U.S. Department of Energy
Hanford Site

February 2, 2021

21-ESQ-000366

Mr. David Bowen, Program Manager
Nuclear Waste Program
Washington State Department of Ecology
3100 Port of Benton Boulevard
Richland, Washington 99354

Ms. Kelly McFadden, Manager
Stationary Source Unit
U.S. Environmental Protection Agency
Region 10
1200 Sixth Avenue, Suite 900, AWT-150
Seattle, Washington 98101

Dear Addressees:

NOTICE OF CONSTRUCTION APPLICATION AND SECOND TIER REVIEW FOR HANFORD SITE WATER SYSTEMS UPGRADE

The U.S. Department of Energy, Richland Operations Office (RL) is planning various infrastructure upgrades to the Hanford Site Export Water, Raw Water, and Sanitary Water Systems (i.e., Hanford Site Water Systems) to support ongoing and planned operations on the Hanford Site. These upgrades will result in the construction and operation of six new emergency-stationary-engine-powered diesel generators, two potable water storage tanks, and one set of wastewater sludge lagoons generated from water system backwash. RL hereby submits this Notice of Construction (NOC) Application for your approval in support of these planned upgrades.

- Attachment 1 is the completed NOC Application form that provides basic project information.

- Attachment 2, "Water Systems Upgrade Notice of Construction Application Technical Information," (DOE/RL-2020-33, Rev. 0), provides detailed project information, including project descriptions, a process flow diagram, site maps, best available control technology and best available control technology for toxics analysis, and emission estimates. This document shows that project criteria air pollutant emissions will be below Washington Administrative Code (WAC) 173-400-110(5) exemption levels, except for particulate matter 2.5 and nitrogen oxides. It also shows that the project will emit 22 toxic air pollutants, of which five will exceed the small quantity emission rate,

and two – diesel engine exhaust particulate; and nitrogen dioxide – will exceed the acceptable Source Impact Level (ASIL). Additionally, this document shows that no ozone depleting substance will be emitted, the project will not result in a violation of an ambient air quality standard, and will not result in a major modification; and therefore will not require prevention of significant deterioration permitting.

- Attachment 3, "Second Tier Review Supporting DOE/RL-2020-33, Water Systems Upgrade Notice of Construction Application Technical Information," (HNF-RPT-65735, Rev. 0), is provided pursuant to WAC 173-460-090 as a result of the ASIL exceedances for diesel engine exhaust particulate and nitrogen dioxide as addressed in Attachment 2. This document provides supplemental air dispersion modeling data, toxicological assessments, and an analysis of hazards and risks associated with the project to support approval of the NOC Application.

- Attachment 4 is the completed Notification of Administrative Permit Amendment that supports incorporation of the intended Washington State Department of Ecology (Ecology) approval order into the Hanford Site Air Operating Permit No: 00-05-006, Renewal 3; in accordance with WAC 173-401-720.

Air dispersion modeling files supporting the ambient air impact analysis, documented in REG-1168, "Water Systems Upgrades Notice of Construction Application AERMOD Modeling Files," will be transmitted to Ecology through the Hanford Site Hanford Mission Integration Solutions, LLC (HMIS) File Transfer website, https://transfer.hanford.gov/. Nuclear Waste Program Public Records Officers, Teresa Booth and Joy Morris, have access to download the files at their convenience upon receipt of this letter. Please contact Tanya Williams, Hanford Mission Integration Solutions, LLC, at (509) 994-4139 or tanya_r_williams@rl.gov, with any questions.

If you have any questions, please contact me, or your staff may contact Glyn D. Trenchard, Acting Assistant Manager for Safety and Environment, RL, on (509) 373-4016.

Sincerely,

Brian T. Vance Digitally signed by Brian T. Vance
Date: 2021.02.02 16:05:03 -08'00'

Brian T. Vance
Manager

ESQ:AET

Attachments: (4)

cc: See page 3

cc w/attachs:
L. M. Bauder, Ecology
M. F. Williams, Ecology
M. Williams, Ecology
Administrative Record
Environmental Portal, G3-35

cc w/o attachs:
J. Bell, NPT
R. Buck, Wanapum
M. J. Demiter, HMIS
A. L. Johnson, HMIS
M. Murphy, CTUIR
L. Contreras, YN
M. B. Wilson, HMIS

Attachment 1
21-ESQ-000366

NOTICE OF CONSTRUCTION APPLICATION

(7 pages including cover sheet)

Notice of Construction Application

A notice of construction permit is required before installing a new source of air pollution or modifying an existing source of air pollution. This application applies to facilities in Ecology's jurisdiction. Submit this application for review of your project. For general information about completing the application, refer to Ecology Forms ECY 070-410a-g, "Instructions for Ecology's Notice of Construction Application."

Ecology offers up to two hours of free pre-application assistance. We encourage you to schedule a pre-application meeting with the contact person specified for the location of your proposal, below. If you use up your two hours of free pre-application assistance, we will continue to assist you after you submit Part 1 of the application and the application fee. You may schedule a meeting with us at any point in the process.

Upon completion of the application, please enclose a check for the initial fee and mail to:

Department of Ecology
Cashiering Unit
P.O. Box 47611
Olympia, WA 98504-7611

For Fiscal Office Use Only:
001-NSR-216-0299-000404

Check the box for the location of your proposal. For assistance, call the contact listed below:		
	Ecology Permitting Office	**Contact**
☐ **CRO**	**Chelan, Douglas, Kittitas, Klickitat, or Okanogan County** Ecology Central Regional Office – Air Quality Program	Lynnette Haller (509) 457-7126 lynnette.haller@ecy.wa.gov
☐ **ERO**	**Adams, Asotin, Columbia, Ferry, Franklin, Garfield, Grant, Lincoln, Pend Oreille, Stevens, Walla Walla or Whitman County** Ecology Eastern Regional Office – Air Quality Program	Karin Baldwin (509) 329-3452 karin.baldwin@ecy.wa.gov
☐ **NWRO**	**San Juan County** Ecology Northwest Regional Office – Air Quality Program	David Adler (425) 649-7267 david.adler@ecy.wa.gov
☐ **IND**	**For actions taken at Kraft and Sulfite Paper Mills and Aluminum Smelters** Ecology Industrial Section – Waste 2 Resources Program Permit manager: _____	James DeMay (360) 407-6868 james.demay@ecy.wa.gov
☒ **NWP**	**For actions taken on the US Department of Energy Hanford Reservation** Ecology Nuclear Waste Program	Lilyann Murphy (509) 372-7951 lilyann.murphy@ecy.wa.gov

Check the box below for the fee that applies to your application.

To request ADA accommodation, call (360) 407-6800, 711 (relay service), or 877-833-6341(TTY).

Notice of Construction Application

New project or equipment:

☒	**$1,500: Basic project** initial fee covers up to 16 hours of review.
☐	**$10,000: Complex project** initial fee covers up to 106 hours of review.

Change to an existing permit or equipment:

☐	**$200: Administrative or simple change** initial fee covers up to 3 hours of review Ecology may determine your change is complex during completeness review of your application. If your project is complex, you must pay the additional $675 before we will continue working on your application.
☐	**$875: Complex change** initial fee covers up to 10 hours of review
☐	**$350** flat fee: **Replace or alter control technology equipment under WAC 173-400-114** Ecology will contact you if we determine your change belongs in another fee category. You must pay the fee associated with that category before we will continue working on your application.

Read each statement, then check the box next to it to acknowledge that you agree.	
☒	The initial fee you submitted may not cover the cost of processing your application. Ecology will track the number of hours spent on your project. If the number of hours Ecology spends exceeds the hours included in your initial fee, Ecology will bill you $95 per hour for the extra time.
☒	You must include all information requested by this application. Ecology may not process your application if it does not include all the information requested.
☒	Submittal of this application allows Ecology staff to visit and inspect your facility.

To request ADA accommodation, call (360) 407-6800, 711 (relay service), or 877-833-6341(TTY).

Notice of Construction Application

Part 1: General Information

I. Project, Facility, and Company Information

1. Project Name Water System Upgrades
2. Facility Name Hanford Site
3. Facility Street Address 2430 Stevens Center Place
4. Facility Legal Description N/A
5. Company Legal Name (if different from Facility Name) U S Department of Energy Richland Operations Office (DOE-RL)
6. Company Mailing Address (street, city, state, zip) P.0. Box 650, Richland WA 99352

II. Contact Information and Certification

1. Facility Contact Name (who will be onsite) Jon Kon	
2. Facility Contact Mailing Address (if different than Company Mailing Address) Mission Support Alliance P.O. Box 650 Richland, WA 99352	
3. Facility Contact Phone Number (509) 373-5366	4. Facility Contact E-mail jonathan_b_kon@rl.gov
5. Billing Contact Name (who should receive billing information) Thomas W. Ferns	
6. Billing Contact Mailing Address (if different than Company Mailing Address)	
7. Billing Contact Phone Number (509) 376-7474	8. Billing Contact E-mail thomas.ferns@rl.doe.gov
9. Consultant Name (optional – if 3rd party hired to complete application elements)	
10. Consultant Organization/Company	
11. Consultant Mailing Address (street, city, state, zip)	
12. Consultant Phone Number	13.Consultant E-mail
14. Responsible Official Name and Title (who is responsible for project policy or decision-making) Brian T. Vance, Manager, DOE-RL	
16. Responsible Official Phone (509) 376-7395	17. Responsible Official E-mail brian.vance@rl.doe.gov
18. Responsible Official Certification and Signature I certify that the information on this application is accurate and complete. Signature Brian T. Vance Digitally signed by Brian T. Vance Date: 2021.02.02 16:06:04 -08'00' Date	

Part 2: Technical Information

To request ADA accommodation, call (360) 407-6800, 711 (relay service), or 877-833-6341(TTY).

Notice of Construction Application

The Technical Information may be sent with this application form to the Cashiering Unit, or may be sent directly to the Ecology regional office with jurisdiction along with a copy of this application form.

For all sections, check the box next to each item as you complete it.

III. Project Description

Please attach the following to your application.

☒ Written narrative describing your proposed project.
☒ Projected construction start and completion dates.
☒ Operating schedule and production rates.
☒ List of all major process equipment with manufacturer and maximum rated capacity.
☒ Process flow diagram with all emission points identified.
☒ Plan view site map.

☐ Manufacturer specification sheets for major process equipment components.
☐ Manufacturer specification sheets for pollution control equipment.
☒ Fuel specifications, including type, consumption (per hour & per year) and percent sulfur.

IV. State Environmental Policy Act (SEPA) Compliance

Check the appropriate box below.

☐ SEPA review is complete:
Include a copy of the final SEPA checklist and SEPA determination (e.g., DNS, MDNS, EIS) with your application.

☒ SEPA review has not been conducted:

☐ If review will be conducted by another agency, list the agency. You must provide a copy of the final SEPA checklist and SEPA determination before Ecology will issue your permit.
Agency Reviewing SEPA:
_____

☒ If the review will be conducted by Ecology, fill out a SEPA checklist and submit it with your application. You can find a SEPA checklist online at https://ecology.wa.gov/Regulations-Permits/SEPA/Environmental-review/SEPA-document-templates

To request ADA accommodation, call (360) 407-6800, 711 (relay service), or 877-833-6341(TTY).

Notice of Construction Application

V. Emissions Estimations of Criteria Pollutants

Does your project generate criteria air pollutant emissions? ☒ Yes ☐ No

If yes, please provide the following information regarding your criteria emissions in your application.

☒ The names of the criteria air pollutants emitted (i.e., NO_x, SO_2, CO, $PM_{2.5}$, PM_{10}, TSP, VOC, and Pb)

☒ Potential emissions of criteria air pollutants in tons per hour, tons per day, and tons per year (include calculations)

☐ If there will be any fugitive criteria pollutant emissions, clearly identify the pollutant and quantity

VI. Emissions Estimations of Toxic Air Pollutants

Does your project generate toxic air pollutant emissions? ☒ Yes ☐ No

If yes, please provide the following information regarding your toxic air pollutant emissions in your application.

☒ The names of the toxic air pollutants emitted (specified in WAC 173-460-150[1])

☒ Potential emissions of toxic air pollutants in pounds per hour, pounds per day, and pounds per year (include calculations)

☐ If there will be any fugitive toxic air pollutant emissions, clearly identify the pollutant and quantity

VII. Emission Standard Compliance

☒ Provide a list of all applicable new source performance standards, national emission standards for hazardous air pollutants, national emission standards for hazardous air pollutants for source categories, and emission standards adopted under Chapter 70.94 RCW.
Does your project comply with all applicable standards identified? ☒ Yes ☐ No

VIII. Best Available Control Technology

☒ Provide a complete evaluation of Best Available Control Technology (BACT) for your proposal.

[1] http://apps.leg.wa.gov/WAC/default.aspx?cite=173-460-150

To request ADA accommodation, call (360) 407-6800, 711 (relay service), or 877-833-6341(TTY).

IX. Ambient Air Impacts Analyses

Please provide the following:

☒ Ambient air impacts analyses for Criteria Air Pollutants (including fugitive emissions)

☒ Ambient air impacts analyses for Toxic Air Pollutants (including fugitive emissions)

☒ Discharge point data for each point included in air impacts analyses (include only if modeling is required)

- ☒ Exhaust height
- ☒ Exhaust inside dimensions (ex. diameter or length and width)
- ☒ Exhaust gas velocity or volumetric flow rate
- ☒ Exhaust gas exit temperature
- ☒ The volumetric flow rate
- ☒ Description of the discharges (i.e., vertically or horizontally) and whether there are any obstructions (ex., raincap)
- ☒ Identification of the emission unit(s) discharging from the point
- ☒ The distance from the stack to the nearest property line
- ☒ Emission unit building height, width, and length
- ☒ Height of tallest building on-site or in the vicinity and the nearest distance of that building to the exhaust
- ☒ Whether the facility is in an urban or rural location

Does your project cause or contribute to a violation of any ambient air quality standard or acceptable source impact level? ☒ Yes ☐ No

To request ADA accommodation, call (360) 407-6800, 711 (relay service), or 877-833-6341(TTY).

Attachment 2
21-ESQ-000366

WATER SYSTEMS UPGRADE NOTICE OF CONSTRUCTION APPLICATION
TECHNICAL INFORMATION

(199 pages including cover sheet)

DOE/RL-2020-33
Rev. 0

Water Systems Upgrade Notice of Construction Application Technical Information

Prepared for the U.S. Department of Energy
Assistant Secretary for Environmental Management

U.S. DEPARTMENT OF ENERGY | Richland Operations Office
P.O. Box 550
Richland, Washington 99352

Approved for public release;
further dissemination unlimited.

TRADEMARK DISCLAIMER

Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise, does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof or its contractors or subcontractors.

This report has been reproduced from the best available copy.

Printed in the United States of America

DOE/RL-2020-33
Rev. 0

Water Systems Upgrade Notice of Construction Application Technical Information

Date Published
January 2021

Prepared for the U.S. Department of Energy
Assistant Secretary for Environmental Management

U.S. DEPARTMENT OF ENERGY | Richland Operations Office
P.O. Box 550
Richland, Washington 99352

_____ _____
Release Approval Date

Approved for public release;
further dissemination unlimited.

This page intentionally left blank.

Executive Summary

This Notice of Construction (NOC) application is being submitted pursuant to WAC 173-400, "General Regulations for Air Pollution Sources," and WAC 173-460, "Controls for New Sources of Toxic Air Pollutants," to obtain Washington State Department of Ecology (Ecology) approval to construct and operate multiple emission units related to the Hanford Site Water Systems. As agreed with Ecology during an August 17, 2020 pre-application meeting, the scope of this NOC application includes 16 different projects that will renovate and upgrade the Hanford Site's Export Water, Raw Water, and Sanitary Water Systems to support ongoing operations on the Hanford Site. New emission units that will be constructed and operated pursuant to this NOC application consist of six new emergency-stationary-engine-powered generators, two potable water storage tanks, and one set of wastewater sludge lagoons.

These emission units will emit four criteria pollutants: carbon monoxide, particulate matter (PM) (PM-2.5 and PM-10), sulfur dioxide, and nitrogen oxides. Two of these criteria pollutants (PM 2.5 and nitrogen oxides) are estimated to exceed the WAC 173-400-110(5) exemption levels. Additionally, total volatile organic compounds are estimated to exceed the WAC 173-400-110(5) exemption levels.

Additionally, these emission units will emit 22 toxic air pollutants (TAP). Of these TAPs, nine are estimated to exceed the WAC 173-460-150 de minimis levels: diesel engine exhaust, particulate; nitrogen dioxide; benzene; formaldehyde; naphthalene; benzo(b)fluoranthene; benzo(a)pyrene; dibenz(a,h)anthracene; and chloroform. Of these nine, diesel engine exhaust, particulate; nitrogen dioxide; benzene; chloroform, and naphthalene are estimated to exceed the WAC 173-460-150 small quantity emission rate (SQER) levels.

Air dispersion modeling for the five TAPs that are estimated to exceed the SQER levels indicates that benzene, chloroform, and naphthalene will remain below the WAC 173-460-150 acceptable source impact levels (ASIL). Modeling data for emissions from the project L-781 and project L-826 River Pump Houses indicate that the ASIL for diesel engine exhaust, particulate, and nitrogen dioxide will be exceeded. Accordingly, a health impact assessment is being developed and will be submitted to Ecology in conjunction with this NOC application.

This page intentionally left blank.

Contents

1.0 Project Description 1-1
1.1 Project L-781 Description 1-6
1.2 Project L-826 Description 1-7
1.3 Project L-849 Description 1-7
1.4 Project L-850 Description 1-9
1.5 Project L-895 Description 1-10
1.6 Project L-897 Description 1-13

2.0 State Environmental Policy Act Compliance 2-1

3.0 Emissions Estimations of Criteria Pollutants 3-1

4.0 Emissions Estimations of Toxic Air Pollutants 4-1

5.0 Emission Standard Compliance 5-1

6.0 Best Available Control Technology 6-1
6.1 Engine BACT & tBACT Analysis 6-1
6.2 Water Systems BACT & tBACT Analysis 6-3

7.0 Ambient Air Impacts Analyses 7-1
7.1 Modeling Parameters 7-1
7.1.1 Modeling Inputs 7-2
7.2 Meteorological Data 7-5
7.3 Modeling Methodology 7-5
7.4 Modeling Results 7-6
7.4.1 National Ambient Air Quality Standards 7-7
7.5 Second Tier Review 7-12

8.0 References 8-1

Appendices

A EMISSION CALCULATIONS ..... A-i
B BACT AND tBACT ANALYSIS ..... B-i
C COST EFFECTIVENESS CALCUALTIONS FOR 55 OPERATING HOURS/YEAR ..... C-i
D COST EFFECTIVENESS CALCUALTIONS FOR 100 OPERATING HOURS/YEAR ..... D-i

Figures

Figure 1-1. Hanford Site Water System Service Conditions at Completion 1-5
Figure 1-2. Water Systems Upgrade Projects with Air Emissions on the Hanford Site 1-6
Figure 1-3. Location of the New Water Tank in the 200-East Area of the Hanford Site 1-9
Figure 1-4. Location of New Water Tank in the 200-West Area of the Hanford Site.....1-11
Figure 1-5. Location of the L-895 Project Emergency Generator 1-12
Figure 1-6. CPWTF Process Flow Diagram 1-14
Figure 1-7. Location of the CPWTF in the 200-West Area 1-16
Figure 7-1. Hanford Site Meteorological Wind Rose – Surface Data 2015 through 2019 7-5
Figure 7-2. Modeling Domain.....7-6
Figure 7-3. Diesel Engine Exhaust Particulate Modeled ASIL Contour 3.30E-03 µg/m^3; Highest Annual Average (2016) for the Project L-781 181-D Pump House Standby Generator = 2.92E-01 µg/m^3 7-9
Figure 7-4. Diesel Engine Exhaust Particulate Modeled ASIL Contour 3.30E-03 µg/m^3; Highest Annual Average (2017) for the Project L-826 181-B Pump House Standby Generator = 4.26E-02 µg/m^3 7-10
Figure 7-5. Summary of Monte Carlo Modeling for Nitrogen Dioxide 1-hour Impacts to the NAAQS 7-12

Tables

Table 3-1. Criteria Pollutant Emission Estimate Summary.....3-2
Table 4-1. Toxic Air Pollutant Total Emission Estimate Summary. 4-2
Table 6-1. Cost-Effectiveness Calculation Summary – 55 Operating Hours Per Year. 6-2
Table 6-2. Cost-Effectiveness Calculation Summary – 100 Operating Hours Per Year.....6-3
Table 7-1. Point Source Emission Unit Parameters. 7-3
Table 7-2. Area Source Emission Unit Parameters. 7-4
Table 7-3. Building Parameters.....7-4
Table 7-4. Modeled Emission Rates 7-4
Table 7-5. 200-Meter Hanford Sitewide Grid Model Output.....7-8
Table 7-6. Project L-781 and L-826 Focused 25-Meter Grid Model Output. 7-9
Table 7-7. 2015-2019 Modeled Nitrogen Dioxide Annual Average and 1-hour High and Particulate Matter-2.5 Annual Average and 24-hour High. 7-11
Table 7-8. Summary of Annual Nitrogen Dioxide Modeled Impacts and Comparison to NAAQS. 7-11
Table 7-9. Summary of Annual Nitrogen Dioxide Modeled Impacts and Comparison to NAAQS.Summary of 1-hour Nitrogen Dioxide Modeled Impacts and Comparison to NAAQS. 7-11

Acronyms

AERMOD	U.S. Environmental Protection Agency Regulatory Model
ARM2	Ambient Ratio Method
ASIL	acceptable source impact levels
BACT	Best Available Control Technology
BHP	brake horsepower
CPWTF	Central Plateau Water Treatment Facility
Ecology	Washington State Department of Ecology
EPA	U.S. Environmental Protection Agency
HIA	Health Impact Assessment
ICE	internal combustion engine
kW	kiloWatt
NFPA	National Fire Protection Association
NOC	Notice of Construction
NSPS	New Source Performance Standard
PM	particle matter
RBLC	Reasonably Available Control Technology/ Best Available Control Technology/ Lowest Achievable Emission Rate Clearinghouse
SCR	Selective Catalytic Reduction
SEPA	State Environmental Policy Act
TAP	toxic air pollutants
tBACT	Best Available Control Technology for toxics
TEDF	Treated Effluent Disposal Facility
ULSD	ultra-low sulfur diesel
VOC	volatile organic compound
WDOH	Washington State Department of Health

This page intentionally left blank.

1.0 Project Description

The U.S. Department of Energy, Richland Operations Office is proposing various upgrades to the Hanford Site Water Systems. These upgrades are needed to ensure the Water Systems infrastructure is adequate throughout the lifecycle of the Hanford Site cleanup mission. The cleanup mission requires that the Export Water System, Raw Water System, and Sanitary Water System undergo significant upgrades. Sixteen upgrade projects are planned to ensure the cleanup mission water needs are met.

The Export Water System upgrades involves installing new river pumps and pipelines to delivering water directly to the Central Plateau reservoirs. The projects are as follows:

- L-781 – "181D Vertical Turbine Pumps, Header, Instrumentation, and Commission": Information on this project is provided in Section 1.1. This project will install two new emission units in the form of two standby diesel generators.

- L-826 – "181B Vertical Turbine Pumps, Header, Instrumentation, and Commission": Information on this project is provided in Section 1.2. This project will install one new emission unit in the form of one standby diesel generator.

- L-851 – "Design and Install Smaller Diameter Export Water Pipe to Replace 42-in. (106.7-cm) Pipe in 100-D": This project will replace 5.62 mi (9 km) of an export water pipeline that runs from 182D to the 1901Y Export Water Line Valve House. The replacement pipeline will be buried below grade parallel to the existing pipeline. This project is needed to modernize and right-size the export water system to provide a more reliable water supply to support site cleanup operations in the 100 Area and 200 Areas. No emission unit will be installed as part of this project. Accordingly, this project will not be addressed further in this NOC application.

- L-852 – "Design and Install Smaller Diameter Export Water Pipe to Replace 42-in. (106.7-cm) Pipe in 100-B": This project will replace 4.28 mi (6.88 km) of an export water pipeline that runs from 182B to the 1901Y Export Water Line Valve House. The replacement pipeline will be buried below grade parallel to the existing pipeline. This project is needed to modernize and right-size the export water system to provide a more reliable water supply to support site cleanup operations in the 100 Area and 200 Areas. No emission unit will be installed as part of this project. Accordingly, this project will not be addressed further in this NOC application.

The Raw Water System is being modified to remove cross connections with the Sanitary Water System and to install new pumps for additional reliability and redundancy. These projects are:

- L-894 – "Eliminate Cross-Connections Between Sanitary, Raw, and Export Water Systems": This project will design and install physical separations between the various Water Systems and will remove all direct export water feeds into the Raw Water System, remove all direct potable water feeds into raw water within the 282EC and 282WC Export Water Pump Houses, and remove the raw water grid feed to the 283W Water Treatment Facility. The purpose of these isolations is to prevent potential cross-contamination between the various Water Systems. No emission unit will be installed as part of this project. Accordingly, this project will not be addressed further in this NOC application.

- L-895 – "Upgrade Raw Water Distribution Pumps": Information on this project is provided in Section 1.5. This project will install one new emission unit in the form of one standby diesel generator.

Upgrades to the Sanitary Water System involve a construction of a new Central Plateau Water Treatment Facility (CPWTF) to ensure adequate sanitary water supply, a new sanitary water storage clear well for the CPWTF, a new water storage tank, and a new sanitary water distribution pumps in the 200 East Area. These projects are as follows:

- L-849 – "Replace 200-East 1.1 M gal (4.1 M-L) Sanitary Water Storage Tank and Distribution Pumps": Information on this project is provided in Section 1.3. This project will install two new emission units in the form of one standby diesel generator and one water storage tank.

- L-850 – "Replace 200-West 1.1 M gal (4.1 M-L) Sanitary Water Storage Tank and Distribution Pumps": Information on this project is provided in Section 1.4. This project will install one new emission unit in the form of one water storage tank.

- L-897 – "Replace 283-W with New CPWTF": Information on this project is provided in Section 1.6. This project will install two new emission units in the form of one standby diesel generator and a modification to the existing sludge lagoons that will result in airborne emissions of TAPs.

The Water Systems infrastructure upgrades also include the following projects that are specific to water distribution lines on the Hanford Site Central Plateau.

- L-839 – "12-Inch Potable Water Loop-Line to Waste Treatment Plant": This project will install a new potable water pipeline that will connect the 282EC Export Water Pump House to the Waste Treatment Plant. In some locations, this pipeline will replace a smaller, 8-in. (20.3-cm), diameter existing pipeline, while in other locations the pipeline will be entirely new. A fiber optic conduit will also be installed along a portion of the pipeline. Lastly, this project will install a fire hydrant that will be used to dispense potable water for fire suppression purposes. This water is expected to contain chloroform and bromodichloromethane, both of which are TAPs. However, as fire suppression equipment is exempt from new source review per WAC 173-400-110(4)(h)(xxii), emissions from this fire hydrant will not be addressed further in this NOC application. No other emission unit will be installed as part of this project. Accordingly, this project will not be addressed further in this NOC application.

- L-927 – "Sanitary Water Cross-Tie Line between 200-East and 200-West Areas": This project will install a redundant sanitary water cross-tie line that will run parallel to the existing 12-in. (30.5-cm) sanitary water line located along Route 3 between 200-East and 200-West Areas. The redundancy will reduce the risk of a sanitary water outage in the event of a line break on the existing sanitary water line. No emission unit will be installed as part of this project. Accordingly, this project will not be addressed further in this NOC application.

- L-838 – "Water Feeds to 622R, 6608 Facility, and 200W Sewer Lagoons": This project will cut, cap, and abandon in place the existing export water line feeding the 622R Meteorology Lab, install a new raw water line that connects the existing raw water grid to the 622R Meteorology Lab, install a new raw water line from the 622R Meteorology Lab to the 200-West Sewer

Lagoons and 6608 Biosolids Handling Facility, install a new sanitary water line from the 622R Meteorology Lab to the 200-West Sewer Lagoons and 6608 Biosolids Handling Facility, install new sanitary water pipelines and connections for various domestic uses at the 6608 Biosolids Handling Facility, install an air gap and backflow preventer on the sanitary water supply near the facility boundary of the 200-West Sewer Lagoons and the 6608 Biosolids Handling Facility, and, if required, install new sewer lines from the 6608 Biosolids Handling Facility and the associated MO2302 Bathroom Trailer to the 200-West Sewer Lagoon. The purpose of these changes is to convert the 622R Meteorology Lab fire protection water supply from the Export Water System to the Raw Water System and to install permanent in-ground sanitary water and raw water supply lines to the 200-West Sewer Lagoons and 6608 Biosolids Handling Facility.

The 200-West Sewer Lagoons are part of the 200-West Area Lagoon Treatment System (LTS), which is subject to Approval Order DE12NWP-001, Revision 2. While Project L-838 may install sewer lines that will transport wastewater to the LTS from the 6608 facility and the MO2302 Bathroom Trailer, these sewer lines would not constitute a modification under WAC 173-400-030(51) because there will be no increase in emissions of any air contaminant. This is because wastewater from these two locations is presently pumped to the LTS via a mobile pumping unit, so changing the facility to include fixed sewer lines would not alter the amount or source of waste received at the LTS, and therefore wouldn't increase emissions from the LTS. Accordingly, this project will not necessitate a change to Approval Order DE12NWP-001, Revision 2. Additionally, as no emission unit will be installed as part of this project, this project will not be addressed further in this NOC application.

- L-928 – "Re-Route Raw and Sanitary Water Lines Near 241AP Tank Farm for Tank-Side Cesium Removal": This project will install a new 12-in. (30.5-cm) raw water mainline that re-routes the existing 12-in. (30.5-cm) line located on the south and east sides of 241AP Tank Farm, and will also install a replacement sanitary water line with a more reliable water main to prevent ongoing failures. The raw water mainline rerouting is needed to avoid the location of the new Tank-Side Cesium Removal complex and associated infrastructure. At least one replacement fire hydrant will be installed as part of this project. As fire suppression equipment is exempt from new source review per WAC 173-400-110(4)(h)(xxii), emissions from this fire hydrant will not be addressed further in this NOC application. No other emission unit will be installed as part of this project. Accordingly, this project will not be addressed further in this NOC application.

- L-352 – "Replace/Extend Raw Water Lines Near 241A Tank Farm": This project will replace an existing section of 14-in. (35.5-cm) and 20-in. (50.8-cm) raw water lines as well as add a new section of 6-, 14-, and 20-in. (15.2-, 35.5-, 50.8-cm) raw water lines to create a re-routed closed loop system in the 200-East Area. No emission unit will be installed as part of this project. Accordingly, this project will not be addressed further in this NOC application.

- L-342 – "Replace 24-inch of Raw Water Feed Line": This project will replace 4,300 ft (1,310.6 m) of 24-in. (61-cm) underground raw water line that runs from the 200-East raw water reservoir to the Plutonium Uranium Extraction Plant and then forms a loop to the Tank Farms and other facilities in the 200-East Area. The existing pipeline is aging and requires replacement to meet ongoing and upcoming needs in the 200-East Area. No emission unit will be installed as part of this project. Accordingly, this project will not be addressed further in this NOC application.

- L-430 – "Replace 8-inch Water Line Loop": This project will replace 3,395 feet of aging 8-in. (20-cm) potable water line that supplies the 2101M Maintenance Shop in the 200-East Area.

The existing pipeline is aging and requires replacement to meet ongoing and upcoming needs in the 200-East Area. No emission unit will be installed as part of this project. Accordingly, this project will not be addressed further in this NOC application.

Fugitive air emissions from water downstream of the Project L-849 and L-850 water storage tanks are unquantifiable due to the vast number of water outlets and varied usage frequencies and durations. These unquantifiable fugitive emission units are excluded from the WAC 173-400-030(84) definition of source, and accordingly these units will not be addressed further in this notice of construction (NOC) application.

Figure 1-1 shows the configuration expected to be present for the Hanford Site Water Systems once these projects are completed. This configuration would be realized in or around fiscal year 2030.

Additional detail on Projects L-781, L-826, L-849, L-850, L-895, and L-897 is provided below. These projects will install non-exempt emission units, which will be addressed in detail in the remainder of this NOC application. Figure 1-2 identifies the location of these projects.

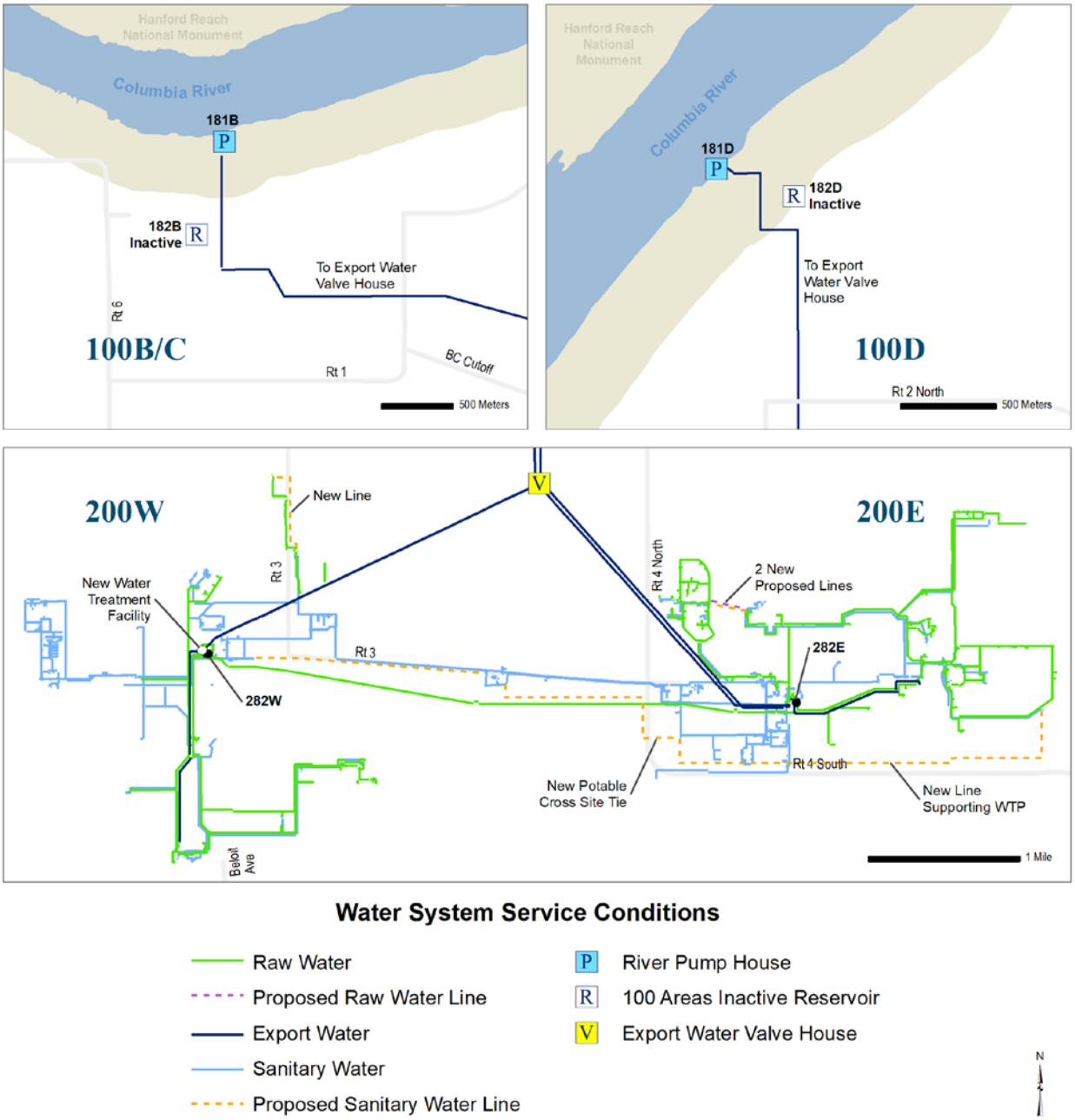


Figure 1-1. Hanford Site Water System Service Conditions at Completion

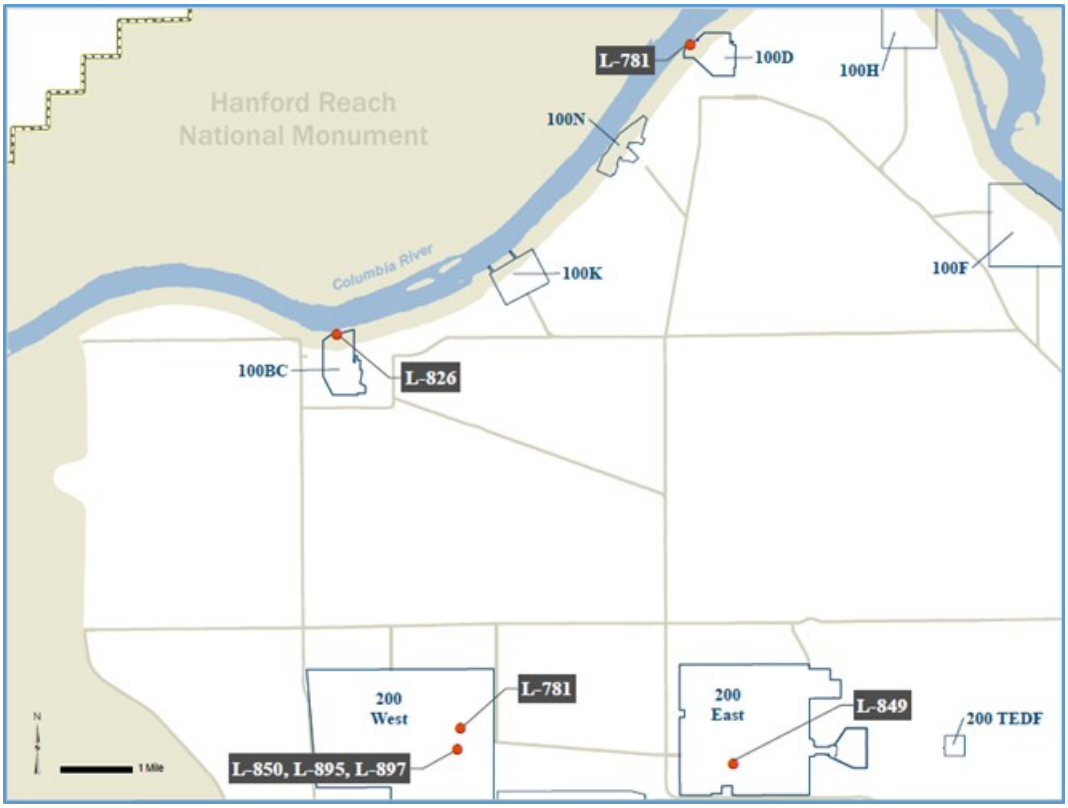


Figure 1-2. Water Systems Upgrade Projects with Air Emissions on the Hanford Site

1.1 Project L-781 Description

Project L-781 reconfigures the Export Water System to bypass the 25M-gal (9.4M-L) reservoir at 182-D and pump directly from the river to the two 3M-gal (1.1 M-L) reservoirs (282-E/282-W) on the Central Plateau. The project provides for new electrical vertical turbine pumps, and new header and piping from the discharge point at 181-D to a point on the existing 42-in. (106.6-cm) pipeline; a new feed pump building in the 200-West Area; new pump controls and instruments; upgrades to electrical capacity; and installation of new diesel standby generators at the 181-D River Pump Station and new feed pump building.

Construction is expected to begin in October 2022 and complete in May 2024.

Operation of the 100-D Area Export Water System will be able to provide approximately 10,788 gallons per minute (gpm) of river water to the Central Plateau. The Export Water System will operate only one of the two River Pump Stations (181D or 181B) at a given time to meet the Export Water System pressure needs.

Specifications for the two standby diesel generators are being developed as part of the overall project design. Selection of the actual make and model of the standby generators will be determined by September 2022, which is when the Project L-781 design is currently scheduled to be completed. Potential standby power needs have been conservatively estimated for this NOC application. The 181-D River Pump Station is assumed to require a 2,250 kilowatt (kW) standby generator with a

3,352 brake horsepower (BHP) engine. The feed pump building is assumed to require a 400 kW standby generator with a 617 BHP engine. Both standby generators will be fueled with ultra-low sulfur diesel (ULSD) fuel (0.0015% sulfur). The 181-D River Pump Station standby generator is assumed to have a maximum fuel consumption of 167.1 gal/hr (632.5 L/hr) and the standby generator for the feed pump building is assumed to have a maximum fuel consumption of 51.9 gal/hr (196.4 L/hr). Both standby generators will be certified to at least the U.S. Environmental Protection Agency's (EPA) Tier 2 emission standard. Both standby generators will operate less than 100 hours per year in a non-standby mode. 55 hours and 100 hours of annual operating time were assumed for best available control technology (BACT) and best available control technology for toxics (tBACT) purposes, whereas 500 hours were conservatively assumed for estimating the potential to emit consistent with EPA guidance (EPA 1995).

1.2 Project L-826 Description

Project L-826 reconfigures the Export Water System to bypass the 25 M-gal (94 M-L) reservoir at 182-D and pump directly from the river to the two 3 M-gal (11M-L) reservoirs (282-E/282-W) on the Central Plateau. It provides for new electrical vertical turbine pumps, and new header and piping from the discharge point at 181-B to the discharge point at 182-B; new pump controls and instruments; upgrades electrical capacity; and installs a new diesel standby generator at the 181-B River Pump Station.

Construction is expected to begin in July 2024 and complete in February 2026.

Upon completion of Project L-826, the existing standby generators approved for operation under the Ecology approval order DE07NWP-002, Revision 2 (Air Operating Permit Discharge Point 1.4.29) will be deactivated and a request will be submitted to Ecology to cancel DE07NWP-002, Revision 2.

Operation of the 100-B Area Export Water System will be able to provide approximately 10,788 gpm of river water to the Central Plateau. The Export Water System will operate only one of the two River Pump Stations (181D or 181B) at a given time to meet the Export Water System pressure needs.

Specifications for the standby diesel generator will be developed as part of the overall project design. Selection of the actual make and model of the standby generator will be determined by October 2022, which is when the Project L-826 design is currently scheduled to be completed. Potential standby power needs have been conservatively estimated for this NOC application. The 181-B River Pump Station is assumed to require a 2,250 kW standby generator with a 3,352 BHP engine. This standby generator will be fueled with ULSD fuel (0.0015% sulfur) and is assumed to have a maximum fuel consumption rate of 167.1 gal/hr (632.5 L/hr). The standby generator will be certified to at least the EPA Tier 2 emission standard. The generator will operate less than 100 hours per year in a non-emergency mode. 55 hours and 100 hours of annual operating time were assumed for BACT and tBACT purposes, whereas 500 hours were conservatively assumed for estimating the potential to emit consistent with EPA guidance (EPA 1995).

1.3 Project L-849 Description

Project L-849 will design and construct a new potable water tank, to replace the existing tank, with a minimum storage capacity of approximately 1.5 M-gal (5.6 M-L) for the Sanitary Water System to

improve the reliability of the System's current 1.1 M-gal (4.1 M-L) tank. The existing tank (283-EA) will be demolished. The new tank will include freeze protection to satisfy National Fire Protection Association (NFPA) requirements and booster chlorination to satisfy Washington State Department of Health (WDOH) disinfection requirements. The existing 283-EA tank shall remain in service to provide fire protection and sanitary water service until the new tank is fully operational, approved by WDOH for use, and connected to the sanitary water grid.

The project will install new sanitary water distribution pumps for pressurizing the sanitary water grid in the 200E Area, as well as a recirculation pump and tank heating system. The new pumps are to be installed in the existing 282EC pump house. The newly installed pumps will replace existing sanitary water distribution pumps located 282E, which will be abandoned in place. Additional piping and reconfiguration will be required to allow for the new sanitary water distribution pumps in the 282EC pump house.

Figure 1-3 identifies the location of the new water tank in the 200-East Area of the Hanford Site.

Construction is expected to begin in May 2022 and complete in March 2024.

The 1.5 M-gal (5.6 M-L) potable water tank will receive chlorinated water and has the potential to generate trihalomethanes (chloroform, bromodichloromethane, and bromoform). The 1.5 M-gal (5.6 M-L) potable water tank will be passively vented and could release the trihalomethanes to the surrounding air.

The project also provides for the installation and operation of a standby generator. Specifications for the standby diesel generator will be developed as part of the overall project design. The design will be complete in October 2022. Selection of the actual make and model of the standby generator will be determined by January 2022, which is when the Project L-849 design is currently scheduled to be completed. Potential standby power needs have been conservatively estimated for this NOC application. The project is assumed to require a 1,250 kW standby generator with a 1,881 BHP engine. The standby generator will be fueled with ULSD fuel (.0015% sulfur). The standby generator is assumed to have a maximum fuel consumption rate of 114.0 gal/hr (431.5 L/hr) and will be certified to at least the EPA Tier 2 emission standard. The standby generator will operate less than 100 hours per year in a non-standby mode. 55 hours and 100 hours of annual operating time were assumed for BACT and tBACT purposes, whereas 500 hours were conservatively assumed for estimating the potential to emit consistent with EPA guidance (EPA 1995).

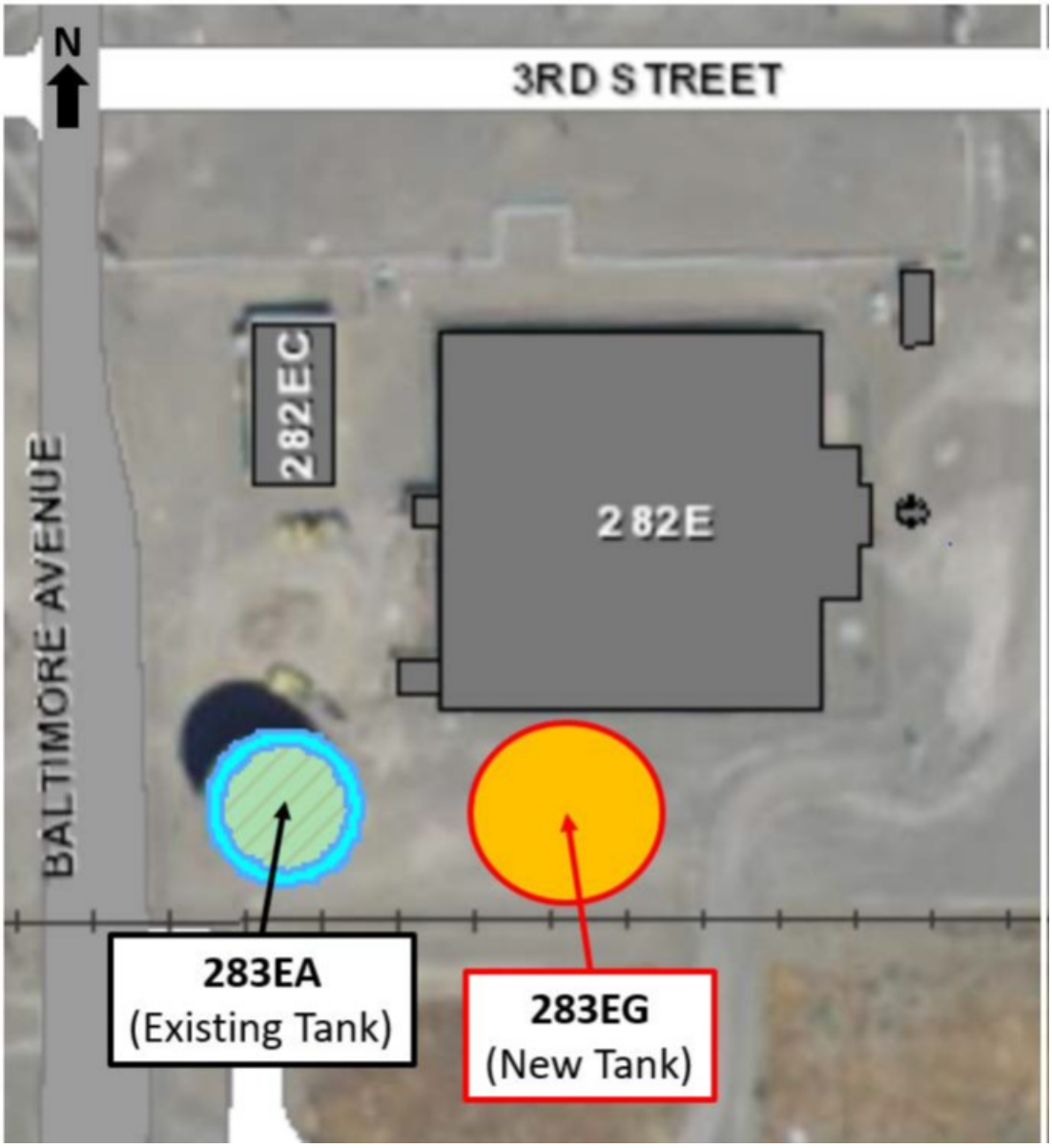


Figure 1-3. Location of the New Water Tank in the 200-East Area of the Hanford Site

1.4 Project L-850 Description

Project L-850 will design and construct a new potable water tank, to replace the existing tank, with a minimum storage capacity of approximately 1.5 M-gal (5.6 M-L) minimum volume potable water tank for the Sanitary Water System. The existing tank (283-WA) will be demolished. The new tank will include freeze protection to satisfy NFPA requirements. The new tank will serve as the chlorine contact time chamber for the proposed new CPWTF, Project L-897. The existing 283-WA tank will remain in service to provide fire protection and sanitary water service until the new tank is fully operational, approved by WDOH for use, and connected to the sanitary water grid.

The project will install new sanitary water distribution pumps for pressurizing the sanitary water in the 200-West Area, as well as a recirculation pump and tank heating system. The new pumps will be installed in the existing 282-WC pump house. The newly installed pumps will replace the existing sanitary water pumps located in 282-W, which will be abandoned in place. Figure 1-4 identifies the location of the new water tank 200-East Area of the Hanford Site. Additional piping and reconfiguration will be required to support the new sanitary water distribution pumps in the 282-WC pump house.

Construction is expected to begin upon issue of an approval order and is scheduled to complete in May 2022.

The 1.5 M-gal (5.6 M-L) potable water tank will receive chlorinated water and has the potential to generate trihalomethanes (chloroform, bromodichloromethane, and bromoform). The 1.5 M-gal (5.6 M-L) potable water tank will be passively vented and could release the trihalomethanes to the surrounding air.

1.5 Project L-895 Description

Project L-895 upgrades the raw water infrastructure to meet current and future forecasted demands by replacing process water infrastructure, which includes installing new raw water process pumps at the 282-East and 282-West raw water reservoir pump houses. New pump motors will be included and upgrades to controls will be also be provided for the 200-East and 200-West pump houses. Suction/discharge piping will be added or reconfigured to accommodate the new pumps. New variable frequency drives and instrumentation control system will be installed to provide for improved remote monitoring and control. Additionally, a new standby generator will be installed as part of the upgrades. Figure 1-5 identifies the location of the standby generator in the 200-West Area of the Hanford Site.

Partial construction on this project began in April 2019, with non-emission-unit-related work continuing through the present time. All construction work on the generator continues to be on hold pending issuance of an approval order. Current planning targets completion of construction in February 2022.

Operation of the distribution pumps at the 282-East and 282-West raw water reservoir pump houses will be a 24/7/365 operation providing process and fire protection water, to support ongoing demands for raw water on the Central Plateau.

Project L-895 will install a 1,250 kW Caterpillar C32 Generator Set, which includes a Caterpillar 1,829 BHP diesel-fueled engine. The manufacturer states that the engine meets the Tier 2 emission standards found in 40 CFR 89, “Control of Emissions from New and In-Use Nonroad Compression-Ignition Engines.”

The standby generator will be fueled with ULSD fuel (.0015% sulfur) and will consume 87.4 gal (330.8 L) of fuel per hour at 100% load.

The standby generator will operate less than 100 hours per year in a non-standby mode. 55 hours and 100 hours of annual operating time were assumed for BACT and tBACT purposes, whereas 500 hours were conservatively assumed for estimating the potential to emit consistent with EPA guidance (EPA 1995).

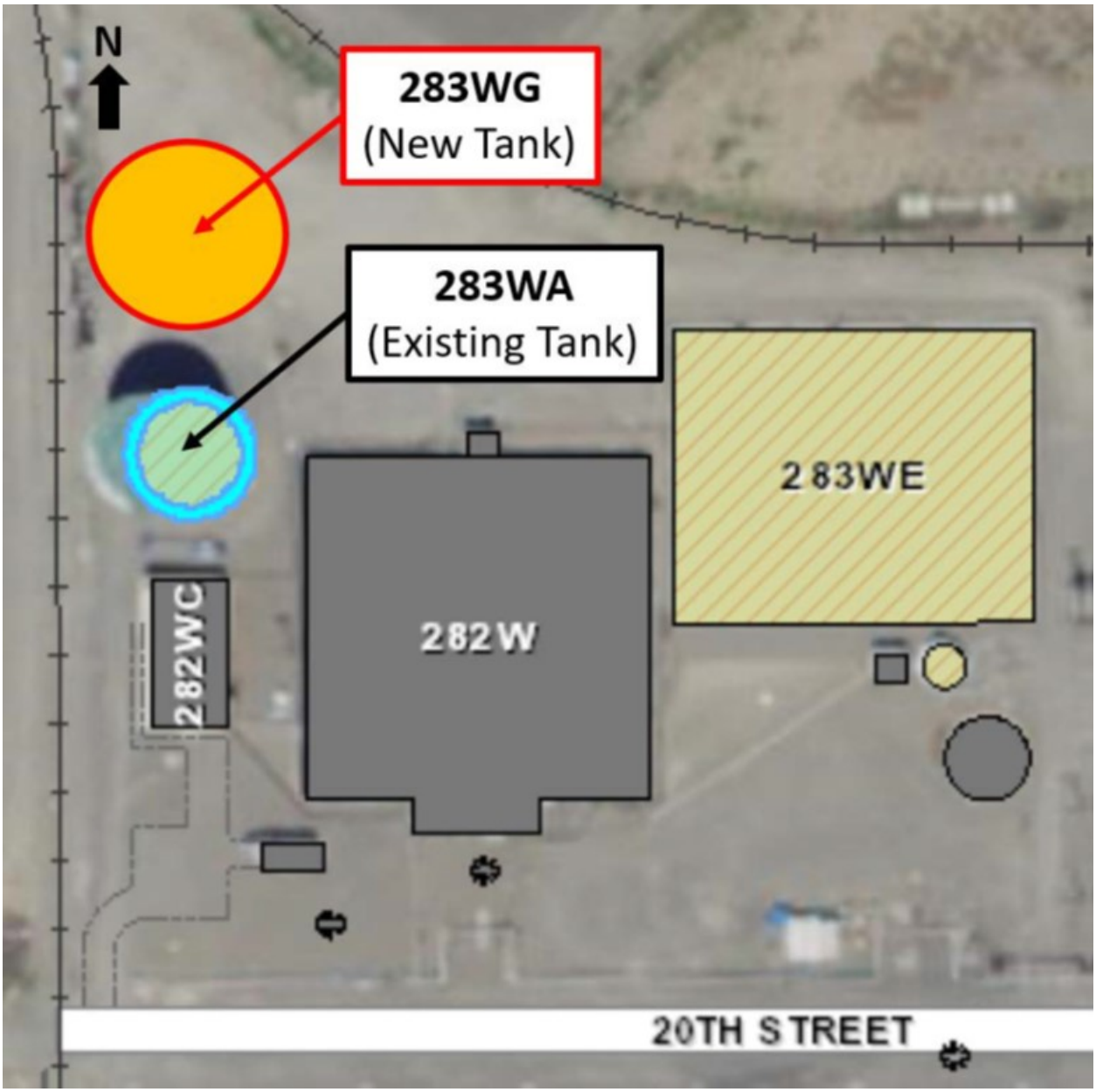


Figure 1-4. Location of New Water Tank in the 200-West Area of the Hanford Site

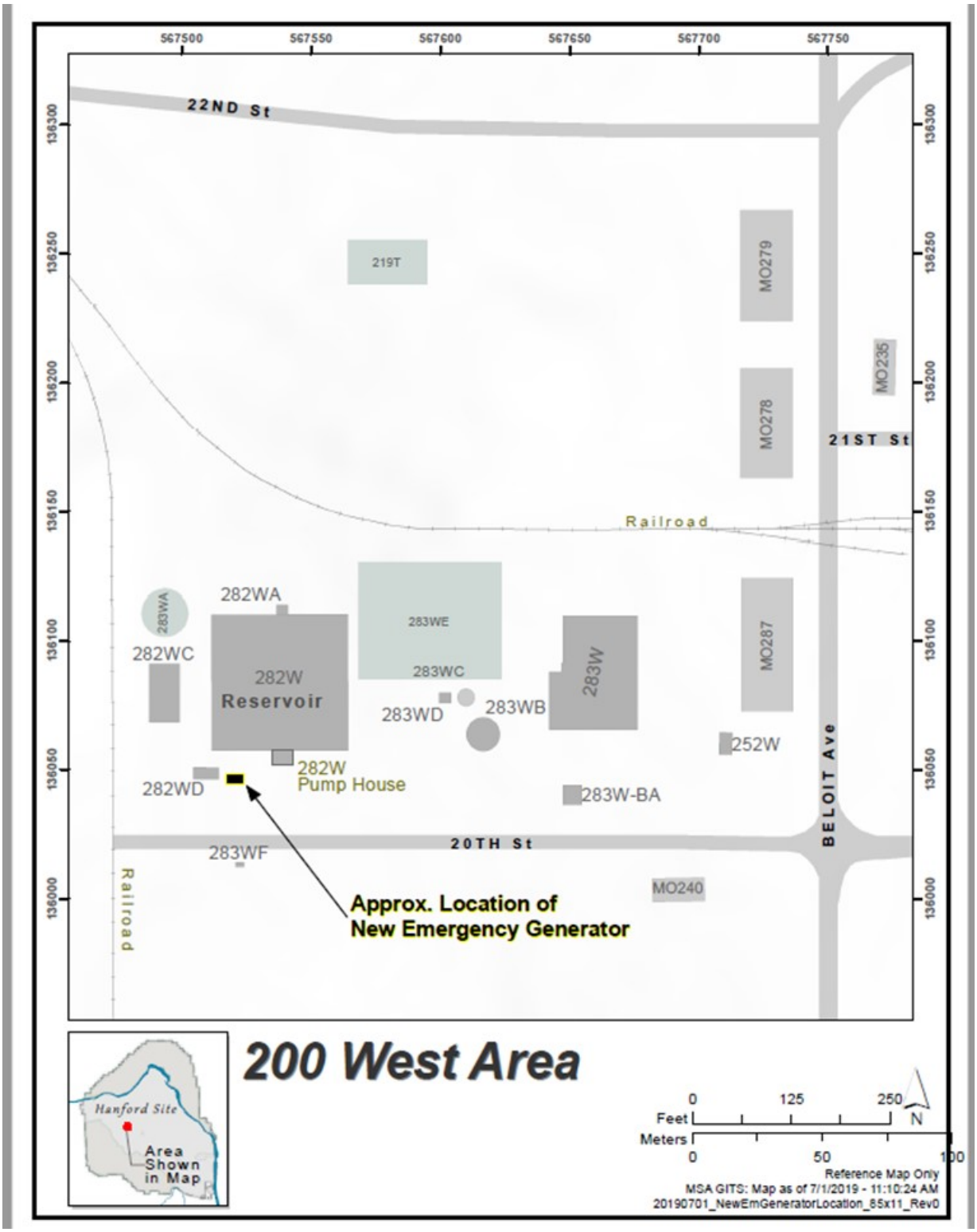


Figure 1-5. Location of the L-895 Project Emergency Generator

1.6 Project L-897 Description

Project L-897, CPWTF, will provide construction and operation of a new potable water treatment facility on the Central Plateau. This new treatment facility will be designed and sized to be capable of producing a minimum of 3.5 M gal/day (13 M L/day) with the ability to expand to 5 M gal/day (18 M L/day) in order to meet current and future forecasted potable water demand. The new water treatment facility will be constructed using modular units fitted with PALL Aria™ microfiltration hollow fiber direct feed membrane system for water filtration. CPWTF will regularly generate wastewater from membrane cleaning. The cleaning operations include use of sodium hypochlorite solution for membrane cleaning. Disinfection byproducts (trihalomethanes) are potentially present in these solutions. (HNF-64154) The trihalomethanes are anticipated to be chloroform and bromodichloromethane.

The CPWTF design provides for the continued use the existing sludge lagoons and Treated Effluent Disposal Facility (TEDF) for process wastewater management and disposal. Wastewater from the CPWTF will be discharged to the existing sewage lagoons for blending to ensure the TEDF limits are met. The sludge lagoons are open to the atmosphere.

A process flow diagram for the CPTWF is provided in Figure 1-6.

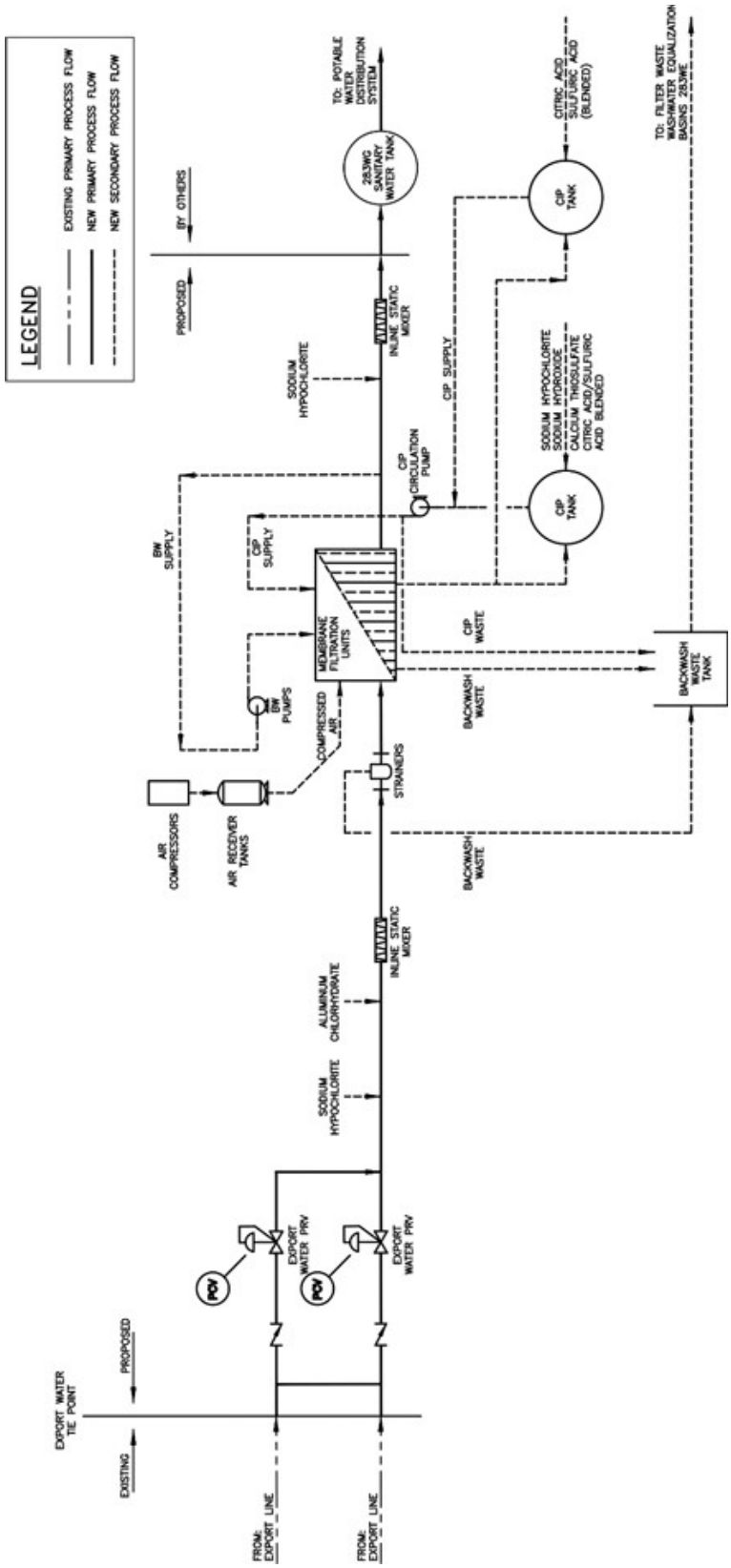


Figure 1-6. CPWTF Process Flow Diagram

The scope includes provisions for potable and export water connections, sanitary sewer, electrical, interior and exterior lighting, fire protection/detection systems, and process wastewater disposal infrastructure connected to a new facility. The new water treatment facility will be connected to the new potable water storage tank, to be installed under Project L-850.

Figure 1-7 identifies the location of the CPWTF in the 200-West Area of the Hanford Site.

Construction is expected to begin upon issue of an approval order and complete in June 2022.

The 1.5 M-gal (5.6 M-L) potable water tank will receive chlorinated water and has the potential to generate trihalomethanes (chloroform, bromodichloromethane, and bromoform). The 1.5 M-gal (5.6 M-L) potable water tank will be passively vented and could release the trihalomethanes to the surrounding air.

Project L-897 will also provide for the installation and operation of a standby generator. As equipment procurement submittals have not yet occurred, the exact make and model have not yet been determined. The generator is estimated to be 750 kW, with a 1,112 BHP diesel-fueled engine that will meet Tier 2 emission standards found in 40 CFR 89.

The standby generator will be fueled with ULSD fuel (.0015% sulfur) and will consume 87.4 gal (330.8 L) of fuel per hour at 100% load.

The standby generator will operate less than 100 hours per year in a non-emergency mode. 55 hours and 100 hours of annual operating time were assumed for BACT and tBACT purposes, whereas 500 hours were conservatively assumed for estimating the potential to emit consistent with EPA guidance (EPA 1995).

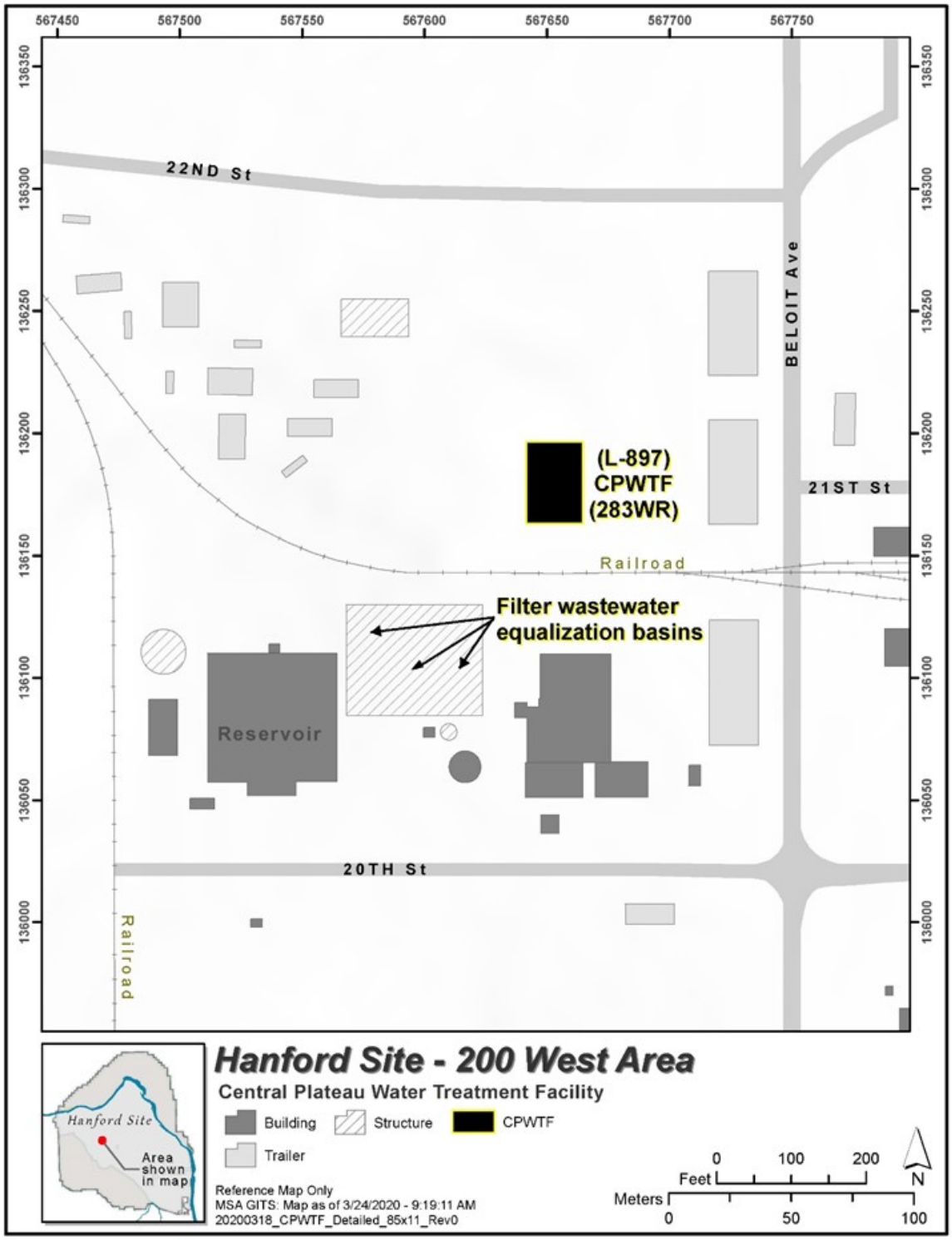


Figure 1-7. Location of the CPWTF in the 200-West Area

2.0 State Environmental Policy Act Compliance

In accordance with WAC 197-11, "State Environmental Policy Act of 1971," and RCW 43.21C, "State Environmental Policy," Ecology requires all government agencies to consider the environmental impacts of a proposal before making decisions. DOE has provided information to Ecology that explains how the National Environmental Policy Act requirements have been fulfilled. The information can be used for State Environmental Policy Act review.

This page intentionally left blank.

3.0 Emissions Estimations of Criteria Pollutants

A criteria pollutant emission estimate summary is provided in Table 3.1 below, with supporting calculations shown in Tables A-1 through A-5 of Appendix A. The emergency stationary engines associated with projects L-897, L-895, L-849, L-826, and L-781 are expected to emit criteria pollutants. The L-897 sludge lagoons, L-850 water tank, and L-849 water tank are not expected to emit criteria pollutants, and accordingly are not addressed in this section.

The emission estimate calculations provided in Tables A-1 through A-5 of Appendix A are based on various engine-specific input parameters including pollutant emission rate, engine power, and fuel consumption rate. The input parameters for the L-897 emergency stationary engine were obtained from a manufacturer's specification for a Caterpillar 750-kW generator with a 1,112 BHP diesel-fueled engine. The input parameters for the L-895 emergency stationary engine were obtained from the manufacturer's specification for the Caterpillar C32 generator set, which will be installed as part of this project.

The power output and fuel consumption rate input parameters for the L-849, L-826, and L-781 emergency stationary engines were obtained from representative engine specifications. First, conservative generator size estimates were developed for these three projects. Then, publicly-available manufacturer specifications for generators of the identified sizes were reviewed to identify engine makes and models used in generators of those sizes, as well as to identify the corresponding engine power outputs and fuel consumption rates. Project L-849 was conservatively estimated to require a 1,250-kW generator, for which four specification documents were found and reviewed. The 1,250-kW generator with the highest identified engine power and fuel consumption rate was the Generac IDLC1250 with a Mitsubishi S12R-Y2PTAW-1 engine. This engine was chosen to conservatively represent the L-849 emergency stationary engine. Project L-826 was conservatively estimated to require a 2,250-kW generator, for which only one specification document was found and reviewed. The specification document was for a Kohler KD2250 generator with a Kohler engine with model number prefix KD62V12, which was chosen to conservatively represent the L-826 emergency stationary engine. Project L-781 will require two generators, one at the 200-West Feed Pump Building, and another at the 181-D Pump House. The 200-West Feed Pump Building was conservatively estimated to require a 400-kW generator, and the 181-D Pump House was conservatively estimated to require a 2,250 kW generator. Two specification documents were found and reviewed for a 400-kW generator, of which the highest identified engine power and fuel consumption rate were found to be present with the Kohler 400REOZJ generator with a John Deere 6135HF485S engine. This engine was chosen to conservatively represent the L-781 emergency stationary engine at the 200-West Feed Pump Building. As with project L-826, the Kohler KD2250 generator with a Kohler model KD62V12 engine was conservatively chosen to represent the 2,250-kW generator that will be needed for the L-781 181-D Pump House.

The pollutant emission rate input parameter for the L-849, L-826, and L-781 emergency stationary engines was obtained from the EPA's "Annual Certification Data for Vehicles, Engines, and Equipment" webpage, available at www.EPA.gov. Once the representative engine models were identified for these projects, the corresponding emission data for those models were obtained from the Nonroad Compression Ignition certification data spreadsheet located at EPA's "Annual Certification Data for Vehicles, Engines, and Equipment." Accordingly, the pollutant-specific emission rates shown in

Column A of Tables A-1, A-2, A-4, and A-5 for the L-849, L-826, and L-781 emergency stationary engines come directly from data sets maintained by EPA.

As shown in Table 3-1, emissions of critieria pollutants carbon monoxide, PM-10, and sulfur dioxide are expected to be below WAC 173-400-110(5) exemption levels. Criteria pollutant emissions for PM-2.5, total volatile organic compound (VOC), and nitrogen oxides (assumed to be nitrogen dioxide) are expected to exceed the exemption levels. Evaluation of violation of the national ambient air quality standards from PM-2.5 and nitrogen oxide emissions, in compliance with WAC 173-400-113(3), is detailed in Section 7.0. Evaluation of VOC control technologies are addressed in Section 6.0, in accordance with WAC 173-400-113(2). The emission units that will be constructed and modified as part of the Hanford Site Water Systems upgrades are not expected to emit any ozone depleting substance, as defined in WAC 173-400-030(65), and accordingly ozone depleting substances will not be addressed further in this application. Additionally, as the pollutant levels in Table 3-1 are below the significant emissions increase levels in 40 CFR 52.21(b)(40), the projects in this NOC application will not constitute a major modification to the existing Hanford Site major stationary source. Accordingly, prevention of significant deterioration permitting requirements do not apply to these projects.

Table 3-1. Criteria Pollutant Emission Estimate Summary

Criteria Pollutant	Total Emission Estimate[a] (Tons/year)	WAC 173-400-110(5) Exemption Level (Tons/year)	Above/Below WAC 173-400-110(5) Exemption Level
Carbon Monoxide	4.7E+00	5.0E+00	Below
Particulate Matter	6.3E-01	5.0E-01 (PM-2.5) 7.5E-01 (PM-10)	Above (PM-2.5) Below (PM-10)
Sulfur Dioxide	3.4E-02	2.0E+00	Below
Total Volatile Organic Compounds	2.9E+00	2.0E+00	Above
Nitrogen Dioxide	2.9E+01	2.0E+00 (Nitrogen oxides)	Above (Nitrogen oxides)

[a] From Tables A-1 through A-5 of Appendix A

4.0 Emissions Estimations of Toxic Air Pollutants

A TAP emission estimate summary is provided below in Table 4-1, with supporting calculations shown in Tables A-6 through A-35 of Appendix A. These estimates are for emissions from the L-897 sludge lagoons and emergency stationary engine, the L-895 emergency stationary engine, the L-850 potable water tank, the L-849 potable water tank and emergency stationary engine, the L-826 emergency stationary engine, and the two L-781 emergency stationary engines.

Emergency stationary engine emissions are addressed in Tables A-6 through A-14 of Appendix A. These emission estimates are calculated using the same engine-specific input parameters specified in Section 3.0. Additionally, as shown in Tables A-10 through A-24 of Appendix A, pollutant emission rates from AP-42, *Compilation of Air Pollutant Emissions Factors,* Volume 1 have been used to calculate emissions of select TAPs.

Calculations for emission estimates from the L-849 and L-850 potable water tanks, as well as from the L-897 sludge lagoons, are provided in Tables A-25 through A-32 of Appendix A. The various input parameters used in the potable water tank emission calculations come from past water sampling reports and tank design documents. As the L-849 potable water tank has not yet been designed, input parameters for this tank have been taken from the design documents for the L-850 potable water tank. The various input parameters used in the sludge lagoon emission calculations come from a water treatment technology analysis document, as well as existing dimensions for the lagoon basins. The basins are pre-existing and will be repurposed to support operation of the CPWTF; as part of that process they will become a new emission unit.

Table 4-1 provides a summary of all TAP emission estimates, as well as a comparison of those estimates to their respective de minimis and SQER values as found in WAC 173-460-150. Of the 22 TAPs expected to be emitted as a result of the Water Systems upgrades, 13 are estimated to be emitted at concentrations that are at or below their respective de minimis levels, and thus are not subject to first tier review requirements of WAC 173-460-080. However, nine TAPs are estimated to exceed their respective de minimis levels. These pollutants are: diesel engine exhaust, particulate; nitrogen dioxide; benzene; formaldehyde; naphthalene; benzo(b)fluoranthene; benzo(a)pyrene; dibenz(a,h)anthracene; and chloroform. Evaluation against the respective SQER levels shows that formaldehyde, benzo(b)fluoranthene, benzo(a)pyrene, and dibenz(a,h)anthracene are below the SQER; accordingly, first tier review requirements are satisfied for these pollutants. The remaining five pollutants (diesel engine exhaust, particulate; nitrogen dioxide; benzene; chloroform; and naphthalene) are estimated to exceed their respective SQER level and accordingly require air dispersion modeling. The results of the air dispersion modeling are provided in Section 7.0.

Table 4-1. Toxic Air Pollutant Total Emission Estimate Summary.

Constituent	Units (from WAC 173-460-150 Averaging Period)	Emission Estimate	De Minimis (WAC 173-460-150)	De Minimis Exceeded?	SQER (WAC 173-460-150)	SQER Met or Exceeded?
Carbon Monoxide	Lbs/Hour	1.1E+00	1.1E+00	No	4.3E+01	No
Diesel Engine Exhaust, Particulate	Lbs/Year	1.3E+03	2.7E-02	Yes	5.4E-01	Yes
Nitrogen Dioxide	Lbs/Hour	6.7E+00	4.6E-01	Yes	8.7E-01	Yes
Sulfur Dioxide	Lbs/Hour	7.7E-03	4.6E-01	No	1.2E+00	No
Benzene	Lbs/Year	3.3E+01	1.0E+00	Yes	2.1E+01	Yes
Toluene	Lbs/24 Hours	3.3E-02	1.9E+01	No	3.7E+02	No
Xylenes	Lbs/24 Hours	2.3E-02	8.2E-01	No	1.6E+01	No
Propylene	Lbs/24 Hours	3.3E-01	1.1E+01	No	2.2E+02	No
Formaldehyde	Lbs/Year	3.4E+00	1.4E+00	Yes	2.7E+01	No
Acetaldehyde	Lbs/Year	1.1E+00	3.0E+00	No	6.0E+01	No
Acrolein	Lbs/24 Hours	9.3E-04	1.3E-03	No	2.6E-02	No
Naphthalene	Lbs/Year	5.5E+00	2.4E-01	Yes	4.8E+00	Yes
Benz(a)anthracene	Lbs/Year	2.6E-02	4.5E-02	No	8.9E-01	No
Chrysene	Lbs/Year	6.6E-02	4.5E-01	No	8.9E+00	No
Benzo(b)fluoranthene	Lbs/Year	4.8E-02	4.5E-02	Yes	8.9E-01	No
Benzo(k)fluoranthene	Lbs/Year	9.3E-03	4.5E-02	No	8.9E-01	No
Benzo(a)pyrene	Lbs/Year	1.1E-02	8.2E-03	Yes	1.6E-01	No
Indeno(1,2,3-cd)pyrene	Lbs/Year	1.8E-02	4.5E-02	No	8.9E-01	No
Dibenz(a,h)anthracene	Lbs/Year	1.5E-02	4.1E-03	Yes	8.2E-02	No
Chloroform	Lbs/Year	2.99E+01	3.5E-01	Yes	7.1E+00	Yes
Bromodichloromethane	Lbs/Year	1.80E-01	2.2E-01	No	4.4E+00	No
Bromoform	Lbs/Year	4.17E-04	7.4E+00	No	1.5E+02	No

5.0 Emission Standard Compliance

Applicable new source performance standards, national emission standards for hazardous air pollutants, national emission standards for hazardous air pollutants for source categories, and emission standards adopted under the RCW 70.94, " Washington Clean Air Act," are listed below.

- 40 CFR 60, "Standards of Performance for New Stationary Sources," Subpart A – General Provisions
- 40 CFR 60, Subpart IIII, "Standards of Performance for Stationary Compression Ignition Internal Combustion Engines"
- 40 CFR 63, "National Emission Standards for Hazardous Air Pollutants for Source Categories," Subpart A – General Provisions
- 40 CFR 63, Subpart ZZZZ, "National Emissions Standards for Hazardous Air Pollutants for Stationary Reciprocating Internal Combustion Engines."

This page intentionally left blank.

6.0 Best Available Control Technology

Provided below is a summary of the BACT and tBACT analysis for the emergency engines and the water storage tanks, the full analysis is in Appendix B. The analysis followed Ecology and EPA guidance and used the recommended top-down BACT analysis process can be considered to contain five basic steps:

- Step 1: Identify all available emission reduction alternatives with practical potential for application to the specific emission unit for the regulated pollutant under evaluation
- Step 2: Eliminate all technically infeasible alternatives
- Step 3: Rank remaining alternatives by effectiveness
- Step 4: Evaluate the economic, energy, and environmental impacts starting with the most effective alternative
- Step 5: Select BACT, which will be the most effective practical alternative not rejected in the previous steps.

However, EPA and Ecology have consistently interpreted the statutory and regulatory BACT definitions as containing two core requirements, which EPA believes must be met by any BACT determination, regardless of whether it is conducted in a "top-down" manner. First, the BACT analysis must include consideration of the most stringent available technologies: i.e., those that provide the "maximum degree of emissions reduction." Second, any decision to require a lesser degree of emissions reduction must be justified by an objective analysis of "energy, environmental, and economic impacts" contained in the record of the permit decisions.

6.1 Engine BACT & tBACT Analysis

DOE will operate these engines as Subpart IIII "emergency" engines (Standards of Performance for Stationary Compression Ignition Internal Combustion Engines). In order to be considered emergency engines per Subpart IIII, the engines must operate in accordance to the following requirement as specified at 40 CFR 60.4211(f):

- There is no time limit on the use of emergency stationary internal combustion engines (ICE) in emergency situations.
- Maintenance checks and readiness testing is limited to 100 hours per year unless the permittee has approval or records indicating that federal, state, or local standards require maintenance and testing beyond 100 hours per year.

There are several other provisions that allow for additional use of the emergency engines but DOE proposes to use these ICE only for maintenance, readiness testing, and during power outages and emergencies. Planned operation of the engines powering the emergency generators for routine testing, maintenance, and inspection purposes is not expected to exceed 55 hours per year and thus the BACT

and tBACT analyses used 55 hours per year as the basis for the emissions estimation. We have provided cost-effectiveness calculation results based on the regulatory annual operating limit (i.e., 100 hours per year) for comparison.

Additionally, the engines must use diesel fuel that meets the following requirements:

1. Sulfur content – 15 ppm maximum

2. Cetane index or aromatic content, as follows:

    i. A minimum Cetane index of 40; or

    ii. A maximum aromatic content of 35% by volume.

Reductions of all pollutants that would be affected by employing a Tier 4 (Final) system on the engines used to power the proposed generator sets were considered along with the cost to purchase, install, and operate the system to obtain a cost effectiveness. For completeness, pollutant emission reductions and costs associated with the emission reduction component systems that comprise the Tier 4 (Final) system were also considered, though it should be noted that the generator set manufacturers and vendors typically provide only complete Tier 4 (Final) systems, not the subsystems. Tables 6-1 and 6-2 summarize the cost-effectiveness calculations for a maximum of 55 operating hours per year and a maximum of 100 operating hours per year, respectively; additional details regarding the BACT and tBACT anslyses and cost-effectiveness calculations are provided in Appendix B.

Table 6-1. Cost-Effectiveness Calculation Summary – 55 Operating Hours Per Year.

Generator Set Rated Power Output (kWe)	Cost Effectiveness ($/ton)[a]				
	SCR	DPF & DOC	DPF	DOC	Tier 4 (Final)
400	$59,797	$233,826	$186,482	$51,827	$83,787
750	$21,794	$194,094	$154,869	$42,313	$32,971
1,250 (Cat)	$17,485	$284,894	$227,559	$59,933	$27,103
1,250 (Generac)	$27,001	$95,683	$76,334	$20,969	$36,657
2,250	$20,948	$44,923	$35,871	$9,549	$25,289

[a] Supporting calculations are provided in Appendices C and D

Table 6-2. Cost-Effectiveness Calculation Summary – 100 Operating Hours Per Year.

Generator Set Rated Power Output (kWe)	Cost Effectiveness ($/ton)[a]				
	SCR	DPF & DOC	DPF	DOC	Tier 4 (Final)
400	$34,144	$128,604	$102,565	$28,505	$47,115
750	$13,242	$106,752	$85,178	$23,272	$19,289
1,250 (Cat)	$10,872	$156,692	$125,158	$32,963	$16,107
1,250 (Generac)	$16,106	$52,625	$41,984	$11,533	$21,186
2,250	$12,777	$24,707	$19,729	$5,252	$14,833

[a] Supporting calculations are provided in Appendices C and D

As shown in Table 6-1, which reflects a more reasonable maximum number of operating hours per year, the calculated cost effectivenesses are prohibitively high cost for each of the considered add-on BACT alternatives, and they are therefore removed from consideration as BACT for NO_X, CO, VOCs, and PM. While the cost effectivnesses in Table 6-2 are less than those is Table 6-1, they are also prohibitively high, particularly when considering that the engines are not likely to ever approach the regulatory limit on non-emergency operating hours. Cost-effectiveness evaluations of reductions in TAPs, which are also discussed in Appendix A, reach similar conclusions. This leaves the baseline emission reduction alternative as BACT, which is combustion process control, achieved by the use of engines that meet applicable Subpart IIII Tier 2 or Tier 3 emission standards, as appropriate for the engine. Pursuant to 40 CFR 60.4205(b), 60.4202(b)(2), and 60.4211(c), the emergency generator engines must be certified to the applicable emission standards in Table 1 of 40 CFR 89.112.

6.2 Water Systems BACT & tBACT Analysis

The CPWTF will produce wastewater and the two water storage tanks will contain water that has been treated with chlorine to kill microorganisms. By-products of the chlorine treatment are expected to include halogenated organics, which are formed by reactions between residual chlorine and organic materials from decayed microorganisms in the form of humic acids, fulvic acids, amines, and urea. Three of these halogenated organics are classified as TAPs by Ecology: chloroform, a.k.a., trichloromethane (CAS No. 67-66-3), bromodichloromethane (75-27-4), and bromoform (75-25-2). Based on maximum potential emission rate calculations, chloroform is only TAP expected to have the potential to exceed the de minimis emission rate threshold provided in WAC 173-460-150. Because chloroform is a chlorinated VOC, strategies typically used to reduce VOC emissions were considered. As with most pollutants, there are two basic strategies to limit emissions: to reduce or eliminate the creation and/or release the pollutant, or to capture the pollutant after it has been created and/or released.

Combined chloroform emissions from the two proposed water tanks is expected to be 28.4 pounds per year (lb/yr), which assumes the baseline control of minimizing the concentration of chloroform in the stored water. Multiple abatement controls were researched, but given the extremely small emission rate, any level of energy usage, environmental consequence, and/or expenditure is unlikely to be justifiable, even if all chloroform is prevented from being emitted to the atmosphere. As a result, the energy, environmental, and cost implications of using adsorption technology to capture chloroform

emissions from the proposed water storage tanks are deemed to be outside the envelope of what is considered reasonable.

DOE proposes that tBACT for the water tanks used to store treated water is the work practice of employing techniques that minimize the quantity of chloroform present in the CPWTF wastewater and the water storage tanks.

7.0 Ambient Air Impacts Analyses

7.1 Modeling Parameters

Modeling protocol contained in HNF-65079, *Hanford Site Toxic Air Permitting and Modeling Protocol*, and REG-1146, *Hanford Site Toxic Air Regulatory Modeling Files*, were used for the ambient air impact analysis. The outline below provides a summary of the modeling parameters.

1. Ambient air concentrations at the Hanford Site boundary were estimated using the EPA's American Meteorological Society/U.S. Environmental Protection Agency Regulatory Model (AERMOD) dispersion model, Version 19191.

2. Receptor Spacing
   a. Ambient Air Boundary receptor spacing = 200 m
   b. Grid receptor spacing = 200 m, centered on the Hanford Site
   c. Fine grid receptor spacing = 25 m, centered on emission sources outside the ambient air boundary
   d. Flagpole receptor height (above ground level): 1.5 m

3. Meteorological Data
   a. 2015-2019
   b. Surface Station number = 12321 (Hanford Meteorological Station)
   c. Upper Air Station number = 4106 (Spokane, Washington, National Weather Service)

4. National Elevation Dataset
   a. Processed using AERMAP Executable – 18081

5. Building Downwash
   a. Sources inside the ambient air boundary
      i. No, due to distance from source to nearest receptor
   b. Sources outside the ambient air boundary
      i. Yes, building downwash calculated to determine worst case near field concentrations due to no regulatory fence line

6. Deposition
   a. Not used

7. Toxic Air Pollutants
   a. Diesel engine exhaust particulate, benzene, chloroform, and naphthalene
      i. Regulatory defaults for concentrations used
   b. Nitrogen Dioxide
      i. Ambient Ratio Method (ARM2) Modeling Methodology
         1. nitrogen dioxide:NOx ratio = 0.2211

7.1.1 Modeling Inputs

The toxic air pollutant new source review indicated 11 emission units contributed to the exceedance of the small quantity emission rates for nitrogen dioxide, diesel engine exhaust, particulate, benzene, naphthalene, and chloroform. Tables 7-1 and 7-2 detail the source parameters used in AERMOD.

Buildings are not necessary for air dispersion models for regulatory permitting on the Hanford Site due to the large distance from the source to the ambient air boundary. However, within this model, two of the emission units are located outside the ambient air boundary. Therefore, buildings located around these emission units were incorporated into the model in order to account for building downwash effects on the plume dispersion. Table 7-3 contains the building names and dimensions.

The modeled emission rates for each emission unit are provided in Table 7-4, Modeled Emission Rates. The emission rates for diesel engine exhaust, particulate, benzene, and naphthalene were annualized over 500 hours of operation per year to provide the annual average concentration for comparison to the acceptable source impact level (ASIL). The emission rate for nitrogen dioxide was calculated based on 8,760 hours of operations per year in order to determine the most conservative hourly concentration across all hours in a year for comparison to the ASIL.

Table 7-1. Point Source Emission Unit Parameters.

ID	Description	Source Type	X Coord (m)	Y Coord (m)	Stack Height (m)	Stack Temp (K)	Stack Velocity (m/s)	Stack Diameter (m)
L895	Standby Generator	Point - Vertical	299205.8	5158927.9	3.454	703.45	64.73	0.305
L897	Standby Generator	Point - Vertical	299337.2	5158917.2	2.675	726.05	69.32	0.229
L781FD	Feed Pump Building Standby Generator	Point - Vertical	299315.07	5159066.07	3.499	744.15	74.01	0.152
L781PH	181-D Pump house	Point - Vertical	305201.2	5174387.3	4.700	773.15	44.08	0.528
L826PH	181-B Pump House	Point - Vertical	296952.6	5168209.6	4.700	773.15	44.08	0.528
L849	282EC Standby Generator	Point - Vertical	305415.05	5158152.63	5.499	773.15	59.74	0.356
L849WTR	283EG	Point - Vertical	305459.32	5158089.62	12.192	0	0.02425522	0.6096
L850WTR	283WG	Point - Vertical	299183.48	5159032.17	12.192	0	0.02425522	0.6096

Table 7-2. Area Source Emission Unit Parameters.

ID	Description	X Coord (m)	Y Coord (m)	Release Ht(m)	Area (m^2)	Side X Length (m)	Side Y Length (m)	Initial Vertical Dimension (m)
SLDGE1	Sludge Lagoon	299256.34	5158965.69	0	327.5	12.5	26.2	0
SLDGE2	Sludge Lagoon	299274.85	5158965.69	0	327.5	12.5	26.2	0
SLDGE3	Sludge Lagoon	299295.17	5158965.69	0	327.5	12.5	26.2	0

Table 7-3. Building Parameters.

ID	Description	X Coord (m)	Y Coord (m)	Elevation (m)	Height (m)
182D	182D (Project L-781)	305438	5174328.2	142.83	10
1804D	1804D (Project L-781)	305331.7	5174406.5	143.01	5
181D	181D (Project L-781)	305162.4	5174350.5	128.26	5
181D102	181D102 (Project L-781)	305246.3	5174342	142.74	5
181B	181B (Project L-826)	296895.8	5168224.9	130.79	10

Table 7-4. Modeled Emission Rates

ID	Description	Nitrogen Dioxide (g/s)	DEEP - Annualized (g/s)	Benzene - Annualized (g/s)	Naphthalene - Annualized (g/s)	Chloroform (g/s)
L895	Standby Generator	3.15E+00	5.80E-04	6.70E-05	1.12E-05	--
L897	Standby Generator	1.81E+00	1.06E-03	4.11E-05	6.89E-06	--
L781FD	Feed Pump Building Standby Generator	4.23E-01	7.29E-04	2.35E-05	3.93E-06	--
L781PH	181-D Pump house	3.67E+00	6.34E-03	1.28E-04	2.15E-05	--
L826PH	181-B Pump House	3.67E+00	6.34E-03	1.28E-04	2.15E-05	--
L849	282EC Standby Generator	1.94E+00	3.11E-03	8.74E-05	1.46E-05	--
SLDGE1	Sludge Lagoon	--	--	--	--	7.41E-06
SLDGE2	Sludge Lagoon	--	--	--	--	7.41E-06
SLDGE3	Sludge Lagoon	--	--	--	--	7.41E-06
L849WTR	283EG	--	--	--	--	2.04E-04
L850WTR	283WG	--	--	--	--	2.04E-04

7.2 Meteorological Data

The surface meteorological inputs were from the Hanford Meteorological Station, the upper air data was obtained from the Spokane, Washington, National Weather Service for the years 2015 through 2019. Figure 7-1 contains wind speed (meters/second), wind direction, and percentage of occurrence for the years 2015 through 2019 from the Hanford Site Meteorological Station.

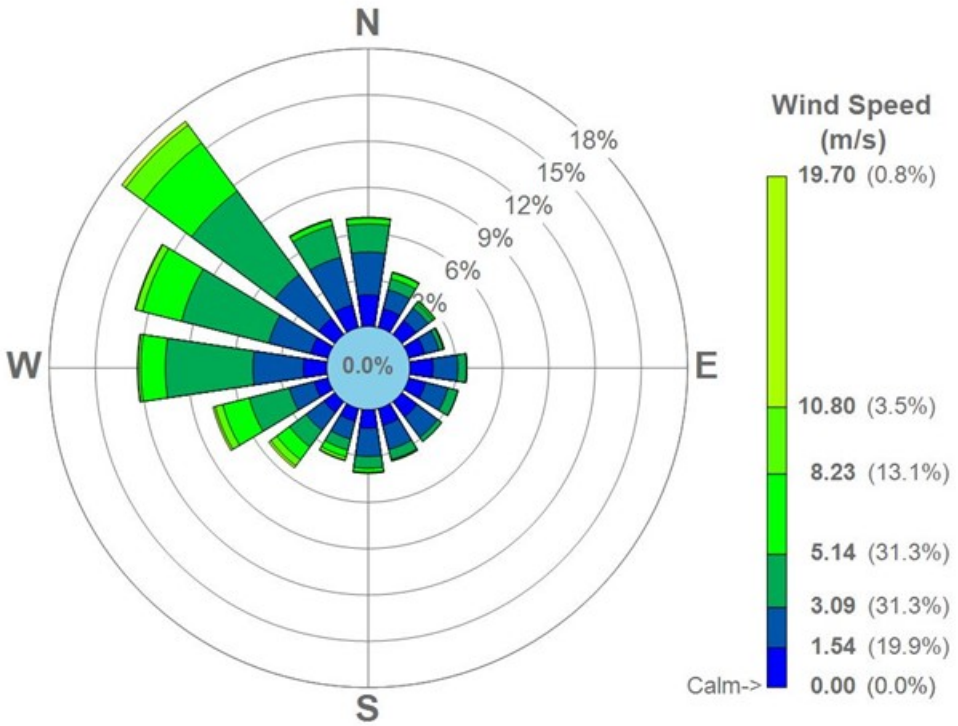


Figure 7-1. Hanford Site Meteorological Wind Rose – Surface Data 2015 through 2019

7.3 Modeling Methodology

The area inside the Hanford Site ambient air boundary (Figure 7-2, Modeling Domain) contains four of the modeled standby generators (Project L-895, L-897, L-781 Feed Pump Building, and L-849), three sludge lagoons, and two Project L-849 and L-850 water tanks. The area outside the ambient air boundary contains two of the modeled standby generators (Project L-781 Pump House and L-826 Pump House). The two standby generators located outside the ambient air boundary are more than 6 mi (approximately 10,000 m) from the closest standby generator contained within the ambient air boundary and approximately 6.5 mi (approximately 10,500 m) from each other. Four different source groups were set up within the model to determine ambient concentrations for the ambient air impact analysis based on location and source constituent emissions:

- Central Plateau: Project L-895, L-897, L-781 Feed Pump Building, and L-849 Engines
- Central Plateau: Sludge Lagoons and Project L-849 and L-850 Water Tanks

- 181-D Pump House: Project L-781
- 181-B Pump House: Project L-826.

The ARM2 for determining nitrogen dioxide concentrations as a result of estimated NOx from air emission sources was used within AERMOD, with an override of the default 0.5 nitrogen dioxide: NOx conversion ratio. After reviewing the EPA database for testing in-stack results for speciation results of NOx, 0.2211 was presented to Ecology as appropriate for the standby generators in the project.

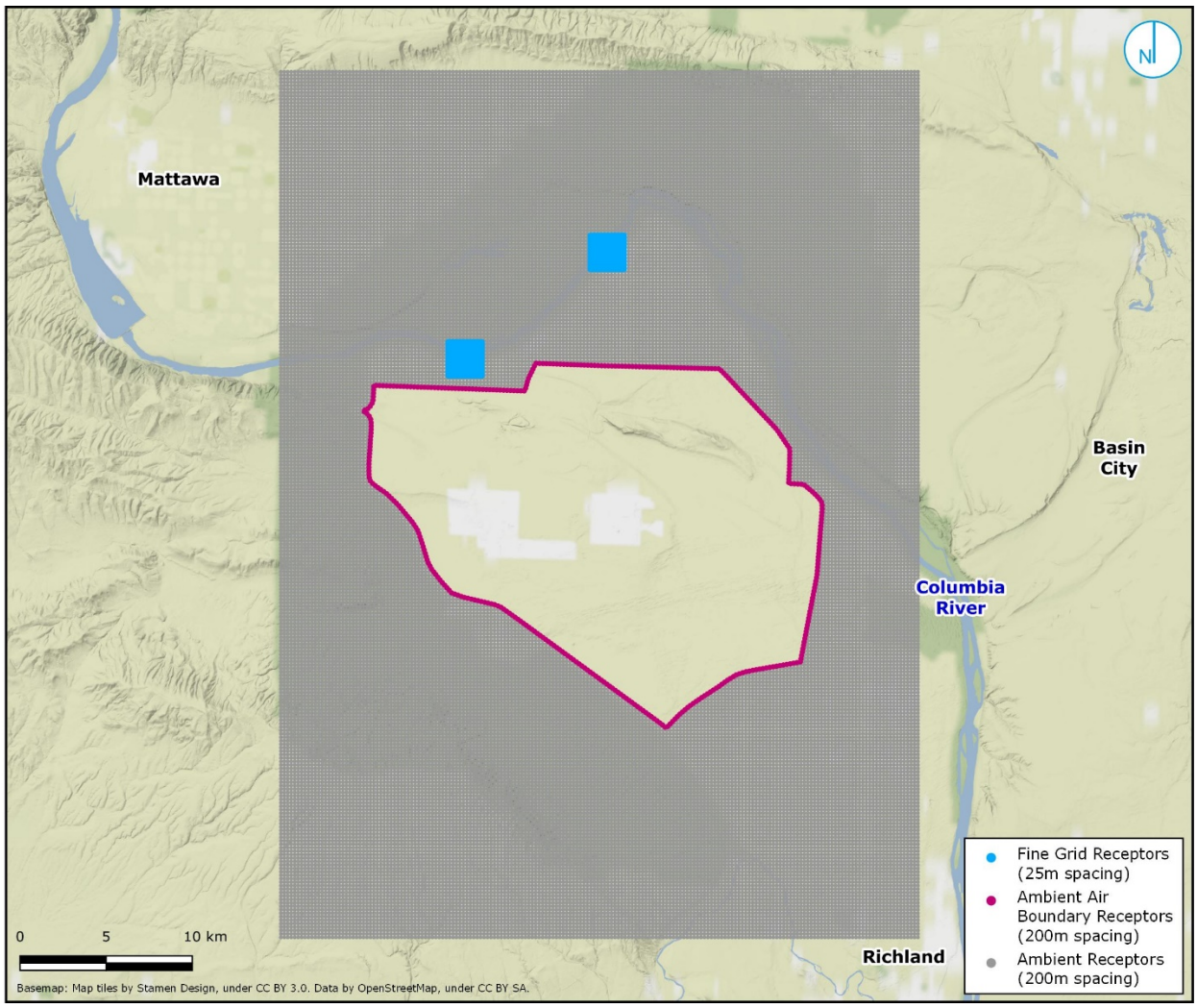


Figure 7-2. Modeling Domain

7.4 Modeling Results

Modeled ambient air concentrations were compared to WAC 173-460-150 ASILs. Table 7-5, 200-Meter Hanford Sitewide Grid Model Output, details modeled ambient concentrations for each TAP from the 200-m receptor grid resolution model and a determination of exceedance of the ASIL threshold. No TAP ambient concentration from either Central Plateau source group exceeded the ASIL thresholds. Diesel

engine exhaust, particulate exceeds the ASIL for the 181-D Pump House (Project L-781) and 181-B Pump House (Project L-826) source groups.

A 25-m receptor grid was modeled within 1 km of the Project L-781 and L-826 emission units to develop more precise estimates of TAP concentrations due to the diesel engine exhaust, particulate ASIL exceedance. Results of the 25-mr focused grid model are provided in Table 7-5, Project L-781 and L-826 Focused 25-m Grid Model Output. All concentrations increased from the 200-m grid model results. Benzene and naphthalene predicted concentrations remain under the ASIL. Diesel engine exhaust, particulate remains over the ASIL. Nitrogen dioxide increased to 670 µg/m^3, indicating an exceedance of the ASIL. Figures 7-3, 7-4, and 7-5 show the modeling results of the diesel engine exhaust, particulate and nitrogen dioxide at the highest model output locations with an ASIL exceedance. Contours represent the WAC 173-460-150 ASIL value, indicating that the area within the contour exceeds the ASIL threshold.

7.4.1 National Ambient Air Quality Standards

As detailed in Section 3.0, the project emissions exceed the WAC 173-400-110(5) exemption levels for PM-2.5 and nitrogen oxides (assumed as nitrogen dioxide). In order to determine whether the project could cause or contribute to a violation of the National Ambient Air Quality Standards (NAAQS), as shown in WAC 173-400-113(4)(a) and in compliance with WAC 173-400-113(3), modeling was performed to determine ambient concentrations at the applicable averaging periods for comparison to the NAAQS. Tables 7-7, 7-8, and 7-9 show the results of the NAAQS modeling. The project is not expected to cause or contribute to a violation of the PM-2.5 or the nitrogen dioxide NAAQS.

Through consultation with Ecology, the Monte Carlo modeling methodology was used to model nitrogen dioxide emissions for analysis of violation of the 1-hour nitrogen dioxide primary NAAQS. Figure 7-5, Summary of Monte Carlo Modeling for Nitrogen Dioxide 1-hour Impacts to the NAAQS, provides the probability of exceeding an ambient concentration of 139.12 µg/m^3 of project-related nitrogen dioxide emissions, which corresponds with a potential violation of the NAAQS, assuming a background concentration of 48.88 µg/m^3. Based on the Monte Carlo processing, there is less than a 10% chance of any receptor within the modeling domain to exceed a value that would cause or contribute to a violation of the NAAQS.

Table 7-5. 200-Meter Hanford Sitewide Grid Model Output.

				Ambient Concentration (µg/m³ per averaging period)					Exceeds ASIL?				
Pollutant	CAS Number	Aver. Period	ASIL (µg/m³)	Central Plateau Engines[a]	Central Plateau Lagoons and Water Tanks	181-D Pump House (Project L-781)	181-B Pump House (Project L-826)	All Sources	Central Plateau Engines[a]	Central Plateau Lagoons and Water Tanks	181-D Pump House (Project L-781)	181-B Pump House (Project L-826)	All Sources
Benzene	71-43-2	year	1.30E-01	1.07E-05	--	2.75E-04	4.68E-04	4.75E-04	No	--	No	No	No
Naphthalene	91-20-3	year	2.90E-02	1.79E-06	--	4.61E-05	7.85E-05	7.96E-05	No	--	No	No	No
Chloroform	67-66-3	year	4.30E-02	--	7.00E-05	--	--	7.00E-05	--	No	--	--	No
Nitrogen dioxide[b]	10102-44-0	1-hr	4.70E+02	1.14E+02	--	1.66E+02	2.26E+02	2.26E+02	No	--	No	No	No
Diesel engine exhaust, particulate	-	year	3.30E-03	2.86E-04	--	1.36E-02	2.32E-02	2.34E-02	No	--	Yes	Yes	Yes

[a] Project L-895, L897, L-781, and L-849
[b] ARM2 modeling method: NO_2:NOx ratio = 0.2211

Table 7-6. Project L-781 and L-826 Focused 25-Meter Grid Model Output.

Pollutant	CAS Number	Aver. Period	ASIL (µg/m³)	Highest 1st High Concentration (µg/m³ per averaging period)	Exceeds ASIL?
Benzene	71-43-2	year	1.30E-01	5.91E-03	No
Naphthalene	91-20-3	year	2.90E-02	9.90E-04	No
Nitrogen dioxide	10102-44-0	1-hr	4.70E+02	6.70E+02	Yes [a]
Diesel engine exhaust, particulate	-	year	3.30E-03	2.92E-01	Yes

[a] The maximum 1-hour average NO_2 concentration predicted by the 25-m grid indicates an ambient impact that exceeds the ASIL; whereas, the 200-m grid predicted a concentration that was below the ASIL.

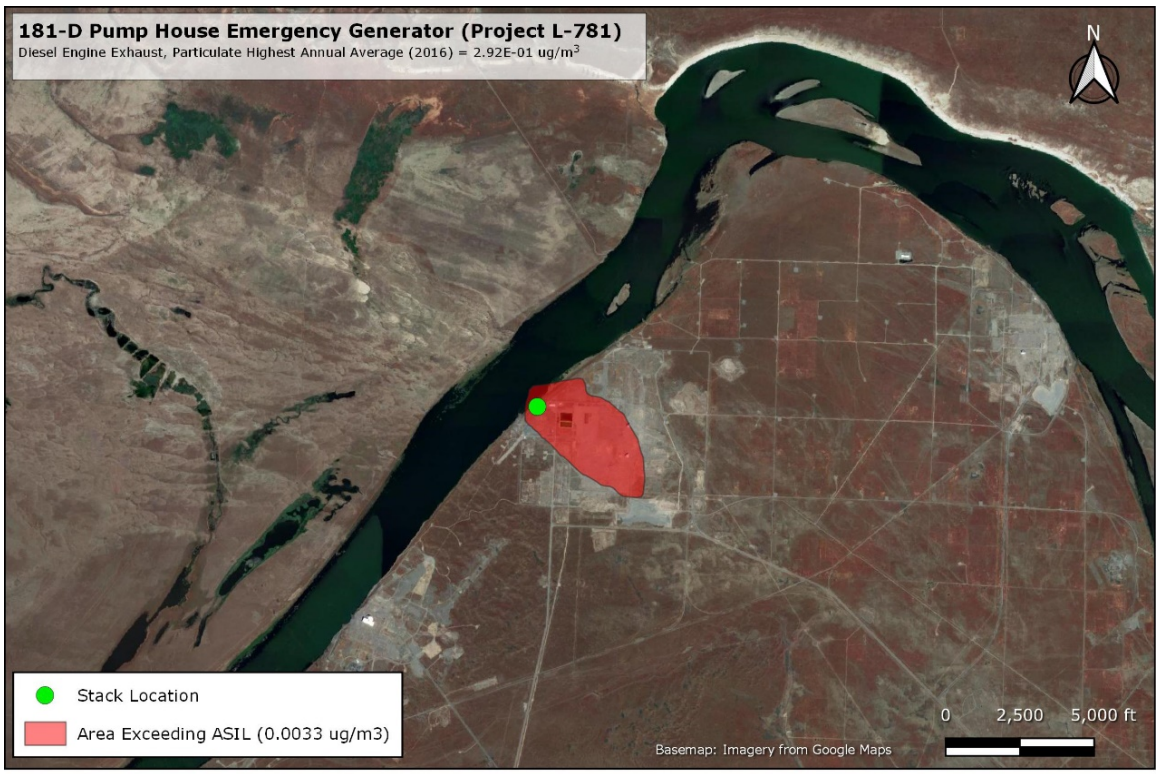


Figure 7-3. Diesel Engine Exhaust Particulate Modeled ASIL Contour 3.30E-03 µg/m³; Highest Annual Average (2016) for the Project L-781 181-D Pump House Standby Generator = 2.92E-01 µg/m³

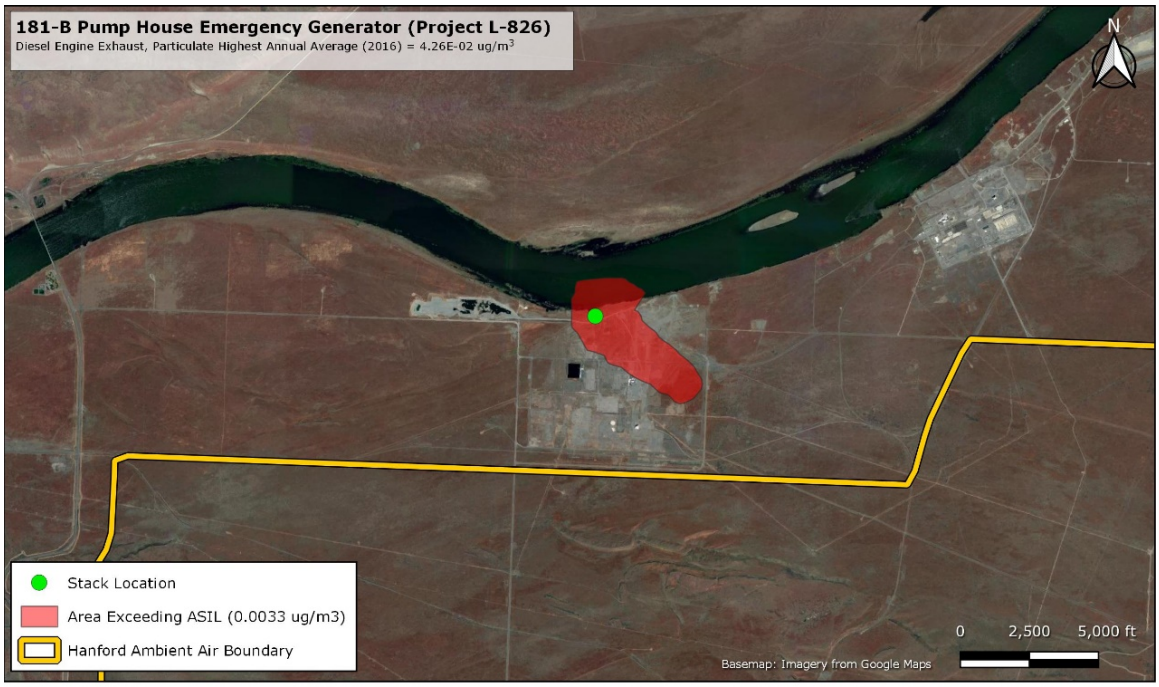


Figure 7-4. Diesel Engine Exhaust Particulate Modeled ASIL Contour 3.30E-03 µg/m³; Highest Annual Average (2017) for the Project L-826 181-B Pump House Standby Generator = 4.26E-02 µg/m³

Figure 7-5. Nitrogen Dioxide Modeled ASIL Contour 470 µg/m³; Highest 1-hour (2019) is Locatedat the 181-D Pump House = 6.70E+02 µg/m³; ASIL Was Not Exceeded for any Other Source Groups

Table 7-7. 2015-2019 Modeled Nitrogen Dioxide Annual Average and 1-hour High and Particulate Matter-2.5 Annual Average and 24-hour High.

Criteria Pollutant	Averaging Period	Significant Impact Levels (µg/m³)	Modeled Highs (µg/m³)	Exceeds SIL?
Nitrogen Dioxide	Annual	1	8.69	***Yes***[a]
	1-hour	7.5	669.80	***Yes***[b]
Particulate Matter – 2.5	Annual	.3	.285	***No***
	24-hour	1.2	.97	***No***

[a]See Table 7-8 for further analysis.
[b]See Table 7-9 for further analysis.

Table 7-8. Summary of Annual Nitrogen Dioxide Modeled Impacts and Comparison to NAAQS.

Modeled Annual Average (µg/m³)	Background Concentration (µg/m³)	Total Ambient Impacts (µg/m³)	Annual NO_2 Primary NAAQS (µg/m³)	Exceeds NAAQS?
8.69	4.51	13.2	100	***No***

Table 7-9. Summary of Annual Nitrogen Dioxide Modeled Impacts and Comparison to NAAQS.Summary of 1-hour Nitrogen Dioxide Modeled Impacts and Comparison to NAAQS.

Modeled 8th Highest 1-Hour (µg/m³)	Background Concentration (µg/m³)	Total Ambient Impacts (µg/m³)	1-Hour NO_2 Primary NAAQS (µg/m³)	Exceeds NAAQS?
326	48.88	374.88	188	***Yes***[a]

[a] See Figure 7-5 for alternative nitrogen dioxide model output using the Monte Carlo modeling method.

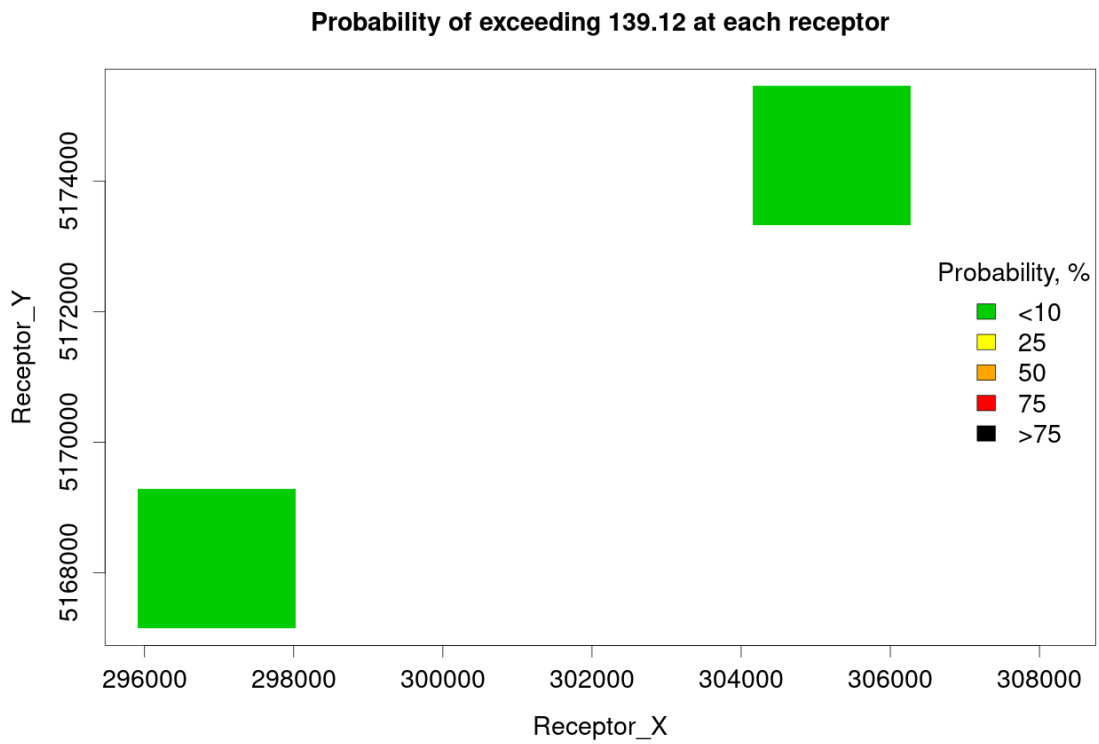


Figure 7-5. Summary of Monte Carlo Modeling for Nitrogen Dioxide 1-hour Impacts to the NAAQS

7.5 Second Tier Review

Pursuant to WAC 173-460-090, "Second Tier Review," if any expected TAP is modeled to exceed the ASIL for a new or modified source, a second tier review, or health impact assessment (HIA), must be performed for that pollutant to demonstrate that the potential emissions do not present an unacceptable health risk to members of the public.

An HIA is being developed for diesel engine exhaust, particulate and nitrogen dioxide. The HIA will follow Washington State guidance, as outlined in the document *Guidance Document: First, Second, and Third Tier Review of Toxic Air Pollution Sources (Chapter 173-460 WAC*) (Ecology 2015).

8.0 References

40 CFR 52.21, "Prevention of Significant Deterioration of Air Quality," *Code of Federal Regulations,* as amended.

40 CFR 60, "Standards of Performance for New Stationary Sources," *Code of Federal Regulations,* as amended.

40 CFR 63, "National Emission Standards for Hazardous Air Pollutants for Source Categories," *Code of Federal Regulations,* as amended.

40 CFR 89, "Control of Emissions from New and In-Use Nonroad Compression-Ignition Engines," *Code of Federal Regulations,* as amended.

AP-42, 1995, *Compilation of Air Pollutant Emissions Factors,"* Volume 1, Fifth Edition, U.S. Environmental Protection Agency, Research Triangle Park, North Carolina.

DOE/EIS-0391, 2012, *Final Tank Closure and Waste Management Environmental Impact Statement for the Hanford Site, Richland, Washington,* Rev. 0, U.S. Department of Energy, U.S. Environmental Protection Agency, and Washington State Department of Ecology, Richland, Washington.

Ecology, 2015, *Guidance Document: First, Second, and Third Tier Review of Toxic Air Pollution Sources (Chapter 173-460 WAC*), 08-02-025, Washington State Department of Ecology, Olympia, Washington.

EPA, 1976, *Interim Treatment Guide for the Control of Chloroform and Other Trihalomethanes,* U.S. Environmental Protection Agency, Cincinnati, Ohio.

EPA, 1981, *Treatment Techniques for Controlling Trihalomethanes in Drinking Water*, U.S. Environmental Protection Agency, Cincinnati, Ohio.

EPA, 1983, *Guidance for Estimating Capital and Annual Costs of Air Pollution Control Systems,* U.S. Environmental Protection Agency, Chicago, Illinois.

EPA, 1987, "Improving New Source Review (NSR) Implementation," internal memorandum to Regional Administrator, Regions I-X, from J. C. Potter, U.S. Environmental Protection Agency, Washington, D.C., December 1.

EPA, 1990, *New Source Review Workshop Manual,* Draft, U.S. Environmental Protection Agency, Washington, D.C.

EPA, 1995, "Calculating Potential to Emit (PTE) for Emergency Generators," internal memorandum to Regional Administrator, Regions I-X, from J. S. Seitz, U.S. Environmental Protection Agency, Washington, D.C., December 1.

EPA, 2005, *Conversion Factors for Hydrocarbon Emission Components*, U.S. Environmental Protection Agency, Washington, D.C.

EPA, 2018, *Cost Report and Guidance for Air Pollution Regulations,* Section 3, Chapter 1, U.S. Environmental Protection Agency, Research Triangle Park, North Carolina.

EPA, 2020, Cost Report and Guidance for Air Pollution Regulations, U.S. Environmental Protection Agency. Accessed September 2020.

EPA-452/F-03-016, *Air Pollution Control Technology Fact Sheet,* U.S. Environmental Protection Agency, Washington, D.C.

HNF-64154, 2019, *BAT/AKART Analysis Project L-897, Central Plateau Water Treatment Facility,* Mission Support Alliance, Richland, Washington.

HNF-65079, 2020, *Hanford Site Toxic Air Permitting and Modeling Protocol,* Rev. 0, Mission Support Alliance, Richland, Washington.

HNF-CALC-63402, 2020, *L-897, FWW EQ Basin Calculation*, Rev. 0, Mission Support Alliance, Richland, Washington.

HNF-SPEC-63005, 2019, *Procurement Specification for L-850 Sanitary Water Storage Tank,* Rev. 0, Mission Support Alliance, Richland, Washington.

RCW 43.21C, "State Environmental Policy Act," *Revised Code of Washington,* as amended.

RCW 70.94. "Washington Clean Air Act." *Revised Code of Washington*, as amended. Olympia, Washington.

REG-1146, 2020, *Hanford Site Toxic Air Regulatory Modeling Files,* Rev. 0, Mission Support Alliance, Richland, Washington.

WAC 173-400, "General Regulations for Air Pollution Sources," *Washington Administrative Code*, Olympia, Washington.

WAC 173-460, "Controls for New Sources of Toxic Air Pollutants," *Washington Administrative Code*, Olympia, Washington.

WAC 197-11, "State Environmental Policy Act of 1971," *Washington Administrative Code*, Olympia, Washington.

APPENDIX A

EMISSION CALCULATIONS

This page intentionally left blank.

Appendix A

Emission Calculations

Table A-1. Carbon Monoxide Emission Estimate.

Stationary Engine	Emissions (g/kW-hr) or (g/HP-hr)[a]	Engine Power (kW) or (HP)[b]	Emission Rate (g/hr)	Annual Emissions (g/year)	Emission Estimate (Tons/year)
	A	B	C=A*B	D=C*500[c]	E=D*0.00000110
L-897	4.1E-01[a]	1.112E+03[b]	4.56E+02	2.28E+05	2.5E-01
L-895	2.1E-01[a]	1.829E+03[b]	3.85E+02	1.92E+05	2.1E-01
L-849	6.0E-01	1.403E+03	8.42E+02	4.21E+05	4.6E-01
L-826	1.3E+00	2.5E+03	3.25E+03	1.63E+06	1.8E+00
L-781 (200-West Feed Pump Building)	6.0E-01	4.6E+02	2.76E+02	1.38E+05	1.5E-01
L-781 (181-D Pump House)	1.3E+00	2.5E+03	3.25E+03	1.63E+06	1.8E+00
Total Carbon Monoxide Emission Estimate (Tons/year)					4.7E+00

[a] g/HP-hr provided in manufacturer's specification instead of g/kW-hr
[b] HP provided in manufacturer's specification instead of kW
[c] 500 operating hours per year assumed based on EPA (1995)

Table A-2. Particulate Matter Emission Estimate.

Stationary Engine	Emissions (g/kW-hr) or (g/HP-hr)[a]	Engine Power (kW) or (HP)[b]	Emission Rate (g/hr)	Annual Emissions (g/year)	Emission Estimate (Tons/year)
	A	B	C=A*B	D=C*500[c]	E=D*0.00000110
L-897	6.0E-02[a]	1.112E+03[b]	6.67E+01	3.34E+04	3.7E-02
L-895	2.0E-02[a]	1.829E+03[b]	3.66E+01	1.83E+04	2.0E-02
L-849	1.4E-01	1.403E+03	1.96E+02	9.8E+04	1.1E-01
L-826	1.6E-01	2.5E+03	4.0E+02	2.0E+05	2.2E-01
L-781 (200-West Feed Pump Building)	1.0E-01	4.6E+02	4.6E+01	2.3E+04	2.5E-02
L-781 (181-D Pump House)	1.6E-01	2.5E+03	4.0E+02	2.0E+05	2.2E-01
Total Particulate Matter Emission Estimate (Tons/year)					6.3E-01

[a] g/HP-hr provided in manufacturer's specification instead of g/kW-hr
[b] HP provided in manufacturer's specification instead of kW
[c] 500 operating hours per year assumed based on EPA (1995)

Table A-3. Sulfur Dioxide Emission Estimate.

Stationary Engine	Operating Time (hrs/year)	Fuel Consumption Rate (gal/hr)	Fuel Density (lbs/gal)	Fuel Sulfur Content by Weight	Molecular Weight Ratio, SO_2:S	Emission Estimate (Tons/year)
	A	B	C	D	E	F=A*B*C*D*E* 5.0E-04
L-897	5.0E+02[a]	5.36E+01	7.2E+00	1.5E+01/1.0E+06	2.0E+00	2.9E-03
L-895	5.0E+02[a]	8.74E+01	7.2E+00	1.5E+01/1.0E+06	2.0E+00	4.7E-03
L-849	5.0E+02[a]	1.14E+02	7.2E+00	1.5E+01/1.0E+06	2.0E+00	6.2E-03
L-826	5.0E+02[a]	1.671E+02	7.2E+00	1.5E+01/1.0E+06	2.0E+00	9.0E-03
L-781 (200-West Feed Pump Building)	5.0E+02[a]	3.06E+01	7.2E+00	1.5E+01/1.0E+06	2.0E+00	1.7E-03
L-781 (181-D Pump House)	5.0E+02[a]	1.671E+02	7.2E+00	1.5E+01/1.0E+06	2.0E+00	9.0E-03
Total Sulfur Dioxide Emission Estimate (Tons/year)						3.4E-02

[a] 500 operating hours per year assumed based on EPA (1995)

Table A-4. Volatile Organic Compound Emission Estimate.

Stationary Engine	NMHC Emission Rate (g/kW-hr) or HC Emission Rate[a] (g/HP-hr)[a]	Engine Power (kW) or (HP)[b]	Emission Rate (g/hr)	Annual Emissions (g/year)	Emission Estimate (Tons/year)	EPA Conversion Factor for Diesel Engines (VOC/THC : NMHC/THC)[d]
	A	B	C=A*B	D=C*500[c]	E=D*0.00000110	F=E*1.053/0.984
L-897	1.1E-01[a]	1.112E+03[b]	1.22E+02	6.12E+04	6.7E-02	7.2E-02
L-895	1.0E-01[a]	1.829E+03[b]	1.83E+02	9.15E+04	1.0E-01	1.1E-01
L-849	5.8E-01	1.403E+03	8.14E+02	4.07E+05	4.5E-01	4.8E-01
L-826	7.5E-01	2.5E+03	1.88E+03	9.38E+05	1.0E+00	1.1E+00
L-781 (200-West Feed Pump Building)	1.1E-01	4.6E+02	5.06E+01	2.53E+04	2.8E-02	3.0E-02
L-781 (181-D Pump House)	7.5E-01	2.5E+03	1.88E+03	9.38E+05	1.0E+00	1.1E+00
Total Volatile Organic Compound Emission Estimate (Tons/year)						2.9E+00

[a] HC emission rate, in g/HP-hr, provided in manufacturer's specification instead of NMHC emission rate in g/kW-hr
[b] HP provided in manufacturer's specification instead of kW
[c] 500 operating hours per year assumed based on EPA (1995)
[d] Conversion factor from EPA (2005)

Table A-5. Nitrogen Dioxide Emission Estimate.

Stationary Engine	Emissions (g/kW-hr) or (g/HP-hr)[a]	Engine Power (kW) or (HP)[b]	Emission Rate (g/hr)	Annual Emissions (g/year)	Emission Estimate (Tons/year)
	A	B	C=A*B	D=C*500[c]	E=D*0.00000110
L-897	5.85E+00[a]	1.112E+03[b]	6.51E+03	3.26E+06	3.6E+00
L-895	6.20E+00[a]	1.829E+03[b]	1.13E+04	5.7E+06	6.3E+00
L-849	4.99E+00	1.403E+03	7.0E+03	3.5E+06	3.9E+00
L-826	5.28E+00	2.5E+03	1.32E+04	6.6E+06	7.3E+00
L-781 (200-West Feed Pump Building)	3.31E+00	4.6E+02	1.52E+03	7.6E+05	8.4E-01
L-781 (181-D Pump House)	5.28E+00	2.5E+03	1.32E+04	6.6E+06	7.3E+00
Total Nitrogen Dioxide Emission Estimate (Tons/year)					2.9E+01

Note: All NO_x data provided in manufacturer's specifications and EPA.gov emission tables assumed to be nitrogen dioxide

[a] g/HP-hr provided in manufacturer's specification instead of g/kW-hr

[b] HP provided in manufacturer's specification instead of kW

[c] 500 operating hours per year assumed based on EPA (1995)

Table A-6. Carbon Monoxide Emission Estimate.

Stationary Engine	Emissions (g/kW-hr) or (g/HP-hr)[a]	Engine Power (kW) or (HP)[b]	Emission Rate (g/hr)	Annual Emissions (g/year)	Average Hourly Emissions (g/hr)	Emission Estimate (lbs/hr)
	A	B	C=A*B	D=C*500[c]	E=D/8760	F=E*0.0022
L-897	4.1E-01[a]	1.112E+03[b]	4.56E+02	2.28E+05	2.6E+01	5.7E-02
L-895	2.1E-01[a]	1.829E+03[b]	3.84E+02	1.92E+05	2.19E+01	4.8E-02
L-849	6.0E-01	1.403E+03	8.42E+02	4.21E+05	4.81E+01	1.1E-01
L-826	1.3E+00	2.5E+03	3.25E+03	1.63E+06	1.86E+02	4.1E-01
L-781 (200-West Feed Pump Building)	6.0E-01	4.6E+02	2.76E+02	1.38E+05	1.58E+01	3.5E-02
L-781 (181-D Pump House)	1.3E+00	2.5E+03	3.25E+03	1.63E+06	1.86E+02	4.1E-01
Total Carbon Monoxide Emission Estimate (lbs/hr)						1.1E+00

[a] g/HP-hr provided in manufacturer's specification instead of g/kW-hr

[b] HP provided in manufacturer's specification instead of kW

[c] 500 operating hours per year assumed based on EPA (1995)

Table A-7. Diesel Engine Exhaust, Particulate Emission Estimate.

Stationary Engine	Emissions[P] (g/kW-hr) or (g/HP-hr)[a]	Engine Power (kW) or (HP)[b]	Emission Rate (g/hr)	Annual Emissions (g/year)	Emission Estimate (lbs/year)
	A	B	C=A*B	D=C*500[c]	E=*0.0022
L-897	6.0E-02[a]	1.112E+03[b]	6.67E+01	3.34E+04	7.4E+01
L-895	2.0E-02[a]	1.829E+03[b]	3.66E+01	1.83E+04	4.0E+01
L-849	1.4E-01	1.403E+03	1.96E+02	9.8E+04	2.2E+02
L-826	1.6E-01	2.5E+03	4.0E+02	2.0E+05	4.4E+02
L-781 (200-West Feed Pump Building)	1.0E-01	4.6E+02	4.6E+01	2.3E+04	5.1E+01
L-781 (181-D Pump House)	1.6E-01	2.5E+03	4.0E+02	2.0E+05	4.4E+02
Total Diesel Engine Exhaust, Particulate Emission Estimate (lbs/year)					1.3E+03

Note: All PM data provided in manufacturer's specifications and EPA.gov emission tables assumed to be diesel engine exhaust, particulate

[a] g/HP-hr provided in manufacturer's specification instead of g/kW-hr

[b] HP provided in manufacturer's specification instead of kW

[c] 500 operating hours per year assumed based on EPA (1995)

Table A-8. Nitrogen Dioxide Emission Estimate.

Stationary Engine	Emissions (g/kW-hr) or (g/HP-hr)[a]	Engine Power (kW) or (HP)[b]	Emission Rate (g/hr)	Annual Emissions (g/year)	Average Hourly Emissions (g/hr)	Emission Estimate (lbs/hr)
	A	B	C=A*B	D=C*500[c]	E=D/8760	F=E*0.0022
L-897	5.85E+00[a]	1.112E+03[b]	6.51E+03	3.26E+06	3.72E+02	8.2E-01
L-895	6.20E+00[a]	1.829E+03[b]	1.13E+04	5.7E+06	6.51E+02	1.4E+00
L-849	4.99E+00	1.403d=03	7.0E+03	3.5E+06	4.0E+02	8.8E-01
L-826	5.28E+00	2.5E+03	1.32E+04	6.6E+06	7.53E+02	1.7E+00
L-781 (200-West Feed Pump Building)	3.31E+00	4.6E+02	1.52E+03	7.6E+05	8.68E+01	1.9E-01
L-781 (181-D Pump House)	5.28E+00	2.5E+03	1.32E+04	6.6E+06	7.53E+02	1.7E+00
Total Nitrogen Dioxide Emission Estimate (lbs/hr)						6.7E+00

Note: All NO_x data provided in manufacturer's specifications and EPA.gov emission tables assumed to be nitrogen dioxide.

[a] g/HP-hr provided in manufacturer's specification instead of g/kW-hr

[b] HP provided in manufacturer's specification instead of kW

[c] 500 operating hours per year assumed based on EPA (1995)

Table A-9. Sulfur Dioxide Emission Estimate.

Stationary Engine	Operating Time (hrs/year)	Fuel Consumption Rate (gal/hr)	Fuel Density (lbs/gal)	Fuel Sulfur Content by Weight	Molecular Weight Ratio, SO_2:S	Emission Estimate (lbs/hour)
	A	B	C	D	E	F=A*B*C*D*E / 8.76E+03
L-897	5.0E+02[a]	5.36E+01	7.2E+00	1.5E+01/1.0E+06	2.0E+00	6.6E-04
L-895	5.0E+02[a]	8.74E+01	7.2E+00	1.5E+01/1.0E+06	2.0E+00	1.1E-03
L-849	5.0E+02[a]	1.14E+02	7.2E+00	1.5E+01/1.0E+06	2.0E+00	1.4E-03
L-826	5.0E+02[a]	1.671E+02	7.2E+00	1.5E+01/1.0E+06	2.0E+00	2.1E-03
L-781 (200-West Feed Pump Building)	5.0E+02[a]	3.06E+01	7.2E+00	1.5E+01/1.0E+06	2.0E+00	3.8E-04
L-781 (181-D Pump House)	5.0E+02[a]	1.671E+02	7.2E+00	1.5E+01/1.0E+06	2.0E+00	2.1E-03
Total Sulfur Dioxide Emission Estimate (lbs/hr)						7.7E-03

[a] 500 operating hours per year assumed based on EPA (1995)

Table A-10. Benzene Emission Estimate.

Stationary Engine	Operating Time (hrs/year)	Fuel Consumption Rate (gal/hr)	Diesel Fuel Energy (MMBTU/gal)	Emission Rate (lbs/MMBTU)	Emission Estimate (lbs/year)
	A	B	C	D	E=A*B*C*D
L-897	5.0E+02[a]	5.36E+01	1.374E-01	7.76E-04[b]	2.9E+00
L-895	5.0E+02[a]	8.74E+01	1.374E-01	7.76E-04[b]	4.7E+00
L-849	5.0E+02[a]	1.14E+02	1.374E-01	7.76E-04[b]	6.1E+00
L-826	5.0E+02[a]	1.671E+02	1.374E-01	7.76E-04[b]	8.9E+00
L-781 (200-West Feed Pump Building)	5.0E+02[a]	3.06E+01	1.374E-01	7.76E-04[b]	1.6E+00
L-781 (181-D Pump House)	5.0E+02[a]	1.671E+02	1.374E-01	7.76E-04[b]	8.9E+00
Total Benzene Emission Estimate (lbs/year)					3.3E+01

[a] 500 operating hours per year assumed based on EPA (1995)

[b] Emission rate obtained from AP-42, *Compilation of Air Pollutant Emissions Factors,* Fifth Edition, Volume 1, Chapter 3, Table 3.4-3

Table A-11. Toluene Emission Estimate.

Stationary Engine	Operating Time (hrs/year)	Fuel Consumption Rate (gal/hr)	Diesel Fuel Energy (MMBTU/gal)	Emission Rate (lbs/MMBTU)	Emission Estimate (lbs/24 Hours)
	A	B	C	D	E=A*B*C*D / 3.65E+02
L-897	5.0E+02[a]	5.36E+01	1.374E-01	2.81E-04[b]	2.8E-03
L-895	5.0E+02[a]	8.74E+01	1.374E-01	2.81E-04[b]	4.6E-03
L-849	5.0E+02[a]	1.14E+02	1.374E-01	2.81E-04[b]	6.0E-03
L-826	5.0E+02[a]	1.671E+02	1.374E-01	2.81E-04[b]	8.8E-03
L-781 (200-West Feed Pump Building)	5.0E+02[a]	3.06E+01	1.374E-01	2.81E-04[b]	1.6E+01
L-781 (181-D Pump House)	5.0E+02[a]	1.671E+02	1.374E-01	2.81E-04[b]	8.8E-03
Total Toluene Emission Estimate (lbs/24 Hours)					3.3E-02

[a] 500 operating hours per year assumed based on EPA (1995)
[b] Emission rate obtained from AP-42, *Compilation of Air Pollutant Emissions Factors,* Fifth Edition, Volume 1, Chapter 3, Table 3.4-3

Table A-12. Xylenes Emission Estimate.

Stationary Engine	Operating Time (hrs/year)	Fuel Consumption Rate (gal/hr)	Diesel Fuel Energy (MMBTU/gal)	Emission Rate (lbs/MMBTU)	Emission Estimate (lbs/24 Hours)
	A	B	C	D	E=A*B*C*D / 3.65E+02
L-897	5.0E+02[a]	5.36E+01	1.374E-01	1.93E-04[b]	2.0E-03
L-895	5.0E+02[a]	8.74E+01	1.374E-01	1.93E-04[b]	3.2E-03
L-849	5.0E+02[a]	1.14E+02	1.374E-01	1.93E-04[b]	4.1E-03
L-826	5.0E+02[a]	1.671E+02	1.374E-01	1.93E-04[b]	6.1E-03
L-781 (200-West Feed Pump Building)	5.0E+02[a]	3.06E+01	1.374E-01	1.93E-04[b]	1.1E-03
L-781 (181-D Pump House)	5.0E+02[a]	1.671E+02	1.374E-01	1.93E-04[b]	6.1E-03
Total Xylenes Emission Estimate (lbs/24 Hours)					2.3E-02

[a] 500 operating hours per year assumed based on EPA (1995)
[b] Emission rate obtained from AP-42, *Compilation of Air Pollutant Emissions Factors,* Fifth Edition, Volume 1, Chapter 3, Table 3.4-3

Table A-13. Propylene Emission Estimate.

Stationary Engine	Operating Time (hrs/year)	Fuel Consumption Rate (gal/hr)	Diesel Fuel Energy (MMBTU/gal)	Emission Rate (lbs/MMBTU)	Emission Estimate (lbs/24 Hours)
	A	B	C	D	E=A*B*C*D / 3.65E+02
L-897	5.0E+02[a]	5.36E+01	1.374E-01	2.79E-03[b]	2.8E-02
L-895	5.0E+02[a]	8.74E+01	1.374E-01	2.79E-03[b]	4.6E-02
L-849	5.0E+02[a]	1.14E+02	1.374E-01	2.79E-03[b]	6.0E-02
L-826	5.0E+02[a]	1.671E+02	1.374E-01	2.79E-03[b]	8.8E-02
L-781 (200-West Feed Pump Building)	5.0E+02[a]	3.06E+01	1.374E-01	2.79E-03[b]	1.6E-02
L-781 (181-D Pump House)	5.0E+02[a]	1.671E+02	1.374E-01	2.79E-03[b]	8.8E-02
Total Propylene Emission Estimate (lbs/24 Hours)					3.3E-01

[a] 500 operating hours per year assumed based on EPA (1995)
[b] Emission rate obtained from AP-42, *Compilation of Air Pollutant Emissions Factors,* Fifth Edition, Volume 1, Chapter 3, Table 3.4-3

Table A-14. Formaldehyde Emission Estimate.

Stationary Engine	Operating Time (hrs/year)	Fuel Consumption Rate (gal/hr)	Diesel Fuel Energy (MMBTU/gal)	Emission Rate (lbs/MMBTU)	Emission Estimate (lbs/year)
	A	B	C	D	E=A*B*C*D
L-897	5.0E+02[a]	5.36E+01	1.374E-01	7.89E-05[b]	2.9E-01
L-895	5.0E+02[a]	8.74E+01	1.374E-01	7.89E-05[b]	4.7E-01
L-849	5.0E+02[a]	1.14E+02	1.374E-01	7.89E-05[b]	6.2E-01
L-826	5.0E+02[a]	1.671E+02	1.374E-01	7.89E-05[b]	9.1E-01
L-781 (200-West Feed Pump Building)	5.0E+02[a]	3.06E+01	1.374E-01	7.89E-05[b]	1.7E-01
L-781 (181-D Pump House)	5.0E+02[a]	1.671E+02	1.374E-01	7.89E-05[b]	9.1E-01
Total Formaldehyde Emission Estimate (lbs/year)					3.4E+00

[a] 500 operating hours per year assumed based on EPA (1995)
[b] Emission rate obtained from AP-42, *Compilation of Air Pollutant Emissions Factors,* Fifth Edition, Volume 1, Chapter 3, Table 3.4-3

Table A-15. Acetaldehyde Emission Estimate. (2 Pages)

Stationary Engine	Operating Time (hrs/year)	Fuel Consumption Rate (gal/hr)	Diesel Fuel Energy (MMBTU/gal)	Emission Rate (lbs/MMBTU)	Emission Estimate (lbs/year)
	A	B	C	D	E=A*B*C*D
L-897	5.0E+02[a]	5.36E+01	1.374E-01	2.52E-05[b]	9.3E-02
L-895	5.0E+02[a]	8.74E+01	1.374E-01	2.52E-05[b]	1.5E-01
L-849	5.0E+02[a]	1.14E+02	1.374E-01	2.52E-05[b]	2.0E-01

Table A-15. Acetaldehyde Emission Estimate. (2 Pages)

Stationary Engine	Operating Time (hrs/year)	Fuel Consumption Rate (gal/hr)	Diesel Fuel Energy (MMBTU/gal)	Emission Rate (lbs/MMBTU)	Emission Estimate (lbs/year)
L-826	5.0E+02[a]	1.671E+02	1.374E-01	2.52E-05[b]	2.9E-01
L-781 (200-West Feed Pump Building)	5.0E+02[a]	3.06E+01	1.374E-01	2.52E-05[b]	5.3E-02
L-781 (181-D Pump House)	5.0E+02[a]	1.671E+02	1.374E-01	2.52E-05[b]	2.9E-01
Total Acetaldehyde Emission Estimate (lbs/year)					1.1E+00

[a] 500 operating hours per year assumed based on EPA (1995)
[b] Emission rate obtained from AP-42, *Compilation of Air Pollutant Emissions Factors,* Fifth Edition, Volume 1, Chapter 3, Table 3.4-3

Table A-16. Acrolein Emission Estimate.

Stationary Engine	Operating Time (hrs/year)	Fuel Consumption Rate (gal/hr)	Diesel Fuel Energy (MMBTU/gal)	Emission Rate (lbs/MMBTU)	Emission Estimate (lbs/24 hours)
	A	B	C	D	E=A*B*C*D / 3.65E+02
L-897	5.0E+02[a]	5.36E+01	1.374E-01	7.88E-06[b]	8.0E-05
L-895	5.0E+02[a]	8.74E+01	1.374E-01	7.88E-06[b]	1.3E-04
L-849	5.0E+02[a]	1.14E+02	1.374E-01	7.88E-06[b]	1.7E-04
L-826	5.0E+02[a]	1.671E+02	1.374E-01	7.88E-06[b]	2.5E-04
L-781 (200-West Feed Pump Building)	5.0E+02[a]	3.06E+01	1.374E-01	7.88E-06[b]	4.5E-05
L-781 (181-D Pump House)	5.0E+02[a]	1.671E+02	1.374E-01	7.88E-06[b]	2.5E-04
Total Acrolein Emission Estimate (lbs/24 hours)					9.3E-04

[a] 500 operating hours per year assumed based on EPA (1995)
[b] Emission rate obtained from AP-42, *Compilation of Air Pollutant Emissions Factors,* Fifth Edition, Volume 1, Chapter 3, Table 3.4-3

Table A-17. Naphthalene Emission Estimate. (2 Pages)

Stationary Engine	Operating Time (hrs/year)	Fuel Consumption Rate (gal/hr)	Diesel Fuel Energy (MMBTU/gal)	Emission Rate (lbs/MMBTU)	Emission Estimate (lbs/year)
	A	B	C	D	E=A*B*C*D
L-897	5.0E+02[a]	5.36E+01	1.374E-01	1.3E-04[b]	4.8E-01
L-895	5.0E+02[a]	8.74E+01	1.374E-01	1.3E-04[b]	7.8E-01
L-849	5.0E+02[a]	1.14E+02	1.374E-01	1.3E-04[b]	1.0E+00
L-826	5.0E+02[a]	1.671E+02	1.374E-01	1.3E-04[b]	1.5E+00
L-781 (200-West Feed Pump Building)	5.0E+02[a]	3.06E+01	1.374E-01	1.3E-04[b]	2.7E-01

Table A-17. Naphthalene Emission Estimate. (2 Pages)

Stationary Engine	Operating Time (hrs/year)	Fuel Consumption Rate (gal/hr)	Diesel Fuel Energy (MMBTU/gal)	Emission Rate (lbs/MMBTU)	Emission Estimate (lbs/year)
L-781 (181-D Pump House)	5.0E+02[a]	1.671E+02	1.374E-01	1.3E-04[b]	1.5E+00
Total Naphthalene Emission Estimate (lbs/year)					5.5E+00

[a] 500 operating hours per year assumed based on EPA (1995)
[b] Emission rate obtained from AP-42, *Compilation of Air Pollutant Emissions Factors,* Fifth Edition, Volume 1, Chapter 3, Table 3.4-4

Table A-18. Benz(a)anthracene Emission Estimate.

Stationary Engine	Operating Time (hrs/year)	Fuel Consumption Rate (gal/hr)	Diesel Fuel Energy (MMBTU/gal)	Emission Rate (lbs/MMBTU)	Emission Estimate (lbs/year)
	A	B	C	D	E=A*B*C*D
L-897	5.0E+02[a]	5.36E+01	1.374E-01	6.22E-07[b]	2.3E-03
L-895	5.0E+02[a]	8.74E+01	1.374E-01	6.22E-07[b]	3.7E-03
L-849	5.0E+02[a]	1.14E+02	1.374E-01	6.22E-07[b]	4.9E-03
L-826	5.0E+02[a]	1.671E+02	1.374E-01	6.22E-07[b]	7.1E-03
L-781 (200-West Feed Pump Building)	5.0E+02[a]	3.06E+01	1.374E-01	6.22E-07[b]	1.3E-03
L-781 (181-D Pump House)	5.0E+02[a]	1.671E+02	1.374E-01	6.22E-07[b]	7.1E-03
Total Benz(a)anthracene Emission Estimate (lbs/year)					2.6E-02

[a] 500 operating hours per year assumed based on EPA (1995)
[b] Emission rate obtained from "AP-42, *Compilation of Air Pollutant Emissions Factors,"* Fifth Edition, Volume 1, Chapter 3, Table 3.4-4

Table A-19. Chrysene Emission Estimate.

Stationary Engine	Operating Time (hrs/year)	Fuel Consumption Rate (gal/hr)	Diesel Fuel Energy (MMBTU/gal)	Emission Rate (lbs/MMBTU)	Emission Estimate (lbs/year)
	A	B	C	D	E=A*B*C*D
L-897	5.0E+02[a]	5.36E+01	1.374E-01	1.53E-06[b]	5.6E-03
L-895	5.0E+02[a]	8.74E+01	1.374E-01	1.53E-06[b]	9.2E-03
L-849	5.0E+02[a]	1.14E+02	1.374E-01	1.53E-06[b]	1.2E-02
L-826	5.0E+02[a]	1.671E+02	1.374E-01	1.53E-06[b]	1.8E-02
L-781 (200-West Feed Pump Building)	5.0E+02[a]	3.06E+01	1.374E-01	1.53E-06[b]	3.2E-03
L-781 (181-D Pump House)	5.0E+02[a]	1.671E+02	1.374E-01	1.53E-06[b]	1.8E-02
Total Chrysene Emission Estimate (lbs/year)					6.6E-02

[a] 500 operating hours per year assumed based on EPA (1995)
[b] Emission rate obtained from AP-42, *Compilation of Air Pollutant Emissions Factors,* Fifth Edition, Volume 1, Chapter 3, Table 3.4-4

Table A-20. Benzo(b)fluoranthene Emission Estimate.

Stationary Engine	Operating Time (hrs/year)	Fuel Consumption Rate (gal/hr)	Diesel Fuel Energy (MMBTU/gal)	Emission Rate (lbs/MMBTU)	Emission Estimate (lbs/year)
	A	B	C	D	E=A*B*C*D
L-897	5.0E+02[a]	5.36E+01	1.374E-01	1.11E-06[b]	4.1E-03
L-895	5.0E+02[a]	8.74E+01	1.374E-01	1.11E-06[b]	6.7E-03
L-849	5.0E+02[a]	1.14E+02	1.374E-01	1.11E-06[b]	8.7E-03
L-826	5.0E+02[a]	1.671E+02	1.374E-01	1.11E-06[b]	1.3E-02
L-781 (200-West Feed Pump Building)	5.0E+02[a]	3.06E+01	1.374E-01	1.11E-06[b]	2.3E-03
L-781 (181-D Pump House)	5.0E+02[a]	1.671E+02	1.374E-01	1.11E-06[b]	1.3E-02
Total Benzo(b)fluoranthene Emission Estimate (lbs/year)					4.8E-02

[a] 500 operating hours per year assumed based on EPA (1995)
[b] Emission rate obtained from AP-42, *Compilation of Air Pollutant Emissions Factors,* Fifth Edition, Volume 1, Chapter 3, Table 3.4-4

Table A-21. Benzo(k)fluoranthene Emission Estimate.

Stationary Engine	Operating Time (hrs/year)	Fuel Consumption Rate (gal/hr)	Diesel Fuel Energy (MMBTU/gal)	Emission Rate (lbs/MMBTU)	Emission Estimate (lbs/year)
	A	B	C	D	E=A*B*C*D
L-897	5.0E+02[a]	5.36E+01	1.374E-01	2.18E-07[b]	8.0E-04
L-895	5.0E+02[a]	8.74E+01	1.374E-01	2.18E-07[b]	1.3E-03
L-849	5.0E+02[a]	1.14E+02	1.374E-01	2.18E-07[b]	1.7E-03
L-826	5.0E+02[a]	1.671E+02	1.374E-01	2.18E-07[b]	2.5E-03
L-781 (200-West Feed Pump Building)	5.0E+02[a]	3.06E+01	1.374E-01	2.18E-07[b]	4.6E-04
L-781 (181-D Pump House)	5.0E+02[a]	1.671E+02	1.374E-01	2.18E-07[b]	2.5E-03
Total Benzo(k)fluoranthene Emission Estimate (lbs/year)					9.3E-03

[a] 500 operating hours per year assumed based on EPA (1995)
[b] Emission rate obtained from AP-42, *Compilation of Air Pollutant Emissions Factors,* Fifth Edition, Volume 1, Chapter 3, Table 3.4-4

Table A-22. Benzo(a)pyrene Emission Estimate.

Stationary Engine	Operating Time (hrs/year)	Fuel Consumption Rate (gal/hr)	Diesel Fuel Energy (MMBTU/gal)	Emission Rate (lbs/MMBTU)	Emission Estimate (lbs/year)
	A	B	C	D	E=A*B*C*D
L-897	5.0E+02[a]	5.36E+01	1.374E-01	2.57E-07[b]	9.5E-04
L-895	5.0E+02[a]	8.74E+01	1.374E-01	2.57E-07[b]	1.5E-03
L-849	5.0E+02[a]	1.14E+02	1.374E-01	2.57E-07[b]	2.0E-03
L-826	5.0E+02[a]	1.671E+02	1.374E-01	2.57E-07[b]	3.0E-03
L-781 (200-West Feed Pump Building)	5.0E+02[a]	3.06E+01	1.374E-01	2.57E-07[b]	5.4E-04
L-781 (181-D Pump House)	5.0E+02[a]	1.671E+02	1.374E-01	2.57E-07[b]	3.0E-03
Total Benzo(a)pyrene Emission Estimate (lbs/year)					1.1E-02

[a] 500 operating hours per year assumed based on EPA (1995)
[b] Emission rate obtained from AP-42, *Compilation of Air Pollutant Emissions Factors,* Fifth Edition, Volume 1, Chapter 3, Table 3.4-4

Table A-23. Indeno(1,2,3-cd)pyrene Emission Estimate.

Stationary Engine	Operating Time (hrs/year)	Fuel Consumption Rate (gal/hr)	Diesel Fuel Energy (MMBTU/gal)	Emission Rate (lbs/MMBTU)	Emission Estimate (lbs/year)
	A	B	C	D	E=A*B*C*D
L-897	5.0E+02[a]	5.36E+01	1.374E-01	4.14E-07[b]	1.5E-03
L-895	5.0E+02[a]	8.74E+01	1.374E-01	4.14E-07[b]	2.5E-03
L-849	5.0E+02[a]	1.14E+02	1.374E-01	4.14E-07[b]	3.2E-03
L-826	5.0E+02[a]	1.671E+02	1.374E-01	4.14E-07[b]	4.8E-03
L-781 (200-West Feed Pump Building)	5.0E+02[a]	3.06E+01	1.374E-01	4.14E-07[b]	8.7E-04
L-781 (181-D Pump House)	5.0E+02[a]	1.671E+02	1.374E-01	4.14E-07[b]	4.8E-03
Total Indeno(1,2,3-cd)pyrene Emission Estimate (lbs/year)					1.8E-02

[a] 500 operating hours per year assumed based on EPA (1995)
[b] Emission rate obtained from AP-42, *Compilation of Air Pollutant Emissions Factors,* Fifth Edition, Volume 1, Chapter 3, Table 3.4-4

Table A-24. Dibenz(a,h)anthracene Emission Estimate.

Stationary Engine	Operating Time (hrs/year)	Fuel Consumption Rate (gal/hr)	Diesel Fuel Energy (MMBTU/gal)	Emission Rate (lbs/MMBTU)	Emission Estimate (lbs/year)
	A	B	C	D	E=A*B*C*D
L-897	5.0E+02[a]	5.36E+01	1.374E-01	3.46E-07[b]	1.3E-03
L-895	5.0E+02[a]	8.74E+01	1.374E-01	3.46E-07[b]	2.1E-03
L-849	5.0E+02[a]	1.14E+02	1.374E-01	3.46E-07[b]	2.7E-03
L-826	5.0E+02[a]	1.671E+02	1.374E-01	3.46E-07[b]	4.0E-03
L-781 (200-West Feed Pump Building)	5.0E+02[a]	3.06E+01	1.374E-01	3.46E-07[b]	7.3E-04
L-781 (181-D Pump House)	5.0E+02[a]	1.671E+02	1.374E-01	3.46E-07[b]	4.0E-03
Total Dibenz(a,h)anthracene Emission Estimate (lbs/year)					1.5E-02

[a] 500 operating hours per year assumed based on EPA (1995)
[b] Emission rate obtained from AP-42, *Compilation of Air Pollutant Emissions Factors,* Fifth Edition, Volume 1, Chapter 3, Table 3.4-4

Table A-25. L-897 Sludge Lagoon Constituent Moles.

Constituent	Liquid Concentration (µg/L)	Molecular Weight (g/mol)	Molar Concentration (mol/L)	Tank Volume (L)	Moles (mol)
	A	B	C=A/B/1.0E+06	D	E=C*D
Chloroform	4.42E+00[a]	1.1938E+02[b]	3.7E-08	2.88E+08[c]	1.07E+01
Bromodichloromethane	7.8E-01[a]	1.6383E+02[b]	4.76E+09	2.88E+08[c]	1.37E+00
Water	-	-	5.55E+01[b]	2.88E+08[c]	1.6E+10
Total Moles (mol)					1.6E+10

[a] From "*BAT/AKART Analysis for Project L-897*", HNF-64154, Table 9, Combined Wastewater Stream at 5.0 million gallons per day throughput; Concentrations shown are based on current operating experience that shows that chloroform accounts for 85% of the total trihalomethanes and bromodichloromethane accounts for the remaining 15%
[b] https://webbook.nist.gov/chemistry/
[c] From "*BAT/AKART Analysis for Project L-897*", HNF-64154, Table 9, Combined Wastewater Stream at 5.0 million gallons per day throughput; 6,336,300 gal/month*3.79 L/gal*12 months/year=288,174,924 L/year

Table A-26. L-897 Sludge Lagoon Henry's Law Calculations.

Constituent	Liquid Mole Fraction		Henry's Law Constant at 25 °C (atm)	Vapor Mole Fraction	Ideal Gas Law (n/v)
	A=Constituent Moles/Total Moles[a]		B	C=A*B	D
Chloroform	6.67E-10		203.0	1.35E-07	4.09E-02
Bromodichloromethane	8.58E-11		88.90	7.63E-09	4.09E-02

[a] Constituent Moles and Total Moles from Table A-25
[b] https://webbook.nist.gov/chemistry/
[c] Molecular Weight from Table A-25, Ideal Gas Law [(n/v) = P/RT] (mol/L) = 1 atm /(0.082057 L atm /K mol * 298 K)

Table A-27. L-897 Sludge Lagoon Fick's Law Calculations.

Constituent	Mass Air Concentration (g/L)	Mass Air Concentration (lb/ft^3)[c]	Diffusion Coefficient (cm^2/sec)	Diffusion Coefficient (ft^2/sec)[4]	Concentration Gradient dC/dx (lb/ft^4)[d]	Diffusion Rate (lbs/ft^2 sec)
	A=Vapor Mole Fraction[a]*Ideal Gas Law[a]*Molecular Weight[b]	B=A*2.832E+01*2.205E+00 / 1.0E+03	C	D=C*1.08E-03	E = (B - 0) / (0 - 1)	F= -1*D*E
Chloroform	6.61E-07	4.13E-08	1.04E-01	1.12E-04	-4.13E-08	4.62E-12
Bromodichloromethane	5.11E-08	3.19E-09	2.98E-02	3.21E-05	-3.19E-09	1.02E-13

[a] Vapor Mole Fraction and Ideal Gas Law from Table A-26

[b] Molecular Weight from Table A-25

[c] Mass Air Concentration (lb/ft3) = Mass Air Concentration (g/L) *28.32 (L/ft3)* (2.205 lb/1000 g) Diffusion Coefficient (ft^2/sec) = Diffusion Coefficient (cm^2/sec) * 0.00107639 ft^2/cm^2

[d] Concentration Gradient dC/dx (lb/ft) = (Surface Diffusion Coefficient (ft^2/sec) - Free Air Diffusion Coefficient (ft^2/sec)/(Surface Height (ft) - Free Air Height (ft))

Table A-28. L-897 Sludge Lagoon Emission Estimate.

Constituent	Seconds/Year	Basin Surface Area (ft^2)[a]	Emission Estimate (lbs/yr)
	A	B = 3.535E+03*3.0E+00[b]	S=Diffusion Rate[c]*A*B
Chloroform	3.1536E+07	1.0605E+04	1.55E+00
Bromodichloromethane	3.1536E+07	1.0605E+04	3.42E-02

[a] Calculation Number: HNF-CALC-63402,
[b] Each basin has a surface area of 3,535 ft^2, there are three basins total
[c] Diffusion Rate from Table A-27

Table A-29. L-849 and L-850 Water Tanks Constituent Moles.

Constituent	Liquid Concentration (µg/L)	Molecular Weight (g/mol)	Molar Concentration (mol/L)	Tank Volume (L)	Moles (mol)
	A	B	C=A/B/1.0E+06	D	E=C*D
Chloroform	8.56E+01[a]	1.1938E+02[c]	7.17E-07	1.89E+07	1.36E+01
Bromodichloromethane	3.5E+00[a]	1.6383E+02[c]	2.14E-08	1.89E+07	4.04E-01
Bromoform	6.0E-02[b]	2.5275E+02[c]	2.37E-10	1.89E+07	4.49E-03
Water	-	-	5.55E+01[‡]	1.89E+07	1.05E+07
Total Moles (mol)					1.05E+07

[a] Highest concentration from quarterly Disinfection By-Product Compounds Reports from February 2017 – May 2020
[b] Method detection limit used as results were non-detectable for all quarterly Disinfection By-Product Compounds Reports from February 2017 through May 2020
[c] https://webbook.nist.gov/chemistry/; Assumes 5.0 million gallons per day output from L-897 CPWTF passes through each tank

Table A-30. L-849 and L-850 Water Tanks Henry's Law Calculations.

Constituent	Liquid Mole Fraction	Henry's Law Constant at 25 °C (atm)	Vapor Mole Fraction	Ideal Gas Law (n/v)
	A=Constituent Moles/Total Moles[a]	B	C=A*B	D
Chloroform	1.29E-08	2.03E+02	2.62E-06	4.09E-02
Bromodichloromethane	3.85E-10	8.89E+01	3.42E-08	4.09E-02
Bromoform	4.28E-12	2.97E+00	1.27E-10	4.09E-02

[a] Constituent Moles and Total Moles from Table A-29
[b] https://webbook.nist.gov/chemistry/
[c] Molecular Weight from Table A-29 Ideal Gas Law [(n/v) = P/RT] (mol/L) = 1 atm /(0.082057 L atm /K mol * 298 K)

Table A-31. L-849 and L-850 Water Tanks Fick's Law Calculations.

Constituent	Mass Air Concentration (g/L)	Mass Air Concentration (lb/ft^3)[c]	Diffusion Coefficient (cm^2/sec)	Diffusion Coefficient (ft^2/sec)[4]	Concentration Gradient dC/dx (lb/ft)[d]	Diffusion Rate (lbs/ft^2 sec)
	A=Vapor Mole Fraction[a]*Ideal Gas Law[a]*Molecular Weight[b]	B=A*28.32*2.205 / 1000	C	D=C*0.00108	E = (B - 0) / (0 - 1)	F= -1*D*E
Chloroform	1.28E-05	7.99E-07	1.04E-01	1.12E-04	-7.99E-07	8.95E-11
Bromodichloromethane	2.29E-07	1.43E-08	2.98E-02	3.21E-05	-1.43E-08	4.59E-13
Bromoform	1.31E-09	8.20E-11	1.49E-02	1.6E-05	-8.20E-11	1.31E-15

[a] Vapor Mole Fraction and Ideal Gas Law from Table A-30

[b] Molecular Weight from Table A-29

[c] Mass Air Concentration (lb/ft3) = Mass Air Concentration (g/L) *28.32 (L/ft3)* (2.205 lb/1,000 g) Diffusion Coefficient (ft^2/sec) = Diffusion Coefficient (cm^2/sec) * 0.00107639 ft^2/cm^2

[d] Concentration Gradient dC/dx (lb/ft) = (Surface Diffusion Coefficient (ft^2/sec) - Free Air Diffusion Coefficient (ft^2/sec))/(Surface Height (ft) - Free Air Height (ft))

Table A-32. L-849 and L-850 Water Tanks Emission Estimate.

Constituent	Seconds/Year	Tank Cross Section Area (ft^2)	Emission Estimate (lbs/yr)
	A	B = 3.14159E+00*4.0E+01[2a]	S=Diffusion Rate[b]*A*B
Chloroform	3.1536E+07	5.027E+03	2.84E+01[c]
Bromodichloromethane	3.1536E+07	5.027E+03	1.46E-01[c]
Bromoform	3.1536E+07	5.027E+03	4.17E-04[cc]

[a] Procurement Specification for L-850 Sanitary Water Storage Tank; HNF-SPEC-63005, Rev. 0
[b] Diffusion Rate from Table A-31
[c] Emission Estimate is for both water tanks

Table A-33. Chloroform Emission Estimate.

Emission Unit	Emission Estimate (lbs/yr)
L-849 Water Tank	1.42E+01 [a]
L-850 Water Tank	1.42E+01[a]
L-897 Sludge Lagoons	1.55E+00[b]
Total Chloroform Emission Estimate (lbs/yr)	2.99E+01

[a] Emission Estimate from Table A-32
[b] Emission Estimate from Table A-28

Table A-34. Bromodichloromethane Emission Estimate.

Emission Unit	Emission Estimate (lbs/yr)
L-849 Water Tank	7.28E-02[a]
L-850 Water Tank	7.28E-02[a]
L-897 Sludge Lagoons	3.42E-02 [b]
Total Bromodichloromethane Emission Estimate (lbs/yr)	1.80E-01

[a] Emission Estimate from Table A-32
[b] Emission Estimate from Table A-28

Table A-35. Bromoform Emission Estimate.

Emission Unit	Emission Estimate (lbs/yr)
L-849 Water Tank	2.08E-04[a]
L-850 Water Tank	2.08E-04[a]
Total Bromoform Emission Estimate (lbs/yr)	4.17E-04

[a] Emission Estimate from Table A-32

APPENDIX B

BACT AND tBACT ANALYSIS

This page intentionally left blank.

Appendix B

B.1 BACT AND tBACT Analysis

B.1 BACT Review Process

BACT, as it applies to regulated pollutants not subject to major new source review, is defined in WAC 173-400-030 as:

"…an emission limitation based on the maximum degree of reduction for each air pollutant subject to regulation under chapter 70.94 RCW emitted from or which results from any new or modified stationary source, which the permitting authority, 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 and available methods, systems, and techniques, including fuel cleaning, clean fuels, or treatment or innovative fuel combustion techniques for control of each such pollutant."

This definition is almost identical to the one applied to sources located in attainment areas and subject to major new source review, which appears in 40 CFR Part 52.21 (i.e., federal PSD regulations).

In a December 1, 1987, memorandum from the U.S. Environmental Protection Agency (EPA) Assistant Administrator for Air and Radiation,[1] the agency provided guidance on the "top-down" methodology for determining BACT. The "top-down" process involves the identification of all applicable control technologies according to control effectiveness. Evaluation begins with the "top," or most stringent, control alternative. If the most stringent option is shown to be technically or economically infeasible, or if environmental impacts are severe enough to preclude its use, then it is eliminated from consideration and then the next most stringent control technology is similarly evaluated. This process continues until the BACT level under consideration cannot be eliminated by technical or economic considerations, energy impacts, or environmental impacts. The top control alternative that is not eliminated in this process becomes the proposed BACT basis.

This top-down BACT analysis process can be considered to contain five basic steps:

- Step 1: Identify all available emission reduction alternatives with practical potential for application to the specific emission unit for the regulated pollutant under evaluation
- Step 2: Eliminate all technically infeasible alternatives
- Step 3: Rank remaining alternatives by effectiveness
- Step 4: Evaluate the economic, energy, and environmental impacts starting with the most effective alternative
- Step 5: Select BACT, which will be the most effective practical alternative not rejected in the previous steps.

[1] https://www.epa.gov/sites/production/files/2015-07/documents/establsh.pdf

Formal use of these steps is not always necessary. However, EPA and Ecology have consistently interpreted the statutory and regulatory BACT definitions as containing two core requirements, which EPA believes must be met by any BACT determination, regardless of whether it is conducted in a "top-down" manner. First, the BACT analysis must include consideration of the most stringent available technologies: i.e., those that provide the "maximum degree of emissions reduction." Second, any decision to require a lesser degree of emissions reduction must be justified by an objective analysis of "energy, environmental, and economic impacts" contained in the record of the permit decisions.

Additionally, the minimum control efficiency to be considered in a BACT analysis must result in an emission rate no less stringent than the applicable New Source Performance Standard (NSPS) emission rate, if any NSPS standard for that pollutant is applicable to the source.

This BACT analysis was conducted in a manner consistent with this stepwise approach. Control options for potential reductions in criteria pollution emissions were identified for each emission unit. These options were identified by researching the EPA database known as the RACT/BACT/LAER Clearinghouse (RBLC), drawing upon previous environmental permitting experience for similar units, a review of available regulatory agency BACT guidelines, and surveying available literature. Available controls that are judged to be technically feasible are further evaluated based on an analysis of economic, environmental, and energy impacts.

Assessing the technical feasibility of emission control alternatives is discussed in EPA's draft "New Source Review Workshop Manual."[2] Using terminology from this manual, if a control technology has been "demonstrated" successfully for the type of emission unit under review, then it would normally be considered technically feasible. For an undemonstrated technology, "availability" and "applicability" determine technical feasibility. An available technology is one that is commercially available; meaning that it has advanced through the following steps:

- Concept stage
- Research and patenting
- Bench-scale or laboratory testing
- Pilot-scale testing
- Licensing and commercial demonstration
- Commercial sales.

Suitability for consideration as a BACT measure involves not only commercial availability (as evidenced by past or expected near-term deployment on the same or similar type of emission unit), but also involves consideration of the physical and chemical characteristics of the gas stream to be controlled. A control method applicable to one emission unit may not be applicable to a similar unit, depending on differences in the gas streams' physical and chemical characteristics.

[2] https://www.epa.gov/sites/production/files/2015-07/documents/1990wman.pdf

B.2 BACT/tBACT Evaluation for Engines Powering Emergency Generator Sets

This NOC application proposes the installation of 6 generator sets that will provide power to water pumps when power is not available from the electrical grid. The power ratings of each generator set and the approximate maximum power output of the engines that will drive them are as follows:

- L-781: 400 kW Generator Set (617 bhp)
- 2,250 kW Generator Set (3,352 bhp)
- L-897: 750 kW Generator Set (1,112 bhp)
- L-895: 1,250 kW Generator Set (1,829 bhp)
- L-849: 1,250 kW Generator Set (1,881 bhp)
- L-826: 2,250 kW Generator Set (3,352 bhp).

Each generator set will be powered by a diesel-fueled, compression-ignition, ICE.

DOE will operate these engines as Subpart IIII "emergency" engines (Standards of Performance for Stationary Compression Ignition Internal Combustion Engines). To be considered emergency engines per Subpart IIII, the engines must operate in accordance with the following requirement as specified at 40 CFR 60.4211(f):

- There is no time limit on the use of emergency stationary ICE in emergency situations.

- Maintenance checks and readiness testing is limited to 100 hours per year unless the permittee has approval or records indicating that Federal, State, or local standards require maintenance and testing beyond 100 hours per year.

There are several other provisions that allow for additional use of the emergency engines but DOE proposes to use these ICE only for maintenance, readiness testing, and during power outages and emergencies. Planned operation for routine testing, maintenance, and inspection purposes of the engines powering the emergency generators is not expected to ever exceed to 55 hours per year, and all annual emission calculations associated with this analysis use that number of annual operating hours as a basis. For completeness, analogous cost-effectiveness calculation summary tables based on the regulatory limit (i.e., 100 hours per year of non-emergency operation) instead of the expected maximum (55 hours per year) are provided in Attachment B2-1 for comparison.

Additionally, the engines must use diesel fuel that meets the following requirements:

1. Sulfur content – 15 ppm maximum
2. Cetane index or aromatic content, as follows:
   i. A minimum Cetane index of 40
   ii. A maximum aromatic content of 35% by volume.

Recent BACT determinations made for emergency engines are summarized in Table B-1.

Table B-1. Recent BACT Determinations for Diesel Emergency Engines.				
Facility Name	**Location**	**Emergency IC Engine Size (HP)**	**BACT Limit**	**Permit & Date**
Sabey Intergate - Quincy Data Center	Quincy, WA	455, 480, 3,280, 3,352, 3,621, 3,633 & 3,640	NSPS Subpart IIII (Tier 2; Tier 3 for 455 and 480 hp engines)	Ecology Approval Order No. 20AQ-E022, Issued 9/16/2020
Cyrus One - Quincy Data Center	Quincy, WA	1,193 & 3,353	NSPS Subpart IIII (Tier 2)	Ecology Approval Order No. 19AQ-E052, Issued 10/23/2019
Fairwood Pump Station	Spokane, WA	762	NSPS Subpart IIII (Tier 2)	SRCAA NOC 1830, issued 6/19/2020
Washington Army National Guard	Tumwater, WA	1,112	NSPS Subpart IIII (Tier 2)	ORCAA 20NOC1425, issued 6/2/2020
Nucor Steel Brandenburg	Meade, KY	700 & 2,922	NSPS Subpart IIII (Tier 2)	7/23/2020
Shady Hills Energy Center	Pasco, FL	2,011	NSPS Subpart IIII (Tier 2)	7/27/2018
St. James Methanol Plant	St. James, LA	1,474	NSPS Subpart IIII (Tier 2)	6/30/2017
LBWL - Erickson Station	Eaton, MI	1,500	NSPS Subpart IIII (Tier 2)	12/21/2018
Thomas Township Energy	Saginaw, MI	1,474	NSPS Subpart IIII (Tier 2)	8/21/2019
Knauf Insulation - Inwood	Berkeley, WV	900	NSPS Subpart IIII (Tier 2)	9/15/2017
BASF - Peony Chemical Manufacturing	Brazoria, TX	1,500	NSPS Subpart IIII (Tier 2)	4/1/2015
CPV Fairview Energy Center	Cambria, PA	1,118	NSPS Subpart IIII (Tier 2)	9/2/2016

B.2.1 NO_X BACT

B.2.1.1 Identification and Technical Feasibility of Available Control Alternatives

There are a limited number of technically feasible NO_X control technologies that are commercially available for internal combustion engines. Two general types of emission reduction options have emerged as technically feasible: combustion process modifications, and post-combustion controls.

Combustion Process Modifications

This option is incorporated in the engine design. Typical design features include electronic fuel/air ratio and timing controllers, pre-chamber ignition, intercoolers, and lean-burn fuel mix. Currently available new engines that must meet Subpart IIII emission standards for emergency engines include these features as standard equipment; accordingly, this measure is deemed the baseline case for purposes of this BACT analysis.

Selective Catalytic Reduction (SCR)
In this option, nitrogen oxides are reduced to gaseous nitrogen by reaction with ammonia in the presence of a supported precious metal catalyst. The SCR system includes a catalyst module in the engine exhaust stream. Just upstream of the catalyst, a reagent liquid (typically ammonia or urea solution) is injected directly into the exhaust stream.

Non-Selective Catalytic Reduction (NSCR)
Similar to automobile catalytic converters, this method employs noble metal catalysts to reduce nitrogen oxides to molecular nitrogen. It operates in regimes with less than 4%t oxygen in the exhaust, which corresponds to fuel-rich operation. The method is not feasible with lean-burn internal combustion engines such as those to be operated at the Facility.

B.2.1.2 Ranking of Available Control Alternatives
With claimed emission reductions of 90% or more when compared to Tier 2 or Tier 3 engines, SCR offers the greatest potential reductions. Combustion process modifications, the option offering the next greatest emission reduction level, would be implemented as standard equipment (i.e. no additional cost) in the selected engines, and is therefore considered the baseline alternative.

B.2.1.3 Consideration of Energy, Environmental, and Cost Factors
Because combustion process controls are a standard feature of the currently available new engines, the emissions reported by vendors for this package are taken as the base case in this BACT analysis. Addition of an SCR system was evaluated as the next-most-effective emission reduction alternative.

There are several distinguishing factors between the two technically feasible alternatives with regard to energy and environmental impacts. One drawback associated with SCR systems is the environmental risk of handling and using ammonia reagent solutions. Most SCR catalyst modules can operate well without excess reagent. However, this requires particular attention to the controlled injection of the reagent in response to changes in load, temperature, and other parameters. Further, it should be assumed that ammonia emissions will occur under some or all operating conditions. This represents an additional air pollutant that is not emitted when SCR is not used for these engines. Also, the handling and storage of substantial volumes of the required ammonia or urea reagent solutions can pose an additional safety risk to facility personnel, and the risk of environmental harm in the event of an accidental release.

The SCR catalyst requires periodic cleaning due to fouling of the surfaces due to the presence of trace contaminants, such as sulfur compounds, particulate, and organic species. This requirement generates a secondary waste stream of contaminated cleaning solutions that must be disposed of as hazardous waste.

When SCR or any add-on emission control technology is used, the presence of the catalyst module adds an increment of pressure drop to the exhaust train. To avoid a substantial drop-off in engine performance, the SCR modules must be designed to minimize the increase in back pressure. However, the energy requirements of auxiliary equipment and even minor backpressure increases reduce the net energy efficiency of the unit.

In contrast, the implementation of combustion process controls does not require an add-on system with increased energy use by auxiliary equipment, or the use of catalyst and reagent materials. There is some additional complexity in the engine controls for this option. Proper engine tuning and fuel/air ratio is

needed across the full load range to achieve reduced emissions while avoiding a reduction in engine efficiency. The automatic fuel/air ratio controller helps accomplish this objective.

SCR systems are part of a Tier 4 (Final) emission reduction alternative which includes additional components (i.e., oxidation catalyst and particulate filter) to reduce pollutants other than NO_X. Therefore, cost-effectiveness calculations were prepared for an SCR emission reduction alternative as well as for an entire Tier 4 (Final) emission reduction alternative capable of reducing multiple pollutants (see Section B.2.3).

A cost quote to install a Tier 4 (Final) emission control system on the 1,829 bhp engine used to power a representative 1,250 kW Caterpillar generator set was provided by the engine vendor (i.e., Western States Equipment Company). Although they provide Tier 4 (Final) emission control systems, and not standalone SCR systems, the vendor estimated that the SCR system comprises approximately 60% of the capital cost of the Tier 4 (Final) system.

The vendor cost quote was scaled using a six-tenths exponential scaling factor[3] and the ratio of the engines' maximum mechanical power output capacities to estimate the costs of the same Tier 4 (Final) compliance solution applied to each of the engines used to power the proposed generator sets.[4] Operating costs of the SCR system were estimated using equations from the Air Pollution Control Cost Manual, Section 4, Chapter 2 (SCR). Catalyst replacements are conservatively not included in the operating cost estimates. Table B-2 below provides a summary of the cost-effectiveness calculations for the SCR emission reduction alternative; details of the cost-effectiveness calculations are provided in Appendices C and D.

Table B-2. Summary of SCR Cost-Effectiveness Analysis.

Project ID	Generator Set Rated Power Output (kWe)	Engine Maximum Rated Power (bhp)	Total Annual NO_X Reduction[a] (tpy)	Total Annual Cost[b]	Cost Effectiveness[c,d] ($/ton)
L-781	400	617	0.08	$4,969	$59,797
L-897	750	1,112	0.35	$7,736	$21,794
L-895	1,250	1,829 (Cat)	0.62	$10,818	$17,485
L-849	1,250	1,881	0.38	$10,312	$27,001
L-781 & L-826	2,250	3,353	0.72	$15,089	$20,948

[a] Expected 90% NO_X emission reduction for SCR control option. Annual engine emissions assume 55 hours per year of actual operation for required testing and readiness checks.
[b] Total annual cost includes annualized SCR capital costs (25-year equipment life and 4% interest) and annual operating costs for SCR equipment.
[c] Cost effectiveness is the Total Annual Cost divided by the Total Annual NO_X Reduction.
[d] Supporting calculations are provided in Appendices C and D.

[3] From "Guidance for Estimating Capital and Annual Costs of Air Pollution Control Systems," prepared by PEDCo Environmental, Inc. for Ohio EPA and EPA Region V, March 1983, Section 3.2 ("Scaled Estimates"). Report is available online attached to Ohio EPA Office of Air Pollution Control, Engineering Section, Engineering Guide #46, https://epa.ohio.gov/portals/27/engineer/eguides/guide46.pdf
[4] Scaled Equipment Cost = Known Equipment Cost * (Scaled Cost Equipment Capacity / Known Cost Equipment Capacity)$^{0.6}$

As shown in Table B-2, the calculated cost effectiveness of the SCR alternative is greater than $17,000 per ton of pollutant reduce for all proposed engines. We believe that these represent prohibitively high costs for this BACT alternative, and it is therefore removed from consideration as BACT for NO_X.

B.2.1.4 Proposed BACT Limits and Control Options for NO_X

DOE proposes that BACT is combustion process control, achieved by the use of engines that meet applicable Subpart IIII Tier 2 or Tier 3 emission standards, as appropriate for the engine. Pursuant to 40 CFR 60.4205(b), 60.4202(b)(2), and 60.4211(c), the emergency generator engines must be certified to the applicable emission standards in Table 1 of 40 CFR 89.112.

B.2.2 CO, PM, and VOC BACT

B.2.2.1 Identification and Technical Feasibility of Available Control Alternatives

Commercially available controls for CO, PM, and VOC emissions from ICEs are:

Combustion Process Modifications

This option is implemented in the design of the internal combustion engine. Typical design features include an electronic fuel/air ratio control and ignition retard, turbocharging, intercoolers, and lean-burn fuel mix. Currently available engines include these features as standard equipment, so these measures are the base case for a BACT cost-effectiveness analysis.

Diesel Oxidation Catalysts (DOC)

This control technology employs a module containing an oxidation catalyst that is located in the exhaust path of the engine. In the catalyst module, the products of combustion diffuse through the surfaces of a ceramic honeycomb structure coated with noble metal catalyst particles. Oxidation reactions on the catalyst surface form carbon dioxide and water. Catalysts have the potential to reduce the soluble organic fraction of PM emissions by up to 25%, and to increase the fraction of NO created by the combustion process that is converted to NO_2.

Diesel Particualte Filter (DPF)

Passive and active DPFs control diesel engine particulate matter emissions using either passive or active methods to clean/regenerate the filters. Passive DPF uses a catalyst to clean the filters, while active DPF uses a continuous fuel burner to clean the filters. DPFs reduce PM emissions by up to 85%. DPF designs that incorporate DOC technology, either as part of the filter or upstream of the filter, are common.

B.2.2.2 Ranking of Available Control Alternatives

Combustion process modifications would be implemented as standard equipment (i.e. no additional cost) in the selected engines and is therefore considered the baseline alternative. The control options include DPF and DOC combined, DPF alone, DPF alone, and combustion process modifications. Table B-3 summarizes the effectivenesses of the emission reduction alternatives.

Table B-3. CO, PM, and VOC Emission Reduction Alternative Effectivenesses.

Control Option	Pollutant Reduction		
	CO	PM	VOC
DPF & DOC	80	88	70
DPF	80	90	70
DOC	80	25	70
Combustion Process Modifications	Baseline		

B.2.2.3 Consideration of Energy, Environmental, and Cost Factors

Combined DPF & DOC

Western States Equipment Company estimated that a combined DPF and DOC system would comprise 40% of the total Tier 4 (Final) system capital cost. The cost estimate to install a combined DPF and DOC system the 1,829 bhp engine used to power the 1,250 kW Caterpillar generator set was used to estimate capital costs for the other generator set engines using each engine's rated mechanical power output and the 0.6 power rule. Operating costs for the Tier 4 option were estimated using equations from the EPA's Air Pollution Control Cost Manual Section 1, Chapter 2 (Cost Estimation). Catalyst and filter media replacements were conservatively not included in the operating cost estimates. Table B-4 provides a summary of the cost-effectiveness calculations for the combined DPF and DOC emission reduction alternative; details of the cost-effectiveness calcuations are provided in Appendices C and D.

Table B-4. Combined DPF and DOC Cost-Effectiveness Calculation Summary.

Project ID	Generator Set Rated Power Output (kWe)	Engine Maximum Rated Power (bhp)	Total Annual Pollutant Reduction[a] (tpy)	Total Annual Cost[b]	Cost Effectiveness[c, d] ($/ton)
L-781	400	617	0.02	$4,207	$233,826
L-897	750	1,112	0.03	$5,990	$194,094
L-895	1,250	1,829 (Cat)	0.03	$8,075	$284,894
L-849	1,250	1,881	0.09	$8,212	$95,683
L-781 & L-826	2,250	3,353	0.26	$11,616	$44,923

[a] Combined reductions of CO, VOCs, and PM emissions resulting from DPF and DOC control option. Annual engine emissions assume 55 hours per year of actual operation for required testing and readiness checks.
[b] Total annual cost includes annualized DPF and DOC equipment capital costs (25-year equipment life and 4% interest) and annual operating costs for DPF and DOC control equipment.
[c] Cost effectiveness is the Total Annual Cost divided by the Total Annual Pollutant Reduction.
[d] Supporting calculations are provided in Appendices C and D.

Based on the cost-effectiveness analysis presented above, a combined DPF and DOC emission reduction alternative is not cost-effective for reducing emissions of CO, VOCs, and PM, and is therefore removed from consideration as BACT for these pollutants.

DPF Control Option

Western States Equipment Company estimated the DPF equipment cost was 32% of the Tier 4 (Final) cost. The cost estimate to install the Tier 4 equipment on the 1,829 bph engine used to power tehe

1,250 kW Caterpillar generator set was used to estimate DPF capital costs for the other generator set engines using each engine's rated mechanical power output and the 0.6 power rule. Operating costs for the DPF option were estimated using equations from the EPA's Air Pollution Control Cost Manual Section 1, Chapter 2 (Cost Estimation). Catalyst and filter media replacements were conservatively not included in the operating cost estimates. Table B-5 provides a summary of the cost-effectiveness calculations for the DPF control option; detailed cost-effectiveness calculations are provided in Appendices C and D.

Table B-5. DPF Cost-Effectiveness Calculation Summary.

Project ID	Generator Set Rated Power Output (kWe)	Engine Maximum Rated Power (bhp)	Total Annual Pollutant Reduction[a] (tpy)	Total Annual Cost[b]	Cost Effectiveness[c, d] ($/ton)
L-781	400	617	0.02	$3,366	$186,482
L-897	750	1,112	0.03	$4,792	$154,869
L-895	1,250	1,829 (Cat)	0.03	$6,460	$227,559
L-849	1,250	1,881	0.09	$6,569	$76,334
L-781 & L-826	2,250	3,353	0.26	$9,293	$35,871

[a] Combined reductions of CO, VOCs, and PM emissions resulting from DPF control option. Annual engine emissions assume 55 hours per year of actual operation for required testing and readiness checks.
[b] Total annual cost includes annualized DPF equipment capital costs (25-year equipment life and 4% interest) and annual operating costs for DPF control equipment.
[c] Cost effectiveness is the Total Annual Cost divided by the Total Annual Pollutant Reduction.
[d] Supporting calculations are provided in Appendices C and D.

Based on the cost-effectiveness analysis presented above, a DPF control option is not cost-effective for reducing emissions of CO, VOCs, and PM, and is therefore removed from consideration as BACT for all of these pollutants.

DOC Control Option

Western States Equipment Company estimated the DOC equipment cost was 8% of the Tier 4 (Final) cost. The cost estimate to install the Tier 4 equipment on the 1,829 bhp engine used to power the 1,250-kW Caterpillar generator set was used to estimate DOC capital costs for the other generator set engines using each engine's rated mechanical power ouput and the 0.6 power rule. Operating costs for the DOC option were estimated using equations from the EPA's Air Pollution Control Cost Manual Section 1, Chapter 2 (Cost Estimation). Catalyst replacements were conservatively not included in the operating cost estimates. Table B-6 provides a summary of the cost-effectiveness calculations for the DPF control option; detailed cost-effectiveness calculations are provided in Appendices C and D.

Table B-6. DOC Cost-Effectiveness Calculation Summary.

Project ID	Generator Set Rated Power Output (kWe)	Engine Maximum Rated Power (bhp)	Total Annual Pollutant Reduction[a] (tpy)	Total Annual Cost[b]	Cost Effectiveness[c, d] ($/ton)
L-781	400	617	0.02	$841	$51,827
L-897	750	1,112	0.03	$1,198	$42,313
L-895	1,250	1,829 (Cat)	0.03	$1,615	$59,933
L-849	1,250	1,881	0.08	$1,642	$20,969
L-781 & L-826	2,250	3,353	0.24	$2,323	$9,549

[a] Combined reductions of CO, VOCs, and PM emissions resulting from DOC control option. Annual engine emissions assume 55 hours per year of actual operation for required testing and readiness checks.
[b] Total annual cost includes annualized DOC equipment capital costs (25-year equipment life and 4% interest) and annual operating costs for DOC control equipment.
[c] Cost effectiveness is the Total Annual Cost divided by the Total Annual Pollutant Reduction.
[d] Supporting calculations are provided in Appendices C and D.

Based on the cost-effectiveness analysis presented above, a DOC control option is not cost-effective for reducing emissions of CO, VOCs, and PM, and is therefore removed from consideration as BACT for all of these pollutants.

B.2.2.4 Proposed BACT Limits and Controls for CO, PM, and VOCs

DOE proposes that BACT for the emergency generator engines is the combustion process controls supplied by the manufacturer as standard equipment that enable the emergency engines to meet the applicable NSPS Subpart IIII Tier 2 and Tier 3 emission standards.

B.2.3 NO_X, CO, PM, and VOC BACT

B.2.3.1 Identification and Technical Feasibility of Available Control Alternatives

Tier 4 (Final) emission reduction systems are a combination of the SCR, DPF, and DOC systems described in Section 2.1 and 2.2.

B.2.3.2 Ranking of Available Control Alternatives

A Tier 4 (Final) system is assumed to reduce NO_X by 90%, CO by 80%, PM by 88%, and VOCs by 70%. Combustion process modifications, the option offering the next greatest emission reduction level, would be implemented as standard equipment (i.e. no additional cost) in the selected engines, and is therefore considered the baseline alternative.

B.2.3.3 Consideration of Energy, Environmental, and Cost Factors

The cost quote provided by Western States Equipment Company to install a Tier 4 (Final) system on the 1,829 bhp engine used to power the proposed 1,250 kW Caterpillar generator set was used to estimate capital costs for the other generator set engines using each engine's rated mechanical power output and the 0.6 power rule. Operating costs for the Tier 4 (Final) system were estimated using equations from the EPA's Air Pollution Control Cost Manual Section 1, Chapter 2 (Cost Estimation) and Section 4, Chapter 2 (SCR). Catalyst and filter media replacements were conservatively not included in the

operating cost estimates. Table B-7 below summarizes the cost-effectiveness calculations for the Tier 4 (Final) system; detailed cost-effectiveness calculations are provided in Appendices C and D.

Table B-7. Tier 4 Cost-Effectiveness Calculation Summary.

Project ID	Generator Set Rated Power Output (kWe)	Engine Maximum Rated Power (bhp)	Total Annual Pollutant Reduction[a] (tpy)	Total Annual Cost[b]	Cost Effectiveness[c, d] ($/ton)
L-781	400	617	0.18	$8,660	$83,787
L-897	750	1,112	0.39	$12,721	$32,971
L-895	1,250	1,829 (Cat)	0.65	$17,538	$27,103
L-849	1,250	1,881	0.47	$17,146	$36,657
L-781 & L-826	2,250	3,353	0.98	$24,756	$25,289

[a] Combined reductions of NOX, CO, VOCs, and PM emissions resulting from Tier 4 control option. Annual engine emissions assume 55 hours per year of actual operation for required testing and readiness checks.
[b] Total annual cost includes annualized Tier 4 equipment capital costs (25-year equipment life and 4% interest) and annual operating costs for Tier 4 control equipment.
[c] Cost effectiveness is the Total Annual Cost divided by the Total Annual Pollutant Reduction.
[d] Supporting calculations are provided in Appendices C and D.

B.2.3.4 *Proposed BACT Limits and Control Options for NO_X, CO, PM, and VOCs*
DOE proposes that BACT is combustion process control, achieved by the use of engines that meet applicable Subpart IIII Tier 2 or Tier 3 emission standards, as appropriate for the engine. Pursuant to40 CFR 60.4205(b), 60.4202(b)(2), and 60.4211(c), the emergency generator engines must be certified to the applicable emission standards in Table 1 of 40 CFR 89.112.

B.2.4 SO_2 BACT

The emergency engines used to power the proposed generators will combust ULSD, which is considered a low-sulfur fuel. Given the low emission rates expected as a result of using ULSD, and the cost-effectiveness analysis completed above for a Tier 4 (Final) emission reduction alternative, there are no available technologies beyond good combustion controls that provide feasible or cost-effective emission reduction. Use of engines certified by manufacturers to meet NSPS Subpart IIII Tier 2 and Tier 3 emission standards, use of ULSD, and limitations on non-emergency operation will minimize emissions of SO_2, and DOE proposes these as BACT measures for these pollutants.

B.2.4 Toxic Air Pollutant BACT

The engines used to power the proposed emergency generator sets are expetected to emit 19 TAPs that exceed the applicable de minimis values provided in WAC 173-460-150; therefore, BACT for TAPs (tBACT) is required for each of these 19 TAPs. Three of the TAPs are also criteria pollutants (i.e., NO_2, CO, and SO_2), one TAP is equivalent to PM (i.e., diesel particulate matter), and the remaining 15 TAPs are VOCs. The BACT proposals for NO_2, CO, and SO_2 are presented in the preceding sections.

The alternatives reviewed for criteria pollutant emission reductions were also evaluated for potential application as tBACT for TAPs emitted as PM and VOC, including a Tier 4 (Final) system, a combined DPF

and DOC system, a DPF alone, and a DOC alone. Table B-8 presents the CO, PM, and VOC control efficiencies for each control option. The capital and operating costs associated with each control option remain the same as presented in Tables B2-3 through B2-7. Emission reductions were grouped into two groups (24-hour average and annual average TAPs[5]) to calculate the cost-effectiveness for each control option.

Table B-8 provides a summary of the TAP cost-effectiveness calculations for each engine and control option; detailed cost-effectiveness calculations are provided in Appendices C and D.

Based on the cost-effectiveness analyses presented here, no additional control options are cost-effective for reducing TAP emissions. The proposed BACT for toxics is meeting BACT for NO_X, CO, SO_2, PM, and VOC discussed above. DOE will purchase engines certified to applicable NSPS Subpart IIII Tier 2 and Tier 3 emission standards.

[5] Toxic Air Pollutant averaging times from WAC 173-460.

Table B-8. tBACT Cost-Effectiveness Calculation Summary.

Generator Set Rated Power Output (kWe)	Cost Effectiveness[a, b] ($/ton reduced)							
	Tier 4		DPF & DOC		DPF		DOC	
	24-hr TAPs[c]	Annual TAPs[d]	24-hr TAPs[c]	Annual TAPs[d]	24-hr TAPs[c]	Annual TAPs[d]	24-hr TAPs[c]	Annual TAPs[d]
400	$31,984,713	$1,877,477	$15,886,482	$1,658,360	$12,709,185	$1,298,140	$3,177,296	$1,079,432
750	$27,424,239	$3,434,860	$12,914,457	$1,617,523	$10,331,565	$1,266,356	$2,582,891	$1,037,219
1,250 (Cat)	$23,187,595	$8,022,415	$10,675,663	$3,693,553	$8,540,530	$2,896,084	$2,135,133	$2,046,866
1,250 (Generac)	$17,379,280	$1,590,103	$8,323,510	$761,553	$6,658,808	$596,079	$1,664,702	$500,359
2,250	$17,119,545	$1,136,032	$8,032,704	$533,041	$6,426,163	$417,147	$1,606,541	$356,761

[a] Cost effectiveness is the Total Annual Cost divided by the Total Annual Pollutant Reduction.

[b] Supporting calculations are provided in Appendices C and D.

[c] "24-hour TAPs" are those that are assigned a 24-hour averaging period in WAC 173-460-150: acrolein, propylene, toluene, and xylenes.

[d] "Annual TAPs" are those that are assigned an annual averaging period in WAC 173-460-150: acetaldehyde, benz(a)anthracene, benzene, benzo(b)fluoranthene, benzo(k)fluoranthene, benzo(a)pyrene, chrysene, dibenz(a,h)anthracene, diesel particulate matter, formaldehyde, indeno(1,2,3-cd)pyrene, and naphthalene.

Attachment B2-1 BACT/tBACT Cost-Effectiveness Calculation Summaries for 100 Operating Hours Per Year

Table B-2a. Summary of SCR Cost-Effectiveness Analysis – 100 Hours Per Year.

Project ID	Generator Set Rated Power Output (kWe)	Engine Maximum Rated Power (bhp)	Total Annual NO_X Reduction[a] (tpy)	Total Annual Cost[b]	Cost Effectiveness[c, d] ($/ton)
L-781	400	617	0.15	$5,159	$34,144
L-897	750	1,112	0.65	$8,546	$13,242
L-895	1,250	1,829 (Cat)	1.12	$12,231	$10,872
L-849	1,250	1,881	0.69	$11,184	$16,106
L-781 & L-826	2,250	3,353	1.31	$16,734	$12,777

[a] Expected 90% NO_X emission reduction for SCR control option. Annual engine emissions assume 100 hours per year of actual operation for required testing and readiness checks.
[b] Total annual cost includes annualized SCR capital costs (25-year equipment life and 4% interest) and annual operating costs for SCR equipment.
[c] Cost effectiveness is the Total Annual Cost divided by the Total Annual NO_X Reduction.
[d] Supporting calculations are provided in Appendices C and D.

Table B-4a. Combined DPF and DOC Cost-Effectiveness Calculation Summary – 100 Hours Per Year.

Project ID	Generator Set Rated Power Output (kWe)	Engine Maximum Rated Power (bhp)	Total Annual Pollutant Reduction[a] (tpy)	Total Annual Cost[b]	Cost Effectiveness[c, d] ($/ton)
L-781	400	617	0.03	$4,207	$128,604
L-897	750	1,112	0.06	$5,990	$106,752
L-895	1,250	1,829 (Cat)	0.05	$8,075	$156,692
L-849	1,250	1,881	0.16	$8,212	$52,625
L-781 & L-826	2,250	3,353	0.47	$11,616	$24,707

[a] Combined reductions of CO, VOCs, and PM emissions resulting from DPF and DOC control option. Annual engine emissions assume 100 hours per year of actual operation for required testing and readiness checks.
[b] Total annual cost includes annualized DPF and DOC equipment capital costs (25-year equipment life and 4% interest) and annual operating costs for DPF and DOC control equipment.
[c] Cost effectiveness is the Total Annual Cost divided by the Total Annual Pollutant Reduction.
[d] Supporting calculations are provided in Appendices C and D.

Table B-5a. DPF Cost-Effectiveness Calculation Summary – 100 Hours Per Year.

Project ID	Generator Set Rated Power Output (kWe)	Engine Maximum Rated Power (bhp)	Total Annual Pollutant Reduction[a] (tpy)	Total Annual Cost[b]	Cost Effectiveness[c, d] ($/ton)
L-781	400	617	0.03	$3,366	$102,565
L-897	750	1,112	0.06	$4,792	$85,178
L-895	1,250	1,829 (Cat)	0.05	$6,460	$125,158
L-849	1,250	1,881	0.16	$6,569	$41,984
L-781 & L-826	2,250	3,353	0.47	$9,293	$19,729

[a] Combined reductions of CO, VOCs, and PM emissions resulting from DPF control option. Annual engine emissions assume 100 hours per year of actual operation for required testing and readiness checks.
[b] Total annual cost includes annualized DPF equipment capital costs (25-year equipment life and 4% interest) and annual operating costs for DPF control equipment.
[c] Cost effectiveness is the Total Annual Cost divided by the Total Annual Pollutant Reduction.
[d] Supporting calculations are provided in Appendices C and D.

Table B-6a. DOC Cost-Effectiveness Calculation Summary – 100 Hours Per Year.

Project ID	Generator Set Rated Power Output (kWe)	Engine Maximum Rated Power (bhp)	Total Annual Pollutant Reduction[a] (tpy)	Total Annual Cost[b]	Cost Effectiveness[c, d] ($/ton)
L-781	400	617	0.03	$841	$28,505
L-897	750	1,112	0.05	$1,198	$23,272
L-895	1,250	1,829 (Cat)	0.05	$1,615	$32,963
L-849	1,250	1,881	0.14	$1,642	$11,533
L-781 & L-826	2,250	3,353	0.44	$2,323	$5,252

[a] Combined reductions of CO, VOCs, and PM emissions resulting from DOC control option. Annual engine emissions assume 100 hours per year of actual operation for required testing and readiness checks.
[b] Total annual cost includes annualized DOC equipment capital costs (25-year equipment life and 4% interest) and annual operating costs for DOC control equipment.
[c] Cost effectiveness is the Total Annual Cost divided by the Total Annual Pollutant Reduction.
[d] Supporting calculations are provided in Appendices C and D.

Table B-7a. Tier 4 Cost-Effectiveness Calculation Summary – 100 Hours Per Year.

Project ID	Generator Set Rated Power Output (kWe)	Engine Maximum Rated Power (bhp)	Total Annual Pollutant Reduction[a] (tpy)	Total Annual Cost[b]	Cost Effectiveness[c, d] ($/ton)
L-781	400	617	0.18	$8,660	$47,115
L-897	750	1,112	0.70	$13,531	$19,289
L-895	1,250	1,829 (Cat)	1.18	$18,950	$16,107
L-849	1,250	1,881	0.85	$18,017	$21,186
L-781 & L-826	2,250	3,353	1.78	$26,400	$14,833

[a] Combined reductions of NOX, CO, VOCs, and PM emissions resulting from Tier 4 control option. Annual engine emissions assume 100 hours per year of actual operation for required testing and readiness checks.

[b] Total annual cost includes annualized Tier 4 equipment capital costs (25-year equipment life and 4% interest) and annual operating costs for Tier 4 control equipment.

[c] Cost effectiveness is the Total Annual Cost divided by the Total Annual Pollutant Reduction.

[d] Supporting calculations are provided in Appendices C and D.

Table B-8a. tBACT Cost-Effectiveness Calculation Summary – 100 Hours Per Year.

Generator Set Rated Power Output (kWe)	Cost Effectiveness[a, b] ($/ton reduced)							
	Tier 4		DPF & DOC		DPF		DOC	
	24-hr TAPs[c]	Annual TAPs[d]	24-hr TAPs[c]	Annual TAPs[d]	24-hr TAPs[c]	Annual TAPs[d]	24-hr TAPs[c]	Annual TAPs[d]
400	$17,985,543	$1,877,477	$8,737,565	$912,098	$6,990,052	$713,977	$1,747,513	$593,688
750	$16,044,018	$2,009,498	$7,102,951	$889,638	$5,682,361	$696,496	$1,420,590	$570,470
1,250 (Cat)	$13,780,199	$4,767,656	$5,871,615	$2,031,454	$4,697,292	$1,592,846	$1,174,323	$1,125,776
1,250 (Generac)	$10,044,602	$919,023	$4,577,930	$418,854	$3,662,344	$327,844	$915,586	$275,197
2,250	$10,041,125	$666,317	$4,417,987	$293,172	$3,534,390	$229,431	$883,597	$196,218

[a] Cost effectiveness is the Total Annual Cost divided by the Total Annual Pollutant Reduction.
[b] Supporting calculations are provided in Appendices C and D.
[c] "24-hour TAPs" are those that are assigned a 24-hour averaging period in WAC 173-460-150: acrolein, propylene, toluene, and xylenes.
[d] "Annual TAPs" are those that are assigned an annual averaging period in WAC 173-460-150: acetaldehyde, benz(a)anthracene, benzene, benzo(b)fluoranthene, benzo(k)fluoranthene, benzo(a)pyrene, chrysene, dibenz(a,h)anthracene, diesel particulate matter, formaldehyde, indeno(1,2,3-cd)pyrene, and naphthalene.

B.3 BACT/tBACT Evaluation for the CPWTF and Water Storage Tanks

The Central Plateau Water Treatment Facility (CPWTF) will produce wastewater and the two water storage tanks will contain water that has been treated with chlorine to kill microorganisms. By-products of the chlorine treatment are expected to include halogenated organics, which are formed by reactions between residual chlorine and organic materials from decayed microorganisms in the form of humic acids, fulvic acids, amines, and urea. Three of these halogenated organics are classified as TAPs by Ecology: chloroform, a.k.a., trichloromethane (CAS No. 67-66-3), bromodichloromethane (75-27-4), and bromoform (75-25-2). Based on maximum potential emission rate calculations, chloroform is only TAP expected to have the potential to exceed the de minimis emission rate threshold provided in WAC 173-460-150. No criteria pollutant emissions are expected from the CPWTF or water storage tanks.

B.3.1 Chloroform BACT

B.3.1.1 Identification and Technical Feasibility of Available Control Alternatives

Because chloroform is a chlorinated VOC, strategies typically used to reduce VOC emissions were considered. As with most pollutants, there are two basic strategies to limit emissions: to reduce or eliminate the creation and/or release the pollutant, or to capture the pollutant after it has been created and/or released. Capture strategies are subdivided into those that preserve the pollutant and those that destroy it. These approaches are summarized as follows:

- Emission Prevention (i.e., to not create or release the pollutant)

- Capture in a manner that preserves the pollutant for potential reuse or subsequent destruction
  - Adsorbers
  - Refrigerated condensers
  - Wet scrubbers

- Capture and destroy the pollutant or convert it to less objectionable compounds
  - Flares
  - Incinerators
    - Thermal
    - Catalytic

The EPA's RACT/BACT/LAER[6] Clearinghouse (RBLC) was queried to identify permits issued to facilities that limited chloroform emissions from one or more processes; results, which does not include permitted projects that were never constructed, are summarized in Table B-9.

[6] RACT = Reasonably Available Control Technology, LAER = Lowest Achievable Emission Rate

Table B-9. Facilities Identified with Issued Permits for Limited Chloroform Emissions.

RBLC ID	Facility Name	County	State	Permit Issuance Date	Process	Control Method	Emission Limit	Emission Limit Unit	Basis
MI-0034	U.S. Aviex Co.	Cass	MI	10/14/1983	Contaminated Ground Water Clean-Up	None	0.09	mg/m^3	BACT-PSD
MN-0011	Boise Cascade (now PCA)	Koochiching	MN	5/12/1989	Bleach Plant	Dual scrubber, caustic & chilled H_2O	1.33	ton/month	Other Case-by-Case
NH-0010	James River Paper Co., Inc.	Coos	NH	5/18/1993	Pulp Bleaching	None	30.25	lb/hr	BACT-PSD
SC-0016	Union Camp Pulp & Paper Mill	Richland	SC	5/1/1989	Bleach Plant	Wet scrubber	25	lb/hr	BACT-PSD
WI-0151	Wausau Paper Mills	Marathon	WI	5/8/1998	Pulping Operations	None	46	lb/yr	BACT-PSD
					Bleach Plant	None	58	lb hypochlorite/ ton paper produced	BACT-PSD
					Wastewater Treatment Plant	Bleach plant hypochlorite usage restriction, eliminate wastewater plant chlorine usage	None	N/A	BACT-PSD

Emission Prevention

For several decades, strategies have been developed to minimize chloroform concentrations in drinking water provided by utilities. Other disinfection technologies that do not use chlorine are available (e.g., ozone, carbon dioxide, ultraviolet light), but chlorination remains the most common technology despite its drawbacks because it is the only technology that provides a disinfection residual that continues to preserve the water after distribution. Strategies to reduce the formation of chloroform as a result of using chlorination technology typically seek to minimize the organic content of the water using filtration or coagulation and settling.[7][8] These strategies are well-developed and ubiquitous where chlorination is utilized and are considered a baseline alternative for reducing chloroform emissions from tanks of treated water.

Adsorbers

Adsorption technology provides a non-destructive means of removing VOCs from low- to medium-concentration gas streams and are typically employed where stringent exhaust concentrations are required and/or recovery of the captured material is desired. Several different adsorber configurations are available including fixed beds, canisters, moving beds, and fluid beds, and the three most common types of adsorbent media are activated carbon, synthetic zeolites, and polymers. In all cases, gas molecules are selectively held to the adsorbent material by attractive forces which are weaker and less specific than those of chemical bonds. Most gases can be removed or "desorbed" from the absorbent media by increasing the temperature, decreasing the pressure, or introducing a stronger adsorbing material to displace the collected gas.[9] Carbon adsorption technology is commonly used to reduce VOC emissions from storage tanks and is considered technically feasible for reducing chloroform emissions from tanks of treated water.

Refrigerated Condensers

Condensers fall into two categories: refrigerated and non-refrigerated. Non-refrigerated condensers are widely used to recover raw material, product, and/or solvents in the chemical process industries upstream of a control device. Refrigerated condensers are used to remove VOCs from high-concentration emission streams such as those from gasoline bulk terminals, gasoline storage, etc. While chloroform would readily condense in a refrigerated condenser and is therefore potentially a technically feasible emission reduction alternative for chloroform emissions from tanks of treated water, there is no evidence that this technology has ever been employed in this way.[10] As a result, this alternative is eliminated from consideration as BACT for reducing chloroform emissions from tanks of treated water.

---

[7] "Interim Treatment Guide for the Control of Chloroform and Other Trihalomethanes," EPA Office of Research and Development, Municipal Environmental Research Laboratory, Water Supply Research Division, Cincinnati, OH, April 1976.

[8] "Treatement Techniques for Controlling Trihalomethanes in Drinking Water," EPA Office of Research and Development, Municipal Environmental Research Laboratory, Drinking Water Research Division, Cincinnati, OH, September 1981.

[9] "EPA Air Pollution Control Cost Manual," Section 3.1 – VOC Recapture Controls, Chapter 1 – Carbon Adsorbers, https://www.epa.gov/sites/production/files/2018-10/documents/final_carbonadsorberschapter_7thedition.pdf

[10] "EPA Air Pollution Control Cost Manual," Section 3.1 – VOC Recapture Controls, Chapter 2 – Refrigerated Condensers, https://www.epa.gov/sites/production/files/2017-12/documents/refrigeratedcondenserschapter_7thedition_final.pdf

Wet Scrubbers
A wet scrubber is an emissions control device that is used to remove particulate matter (PM), inorganic gases (e.g., SO_2), and VOCs. Gaseous pollutants are removed from gas streams by absorption, which is primarily a physical process, but can include a chemical component, in which a pollutant in the gas phase is contacted by a scrubbing liquid and dissolved into the liquid. A key component dictating the performance of a wet scrubber is the solubility of the pollutant of concern in the scrubbing liquid. Water is commonly used as the scrubbing liquid in a wet scrubber due to low cost, but other materials can be used depending on the pollutant(s) to be removed from the gas stream undergoing treatment. There are several types of wet scrubbers, including spray towers, tray-type, and packed-bed scrubbers.[11] Chloroform is only slightly soluble in water. Given the lack of evidence that this technology has ever been employed to reduce chloroform emissions from tanks of treated water, it is removed from consideration as BACT for that purpose.

Destruction Techniques
Flaring and incineration are combustion processes commonly used to dispose of VOCs in gas streams by converting them to unobjectionable compounds (e.g., carbon dioxide and water). Flares are commonly employed as safety equipment in situations where there is potential for a large quantity of combustible gas to require disposal in a short period of time (e.g., as a result of process upset, etc.). Incinerators are commonly used to dispose of VOCs in gas streams with relatively consistent concentrations. In many cases, the incineration can use the heating value of the gases to be reduced to provide the heat required for incineration. In cases where the concentrations of combustible materials in the gas stream is insufficient to support combustion, a fuel such as natural gas can be added to achieve combustion temperatures that ensure complete conversion of the VOCs to be reduced. Chloroform is not flammable, so cannot support combustion on its own, but can be mixed with a fuel and combusted. When combusted, it forms compounds that are pollutants in their own right (e.g., phosgene, dichloromethane, hydrogen chloride) which must be removed by an additional emission reduction system. Because chloroform is not flammable, produces other pollutants when combusted, and there is no evidence that chloroform emissions from tanks of treated water have ever been reduced using a flare or incineration technique, these destruction techniques are removed from consideration as BACT for that purpose.

B.3.1.2 Ranking of Available Control Alternatives
The only emission reduction alternative other than the baseline alternative of minimizing the concentration of chloroform in the water stored in the proposed tanks is the use of an adsorber.

B.3.1.3 Consideration of Energy, Environmental, and Cost Factors
Combined chloroform emissions from the two proposed water tanks is expected to be 28.4 lb/yr, which assumes the baseline control of minimizing the concentration of chloroform in the stored water. Given the extremely small emission rate, any level of energy usage, environmental consequence, and/or expenditure is unlikely to be justifiable, even if all chloroform is prevented from being emitted to the atmosphere. As a result, the energy, environmental, and cost implications of using adsorption technology to capture chloroform emissions from the proposed water storage tanks are deemed to be outside the envelope of what is considered reasonable.

[11] "Air Pollution Control Technology Fact Sheet: Spray-Chamber/Spray-Tower Wet Scrubber," EPA-452/F-03-016, https://nepis.epa.gov/Exe/ZyPDF.cgi?Dockey=P1008OGT.PDF

B.3.1.4 Proposed BACT

DOE proposes that BACT for the water tanks used to store treated water is the work practice of employing techniques that minimize the quantity of chloroform present in the CPWTF wastewater and the water storage tanks.

APPENDIX C

COST EFFECTIVENESS CALCUALTIONS FOR 55 OPERATING HOURS/YEAR

This page intentionally left blank.

Appendix C

Cost Effectiveness Calcualtions for 55 Operating Hours/Year

TABLE B2.2-1a
COST EFFECTIVENESS CALCULATIONS
Criteria Air Pollutants
Tier 4 (Final) Control System
Diesel-Fired 400 kW Emergency Generator
Operating Hours 55 hours/year

Cost Item			Factor	Cost
Direct Costs				
Purchased Equipment Costs				
	Primary Equipment[1]		A	104,201
	Sales Tax[2]		B = 0.065 * A	6,773
	Shipping		Included in A	-----
		Purchased Equipment Cost (PEC)	PEC = A + B	110,974
Direct Installation Costs				
	Foundations & Supports		Included in A	-----
	Handling & Erection		Included in A	-----
	Electrical		Included in A	-----
	Piping		Included in A	-----
	Insulation for Ductwork		Included in A	-----
	Painting		Included in A	-----
		Direct Installation Cost	Included in A	-----
Total Direct Costs (DC)				110,974
Indirect Costs				
Installation				
	Engineering		Included in A	-----
	Construction & Field Expenses		Included in A	-----
	Contractor Fees		Included in A	-----
	Start-Up		Included in A	-----
	Contingencies[3]		0.03 * PEC	3,329
Total Indirect Costs (IC)				3,329
TOTAL CAPITAL INVESTMENT = DC + IC				**114,304**
Direct Annual Costs				
Operating Labor				
	Operator		Negligible	-----
	Supervisor		Negligible	-----
		Total Operating Labor		-----
Maintenance				
	Labor		-----	-----
	Materials		-----	-----
		Total Maintenance[4]	0.005 * TCI	572
Utilities				
	Electricity		Negligible	-----
	Water		-----	-----
	Reagent[4]		-----	232
		Total Utilities		-----
Catalyst Cost				
	Catalyst Replacement		Catalyst life > SCR Service Life	-----
		Total Catalyst Cost	-----	-----
Miscellaneous				
	Performance Tests		-----	-----
	Record Keeping & Reporting		-----	-----
		Total Miscellaneous Costs		-----
Total Direct Annual Costs (DAC)				**803**
Indirect Annual Costs				
Overhead[5]			60% of operating, supervisor, maintenance labor & materials	343
Administrative Charges[6]			0.03 * (Op. Labor Cost + 0.4 * Ann. Maint. Cost))	7
Capital Recovery Factor[7]			CRF	0.0640
Capital Recovery			CRF * TCI	7,317
Total Indirect Annual Costs (IAC)				**7,667**
TOTAL ANNUAL COST = DAC + IAC				**8,470**
Uncontrolled NOx, CO, VOC, and PM emissions			tons/yr	0.11
NOx, CO, VOC, and PM Emissions with Tier 4 Controls			tons/yr	0.01
Percent reduction from uncontrolled				88%
Total emissions reduction			tons/yr	0.10
Cost per Ton Controlled			**$/ton**	**83,787**

[1] Capital cost provided by the engine vendor (Brant Briody of Western States Equipment Co.)
[2] Washington sales tax
[3] Minimum cost from most recent Sabey, Vantage, and Cyrus One cost-effectiveness analyses
[4] Estimated using equations from EPA's Air Pollution Control Cost Estimation Spreadsheet for Selective Catalytic Reduction (SCR) found at https://www.epa.gov/sites/production/files/2019-06/scrcostmanualspreadsheet_june-2019vf.xlsm
[5] EPA's Air Pollution Control Cost Manual, Section 1, Chapter 2 (Cost Estimation), Section 2.6.5.7
[6] EPA's Air Pollution Control Cost Manual, Section 4, Chapter 2 (SCR)
[7] The capital recovery factor was calculated assuming a 25-year equipment life and a 4% interest rate

TABLE B2.2-1a
COST EFFECTIVENESS CALCULATIONS
Toxic Air Pollutants
Tier 4 (Final) Control System
Diesel-Fired 400 kW Emergency Generator
Operating Hours 55 hours/year

TAP Avg Period [1]	Toxic Air Pollutant	Emission Factor [2] (lb/MMBTU)	Uncontrolled Emissions (tpy)	Control Factor [3]	Emission Reduction (tpy)	Cost-Effectiveness [4] ($/ton)
24-Hour	Acrolein	7.88E-06	9.11E-07	0.70	6.38E-07	31,984,713
	Toluene	2.81E-04	3.25E-05	0.70	2.27E-05	
	Xylenes	1.93E-04	2.23E-05	0.70	1.56E-05	
	Propylene	2.79E-03	3.23E-04	0.70	2.26E-04	
Annual	Benzene	7.76E-04	8.97E-05	0.70	6.28E-05	3,338,824
	Formaldehyde	7.89E-05	9.12E-06	0.70	6.39E-06	
	Acetaldehyde	2.52E-05	2.91E-06	0.70	2.04E-06	
	Naphthalene	1.30E-04	1.50E-05	0.70	1.05E-05	
	Benz(a)anthracene	6.22E-07	7.19E-08	0.70	5.03E-08	
	Chrysene	1.53E-06	1.77E-07	0.70	1.24E-07	
	Benz(b)fluoranthcene	1.11E-06	1.28E-07	0.70	8.98E-08	
	Benz(k)fluoranthcene	2.18E-07	2.52E-08	0.70	1.76E-08	
	Benzo(a)pyrene	2.57E-07	2.97E-08	0.70	2.08E-08	
	Indeno(1,2,3-cd)pyrene	4.14E-07	4.79E-08	0.70	3.35E-08	
	Dibenz(a,h)anthracene	3.46E-07	4.00E-08	0.70	2.80E-08	
	DPM	--	2.79E-03	0.88	2.45E-03	

[1] ASIL information from WAC 173-460
[2] SO2, NO2, CO, and DPM based on criteria pollutant emission calculations, assuming 90% of NOx as NO2. Other TAPs from AP-42 Chapter 3.4 (Large Stationary Diesel Engines)
[3] Control factors used in recent Sabey, Vantage, and Cyrus One data center NOC applications.
[4] Cost-effectiveness based on total annual control cost and emission reduction by TAP averaging period group.

TABLE B2.2-2a
COST EFFECTIVENESS CALCULATIONS
Criteria Air Pollutants
Tier 4 (Final) Control System
Diesel-Fired 750 kW Emergency Generator
Operating Hours 55 hours/year

Cost Item			Factor	Cost
Direct Costs				
Purchased Equipment Costs				
	Primary Equipment[1]		A	148,376
	Sales Tax[2]		B = 0.065 * A	9,644
	Shipping		Included in A	----
		Purchased Equipment Cost (PEC)	PEC = A + B	158,021
Direct Installation Costs				
	Foundations & Supports		Included in A	----
	Handling & Erection		Included in A	----
	Electrical		Included in A	----
	Piping		Included in A	----
	Insulation for Ductwork		Included in A	----
	Painting		Included in A	----
		Direct Installation Cost	Included in A	----
Total Direct Costs (DC)				158,021
Indirect Costs				
Installation				
	Engineering		Included in A	----
	Construction & Field Expenses		Included in A	----
	Contractor Fees		Included in A	----
	Start-Up		Included in A	----
	Contingencies[3]		0.03 * PEC	4,741
Total Indirect Costs (IC)				4,741
TOTAL CAPITAL INVESTMENT = DC + IC				**162,761**
Direct Annual Costs				
Operating Labor				
	Operator		Negligible	----
	Supervisor		Negligible	----
		Total Operating Labor		----
Maintenance				
	Labor		----	----
	Materials		----	----
		Total Maintenance[4]	0.005 * TCI	814
Utilities				
	Electricity		Negligible	----
	Water		----	----
	Reagent[4]		----	990
		Total Utilities		----
Catalyst Cost				
	Catalyst Replacement		Catalyst life > SCR Service Life	----
		Total Catalyst Cost	----	----
Miscellaneous				
	Performance Tests		----	----
	Record Keeping & Reporting		----	----
		Total Miscellaneous Costs		----
Total Direct Annual Costs (DAC)				**1,804**
Indirect Annual Costs				
Overhead[5]			60% of operating, supervisor, maintenance labor & materials	488
Administrative Charges[6]			0.03 * (Op. Labor Cost + 0.4 * Ann. Maint. Cost))	10
Capital Recovery Factor[7]			CRF	0.0640
Capital Recovery			CRF * TCI	10,419
Total Indirect Annual Costs (IAC)				**10,917**
TOTAL ANNUAL COST = DAC + IAC				**12,721**
Uncontrolled NOx, CO, VOC, and PM emissions			tons/yr	0.43
NOx, CO, VOC, and PM Emissions with Tier 4 Controls			tons/yr	0.05
Percent reduction from uncontrolled				89%
Total emissions reduction			tons/yr	0.39
Cost per Ton Controlled			**$/ton**	**32,971**

[1] Captial cost provided by the engine vendor (Brant Briody of Western States Equipment Co.)
[2] Washington sales tax
[3] Minimum cost from most recent Sabey, Vantage, and Cyrus One cost-effectiveness analyses
[4] Estimated using equations from EPA's Air Pollution Control Cost Estimation Spreadsheet for Selective Catalytic Reduction (SCR) found at https://www.epa.gov/sites/production/files/2019-06/scrcostmanualspreadsheet_june-2019vf.xlsm
[5] EPA's Air Pollution Control Cost Manual, Section 1, Chapter 2 (Cost Estimation), Section 2.6.5.7
[6] EPA's Air Pollution Control Cost Manual, Section 4, Chapter 2 (SCR)
[7] The capital recovery factor was calculated assuming a 25-year equipment life and a 4% interest rate

TABLE B2.2-2a
COST EFFECTIVENESS CALCULATIONS
Toxic Air Pollutants
Tier 4 (Final) Control System
Diesel-Fired 750 kW Emergency Generator
Operating Hours 55 hours/year

TAP Avg Period [1]	Toxic Air Pollutant	Emission Factor [2] (lb/MMBTU)	Uncontrolled Emissions (tpy)	Control Factor [3]	Emission Reduction (tpy)	Cost-Effectiveness [4] ($/ton)
24-Hour	Acrolein	7.88E-06	1.60E-06	0.70	1.12E-06	27,424,239
	Toluene	2.81E-04	5.69E-05	0.70	3.98E-05	
	Xylenes	1.93E-04	3.91E-05	0.70	2.74E-05	
	Propylene	2.79E-03	5.65E-04	0.70	3.96E-04	
Annual	Benzene	7.76E-04	1.57E-04	0.70	1.10E-04	3,434,860
	Formaldehyde	7.89E-05	1.60E-05	0.70	1.12E-05	
	Acetaldehyde	2.52E-05	5.10E-06	0.70	3.57E-06	
	Naphthalene	1.30E-04	2.63E-05	0.70	1.84E-05	
	Benz(a)anthracene	6.22E-07	1.26E-07	0.70	8.82E-08	
	Chrysene	1.53E-06	3.10E-07	0.70	2.17E-07	
	Benz(b)fluoranthcene	1.11E-06	2.25E-07	0.70	1.57E-07	
	Benz(k)fluoranthcene	2.18E-07	4.42E-08	0.70	3.09E-08	
	Benzo(a)pyrene	2.57E-07	5.20E-08	0.70	3.64E-08	
	Indeno(1,2,3-cd)pyrene	4.14E-07	8.38E-08	0.70	5.87E-08	
	Dibenz(a,h)anthracene	3.46E-07	7.01E-08	0.70	4.91E-08	
	DPM	--	4.05E-03	0.88	3.56E-03	

[1] ASIL information from WAC 173-460
[2] SO2, NO2, CO, and DPM based on criteria pollutant emission calculations, assuming 90% of NOx as NO2. Other TAPs from AP-42 Chapter 3.4 (Large Stationary Diesel Engines)
[3] Control factors used in recent Sabey, Vantage, and Cyrus One data center NOC applications.
[4] Cost-effectiveness based on total annual control cost and emission reduction by TAP averaging period group.

TABLE B2.2-3a
COST EFFECTIVENESS CALCULATIONS
Criteria Air Pollutants
Tier 4 (Final) Control System
Diesel-Fired 1.25 MW Caterpillar Emergency Generator
Operating Hours 55 hours/year

Cost Item			Factor	Cost
Direct Costs				
Purchased Equipment Costs				
	Primary Equipment[1]		A	200,000
	Sales Tax[2]		B = 0.065 * A	13,000
	Shipping		Included in A	-----
		Purchased Equipment Cost (PEC)	PEC = A + B	213,000
Direct Installation Costs				
	Foundations & Supports		Included in A	-----
	Handling & Erection		Included in A	-----
	Electrical		Included in A	-----
	Piping		Included in A	-----
	Insulation for Ductwork		Included in A	-----
	Painting		Included in A	-----
		Direct Installation Cost	Included in A	-----
Total Direct Costs (DC)				213,000
Indirect Costs				
Installation				
	Engineering		Included in A	-----
	Construction & Field Expenses		Included in A	-----
	Contractor Fees		Included in A	-----
	Start-Up		Included in A	-----
	Contingencies[3]		0.03 * PEC	6,390
Total Indirect Costs (IC)				6,390
TOTAL CAPITAL INVESTMENT = DC + IC				**219,390**
Direct Annual Costs				
Operating Labor				
	Operator		Negligible	-----
	Supervisor		Negligible	-----
		Total Operating Labor		-----
Maintenance				
	Labor		-----	-----
	Materials		-----	-----
		Total Maintenance[4]	0.005 * TCI	1,097
Utilities				
	Electricity		Negligible	-----
	Water		-----	-----
	Reagent[4]		-----	1,726
		Total Utilities		-----
Catalyst Cost				
	Catalyst Replacement		Catalyst life > SCR Service Life	-----
		Total Catalyst Cost	-----	-----
Miscellaneous				
	Performance Tests		-----	-----
	Record Keeping & Reporting		-----	-----
		Total Miscellaneous Costs		-----
Total Direct Annual Costs (DAC)				**2,823**
Indirect Annual Costs				
Overhead[5]			60% of operating, supervisor, maintenance labor & materials	658
Administrative Charges[6]			0.03 * (Op. Labor Cost + 0.4 * Ann. Maint. Cost)	13
Capital Recovery Factor[7]			CRF	0.0640
Capital Recovery			CRF * TCI	14,044
Total Indirect Annual Costs (IAC)				**14,715**
TOTAL ANNUAL COST = DAC + IAC				**17,538**
Uncontrolled NOx, CO, VOC, and PM emissions			tons/yr	0.72
NOx, CO, VOC, and PM Emissions with Tier 4 Controls			tons/yr	0.08
Percent reduction from uncontrolled				89%
Total emissions reduction			tons/yr	0.65
Cost per Ton Controlled			**$/ton**	**27,103**

[1] Capital cost provided by the engine vendor (Brant Briody of Western States Equipment Co.)
[2] Washington sales tax
[3] Minimum cost from most recent Sabey, Vantage, and Cyrus One cost-effectiveness analyses
[4] Estimated using equations from EPA's Air Pollution Control Cost Estimation Spreadsheet for Selective Catalytic Reduction (SCR) found at https://www.epa.gov/sites/production/files/2019-06/scrcostmanualspreadsheet_june-2019vf.xlsm
[5] EPA's Air Pollution Control Cost Manual, Section 1, Chapter 2 (Cost Estimation), Section 2.6.5.7
[6] EPA's Air Pollution Control Cost Manual, Section 4, Chapter 2 (SCR)
[7] The capital recovery factor was calculated assuming a 25-year equipment life and a 4% interest rate

TABLE B2.2-3a
COST EFFECTIVENESS CALCULATIONS
Toxic Air Pollutants
Tier 4 (Final) Control System
Diesel-Fired 1.25 MW Caterpillar Emergency Generator
Operating Hours 55 hours/year

TAP Avg Period [1]	Toxic Air Pollutant	Emission Factor [2] (lb/MMBTU)	Uncontrolled Emissions (tpy)	Control Factor [3]	Emission Reduction (tpy)	Cost-Effectiveness [4] ($/ton)
24-Hour	Acrolein	7.88E-06	2.60E-06	0.70	1.82E-06	23,187,595
	Toluene	2.91E-04	9.28E-05	0.70	6.50E-05	
	Xylenes	1.93E-04	6.37E-05	0.70	4.46E-05	
	Propylene	2.79E-03	9.21E-04	0.70	6.45E-04	
Annual	Benzene	7.76E-04	2.56E-04	0.70	1.79E-04	8,022,415
	Formaldehyde	7.89E-05	2.61E-05	0.70	1.82E-05	
	Acetaldehyde	2.52E-05	8.32E-06	0.70	5.83E-06	
	Naphthalene	1.30E-04	4.29E-05	0.70	3.01E-05	
	Benz(a)anthracene	6.22E-07	2.05E-07	0.70	1.44E-07	
	Chrysene	1.53E-06	5.05E-07	0.70	3.54E-07	
	Benz(b)fluoranthcene	1.11E-06	3.67E-07	0.70	2.57E-07	
	Benz(k)fluoranthcene	2.18E-07	7.20E-08	0.70	5.04E-08	
	Benzo(a)pyrene	2.57E-07	8.48E-08	0.70	5.94E-08	
	Indeno(1,2,3-cd)pyrene	4.14E-07	1.37E-07	0.70	9.57E-08	
	Dibenz(a,h)anthracene	3.46E-07	1.14E-07	0.70	8.00E-08	
	DPM	--	2.22E-03	0.88	1.95E-03	

[1] ASIL information from WAC 173-460
[2] SO2, NO2, CO, and DPM based on criteria pollutant emission calculations, assuming 90% of NOx as NO2. Other TAPs from AP-42 Chapter 3.4 (Large Stationary Diesel Engines)
[3] Control factors used in recent Sabey, Vantage, and Cyrus One data center NOC applications.
[4] Cost-effectiveness based on total annual control cost and emission reduction by TAP averaging period group.

TABLE B2.2-4a
COST EFFECTIVENESS CALCULATIONS
Criteria Air Pollutants
Tier 4 (Final) Control System
Diesel-Fired 1.25 MW Generac Emergency Generator
Operating Hours 55 hours/year

Cost Item			Factor	Cost
Direct Costs				
Purchased Equipment Costs				
	Primary Equipment[1]		A	203,393
	Sales Tax[2]		B = 0.065 * A	13,221
	Shipping		Included in A	-----
		Purchased Equipment Cost (PEC)	PEC = A + B	216,613
Direct Installation Costs				
	Foundations & Supports		Included in A	-----
	Handling & Erection		Included in A	-----
	Electrical		Included in A	-----
	Piping		Included in A	-----
	Insulation for Ductwork		Included in A	-----
	Painting		Included in A	-----
		Direct Installation Cost	Included in A	-----
Total Direct Costs (DC)				216,613
Indirect Costs				
Installation				
	Engineering		Included in A	-----
	Construction & Field Expenses		Included in A	-----
	Contractor Fees		Included in A	-----
	Start-Up		Included in A	-----
	Contingencies[3]		0.03 * PEC	6,498
Total Indirect Costs (IC)				6,498
TOTAL CAPITAL INVESTMENT = DC + IC				**223,111**
Direct Annual Costs				
Operating Labor				
	Operator		Negligible	-----
	Supervisor		Negligible	-----
		Total Operating Labor		-----
Maintenance				
	Labor		-----	-----
	Materials		-----	-----
		Total Maintenance[4]	0.005 * TCI	1,116
Utilities				
	Electricity		Negligible	-----
	Water		-----	-----
	Reagent[4]		-----	1,065
		Total Utilities		-----
Catalyst Cost				
	Catalyst Replacement		Catalyst life > SCR Service Life	-----
		Total Catalyst Cost	-----	-----
Miscellaneous				
	Performance Tests		-----	-----
	Record Keeping & Reporting		-----	-----
		Total Miscellaneous Costs		-----
Total Direct Annual Costs (DAC)				**2,181**
Indirect Annual Costs				
Overhead[5]			60% of operating, supervisor, maintenance labor & materials	869
Administrative Charges[6]			0.03 * (Op. Labor Cost + 0.4 * Ann. Maint. Cost))	13
Capital Recovery Factor[7]			CRF	0.0640
Capital Recovery			CRF * TCI	14,282
Total Indirect Annual Costs (IAC)				**14,965**
TOTAL ANNUAL COST = DAC + IAC				**17,146**
Uncontrolled NOx, CO, VOC, and PM emissions			tons/yr	0.54
NOx, CO, VOC, and PM Emissions with Tier 4 Controls			tons/yr	0.07
Percent reduction from uncontrolled				87%
Total emissions reduction			tons/yr	0.47
Cost per Ton Controlled			**$/ton**	**36,657**

[1] Capital cost provided by the engine vendor (Brant Briody of Western States Equipment Co.)
[2] Washington sales tax
[3] Minimum cost from most recent Sabey, Vantage, and Cyrus One cost-effectiveness analyses
[4] Estimated using equations from EPA's Air Pollution Control Cost Estimation Spreadsheet for Selective Catalytic Reduction (SCR) found at https://www.epa.gov/sites/production/files/2019-06/scrcostmanualspreadsheet_june-2019vf.xlsm
[5] EPA's Air Pollution Control Cost Manual, Section 1, Chapter 2 (Cost Estimation), Section 2.6.5.7
[6] EPA's Air Pollution Control Cost Manual, Section 4, Chapter 2 (SCR)
[7] The capital recovery factor was calculated assuming a 25-year equipment life and a 4% interest rate

TABLE B2.2-4a
COST EFFECTIVENESS CALCULATIONS
Toxic Air Pollutants
Tier 4 (Final) Control System
Diesel-Fired 1.25 MW Generac Emergency Generator
Operating Hours 55 hours/year

TAP Avg Period [1]	Toxic Air Pollutant	Emission Factor [2] (lb/MMBTU)	Uncontrolled Emissions (tpy)	Control Factor [3]	Emission Reduction (tpy)	Cost-Effectiveness [4] ($/ton)
24-Hour	Acrolein	7.88E-06	3.39E-06	0.70	2.38E-06	17,379,280
	Toluene	2.81E-04	1.21E-04	0.70	8.47E-05	
	Xylenes	1.93E-04	8.31E-05	0.70	5.82E-05	
	Propylene	2.79E-03	1.20E-03	0.70	8.41E-04	
Annual	Benzene	7.76E-04	3.34E-04	0.70	2.34E-04	1,590,103
	Formaldehyde	7.89E-05	3.40E-05	0.70	2.38E-05	
	Acetaldehyde	2.52E-05	1.09E-05	0.70	7.60E-06	
	Naphthalene	1.30E-04	5.60E-05	0.70	3.92E-05	
	Benz(a)anthracene	6.22E-07	2.68E-07	0.70	1.88E-07	
	Chrysene	1.53E-06	6.59E-07	0.70	4.61E-07	
	Benz(b)fluoranthcene	1.11E-06	4.76E-07	0.70	3.35E-07	
	Benz(k)fluoranthcene	2.18E-07	9.39E-08	0.70	6.57E-08	
	Benzo(a)pyrene	2.57E-07	1.11E-07	0.70	7.75E-08	
	Indeno(1,2,3-cd)pyrene	4.14E-07	1.78E-07	0.70	1.25E-07	
	Dibenz(a,h)anthracene	3.46E-07	1.49E-07	0.70	1.04E-07	
	DPM	--	1.19E-02	0.88	1.05E-02	

[1] ASIL information from WAC 173-460
[2] SO2, NO2, CO, and DPM based on criteria pollutant emission calculations, assuming 90% of NOx as NO2. Other TAPs from AP-42 Chapter 3.4 (Large Stationary Diesel Engines)
[3] Control factors used in recent Sabey, Vantage, and Cyrus One data center NOC applications.
[4] Cost-effectiveness based on total annual control cost and emission reduction by TAP averaging period group.

TABLE B2.2-5a
COST EFFECTIVENESS CALCULATIONS
Criteria Air Pollutants
Tier 4 (Final) Control System
Diesel-Fired 2.25 MW Emergency Generator
Operating Hours 55 hours/year

Cost Item			Factor	Cost
Direct Costs				
Purchased Equipment Costs				
	Primary Equipment[1]		A	287,715
	Sales Tax[2]		B = 0.065 * A	18,701
	Shipping		Included in A	-----
		Purchased Equipment Cost (PEC)	PEC = A + B	306,416
Direct Installation Costs				
	Foundations & Supports		Included in A	-----
	Handling & Erection		Included in A	-----
	Electrical		Included in A	-----
	Piping		Included in A	-----
	Insulation for Ductwork		Included in A	-----
	Painting		Included in A	-----
		Direct Installation Cost	Included in A	-----
Total Direct Costs (DC)				306,416
Indirect Costs				
Installation				
	Engineering		Included in A	-----
	Construction & Field Expenses		Included in A	-----
	Contractor Fees		Included in A	-----
	Start-Up		Included in A	-----
	Contingencies[3]		0.03 * PEC	9,192
Total Indirect Costs (IC)				9,192
TOTAL CAPITAL INVESTMENT = DC + IC				**315,609**
Direct Annual Costs				
Operating Labor				
	Operator		Negligible	-----
	Supervisor		Negligible	-----
		Total Operating Labor		-----
Maintenance				
	Labor		-----	-----
	Materials		-----	-----
		Total Maintenance[4]	0.005 * TCI	1,578
Utilities				
	Electricity		Negligible	-----
	Water		-----	-----
	Reagent[4]		-----	2,010
		Total Utilities		-----
Catalyst Cost				
	Catalyst Replacement		Catalyst life > SCR Service Life	-----
		Total Catalyst Cost	-----	-----
Miscellaneous				
	Performance Tests		-----	-----
	Record Keeping & Reporting		-----	-----
		Total Miscellaneous Costs		-----
Total Direct Annual Costs (DAC)				**3,588**
Indirect Annual Costs				
Overhead[5]			60% of operating, supervisor, maintenance labor & materials	947
Administrative Charges[6]			0.03 * (Op. Labor Cost + 0.4 * Ann. Maint. Cost))	19
Capital Recovery Factor[7]			CRF	0.0640
Capital Recovery			CRF * TCI	20,203
Total Indirect Annual Costs (IAC)				**21,168**
TOTAL ANNUAL COST = DAC + IAC				**24,756**
Uncontrolled NOx, CO, VOC, and PM emissions			tons/yr	1.14
NOx, CO, VOC, and PM Emissions with Tier 4 Controls			tons/yr	0.16
Percent reduction from uncontrolled				86%
Total emissions reduction			tons/yr	0.98
Cost per Ton Controlled			**$/ton**	**25,289**

[1] Captial cost provided by the engine vendor (Brant Briody of Western States Equipment Co.)
[2] Washington sales tax
[3] Minimum cost from most recent Sabey, Vantage, and Cyrus One cost-effectiveness analyses
[4] Estimated using equations from EPA's Air Pollution Control Cost Estimation Spreadsheet for Selective Catalytic Reduction (SCR) found at
[6] EPA's Air Pollution Control Cost Manual, Section 1, Chapter 2 (Cost Estimation), Section 2.6.5.7
[6] EPA's Air Pollution Control Cost Manual, Section 4, Chapter 2 (SCR)
[7] The capital recovery factor was calculated assuming a 25-year equipment life and a 4% interest rate

TABLE B2.2-5a
COST EFFECTIVENESS CALCULATIONS
Toxic Air Pollutants
Tier 4 (Final) Control System
Diesel-Fired 2.25 MW Emergency Generator
Operating Hours 55 hours/year

TAP Avg Period [1]	Toxic Air Pollutant	Emission Factor [2] (lb/MMBTU)	Uncontrolled Emissions (tpy)	Control Factor [3]	Emission Reduction (tpy)	Cost-Effectiveness [4] ($/ton)
24-Hour	Acrolein	7.88E-06	4.98E-06	0.70	3.48E-06	17,119,545
	Toluene	2.81E-04	1.77E-04	0.70	1.24E-04	
	Xylenes	1.93E-04	1.22E-04	0.70	8.53E-05	
	Propylene	2.79E-03	1.76E-03	0.70	1.23E-03	
Annual	Benzene	7.76E-04	4.90E-04	0.70	3.43E-04	1,136,082
	Formaldehyde	7.89E-05	4.98E-05	0.70	3.48E-05	
	Acetaldehyde	2.52E-05	1.59E-05	0.70	1.11E-05	
	Naphthalene	1.30E-04	8.21E-05	0.70	5.75E-05	
	Benz(a)anthracene	6.22E-07	3.93E-07	0.70	2.75E-07	
	Chrysene	1.53E-06	9.66E-07	0.70	6.76E-07	
	Benz(b)fluoranthcene	1.11E-06	7.01E-07	0.70	4.91E-07	
	Benz(k)fluoranthcene	2.18E-07	1.38E-07	0.70	9.63E-08	
	Benzo(a)pyrene	2.57E-07	1.62E-07	0.70	1.14E-07	
	Indeno(1,2,3-cd)pyrene	4.14E-07	2.61E-07	0.70	1.83E-07	
	Dibenz(a,h)anthracene	3.46E-07	2.18E-07	0.70	1.53E-07	
	DPM	--	2.43E-02	0.88	2.13E-02	

[1] ASIL information from WAC 173-460.
[2] SO2, NO2, CO, and DPM based on criteria pollutant emission calculations, assuming 90% of NOx as NO2. Other TAPs from AP-42 Chapter 3.4 (Large Stationary Diesel Engines)
[3] Control factors used in recent Sabey, Vantage, and Cyrus One data center NOC applications.
[4] Cost-effectiveness based on total annual control cost and emission reduction by TAP averaging period group.

TABLE B2.2-6a
COST EFFECTIVENESS CALCULATIONS
Criteria Air Pollutants
Selective Catalytic Reduction (SCR) Control System
Diesel-Fired 400 kW Emergency Generator
Operating Hours 55 hours/year

Cost Item		Factor	Cost
Direct Costs			
Purchased Equipment Costs			
	Primary Equipment[1]	A	62,521
	Sales Tax[2]	B = 0.065 * A	4,064
	Shipping	Included in A	-----
	Purchased Equipment Cost (PEC)	PEC = A + B	66,585
Direct Installation Costs			
	Foundations & Supports	Included in A	-----
	Handling & Erection	Included in A	-----
	Electrical	Included in A	-----
	Piping	Included in A	-----
	Insulation for Ductwork	Included in A	-----
	Painting	Included in A	-----
	Direct Installation Cost	Included in A	-----
Total Direct Costs (DC)			66,585
Indirect Costs			
Installation			
	Engineering	Included in A	-----
	Construction & Field Expenses	Included in A	-----
	Contractor Fees	Included in A	-----
	Start-Up	Included in A	-----
	Contingencies[3]	0.03 * PEC	1,998
Total Indirect Costs (IC)			1,998
TOTAL CAPITAL INVESTMENT = DC + IC			**68,582**
Direct Annual Costs			
Operating Labor			
	Operator	Negligible	-----
	Supervisor	Negligible	-----
	Total Operating Labor		-----
Maintenance			
	Labor	-----	-----
	Materials	-----	-----
	Total Maintenance[4]	0.005 * TCI	343
Utilities			
	Electricity	Negligible	-----
	Water	-----	-----
	Reagent[4]	-----	232
	Total Utilities		-----
Catalyst Cost			
	Catalyst Replacement	Catalyst life > SCR Service Life	-----
	Total Catalyst Cost	-----	-----
Miscellaneous			
	Performance Tests	-----	-----
	Record Keeping & Reporting	-----	-----
	Total Miscellaneous Costs		-----
Total Direct Annual Costs (DAC)			**575**
Indirect Annual Costs			
Administrative Charges[5]		0.03 * (Op. Labor Cost + 0.4 * Ann. Maint. Cost)	4
Capital Recovery Factor[6]		CRF	0.0640
Capital Recovery		CRF * TCI	4,390
Total Indirect Annual Costs (IAC)			**4,394**
TOTAL ANNUAL COST = DAC + IAC			**4,969**
Uncontrolled NOx, CO, VOC, and PM emissions		tons/yr	0.11
NOx, CO, VOC, and PM Emissions with SCR		tons/yr	0.03
Percent reduction from uncontrolled			72%
Total emissions reduction		tons/yr	0.08
Cost per Ton Controlled		**$/ton**	**59,797**

[1] Capital cost provided by the engine vendor (Brant Briody of Western States Equipment Co.)
[2] Washington sales tax
[3] Minimum cost from most recent Sabey, Vantage, and Cyrus One cost-effectiveness analyses
[4] Estimated using equations from EPA's Air Pollution Control Cost Estimation Spreadsheet for Selective Catalytic Reduction (SCR) found at https://www.epa.gov/sites/production/files/2019-06/scrcostmanualspreadsheet_june-2019vf.xlsm
[5] EPA's Air Pollution Control Cost Manual, Section 4, Chapter 2 (SCR)
[6] The capital recovery factor was calculated assuming a 25-year equipment life and a 4% interest rate

TABLE B2.2-6a
COST EFFECTIVENESS CALCULATIONS
Toxic Air Pollutants
Selective Catalytic Reduction (SCR) Control System
Diesel-Fired 400 kW Emergency Generator
Operating Hours 55 hours/year

TAP Avg Period [1]	Toxic Air Pollutant	Emission Factor [2] (lb/MMBTU)	Uncontrolled Emissions (tpy)	Control Factor [3]	Emission Reduction (tpy)	Cost-Effectiveness [4] ($/ton)
24-Hour	Acrolein	7.88E-06	9.11E-07	0.00	0.00E+00	--
	Toluene	2.81E-04	3.25E-05	0.00	0.00E+00	
	Xylenes	1.93E-04	2.23E-05	0.00	0.00E+00	
	Propylene	2.79E-03	3.23E-04	0.00	0.00E+00	
Annual	Benzene	7.76E-04	8.97E-05	0.00	0.00E+00	--
	Formaldehyde	7.89E-05	9.12E-06	0.00	0.00E+00	
	Acetaldehyde	2.52E-05	2.91E-06	0.00	0.00E+00	
	Naphthalene	1.30E-04	1.50E-05	0.00	0.00E+00	
	Benz(a)anthracene	6.22E-07	7.19E-08	0.00	0.00E+00	
	Chrysene	1.53E-06	1.77E-07	0.00	0.00E+00	
	Benz(b)fluoranthcene	1.11E-06	1.28E-07	0.00	0.00E+00	
	Benz(k)fluoranthcene	2.18E-07	2.52E-08	0.00	0.00E+00	
	Benzo(a)pyrene	2.57E-07	2.97E-08	0.00	0.00E+00	
	Indeno(1,2,3-cd)pyrene	4.14E-07	4.79E-08	0.00	0.00E+00	
	Dibenz(a,h)anthracene	3.46E-07	4.00E-08	0.00	0.00E+00	
	DPM	--	2.79E-03	0.00	0.00E+00	

[1] ASIL information from WAC 173-460
[2] SO2, NO2, CO, and DPM based on criteria pollutant emission calculations, assuming 90% of NOx as NO2. Other TAPs from AP-42 Chapter 3.4 (Large Stationary Diesel Engines)
[3] Control factors used in recent Sabey, Vantage, and Cyrus One data center NOC applications.
[4] Cost-effectiveness based on total annual control cost and emission reduction by TAP averaging period group.

TABLE B2.2-7a
COST EFFECTIVENESS CALCULATIONS
Criteria Air Pollutants
Selective Catalytic Reduction (SCR) Control System
Diesel-Fired 750 kW Emergency Generator
Operating Hours 55 hours/year

Cost Item		Factor	Cost
Direct Costs			
Purchased Equipment Costs			
	Primary Equipment[1]	A	89,026
	Sales Tax[2]	B = 0.065 * A	5,787
	Shipping	Included in A	-----
	Purchased Equipment Cost (PEC)	PEC = A + B	94,812
Direct Installation Costs			
	Foundations & Supports	Included in A	-----
	Handling & Erection	Included in A	-----
	Electrical	Included in A	-----
	Piping	Included in A	-----
	Insulation for Ductwork	Included in A	-----
	Painting	Included in A	-----
	Direct Installation Cost	Included in A	-----
Total Direct Costs (DC)			94,812
Indirect Costs			
Installation			
	Engineering	Included in A	-----
	Construction & Field Expenses	Included in A	-----
	Contractor Fees	Included in A	-----
	Start-Up	Included in A	-----
	Contingencies[3]	0.03 * PEC	2,844
Total Indirect Costs (IC)			2,844
TOTAL CAPITAL INVESTMENT = DC + IC			**97,657**
Direct Annual Costs			
Operating Labor			
	Operator	Negligible	-----
	Supervisor	Negligible	-----
	Total Operating Labor		-----
Maintenance			
	Labor	-----	-----
	Materials	-----	-----
	Total Maintenance[4]	0.005 * TCI	489
Utilities			
	Electricity	Negligible	-----
	Water	-----	-----
	Reagent[4]	-----	990
	Total Utilities		-----
Catalyst Cost			
	Catalyst Replacement	Catalyst life > SCR Service Life	-----
	Total Catalyst Cost	-----	-----
Miscellaneous			
	Performance Tests	-----	-----
	Record Keeping & Reporting	-----	-----
	Total Miscellaneous Costs		-----
Total Direct Annual Costs (DAC)			**1,479**
Indirect Annual Costs			
Administrative Charges[5]		0.03 * (Op. Labor Cost + 0.4 * Ann. Maint. Cost)	6
Capital Recovery Factor[6]		CRF	0.0640
Capital Recovery		CRF * TCI	6,251
Total Indirect Annual Costs (IAC)			**6,257**
TOTAL ANNUAL COST = DAC + IAC			**7,736**
Uncontrolled NOx, CO, VOC, and PM emissions		tons/yr	0.43
NOx, CO, VOC, and PM Emissions with SCR		tons/yr	0.08
Percent reduction from uncontrolled			82%
Total emissions reduction		tons/yr	0.35
Cost per Ton Controlled		**$/ton**	**21,794**

[1] Capital cost provided by the engine vendor (Brant Briody of Western States Equipment Co.)
[2] Washington sales tax
[3] Minimum cost from most recent Sabey, Vantage, and Cyrus One cost-effectiveness analyses
[4] Estimated using equations from EPA's Air Pollution Control Cost Estimation Spreadsheet for Selective Catalytic Reduction (SCR) found at https://www.epa.gov/sites/production/files/2019-06/scrcostmanualspreadsheet_june-2019vf.xlsm
[5] EPA's Air Pollution Control Cost Manual, Section 4, Chapter 2 (SCR)
[6] The capital recovery factor was calculated assuming a 25-year equipment life and a 4% interest rate

TABLE B2.2-7a
COST EFFECTIVENESS CALCULATIONS
Toxic Air Pollutants
Selective Catalytic Reduction (SCR) Control System
Diesel-Fired 750 kW Emergency Generator
Operating Hours 55 hours/year

TAP Avg Period [1]	Toxic Air Pollutant	Emission Factor [2] (lb/MMBTU)	Uncontrolled Emissions (tpy)	Control Factor [3]	Emission Reduction (tpy)	Cost-Effectiveness [4] ($/ton)
24-Hour	Acrolein	7.88E-06	1.60E-06	0.00	0.00E+00	--
	Toluene	2.81E-04	5.69E-05	0.00	0.00E+00	
	Xylenes	1.93E-04	3.91E-05	0.00	0.00E+00	
	Propylene	2.79E-03	5.65E-04	0.00	0.00E+00	
Annual	Benzene	7.76E-04	1.57E-04	0.00	0.00E+00	--
	Formaldehyde	7.89E-05	1.60E-05	0.00	0.00E+00	
	Acetaldehyde	2.52E-05	5.10E-06	0.00	0.00E+00	
	Naphthalene	1.30E-04	2.63E-05	0.00	0.00E+00	
	Benz(a)anthracene	6.22E-07	1.26E-07	0.00	0.00E+00	
	Chrysene	1.53E-06	3.10E-07	0.00	0.00E+00	
	Benz(b)fluoranthcene	1.11E-06	2.25E-07	0.00	0.00E+00	
	Benz(k)fluoranthcene	2.18E-07	4.42E-08	0.00	0.00E+00	
	Benzo(a)pyrene	2.57E-07	5.20E-08	0.00	0.00E+00	
	Indeno(1,2,3-cd)pyrene	4.14E-07	8.38E-08	0.00	0.00E+00	
	Dibenz(a,h)anthracene	3.46E-07	7.01E-08	0.00	0.00E+00	
	DPM	--	4.05E-03	0.00	0.00E+00	

[1] ASIL information from WAC 173-460
[2] SO2, NO2, CO, and DPM based on criteria pollutant emission calculations, assuming 90% of NOx as NO2. Other TAPs from AP-42 Chapter 3.4 (Large Stationary Diesel Engines)
[3] Control factors used in recent Sabey, Vantage, and Cyrus One data center NOC applications.
[4] Cost-effectiveness based on total annual control cost and emission reduction by TAP averaging period group.

TABLE B2.2-8a
COST EFFECTIVENESS CALCULATIONS
Criteria Air Pollutants
Selective Catalytic Reduction (SCR) Control System
Diesel-Fired 1.25 MW Caterpillar Emergency Generator
Operating Hours 55 hours/year

Cost Item			Factor	Cost
Direct Costs				
Purchased Equipment Costs				
	Primary Equipment[1]		A	120,000
	Sales Tax[2]		B = 0.065 * A	7,800
	Shipping		Included in A	-----
		Purchased Equipment Cost (PEC)	PEC = A + B	127,800
Direct Installation Costs				
	Foundations & Supports		Included in A	-----
	Handling & Erection		Included in A	-----
	Electrical		Included in A	-----
	Piping		Included in A	-----
	Insulation for Ductwork		Included in A	-----
	Painting		Included in A	-----
		Direct Installation Cost	Included in A	-----
Total Direct Costs (DC)				127,800
Indirect Costs				
Installation				
	Engineering		Included in A	-----
	Construction & Field Expenses		Included in A	-----
	Contractor Fees		Included in A	-----
	Start-Up		Included in A	-----
	Contingencies[3]		0.03 * PEC	3,834
Total Indirect Costs (IC)				3,834
TOTAL CAPITAL INVESTMENT = DC + IC				**131,634**
Direct Annual Costs				
Operating Labor				
	Operator		Negligible	-----
	Supervisor		Negligible	-----
		Total Operating Labor		-----
Maintenance				
	Labor		-----	-----
	Materials		-----	-----
		Total Maintenance[4]	0.005 * TCI	658
Utilities				
	Electricity		Negligible	-----
	Water		-----	-----
	Reagent[4]		-----	1,726
		Total Utilities		-----
Catalyst Cost				
	Catalyst Replacement		Catalyst life > SCR Service Life	-----
		Total Catalyst Cost	-----	-----
Miscellaneous				
	Performance Tests		-----	-----
	Record Keeping & Reporting		-----	-----
		Total Miscellaneous Costs		-----
Total Direct Annual Costs (DAC)				**2,384**
Indirect Annual Costs				
Administrative Charges[6]			0.03 * (Op. Labor Cost + 0.4 * Ann. Maint. Cost))	8
Capital Recovery Factor[5]			CRF	0.0640
Capital Recovery			CRF * TCI	8,426
Total Indirect Annual Costs (IAC)				**8,434**
TOTAL ANNUAL COST = DAC + IAC				**10,818**
Uncontrolled NOx, CO, VOC, and PM emissions			tons/yr	0.72
NOx, CO, VOC, and PM Emissions with SCR			tons/yr	0.11
Percent reduction from uncontrolled				85%
Total emissions reduction			tons/yr	0.62
Cost per Ton Controlled			**$/ton**	**17,485**

[1] Capital cost provided by the engine vendor (Brant Briody of Western States Equipment Co.)
[2] Washington sales tax
[3] Minimum cost from most recent Sabey, Vantage, and Cyrus One cost-effectiveness analyses
https://www.epa.gov/ttnecas1/productionfiles/2019-06/scrcostmanualspreadsheet_june-2019vf.xlsm
[5] EPA's Air Pollution Control Cost Manual, Section 4, Chapter 2 (SCR)
[6] The capital recovery factor was calculated assuming a 25-year equipment life and a 4% interest rate

TABLE B2.2-8a
COST EFFECTIVENESS CALCULATIONS
Toxic Air Pollutants
Selective Catalytic Reduction (SCR) Control System
Diesel-Fired 1.25 MW Caterpillar Emergency Generator
Operating Hours 55 hours/year

TAP Avg Period [1]	Toxic Air Pollutant	Emission Factor [2] (lb/MMBTU)	Uncontrolled Emissions (tpy)	Control Factor [3]	Emission Reduction (tpy)	Cost-Effectiveness [4] ($/ton)
24-Hour	Acrolein	7.88E-06	2.60E-06	0.00	0.00E+00	--
	Toluene	2.81E-04	9.28E-05	0.00	0.00E+00	
	Xylenes	1.93E-04	6.37E-05	0.00	0.00E+00	
	Propylene	2.79E-03	9.21E-04	0.00	0.00E+00	
Annual	Benzene	7.76E-04	2.56E-04	0.00	0.00E+00	--
	Formaldehyde	7.89E-05	2.61E-05	0.00	0.00E+00	
	Acetaldehyde	2.52E-05	8.32E-06	0.00	0.00E+00	
	Naphthalene	1.30E-04	4.29E-05	0.00	0.00E+00	
	Benz(a)anthracene	6.22E-07	2.05E-07	0.00	0.00E+00	
	Chrysene	1.53E-06	5.05E-07	0.00	0.00E+00	
	Benz(b)fluoranthcene	1.11E-06	3.67E-07	0.00	0.00E+00	
	Benz(k)fluoranthcene	2.18E-07	7.20E-08	0.00	0.00E+00	
	Benzo(a)pyrene	2.57E-07	8.48E-08	0.00	0.00E+00	
	Indeno(1,2,3-cd)pyrene	4.14E-07	1.37E-07	0.00	0.00E+00	
	Dibenz(a,h)anthracene	3.46E-07	1.14E-07	0.00	0.00E+00	
	DPM	--	2.22E-03	0.00	0.00E+00	

[1] ASIL information from WAC 173-460
[2] SO2, NO2, CO, and DPM based on criteria pollutant emission calculations, assuming 90% of NOx as NO2. Other TAPs from AP-42 Chapter 3.4 (Large Stationary Diesel Engines)
[3] Control factors used in recent Sabey, Vantage, and Cyrus One data center NOC applications.
[4] Cost-effectiveness based on total annual control cost and emission reduction by TAP averaging period group.

TABLE B2.2-9a
COST EFFECTIVENESS CALCULATIONS
Criteria Air Pollutants
Selective Catalytic Reduction (SCR) Control System
Diesel-Fired 1.25 MW Generac Emergency Generator
Operating Hours 55 hours/year

Cost Item			Factor	Cost
Direct Costs				
Purchased Equipment Costs				
	Primary Equipment[1]		A	122,036
	Sales Tax[2]		B = 0.065 * A	7,932
	Shipping		Included in A	-----
		Purchased Equipment Cost (PEC)	PEC = A + B	129,968
Direct Installation Costs				
	Foundations & Supports		Included in A	-----
	Handling & Erection		Included in A	-----
	Electrical		Included in A	-----
	Piping		Included in A	-----
	Insulation for Ductwork		Included in A	-----
	Painting		Included in A	-----
		Direct Installation Cost	Included in A	-----
Total Direct Costs (DC)				129,968
Indirect Costs				
Installation				
	Engineering		Included in A	-----
	Construction & Field Expenses		Included in A	-----
	Contractor Fees		Included in A	-----
	Start-Up		Included in A	-----
	Contingencies[3]		0.03 * PEC	3,899
Total Indirect Costs (IC)				3,899
TOTAL CAPITAL INVESTMENT = DC + IC				**133,867**
Direct Annual Costs				
Operating Labor				
	Operator		Negligible	-----
	Supervisor		Negligible	-----
		Total Operating Labor		-----
Maintenance				
	Labor		-----	-----
	Materials		-----	-----
		Total Maintenance[4]	0.005 * TCI	669
Utilities				
	Electricity		Negligible	-----
	Water		-----	-----
	Reagent[4]		-----	1,065
		Total Utilities		-----
Catalyst Cost				
	Catalyst Replacement		Catalyst life > SCR Service Life	-----
		Total Catalyst Cost	-----	-----
Miscellaneous				
	Performance Tests		-----	-----
	Record Keeping & Reporting		-----	-----
		Total Miscellaneous Costs		-----
Total Direct Annual Costs (DAC)				**1,736**
Indirect Annual Costs				
Administrative Charges[5]			0.03 * (Op. Labor Cost + 0.4 * Ann. Maint. Cost))	8
Capital Recovery Factor[6]			CRF	0.0640
Capital Recovery			CRF * TCI	8,569
Total Indirect Annual Costs (IAC)				**8,577**
TOTAL ANNUAL COST = DAC + IAC				**10,312**
Uncontrolled NOx, CO, VOC, and PM emissions			tons/yr	0.54
NOx, CO, VOC, and PM Emissions with SCR			tons/yr	0.15
Percent reduction from uncontrolled				71%
Total emissions reduction			tons/yr	0.38
Cost per Ton Controlled			**$/ton**	**27,001**

[1] Captial cost provided by the engine vendor (Brant Briody of Western States Equipment Co.)
[2] Washington sales tax
[3] Minimum cost from most recent Sabey, Vantage, and Cyrus One cost-effectiveness analyses
[4] Estimated using equations from EPA's Air Pollution Control Cost Estimation Spreadsheet for Selective Catalytic Reduction (SCR) found at https://www.epa.gov/sites/production/files/2019-06/scrcostmanualspreadsheet_june-2019vf.xlsm
[5] EPA's Air Pollution Control Cost Manual, Section 4, Chapter 2 (SCR)
[6] The capital recovery factor was calculated assuming a 25-year equipment life and a 4% interest rate

TABLE B2.2-9a
COST EFFECTIVENESS CALCULATIONS
Toxic Air Pollutants
Selective Catalytic Reduction (SCR) Control System
Diesel-Fired 1.25 MW Generac Emergency Generator
Operating Hours 55 hours/year

TAP Avg Period [1]	Toxic Air Pollutant	Emission Factor [2] (lb/MMBTU)	Uncontrolled Emissions (tpy)	Control Factor [3]	Emission Reduction (tpy)	Cost-Effectiveness [4] ($/ton)
24-Hour	Acrolein	7.88E-06	3.39E-06	0.00	0.00E+00	--
	Toluene	2.81E-04	1.21E-04	0.00	0.00E+00	
	Xylenes	1.93E-04	8.31E-05	0.00	0.00E+00	
	Propylene	2.79E-03	1.20E-03	0.00	0.00E+00	
Annual	Benzene	7.76E-04	3.34E-04	0.00	0.00E+00	--
	Formaldehyde	7.89E-05	3.40E-05	0.00	0.00E+00	
	Acetaldehyde	2.52E-05	1.08E-05	0.00	0.00E+00	
	Naphthalene	1.30E-04	5.60E-05	0.00	0.00E+00	
	Benz(a)anthracene	6.22E-07	2.68E-07	0.00	0.00E+00	
	Chrysene	1.53E-06	6.59E-07	0.00	0.00E+00	
	Benz(b)fluoranthcene	1.11E-06	4.78E-07	0.00	0.00E+00	
	Benz(k)fluoranthcene	2.18E-07	9.39E-08	0.00	0.00E+00	
	Benzo(a)pyrene	2.57E-07	1.11E-07	0.00	0.00E+00	
	Indeno(1,2,3-cd)pyrene	4.14E-07	1.78E-07	0.00	0.00E+00	
	Dibenz(a,h)anthracene	3.46E-07	1.49E-07	0.00	0.00E+00	
	DPM	--	1.19E-02	0.00	0.00E+00	

[1] ASIL information from WAC 173-460
[2] SO2, NO2, CO, and DPM based on criteria pollutant emission calculations, assuming 90% of NOx as NO2. Other TAPs from AP-42 Chapter 3.4 (Large Stationary Diesel Engines)
[3] Control factors used in recent Sabey, Vantage, and Cyrus One data center NOC applications.
[4] Cost-effectiveness based on total annual control cost and emission reduction by TAP averaging period group.

TABLE B2.2-10a
COST EFFECTIVENESS CALCULATIONS
Criteria Air Pollutants
Selective Catalytic Reduction (SCR) Control System
Diesel-Fired 2.25 MW Emergency Generator
Operating Hours 55 hours/year

Cost Item			Factor	Cost
Direct Costs				
Purchased Equipment Costs				
	Primary Equipment[1]		A	172,629
	Sales Tax[2]		B = 0.065 * A	11,221
	Shipping		Included in A	-----
		Purchased Equipment Cost (PEC)	PEC = A + B	183,850
Direct Installation Costs				
	Foundations & Supports		Included in A	-----
	Handling & Erection		Included in A	-----
	Electrical		Included in A	-----
	Piping		Included in A	-----
	Insulation for Ductwork		Included in A	-----
	Painting		Included in A	-----
		Direct Installation Cost	Included in A	-----
Total Direct Costs (DC)				183,850
Indirect Costs				
Installation				
	Engineering		Included in A	-----
	Construction & Field Expenses		Included in A	-----
	Contractor Fees		Included in A	-----
	Start-Up		Included in A	-----
	Contingencies[3]		0.03 * PEC	5,515
Total Indirect Costs (IC)				5,515
TOTAL CAPITAL INVESTMENT = DC + IC				**189,365**
Direct Annual Costs				
Operating Labor				
	Operator		Negligible	-----
	Supervisor		Negligible	-----
		Total Operating Labor		-----
Maintenance				
	Labor		-----	-----
	Materials		-----	-----
		Total Maintenance[4]	0.005 * TCI	947
Utilities				
	Electricity		Negligible	-----
	Water		-----	-----
	Reagent[4]		-----	2,010
		Total Utilities		-----
Catalyst Cost				
	Catalyst Replacement		Catalyst life > SCR Service Life	-----
		Total Catalyst Cost	-----	-----
Miscellaneous				
	Performance Tests		-----	-----
	Record Keeping & Reporting		-----	-----
		Total Miscellaneous Costs		-----
Total Direct Annual Costs (DAC)				**2,956**
Indirect Annual Costs				
Administrative Charges[5]			0.03 * (Op. Labor Cost + 0.4 * Ann. Maint. Cost)	11
Capital Recovery Factor[6]			CRF	0.0640
Capital Recovery			CRF * TCI	12,122
Total Indirect Annual Costs (IAC)				**12,133**
TOTAL ANNUAL COST = DAC + IAC				**15,089**
Uncontrolled NOx, CO, VOC, and PM emissions			tons/yr	1.14
NOx, CO, VOC, and PM Emissions with SCR			tons/yr	0.42
Percent reduction from uncontrolled				63%
Total emissions reduction			tons/yr	0.72
Cost per Ton Controlled			**$/ton**	**20,948**

[1] Capital cost provided by the engine vendor (Brent Briody of Western States Equipment Co.)
[2] Washington sales tax
[3] Minimum cost from most recent Safeway, Vantage, and Cyrus One cost-effectiveness analyses
[4] Estimated using equations from EPA's Air Pollution Control Cost Estimation Spreadsheet for Selective Catalytic Reduction (SCR) found at https://www.epa.gov/sites/production/files/2019-06/scrcostmanualspreadsheet_june-2019v1.xlsm
[5] EPA's Air Pollution Control Cost Manual, Section 4, Chapter 2 (SCR)
[6] The capital recovery factor was calculated assuming a 25-year equipment life and a 4% interest rate

TABLE B2.2-10a
COST EFFECTIVENESS CALCULATIONS
Toxic Air Pollutants
Selective Catalytic Reduction (SCR) Control System
Diesel-Fired 2.25 MW Emergency Generator
Operating Hours 55 hours/year

TAP Avg Period [1]	Toxic Air Pollutant	Emission Factor [2] (lb/MMBTU)	Uncontrolled Emissions (tpy)	Control Factor [3]	Emission Reduction (tpy)	Cost-Effectiveness [4] ($/ton)
24-Hour	Acrolein	7.89E-06	4.90E-06	0.00	0.00E+00	--
	Toluene	2.81E-04	1.77E-04	0.00	0.00E+00	
	Xylenes	1.93E-04	1.22E-04	0.00	0.00E+00	
	Propylene	2.79E-03	1.76E-03	0.00	0.00E+00	
Annual	Benzene	7.76E-04	4.90E-04	0.00	0.00E+00	--
	Formaldehyde	7.89E-05	4.98E-05	0.00	0.00E+00	
	Acetaldehyde	2.52E-05	1.59E-05	0.00	0.00E+00	
	Naphthalene	1.30E-04	8.21E-05	0.00	0.00E+00	
	Benz(a)anthracene	6.22E-07	3.93E-07	0.00	0.00E+00	
	Chrysene	1.53E-06	9.66E-07	0.00	0.00E+00	
	Benz(b)fluoranthcene	1.11E-06	7.01E-07	0.00	0.00E+00	
	Benz(k)fluoranthcene	2.19E-07	1.38E-07	0.00	0.00E+00	
	Benzo(a)pyrene	2.57E-07	1.62E-07	0.00	0.00E+00	
	Indeno(1,2,3-cd)pyrene	4.14E-07	2.61E-07	0.00	0.00E+00	
	Dibenz(a,h)anthracene	3.46E-07	2.18E-07	0.00	0.00E+00	
	DPM	--	2.43E-02	0.00	0.00E+00	

[1] ASIL information from WAC 173-460

[2] SO2, NO2, CO, and DPM based on criteria pollutant emission calculations, assuming 90% of NOx as NO2. Other TAP's from AP-42 Chapter 3.4 (Large Stationary Diesel Engines)

[3] Control factors used in recent Sabey, Vantage, and Cyrus One data center NOC applications.

[4] Cost-effectiveness based on total annual control cost and emission reduction by TAP averaging period group.

TABLE B2.2-10b
COST EFFECTIVENESS CALCULATIONS
Toxic Air Pollutants
Diesel Particulate Filter (DPF)/Diesel Oxidation Catalyst (DOC) Control System
Diesel-Fired 400 kW Emergency Generator

TABLE B2.2-11a
COST EFFECTIVENESS CALCULATIONS
Criteria Air Pollutants
Diesel Particulate Filter (DPF)/Diesel Oxidation Catalyst (DOC) Control System
Diesel-Fired 400 kW Emergency Generator
Operating Hours 55 hours/year

Cost Item			Factor	Cost
Direct Costs				
Purchased Equipment Costs				
	Primary Equipment[1]		A	41,680
	Sales Tax[2]		B = 0.065 * A	2,709
	Shipping		Included in A	-----
		Purchased Equipment Cost (PEC)	PEC = A + B	44,390
Direct Installation Costs				
	Foundations & Supports		Included in A	-----
	Handling & Erection		Included in A	-----
	Electrical		Included in A	-----
	Piping		Included in A	-----
	Insulation for Ductwork		Included in A	-----
	Painting		Included in A	-----
		Direct Installation Cost	Included in A	-----
Total Direct Costs (DC)				44,390
Indirect Costs				
Installation				
	Engineering		Included in A	-----
	Construction & Field Expenses		Included in A	-----
	Contractor Fees		Included in A	-----
	Start-Up		Included in A	-----
	Contingencies[7]		0.03 * PEC	1,332
Total Indirect Costs (IC)				1,332
TOTAL CAPITAL INVESTMENT = DC + IC				**45,721**
Direct Annual Costs				
Operating Labor				
	Operator		Negligible	-----
	Supervisor		Negligible	-----
		Total Operating Labor		-----
Maintenance				
	Labor		-----	-----
	Materials		-----	-----
		Total Maintenance[8]	0.005 * TCI	229
Utilities				
	Electricity		Negligible	-----
	Water		-----	-----
	Reagent		-----	-----
		Total Utilities		-----
Catalyst Cost				
	Catalyst Replacement		Catalyst life > DOC Service Life	-----
		Total Catalyst Cost	-----	-----
Miscellaneous				
	Performance Tests		-----	-----
	Record Keeping & Reporting		-----	-----
		Total Miscellaneous Costs		-----
Total Direct Annual Costs (DAC)				**229**
Indirect Annual Costs				
Overhead[6]			60% of operating, supervisor, maintenance labor & materials	137
Administrative Charges[9]			0.02 * TCI	914
Capital Recovery Factor[7]			CRF	0.0640
Capital Recovery			CRF * TCI	2,927
Total Indirect Annual Costs (IAC)				**3,978**
TOTAL ANNUAL COST = DAC + IAC				**4,207**
Uncontrolled NOx, CO, VOC, and PM emissions			tons/yr	0.11
NOx, CO, VOC, and PM Emissions with DPF & DOC Controls			tons/yr	0.10
Percent reduction from uncontrolled				16%
Total emissions reduction			tons/yr	0.02
Cost per Ton Controlled			**$/ton**	**233,826**

[1] Capital cost provided by the engine vendor (Brant Briody of Western States Equipment Co.)
[2] Washington sales tax
[3] Minimum cost from most recent Sabey, Vantage, and Cyrus One cost-effectiveness analyses
[4] Estimated using equations from EPA's Air Pollution Control Cost Estimation Spreadsheet for Selective Catalytic Reduction (SCR.) found at https://www.epa.gov/sites/production/files/2019-06/scrcostmanualspreadsheet_june-2019vf.xlsm
[5] EPA's Air Pollution Control Cost Manual, Section 1, Chapter 2 (Cost Estimation), Section 2.6.5.7
[6] EPA's Air Pollution Control Cost Manual, Section 1, Chapter 2 (Cost Estimation), Section 2.6.5.8
[7] The capital recovery factor was calculated assuming a 25-year equipment life and a 4% interest rate

TABLE B2.2-11a
COST EFFECTIVENESS CALCULATIONS
Toxic Air Pollutants
Diesel Particulate Filter (DPF)/Diesel Oxidation Catalyst (DOC) Control System
Diesel-Fired 400 kW Emergency Generator
Operating Hours 55 hours/year

TAP Avg Period [1]	Toxic Air Pollutant	Emission Factor [2] (lb/MMBTU)	Uncontrolled Emissions (tpy)	Control Factor [3]	Emission Reduction (tpy)	Cost-Effectiveness [4] ($/ton)
24-Hour	Acrolein	7.88E-06	9.11E-07	0.70	6.38E-07	15,886,482
	Toluene	2.81E-04	3.25E-05	0.70	2.27E-05	
	Xylenes	1.93E-04	2.23E-05	0.70	1.56E-05	
	Propylene	2.79E-03	3.23E-04	0.70	2.26E-04	
Annual	Benzene	7.76E-04	8.97E-05	0.70	6.28E-05	1,658,360
	Formaldehyde	7.89E-05	9.12E-06	0.70	6.39E-06	
	Acetaldehyde	2.52E-05	2.91E-06	0.70	2.04E-06	
	Naphthalene	1.30E-04	1.50E-05	0.70	1.05E-05	
	Benz(a)anthracene	6.22E-07	7.19E-08	0.70	5.03E-08	
	Chrysene	1.53E-06	1.77E-07	0.70	1.24E-07	
	Benz(b)fluoranthcene	1.11E-06	1.28E-07	0.70	8.98E-08	
	Benz(k)fluoranthcene	2.18E-07	2.52E-08	0.70	1.76E-08	
	Benzo(a)pyrene	2.57E-07	2.97E-08	0.70	2.08E-08	
	Indeno(1,2,3-cd)pyrene	4.14E-07	4.79E-08	0.70	3.35E-08	
	Dibenz(a,h)anthracene	3.46E-07	4.00E-08	0.70	2.80E-08	
	DPM	--	2.79E-03	0.88	2.46E-03	

[1] ASIL information from WAC 173-460

[2] SO2, NO2, CO, and DPM based on criteria pollutant emission calculations, assuming 90% of NOx as NO2. Other TAP s from AP-42 Chapter 3.4 (Large Stationary Diesel Engines)

[3] Control factors used in recent Sabey, Vantage, and Cyrus One data center NOC applications.

[4] Cost-effectiveness based on total annual control cost and emission reduction by TAP averaging period group.

TABLE B2.2-12a
COST EFFECTIVENESS CALCULATIONS
Criteria Air Pollutants
Diesel Particulate Filter (DPF)/Diesel Oxidation Catalyst (DOC) Control System
Diesel-Fired 750 kW Emergency Generator
Operating Hours 55 hours/year

Cost Item		Factor	Cost
Direct Costs			
Purchased Equipment Costs			
	Primary Equipment[1]	A	59,351
	Sales Tax[2]	B = 0.065 * A	3,858
	Shipping	Included in A	----
	Purchased Equipment Cost (PEC)	PEC = A + B	63,208
Direct Installation Costs			
	Foundations & Supports	Included in A	----
	Handling & Erection	Included in A	----
	Electrical	Included in A	----
	Piping	Included in A	----
	Insulation for Ductwork	Included in A	----
	Painting	Included in A	----
	Direct Installation Cost	Included in A	----
Total Direct Costs (DC)			63,208
Indirect Costs			
Installation			
	Engineering	Included in A	----
	Construction & Field Expenses	Included in A	----
	Contractor Fees	Included in A	----
	Start-Up	Included in A	----
	Contingencies[3]	0.03 * PEC	1,896
Total Indirect Costs (IC)			1,896
TOTAL CAPITAL INVESTMENT = DC + IC			**65,105**
Direct Annual Costs			
Operating Labor			
	Operator	Negligible	----
	Supervisor	Negligible	----
	Total Operating Labor		----
Maintenance			
	Labor	----	----
	Materials	----	----
	Total Maintenance[4]	0.005 * TCI	326
Utilities			
	Electricity	Negligible	----
	Water	----	----
	Reagent	----	----
	Total Utilities		----
Catalyst Cost			
	Catalyst Replacement	Catalyst life > DOC Service Life	----
	Total Catalyst Cost	----	----
Miscellaneous			
	Performance Tests	----	----
	Record Keeping & Reporting	----	----
	Total Miscellaneous Costs		----
Total Direct Annual Costs (DAC)			**326**
Indirect Annual Costs			
Overhead[6]		60% of operating, supervisor, maintenance labor & materials	195
Administrative Charges[5]		0.02 * TCI	1,302
Capital Recovery Factor[7]		CRF	0.0640
Capital Recovery		CRF * TCI	4,167
Total Indirect Annual Costs (IAC)			**5,665**
TOTAL ANNUAL COST = DAC + IAC			**5,990**
Uncontrolled NOx, CO, VOC, and PM emissions		tons/yr	0.43
NOx, CO, VOC, and PM Emissions with DPF & DOC Controls		tons/yr	0.40
Percent reduction from uncontrolled			7%
Total emissions reduction		tons/yr	0.03
Cost per Ton Controlled		**$/ton**	**194,094**

[1] Captial cost provided by the engine vendor (Brant Briody of Western States Equipment Co.)
[2] Washington sales tax
[3] Minimum cost from most recent Sabey, Vantage, and Cyrus One cost-effectiveness analyses
[4] Estimated using equations from EPA's Air Pollution Control Cost Estimation Spreadsheet for Selective Catalytic Reduction (SCR) found at https://www.epa.gov/sites/production/files/2019-09/scrcostmanualspreadsheet_june-2019xlsx.xlsm
[5] EPA's Air Pollution Control Cost Manual, Section 1, Chapter 2 (Cost Estimation), Section 2.6.5.7
[6] EPA's Air Pollution Control Cost Manual, Section 1, Chapter 2 (Cost Estimation), Section 2.6.5.8
[7] The capital recovery factor was calculated assuming a 25-year equipment life and a 4% interest rate

TABLE B2.2-12a
COST EFFECTIVENESS CALCULATIONS
Toxic Air Pollutants
Diesel Particulate Filter (DPF)/Diesel Oxidation Catalyst (DOC) Control System
Diesel-Fired 750 kW Emergency Generator
Operating Hours 55 hours/year

TAP Avg Period [1]	Toxic Air Pollutant	Emission Factor [2] (lb/MMBTU)	Uncontrolled Emissions (tpy)	Control Factor [3]	Emission Reduction (tpy)	Cost-Effectiveness [4] ($/ton)
24-Hour	Acrolein	7.88E-06	1.60E-06	0.70	1.12E-06	12,914,457
	Toluene	2.81E-04	5.69E-05	0.70	3.98E-05	
	Xylenes	1.93E-04	3.91E-05	0.70	2.74E-05	
	Propylene	2.79E-03	5.65E-04	0.70	3.96E-04	
Annual	Benzene	7.76E-04	1.57E-04	0.70	1.10E-04	1,617,523
	Formaldehyde	7.89E-05	1.60E-05	0.70	1.12E-05	
	Acetaldehyde	2.52E-05	5.10E-06	0.70	3.57E-06	
	Naphthalene	1.30E-04	2.63E-05	0.70	1.84E-05	
	Benz(a)anthracene	6.22E-07	1.26E-07	0.70	8.82E-08	
	Chrysene	1.53E-06	3.10E-07	0.70	2.17E-07	
	Benz(b)fluoranthcene	1.11E-06	2.25E-07	0.70	1.57E-07	
	Benz(k)fluoranthcene	2.18E-07	4.42E-08	0.70	3.09E-08	
	Benzo(a)pyrene	2.57E-07	5.20E-08	0.70	3.64E-08	
	Indeno(1,2,3-cd)pyrene	4.14E-07	8.38E-08	0.70	5.87E-08	
	Dibenz(a,h)anthracene	3.46E-07	7.01E-08	0.70	4.91E-08	
	DPM	--	4.05E-03	0.88	3.56E-03	

[1] ASIL information from WAC 173-460
[2] SO2, NO2, CO, and DPM based on criteria pollutant emission calculations, assuming 90% of NOx as NO2. Other TAPs from AP-42 Chapter 3.4 (Large Stationary Diesel Engines)
[3] Control factors used in recent Sabey, Vantage, and Cyrus One data center NOC applications.
[4] Cost-effectiveness based on total annual control cost and emission reduction by TAP averaging period group.

TABLE B2.2-13a
COST EFFECTIVENESS CALCULATIONS
Criteria Air Pollutants
Diesel Particulate Filter (DPF)/Diesel Oxidation Catalyst (DOC) Control System
Diesel-Fired 1.25 MW Caterpillar Emergency Generator
Operating Hours 55 hours/year

Cost Item		Factor	Cost
Direct Costs			
Purchased Equipment Costs			
	Primary Equipment[1]	A	80,000
	Sales Tax[2]	B = 0.065 * A	5,200
	Shipping	Included in A	-----
	Purchased Equipment Cost (PEC)	PEC = A + B	85,200
Direct Installation Costs			
	Foundations & Supports	Included in A	-----
	Handling & Erection	Included in A	-----
	Electrical	Included in A	-----
	Piping	Included in A	-----
	Insulation for Ductwork	Included in A	-----
	Painting	Included in A	-----
	Direct Installation Cost	Included in A	-----
Total Direct Costs (DC)			85,200
Indirect Costs			
Installation			
	Engineering	Included in A	-----
	Construction & Field Expenses	Included in A	-----
	Contractor Fees	Included in A	-----
	Start-Up	Included in A	-----
	Contingencies[3]	0.03 * PEC	2,556
Total Indirect Costs (IC)			2,556
TOTAL CAPITAL INVESTMENT = DC + IC			**87,756**
Direct Annual Costs			
Operating Labor			
	Operator	Negligible	-----
	Supervisor	Negligible	-----
	Total Operating Labor		-----
Maintenance			
	Labor	-----	-----
	Materials	-----	-----
	Total Maintenance[4]	0.005 * TCI	439
Utilities			
	Electricity	Negligible	-----
	Water	-----	-----
	Reagent	-----	-----
	Total Utilities		-----
Catalyst Cost			
	Catalyst Replacement	Catalyst life > DOC Service Life	-----
	Total Catalyst Cost	-----	-----
Miscellaneous			
	Performance Tests	-----	-----
	Record Keeping & Reporting	-----	-----
	Total Miscellaneous Costs		-----
Total Direct Annual Costs (DAC)			**439**
Indirect Annual Costs			
Overhead[5]		60% of operating, supervisor, maintenance labor & materials	263
Administrative Charges[6]		0.02 * TCI	1,755
Capital Recovery Factor[7]		CRF	0.0640
Capital Recovery		CRF * TCI	5,617
Total Indirect Annual Costs (IAC)			**7,636**
TOTAL ANNUAL COST = DAC + IAC			**8,075**
Uncontrolled NOx, CO, VOC, and PM emissions		tons/yr	0.72
NOx, CO, VOC, and PM Emissions with DPF & DOC Controls		tons/yr	0.70
Percent reduction from uncontrolled			4%
Total emissions reduction		tons/yr	0.03
Cost per Ton Controlled		**$/ton**	**284,894**

[1] Captial cost provided by the engine vendor (Brant Briody of Western States Equipment Co.)
[2] Washington sales tax
[3] Minimum cost from most recent Sabey, Vantage, and Cyrus One cost-effectiveness analyses
[4] Estimated using equations from EPA's Air Pollution Control Cost Estimation Spreadsheet for Selective Catalytic Reduction (SCR) found at https://www.epa.gov/sites/production/files/2019-06/scrcostmanualspreadsheet_june-2019vf.xlsm
[5] EPA's Air Pollution Control Cost Manual, Section 1, Chapter 2 (Cost Estimation), Section 2.6.5.7
[6] EPA's Air Pollution Control Cost Manual, Section 1, Chapter 2 (Cost Estimation), Section 2.6.5.8
[7] The capital recovery factor was calculated assuming a 25-year equipment life and a 4% interest rate

TABLE B2.2-13a
COST EFFECTIVENESS CALCULATIONS
Toxic Air Pollutants
Diesel Particulate Filter (DPF)/Diesel Oxidation Catalyst (DOC) Control System
Diesel-Fired 1.25 MW Caterpillar Emergency Generator
Operating Hours 55 hours/year

TAP Avg Period [1]	Toxic Air Pollutant	Emission Factor [2] (lb/MMBTU)	Uncontrolled Emissions (tpy)	Control Factor [3]	Emission Reduction (tpy)	Cost-Effectiveness [4] ($/ton)
24-Hour	Acrolein	7.88E-06	2.60E-06	0.70	1.82E-06	10,675,663
	Toluene	2.81E-04	9.26E-05	0.70	6.50E-05	
	Xylenes	1.93E-04	6.37E-05	0.70	4.46E-05	
	Propylene	2.79E-03	9.21E-04	0.70	6.45E-04	
Annual	Benzene	7.76E-04	2.56E-04	0.70	1.79E-04	3,693,553
	Formaldehyde	7.89E-05	2.61E-05	0.70	1.82E-05	
	Acetaldehyde	2.52E-05	8.32E-06	0.70	5.83E-06	
	Naphthalene	1.30E-04	4.29E-05	0.70	3.01E-05	
	Benz(a)anthracene	6.22E-07	2.05E-07	0.70	1.44E-07	
	Chrysene	1.53E-06	5.05E-07	0.70	3.54E-07	
	Benz(b)fluoranthcene	1.11E-06	3.67E-07	0.70	2.57E-07	
	Benz(k)fluoranthcene	2.18E-07	7.20E-08	0.70	5.04E-08	
	Benzo(a)pyrene	2.57E-07	8.49E-08	0.70	5.94E-08	
	Indeno(1,2,3-cd)pyrene	4.14E-07	1.37E-07	0.70	9.57E-08	
	Dibenz(a,h)anthracene	3.46E-07	1.14E-07	0.70	8.00E-08	
	DPM	--	2.22E-03	0.88	1.95E-03	

[1] ASIL information from WAC 173-460
[2] SO2, NO2, CO, and DPM based on criteria pollutant emission calculations, assuming 90% of NOx as NO2. Other TAPs from AP-42 Chapter 3.4 (Large Stationary Diesel Engines)
[3] Control factors used in recent Sabey, Vantage, and Cyrus One data center NOC applications.
[4] Cost-effectiveness based on total annual control cost and emission reduction by TAP averaging period group.

TABLE B2.2-14a
COST EFFECTIVENESS CALCULATIONS
Criteria Air Pollutants
Diesel Particulate Filter (DPF)/Diesel Oxidation Catalyst (DOC) Control System
Diesel-Fired 1.25 MW Generac Emergency Generator
Operating Hours 55 hours/year

Cost Item		Factor	Cost
Direct Costs			
Purchased Equipment Costs			
	Primary Equipment[1]	A	81,357
	Sales Tax[2]	B = 0.065 * A	5,288
	Shipping	Included in A	-----
	Purchased Equipment Cost (PEC)	PEC = A + B	86,645
Direct Installation Costs			
	Foundations & Supports	Included in A	-----
	Handling & Erection	Included in A	-----
	Electrical	Included in A	-----
	Piping	Included in A	-----
	Insulation for Ductwork	Included in A	-----
	Painting	Included in A	-----
	Direct Installation Cost	Included in A	-----
Total Direct Costs (DC)			86,645
Indirect Costs			
Installation			
	Engineering	Included in A	-----
	Construction & Field Expenses	Included in A	-----
	Contractor Fees	Included in A	-----
	Start-Up	Included in A	-----
	Contingencies[3]	0.03 * PEC	2,599
Total Indirect Costs (IC)			2,599
TOTAL CAPITAL INVESTMENT = DC + IC			**89,245**
Direct Annual Costs			
Operating Labor			
	Operator	Negligible	-----
	Supervisor	Negligible	-----
	Total Operating Labor		-----
Maintenance			
	Labor	-----	-----
	Materials	-----	-----
	Total Maintenance[4]	0.005 * TCI	446
Utilities			
	Electricity	Negligible	-----
	Water	-----	-----
	Reagent	-----	-----
	Total Utilities		-----
Catalyst Cost			
	Catalyst Replacement	Catalyst life > DOC Service Life	-----
	Total Catalyst Cost	-----	-----
Miscellaneous			
	Performance Tests	-----	-----
	Record Keeping & Reporting	-----	-----
	Total Miscellaneous Costs		-----
Total Direct Annual Costs (DAC)			**446**
Indirect Annual Costs			
Overhead[5]		60% of operating, supervisor, maintenance labor & materials	268
Administrative Charges[6]		0.02 * TCI	1,785
Capital Recovery Factor[7]		CRF	0.0640
Capital Recovery		CRF * TCI	5,713
Total Indirect Annual Costs (IAC)			**7,765**
TOTAL ANNUAL COST = DAC + IAC			**8,212**
Uncontrolled NOx, CO, VOC, and PM emissions		tons/yr	0.54
NOx, CO, VOC, and PM Emissions with DPF & DOC Controls		tons/yr	0.45
Percent reduction from uncontrolled			16%
Total emissions reduction		tons/yr	0.09
Cost per Ton Controlled		**$/ton**	**95,683**

[1] Capital cost provided by the engine vendor (Brent Briody of Western States Equipment Co.)
[2] Washington sales tax
[3] Minimum cost from most recent Sabey, Vantage, and Cyrus One cost-effectiveness analyses
[4] Estimated using equations from EPA's Air Pollution Control Cost Estimation Spreadsheet for Selective Catalytic Reduction (SCR) found at https://www.epa.gov/sites/production/files/2019-06/scrcostmanualspreadsheet_june-2019-v1.xlsm
[5] EPA's Air Pollution Control Cost Manual, Section 1, Chapter 2 (Cost Estimation), Section 2.6.5.7
[6] EPA's Air Pollution Control Cost Manual, Section 1, Chapter 2 (Cost Estimation), Section 2.6.5.8
[7] The capital recovery factor was calculated assuming a 25-year equipment life and a 4% interest rate

TABLE B2.2-14a
COST EFFECTIVENESS CALCULATIONS
Toxic Air Pollutants
Diesel Particulate Filter (DPF)/Diesel Oxidation Catalyst (DOC) Control System
Diesel-Fired 1.25 MW Generac Emergency Generator
Operating Hours 55 hours/year

TAP Avg Period [1]	Toxic Air Pollutant	Emission Factor [2] (lb/MMBTU)	Uncontrolled Emissions (tpy)	Control Factor [3]	Emission Reduction (tpy)	Cost-Effectiveness [4] ($/ton)
24-Hour	Acrolein	7.88E-06	3.39E-06	0.70	2.38E-06	8,323,510
	Toluene	2.81E-04	1.21E-04	0.70	8.47E-05	
	Xylenes	1.93E-04	8.31E-05	0.70	5.82E-05	
	Propylene	2.79E-03	1.20E-03	0.70	8.41E-04	
Annual	Benzene	7.76E-04	3.34E-04	0.70	2.34E-04	761,553
	Formaldehyde	7.89E-05	3.40E-05	0.70	2.38E-05	
	Acetaldehyde	2.52E-05	1.09E-05	0.70	7.60E-06	
	Naphthalene	1.30E-04	5.60E-05	0.70	3.92E-05	
	Benz(a)anthracene	6.22E-07	2.68E-07	0.70	1.88E-07	
	Chrysene	1.53E-06	6.59E-07	0.70	4.61E-07	
	Benz(b)fluoranthcene	1.11E-06	4.78E-07	0.70	3.35E-07	
	Benz(k)fluoranthcene	2.18E-07	9.39E-08	0.70	6.57E-08	
	Benzo(a)pyrene	2.57E-07	1.11E-07	0.70	7.75E-08	
	Indeno(1,2,3-cd)pyrene	4.14E-07	1.78E-07	0.70	1.25E-07	
	Dibenz(a,h)anthracene	3.46E-07	1.49E-07	0.70	1.04E-07	
	DPM	--	1.19E-02	0.88	1.05E-02	

[1] ASIL information from WAC 173-460

[2] SO2, NO2, CO, and DPM based on criteria pollutant emission calculations, assuming 90% of NOx as NO2. Other TAPs from AP-42 Chapter 3.4 (Large Stationary Diesel Engines)

[3] Control factors used in recent Sabey, Vantage, and Cyrus One data center NOC applications.

[4] Cost-effectiveness based on total annual control cost and emission reduction by TAP averaging period group.

TABLE B2.2-15a
COST EFFECTIVENESS CALCULATIONS
Criteria Air Pollutants
Diesel Particulate Filter (DPF)/Diesel Oxidation Catalyst (DOC) Control System
Diesel-Fired 2.25 MW Emergency Generator
Operating Hours 55 hours/year

Cost Item		Factor	Cost
Direct Costs			
Purchased Equipment Costs			
	Primary Equipment[1]	A	115,086
	Sales Tax[2]	B = 0.065 * A	7,481
	Shipping	Included in A	----
	Purchased Equipment Cost (PEC)	PEC = A + B	122,566
Direct Installation Costs			
	Foundations & Supports	Included in A	----
	Handling & Erection	Included in A	----
	Electrical	Included in A	----
	Piping	Included in A	----
	Insulation for Ductwork	Included in A	----
	Painting	Included in A	----
	Direct Installation Cost	Included in A	----
Total Direct Costs (DC)			122,566
Indirect Costs			
Installation			
	Engineering	Included in A	----
	Construction & Field Expenses	Included in A	----
	Contractor Fees	Included in A	----
	Start-Up	Included in A	----
	Contingencies[3]	0.03 * PEC	3,677
Total Indirect Costs (IC)			3,677
TOTAL CAPITAL INVESTMENT = DC + IC			**126,243**
Direct Annual Costs			
Operating Labor			
	Operator	Negligible	----
	Supervisor	Negligible	----
	Total Operating Labor		----
Maintenance			
	Labor	----	----
	Materials	----	----
	Total Maintenance[4]	0.005 * TCI	631
Utilities			
	Electricity	Negligible	----
	Water	----	----
	Reagent	----	----
	Total Utilities		----
Catalyst Cost			
	Catalyst Replacement	Catalyst life > DOC Service Life	----
	Total Catalyst Cost	----	----
Miscellaneous			
	Performance Tests	----	----
	Record Keeping & Reporting	----	----
	Total Miscellaneous Costs		----
Total Direct Annual Costs (DAC)			**631**
Indirect Annual Costs			
Overhead[5]		60% of operating, supervisor, maintenance labor & materials	379
Administrative Charges[6]		0.02 * TCI	2,525
Capital Recovery Factor[7]		CRF	0.0640
Capital Recovery		CRF * TCI	8,081
Total Indirect Annual Costs (IAC)			**10,985**
TOTAL ANNUAL COST = DAC + IAC			**11,616**
Uncontrolled NOx, CO, VOC, and PM emissions		tons/yr	1.14
NOx, CO, VOC, and PM Emissions with DPF & DOC Controls		tons/yr	0.88
Percent reduction from uncontrolled			23%
Total emissions reduction		tons/yr	0.26
Cost per Ton Controlled		**$/ton**	**44,923**

[1] Capital cost provided by the engine vendor (Brent Briody of Western States Equipment Co.)
[2] Washington sales tax
[3] Minimum cost from most recent Sabey, Vantage, and Cyrus One cost-effectiveness analyses
[4] Estimated using equations from EPA's Air Pollution Control Cost Estimation Spreadsheet for Selective Catalytic Reduction (SCR) found at https://www.epa.gov/sites/production/files/2019-06/scrcostmanualspreadsheet_june-2019v1.xlsm
[5] EPA's Air Pollution Control Cost Manual, Section 1, Chapter 2 (Cost Estimation), Section 2.6.5.7
[6] EPA's Air Pollution Control Cost Manual, Section 1, Chapter 2 (Cost Estimation), Section 2.6.5.8
[7] The capital recovery factor was calculated assuming a 25-year equipment life and a 4% interest rate

TABLE B2.2-15a
COST EFFECTIVENESS CALCULATIONS
Toxic Air Pollutants
Diesel Particulate Filter (DPF)/Diesel Oxidation Catalyst (DOC) Control System
Diesel-Fired 2.25 MW Emergency Generator
Operating Hours 55 hours/year

TAP Avg Period [1]	Toxic Air Pollutant	Emission Factor [2] (lb/MMBTU)	Uncontrolled Emissions (tpy)	Control Factor [3]	Emission Reduction (tpy)	Cost-Effectiveness [4] ($/ton)
24-Hour	Acrolein	7.88E-06	4.98E-06	0.70	3.48E-06	8,032,704
	Toluene	2.81E-04	1.77E-04	0.70	1.24E-04	
	Xylenes	1.93E-04	1.22E-04	0.70	8.53E-05	
	Propylene	2.79E-03	1.76E-03	0.70	1.23E-03	
Annual	Benzene	7.76E-04	4.90E-04	0.70	3.43E-04	533,041
	Formaldehyde	7.89E-05	4.98E-05	0.70	3.49E-05	
	Acetaldehyde	2.52E-05	1.59E-05	0.70	1.11E-05	
	Naphthalene	1.30E-04	8.21E-05	0.70	5.75E-05	
	Benz(a)anthracene	6.22E-07	3.93E-07	0.70	2.75E-07	
	Chrysene	1.53E-06	9.66E-07	0.70	6.76E-07	
	Benz(b)fluoranthcene	1.11E-06	7.01E-07	0.70	4.91E-07	
	Benz(k)fluoranthcene	2.18E-07	1.38E-07	0.70	9.63E-08	
	Benzo(a)pyrene	2.57E-07	1.62E-07	0.70	1.14E-07	
	Indeno(1,2,3-cd)pyrene	4.14E-07	2.61E-07	0.70	1.83E-07	
	Dibenz(a,h)anthracene	3.46E-07	2.18E-07	0.70	1.53E-07	
	DPM	--	2.43E-02	0.88	2.13E-02	

[1] ASIL information from WAC 173-460

[2] SO2, NO2, CO, and DPM based on criteria pollutant emission calculations, assuming 90% of NOx as NO2. Other TAPs from AP-42 Chapter 3.4 (Large Stationary Diesel Engines)

[3] Control factors used in recent Sabey, Vantage, and Cyrus One data center NOC applications.

[4] Cost-effectiveness based on total annual control cost and emission reduction by TAP averaging period group.

TABLE B2.2-16a
COST EFFECTIVENESS CALCULATIONS
Criteria Air Pollutants
Diesel Particulate Filter (DPF) Control System
Diesel-Fired 400 kW Emergency Generator
Operating Hours 55 hours/year

Cost Item			Factor	Cost
Direct Costs				
Purchased Equipment Costs				
	Primary Equipment[1]		A	33,344
	Sales Tax[2]		B = 0.065 * A	2,167
	Shipping		Included in A	-----
		Purchased Equipment Cost (PEC)	PEC = A + B	35,512
Direct Installation Costs				
	Foundations & Supports		Included in A	-----
	Handling & Erection		Included in A	-----
	Electrical		Included in A	-----
	Piping		Included in A	-----
	Insulation for Ductwork		Included in A	-----
	Painting		Included in A	-----
		Direct Installation Cost	Included in A	-----
Total Direct Costs (DC)				35,512
Indirect Costs				
Installation				
	Engineering		Included in A	-----
	Construction & Field Expenses		Included in A	-----
	Contractor Fees		Included in A	-----
	Start-Up		Included in A	-----
	Contingencies[3]		0.03 * PEC	1,065
Total Indirect Costs (IC)				1,065
TOTAL CAPITAL INVESTMENT = DC + IC				**36,577**
Direct Annual Costs				
Operating Labor				
	Operator		Negligible	-----
	Supervisor		Negligible	-----
		Total Operating Labor		-----
Maintenance				
	Labor		-----	-----
	Materials		-----	-----
		Total Maintenance[4]	0.005 * TCI	183
Utilities				
	Electricity		Negligible	-----
	Water		-----	-----
	Reagent		-----	-----
		Total Utilities		-----
Catalyst Cost				
	Catalyst Replacement		-----	-----
		Total Catalyst Cost	-----	-----
Miscellaneous				
	Performance Tests		-----	-----
	Record Keeping & Reporting		-----	-----
		Total Miscellaneous Costs		-----
Total Direct Annual Costs (DAC)				**183**
Indirect Annual Costs				
Overhead[6]			60% of operating, supervisor, maintenance labor & materials	110
Administrative Charges[5]			0.02 * TCI	732
Capital Recovery Factor[7]			CRF	0.0640
Capital Recovery			CRF * TCI	2,341
Total Indirect Annual Costs (IAC)				**3,183**
TOTAL ANNUAL COST = DAC + IAC				**3,366**
Uncontrolled NOx, CO, VOC, and PM emissions			tons/yr	0.11
NOx, CO, VOC, and PM Emissions with DPF			tons/yr	0.10
Percent reduction from uncontrolled				16%
Total emissions reduction			tons/yr	0.02
Cost per Ton Controlled			**$/ton**	**186,482**

[1] Captial cost provided by the engine vendor (Brant Briody of Western States Equipment Co.)
[2] Washington sales tax
[3] Minimum cost from most recent Sabey, Vantage, and Cyrus One cost-effectiveness analyses
[4] Estimated using equations from EPA's Air Pollution Control Cost Estimation Spreadsheet for Selective Catalytic Reduction (SCR) found at https://www.epa.gov/sites/production/files/2019-06/scrc ostmanualspreadsheet_june-2019vf.xlsm
[5] EPA's Air Pollution Control Cost Manual, Section 1, Chapter 2 (Cost Estimation), Section 2.6.5.7
[6] EPA's Air Pollution Control Cost Manual, Section 1, Chapter 2 (Cost Estimation), Section 2.6.5.8
[7] The capital recovery factor was calculated assuming a 25-year equipment life and a 4% interest rate

TABLE B2.2-16a
COST EFFECTIVENESS CALCULATIONS
Toxic Air Pollutants
Diesel Particulate Filter (DPF) Control System
Diesel-Fired 400 kW Emergency Generator
Operating Hours 55 hours/year

TAP Avg Period [1]	Toxic Air Pollutant	Emission Factor [2] (lb/MMBTU)	Uncontrolled Emissions (tpy)	Control Factor [3]	Emission Reduction (tpy)	Cost-Effectiveness [4] ($/ton)
24-Hour	Acrolein	7.88E-06	9.11E-07	0.70	6.38E-07	12,709,185
	Toluene	2.81E-04	3.25E-05	0.70	2.27E-05	
	Xylenes	1.93E-04	2.23E-05	0.70	1.56E-05	
	Propylene	2.79E-03	3.23E-04	0.70	2.26E-04	
Annual	Benzene	7.76E-04	8.97E-05	0.70	6.28E-05	1,298,140
	Formaldehyde	7.89E-05	9.12E-06	0.70	6.39E-06	
	Acetaldehyde	2.52E-05	2.91E-06	0.70	2.04E-06	
	Naphthalene	1.30E-04	1.50E-05	0.70	1.05E-05	
	Benz(a)anthracene	6.22E-07	7.19E-08	0.70	5.03E-08	
	Chrysene	1.53E-06	1.77E-07	0.70	1.24E-07	
	Benz(b)fluoranthcene	1.11E-06	1.28E-07	0.70	8.98E-08	
	Benz(k)fluoranthcene	2.18E-07	2.52E-08	0.70	1.76E-08	
	Benzo(a)pyrene	2.57E-07	2.97E-08	0.70	2.08E-08	
	Indeno(1,2,3-cd)pyrene	4.14E-07	4.79E-08	0.70	3.35E-08	
	Dibenz(a,h)anthracene	3.46E-07	4.00E-08	0.70	2.80E-08	
	DPM	--	2.79E-03	0.90	2.51E-03	

[1] ASIL information from WAC 173-460
[2] SO2, NO2, CO, and DPM based on criteria pollutant emission calculations, assuming 90% of NOx as NO2. Other TAPs from AP-42 Chapter 3.4 (Large Stationary Diesel Engines)
[3] Control factors used in recent Sabey, Vantage, and Cyrus One data center NOC applications.
[4] Cost-effectiveness based on total annual control cost and emission reduction by TAP averaging period group.

TABLE B2.2-17a
COST EFFECTIVENESS CALCULATIONS
Criteria Air Pollutants
Diesel Particulate Filter (DPF) Control System
Diesel-Fired 750 kW Emergency Generator
Operating Hours 55 hours/year

Cost Item			Factor	Cost
Direct Costs				
Purchased Equipment Costs				
	Primary Equipment[1]		A	47,480
	Sales Tax[2]		B = 0.065 * A	3,086
	Shipping		Included in A	----
		Purchased Equipment Cost (PEC)	PEC = A + B	50,567
Direct Installation Costs				
	Foundations & Supports		Included in A	----
	Handling & Erection		Included in A	----
	Electrical		Included in A	----
	Piping		Included in A	----
	Insulation for Ductwork		Included in A	----
	Painting		Included in A	----
		Direct Installation Cost	Included in A	----
Total Direct Costs (DC)				50,567
Indirect Costs				
Installation				
	Engineering		Included in A	----
	Construction & Field Expenses		Included in A	----
	Contractor Fees		Included in A	----
	Start-Up		Included in A	----
	Contingencies[3]		0.03 * PEC	1,517
Total Indirect Costs (IC)				1,517
TOTAL CAPITAL INVESTMENT = DC + IC				**52,084**
Direct Annual Costs				
Operating Labor				
	Operator		Negligible	----
	Supervisor		Negligible	----
		Total Operating Labor		----
Maintenance				
	Labor		----	----
	Materials		----	----
		Total Maintenance[4]	0.005 * TCI	260
Utilities				
	Electricity		Negligible	----
	Water		----	----
	Reagent		----	----
		Total Utilities		----
Catalyst Cost				
	Catalyst Replacement		----	----
		Total Catalyst Cost	----	----
Miscellaneous				
	Performance Tests		----	----
	Record Keeping & Reporting		----	----
		Total Miscellaneous Costs		----
Total Direct Annual Costs (DAC)				**260**
Indirect Annual Costs				
Overhead[5]			60% of operating, supervisor, maintenance labor & materials	156
Administrative Charges[6]			0.02 * TCI	1,042
Capital Recovery Factor[7]			CRF	0.0640
Capital Recovery			CRF * TCI	3,334
Total Indirect Annual Costs (IAC)				**4,532**
TOTAL ANNUAL COST = DAC + IAC				**4,792**
Uncontrolled NOx, CO, VOC, and PM emissions			tons/yr	0.43
NOx, CO, VOC, and PM Emissions with DPF			tons/yr	0.40
Percent reduction from uncontrolled				7%
Total emissions reduction			tons/yr	0.03
Cost per Ton Controlled			**$/ton**	**154,869**

[1] Capital cost provided by the engine vendor (Brant Briody of Western States Equipment Co.)
[2] Washington sales tax
[3] Minimum cost from most recent Sabey, Vantage, and Cyrus One cost-effectiveness analyses
[4] Estimated using equations from EPA's Air Pollution Control Cost Estimation Spreadsheet for Selective Catalytic Reduction (SCR) found at https://www.epa.gov/sites/production/files/2019-06/scrcostmanualspreadsheet_june-2019vf.xlsm
[5] EPA's Air Pollution Control Cost Manual, Section 1, Chapter 2 (Cost Estimation), Section 2.6.5.7
[6] EPA's Air Pollution Control Cost Manual, Section 1, Chapter 2 (Cost Estimation), Section 2.6.5.8
[7] The capital recovery factor was calculated assuming a 25-year equipment life and a 4% interest rate

TABLE B2.2-17a
COST EFFECTIVENESS CALCULATIONS
Toxic Air Pollutants
Diesel Particulate Filter (DPF) Control System
Diesel-Fired 750 kW Emergency Generator
Operating Hours 55 hours/year

TAP Avg Period [1]	Toxic Air Pollutant	Emission Factor [2] (lb/MMBTU)	Uncontrolled Emissions (tpy)	Control Factor [3]	Emission Reduction (tpy)	Cost-Effectiveness [4] ($/ton)
24-Hour	Acrolein	7.88E-06	1.60E-06	0.70	1.12E-06	10,331,565
	Toluene	2.81E-04	5.69E-05	0.70	3.98E-05	
	Xylenes	1.93E-04	3.91E-05	0.70	2.74E-05	
	Propylene	2.79E-03	5.65E-04	0.70	3.96E-04	
Annual	Benzene	7.76E-04	1.57E-04	0.70	1.10E-04	1,266,356
	Formaldehyde	7.89E-05	1.60E-05	0.70	1.12E-05	
	Acetaldehyde	2.52E-05	5.10E-06	0.70	3.57E-06	
	Naphthalene	1.30E-04	2.63E-05	0.70	1.84E-05	
	Benz(a)anthracene	6.22E-07	1.26E-07	0.70	8.82E-08	
	Chrysene	1.53E-06	3.10E-07	0.70	2.17E-07	
	Benz(b)fluoranthcene	1.11E-06	2.25E-07	0.70	1.57E-07	
	Benz(k)fluoranthcene	2.18E-07	4.42E-08	0.70	3.09E-08	
	Benzo(a)pyrene	2.57E-07	5.20E-08	0.70	3.64E-08	
	Indeno(1,2,3-cd)pyrene	4.14E-07	8.38E-08	0.70	5.87E-08	
	Dibenz(a,h)anthracene	3.46E-07	7.01E-08	0.70	4.91E-08	
	DPM	--	4.05E-03	0.90	3.64E-03	

[1] ASIL information from WAC 173-460
[2] SO2, NO2, CO, and DPM based on criteria pollutant emission calculations, assuming 90% of NOx as NO2. Other TAPs from AP-42 Chapter 3.4 (Large Stationary Diesel Engines)
[3] Control factors used in recent Sabey, Vantage, and Cyrus One data center NOC applications.
[4] Cost-effectiveness based on total annual control cost and emission reduction by TAP averaging period group.

TABLE B2.2-18a
COST EFFECTIVENESS CALCULATIONS
Criteria Air Pollutants
Diesel Particulate Filter (DPF) Control System
Diesel-Fired 1.25 MW Caterpillar Emergency Generator
Operating Hours 55 hours/year

Cost Item		Factor	Cost
Direct Costs			
Purchased Equipment Costs			
	Primary Equipment[1]	A	64,000
	Sales Tax[2]	B = 0.065 * A	4,160
	Shipping	Included in A	----
	Purchased Equipment Cost (PEC)	PEC = A + B	68,160
Direct Installation Costs			
	Foundations & Supports	Included in A	----
	Handling & Erection	Included in A	----
	Electrical	Included in A	----
	Piping	Included in A	----
	Insulation for Ductwork	Included in A	----
	Painting	Included in A	----
	Direct Installation Cost	Included in A	----
Total Direct Costs (DC)			68,160
Indirect Costs			
Installation			
	Engineering	Included in A	----
	Construction & Field Expenses	Included in A	----
	Contractor Fees	Included in A	----
	Start-Up	Included in A	----
	Contingencies[3]	0.03 * PEC	2,045
Total Indirect Costs (IC)			2,045
TOTAL CAPITAL INVESTMENT = DC + IC			**70,205**
Direct Annual Costs			
Operating Labor			
	Operator	Negligible	----
	Supervisor	Negligible	----
	Total Operating Labor		----
Maintenance			
	Labor	----	----
	Materials	----	----
	Total Maintenance[4]	0.005 * TCI	351
Utilities			
	Electricity	Negligible	----
	Water	----	----
	Reagent	----	----
	Total Utilities		----
Catalyst Cost			
	Catalyst Replacement	----	----
	Total Catalyst Cost	----	----
Miscellaneous			
	Performance Tests	----	----
	Record Keeping & Reporting	----	----
	Total Miscellaneous Costs		----
Total Direct Annual Costs (DAC)			**351**
Indirect Annual Costs			
Overhead[5]		60% of operating, supervisor, maintenance labor & materials	211
Administrative Charges[6]		0.02 * TCI	1,404
Capital Recovery Factor[7]		CRF	0.0640
Capital Recovery		CRF * TCI	4,494
Total Indirect Annual Costs (IAC)			**6,109**
TOTAL ANNUAL COST = DAC + IAC			**6,460**
Uncontrolled NOx, CO, VOC, and PM emissions		tons/yr	0.72
NOx, CO, VOC, and PM Emissions with DPF		tons/yr	0.70
Percent reduction from uncontrolled			4%
Total emissions reduction		tons/yr	0.03
Cost per Ton Controlled		**$/ton**	**227,559**

[1] Capital cost provided by the engine vendor (Brant Briody of Western States Equipment Co.)
[2] Washington sales tax
[3] Minimum cost from most recent Sabey, Vantage, and Cyrus One cost-effectiveness analyses
[4] Estimated using equations from EPA's Air Pollution Control Cost Estimation Spreadsheet for Selective Catalytic Reduction (SCR) found at https://www.epa.gov/sites/production/files/2019-06/scrcostmanualspreadsheet_june-2019vf.xlsm
[5] EPA's Air Pollution Control Cost Manual, Section 1, Chapter 2 (Cost Estimation), Section 2.6.5.7
[6] EPA's Air Pollution Control Cost Manual, Section 1, Chapter 2 (Cost Estimation), Section 2.6.5.8
[7] The capital recovery factor was calculated assuming a 25-year equipment life and a 4% interest rate

TABLE B2.2-18a
COST EFFECTIVENESS CALCULATIONS
Toxic Air Pollutants
Diesel Particulate Filter (DPF) Control System
Diesel-Fired 1.25 MW Caterpillar Emergency Generator
Operating Hours 55 hours/year

TAP Avg Period [1]	Toxic Air Pollutant	Emission Factor [2] (lb/MMBTU)	Uncontrolled Emissions (tpy)	Control Factor [3]	Emission Reduction (tpy)	Cost-Effectiveness [4] ($/ton)
24-Hour	Acrolein	7.88E-06	2.60E-06	0.70	1.82E-06	8,540,530
	Toluene	2.81E-04	9.28E-05	0.70	6.50E-05	
	Xylenes	1.93E-04	6.37E-05	0.70	4.46E-05	
	Propylene	2.79E-03	9.21E-04	0.70	6.45E-04	
Annual	Benzene	7.76E-04	2.56E-04	0.70	1.79E-04	2,896,084
	Formaldehyde	7.89E-05	2.61E-05	0.70	1.82E-05	
	Acetaldehyde	2.52E-05	8.32E-06	0.70	5.83E-06	
	Naphthalene	1.30E-04	4.29E-05	0.70	3.01E-05	
	Benz(a)anthracene	6.22E-07	2.05E-07	0.70	1.44E-07	
	Chrysene	1.53E-06	5.05E-07	0.70	3.54E-07	
	Benz(b)fluoranthcene	1.11E-06	3.67E-07	0.70	2.57E-07	
	Benz(k)fluoranthcene	2.18E-07	7.20E-08	0.70	5.04E-08	
	Benzo(a)pyrene	2.57E-07	8.49E-08	0.70	5.94E-08	
	Indeno(1,2,3-cd)pyrene	4.14E-07	1.37E-07	0.70	9.57E-08	
	Dibenz(a,h)anthracene	3.46E-07	1.14E-07	0.70	8.00E-08	
	DPM	–	2.22E-03	0.90	2.00E-03	

[1] ASIL information from WAC 173-460
[2] SO2, NO2, CO, and DPM based on criteria pollutant emission calculations, assuming 90% of NOx as NO2. Other TAPs from AP-42 Chapter 3.4 (Large Stationary Diesel Engines)
[3] Control factors used in recent Sabey, Vantage, and Cyrus One data center NOC applications.
[4] Cost-effectiveness based on total annual control cost and emission reduction by TAP averaging period group.

TABLE B2.2-19a
COST EFFECTIVENESS CALCULATIONS
Criteria Air Pollutants
Diesel Particulate Filter (DPF) Control System
Diesel-Fired 1.25 MW Generac Emergency Generator
Operating Hours 55 hours/year

Cost Item		Factor	Cost
Direct Costs			
Purchased Equipment Costs			
	Primary Equipment[1]	A	65,086
	Sales Tax[2]	B = 0.065 * A	4,231
	Shipping	Included in A	----
	Purchased Equipment Cost (PEC)	PEC = A + B	69,316
Direct Installation Costs			
	Foundations & Supports	Included in A	----
	Handling & Erection	Included in A	----
	Electrical	Included in A	----
	Piping	Included in A	----
	Insulation for Ductwork	Included in A	----
	Painting	Included in A	----
	Direct Installation Cost	Included in A	----
Total Direct Costs (DC)			69,316
Indirect Costs			
Installation			
	Engineering	Included in A	----
	Construction & Field Expenses	Included in A	----
	Contractor Fees	Included in A	----
	Start-Up	Included in A	----
	Contingencies[3]	0.03 * PEC	2,079
Total Indirect Costs (IC)			2,079
TOTAL CAPITAL INVESTMENT = DC + IC			**71,396**
Direct Annual Costs			
Operating Labor			
	Operator	Negligible	----
	Supervisor	Negligible	----
	Total Operating Labor		----
Maintenance			
	Labor	----	----
	Materials	----	----
	Total Maintenance[4]	0.005 * TCI	357
Utilities			
	Electricity	Negligible	----
	Water	----	----
	Reagent	----	----
	Total Utilities		----
Catalyst Cost			
	Catalyst Replacement	----	----
	Total Catalyst Cost	----	----
Miscellaneous			
	Performance Tests	----	----
	Record Keeping & Reporting	----	----
	Total Miscellaneous Costs		----
Total Direct Annual Costs (DAC)			**357**
Indirect Annual Costs			
Overhead[5]		60% of operating, supervisor, maintenance labor & materials	214
Administrative Charges[6]		0.02 * TCI	1,428
Capital Recovery Factor[7]		CRF	0.0640
Capital Recovery		CRF * TCI	4,570
Total Indirect Annual Costs (IAC)			**6,212**
TOTAL ANNUAL COST = DAC + IAC			**6,569**
Uncontrolled NOx, CO, VOC, and PM emissions		tons/yr	0.54
NOx, CO, VOC, and PM Emissions with DPF		tons/yr	0.45
Percent reduction from uncontrolled			16%
Total emissions reduction		tons/yr	0.09
Cost per Ton Controlled		**$/ton**	**76,334**

[1] Captial cost provided by the engine vendor (Brant Briody of Western States Equipment Co.)
[2] Washington sales tax
[3] Minimum cost from most recent Sabey, Vantage, and Cyrus One cost-effectiveness analyses
[4] Estimated using equations from EPA's Air Pollution Control Cost Estimation Spreadsheet for Selective Catalytic Reduction (SCR) found at https://www.epa.gov/sites/production/files/2019-09/scrcostmanualspreadsheet_june-2019vf.xlsm
[5] EPA's Air Pollution Control Cost Manual, Section 1, Chapter 2 (Cost Estimation), Section 2.6.5.7
[6] EPA's Air Pollution Control Cost Manual, Section 1, Chapter 2 (Cost Estimation), Section 2.6.5.8
[7] The capital recovery factor was calculated assuming a 25-year equipment life and a 4% interest rate

TABLE B2.2-19a
COST EFFECTIVENESS CALCULATIONS
Toxic Air Pollutants
Diesel Particulate Filter (DPF) Control System
Diesel-Fired 1.25 MW Generac Emergency Generator
Operating Hours 55 hours/year

TAP Avg Period [1]	Toxic Air Pollutant	Emission Factor [2] (lb/MMBTU)	Uncontrolled Emissions (tpy)	Control Factor [3]	Emission Reduction (tpy)	Cost-Effectiveness [4] ($/ton)
24-Hour	Acrolein	7.88E-06	3.39E-06	0.70	2.38E-06	6,658,808
	Toluene	2.81E-04	1.21E-04	0.70	8.47E-05	
	Xylenes	1.93E-04	8.31E-05	0.70	5.82E-05	
	Propylene	2.79E-03	1.20E-03	0.70	8.41E-04	
Annual	Benzene	7.76E-04	3.34E-04	0.70	2.34E-04	596,079
	Formaldehyde	7.89E-05	3.40E-05	0.70	2.38E-05	
	Acetaldehyde	2.52E-05	1.09E-05	0.70	7.60E-06	
	Naphthalene	1.30E-04	5.60E-05	0.70	3.92E-05	
	Benz(a)anthracene	6.22E-07	2.68E-07	0.70	1.88E-07	
	Chrysene	1.53E-06	6.59E-07	0.70	4.61E-07	
	Benz(b)fluoranthcene	1.11E-06	4.78E-07	0.70	3.35E-07	
	Benz(k)fluoranthcene	2.18E-07	9.39E-08	0.70	6.57E-08	
	Benzo(a)pyrene	2.57E-07	1.11E-07	0.70	7.75E-08	
	Indeno(1,2,3-cd)pyren	4.14E-07	1.78E-07	0.70	1.25E-07	
	Dibenz(a,h)anthracene	3.46E-07	1.49E-07	0.70	1.04E-07	
	DPM	--	1.19E-02	0.90	1.07E-02	

[1] ASIL information from WAC 173-460
[2] SO2, NO2, CO, and DPM based on criteria pollutant emission calculations, assuming 90% of NOx as NO2. Other TAPs from AP-42 Chapter 3.4 (Large Stationary Diesel Engines)
[3] Control factors used in recent Sabey, Vantage, and Cyrus One data center NOC applications
[4] Cost-effectiveness based on total annual control cost and emission reduction by TAP averaging period group.

TABLE B2.2-20a
COST EFFECTIVENESS CALCULATIONS
Criteria Air Pollutants
Diesel Particulate Filter (DPF) Control System
Diesel-Fired 2.25 MW Emergency Generator
Operating Hours 55 hours/year

Cost Item		Factor	Cost
Direct Costs			
Purchased Equipment Costs			
	Primary Equipment[1]	A	92,069
	Sales Tax[2]	B = 0.065 * A	5,984
	Shipping	Included in A	----
	Purchased Equipment Cost (PEC)	PEC = A + B	98,053
Direct Installation Costs			
	Foundations & Supports	Included in A	----
	Handling & Erection	Included in A	----
	Electrical	Included in A	----
	Piping	Included in A	----
	Insulation for Ductwork	Included in A	----
	Painting	Included in A	----
	Direct Installation Cost	Included in A	----
Total Direct Costs (DC)			98,053
Indirect Costs			
Installation			
	Engineering	Included in A	----
	Construction & Field Expenses	Included in A	----
	Contractor Fees	Included in A	----
	Start-Up	Included in A	----
	Contingencies[3]	0.03 * PEC	2,942
Total Indirect Costs (IC)			2,942
TOTAL CAPITAL INVESTMENT = DC + IC			**100,995**
Direct Annual Costs			
Operating Labor			
	Operator	Negligible	----
	Supervisor	Negligible	----
	Total Operating Labor		----
Maintenance			
	Labor	----	----
	Materials	----	----
	Total Maintenance[4]	0.005 * TCI	505
Utilities			
	Electricity	Negligible	----
	Water	----	----
	Reagent	----	----
	Total Utilities		----
Catalyst Cost			
	Catalyst Replacement	----	----
	Total Catalyst Cost	----	----
Miscellaneous			
	Performance Tests	----	----
	Record Keeping & Reporting	----	----
	Total Miscellaneous Costs		----
Total Direct Annual Costs (DAC)			**505**
Indirect Annual Costs			
Overhead[5]		60% of operating, supervisor, maintenance labor & materials	303
Administrative Charges[6]		0.02 * TCI	2,020
Capital Recovery Factor[7]		CRF	0.0640
Capital Recovery		CRF * TCI	6,465
Total Indirect Annual Costs (IAC)			**8,788**
TOTAL ANNUAL COST = DAC + IAC			**9,293**
Uncontrolled NOx, CO, VOC, and PM emissions		tons/yr	1.14
NOx, CO, VOC, and PM Emissions with DPF		tons/yr	0.88
Percent reduction from uncontrolled			23%
Total emissions reduction		tons/yr	0.26
Cost per Ton Controlled		**$/ton**	**35,871**

[1] Capital cost provided by the engine vendor (Brant Briody of Western States Equipment Co.)
[2] Washington sales tax
[3] Minimum cost from most recent Sabey, Vantage, and Cyrus One cost-effectiveness analyses
[4] Estimated using equations from EPA's Air Pollution Control Cost Estimation Spreadsheet for Selective Catalytic Reduction (SCR) found at https://www.epa.gov/sites/production/files/2019-09/scrcostmanualspreadsheet_june-2019v5.xlsm
[5] EPA's Air Pollution Control Cost Manual, Section 1, Chapter 2 (Cost Estimation), Section 2.6.5.7
[6] EPA's Air Pollution Control Cost Manual, Section 1, Chapter 2 (Cost Estimation), Section 2.6.5.8
[7] The capital recovery factor was calculated assuming a 25-year equipment life and a 4% interest rate

TABLE B2.2-20a
COST EFFECTIVENESS CALCULATIONS
Toxic Air Pollutants
Diesel Particulate Filter (DPF) Control System
Diesel-Fired 2.25 MW Emergency Generator
Operating Hours 55 hours/year

TAP Avg Period [1]	Toxic Air Pollutant	Emission Factor [2] (lb/MMBTU)	Uncontrolled Emissions (tpy)	Control Factor [3]	Emission Reduction (tpy)	Cost-Effectiveness [4] ($/ton)
24-Hour	Acrolein	7.88E-06	4.98E-06	0.70	3.48E-06	6,426,163
	Toluene	2.81E-04	1.77E-04	0.70	1.24E-04	
	Xylenes	1.93E-04	1.22E-04	0.70	8.53E-05	
	Propylene	2.79E-03	1.76E-03	0.70	1.23E-03	
Annual	Benzene	7.76E-04	4.90E-04	0.70	3.43E-04	417,147
	Formaldehyde	7.89E-05	4.98E-05	0.70	3.49E-05	
	Acetaldehyde	2.52E-05	1.59E-05	0.70	1.11E-05	
	Naphthalene	1.30E-04	8.21E-05	0.70	5.75E-05	
	Benz(a)anthracene	6.22E-07	3.93E-07	0.70	2.75E-07	
	Chrysene	1.53E-06	9.66E-07	0.70	6.76E-07	
	Benz(b)fluoranthcene	1.11E-06	7.01E-07	0.70	4.91E-07	
	Benz(k)fluoranthcene	2.18E-07	1.38E-07	0.70	9.63E-08	
	Benzo(a)pyrene	2.57E-07	1.62E-07	0.70	1.14E-07	
	Indeno(1,2,3-cd)pyren	4.14E-07	2.61E-07	0.70	1.83E-07	
	Dibenz(a,h)anthracen	3.46E-07	2.18E-07	0.70	1.53E-07	
	DPM	--	2.43E-02	0.90	2.18E-02	

[1] ASIL information from WAC 173-460
[2] SO2, NO2, CO, and DPM based on criteria pollutant emission calculations, assuming 90% of NOx as NO2. Other TAPs from AP-42 Chapter 3.4 (Large Stationary Diesel Engines)
[3] Control factors used in recent Sabey, Vantage, and Cyrus One data center NOC applications
[4] Cost-effectiveness based on total annual control cost and emission reduction by TAP averaging period group.

TABLE B2.2-21a
COST EFFECTIVENESS CALCULATIONS
Criteria Air Pollutants
Diesel Oxidation Catalyst (DOC) Control System
Diesel-Fired 400 kW Emergency Generator
Operating Hours 55 hours/year

Cost Item		Factor	Cost
Direct Costs			
Purchased Equipment Costs			
	Primary Equipment[1]	A	8,336
	Sales Tax[2]	B = 0.065 * A	542
	Shipping	Included in A	----
	Purchased Equipment Cost (PEC)	PEC = A + B	8,878
Direct Installation Costs			
	Foundations & Supports	Included in A	----
	Handling & Erection	Included in A	----
	Electrical	Included in A	----
	Piping	Included in A	----
	Insulation for Ductwork	Included in A	----
	Painting	Included in A	----
	Direct Installation Cost	Included in A	----
Total Direct Costs (DC)			8,878
Indirect Costs			
Installation			
	Engineering	Included in A	----
	Construction & Field Expenses	Included in A	----
	Contractor Fees	Included in A	----
	Start-Up	Included in A	----
	Contingencies[3]	0.03 * PEC	266
Total Indirect Costs (IC)			266
TOTAL CAPITAL INVESTMENT = DC + IC			**9,144**
Direct Annual Costs			
Operating Labor			
	Operator	Negligible	----
	Supervisor	Negligible	----
	Total Operating Labor		----
Maintenance			
	Labor	----	----
	Materials	----	----
	Total Maintenance[4]	0.005 * TCI	46
Utilities			
	Electricity	Negligible	----
	Water	----	----
	Reagent	----	----
	Total Utilities		----
Catalyst Cost			
	Catalyst Replacement	Catalyst life > DOC Service Life	----
	Total Catalyst Cost	----	----
Miscellaneous			
	Performance Tests	----	----
	Record Keeping & Reporting	----	----
	Total Miscellaneous Costs		----
Total Direct Annual Costs (DAC)			**46**
Indirect Annual Costs			
Overhead[5]		60% of operating, supervisor, maintenance labor & materials	27
Administrative Charges[6]		0.02 * TCI	183
Capital Recovery Factor[7]		CRF	0.0640
Capital Recovery		CRF * TCI	585
Total Indirect Annual Costs (IAC)			**796**
TOTAL ANNUAL COST = DAC + IAC			**841**
Uncontrolled NOx, CO, VOC, and PM emissions		tons/yr	0.11
NOx, CO, VOC, and PM Emissions with DOC		tons/yr	0.10
Percent reduction from uncontrolled			14%
Total emissions reduction		tons/yr	0.02
Cost per Ton Controlled		**$/ton**	**51,827**

[1] Captial cost provided by the engine vendor (Brant Briody of Western States Equipment Co.)
[2] Washington sales tax
[3] Minimum cost from most recent Sabey, Vantage, and Cyrus One cost-effectiveness analyses
[4] Estimated using equations from EPA's Air Pollution Control Cost Estimation Spreadsheet for Selective Catalytic Reduction (SCR) found at https://www.epa.gov/sites/production/files/2019-08/scrcostmanualspreadsheet_june-2019vf.xlsm
[5] EPA's Air Pollution Control Cost Manual, Section 1, Chapter 2 (Cost Estimation), Section 2.6.5.7
[6] EPA's Air Pollution Control Cost Manual, Section 1, Chapter 2 (Cost Estimation), Section 2.6.5.8
[7] The capital recovery factor was calculated assuming a 25-year equipment life and a 4% interest rate

TABLE B2.2-21a
COST EFFECTIVENESS CALCULATIONS
Toxic Air Pollutants
Diesel Oxidation Catalyst (DOC) Control System
Diesel-Fired 400 kW Emergency Generator
Operating Hours 55 hours/year

TAP Avg Period [1]	Toxic Air Pollutant	Emission Factor [2] (lb/MMBTU)	Uncontrolled Emissions (tpy)	Control Factor [3]	Emission Reduction (tpy)	Cost-Effectiveness [4] ($/ton)
24-Hour	Acrolein	7.88E-06	9.11E-07	0.70	6.38E-07	3,177,296
	Toluene	2.81E-04	3.25E-05	0.70	2.27E-05	
	Xylenes	1.93E-04	2.23E-05	0.70	1.56E-05	
	Propylene	2.79E-03	3.23E-04	0.70	2.26E-04	
Annual	Benzene	7.76E-04	8.97E-05	0.70	6.28E-05	1,079,432
	Formaldehyde	7.89E-05	9.12E-06	0.70	6.39E-06	
	Acetaldehyde	2.52E-05	2.91E-06	0.70	2.04E-06	
	Naphthalene	1.30E-04	1.50E-05	0.70	1.05E-05	
	Benz(a)anthracene	6.22E-07	7.19E-08	0.70	5.03E-08	
	Chrysene	1.53E-06	1.77E-07	0.70	1.24E-07	
	Benz(b)fluoranthcene	1.11E-06	1.28E-07	0.70	8.98E-08	
	Benz(k)fluoranthcene	2.18E-07	2.52E-08	0.70	1.76E-08	
	Benzo(a)pyrene	2.57E-07	2.97E-08	0.70	2.08E-08	
	Indeno(1,2,3-cd)pyrene	4.14E-07	4.79E-08	0.70	3.35E-08	
	Dibenz(a,h)anthracene	3.46E-07	4.00E-08	0.70	2.80E-08	
	DPM	--	2.79E-03	0.25	6.97E-04	

[1] ASIL information from WAC 173-460
[2] SO2, NO2, CO, and DPM based on criteria pollutant emission calculations, assuming 90% of NOx as NO2. Other TAPs from AP-42 Chapter 3.4 (Large Stationary Diesel Engines)
[3] Control factors used in recent Sabey, Vantage, and Cyrus One data center NOC applications.
[4] Cost-effectiveness based on total annual control cost and emission reduction by TAP averaging period group.

TABLE B2.2-22a
COST EFFECTIVENESS CALCULATIONS
Criteria Air Pollutants
Diesel Oxidation Catalyst (DOC) Control System
Diesel-Fired 750 kW Emergency Generator
Operating Hours 55 hours/year

Cost Item			Factor	Cost
Direct Costs				
Purchased Equipment Costs				
	Primary Equipment[1]		A	11,870
	Sales Tax[2]		B = 0.065 * A	772
	Shipping		Included in A	----
		Purchased Equipment Cost (PEC)	PEC = A + B	12,642
Direct Installation Costs				
	Foundations & Supports		Included in A	----
	Handling & Erection		Included in A	----
	Electrical		Included in A	----
	Piping		Included in A	----
	Insulation for Ductwork		Included in A	----
	Painting		Included in A	----
		Direct Installation Cost	Included in A	----
Total Direct Costs (DC)				12,642
Indirect Costs				
Installation				
	Engineering		Included in A	----
	Construction & Field Expenses		Included in A	----
	Contractor Fees		Included in A	----
	Start-Up		Included in A	----
	Contingencies[3]		0.03 * PEC	379
Total Indirect Costs (IC)				379
TOTAL CAPITAL INVESTMENT = DC + IC				**13,021**
Direct Annual Costs				
Operating Labor				
	Operator		Negligible	----
	Supervisor		Negligible	----
		Total Operating Labor		----
Maintenance				
	Labor		----	----
	Materials		----	----
		Total Maintenance[4]	0.005 * TCI	65
Utilities				
	Electricity		Negligible	----
	Water		----	----
	Reagent		----	----
		Total Utilities		----
Catalyst Cost				
	Catalyst Replacement		Catalyst life > DOC Service Life	----
		Total Catalyst Cost	----	----
Miscellaneous				
	Performance Tests		----	----
	Record Keeping & Reporting		----	----
		Total Miscellaneous Costs		----
Total Direct Annual Costs (DAC)				**65**
Indirect Annual Costs				
Overhead[5]			60% of operating, supervisor, maintenance labor & materials	39
Administrative Charges[6]			0.02 * TCI	260
Capital Recovery Factor[7]			CRF	0.0640
Capital Recovery			CRF * TCI	833
Total Indirect Annual Costs (IAC)				**1,133**
TOTAL ANNUAL COST = DAC + IAC				**1,198**
Uncontrolled NOx, CO, VOC, and PM emissions			tons/yr	0.43
NOx, CO, VOC, and PM Emissions with DOC			tons/yr	0.41
Percent reduction from uncontrolled				7%
Total emissions reduction			tons/yr	0.03
Cost per Ton Controlled			**$/ton**	**42,313**

[1] Capital cost provided by the engine vendor (Brant Briody of Western States Equipment Co.)
[2] Washington sales tax
[3] Minimum cost from most recent Sabey, Vantage, and Cyrus One cost-effectiveness analyses
[4] Estimated using equations from EPA's Air Pollution Control Cost Estimation Spreadsheet for Selective Catalytic Reduction (SCR) found at https://www.epa.gov/sites/production/files/2019-08/scrcostmanualspreadsheet_june-2019rf.xlsm
[5] EPA's Air Pollution Control Cost Manual, Section 1, Chapter 2 (Cost Estimation), Section 2.6.5.7
[6] EPA's Air Pollution Control Cost Manual, Section 1, Chapter 2 (Cost Estimation), Section 2.6.5.8
[7] The capital recovery factor was calculated assuming a 25-year equipment life and a 4% interest rate

TABLE B2.2-22a
COST EFFECTIVENESS CALCULATIONS
Toxic Air Pollutants
Diesel Oxidation Catalyst (DOC) Control System
Diesel-Fired 750 kW Emergency Generator
Operating Hours 55 hours/year

TAP Avg Period [1]	Toxic Air Pollutant	Emission Factor [2] (lb/MMBTU)	Uncontrolled Emissions (tpy)	Control Factor [3]	Emission Reduction (tpy)	Cost-Effectiveness [4] ($/ton)
24-Hour	Acrolein	7.88E-06	1.60E-06	0.70	1.12E-06	2,582,891
	Toluene	2.81E-04	5.69E-05	0.70	3.99E-05	
	Xylenes	1.93E-04	3.91E-05	0.70	2.74E-05	
	Propylene	2.79E-03	5.65E-04	0.70	3.96E-04	
Annual	Benzene	7.76E-04	1.57E-04	0.70	1.10E-04	1,037,219
	Formaldehyde	7.89E-05	1.60E-05	0.70	1.12E-05	
	Acetaldehyde	2.52E-05	5.10E-06	0.70	3.57E-06	
	Naphthalene	1.30E-04	2.63E-05	0.70	1.84E-05	
	Benz(a)anthracene	6.22E-07	1.26E-07	0.70	8.82E-08	
	Chrysene	1.53E-06	3.10E-07	0.70	2.17E-07	
	Benz(b)fluoranthcene	1.11E-06	2.25E-07	0.70	1.57E-07	
	Benz(k)fluoranthcene	2.18E-07	4.42E-08	0.70	3.09E-08	
	Benzo(a)pyrene	2.57E-07	5.20E-08	0.70	3.64E-08	
	Indeno(1,2,3-cd)pyrene	4.14E-07	8.38E-08	0.70	5.87E-08	
	Dibenz(a,h)anthracene	3.46E-07	7.01E-08	0.70	4.91E-08	
	DPM	--	4.05E-03	0.25	1.01E-03	

[1] ASIL information from WAC 173-460

[2] SO2, NO2, CO, and DPM based on criteria pollutant emission calculations, assuming 90% of NOx as NO2. Other TAPs from AP-42 Chapter 3.4 (Large Stationary Diesel Engines)

[3] Control factors used in recent Sabey, Vantage, and Cyrus One data center NOC applications.

[4] Cost-effectiveness based on total annual control cost and emission reduction by TAP averaging period group.

TABLE B2.2-23a
COST EFFECTIVENESS CALCULATIONS
Criteria Air Pollutants
Diesel Oxidation Catalyst (DOC) Control System
Diesel-Fired 1.25 MW Caterpillar Emergency Generator
Operating Hours 55 hours/year

Cost Item		Factor	Cost
Direct Costs			
Purchased Equipment Costs			
	Primary Equipment[1]	A	16,000
	Sales Tax[2]	B = 0.065 * A	1,040
	Shipping	Included in A	-----
	Purchased Equipment Cost (PEC)	PEC = A + B	17,040
Direct Installation Costs			
	Foundations & Supports	Included in A	-----
	Handling & Erection	Included in A	-----
	Electrical	Included in A	-----
	Piping	Included in A	-----
	Insulation for Ductwork	Included in A	-----
	Painting	Included in A	-----
	Direct Installation Cost	Included in A	-----
Total Direct Costs (DC)			17,040
Indirect Costs			
Installation			
	Engineering	Included in A	-----
	Construction & Field Expenses	Included in A	-----
	Contractor Fees	Included in A	-----
	Start-Up	Included in A	-----
	Contingencies[3]	0.03 * PEC	511
Total Indirect Costs (IC)			511
TOTAL CAPITAL INVESTMENT = DC + IC			**17,551**
Direct Annual Costs			
Operating Labor			
	Operator	Negligible	-----
	Supervisor	Negligible	-----
	Total Operating Labor		-----
Maintenance			
	Labor	-----	-----
	Materials	-----	-----
	Total Maintenance[4]	0.005 * TCI	88
Utilities			
	Electricity	Negligible	-----
	Water	-----	-----
	Reagent	-----	-----
	Total Utilities		-----
Catalyst Cost			
	Catalyst Replacement	Catalyst life > DOC Service Life	-----
	Total Catalyst Cost	-----	-----
Miscellaneous			
	Performance Tests	-----	-----
	Record Keeping & Reporting	-----	-----
	Total Miscellaneous Costs		-----
Total Direct Annual Costs (DAC)			**88**
Indirect Annual Costs			
Overhead[5]		60% of operating, supervisor, maintenance labor & materials	53
Administrative Charges[6]		0.02 * TCI	351
Capital Recovery Factor[7]		CRF	0.0640
Capital Recovery		CRF * TCI	1,123
Total Indirect Annual Costs (IAC)			**1,527**
TOTAL ANNUAL COST = DAC + IAC			**1,615**
Uncontrolled NOx, CO, VOC, and PM emissions		tons/yr	0.72
NOx, CO, VOC, and PM Emissions with DOC		tons/yr	0.70
Percent reduction from uncontrolled			4%
Total emissions reduction		tons/yr	0.03
Cost per Ton Controlled		**$/ton**	**59,933**

[1] Capital cost provided by the engine vendor (Brant Briody of Western States Equipment Co.)
[2] Washington sales tax
[3] Minimum cost from most recent Sabey, Vantage, and Cyrus One cost-effectiveness analyses
[4] Estimated using equations from EPA's Air Pollution Control Cost Estimation Spreadsheet for Selective Catalytic Reduction (SCR) found at https://www.epa.gov/sites/production/files/2019-09/scrcostmanualspreadsheet_june-2019vf.xlsm
[5] EPA's Air Pollution Control Cost Manual, Section 1, Chapter 2 (Cost Estimation), Section 2.6.5.7
[6] EPA's Air Pollution Control Cost Manual, Section 1, Chapter 2 (Cost Estimation), Section 2.6.5.8
[7] The capital recovery factor was calculated assuming a 25-year equipment life and a 4% interest rate

TABLE B2.2-23a
COST EFFECTIVENESS CALCULATIONS
Toxic Air Pollutants
Diesel Oxidation Catalyst (DOC) Control System
Diesel-Fired 1.25 MW Caterpillar Emergency Generator
Operating Hours 55 hours/year

TAP Avg Period [1]	Toxic Air Pollutant	Emission Factor [2] (lb/MMBTU)	Uncontrolled Emissions (tpy)	Control Factor [3]	Emission Reduction (tpy)	Cost-Effectiveness [4] ($/ton)
24-Hour	Acrolein	7.88E-06	2.60E-06	0.70	1.82E-06	2,135,133
	Toluene	2.81E-04	9.28E-05	0.70	6.50E-05	
	Xylenes	1.93E-04	6.37E-05	0.70	4.46E-05	
	Propylene	2.79E-03	9.21E-04	0.70	6.45E-04	
Annual	Benzene	7.76E-04	2.56E-04	0.70	1.79E-04	2,046,866
	Formaldehyde	7.89E-05	2.61E-05	0.70	1.82E-05	
	Acetaldehyde	2.52E-05	8.32E-06	0.70	5.83E-06	
	Naphthalene	1.30E-04	4.29E-05	0.70	3.01E-05	
	Benz(a)anthracene	6.22E-07	2.05E-07	0.70	1.44E-07	
	Chrysene	1.53E-06	5.05E-07	0.70	3.54E-07	
	Benz(b)fluoranthcene	1.11E-06	3.67E-07	0.70	2.57E-07	
	Benz(k)fluoranthcene	2.18E-07	7.20E-08	0.70	5.04E-08	
	Benzo(a)pyrene	2.57E-07	8.49E-08	0.70	5.94E-08	
	Indeno(1,2,3-cd)pyrene	4.14E-07	1.37E-07	0.70	9.57E-08	
	Dibenz(a,h)anthracene	3.46E-07	1.14E-07	0.70	8.00E-08	
	DPM	--	2.22E-03	0.25	5.54E-04	

[1] ASIL information from WAC 173-460
[2] SO2, NO2, CO, and DPM based on criteria pollutant emission calculations, assuming 90% of NOx as NO2. Other TAPs from AP-42 Chapter 3.4 (Large Stationary Diesel Engines)
[3] Control factors used in recent Sabey, Vantage, and Cyrus One data center NOC applications.
[4] Cost-effectiveness based on total annual control cost and emission reduction by TAP averaging period group.

TABLE B2.2-24a
COST EFFECTIVENESS CALCULATIONS
Criteria Air Pollutants
Diesel Oxidation Catalyst (DOC) Control System
Diesel-Fired 1.25 MW Generac Emergency Generator
Operating Hours 55 hours/year

Cost Item		Factor	Cost
Direct Costs			
Purchased Equipment Costs			
	Primary Equipment[1]	A	16,271
	Sales Tax[2]	B = 0.065 * A	1,058
	Shipping	Included in A	-----
	Purchased Equipment Cost (PEC)	PEC = A + B	17,329
Direct Installation Costs			
	Foundations & Supports	Included in A	-----
	Handling & Erection	Included in A	-----
	Electrical	Included in A	-----
	Piping	Included in A	-----
	Insulation for Ductwork	Included in A	-----
	Painting	Included in A	-----
	Direct Installation Cost	Included in A	-----
Total Direct Costs (DC)			17,329
Indirect Costs			
Installation			
	Engineering	Included in A	-----
	Construction & Field Expenses	Included in A	-----
	Contractor Fees	Included in A	-----
	Start-Up	Included in A	-----
	Contingencies[3]	0.03 * PEC	520
Total Indirect Costs (IC)			520
TOTAL CAPITAL INVESTMENT = DC + IC			**17,849**
Direct Annual Costs			
Operating Labor			
	Operator	Negligible	-----
	Supervisor	Negligible	-----
	Total Operating Labor		-----
Maintenance			
	Labor	-----	-----
	Materials	-----	-----
	Total Maintenance[4]	0.005 * TCI	89
Utilities			
	Electricity	Negligible	-----
	Water	-----	-----
	Reagent	-----	-----
	Total Utilities		-----
Catalyst Cost			
	Catalyst Replacement	Catalyst life > DOC Service Life	-----
	Total Catalyst Cost	-----	-----
Miscellaneous			
	Performance Tests	-----	-----
	Record Keeping & Reporting	-----	-----
	Total Miscellaneous Costs		-----
Total Direct Annual Costs (DAC)			**89**
Indirect Annual Costs			
Overhead[5]		60% of operating, supervisor, maintenance labor & materials	54
Administrative Charges[6]		0.02 * TCI	357
Capital Recovery Factor[7]		CRF	0.0640
Capital Recovery		CRF * TCI	1,143
Total Indirect Annual Costs (IAC)			**1,553**
TOTAL ANNUAL COST = DAC + IAC			**1,642**
Uncontrolled NOx, CO, VOC, and PM emissions		tons/yr	0.54
NOx, CO, VOC, and PM Emissions with DOC		tons/yr	0.46
Percent reduction from uncontrolled			15%
Total emissions reduction		tons/yr	0.08
Cost per Ton Controlled		**$/ton**	**20,969**

[1] Capital cost provided by the engine vendor (Brant Briody of Western States Equipment Co.)
[2] Washington sales tax
[3] Minimum cost from most recent Sabey, Vantage, and Cyrus One cost-effectiveness analyses
[4] Estimated using equations from EPA's Air Pollution Control Cost Estimation Spreadsheet for Selective Catalytic Reduction (SCR) found at https://www.epa.gov/sites/production/files/2019-06/scrcostmanualspreadsheet_june-2019vf.xlsm
[5] EPA's Air Pollution Control Cost Manual, Section 1, Chapter 2 (Cost Estimation), Section 2.6.5.7
[6] EPA's Air Pollution Control Cost Manual, Section 1, Chapter 2 (Cost Estimation), Section 2.6.5.8
[7] The capital recovery factor was calculated assuming a 25-year equipment life and a 4% interest rate

TABLE B2.2-24a
COST EFFECTIVENESS CALCULATIONS
Toxic Air Pollutants
Diesel Oxidation Catalyst (DOC) Control System
Diesel-Fired 1.25 MW Generac Emergency Generator
Operating Hours 55 hours/year

TAP Avg Period [1]	Toxic Air Pollutant	Emission Factor [2] (lb/MMBTU)	Uncontrolled Emissions (tpy)	Control Factor [3]	Emission Reduction (tpy)	Cost-Effectiveness [4] ($/ton)
24-Hour	Acrolein	7.88E-06	3.39E-06	0.70	2.38E-06	1,664,702
	Toluene	2.81E-04	1.21E-04	0.70	8.47E-05	
	Xylenes	1.93E-04	8.31E-05	0.70	5.82E-05	
	Propylene	2.79E-03	1.20E-03	0.70	8.41E-04	
Annual	Benzene	7.76E-04	3.34E-04	0.70	2.34E-04	500,359
	Formaldehyde	7.89E-05	3.40E-05	0.70	2.38E-05	
	Acetaldehyde	2.52E-05	1.09E-05	0.70	7.60E-06	
	Naphthalene	1.30E-04	5.60E-05	0.70	3.92E-05	
	Benz(a)anthracene	6.22E-07	2.68E-07	0.70	1.88E-07	
	Chrysene	1.53E-06	6.59E-07	0.70	4.61E-07	
	Benz(b)fluoranthcene	1.11E-06	4.78E-07	0.70	3.35E-07	
	Benz(k)fluoranthcene	2.18E-07	9.39E-08	0.70	6.57E-08	
	Benzo(a)pyrene	2.57E-07	1.11E-07	0.70	7.75E-08	
	Indeno(1,2,3-cd)pyrene	4.14E-07	1.78E-07	0.70	1.25E-07	
	Dibenz(a,h)anthracene	3.46E-07	1.49E-07	0.70	1.04E-07	
	DPM	--	1.19E-02	0.25	2.98E-03	

[1] ASIL information from WAC 173-460
[2] SO2, NO2, CO, and DPM based on criteria pollutant emission calculations, assuming 90% of NOx as NO2. Other TAPs from AP-42 Chapter 3.4 (Large Stationary Diesel Engines)
[3] Control factors used in recent Sabey, Vantage, and Cyrus One data center NOC applications.
[4] Cost-effectiveness based on total annual control cost and emission reduction by TAP averaging period group.

TABLE B2.2-25a
COST EFFECTIVENESS CALCULATIONS
Criteria Air Pollutants
Diesel Oxidation Catalyst (DOC) Control System
Diesel-Fired 2.25 MW Emergency Generator
Operating Hours 55 hours/year

Cost Item			Factor	Cost
Direct Costs				
Purchased Equipment Costs				
	Primary Equipment[1]		A	23,017
	Sales Tax[2]		B = 0.065 * A	1,496
	Shipping		Included in A	----
		Purchased Equipment Cost (PEC)	PEC = A + B	24,513
Direct Installation Costs				
	Foundations & Supports		Included in A	----
	Handling & Erection		Included in A	----
	Electrical		Included in A	----
	Piping		Included in A	----
	Insulation for Ductwork		Included in A	----
	Painting		Included in A	----
		Direct Installation Cost	Included in A	----
Total Direct Costs (DC)				24,513
Indirect Costs				
Installation				
	Engineering		Included in A	----
	Construction & Field Expenses		Included in A	----
	Contractor Fees		Included in A	----
	Start-Up		Included in A	----
	Contingencies[3]		0.03 * PEC	735
Total Indirect Costs (IC)				735
TOTAL CAPITAL INVESTMENT = DC + IC				**25,249**
Direct Annual Costs				
Operating Labor				
	Operator		Negligible	----
	Supervisor		Negligible	----
		Total Operating Labor		----
Maintenance				
	Labor		-----	----
	Materials		-----	----
		Total Maintenance[4]	0.005 * TCI	126
Utilities				
	Electricity		Negligible	----
	Water		-----	----
	Reagent		-----	----
		Total Utilities		----
Catalyst Cost				
	Catalyst Replacement		Catalyst life > DOC Service Life	----
		Total Catalyst Cost	-----	----
Miscellaneous				
	Performance Tests		-----	----
	Record Keeping & Reporting		-----	----
		Total Miscellaneous Costs		----
Total Direct Annual Costs (DAC)				**126**
Indirect Annual Costs				
Overhead[5]			60% of operating, supervisor, maintenance labor & materials	76
Administrative Charges[6]			0.02 * TCI	505
Capital Recovery Factor[7]			CRF	0.0640
Capital Recovery			CRF * TCI	1,616
Total Indirect Annual Costs (IAC)				**2,197**
TOTAL ANNUAL COST = DAC + IAC				**2,323**
Uncontrolled NOx, CO, VOC, and PM emissions			tons/yr	1.14
NOx, CO, VOC, and PM Emissions with DOC			tons/yr	0.89
Percent reduction from uncontrolled				21%
Total emissions reduction			tons/yr	0.24
Cost per Ton Controlled			**$/ton**	**9,549**

[1] Capital cost provided by the engine vendor (Brant Briody of Western States Equipment Co.)
[2] Washington sales tax
[3] Minimum cost from most recent Sabey, Vantage, and Cyrus One cost-effectiveness analyses
[4] Estimated using equations from EPA's Air Pollution Control Cost Estimation Spreadsheet for Selective Catalytic Reduction (SCR) found at https://www.epa.gov/sites/production/files/2019-06/scrcostmanualspreadsheet_june-2019v1.xlsm
[5] EPA's Air Pollution Control Cost Manual, Section 1, Chapter 2 (Cost Estimation), Section 2.6.5.7
[6] EPA's Air Pollution Control Cost Manual, Section 1, Chapter 2 (Cost Estimation), Section 2.6.5.8
[7] The capital recovery factor was calculated assuming a 25-year equipment life and a 4% interest rate

TABLE B2.2-25a
COST EFFECTIVENESS CALCULATIONS
Toxic Air Pollutants
Diesel Oxidation Catalyst (DOC) Control System
Diesel-Fired 2.25 MW Emergency Generator
Operating Hours 55 hours/year

TAP Avg Period [1]	Toxic Air Pollutant	Emission Factor [2] (lb/MMBTU)	Uncontrolled Emissions (tpy)	Control Factor [3]	Emission Reduction (tpy)	Cost-Effectiveness [4] ($/ton)
24-Hour	Acrolein	7.88E-06	4.98E-06	0.70	3.48E-06	1,606,541
	Toluene	2.81E-04	1.77E-04	0.70	1.24E-04	
	Xylenes	1.93E-04	1.22E-04	0.70	8.53E-05	
	Propylene	2.79E-03	1.76E-03	0.70	1.23E-03	
Annual	Benzene	7.76E-04	4.90E-04	0.70	3.43E-04	356,761
	Formaldehyde	7.89E-05	4.98E-05	0.70	3.49E-05	
	Acetaldehyde	2.52E-05	1.59E-05	0.70	1.11E-05	
	Naphthalene	1.30E-04	8.21E-05	0.70	5.75E-05	
	Benz(a)anthracene	6.22E-07	3.93E-07	0.70	2.75E-07	
	Chrysene	1.53E-06	9.66E-07	0.70	6.76E-07	
	Benz(b)fluoranthcene	1.11E-06	7.01E-07	0.70	4.91E-07	
	Benz(k)fluoranthcene	2.18E-07	1.38E-07	0.70	9.63E-08	
	Benzo(a)pyrene	2.57E-07	1.62E-07	0.70	1.14E-07	
	Indeno(1,2,3-cd)pyrene	4.14E-07	2.61E-07	0.70	1.83E-07	
	Dibenz(a,h)anthracene	3.46E-07	2.18E-07	0.70	1.53E-07	
	DPM	--	2.43E-02	0.25	6.06E-03	

[1] ASIL information from WAC 173-460
[2] SO2, NO2, CO, and DPM based on criteria pollutant emission calculations, assuming 90% of NOx as NO2. Other TAPs from AP-42 Chapter 3.4 (Large Stationary Diesel Engines)
[3] Control factors used in recent Sabey, Vantage, and Cyrus One data center NOC applications.
[4] Cost-effectiveness based on total annual control cost and emission reduction by TAP averaging period group.

APPENDIX D

COST EFFECTIVENESS CALCUALTIONS FOR 100 OPERATING HOURS/YEAR

This page intentionally left blank.

Appendix D

Cost Effectiveness Calcualtions for 100 Operating Hours/Year

TABLE B2.2-1b
COST EFFECTIVENESS CALCULATIONS
Criteria Air Pollutants
Tier 4 (Final) Control System
Diesel-Fired 400 kW Emergency Generator
Operating Hours 100 hours/year

Cost Item			Factor	Cost
Direct Costs				
Purchased Equipment Costs				
	Primary Equipment[1]		A	104,201
	Sales Tax[2]		B = 0.065 * A	6,773
	Shipping		Included in A	-----
		Purchased Equipment Cost (PEC)	PEC = A + B	110,974
Direct Installation Costs				
	Foundations & Supports		Included in A	-----
	Handling & Erection		Included in A	-----
	Electrical		Included in A	-----
	Piping		Included in A	-----
	Insulation for Ductwork		Included in A	-----
	Painting		Included in A	-----
		Direct Installation Cost	Included in A	-----
Total Direct Costs (DC)				110,974
Indirect Costs				
Installation				
	Engineering		Included in A	-----
	Construction & Field Expenses		Included in A	-----
	Contractor Fees		Included in A	-----
	Start-Up		Included in A	-----
	Contingencies[3]		0.03 * PEC	3,329
Total Indirect Costs (IC)				3,329
TOTAL CAPITAL INVESTMENT = DC + IC				**114,304**
Direct Annual Costs				
Operating Labor				
	Operator		Negligible	-----
	Supervisor		Negligible	-----
		Total Operating Labor		-----
Maintenance				
	Labor		-----	-----
	Materials		-----	-----
		Total Maintenance[4]	0.005 * TCI	572
Utilities				
	Electricity		Negligible	-----
	Water		-----	-----
	Reagent[4]		-----	422
		Total Utilities		-----
Catalyst Cost				
	Catalyst Replacement		Catalyst life > SCR Service Life	-----
		Total Catalyst Cost	-----	-----
Miscellaneous				
	Performance Tests		-----	-----
	Record Keeping & Reporting		-----	-----
		Total Miscellaneous Costs		-----
Total Direct Annual Costs (DAC)				**993**
Indirect Annual Costs				
Overhead[5]			60% of operating, supervisor, maintenance labor & materials	343
Administrative Charges[6]			0.03 * (Op. Labor Cost + 0.4 * Ann. Maint. Cost))	7
Capital Recovery Factor[7]			CRF	0.0640
Capital Recovery			CRF * TCI	7,317
Total Indirect Annual Costs (IAC)				**7,667**
TOTAL ANNUAL COST = DAC + IAC				**8,660**
Uncontrolled NOx, CO, VOC, and PM emissions			tons/yr	0.21
NOx, CO, VOC, and PM Emissions with Tier 4 Controls			tons/yr	0.03
Percent reduction from uncontrolled				88%
Total emissions reduction			tons/yr	0.18
Cost per Ton Controlled			**$/ton**	**47,115**

[1] Capital cost provided by the engine vendor (Brant Briody of Western States Equipment Co.)
[2] Washington sales tax
[3] Minimum cost from most recent Sabey, Vantage, and Cyrus One cost-effectiveness analyses
[4] Estimated using equations from EPA's Air Pollution Control Cost Estimation Spreadsheet for Selective Catalytic Reduction (SCR) found at https://www.epa.gov/sites/production/files/2019-06/scrcostmanualspreadsheet_june-2019vf.xlsm
[5] EPA's Air Pollution Control Cost Manual, Section 1, Chapter 2 (Cost Estimation), Section 2.6.5.7
[6] EPA's Air Pollution Control Cost Manual, Section 4, Chapter 2 (SCR)
[7] The capital recovery factor was calculated assuming a 25-year equipment life and a 4% interest rate

TABLE B2.2-1b
COST EFFECTIVENESS CALCULATIONS
Toxic Air Pollutants
Tier 4 (Final) Control System
Diesel-Fired 400 kW Emergency Generator
Operating Hours 100 hours/year

TAP Avg Period [1]	Toxic Air Pollutant	Emission Factor [2] (lb/MMBTU)	Uncontrolled Emissions (tpy)	Control Factor [3]	Emission Reduction (tpy)	Cost-Effectiveness [4] ($/ton)
24-Hour	Acrolein	7.88E-06	1.66E-06	0.70	1.16E-06	17,985,543
	Toluene	2.81E-04	5.91E-05	0.70	4.14E-05	
	Xylenes	1.93E-04	4.06E-05	0.70	2.84E-05	
	Propylene	2.79E-03	5.87E-04	0.70	4.11E-04	
Annual	Benzene	7.76E-04	1.63E-04	0.70	1.14E-04	1,877,477
	Formaldehyde	7.89E-05	1.66E-05	0.70	1.16E-05	
	Acetaldehyde	2.52E-05	5.30E-06	0.70	3.71E-06	
	Naphthalene	1.30E-04	2.73E-05	0.70	1.91E-05	
	Benz(a)anthracene	6.22E-07	1.31E-07	0.70	9.15E-08	
	Chrysene	1.53E-06	3.22E-07	0.70	2.25E-07	
	Benz(b)fluoranthcene	1.11E-06	2.33E-07	0.70	1.63E-07	
	Benz(k)fluoranthcene	2.18E-07	4.58E-08	0.70	3.21E-08	
	Benzo(a)pyrene	2.57E-07	5.40E-08	0.70	3.78E-08	
	Indeno(1,2,3-cd)pyrene	4.14E-07	8.70E-08	0.70	6.09E-08	
	Dibenz(a,h)anthracene	3.46E-07	7.27E-08	0.70	5.09E-08	
	DPM	--	5.07E-03	0.88	4.46E-03	

[1] ASIL information from WAC 173-460
[2] SO2, NO2, CO, and DPM based on criteria pollutant emission calculations, assuming 90% of NOx as NO2. Other TAPs from AP-42 Chapter 3.4 (Large Stationary Diesel Engines)
[3] Control factors used in recent Sabey, Vantage, and Cyrus One data center NOC applications.
[4] Cost-effectiveness based on total annual control cost and emission reduction by TAP averaging period group.

TABLE B2.2-2b
COST EFFECTIVENESS CALCULATIONS
Criteria Air Pollutants
Tier 4 (Final) Control System
Diesel-Fired 750 kW Emergency Generator
Operating Hours 100 hours/year

Cost Item			Factor	Cost
Direct Costs				
Purchased Equipment Costs				
	Primary Equipment[1]		A	148,376
	Sales Tax[2]		B = 0.065 * A	9,644
	Shipping		Included in A	----
		Purchased Equipment Cost (PEC)	PEC = A + B	158,021
Direct Installation Costs				
	Foundations & Supports		Included in A	----
	Handling & Erection		Included in A	----
	Electrical		Included in A	----
	Piping		Included in A	----
	Insulation for Ductwork		Included in A	----
	Painting		Included in A	----
		Direct Installation Cost	Included in A	----
Total Direct Costs (DC)				158,021
Indirect Costs				
Installation				
	Engineering		Included in A	----
	Construction & Field Expenses		Included in A	----
	Contractor Fees		Included in A	----
	Start-Up		Included in A	----
	Contingencies[3]		0.03 * PEC	4,741
Total Indirect Costs (IC)				4,741
TOTAL CAPITAL INVESTMENT = DC + IC				**162,761**
Direct Annual Costs				
Operating Labor				
	Operator		Negligible	----
	Supervisor		Negligible	----
		Total Operating Labor		----
Maintenance				
	Labor		----	----
	Materials		----	----
		Total Maintenance[4]	0.005 * TCI	814
Utilities				
	Electricity		Negligible	----
	Water		----	----
	Reagent[4]		----	1,800
		Total Utilities		----
Catalyst Cost				
	Catalyst Replacement		Catalyst life > SCR Service Life	----
		Total Catalyst Cost	----	----
Miscellaneous				
	Performance Tests		----	----
	Record Keeping & Reporting		----	----
		Total Miscellaneous Costs		----
Total Direct Annual Costs (DAC)				**2,614**
Indirect Annual Costs				
Overhead[5]			60% of operating, supervisor, maintenance labor & materials	488
Administrative Charges[6]			0.03 * (Op. Labor Cost + 0.4 * Ann. Maint. Cost))	10
Capital Recovery Factor[7]			CRF	0.0640
Capital Recovery			CRF * TCI	10,419
Total Indirect Annual Costs (IAC)				**10,917**
TOTAL ANNUAL COST = DAC + IAC				**13,531**
Uncontrolled NOx, CO, VOC, and PM emissions			tons/yr	0.79
NOx, CO, VOC, and PM Emissions with Tier 4 Controls			tons/yr	0.09
Percent reduction from uncontrolled				89%
Total emissions reduction			tons/yr	0.70
Cost per Ton Controlled			**$/ton**	**19,289**

[1] Captial cost provided by the engine vendor (Brant Briody of Western States Equipment Co.)
[2] Washington sales tax
[3] Minimum cost from most recent Sabey, Vantage, and Cyrus One cost-effectiveness analyses
[4] Estimated using equations from EPA's Air Pollution Control Cost Estimation Spreadsheet for Selective Catalytic Reduction (SCR) found at https://www.epa.gov/sites/production/files/2019-06/scrcostmanualspreadsheet_june-2019vf.xlsm
[5] EPA's Air Pollution Control Cost Manual, Section 1, Chapter 2 (Cost Estimation), Section 2.6.5.7
[6] EPA's Air Pollution Control Cost Manual, Section 4, Chapter 2 (SCR)
[7] The capital recovery factor was calculated assuming a 25-year equipment life and a 4% interest rate

TABLE B2.2-2b
COST EFFECTIVENESS CALCULATIONS
Toxic Air Pollutants
Tier 4 (Final) Control System
Diesel-Fired 750 kW Emergency Generator
Operating Hours 100 hours/year

TAP Avg Period [1]	Toxic Air Pollutant	Emission Factor [2] (lb/MMBTU)	Uncontrolled Emissions (tpy)	Control Factor [3]	Emission Reduction (tpy)	Cost-Effectiveness [4] ($/ton)
24-Hour	Acrolein	7.88E-06	2.90E-06	0.70	2.03E-06	16,044,018
	Toluene	2.81E-04	1.03E-04	0.70	7.24E-05	
	Xylenes	1.93E-04	7.11E-05	0.70	4.97E-05	
	Propylene	2.79E-03	1.03E-03	0.70	7.19E-04	
Annual	Benzene	7.76E-04	2.86E-04	0.70	2.00E-04	2,009,498
	Formaldehyde	7.89E-05	2.91E-05	0.70	2.03E-05	
	Acetaldehyde	2.52E-05	9.28E-06	0.70	6.50E-06	
	Naphthalene	1.30E-04	4.79E-05	0.70	3.35E-05	
	Benz(a)anthracene	6.22E-07	2.29E-07	0.70	1.60E-07	
	Chrysene	1.53E-06	5.63E-07	0.70	3.94E-07	
	Benz(b)fluoranthcene	1.11E-06	4.09E-07	0.70	2.86E-07	
	Benz(k)fluoranthcene	2.18E-07	8.03E-08	0.70	5.62E-08	
	Benzo(a)pyrene	2.57E-07	9.46E-08	0.70	6.62E-08	
	Indeno(1,2,3-cd)pyrene	4.14E-07	1.52E-07	0.70	1.07E-07	
	Dibenz(a,h)anthracene	3.46E-07	1.27E-07	0.70	8.92E-08	
	DPM	--	7.35E-03	0.88	6.47E-03	

[1] ASIL information from WAC 173-460
[2] SO2, NO2, CO, and DPM based on criteria pollutant emission calculations, assuming 90% of NOx as NO2. Other TAPs from AP-42 Chapter 3.4 (Large Stationary Diesel Engines)
[3] Control factors used in recent Sabey, Vantage, and Cyrus One data center NOC applications.
[4] Cost-effectiveness based on total annual control cost and emission reduction by TAP averaging period group.

TABLE B2.2-3b
COST EFFECTIVENESS CALCULATIONS
Criteria Air Pollutants
Tier 4 (Final) Control System
Diesel-Fired 1.25 MW Caterpillar Emergency Generator
Operating Hours 100 hours/year

Cost Item			Factor	Cost
Direct Costs				
Purchased Equipment Costs				
	Primary Equipment[1]		A	200,000
	Sales Tax[2]		B = 0.065 * A	13,000
	Shipping		Included in A	-----
		Purchased Equipment Cost (PEC)	PEC = A + B	213,000
Direct Installation Costs				
	Foundations & Supports		Included in A	-----
	Handling & Erection		Included in A	-----
	Electrical		Included in A	-----
	Piping		Included in A	-----
	Insulation for Ductwork		Included in A	-----
	Painting		Included in A	-----
		Direct Installation Cost	Included in A	-----
Total Direct Costs (DC)				213,000
Indirect Costs				
Installation				
	Engineering		Included in A	-----
	Construction & Field Expenses		Included in A	-----
	Contractor Fees		Included in A	-----
	Start-Up		Included in A	-----
	Contingencies[3]		0.03 * PEC	6,390
Total Indirect Costs (IC)				6,390
TOTAL CAPITAL INVESTMENT = DC + IC				**219,390**
Direct Annual Costs				
Operating Labor				
	Operator		Negligible	-----
	Supervisor		Negligible	-----
		Total Operating Labor		-----
Maintenance				
	Labor		-----	-----
	Materials		-----	-----
		Total Maintenance[4]	0.005 * TCI	1,097
Utilities				
	Electricity		Negligible	-----
	Water		-----	-----
	Reagent[4]		-----	3,139
		Total Utilities		-----
Catalyst Cost				
	Catalyst Replacement		Catalyst life > SCR Service Life	-----
		Total Catalyst Cost	-----	-----
Miscellaneous				
	Performance Tests		-----	-----
	Record Keeping & Reporting		-----	-----
		Total Miscellaneous Costs		-----
Total Direct Annual Costs (DAC)				**4,236**
Indirect Annual Costs				
Overhead[5]			60% of operating, supervisor, maintenance labor & materials	658
Administrative Charges[6]			0.03 * (Op. Labor Cost + 0.4 * Ann. Maint. Cost))	13
Capital Recovery Factor[7]			CRF	0.0640
Capital Recovery			CRF * TCI	14,044
Total Indirect Annual Costs (IAC)				**14,715**
TOTAL ANNUAL COST = DAC + IAC				**18,950**
Uncontrolled NOx, CO, VOC, and PM emissions			tons/yr	1.32
NOx, CO, VOC, and PM Emissions with Tier 4 Controls			tons/yr	0.14
Percent reduction from uncontrolled				89%
Total emissions reduction			tons/yr	1.18
Cost per Ton Controlled			**$/ton**	**16,107**

[1] Capital cost provided by the engine vendor (Brant Briody of Western States Equipment Co.)
[2] Washington sales tax
[3] Minimum cost from most recent Sabey, Vantage, and Cyrus One cost-effectiveness analyses
[4] Estimated using equations from EPA's Air Pollution Control Cost Estimation Spreadsheet for Selective Catalytic Reduction (SCR) found at https://www.epa.gov/sites/production/files/2019-06/scrcostmanualspreadsheet_june-2019vf.xlsm
[5] EPA's Air Pollution Control Cost Manual, Section 1, Chapter 2 (Cost Estimation), Section 2.6.5.7
[6] EPA's Air Pollution Control Cost Manual, Section 4, Chapter 2 (SCR)
[7] The capital recovery factor was calculated assuming a 25-year equipment life and a 4% interest rate

TABLE B2.2-3b
COST EFFECTIVENESS CALCULATIONS
Toxic Air Pollutants
Tier 4 (Final) Control System
Diesel-Fired 1.25 MW Caterpillar Emergency Generator
Operating Hours 100 hours/year

TAP Avg Period [1]	Toxic Air Pollutant	Emission Factor [2] (lb/MMBTU)	Uncontrolled Emissions (tpy)	Control Factor [3]	Emission Reduction (tpy)	Cost-Effectiveness [4] ($/ton)
24-Hour	Acrolein	7.88E-06	4.73E-06	0.70	3.31E-06	13,780,199
	Toluene	2.91E-04	1.69E-04	0.70	1.18E-04	
	Xylenes	1.93E-04	1.16E-04	0.70	8.11E-05	
	Propylene	2.79E-03	1.68E-03	0.70	1.17E-03	
Annual	Benzene	7.76E-04	4.66E-04	0.70	3.26E-04	4,767,656
	Formaldehyde	7.89E-05	4.74E-05	0.70	3.32E-05	
	Acetaldehyde	2.52E-05	1.51E-05	0.70	1.06E-05	
	Naphthalene	1.30E-04	7.81E-05	0.70	5.46E-05	
	Benz(a)anthracene	6.22E-07	3.73E-07	0.70	2.61E-07	
	Chrysene	1.53E-06	9.19E-07	0.70	6.43E-07	
	Benz(b)fluoranthcene	1.11E-06	6.66E-07	0.70	4.67E-07	
	Benz(k)fluoranthcene	2.18E-07	1.31E-07	0.70	9.16E-08	
	Benzo(a)pyrene	2.57E-07	1.54E-07	0.70	1.08E-07	
	Indeno(1,2,3-cd)pyrene	4.14E-07	2.48E-07	0.70	1.74E-07	
	Dibenz(a,h)anthracene	3.46E-07	2.08E-07	0.70	1.45E-07	
	DPM	--	4.03E-03	0.88	3.55E-03	

[1] ASIL information from WAC 173-460
[2] SO2, NO2, CO, and DPM based on criteria pollutant emission calculations, assuming 90% of NOx as NO2. Other TAPs from AP-42 Chapter 3.4 (Large Stationary Diesel Engines)
[3] Control factors used in recent Sabey, Vantage, and Cyrus One data center NOC applications.
[4] Cost-effectiveness based on total annual control cost and emission reduction by TAP averaging period group.

TABLE B2.2-4b
COST EFFECTIVENESS CALCULATIONS
Criteria Air Pollutants
Tier 4 (Final) Control System
Diesel-Fired 1.25 MW Generac Emergency Generator
Operating Hours 100 hours/year

Cost Item			Factor	Cost
Direct Costs				
Purchased Equipment Costs				
	Primary Equipment[1]		A	203,393
	Sales Tax[2]		B = 0.065 * A	13,221
	Shipping		Included in A	-----
		Purchased Equipment Cost (PEC)	PEC = A + B	216,613
Direct Installation Costs				
	Foundations & Supports		Included in A	-----
	Handling & Erection		Included in A	-----
	Electrical		Included in A	-----
	Piping		Included in A	-----
	Insulation for Ductwork		Included in A	-----
	Painting		Included in A	-----
		Direct Installation Cost	Included in A	-----
Total Direct Costs (DC)				216,613
Indirect Costs				
Installation				
	Engineering		Included in A	-----
	Construction & Field Expenses		Included in A	-----
	Contractor Fees		Included in A	-----
	Start-Up		Included in A	-----
	Contingencies[3]		0.03 * PEC	6,498
Total Indirect Costs (IC)				6,498
TOTAL CAPITAL INVESTMENT = DC + IC				**223,111**
Direct Annual Costs				
Operating Labor				
	Operator		Negligible	-----
	Supervisor		Negligible	-----
		Total Operating Labor		-----
Maintenance				
	Labor		-----	-----
	Materials		-----	-----
		Total Maintenance[4]	0.005 * TCI	1,116
Utilities				
	Electricity		Negligible	-----
	Water		-----	-----
	Reagent[4]		-----	1,937
		Total Utilities		-----
Catalyst Cost				
	Catalyst Replacement		Catalyst life > SCR Service Life	-----
		Total Catalyst Cost	-----	-----
Miscellaneous				
	Performance Tests		-----	-----
	Record Keeping & Reporting		-----	-----
		Total Miscellaneous Costs		-----
Total Direct Annual Costs (DAC)				**3,053**
Indirect Annual Costs				
Overhead[5]			60% of operating, supervisor, maintenance labor & materials	869
Administrative Charges[6]			0.03 * (Op. Labor Cost + 0.4 * Ann. Maint. Cost))	13
Capital Recovery Factor[7]			CRF	0.0640
Capital Recovery			CRF * TCI	14,282
Total Indirect Annual Costs (IAC)				**14,965**
TOTAL ANNUAL COST = DAC + IAC				**18,017**
Uncontrolled NOx, CO, VOC, and PM emissions			tons/yr	0.98
NOx, CO, VOC, and PM Emissions with Tier 4 Controls			tons/yr	0.13
Percent reduction from uncontrolled				87%
Total emissions reduction			tons/yr	0.85
Cost per Ton Controlled			**$/ton**	**21,186**

[1] Capital cost provided by the engine vendor (Brant Briody of Western States Equipment Co.)
[2] Washington sales tax
[3] Minimum cost from most recent Sabey, Vantage, and Cyrus One cost-effectiveness analyses
[4] Estimated using equations from EPA's Air Pollution Control Cost Estimation Spreadsheet for Selective Catalytic Reduction (SCR) found at https://www.epa.gov/sites/production/files/2019-06/scrcostmanualspreadsheet_june-2019vf.xlsm
[5] EPA's Air Pollution Control Cost Manual, Section 1, Chapter 2 (Cost Estimation), Section 2.6.5.7
[6] EPA's Air Pollution Control Cost Manual, Section 4, Chapter 2 (SCR)
[7] The capital recovery factor was calculated assuming a 25-year equipment life and a 4% interest rate

TABLE B2.2-4b
COST EFFECTIVENESS CALCULATIONS
Toxic Air Pollutants
Tier 4 (Final) Control System
Diesel-Fired 1.25 MW Generac Emergency Generator
Operating Hours 100 hours/year

TAP Avg Period [1]	Toxic Air Pollutant	Emission Factor [2] (lb/MMBTU)	Uncontrolled Emissions (tpy)	Control Factor [3]	Emission Reduction (tpy)	Cost-Effectiveness [4] ($/ton)
24-Hour	Acrolein	7.88E-06	6.17E-06	0.70	4.32E-06	10,044,602
	Toluene	2.81E-04	2.20E-04	0.70	1.54E-04	
	Xylenes	1.93E-04	1.51E-04	0.70	1.06E-04	
	Propylene	2.79E-03	2.19E-03	0.70	1.53E-03	
Annual	Benzene	7.76E-04	6.08E-04	0.70	4.25E-04	919,023
	Formaldehyde	7.89E-05	6.18E-05	0.70	4.33E-05	
	Acetaldehyde	2.52E-05	1.97E-05	0.70	1.38E-05	
	Naphthalene	1.30E-04	1.02E-04	0.70	7.13E-05	
	Benz(a)anthracene	6.22E-07	4.87E-07	0.70	3.41E-07	
	Chrysene	1.53E-06	1.20E-06	0.70	8.39E-07	
	Benz(b)fluoranthcene	1.11E-06	8.69E-07	0.70	6.09E-07	
	Benz(k)fluoranthcene	2.18E-07	1.71E-07	0.70	1.20E-07	
	Benzo(a)pyrene	2.57E-07	2.01E-07	0.70	1.41E-07	
	Indeno(1,2,3-cd)pyrene	4.14E-07	3.24E-07	0.70	2.27E-07	
	Dibenz(a,h)anthracene	3.46E-07	2.71E-07	0.70	1.90E-07	
	DPM	--	2.16E-02	0.88	1.90E-02	

[1] ASIL information from WAC 173-460
[2] SO2, NO2, CO, and DPM based on criteria pollutant emission calculations, assuming 90% of NOx as NO2. Other TAPs from AP-42 Chapter 3.4 (Large Stationary Diesel Engines)
[3] Control factors used in recent Sabey, Vantage, and Cyrus One data center NOC applications.
[4] Cost-effectiveness based on total annual control cost and emission reduction by TAP averaging period group.

TABLE B2.2-5b
COST EFFECTIVENESS CALCULATIONS
Criteria Air Pollutants
Tier 4 (Final) Control System
Diesel-Fired 2.25 MW Emergency Generator
Operating Hours 100 hours/year

Cost Item			Factor	Cost
Direct Costs				
Purchased Equipment Costs				
	Primary Equipment[1]		A	287,715
	Sales Tax[2]		B = 0.065 * A	18,701
	Shipping		Included in A	-----
		Purchased Equipment Cost (PEC)	PEC = A + B	306,416
Direct Installation Costs				
	Foundations & Supports		Included in A	-----
	Handling & Erection		Included in A	-----
	Electrical		Included in A	-----
	Piping		Included in A	-----
	Insulation for Ductwork		Included in A	-----
	Painting		Included in A	-----
		Direct Installation Cost	Included in A	-----
Total Direct Costs (DC)				306,416
Indirect Costs				
Installation				
	Engineering		Included in A	-----
	Construction & Field Expenses		Included in A	-----
	Contractor Fees		Included in A	-----
	Start-Up		Included in A	-----
	Contingencies[3]		0.03 * PEC	9,192
Total Indirect Costs (IC)				9,192
TOTAL CAPITAL INVESTMENT = DC + IC				**315,609**
Direct Annual Costs				
Operating Labor				
	Operator		Negligible	-----
	Supervisor		Negligible	-----
		Total Operating Labor		-----
Maintenance				
	Labor		-----	-----
	Materials		-----	-----
		Total Maintenance[4]	0.005 * TCI	1,578
Utilities				
	Electricity		Negligible	-----
	Water		-----	-----
	Reagent[4]		-----	3,654
		Total Utilities		-----
Catalyst Cost				
	Catalyst Replacement		Catalyst life > SCR Service Life	-----
		Total Catalyst Cost	-----	-----
Miscellaneous				
	Performance Tests		-----	-----
	Record Keeping & Reporting		-----	-----
		Total Miscellaneous Costs		-----
Total Direct Annual Costs (DAC)				**5,232**
Indirect Annual Costs				
Overhead[5]			60% of operating, supervisor, maintenance labor & materials	947
Administrative Charges[6]			0.03 * (Op. Labor Cost + 0.4 * Ann. Maint. Cost))	19
Capital Recovery Factor[7]			CRF	0.0640
Capital Recovery			CRF * TCI	20,203
Total Indirect Annual Costs (IAC)				**21,168**
TOTAL ANNUAL COST = DAC + IAC				**26,400**
Uncontrolled NOx, CO, VOC, and PM emissions			tons/yr	2.06
NOx, CO, VOC, and PM Emissions with Tier 4 Controls			tons/yr	0.28
Percent reduction from uncontrolled				86%
Total emissions reduction			tons/yr	1.78
Cost per Ton Controlled			**$/ton**	**14,833**

[1] Captial cost provided by the engine vendor (Brant Briody of Western States Equipment Co.)
[2] Washington sales tax
[3] Minimum cost from most recent Sabey, Vantage, and Cyrus One cost-effectiveness analyses
[4] Estimated using equations from EPA's Air Pollution Control Cost Estimation Spreadsheet for Selective Catalytic Reduction (SCR) found at
[5] EPA's Air Pollution Control Cost Manual, Section 1, Chapter 2 (Cost Estimation), Section 2.6.5.7
[6] EPA's Air Pollution Control Cost Manual, Section 4, Chapter 2 (SCR)
[7] The capital recovery factor was calculated assuming a 25-year equipment life and a 4% interest rate

TABLE B2.2-5b
COST EFFECTIVENESS CALCULATIONS
Toxic Air Pollutants
Tier 4 (Final) Control System
Diesel-Fired 2.25 MW Emergency Generator
Operating Hours 100 hours/year

TAP Avg Period [1]	Toxic Air Pollutant	Emission Factor [2] (lb/MMBTU)	Uncontrolled Emissions (tpy)	Control Factor [3]	Emission Reduction (tpy)	Cost-Effectiveness [4] ($/ton)
24-Hour	Acrolein	7.88E-06	9.05E-06	0.70	6.33E-06	10,041,125
	Toluene	2.81E-04	3.23E-04	0.70	2.26E-04	
	Xylenes	1.93E-04	2.22E-04	0.70	1.55E-04	
	Propylene	2.79E-03	3.20E-03	0.70	2.24E-03	
Annual	Benzene	7.76E-04	8.91E-04	0.70	6.24E-04	666,317
	Formaldehyde	7.89E-05	9.06E-05	0.70	6.34E-05	
	Acetaldehyde	2.52E-05	2.89E-05	0.70	2.03E-05	
	Naphthalene	1.30E-04	1.49E-04	0.70	1.04E-04	
	Benz(a)anthracene	6.22E-07	7.14E-07	0.70	5.00E-07	
	Chrysene	1.53E-06	1.76E-06	0.70	1.23E-06	
	Benz(b)fluoranthcene	1.11E-06	1.27E-06	0.70	8.92E-07	
	Benz(k)fluoranthcene	2.18E-07	2.50E-07	0.70	1.75E-07	
	Benzo(a)pyrene	2.57E-07	2.95E-07	0.70	2.07E-07	
	Indeno(1,2,3-cd)pyrene	4.14E-07	4.75E-07	0.70	3.33E-07	
	Dibenz(a,h)anthracene	3.46E-07	3.97E-07	0.70	2.78E-07	
	DPM	--	4.41E-02	0.88	3.88E-02	

[1] ASIL information from WAC 173-460.
[2] SO2, NO2, CO, and DPM based on criteria pollutant emission calculations, assuming 90% of NOx as NO2. Other TAPs from AP-42 Chapter 3.4 (Large Stationary Diesel Engines)
[3] Control factors used in recent Sabey, Vantage, and Cyrus One data center NOC applications.
[4] Cost-effectiveness based on total annual control cost and emission reduction by TAP averaging period group.

TABLE B2.2-6b
COST EFFECTIVENESS CALCULATIONS
Criteria Air Pollutants
Selective Catalytic Reduction (SCR) Control System
Diesel-Fired 400 kW Emergency Generator
Operating Hours 100 hours/year

Cost Item		Factor	Cost
Direct Costs			
Purchased Equipment Costs			
	Primary Equipment[1]	A	62,521
	Sales Tax[2]	B = 0.065 * A	4,064
	Shipping	Included in A	-----
	Purchased Equipment Cost (PEC)	PEC = A + B	66,585
Direct Installation Costs			
	Foundations & Supports	Included in A	-----
	Handling & Erection	Included in A	-----
	Electrical	Included in A	-----
	Piping	Included in A	-----
	Insulation for Ductwork	Included in A	-----
	Painting	Included in A	-----
	Direct Installation Cost	Included in A	-----
Total Direct Costs (DC)			66,585
Indirect Costs			
Installation			
	Engineering	Included in A	-----
	Construction & Field Expenses	Included in A	-----
	Contractor Fees	Included in A	-----
	Start-Up	Included in A	-----
	Contingencies[3]	0.03 * PEC	1,998
Total Indirect Costs (IC)			1,998
TOTAL CAPITAL INVESTMENT = DC + IC			**68,582**
Direct Annual Costs			
Operating Labor			
	Operator	Negligible	-----
	Supervisor	Negligible	-----
	Total Operating Labor		-----
Maintenance			
	Labor	-----	-----
	Materials	-----	-----
	Total Maintenance[4]	0.005 * TCI	343
Utilities			
	Electricity	Negligible	-----
	Water	-----	-----
	Reagent[4]	-----	422
	Total Utilities		-----
Catalyst Cost			
	Catalyst Replacement	Catalyst life > SCR Service Life	-----
	Total Catalyst Cost	-----	-----
Miscellaneous			
	Performance Tests	-----	-----
	Record Keeping & Reporting	-----	-----
	Total Miscellaneous Costs		-----
Total Direct Annual Costs (DAC)			**764**
Indirect Annual Costs			
Administrative Charges[5]		0.03 * (Op. Labor Cost + 0.4 * Ann. Maint. Cost)	4
Capital Recovery Factor[6]		CRF	0.0640
Capital Recovery		CRF * TCI	4,390
Total Indirect Annual Costs (IAC)			**4,394**
TOTAL ANNUAL COST = DAC + IAC			**5,159**
Uncontrolled NOx, CO, VOC, and PM emissions		tons/yr	0.21
NOx, CO, VOC, and PM Emissions with SCR		tons/yr	0.06
Percent reduction from uncontrolled			72%
Total emissions reduction		tons/yr	0.15
Cost per Ton Controlled		**$/ton**	**34,144**

[1] Capital cost provided by the engine vendor (Brant Briody of Western States Equipment Co.)
[2] Washington sales tax
[3] Minimum cost from most recent Sabey, Vantage, and Cyrus One cost-effectiveness analyses
[4] Estimated using equations from EPA's Air Pollution Control Cost Estimation Spreadsheet for Selective Catalytic Reduction (SCR) found at https://www.epa.gov/sites/production/files/2019-06/scrcostmanualspreadsheet_june-2019vf.xlsm
[5] EPA's Air Pollution Control Cost Manual, Section 4, Chapter 2 (SCR)
[6] The capital recovery factor was calculated assuming a 25-year equipment life and a 4% interest rate

TABLE B2.2-6b
COST EFFECTIVENESS CALCULATIONS
Toxic Air Pollutants
Selective Catalytic Reduction (SCR) Control System
Diesel-Fired 400 kW Emergency Generator
Operating Hours 100 hours/year

TAP Avg Period [1]	Toxic Air Pollutant	Emission Factor [2] (lb/MMBTU)	Uncontrolled Emissions (tpy)	Control Factor [3]	Emission Reduction (tpy)	Cost-Effectiveness [4] ($/ton)
24-Hour	Acrolein	7.88E-06	1.66E-06	0.00	0.00E+00	--
	Toluene	2.81E-04	5.91E-05	0.00	0.00E+00	
	Xylenes	1.93E-04	4.06E-05	0.00	0.00E+00	
	Propylene	2.79E-03	5.87E-04	0.00	0.00E+00	
Annual	Benzene	7.76E-04	1.63E-04	0.00	0.00E+00	--
	Formaldehyde	7.89E-05	1.66E-05	0.00	0.00E+00	
	Acetaldehyde	2.52E-05	5.30E-06	0.00	0.00E+00	
	Naphthalene	1.30E-04	2.73E-05	0.00	0.00E+00	
	Benz(a)anthracene	6.22E-07	1.31E-07	0.00	0.00E+00	
	Chrysene	1.53E-06	3.22E-07	0.00	0.00E+00	
	Benz(b)fluoranthcene	1.11E-06	2.33E-07	0.00	0.00E+00	
	Benz(k)fluoranthcene	2.18E-07	4.58E-08	0.00	0.00E+00	
	Benzo(a)pyrene	2.57E-07	5.40E-08	0.00	0.00E+00	
	Indeno(1,2,3-cd)pyrene	4.14E-07	8.70E-08	0.00	0.00E+00	
	Dibenz(a,h)anthracene	3.46E-07	7.27E-08	0.00	0.00E+00	
	DPM	--	5.07E-03	0.00	0.00E+00	

[1] ASIL information from WAC 173-460
[2] SO2, NO2, CO, and DPM based on criteria pollutant emission calculations, assuming 90% of NOx as NO2. Other TAP's from AP-42 Chapter 3.4 (Large Stationary Diesel Engines)
[3] Control factors used in recent Sabey, Vantage, and Cyrus One data center NOC applications.
[4] Cost-effectiveness based on total annual control cost and emission reduction by TAP averaging period group.

TABLE B2.2-7b
COST EFFECTIVENESS CALCULATIONS
Criteria Air Pollutants
Selective Catalytic Reduction (SCR) Control System
Diesel-Fired 750 kW Emergency Generator
Operating Hours 100 hours/year

Cost Item		Factor	Cost
Direct Costs			
Purchased Equipment Costs			
	Primary Equipment[1]	A	89,026
	Sales Tax[2]	B = 0.065 * A	5,787
	Shipping	Included in A	-----
	Purchased Equipment Cost (PEC)	PEC = A + B	94,812
Direct Installation Costs			
	Foundations & Supports	Included in A	-----
	Handling & Erection	Included in A	-----
	Electrical	Included in A	-----
	Piping	Included in A	-----
	Insulation for Ductwork	Included in A	-----
	Painting	Included in A	-----
	Direct Installation Cost	Included in A	-----
Total Direct Costs (DC)			94,812
Indirect Costs			
Installation			
	Engineering	Included in A	-----
	Construction & Field Expenses	Included in A	-----
	Contractor Fees	Included in A	-----
	Start-Up	Included in A	-----
	Contingencies[3]	0.03 * PEC	2,844
Total Indirect Costs (IC)			2,844
TOTAL CAPITAL INVESTMENT = DC + IC			**97,657**
Direct Annual Costs			
Operating Labor			
	Operator	Negligible	-----
	Supervisor	Negligible	-----
	Total Operating Labor		-----
Maintenance			
	Labor	-----	-----
	Materials	-----	-----
	Total Maintenance[4]	0.005 * TCI	489
Utilities			
	Electricity	Negligible	-----
	Water	-----	-----
	Reagent[4]	-----	1,800
	Total Utilities		-----
Catalyst Cost			
	Catalyst Replacement	Catalyst life > SCR Service Life	-----
	Total Catalyst Cost	-----	-----
Miscellaneous			
	Performance Tests	-----	-----
	Record Keeping & Reporting	-----	-----
	Total Miscellaneous Costs		-----
Total Direct Annual Costs (DAC)			**2,289**
Indirect Annual Costs			
Administrative Charges[5]		0.03 * (Op. Labor Cost + 0.4 * Ann. Maint. Cost)	6
Capital Recovery Factor[6]		CRF	0.0640
Capital Recovery		CRF * TCI	6,251
Total Indirect Annual Costs (IAC)			**6,257**
TOTAL ANNUAL COST = DAC + IAC			**8,546**
Uncontrolled NOx, CO, VOC, and PM emissions		tons/yr	0.79
NOx, CO, VOC, and PM Emissions with SCR		tons/yr	0.14
Percent reduction from uncontrolled			82%
Total emissions reduction		tons/yr	0.65
Cost per Ton Controlled		**$/ton**	**13,242**

[1] Capital cost provided by the engine vendor (Brant Briody of Western States Equipment Co.)
[2] Washington sales tax
[3] Minimum cost from most recent Sabey, Vantage, and Cyrus One cost-effectiveness analyses
[4] Estimated using equations from EPA's Air Pollution Control Cost Estimation Spreadsheet for Selective Catalytic Reduction (SCR) found at https://www.epa.gov/sites/production/files/2019-06/scrcostmanualspreadsheet_june-2019vf.xlsm
[5] EPA's Air Pollution Control Cost Manual, Section 4, Chapter 2 (SCR)
[6] The capital recovery factor was calculated assuming a 25-year equipment life and a 4% interest rate

TABLE B2.2-7b
COST EFFECTIVENESS CALCULATIONS
Toxic Air Pollutants
Selective Catalytic Reduction (SCR) Control System
Diesel-Fired 750 kW Emergency Generator
Operating Hours 100 hours/year

TAP Avg Period [1]	Toxic Air Pollutant	Emission Factor [2] (lb/MMBTU)	Uncontrolled Emissions (tpy)	Control Factor [3]	Emission Reduction (tpy)	Cost-Effectiveness [4] ($/ton)
24-Hour	Acrolein	7.88E-06	2.90E-06	0.00	0.00E+00	--
	Toluene	2.81E-04	1.03E-04	0.00	0.00E+00	
	Xylenes	1.93E-04	7.11E-05	0.00	0.00E+00	
	Propylene	2.79E-03	1.03E-03	0.00	0.00E+00	
Annual	Benzene	7.76E-04	2.86E-04	0.00	0.00E+00	--
	Formaldehyde	7.89E-05	2.91E-05	0.00	0.00E+00	
	Acetaldehyde	2.52E-05	9.28E-06	0.00	0.00E+00	
	Naphthalene	1.30E-04	4.79E-05	0.00	0.00E+00	
	Benz(a)anthracene	6.22E-07	2.29E-07	0.00	0.00E+00	
	Chrysene	1.53E-06	5.63E-07	0.00	0.00E+00	
	Benz(b)fluoranthcene	1.11E-06	4.09E-07	0.00	0.00E+00	
	Benz(k)fluoranthcene	2.18E-07	8.03E-08	0.00	0.00E+00	
	Benzo(a)pyrene	2.57E-07	9.46E-08	0.00	0.00E+00	
	Indeno(1,2,3-cd)pyrene	4.14E-07	1.52E-07	0.00	0.00E+00	
	Dibenz(a,h)anthracene	3.46E-07	1.27E-07	0.00	0.00E+00	
	DPM	--	7.35E-03	0.00	0.00E+00	

[1] ASIL information from WAC 173-460
[2] SO2, NO2, CO, and DPM based on criteria pollutant emission calculations, assuming 90% of NOx as NO2. Other TAPs from AP-42 Chapter 3.4 (Large Stationary Diesel Engines)
[3] Control factors used in recent Sabey, Vantage, and Cyrus One data center NOC applications.
[4] Cost-effectiveness based on total annual control cost and emission reduction by TAP averaging period group.

TABLE B2.2-8b
COST EFFECTIVENESS CALCULATIONS
Criteria Air Pollutants
Selective Catalytic Reduction (SCR) Control System
Diesel-Fired 1.25 MW Caterpillar Emergency Generator
Operating Hours 100 hours/year

Cost Item		Factor	Cost
Direct Costs			
Purchased Equipment Costs			
	Primary Equipment[1]	A	120,000
	Sales Tax[2]	B = 0.065 * A	7,800
	Shipping	Included in A	-----
	Purchased Equipment Cost (PEC)	PEC = A + B	127,800
Direct Installation Costs			
	Foundations & Supports	Included in A	-----
	Handling & Erection	Included in A	-----
	Electrical	Included in A	-----
	Piping	Included in A	-----
	Insulation for Ductwork	Included in A	-----
	Painting	Included in A	-----
	Direct Installation Cost	Included in A	-----
Total Direct Costs (DC)			127,800
Indirect Costs			
Installation			
	Engineering	Included in A	-----
	Construction & Field Expenses	Included in A	-----
	Contractor Fees	Included in A	-----
	Start-Up	Included in A	-----
	Contingencies[3]	0.03 * PEC	3,834
Total Indirect Costs (IC)			3,834
TOTAL CAPITAL INVESTMENT = DC + IC			**131,634**
Direct Annual Costs			
Operating Labor			
	Operator	Negligible	-----
	Supervisor	Negligible	-----
	Total Operating Labor		-----
Maintenance			
	Labor	-----	-----
	Materials	-----	-----
	Total Maintenance[4]	0.005 * TCI	658
Utilities			
	Electricity	Negligible	-----
	Water	-----	-----
	Reagent[4]	-----	3,139
	Total Utilities		-----
Catalyst Cost			
	Catalyst Replacement	Catalyst life > SCR Service Life	-----
	Total Catalyst Cost	-----	-----
Miscellaneous			
	Performance Tests	-----	-----
	Record Keeping & Reporting	-----	-----
	Total Miscellaneous Costs		-----
Total Direct Annual Costs (DAC)			**3,797**
Indirect Annual Costs			
Administrative Charges[6]		0.03 * (Op. Labor Cost + 0.4 * Ann. Maint. Cost))	8
Capital Recovery Factor[5]		CRF	0.0640
Capital Recovery		CRF * TCI	8,428
Total Indirect Annual Costs (IAC)			**8,434**
TOTAL ANNUAL COST = DAC + IAC			**12,231**
Uncontrolled NOx, CO, VOC, and PM emissions		tons/yr	1.32
NOx, CO, VOC, and PM Emissions with SCR		tons/yr	0.19
Percent reduction from uncontrolled			85%
Total emissions reduction		tons/yr	1.12
Cost per Ton Controlled		**$/ton**	**10,872**

[1] Capital cost provided by the engine vendor (Brant Brody of Western States Equipment Co.)
[2] Washington sales tax
[3] Minimum cost from most recent Sabey, Vantage, and Cyrus One cost-effectiveness analyses
https://www.epa.gov/ttnecas1/productionfiles/2019-06/scrcostmanualspreadsheet_june-2019vf.xlsm
[5] EPA's Air Pollution Control Cost Manual, Section 4, Chapter 2 (SCR)
[6] The capital recovery factor was calculated assuming a 25-year equipment life and a 4% interest rate

TABLE B2.2-8b
COST EFFECTIVENESS CALCULATIONS
Toxic Air Pollutants
Selective Catalytic Reduction (SCR) Control System
Diesel-Fired 1.25 MW Caterpillar Emergency Generator
Operating Hours 100 hours/year

TAP Avg Period [1]	Toxic Air Pollutant	Emission Factor [2] (lb/MMBTU)	Uncontrolled Emissions (tpy)	Control Factor [3]	Emission Reduction (tpy)	Cost-Effectiveness [4] ($/ton)
24-Hour	Acrolein	7.88E-06	4.73E-06	0.00	0.00E+00	--
	Toluene	2.81E-04	1.69E-04	0.00	0.00E+00	
	Xylenes	1.93E-04	1.16E-04	0.00	0.00E+00	
	Propylene	2.76E-03	1.66E-03	0.00	0.00E+00	
Annual	Benzene	7.76E-04	4.66E-04	0.00	0.00E+00	--
	Formaldehyde	7.89E-05	4.74E-05	0.00	0.00E+00	
	Acetaldehyde	2.52E-05	1.51E-05	0.00	0.00E+00	
	Naphthalene	1.30E-04	7.81E-05	0.00	0.00E+00	
	Benz(a)anthracene	6.22E-07	3.73E-07	0.00	0.00E+00	
	Chrysene	1.53E-06	9.19E-07	0.00	0.00E+00	
	Benz(b)fluoranthcene	1.11E-06	6.66E-07	0.00	0.00E+00	
	Benz(k)fluoranthcene	2.18E-07	1.31E-07	0.00	0.00E+00	
	Benzo(a)pyrene	2.57E-07	1.54E-07	0.00	0.00E+00	
	Indeno(1,2,3-cd)pyrene	4.14E-07	2.48E-07	0.00	0.00E+00	
	Dibenz(a,h)anthracene	3.46E-07	2.08E-07	0.00	0.00E+00	
	DPM	--	4.03E-03	0.00	0.00E+00	

[1] ASIL information from WAC 173-460
[2] SO2, NO2, CO, and DPM based on criteria pollutant emission calculations, assuming 90% of NOx as NO2. Other TAPs from AP-42 Chapter 3.4 (Large Stationary Diesel Engines)
[3] Control factors used in recent Sabey, Vantage, and Cyrus One data center NOC applications.
[4] Cost-effectiveness based on total annual control cost and emission reduction by TAP averaging period group.

TABLE B2.2-9b
COST EFFECTIVENESS CALCULATIONS
Criteria Air Pollutants
Selective Catalytic Reduction (SCR) Control System
Diesel-Fired 1.25 MW Generac Emergency Generator
Operating Hours 100 hours/year

Cost Item			Factor	Cost
Direct Costs				
Purchased Equipment Costs				
	Primary Equipment[1]		A	122,036
	Sales Tax[2]		B = 0.065 * A	7,932
	Shipping		Included in A	-----
		Purchased Equipment Cost (PEC)	PEC = A + B	129,968
Direct Installation Costs				
	Foundations & Supports		Included in A	-----
	Handling & Erection		Included in A	-----
	Electrical		Included in A	-----
	Piping		Included in A	-----
	Insulation for Ductwork		Included in A	-----
	Painting		Included in A	-----
		Direct Installation Cost	Included in A	-----
Total Direct Costs (DC)				129,968
Indirect Costs				
Installation				
	Engineering		Included in A	-----
	Construction & Field Expenses		Included in A	-----
	Contractor Fees		Included in A	-----
	Start-Up		Included in A	-----
	Contingencies[3]		0.03 * PEC	3,899
Total Indirect Costs (IC)				3,899
TOTAL CAPITAL INVESTMENT = DC + IC				**133,867**
Direct Annual Costs				
Operating Labor				
	Operator		Negligible	-----
	Supervisor		Negligible	-----
		Total Operating Labor		-----
Maintenance				
	Labor		-----	-----
	Materials		-----	-----
		Total Maintenance[4]	0.005 * TCI	669
Utilities				
	Electricity		Negligible	-----
	Water		-----	-----
	Reagent[4]		-----	1,937
		Total Utilities		-----
Catalyst Cost				
	Catalyst Replacement		Catalyst life > SCR Service Life	-----
		Total Catalyst Cost	-----	-----
Miscellaneous				
	Performance Tests		-----	-----
	Record Keeping & Reporting		-----	-----
		Total Miscellaneous Costs		-----
Total Direct Annual Costs (DAC)				**2,607**
Indirect Annual Costs				
Administrative Charges[5]			0.03 * (Op. Labor Cost + 0.4 * Ann. Maint. Cost))	8
Capital Recovery Factor[6]			CRF	0.0640
Capital Recovery			CRF * TCI	8,569
Total Indirect Annual Costs (IAC)				**8,577**
TOTAL ANNUAL COST = DAC + IAC				**11,184**
Uncontrolled NOx, CO, VOC, and PM emissions			tons/yr	0.98
NOx, CO, VOC, and PM Emissions with SCR			tons/yr	0.28
Percent reduction from uncontrolled				71%
Total emissions reduction			tons/yr	0.69
Cost per Ton Controlled			**$/ton**	**16,106**

[1] Captial cost provided by the engine vendor (Brant Briody of Western States Equipment Co.)
[2] Washington sales tax
[3] Minimum cost from most recent Sabey, Vantage, and Cyrus One cost-effectiveness analyses
[4] Estimated using equations from EPA's Air Pollution Control Cost Estimation Spreadsheet for Selective Catalytic Reduction (SCR) found at https://www.epa.gov/sites/production/files/2019-06/scrcostmanualspreadsheet_june-2019vf.xlsm
[5] EPA's Air Pollution Control Cost Manual, Section 4, Chapter 2 (SCR)
[6] The capital recovery factor was calculated assuming a 25-year equipment life and a 4% interest rate

TABLE B2.2-9b
COST EFFECTIVENESS CALCULATIONS
Toxic Air Pollutants
Selective Catalytic Reduction (SCR) Control System
Diesel-Fired 1.25 MW Generac Emergency Generator
Operating Hours 100 hours/year

TAP Avg Period [1]	Toxic Air Pollutant	Emission Factor [2] (lb/MMBTU)	Uncontrolled Emissions (tpy)	Control Factor [3]	Emission Reduction (tpy)	Cost-Effectiveness [4] ($/ton)
24-Hour	Acrolein	7.88E-06	6.17E-06	0.00	0.00E+00	--
	Toluene	2.81E-04	2.20E-04	0.00	0.00E+00	
	Xylenes	1.93E-04	1.51E-04	0.00	0.00E+00	
	Propylene	2.79E-03	2.19E-03	0.00	0.00E+00	
Annual	Benzene	7.76E-04	6.08E-04	0.00	0.00E+00	--
	Formaldehyde	7.89E-05	6.18E-05	0.00	0.00E+00	
	Acetaldehyde	2.52E-05	1.97E-05	0.00	0.00E+00	
	Naphthalene	1.30E-04	1.02E-04	0.00	0.00E+00	
	Benz(a)anthracene	6.22E-07	4.87E-07	0.00	0.00E+00	
	Chrysene	1.53E-06	1.20E-06	0.00	0.00E+00	
	Benz(b)fluoranthcene	1.11E-06	8.69E-07	0.00	0.00E+00	
	Benz(k)fluoranthcene	2.18E-07	1.71E-07	0.00	0.00E+00	
	Benzo(a)pyrene	2.57E-07	2.01E-07	0.00	0.00E+00	
	Indeno(1,2,3-cd)pyrene	4.14E-07	3.24E-07	0.00	0.00E+00	
	Dibenz(a,h)anthracene	3.46E-07	2.71E-07	0.00	0.00E+00	
	DPM	--	2.16E-02	0.00	0.00E+00	

[1] ASIL information from WAC 173-460
[2] SO2, NO2, CO, and DPM based on criteria pollutant emission calculations, assuming 90% of NOx as NO2. Other TAPs from AP-42 Chapter 3.4 (Large Stationary Diesel Engines)
[3] Control factors used in recent Sabey, Vantage, and Cyrus One data center NOC applications.
[4] Cost-effectiveness based on total annual control cost and emission reduction by TAP averaging period group.

TABLE B2.2-10b
COST EFFECTIVENESS CALCULATIONS
Criteria Air Pollutants
Selective Catalytic Reduction (SCR) Control System
Diesel-Fired 2.25 MW Emergency Generator
Operating Hours 100 hours/year

Cost Item		Factor	Cost
Direct Costs			
Purchased Equipment Costs			
	Primary Equipment[1]	A	172,629
	Sales Tax[2]	B = 0.065 * A	11,221
	Shipping	Included in A	-----
	Purchased Equipment Cost (PEC)	PEC = A + B	183,850
Direct Installation Costs			
	Foundations & Supports	Included in A	-----
	Handling & Erection	Included in A	-----
	Electrical	Included in A	-----
	Piping	Included in A	-----
	Insulation for Ductwork	Included in A	-----
	Painting	Included in A	-----
	Direct Installation Cost	Included in A	-----
Total Direct Costs (DC)			183,850
Indirect Costs			
Installation			
	Engineering	Included in A	-----
	Construction & Field Expenses	Included in A	-----
	Contractor Fees	Included in A	-----
	Start-Up	Included in A	-----
	Contingencies[3]	0.03 * PEC	5,515
Total Indirect Costs (IC)			5,515
TOTAL CAPITAL INVESTMENT = DC + IC			**189,365**
Direct Annual Costs			
Operating Labor			
	Operator	Negligible	-----
	Supervisor	Negligible	-----
	Total Operating Labor		-----
Maintenance			
	Labor	-----	-----
	Materials	-----	-----
	Total Maintenance[4]	0.005 * TCI	947
Utilities			
	Electricity	Negligible	-----
	Water	-----	-----
	Reagent[4]	-----	3,654
	Total Utilities		-----
Catalyst Cost			
	Catalyst Replacement	Catalyst life > SCR Service Life	-----
	Total Catalyst Cost	-----	-----
Miscellaneous			
	Performance Tests	-----	-----
	Record Keeping & Reporting	-----	-----
	Total Miscellaneous Costs		-----
Total Direct Annual Costs (DAC)			**4,601**
Indirect Annual Costs			
Administrative Charges[5]		0.03 * (Op. Labor Cost + 0.4 * Ann. Maint. Cost)	11
Capital Recovery Factor[6]		CRF	0.0640
Capital Recovery		CRF * TCI	12,122
Total Indirect Annual Costs (IAC)			**12,133**
TOTAL ANNUAL COST = DAC + IAC			**16,734**
Uncontrolled NOx, CO, VOC, and PM emissions		tons/yr	2.06
NOx, CO, VOC, and PM Emissions with SCR		tons/yr	0.75
Percent reduction from uncontrolled			63%
Total emissions reduction		tons/yr	1.31
Cost per Ton Controlled		**$/ton**	**12,777**

[1] Capital cost provided by the engine vendor (Brent Briody of Western States Equipment Co.)
[2] Washington sales tax
[3] Minimum cost from most recent Safeway, Vantage, and Cyrus One cost-effectiveness analyses
[4] Estimated using equations from EPA's Air Pollution Control Cost Estimation Spreadsheet for Selective Catalytic Reduction (SCR) found at https://www.epa.gov/sites/production/files/2019-06/scrcostmanualspreadsheet_june-2019v1.xlsm
[5] EPA's Air Pollution Control Cost Manual, Section 4, Chapter 2 (SCR)
[6] The capital recovery factor was calculated assuming a 25-year equipment life and a 4% interest rate

TABLE B2.2-10b
COST EFFECTIVENESS CALCULATIONS
Toxic Air Pollutants
Selective Catalytic Reduction (SCR) Control System
Diesel-Fired 2.25 MW Emergency Generator
Operating Hours 100 hours/year

TAP Avg Period [1]	Toxic Air Pollutant	Emission Factor [2] (lb/MMBTU)	Uncontrolled Emissions (tpy)	Control Factor [3]	Emission Reduction (tpy)	Cost-Effectiveness [4] ($/ton)
24-Hour	Acrolein	7.88E-06	9.05E-06	0.00	0.00E+00	--
	Toluene	2.81E-04	3.23E-04	0.00	0.00E+00	
	Xylenes	1.93E-04	2.22E-04	0.00	0.00E+00	
	Propylene	2.79E-03	3.20E-03	0.00	0.00E+00	
Annual	Benzene	7.76E-04	8.91E-04	0.00	0.00E+00	--
	Formaldehyde	7.89E-05	9.06E-05	0.00	0.00E+00	
	Acetaldehyde	2.52E-05	2.89E-05	0.00	0.00E+00	
	Naphthalene	1.30E-04	1.49E-04	0.00	0.00E+00	
	Benz(a)anthracene	6.22E-07	7.14E-07	0.00	0.00E+00	
	Chrysene	1.53E-06	1.76E-06	0.00	0.00E+00	
	Benz(b)fluoranthcene	1.11E-06	1.27E-06	0.00	0.00E+00	
	Benz(k)fluoranthcene	2.18E-07	2.50E-07	0.00	0.00E+00	
	Benzo(a)pyrene	2.57E-07	2.95E-07	0.00	0.00E+00	
	Indeno(1,2,3-cd)pyrene	4.14E-07	4.75E-07	0.00	0.00E+00	
	Dibenz(a,h)anthracene	3.46E-07	3.97E-07	0.00	0.00E+00	
	DPM	--	4.41E-02	0.00	0.00E+00	

[1] ASIL information from WAC 173-460

[2] SO2, NO2, CO, and DPM based on criteria pollutant emission calculations, assuming 90% of NOx as NO2. Other TAP's from AP-42 Chapter 3.4 (Large Stationary Diesel Engines)

[3] Control factors used in recent Sabey, Vantage, and Cyrus One data center NOC applications.

[4] Cost-effectiveness based on total annual control cost and emission reduction by TAP averaging period group.

TABLE B2.2-10b
COST EFFECTIVENESS CALCULATIONS
Toxic Air Pollutants
Diesel Particulate Filter (DPF)/Diesel Oxidation Catalyst (DOC) Control System
Diesel-Fired 400 kW Emergency Generator

TABLE B2.2-11b
COST EFFECTIVENESS CALCULATIONS
Criteria Air Pollutants
Diesel Particulate Filter (DPF)/Diesel Oxidation Catalyst (DOC) Control System
Diesel-Fired 400 kW Emergency Generator
Operating Hours 100 hours/year

Cost Item			Factor	Cost
Direct Costs				
Purchased Equipment Costs				
	Primary Equipment[1]		A	41,690
	Sales Tax[2]		B = 0.065 * A	2,709
	Shipping		Included in A	-----
		Purchased Equipment Cost (PEC)	PEC = A + B	44,390
Direct Installation Costs				
	Foundations & Supports		Included in A	-----
	Handling & Erection		Included in A	-----
	Electrical		Included in A	-----
	Piping		Included in A	-----
	Insulation for Ductwork		Included in A	-----
	Painting		Included in A	-----
		Direct Installation Cost	Included in A	-----
Total Direct Costs (DC)				44,390
Indirect Costs				
Installation				
	Engineering		Included in A	-----
	Construction & Field Expenses		Included in A	-----
	Contractor Fees		Included in A	-----
	Start-Up		Included in A	-----
	Contingencies[3]		0.03 * PEC	1,332
Total Indirect Costs (IC)				1,332
TOTAL CAPITAL INVESTMENT = DC + IC				**45,721**
Direct Annual Costs				
Operating Labor				
	Operator		Negligible	-----
	Supervisor		Negligible	-----
		Total Operating Labor		-----
Maintenance				
	Labor		-----	-----
	Materials		-----	-----
		Total Maintenance[4]	0.005 * TCI	229
Utilities				
	Electricity		Negligible	-----
	Water		-----	-----
	Reagent		-----	-----
		Total Utilities		-----
Catalyst Cost				
	Catalyst Replacement		Catalyst life > DOC Service Life	-----
		Total Catalyst Cost	-----	-----
Miscellaneous				
	Performance Tests		-----	-----
	Record Keeping & Reporting		-----	-----
		Total Miscellaneous Costs		-----
Total Direct Annual Costs (DAC)				**229**
Indirect Annual Costs				
Overhead[5]			60% of operating, supervisor, maintenance labor & materials	137
Administrative Charges[3]			0.02 * TCI	914
Capital Recovery Factor[7]			CRF	0.0640
Capital Recovery			CRF * TCI	2,927
Total Indirect Annual Costs (IAC)				**3,978**
TOTAL ANNUAL COST = DAC + IAC				**4,207**
Uncontrolled NOx, CO, VOC, and PM emissions			tons/yr	0.21
NOx, CO, VOC, and PM Emissions with DPF & DOC Controls			tons/yr	0.18
Percent reduction from uncontrolled				16%
Total emissions reduction			tons/yr	0.03
Cost per Ton Controlled			**$/ton**	**129,604**

[1] Capital cost provided by the engine vendor (Brent Briody of Western States Equipment Co.)
[2] Washington sales tax
[3] Minimum cost from most recent Sabey, Vantage, and Cyrus One cost-effectiveness analyses
[4] Estimated using equations from EPA's Air Pollution Control Cost Estimation Spreadsheet for Selective Catalytic Reduction (SCR) found at https://www.epa.gov/sites/production/files/2019-06/scrcostmanualspreadsheet_june-2019vf.xlsm
[5] EPA's Air Pollution Control Cost Manual, Section 1, Chapter 2 (Cost Estimation), Section 2.6.5.7
[6] EPA's Air Pollution Control Cost Manual, Section 1, Chapter 2 (Cost Estimation), Section 2.6.5.8
[7] The capital recovery factor was calculated assuming a 25-year equipment life and a 4% interest rate

TABLE B2.2-11b
COST EFFECTIVENESS CALCULATIONS
Toxic Air Pollutants
Diesel Particulate Filter (DPF)/Diesel Oxidation Catalyst (DOC) Control System
Diesel-Fired 400 kW Emergency Generator
Operating Hours 100 hours/year

TAP Avg Period [1]	Toxic Air Pollutant	Emission Factor [2] (lb/MMBTU)	Uncontrolled Emissions (tpy)	Control Factor [3]	Emission Reduction (tpy)	Cost-Effectiveness [4] ($/ton)
24-Hour	Acrolein	7.88E-06	1.66E-06	0.70	1.16E-06	8,737,565
	Toluene	2.81E-04	5.91E-05	0.70	4.14E-05	
	Xylenes	1.93E-04	4.06E-05	0.70	2.84E-05	
	Propylene	2.79E-03	5.87E-04	0.70	4.11E-04	
Annual	Benzene	7.76E-04	1.63E-04	0.70	1.14E-04	912,098
	Formaldehyde	7.89E-05	1.66E-05	0.70	1.16E-05	
	Acetaldehyde	2.52E-05	5.30E-06	0.70	3.71E-06	
	Naphthalene	1.30E-04	2.73E-05	0.70	1.91E-05	
	Benz(a)anthracene	6.22E-07	1.31E-07	0.70	9.15E-08	
	Chrysene	1.53E-06	3.22E-07	0.70	2.25E-07	
	Benz(b)fluoranthcene	1.11E-06	2.33E-07	0.70	1.63E-07	
	Benz(k)fluoranthcene	2.18E-07	4.58E-08	0.70	3.21E-08	
	Benzo(a)pyrene	2.57E-07	5.40E-08	0.70	3.78E-08	
	Indeno(1,2,3-cd)pyrene	4.14E-07	8.70E-08	0.70	6.09E-08	
	Dibenz(a,h)anthracene	3.46E-07	7.27E-08	0.70	5.09E-08	
	DPM	--	5.07E-03	0.88	4.46E-03	

[1] ASIL information from WAC 173-460

[2] SO2, NO2, CO, and DPM based on criteria pollutant emission calculations, assuming 90% of NOx as NO2. Other TAPs from AP-42 Chapter 3.4 (Large Stationary Diesel Engines)

[3] Control factors used in recent Sidney, Vantage, and Cyrus One data center NOC applications.

[4] Cost-effectiveness based on total annual control cost and emission reduction by TAP averaging period group.

TABLE B2.2-12b
COST EFFECTIVENESS CALCULATIONS
Criteria Air Pollutants
Diesel Particulate Filter (DPF)/Diesel Oxidation Catalyst (DOC) Control System
Diesel-Fired 750 kW Emergency Generator
Operating Hours 100 hours/year

Cost Item		Factor	Cost
Direct Costs			
Purchased Equipment Costs			
	Primary Equipment[1]	A	59,351
	Sales Tax[2]	B = 0.065 * A	3,858
	Shipping	Included in A	----
	Purchased Equipment Cost (PEC)	PEC = A + B	63,208
Direct Installation Costs			
	Foundations & Supports	Included in A	----
	Handling & Erection	Included in A	----
	Electrical	Included in A	----
	Piping	Included in A	----
	Insulation for Ductwork	Included in A	----
	Painting	Included in A	----
	Direct Installation Cost	Included in A	----
Total Direct Costs (DC)			63,208
Indirect Costs			
Installation			
	Engineering	Included in A	----
	Construction & Field Expenses	Included in A	----
	Contractor Fees	Included in A	----
	Start-Up	Included in A	----
	Contingencies[3]	0.03 * PEC	1,896
Total Indirect Costs (IC)			1,896
TOTAL CAPITAL INVESTMENT = DC + IC			**65,105**
Direct Annual Costs			
Operating Labor			
	Operator	Negligible	----
	Supervisor	Negligible	----
	Total Operating Labor		----
Maintenance			
	Labor	----	----
	Materials	----	----
	Total Maintenance[4]	0.005 * TCI	326
Utilities			
	Electricity	Negligible	----
	Water	----	----
	Reagent	----	----
	Total Utilities		----
Catalyst Cost			
	Catalyst Replacement	Catalyst life > DOC Service Life	----
	Total Catalyst Cost	----	----
Miscellaneous			
	Performance Tests	----	----
	Record Keeping & Reporting	----	----
	Total Miscellaneous Costs		----
Total Direct Annual Costs (DAC)			**326**
Indirect Annual Costs			
Overhead[6]		60% of operating, supervisor, maintenance labor & materials	195
Administrative Charges[5]		0.02 * TCI	1,302
Capital Recovery Factor[7]		CRF	0.0640
Capital Recovery		CRF * TCI	4,167
Total Indirect Annual Costs (IAC)			**5,665**
TOTAL ANNUAL COST = DAC + IAC			**5,990**
Uncontrolled NOx, CO, VOC, and PM emissions		tons/yr	0.79
NOx, CO, VOC, and PM Emissions with DPF & DOC Controls		tons/yr	0.73
Percent reduction from uncontrolled			7%
Total emissions reduction		tons/yr	0.06
Cost per Ton Controlled		**$/ton**	**106,752**

[1] Captial cost provided by the engine vendor (Brant Briody of Western States Equipment Co.)
[2] Washington sales tax
[3] Minimum cost from most recent Sabey, Vantage, and Cyrus One cost-effectiveness analyses
[4] Estimated using equations from EPA's Air Pollution Control Cost Estimation Spreadsheet for Selective Catalytic Reduction (SCR) found at https://www.epa.gov/sites/production/files/2019-06/scrcostmanualspreadsheet_june-2019xlsx.xlsm
[5] EPA's Air Pollution Control Cost Manual, Section 1, Chapter 2 (Cost Estimation), Section 2.6.5.7
[6] EPA's Air Pollution Control Cost Manual, Section 1, Chapter 2 (Cost Estimation), Section 2.6.5.8
[7] The capital recovery factor was calculated assuming a 25-year equipment life and a 4% interest rate

TABLE B2.2-12b
COST EFFECTIVENESS CALCULATIONS
Toxic Air Pollutants
Diesel Particulate Filter (DPF)/Diesel Oxidation Catalyst (DOC) Control System
Diesel-Fired 750 kW Emergency Generator
Operating Hours 100 hours/year

TAP Avg Period [1]	Toxic Air Pollutant	Emission Factor [2] (lb/MMBTU)	Uncontrolled Emissions (tpy)	Control Factor [3]	Emission Reduction (tpy)	Cost-Effectiveness [4] ($/ton)
24-Hour	Acrolein	7.88E-06	2.90E-06	0.70	2.03E-06	7,102,951
	Toluene	2.81E-04	1.03E-04	0.70	7.24E-05	
	Xylenes	1.93E-04	7.11E-05	0.70	4.97E-05	
	Propylene	2.79E-03	1.03E-03	0.70	7.19E-04	
Annual	Benzene	7.76E-04	2.86E-04	0.70	2.00E-04	889,638
	Formaldehyde	7.89E-05	2.91E-05	0.70	2.03E-05	
	Acetaldehyde	2.52E-05	9.28E-06	0.70	6.50E-06	
	Naphthalene	1.30E-04	4.79E-05	0.70	3.35E-05	
	Benz(a)anthracene	6.22E-07	2.29E-07	0.70	1.60E-07	
	Chrysene	1.53E-06	5.63E-07	0.70	3.94E-07	
	Benz(b)fluoranthcene	1.11E-06	4.09E-07	0.70	2.86E-07	
	Benz(k)fluoranthcene	2.18E-07	8.03E-08	0.70	5.62E-08	
	Benzo(a)pyrene	2.57E-07	9.46E-08	0.70	6.62E-08	
	Indeno(1,2,3-cd)pyrene	4.14E-07	1.52E-07	0.70	1.07E-07	
	Dibenz(a,h)anthracene	3.46E-07	1.27E-07	0.70	8.92E-08	
	DPM	--	7.35E-03	0.88	6.47E-03	

[1] ASIL information from WAC 173-460
[2] SO2, NO2, CO, and DPM based on criteria pollutant emission calculations, assuming 90% of NOx as NO2. Other TAPs from AP-42 Chapter 3.4 (Large Stationary Diesel Engines)
[3] Control factors used in recent Sabey, Vantage, and Cyrus One data center NOC applications.
[4] Cost-effectiveness based on total annual control cost and emission reduction by TAP averaging period group.

TABLE B2.2-13b
COST EFFECTIVENESS CALCULATIONS
Criteria Air Pollutants
Diesel Particulate Filter (DPF)/Diesel Oxidation Catalyst (DOC) Control System
Diesel-Fired 1.25 MW Caterpillar Emergency Generator
Operating Hours 100 hours/year

Cost Item		Factor	Cost
Direct Costs			
Purchased Equipment Costs			
	Primary Equipment[1]	A	80,000
	Sales Tax[2]	B = 0.065 * A	5,200
	Shipping	Included in A	-----
	Purchased Equipment Cost (PEC)	PEC = A + B	85,200
Direct Installation Costs			
	Foundations & Supports	Included in A	-----
	Handling & Erection	Included in A	-----
	Electrical	Included in A	-----
	Piping	Included in A	-----
	Insulation for Ductwork	Included in A	-----
	Painting	Included in A	-----
	Direct Installation Cost	Included in A	-----
Total Direct Costs (DC)			85,200
Indirect Costs			
Installation			
	Engineering	Included in A	-----
	Construction & Field Expenses	Included in A	-----
	Contractor Fees	Included in A	-----
	Start-Up	Included in A	-----
	Contingencies[3]	0.03 * PEC	2,556
Total Indirect Costs (IC)			2,556
TOTAL CAPITAL INVESTMENT = DC + IC			**87,756**
Direct Annual Costs			
Operating Labor			
	Operator	Negligible	-----
	Supervisor	Negligible	-----
	Total Operating Labor		-----
Maintenance			
	Labor	-----	-----
	Materials	-----	-----
	Total Maintenance[4]	0.005 * TCI	439
Utilities			
	Electricity	Negligible	-----
	Water	-----	-----
	Reagent	-----	-----
	Total Utilities		-----
Catalyst Cost			
	Catalyst Replacement	Catalyst life > DOC Service Life	-----
	Total Catalyst Cost	-----	-----
Miscellaneous			
	Performance Tests	-----	-----
	Record Keeping & Reporting	-----	-----
	Total Miscellaneous Costs		-----
Total Direct Annual Costs (DAC)			**439**
Indirect Annual Costs			
Overhead[5]		60% of operating, supervisor, maintenance labor & materials	263
Administrative Charges[6]		0.02 * TCI	1,755
Capital Recovery Factor[7]		CRF	0.0640
Capital Recovery		CRF * TCI	5,617
Total Indirect Annual Costs (IAC)			**7,636**
TOTAL ANNUAL COST = DAC + IAC			**8,075**
Uncontrolled NOx, CO, VOC, and PM emissions		tons/yr	1.32
NOx, CO, VOC, and PM Emissions with DPF & DOC Controls		tons/yr	1.26
Percent reduction from uncontrolled			4%
Total emissions reduction		tons/yr	0.05
Cost per Ton Controlled		**$/ton**	**156,692**

[1] Captial cost provided by the engine vendor (Brant Briody of Western States Equipment Co.)
[2] Washington sales tax
[3] Minimum cost from most recent Sabey, Vantage, and Cyrus One cost-effectiveness analyses
[4] Estimated using equations from EPA's Air Pollution Control Cost Estimation Spreadsheet for Selective Catalytic Reduction (SCR) found at https://www.epa.gov/sites/production/files/2019-06/scrcostmanualspreadsheet_june-2019vf.xlsm
[5] EPA's Air Pollution Control Cost Manual, Section 1, Chapter 2 (Cost Estimation), Section 2.6.5.7
[6] EPA's Air Pollution Control Cost Manual, Section 1, Chapter 2 (Cost Estimation), Section 2.6.5.8
[7] The capital recovery factor was calculated assuming a 25-year equipment life and a 4% interest rate

TABLE B2.2-13b
COST EFFECTIVENESS CALCULATIONS
Toxic Air Pollutants
Diesel Particulate Filter (DPF)/Diesel Oxidation Catalyst (DOC) Control System
Diesel-Fired 1.25 MW Caterpillar Emergency Generator
Operating Hours 100 hours/year

TAP Avg Period [1]	Toxic Air Pollutant	Emission Factor [2] (lb/MMBTU)	Uncontrolled Emissions (tpy)	Control Factor [3]	Emission Reduction (tpy)	Cost-Effectiveness [4] ($/ton)
24-Hour	Acrolein	7.88E-06	4.73E-06	0.70	3.31E-06	5,871,615
	Toluene	2.81E-04	1.69E-04	0.70	1.18E-04	
	Xylenes	1.93E-04	1.16E-04	0.70	8.11E-05	
	Propylene	2.79E-03	1.68E-03	0.70	1.17E-03	
Annual	Benzene	7.76E-04	4.66E-04	0.70	3.26E-04	2,031,454
	Formaldehyde	7.89E-05	4.74E-05	0.70	3.32E-05	
	Acetaldehyde	2.52E-05	1.51E-05	0.70	1.06E-05	
	Naphthalene	1.30E-04	7.81E-05	0.70	5.46E-05	
	Benz(a)anthracene	6.22E-07	3.73E-07	0.70	2.61E-07	
	Chrysene	1.53E-06	9.19E-07	0.70	6.43E-07	
	Benz(b)fluoranthcene	1.11E-06	6.66E-07	0.70	4.67E-07	
	Benz(k)fluoranthcene	2.18E-07	1.31E-07	0.70	9.16E-08	
	Benzo(a)pyrene	2.57E-07	1.54E-07	0.70	1.08E-07	
	Indeno(1,2,3-cd)pyrene	4.14E-07	2.49E-07	0.70	1.74E-07	
	Dibenz(a,h)anthracene	3.46E-07	2.08E-07	0.70	1.45E-07	
	DPM	--	4.03E-03	0.88	3.55E-03	

[1] ASIL information from WAC 173-460
[2] SO2, NO2, CO, and DPM based on criteria pollutant emission calculations, assuming 90% of NOx as NO2. Other TAPs from AP-42 Chapter 3.4 (Large Stationary Diesel Engines)
[3] Control factors used in recent Sabey, Vantage, and Cyrus One data center NOC applications.
[4] Cost-effectiveness based on total annual control cost and emission reduction by TAP averaging period group.

TABLE B2.2-14b
COST EFFECTIVENESS CALCULATIONS
Criteria Air Pollutants
Diesel Particulate Filter (DPF)/Diesel Oxidation Catalyst (DOC) Control System
Diesel-Fired 1.25 MW Generac Emergency Generator
Operating Hours 100 hours/year

Cost Item			Factor	Cost
Direct Costs				
Purchased Equipment Costs				
	Primary Equipment[1]		A	81,357
	Sales Tax[2]		B = 0.065 * A	5,288
	Shipping		Included in A	-----
		Purchased Equipment Cost (PEC)	PEC = A + B	86,645
Direct Installation Costs				
	Foundations & Supports		Included in A	-----
	Handling & Erection		Included in A	-----
	Electrical		Included in A	-----
	Piping		Included in A	-----
	Insulation for Ductwork		Included in A	-----
	Painting		Included in A	-----
		Direct Installation Cost	Included in A	-----
Total Direct Costs (DC)				86,645
Indirect Costs				
Installation				
	Engineering		Included in A	-----
	Construction & Field Expenses		Included in A	-----
	Contractor Fees		Included in A	-----
	Start-Up		Included in A	-----
	Contingencies[3]		0.03 * PEC	2,599
Total Indirect Costs (IC)				2,599
TOTAL CAPITAL INVESTMENT = DC + IC				**89,245**
Direct Annual Costs				
Operating Labor				
	Operator		Negligible	-----
	Supervisor		Negligible	-----
		Total Operating Labor		-----
Maintenance				
	Labor		-----	-----
	Materials		-----	-----
		Total Maintenance[4]	0.005 * TCI	446
Utilities				
	Electricity		Negligible	-----
	Water		-----	-----
	Reagent		-----	-----
		Total Utilities		-----
Catalyst Cost				
	Catalyst Replacement		Catalyst life > DOC Service Life	-----
		Total Catalyst Cost	-----	-----
Miscellaneous				
	Performance Tests		-----	-----
	Record Keeping & Reporting		-----	-----
		Total Miscellaneous Costs		-----
Total Direct Annual Costs (DAC)				**446**
Indirect Annual Costs				
Overhead[5]			60% of operating, supervisor, maintenance labor & materials	268
Administrative Charges[6]			0.02 * TCI	1,785
Capital Recovery Factor[7]			CRF	0.0640
Capital Recovery			CRF * TCI	5,713
Total Indirect Annual Costs (IAC)				**7,765**
TOTAL ANNUAL COST = DAC + IAC				**8,212**
Uncontrolled NOx, CO, VOC, and PM emissions			tons/yr	0.98
NOx, CO, VOC, and PM Emissions with DPF & DOC Controls			tons/yr	0.82
Percent reduction from uncontrolled				16%
Total emissions reduction			tons/yr	0.16
Cost per Ton Controlled			**$/ton**	**52,625**

[1] Capital cost provided by the engine vendor (Brent Briody of Western States Equipment Co.)
[2] Washington sales tax
[3] Minimum cost from most recent Sabey, Vantage, and Cyrus One cost-effectiveness analyses
[4] Estimated using equations from EPA's Air Pollution Control Cost Estimation Spreadsheet for Selective Catalytic Reduction (SCR) found at https://www.epa.gov/sites/production/files/2019-06/scrcostmanualspreadsheet_june-2019-v1.xlsm
[5] EPA's Air Pollution Control Cost Manual, Section 1, Chapter 2 (Cost Estimation), Section 2.6.5.7
[6] EPA's Air Pollution Control Cost Manual, Section 1, Chapter 2 (Cost Estimation), Section 2.6.5.8
[7] The capital recovery factor was calculated assuming a 25-year equipment life and a 4% interest rate

TABLE B2.2-14b
COST EFFECTIVENESS CALCULATIONS
Toxic Air Pollutants
Diesel Particulate Filter (DPF)/Diesel Oxidation Catalyst (DOC) Control System
Diesel-Fired 1.25 MW Generac Emergency Generator
Operating Hours 100 hours/year

TAP Avg Period [1]	Toxic Air Pollutant	Emission Factor [2] (lb/MMBTU)	Uncontrolled Emissions (tpy)	Control Factor [3]	Emission Reduction (tpy)	Cost-Effectiveness [4] ($/ton)
24-Hour	Acrolein	7.88E-06	6.17E-06	0.70	4.32E-06	4,577,930
	Toluene	2.81E-04	2.20E-04	0.70	1.54E-04	
	Xylenes	1.93E-04	1.51E-04	0.70	1.06E-04	
	Propylene	2.79E-03	2.19E-03	0.70	1.53E-03	
Annual	Benzene	7.76E-04	6.08E-04	0.70	4.25E-04	418,854
	Formaldehyde	7.89E-05	6.18E-05	0.70	4.33E-05	
	Acetaldehyde	2.52E-05	1.97E-05	0.70	1.38E-05	
	Naphthalene	1.30E-04	1.02E-04	0.70	7.13E-05	
	Benz(a)anthracene	6.22E-07	4.87E-07	0.70	3.41E-07	
	Chrysene	1.53E-06	1.20E-06	0.70	8.39E-07	
	Benz(b)fluoranthcene	1.11E-06	8.69E-07	0.70	6.09E-07	
	Benz(k)fluoranthcene	2.18E-07	1.71E-07	0.70	1.20E-07	
	Benzo(a)pyrene	2.57E-07	2.01E-07	0.70	1.41E-07	
	Indeno(1,2,3-cd)pyrene	4.14E-07	3.24E-07	0.70	2.27E-07	
	Dibenz(a,h)anthracene	3.46E-07	2.71E-07	0.70	1.90E-07	
	DPM	--	2.16E-02	0.88	1.90E-02	

[1] ASIL information from WAC 173-460

[2] SO2, NO2, CO, and DPM based on criteria pollutant emission calculations, assuming 90% of NOx as NO2. Other TAPs from AP-42 Chapter 3.4 (Large Stationary Diesel Engines)

[3] Control factors used in recent Sabey, Vantage, and Cyrus One data center NOC applications.

[4] Cost-effectiveness based on total annual control cost and emission reduction by TAP averaging period group.

TABLE B2.2-15b
COST EFFECTIVENESS CALCULATIONS
Criteria Air Pollutants
Diesel Particulate Filter (DPF)/Diesel Oxidation Catalyst (DOC) Control System
Diesel-Fired 2.25 MW Emergency Generator
Operating Hours 100 hours/year

Cost Item		Factor	Cost
Direct Costs			
Purchased Equipment Costs			
	Primary Equipment[1]	A	115,086
	Sales Tax[2]	B = 0.065 * A	7,481
	Shipping	Included in A	----
	Purchased Equipment Cost (PEC)	PEC = A + B	122,566
Direct Installation Costs			
	Foundations & Supports	Included in A	----
	Handling & Erection	Included in A	----
	Electrical	Included in A	----
	Piping	Included in A	----
	Insulation for Ductwork	Included in A	----
	Painting	Included in A	----
	Direct Installation Cost	Included in A	----
Total Direct Costs (DC)			122,566
Indirect Costs			
Installation			
	Engineering	Included in A	----
	Construction & Field Expenses	Included in A	----
	Contractor Fees	Included in A	----
	Start-Up	Included in A	----
	Contingencies[3]	0.03 * PEC	3,677
Total Indirect Costs (IC)			3,677
TOTAL CAPITAL INVESTMENT = DC + IC			**126,243**
Direct Annual Costs			
Operating Labor			
	Operator	Negligible	----
	Supervisor	Negligible	----
	Total Operating Labor		----
Maintenance			
	Labor	----	----
	Materials	----	----
	Total Maintenance[4]	0.005 * TCI	631
Utilities			
	Electricity	Negligible	----
	Water	----	----
	Reagent	----	----
	Total Utilities		----
Catalyst Cost			
	Catalyst Replacement	Catalyst life > DOC Service Life	----
	Total Catalyst Cost	----	----
Miscellaneous			
	Performance Tests	----	----
	Record Keeping & Reporting	----	----
	Total Miscellaneous Costs		----
Total Direct Annual Costs (DAC)			**631**
Indirect Annual Costs			
Overhead[5]		60% of operating, supervisor, maintenance labor & materials	379
Administrative Charges[6]		0.02 * TCI	2,525
Capital Recovery Factor[7]		CRF	0.0640
Capital Recovery		CRF * TCI	8,081
Total Indirect Annual Costs (IAC)			**10,985**
TOTAL ANNUAL COST = DAC + IAC			**11,616**
Uncontrolled NOx, CO, VOC, and PM emissions		tons/yr	2.06
NOx, CO, VOC, and PM Emissions with DPF & DOC Controls		tons/yr	1.59
Percent reduction from uncontrolled			23%
Total emissions reduction		tons/yr	0.47
Cost per Ton Controlled		**$/ton**	**24,707**

[1] Capital cost provided by the engine vendor (Brent Briody of Western States Equipment Co.)
[2] Washington sales tax
[3] Minimum cost from most recent Sabey, Vantage, and Cyrus One cost-effectiveness analyses
[4] Estimated using equations from EPA's Air Pollution Control Cost Estimation Spreadsheet for Selective Catalytic Reduction (SCR) found at https://www.epa.gov/sites/production/files/2019-06/scrcostmanualspreadsheet_june-2019v1.xlsm
[5] EPA's Air Pollution Control Cost Manual, Section 1, Chapter 2 (Cost Estimation), Section 2.6.5.7
[6] EPA's Air Pollution Control Cost Manual, Section 1, Chapter 2 (Cost Estimation), Section 2.6.5.8
[7] The capital recovery factor was calculated assuming a 25-year equipment life and a 4% interest rate

TABLE B2.2-15b
COST EFFECTIVENESS CALCULATIONS
Toxic Air Pollutants
Diesel Particulate Filter (DPF)/Diesel Oxidation Catalyst (DOC) Control System
Diesel-Fired 2.25 MW Emergency Generator
Operating Hours 100 hours/year

TAP Avg Period [1]	Toxic Air Pollutant	Emission Factor [2] (lb/MMBTU)	Uncontrolled Emissions (tpy)	Control Factor [3]	Emission Reduction (tpy)	Cost-Effectiveness [4] ($/ton)
24-Hour	Acrolein	7.88E-06	9.05E-06	0.70	6.33E-06	4,417,987
	Toluene	2.81E-04	3.23E-04	0.70	2.26E-04	
	Xylenes	1.93E-04	2.22E-04	0.70	1.55E-04	
	Propylene	2.79E-03	3.20E-03	0.70	2.24E-03	
Annual	Benzene	7.76E-04	8.91E-04	0.70	6.24E-04	293,172
	Formaldehyde	7.89E-05	9.06E-05	0.70	6.34E-05	
	Acetaldehyde	2.52E-05	2.89E-05	0.70	2.03E-05	
	Naphthalene	1.30E-04	1.49E-04	0.70	1.04E-04	
	Benz(a)anthracene	6.22E-07	7.14E-07	0.70	5.00E-07	
	Chrysene	1.53E-06	1.76E-06	0.70	1.23E-06	
	Benz(b)fluoranthcene	1.11E-06	1.27E-06	0.70	8.92E-07	
	Benz(k)fluoranthcene	2.18E-07	2.50E-07	0.70	1.75E-07	
	Benzo(a)pyrene	2.57E-07	2.95E-07	0.70	2.07E-07	
	Indeno(1,2,3-cd)pyrene	4.14E-07	4.75E-07	0.70	3.33E-07	
	Dibenz(a,h)anthracene	3.46E-07	3.97E-07	0.70	2.78E-07	
	DPM	--	4.41E-02	0.88	3.88E-02	

[1] ASIL information from WAC 173-460

[2] SO2, NO2, CO, and DPM based on criteria pollutant emission calculations, assuming 90% of NOx as NO2. Other TAPs from AP-42 Chapter 3.4 (Large Stationary Diesel Engines)

[3] Control factors used in recent Sabey, Vantage, and Cyrus One data center NOC applications.

[4] Cost-effectiveness based on total annual control cost and emission reduction by TAP averaging period group.

TABLE B2.2-16b
COST EFFECTIVENESS CALCULATIONS
Criteria Air Pollutants
Diesel Particulate Filter (DPF) Control System
Diesel-Fired 400 kW Emergency Generator
Operating Hours 100 hours/year

Cost Item			Factor	Cost
Direct Costs				
Purchased Equipment Costs				
	Primary Equipment[1]		A	33,344
	Sales Tax[2]		B = 0.065 * A	2,167
	Shipping		Included in A	-----
		Purchased Equipment Cost (PEC)	PEC = A + B	35,512
Direct Installation Costs				
	Foundations & Supports		Included in A	-----
	Handling & Erection		Included in A	-----
	Electrical		Included in A	-----
	Piping		Included in A	-----
	Insulation for Ductwork		Included in A	-----
	Painting		Included in A	-----
		Direct Installation Cost	Included in A	-----
Total Direct Costs (DC)				35,512
Indirect Costs				
Installation				
	Engineering		Included in A	-----
	Construction & Field Expenses		Included in A	-----
	Contractor Fees		Included in A	-----
	Start-Up		Included in A	-----
	Contingencies[3]		0.03 * PEC	1,065
Total Indirect Costs (IC)				1,065
TOTAL CAPITAL INVESTMENT = DC + IC				**36,577**
Direct Annual Costs				
Operating Labor				
	Operator		Negligible	-----
	Supervisor		Negligible	-----
		Total Operating Labor		-----
Maintenance				
	Labor		-----	-----
	Materials		-----	-----
		Total Maintenance[4]	0.005 * TCI	183
Utilities				
	Electricity		Negligible	-----
	Water		-----	-----
	Reagent		-----	-----
		Total Utilities		-----
Catalyst Cost				
	Catalyst Replacement		-----	-----
		Total Catalyst Cost	-----	-----
Miscellaneous				
	Performance Tests		-----	-----
	Record Keeping & Reporting		-----	-----
		Total Miscellaneous Costs		-----
Total Direct Annual Costs (DAC)				**183**
Indirect Annual Costs				
Overhead[6]			60% of operating, supervisor, maintenance labor & materials	110
Administrative Charges[5]			0.02 * TCI	732
Capital Recovery Factor[7]			CRF	0.0640
Capital Recovery			CRF * TCI	2,341
Total Indirect Annual Costs (IAC)				**3,183**
TOTAL ANNUAL COST = DAC + IAC				**3,366**
Uncontrolled NOx, CO, VOC, and PM emissions			tons/yr	0.21
NOx, CO, VOC, and PM Emissions with DPF			tons/yr	0.18
Percent reduction from uncontrolled				16%
Total emissions reduction			tons/yr	0.03
Cost per Ton Controlled			**$/ton**	**102,565**

[1] Captial cost provided by the engine vendor (Brant Briody of Western States Equipment Co.).
[2] Washington sales tax
[3] Minimum cost from most recent Sabey, Vantage, and Cyrus One cost-effectiveness analyses
[4] Estimated using equations from EPA's Air Pollution Control Cost Estimation Spreadsheet for Selective Catalytic Reduction (SCR) found at https://www.epa.gov/sites/production/files/2019-06/scrc ostmanualspreadsheet_june-2019vf.xlsm
[5] EPA's Air Pollution Control Cost Manual, Section 1, Chapter 2 (Cost Estimation), Section 2.6.5.7
[6] EPA's Air Pollution Control Cost Manual, Section 1, Chapter 2 (Cost Estimation), Section 2.6.5.8
[7] The capital recovery factor was calculated assuming a 25-year equipment life and a 4% interest rate

TABLE B2.2-16b
COST EFFECTIVENESS CALCULATIONS
Toxic Air Pollutants
Diesel Particulate Filter (DPF) Control System
Diesel-Fired 400 kW Emergency Generator
Operating Hours 100 hours/year

TAP Avg Period [1]	Toxic Air Pollutant	Emission Factor [2] (lb/MMBTU)	Uncontrolled Emissions (tpy)	Control Factor [3]	Emission Reduction (tpy)	Cost-Effectiveness [4] ($/ton)
24-Hour	Acrolein	7.88E-06	1.66E-06	0.70	1.16E-06	6,990,052
	Toluene	2.81E-04	5.91E-05	0.70	4.14E-05	
	Xylenes	1.93E-04	4.06E-05	0.70	2.84E-05	
	Propylene	2.79E-03	5.97E-04	0.70	4.11E-04	
Annual	Benzene	7.76E-04	1.63E-04	0.70	1.14E-04	713,977
	Formaldehyde	7.89E-05	1.66E-05	0.70	1.16E-05	
	Acetaldehyde	2.52E-05	5.30E-06	0.70	3.71E-06	
	Naphthalene	1.30E-04	2.73E-05	0.70	1.91E-05	
	Benz(a)anthracene	6.22E-07	1.31E-07	0.70	9.15E-08	
	Chrysene	1.53E-06	3.22E-07	0.70	2.25E-07	
	Benz(b)fluoranthcene	1.11E-06	2.33E-07	0.70	1.63E-07	
	Benz(k)fluoranthcene	2.18E-07	4.58E-08	0.70	3.21E-08	
	Benzo(a)pyrene	2.57E-07	5.40E-08	0.70	3.78E-08	
	Indeno(1,2,3-cd)pyrene	4.14E-07	8.70E-08	0.70	6.09E-08	
	Dibenz(a,h)anthracene	3.46E-07	7.27E-08	0.70	5.09E-08	
	DPM	--	5.07E-03	0.90	4.56E-03	

[1] ASIL information from WAC 173-460
[2] SO2, NO2, CO, and DPM based on criteria pollutant emission calculations, assuming 90% of NOx as NO2. Other TAPs from AP-42 Chapter 3.4 (Large Stationary Diesel Engines)
[3] Control factors used in recent Sabey, Vantage, and Cyrus One data center NOC applications.
[4] Cost-effectiveness based on total annual control cost and emission reduction by TAP averaging period group.

TABLE B2.2-17b
COST EFFECTIVENESS CALCULATIONS
Criteria Air Pollutants
Diesel Particulate Filter (DPF) Control System
Diesel-Fired 750 kW Emergency Generator
Operating Hours 100 hours/year

Cost Item			Factor	Cost
Direct Costs				
Purchased Equipment Costs				
	Primary Equipment[1]		A	47,480
	Sales Tax[2]		B = 0.065 * A	3,086
	Shipping		Included in A	----
		Purchased Equipment Cost (PEC)	PEC = A + B	50,567
Direct Installation Costs				
	Foundations & Supports		Included in A	----
	Handling & Erection		Included in A	----
	Electrical		Included in A	----
	Piping		Included in A	----
	Insulation for Ductwork		Included in A	----
	Painting		Included in A	----
		Direct Installation Cost	Included in A	----
Total Direct Costs (DC)				50,567
Indirect Costs				
Installation				
	Engineering		Included in A	----
	Construction & Field Expenses		Included in A	----
	Contractor Fees		Included in A	----
	Start-Up		Included in A	----
	Contingencies[3]		0.03 * PEC	1,517
Total Indirect Costs (IC)				1,517
TOTAL CAPITAL INVESTMENT = DC + IC				**52,084**
Direct Annual Costs				
Operating Labor				
	Operator		Negligible	----
	Supervisor		Negligible	----
		Total Operating Labor		----
Maintenance				
	Labor		----	----
	Materials		----	----
		Total Maintenance[4]	0.005 * TCI	260
Utilities				
	Electricity		Negligible	----
	Water		----	----
	Reagent		----	----
		Total Utilities		----
Catalyst Cost				
	Catalyst Replacement		----	----
		Total Catalyst Cost	----	----
Miscellaneous				
	Performance Tests		----	----
	Record Keeping & Reporting		----	----
		Total Miscellaneous Costs		----
Total Direct Annual Costs (DAC)				**260**
Indirect Annual Costs				
Overhead[5]			60% of operating, supervisor, maintenance labor & materials	156
Administrative Charges[6]			0.02 * TCI	1,042
Capital Recovery Factor[7]			CRF	0.0640
Capital Recovery			CRF * TCI	3,334
Total Indirect Annual Costs (IAC)				**4,532**
TOTAL ANNUAL COST = DAC + IAC				**4,792**
Uncontrolled NOx, CO, VOC, and PM emissions			tons/yr	0.79
NOx, CO, VOC, and PM Emissions with DPF			tons/yr	0.73
Percent reduction from uncontrolled				7%
Total emissions reduction			tons/yr	0.06
Cost per Ton Controlled			**$/ton**	**85,178**

[1] Capital cost provided by the engine vendor (Brant Briody of Western States Equipment Co.)
[2] Washington sales tax
[3] Minimum cost from most recent Sabey, Vantage, and Cyrus One cost-effectiveness analyses
[4] Estimated using equations from EPA's Air Pollution Control Cost Estimation Spreadsheet for Selective Catalytic Reduction (SCR) found at https://www.epa.gov/sites/production/files/2019-06/scrcostmanualspreadsheet_june-2019vf.xlsm
[5] EPA's Air Pollution Control Cost Manual, Section 1, Chapter 2 (Cost Estimation), Section 2.6.5.7
[6] EPA's Air Pollution Control Cost Manual, Section 1, Chapter 2 (Cost Estimation), Section 2.6.5.8
[7] The capital recovery factor was calculated assuming a 25-year equipment life and a 4% interest rate

TABLE B2.2-17b
COST EFFECTIVENESS CALCULATIONS
Toxic Air Pollutants
Diesel Particulate Filter (DPF) Control System
Diesel-Fired 750 kW Emergency Generator
Operating Hours 100 hours/year

TAP Avg Period [1]	Toxic Air Pollutant	Emission Factor [2] (lb/MMBTU)	Uncontrolled Emissions (tpy)	Control Factor [3]	Emission Reduction (tpy)	Cost-Effectiveness [4] ($/ton)
24-Hour	Acrolein	7.88E-06	2.90E-06	0.70	2.03E-06	5,682,361
	Toluene	2.81E-04	1.03E-04	0.70	7.24E-05	
	Xylenes	1.93E-04	7.11E-05	0.70	4.97E-05	
	Propylene	2.79E-03	1.03E-03	0.70	7.19E-04	
Annual	Benzene	7.76E-04	2.86E-04	0.70	2.00E-04	696,496
	Formaldehyde	7.89E-05	2.91E-05	0.70	2.03E-05	
	Acetaldehyde	2.52E-05	9.28E-06	0.70	6.50E-06	
	Naphthalene	1.30E-04	4.79E-05	0.70	3.35E-05	
	Benz(a)anthracene	6.22E-07	2.29E-07	0.70	1.60E-07	
	Chrysene	1.53E-06	5.63E-07	0.70	3.94E-07	
	Benz(b)fluoranthcene	1.11E-06	4.09E-07	0.70	2.86E-07	
	Benz(k)fluoranthcene	2.18E-07	8.03E-08	0.70	5.62E-08	
	Benzo(a)pyrene	2.57E-07	9.46E-08	0.70	6.62E-08	
	Indeno(1,2,3-cd)pyrene	4.14E-07	1.52E-07	0.70	1.07E-07	
	Dibenz(a,h)anthracene	3.46E-07	1.27E-07	0.70	8.92E-08	
	DPM	--	7.35E-03	0.90	6.62E-03	

[1] ASIL information from WAC 173-460
[2] SO2, NO2, CO, and DPM based on criteria pollutant emission calculations, assuming 90% of NOx as NO2. Other TAPs from AP-42 Chapter 3.4 (Large Stationary Diesel Engines)
[3] Control factors used in recent Sabey, Vantage, and Cyrus One data center NOC applications.
[4] Cost-effectiveness based on total annual control cost and emission reduction by TAP averaging period group.

TABLE B2.2-18b
COST EFFECTIVENESS CALCULATIONS
Criteria Air Pollutants
Diesel Particulate Filter (DPF) Control System
Diesel-Fired 1.25 MW Caterpillar Emergency Generator
Operating Hours 100 hours/year

Cost Item		Factor	Cost
Direct Costs			
Purchased Equipment Costs			
	Primary Equipment[1]	A	64,000
	Sales Tax[2]	B = 0.065 * A	4,160
	Shipping	Included in A	----
	Purchased Equipment Cost (PEC)	PEC = A + B	68,160
Direct Installation Costs			
	Foundations & Supports	Included in A	----
	Handling & Erection	Included in A	----
	Electrical	Included in A	----
	Piping	Included in A	----
	Insulation for Ductwork	Included in A	----
	Painting	Included in A	----
	Direct Installation Cost	Included in A	----
Total Direct Costs (DC)			68,160
Indirect Costs			
Installation			
	Engineering	Included in A	----
	Construction & Field Expenses	Included in A	----
	Contractor Fees	Included in A	----
	Start-Up	Included in A	----
	Contingencies[3]	0.03 * PEC	2,045
Total Indirect Costs (IC)			2,045
TOTAL CAPITAL INVESTMENT = DC + IC			**70,205**
Direct Annual Costs			
Operating Labor			
	Operator	Negligible	----
	Supervisor	Negligible	----
	Total Operating Labor		----
Maintenance			
	Labor	----	----
	Materials	----	----
	Total Maintenance[4]	0.005 * TCI	351
Utilities			
	Electricity	Negligible	----
	Water	----	----
	Reagent	----	----
	Total Utilities		----
Catalyst Cost			
	Catalyst Replacement	----	----
	Total Catalyst Cost	----	----
Miscellaneous			
	Performance Tests	----	----
	Record Keeping & Reporting	----	----
	Total Miscellaneous Costs		----
Total Direct Annual Costs (DAC)			**351**
Indirect Annual Costs			
Overhead[5]		60% of operating, supervisor, maintenance labor & materials	211
Administrative Charges[6]		0.02 * TCI	1,404
Capital Recovery Factor[7]		CRF	0.0640
Capital Recovery		CRF * TCI	4,494
Total Indirect Annual Costs (IAC)			**6,109**
TOTAL ANNUAL COST = DAC + IAC			**6,460**
Uncontrolled NOx, CO, VOC, and PM emissions		tons/yr	1.32
NOx, CO, VOC, and PM Emissions with DPF		tons/yr	1.26
Percent reduction from uncontrolled			4%
Total emissions reduction		tons/yr	0.05
Cost per Ton Controlled		**$/ton**	**125,159**

[1] Capital cost provided by the engine vendor (Brant Briody of Western States Equipment Co.)
[2] Washington sales tax
[3] Minimum cost from most recent Sabey, Vantage, and Cyrus One cost-effectiveness analyses
[4] Estimated using equations from EPA's Air Pollution Control Cost Estimation Spreadsheet for Selective Catalytic Reduction (SCR) found at https://www.epa.gov/sites/production/files/2019-06/scrcostmanualspreadsheet_june-2019vf.xlsm
[5] EPA's Air Pollution Control Cost Manual, Section 1, Chapter 2 (Cost Estimation), Section 2.6.5.7
[6] EPA's Air Pollution Control Cost Manual, Section 1, Chapter 2 (Cost Estimation), Section 2.6.5.8
[7] The capital recovery factor was calculated assuming a 25-year equipment life and a 4% interest rate

TABLE B2.2-18b
COST EFFECTIVENESS CALCULATIONS
Toxic Air Pollutants
Diesel Particulate Filter (DPF) Control System
Diesel-Fired 1.25 MW Caterpillar Emergency Generator
Operating Hours 100 hours/year

TAP Avg Period [1]	Toxic Air Pollutant	Emission Factor [2] (lb/MMBTU)	Uncontrolled Emissions (tpy)	Control Factor [3]	Emission Reduction (tpy)	Cost-Effectiveness [4] ($/ton)
24-Hour	Acrolein	7.88E-06	4.73E-06	0.70	3.31E-06	4,697,292
	Toluene	2.81E-04	1.69E-04	0.70	1.18E-04	
	Xylenes	1.93E-04	1.16E-04	0.70	8.11E-05	
	Propylene	2.79E-03	1.68E-03	0.70	1.17E-03	
Annual	Benzene	7.76E-04	4.66E-04	0.70	3.26E-04	1,592,846
	Formaldehyde	7.89E-05	4.74E-05	0.70	3.32E-05	
	Acetaldehyde	2.52E-05	1.51E-05	0.70	1.06E-05	
	Naphthalene	1.30E-04	7.81E-05	0.70	5.46E-05	
	Benz(a)anthracene	6.22E-07	3.73E-07	0.70	2.61E-07	
	Chrysene	1.53E-06	9.19E-07	0.70	6.43E-07	
	Benz(b)fluoranthcene	1.11E-06	6.66E-07	0.70	4.67E-07	
	Benz(k)fluoranthcene	2.18E-07	1.31E-07	0.70	9.16E-08	
	Benzo(a)pyrene	2.57E-07	1.54E-07	0.70	1.08E-07	
	Indeno(1,2,3-cd)pyrene	4.14E-07	2.49E-07	0.70	1.74E-07	
	Dibenz(a,h)anthracene	3.46E-07	2.08E-07	0.70	1.45E-07	
	DPM	–	4.03E-03	0.90	3.63E-03	

[1] ASIL information from WAC 173-460
[2] SO2, NO2, CO, and DPM based on criteria pollutant emission calculations, assuming 90% of NOx as NO2. Other TAPs from AP-42 Chapter 3.4 (Large Stationary Diesel Engines)
[3] Control factors used in recent Sabey, Vantage, and Cyrus One data center NOC applications.
[4] Cost-effectiveness based on total annual control cost and emission reduction by TAP averaging period group.

TABLE B2.2-19b
COST EFFECTIVENESS CALCULATIONS
Criteria Air Pollutants
Diesel Particulate Filter (DPF) Control System
Diesel-Fired 1.25 MW Generac Emergency Generator
Operating Hours 100 hours/year

Cost Item		Factor	Cost
Direct Costs			
Purchased Equipment Costs			
	Primary Equipment[1]	A	65,086
	Sales Tax[2]	B = 0.065 * A	4,231
	Shipping	Included in A	----
	Purchased Equipment Cost (PEC)	PEC = A + B	69,316
Direct Installation Costs			
	Foundations & Supports	Included in A	----
	Handling & Erection	Included in A	----
	Electrical	Included in A	----
	Piping	Included in A	----
	Insulation for Ductwork	Included in A	----
	Painting	Included in A	----
	Direct Installation Cost	Included in A	----
Total Direct Costs (DC)			69,316
Indirect Costs			
Installation			
	Engineering	Included in A	----
	Construction & Field Expenses	Included in A	----
	Contractor Fees	Included in A	----
	Start-Up	Included in A	----
	Contingencies[3]	0.03 * PEC	2,079
Total Indirect Costs (IC)			2,079
TOTAL CAPITAL INVESTMENT = DC + IC			**71,396**
Direct Annual Costs			
Operating Labor			
	Operator	Negligible	----
	Supervisor	Negligible	----
	Total Operating Labor		----
Maintenance			
	Labor	----	----
	Materials	----	----
	Total Maintenance[4]	0.005 * TCI	357
Utilities			
	Electricity	Negligible	----
	Water	----	----
	Reagent	----	----
	Total Utilities		----
Catalyst Cost			
	Catalyst Replacement	----	----
	Total Catalyst Cost	----	----
Miscellaneous			
	Performance Tests	----	----
	Record Keeping & Reporting	----	----
	Total Miscellaneous Costs		----
Total Direct Annual Costs (DAC)			**357**
Indirect Annual Costs			
Overhead[5]		60% of operating, supervisor, maintenance labor & materials	214
Administrative Charges[6]		0.02 * TCI	1,428
Capital Recovery Factor[7]		CRF	0.0640
Capital Recovery		CRF * TCI	4,570
Total Indirect Annual Costs (IAC)			**6,212**
TOTAL ANNUAL COST = DAC + IAC			**6,569**
Uncontrolled NOx, CO, VOC, and PM emissions		tons/yr	0.98
NOx, CO, VOC, and PM Emissions with DPF		tons/yr	0.82
Percent reduction from uncontrolled			16%
Total emissions reduction		tons/yr	0.16
Cost per Ton Controlled		**$/ton**	**41,984**

[1] Captial cost provided by the engine vendor (Brant Briody of Western States Equipment Co.)
[2] Washington sales tax
[3] Minimum cost from most recent Sabey, Vantage, and Cyrus One cost-effectiveness analyses
[4] Estimated using equations from EPA's Air Pollution Control Cost Estimation Spreadsheet for Selective Catalytic Reduction (SCR) found at https://www.epa.gov/sites/production/files/2019-09/scrcostmanualspreadsheet_june-2019vf.xlsm
[5] EPA's Air Pollution Control Cost Manual, Section 1, Chapter 2 (Cost Estimation), Section 2.6.5.7
[6] EPA's Air Pollution Control Cost Manual, Section 1, Chapter 2 (Cost Estimation), Section 2.6.5.8
[7] The capital recovery factor was calculated assuming a 25-year equipment life and a 4% interest rate

TABLE B2.2-19b
COST EFFECTIVENESS CALCULATIONS
Toxic Air Pollutants
Diesel Particulate Filter (DPF) Control System
Diesel-Fired 1.25 MW Generac Emergency Generator
Operating Hours 100 hours/year

TAP Avg Period [1]	Toxic Air Pollutant	Emission Factor [2] (lb/MMBTU)	Uncontrolled Emissions (tpy)	Control Factor [3]	Emission Reduction (tpy)	Cost-Effectiveness [4] ($/ton)
24-Hour	Acrolein	7.88E-06	6.17E-06	0.70	4.32E-06	3,662,344
	Toluene	2.81E-04	2.20E-04	0.70	1.54E-04	
	Xylenes	1.93E-04	1.51E-04	0.70	1.06E-04	
	Propylene	2.79E-03	2.19E-03	0.70	1.53E-03	
Annual	Benzene	7.76E-04	6.08E-04	0.70	4.25E-04	327,844
	Formaldehyde	7.89E-05	6.18E-05	0.70	4.33E-05	
	Acetaldehyde	2.52E-05	1.97E-05	0.70	1.38E-05	
	Naphthalene	1.30E-04	1.02E-04	0.70	7.13E-05	
	Benz(a)anthracene	6.22E-07	4.87E-07	0.70	3.41E-07	
	Chrysene	1.53E-06	1.20E-06	0.70	8.39E-07	
	Benz(b)fluoranthcene	1.11E-06	8.69E-07	0.70	6.09E-07	
	Benz(k)fluoranthcene	2.18E-07	1.71E-07	0.70	1.20E-07	
	Benzo(a)pyrene	2.57E-07	2.01E-07	0.70	1.41E-07	
	Indeno(1,2,3-cd)pyren	4.14E-07	3.24E-07	0.70	2.27E-07	
	Dibenz(a,h)anthracene	3.46E-07	2.71E-07	0.70	1.90E-07	
	DPM	--	2.16E-02	0.90	1.95E-02	

[1] ASIL information from WAC 173-460
[2] SO2, NO2, CO, and DPM based on criteria pollutant emission calculations, assuming 90% of NOx as NO2. Other TAPs from AP-42 Chapter 3.4 (Large Stationary Diesel Engines)
[3] Control factors used in recent Sabey, Vantage, and Cyrus One data center NOC applications
[4] Cost-effectiveness based on total annual control cost and emission reduction by TAP averaging period group.

TABLE B2.2-20b
COST EFFECTIVENESS CALCULATIONS
Criteria Air Pollutants
Diesel Particulate Filter (DPF) Control System
Diesel-Fired 2.25 MW Emergency Generator
Operating Hours 100 hours/year

Cost Item		Factor	Cost
Direct Costs			
Purchased Equipment Costs			
	Primary Equipment[1]	A	92,069
	Sales Tax[2]	B = 0.065 * A	5,984
	Shipping	Included in A	----
	Purchased Equipment Cost (PEC)	PEC = A + B	98,053
Direct Installation Costs			
	Foundations & Supports	Included in A	----
	Handling & Erection	Included in A	----
	Electrical	Included in A	----
	Piping	Included in A	----
	Insulation for Ductwork	Included in A	----
	Painting	Included in A	----
	Direct Installation Cost	Included in A	----
Total Direct Costs (DC)			98,053
Indirect Costs			
Installation			
	Engineering	Included in A	----
	Construction & Field Expenses	Included in A	----
	Contractor Fees	Included in A	----
	Start-Up	Included in A	----
	Contingencies[3]	0.03 * PEC	2,942
Total Indirect Costs (IC)			2,942
TOTAL CAPITAL INVESTMENT = DC + IC			**100,995**
Direct Annual Costs			
Operating Labor			
	Operator	Negligible	----
	Supervisor	Negligible	----
	Total Operating Labor		----
Maintenance			
	Labor	----	----
	Materials	----	----
	Total Maintenance[4]	0.005 * TCI	505
Utilities			
	Electricity	Negligible	----
	Water	----	----
	Reagent	----	----
	Total Utilities		----
Catalyst Cost			
	Catalyst Replacement	----	----
	Total Catalyst Cost	----	----
Miscellaneous			
	Performance Tests	----	----
	Record Keeping & Reporting	----	----
	Total Miscellaneous Costs		----
Total Direct Annual Costs (DAC)			**505**
Indirect Annual Costs			
Overhead[5]		60% of operating, supervisor, maintenance labor & materials	303
Administrative Charges[6]		0.02 * TCI	2,020
Capital Recovery Factor[7]		CRF	0.0640
Capital Recovery		CRF * TCI	6,465
Total Indirect Annual Costs (IAC)			**8,788**
TOTAL ANNUAL COST = DAC + IAC			**9,293**
Uncontrolled NOx, CO, VOC, and PM emissions		tons/yr	2.06
NOx, CO, VOC, and PM Emissions with DPF		tons/yr	1.59
Percent reduction from uncontrolled			23%
Total emissions reduction		tons/yr	0.47
Cost per Ton Controlled		**$/ton**	**19,729**

[1] Capital cost provided by the engine vendor (Brant Briody of Western States Equipment Co.)
[2] Washington sales tax
[3] Minimum cost from most recent Sabey, Vantage, and Cyrus One cost-effectiveness analyses
[4] Estimated using equations from EPA's Air Pollution Control Cost Estimation Spreadsheet for Selective Catalytic Reduction (SCR) found at https://www.epa.gov/sites/production/files/2019-09/scrcostmanualspreadsheet_june-2019v5.xlsm
[5] EPA's Air Pollution Control Cost Manual, Section 1, Chapter 2 (Cost Estimation), Section 2.6.5.7
[6] EPA's Air Pollution Control Cost Manual, Section 1, Chapter 2 (Cost Estimation), Section 2.6.5.8
[7] The capital recovery factor was calculated assuming a 25-year equipment life and a 4% interest rate

TABLE B2.2-20b
COST EFFECTIVENESS CALCULATIONS
Toxic Air Pollutants
Diesel Particulate Filter (DPF) Control System
Diesel-Fired 2.25 MW Emergency Generator
Operating Hours 100 hours/year

TAP Avg Period [1]	Toxic Air Pollutant	Emission Factor [2] (lb/MMBTU)	Uncontrolled Emissions (tpy)	Control Factor [3]	Emission Reduction (tpy)	Cost-Effectiveness [4] ($/ton)
24-Hour	Acrolein	7.88E-06	9.05E-06	0.70	6.33E-06	3,534,390
	Toluene	2.81E-04	3.23E-04	0.70	2.26E-04	
	Xylenes	1.93E-04	2.22E-04	0.70	1.55E-04	
	Propylene	2.79E-03	3.20E-03	0.70	2.24E-03	
Annual	Benzene	7.76E-04	8.91E-04	0.70	6.24E-04	229,431
	Formaldehyde	7.89E-05	9.06E-05	0.70	6.34E-05	
	Acetaldehyde	2.52E-05	2.89E-05	0.70	2.03E-05	
	Naphthalene	1.30E-04	1.49E-04	0.70	1.04E-04	
	Benz(a)anthracene	6.22E-07	7.14E-07	0.70	5.00E-07	
	Chrysene	1.53E-06	1.76E-06	0.70	1.23E-06	
	Benz(b)fluoranthcene	1.11E-06	1.27E-06	0.70	8.92E-07	
	Benz(k)fluoranthcene	2.18E-07	2.50E-07	0.70	1.75E-07	
	Benzo(a)pyrene	2.57E-07	2.95E-07	0.70	2.07E-07	
	Indeno(1,2,3-cd)pyren	4.14E-07	4.75E-07	0.70	3.33E-07	
	Dibenz(a,h)anthracen	3.46E-07	3.97E-07	0.70	2.78E-07	
	DPM	--	4.41E-02	0.90	3.97E-02	

[1] ASIL information from WAC 173-460
[2] SO2, NO2, CO, and DPM based on criteria pollutant emission calculations, assuming 90% of NOx as NO2. Other TAPs from AP-42 Chapter 3.4 (Large Stationary Diesel Engines)
[3] Control factors used in recent Sabey, Vantage, and Cyrus One data center NOC applications
[4] Cost-effectiveness based on total annual control cost and emission reduction by TAP averaging period group.

TABLE B2.2-21b
COST EFFECTIVENESS CALCULATIONS
Criteria Air Pollutants
Diesel Oxidation Catalyst (DOC) Control System
Diesel-Fired 400 kW Emergency Generator
Operating Hours 100 hours/year

Cost Item		Factor	Cost
Direct Costs			
Purchased Equipment Costs			
	Primary Equipment[1]	A	8,336
	Sales Tax[2]	B = 0.065 * A	542
	Shipping	Included in A	----
	Purchased Equipment Cost (PEC)	PEC = A + B	8,878
Direct Installation Costs			
	Foundations & Supports	Included in A	----
	Handling & Erection	Included in A	----
	Electrical	Included in A	----
	Piping	Included in A	----
	Insulation for Ductwork	Included in A	----
	Painting	Included in A	----
	Direct Installation Cost	Included in A	----
Total Direct Costs (DC)			8,878
Indirect Costs			
Installation			
	Engineering	Included in A	----
	Construction & Field Expenses	Included in A	----
	Contractor Fees	Included in A	----
	Start-Up	Included in A	----
	Contingencies[3]	0.03 * PEC	266
Total Indirect Costs (IC)			266
TOTAL CAPITAL INVESTMENT = DC + IC			**9,144**
Direct Annual Costs			
Operating Labor			
	Operator	Negligible	----
	Supervisor	Negligible	----
	Total Operating Labor		----
Maintenance			
	Labor	----	----
	Materials	----	----
	Total Maintenance[4]	0.005 * TCI	46
Utilities			
	Electricity	Negligible	----
	Water	----	----
	Reagent	----	----
	Total Utilities		----
Catalyst Cost			
	Catalyst Replacement	Catalyst life > DOC Service Life	----
	Total Catalyst Cost	----	----
Miscellaneous			
	Performance Tests	----	----
	Record Keeping & Reporting	----	----
	Total Miscellaneous Costs		----
Total Direct Annual Costs (DAC)			**46**
Indirect Annual Costs			
Overhead[5]		60% of operating, supervisor, maintenance labor & materials	27
Administrative Charges[6]		0.02 * TCI	183
Capital Recovery Factor[7]		CRF	0.0640
Capital Recovery		CRF * TCI	585
Total Indirect Annual Costs (IAC)			**796**
TOTAL ANNUAL COST = DAC + IAC			**841**
Uncontrolled NOx, CO, VOC, and PM emissions		tons/yr	0.21
NOx, CO, VOC, and PM Emissions with DOC		tons/yr	0.18
Percent reduction from uncontrolled			14%
Total emissions reduction		tons/yr	0.03
Cost per Ton Controlled		**$/ton**	**28,505**

[1] Captial cost provided by the engine vendor (Brant Briody of Western States Equipment Co.)
[2] Washington sales tax
[3] Minimum cost from most recent Sabey, Vantage, and Cyrus One cost-effectiveness analyses
[4] Estimated using equations from EPA's Air Pollution Control Cost Estimation Spreadsheet for Selective Catalytic Reduction (SCR) found at https://www.epa.gov/sites/production/files/2019-08/scrcostmanualspreadsheet_june-2019vf.xlsm
[5] EPA's Air Pollution Control Cost Manual, Section 1, Chapter 2 (Cost Estimation), Section 2.6.5.7
[6] EPA's Air Pollution Control Cost Manual, Section 1, Chapter 2 (Cost Estimation), Section 2.6.5.8
[7] The capital recovery factor was calculated assuming a 25-year equipment life and a 4% interest rate

TABLE B2.2-21b
COST EFFECTIVENESS CALCULATIONS
Toxic Air Pollutants
Diesel Oxidation Catalyst (DOC) Control System
Diesel-Fired 400 kW Emergency Generator
Operating Hours 100 hours/year

TAP Avg Period [1]	Toxic Air Pollutant	Emission Factor [2] (lb/MMBTU)	Uncontrolled Emissions (tpy)	Control Factor [3]	Emission Reduction (tpy)	Cost-Effectiveness [4] ($/ton)
24-Hour	Acrolein	7.88E-06	1.66E-06	0.70	1.16E-06	1,747,513
	Toluene	2.81E-04	5.91E-05	0.70	4.14E-05	
	Xylenes	1.93E-04	4.06E-05	0.70	2.84E-05	
	Propylene	2.79E-03	5.87E-04	0.70	4.11E-04	
Annual	Benzene	7.76E-04	1.63E-04	0.70	1.14E-04	593,688
	Formaldehyde	7.89E-05	1.66E-05	0.70	1.16E-05	
	Acetaldehyde	2.52E-05	5.30E-06	0.70	3.71E-06	
	Naphthalene	1.30E-04	2.73E-05	0.70	1.91E-05	
	Benz(a)anthracene	6.22E-07	1.31E-07	0.70	9.15E-08	
	Chrysene	1.53E-06	3.22E-07	0.70	2.25E-07	
	Benz(b)fluoranthcene	1.11E-06	2.33E-07	0.70	1.63E-07	
	Benz(k)fluoranthcene	2.18E-07	4.58E-08	0.70	3.21E-08	
	Benzo(a)pyrene	2.57E-07	5.40E-08	0.70	3.78E-08	
	Indeno(1,2,3-cd)pyrene	4.14E-07	8.70E-08	0.70	6.09E-08	
	Dibenz(a,h)anthracene	3.46E-07	7.27E-08	0.70	5.09E-08	
	DPM	--	5.07E-03	0.25	1.27E-03	

[1] ASIL information from WAC 173-460
[2] SO2, NO2, CO, and DPM based on criteria pollutant emission calculations, assuming 90% of NOx as NO2. Other TAPs from AP-42 Chapter 3.4 (Large Stationary Diesel Engines)
[3] Control factors used in recent Sabey, Vantage, and Cyrus One data center NOC applications.
[4] Cost-effectiveness based on total annual control cost and emission reduction by TAP averaging period group.

TABLE B2.2-22b
COST EFFECTIVENESS CALCULATIONS
Criteria Air Pollutants
Diesel Oxidation Catalyst (DOC) Control System
Diesel-Fired 750 kW Emergency Generator
Operating Hours 100 hours/year

Cost Item			Factor	Cost
Direct Costs				
Purchased Equipment Costs				
	Primary Equipment[1]		A	11,870
	Sales Tax[2]		B = 0.065 * A	772
	Shipping		Included in A	----
		Purchased Equipment Cost (PEC)	PEC = A + B	12,642
Direct Installation Costs				
	Foundations & Supports		Included in A	----
	Handling & Erection		Included in A	----
	Electrical		Included in A	----
	Piping		Included in A	----
	Insulation for Ductwork		Included in A	----
	Painting		Included in A	----
		Direct Installation Cost	Included in A	----
Total Direct Costs (DC)				12,642
Indirect Costs				
Installation				
	Engineering		Included in A	----
	Construction & Field Expenses		Included in A	----
	Contractor Fees		Included in A	----
	Start-Up		Included in A	----
	Contingencies[3]		0.03 * PEC	379
Total Indirect Costs (IC)				379
TOTAL CAPITAL INVESTMENT = DC + IC				**13,021**
Direct Annual Costs				
Operating Labor				
	Operator		Negligible	----
	Supervisor		Negligible	----
		Total Operating Labor		----
Maintenance				
	Labor		----	----
	Materials		----	----
		Total Maintenance[4]	0.005 * TCI	65
Utilities				
	Electricity		Negligible	----
	Water		----	----
	Reagent		----	----
		Total Utilities		----
Catalyst Cost				
	Catalyst Replacement		Catalyst life > DOC Service Life	----
		Total Catalyst Cost	----	----
Miscellaneous				
	Performance Tests		----	----
	Record Keeping & Reporting		----	----
		Total Miscellaneous Costs		----
Total Direct Annual Costs (DAC)				**65**
Indirect Annual Costs				
Overhead[5]			60% of operating, supervisor, maintenance labor & materials	39
Administrative Charges[6]			0.02 * TCI	260
Capital Recovery Factor[7]			CRF	0.0640
Capital Recovery			CRF * TCI	833
Total Indirect Annual Costs (IAC)				**1,133**
TOTAL ANNUAL COST = DAC + IAC				**1,198**
Uncontrolled NOx, CO, VOC, and PM emissions			tons/yr	0.79
NOx, CO, VOC, and PM Emissions with DOC			tons/yr	0.74
Percent reduction from uncontrolled				7%
Total emissions reduction			tons/yr	0.05
Cost per Ton Controlled			**$/ton**	**23,272**

[1] Capital cost provided by the engine vendor (Brant Briody of Western States Equipment Co.)
[2] Washington sales tax
[3] Minimum cost from most recent Sabey, Vantage, and Cyrus One cost-effectiveness analyses
[4] Estimated using equations from EPA's Air Pollution Control Cost Estimation Spreadsheet for Selective Catalytic Reduction (SCR) found at https://www.epa.gov/sites/production/files/2019-08/scrcostmanualspreadsheet_june-2019rf.xlsm
[5] EPA's Air Pollution Control Cost Manual, Section 1, Chapter 2 (Cost Estimation), Section 2.6.5.7
[6] EPA's Air Pollution Control Cost Manual, Section 1, Chapter 2 (Cost Estimation), Section 2.6.5.8
[7] The capital recovery factor was calculated assuming a 25-year equipment life and a 4% interest rate

TABLE B2.2-22b
COST EFFECTIVENESS CALCULATIONS
Toxic Air Pollutants
Diesel Oxidation Catalyst (DOC) Control System
Diesel-Fired 750 kW Emergency Generator
Operating Hours 100 hours/year

TAP Avg Period [1]	Toxic Air Pollutant	Emission Factor [2] (lb/MMBTU)	Uncontrolled Emissions (tpy)	Control Factor [3]	Emission Reduction (tpy)	Cost-Effectiveness [4] ($/ton)
24-Hour	Acrolein	7.88E-06	2.90E-06	0.70	2.03E-06	1,420,590
	Toluene	2.81E-04	1.03E-04	0.70	7.24E-05	
	Xylenes	1.93E-04	7.11E-05	0.70	4.97E-05	
	Propylene	2.79E-03	1.03E-03	0.70	7.19E-04	
Annual	Benzene	7.76E-04	2.86E-04	0.70	2.00E-04	570,470
	Formaldehyde	7.89E-05	2.91E-05	0.70	2.03E-05	
	Acetaldehyde	2.52E-05	9.28E-06	0.70	6.50E-06	
	Naphthalene	1.30E-04	4.79E-05	0.70	3.35E-05	
	Benz(a)anthracene	6.22E-07	2.29E-07	0.70	1.60E-07	
	Chrysene	1.53E-06	5.63E-07	0.70	3.94E-07	
	Benz(b)fluoranthcene	1.11E-06	4.09E-07	0.70	2.86E-07	
	Benz(k)fluoranthcene	2.18E-07	8.03E-08	0.70	5.62E-08	
	Benzo(a)pyrene	2.57E-07	9.46E-08	0.70	6.62E-08	
	Indeno(1,2,3-cd)pyrene	4.14E-07	1.52E-07	0.70	1.07E-07	
	Dibenz(a,h)anthracene	3.46E-07	1.27E-07	0.70	8.92E-08	
	DPM	--	7.35E-03	0.25	1.84E-03	

[1] ASIL information from WAC 173-460

[2] SO2, NO2, CO, and DPM based on criteria pollutant emission calculations, assuming 90% of NOx as NO2. Other TAPs from AP-42 Chapter 3.4 (Large Stationary Diesel Engines)

[3] Control factors used in recent Sabey, Vantage, and Cyrus One data center NOC applications.

[4] Cost-effectiveness based on total annual control cost and emission reduction by TAP averaging period group.

TABLE B2.2-23b
COST EFFECTIVENESS CALCULATIONS
Criteria Air Pollutants
Diesel Oxidation Catalyst (DOC) Control System
Diesel-Fired 1.25 MW Caterpillar Emergency Generator
Operating Hours 100 hours/year

Cost Item		Factor	Cost
Direct Costs			
Purchased Equipment Costs			
	Primary Equipment[1]	A	16,000
	Sales Tax[2]	B = 0.065 * A	1,040
	Shipping	Included in A	-----
	Purchased Equipment Cost (PEC)	PEC = A + B	17,040
Direct Installation Costs			
	Foundations & Supports	Included in A	-----
	Handling & Erection	Included in A	-----
	Electrical	Included in A	-----
	Piping	Included in A	-----
	Insulation for Ductwork	Included in A	-----
	Painting	Included in A	-----
	Direct Installation Cost	Included in A	-----
Total Direct Costs (DC)			17,040
Indirect Costs			
Installation			
	Engineering	Included in A	-----
	Construction & Field Expenses	Included in A	-----
	Contractor Fees	Included in A	-----
	Start-Up	Included in A	-----
	Contingencies[3]	0.03 * PEC	511
Total Indirect Costs (IC)			511
TOTAL CAPITAL INVESTMENT = DC + IC			**17,551**
Direct Annual Costs			
Operating Labor			
	Operator	Negligible	-----
	Supervisor	Negligible	-----
	Total Operating Labor		-----
Maintenance			
	Labor	-----	-----
	Materials	-----	-----
	Total Maintenance[4]	0.005 * TCI	88
Utilities			
	Electricity	Negligible	-----
	Water	-----	-----
	Reagent	-----	-----
	Total Utilities		-----
Catalyst Cost			
	Catalyst Replacement	Catalyst life > DOC Service Life	-----
	Total Catalyst Cost	-----	-----
Miscellaneous			
	Performance Tests	-----	-----
	Record Keeping & Reporting	-----	-----
	Total Miscellaneous Costs		-----
Total Direct Annual Costs (DAC)			**88**
Indirect Annual Costs			
Overhead[5]		60% of operating, supervisor, maintenance labor & materials	53
Administrative Charges[6]		0.02 * TCI	351
Capital Recovery Factor[7]		CRF	0.0640
Capital Recovery		CRF * TCI	1,123
Total Indirect Annual Costs (IAC)			**1,527**
TOTAL ANNUAL COST = DAC + IAC			**1,615**
Uncontrolled NOx, CO, VOC, and PM emissions		tons/yr	1.32
NOx, CO, VOC, and PM Emissions with DOC		tons/yr	1.27
Percent reduction from uncontrolled			4%
Total emissions reduction		tons/yr	0.05
Cost per Ton Controlled		**$/ton**	**32,963**

[1] Capital cost provided by the engine vendor (Brant Briody of Western States Equipment Co.)
[2] Washington sales tax
[3] Minimum cost from most recent Sabey, Vantage, and Cyrus One cost-effectiveness analyses
[4] Estimated using equations from EPA's Air Pollution Control Cost Estimation Spreadsheet for Selective Catalytic Reduction (SCR) found at https://www.epa.gov/sites/production/files/2019-09/scrcostmanualspreadsheet_june-2019xlsm
[5] EPA's Air Pollution Control Cost Manual, Section 1, Chapter 2 (Cost Estimation), Section 2.6.5.7
[6] EPA's Air Pollution Control Cost Manual, Section 1, Chapter 2 (Cost Estimation), Section 2.6.5.8
[7] The capital recovery factor was calculated assuming a 25-year equipment life and a 4% interest rate

TABLE B2.2-23b
COST EFFECTIVENESS CALCULATIONS
Toxic Air Pollutants
Diesel Oxidation Catalyst (DOC) Control System
Diesel-Fired 1.25 MW Caterpillar Emergency Generator
Operating Hours 100 hours/year

TAP Avg Period [1]	Toxic Air Pollutant	Emission Factor [2] (lb/MMBTU)	Uncontrolled Emissions (tpy)	Control Factor [3]	Emission Reduction (tpy)	Cost-Effectiveness [4] ($/ton)
24-Hour	Acrolein	7.88E-06	4.73E-06	0.70	3.31E-06	1,174,323
	Toluene	2.81E-04	1.69E-04	0.70	1.18E-04	
	Xylenes	1.93E-04	1.16E-04	0.70	8.11E-05	
	Propylene	2.79E-03	1.68E-03	0.70	1.17E-03	
Annual	Benzene	7.76E-04	4.66E-04	0.70	3.26E-04	1,125,776
	Formaldehyde	7.89E-05	4.74E-05	0.70	3.32E-05	
	Acetaldehyde	2.52E-05	1.51E-05	0.70	1.06E-05	
	Naphthalene	1.30E-04	7.81E-05	0.70	5.46E-05	
	Benz(a)anthracene	6.22E-07	3.73E-07	0.70	2.61E-07	
	Chrysene	1.53E-06	9.19E-07	0.70	6.43E-07	
	Benz(b)fluoranthcene	1.11E-06	6.66E-07	0.70	4.67E-07	
	Benz(k)fluoranthcene	2.18E-07	1.31E-07	0.70	9.16E-08	
	Benzo(a)pyrene	2.57E-07	1.54E-07	0.70	1.08E-07	
	Indeno(1,2,3-cd)pyrene	4.14E-07	2.49E-07	0.70	1.74E-07	
	Dibenz(a,h)anthracene	3.46E-07	2.08E-07	0.70	1.45E-07	
	DPM	--	4.03E-03	0.25	1.01E-03	

[1] ASIL information from WAC 173-460
[2] SO2, NO2, CO, and DPM based on criteria pollutant emission calculations, assuming 90% of NOx as NO2. Other TAPs from AP-42 Chapter 3.4 (Large Stationary Diesel Engines)
[3] Control factors used in recent Sabey, Vantage, and Cyrus One data center NOC applications.
[4] Cost-effectiveness based on total annual control cost and emission reduction by TAP averaging period group.

TABLE B2.2-24b
COST EFFECTIVENESS CALCULATIONS
Criteria Air Pollutants
Diesel Oxidation Catalyst (DOC) Control System
Diesel-Fired 1.25 MW Generac Emergency Generator
Operating Hours 100 hours/year

Cost Item		Factor	Cost
Direct Costs			
Purchased Equipment Costs			
	Primary Equipment[1]	A	16,271
	Sales Tax[2]	B = 0.065 * A	1,058
	Shipping	Included in A	-----
	Purchased Equipment Cost (PEC)	PEC = A + B	17,329
Direct Installation Costs			
	Foundations & Supports	Included in A	-----
	Handling & Erection	Included in A	-----
	Electrical	Included in A	-----
	Piping	Included in A	-----
	Insulation for Ductwork	Included in A	-----
	Painting	Included in A	-----
	Direct Installation Cost	Included in A	-----
Total Direct Costs (DC)			17,329
Indirect Costs			
Installation			
	Engineering	Included in A	-----
	Construction & Field Expenses	Included in A	-----
	Contractor Fees	Included in A	-----
	Start-Up	Included in A	-----
	Contingencies[3]	0.03 * PEC	520
Total Indirect Costs (IC)			520
TOTAL CAPITAL INVESTMENT = DC + IC			**17,849**
Direct Annual Costs			
Operating Labor			
	Operator	Negligible	-----
	Supervisor	Negligible	-----
	Total Operating Labor		-----
Maintenance			
	Labor	-----	-----
	Materials	-----	-----
	Total Maintenance[4]	0.005 * TCI	89
Utilities			
	Electricity	Negligible	-----
	Water	-----	-----
	Reagent	-----	-----
	Total Utilities		-----
Catalyst Cost			
	Catalyst Replacement	Catalyst life > DOC Service Life	-----
	Total Catalyst Cost	-----	-----
Miscellaneous			
	Performance Tests	-----	-----
	Record Keeping & Reporting	-----	-----
	Total Miscellaneous Costs		-----
Total Direct Annual Costs (DAC)			**89**
Indirect Annual Costs			
Overhead[5]		60% of operating, supervisor, maintenance labor & materials	54
Administrative Charges[6]		0.02 * TCI	357
Capital Recovery Factor[7]		CRF	0.0640
Capital Recovery		CRF * TCI	1,143
Total Indirect Annual Costs (IAC)			**1,553**
TOTAL ANNUAL COST = DAC + IAC			**1,642**
Uncontrolled NOx, CO, VOC, and PM emissions		tons/yr	0.98
NOx, CO, VOC, and PM Emissions with DOC		tons/yr	0.83
Percent reduction from uncontrolled			15%
Total emissions reduction		tons/yr	0.14
Cost per Ton Controlled		**$/ton**	**11,533**

[1] Capital cost provided by the engine vendor (Brant Briody of Western States Equipment Co.)
[2] Washington sales tax
[3] Minimum cost from most recent Sabey, Vantage, and Cyrus One cost-effectiveness analyses
[4] Estimated using equations from EPA's Air Pollution Control Cost Estimation Spreadsheet for Selective Catalytic Reduction (SCR) found at https://www.epa.gov/sites/production/files/2019-06/scrcostmanualspreadsheet_june-2019vf.xlsm
[5] EPA's Air Pollution Control Cost Manual, Section 1, Chapter 2 (Cost Estimation), Section 2.6.5.7
[6] EPA's Air Pollution Control Cost Manual, Section 1, Chapter 2 (Cost Estimation), Section 2.6.5.8
[7] The capital recovery factor was calculated assuming a 25-year equipment life and a 4% interest rate

TABLE B2.2-24b
COST EFFECTIVENESS CALCULATIONS
Toxic Air Pollutants
Diesel Oxidation Catalyst (DOC) Control System
Diesel-Fired 1.25 MW Generac Emergency Generator
Operating Hours 100 hours/year

TAP Avg Period [1]	Toxic Air Pollutant	Emission Factor [2] (lb/MMBTU)	Uncontrolled Emissions (tpy)	Control Factor [3]	Emission Reduction (tpy)	Cost-Effectiveness [4] ($/ton)
24-Hour	Acrolein	7.88E-06	6.17E-06	0.70	4.32E-06	915,586
	Toluene	2.81E-04	2.20E-04	0.70	1.54E-04	
	Xylenes	1.93E-04	1.51E-04	0.70	1.06E-04	
	Propylene	2.79E-03	2.19E-03	0.70	1.53E-03	
Annual	Benzene	7.76E-04	6.08E-04	0.70	4.25E-04	275,197
	Formaldehyde	7.89E-05	6.18E-05	0.70	4.33E-05	
	Acetaldehyde	2.52E-05	1.97E-05	0.70	1.38E-05	
	Naphthalene	1.30E-04	1.02E-04	0.70	7.13E-05	
	Benz(a)anthracene	6.22E-07	4.87E-07	0.70	3.41E-07	
	Chrysene	1.53E-06	1.20E-06	0.70	8.39E-07	
	Benz(b)fluoranthcene	1.11E-06	8.69E-07	0.70	6.08E-07	
	Benz(k)fluoranthcene	2.18E-07	1.71E-07	0.70	1.20E-07	
	Benzo(a)pyrene	2.57E-07	2.01E-07	0.70	1.41E-07	
	Indeno(1,2,3-cd)pyrene	4.14E-07	3.24E-07	0.70	2.27E-07	
	Dibenz(a,h)anthracene	3.46E-07	2.71E-07	0.70	1.90E-07	
	DPM	--	2.16E-02	0.25	5.41E-03	

[1] ASIL information from WAC 173-460
[2] SO2, NO2, CO, and DPM based on criteria pollutant emission calculations, assuming 90% of NOx as NO2. Other TAPs from AP-42 Chapter 3.4 (Large Stationary Diesel Engines)
[3] Control factors used in recent Sabey, Vantage, and Cyrus One data center NOC applications.
[4] Cost-effectiveness based on total annual control cost and emission reduction by TAP averaging period group.

TABLE B2.2-25b
COST EFFECTIVENESS CALCULATIONS
Criteria Air Pollutants
Diesel Oxidation Catalyst (DOC) Control System
Diesel-Fired 2.25 MW Emergency Generator
Operating Hours 100 hours/year

Cost Item			Factor	Cost
Direct Costs				
Purchased Equipment Costs				
	Primary Equipment[1]		A	23,017
	Sales Tax[2]		B = 0.065 * A	1,496
	Shipping		Included in A	----
		Purchased Equipment Cost (PEC)	PEC = A + B	24,513
Direct Installation Costs				
	Foundations & Supports		Included in A	----
	Handling & Erection		Included in A	----
	Electrical		Included in A	----
	Piping		Included in A	----
	Insulation for Ductwork		Included in A	----
	Painting		Included in A	----
		Direct Installation Cost	Included in A	----
Total Direct Costs (DC)				24,513
Indirect Costs				
Installation				
	Engineering		Included in A	----
	Construction & Field Expenses		Included in A	----
	Contractor Fees		Included in A	----
	Start-Up		Included in A	----
	Contingencies[3]		0.03 * PEC	735
Total Indirect Costs (IC)				735
TOTAL CAPITAL INVESTMENT = DC + IC				**25,249**
Direct Annual Costs				
Operating Labor				
	Operator		Negligible	----
	Supervisor		Negligible	----
		Total Operating Labor		----
Maintenance				
	Labor		-----	----
	Materials		-----	----
		Total Maintenance[4]	0.005 * TCI	126
Utilities				
	Electricity		Negligible	----
	Water		-----	----
	Reagent		-----	----
		Total Utilities		----
Catalyst Cost				
	Catalyst Replacement		Catalyst life > DOC Service Life	----
		Total Catalyst Cost	-----	----
Miscellaneous				
	Performance Tests		-----	----
	Record Keeping & Reporting		-----	----
		Total Miscellaneous Costs		----
Total Direct Annual Costs (DAC)				**126**
Indirect Annual Costs				
Overhead[5]			60% of operating, supervisor, maintenance labor & materials	76
Administrative Charges[6]			0.02 * TCI	505
Capital Recovery Factor[7]			CRF	0.0640
Capital Recovery			CRF * TCI	1,616
Total Indirect Annual Costs (IAC)				**2,197**
TOTAL ANNUAL COST = DAC + IAC				**2,323**
Uncontrolled NOx, CO, VOC, and PM emissions			tons/yr	2.06
NOx, CO, VOC, and PM Emissions with DOC			tons/yr	1.62
Percent reduction from uncontrolled				21%
Total emissions reduction			tons/yr	0.44
Cost per Ton Controlled			**$/ton**	**5,252**

[1] Capital cost provided by the engine vendor (Brant Briody of Western States Equipment Co.)
[2] Washington sales tax
[3] Minimum cost from most recent Sabey, Vantage, and Cyrus One cost-effectiveness analyses
[4] Estimated using equations from EPA's Air Pollution Control Cost Estimation Spreadsheet for Selective Catalytic Reduction (SCR) found at https://www.epa.gov/sites/production/files/2019-06/scrcostmanualspreadsheet_june-2019v1.xlsm
[5] EPA's Air Pollution Control Cost Manual, Section 1, Chapter 2 (Cost Estimation), Section 2.6.5.7
[6] EPA's Air Pollution Control Cost Manual, Section 1, Chapter 2 (Cost Estimation), Section 2.6.5.8
[7] The capital recovery factor was calculated assuming a 25-year equipment life and a 4% interest rate

TABLE B2.2-25b
COST EFFECTIVENESS CALCULATIONS
Toxic Air Pollutants
Diesel Oxidation Catalyst (DOC) Control System
Diesel-Fired 2.25 MW Emergency Generator
Operating Hours 100 hours/year

TAP Avg Period [1]	Toxic Air Pollutant	Emission Factor [2] (lb/MMBTU)	Uncontrolled Emissions (tpy)	Control Factor [3]	Emission Reduction (tpy)	Cost-Effectiveness [4] ($/ton)
24-Hour	Acrolein	7.88E-06	9.05E-06	0.70	6.33E-06	883,597
	Toluene	2.81E-04	3.23E-04	0.70	2.26E-04	
	Xylenes	1.93E-04	2.22E-04	0.70	1.55E-04	
	Propylene	2.79E-03	3.20E-03	0.70	2.24E-03	
Annual	Benzene	7.76E-04	8.91E-04	0.70	6.24E-04	196,218
	Formaldehyde	7.89E-05	9.06E-05	0.70	6.34E-05	
	Acetaldehyde	2.52E-05	2.89E-05	0.70	2.03E-05	
	Naphthalene	1.30E-04	1.49E-04	0.70	1.04E-04	
	Benz(a)anthracene	6.22E-07	7.14E-07	0.70	5.00E-07	
	Chrysene	1.53E-06	1.76E-06	0.70	1.23E-06	
	Benz(b)fluoranthcene	1.11E-06	1.27E-06	0.70	8.92E-07	
	Benz(k)fluoranthcene	2.18E-07	2.50E-07	0.70	1.75E-07	
	Benzo(a)pyrene	2.57E-07	2.95E-07	0.70	2.07E-07	
	Indeno(1,2,3-cd)pyrene	4.14E-07	4.75E-07	0.70	3.33E-07	
	Dibenz(a,h)anthracene	3.46E-07	3.97E-07	0.70	2.78E-07	
	DPM	--	4.41E-02	0.25	1.10E-02	

[1] ASIL information from WAC 173-460
[2] SO2, NO2, CO, and DPM based on criteria pollutant emission calculations, assuming 90% of NOx as NO2. Other TAPs from AP-42 Chapter 3.4 (Large Stationary Diesel Engines)
[3] Control factors used in recent Sabey, Vantage, and Cyrus One data center NOC applications.
[4] Cost-effectiveness based on total annual control cost and emission reduction by TAP averaging period group.

Attachment 3
21-ESQ-000366

SECOND TIER REVIEW SUPPORTING DOE/RL-2020-33, WATER SYSTEMS UPGRADE NOTICE OF CONSTRUCTION APPLICATION TECHNICAL INFORMATION

Consisting of 149 pages, including this cover page

HNF-RPT-65735

Revision 0

Second Tier Review Supporting DOE/RL-2020-33, Water Systems Upgrade Notice of Construction Application Technical Information

Prepared for the U.S. Department of Energy
Assistant Secretary for Environmental Management

Contractor for the U.S. Department of Energy under
Contract DE-AC06-09RL14728

P.O. Box 650
Richland, Washington 99352

Approved for Public Release;
Further Dissemination Unlimited

This Page Intentionally Left Blank

Second Tier Review Supporting DOE/RL-2020-33, Water Systems Upgrade Notice of Construction Application Technical

Information

Mission Support Alliance
Richland, WA

Ramboll US Corporation
Lynnwood, WA

Date Published
December 2020

Prepared for the U.S. Department of Energy
Assistant Secretary for Environmental Management

P.O. Box 550
Richland, Washington 99352

APPROVED
By Sarah Harrison at 4:03 pm, Jan 11, 2021

Release Approval Date

Approved for Public Release;
Further Dissemination Unlimited

TRADEMARK DISCLAIMER

Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise, does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof or its contractors or subcontractors.

This report has been reproduced from the best available copy.

Printed in the United States of America

CONTENTS

1.0 INTRODUCTION 1-1

2.0 PROJECT DESCRIPTION 2-1
2.1 TOXICS AIR POLLUTANT EMISSIONS.....2-2
2.2 CONTROL TECHNOLOGY 2-4
2.2.1 Best Available Control Technology for Toxics 2-4
2.2.2 Emissions Standards.....2-4

3.0 HAZARD IDENTIFICATION 3-1
3.1 DIESEL PARTICULATE MATTER.....3-1
3.1.1 Chemical and Physical Properties 3-1
3.1.2 Environmental Fate and Transport 3-2
3.1.3 Health Effects 3-2
3.2 BENZENE 3-3
3.2.1 Chemical and Physical Properties 3-3
3.2.2 Environmental Fate and Transport 3-3
3.2.3 Health Effects 3-3
3.3 NAPHTHALENE 3-5
3.3.1 Chemical and Physical Properties 3-5
3.3.2 Environmental Fate and Transport 3-5
3.3.3 Health Effects 3-5
3.4 NITROGEN DIOXIDE.....3-6
3.4.1 Chemical and Physical Properties 3-6
3.4.2 Environmental Fate and Transport 3-6
3.4.3 Health Effects 3-7

4.0 POLLUTANT CONCENTRATION CALCULATIONS 4-1
4.1 MODELING METHODOLOGY 4-1
4.2 MODEL SELECTION.....4-1
4.3 MODELING PROCEDURES 4-1
4.3.1 Setup and Application 4-1
4.3.2 Averaging Periods 4-1 4.3.3
Terrain Elevation Data and Receptor Network.....4-2
4.3.4 Meteorological Data 4-3
4.3.5 Emission Unit Characterization.....4-4
4.4 MODELING RESULTS 4-5
4.5 BACKGROUND CONCENTRATION 4-19

5.0 IDENTIFICATION OF POTENTIALLY EXPOSED POPULATIONS 5-1
5.1 RECEPTORS OF CONCERN.....5-1
5.2 SENSITIVE POPULATIONS 5-1

6.0 EXPOSURE ASSESSMENT 6-1

6.1 IDENTIFICATION OF EXPOSURE PATHWAYS.....6-1 6.2 EXPOSURE CONCENTRATIONS 6-1
6.2.1 Calculating ECs 6-10
6.2.2 Background ECs 6-11
6.2.3 Cumulative ECs 6-11

7.0 TOXICITY ASSESSMENT 7-1

8.0 RISK CHARACTERIZATION 8-1
8.1 CALCULATION OF NON-CANCER HAZARDS 8-1
8.2 QUANTIFYING INCREASED CANCER RISK 8-4

9.0 UNCERTAINTY CHARACTERIZATION 9-1
9.1 UNCERTAINTY CHARACTERIZATION 9-1
9.1.1 Emissions Rate Calculations .....9-1 9.1.2 Air Dispersion Modeling 9-1
9.1.3 Background Concentrations 9-2
9.1.4 Toxicity Values 9-2
9.2 CONCLUSIONS 9-2
9.2.1 Non-Cancer Hazards 9-3
9.2.2 Cancer Risk 9-3

10.0 REFERENCES 10-1

APPENDICES

A PROJECT EMISSION RATE CALCULATIONS ..... A-i
B LAND USE DATA .....B-i
C WHITE PAPER ON DIESEL EXHAUST QUANTITATIVE HEALTH RISK ASSESSMENT VALUES FOR LUNCH CANCER .....C-i

FIGURES

Figure 2-1. Locations of Diesel-Powered Generator Sets 2-2
Figure 4-1. Receptor Locations 4-3
Figure 4-2. Hanford Meteorological Station Windrose for 2015 through 2019 4-4
Figure 4-3. Spatial Variation of 1-Hour Average Benzene Concentrations 4-7
Figure 4-4. Spatial Variation of 8-Hour Average Benzene Concentrations 4-8
Figure 4-5. Spatial Variation of Annual Average Benzene Concentrations 4-9
Figure 4-6. Spatial Variation of 1-Hour Average DPM Concentrations 4-10
Figure 4-7. Spatial Variation of 8-Hour Average DPM Concentrations 4-11
Figure 4-8. Spatial Variation of Annual Average DPM Concentrations.....4-12
Figure 4-9. Spatial Variation of 1-Hour Average Naphthalene Concentrations 4-13

Figure 4-10. Spatial Variation of 8-Hour Average Naphthalene Concentrations 4-14
Figure 4-11. Spatial Variation of Annual Average Naphthalene Concentrations 4-15
Figure 4-12. Spatial Variation of 1-Hour Average Nitrogen Dioxide Concentrations.....4-16

Figure 4-13. Spatial Variation of 8-Hour Average Nitrogen Dioxide Concentrations.....4-17
Figure 4-14. Spatial Variation of Annual Average Nitrogen Dioxide Concentrations.....4-18
Figure 5-1. Sensitive Receptor Locations..... 5-2
Figure 6-1. Locations of MIR 6-6
Figure 6-2. Locations of MIRR 6-7
Figure 6-3. Locations of MICR 6-8
Figure 6-4. Locations of MIAR 6-9

TABLES

Table 2-1. Proposed Generator Sets.....2-1
Table 2-2. Toxic Air Pollutant Total Emissions Estimate Summary.....2-2
Table 4-1. Release Parameters 4-4
Table 4-2. Significant Onsite Structure Heights. 4-5
Table 4-3. Maximum Predicted Project Toxic Air Pollutant Concentrations.....4-6
Table 4-4. NATA 2014 and NW Airquest Predicted Toxic Air Pollutant Concentrations.. 4-19
Table 5-1. Sensitive Receptors. 5-2
Table 6-1. MIR Concentrations and Receptors.....6-2
Table 6-2. MIRR Concentrations and Receptors. 6-3
Table 6-3. MICR Concentrations and Receptors. 6-4
Table 6-4. MIAR Concentrations and Receptors. 6-5
Table 6-5. Exposure Parameters Used to Calculate ECs for Increased Cancer Risk. 6-10
Table 7-1. Non-Cancer, Risk-Based Concentrations.....7-1
Table 7-2. Cancer Inhalation Unit Risk Values. 7-2
Table 8-1. Acute and Chronic Non-Cancer Hazard Indices.....8-2
Table 8-2. Calculated Cancer Risk Increases. 8-5

This Page Intentionally Left Blank

ACRONYMS

AERMOD	American Meteorological Society/Environmental Protection Agency Regulatory modeling system
ALC	absolute lymphocyte counts
ASIL	acceptable source impact levels
ATSDR	Agency for Toxic Substances and Diseases Registry
BPIP	Building Profile Input Program
CI	compression ignition
DOE	U.S. Department of Energy
EC	exposure concentration
Ecology	Washington State Department of Ecology
EPA	U.S. Environmental Protection Agency
HAP	hazardous air pollutants
HEC	human equivalent concentration
HI	hazard index
HIA	Health Impact Assessment
HQ	hazard quotient
ICE	internal combustion engines
IRIS	Integrated Risk Information System
LOAEL	lowest observed adverse effect level
MIAR	maximally-impacted angler receptor
MIBR	maximally-impacted boundary receptor
MICR	maximally-impacted commercial receptor
MIR	maximally-impacted receptor
MIRR	maximally-impacted residential receptor
MRL	minimum risk level
NATA	National-Scale Air Toxics Assessment
NED	National Elevation Dataset
NOC	Notice of Construction
NOAEL	no adverse effects level
NTP	National Toxicology Program
OEHHA	California Office of Environmental Health Hazard Assessment
PAH	polycyclic aromatic hydrocarbon
ppb	parts per billion
ppm	parts per million
REL	reference exposure level
RfC	reference concentration
RICE	reciprocating internal combustion engines
SQER	small quantity emission rate
TAP	toxic air pollutant
tBACT	Best Available Control Technology for toxics
ULSD	ultra-low sulfur diesel

USGS	United States Geological Survey

This Page Intentionally Left Blank

1.0 INTRODUCTION

The U.S. Department of Energy (DOE) is proposing several projects that will renovate and upgrade the Hanford Site's Export Water, Raw Water, and Sanitary Water Systems to support ongoing operations on the Hanford Site ("the facility"). New emissions of criteria (CAP) and toxic air pollutants (TAP) from sources in these projects may require a minor source operating permit. Among the new emission units proposed for these projects, six new diesel enginepowered emergency generator sets will be installed and operated. Washington State Department of Ecology (Ecology) will review the emissions of CAPs and TAPs from these new stationary air pollution sources as part of the Notice of Construction permit process.

The proposed diesel engines are expected to emit toxic air pollutants (TAP), four of which (i.e., benzene, diesel particulate matter, naphthalene, and nitrogen dioxide) are estimated to exceed the WAC 173-460-150, "Table of ASIL, SQER and de minimis emission values," small quantity emission rate (SQER) levels. Of these four, diesel particulate matter and nitrogen dioxide have been predicted by air dispersion modeling to exceed the applicable WAC 173-460-150 acceptable source impact levels (ASILs). In cases where a modeling analysis predicts concentration increases that exceed one or more ASILs, WAC 173-460-090, "Second tier review," provides a second-tier review process to determine a means of compliance with the ambient impact requirement.

Ramboll US Consulting, Inc. (Ramboll) submitted a Health Impact Assessment (HIA) Protocol to the Ecology on behalf of Mission Support Alliance (MSA), in contract with DOE, on December 2, 2020, and Ecology notified MSA via email on December 2, 2020, that it had been reviewed and approved for use in developing an HIA.

The remainder of this document describes the methodology and results of the HIA, which includes descriptions of the project and project location, identification of exposed populations, a discussion of the toxicity of the TAPs of concern, an outline of the air dispersion modeling methodology used to estimate exposure, and a description of the calculations used to quantify increased hazards and risks attributable to the project, as well as the results of those calculations, all of which conforms with the HIA protocol.

This Page Intentionally Left Blank

2.0 PROJECT DESCRIPTION

The DOE is preparing for several upgrades to the Hanford Site Water Systems. These upgrades are necessary to ensure the Water Systems infrastructure is adequate throughout the lifecycle of the Hanford Site cleanup mission. The various water infrastructure upgrade projects (hereafter, "the Projects") include installation and operation of six diesel engine-powered emergency generator sets (Table 2-1). The locations of the proposed emergency generator sets are shown in Figure 2-1.

Table 2-1. Proposed Generator Sets.

Proj. ID	Description	Rated Capacity (kWe)	Approx. Engine Power (bhp)
L895	Standby Generator	1,250	1,829
L897	Standby Generator	750	1,112
L781 Feed Pump	Feed Pump Building Standby Generator	400	617
L781 Pump House	181-D Pumphouse	2,500	3,352
L826 Pump House	181-B Pumphouse	2,500	3,352
L849	282EC Standby Generator	1,250	1,881

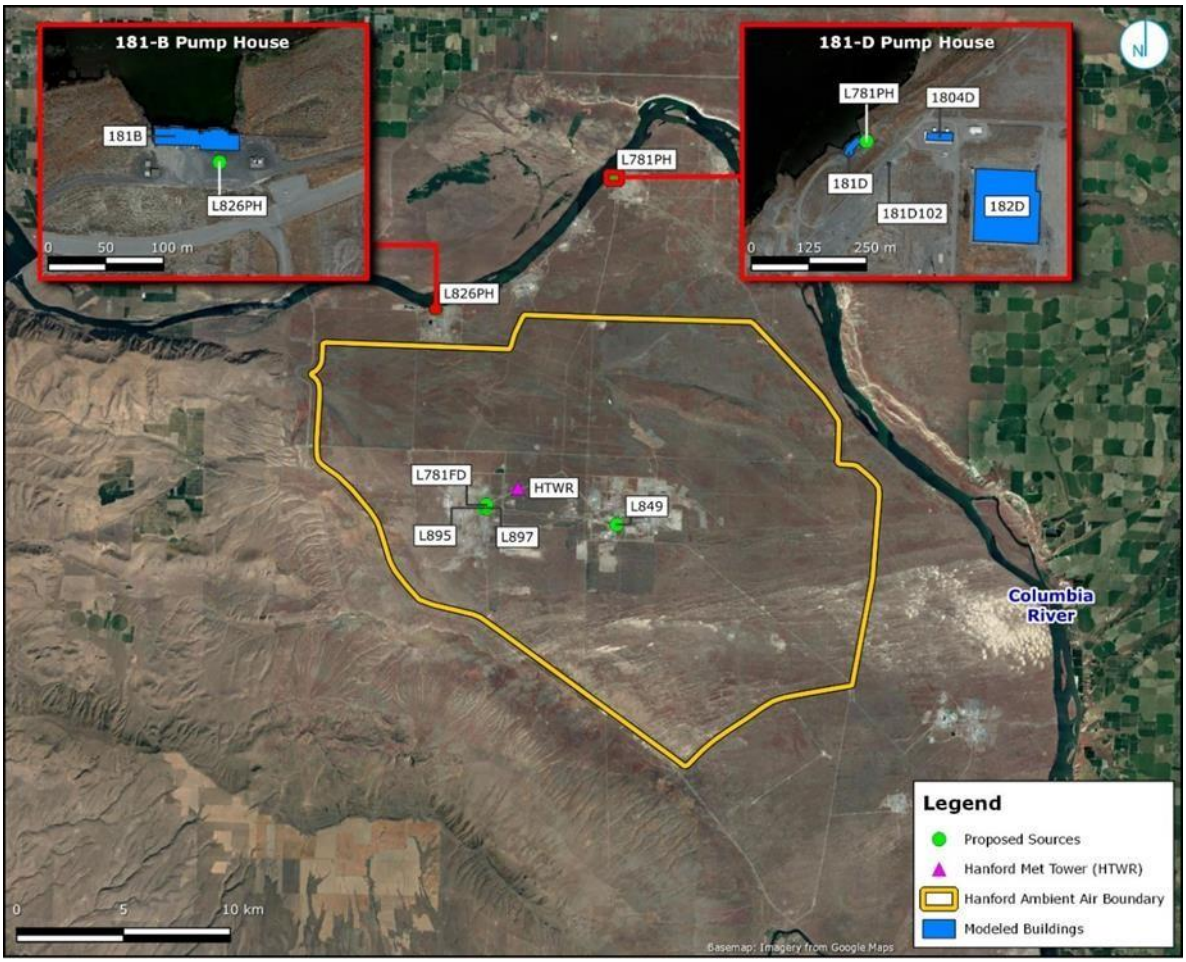


Figure 2-1. Locations of Diesel-Powered Generator Sets

2.1 TOXICS AIR POLLUTANT EMISSIONS

TAP emission totals for all emission units associated with the various water systems upgrade projects are summarized in Table 2-2. Additional emission calculation details for all emission units associated with the proposed Projects were developed for the Notice of Construction (NOC) application submitted to Ecology (DOE/RL-2020-33, in draft), are also provided in Appendix A of this document for convenience.

Table 2-2. Toxic Air Pollutant Total Emissions Estimate Summary. (2 Pages)

Common Name	CAS #	Averaging Period	Total (lb/avg. period)	De Minimis (lb/avg. period)	Exceeds De Minimis?	SQER (lb/avg. period)	Exceeds SQER?
Acetaldehyde	75-07-0	year	1.073023	3	No	60	No

Table 2-2. Toxic Air Pollutant Total Emissions Estimate Summary. (2 Pages)

Common Name	CAS #	Averaging Period	Total (lb/avg. period)	De Minimis (lb/avg. period)	Exceeds De Minimis?	SQER (lb/avg. period)	Exceeds SQER?
Acrolein	107-02-8	24-hr	0.000919	0.0013	No	0.026	No
Benz[a]anthracene	56-55-3	year	0.026485	0.045	No	0.89	No
Benzene	71-43-2	year	33.04228	1	Yes	21	Yes
Benzo[a]pyrene	50-32-8	year	0.010943	0.0082	Yes	0.16	No
Benzo[b]fluoranthene	205-99-2	year	0.047264	0.045	Yes	0.89	No
Benzo[k]fluoranthene	207-08-9	year	0.009282	0.045	No	0.89	No
Bromodichloromethane	75-27-4	year	0.179824	0.22	No	4.4	No
Bromoform	75-25-2	year	0.000417	7.4	No	150	No
Carbon monoxide	630-08-0	1-hr	1.064468	1.1	No	43	No
Chloroform	67-66-3	year	29.92262	0.35	Yes	7.1	Yes
Chrysene	218-01-9	year	0.065148	0.45	No	8.9	No
Dibenz[a,h]anthracene	53-70-3	year	0.014733	0.0041	Yes	0.082	No
Diesel engine exhaust, particulate	-	year	1263.156	0.027	Yes	0.54	Yes
Formaldehyde	50-00-0	year	3.359583	1.4	Yes	27	No
Indeno[1,2,3-cd]pyrene	193-39-5	year	0.017628	0.045	No	0.89	No
Naphthalene	91-20-3	year	5.535434	0.24	Yes	4.8	Yes
Nitrogen dioxide	10102-44-0	1-hr	6.64125	0.46	Yes	0.87	Yes

o-Xylene	95-47-6	24-hr	0.022515	0.82	No	16	No
Propylene	115-07-1	24-hr	0.325477	11	No	220	No
Sulfur Dioxide	7446-09-5	1-hr	0.007641	0.46	No	1.2	No
Toluene	108-88-3	24-hr	0.032781	19	No	370	No

SQER = small quantity emission rate

2.2 CONTROL TECHNOLOGY

2.2.1 Best Available Control Technology for Toxics

Per WAC 173-460-060, "Control technology requirements," new or modified sources that increase TAP emission rates must employ Best Available Control Technology for toxics (tBACT). In the NOC application submitted to Ecology, DOE proposed that tBACT for the diesel engines that would power the proposed emergency generator sets is:

- Tier 2 engine certification for engines with a rated power output greater than 751 bhp
- Tier 3 engine certification for engines with rated power outputs of between 100 and 751 bhp, exclusive combustion of ultra-low sulfur diesel (ULSD), and use of proper operation and maintenance procedures recommended by the engine manufacturer.

2.2.2 Emissions Standards

As stated in the NOC application, the proposed emergency generator sets will comply with applicable new source performance standards, national emission standards for hazardous air pollutants, and state emission standards. The applicable standards have the potential to require work practices or add-on controls that could affect TAP emissions. This section provides an evaluation of these potentially applicable standards and the effect, if any, on TAP emissions relevant to this analysis.

40 CFR 60,"Standards of Performance for New Stationary Sources," Subpart IIII, "Standards of Performance for Stationary Compression Ignition Internal Combustion Engines," applies to manufacturers, owners, and operators of certain stationary compression ignition (CI) internal combustion engines (ICE). Specifically, this regulation applies to owners and operators of a stationary CI engine that commenced construction after July 11, 2005, was manufactured after April 1, 2016, and is not used to drive a fire pump. As part of the Projects, DOE proposes to install and operate six emergency CI ICEs that meet the criteria for applicability to this Subpart.

Subpart IIII requires that the affected emergency engines burn only ULSD with a sulfur content equal to or less than 15 parts per million by weight, and that the owner install a non-resettable hour meter, operate the engine according to emergency provisions (i.e., no limit to emergency operation, 100 hours per year of non-emergency operation, 50 of which can be non-emergency, non-maintenance, and/or non-testing operation), and purchase a certified engine that has a permanent label demonstrating that it meets the emission limits in 40 CFR 89.112, "Oxides of nitrogen, carbon monoxide,hydrocarbon, and particulate matter exhaust emission standards," and 40 CFR 89.113, "Smoke emission standard," applicable for its model year and power rating. DOE will be in compliance with this Subpart as a result of installing certified engines that meet the emission limits applicable for its model year and power rating and operating the engines in accordance with the requirements of this Subpart. No performance testing, notification, or reporting is required by Subpart IIII, and, other than the required engine certification, the rule will have no effect on pollutant emissions attributable to the proposed engines.

40 CFR 63, "National Emission Standards for Hazardous Air Pollutants for Source Categories," Subpart ZZZZ, "National Emissions Standards for Hazardous Air Pollutants for Stationary Reciprocating Internal Combustion Engines," regulates emissions of hazardous air pollutants (HAPs) from existing, new, and reconstructed stationary reciprocating internal combustion engines (RICE) located at area and major sources of HAP emissions. The generator set engines proposed for the Projects are subject to this rule.

Under Subpart ZZZZ, a RICE located at a major source[1] is considered "new" and not "existing" if it meets one of two criteria:

- A power rating equal to or less than 500 bhp and is constructed on or after June 12, 2006
- A power rating greater than 500 bhp and is constructed on or after December 19, 2002.

The proposed generator set engines will all have power ratings greater than 500 bhp and will have been constructed after December 19, 2002; therefore, each of the proposed engines will be considered new.

In accordance with Subpart ZZZZ, a new emergency RICE with a power rating greater than 500 bhp located at a major source that does not operate or is not contractually obligated to be available for more than 15 hours per calendar year for the purposes specified in 40 CFR 63 (i.e., an Energy Emergency Alert Level 2 under the North American Electric Reliability Corporation
Reliability Standard or where there is a deviation of voltage or frequency of 5% or greater below standard voltage or frequency) does not have to meet the requirements of 40 CFR 63 Subparts A

[1] The Hanford Site, currently operating under Air Operating Permit Number 00-05-006 Renewal 3 (July 15, 2019), is a "major source" of hazardous air pollutants as defined in the *Clean Air Act* Section 112. Section 112 defines the term "major source" as "any stationary source or group of stationary sources located within a contiguous area and under common control that emits or has the potential to emit considering controls, in the aggregate, 10 tons per year or more of any hazardous air pollutant or 25 tons per year or more of any combination of hazardous air pollutants."

and ZZZZ, except for the initial notification requirements. Because the proposed generator sets will not operate or be contractually obligated to be available for the purposes specified in 40 CFR 63, the proposed engines will not be subject to the requirements of 40 CFR 63 Subparts A and ZZZZ, except for the notification requirements; the rule will have no effect on pollutant emissions attributable to the proposed engines.

This Page Intentionally Left Blank

3.0 HAZARD IDENTIFICATION

As noted in the previous section, the maximum potential emission rates of four TAPs are expected to exceed the assigned SQERs, and diesel particulate matter and nitrogen dioxide are predicted by the dispersion modeling to exceed the assigned ASILs. Diesel particulate matter and nitrogen dioxide, which exceeded the applicable ASILs (see Section 4), along with the TAPs that exceeded the SQERs but did not exceed the ASILs (i.e., benzene and naphthalene), were also included in the second-tier analysis. This section presents the physical properties, environmental fate and transport (e.g. chemical reactions and transportation in the atmosphere), and general health effects when humans are exposed to these four TAPs. Principal sources of this information include the Integrated Risk Information System (IRIS), Agency for Toxic Substances and Diseases Registry (ATSDR), and California Office of Environmental Health Hazard Assessment (OEHHA) toxic air contaminant databases.

3.1 DIESEL PARTICULATE MATTER

3.1.1 Chemical and Physical Properties

Diesel exhaust is a complex mixture of hundreds of constituents that exist either in the gas phase or in particle form, produced during the combustion of diesel fuel. Gaseous components of diesel exhaust include water vapor, carbon dioxide, carbon monoxide, oxygen, nitrogen, nitrogen compounds, sulfur compounds, and numerous low-molecular-weight volatile organic hydrocarbons (including aldehydes [e.g., formaldehyde, acetaldehyde, acrolein, benzene, 1,3-butadiene, polycyclic aromatic hydrocarbons (PAHs) and nitro-PAHs]).

Diesel particulate matter is a source-specific type of particulate matter formed by various physical processes as diesel engine exhaust cools and dilutes. Diesel exhaust emissions vary significantly in chemical composition and particle sizes are dependent on engine types (heavyduty, light-duty), engine operating conditions (idle, accelerate, decelerate), and fuel formulations (high/low sulfur fuel).

The structure of diesel particulate matter is similar to particulate matter in general, in that it consists of a solid core consisting of elemental carbon, with other compounds such as organic compounds, sulfate, nitrate, metals, and other trace elements adsorbed to the surface. The solid portion includes particulate matter less than 2.5 microns (i.e., $PM_{2.5}$), fine, and ultrafine particles. These particulate size classes have a large surface area-to-volume ratio that makes them an efficient medium for adsorbing organics and allows them to penetrate deep into the lung (EPA 2002).

Diesel exhaust composition has changed considerably over the years due to changes in the combustion process as well as the application of filters and after-treatment technologies to diesel engines. This is especially important when comparing results of health studies that rest on health endpoints with long latency periods, such as those for lung cancer, as the epidemiology studies that these assessments are based on need to examine workers whose exposures started more than 20 years earlier. Starting in 1988 (trucks) and continuing in 1991 (trucks), 1994 (trucks),

1996 (buses), 1997 (locomotives), 2007 (trucks), and 2008 (locomotives), the U.S. Environmental Protection Agency (EPA) has progressively tightened standards for particulate emissions from heavy-duty diesel engines, resulting in the development of new technology diesel engines that emit lower amounts of particulate matter and other emitted pollutants (e.g., gases), and diesel exhaust with an inherently different composition. These changes have not only resulted in the quantitative reduction in mass emitted by new technology diesel engines as compared to engines pre-regulation but have also resulted in qualitative differences in the composition of what is emitted, both with respect to size and with respect to chemicals associated with the exhaust (Hesterberg et al. 2011). Thus, depending on the components of diesel exhaust that may be causally linked to the increased risk of lung cancer, simple dependence on particle mass (i.e., expressing cancer risk as "per $\mu g/m^3$") may not be an accurate metric of exposure, as the composition of the particles has changed dramatically.

3.1.2 Environmental Fate and Transport

Diesel particulate matter is directly emitted from combustion engines as a component of diesel engine exhaust. Like $PM_{2.5}$, diesel particulate matter is removed from the atmosphere through both wet and dry deposition, although less efficiently than larger particles, resulting in longer atmospheric residence times. Studies have shown that diesel particulate matter can be dispersed widely after emission (EPA 2002). In addition, diesel exhaust may "age" in the atmosphere, undergoing chemical and physical transformation and dispersion over a period of days. The physical and chemical transformation of diesel exhaust will vary depending on the environment. In an urban or industrial environment, there may be high concentrations of oxidizing and nitrating radicals present, which may affect chemical stability and atmospheric residence time of the resulting "aged" particles.

3.1.3 Health Effects

There is a large body of literature examining cancer risk specific to diesel particulate matter. As early as the early 1990s, several epidemiology studies addressing the association between exposure to diesel particulate matter and lung cancer were available. These included a casecontrol and a retrospective cohort study of US railroad workers (Garshick et al. 1988) along with an associated industrial hygiene survey (Hammond et al. 1988; Woskie et al. 1988a, 1988b), and a case-control study and exposure-response analysis of truckers (Steenland et al. 1990, 1992) along with an industrial hygiene study (Zaebst et al. 1991) and an exposure-response analysis (Steenland et al. 1998).

More recently, several epidemiology studies have been published that examine occupational exposure among non-metal miners, railroad workers, and workers in the trucking industry. The Trucking Industry Particle Study (Garshick et al. 2012) reflects a large cohort in the U.S. trucking industry of drivers and dockworkers with regular exposure to diesel exhaust. The Diesel Exhaust in Miners Study (Attfield et al. 2012; Silverman et al. 2012) included a cohort analysis and a nested case–control analysis that was adjusted for tobacco smoking. Both of these studies show positive trends in lung cancer risk with increasing exposure to diesel exhaust, using elemental carbon as a measure of diesel exposure.

In 2012, the World Health Organization International Agency for Research on Cancer assembled an expert working group to evaluate the scientific literature and assess the carcinogenicity of diesel exhaust (along with gasoline engine exhausts, and some nitroarenes) (IARC 2014). Based on a number of occupational cohort studies, as well as supporting case-control studies, the expert group concluded that the epidemiological literature supports a causal association between exposure to diesel engine exhaust and lung cancer in people. An increased risk for bladder cancer was also noted in some (but not all) available case–control studies. This finding was not observed in cohort studies. The expert group concluded that there was "sufficient evidence" in humans for the carcinogenicity of diesel-engine exhaust. Furthermore, their assessment of animal studies and other related studies supported this assessment, leading to an overall assessment of diesel particulate matter as "carcinogenic to humans" (Group 1) (IARC 2014).

3.2 BENZENE

3.2.1 Chemical and Physical Properties

Benzene is a colorless liquid with a sweet odor that evaporates quickly into the air (ATSDR 2007). It is slightly soluble in water and highly flammable.

3.2.2 Environmental Fate and Transport

Benzene is found primarily in the vapor phase. It is a multipurpose solvent and a chemical intermediate (OEHHA 2014). It is used in the manufacturing of various chemicals (e.g., styrene, phenol, cyclohexane) and in various industries (e.g., fertilizer, pharmaceutical, tire, and shoe manufacturing). Benzene is produced during petroleum refining, released from underground tanks, and emitted from mobile sources. Indoor sources of benzene include cigarette smoke and use of some solvents.

3.2.3 Health Effects

Non-cancer effects from benzene exposure include irritation of the eyes, nose, and throat and depression of the central nervous system at very high levels of exposure (greater than 50 parts per million (ppm) or greater than 150 mg/m^3) for short periods of time (~1 hr) to effects on the hematopoietic and immune systems (NAC 2009).

The EPA reference concentration (RfC) of 30 µg/m^3 was based on an occupational study of exposed workers and levels of absolute lymphocyte counts (ALC) as a measure of adverse hematologic effects (Rothman et al. 1996). The study included 44 workers exposed to measured benzene concentrations and 44 unexposed controls for which hematologic outcomes were determined (i.e., absolute lymphocyte count, white blood cells, red blood cells, and platelets). The study results reported statistically significant differences in ALC vs. controls at median 8-hour time weighted average of 7.6 ppm (25 mg/m^3) benzene for a subgroup of 11 workers. EPA used benchmark dose (BMD) modeling to derive a benchmark concentration of 13.7 ppm (44 mg/m^3), with the point of departure set as the 95% lower bound estimate of 7.2 ppm (23 mg/m^3). This value was adjusted for continuous exposures (24 hours a day, 7 days a week), and a 300-fold uncertainty factor representing effect-level extrapolation (3), human variability (10),

subchronic-to-chronic extrapolation (3), and database deficiencies (3) to obtain the RfC value 30 µg/m^3.

OEHHA (2014) based the chronic reference exposure level (REL) of 1 parts per billion (ppb) (3 µg/m^3) on different occupational study involving workers in the shoe manufacturing industry in China with an average employment duration of 6.1 (±2.1) years as compared to clothing manufacturing workers in China (Lan et al. 2004). As with EPA RfC, decreased peripheral blood cell counts were the basis of the chronic REL. While higher exposure groups showed effects in up to 7 blood cell types, the most sensitive cell type was identified as the B-lymphoblast. Benchmark dose modeling was applied using a benchmark concentration of 1.62 ppm (5.2 mg/m^3) and a lower of 0.476 ppm (1.5 mg/m^3). This value was further adjusted for continuous exposure and default minute ventilation to obtain the human equivalent concentration (HEC) of 0.204 ppm (0.66 mg/m^3). To obtain the chronic REL the HEC was further adjusted by applying a 200-fold uncertainty factor, taking into account human variability (60) and subchronic-to-chronic extrapolation (√10 or approximately 3). OEHHA (2014) set the 8-hr REL equal to the chronic REL based on the same study and assumptions.

The OEHHA (2014) acute benzene REL is based on hematotoxicity (decreased early nucleated red cell counts) in an animal study of fetal and neonatal mice exposed 6 hours per day for 10 days. The lowest exposure concentration (5 ppm or 16 mg/m^3) was considered to be the lowest observed adverse effect level (LOAEL), and OEHHA then applied an uncertainty factor of 600 taking into account factors for human equivalent concentrations (1), use of a LOAEL (√10 or approximately 3), interspecies extrapolation (2 * √10 or approximately 6), human variability (10* √10 or approximately 33), and database uncertainty (1) to obtain the value of 27 µg/m^3. ATSDR (2007) developed acute (14 days or less), intermediate duration (15 to 364 days), and chronic (greater than 365 days) minimum risk level (MRL) for benzene. The acute-duration inhalation MRL of 0.009 ppm (29 µg/m^3) was based on a study in mice exposed to 0, 10.2, 31, 100, and 301 ppm benzene for 6 hours/day for 6 days (Rozen et al. 1984). The LOAEL in this study was reduced mitogen-induced B-lymphocyte proliferation, observed at 10.2 ppm (33 mg/m^3). This value was adjusted for a full day exposure (6 hours vs 24 hours), converted to HEC, and adjusted using an uncertainty factor of 300 (10 for the use of LOAEL, 3 for extrapolation from animals to humans, and 10 for human variability).

ATSDR (2007) based the intermediate duration MRL for inhalation exposures of 6 ppb (19 µg/m^3) on delayed splenic lymphocyte reactions to foreign antigens following exposure of male mice to benzene 6 hours per day, 5 days a week for 20 days (Rosenthal and Snyder 1987). These effects were observed at the lowest exposure concentration of 10 ppm (32 µg/m^3) and this was used at the LOAEL. The value was adjusted for continuous exposure (24 hours/day, 5 days/week) and converted to a human equivalent concentration, then adjusted using an uncertainty factor of 300 (10 for use of a LOAEL; 3 for extrapolation from animals to humans, and 10 for human variability).

The chronic ATSDR (2007) MRL for inhalation exposure of 0.003 ppm (3000 ppb; 9.7 µg/m^3) was based on the same occupational study of Chinese workers used by OEHHA (Lan et al.

2004), and the same endpoint (decreased B-lymphocyte cell counts) to develop the inhalation chronic duration REL of 3 ppb (0.003 ppm; 9.7 µg/m^3). ATSDR employed benchmark dose modeling to determine the point of departure of 0.1 ppm. This value was then adjusted for continuous exposure, then adjusted with an uncertainty value of 10 (human variability) to yield the chronic duration MRL.

Benzene is a known human carcinogen based on occupational studies in humans and supporting evidence from animal studies (EPA 2002). Specifically, occupational exposures to certain concentrations of benzene are associated with hematopoietic cancer. EPA developed an inhalation unit risk factor for benzene that ranges from 2.2×10^{-6} to 7.8×10^{-6} per µg/m^3 benzene. This range is based on a low-dose linear model using maximum likelihood estimates of occupational data collected from Pliofilm workers exposed to benzene (e.g., Rinsky et al. 1981, 1987). The range of values reflects differences in model selection, exposure estimates, and the dose-response model used.

The OEHHA (2009) inhalation unit risk factor for benzene is based on analysis of both human occupational studies and animal studies (OEHHA 2009, Appendix B). This value, 2.9×10^{-5} (µg/m^3)$^{-1}$, was recommended for use in 1988 by OEHHA as part of Proposition 65 regulations to estimate risk from benzene exposures.

3.3 NAPHTHALENE

3.3.1 Chemical and Physical Properties

Naphthalene is a white, solid aromatic hydrocarbon at room temperature and insoluble in water. It is produced by distillation, petroleum, or coal tar (EPA 1998).

3.3.2 Environmental Fate and Transport

Naphthalene is primarily used in an intermediate to produce phthalic anhydride, which is used to manufacture a range of chemicals including plasticizers, resins, dyes, leather tanning agents, deodorants and insecticides. Indoor exposures are typically from the use of Naphthalene as a moth repellent and/or a deodorizer for diaper pails and toilets (EPA 1998).

3.3.3 Health Effects

Inhaled naphthalene is readily absorbed in the lungs and distributed throughout the body. It is metabolized by the cytochrome P-450 family of enzymes, with significant differences observed across species. Rats metabolize naphthalene much faster than other rodent species or primates (including humans). Naphthalene may cause respiratory system damage in animals, with effects differing between rats and mice. Short-term exposure to high concentrations of naphthalene may cause hemolytic anemia, cataracts, and respiratory toxicity (Alberta Environment and Parks 2015).

The EPA (1998) RfC for naphthalene is based on a chronic inhalation study in mice (NTP 1992). Mice were exposed by inhalation to concentrations of naphthalene of 0, 10, and 30 ppm

(corresponding to 0, 52, and 157 mg/m^3, respectively) 6 hr/day, 5 days/week, for 103 weeks. Nasal effects (hyperplasia and metaplasia in respiratory and olfactory epithelium) were identified as the most sensitive endpoint, with a LOAEL of 10 ppm (52 mg/m^3). The value was adjusted for a continuous exposure (24 hr/day for 7 days) to obtain a human equivalent LOAEL and then adjusted using an uncertainty factor of 3,000 (10 to extrapolate from mice to humans, 10 for human variability, 10 for use of a LOAEL, and 3 for database deficiencies) to obtain the RfC of 0.57 ppb (3 µg/m^3).

The OEHHA (2014) chronic inhalation REL was based on the same chronic mouse study as the EPA RfC using respiratory endpoints (i.e., respiratory and olfactory epithelial metaplasia and hyperplasia) as the most sensitive endpoint. As with the RfC, 10 ppm (52 mg/m^3) was identified as the LOAEL. This value was adjusted for continuous exposure (24 hours/day, 7 days/week) and an uncertainty factor of 1,000 (10 to extrapolate from mice to humans, 10 for human variability, 10 for use of a LOAEL) to obtain a chronic inhalation REL of 2 ppb (9 µg/m^3).

The ATSDR (2005) chronic inhalation MRL for naphthalene was based on two studies, the National Toxicology Program (NTP) (1992) study in mice as well as a chronic inhalation study in rats where rats were exposed to naphthalene at concentrations of 0, 10, 30, or 60 ppm (NTP 2000). The lowest exposure concentration associated with effects in either study was 10 ppm (52 mg/m^3), based on nonneoplastic lesions in the olfactory and respiratory epithelium of the nose of rats and mice. This LOAEL was adjusted to a human-equivalent concentration, and then adjusted using an uncertainty factor of 300 (10 for the use of a LOAEL, 3 for animal to human extrapolation, and 10 for human variability) to derive the chronic inhalation MRL of 0.0007 ppm (3.7 µg/m^3).

In 2009, OEHHA published a unit risk factor based on the incidence of male rat nasal respiratory epithelial adenoma and nasal olfactory epithelial neuroblastoma reported in NTP (2000). The inhalation unit risk of 3.4 x 10^{-5} (µg/m3)$^{-1}$ was derived using a linearized multistage procedure. In the 1998 Toxicological Review of Naphthalene (EPA 1998), EPA concluded that there was inadequate evidence in humans and limited evidence in animals of naphthalene carcinogenicity. In female mice, there was an increased incidence of lung tumors. Furthermore, the mechanisms for these observed effects in mice is not well understood.

3.4 NITROGEN DIOXIDE

3.4.1 Chemical and Physical Properties

Nitrogen dioxide is a highly reactive gas, and one of the gases in a group known as "oxides of nitrogen" or "nitrogen oxides (NO_X)."

3.4.2 Environmental Fate and Transport

The major sources of nitrogen dioxide are in its use as a nitrating agent, a component of rocket fuels, and as an intermediate in the making of nitric acid (OEHHA 2008, Appendix B). Occupational exposures result from formation of nitrogen dioxide as a byproduct of nitrate

decomposition, various processes that involve formation of nitric oxide, or from vehicle engine exhaust. In indoor air, exposures to nitrogen dioxide can occur from unvented gas stoves or other gas appliances and from kerosene heaters. Outdoor exposures are primarily from vehicles, locomotives, aircraft, and stationary combustion sources (such as oil and gas production, refining, manufacturing/industrial, and electric utilities).

3.4.3 Health Effects

Health effects of nitrogen dioxide are primarily related to effects of the respiratory system. Short-term exposures can produce irritation of the airways and can exacerbate respiratory diseases such as asthma or result in increased respiratory symptoms such as coughing, wheezing, or difficulty breathing. The OEHHA (2008) acute REL of 0.25 ppm (470 $\mu g/m^3$) is the California Air Quality Standard for nitrogen dioxide for a 1-hour exposure and is based on airway hyperreactivity in asthmatic subjects (CARB 1992). This level is considered to be the no adverse effects level (NOAEL) and was not adjusted for any uncertainty because the results are for a sensitive population group (i.e., asthmatics).

This Page Intentionally Left Blank

4.0 POLLUTANT CONCENTRATION CALCULATIONS

4.1 MODELING METHODOLOGY

Air dispersion modeling is frequently used to estimate ambient air concentrations for calculating inhalation exposure to airborne toxic compounds. This section provides the methodology used to calculate ambient concentrations and the results of the modeling analysis.

4.2 MODEL SELECTION

Regulatory modeling techniques were reviewed to select the most appropriate air quality dispersion model to simulate dispersion of the air pollutant emissions of concern. The American Meteorological Society/Environmental Protection Agency Regulatory modeling system (AERMOD), the preferred model in the EPA's "Guideline on Air Quality Models" (codified as Appendix W to 40 CFR 51, hereafter referred to as "the Guideline") was selected for the modeling analysis primarily because it is the most up-to-date dispersion model currently available, and is recommended for use in Ecology's Second Tier guidance document.

4.3 MODELING PROCEDURES

AERMOD was applied using regulatory defaults to evaluate benzene, diesel particulate matter, and naphthalene concentrations. In consultation with Ecology, nitrogen dioxide concentrations were evaluated using the Ambient Ratio Method (ARM2) option and a lower, more representative minimum nitrogen dioxide-to-oxides of nitrogen (NO_2/NOx) conversion ratio than the regulatory default. Modeling options and data used in the analysis are discussed in this section.

4.3.1 Setup and Application

The most up-to-date version of AERMOD (Version 19191) available was applied using options for dispersion that depend on local meteorological data, regional upper air data, and the local physical characteristics of land use surrounding the facility. The facility was categorized as rural, as opposed to urban, for modeling purposes and rural dispersion coefficients were used.

4.3.2 Averaging Periods

The TAPs listed in WAC 173-460-150 have assigned averaging periods: 1-hour, 24-hour, or annual. Of the four TAPs expected to exceed the assigned SQERs, benzene, diesel particulate matter, and naphthalene are assigned an annual averaging period, and nitrogen dioxide is assigned a 1-hour averaging period. AERMOD was executed to provide ambient concentrations averaged over those periods. However, based on the different characteristics of potentially exposed receptors and the possibility for acute and chronic effects, AERMOD was also configured to provide concentrations averaged over periods that can be used to estimate acute effects (i.e., 1-hour and 8-hour) and chronic effects (i.e., annual) results for all four TAPs.

4.3.3 Terrain Elevation Data and Receptor Network

Receptor terrain elevation data were obtained using 1/3 arc-second elevation data from the National Elevation Dataset (NED), which is a product of the United States Geological Survey (USGS). The NED is a seamless elevation dataset covering the continental United States, Alaska, and Hawaii. The elevation dataset for the modeling demonstration was downloaded from the USGS National Map Viewer. These data have a horizontal spatial resolution of approximately 10 m.

Model receptor grids were developed in consultation with Ecology. Receptors were located at 200-m intervals along the ambient air boundary of the facility. Beyond the ambient air boundary, receptors were modeled with 200-m spacing in an area 37 km wide by 50.2 km tall, centered on the facility. Additional receptors were located every 25-m within 1 km of emission units located outside the Hanford Site's ambient air boundary. The flagpole receptor option was used to set the height of each receptor at 1.5 m above ground level. The final receptor locations are shown in Figure 4-1. The base elevation and hill height scale for each receptor were determined using the EPA’s terrain processor AERMAP (Version 18081), which generates the receptor output files that are read by AERMOD. All receptor locations are in Universal Transverse Mercator, Zone 11 coordinates using the spatial reference of NAD 83.

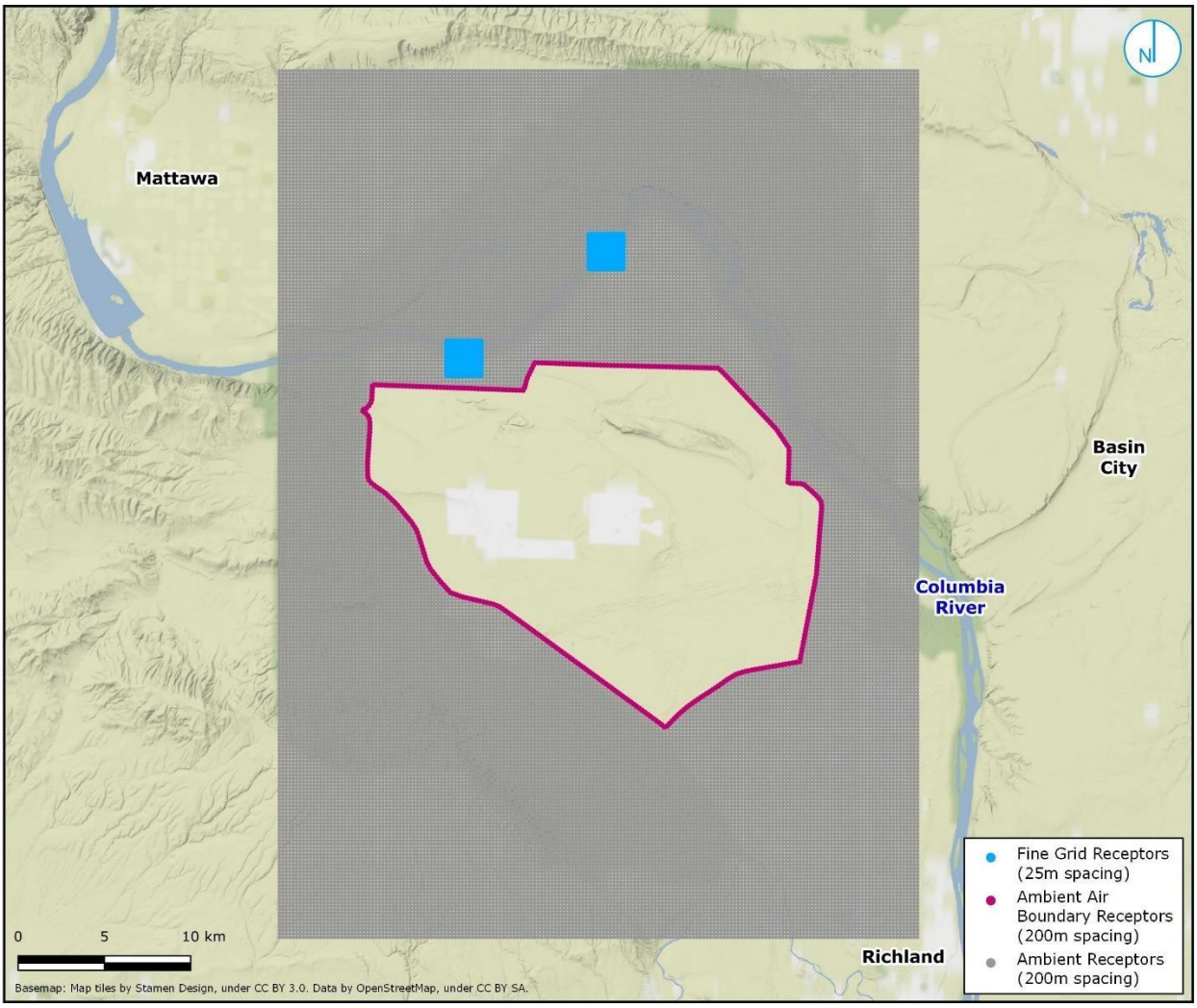


Figure 4-1. Receptor Locations

4.3.4 Meteorological Data

Pollutant dispersion was evaluated with surface and upper air data for the years 2015 through 2019. Surface meteorological data from the Hanford meteorological station and upper air data collected at the Spokane, Washington, National Weather Service station were processed with the latest version of AERMET (Version 19191). A windrose summarizing the wind speed and wind direction data is provided in Figure 4-2. This meteorological dataset, as processed, was approved by Ecology for air dispersion modeling in support of air permit applications prepared for projects at the Hanford Site.

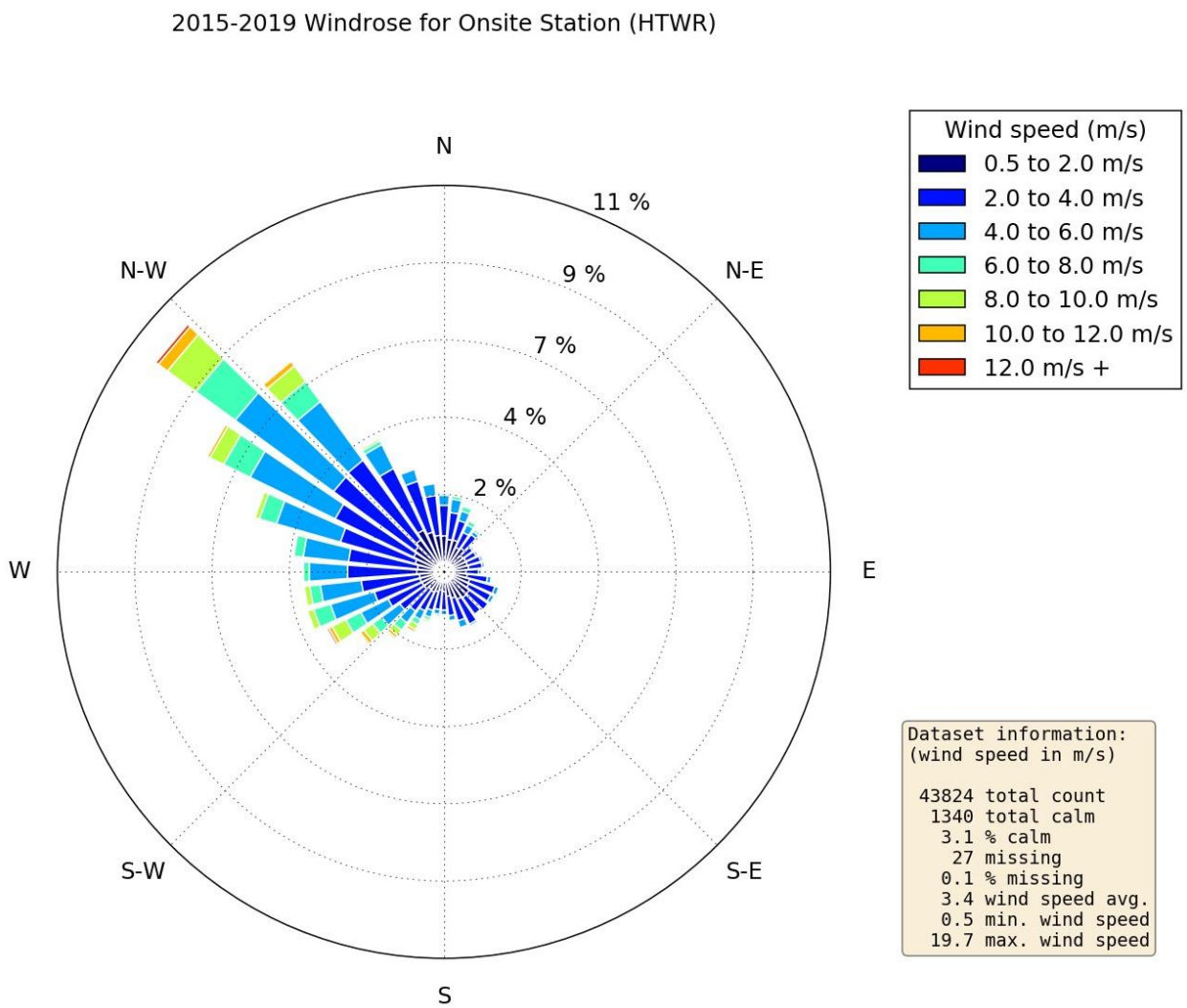


Figure 4-2. Hanford Meteorological Station Windrose for 2015 through 2019

4.3.5 Emission Unit Characterization

Figure 2-1 shows the locations of emission units at the facility, as well as significant structures that could potentially influence emissions. It should be noted that the modified facility will include both new buildings and existing buildings that remain. Table 4-1 provides a summary of the parameters used to represent exhaust from the diesel engines. All emission units were represented in the model as vertical point sources.

Table 4-1. Release Parameters. (2 Pages)

ID	Description	X Coord (m)	Y Coord (m)	Stack Height (m)	Stack Temp (K)	Stack Velocity (m/s)	Stack Diameter (m)
L895	Standby Generator	299205.85	5158927.99	3.45	703.45	64.73	0.31
L897	Standby Generator	299337.22	5158917.27	2.68	726.05	69.32	0.23

Table 4-1. Release Parameters. (2 Pages)

ID	Description	X Coord (m)	Y Coord (m)	Stack Height (m)	Stack Temp (K)	Stack Velocity (m/s)	Stack Diameter (m)
L781FD	Feed Pump Building Standby Generator	299315.07	5159066.07	3.50	744.15	74.01	0.15
L781PH	181-D Pump house	305201.20	5174387.30	4.70	773.15	44.08	0.53
L826PH	181-B Pump House	296952.60	5168209.60	4.70	773.15	44.08	0.53
L849	282EC Standby Generator	305415.05	5158152.63	5.50	773.15	59.74	0.36

Emission units modeled within the Hanford Site ambient air boundary are located at such a large distance from receptors that the effects of building downwash do not meaningfully impact dispersion. Therefore, downwash effects from buildings within the ambient air boundary were not evaluated. However, two of the emission units (L781PH and L826PH) are located outside the ambient air boundary. Building dimensions from structures near units L781PH and L826PH were processed using EPA's Building Profile Input Program (BPIP) including the PRIME algorithm (BPIP PRIME Version 04274). The facility layout and heights of structures, as shown in Figure 2-1 and Table 4-2, were used to prepare data for BPIP PRIME, which calculates the necessary input data for AERMOD.

Table 4-2. Significant Onsite Structure Heights.

ID	Description	X Coord (m)	Y Coord (m)	Elevation (m)	Height (m)
182D	182D (Project L-781)	305438.0	5174328.2	142.8	10
1804D	1804D (Project L-781)	305331.7	5174406.5	143.0	5
181D	181D (Project L-781)	305162.4	5174350.5	128.3	5
181D102	181D102 (Project L-781)	305246.3	5174342.0	142.7	5
181B	181B (Project L-826)	296895.8	5168224.9	130.8	10

For the TAPs modeling, positive maximum potential emission rates attributable to the proposed diesel engines were provided to AERMOD along with building profile information unique to each diesel engine. Using those inputs, AERMOD calculates the net concentrations for comparison to the ASILs.

4.4 MODELING RESULTS

To evaluate ambient concentrations (i.e., impacts on air quality) attributable to the Project for each TAP with the potential to exceed its assigned SQER, the emission rates and source release parameters described in the previous sections were applied using the modeling methodology

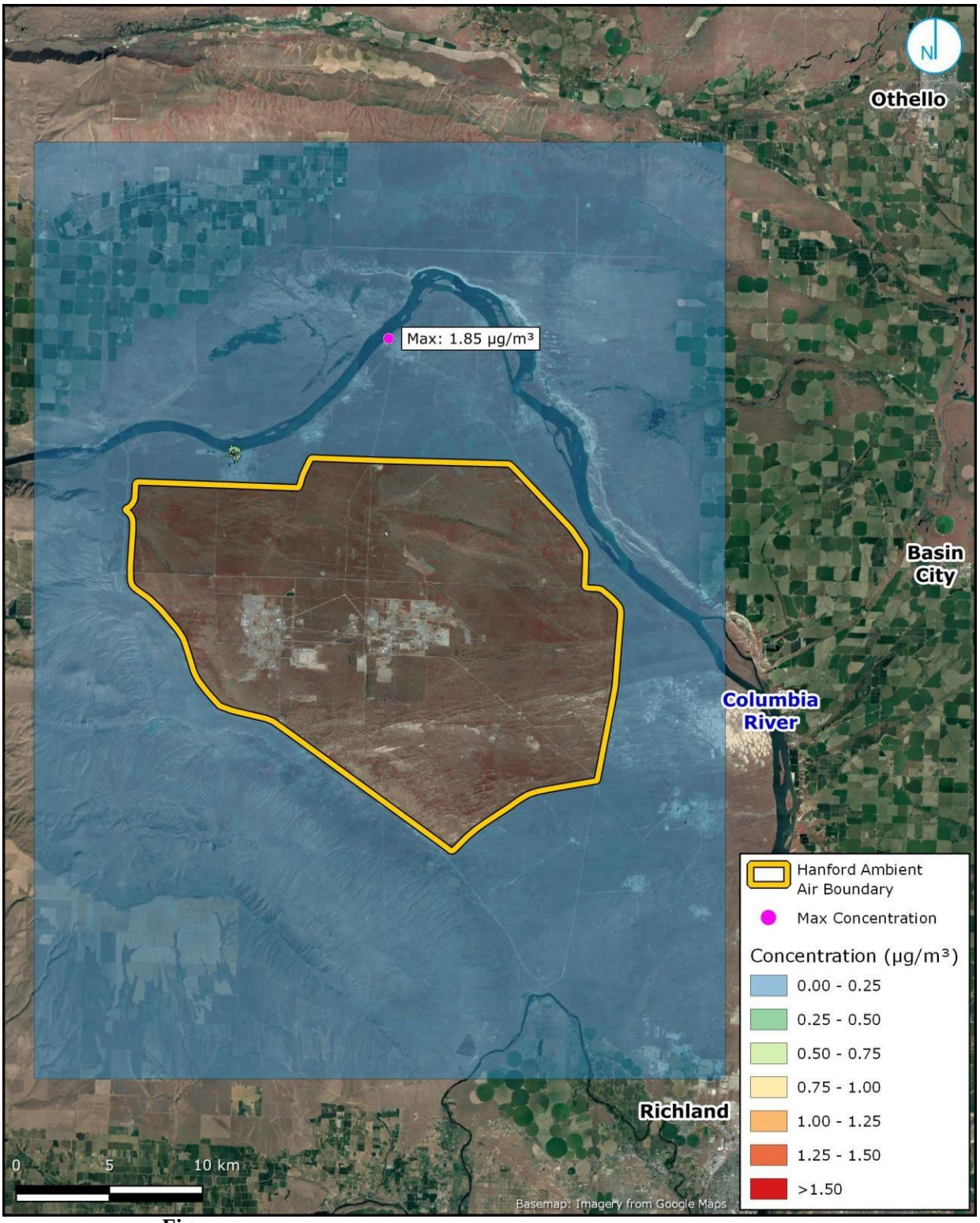
outlined above. The maximum predicted concentrations for all TAPs with the potential to exceed the assigned SQERs are presented in Table 4-3.

Table 4-3. Maximum Predicted Project Toxic Air Pollutant Concentrations.

Toxic Air Pollutant	Averaging Period	Highest 1st High Concentration[a] (µg/m³)	ASIL (µg/m³)	ASIL Exceeded?
Benzene	1-hr	1.85	--	--
	8-hr	0.885	--	--
	Annual	0.00591	0.13	No
Diesel Particulate Matter	1-hr	91.8	--	--
	8-hr	43.8	--	--
	Annual	0.292	0.0033	Yes
Naphthalene	1-hr	0.311	--	--
	8-hr	0.148	--	--
	Annual	0.00099	0.029	No
Nitrogen Dioxide	1-hr	670	470	Yes
	8-hr	320	--	--
	Annual	8.69	--	--

[a] Highest first high concentration represents the maximum concentration modeled over the 2015 to 2019 5-year meteorological data set.

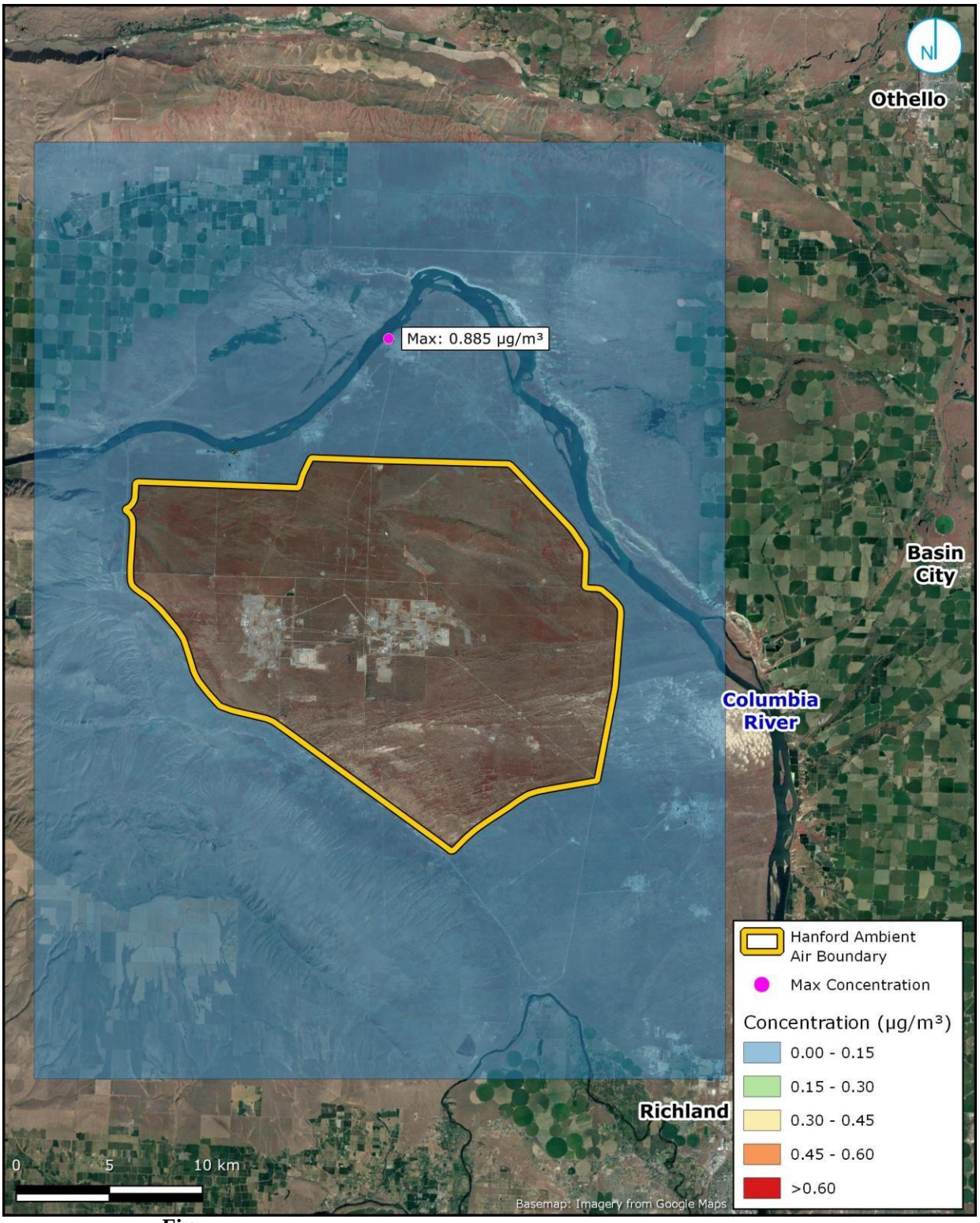
The maximum concentration receptor for all TAPs and averaging periods of interest occurred in the fine receptor grid near L781PH. Contour plots showing the spatial variation of the 1-hour average, 8-hour average, and annual average benzene, diesel particulate matter, naphthalene, and nitrogen dioxide concentrations throughout the modeling domain are provided in Figures 4-3 through 4-14.


N
Othello
Max: 1.85 µg/m³
Basin City
Columbia River
Richland
0
5
10 km
Basemap: Imagery from Google Maps
Hanford Ambient Air Boundary
Max Concentration
Concentration (µg/m³)
0.00 - 0.25
0.25 - 0.50
0.50 - 0.75
0.75 - 1.00
1.00 - 1.25
1.25 - 1.50
>1.50

Figure

4-3. Spatial Variation of 1-Hour Average Benzene Concentrations

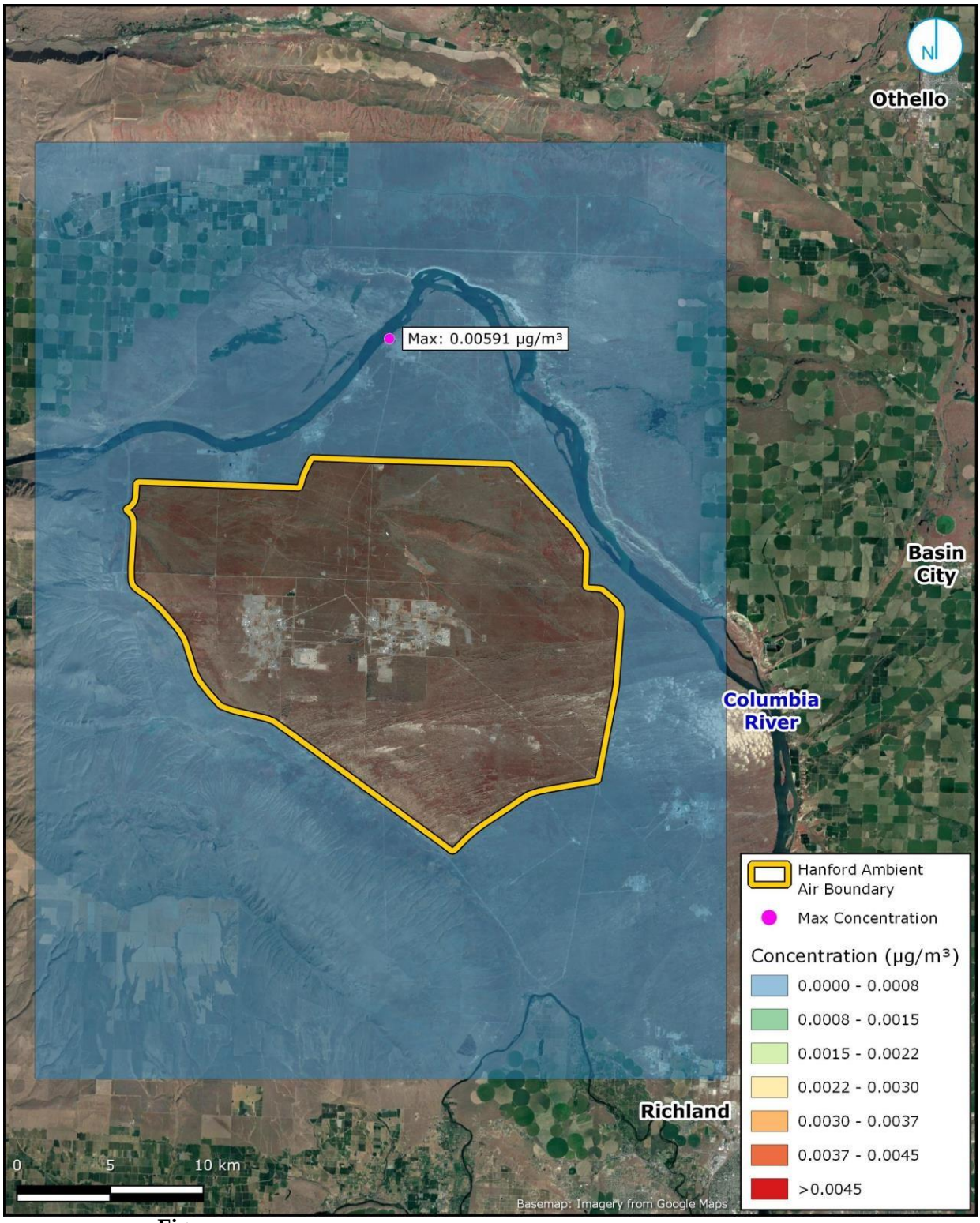
Figure


N
Othello
Max: 0.885 µg/m³
Basin City
Columbia River
Richland
Hanford Ambient Air Boundary
Max Concentration
Concentration (µg/m³)
0.00 - 0.15
0.15 - 0.30
0.30 - 0.45
0.45 - 0.60
>0.60
0
5
10 km
Basemap: Imagery from Google Maps

Figure

4-4. Spatial Variation of 8-Hour Average Benzene Concentrations

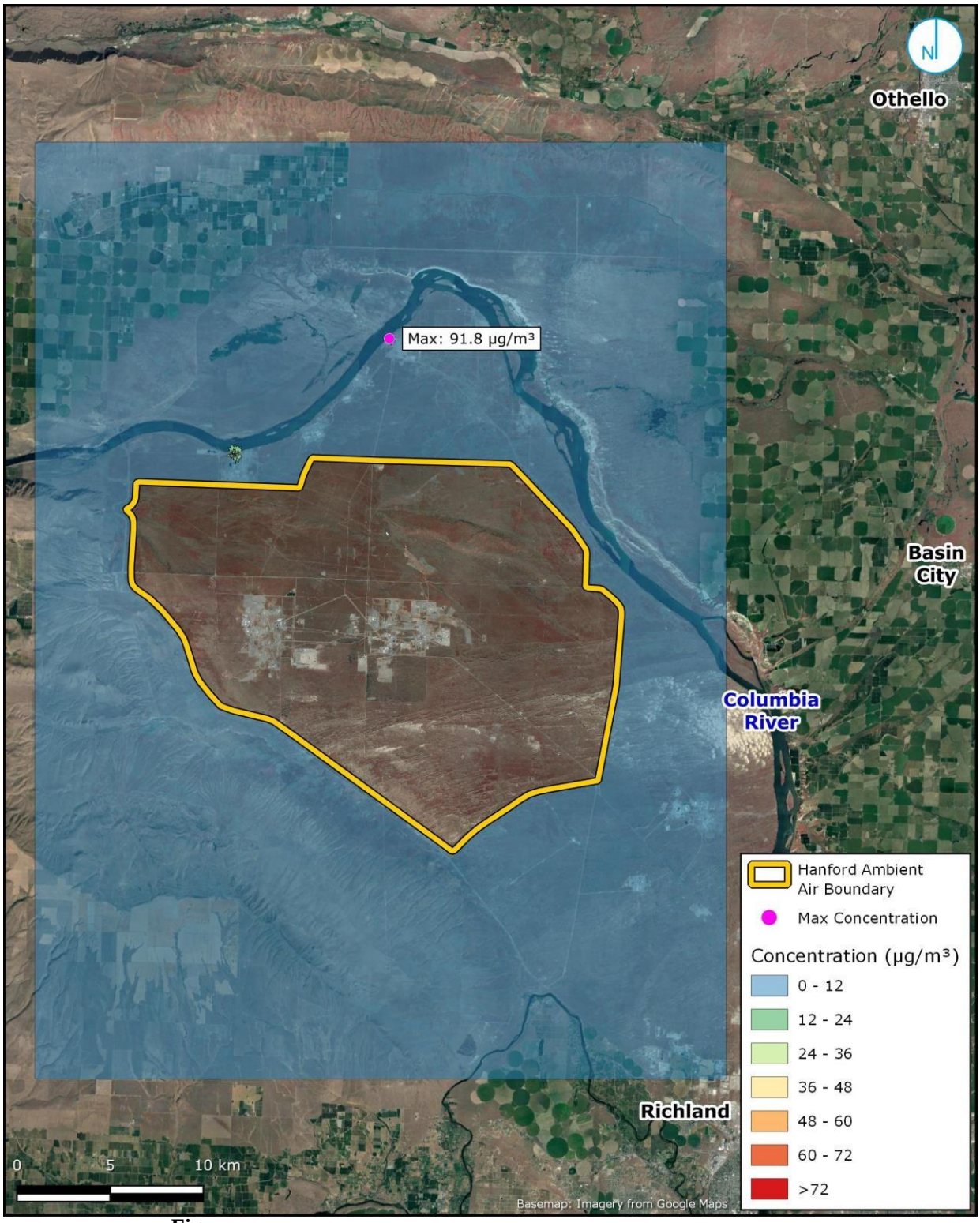
Figure


N
Othello
Max: 0.00591 µg/m³
Basin City
Columbia River
Richland
0
5
10 km
Basemap: Imagery from Google Maps
Hanford Ambient Air Boundary
Max Concentration
Concentration (µg/m³)
0.0000 - 0.0008
0.0008 - 0.0015
0.0015 - 0.0022
0.0022 - 0.0030
0.0030 - 0.0037
0.0037 - 0.0045
>0.0045

Figure

4-5. Spatial Variation of Annual Average Benzene Concentrations

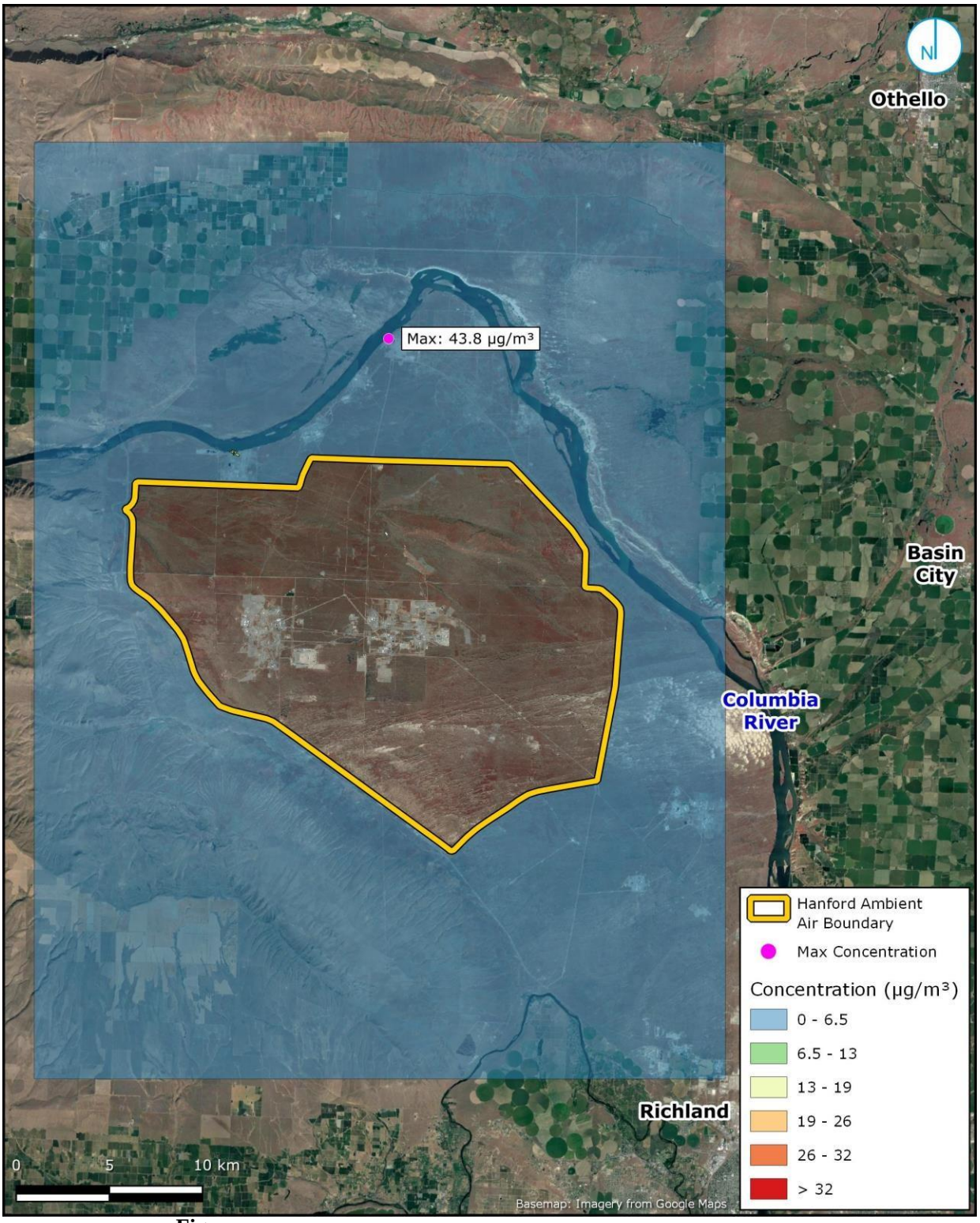
Figure


N
Othello
Max: 91.8 µg/m³
Basin City
Columbia River
Richland
0
5
10 km
Basemap: Imagery from Google Maps
Hanford Ambient Air Boundary
Max Concentration
Concentration (µg/m³)
0 - 12
12 - 24
24 - 36
36 - 48
48 - 60
60 - 72
>72

Figure

4-6. Spatial Variation of 1-Hour Average DPM Concentrations

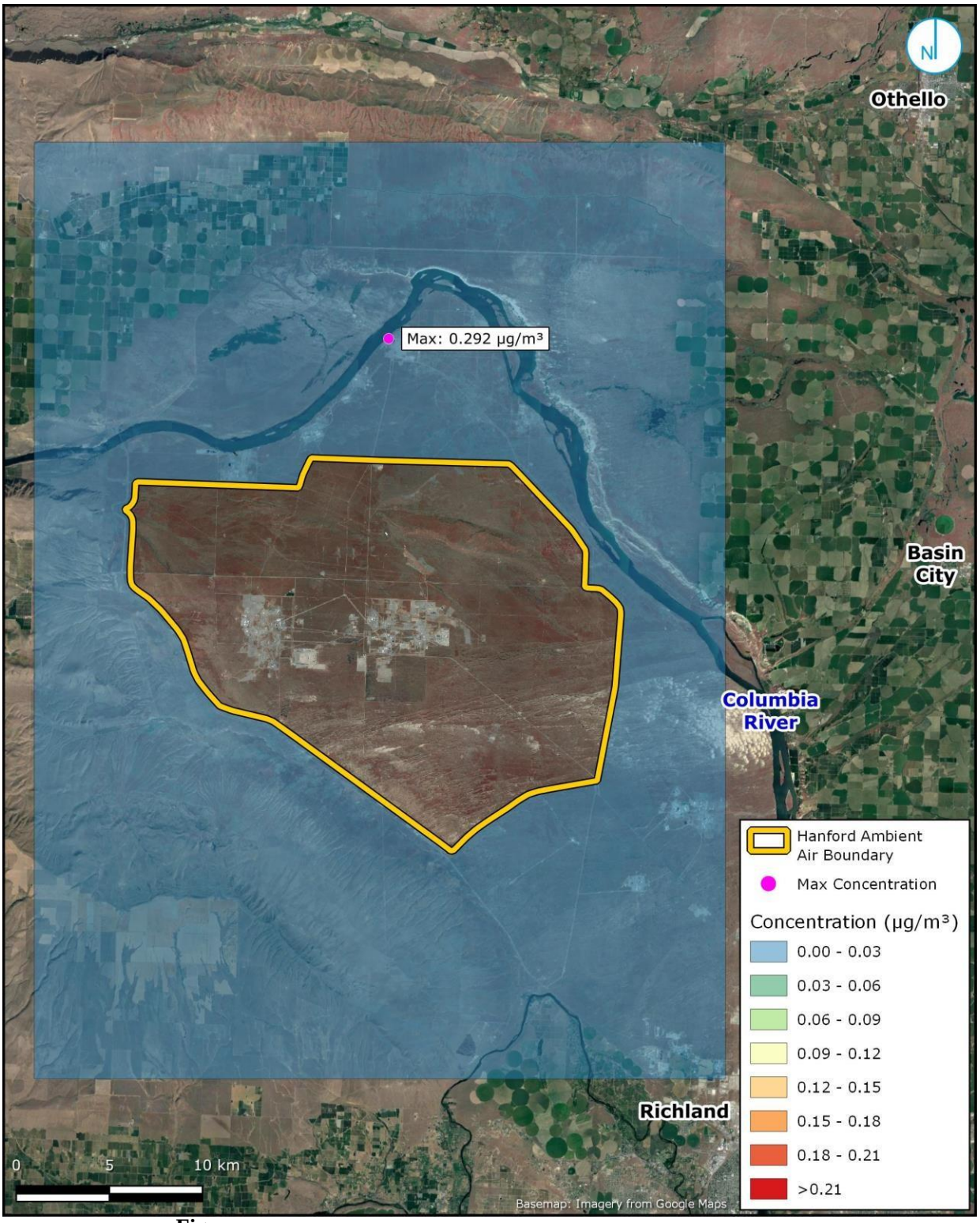
Figure


N
Othello
Max: 43.8 µg/m³
Basin City
Columbia River
Richland
0
5
10 km
Basemap: Imagery from Google Maps
Hanford Ambient Air Boundary
Max Concentration
Concentration (µg/m³)
0 - 6.5
6.5 - 13
13 - 19
19 - 26
26 - 32
> 32

Figure

4-7. Spatial Variation of 8-Hour Average DPM Concentrations

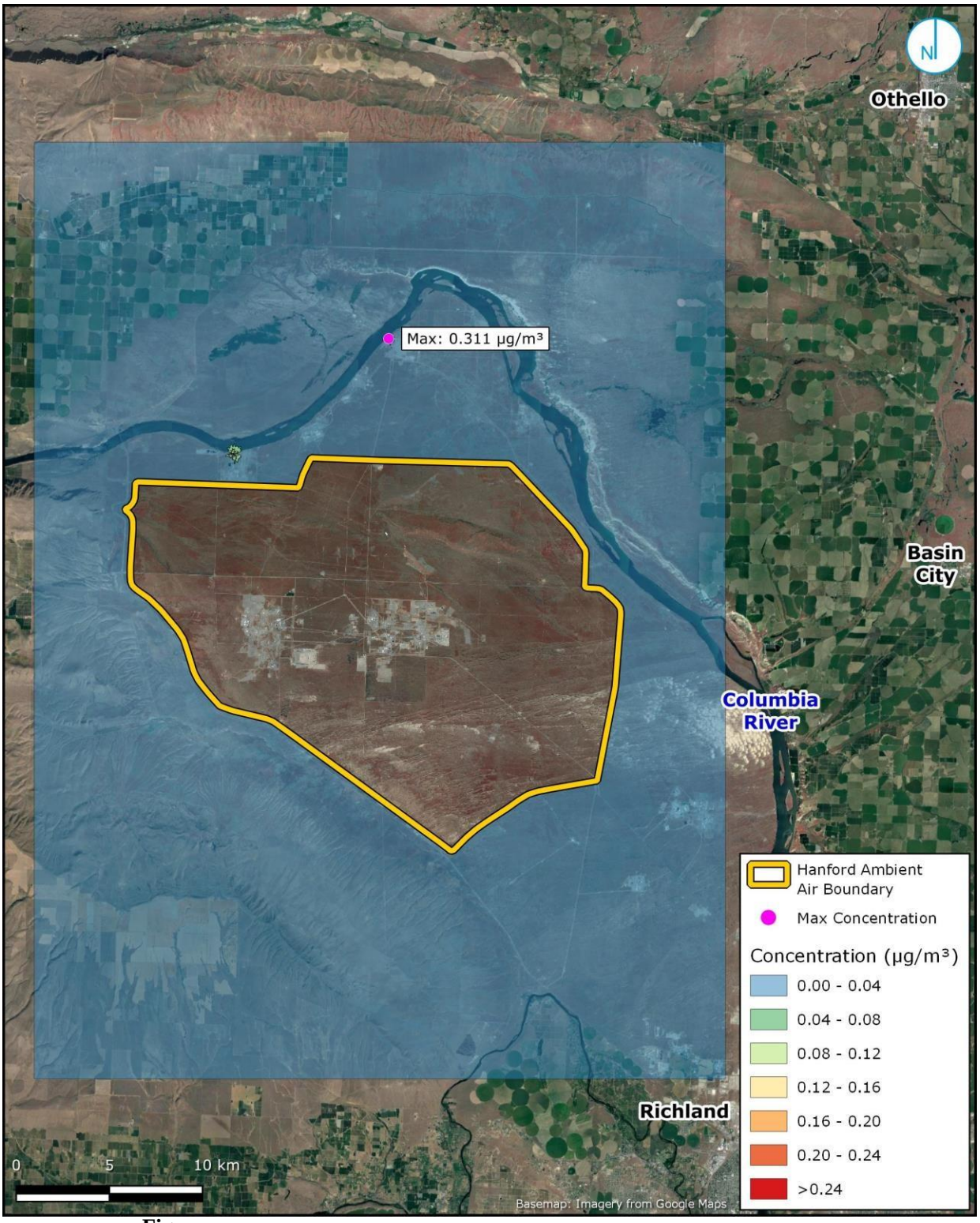
Figure


N
Othello
Max: 0.292 µg/m³
Basin City
Columbia River
Richland
Hanford Ambient Air Boundary
Max Concentration
Concentration (µg/m³)
0.00 - 0.03
0.03 - 0.06
0.06 - 0.09
0.09 - 0.12
0.12 - 0.15
0.15 - 0.18
0.18 - 0.21
>0.21
0
5
10 km
Basemap: Imagery from Google Maps

Figure

4-8. Spatial Variation of Annual Average DPM Concentrations

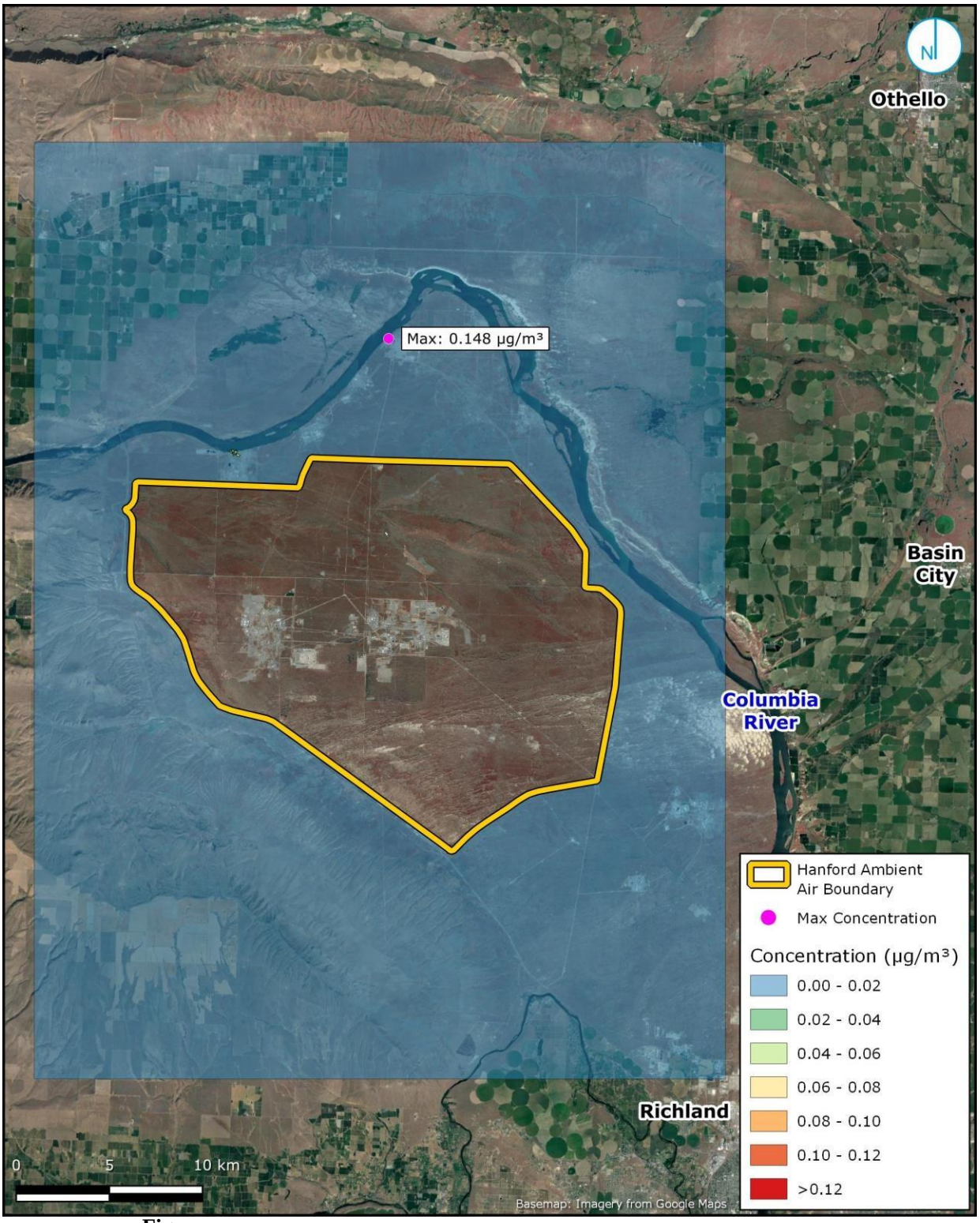
Figure


N
Othello
Max: 0.311 µg/m³
Basin City
Columbia River
Richland
0
5
10 km
Basemap: Imagery from Google Maps
Hanford Ambient Air Boundary
Max Concentration
Concentration (µg/m³)
0.00 - 0.04
0.04 - 0.08
0.08 - 0.12
0.12 - 0.16
0.16 - 0.20
0.20 - 0.24
>0.24

Figure

4-9. Spatial Variation of 1-Hour Average Naphthalene Concentrations

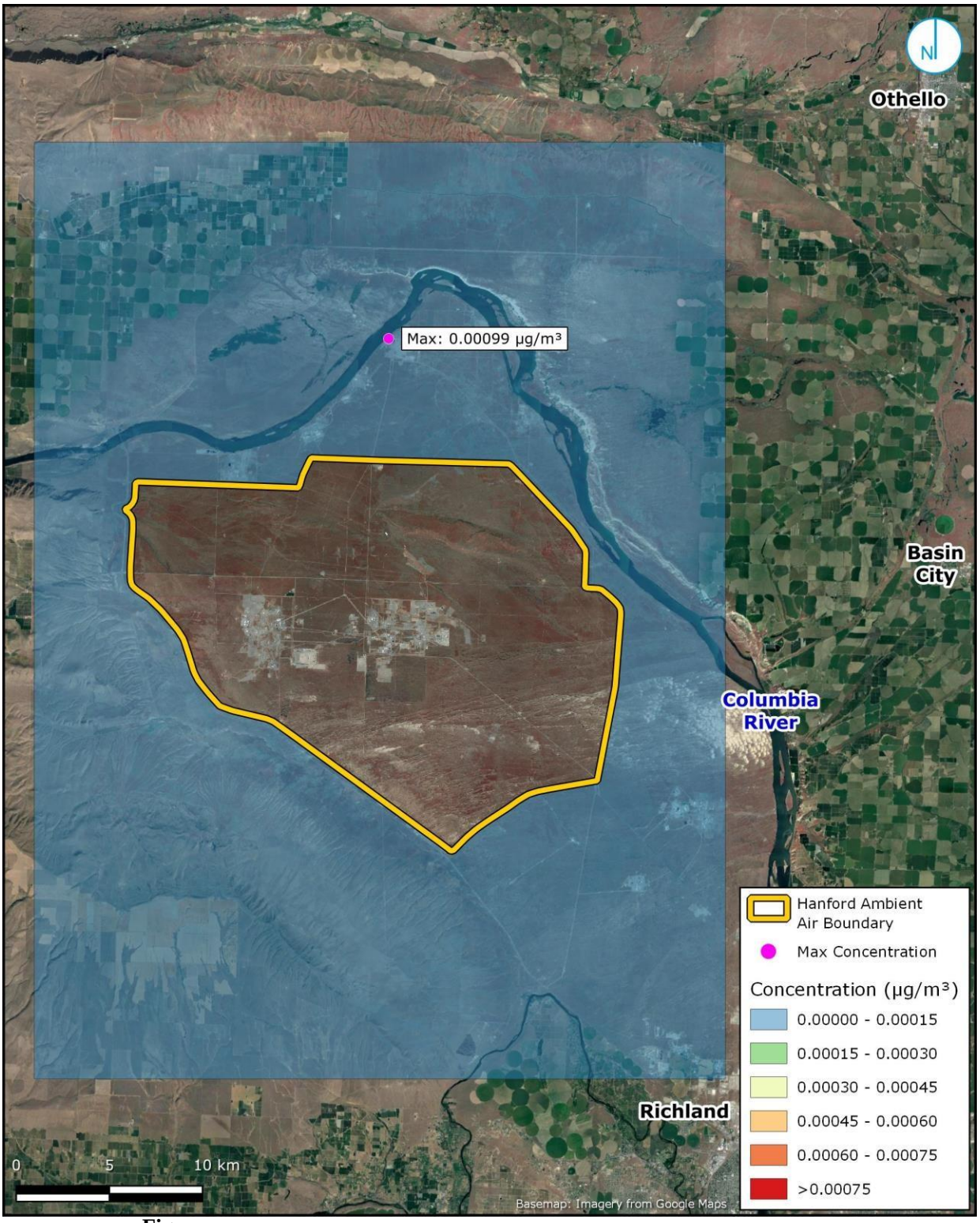
Figure


N
Othello
Max: 0.148 µg/m³
Basin City
Columbia River
Richland
0
5
10 km
Basemap: Imagery from Google Maps
Hanford Ambient Air Boundary
Max Concentration
Concentration (µg/m³)
0.00 - 0.02
0.02 - 0.04
0.04 - 0.06
0.06 - 0.08
0.08 - 0.10
0.10 - 0.12
>0.12

Figure

4-10. Spatial Variation of 8-Hour Average Naphthalene Concentrations

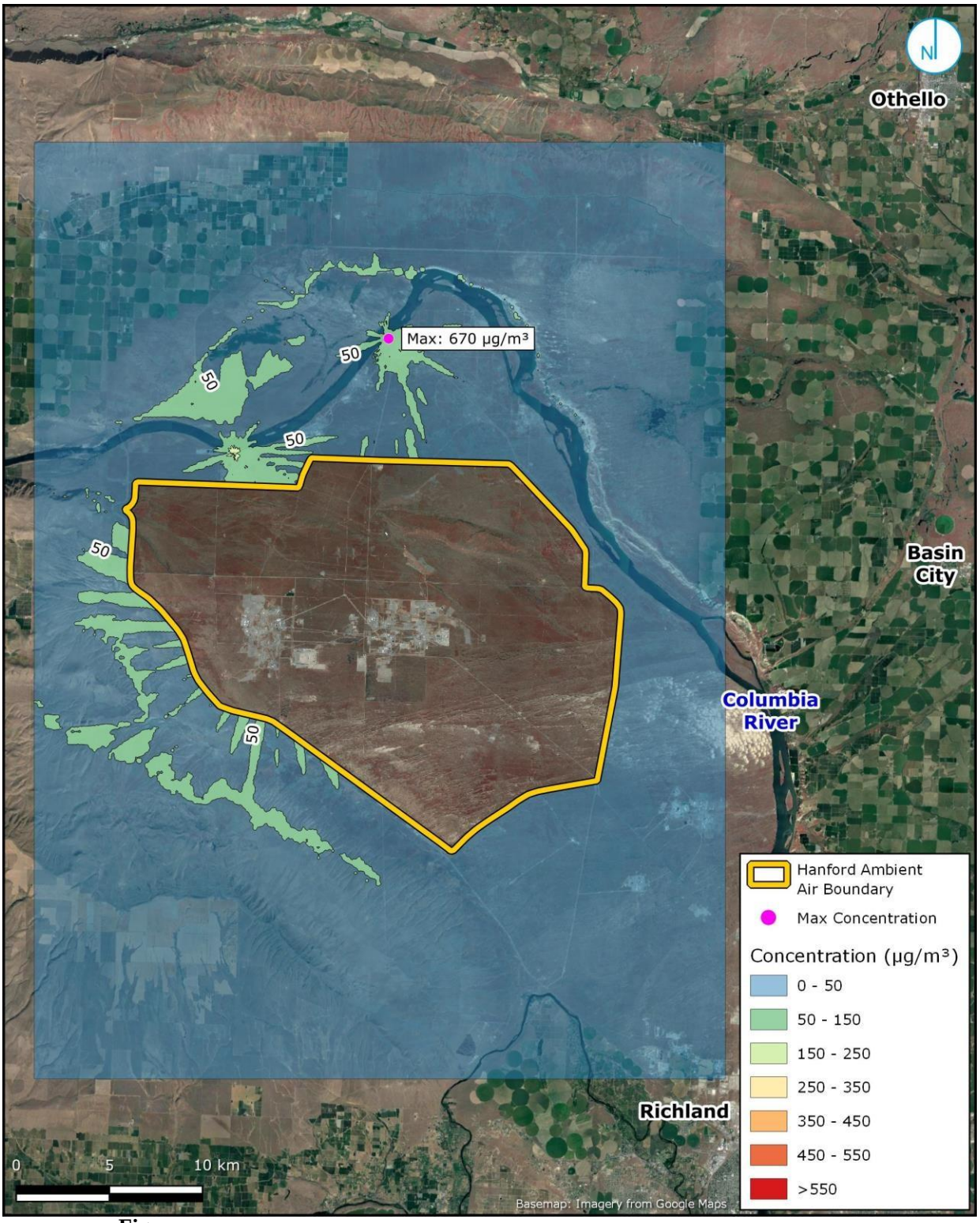
Figure


N
Othello
Max: 0.00099 µg/m³
Basin City
Columbia River
Richland
Hanford Ambient Air Boundary
Max Concentration
Concentration (µg/m³)
0.00000 - 0.00015
0.00015 - 0.00030
0.00030 - 0.00045
0.00045 - 0.00060
0.00060 - 0.00075
>0.00075
0
5
10 km
Basemap: Imagery from Google Maps

Figure

4-11. Spatial Variation of Annual Average Naphthalene Concentrations

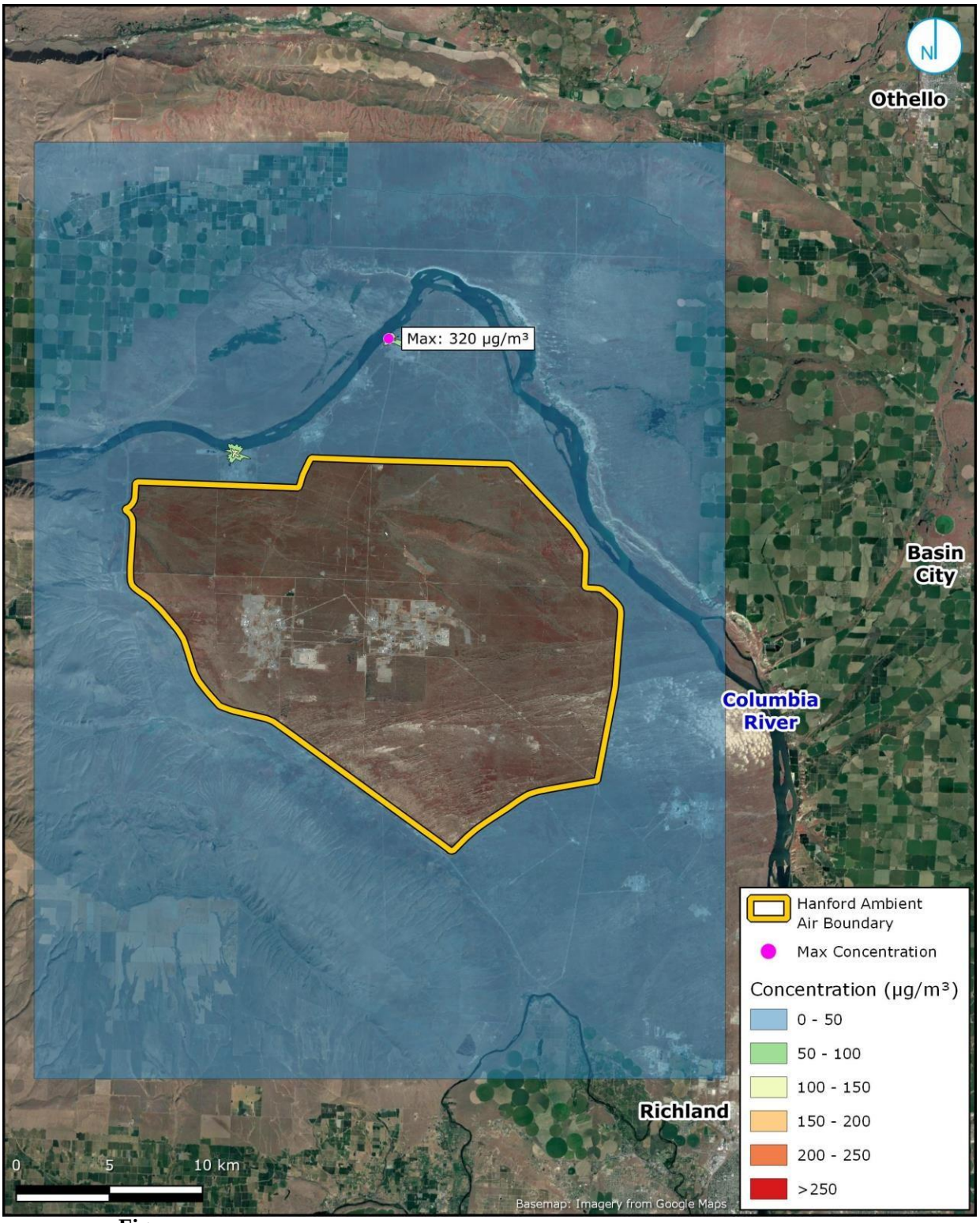
Figure


N
Othello
Max: 670 µg/m³
50
50
50
50
50
Basin City
Columbia River
Richland
Hanford Ambient Air Boundary
Max Concentration
Concentration (µg/m³)
0 - 50
50 - 150
150 - 250
250 - 350
350 - 450
450 - 550
>550
0
5
10 km
Basemap: Imagery from Google Maps

Figure

4-12. Spatial Variation of 1-Hour Average Nitrogen Dioxide Concentrations

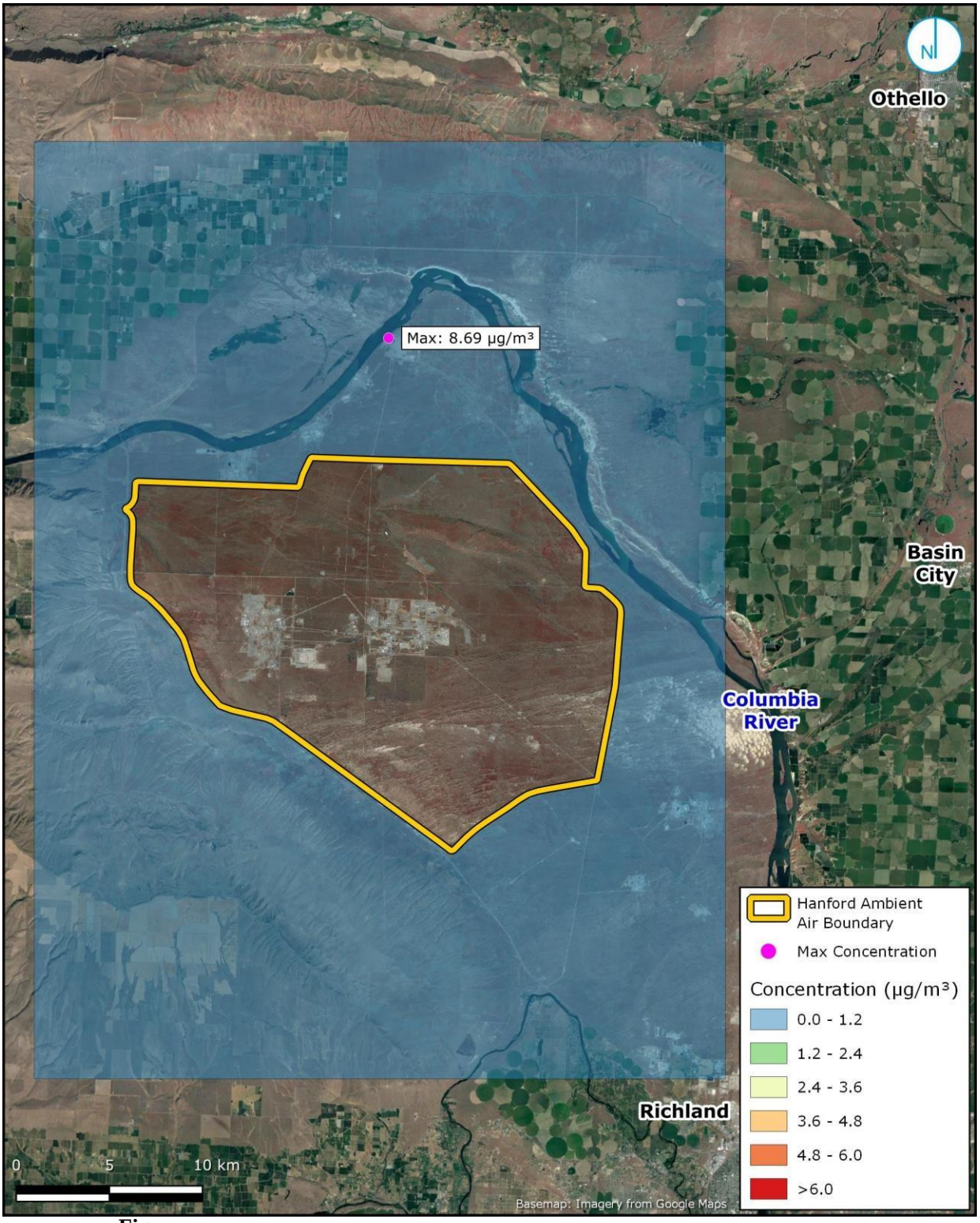
Figure


N
Othello
Max: 320 µg/m³
Basin City
Columbia River
Richland
Hanford Ambient Air Boundary
Max Concentration
Concentration (µg/m³)
0 - 50
50 - 100
100 - 150
150 - 200
200 - 250
>250
0
5
10 km
Basemap: Imagery from Google Maps

Figure

4-13. Spatial Variation of 8-Hour Average Nitrogen Dioxide Concentrations

Figure


N
Othello
Max: 8.69 µg/m³
Basin City
Columbia River
Richland
Hanford Ambient Air Boundary
Max Concentration
Concentration (µg/m³)
0.0 - 1.2
1.2 - 2.4
2.4 - 3.6
3.6 - 4.8
4.8 - 6.0
>6.0
0
5
10 km
Basemap: Imagery from Google Maps

Figure

4-14. Spatial Variation of Annual Average Nitrogen Dioxide Concentrations

Figure

4.5 BACKGROUND CONCENTRATION

The EPA has developed, and periodically updates, the National-Scale Air Toxics Assessment (NATA) to identify and prioritize air toxics, sources, and locations of concern. The most recently issued NATA was for 2014 (https://www.epa.gov/national-air-toxics-assessment/2014-nationalair-toxics-assessment). The total modeled benzene, diesel particulate matter, and naphthalene concentrations in the census tract and and two nearby census tracts are presented in Table 4-4. Because nitrogen dioxide is not included in the NATA, data at the node closest to the maximally impacted receptors from the current Northwest Airquest (https://arcg.is/1jXmHH) was used as nitrogen dioxide background concentrations.

Table 4-4. NATA 2014 and NW Airquest Predicted Toxic Air Pollutant Concentrations.

Toxic Air Pollutant	Census Tract/Receptor	Background Concentration[a] (µg/m³)	
		Hourly Average	Annual Average
Benzene	53005012000	--	0.193
	53025011402	--	0.188
	53021020800	--	0.190
Diesel Particulate Matter	53005012000	--	0.104
	53025011402	--	0.0799
	53021020800	--	0.0967
Naphthalene	53005012000	--	0.0243
	53025011402	--	0.0331
	53021020800	--	0.0265
Nitrogen Dioxide	Preliminary MIR	22.0	4.51
	Preliminary MIRR	14.3	3.01
	Preliminary MICR	19.9	4.32
	Preliminary MIAR	22.0	4.20

[a] Benzene, diesel particulate matter, and naphthalene background concentrations were taken from NATA (2014); nitrogen dioxide background concentrations were taken from NW Airquest (https://arcg.is/1jXmHH), accessed October 2020.

MIAR = maximally-impacted angler receptor
MICR = maximally-impacted commercial receptor
MIR = maximally-impacted receptor MIRR = maximally-impacted residential receptor

Ramboll is unaware of any ambient monitoring studies involving benzene, diesel particulate matter, naphthalene, or nitrogen dioxide. In the absence of site-specific monitoring data, Ecology typically concurs that the use of NATA and NW Airquest estimates to quantify background concentrations are appropriate for analyses.

This Page Intentionally Left Blank

5.0 IDENTIFICATION OF POTENTIALLY EXPOSED POPULATIONS

The HIA evaluates potential airborne exposure to modeled benzene, diesel particulate matter, naphthalene, and nitrogen dioxide concentrations attributable to the projects. Potentially exposed populations within the simulation domain are identified in this section. Various population groups include residents and workers as well as sensitive subpopulations.

5.1 RECEPTORS OF CONCERN

The primary populations that may be exposed to facility emissions include residents and workers. The maximally-impacted residential receptor (MIRR) and maximally-impacted commercial receptor (MICR) were identified for each type of exposure (i.e., acute noncarcinogenic, chronic non-carcinogenic, and carcinogenic) and hazards were quantified at these receptor locations. The locations of these receptor categories were identified using land use data: receptors in residential areas were designated MIRR and receptors in commercial and industrial areas were designated MICR. A visual representation of the land use data employed to make these designations is provided in Appendix B.

Typically, the HIA also identifies the maximally-impacted boundary receptor (MIBR) location for those receptors that experience the highest concentration of TAPs of interest along an ambient air perimeter that serves as the boundary for publicly-accessible land, but, in this case, because two of the proposed generator sets will be located outside of the ambient air boundary (see Figure 2-1), the maximally-impacted receptor (MIR) was used to quantify periodic exposures of short duration. Potential receptors that may be periodically present at the MIR include DOE employees or contractors.

A special type of receptor, the maximally-impacted angler receptor (MIAR), was developed for the analysis to account for anglers on the Columbia River that are participating in the Pikeminnow Sport Reward Fishery Program funded by the Bonneville Power Administration and administered by the Pacific States Marine Fisheries Commission, which pays anglers for each Northern Pikeminnow that they catch. Receptors located in the Columbia River were designated as MIAR.

5.2 SENSITIVE POPULATIONS

For the purpose of this HIA, sensitive populations are identified as children, the infirm, and elderly persons. These subpopulations may be more sensitive to the effects of TAPs on their immune systems. The nearest identified sensitive receptors are listed in Table 5-1, and the locations relative to the Project are presented in Figure 5-1. Concentrations of all TAPs were predicted by the modeling to be less than all applicable ASILs, so adverse impacts are not expected at any sensitive receptors as a result of the Projects being implemented.

Table 5-1. Sensitive Receptors.

Sensitive Receptor Type	Receptor Name	Receptor Address	Distance[a] (mi / km)
Daycare/Preschool	Maria's Childcare Center	517 1st St Mattawa, WA 99349	14 / 22
Convalescent Home	Coventry House Assisted Living	430 N 2nd Ave Othello, WA 99344	20 / 32
Hospital	Othello Community Hospital	315 N 14th Ave Othello, WA 99344	20 / 33
School	Sentinel Tech Alternative School	505 N Boundary Rd Mattawa, WA 99349	14 / 22

[a] Distance from the sensitive receptor to the nearest Project emission unit.

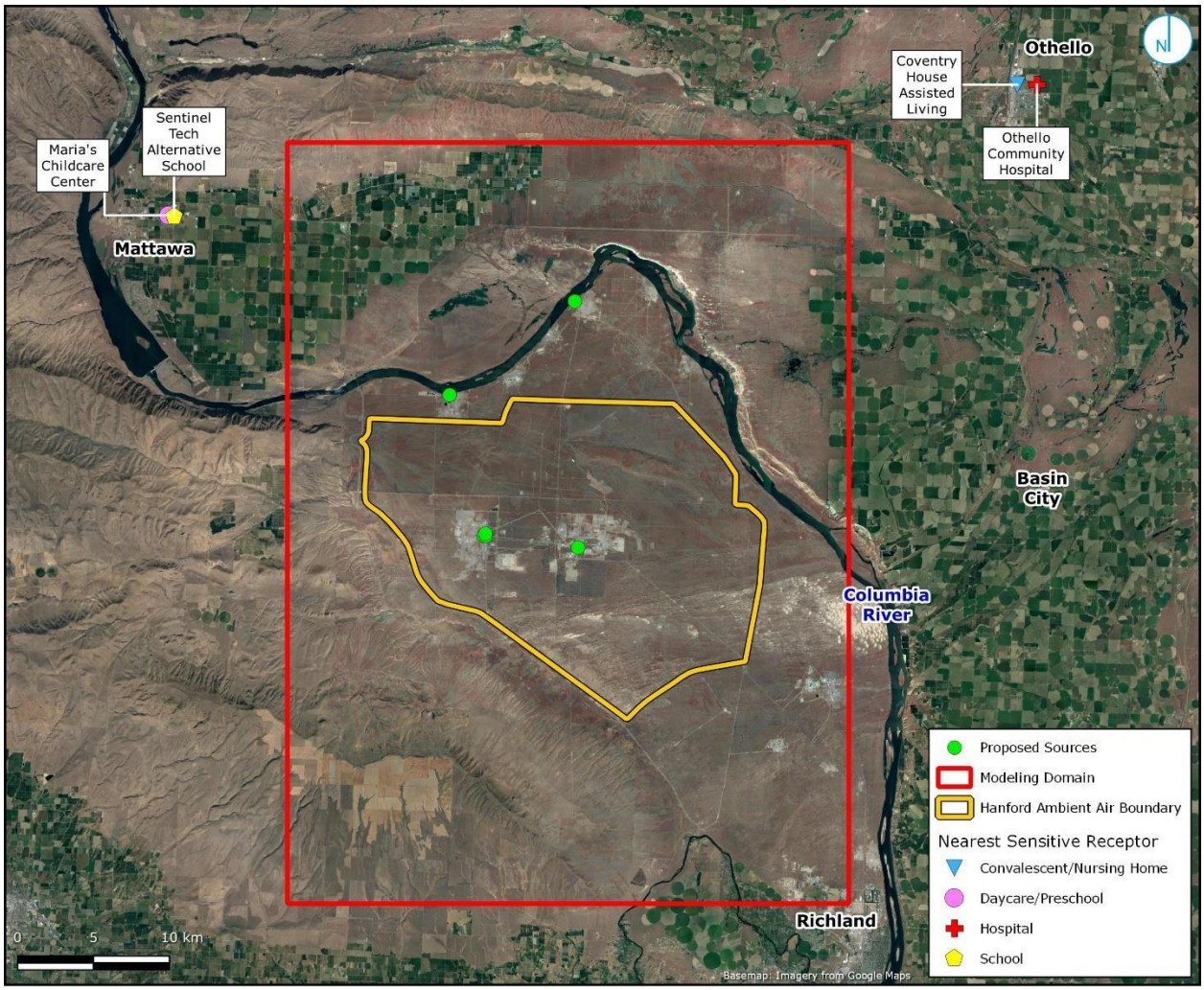


Figure 5-1. Sensitive Receptor Locations

It is possible that individuals with heightened sensitivity to NO_2 (i.e., asthmatics) could experience acute exposure while located near one of the proposed engines. However, based on the engines' expected infrequent operation and remote location, it is unlikely that sensitive individuals will be located sufficiently close to the engines during operation to receive a significant acute exposure. DPM has chronic rather than acute health effects and sub-populations with heightened sensitivity to these chronic effects have not been identified.

This Page Intentionally Left Blank

6.0 EXPOSURE ASSESSMENT

This section describes the routes and manner by which population groups identified in the previous section may be exposed to new sources of benzene, diesel particulate matter, naphthalene, and nitrogen dioxide emitted by the Project. Concentrations to which receptor populations may be exposed and key exposure assumptions also are described.

6.1 IDENTIFICATION OF EXPOSURE PATHWAYS

Receptors presented in the previous section (residents, workers, and sensitive subpopulations) may be exposed to chemicals in the environment. Specifically, contact with emissions from the facility may occur primarily through direct inhalation. Contact with emissions attributable to the facility may also occur indirectly, through incidental ingestion of and skin contact with emissions deposited on area surface soils. However, for the TAPs of interest, indirect exposures through ingestion and skin contact pathways are not considered significant in comparison with the direct inhalation pathway.

Ecology's Second Tier guidance document (Ecology 2011) references California Air Toxic Hot Spots Program guidance to assess the need for consideration of indirect exposure pathways in addition to consideration of inhalation exposure. Benzene, diesel particulate matter, naphthalene, and nitrogen dioxide are not chemicals for which the California Air Toxic Hot Spots Program recommends consideration of multiple exposure pathways. Typically, chemicals considered for alternate ingestion pathways (e.g., soil, produce, breast milk, livestock/game) are those that are persistent and bioaccumulative. Benzene, diesel particulate matter, naphthalene, and nitrogen dioxide do not bio-accumulate and are, therefore, not prioritized for multi-pathway evaluation. Based on Ecology and California Air Toxic Hot Spots Program guidance, inhalation was the only exposure pathway assessed in the HIA.

6.2 EXPOSURE CONCENTRATIONS

Airborne exposure concentrations (ECs) of benzene, diesel particulate matter, naphthalene, and nitrogen dioxide were estimated for each type of maximally impacted receptor (e.g., MIRR, MICR, MIR, and MIAR). The MIR, MIRR, MICR, and MIAR concentrations are presented in Tables 6-1, 6-2, 6-3, and 6-4, respectively. The locations of the maximally impacted receptors are shown in Figure 6-1.

Table 6-1. MIR Concentrations and Receptors.

Chemical	Averaging Period	Concentration (µg/m³)	Coordinates (UTM Zone 11N)
Benzene	1-hr	1.85	305238.0 5174362.8
	8-hr	0.885	305238.0 5174362.8
	Annual	0.00591	305238.0 5174362.8
Diesel Particulate Matter	1-hr	91.8	305238.0 5174362.8
	8-hr	43.8	305238.0 5174362.8
	Annual	0.292	305238.0 5174362.8
Naphthalene	1-hr	0.311	305238.0 5174362.8
	8-hr	0.148	305238.0 5174362.8
	Annual	0.000990	305238.0 5174362.8
Diesel Particulate Matter	1-hr	91.8	305238.0 5174362.8
	8-hr	43.8	305238.0 5174362.8
	Annual	0.292	305238.0 5174362.8
Nitrogen Dioxide	1-hr	669.8	305238.0 5174362.8

Table

	8-hr	319.8	305238.0 5174362.8
	Annual	8.688	305238.0 5174362.8

6-2. MIRR Concentrations and Receptors.

Chemical	Averaging Period	Concentration (µg/m³)	Coordinates (UTM Zone 11N)
Benzene	1-hr	0.0176	287463.0 5173262.8
	8-hr	0.00553	295663.0 5178662.8
	Annual	9.03E-06	296463.0 5178462.8
Diesel Particulate Matter	1-hr	0.772	295663.0 5178662.8
	8-hr	0.165	296463.0 5178462.8
	Annual	0.000361	296463.0 5178462.8
Naphthalene	1-hr	0.00294	287463.0 5173262.8
	8-hr	0.000927	295663.0 5178662.8
	Annual	1.51E-06	296463.0 5178462.8
Diesel Particulate Matter	1-hr	0.772	295663.0 5178662.8
	8-hr	0.165	296463.0 5178462.8

	Annual	0.000361	296463.0 5178462.8
Nitrogen Dioxide	1-hr	29.2	296063.0 5178462.8
	8-hr	10.3	295663.0 5178662.8
	Annual	0.014	296463.0 5178462.8

Table 6-3. MICR Concentrations and Receptors.

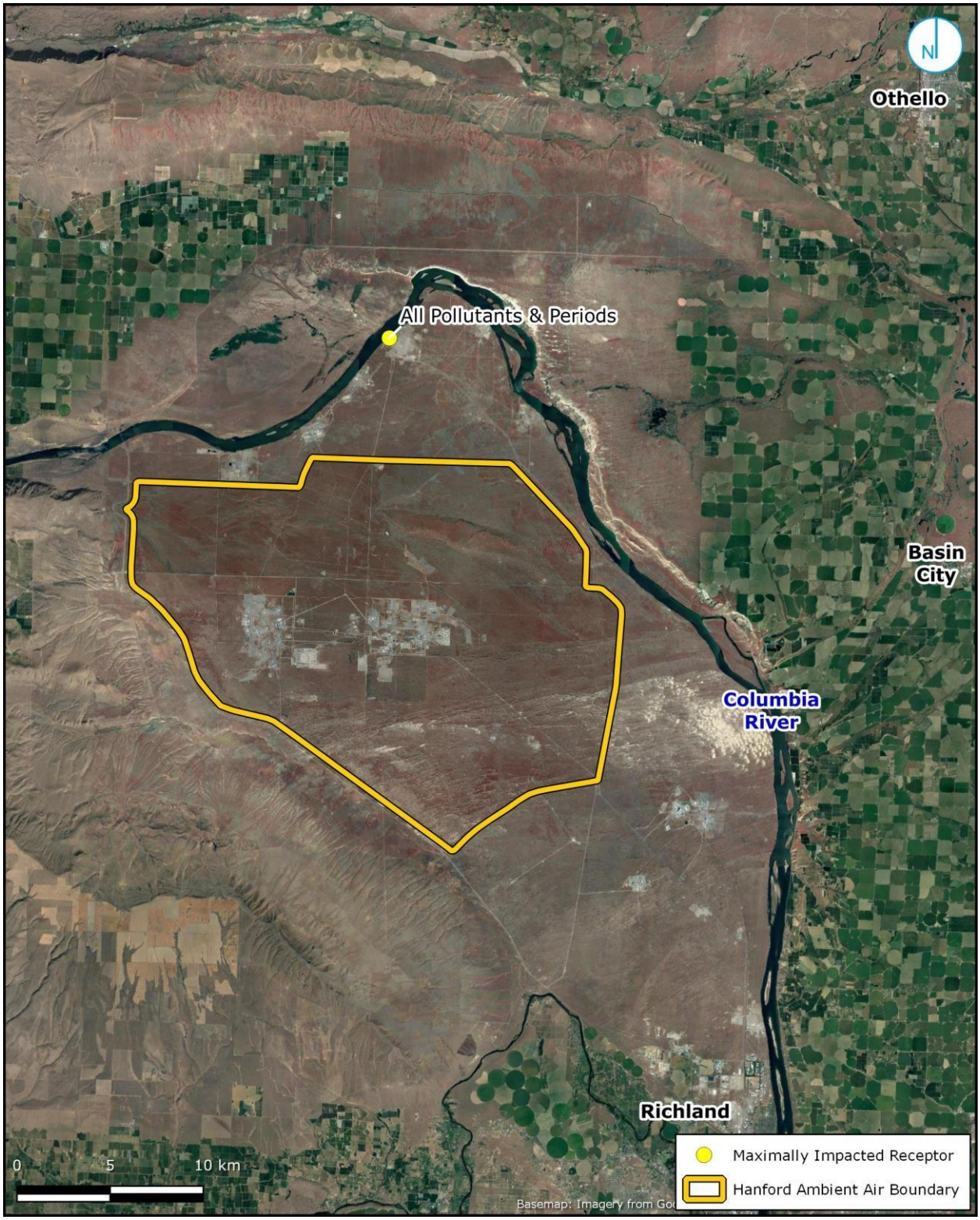
Chemical	Averaging Period	Concentration (µg/m³)	Coordinates (UTM Zone 11N)
Benzene	1-hr	0.0292	287463.0 5170062.8
	8-hr	0.00623	295663.0 5177062.8
	Annual	1.43E-05	313477.5 5150107.6
Diesel Particulate Matter	1-hr	1.44	287463.0 5170062.8
	8-hr	0.209	291463.0 5175062.8
	Annual	0.000480	313089.4 5150013.6
Naphthalene	1-hr	0.00490	287463.0 5170062.8
	8-hr	0.00104	295663.0 5177062.8
	Annual	2.39E-06	313477.5 5150107.6
Diesel Particulate Matter	1-hr	1.44	287463.0 5170062.8
	8-hr	0.209	291463.0 5175062.8
	Annual	0.000480	313089.4 5150013.6
Nitrogen Dioxide	1-hr	55.8	286263.0 5166462.8
	8-hr	11.3	295663.0 5177062.8
	Annual	0.023	313477.5 5150107.6

6-4. MIAR Concentrations and Receptors.

Chemical	Averaging Period	Concentration (µg/m³)	Coordinates (UTM Zone 11N)
Benzene	1-hr	0.740	305113.0 5174362.8
	8-hr	0.412	296938.0 5168262.8
	Annual	0.000694	296938.0 5168237.8
Diesel Particulate Matter	1-hr	36.6	305113.0 5174362.8
	8-hr	20.4	296938.0 5168262.8
	Annual	0.0343	296938.0 5168237.8
Naphthalene	1-hr	0.124	305113.0 5174362.8
	8-hr	0.0690	296938.0 5168262.8
	Annual	0.000116	296938.0 5168237.8
Diesel Particulate Matter	1-hr	36.6	305113.0 5174362.8
	8-hr	20.4	296938.0 5168262.8
	Annual	0.0343	296938.0 5168237.8
Nitrogen Dioxide	1-hr	267.1	305113.0 5174362.8
	8-hr	167.1	296938.0 5168262.8

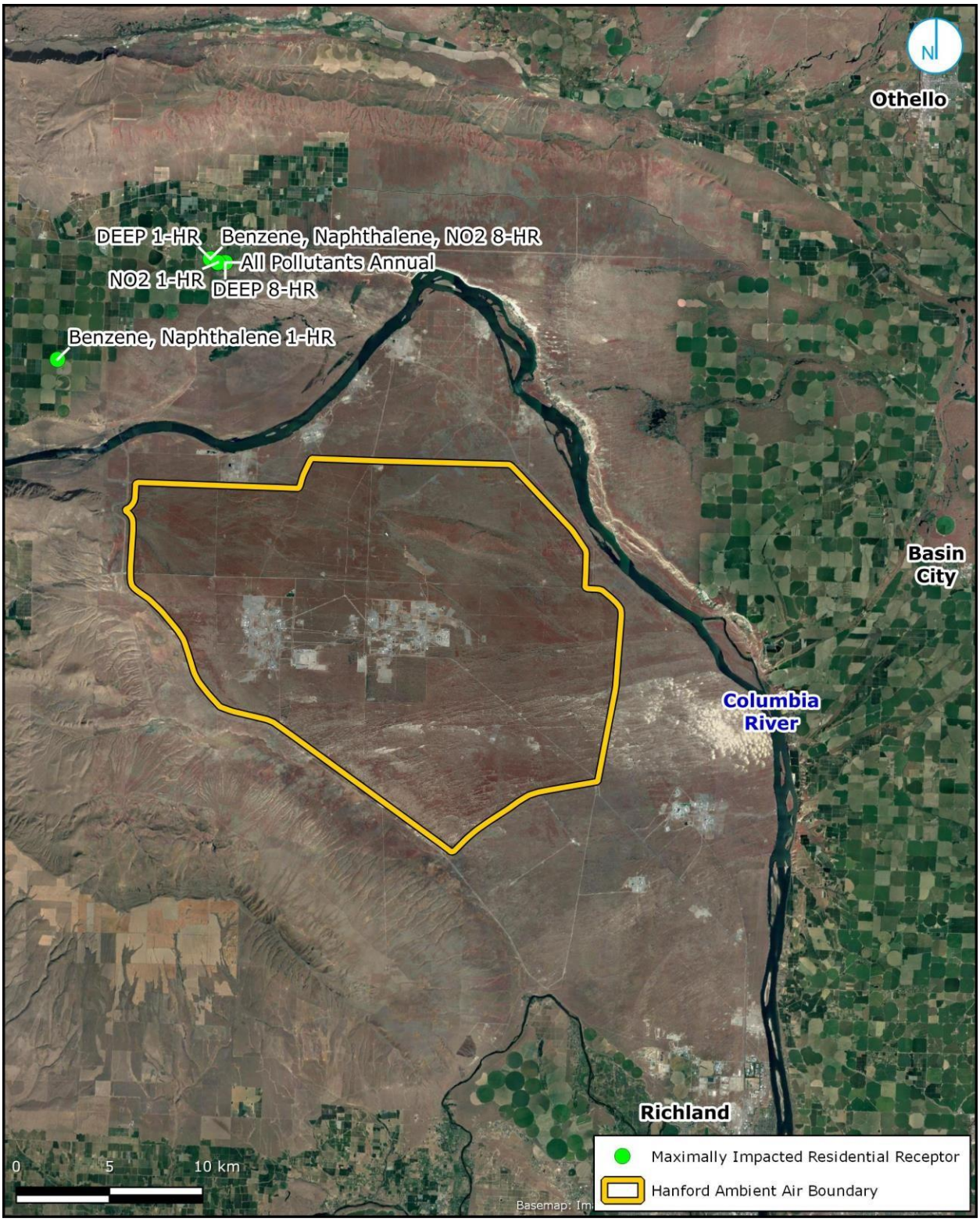
Table

	Annual	1.022	296938.0 5168237.8


N
Othello
All Pollutants & Periods
Basin City
Columbia River
Richland
0
5
10 km
Maximally Impacted Receptor
Hanford Ambient Air Boundary

Table

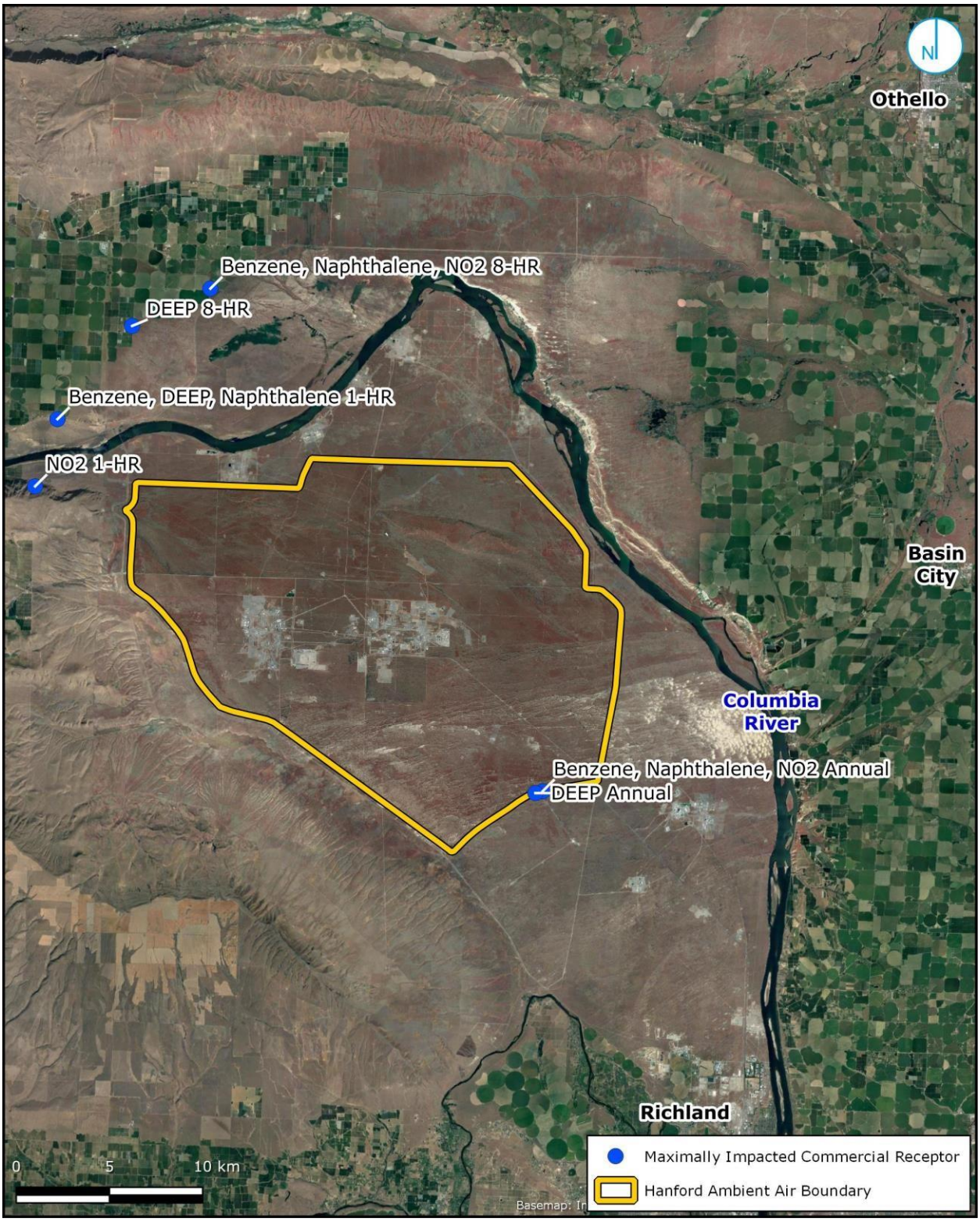
Figure 6-1. Locations of MIR


N
Othello
DEEP 1-HR
Benzene, Naphthalene, NO2 8-HR
All Pollutants Annual
NO2 1-HR
DEEP 8-HR
Benzene, Naphthalene 1-HR
Basin City
Columbia River
Richland
0
5
10 km
Maximally Impacted Residential Receptor
Hanford Ambient Air Boundary

Figure

6-2. Locations of MIRR

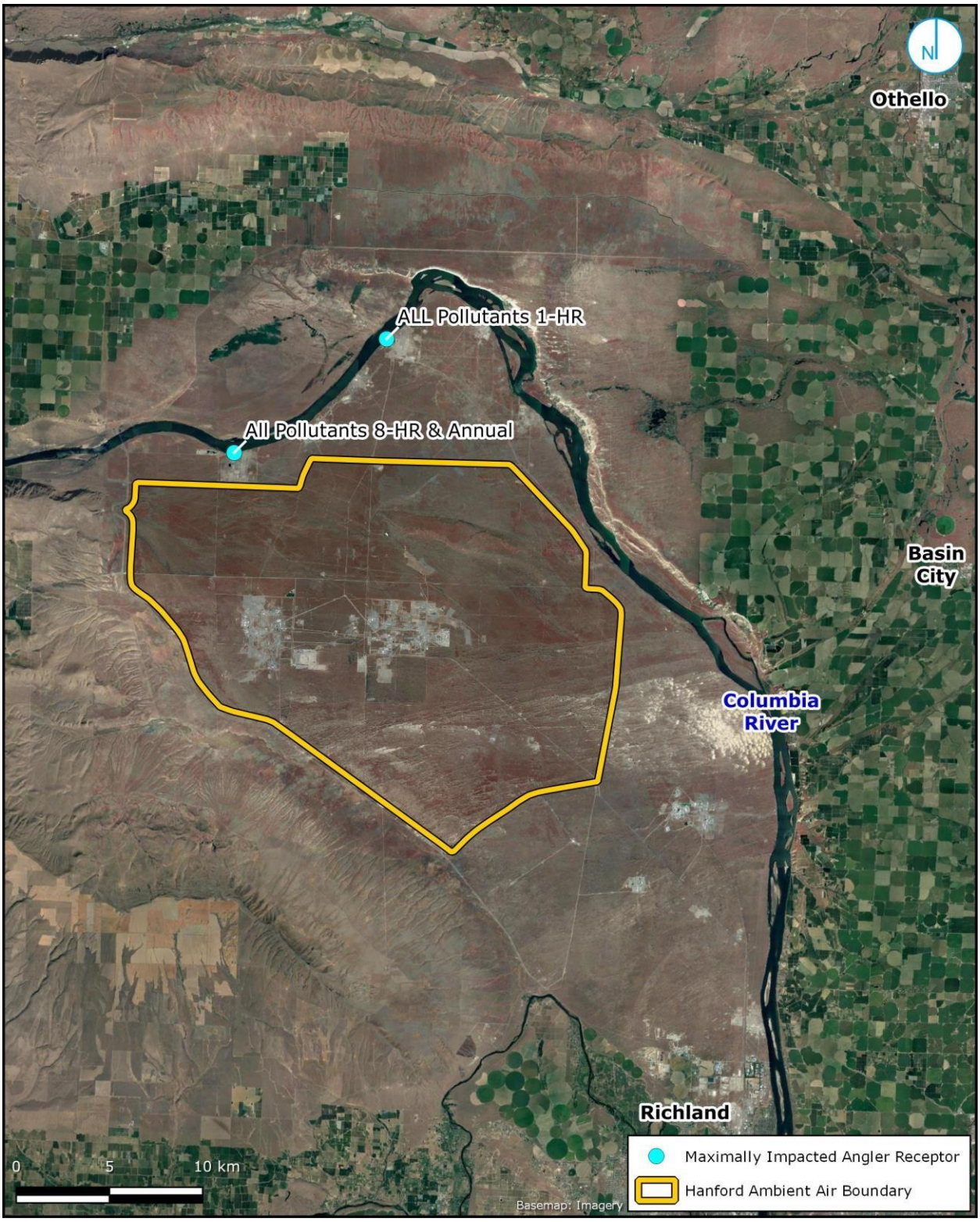
Figure


N
Othello
Benzene, Naphthalene, NO2 8-HR
DEEP 8-HR
Benzene, DEEP, Naphthalene 1-HR
NO2 1-HR
Basin City
Columbia River
Benzene, Naphthalene, NO2 Annual
DEEP Annual
Richland
0
5
10 km
Maximally Impacted Commercial Receptor
Hanford Ambient Air Boundary

Figure

6-3. Locations of MICR

Figure


N
Othello
ALL Pollutants 1-HR
All Pollutants 8-HR & Annual
Basin City
Columbia River
Richland
0
5
10 km
Basemap: Imagery
Maximally Impacted Angler Receptor
Hanford Ambient Air Boundary

Figure

6-4. Locations of MIAR

Figure

6.2.1 Calculating ECs

For noncancer hazards, acute exposures were calculated using the model-predicted maximum 1-hour and 8-hour average concentrations at the maximally impacted receptors, and the maximum annual average concentrations were used to calculate chronic exposures.

It is important to note that EPA and OEHHA offer slightly different guidance for assessing chronic hazards to offsite workers. EPA recommends adjusting the long-term exposure concentration to account for the fact that workers may not be present in the vicinity of a facility on a continuous basis. In the absence of 8-hour RELs, OEHHA recommends using the chronic REL and the annual average air concentration at maximally impacted commercial receptors without adjustments to estimate chronic hazards at nearby workplace. OEHHA Hot Spots guidance also notes that, if available, "the 8-hour RELs can be used to evaluate the potential for health impacts (including effects of repeated exposures) in offsite workers, and to children and teachers exposed during school hours." In this case, 8-hour RELs are available only for benzene and were used to estimate the potential for health impacts at the MICR.

ECs for increased cancer risk were based on the maximum annual modeled air concentration, modified by a representative exposure time (ET), exposure frequency (EF), exposure duration (ED), and averaging time (AT), as shown in the following equation:

$$\text{EC } (\mu g/m^3) = [\text{modeled air concentration } (\mu g/m^3) \times ET \times EF \times ED] / AT$$

Exposure parameter values used to calculate the increased cancer risk ECs are presented in Table 6-5.

Table 6-5. Exposure Parameters Used to Calculate ECs for Increased Cancer Risk.

Exposure Parameter	Resident	Commercial/Industrial Worker	Angler	Maximum Receptor
Exposure Time (hours per day)	24	8	4	2
Exposure Frequency (days per year)	350	250	180	250
Exposure Duration (years)	70	40	30	30
Averaging Time (hours) (70 years x 365 days/year x 24 hr/day)	613,200	613,200	613,200	613,200
Fraction of 70-Year Continuous Exposure	0.959	0.130	0.0352	0.0245

The assumed angler exposure duration is based on the Washington Department of Fish and

Wildlife's Northern Pikeminnow Sport-Reward Fishery Program, which is in effect annually from May 11 through September 30.[2] As for the assumed maximum receptor exposure duration, the angler exposure duration was inflated somewhat to ensure a conservative risk estimate.

6.2.2 Background ECs

The second tier review outlined in WAC 173-460-090 includes a requirement that TAP background concentrations be considered as part of the second tier review but does not describe the form or method of this consideration. To satisfy this requirement, ambient background concentrations at the locations where the maximally-impacted receptors are located were estimated using the latest NATA data for benzene, diesel particulate matter, and naphthalene, as well as the Northwest Airquest data for nitrogen dioxide (see Section 4.5).

6.2.3 Cumulative ECs

Cumulative exposures were evaluated by combining ECs based on the modeled concentrations with those based on background air concentrations. The resulting cumulative ECs were used to estimate non-cancer hazards and cancer risk for all identified receptor groups.

[2] https://wdfw.wa.gov/fishing/reports/creel/pikeminnow#:~:text=Anglers%20are%20paid%20%246%20for,for%20s pecially%20tagged%20Northern%20Pikeminnow!

This Page Intentionally Left Blank

7.0 TOXICITY ASSESSMENT

This section contains specific information on the toxicity of TAPs of concern, which, in this case, are benzene, diesel particulate matter, naphthalene, and nitrogen dioxide. Risk-based concentrations from EPA (IRIS and National Ambient Air Quality Standards), ATSDR, and OEHHA were compiled in order to determine quantitative estimates of acute and chronic toxicity, as well as cancer risk. Table 7-1 provides the non-cancer values for each chemical and Table 7-2 provides the cancer unit risk values. Section 3 discusses the details of how each value was derived and the uncertainty factors used in the derivation. All conflicting values were carried through the risk characterization.

Table 7-1. Non-Cancer, Risk-Based Concentrations.

Chemical	Source	Type	Concentration ($\mu g/m^3$)
Benzene	EPA	Chronic RfC	30
	OEHHA	Acute REL	27
		8-Hour REL	3
		Chronic REL	3
	ATSDR	Acute MRL	29.2
		8-Hour MRL	19.5
		Chronic MRL	9.74
Diesel Particulate Matter	EPA	Chronic RfC	5
	OEHHA	Chronic REL	5
Naphthalene	EPA	Chronic RfC	3
	OEHHA	Chronic REL	9
	ATSDR	Chronic MRL	3.73
Nitrogen Dioxide	OEHHA	Acute REL	470

ATSDR = Agency for Toxic Substances adn Disease Registry EPA
= U.S. Environmental Protection Agency
OEHHA = Office of Environmental Health Hazard Assessment
MRL = minimum risk level REL =
reference exposure level
RfC = reference concentration

Table 7-2. Cancer Inhalation Unit Risk Values.

Chemical	Source	Inhalation Unit Risk (per µg/m^3)
Benzene	EPA	2.20E-06 to 7.8E-06[a]
	OEHHA	2.90E-05
Diesel Particulate Matter	EPA	1E-05 to 1E-03[b]
	OEHHA	3.0E-04
Naphthalene	EPA	--[c]
	OEHHA	3.4E-05

[a] The true cancer risk from exposure to benzene cannot be ascertained because of uncertainties in the low-dose exposure scenarios and lack of clear understanding of the mode of action. A range of estimates of risk is recommended, each having equal scientific plausibility, EPA recommends this range of lifetime risk increases. (EPA 2002)

[b] As a result of broad uncertainties and issues, which are outlined in a white paper provided in Appendix C to this document, Ramboll recommends this range of lifetime risk increases. [c] EPA has classified naphthalene as a Group C carcinogen, which classifies it as a "possible human carcinogen;" naphthalene's carcinogenicity "cannot be determined" based on human and animal data. (EPA 1998)

EPA = U.S. Environmental Protection Agency
OEHHA = Office of Environmental Health Hazard Assessment

8.0 RISK CHARACTERIZATION

For the risk characterization, the results of the exposure and toxicity assessments were integrated into quantitative estimates of potential health hazards. Cancer risk and non-cancer hazard estimates were quantified for the MIRR, MICR, MIR, and MIAR. Where available, the cancer risk attributable to background concentrations were added to the calculated cumulative cancer risk increases attributable to the project emission increases.

8.1 CALCULATION OF NON-CANCER HAZARDS

The potential for non-cancer adverse health effects from exposure to benzene, diesel particulate matter, naphthalene, and nitrogen dioxide was evaluated by comparing exposure concentrations at the identified receptors to relevant non-cancer toxicological reference values presented in Table 7-1. A concentration that exceeds the relevant value indicates the potential for an adverse health effect. The magnitude of the potential is quantified by the hazard quotient (HQ), which is the calculated ambient concentration divided by the relevant toxicological value. An HQ of one or less indicates that the predicted exposure is unlikely to result in adverse non-cancer health effects, while values greater than one indicate increased probability of health effects. However, because uncertainty factors are employed in the derivation of toxicological reference values, a value greater than one does not necessarily mean a negative health impact will occur.

In cases where there are multiple chemicals with similar toxic effects (i.e., the same tissue or organ system is affected), a Hazard Index (HI) is calculated by summing the HQs with the same averaging periods for all TAPs that exceed the SQER and have similar toxic effects. As indicated in Section 3, benzene, diesel particulate matter, naphthalene, and nitrogen dioxide all target the respiratory tract, so HIs were calculated for each maximally impacted receptor and averaging period.

Non-cancer hazards are presented with ranges where the toxicity values from different agencies are carried through the analysis, as described in Section 7. The non-cancer HIs calculated for ambient concentration increases attributable to the project, as well as for project increases combined with background concentrations, are summarized in Table 8-1. All calculated HIs except one are less than unity, which indicates no adverse health impacts are expected for acute and chronic exposures. Only 1-hour average exposure to NO_2 concentration increases attributable to the project at the maximally-impacted boundary receptor, as well as to project increases combined with background at the same receptor, is greater than unity. We believe it is highly unlikely that engine operation (i.e., an engine test/maintenance event) will coincide with meteorological conditions that produce the maximum NO_2 concentration and a member of the sensitive population upon which the adverse health effect is based (i.e., asthmatics) being located at the maximally-impacted receptor.

Table 8-1. Acute and Chronic Non-Cancer Hazard Indices. (3 Pages)

Receptor	Avg. Per.	Pollutant	Project			Project + Background		
			EPA	OEHHA	ATSDR	EPA	OEHHA	ATSDR
MIRR	1-Hr	Benzene	--	0.00065	0.00060	--	0.0076	0.0070
		DPM	--	--	--	--	--	--
		Naphthalene	--	--	--	--	--	--
		NO_2	--	0.062	--	--	0.092	--
MIRR 1-Hr Hazard Index			**--**	**0.063**	**0.00060**	**--**	**0.10**	**0.0070**
MIRR	8-HR	Benzene	--	0.0018	0.00028	--	0.064	0.0099
		DPM	--	--	--	--	--	--
		Naphthalene	--	--	--	--	--	--
		NO_2	--	--	--	--	--	--
MIRR 8-Hr Hazard Index			**--**	**0.0018**	**0.00028**	**--**	**0.064**	**0.010**
		Benzene	3.0E-07	3.0E-06	9.3E-07	0.0063	0.063	0.019
		DPM	7.2E-05	7.2E-05	--	0.016	0.016	--
		Naphthalene	5.0E-07	1.7E-07	4.1E-07	0.011	0.0037	0.0089
MIRR	Annual	NO_2	--	--	--	--	--	--
MIRR Annual Hazard Index			**7.3E-05**	**7.5E-05**	**1.3E-06**	**0.033**	**0.082**	**0.028**
MICR	1-HR	Benzene	--	0.0011	0.0010	--	0.0082	0.0076
		DPM	--	--	--	--	--	--
		Naphthalene	--	--	--	--	--	--
		NO_2	--	0.12	--	--	0.16	--
MICR 1-Hr Hazard Index			**--**	**0.12**	**0.0010**	**--**	**0.17**	**0.0076**
MICR	8-Hr	Benzene	--	0.0021	0.00032	--	0.066	0.010
		DPM	--	--	--	--	--	--
		Naphthalene	--	--	--	--	--	--
		NO_2	--	--	--	--	--	--
MICR 8-Hr Hazard Index			**--**	**0.0021**	**0.00032**	**--**	**0.066**	**0.010**
MICR	Annual	Benzene	4.8E-07	4.8E-06	1.5E-06	0.0064	0.064	0.020

Table 8-1. Acute and Chronic Non-Cancer Hazard Indices. (3 Pages)

		DPM	9.6E-05	9.6E-05	0.0E+00	0.021	0.021	--
		Naphthalene	8.0E-07	2.7E-07	6.4E-07	0.0081	0.0027	0.0065

Receptor	Avg. Per.	Pollutant	Project			Project + Background		
			EPA	OEHHA	ATSDR	EPA	OEHHA	ATSDR
		NO_2	--	--	--	--	--	--
MICR Annual Hazard Index			**9.7E-05**	**1.0E-04**	**2.1E-06**	**0.036**	**0.088**	**0.026**
MIBR	1-Hr	Benzene	--	0.069	0.064	--	0.076	0.070
		DPM	--	--	--	--	--	--
		Naphthalene	--	--	--	--	--	--
		NO_2	--	1.4	--	--	1.5	--
MIBR 1-Hr Hazard Index			**--**	**1.5**	**0.064**	**--**	**1.5**	**0.070**
MIBR	8-Hr	Benzene	--	0.30	0.045	--	0.36	0.055
		DPM	--	--	--	--	--	--
		Naphthalene	--	--	--	--	--	--
		NO_2	--	--	--	--	--	--
MIBR 8-Hr Hazard Index			**--**	**0.30**	**0.045**	**--**	**0.36**	**0.055**
MIBR	Annual	Benzene	0.00020	0.0020	0.00061	0.007	0.066	0.020
		DPM	0.058	0.058	--	0.079	0.079	--
		Naphthalene	0.00033	0.00011	0.00027	0.0084	0.0028	0.0068
		NO_2	--	--	--	--	--	--
MIBR Annual Hazard Index			**0.059**	**0.061**	**0.00087**	**0.094**	**0.15**	**0.027**
		Benzene	--	0.027	0.025	--	0.035	0.032
		DPM	--	--	--	--	--	--
		Naphthalene	--	--	--	--	--	--
MIAR	1-Hr	NO_2	--	0.57	--	--	0.62	--
MIAR 1-Hr Hazard Index			**--**	**0.60**	**0.025**	**--**	**0.65**	**0.032**
MIAR	8-HR	Benzene	--	0.14	0.021	--	0.20	0.031
		DPM	--	--	--	--	--	--

Table 8-1. Acute and Chronic Non-Cancer Hazard Indices. (3 Pages)

		Naphthalene	--	--	--	--	--	--
		NO_2	--	--	--	--	--	--
MIAR 8-Hr Hazard Index			**--**	**0.14**	**0.021**	**--**	**0.20**	**0.031**
MIAR	Annual	Benzene	2.3E-05	2.3E-04	7.1E-05	0.0065	0.065	0.020
Receptor	**Avg. Per.**	**Pollutant**	**Project**			**Project + Background**		
			EPA	**OEHHA**	**ATSDR**	**EPA**	**OEHHA**	**ATSDR**
		DPM	0.0069	0.0069	--	0.028	0.028	--
		Naphthalene	3.9E-05	1.3E-05	3.1E-05	0.0082	0.0027	0.0066
		NO_2	--	--	--	--	--	--
MIAR Annual Hazard Index			**0.0069**	**0.0071**	**0.00010**	**0.042**	**0.095**	**0.026**

ATSDR = Agency for Toxic Substances and Disease Registry
DPM = diesel particulate matter
EPA = U.S. Environmental Protection Agency
NO_2 = nitrogen dioxide
OEHHA = Office of Environmental Health Hazard Assessment TAP
= toxic air pollutant

8.2 QUANTIFYING INCREASED CANCER RISK

Quantified cancer risk reflects the hypothetical increase in cancers within a given exposed population. Ecology's acceptable increased cancer risk is no more than 1 person per 100,000 exposed people, which is commonly reported as 1E-05 (i.e., 1/100,000). The cancer risk value is calculated by multiplying the annual air concentration for a TAP by the inhalation unit risk factor for that TAP (provided in Table 7-2) and summing the resulting risk values. The cancer risk calculations include only benzene, diesel particulate matter, and naphthalene,[3] because nitrogen dioxide is not classified as a carcinogen.

EPA and OEHHA provide different inhalation unit risk factors for benzene and diesel particulate matter, so cancer risk increases were calculated using both the EPA and OEHHA values. The cancer risk increases calculated for benzene, diesel particulate matter, and naphthalene were summed to obtain a cumulative cancer risk increase attributable to proposed project emission increases. Per WAC 173-460-090(7), Ecology's project approval threshold is an increased cancer risk of no more than one in one hundred thousand (i.e., 1E-05).

[3] EPA has classified naphthalene as a Group C carcinogen, which classifies it as a "possible human carcinogen;" naphthalene's carcinogenicity "cannot be determined" based on human and animal data; therefore, naphthalene was not included in cancer risk calculations based on risk factors developed by EPA.

Table 8-1. Acute and Chronic Non-Cancer Hazard Indices. (3 Pages)

As discussed in Section 6.2.3, the calculated cancer risk increases were combined with background concentrations to satisfy a regulatory requirement, but the resulting concentrations are not intended for comparison to the project approval threshold or for use as the basis for Ecology's decision to recommend approval of the project.

As shown in Table 8-2, calculated cumulative cancer risk increases attributable to the project at the maximum impacted receptors are all predicted to be less than Ecology's project approval threshold of 1 in 100,000 (i.e., 1E-05).

Table 8-2. Calculated Cancer Risk Increases.

Receptor	Pollutant	Project		Project + Background	
		EPA	OEHHA	EPA	OEHHA
MIRR	Benzene	2E-11 to 7E-11	3E-10	4E-7 to 1E-6	5E-6
	DPM	3E-9 to 3E-7	1E-7	8E-7 to 8E-5	2E-5
	Naphthalene	--	5E-11	--	1E-6
MIRR Cancer Risk		3E-9 to 3E-7	1E-7	1E-6 to 8E-5	3E-5
MICR	Benzene	4E-12 to 1E-11	5E-11	6E-8 to 2E-7	7E-7
	DPM	6E-10 to 6E-8	2E-8	1E-7 to 1E-5	4E-6
	Naphthalene	--	1E-11	--	1E-7
MICR Cancer Risk		6E-10 to 6E-8	2E-8	1E-7 to 1E-5	4E-6
MIBR	Benzene	3E-10 to 1E-9	4E-9	1E-8 to 4E-8	1E-7
	DPM	7E-8 to 7E-6	2E-6	1E-7 to 1E-5	3E-6
	Naphthalene	--	8E-10	--	2E-8
MIBR Cancer Risk		7E-8 to 7E-6	2E-6	1E-7 to 1E-5	3E-6
MIAR	Benzene	5E-11 to 2E-10	7E-10	1E-8 to 5E-8	2E-7
	DPM	1E-8 to 1E-6	4E-7	5E-8 to 5E-6	1E-6
	Naphthalene	--	1E-10	--	3E-8
MIAR Cancer Risk		1E-8 to 1E-6	4E-7	6E-8 to 5E-6	2E-6

DPM = diesel particulate matter
EPA = U.S. Environmental Protection Agency
NO_2 = nitrogen dooxide
OEHHA = Office of Environmental Health Hazard Assessment TAP
= toxic air pollutant

This Page Intentionally Left Blank

9.0 UNCERTAINTY CHARACTERIZATION

9.1 UNCERTAINTY CHARACTERIZATION

This HIA employs several assumptions, each with an associated uncertainty. There are uncertainties associated with the emissions rate calculations, air dispersion modeling, background concentrations, and toxicity values. Wherever possible, assumptions were designed to overestimate rather than underestimate hazards and risks to enable regulators to make decisions and recommendations confident that risks and hazards were not underestimated.

9.1.1 Emissions Rate Calculations

An emission rate, which is a quantity of pollutant per unit time (e.g., pounds per hour), is calculated from an emission factor, which is a quantity of pollutant per unit of an activity (e.g., pounds per brake-horsepower), and an activity rate, which is a measure of an activity per unit time (e.g., brake-horsepower per hour).

For analyses conducted in support of a permitting action, worst-case emission factors and activity rates are employed to ensure that regulatory limits or levels are not exceeded. As a result of these unrealistic assumptions, the exposures calculated by the model and the risk characterizations presented in this report are likely to overstate, rather than underestimate, the potential.

9.1.2 Air Dispersion Modeling

Any attempt to mathematically model a physical process will involve uncertainties. In this case, potential exposures were based on short-term and annual average ambient concentrations calculated using AERMOD, a regulatory model designed and demonstrated to over-predict ambient concentrations. In addition, the concentrations used to calculate exposure are outdoor concentrations, which do not account for effects that tend to diminish concentrations as air migrates indoors (e.g., absorption by building materials, deterioration, chemical reactions, or filtration by ventilation systems). Uncertainty associated with the design of the dispersion model is most likely characterized as the degree to which the predicted concentrations overestimate the actual concentrations.

The meteorological data provided to the model can be a source of uncertainty, related to the quality of the data, and whether the selected data are representative of conditions at the area of interest. In this case, the level of uncertainty has been mitigated by selecting data gathered at the Hanford Meteorological Tower. Based on the quality of the data and the proximity of the source to the location where the data were collected, the meteorological data is not considered a significant source of uncertainty.

While there are uncertainties associated with estimating ambient concentrations using an air dispersion model, we believe that reasonable care has been taken to consistently err on the side of more exposure rather than less.

9.1.3 Background Concentrations

Background concentrations of a compound are typically added to modeled concentration attributable to emissions from a given source to obtain a more realistic estimate of the exposure that a population of interest will experience. Because no monitoring data are available in the vicinity of the facility, background concentrations for benzene, naphthalene, and diesel particulate matter were estimated using an annual average concentration from the 2014 NATA. The NATA provides only annual average concentrations, so short-term background concentrations were not estimated. Because nitrogen dioxide is not included in the NATA, data at the node closest to the maximally impacted receptors from the current Northwest Airquest were used as nitrogen dioxide background concentrations.

9.1.4 Toxicity Values

There is uncertainty associated with development of toxicity values due to study interpretation and agency method of value derivation. To derive non-cancer toxicity values, agencies such as the EPA, OEHHA, and ATSDR choose critical studies that show effects from exposure to the chemical of interest. Agencies do not always choose the same studies, which may result in variation between the animal species or chemical formulation tested, the exposure duration, and the exposure concentrations. These differences can result in different LOAEL and NOAEL values. Some studies also may not present a NOAEL if only high concentrations of the chemicals were tested. The database of studies on any given chemical expands over time and new studies may present different NOAEL or LOAEL values. Even if two agencies choose the same critical study, if benchmark dose methodology is used in place of a NOAEL or LOAEL, the resulting toxicity values will differ.

Once a LOAEL/NOAEL or benchmark concentration is chosen, the agency then extrapolates to a value relevant to humans for an exposure duration (acute or chronic). This requires the use of uncertainty factors, which are intended to account for sensitive populations. Uncertainty factors are intended to reflect intra-individual variation and early-life exposure, and their magnitude is often based on professional judgment and may differ between agencies.

It should be noted that OEHHA developed an inhalation lifetime unit risk value for diesel exhaust, where several other authoritative groups, including the EPA, have examined the same epidemiology evidence used by OEHHA and determined that it is inadequate for derivation of a discrete, quantitative estimate of human risk, and have offered a range of risk values. In the case of diesel exhaust, we believe that the range of risk values derived by EPA should be used to evaluate potential cancer risks; while this report presents risk calculations that include the OEHHA risk value for diesel exhaust, we do not believe it is appropriate to base decisions on calculations that rely on this OEHHA risk value.

9.2 CONCLUSIONS

Our conclusions, based on the results from the risk characterization as well as the uncertainties explained above, are presented for the non-cancer hazards and the cancer risks.

9.2.1 Non-Cancer Hazards

The acute and chronic non-cancer hazard indices calculated for ambient concentrations attributable to the project do not exceed unity for all types of receptors, with the exception of acute 1-hour average exposure at the maximum impacted boundary receptor, which is almost entirely caused by the NO_2 concentration predicted by the modeling. We believe that the likelihood of adverse health impacts at this location is unlikely, and that the analysis results indicate that non-carcinogenic hazards are not likely to occur at any ambient receptor.

9.2.2 Cancer Risk

The calculated cumulative cancer risk increases attributable to TAP emission increases associated with the project are not predicted to exceed one per hundred thousand (i.e., 1E-05) at any ambient receptor, which is the cancer risk increase project approval threshold for the second tier methodology provided in WAC 173-460-090.

This Page Intentionally Left Blank

10.0 REFERENCES

40 CFR 51 Subpart A. "Air Emissions Reporting Requirements." *Code of Federal Regulations*, as amended. Online at https://www.ecfr.gov/cgibin/textidx?SID=8498d0b1c1a8842c400748eeb565ff5a&mc=true&node=pt40.2.51&rgn =div5.

40 CFR 60. "Standards of Performance for New Stationary Sources." *Code of Federal Regulations*, as amended. Online at https://www.ecfr.gov/cgi-bin/textidx?SID=24a108a1db51447fd1cfd51ed65a70b7&mc=true&node=pt40.7.60&rgn =div5.

40 CFR 63. "National Emission Standards for Hazardous Air Pollutants for Source Categories," *Code of Federal Regulations*, as amended. Online at http://www.ecfr.gov/cgibin/textidx?SID=7488a2f4120e611881cbab65c27466f0&mc=true&node=pt40.11.63&rg n=div5.

40 CFR 89, "Control of Emissions From New and In-Use Nonroad Compression-Ignition Engines," *Code of Federal Regulations*, as amended. Online at https://www.ecfr.gov/cgibin/text-idx?tpl=/ecfrbrowse/Title40/40cfr89_main_02.tpl.

Alberta Environment and Parks. 2015. *Assessment Report on Napthalene for Developing Ambient Air Quality Objectives: 2013 Update*. Alberta Environment and Parks, Edmonton, Alberta. Online at https://open.alberta.ca/publications/9781460125830.

ATSDR, 2005, *Toxicological Profile for Naphthalene, 1-Methylnaphthalene, And 2-Methylnaphthalene*. Agency for Toxic Substances and Disease Registry, U.S. Department of Health and Human Services, Public Health Service, Atlanta, Georgia. Online at https://www.atsdr.cdc.gov/toxprofiles/tp67.pdf.

ATSDR, 2007, *Toxicological Profile for Benzene*. Agency for Toxic Substances and Disease Registry, U.S. Department of Health and Human Services, Public Health Service, Atlanta, Georgia. Online at https://www.atsdr.cdc.gov/toxprofiles/tp3.pdf.

Attfield, M. D., P. L. Schleiff, J. H. Lubin, A. Blair, P. A. Stewart, R. Vermeulen, D. T. Silverman, 2012, "The diesel exhaust in miners study: A cohort mortality study with emphasis on lung cancer," *Journal of the National Cancer Institute*, 104(11), 869–883.

CARB, 1992, *Review of the one-hour ambient air quality standard for nitrogen dioxide technical support document*. California Air Resources Board, Sacramento, California.

Clean Air Act of 1963. 42 U.S.C. 7401 et seq., Public Law 88-206, as amended. Online at https://www.epa.gov/laws-regulations/summary-clean-air-act.

Ecology, 2011, "Requirements for New Sources of Air Pollution," 08-0-015, Washington State Department of Ecology, Olympia, Washington.

EPA 1998. *Toxicological Review of Naphthalene (CAS No. 91-20-3) In Support of Summary Information on the Integrated Risk Information System (IRIS)*. U.S. Environmental Protection Agency, Washington, D.C. Online at https://cfpub.epa.gov/ncea/iris/iris_documents/documents/toxreviews/0436tr.pdf.

EPA, 2002, *Toxicological Review of Benzene (Noncancer Effects) (CAS No. 71-43-2) In Support of Summary Information on the Integrated Risk Information System (IRIS)*. U.S. Environmental Protection Agency, Washington, D.C. Online at https://cfpub.epa.gov/ncea/iris/iris_documents/documents/toxreviews/0276tr.pdf.

Garshick, E., M. B. Schenker, A. Munoz, M. Segal, T. J. Smith, S. R. Woskie, F. E. Speizer, 1988, "A retrospective cohort study of lung cancer and diesel exhaust exposure in railroad workers," *American Review of Respiratory Disease*, 137, 820–825.

Garshick, E., F. Laden, J. E. Hart, M. E. Davis, E. A. Eisen, T. J. Smith, 2012, "Lung cancer and elemental carbon exposure in trucking industry workers," *Environmental Health Perspectives*, 120(9), 1301–1306.

Hammond, S. K., T. J. Smith, S. R. Woskie, B. P. Leaderer, N. Bettinger, 1988, "Markers of exposure to diesel exhaust and cigarette smoke in railroad workers," *American Industrial Hygiene Association Journal*, 49(10), 516–522.

Hesterberg, T. W., C. M. Long, S. N. Sax, C. A. Lapin, R. O. McClellan, W. B. Bunn, P. A. Valberg, 2011, "Particulate Matter in New Technology Diesel Exhaust (NTDE) is Quantitatively and Qualitatively Very Different from that Found in Traditional Diesel Exhaust (TDE)," *Journal of the Air & Waste Management Association*, 61(9), 894–913.

IARC, 2014, "Diesel and gasoline engine exhausts and some nitrosamenes. IARC monographs on the evaluation of carcinogenic risks to humans," World Health Organization, International Agency for Research on Cancer, Vol. 105.

Lan Q., L. Zhang, G. Li, R. Vermeulen, R.S. Weinberg, M. Dosemeci, S.M. Rappaport, M. Shen, B.P. Alter, Y. Wu, W. Kopp, S. Waidyanatha, C. Rabkin, W. Guo, S. Chanock, R.B. Hayes, M. Linet, S. Kim, S. Yin, N. Rothman, M.T. Smith, 2004, "Hematotoxicity in workers exposed to low levels of benzene," *Science* 306(5702): 1774-6.

NAC, 2009, *Benzene (CAS 71-43-2) Interim Acute Exposure Guideline*. National Advisory Committee, U.S. Environmental Protection Agency, Washington, D.C. Available at https://www.epa.gov/sites/production/files/2014-08/documents/benzene_interim_dec_2008_v1.pdf.

NTP, 1992, *Toxicology and Carcinogenesis Studies of Naphthalene (CAS No. 91-20-3) in B6C3F1 Mice (Inhalation Studies)*, Technical Report Series No. 410. NIH Publication No. 92-3141. National Toxicology Program, U.S. Department of Health and Human Services, Public Health Service, National Institutes of Health, Research Triangle Park, North Carolina.

NTP, 2000, *Toxicology and Carcinogenesis Studies of Naphthalene (CAS No. 91-20-3) in F344/N Rats (Inhalation Studies)*, Technical Report Series No. 500. NIH Publication No. 00-4434. National Toxicology Program, U.S. Department of Health and Human Services, Public Health Service, National Institutes of Health, Research Triangle Park, North Carolina. Online at https://ntp.niehs.nih.gov/ntp/htdocs/lt_rpts/tr500.pdf?utm_source=direct&utm_medium= prod&utm_campaign=ntpgolinks&utm_term=tr500.

OEHHA, 2008, *Technical Support Document for NonCancer REL*, California Office of Environmental Health and Human Assessment, Sacrament, California. Online at https://oehha.ca.gov/media/downloads/crnr/appendixd3final.pdf.

OEHHA, 2009, *Technical Support Document for Cancer Potency Factors*. California Office of Environmental Health and Human Assessment, Sacramento, California. Online at https://oehha.ca.gov/media/downloads/crnr/appendixb.pdf.

OEHHA, 2014, *Technical Support Document for Non Cancer REL*, California Office of Environmental Health and Human Assessment, Sacramento, California. Online at https://oehha.ca.gov/media/downloads/crnr/appendixd1final.pdf.

Rinsky, R.A., A. B. Smith, R. Hornung, T. G. Filloon, R. J. Young, A. H. Okun, P. J. Landrigan, 1987, "Benzene and leukemia. An epidemiologic risk assessment," *New England Journal Medicine*, 316(17):1044-50.

Rinsky, R.A., R. J. Young, A. B. Smith, 1981, "Leukemia in benzene workers," *American Journal of Industrial Medicine*, 2: 217-245. https://doi.org/10.1002/ajim.4700020305.

Rothman, N., G.L. Li, M. Dosemeci, W.E. Bechtold, G.E. Marti, Y.Z. Wang, M. Linet, L.Q. Xi, W. Lu, M.T. Smith, N. Titenko-Holland, L.P. Zhang, W. Blot, S.N. Yin, and R.B. Hayes, 1996, "Hematotoxicity among Chinese workers heavily exposed to benzene." *Am. J. Ind. Med*. 29: 236-246.

Rosenthal G.J., C.A. Snyder, 1987, "Inhaled benzene reduces aspects of cell-mediated tumor surveillance in mice," *Toxicol Appl Pharmacol* 88:35-43.

Rozen M.G., C.A. Snyder, R.E. Albert, 1984, "Depression in B- and T-lymphocyte mitogeninduced blastogenesis in mice exposed to low concentrations of benzene," *Toxicol Lett* 20:343-349.

Silverman, D. T., C. M. Samanic, J. H. Lubin, A. E. Blair, P. A. Stewart, R. Vermeulen, M. D. Attfield, 2012, "The diesel exhaust in miners study: A nested case-control study of lung cancer and diesel exhaust," *Journal of the National Cancer Institute*, 104(11), 855–868.

Steenland, N. K., D. T. Silverman, R. W. Hornung, 1990, "Case-control study of lung cancer and truck driving in the teamsters union," *American Journal of Public Health*, 80(6), 670– 674.

Steenland, K., D. Silverman, D. Zaebst, 1992, "Exposure to diesel exhaust in the trucking industry and possible relationships with lung cancer," *American Journal of Industrial Medicine*, 21(6), 887–890.

Steenland, K., J. Deddens, L. Stayner, 1998, "Diesel exhaust and lung cancer in the trucking industry: exposure-response analyses and risk assessment," *American Journal of Industrial Medicine*, 34(3), 220–8.

WAC 173-460, "Controls for New Sources of Toxic Air Pollutants." *Washington Administrative Code*, Olympia, Washington. Online at http://apps.leg.wa.gov/wac/default.aspx?cite=173-460.

Woskie, S., T. Smith, S. Hammond, M. Schenker, E. Garshick, F. Speizer, 1988a, "Estimation of the diesel exhaust exposures of railroad workers: I. Current exposures," *American Journal of Industrial Medicine*, 13(3):381-94.

Woskie, S., T. Smith, S. Hammond, M. Schenker, E. Garshick, F. Speizer, 1988b, "Estimation of the diesel exhaust exposures of railroad workers: II. National and historical exposures," *American Journal of Industrial Medicine*, 13(3), 395–404.

APPENDIX A

PROJECT EMISSION RATE CALCULATIONS

This Page Intentionally Left Blank

APPENDIX A
PROJECT EMISSION RATE CALCULATIONS

Table A-1. Carbon Monoxide Emission Estimate.

Stationary Engine	Emissions (g/kW-hr) or (g/HP-hr)[a]	Engine Power (kW) or (HP)[b]	Emission Rate (g/hr)	Annual Emissions (g/year)	Emission Estimate (Tons/year)
	A	B	C=A*B	D=C*500[c]	E=D*0.00000110
L-897	4.1E-01[a]	1.112E+03[b]	4.56E+02	2.28E+05	2.5E-01
L-895	2.1E-01[a]	1.829E+03[b]	3.85E+02	1.92E+05	2.1E-01
L-849	6.0E-01	1.403E+03	8.42E+02	4.21E+05	4.6E-01
L-826	1.3E+00	2.5E+03	3.25E+03	1.63E+06	1.8E+00
L-781 (200-West Feed Pump Building)	6.0E-01	4.6E+02	2.76E+02	1.38E+05	1.5E-01
L-781 (181-D Pump House)	1.3E+00	2.5E+03	3.25E+03	1.63E+06	1.8E+00
Total Carbon Monoxide Emission Estimate (Tons/year)					4.7E+00

[a] g/HP-hr provided in manufacturer's specification instead of g/kW-hr [b] HP provided in manufacturer's specification instead of kW [c] 500 operating hours per year assumed based on EPA (1995)

Table A-2. Particulate Matter Emission Estimate.

Stationary Engine	Emissions (g/kW-hr) or (g/HP-hr)[a]	Engine Power (kW) or (HP)[b]	Emission Rate (g/hr)	Annual Emissions (g/year)	Emission Estimate (Tons/year)
	A	B	C=A*B	D=C*500[c]	E=D*0.00000110
L-897	6.0E-02[a]	1.112E+03[b]	6.67E+01	3.34E+04	3.7E-02
L-895	2.0E-02[a]	1.829E+03[b]	3.66E+01	1.83E+04	2.0E-02
L-849	1.4E-01	1.403E+03	1.96E+02	9.8E+04	1.1E-01
L-826	1.6E-01	2.5E+03	4.0E+02	2.0E+05	2.2E-01
L-781 (200-West Feed Pump Building)	1.0E-01	4.6E+02	4.6E+01	2.3E+04	2.5E-02
L-781 (181-D Pump House)	1.6E-01	2.5E+03	4.0E+02	2.0E+05	2.2E-01
Total Particulate Matter Emission Estimate (Tons/year)					6.3E-01

[a] g/HP-hr provided in manufacturer's specification instead of g/kW-hr [b] HP provided in manufacturer's specification instead of kW [c] 500 operating hours per year assumed based on EPA (1995)

Table A-3. Sulfur Dioxide Emission Estimate.

Stationary Engine	Operating Time (hrs/year)	Fuel Consumption Rate (gal/hr)	Fuel Density (lbs/gal)	Fuel Sulfur Content by Weight	Molecular Weight Ratio, SO_2:S	Emission Estimate (Tons/year)
	A	B	C	D	E	F=A*B*C*D*E* 5.0E-04
L-897	5.0E+02[a]	5.36E+01	7.2E+00	1.5E+01/1.0E+06	2.0E+00	2.9E-03
L-895	5.0E+02[a]	8.74E+01	7.2E+00	1.5E+01/1.0E+06	2.0E+00	4.7E-03
L-849	5.0E+02[a]	1.14E+02	7.2E+00	1.5E+01/1.0E+06	2.0E+00	6.2E-03
L-826	5.0E+02[a]	1.671E+02	7.2E+00	1.5E+01/1.0E+06	2.0E+00	9.0E-03
L-781 (200-West Feed Pump Building)	5.0E+02[a]	3.06E+01	7.2E+00	1.5E+01/1.0E+06	2.0E+00	1.7E-03
L-781 (181-D Pump House)	5.0E+02[a]	1.671E+02	7.2E+00	1.5E+01/1.0E+06	2.0E+00	9.0E-03
Total Sulfur Dioxide Emission Estimate (Tons/year)						3.4E-02

[a] 500 operating hours per year assumed based on EPA (1995)

Table A-4. Volatile Organic Compound Emission Estimate.

Stationary Engine	NMHC Emission Rate (g/kW-hr) or HC Emission Rate[a] (g/HP-hr)[a]	Engine Power (kW) or (HP)[b]	Emission Rate (g/hr)	Annual Emissions (g/year)	Emission Estimate (Tons/year)	EPA Conversion Factor for Diesel Engines (VOC/THC : NMHC/THC)[d]
	A	B	C=A*B	D=C*500[c]	E=D*0.00000110	F=E*1.053/0.984
L-897	1.1E-01[a]	1.112E+03[b]	1.22E+02	6.12E+04	6.7E-02	7.2E-02
L-895	1.0E-01[a]	1.829E+03[b]	1.83E+02	9.15E+04	1.0E-01	1.1E-01
L-849	5.8E-01	1.403E+03	8.14E+02	4.07E+05	4.5E-01	4.8E-01

L-826	7.5E-01	2.5E+03	1.88E+03	9.38E+05	1.0E+00	1.1E+00
L-781 (200-West Feed Pump Building)	1.1E-01	4.6E+02	5.06E+01	2.53E+04	2.8E-02	3.0E-02
L-781 (181-D Pump House)	7.5E-01	2.5E+03	1.88E+03	9.38E+05	1.0E+00	1.1E+00
Total Volatile Organic Compound Emission Estimate (Tons/year)						2.9E+00

[a] HC emission rate in g/HP-hr provided in manufact. specification instead of NMHC emission rate in g/kW-hr [b] HP provided in manufacturer's specification instead of kW [c] 500 operating hours per year assumed based on EPA (1995) [d] Conversion factor from EPA (2005)

Table A-5. Nitrogen Dioxide Emission Estimate.

Stationary Engine	Emissions (g/kW-hr) or (g/HP-hr)[a]	Engine Power (kW) or (HP)[b]	Emission Rate (g/hr)	Annual Emissions (g/year)	Emission Estimate (Tons/year)
	A	B	C=A*B	D=C*500[c]	E=D*0.00000110
L-897	5.85E+00[a]	1.112E+03[b]	6.51E+03	3.26E+06	3.6E+00
L-895	6.20E+00[a]	1.829E+03[b]	1.13E+04	5.7E+06	6.3E+00
L-849	4.99E+00	1.403E+03	7.0E+03	3.5E+06	3.9E+00
L-826	5.28E+00	2.5E+03	1.32E+04	6.6E+06	7.3E+00
L-781 (200-West Feed Pump Building)	3.31E+00	4.6E+02	1.52E+03	7.6E+05	8.4E-01
L-781 (181-D Pump House)	5.28E+00	2.5E+03	1.32E+04	6.6E+06	7.3E+00
Total Nitrogen Dioxide Emission Estimate (Tons/year)					2.9E+01

Note: All NO_x data provided in manufacturer's specifications and EPA.gov emission tables assumed to be nitrogen dioxide

[a] g/HP-hr provided in manufacturer's specification instead of g/kW-hr [b] HP provided in manufacturer's specification instead of kW [c] 500 operating hours per year assumed based on EPA (1995)

Table A-6. Carbon Monoxide Emission Estimate.

Stationary Engine	Emissions (g/kW-hr) or (g/HP-hr)[a]	Engine Power (kW) or (HP)[b]	Emission Rate (g/hr)	Annual Emissions (g/year)	Average Hourly Emissions (g/hr)	Emission Estimate (lbs/hr)
	A	B	C=A*B	D=C*500[c]	E=D/8760	F=E*0.0022
L-897	4.1E-01[a]	1.112E+03[b]	4.56E+02	2.28E+05	2.6E+01	5.7E-02
L-895	2.1E-01[a]	1.829E+03[b]	3.84E+02	1.92E+05	2.19E+01	4.8E-02
L-849	6.0E-01	1.403E+03	8.42E+02	4.21E+05	4.81E+01	1.1E-01
L-826	1.3E+00	2.5E+03	3.25E+03	1.63E+06	1.86E+02	4.1E-01
L-781 (200-West Feed Pump Building)	6.0E-01	4.6E+02	2.76E+02	1.38E+05	1.58E+01	3.5E-02
L-781 (181-D Pump House)	1.3E+00	2.5E+03	3.25E+03	1.63E+06	1.86E+02	4.1E-01
Total Carbon Monoxide Emission Estimate (lbs/hr)						1.1E+00

[a] g/HP-hr provided in manufacturer's specification instead of g/kW-hr [b] HP provided in manufacturer's specification instead of kW
[c] 500 operating hours per year assumed based on EPA (1995)

Table A-7. Diesel Engine Exhaust, Particulate Emission Estimate.

Stationary Engine	Emissions (g/kW-hr) or (g/HP-hr)[a]	Engine Power (kW) or (HP)[b]	Emission Rate (g/hr)	Annual Emissions (g/year)	Emission Estimate (lbs/year)
	A	B	C=A*B	D=C*500[c]	E=*0.0022
L-897	6.0E-02[a]	1.112E+03[b]	6.67E+01	3.34E+04	7.4E+01
L-895	2.0E-02[a]	1.829E+03[b]	3.66E+01	1.83E+04	4.0E+01
L-849	1.4E-01	1.403E+03	1.96E+02	9.8E+04	2.2E+02
L-826	1.6E-01	2.5E+03	4.0E+02	2.0E+05	4.4E+02
L-781 (200-West Feed Pump Building)	1.0E-01	4.6E+02	4.6E+01	2.3E+04	5.1E+01
L-781 (181-D Pump House)	1.6E-01	2.5E+03	4.0E+02	2.0E+05	4.4E+02
Total Diesel Engine Exhaust, Particulate Emission Estimate (lbs/year)					1.3E+03

Note: All PM data provided in manufacturer's specifications and EPA.gov emission tables assumed to be diesel engine exhaust, particulate
[a] g/HP-hr provided in manufacturer's specification instead of g/kW-hr [b] HP provided in manufacturer's specification instead of kW [c] 500 operating hours per year assumed based on EPA (1995)

Table A-8. Nitrogen Dioxide Emission Estimate.

Stationary Engine	Emissions (g/kW-hr) or (g/HP-hr)[a]	Engine Power (kW) or (HP)[b]	Emission Rate (g/hr)	Annual Emissions (g/year)	Average Hourly Emissions (g/hr)	Emission Estimate (lbs/hr)
	A	B	C=A*B	D=C*500[c]	E=D/8760	F=E*0.0022
L-897	5.85E+00[a]	1.112E+03[b]	6.51E+03	3.26E+06	3.72E+02	8.2E-01
L-895	6.20E+00[a]	1.829E+03[b]	1.13E+04	5.7E+06	6.51E+02	1.4E+00
L-849	4.99E+00	1.403d=03	7.0E+03	3.5E+06	4.0E+02	8.8E-01
L-826	5.28E+00	2.5E+03	1.32E+04	6.6E+06	7.53E+02	1.7E+00
L-781 (200West Feed Pump Building)	3.31E+00	4.6E+02	1.52E+03	7.6E+05	8.68E+01	1.9E-01
L-781 (181-D Pump House)	5.28E+00	2.5E+03	1.32E+04	6.6E+06	7.53E+02	1.7E+00
Total Nitrogen Dioxide Emission Estimate (lbs/hr)						6.7E+00

Note: All NO_x data provided in manufacturer's specifications and EPA.gov emission tables assumed to be nitrogen dioxide

[a] g/HP-hr provided in manufacturer's specification instead of g/kW-hr [b] HP provided in manufacturer's specification instead of kW [c] 500 operating hours per year assumed based on EPA (1995)

Table A-9. Sulfur Dioxide Emission Estimate.

Stationary Engine	Operating Time (hrs/year)	Fuel Consumption Rate (gal/hr)	Fuel Density (lbs/gal)	Fuel Sulfur Content by Weight	Molecular Weight Ratio, SO_2:S	Emission Estimate (lbs/hour)
	A	B	C	D	E	F=A*B*C*D*E / 8.76E+03
L-897	5.0E+02[a]	5.36E+01	7.2E+00	1.5E+01/1.0E+06	2.0E+00	6.6E-04
L-895	5.0E+02[a]	8.74E+01	7.2E+00	1.5E+01/1.0E+06	2.0E+00	1.1E-03
L-849	5.0E+02[a]	1.14E+02	7.2E+00	1.5E+01/1.0E+06	2.0E+00	1.4E-03
L-826	5.0E+02[a]	1.671E+02	7.2E+00	1.5E+01/1.0E+06	2.0E+00	2.1E-03

L-781 (200-West Feed Pump Building)	5.0E+02[a]	3.06E+01	7.2E+00	1.5E+01/1.0E+06	2.0E+00	3.8E-04
L-781 (181-D Pump House)	5.0E+02[a]	1.671E+02	7.2E+00	1.5E+01/1.0E+06	2.0E+00	2.1E-03
Total Sulfur Dioxide Emission Estimate (lbs/hr)						7.7E-03

[a] 500 operating hours per year assumed based on EPA (1995)

Table A-10. Benzene Emission Estimate.

Stationary Engine	Operating Time (hrs/year)	Fuel Consumption Rate (gal/hr)	Diesel Fuel Energy (MMBTU/gal)	Emission Rate (lbs/MMBTU)	Emission Estimate (lbs/year)
	A	B	C	D	E=A*B*C*D
L-897	5.0E+02[a]	5.36E+01	1.374E-01	7.76E-04[b]	2.9E+00
L-895	5.0E+02[a]	8.74E+01	1.374E-01	7.76E-04[b]	4.7E+00
L-849	5.0E+02[a]	1.14E+02	1.374E-01	7.76E-04[b]	6.1E+00
L-826	5.0E+02[a]	1.671E+02	1.374E-01	7.76E-04[b]	8.9E+00
L-781 (200-West Feed Pump Building)	5.0E+02[a]	3.06E+01	1.374E-01	7.76E-04[b]	1.6E+00
L-781 (181-D Pump House)	5.0E+02[a]	1.671E+02	1.374E-01	7.76E-04[b]	8.9E+00
Total Benzene Emission Estimate (lbs/year)					3.3E+01

[a] 500 operating hours per year assumed based on EPA (1995) [b] Emission rate obtained from AP-42, *Compilation of Air Pollutant Emissions Factors,* Fifth Edition, Volume 1, Chapter 3, Table 3.4-3

Table A-11. Toluene Emission Estimate.

Stationary Engine	Operating Time (hrs/year)	Fuel Consumption Rate (gal/hr)	Diesel Fuel Energy (MMBTU/gal)	Emission Rate (lbs/MMBTU)	Emission Estimate (lbs/24 Hours)
	A	B	C	D	$E=\frac{A*B*C*D}{3.65E+02}$
L-897	5.0E+02[a]	5.36E+01	1.374E-01	2.81E-04[b]	2.8E-03

L-895	5.0E+02[a]	8.74E+01	1.374E-01	2.81E-04[b]	4.6E-03
L-849	5.0E+02[a]	1.14E+02	1.374E-01	2.81E-04[b]	6.0E-03
L-826	5.0E+02[a]	1.671E+02	1.374E-01	2.81E-04[b]	8.8E-03
L-781 (200-West Feed Pump Building)	5.0E+02[a]	3.06E+01	1.374E-01	2.81E-04[b]	1.6E+01
L-781 (181-D Pump House)	5.0E+02[a]	1.671E+02	1.374E-01	2.81E-04[b]	8.8E-03
Total Toluene Emission Estimate (lbs/24 Hours)					3.3E-02

[a] 500 operating hours per year assumed based on EPA (1995)

[b] Emission rate obtained from AP-42, *Compilation of Air Pollutant Emissions Factors,* Fifth Edition, Volume 1, Chapter 3, Table 3.4-3

Table A-12. Xylenes Emission Estimate.

Stationary Engine	Operating Time (hrs/year)	Fuel Consumption Rate (gal/hr)	Diesel Fuel Energy (MMBTU/gal)	Emission Rate (lbs/MMBTU)	Emission Estimate (lbs/24 Hours)
	A	B	C	D	$E=\frac{A*B*C*D}{3.65E+02}$
L-897	5.0E+02[a]	5.36E+01	1.374E-01	1.93E-04[b]	2.0E-03
L-895	5.0E+02[a]	8.74E+01	1.374E-01	1.93E-04[b]	3.2E-03
L-849	5.0E+02[a]	1.14E+02	1.374E-01	1.93E-04[b]	4.1E-03
L-826	5.0E+02[a]	1.671E+02	1.374E-01	1.93E-04[b]	6.1E-03
L-781 (200-West Feed Pump Building)	5.0E+02[a]	3.06E+01	1.374E-01	1.93E-04[b]	1.1E-03
L-781 (181-D Pump House)	5.0E+02[a]	1.671E+02	1.374E-01	1.93E-04[b]	6.1E-03
Total Xylenes Emission Estimate (lbs/24 Hours)					2.3E-02

[a] 500 operating hours per year assumed based on EPA (1995)

[b] Emission rate obtained from AP-42, *Compilation of Air Pollutant Emissions Factors,* Fifth Edition, Volume 1, Chapter 3, Table 3.4-3

Table A-13. Propylene Emission Estimate.

Stationary Engine	Operating Time (hrs/year)	Fuel Consumption Rate (gal/hr)	Diesel Fuel Energy (MMBTU/gal)	Emission Rate (lbs/MMBTU)	Emission Estimate (lbs/24 Hours)
	A	B	C	D	E=A*B*C*D / 3.65E+02
L-897	5.0E+02[a]	5.36E+01	1.374E-01	2.79E-03[b]	2.8E-02
L-895	5.0E+02[a]	8.74E+01	1.374E-01	2.79E-03[b]	4.6E-02
L-849	5.0E+02[a]	1.14E+02	1.374E-01	2.79E-03[b]	6.0E-02
L-826	5.0E+02[a]	1.671E+02	1.374E-01	2.79E-03[b]	8.8E-02
L-781 (200-West Feed Pump Building)	5.0E+02[a]	3.06E+01	1.374E-01	2.79E-03[b]	1.6E-02
L-781 (181-D Pump House)	5.0E+02[a]	1.671E+02	1.374E-01	2.79E-03[b]	8.8E-02
Total Propylene Emission Estimate (lbs/24 Hours)					3.3E-01

[a] 500 operating hours per year assumed based on EPA (1995)

[b] Emission rate obtained from AP-42, *Compilation of Air Pollutant Emissions Factors,* Fifth Edition, Volume 1, Chapter 3, Table 3.4-3

Table A-14. Formaldehyde Emission Estimate.

Stationary Engine	Operating Time (hrs/year)	Fuel Consumption Rate (gal/hr)	Diesel Fuel Energy (MMBTU/gal)	Emission Rate (lbs/MMBTU)	Emission Estimate (lbs/year)
	A	B	C	D	E=A*B*C*D
L-897	5.0E+02[a]	5.36E+01	1.374E-01	7.89E-05[b]	2.9E-01
L-895	5.0E+02[a]	8.74E+01	1.374E-01	7.89E-05[b]	4.7E-01
L-849	5.0E+02[a]	1.14E+02	1.374E-01	7.89E-05[b]	6.2E-01
L-826	5.0E+02[a]	1.671E+02	1.374E-01	7.89E-05[b]	9.1E-01
L-781 (200-West Feed Pump Building)	5.0E+02[a]	3.06E+01	1.374E-01	7.89E-05[b]	1.7E-01
L-781 (181-D Pump House)	5.0E+02[a]	1.671E+02	1.374E-01	7.89E-05[b]	9.1E-01
Total Formaldehyde Emission Estimate (lbs/year)					3.4E+00

[a] 500 operating hours per year assumed based on EPA (1995)

[b] Emission rate obtained from AP-42, *Compilation of Air Pollutant Emissions Factors,* Fifth Edition, Volume 1, Chapter 3, Table 3.4-3

Table A-15. Acetaldehyde Emission Estimate. (2 pages)

Stationary Engine	Operating Time (hrs/year)	Fuel Consumption Rate (gal/hr)	Diesel Fuel Energy (MMBTU/gal)	Emission Rate (lbs/MMBTU)	Emission Estimate (lbs/year)
	A	B	C	D	E=A*B*C*D
L-897	5.0E+02[a]	5.36E+01	1.374E-01	2.52E-05[b]	9.3E-02
L-895	5.0E+02[a]	8.74E+01	1.374E-01	2.52E-05[b]	1.5E-01
L-849	5.0E+02[a]	1.14E+02	1.374E-01	2.52E-05[b]	2.0E-01

Table A-15. Acetaldehyde Emission Estimate. (2 pages)

Stationary Engine	Operating Time (hrs/year)	Fuel Consumption Rate (gal/hr)	Diesel Fuel Energy (MMBTU/gal)	Emission Rate (lbs/MMBTU)	Emission Estimate (lbs/year)
L-826	5.0E+02[a]	1.671E+02	1.374E-01	2.52E-05[b]	2.9E-01
L-781 (200-West Feed Pump Building)	5.0E+02[a]	3.06E+01	1.374E-01	2.52E-05[b]	5.3E-02
L-781 (181-D Pump House)	5.0E+02[a]	1.671E+02	1.374E-01	2.52E-05[b]	2.9E-01
Total Acetaldehyde Emission Estimate (lbs/year)					1.1E+00

[a] 500 operating hours per year assumed based on EPA (1995)

[b] Emission rate obtained from AP-42, *Compilation of Air Pollutant Emissions Factors,* Fifth Edition, Volume 1, Chapter 3, Table 3.4-3

Table A-16. Acrolein Emission Estimate.

Stationary Engine	Operating Time (hrs/year)	Fuel Consumption Rate (gal/hr)	Diesel Fuel Energy (MMBTU/gal)	Emission Rate (lbs/MMBTU)	Emission Estimate (lbs/24 hours)
	A	B	C	D	$E=\frac{A*B*C*D}{3.65E+02}$
L-897	5.0E+02[a]	5.36E+01	1.374E-01	7.88E-06[b]	8.0E-05
L-895	5.0E+02[a]	8.74E+01	1.374E-01	7.88E-06[b]	1.3E-04
L-849	5.0E+02[a]	1.14E+02	1.374E-01	7.88E-06[b]	1.7E-04
L-826	5.0E+02[a]	1.671E+02	1.374E-01	7.88E-06[b]	2.5E-04
L-781 (200-West Feed Pump Building)	5.0E+02[a]	3.06E+01	1.374E-01	7.88E-06[b]	4.5E-05
L-781 (181-D Pump House)	5.0E+02[a]	1.671E+02	1.374E-01	7.88E-06[b]	2.5E-04
Total Acrolein Emission Estimate (lbs/24 hours)					9.3E-04

[a] 500 operating hours per year assumed based on EPA (1995)
[b] Emission rate obtained from AP-42, *Compilation of Air Pollutant Emissions Factors,* Fifth Edition, Volume 1, Chapter 3, Table 3.4-3

Table A-17. Naphthalene Emission Estimate. (2 pages)

Stationary Engine	Operating Time (hrs/year)	Fuel Consumption Rate (gal/hr)	Diesel Fuel Energy (MMBTU/gal)	Emission Rate (lbs/MMBTU)	Emission Estimate (lbs/year)
	A	B	C	D	E=A*B*C*D
L-897	5.0E+02[a]	5.36E+01	1.374E-01	1.3E-04[b]	4.8E-01
L-895	5.0E+02[a]	8.74E+01	1.374E-01	1.3E-04[b]	7.8E-01
L-849	5.0E+02[a]	1.14E+02	1.374E-01	1.3E-04[b]	1.0E+00
L-826	5.0E+02[a]	1.671E+02	1.374E-01	1.3E-04[b]	1.5E+00
L-781 (200-West Feed Pump Building)	5.0E+02[a]	3.06E+01	1.374E-01	1.3E-04[b]	2.7E-01

Table A-17. Naphthalene Emission Estimate. (2 pages)

Stationary Engine	Operating Time (hrs/year)	Fuel Consumption Rate (gal/hr)	Diesel Fuel Energy (MMBTU/gal)	Emission Rate (lbs/MMBTU)	Emission Estimate (lbs/year)
L-781 (181-D Pump House)	5.0E+02[a]	1.671E+02	1.374E-01	1.3E-04[b]	1.5E+00
Total Naphthalene Emission Estimate (lbs/year)					5.5E+00

[a] 500 operating hours per year assumed based on EPA (1995)
[b] Emission rate obtained from AP-42, *Compilation of Air Pollutant Emissions Factors,* Fifth Edition, Volume 1, Chapter 3, Table 3.4-4

Table A-18. Benz(a)anthracene Emission Estimate.

Stationary Engine	Operating Time (hrs/year)	Fuel Consumption Rate (gal/hr)	Diesel Fuel Energy (MMBTU/gal)	Emission Rate (lbs/MMBTU)	Emission Estimate (lbs/year)
	A	B	C	D	E=A*B*C*D
L-897	5.0E+02[a]	5.36E+01	1.374E-01	6.22E-07[b]	2.3E-03
L-895	5.0E+02[a]	8.74E+01	1.374E-01	6.22E-07[b]	3.7E-03
L-849	5.0E+02[a]	1.14E+02	1.374E-01	6.22E-07[b]	4.9E-03
L-826	5.0E+02[a]	1.671E+02	1.374E-01	6.22E-07[b]	7.1E-03

L-781 (200-West Feed Pump Building)	5.0E+02[a]	3.06E+01	1.374E-01	6.22E-07[b]	1.3E-03
L-781 (181-D Pump House)	5.0E+02[a]	1.671E+02	1.374E-01	6.22E-07[b]	7.1E-03
Total Benz(a)anthracene Emission Estimate (lbs/year)					2.6E-02

[a] 500 operating hours per year assumed based on EPA (1995)

[b] Emission rate obtained from "AP-42, *Compilation of Air Pollutant Emissions Factors,"* Fifth Edition, Volume 1, Chapter 3, Table 3.4-4

Table A-19. Chrysene Emission Estimate.

Stationary Engine	Operating Time (hrs/year)	Fuel Consumption Rate (gal/hr)	Diesel Fuel Energy (MMBTU/gal)	Emission Rate (lbs/MMBTU)	Emission Estimate (lbs/year)
	A	B	C	D	E=A*B*C*D
L-897	5.0E+02[a]	5.36E+01	1.374E-01	1.53E-06[b]	5.6E-03
L-895	5.0E+02[a]	8.74E+01	1.374E-01	1.53E-06[b]	9.2E-03
L-849	5.0E+02[a]	1.14E+02	1.374E-01	1.53E-06[b]	1.2E-02
L-826	5.0E+02[a]	1.671E+02	1.374E-01	1.53E-06[b]	1.8E-02
L-781 (200-West Feed Pump Building)	5.0E+02[a]	3.06E+01	1.374E-01	1.53E-06[b]	3.2E-03
L-781 (181-D Pump House)	5.0E+02[a]	1.671E+02	1.374E-01	1.53E-06[b]	1.8E-02
Total Chrysene Emission Estimate (lbs/year)					6.6E-02

[a] 500 operating hours per year assumed based on EPA (1995)

[b] Emission rate obtained from AP-42, *Compilation of Air Pollutant Emissions Factors,* Fifth Edition, Volume 1, Chapter 3, Table 3.4-4

Table A-20. Benzo(b)fluoranthene Emission Estimate.

Stationary Engine	Operating Time (hrs/year)	Fuel Consumption Rate (gal/hr)	Diesel Fuel Energy (MMBTU/gal)	Emission Rate (lbs/MMBTU)	Emission Estimate (lbs/year)
	A	B	C	D	E=A*B*C*D
L-897	5.0E+02[a]	5.36E+01	1.374E-01	1.11E-06[b]	4.1E-03
L-895	5.0E+02[a]	8.74E+01	1.374E-01	1.11E-06[b]	6.7E-03
L-849	5.0E+02[a]	1.14E+02	1.374E-01	1.11E-06[b]	8.7E-03
L-826	5.0E+02[a]	1.671E+02	1.374E-01	1.11E-06[b]	1.3E-02

L-781 (200-West Feed Pump Building)	5.0E+02[a]	3.06E+01	1.374E-01	1.11E-06[b]	2.3E-03
L-781 (181-D Pump House)	5.0E+02[a]	1.671E+02	1.374E-01	1.11E-06[b]	1.3E-02
Total Benzo(b)fluoranthene Emission Estimate (lbs/year)					4.8E-02

[a] 500 operating hours per year assumed based on EPA (1995)

[b] Emission rate obtained from AP-42, *Compilation of Air Pollutant Emissions Factors,* Fifth Edition, Volume 1, Chapter 3, Table 3.4-4

Table A-21. Benzo(k)fluoranthene Emission Estimate.

Stationary Engine	Operating Time (hrs/year)	Fuel Consumption Rate (gal/hr)	Diesel Fuel Energy (MMBTU/gal)	Emission Rate (lbs/MMBTU)	Emission Estimate (lbs/year)
	A	B	C	D	E=A*B*C*D
L-897	5.0E+02[a]	5.36E+01	1.374E-01	2.18E-07[b]	8.0E-04
L-895	5.0E+02[a]	8.74E+01	1.374E-01	2.18E-07[b]	1.3E-03
L-849	5.0E+02[a]	1.14E+02	1.374E-01	2.18E-07[b]	1.7E-03
L-826	5.0E+02[a]	1.671E+02	1.374E-01	2.18E-07[b]	2.5E-03
L-781 (200-West Feed Pump Building)	5.0E+02[a]	3.06E+01	1.374E-01	2.18E-07[b]	4.6E-04
L-781 (181-D Pump House)	5.0E+02[a]	1.671E+02	1.374E-01	2.18E-07[b]	2.5E-03
Total Benzo(k)fluoranthene Emission Estimate (lbs/year)					9.3E-03

[a] 500 operating hours per year assumed based on EPA (1995)

[b] Emission rate obtained from AP-42, *Compilation of Air Pollutant Emissions Factors,* Fifth Edition, Volume 1, Chapter 3, Table 3.4-4

Table A-22. Benzo(a)pyrene Emission Estimate.

Stationary Engine	Operating Time (hrs/year)	Fuel Consumption Rate (gal/hr)	Diesel Fuel Energy (MMBTU/gal)	Emission Rate (lbs/MMBTU)	Emission Estimate (lbs/year)
	A	B	C	D	E=A*B*C*D
L-897	5.0E+02[a]	5.36E+01	1.374E-01	2.57E-07[b]	9.5E-04
L-895	5.0E+02[a]	8.74E+01	1.374E-01	2.57E-07[b]	1.5E-03
L-849	5.0E+02[a]	1.14E+02	1.374E-01	2.57E-07[b]	2.0E-03
L-826	5.0E+02[a]	1.671E+02	1.374E-01	2.57E-07[b]	3.0E-03

L-781 (200-West Feed Pump Building)	5.0E+02[a]	3.06E+01	1.374E-01	2.57E-07[b]	5.4E-04
L-781 (181-D Pump House)	5.0E+02[a]	1.671E+02	1.374E-01	2.57E-07[b]	3.0E-03
Total Benzo(a)pyrene Emission Estimate (lbs/year)					1.1E-02

[a] 500 operating hours per year assumed based on EPA (1995)
[b] Emission rate obtained from AP-42, *Compilation of Air Pollutant Emissions Factors,* Fifth Edition, Volume 1, Chapter 3, Table 3.4-4

Table A-23. Indeno(1,2,3-cd)pyrene Emission Estimate.

Stationary Engine	Operating Time (hrs/year)	Fuel Consumption Rate (gal/hr)	Diesel Fuel Energy (MMBTU/gal)	Emission Rate (lbs/MMBTU)	Emission Estimate (lbs/year)
	A	B	C	D	E=A*B*C*D
L-897	5.0E+02[a]	5.36E+01	1.374E-01	4.14E-07[b]	1.5E-03
L-895	5.0E+02[a]	8.74E+01	1.374E-01	4.14E-07[b]	2.5E-03
L-849	5.0E+02[a]	1.14E+02	1.374E-01	4.14E-07[b]	3.2E-03
L-826	5.0E+02[a]	1.671E+02	1.374E-01	4.14E-07[b]	4.8E-03
L-781 (200-West Feed Pump Building)	5.0E+02[a]	3.06E+01	1.374E-01	4.14E-07[b]	8.7E-04
L-781 (181-D Pump House)	5.0E+02[a]	1.671E+02	1.374E-01	4.14E-07[b]	4.8E-03
Total Indeno(1,2,3-cd)pyrene Emission Estimate (lbs/year)					1.8E-02

[a] 500 operating hours per year assumed based on EPA (1995) [b] Emission rate obtained from AP-42, *Compilation of Air Pollutant Emissions Factors,* Fifth Edition, Volume 1, Chapter 3, Table 3.4-4

Table A-24. Dibenz(a,h)anthracene Emission Estimate.

Stationary Engine	Operating Time (hrs/year)	Fuel Consumption Rate (gal/hr)	Diesel Fuel Energy (MMBTU/gal)	Emission Rate (lbs/MMBTU)	Emission Estimate (lbs/year)
	A	B	C	D	E=A*B*C*D
L-897	5.0E+02[a]	5.36E+01	1.374E-01	3.46E-07[b]	1.3E-03
L-895	5.0E+02[a]	8.74E+01	1.374E-01	3.46E-07[b]	2.1E-03
L-849	5.0E+02[a]	1.14E+02	1.374E-01	3.46E-07[b]	2.7E-03
L-826	5.0E+02[a]	1.671E+02	1.374E-01	3.46E-07[b]	4.0E-03

L-781 (200-West Feed Pump Building)	5.0E+02[a]	3.06E+01	1.374E-01	3.46E-07[b]	7.3E-04
L-781 (181-D Pump House)	5.0E+02[a]	1.671E+02	1.374E-01	3.46E-07[b]	4.0E-03
Total Dibenz(a,h)anthracene Emission Estimate (lbs/year)					1.5E-02

[a] 500 operating hours per year assumed based on EPA (1995)

[b] Emission rate obtained from AP-42, *Compilation of Air Pollutant Emissions Factors,* Fifth Edition, Volume 1, Chapter 3, Table 3.4-4

Table A-25. L-897 Sludge Lagoon Constituent Moles.

Constituent	Liquid Concentration (µg/L)	Molecular Weight (g/mol)	Molar Concentration (mol/L)	Tank Volume (L)	Moles (mol)
	A	B	C=A/B/1.0E+06	D	E=C*D
Chloroform	4.42E+00[a]	1.1938E+02[b]	3.7E-08	2.88E+08[c]	1.07E+01
Bromodichloromethane	7.8E-01[a]	1.6383E+02[b]	4.76E+09	2.88E+08[c]	1.37E+00
Water	-	-	5.55E+01[b]	2.88E+08[c]	1.6E+10
Total Moles (mol)					1.6E+10

[a] From "*BAT/AKART Analysis for Project L-897*", HNF-64154, Table 9, Combined Wastewater Stream at 5.0 million gallons per day throughput; Concentrations shown are based on current operating experience that shows that chloroform accounts for 85% of the total trihalomethanes and bromodichloromethane accounts for the remaining 15%

[b] https://webbook.nist.gov/chemistry/ [c] From "*BAT/AKART Analysis for Project L-897*", HNF-64154, Table 9, Combined Wastewater Stream at 5.0 million gallons per day throughput; 6,336,300 gal/month*3.79 L/gal*12 months/year=288,174,924 L/year

Table A-26. L-897 Sludge Lagoon Henry's Law Calculations.

Constituent	Liquid Mole Fraction	Henry's Law Constant at 25 □C (atm)	Vapor Mole Fraction	Ideal Gas Law (n/v)
	A=Constituent Moles/Total Moles[a]	B	C=A*B	D
Chloroform	6.67E-10	203.0	1.35E-07	4.09E-02
Bromodichloromethane	8.58E-11	88.90	7.63E-09	4.09E-02

[a] Constituent Moles and Total Moles from Table A-25

[b] https://webbook.nist.gov/chemistry/

[c] Molecular Weight from Table A-25, Ideal Gas Law [(n/v) = P/RT] (mol/L) = 1 atm /(0.082057 L atm /K mol * 298 K)

Table A-27. L-897 Sludge Lagoon Fick's Law Calculations.

Constituent	Mass Air Concentration (g/L)	Mass Air Concentration (lb/ft^3)[c]	Diffusion Coefficient (cm^2/sec)	Diffusion Coefficient (ft^2/sec)[4]	Concentration Gradient dC/dx (lb/ft^4)[d]	Diffusion Rate (lbs/ft^2 sec)
	A=Vapor Mole Fraction[a]*Ideal Gas Law[a]*Molecular Weight[b]	B=A*2.832E+01*2.205E+00 / 1.0E+03	C	D=C*1.08E03	E = (B - 0) / (0 - 1)	F= -1*D*E
Chloroform	6.61E-07	4.13E-08	1.04E-01	1.12E-04	-4.13E-08	4.62E-12
Bromodichloromethane	5.11E-08	3.19E-09	2.98E-02	3.21E-05	-3.19E-09	1.02E-13

[a] Vapor Mole Fraction and Ideal Gas Law from Table A-26

[b] Molecular Weight from Table A-25

[c] Mass Air Concentration (lb/ft3) = Mass Air Concentration (g/L) *28.32 (L/ft3)* (2.205 lb/1000 g) Diffusion Coefficient (ft^2/sec) = Diffusion Coefficient (cm^2/sec) * 0.00107639 ft^2/cm^2

[d] Concentration Gradient dC/dx (lb/ft) = (Surface Diffusion Coefficient (ft^2/sec) - Free Air Diffusion Coefficient (ft^2/sec)/(Surface Height (ft) - Free Air Height (ft))

Table A-28. L-897 Sludge Lagoon Emission Estimate.

Constituent	Seconds/Year	Basin Surface Area (ft^2)[a]	Emission Estimate (lbs/yr)
	A	B = 3.535E+03*3.0E+00[b]	S=Diffusion Rate[c]*A*B
Chloroform	3.1536E+07	1.0605E+04	1.55E+00
Bromodichloromethane	3.1536E+07	1.0605E+04	3.42E-02

[a] Calculation Number: HNF-CALC-63402,
[b] Each basin has a surface area of 3,535 ft^2, there are three basins total [c] Diffusion Rate from Table A-27

Table A-29. L-849 and L-850 Water Tanks Constituent Moles.

Constituent	Liquid Concentration (µg/L)	Molecular Weight (g/mol)	Molar Concentration (mol/L)	Tank Volume (L)	Moles (mol)
	A	B	C=A/B/1.0E+06	D	E=C*D
Chloroform	8.56E+01[a]	1.1938E+02[c]	7.17E-07	1.89E+07	1.36E+01
Bromodichloromethane	3.5E+00[a]	1.6383E+02[c]	2.14E-08	1.89E+07	4.04E-01
Bromoform	6.0E-02[b]	2.5275E+02[c]	2.37E-10	1.89E+07	4.49E-03
Water	-	-	5.55E+01[‡]	1.89E+07	1.05E+07
Total Moles (mol)					1.05E+07

[a] Highest concentration from quarterly Disinfection By-Product Compounds Reports from February 2017 – May 2020
[b] Method detection limit used as results were non-detectable for all quarterly Disinfection By-Product Compounds Reports from February 2017 through May 2020
[c] https://webbook.nist.gov/chemistry/; Assumes 5.0 million gallons per day output from L-897 CPWTF passes through each tank

Table A-30. L-849 and L-850 Water Tanks Henry's Law Calculations.

Constituent	Liquid Mole Fraction		Henry's Law Constant at 25 □C (atm)	Vapor Mole Fraction	Ideal Gas Law (n/v)
	A=Constituent Moles/Total Moles[a]		B	C=A*B	D
Chloroform	1.29E-08		2.03E+02	2.62E-06	4.09E-02
Bromodichloromethane	3.85E-10		8.89E+01	3.42E-08	4.09E-02

Bromoform	4.28E-12		2.97E+00	1.27E-10	4.09E-02

[a] Constituent Moles and Total Moles from Table A-29

[b] https://webbook.nist.gov/chemistry/

[c] Molecular Weight from Table A-29 Ideal Gas Law [(n/v) = P/RT] (mol/L) = 1 atm /(0.082057 L atm /K mol * 298 K)

Table A-31. L-849 and L-850 Water Tanks Fick's Law Calculations.

Constituent	Mass Air Concentration (g/L)	Mass Air Concentration (lb/ft^3)[c]	Diffusion Coefficient (cm^2/sec)	Diffusion Coefficient (ft^2/sec)[4]	Concentration Gradient dC/dx (lb/ft)[d]	Diffusion Rate (lbs/ft^2 sec)
	A=Vapor Mole Fraction[a]*Ideal Gas Law[a]*Molecular Weight[b]	$B = \frac{A*28.32*2.205}{1000}$	C	D=C*0.00108	$E = \frac{(B - 0)}{(0 - 1)}$	F= -1*D*E
Chloroform	1.28E-05	7.99E-07	1.04E-01	1.12E-04	-7.99E-07	8.95E-11
Bromodichloromethane	2.29E-07	1.43E-08	2.98E-02	3.21E-05	-1.43E-08	4.59E-13
Bromoform	1.31E-09	8.20E-11	1.49E-02	1.6E-05	-8.20E-11	1.31E-15

[a] Vapor Mole Fraction and Ideal Gas Law from Table A-30

[b] Molecular Weight from Table A-29

[c] Mass Air Concentration (lb/ft3) = Mass Air Concentration (g/L) *28.32 (L/ft3)* (2.205 lb/1,000 g) Diffusion Coefficient (ft^2/sec) = Diffusion Coefficient (cm^2/sec) * 0.00107639 ft^2/cm^2

[d] Concentration Gradient dC/dx (lb/ft) = (Surface Diffusion Coefficient (ft^2/sec) - Free Air Diffusion Coefficient (ft^2/sec))/(Surface Height (ft) - Free Air Height (ft))

Table A-32. L-849 and L-850 Water Tanks Emission Estimate.

Constituent	Seconds/Year	Tank Cross Section Area (ft^2)	Emission Estimate (lbs/yr)
	A	B = 3.14159E+00*4.0E+01[2a]	S=Diffusion Rate[b]*A*B
Chloroform	3.1536E+07	5.027E+03	2.84E+01[c]
Bromodichloromethane	3.1536E+07	5.027E+03	1.46E-01[c]
Bromoform	3.1536E+07	5.027E+03	4.17E-04[cc]

[a] Procurement Specification for L-850 Sanitary Water Storage Tank; HNF-SPEC-63005, Rev. 0 [b] Diffusion Rate from Table A-31 [c] Emission Estimate is for both water tanks

Table A-33. Chloroform Emission Estimate.

Emission Unit	Emission Estimate (lbs/yr)
L-849 Water Tank	1.42E+01 [a]
L-850 Water Tank	1.42E+01[a]
L-897 Sludge Lagoons	1.55E+00[b]
Total Chloroform Emission Estimate (lbs/yr)	2.99E+01

[a] Emission Estimate from Table A-32
[b] Emission Estimate from Table A-28

Table A-34. Bromodichloromethane Emission Estimate.

Emission Unit	Emission Estimate (lbs/yr)
L-849 Water Tank	7.28E-02[a]
L-850 Water Tank	7.28E-02[a]
L-897 Sludge Lagoons	3.42E-02 [b]
Total Bromodichloromethane Emission Estimate (lbs/yr)	1.80E-01

[a] Emission Estimate from Table A-32
[b] Emission Estimate from Table A-28

Table A-35. Bromoform Emission Estimate.

Emission Unit	Emission Estimate (lbs/yr)
L-849 Water Tank	2.08E-04[a]
L-850 Water Tank	2.08E-04[a]
Total Bromoform Emission Estimate (lbs/yr)	4.17E-04

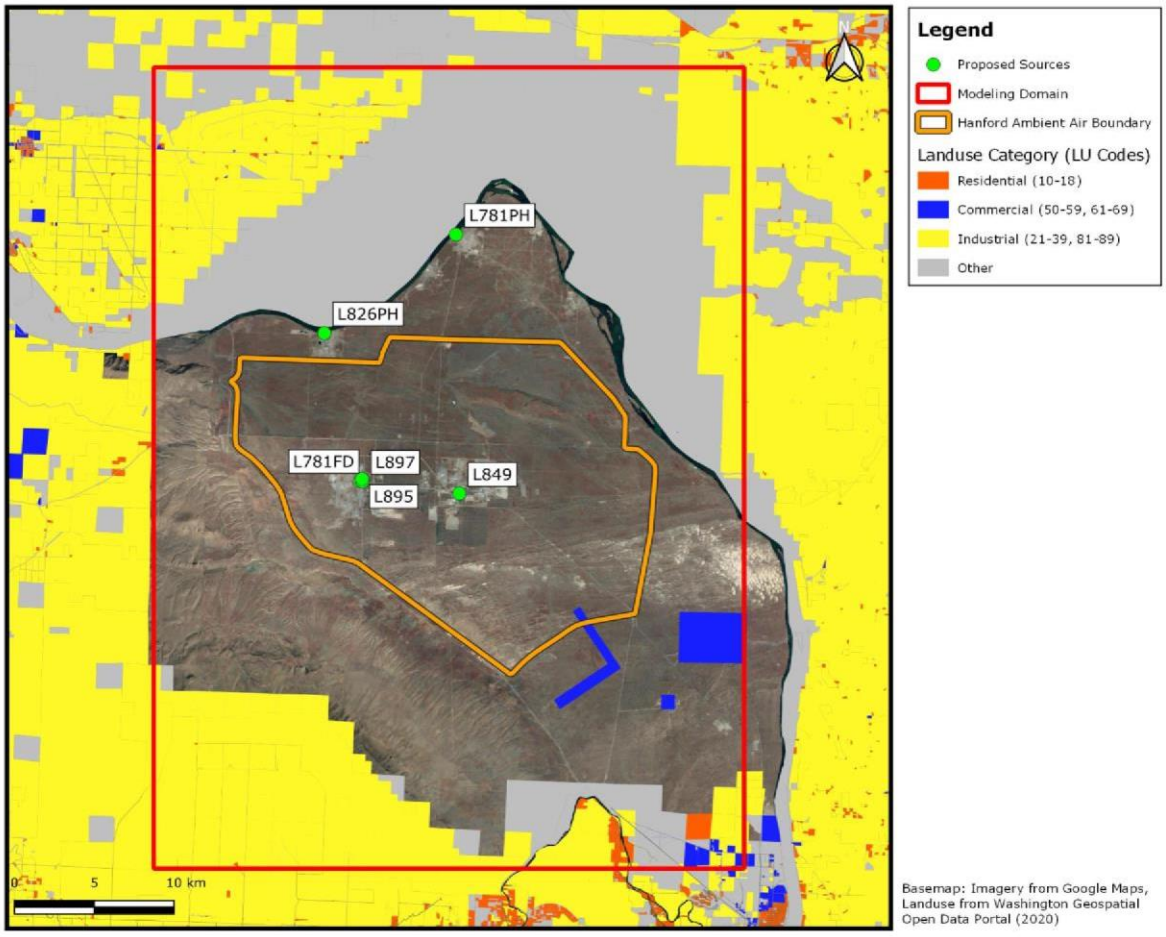
[a] Emission Estimate from Table A-32

APPENDIX B

LAND USE DATA

This Page Intentionally Left Blank

APPENDIX B LAND USE DATA



This Page Intentionally Left Blank

APPENDIX C

WHITE PAPER ON DIESEL EXHAUST QUANTITATIVE HEALTH RISK ASSESSMENT VALUES FOR LUNG CANCER

This Page Intentionally Left Blank

Prepared for:
Moffatt & Nichol
Seattle, Washington

On behalf of:
Port of Seattle Seattle, Washington

Prepared by:
Ramboll Environ US Corporation
Seattle, Washington

Date
April 2016

WHITE PAPER ON DIESEL EXHAUST QUANTITATIVE HEALTH RISK ASSESSMENT VALUES FOR LUNG CANCER

EXECUTIVE SUMMARY

This paper is written for a technical audience interested in understanding the rationale and justification for use of a range in "unit risk factors" for estimating potential cancer risk from exposure to diesel exhaust rather than a single number (for example, that proposed by the California Office of Environmental Health Hazard Assessment [OEHHA]). The paper is not focused on a specific project but may be incorporated into project-specific risk assessments as supporting documentation for the selection of alternative unit risk factors.

Typically, a single unit risk factor, derived from one or more studies in the scientific literature, is applied to a monitored or modelled air concentration to estimate potential

RAMBOLL ENVIRON

cancer risk that might result from the project. However, in the case of diesel engine exhaust, the use of a single, discrete value representing potential cancer potency of diesel exhaust attributes greater confidence to cancer risk estimates than is appropriate given the underlying shortcomings in the quantitative assessment of diesel exhaust risk. To adequately understand the limitations in current unit risk estimates for diesel engine exhaust, one must appreciate the historical process and causes for continued evaluation of the relationship between exposure to diesel engine exhaust and potential adverse health effects.

When fully considering the conclusions of multiple science review panels and risk assessment investigators, it is apparent that the current quantitative assessments for diesel exhaust are inadequate for deriving a single cancer potency number. While it is apparent that the body of research as a whole supports a positive relationship between exposure to diesel exhaust (particularly those with the composition of older diesel engines) and lung cancer, the numerical values that estimate potential cancer risk are hampered by a large range of uncertainty that is rarely communicated and considered in project planning and risk communication efforts. This dilemma can frustrate regulatory agencies, project proponents, and affected communities alike.

This document presents a summary of this dilemma and a proposal for addressing the inadequacies in unit risk estimates currently available. It consists of several sections that discuss the problem and offer a solution:

- Introduction to quantitative health risk assessment process;
- Overview of various Agency, Expert Panel, and Risk Assessment Investigator evaluations of the state-of-the-science related to the exposure-response relationship for diesel exhaust and cancer, along with a descriptions of key studies and their limitations;
- Description of the problems underlying the current quantitative estimates, along with a summary of different estimates for proposed unit risk factors;
- Proposal for estimating cancer risks associated with diesel exhaust until further assessment is complete

We conclude that, rather than selecting a single diesel exhaust risk estimate for appraising potential lung cancer risk, applying a range of unit risk factors allows project managers to compare relative ranges in impacts of each alternative, which can better support project planning and design decision-making. Given the uncertainties, we propose a range of numbers to be used to assess cancer risks, which range from 10^{-3} to 10^{-5} per $\mu g/m^3$, and propose to use these numbers to compare relative risks for different projects and exposure scenarios. Consideration of a plausible spectrum of risks for each proposed project alternative may provide greater insights into the relative differences in impacts between each alternative.

1. INTRODUCTION

Quantitative health risk assessments (HRAs) are based on combining exposure data with exposure-response information to quantitatively estimate potential risk. The National Research Council (1993) describes the risk assessment process as having four components: (1) a systematic review of evidence from epidemiology and other scientific disciplines concerning the association between environmental factors and human health (risk assessment hazard identification); (2) the understanding of the relationship between

exposure and response (exposure-response assessment); (3) the compilation of exposure data (exposure assessment), and (4) estimation of the health impacts following exposure to risk factors (risk characterization). Each step is critical in deriving a useful estimate of risk.

This document summarizes existing information supporting steps 1 and 2 by examining the evidence and application of scientific information to understand quantitative health risks from exposure to diesel exhaust, specifically for cancer as a health endpoint. This information may then be carried forward to support the latter two steps in quantifying risks attributed to a specific source.

2. THE RISK ASSESSMENT PROCESS

2.1 Step 1: Diesel Exhaust Hazard Identification

Several authoritative bodies have examined the risk assessment hazard identification step of the HRA process, asking "*Is exposure to diesel exhaust associated with an increased risk of cancer (particularly lung cancer) at some level of exposure?*" A large body of more than 50 epidemiology studies of diesel exhaust-exposed occupational populations are available, including of miners (*e.g.*, non-metal and metal), bus drivers and bus garage workers, trucking industry workers, and railroad workers (Hesterberg et al., 2012; IARC, 2014). A number of critical reviews, epidemiology meta-analyses, and regulatory cancer hazard assessments have interpreted this body of diesel exhaust epidemiology studies as providing support for a causal relationship between diesel exhaust exposure and lung cancer risk (*e.g.*, Bhatia et al., 1998; HEI, 1995; Lipsett & Campleman, 1999; Lloyd & Cackette, 2001; Wichmann, 2007; IARC 2014; National Toxicology Program (NTP), 2011). In 2012, the International Agency for Research on Cancer (IARC) classified diesel exhaust as a Group 1 "known human carcinogen" based on "sufficient" human data from occupational studies of non-metal miners, railroad workers, and workers in the trucking industry (International Agency for Research on Cancer, 2014).

Due to the substantial uncertainties and limitations in the diesel exhaust epidemiology literature, other published evaluations of the diesel exhaust-lung cancer evidence have concluded that the epidemiology data are not sufficiently reliable to establish a causal association between exposure to diesel exhaust and lung cancer (Boffetta, 2012; Bunn et al., 2004; Gamble et al., 2012; Gamble, 2010; Hesterberg et al., 2006, 2012; Morgan et al., 1997; Muscat and Wynder, 1995; Stober and Abel, 1996). These analyses have highlighted inconsistencies in the epidemiology findings (*e.g.*, weak or a lack of statistically significant associations between diesel exhaust exposure and lung cancer and even negative doseresponse trends in some studies), and a number of critical study limitations that include unreliable exposure assessments and often a general lack of quantitative data on workers' historical exposures to diesel exhaust, as well as inadequate control of confounding exposures, both from other air pollutants as well as for smoking (Hesterberg et al., 2012). While some of the more recently published diesel exhaust epidemiology studies (Attfield et al., 2012; Garshick et al., 2012; Silverman et al., 2012) have reported some of the strongest diesel-lung cancer associations, they remain affected by inconsistent exposure-response findings and possible effects of bias and exposure misclassification (Boffetta, 2012; Hesterberg et al., 2012; Moolgavkar et al., 2015). Nevertheless, the body of evidence suggests a need for assessing the potential cancer risk due exposures to diesel exhaust.

2.2 Step 2: Diesel Exhaust and Exposure-Response Assessment

A description of the forms exposure-response assessments may take is provided here for background in understanding the current body of scientific literature regarding diesel exhaust exposure-response research. Following this introduction are summaries of the critical diesel exhaust studies considered by regulatory bodies to date and a history of their consideration for use in quantifying the exposure-response relationship. An understanding of the basic study design and inherent limitations and uncertainties and regulatory review history is critical in applying quantitative unit risk estimates for diesel exhaust and interpreting cancer risk estimates in site-specific risk evaluations.

For the exposure-response assessment step of quantitative HRAs, the preferred basis for the exposure-response function are studies in human populations. When sufficient human data are not available, the exposure-response function is often based on experimental animal studies, but these are associated with additional uncertainties due to inter-species extrapolation. Studies in human populations may take the form of experimental exposure studies or observational (epidemiology) studies. Experimental studies are controlled studies in which the researcher controls the environment (such as the exposure), then observes what happens as a consequence of changing that environment. In an observational epidemiology study, the researcher studies the outcome, but the conditions cannot be controlled (*e.g.*, the exposures). Although experimental study designs are sometimes used to understand non-cancer endpoints in the drug development process (for example, clinical trials) or for substances that people are normally exposed to in the environment (controlled human exposure studies, or chamber studies) the more common approach to understanding toxicity to substances in humans is through epidemiology studies, where groups of people who are exposed to a chemical or substance in their environment are studied. These exposures may be due to exposure in a workplace environment, or to exposures in ambient air as people go about their lives. Various scientific procedures and tools have been devised to conduct such epidemiology studies.

There are several types of epidemiology studies, including cohort studies, case control studies, and cross-sectional studies. Some of these study designs are stronger than others. A cohort study (also sometimes called a longitudinal or prospective study) involves identifying groups of individuals with common exposures and then comparing subsequent rates of certain diseases in those groups with the rates of disease in similar groups with lower exposures. A case-control study (also sometimes called a retrospective study) identifies groups of people who have a certain disease and compares their exposure histories to similar groups of people who do not have the disease. A cross-sectional study examines the prevalence of a disease or health endpoint in one sample of people with a particular characteristic, and information about their health is then collected and interpreted in a systematic manner. This latter design is relatively weak for drawing conclusions about causation.

3. EVALUATIONS OF THE DIESEL EPIDEMIOLOGY LITERATURE

3.1 Evaluation of the Quality of the Science: The Health Effects Institute Diesel Epidemiology Expert Panel (1996 -1999)

While data from epidemiology studies have been useful in the hazard identification component associated with exposure to diesel exhaust, the usefulness of applying these data to develop reliable estimates of the magnitude of risk for lung cancer through quantitative HRAs has been questioned. In 1994, both the federal Environmental Protection Agency (US EPA) and the California Environmental Protection Agency, through their Office of Environmental Health Hazard Assessment (OEHHA), released draft cancer risk assessments for diesel exhaust through the inhalation pathway. Both agencies depended on the same set of scientific literature, but came to different conclusions. Although they considered the retrospective cohort study of US railroad workers (Garshick et al., 1988) and associated industrial hygiene survey (Hammond et al., 1988; Woskie et al., 1988a, 1988b) to derive an exposure-response function (Crump et al. 1991), the US EPA concluded that the data were too limited to support a quantitative HRA, and thus based their assessment on chronic animal studies. In contrast, OEHHA (Office of Environmental Health Hazard Assessment (OEHHA), 1998) chose to use the US railroad workers data, in spite of their limitations, as a basis of their quantitative HRA, as they viewed these data as more appropriate than using animal data.

In response to differences in addressing the exposure-response relationship, the Health Effects Institute (HEI) assembled a special panel, termed the Diesel Epidemiology Expert Panel, in the late 1990's. This Panel was charged with (1) reviewing the epidemiologic data that form the basis of the then-current quantitative HRAs for diesel exhaust, (2) identifying data gaps and sources of uncertainty, (3) making recommendations about the usefulness of extending or conducting further analyses of existing data sets, and (4) making recommendations for the design of new studies that would provide a stronger basis for risk assessment. In addition to the chair, the Panel was comprised of six senior scientists with expertise in epidemiology, biostatistics, exposure characterization, and exposure assessment. They focused on available epidemiology in railroad workers and teamsters, including the following studies and follow-up publications and research: **Railroad Worker Studies**

- Case-control: Garshick et al. 1987
- Cohort: Garshick et al. (1988)
- Industrial hygiene: Hammond et al. (1988), and Woskie et al. (1988a, 1988b)
  - Exposure-response analyses: Crump et al. (1991); Crump (1999); Office of Environmental Health Hazard Assessment [OEHHA] (1998)

Teamster (Trucker) Studies

- Case-control: Steenland et al. (1992); Steenland et al. (1990)
- Industrial hygiene: Zaebst et al. (1991)
- Exposure-response analysis: Steenland et al. (1998)

The review performed by this Panel identified evidence for weak increases in lung cancer risk in exposed workers relative to unexposed workers. The Panel then examined whether the available epidemiology studies were of sufficient quality in terms of their design and performance to be useful for input for quantitative HRA, or if the limitations of the individual studies being considered rendered the study insufficient for this application. Their analysis also examined whether each study had a sufficient quality of retrospective data for estimating job-related work exposures. Such data are often difficult to acquire and investigators often need to make assumptions that cannot be validated in their attempts to reconstruct past exposures to diesel engine emissions. The Panel noted that many studies suffered from inadequate exposure assessment, incomplete adjustment for smoking, unmeasured confounding variables (*e.g.*, other job category differences), and latency periods being too short. While reasonable for the individual study, limitations that authors recognize and acknowledge are often ignored when risk assessors or other researchers apply the results of the studies in ways that go beyond the intent of the original investigators.

3.1.1 Garshick et al. (1987): US Railroad Worker Studies

The Garshick et al. (1987) case-control study, along with the Garshick et al. (1988) cohort study of US railroad workers have often been considered as a basis of estimating the risk of lung cancer in the general population. Garshick et al. (1987) examined Railroad Retirement Board registrants who died between March 1, 1981, and February 28, 1982. Among 650,000 active and retired male railroad workers born in or after 1900 who had at least 10 years of railroad employment, 15,059 deaths were reported to the Railroad Retirement Board. This study was actually designed primarily to investigate the relationship between smoking (*i.e.*, not occupations or environmental exposures) and lung cancer. This study evaluated exposure to diesel exhaust using job histories beginning in 1959 as well as the last job worked before retirement for workers who retired prior to 1959. Jobs were divided into "exposed" or "unexposed" categories, and cumulative diesel-years of exposure were estimated for each worker. For 39 job categories, an industrial hygienist (Woskie et al., 1988a, 1988b) helped define exposures. But workers whose jobs fell outside this group of 39 categories were assigned as either "exposed" or "unexposed" based on comparing their activities to the primary 39 job categories. The extent of contact with operating diesel equipment was also taken into consideration. The analysis in the Garshick et al. (1987) study found that, after adjusting for asbestos and smoking, the relative odds for continuous exposure to diesel exhaust were 1.39 (95% CI = 1.05, 1.83). Furthermore, among the younger workers with longer diesel exhaust exposure, the risk of lung cancer increased with duration of exposure after adjusting for asbestos and smoking.

Although this study was well-designed and conducted, it has several important limitations. The most important limitation was that occupations were not coded into exposures for different chemical and physical agents. This prevented calculating relative risks for diesel exposure. Instead, Interstate Commerce Commission (ICC) job classification were used as a surrogate for exposure, which may have led to misclassification of diesel exhaust exposure jobs with low intensity and intermittent exposure, such as railroad police and bus drivers, as unexposed. Use of a simple "exposed" and "unexposed" scheme for exposure also may have resulted in exposure misclassification. Another exposure limitation was that the year when workers were first exposed to diesel was unknown, as dieselization was being gradually introduced in the early 1950s. Finally, the relative risks decreases with duration of

employment, so exposure-response functions cannot be derived. This weakens the study's potential to provide a reliable quantitative estimate of risk from exposure to diesel exhaust.

3.1.2 Garshick et al. (1988): US Railroad Worker Study

The Garshick et al. (1988) cohort study of US railroad workers was one of only a few studies at the time that included industrial hygiene measurements of diesel exhaust. These measurements were correlated with job titles, and number of years of employment was used as a surrogate for exposure dose. The study found an elevated risk ratio (RR: 1.57 and 1.34); however, the youngest workers were found to have the highest risk of lung cancer, which is counter-intuitive. And this is not the only study showing a negative dose-response relationship. Re-analysis of the same data by OEHHA yielded a positive dose response relationship and reported a steadily increasing risk of lung cancer for exposed workers with increasing years of employment when examined by overall job category (*e.g.*, train workers compared to clerks). However, a subsequent analysis in the railroad workers (as presented by Dr. Garshick in a letter to US EPA in 1991[1]) did not confirm this result. Furthermore, additional analysis of the data using several metrics of cumulative diesel exhaust exposure indicated that the greater the exposure to diesel exhaust, the lower the risk of lung cancer (Crump et al. 1991; 1999).

When OEHHA altered the assumptions of the Crump exposure assessment, they found a positive association between exposure and risk for cumulative exposure. The OEHHA assumptions for diesel exposure were higher than the Crump (1991) or Garshick et al. (1988) assumptions, resulting in peak exposures that were twice as high as assumed in the exposure patterns by Garshick et al. (1988) and Crump et al. (1991). Crump (1999) has explained the OEHHA results as resting on the difference between train workers and clerks/signalmen; the HEI Panel agreed with this assessment. The HEI Panel concluded "These findings are not consistent with a steadily increasing association between cumulative diesel exposure and lung cancer risk." They concluded "At present, the railroad worker cohort study (Garshick et al. 1988), though part of a larger body of hazard identification studies, has very limited utility for QRA of lifetime lung cancer risk from exposure to ambient levels of diesel exhaust…" and listed (1) limitations in the then-available exposure data; and (2) the dependence on comparing entire job classifications against each other (train workers with higher exposures as compared to clerks with lower exposures) as serious limitations to interpreting the data. The HEI Panel noted several possible explanations for the associations claimed by authors, including exposure misclassification, incomplete ascertainment of lung cancer deaths by job category, lack of information on other occupational exposures and air pollutants, a healthy worker effect, confounding by cigarette smoking, and analysis of relative risks rather than absolute risks.

[1] Cited in US EPA 2002 as "letter from Garshick, Harvard Medical School, to Chao Chen, U.S. EPA, dated August 15, 1991."

3.1.3 Steenland et al. (1998): Truckers Study

Steenland et al. (1990) reported an increased risk of lung cancer mortality from a casecontrol study of truckers belonging to the Central States Teamsters Union, with

increased risk associated with increasing years of employment. The investigator group then performed an exposure-response analysis for the study (Steenland et al., 1998). However, the HEI Panel had concerns about several of the assumptions used in the exposure-response analysis including the following: (1) 1990 emissions data were used to estimate past exposures to diesel exhaust, even though more recent data indicate there may have been higher emissions during that period (which might underestimate average exposures); (2) date assumed for dieselization in the trucking industry, which, if too early, may overestimate exposures; (3) assumptions using vehicle miles travelled as a surrogate for exposure to diesel exhaust for various job groups (may over- or underestimate exposures); (4) accounting for fleet turnover in the trucking industry; and (5) difficulties in distinguishing diesel exposure from trucks from background diesel exposures.

This study uses elemental carbon as a measure of diesel exhaust; however, there are also non-diesel sources of elemental carbon in ambient air, particularly in highway settings where gasoline vehicles can contribute. Although gasoline vehicles emit less elemental carbon per vehicle, there are many more gasoline-powered vehicles on the road than diesel, so the gasoline vehicles may have contributed to elemental carbon concentrations. Although the range of exposures in the Teamsters study is closer to the exposures anticipated for the general population than that of the railroad workers, the HEI Panel (and the authors themselves) were cautious about immediate application of the exposure-response function before further validation could be achieved because exposure estimates were based on broad assumptions rather than measurements of exposure.

Overall, the HEI Panel concluded that the studies they reviewed had a number of limitations that precluded their use in quantitative HRAs. These limitations included (1) questions about the quality and specificity of the exposure assessments for diesel exhaust, (2) a lack of quantitative estimates of exposure to allow derivation of an exposure–response function, and (3) lack of adequate data to account quantitatively for individual worker exposures to other factors that might also be associated with lung cancer, such as smoking.

3.2 The US Environmental Protection Agency Response (2002)

Following the HEI Panel's assessment, the US EPA concluded that diesel exhaust is likely to be carcinogenic to humans at environmental levels of exposure, but found that the data from health studies available at the time were not suitable for estimating cancer potency (U.S. Environmental Protection Agency [EPA], 2002). Among the occupational studies, the US EPA considered the US railroad worker studies (Garshick et al., 1987, 1988) and the Teamsters Union truck driver studies (Steenland et al., 1990, 1998) to have the best available exposure data for their possible use in establishing exposure-response relationships in support of a cancer unit risk. Given the equivocal evidence for the presence or absence of an exposureresponse relationship for the study of railroad workers, and exposure uncertainties for the study of truck drivers, the US EPA concluded that even though the scientific evidence supported an association between exposure to diesel exhaust and lung cancer, available data were too uncertain to be used as the basis of a confident quantitative dose-response analysis and subsequent derivation of cancer unit risk for diesel exhaust.

Instead, the US EPA chose to take a set of exploratory approaches to estimate the possible magnitude of cancer risk. The first exploratory approach involved examining the differences between the exposure concentrations in occupational-exposed cohorts along with their

cumulative life-time exposures, as compared to ambient environmental exposures that communities might experience, and infer risks based on how large a difference there was between the occupational and community exposure estimates. The second approach explored possible cancer risks from exposure to diesel exhaust in the general population in a more quantitative manner. This approach examined the risk observed in diesel exhaustexposed workers, and then made assumptions as to how these risks could be extrapolated to environmental exposure conditions. This exploratory analysis concluded that environmental cancer risks from exposure to diesel exhaust were possibly in the range of 10^{-5} to almost 10^{-3}, while acknowledging numerous uncertainties and assumptions in reaching this conclusion.

3.3 The California OEHHA Response

In contrast to the US EPA, OEHHA (1998) opted to retain their unit risk estimates for lung cancer on the then-available epidemiology studies, using the concentration-response information from two studies in US railroad workers (Garshick et al. 1987; Garshick et al. 1988). They considered a variety of exposure patterns based on average exposure concentration for the workers (as measured by Woskie et al. 1988) and the extent of change in exposures during the periods of 1959 - 1980. Using this approach, OEHHA derived a series of lifetime risk estimates ranging from 1.3×10^{-4} per μg/m^3 to 2.4×10^{-3} per μg/m^3, with a geometric mean risk of 6×10^{-4} per μg/m^3. For risk assessment purposes, OEHHA selected[4] 3×10^{-4} per μg/m^3. OEHHA did not change this approach or update their findings following the HEI 1999 publication, or after the US EPA 2002 health assessment.

3.4 Evaluation of the Quality of the Science: The Health Effects Institute Diesel Epidemiology Expert Panel (2013-2015)

More recently, HEI assembled another expert panel to review new epidemiology studies of diesel exhaust and lung cancer, including key studies in the 2012 IARC evaluation of diesel exhaust (Health Effects Institute [HEI], 2015). This Panel focused on two studies, the Trucking Industry Particle Study (the Truckers study; Eric Garshick et al., 2012), and the Diesel Exhaust in Miners Study (DEMS) (Attfield et al., 2012; Silverman et al., 2012). As with the previous HEI Panel, this Panel's overall charge was to evaluate the data and results in these two large studies for their utility in quantitative characterization of the exposure–response relationship between diesel e xhaust and lung cancer. In this evaluation, the Panel found that both the Truckers and DEMS were well-designed, well-conducted studies that made considerable progress toward addressing a number of the serious limitations identified in previous studies of diesel exhaust and lung cancer. The studies included better metrics to specifically quantify diesel exposure, and used better models of historical exposures. Because of these stronger methods, the 2013-2015 HEI Panel concluded that the studies would be useful for quantitative estimates of historical exposures to diesel exhaust, and thus be appropriate for quantitative HRA.

The 2013-2015 HEI Panel also opined on whether findings of these occupational exposures were generalizable to estimate lung cancer risk in the general populations exposed to diesel exhaust at lower concentrations (*e.g.*, found in urban areas). They noted that there were broad and overlapping ranges of exposures to submicron and respirable elemental carbon in

[4] http://www.arb.ca.gov/toxics/dieseltac/de-fnds.htm

these studies, and that the lower end of these exposures was similar to the higher end of exposures in ambient air.

The decision about whether a given study or set of studies provide data of sufficient accuracy, precision, and relevance to be useful for quantitative HRAs is often a policy decision. However, the policy should rest upon basic principles of sound study design and analysis, while recognizing the strengths and weaknesses of each study. When applied to quantitative HRAs, the scientific evidence needs to be weighed against uncertainties and other factors to provide a useful tool. To date, because of the significant uncertainties in the diesel exhaust epidemiology literature, few regulatory agencies and authoritative bodies have made quantitative predictions of increased lung cancer risk as a function of diesel exposure.

3.5 Meta-Analyses of Diesel Epidemiology Studies and Associated Risk Estimates

One method of addressing this issue is to examine the more recent Truckers Study and DEMS – studies which have been deemed by the 2013-2015 HEI Panel to have sufficient quality to develop more robust unit risk values. The 2013-2015 HEI Panel stopped short of doing this, but noted that these studies were appropriate for use in a quantitative HRA. US EPA will likely be following this recommendation and developing such risk numbers in the future, but the timing is uncertain and until then there is a need for an alternative that is better justified by the science. In the meanwhile, it is possible to take a meta-analysis approach to develop risk numbers. Vermeulen et al. (2014) performed a meta-analysis of the risk of lung cancer from exposure to diesel exhaust using data from three case–control studies—two of workers in the trucking industry (Garshick et al., 2012; Steenland et al., 1998) and one from DEMS (Silverman et al., 2012). From these three studies, Vermeulen et al. (2014) generated an exposure–response curve based on a log-linear regression model using relative risk estimates. Individual relative risk estimates were plotted (with their 95% confidence interval bounds) along with a 95% confidence interval for the exposure-response curve based on the log-linear model. Figure 1 (from Vermeulen et al., 2014) plots the relative risks at different levels of cumulative exposure from each of the three studies, estimated at 5- or 15-year exposure lags (depending on the study).

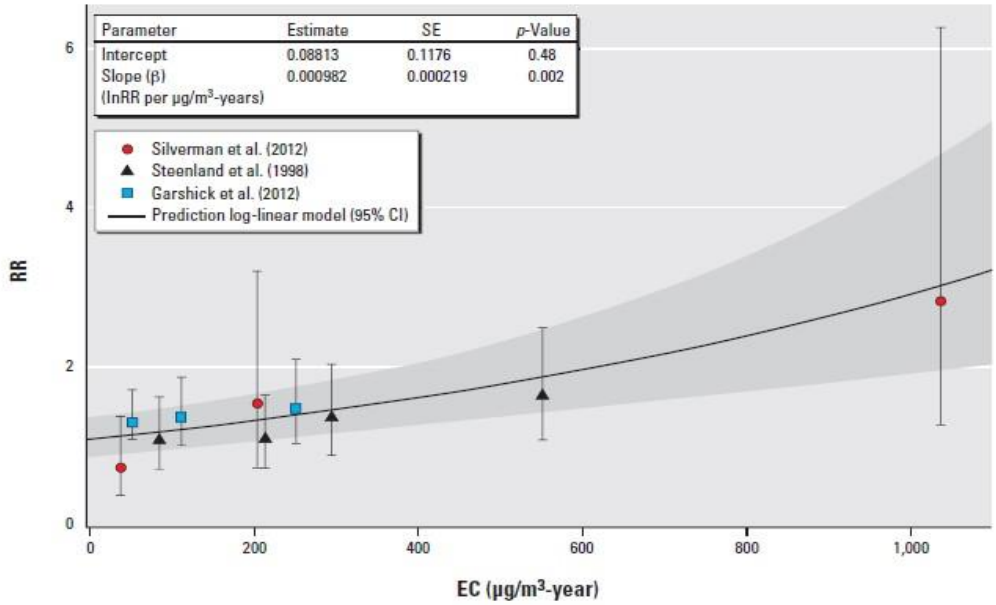


Figure 1. Predicted exposure–response curve based on a log-linear regression model using RR estimates from three cohort studies of DEE and lung cancer mortality. Individual RR estimates [based on HRs reported by Garshick et al. (2012) or ORs reported by Silverman et al. (2012) and Steenland et al. (1998)] are plotted with their 95% CI bounds indicated by the whiskers. The shaded area indicates the 95% CI estimated based on the log-linear model. The insert presents the estimates of the intercept and beta slope factor, the SE of these estimates, and the associated *p*-values.

Crump (2014) criticized the Vermeulen et al. (2014) meta-analysis for inappropriately mixing data from exposures with lags of 5 years and 15 years. Crump re-ran the analysis using several different assumption conditions, and, depending on the assumptions, got different results. Morfeld and Spallek (2015) performed a re-analysis of the same data using different modelling approaches. They reported that the data used by Vermeulen et al. (2014) led to the highest relative risk estimate across all sensitivity analyses performed, and cautioned against using the meta-analysis of Vermeulen et al. (2014) in risk assessments, especially at lower exposures.

4. THE DILEMMA AND A PATH FORWARD

At the time that OEEHA (1998) developed their inhalation lifetime unit risk value for diesel exhaust, several other authoritative groups had examined the same epidemiology evidence and judged it inadequate for derivation of a discrete, quantitative estimate of human risk (HEI 1999; US EPA 2002; Hesterberg et al., 2011; International Program for Chemical Safety (IPCS), 1996; see Table 1). OEEHA took the position that, in spite of the uncertainties, they would develop a unit risk value from this literature. Other organizations judged that the uncertainties were too great to take this step, and offered alternative numbers or ranges of numbers for this type of assessment. It is possible that the more recent literature evaluated by the HEI 2015 Panel will be of sufficient quality to develop more robust unit risk values, but no cancer risk estimates have been developed to date and some find that the available results are not sufficiently consistency and of sufficient quality to be used in a risk assessment (*e.g.*, Moolgavkar et al., 2015). Therefore, we face the dilemma of needing a

risk-based number to evaluate health risks potentially resulting from proposed or existing projects despite a lack of faith in the numbers generated from the current body of literature.

The various meta-analyses of the same set of 3 studies show the uncertainty inherent in developing cancer risk estimates. It is important to keep this uncertainty in mind as risk numbers are developed. Table 1 presents the range of numbers from these meta-analyses, which vary considerably even though they are based on the same underlying studies. Table 1 also presents other cancer risk factors proposed by other Agencies and groups. **Table 1. Evaluation of studies for developing cancer risk estimates**

Reference	Unit risks (per µg/m³)	Approach
Vermeulen et al. (2014)	1.7×10^{-3}	Meta-analysis of 3 studies: Silverman et al. (2012) Steenland et al. (1998) Garshick et al. (2012)
Crump (2014) letter to the editor	6.7×10^{-4} (n.s.)[a]	Reanalysis of the same 3 studies with consistent lag period
Vermeulen et al. (2014) response to letter to the editor	1.1×10^{-3}	Reanalysis of the same 3 studies with consistent lag period, using different methods
Morfeld and Spallek (2015)	Discussion of variables for deriving exposure-response relationship and proposal of a threshold for cancer risk	Reanalysis of the same 3 studies using different modelling approaches; other studies considered as well
US EPA (2002)	10^{-3}- 10^{-5}	Qualitative approaches to evaluate risk
OEHHA (1998)	3×10^{-4} [b]	Based on Garshick et al. (1998) study
WHO (1996)	3.4×10^{-5} [c]	Based on rat data, using modeling to extrapolate to human lungs
EPA (1994) *DRAFT*	1.6×10^{-5} - 7.5×10^{-5} [d]	Based on rat data and epidemiology data

[a] n.s.: not statistically significant

[b] Range of 1.3×10^{-4} – 2.4×10^{-3} with a geometric mean of 6×10^{-4}

[c] Range from 1.6×10^{-5} - 7.1×10^{-5} with a geometric mean of 3.4×10^{-5}

[d] Geometric mean of upper bound estimates 3.4×10^{-5}

Another important issue in extrapolating results from these older epidemiology studies (Garshick et al. 1987; Garshick et al. 1988) is that diesel exhaust in these epidemiology studies are based on diesel exhaust composition that is very different compared to more contemporary diesel exhaust. Due to the long latency period for lung cancer, epidemiology studies need to examine workers whose exposures started more than 20 years earlier. These particular studies are based on exposures from the 1950's and 1960's. However, starting in 1988 (trucks) and continuing in 1991 (trucks), 1994 (trucks), 1996 (buses), and 2007 (trucks), the US EPA has progressively tightened standards for particulate emissions from on-road heavy-duty diesel engines, resulting in the development of new technology diesel

engines that emit lower amounts of particulate matter and other emitted pollutants (*e.g.*, gases), and diesel exhaust with an inherently different composition. That is, these changes have not only resulted in the quantitative reduction in mass emitted by new technology diesel engines as compared to engines pre-regulation, but have also resulted in qualitative differences in the composition of what is emitted, both with respect to size and with respect to chemicals associated with the exhaust (Hesterberg et al., 2011). Thus, depending on the components of diesel exhaust that may be causally linked to the increased risk of lung cancer, simple dependence on particle mass (*i.e.*, expressing cancer risk as "per $\mu g/m^3$") may not be an accurate metric of exposure, as the composition of the particles has changed dramatically.

To reflect these broad uncertainties and issues, we propose using a range of unit risk values to evaluate potential cancer risks: 10^{-3}- 10^{-5}. This range, which encompasses the various unit risk values presented in Table 1, better reflects the uncertainty of defining the exposureresponse curve for assessing potential cancer risk from diesel exhaust, yet allows comparisons across different exposure scenarios.

5. SUMMARY

The OEEHA (1998) inhalation lifetime unit risk value for diesel exhaust is based on the study of Garshick et al. (1988), a study that has been judged by several authoritative bodies to be inadequate for use in developing a quantitative estimate of human risk for cancer (HEI 1999; US EPA 2002; WHO, 1996). Nevertheless, the absence of an alternative number has left agencies and others with a dilemma: either ignore the potential of diesel exhaust to result in elevated risk of lung cancer, or use a number derived from a study that cannot support such an application. More recently, a set of epidemiology studies in diesel miners (DEMS) and in truckers (Garshick et al., 2012) were published that were judged adequate for application in quantitative risk assessment. Although there have been some attempts to use these studies to develop quantitative estimates of cancer risk (Vermeulen et al. 2014; Crump 2014; Morfeld and Spallek, 2015), the numbers they generate can vary considerably. Given the uncertainties, we propose a range of numbers to be used to assess cancer risks, which range from 10^{-3} to 10^{-5} per $\mu g/m^3$, and propose to use these numbers to compare relative risks for different projects and exposure scenarios.

6. REFERENCES

Attfield, M. D., Schleiff, P. L., Lubin, J. H., Blair, A., Stewart, P. a., Vermeulen, R., … Silverman, D. T. (2012). The diesel exhaust in miners study: A cohort mortality study with emphasis on lung cancer. *Journal of the National Cancer Institute*, *104*(11), 869–883. doi:10.1093/jnci/djs035

Bhatia, R., Lopopero, P., & Smith, A. (1998). Bhatia_1998.pdf. *Epidemiology (Cambridge, Mass.)*, *9*(1), 84–91.

Boffetta, P. (2012). Re: The diesel exhaust in miners study: A nested case-control study of lung cancer and diesel exhaust and a cohort mortality study with emphasis on lung cancer. *Journal of the National Cancer Institute*, *104*(23), 1842–1843. doi:10.1093/jnci/djs416

Bunn, W. B., Hesterberg, T. W., Valberg, P. a, Slavin, T. J., Hart, G., & Lapin, C. a. (2004). A reevaluation of the literature regarding the health assessment of diesel engine exhaust. *Inhalation Toxicology*, *16*(14), 889–900. doi:10.1080/08958370490883783

Crump. (2014). Perspectives | Correspondence. *Environmental Health Perspectives*, *119*(11), 230–231. doi:10. Crump. (2014). Perspectives | Correspondence. *Environmental Health Perspectives*, *119*(11), 230–231. doi:10.1289/ehp.0901276

Crump, K. S. (1999). Lung cancer mortality and diesel exhaust: Reanalysis of a retrospective cohort study of US railroad workers. *Inhalation Toxicology*, *11*(1), 1–17. doi:10.1080/089583799197230

Crump KS, Lambert T, Chen C. (1991). Assessment of risk from exposure to diesel engine emissions: Report to U.S. Environmental Protection Agency. Contract 68-02-4601 (Work Assignment No. 182, July). Office of Health Assessment, U.S. Environmental Protection Agency, Washington, DC.

Gamble, J. (2010). Lung cancer and diesel exhaust: A critical review of the occupational epidemiology literature. *Critical Reviews in Toxicology*. Retrieved from http://www.tandfonline.com/doi/abs/10.3109/10408440903352818#.VgW0TzyWK2o.mendeley

Gamble, J. F., Nicolich, M. J., & Boffetta, P. (2012). Lung cancer and diesel exhaust: an updated critical review of the occupational epidemiology literature. *Critical Reviews in Toxicology*, *42*(7), 549–98. doi:10.3109/10408444.2012.690725

Garshick, E., Laden, F., Hart, J. E., Davis, M. E., Eisen, E. A., & Smith, T. J. (2012). Lung cancer and elemental carbon exposure in trucking industry workers. *Environmental Health Perspectives*, *120*(9), 1301–1306. doi:10.1289/ehp.1204989

Garshick, E., Schenker, M. B., Munoz, A., Segal, M., Smith, T. J., Woskie, S. R., … Speizer, F. E. (1988). A retrospective cohort study of lung cancer and diesel exhaust exposure in railroad workers. *American Review of Respiratory Disease*, *137*, 820–825. doi:10.1164/ajrccm/137.4.820

Garshick E, Schenker MB, Muñoz A, Segal M, Smith TJ, Woskie SR, Hammond SK, Speizer FE. 1987. A case-control study of lung cancer and diesel exhaust exposure in railroad workers. Am Rev Respir Dis 135:1242–1248.

Hammond, S. K., Smith, T. J., Woskie, S. R., Leaderer, B. P., & Bettinger, N. (1988). Markers of exposure to diesel exhaust and cigarette smoke in railroad workers. *American Industrial Hygiene Association Journal*, *49*(10), 516–522. doi:10.1080/15298668891380150

Health Effects Institute (HEI). (2015). *Diesel Emissions and Lung Cancer: An Evaluation of Recent Epidemiological Evidence for Quantitative Risk Assessment*.

Health Effects Institute (HEI). (1995). *Diesel Emissions and Lung Cancer: Epidemiology and Quantitative Risk Assessment. A Special Report of the Institute's Diesel Epidemiology Expert Panel.*

Hesterberg, T. W., Bunn Iii, W. B., Chase, G. R., Valberg, P. A., Slavin, T. J., Lapin, C. A., & Hart, G. A. (2006). A Critical Assessment of Studies on the Carcinogenic Potential of

Diesel Exhaust. *Critical Reviews in Toxicology*, *36*, 727–776. doi:10.1080/10408440600908821

Hesterberg, T. W., Long, C. M., Bunn, W. B., Lapin, C. a., McClellan, R. O., & Valberg, P. a. (2012). Health effects research and regulation of diesel exhaust: an historical overview focused on lung cancer risk. *Inhalation Toxicology*, *24*(S1), 1–45. doi:10.3109/08958378.2012.691913

Hesterberg, T. W., Long, C. M., Sax, S. N., Lapin, C. A., McClellan, R. O., Bunn, W. B., & Valberg, P. A. (2011). Particulate Matter in New Technology Diesel Exhaust (NTDE) is Quantitatively and Qualitatively Very Different from that Found in Traditional Diesel Exhaust (TDE). *Journal of the Air & Waste Management Association*, *61*(9), 894–913. doi:10.1080/10473289.2011.599277

International Agency for Research on Cancer. (2014). *Diesel and gasoline engine exhausts and some nitrosamenes*. *IARC monographs on the evaluation of carcinogenic risks to humans / World Health Organization, International Agency for Research on Cancer* (Vol. 105).

International Program for Chemical Safety (IPCS). (1996). Diesel fuel and exhaust emissions.

Lipsett, M., & Campleman, S. (1999). Occupational exposure to diesel exhaust and lung cancer: a meta-analysis. *American Journal of Public Health*, *89*(7), 1009–17. doi:10.2105/AJPH.89.7.1009

Lloyd, a. C., & Cackette, T. a. (2001). Diesel engines: environmental impact and control. *J. Air & Waste Manage. Assoc.*, *51*(6), 809–47.1289/ehp.0901276

Moolgavkar, S. H., Chang, E. T., Luebeck, G., Lau, E. C., Watson, H. N., Crump, K. S., … McClellan, R. (2015). Diesel Engine Exhaust and Lung Cancer Mortality: Time-Related Factors in Exposure and Risk. *Risk Analysis*, *35*(4), 663–675. doi:10.1111/risa.12315

Morfeld, P., & Spallek, M. (2015). Diesel engine exhaust and lung cancer risks – evaluation of the meta-analysis by Vermeulen et al. 2014. *Journal of Occupational Medicine and Toxicology*, *10*(1), 31. doi:10.1186/s12995-015-0073-6

Morgan, W., Reger, R., & Tucker, D. (1997). Health effects of diesel emissions. *Annals of Occupational Hygiene*, *41*(6), 643–658.

Muscat, J. E., & Wynder, E. L. (1995). Diesel exhaust, diesel fumes, and laryngeal cancer. *Otolaryngology--Head and Neck Surgery : Official Journal of American Academy of Otolaryngology-Head and Neck Surgery*, *112*(3), 437–440.

National Toxicology Program (NTP). (2011). *Report on Carcinogens, Twelfth Edition*.

Office of Environmental Health Hazard Assessment (OEHHA). (1998). *Part B: Health Risk Assessment for Diesel Exhaust*. *Proposed Identification of Diesel Exhaust as a Toxic Air Contaminant* (Vol. 1). doi:10.1017/CBO9781107415324.004

Silverman, D. T., Samanic, C. M., Lubin, J. H., Blair, A. E., Stewart, P. a., Vermeulen, R., … Attfield, M. D. (2012). The diesel exhaust in miners study: A nested case-control study of lung cancer and diesel exhaust. *Journal of the National Cancer Institute*, *104*(11), 855–868. doi:10.1093/jnci/djs034

Steenland, K., Deddens, J., & Stayner, L. (1998). Diesel exhaust and lung cancer in the trucking industry: exposure-response analyses and risk assessment. *American Journal of Industrial Medicine*, *34*(3), 220–8. doi:10.1002/(SICI)1097-0274(199809)34:3<220::AID-AJIM3>3.0.CO;2-Z

Steenland, K., Silverman, D., & Zaebst, D. (1992). Exposure to diesel exhaust in the trucking industry and possible relationships with lung cancer. *American Journal of Industrial Medicine*, *21*(6), 887–890. doi:10.1002/ajim.4700210612

Steenland, N. K., Silverman, D. T., & Hornung, R. W. (1990). Case-control study of lung cancer and truck driving in the teamsters union. *American Journal of Public Health*, *80*(6), 670–674. doi:10.2105/AJPH.80.6.670

Stober, W., & Abel, U. R. (1996). Lung cancer due to diesel soot particles in ambient air? A critical appraisal of epidemiological studies addressing this question. *International Archives of Occupational and Environmental Health*, *68 Suppl*, S3–61.

U.S. Environmental Protection Agency (EPA). (2002). *Health Assessment Document For Diesel Engine Exhaust*.

Vermeulen, R., Silverman, D. T., Garshick, E., Vlaanderen, J., Portengen, L., & Steenland, K. (2014). Exposure-Response Estimates for Diesel Engine Exhaust and Lung Cancer Mortality Based on Data from Three Occupational Cohorts. *Environmental Health Perspectives*, *122*(2), 172–7. doi:10.1289/ehp.1306880

Wichmann, H.E., 2007. Diesel exhaust particles. Inhalation toxicology, 19(sup1), pp.241244.

Woskie, S., Smith, T., Hammond, S., Schenker, M., Garshick, E., & Speizer, F. (1988). Estimation of the diesel exhaust exposures of railroad workers: II. National and historical exposures. *American Journal of Industrial Medicine*, *13*(3), 395–404. doi:10.1002/ajim.4700130308

Zaebst, D. D., Clapp, D. E., Blade, L. M., Marlow, D. A., Steenland, K., Hornung, R. W., … Butler, J. (1991). Quantitative determination of trucking industry workers' exposures to diesel exhaust particles. *American Industrial Hygiene Association Journal*, *52*(12), 529–41. doi:10.1080/15298669191365162

Attachment 4
21-ESQ-000366

HANFORD SITE AIR OPERATING PERMIT 00-05-006, RENEWAL 3,
NOTIFICATION OF ADMINISTRATIVE PERMIT AMENDMENT

Consisting of 3 pages,
including this cover page

HANFORD SITE AIR OPERATING PERMIT

Notification of Administrative Permit Amendment

This notification is provided to the Washington State Department of Ecology, Washington State Department of Health, and the U.S. Environmental Protection Agency as notice of an administrative amendment described as follows.

The following changes are allowed pursuant to WAC 173-401-720(1) and WAC 173-401-720(2):
1. Correct typographical errors,

Description of the Change:
DOE/RL-2020-33, Revision 0, "Water Systems Upgrade Notice of Construction Application Technical Information,' submitted with the NOC application form provides a complete description of the change.
Submittal Date of Change:
The date of change will be determined by the Washington State Department of Ecology upon issuance of approval.
Describe the emissions resulting from orders approving notice of construction applications processed under an EPA-approved program; provided that the program meets procedural requirements listed in WAC 173-401:
DOE/RL-2020-33, Revision 0, "Water Systems Upgrade Notice of Construction Application Technical Information," submitted with the NOC application form provides a complete description of the emissions.
List the terms, conditions, and provisions from orders approving notice of construction applications processed under an EPA-approved program; provided that the program meets procedural requirements listed in WAC 173-401:

The terms, conditions, and provisions will be identified in the Ecology issued approval order.

2. Identifies a change in the name, address, or phone number of any person identified in the permit, or provides a similar minor administrative change at the source,
3. Requires more frequent monitoring or reporting by the permittee;
4. Allows for a change in ownership or operational control of a source where the permitting authority determines that no other change is necessary provided that a written agreement containing the specific information of the transfer between the current and new permittee has been submitted to the permitting authority,
5. Incorporates into the chapter 401 permit the terms, conditions, and provisions from orders approving notice of construction applications processed under an EPA-approved program; provided that the program meets procedural requirements listed in WAC 173-401, and
6. Changes addressed in the administrative permit amendment can be implemented immediately upon submittal.

Permit Number: 00-05-006

Provide the following information pursuant to WAC 173-401-720: