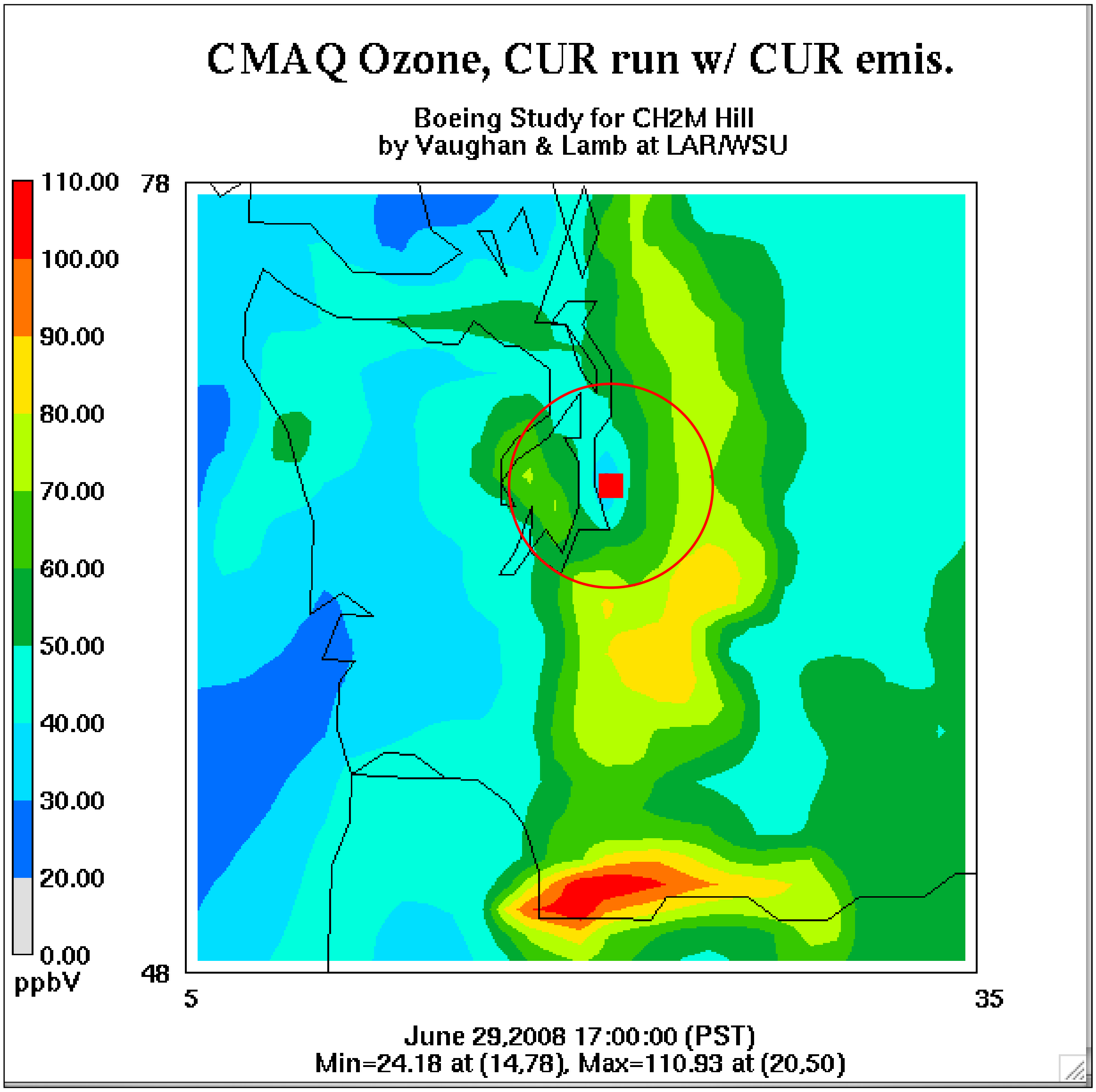

Figure J4. Maximum O3 in CURRENT case run for Sunday June 29th, 2008, is 110.9 ppb at 17 PST along the Columbia Gorge, east of Portland, OR. Ozone is modeled to be 80-90 ppb in the Mt. Rainier National Park. Also shown is the location of the subject Boeing facilities (cells at column 22, row 67 and column 23, row 67) centered within a circle of radius ~50 km.

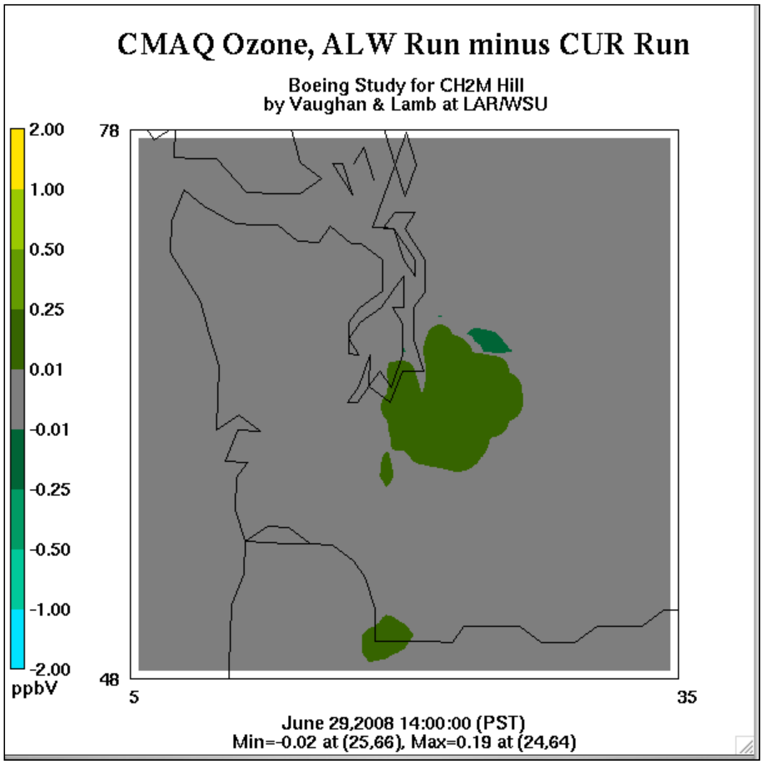

Figure J5. Maximum surface layer ozone difference between CURRENT case and ALLOWED case of 0.19 ppb occurs at 14 PST on June 29th, 2008.

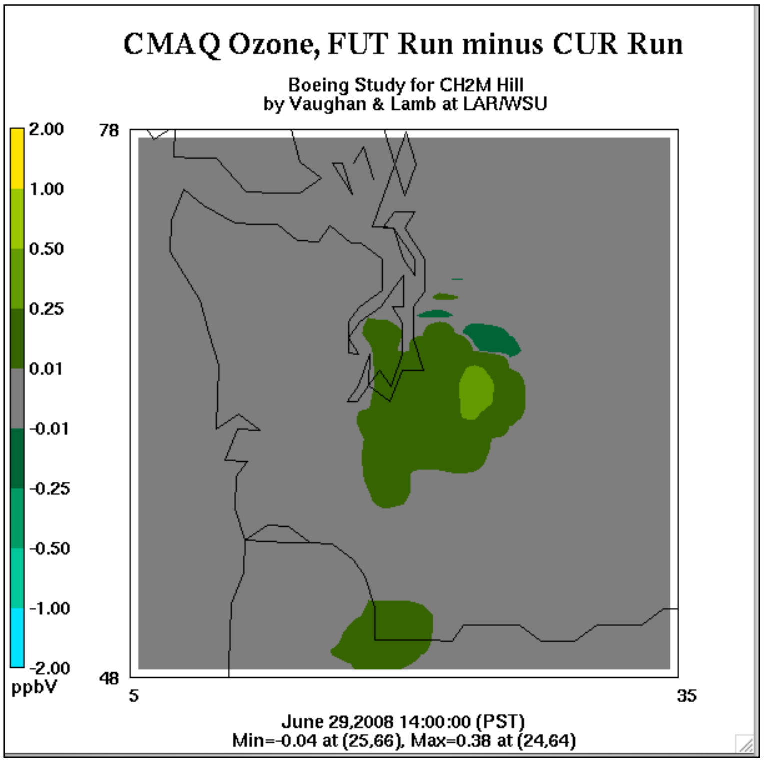

Figure J6. Maximum surface layer ozone difference between CURRENT case and FUTURE case of 0.38 ppb occurs at 14 PST on June 29th, 2008.

AUGUST 14 OZONE

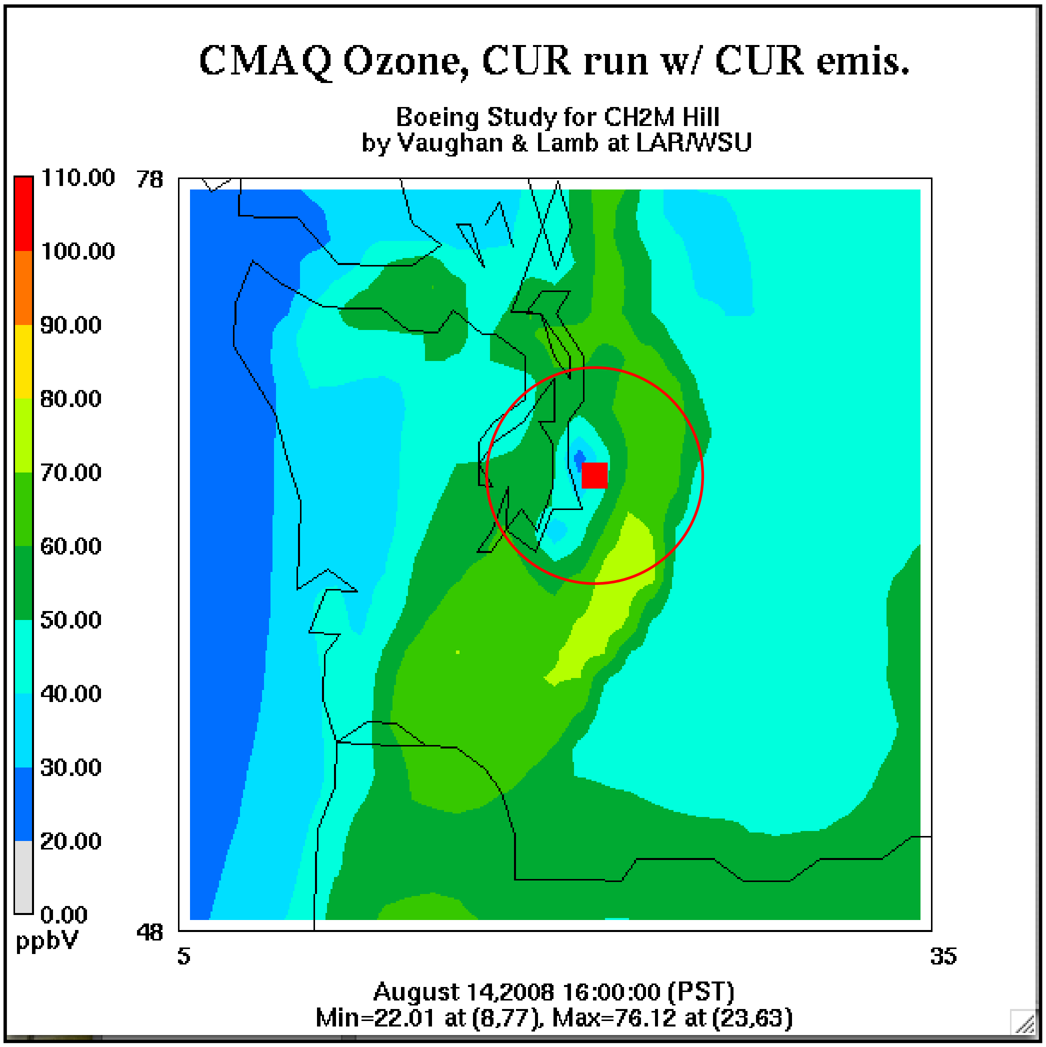

Figure A1. Maximum O3 in CURRENT case run for Thursday August 14, 2008, is 76 ppb in the vicinity of Mt. Rainier National Park at 16 PST. Also shown is the location of the subject Boeing facilities (cells at column 22, row 67 and column 23, row 67) centered within a circle of radius ~50 km.

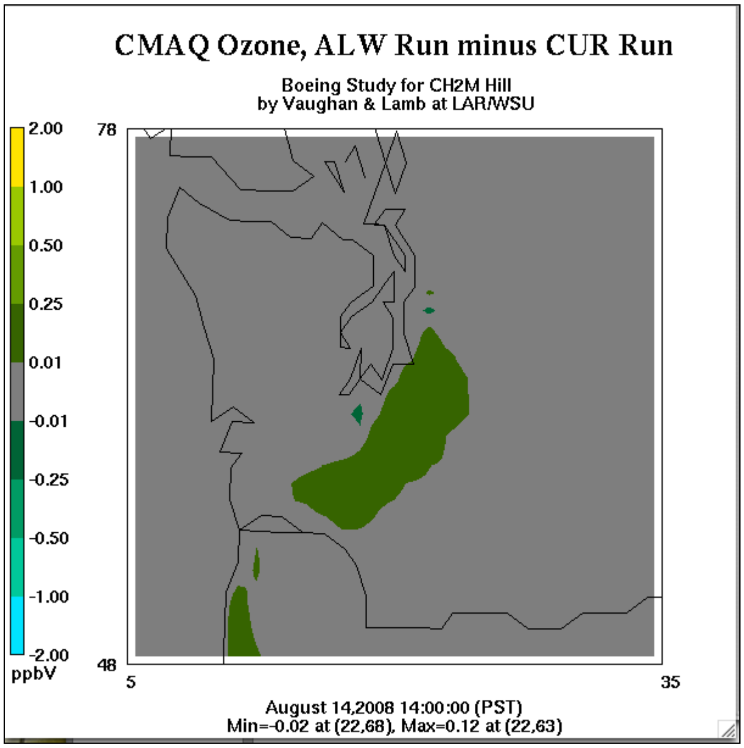

Figure A2. Maximum surface layer ozone difference between CURRENT case and ALLOWED case of 0.12 ppb occurs at two times. Shown here is 14 PST, August 14, 2008.

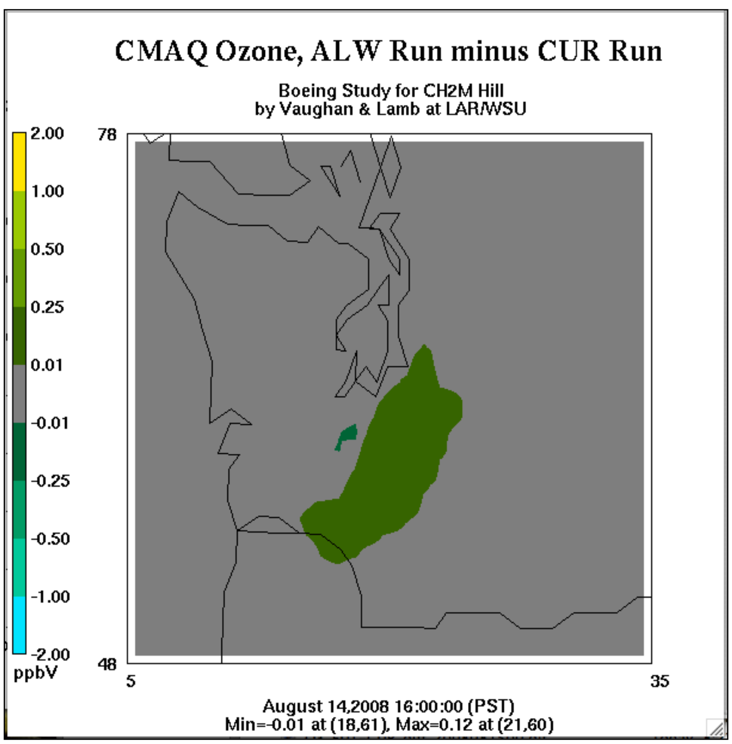

Figure A3. Maximum surface layer ozone difference between CURRENT case and ALLOWED case of 0.12 ppb occurs at two times. Shown here is 16 PST, August 14, 2008.

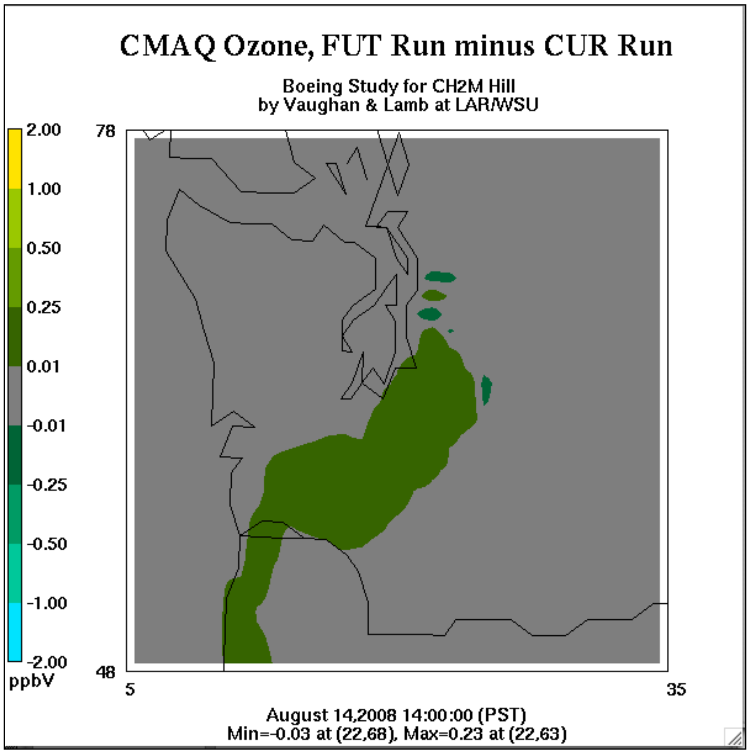

Figure A4. Maximum surface layer ozone difference between CURRENT case and FUTURE case of 0.23 ppb occurs at two times. Shown here is 14 PST, August 14, 2008.

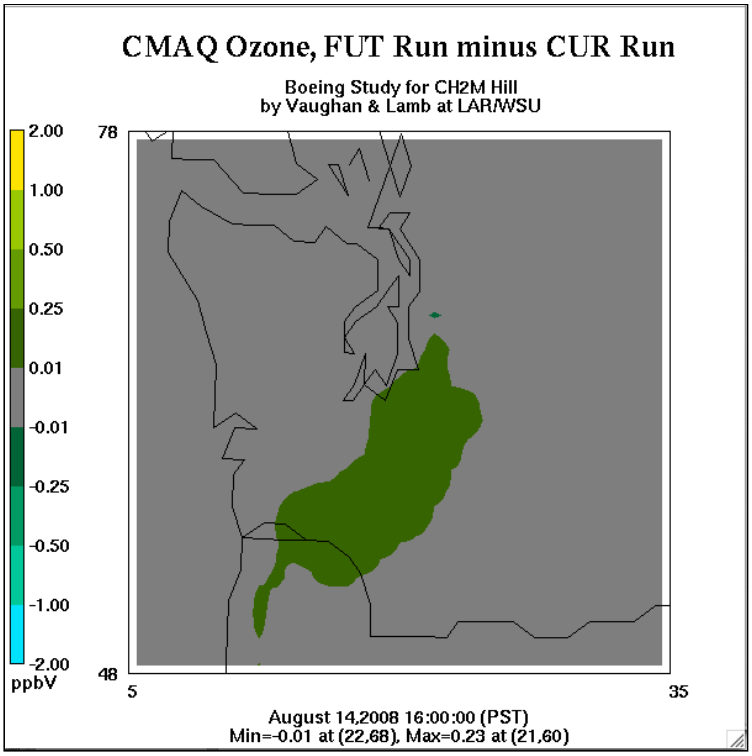

Figure A5. Maximum surface layer ozone difference between CURRENT case and FUTURE case of 0.23 ppb occurs at two times. Shown here is 16 PST, August 14, 2008.

AUGUST 15 OZONE

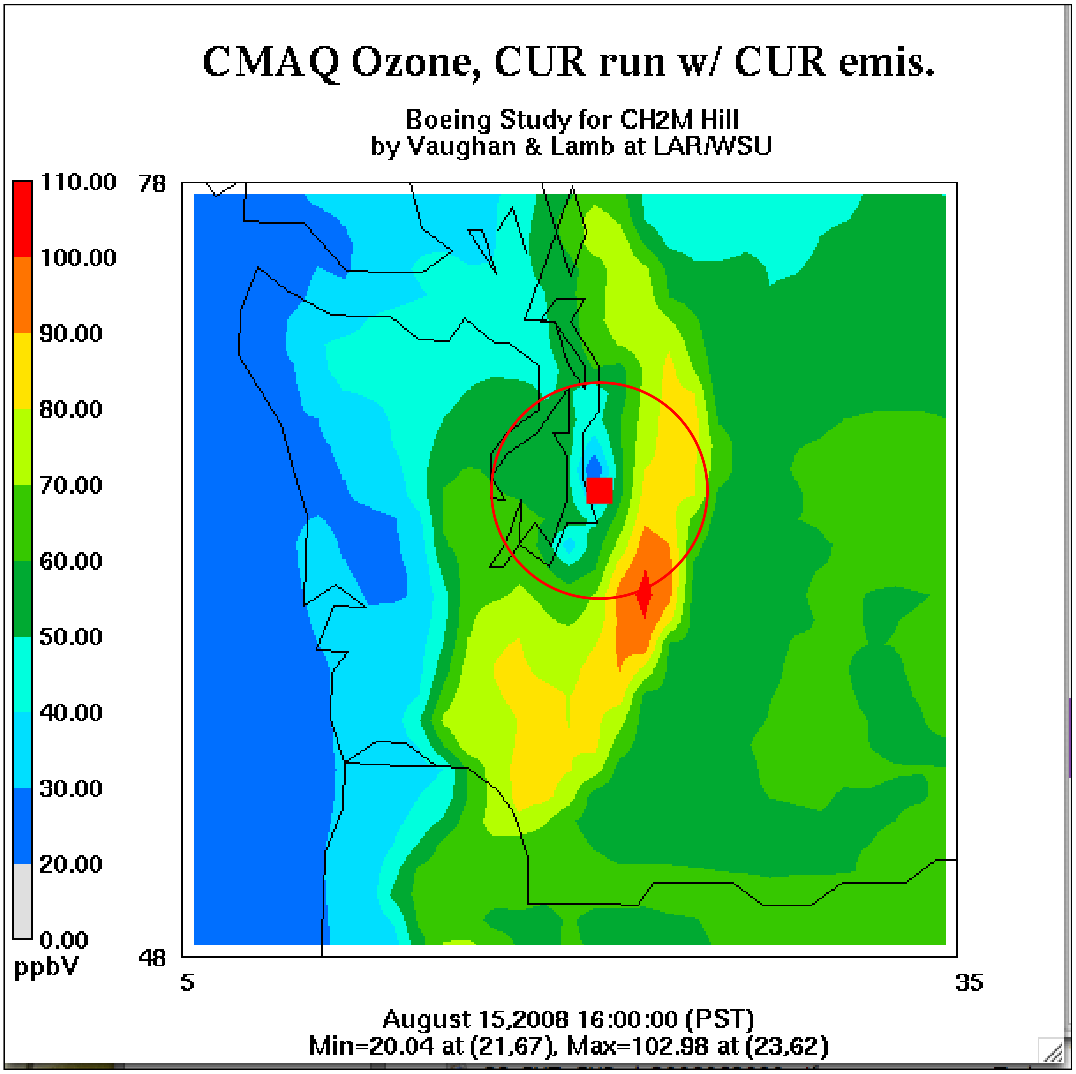

Figure A6. Maximum O3 in CURRENT case run for Friday August 15, 2008, is 103 ppb in the vicinity of Mt. Rainier National Park at 16 PST. Also shown is the location of the subject Boeing facilities (cells at column 22, row 67 and column 23, row 67) centered within a circle of radius ~50 km.

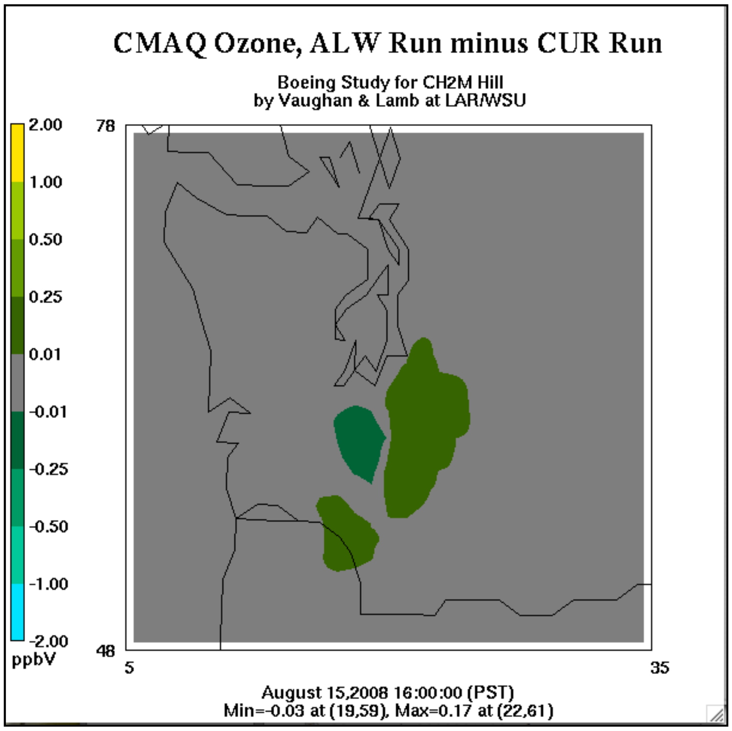

Figure A7. Maximum surface layer ozone difference between CURRENT case and ALLOWED case of 0.17 ppb occurs over three hours. Shown here is 16 PST on August 15, 2008.

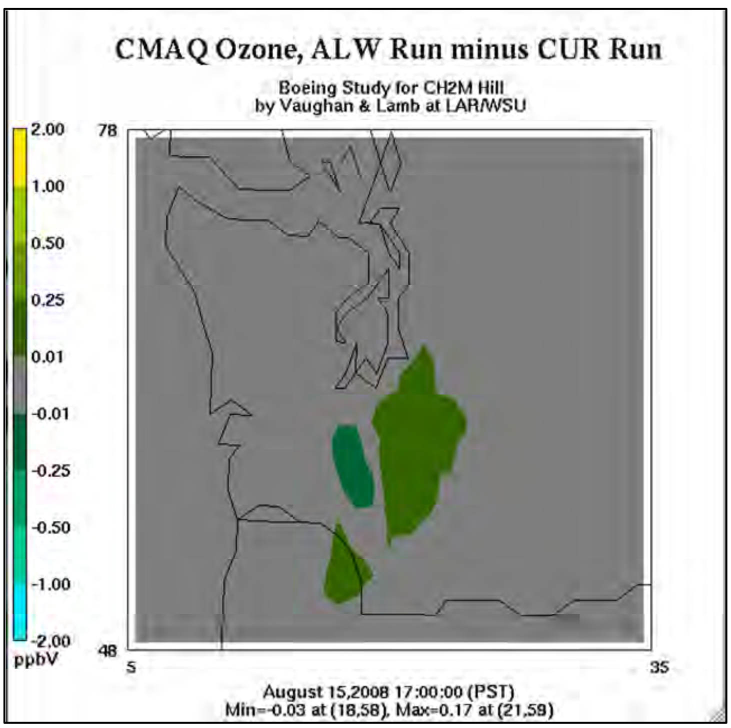

Figure A8. Maximum surface layer ozone difference between CURRENT case and ALLOWED case of 0.17 ppb occurs over three hours. Shown here is 17 PST on August 15, 2008.

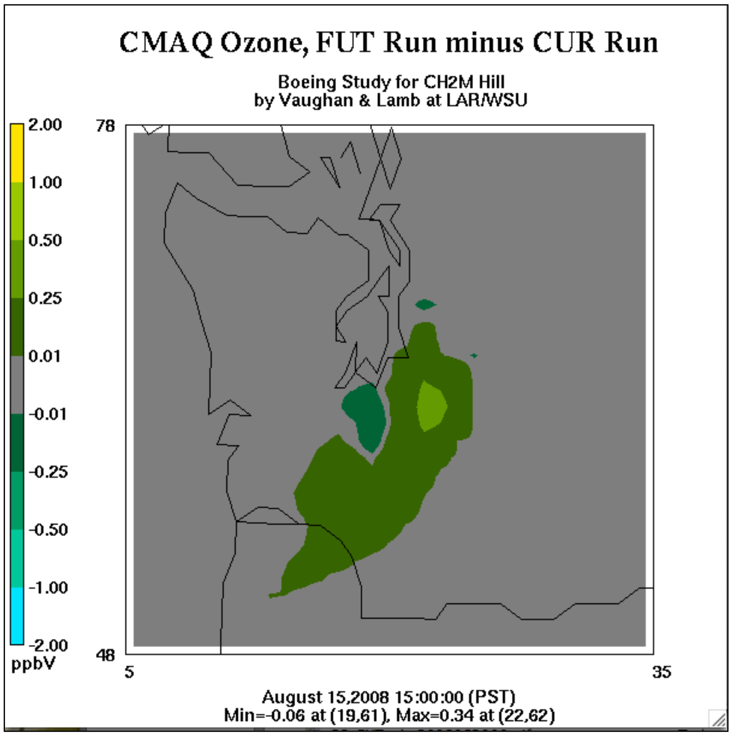

Figure A9. Maximum surface layer ozone difference between CURRENT case and FUTURE case of 0.34 ppb occurs over three hours. Shown here is 15 PST on August 15, 2008.

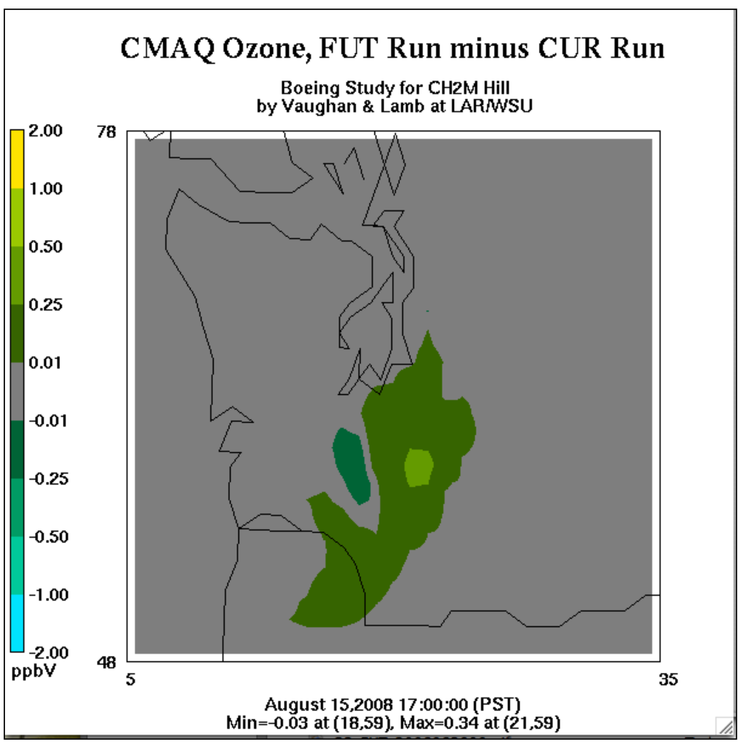

Figure A10. Maximum surface layer ozone difference between CURRENT case and FUTURE case of 0.34 ppb occurs over three hours. Shown here is 17 PST on August 15, 2008.

AUGUST 16 OZONE

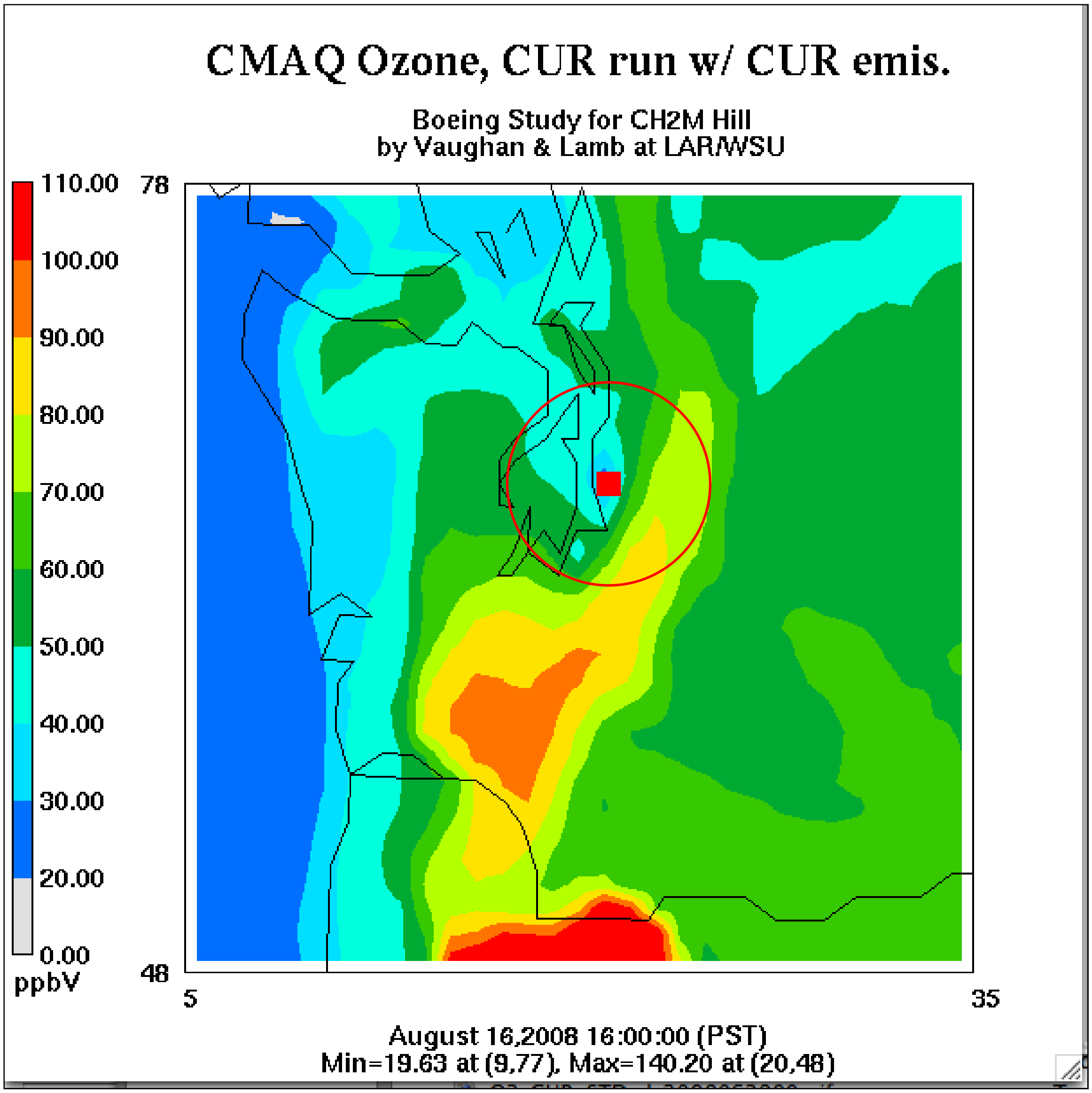

Figure A11. Maximum O3 in CURRENT case run for Saturday August 16, 2008, is 140 ppb at 16 PST in the Portland area and nearby Columbia Gorge. Ozone is 80-90 ppb in the vicinity of the Mt. Rainier National Park. Also shown is the location of the subject Boeing facilities (cells at column 22, row 67 and column 23, row 67) centered within a circle of radius ~50 km.

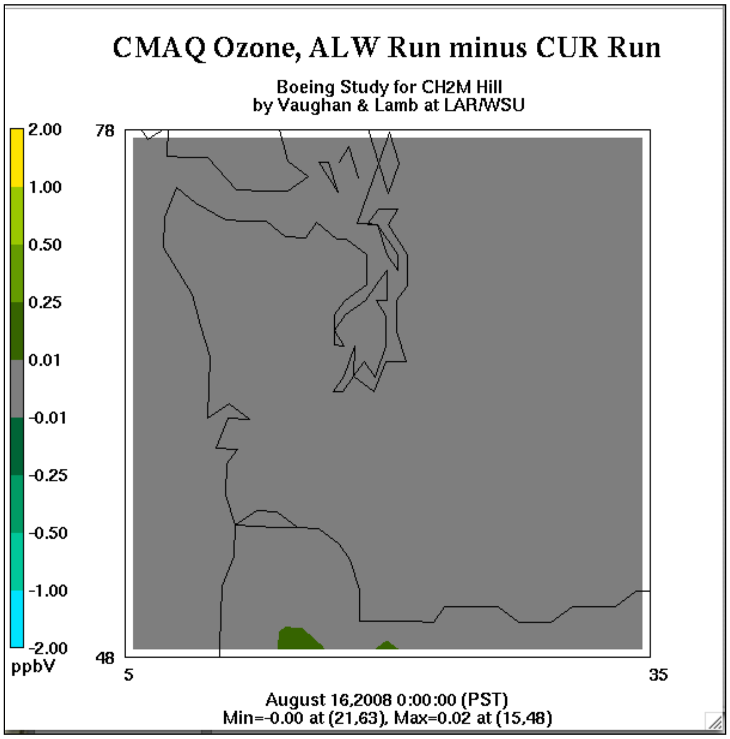

Figure A12. Maximum surface layer ozone difference between CURRENT case and ALLOWED case of 0.02 ppb occurs in the earliest hours for Saturday August 16, 2008, basically just a remnant of the previous day.

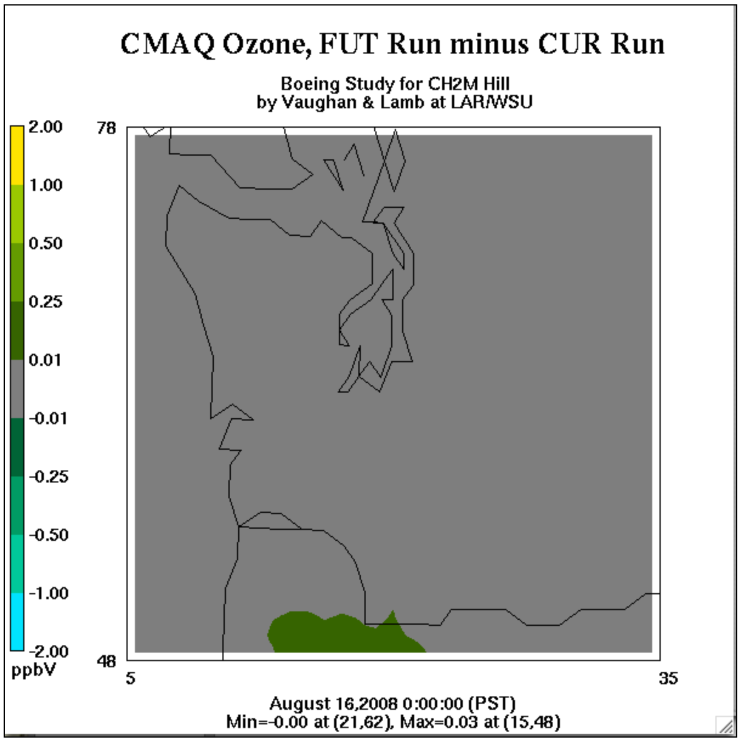

Figure A13. Maximum surface layer ozone difference between CURRENT case and FUTURE case of 0.03 ppb occurs in the earliest hours for Saturday August 16, 2008, basically just a remnant of the previous day.

SUMMARY of SIMULATION RESULTS

The June 2008 ozone episode simulations for three emissions cases show very small increases in surface-level ozone. The maximum (high ozone day) difference (increase) in surface-level ozone, from the CURRENT emissions case to the ALLOWED emissions case, is 0.19 ppbv (190 parts per trillion) on Sunday June 29th, 2008. The maximum (high ozone day) difference (increase) in surface-level ozone, from the CURRENT emissions case to the FUTURE emissions case, is 0.38 ppbv (380 parts per trillion), also on June 29th, 2008. Due to the seven-days-of-seven emissions profile that was applied for the June episode, emission rates are constant in time within each of the emissions cases. Simulated ozone levels decrease on June 30 to a maximum <= 80 ppb, and decrease again on July 1 to a maximum < 70 ppb, presumably due to a decline in ozone-favorable conditions.

The August 2008 ozone episode simulations for three emissions cases also show very small increases in surface-level ozone. The maximum (high ozone day) difference (increase) in surface-level ozone, from the CURRENT emissions case to the ALLOWED emissions case, is 0.17 ppbv (170 parts per trillion). The maximum (high ozone day) difference (increase) in surface-level ozone, from the CURRENT emissions case to the FUTURE emissions case, is 0.34 ppbv (340 parts per trillion). Both these maximum differences in surface-level ozone were seen in results for Friday August 15th. Due to the five-days-of-seven emissions profile that was applied for the August episode, the Saturday and Sunday emissions return to relative background rates. For both the ALLOWED and FUTURE cases, the residual ozone differences seen for Friday August 15 decrease as ozone-favorable conditions weaken.

The results for the simulation of both episodes indicate that the proposed changes in VOC emissions at the two Boeing plants will have a very small and negligible effect upon ambient ozone levels within the western Washington region. These results are consistent with the relatively small change in VOC emissions as a portion of total VOCs emitted within the urban region of Puget Sound.

----------- End of Report ---------